Public Hearing (3/20/13)
Bay-Delta Plan SED
Deadline: 3/29/13 by 12 noon

SOUTH DELTA WATER AGENCY

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SWRCB Clerk

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Via E-Mail commentletters@waterboards.ca.gov

Ms. Jeanine Townsend, Clerk to the Board
Executive Office
State Water Resources Control Board
P. O. Box 100
Sacramento, CA 95814-0100

Re: Comment Letter – Bay-Delta Plan SED

Dear Ms. Townsend:

The following are South Delta Water Agency's comments to the Substitute Environmental Document for the Proposed Changes to the Bay-Delta Water Quality Control Plan.

PROCEDURAL ISSUES

CEQA generally prohibits the segmentation of a project, requiring that the entirety of the project, including reasonably foreseeable actions be included in the review (14 Cal Code Regs Section 15378(a). It is not at all clear how the SWRCB anticipates avoiding the segmentation of its Bay-Delta process when it has specifically decided to just that.

The review of the Bay-Delta Water Quality Control Plan includes not only the San Joaquin River fishery flows and southern Delta salinity objectives, but also such things as export limitations, outlfow requirements, other Delta tributary flows, etc. Each of these can affect the other, but the SED ignores this segmentation and treats the San Joaquin River fishery flows and salinity objectives as separate and distinct issues.

It is incumbent upon the SWRCB to explain how it expects to comply with CEQA while examining only portions of the Bay-Delta plan.

It is clear from the SED that the economic analysis and balancing being done is incorrect. The required balancing of economic considerations set forth in Cal. Water Code Section 13241 is not satisfied by examining the impacts on the providers of fish flow water. Those impacts must be balanced against the value of the fisheries and the estuary. Thus the obligation of the SWRCB is not to decide if $X dollars of impacts to tributary water interests is acceptable or not, rather it is to compare the $X impacts to those interests against the $Y costs of the decrease, destruction or improvement of the fisheries and estuary. The SED contains no information on what public trust interests of what value are being balanced.

This raises another point, further touched upon herein below. Before considering ordering upstream interests to forego water for the protection of tributary, San Joaquin River and Delta fisheries, it must first be determined what and who caused the crash of the fisheries. Many parties seek to avoid this determination, warning of its complexity and difficulty. However those who caused a problem should not be able to shift the burden of mitigating the problem onto others by claiming its too hard to identify the guilty party. At the very minimum, the SWRCB already determined in 1978 that in order to fully mitigate the impacts of the projects on fisheries the pumps would have to be shut down (D-1485). Until the export projects mitigate this know impact, there is no justification to make others do the mitigation.

<u>SDWQ ALTERNATIVE #2</u>

SDWQ #2 is based upon the work and report done by Dr. Glenn Hoffman and this section deals mainly with Dr. Hoffman's Report.

The proposed changes to the southern Delta water quality objectives for agricultural beneficial uses are not supported by the data presented, and in fact are not supported by any data. This is because Dr. Hoffman calculated leaching fractions for the area by using information which is not relevant to how much water/salt was applied to the soil and how much water/salt passed through the soil. The tile drainage data he used does not properly reflect the root zone drainage.

Hoffman describes/defines the leaching of salts from a soil column on page 50 of his Report under section 3.13. In order to make sure that salts do not accumulate in the root zone of a crop, the salts must "leach" out of that root zone. For the most part, this is done under normal agricultural practices by insuring that enough applied water (of a certain quality) passes through the root zone to transport enough of the salts out of that zone so they do not accumulate. Depending on the soil type and soil salinity, the quality of water needed may vary. This is of course also dependent on the amount of salt in the soil which can be tolerated by any particular crop. The amount of water needed to do this is commonly known as the "leaching requirement."

Basically, the leaching requirement is the fraction of total water applied that must drain below the root zone to restrict salinity to a specified level according to the level of the tolerance of the crop. Or as Dr. Hoffman puts it "[T]he minimum leaching fraction that a crop can endure without yield reduction is termed the leaching requirement." (Hoffman Report page 50.)

At first Dr. Hoffman recognizes the significant lack of data in the southern Delta situation by noting ". . . measurements of soil salinity or salt concentration of drainage water are not measured routinely . . ." in the area. (Hoffman Report, page 51). However, it is here Dr. Hoffman makes his most important mistake. Because of the lack of drain water data, Dr. Hoffman instead uses subsurface tile drain information, of which there is some old data. On page 51 and thereafter, Dr. Hoffman cites to a number of studies on which he relied. Those studies contain for the most part (and among other things) EC values for certain tile drainage systems.

However, measurements of tile drainage is not measurements of (only) the excess water applied to the surface which passes through the root zone and flushes or leaches out salt. Dr. Hoffman has confused the drain water from laboratory experiments with tile drain water. In the laboratory, a scientist seeking to determine leaching fractions would measure the amount and salinity of the applied water and the amount of salinity of the "drain" water to see how much salt passed through the root zone and was therefore leached. The "drain" water in this circumstance is, and is only the amount of water that went from surface application (applied water) and then made its way through the soil and "out the other end."

In the crop production fields of ongoing agriculture, there are a number of types of drain water. The first is excess applied water which runs off the end of the field. That water has never passed through the root zone and is therefore not relevant to how much water and salt made their way out of the soil. A second type of drain water is the water that indeed passes through the root zone and leaches some amount of salt and therefore would be valuable in determining leaching fractions. However, it is practically impossible to actually measure this water as it would take some sort of isolated collection facility or mechanism to gather this water under the root zone. This brings us to the third type of drainage, which is tile drainage. It is here that Dr. Hoffman makes his error.

Tile drains are (generally) perforated pipes or gravel lined collection pipes which allow the water at or reaching a certain depth to drain into the pipes where it flows to some sort of pump which withdraws it from the ground for discharge. A tile drain can either collect only applied surface water,[1] or it can collect ground water, or it can do both. For the most part, and certainly in the southern Delta, tile drains are installed to control ground water. Especially in those areas of the southern Delta that are at or below 10 feet MSL, the tile drains are for the specific purpose of keeping the poor quality shallow ground water at or below a set depth and out of the root zone. It is of course possible, and in most cases probable that any excess applied

[1] For the purposes of this analysis I am ignoring any rain water in the system.

surface water that does migrate through the root zone could also end up in the tile drain, but once there it would mix with the ground water. Once mixed, no reasonable conclusion about how much of the salt in the tile drain is due to leaching and how much is due to ground water can be made. Clearly, Dr. Hoffman simple assumed that the subsurface or tile drain information in the studies he referenced were in fact samples of excess applied surface water and not ground water.

Thus we see that in order to calculate leaching fractions for the southern Delta Dr. Hoffman used inappropriate data. He compared applied water quality with tile drainage water quality to calculate how much salt passed through the root zone. Unfortunately the salt in the tile drain ground water is not any meaningful indication of the amount of salt that passed through the root zone. Dr. Hoffman's conclusions have no basis in fact.

As further evidence of the above, SDWA is also submitting the declarations of a number of local farmers (Exhibits "A"). In the recent hearing on the draft SED SDWA referenced a communication with someone from the New Jerusalem Drainage District. The referenced discussion dealt with an assertion that the NJDD drains (the data of which was used by Dr. Hoffman) contain very little if any ground water as they were designed and installed to intercept the problem ground water. That representative decided to not provide a declaration, but the SWRCB staff can certainly investigate this particular issue. The declarations which are provided herewith include Greg Pombo, a local farmer and Board member of the Pescadero Reclamation District who currently owns a tile drain on Pescadero Tract, and is familiar with a nearby tile drain which was sampled in one of the repots relied upon by Dr. Hoffman. Mr. Pombo indicates that tile drain is for the purpose of maintaining ground water levels and very little excess applied surface water enters it. Similarly, the declaration of Jack Alvarez, board member of the South Delta Water Agency and West Side Irrigation District indicates that the tile drains in his area, on which Dr. Hoffman relied also are for the most part intercepting ground water (from upslope irrigation) and have very little excess applied surface water in them.

Per Table 3.10 of his Report, Dr. Hoffman calculates a leaching fraction for the tile drains from the Chilcott, et. al. Report. For the drain location identified as "11 Delta Ave." (which is the Pescadero Tract drain mentioned above) Dr. Hoffman calculates a leaching fraction of 0.21 from an assumed applied water of 0.5 EC and a drain sample of 2.4 EC (0.5 divided by 2.4 equals 0.208). Obviously if the ground water is 2.4 EC we know nothing of the quality of the water which leached into that ground water. It could have been 2.4, 1.5, 0.7, 0.5, or 0.2 EC. Each would result in significantly different leaching fractions, but each is irrelevant until we know the actual drain water quality. By simply assuming the quality of the drain water we can get any number of results; which is what Dr. Hoffman did by using tile drain water. Perhaps the tile drain data showed a water quality of 9.0 EC (the highest ground water EC in the Montoya Report cited by Dr. Hoffman). The 9.0 EC sample when compared to an applied water EC of 0.7 would show lots of salt being leached out, but again would not mean anything unless the 9.0 EC was the water that passed through the soils and only that water. Without knowing what the quality of the leached water was before it mixed with the bad ground water, we cannot know and cannot calculate the leaching fraction. This becomes even more unreliable when we consider that the assumptions of the applied water are likely wrong also. As set forth below, assuming that diversions from Delta water channels are 0.5 EC or 0.7 EC is completely wrong. In typical summer months, the supply water quality from those channels is always over 0.7 EC. Obviously, from a scientific perspective one cannot hope that two sets of useless data will counteract each other to produce reliable conclusions.

Turning to the Montoya Report referenced above, that Report was one of those relied upon by Dr. Hoffman for data gathered on water quality (Hoffman Report pages 51- 52). As Dr. Hoffman notes, using some of the Montoya data results in some very high leaching fractions. Dr. Hoffman states: "The average electrical conductivity of the 26 outlets was 1.5 d/S/m. If the salinity of the applied water was 0.7 dS/m then the leaching fraction would be 0.7/1.5=0.47. This is a very high leaching fraction and based on these data one would surmise that the irrigation efficiency, on average, is low and/or a great deal of low salinity water was entering the drains without passing through the crop root zone. If the main drains were open surface drains then it is possible that much of the discharge from these drains was irrigation return flow rather than subsurface drainage." (Hoffman Report, page 52).

As Dr. Hoffman concludes, an open, surface drain does indeed contain excess applied surface water, as well as seepage from the shallow ground water, which itself contains some amount of excess surface water that was applied to the crops and which passed through the root zone. Dr. Hoffman's caution at using this data confirms the unreliability of the subsurface tile drain data he used, as in that case we also do not know what proportion if any of that water is the water which passed through the root zone. (See Declarations of Pombo and Alvarez, Exhibit "A")

Further complicating the Montoya report is its reference to samples taken by DWR of numerous surface drains. The record reveals no such sampling study, only the authors citation to "Unpublished DWR Operations and Maintenance Surveys" and other "MWQI data query requests." We cannot possibly know if the samples of these drains were from someone taking grab samples from a ditch, from a waterway into which the drainage is discharged or the flow of water out of the pipe before it reached the waterway. In sum, there is no data of the salts in the water which passed through the root zones in the southern Delta by which on might calculate an estimated leaching fraction.

Without knowing the amount of leaching which occurred at any particular time or at any particular place, there is no basis on which to proposed changes to water quality objectives for agricultural beneficial uses in the southern Delta.

If one assumes that the tile drain water quality used by Dr. Hoffman can be sued to calculate leaching fractions, there is still no basis on which to make changes to the water quality objectives for agricultural beneficial uses in the southern Delta. This is because Dr. Hoffman used water quality information that is not indicative of the channels of the southern Delta or the lands which use that water.

Dr. Hoffman used assumed water quality data because no actual sampling data existed. He was apparently not able to find any actual data for the water quality for the years for which he had tile drainage water quality data. A review of CDEC (the California Department of Water Resources Data Exchange Center which contains current and historic flow and quality data) indicates that water quality data exists for the Old River at Tracy Blvd. Bridge site only back through 2005. The record does not contain any efforts by Dr. Hoffman to see if the West Side Irrigation District (which diverts just downstream of this site) water quality data was available (see declaration of Jack Alvarez) or why he did not use the historic data contained in the SED

A survey of recent dry years (see Exhibit "B") indicates that water quality at this Old River site is regularly above the 0.7 standard in the summer months, indicating that Dr. Hoffman's assumptions are not justified. In addition, the SWRCB records contain the reports by DWR of water quality violations of the standards. These reports are pursuant to the Cease and Desist Order against DWR and USBR. We see from the most recent water quality data, that even the 1.0 EC standard was violated in February 2013 (see Exhibit "C").

Further, the areas where the tile drainage data was derived are for the most part within West Side Irrigation District and Banta-Carbona Irrigation District. West Side ID gets water from Old River just downstream of the monitoring station referenced above as well as water from the CVP Delta Mendota Canal (DMC). Banta-Carbona gets water from the San Joaquin River just downstream of the Vernalis monitoring station as well as from the same DMC. The West Side ID intake water quality might be the same, worse or better quality than that recorded at the Tracy Blvd Bridge location. Dr. Hoffman uses data of tile drains generated in roughly the late 1980's (see Chilcott, et. al. and Belden, et. al.). That information predates the current USBR operations which control water quality at Vernalis and predates the yearly installation of the temporary rock barriers installed in Old River, Middle River and Grant Line Canal (from approximately My through October).

This out-of-date data is important for a number of reasons. First, the record fails to note that water quality in the south Delta channels predating the current operation of New Melones is generally worse, depending on the location. A worse water quality (applied water) would result in a lower leaching fraction when compared to the drainage EC). Second, although the barriers help improve water levels lowered due to the operation of the export pumps, they also affect the location and extent of null, or no-net flow zones where salts collect and concentrate. Finally, by not knowing or describing the water year types for the years in which tile drainage information was obtained, one cannot even guess as to what the applied water quality was that resulted in the drainage water.

In addition to the lack of actual, current water quality data, Dr. Hoffman used tile drainage water from areas with significantly different soils types and characteristics. These differences are actually noted in his Report at pages 7 et seq .and especially Figure 2.4. The areas of concern in the South Delta are those which rely on the worst quality of water. Such areas as those portions of Fabian Tract, Naglee-Burke, Union Island, Pescadero Tract and Upper and Middle Roberts Island which rely on water from null zones and dead-end sloughs. Figure 2.4 graphically shows how theses area of concern in the southern Delta have different soil types than those where the tile drain data came from (see SDWA Power Point attached hereto as Exhibit “D”). Dr. Hoffman also shows us in Figure 3.7 of his Report that a strip of saline soil divides the area of the tile drains from the areas which divert from the channels, but fails to consider how that might be affecting his data..

Per the SDWA Power Point referenced above, the elevations of the tile drain sites range from 3 feet above sea level to 109 feet above sea level, with most of the sites being in the range of 21-70 feet above sea level. The areas of the southern Delta which rely on the channel water are generally from -5 to +10 feet above sea level where the tides affect the shallow ground water. The locations of the tile drains used by Dr. Hoffman are unaffected by tides (see Declaration of Jack Alvarez).

As described above, most of the tile drains from which data was derived are located within the West Side Irrigation District service area. WSID’s intake on Old River is between a temporary barrier site and the compliance location for the Old River at Tracy Blvd. Bridge objective. DWR modeling and information submitted herewith show that this area between the barrier and Tracy Blvd. is a null zone. With net flow upstream at the barrier and downstream at the Bridge, the center area null zone is where salts collect and concentrate. Dr. Hoffman therefore presents no information as to whether the irrigation supply water for the lands over the tile drains within WSID was 0.5, 0.7, 1.0 or 2.0 EC. Without having any measurements of water quality from Old River, no assumption about its quality can be made and thus no leaching calculation can be made.

It is of note that the data in the studies used by Dr. Hoffman are for the most part samples from the early spring months (see Chilcott, et. al., page 5). Typically, the flows in the Delta are fresher during the higher flow spring months meaning that the water quality is better. This means that even if the assumptions of Dr. Hoffman can be defended, he is analyzing leaching fractions at a time when there may have been no real salt problem

Thus we see that even if the data used by Dr. Hoffman can be used to calculate leaching fractions, it could only be used for such calculations in areas not dependent on the current water quality standards. Using incorrect/unknown applied water quality from areas well above the tidal effects on ground water, in soils different from the areas using Delta channel waters with high ground water does not pass as reliable data.

In light of all this, we see that Dr. Hoffman used data that was simply not indicative of current conditions.

REPORTS RELIED UPON BY HOFFMAN

The Chilcott, et. al. Report consisted of tile drain sampling and testing during 1986 and 1987. The 1986 samples were taken in April and the 1987 samples were taken in June; neither being a time when poor water quality is commonly a problem in the south Delta. The data used by Dr. Hoffman was for the "Zone C" area in the Chilcott Report, which Zone included "14 sites" page 10 therein) though the chart of Zone C sites lists only 13, (page 44) and the map (page 32) also shows only 13 sites. However, Dr. Hoffman in his Figure 3.18 and Table 3.10 identifies 24 sites from the Chilcott, et. al report. The source of this additional data should be clarified.

The Belden, et. al. Report cited by Dr. Hoffman includes data from 1986 and 1987 and only from those years, but Dr. Hoffman references data from 1977 - 2005. The record does not indicate from where this additional data comes. Similarly, DR. Hoffman cites the same Belden, et. al. Report for "Tracy Boulevard Tile Drain Sump" data from 1982 - 1987. However the Belden report again only contains data from 1986 and 1987. Dr. Hoffman makes reference to a personal communication with D. Wescott in 2009, but we find no record of that communication in the record or any data that may have been provided therewith.

The Montoya report cited by Dr. Hoffman can be disregarded as merely a position paper arguing why DWR is not responsible for any of the problems in the southern Delta. It does not appear to include any real science given its numerous factual errors. It attempts to identify agricultural discharges in the south Delta as the "source" of the salts in the area while being completely silent about the hundreds of thousands of tons of CVP salt entering the area each year. The report includes references to Chilcott, et. al. And Belden, et. al., and then sites to "other" DWR sampling data, the source of which is not provided. As counsel for the SDWA, I can assure the SWRCB and its staff that no local farmer would have authorized DWR to sample his/her drains for this study.

We repeat that the data used from these studies/reports predates all of the current operations and water quality standards, and is of tile drain water, not just the water that passed through the soil profile.

LEACHING MODELING

Models are typically used when it is either impossible or impractical to create experimental conditions where outcomes can be directly measured. Direct measurement of outcomes under controlled conditions will always be more reliable than modeled estimates of outcomes. Because of this, a model should and cannot be used to confirm an analysis that used inadequate or false data. Models can only attempt to reflect relationships determined by actual conditions and cause/effect processes. In this case, Dr. Hoffman came up with leaching fractions based on inaccurate information and then adjusted the various models and inputs in order to have one model agree with the incorrect leaching fractions.

The models examined by Dr. Hoffman include steady-state and transient. Each has numerous assumptions which determine how the model treats inputs and thus how it calculates leaching fractions. In order to make a model, or permutation thereof match the leaching fractions he calculated, Dr. Hoffman adjusted the steady state model. First of all he included data on rainfall. While it is true that rainfall can affect the amount of water added to the soil column and thus affect leaching, a generalization of that rainfall's effect is near meaningless. Dr. Hoffman looked at average rainfall for the area, and his assumption of that average may or may not be useful. However, what is important is when and how much rain falls.

For example, if our area experiences a half inch of rain, that half inch will likely never move very far through the soil profile; evaporation or evapo-transpiration via weeds or other ground cover would prevent such movement by totally "consuming" all of the rain. If the rainfall for any particular year comes in small increments, then the total amount of leaching from it may be zero. As is common in our area, rainfall does indeed come in spurts, with the extended events being much more rare. However, using the average rainfall and calculating its effectiveness as Dr. Hoffman proposes would result in the conclusion that leaching due to rainfall does occur every year, and thus any leaching fraction would be based on this false assumption.

It does not matter that the rainfall episodes over time might somehow average out so that over time some leaching is accomplished; a lack of a certain level of leaching in one year is not somehow undone by leaching in another year.

While Dr. Hoffman added a leaching provision for rainfall, he failed to decrease the leaching which occurs due to the shallow ground water in the South Delta. As we see from the Declaration of Joseph Ratto (Exhibit "A") in some places the ground water in the area is at 3 feet below the surface. Since the tidal action in the channels pushes the salt which leached into the ground water back up [See Exhibit "T"], that increment of salt must be put back in to calculate a leaching fraction. Once the salt left the root zone the model counts that as a loss, so if the salt returns to the root zone there must be a gain. Dr. Hoffman also discounts the effects of shallow ground water at a depth of 5 feet and does not provide for the crops using any of this shallow groundwater. He postulates without citation that most crops in the area don't have roots that go that deep. Pursuant to the attached Declaration of Jerry Robinson (Exhibit "R"), many local crops do indeed have roots which extend to the shallow, poor quality groundwater.

Two water uptake distribution functions were utilized for steady state modeling; the 40-30-20-10 water uptake and the exponential water uptake. Hoffman recommends the exponential uptake distribution over the 40-30-20-10 water distribution in steady state modeling because the exponential distribution agrees more closely with the transient model results than does the 40-30-20-10 distribution.

Dr. Hoffman also chose to include an exponential water uptake component to the steady state model in contrast to the 40-30-20-10 water uptake function. However, the decision to use that component ***determines*** whether 0.7 or 1.0 EC is effective in protecting the crops. This choice was made by Dr. Hoffman in order to find the model configuration which would coincide with the leaching fraction conclusions he made so he could identify the model which best reflects his data. He states the reason for doing so is ". . . the exponential distribution agrees more closely with transient model results than the 40-30-20-10 distribution." However, the transient models lack field validation. This is chicken and egg; if the leaching fractions calculated were wrong then the model configuration to also arrive at those leaching fractions is wrong. Choosing that which agrees with your conclusions is not confirmation of your conclusions. Again, models are used to predict the future because there is inadequate data. Therefore when you choose a model which seems to confirm your contention is not a confirmation, it is choosing agreement; not proving agreement. This point was confirmed a number of times in the Hoffman Report where the Dr. notes field studies and new data is necessary to confirm both his findings and modeling results. To date, not such other studies or validation has occurred.

Tellingly, the modeling Dr. Hoffman chooses as most representative of his calculated leaching fractions does not work if water flows through the root zone in more than one direction. Hence, if there is a groundwater contribution and a raising of that groundwater via the tides, Dr. Hoffman's modeling is invalid according to his own paper. (See Hoffman, G. J. and M. Th. Van Genuchten, 1983 cited in the Hoffman Report.)

The claims and data regarding the salt tolerances of beans is misplaced. We can't start the investigation by identifying the leaching fraction beans may need, we must first determine what leaching is occurring and then see what crop can tolerate that amount of leaching. The discussion about selecting beans as the indicator crop are misplaced. As Alex Hildebrand stated repeatedly, since some areas simply cannot get very much leaching if any at some times, the salt tolerance of the crop is not the issue. The ability to leach is. (Exhibit "E") is the undated Study coauthored by Dr. Hoffman and Terry Prichard. In that study the very low permeabilities of southern Delta soils were identified as inhibiting the ability to leach. However, Dr. Hoffman has now changed his mind and now asserts that saltier water will increase permeability!

Regardless, the Hoffman Report does not explain how any crop can tolerate any level of salt i the applied water when the soil only allows water to pass at a rate of 0.2 feet per hour. It doesn't matter if the crop is alfalfa , beans or anything else; if the water cannot move through the soil column leaching does not occur.[2]

PROGRAM OF IMPLEMENTATION

Appendix K sets forth the Program of Implementation for the proposed changes to the Water Quality Control Plan currently being considered. With regard to the SDWQ, the Program appears to be insufficient and prejudicial to the eventual water rights proceeding which is necessary to implement the Plan (by assigning responsibilities via changes to water right permitees and licensees).

The 1995 WQCP's Program of Implementation (with regard to the salinity objectives) first specified when the objectives would become effective. It noted the various causes of the salinity problems in the southern Delta. It also noted that USBR was (then) currently responsible for meeting a different Vernalis standard and that other salt related processes were ongoing which might help achieve the new standards. Thereafter it noted that the SWRCB would evaluate implementation measures for the salinity objectives in the water rights proceeding.

In D-1641, after an evidentiary hearing of 80+ days the SWRCB found that the CVP was primarily responsible for the elevated salts in the San Joaquin River and southern Delta and that the operation of both projects adversely affected salinity in the southern Delta. D-1641 therefore assigned responsibility for meting the four southern Delta objectives to USBR and DWR.

The 2006 WQCP's Program of Implementation also listed the causes of the salt problem in the southern Delta and also noted the ongoing obligation of the projects to meet these objectives.

The proposed Program of Implementation contained in the SED appears to be indicating that the permits of DWR and USBR will not be conditioned to meet the interior southern Delta salinity standards. This is of course unsupportable unless or until an evidentiary hearing (such as the one which will follow any changes to the WQCP) determines that the projects are not somehow responsible for the conditions in the southern Delta.

The proposed Program correctly notes that USBR should/would still meet the Vernalis objective of 0.7 EC (Apr-Aug) in order that the three interior standards can be met. The Program could just as easily have simply required that the Brandt Bridge standard be met which would

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[2] SDWA is including with these comments its exhibits from the CDO hearing and the Delta Protection Commission's Economic Sustainability Report given their relevance to these issues, and identified as Exhibits "Q" and "S."

have of course resulted in the Vernalis standard also being met, and likely improve conditions throughout the southern Delta.

The proposed Program goes on to require (again before any evidentiary hearing on water rights) a number of studies and actions by the projects which appear to not only gather more information, but to gather information for the purpose of determining the extent of the projects' responsibility for the southern Delta salinity problems and mitigating project effects. These conditions in a WQCP are not self-effectuating and not binding unless and until a water rights proceeding is completed. It appears that the SWRCB has already decided what will occur in the water rights proceeding; that the projects will not longer be responsible for meeting the interior southern Delta objectives.

It should be noted that the SWRCB conducted and concluded two evidentiary hearing for a Cease and Desist Order, which orders reaffirmed the projects responsibilities for the salinity conditions in the southern Delta and which confirmed their ongoing permit obligations to take actions to meet the objectives. As stated above, the proposed Program suggests that the SWRCB has already concluded factual issues relating to the projects obligations prior to the evidentiary water rights proceeding and contrary to the existing findings and conclusions from the CDO hearings.

Therefore the proposed Program of Implementation should be altered to clearly state that the USBR and DWR obligations for meeting the southern Delta water quality objectives remains unless and until the to-be-conducted water rights proceeding determines and assigns otherwise.

CAUSES OF SALINITY PROBLEMS

In the review of the salinity standards other parties including exporters, DWR and USBR presented testimony and documents dealing with the projects' effects on San Joaquin River and southern Delta water quality. Such information was not the subject of these proceedings and should not be considered when adopting any changes to the objectives. However, since such information was presented, SDWA believes it appropriate to provide information in opposition to that provided by exporters, DWR and USBR.

Certain export interests suggested that the balancing done under Water Code Section 13241 would result in a determination that the cost of meeting the salinity standards far outweighs the benefits of meeting them. Such a position is untenable. The balancing required by the Water Code deals with the overall, or gross considerations to be evaluated when deciding the level to which we should preserve good water quality and protect a beneficial use or public trust interest. In this instance, the exporters, DWR and USBR are directly responsible for decreasing San Joaquin River flows by hundreds of thousands of acre feet each year, adding hundreds of thousands of ton of imported salt into the San Joaquin River and Delta, radically altering flows in the southern Delta, creating and exacerbating null zones, and decreasing water levels to the point where local diversions cannot occur. (See 1980 Report, Exhibit "F" hereto). A partial mitigation of some of these impacts (the temporary barriers) further exacerbates the null zones in the area causing increased salinity in portions of the channels. The parties causing these effects cannot legally complain that forcing them to address and mitigate these effects must be balanced against the benefits to those being injured.

The exporter and project position is like Exxon (as in Exxon Valdez) arguing it need not clean up hundreds of miles of oil drenched Alaskan coastline "because it costs too much." Those parties polluting the River and Delta cannot weigh the impacts of stopping illegal and harmful activities against complying with state and federal water quality laws and principles of tort. To the extent all users of the River and Delta jointly contribute to an overall degradation, the SWRCB can balance the overall costs of requiring protective actions on them against the benefits of such actions. However, such balancing does not apply to stopping polluters.

DWR suggested that it mitigates its impacts on water levels via the barrier program, and that with the barriers the southern Delta is in virtually the same condition as it was prior to the projects. This is of course not true. In the absence of the CVP and SWP, there ***were*** times when San Joaquin River flow was such that null zones existed in certain channels in the south Delta. This of course is due to the incoming tidal flows blocking the River flow from passing through the system. When the River flow meets the tidal flow and local consumptive use (including evaporation, riverine vegetation, agricultural use, etc.) reaches a certain level the amount of River flow is insufficient to create a net flow in the downstream direction. However, when this occurred pre-project, the River flow was of excellent quality (see Exhibit "G" which is Figure VI-27 from the 1980 Report), and the null zones sloshed back and forth on the tides causing the mixing/dilution of the salts.

Under the current situation, the projects must install barriers to mitigate their adverse impacts to water levels. These barriers now trap virtually all of the CVP introduced River salts, and rather than there being mixing and dilution, most of the CVP salt cannot pass beyond the barriers and is thus always in the southern Delta channels where it concentrates to levels which are magnitudes above historic conditions. Included herewith is the 1980 Report on the Effects of the CVP authored by SDWA and USBR. This document clearly identifies and quantifies these impacts. No amount of "new modeling" can change the underlying facts.

DWR also asserted that rather than the hundreds of thousands of tons of CVP salt being the problem in the area, that there must be a "salt source" somewhere in the south Delta, likely in Paradise Cut. Initially one must ask why some other source than the hundreds of thousand of tons of foreign salt would even be considered. A few years ago DWR was speculating that some sort of ground water accreting to the River was the cause of the Old River salt problem; now it is Paradise Cut.

Of course further study is necessary to confirm or deny any "source" of salt and SDWA will cooperate with such inquiries and evaluations. Questions need to be asked, such as "what amount of salt must exit Paradise Cut to significantly degrade Old River at Tracy Blvd. Bridge?" Can a channel that has a net outflow of 20 cfs or less (speculation) contain enough salt to affect Old River flows? What could be producing that amount of salt in this small channel? Do the barriers exacerbate this "new source" of salt? There are many variables and questions, none of which have been addressed. However, it bears noting that if this "new source" of salt is simply the result of farming on Pescadero Tract (which generally drains into the Cut) and the accretion of poor local ground water, then the projects cannot therefore shirk their responsibilities. The farmers' drains and the ground water are a function of the 50+ years of CVP salts entering the area and mostly staying in the area. The projects cannot create a system whereby local farmers must use poor quality water and then complain those same farmers have poor quality drain water.

Lastly, DWR argues that the temporary barriers fully mitigate their effects on water levels; DWR made no mention of whether this position held true for the Bureau as well. As per Chapter VII of the 1980 Report referenced above, the CVP export pumps run 24 hours a day. This means they decrease water levels on every tide at ever stage. The 1980 Report estimates the effect at about 0.10 tenth of a foot per 1,000 cfs of CVP exports. For the SWP (not at full capacity at the time of the Report and not operating under current CCF criteria) is estimated the effect of a similar 0.10 tenth of a foot on the high tide per 1,000 cfs of export.

As you can see, and as estimated by the Report, this means that at full capacity, the projects would lower the high tide from 1.34-1.76 feet on the high tide, with the corresponding lowering on all other stages of tide by the CVP. The caveat to this is that the SWP has developed different operating criteria for its CCF radial gates. Exhibit "H" sets forth the three main operating "Priorities" for those gates. As you can see, the SWP now alters the timing (tidal-wise) of letting water into CCF, not limiting itself to only taking water during the high tide as analyzed in the 1980 Report. We see then that the SWP sometimes also takes water on the low-high tide, sometimes on both high tides, and sometimes on both high, and the high-low tides. I am informed that the SWP operations under Priority 1 are the best for SDWA water levels, but are only used when exports are extremely low. You will note that SWP operations appear to be based on export needs and not on the protection of local diverters.

Exhibit "I" includes some recent data provided by DWR showing water level impacts under different scenarios, with no tidal barriers in place. As can be seen, the actual, measured water levels are sometimes up to one foot higher than the modeled water levels indicating that the modeling of impacts to water levels is sometimes understated by a foot. [Exhibit "J" is the export data for this time period; showing that these impacts to water levels are occurring during low export times.]

It is difficult to read the graphs, but given the nature of export pumping, the lowering of the low tides cannot but be significant also. During this time, numerous diverters along Old River, Middle River and Tom Paine Slough were unable to divert as needed.

What is less clear are the exact effects on water levels behind the barriers. The crests of the barriers are lower than the high tide, meaning they do not hold all of the tide, but that some flows back downstream over the tops during the ebb tide. In addition, the barriers are made of rocks which means some water flows back downstream through them. The result is that although the barriers hold water at a higher stage for a longer time period than would occur under "normal" conditions, they do not hold the high tide. The projects' export pumping (while the barriers are in) still decreases the tide coming in, which means some amount of water and energy of the tides is lost. So too are lost the benefits of that water and energy on dilution, supply and mixing (assimilation). The degree of these effects needs to be determined in an evidentiary proceeding, but it is clear that although the barriers are needed to allow local diversions in the presence of exports, local diverters are much worse off by not having the flow and stage and quality that existed pre-project.

Quantifying the degree to which the CVP and SWP affect levels and salinity in the area can be complicated and is not fully explained by DWR's efforts to simplify the situation before the Board. What should be remembered is that prior to the CVP and SWP, the local farmer grew crops and prospered even during low flow times. Now, nearly each year water level problems occur and hundreds of thousands of tons of CVP salts enter the area and concentrate.[3]

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[3] Exhibit "L" is the DWR 1956 Study indicating that the River salts typically accumulate in the soils during summer months, improving export water quality. This collection and storage of salts is not considered by Dr. Hoffman.

ANALYSIS OF SDWQ ALTERNATIVES

The SED's evaluation of alternatives under CEQA presents some problems. As described in Section 3.4.1 and at other places, the SED compares a "no project" and two other alternatives to the "baseline" conditions. The baseline is the current conditions at the time the time the project was proposed (when the NOP is published), the no project alternative is what would happen now and in the future if the project does no go forth, and the other two alternatives are possible projects to be considered for adoption.

Oddly, the SED specifies that for the no project alternative it is assumed that there will be "full compliance with flow and water quality objectives in the 2006 Bay-Delta Plan." This is of course false. Notwithstanding the peculiarities of CEQA, one cannot assume for any purpose that the no project alternative would include full compliance with the southern Delta water quality objectives.

As is so succinctly put forth in the SED, the objectives were adopted in 1978 but not implemented until the 1995 WQCP was implemented through D-1641 on 2000. Even then, D-1641 failed to implement the objectives as set forth in the program of implementation in the 1995 Plan. Only the Vernalis objective was immediately" implemented with the other three delayed until 2005, and then they could be "changed under certain conditions (a provision found to be illegal by the courts). Once the objectives became effective, the projects immediately petitioned for them to be relaxed or the obligation of the projects to meet them be altered/removed. Numerous violations occurred thereafter (see for example Exhibit "K"). The SWRCB then held two hearings, the first to adopt a CDO against the USBR and DWR, and then a second on the same CDO in order to change the provisions therein that the projects were going to violate.

The CDO did not even require compliance with the existing permit obligations of the projects to meet the objectives, but rather blandly directed that "future threatened violations be obviated;" which in hindsight confirms the SWRCB's lack of desire to burden the projects. Thereafter, the SWRCB began this process to "re-examine" the salinity standards which translates into "find a way to not enforce the rules against the projects."

Thus, the clear, uninterrupted and unchanging history of the southern Delta salinity objectives is one of non-compliance, not compliance. As recently as February 2013, the Old River at Tracy Blvd. Bridge compliance location was being violated (the 1.0 EC standard not the 0.7 EC standard.).

It also should be noted that the 2006 WQCP clarified that the objectives applied throughout the channels and not just at the compliance/monitoring stations. It is not clear how the SED considered the means by which such compliance would be achieved in the null zone in Old River when the temporary barriers are installed.

The SED's analysis of the alternatives begins with description of the monthly average EC levels at the four objective compliance locations. This is inappropriate for two reason. The first is that averages of monthly EC levels masks the impacts of high salinity events/times. If the EC rises above the point where impacts to crops occur, it does not matter if a lower salinity occurred in the same 30 day period. Once the adverse impacts occur, a later improvement does not undo those impacts. Neither the SED or Dr. Hoffman take this into consideration.

Second, the monthly EC values for the four stations does not adequately describe what is happening in the null zones. The worst water quality in the southern Delta is in Old River between the Tracy Blvd Bridge station and the Old River barrier downstream thereof. By not evaluating the conditions in this worst area, the analysis is incomplete. What happens in the worst area is surely an environmental effect that must be analyzed under CEQA.

In addition, the time frame analyzed is too short. The SED looks at EC values from 1993-2009 when much more extensive data exists. A better approach would be to examine a broader set of years and look at each years EC's and projected effects thereto caused by the alternatives. Again, the damages from a bad year of salt is not somehow undo or cured by a following good year.

Another problem with the SED is that is ignores export pumping by the projects and the delivery of water to those areas of the CVP service area which drain salts into the River. The SED goes to great lengths to avoid mentioning this universally recognized cause of the San Joaquin River salinity problems, mentioning only that drainage from Salt and Mud Sloughs contribute salts. When looking at alternatives, the analysis should include changes in deliveries to the CVP service area and changes to export operations.

The SED mentions that minimum flows on the tributaries would not change, but those flows are only a portion of the summer and fall flows in the River. Much of that flow is return flow from tributary users. Obviously, if the tributaries are forced to release more water in winter and spring, they will make best efforts to decrease any losses to the River at other times of the year.

The SED then compares the number of months when EC values exceed the objectives over the 82-year period for each LSJR alternative to evaluate those alternatives. Again, this appears to mask any effects of the alternatives. The degree to which the EC in any particular month exceeds an objective is the measure by which damage can be determined, not whether that month had an exceedence. It is not clear how measuring the LSJR alternatives' effects on EC at the various compliance locations should be handled. Does the SED not anticipate additional actions would be necessary to mitigate or offset those adverse effects identified in the Tables in Chapter 5?

Appendix F analysis/presentation of the flow and salinity modeling appears to only cover the years 2000-2003 in its evaluation of historic flows and salinity at different locations. However, the failure to include years when the San Joaquin River flow dropped to approximately 500 cfs in July and/or August suggests that the data used is insufficient to give a complete and reliable representation of conditions or the effects of the alternatives on the environment. (See Exhibit "M").

It appears that the sum total of the SED's analysis of the proposed changes to the salinity objectives is the conclusion that by requiring the USBR to continue to meet the 0.7 EC at Vernalis, there will be no changes when compared to the baseline and therefore no environmental impacts. Although there is some perverse logic in this approach, it is not adequate.

The purpose of adopting water quality objectives is to protect specified beneficial uses. The proposed changes to the salinity objectives are (purportedly) to protect agricultural beneficial uses. As written, the SED's analysis of those changes concludes that since the current objectives are not enforced or regularly met, any changes to the objectives that do not alter the current situation are acceptable and without environmental effect.

This approach assumes that the SWRCB will adopt water quality objectives but not enforce them. This is not only contrary to the policies underlying water quality control plans, but is in direct conflict with the requirement to provide a program of implementation. As can be seen from Exhibit "C", just this year the 1.0 EC objective was violated in February. Per the SED, nothing will change this and we should expect that this objective will continue to be violated. Since we violate the objective now, violating it under the new objectives is irrelevant. To the contrary, the SWRCB must identify the beneficial use, propose and adopt water quality objectives to protect that use, and implement those objectives. The process breaks down if it is assumed that the Board will perpetuate and authorize continued violations.

The SED should analyze full compliance with the proposed alternatives not being enforced to get an accurate picture of the effects of the project.

It is important to note that the USBR currently betters the Vernalis standard when that standard is 0.7 EC (see Exhibit "N"). The SED should include an analysis of what would result if the Bureau now simply meets the 0,7 and does not better it. In that event, the conditions downstream at the three other compliance locations would be worse. The reason for such an analysis is that the incentives for USBR are different when the Vernalis objective is 0.7 as compared to the objective being 1.0 but with an implementation requirement of 0.7. When the objective is 0.7, the Bureau acts with caution to not violate it and thus adds a "cushion" and betters the objective. When the objective is 1.0, the incentive to better the implementation requirement disappears since the Bureau is no longer worried about violating Vernalis.

LSJR ALTERNATIVES

SDWA does not take a position on what flows are necessary to protect and recover fisheries. However, a few comments are warranted. The SED's selection of alternatives appears to ignores various existing laws. For example, Federal law (CVPIA) requires the doubling of certain anadromous fish populations, but the SED has no alternative to implement the AFRP flow goals.

Similarly, Federal law (HR 2828) requires that the Bureau decrease its use of New Melones water in meeting its obligations for water quality standards on the San Joaquin River, yet no alternative does this or models this. HR 2828 also requires the Bureau to (have already) develop(ed) a plan to meet its obligations for water quality, yet there is no such plan provided by the Bureau or included in the SED.

Current DWR and USBR permits require them to be in compliance with state and federal ESA law. However DWR for many years was in violation for not having any CESA take permit. Its recent compliance was based on consistency opinions from DFG (now CDFW) which were based on Biological Opinions. However, recent judicial opinions nullified some of those BiOP provisions bringing into question DWR compliance once again.

SILTATION AND FLOODING

Chapter 6 at page 6-8 in Table 6-3 indicates that the capacity of the San Joaquin River at Vernalis is 66,000 cfs, and 14,000 cfs in excess of design capacity. This appears to be incorrect. Recent flood events, especially 1995 indicated that the capacity at Vernalis was substantially less that the design capacity.

This Chapter does not appear to analyze the effects of additional siltation occurring if greater fishery flows are required. The LSJR alternatives would not only shift the timing of flows and the amount of flow reaching the Delta, but also increase the magnitude of flows. These changes should alter the timing and amount of siltation reaching the Delta, where slower flows result in the sediments settling out of the water. Any changes in the amount or location of these sediments could affect channel capacities, which affects flows and quality.

AQUATIC RESOURCES

Chapter 7 of the SED does not examine how the proposed salinity changes might affect aquatic life. EPA promulgated water quality standards for the protection of striped bass in 1995 that are still in effect (see 40 CFR 131.37, beginning at page 4696, attached hereto as Exhibit "O"). Those standards set an EC standard of 0.44 micromhos, 14-day running average, in April and May for Vernalis, Mossdale, Brandt Bridge, Rough & Ready Island, Buckley Cove et al. when the SJR index was greater than 2.5. Below 2.5, the standard only applied at Jersey Point, San Andreas Landing and Prisoners Point. The criteria was based on a number of identified studies (attached hereto as Exhibit "P"). The SED must examine how the proposed changes in the salinity objectives might affect striped bass and any other fish or aquatic plant species regardless of the current conditions or standards.

GROUND WATER RESOURCES

Chapter 9 contains no evaluation of how the increased fishery flows will affect the ground water the Delta. The issue is how elevated flows might affect the movement of the poor quality ground water into the Delta channels and the corresponding effects on water quality. It is not clearly understood how and when flows activate the local ground water, but it is generally accepted that when flows rise to a certain level, they begin to move more of the ground water into the channels where it is transported out of the area. This movement of the salts stored in the ground water is recognized in a DWR report, included herewith as Exhibit "L." If the increased fishery flows correspond to times when the 1.0 EC objective is at risk (many winters), then the potential effects must be analyzed.

We note here that just because an objective is not exceeded, and increase in the channel EC can still be adverse to beneficial users.

ANTI-DEGRADATION

The SED's three page chapter titled "Anti-degradation Analysis" does nothing more than briefly describe and refer to the state and federal anti-degradation policy. No analysis of either policy is included and there is no discussion of how anti-degradation policies are implemented. Further, the SED fails to discuss the Board's Administrative Procedures Update regarding anti-degradation analysis (APU 90-004) and neglects to incorporate the Board's 1987 Guidance Memorandum Implementing Federal Anti-degradation Policy by its then Chief Counsel William Atwater.

These omissions have deprived stakeholders, and members of the Board for that matter, of an opportunity to fully examine and comment upon same. Nevertheless, an examination of the federal and state anti-degradation policies clearly indicates that lessening of water quality standards in the south Delta cannot and will not be consistent with the federal and state anti-degradation policies. For this reason alone the SED is wholly inadequate.

A. The Relationship of the Federal and State Anti-degradation Policies

The federal anti-degradation policy set forth in 40 CFR §131.12 applies to changes in water quality to any "waters of the United States."[4] The term "waters of the United States" is broadly defined to include essentially all surface waters.[5] The federal Environmental Protection Agency Water Quality Standards regulations require that each state adopt an anti-degradation policy.

Before the State Board can approve any reduction in water quality to waters of the United States within the state of California, it must adhere to both the state and federal ant degradation policies:

> Before approving any reduction in water quality or any activity that would result in a reduction in water quality, the Regional Board must first determine that the change in water quality would not be in violation of State Board Resolution No. 68-16 or the federal antidegradation policy.[6]

In all cases where the federal anti-degradation policy is applicable, the state anti-degradation policy (set forth in State Board Order No. 68-16) requires that, at a minimum, the three part test established by the federal anti-degradation policy must be satisfied.[7]

B. The Federal Anti-degradation Policy

The general federal anti-degradation policy objectives, adopted in 1975, are set forth in 40 CFR §131.12, which provide in pertinent part:

> . . . (a) The State shall develop and adopt a statewide anti-degradation policy and identify the methods for implementing such policy pursuant to this subpart. The anti-degradation policy

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[4] See generally Clean Water Act sections 303(e)(3), 1362(7); 33 U.S.C. 1313(e)(3), 33 U.S.C. 1362(7).

[5] See Calvary Mining Co. v. United States Environmental Protection Agency (1985) 765 F.2d 126, 129.

[6] State Water Resources Control Board Order WR 86-17, p. 17.

[7] *Id.* at p. 17-18, also see Memorandum to California Regional Water Quality Control Board Executive Officers from William R. Attwater, Chief Counsel, State Water Resources Control Board, entitled "Federal Anti Degradation Policy," October 7, 1987, at p. 17-18.

> and implementation methods shall, at a minimum, be consistent with the following:
>
> (1) Existing instream water uses and the level of water quality necessary to protect the existing uses shall be maintained and protected.
>
> (2) Where the quality of the waters exceeds levels necessary to support propagation of fish, shellfish, and wildlife and recreation in and on the water, that quality shall be maintained and protected unless the State finds, after full satisfaction of the intergovernmental coordination and public participation provisions of the State's continuing planning process, that allowing lower water quality is necessary to accommodate important economic or social development in the area in which waters are located. In allowing such degradation or lower water quality, the State shall assure water quality adequate to protect existing uses fully. Further, the State shall assure that there shall be achieved the highest statutory and regulatory requirements for new and existing point sources and all cost-effective and reasonable best management practices for nonpoint source control. " (emphasis added).
>
> (3) Where high quality waters constitute an outstanding national resource, such as waters of national and State parks and wildlife refuges and waters of exceptional recreational or ecological significance, that water quality should be maintained and protected.

The above sections of the federal anti-degradation policy classify waters into three "tiers," with each tier requiring particular analysis in light of any proposed action that would lower water quality, which is known as the "three part test" under the federal anti-degradation policy. According to the SED, the Delta and San Joaquin River are Tier II waterbodies.

C. The State Anti-degradation Policy

California's anti-degradation policy was adopted by State Board Order No. 68-16, and provides in pertinent part:

> . . .WHEREAS, water quality control policies have been and are being adopted for waters of the State; and

> WHEREAS, the quality of some waters of the State is higher than that established by the adopted policies and it is the intent and purpose of this Board [SWRCB] that such higher quality shall be maintained to the maximum extent possible consistent with the declaration of the Legislature:
>
> 1) Whenever the existing quality of water is better than the quality established in the policies as of the date on which such policies become effective, such existing high quality will be maintained until it has been demonstrated to the State that any such change will be consistent with maximum benefit to the people of the State, will not unreasonably affect present and anticipated beneficial use of such water, and will not result in water quality less than that prescribed in the policies.
>
> 2) Any activity which produces or may produce a waste or increased volume or concentration of waste and which discharges or proposes to discharge to such high quality waters will be required to meet waste discharge requirements which will result in the best practicable treatment or control of the discharge necessary to assure that (a) a pollution or nuisance will not occur and (b) the highest quality consistent with maximum benefit to the people of the state will be maintained.[8] (Emphasis added).

D. Analysis of the Federal and State Policies Relative to the Proposed Action to Diminish South Delta Water Quality Standards

1. Any decision to adopt an alternative regarding southern Delta water quality that would lower existing water quality objectives in the south Delta by allowing for increased salinity would violate both federal and state anti-degradation policies.

VIOLATION OF FEDERAL ANTI-DEGRADATION POLICY

The federal anti-degradation policy is applicable and triggered where there is a proposed relaxation of water quality objectives, where such water quality objectives were adopted after the enactment of the federal anti-degradation policy in 1975, water quality in the affected area has declined since 1975, and the proposed objectives are based upon the existing, lower level of

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[8] State Water Resources Control Board Resolution No. 68-16 ("Statement of Policy With Respect to Maintaining High Quality of Waters in California," adopted October 28, 1968).

water quality.[9] The present salinity objectives for the South Delta were established by the State Water Resources Control Board in its 1978 Bay Delta Plan, which set a standard of 0.7 dS/m from April through August, and 1.0 dS/m September through March.

Adoption of any alternative which allows for a relaxation of present water quality objectives, where proposed new objectives are based on the existing, lower level of water quality violates the federal anti-degradation policy. Clearly, such alternatives do not serve to maintain and protect existing instream water uses and the level of water quality necessary for such uses, as those uses existed at the time of the enactment of the federal anti-degradation policy, as is required under 40 CFR §131.12(a)(1). Relaxing the salinity standards in the South Delta would not protect existing agricultural uses and aquatic beneficial uses. Similarly, allowing lower water quality in the south Delta clearly is not necessary to accommodate important social development in the area in which the waters are located. Quite to the contrary, relaxation of water quality objectives that result in increased salinity in the South Delta would negatively impact economic and social development in the South Delta by impairing water use for agricultural irrigation and impacting fisheries. Those that seek to benefit from diminished water quality in the south Delta reside elsewhere.

<u>VIOLATION OF THE STATE ANTI-DEGRADATION POLICY</u>

The state anti-degradation policy provides in pertinent part:

> [w]e never the existing quality of water is better than the quality established in the policies as of the date on which such policies become effective, such existing high quality will be maintained until it has been demonstrated to the State that any such change will be consistent with maximum benefit to the people of the State, will not unreasonably affect present and anticipated beneficial use of such water, and will not result in water quality less than that prescribed in the policies.

In essence, the state anti-degradation policy mandates that where water quality exceeds that set forth in adopted policies, this higher quality must be maintained unless there is ample justification for allowing the water quality to be reduced, even if such reduction to water quality does not dip below the "baseline" water quality set forth by policy.

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[9] Memorandum to California Regional Water Quality Control Board Executive Officers from William R. Attwater, Chief Counsel, State Water Resources Control Board, entitled "Federal Anti Degradation Policy," October 7, 1987, at p. 8.

The first requirement in considering a change to existing water quality under the state anti-degradation policy, is that such change is consistent with maximum benefit to the people of the State. The SED provides no such analysis, much less justification, under the anti-degradation analysis, and therefore is inadequate.

However, even if an analysis were present, the proposed alternative cannot comply the state anti-degradation policy. Here, the existing salinity standards were adopted in 1978, and represented the maximum allowable salinity in order to protect agricultural uses in the Southern Delta. The existing quality of water is not better than the objectives set in 1978, rather, the water quality has declined since 1978 causing negative agricultural impacts in the South Delta. To simply "reset" the water quality baseline to justify the present and projected inability of the projects to meet the existing standards is contrary to the express intention of the state anti-degradation policy. Moreover, the fact that the projects are, on many occasions, unable to meet the current standards cannot be used in support of a position that baseline conditions already exceed the standard and, thus, salinity above .07 from April through August should be the basis of the analysis. Such circular reasoning will not survive legal scrutiny.

Any proposed change to water quality objectives cannot unreasonably affect present and beneficial use of present and anticipated use of such water, and cannot result in water quality less than that prescribed by policy. By allowing increased salinity, the present and beneficial use of South Delta water will necessarily be unreasonably affected in that increased salt loads have a negative impact on agriculture, creating salt-related crop losses. Any increase of allowable salt concentrations over and above those allowed by current policy necessarily results in a lesser water quality than that already prescribed.

The SWRCB proposed relaxation of the current water quality objectives creates a method by which anti-degradation policies can be avoided or frustrated. By not enforcing a standard it has adopted (e.g. the southern Delta salinity objectives) the SWRCB can approve a degradation of the water and justify it by its failure to previously enforce the standard. The Board actually caused the degradation by not enforcing its own standard, then justifies a relaxation thereof as no real change in conditions. Such a practice makes an absurdity of the law.

A. Delaying an Anti-degradation Analysis Until the Implementation Phase is Unacceptable

There is no legally logically supportable basis for the position that the anti-degradation analysis can be postponed until the implementation phase. Like a traditional CEQA document the SED is required to address and disclose any all known impacts. In doing so the SED cannot effectively ignore or delay established federal and state anti-degradation policy. The preferred alternative's inability to satisfy these policies must be addressed now.

MISCELLANEOUS COMMENTS

ES2.1. The LSJR alternatives are described as having a goal to protect fish populations migrating through the Delta. As in the 1995 Plan and D-1641, setting flow objectives at Vernalis or above constitutes only a part of accomplishing this goal. An integral part of having flows to help fish migrate through the Delta is having those flows pass through the Delta. Thus, the issue of export levels and restrictions is a necessary part of the establishment of San Joaquin fishery flows. In D-1641, the Board created the fiction that fishery flows were available for export, and if fishery concerns prevented that export, the projects got a credit; the "no-net loss" provision. Obviously, that provision was in effect during the time the fishery populations dropped precipitously. Delta inflows to protect fish cannot be determined without also considering export restrictions.

ES3.2 summarizes the history of the salinity standards, but should also include a note that the current compliance locations were always anticipated to be re-evaluated so that they would eventually be reliable representations of local water quality conditions. The current locations do not show conditions in the null zones in the southern Delta and so should be moved.

1.6.5. As alluded to above, we suggest the SWRCB make the distinction between mitigation measures which may be necessary to lessen significant effects of the project and the mitigation that should be required of parties who have caused the conditions which now require water quality objectives to be set. The SWRCB has approached the issue of water quality in the wrong way. The Board should start with the identification of what actions and what parties have caused the degradation of water, and then require/force mitigation thereof by those parties. The clearest example is San Joaquin River salt. There is no doubt that the operation of the CVP is the major cause of the salt problem. Forcing it to mitigate its effects on the River water quality should precede the effort to establish objectives, as the mitigation might in and of itself provide the water quality needed to protect beneficial uses.

Similarly, if the Bureau was required to mitigate the decrease in flows it caused (Friant Division) That might go a long way toward protecting fish. By not requiring this mitigation first, the Board runs the risk of shifting obligations onto parties who are not the cause of any particular problem.

2.1.1 As mentioned a number of times at the recent SWRCB hearing on the draft SED, there is no explanation for the SED and proposed new objectives ignoring the upper portion of the San Joaquin River. Without a doubt, the flows from that upper end (quantified in Exhibit "F") provided benefits to River fisheries, including tributary fisheries and in-Delta fisheries. No logical or legal justification has been given as to why that portion of the River is given a pass.

2.1.2. The SED incompletely notes that the projects convey water released from the Sacramento River basin through the Delta for export. A significant amount of "excess" flow from the San Joaquin River is included in those exports, and many times San Joaquin River water that is not excess.

2.6.3 Agricultural Discharges. The description suggests that drainage and subsurface seepage is only pumped during winter months. Agriculture continues throughout the year, and many if not most discharge pumps operate all year, not just in the winter.

Page 3-28; SJRGA Alternatives.. SJRGA's proposal that salinity standards only apply during some months of the year ignores the fact that agriculture and irrigation continues through out all months, depending on rainfall. Thus, standards are needed throughout the year.

Page 5-15 Salinity and Water Temperature. These paragraphs highlight how the SED tries to avoid a complete description of the causes of the salt problem. Rather than saying that salt comes from Salt and Mud slough, or that water is recirculated from the Delta via the DMC, the SED should explicitly state that the CVP delivers hundreds of thousands of tons of salt to the valley that is drained to the River in concentrations many times the current standards. The amounts of salt, the decrease in River flows and other effects of the CVP have been quantified and published and should not be avoided.

Page 5-36 Effects of Pumping and Barriers on Water Levels and Flows. This section needs to be corrected. As referenced above, the SWP operates the CCF radial gates according to three possible priorities. (Exhibit "H"). According to these priorities, CCF operates to only avoid a portion of the flood tide for the high-high tide, and normally takes water throughout the flood and ebb tide on the low-high. This decapitation of one of the high tides creates a "hole" in the Delta pool that must be refilled (or partially refilled) when the high-high tides comes in. This of course decreases that high-high tide, and thus does not maximize elevations in the southern Delta. Especially when the barriers are not installed and operating, shutting down exports when they prevent local diversions (lowered water levels) would be the way to protect channel elevations.

Page 5-44 Water Quality and Salinity. Missing from all SED discussions of the salt problem in the southern Delta is a discussion about why or how local diversions affect salinity in the channels. Although it is true that an agricultural diversion from the channels usually results in the discharge (at some time) of a saltier water, that should not be considered as a cause of elevated salt levels. The southern Delta farmers have for over 120 years diverted channel water and discharged back into the same. It was only when the CVP started adding salts and decreasing the flow that salt became an issue in the south Delta. When the water quality of the River was at historic levels (see Exhibit "G") the diversion and discharge practices of the local farmers were irrelevant. However, when CVP salts started coming into the Delta at two and three times the concentrations than before, local discharges naturally and unavoidably became more saline. All consumptive uses concentrate the salts in the water, but this is only important now because the CVP has salted up the River.

three times the concentrations than before, local discharges naturally and unavoidably became more saline. All consumptive uses concentrate the salts in the water, but this is only important now because the CVP has salted up the River.

When the CVP just meets the standard (whatever it may be) then no downstream users can use water without having a discharge that exceeds the standard. In this case, meeting the standard at Vernalis precludes any downstream user from using the water even though the standard is to specifically protect his use! It like a polluter of air complaining that he has to decrease emissions and tries to blame all those other people who are breathing and exhaling carbon dioxide. The SED should explain this so that the public does not somehow think that southern Delta agriculture is the cause of the salt problem It is clearly not.

CONCLUSION

The data used to support the conclusion that the southern Delta salinity objectives can be relaxed is not relevant to the issue, and therefore cannot support the conclusion. SDWA is currently helping fund a study in conjunction with the UC Davis Agricultural Cooperative Extension Service to actually measure leaching at various locations. No action should be taken by the SWRCB until this new data is completed and reviewed.

Very truly yours,

JOHN HERRICK

Exhibit “A”

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Attorney for SOUTH DELTA
WATER AGENCY

BEFORE THE

STATE WATER RESOURCES CONTROL BOARD

Potential Changes to the Bay-Delta Water Quality Control Plan; Draft Substitute Environmental Documents in Support thereof	DECLARATION OF JACK ALVAREZ

I, Jack Alvarez, declare as follows:

1. I am 56 years old and have resided in San Joaquin County all of my life.

2. My family has farmed land in the Tracy area since 1931 and I have been involved in those farming operations for approximately 35 years. I am a board member of the South Delta Water Agency and of the West Side Irrigation District.

3. As part of my duties/responsibilities as a board member of SDWA and WSID, I am generally familiar with the Hoffman Report of 2010 which supports the SWRCB's proposed relaxation of the salinity standards in the southern Delta. I have reviewed portions of that Report, especially Figure 3.18 which identifies a number of subsurface drains which were reportedly sampled by Chilcott, et. al. Most of the drains shown on Figure 3.18 are located withing the boundaries of WSID, and I am generally familiar with their locations.

4. Although I cannot testify to the depth or specific use of all of the drains identified in Figure 3.18, I can state that at least most of them are for the purpose of controlling ground water. That ground water is a result of upslope farming and the control of it is absolutely necessary to farm in our area. These tile drain system, like the others in the South Delta are for

the specific purpose of intercepting/controlling (as far as possible) the ground water and to keep it out of the root zone of the crops because that ground water is generally too salty for the crops grown in this area and/or the root zone cannot be constantly wet. These drains, like the others in this area may also receive excess applied surface water that passed through the root zone, but that excess surface water and the amount of salt it contains is extremely small when compared to the ground water and the salt therein.

5. WSID receives its water from both a diversion off Old River a few miles downstream of the Tracy Blvd. Bridge and from the Central Valley Project's Delta-Mendota Canal. Although flow conditions and installation of the temporary barriers can affect local water quality, it generally true that the water from the DMC is of better quality than that from our Old River intake. Many times in the summer months, the Old River intake water is of a worse quality than the 0.7 EC standard. The lands within WSID receive either only Old River water, DMC water, or a mix of both; most of the lands receive a mix of both.

6. In the past, my farms have experienced what I have concluded was crop damage due to elevated levels of salt in the supply water. In a few years, I noticed a white residue after an early season irrigation which I concluded was an indication of the salts in the supply water.

7. Because the federal Central Valley Project causes hundreds of thousands of tons of salt to enter the San Joaquin River upstream of the Delta, local farmers have been forced to take actions necessary to lessen the effects of that salt through good management practices. I do not believe the current salinity standards in our area are protective of agriculture given my experience.

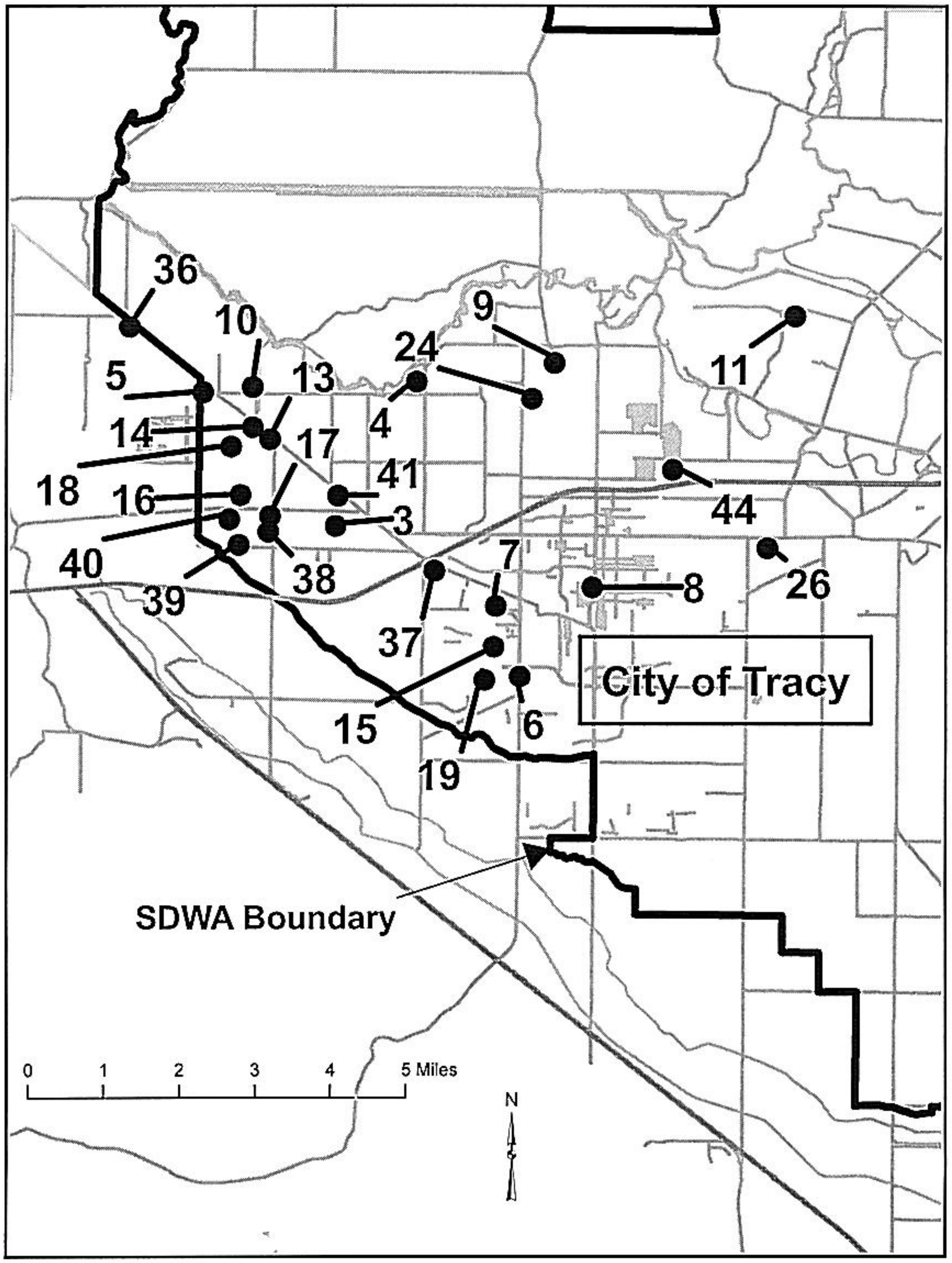
I declare under penalty of perjury under the laws of the State of California that the foregoing is true and correct.

Dated: 3-28-13

Jack Alvarez

Jack Alvarez

Figure 3.18. Location of subsurface tile drains sampled on the west side of the SDWA (Chilcott, et al., 1988).



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Attorney for SOUTH DELTA
WATER AGENCY

BEFORE THE

STATE WATER RESOURCES CONTROL BOARD

Potential Changes to the Bay-Delta Water Quality Control Plan; Draft Substitute Environmental Documents in Support thereof	DECLARATION OF GREG POMBO

I, Greg Pombo, declare as follows:

1. I am 50 years old and have resided in San Joaquin County all of my life.

2. I farm land on Pescadero Tract and other local areas and have done so for approximately 30 years on behalf of myself and/or family related farming entities or partnerships.

3. Based on my review of Figure 3.18 attached hereto, I understand that tile drainage sampling data in the Chilcott, et. al., Report included the location designated "11" on that Figure. The location of this tile drain appears to be the Perry farm on Delta Avenue on Pescadero Tract with which I am familiar. This Perry tile drain system, like the others in the area are for the specific purpose of intercepting (as far as possible) the ground water and to keep it out of the root zone of the crops because that ground water is generally too salty for the crops grown in this area. This drain, like the others in the southern Delta area may also receive excess applied surface water that passed through the root zone, but that excess surface water and the amount of salt it contains is extremely small when compared to the ground water and the salt therein. My family also has a tile drain on Pescadero Tract at the end of Delta Avenue, and it too is for the purpose of controlling the ground water, not for the purpose of collecting excess applied surface water,

though again, some excess surface water will enter the drain.

4. Local measurements of the ground water under Pescadero Tract indicate that it has an EC many times higher that then EC of the applied water.

5. The shallow ground water under Pescadero Tract and the neighboring islands and tracts in the southern Delta is hydraulically connected to the surface water of the rivers and channels such that as the tide rises and falls in the Delta, the ground water also rises and falls. In years when the flow of the San Joaquin River and interior southern Delta channels is high, the salts in the shallow ground water are raised back into the root zone of the land. This means that all of the salts that leached out of the soils during irrigation are re-introduced back into the root zone where they must again be removed either by flooding the field or otherwise applying water to force the salts back down out of the root zone. I have seen this and done this many times during my years farming in this area.

6. In addition to this attempt to control salts introduced due to high flows, the normal occurrence of the tides rising and falling twice daily also raises the shallow ground water and its salts back into the root zone, depending on each area's soil types, crops and tidal stage. This situation requires local farmers to implement good management practices for the control of salt.

7. In our area we also have open drain ditches which too serve as methods of lowering the ground water. As the open ditch drain fills with water (seeping from the neighboring soils) it is pumped out, back into the river. However, because the soils in the area are not uniform in composition, the water does not flow evenly or consistently. This means that as we pump out the deep open drain ditches the water surface in those drains is actually lower than the neighboring ground water.

8. Because the federal Central Valley Project causes hundreds of thousands of tons of salt to enter the San Joaquin River upstream of the Delta, local farmers have been forced to take actions necessary to lessen the effects of that salt through good management practices. I do not believe the current salinity standards in our area are protective of agriculture given my experience.

/// ///

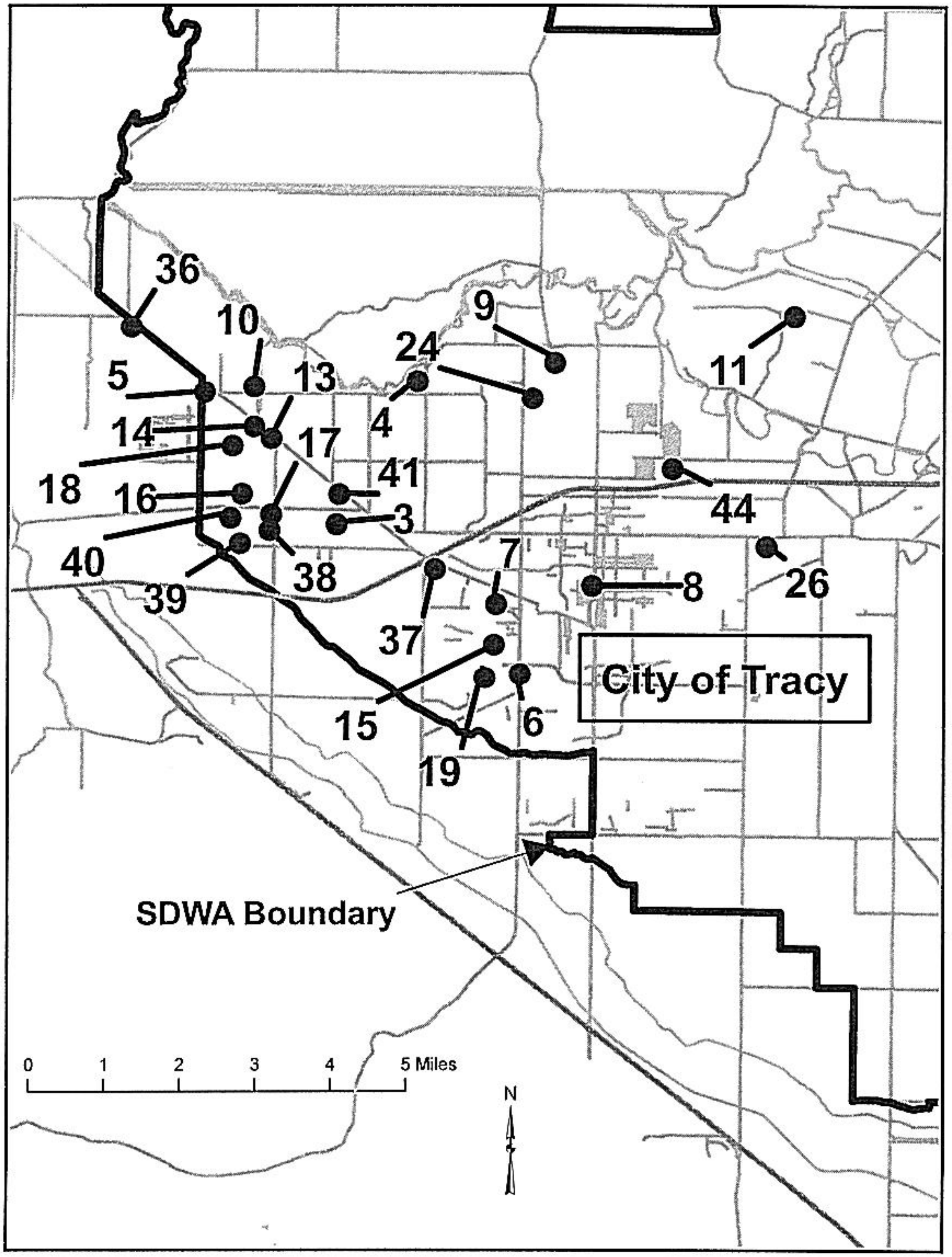
I declare under penalty of perjury under the laws of the State of California that the foregoing is true and correct.

Dated: 3/27/13

Greg Pombo

Greg Pombo

Figure 3.18. Location of subsurface tile drains sampled on the west side of the SDWA (Chilcott, et al., 1988).



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Attorney for SOUTH DELTA
WATER AGENCY

BEFORE THE

STATE WATER RESOURCES CONTROL BOARD

Potential Changes to the Bay-Delta Water Quality Control Plan; Draft Substitute Environmental Documents in Support thereof	DECLARATION OF WILLIAM SALMON

I, William Salmon, declare as follows:

1. I am 47 years old and reside on Union Island, San Joaquin County.

2. I am currently general manager of Augusta-Bixler Farms ("ABF") which owns and operates a farming business on Union Island. I also have separate family related farming enterprises in San Joaquin County.

3. Portions of the ABF Union Island farm have tile drain systems installed and operated for the purpose of controlling the shallow ground water. These drains are placed approximately 5 feet below the land surface. ABF's tile drain system, like the others in the area are for the specific purpose of intercepting (as far as possible) the ground water and to keep it out of the root zone of the crops because that ground water is generally too salty for the crops grown in this area. My tile drain, like the others in this area may also receive excess applied surface water that passed through the root zone, but that excess surface water and the amount of salt it contains is extremely small when compared to the ground water and the salt therein.

4. Local measurements of the ground water under Union Island indicate that it has an EC many times higher that then EC of the applied water.

5. The shallow ground water under Union Island and the neighboring islands and tracts in the southern Delta is hydraulically connected to the surface water of the rivers and channels such that as the tide rises and falls in the Delta, the ground water also rises and falls. In years when the flow of the San Joaquin River, Middle River and Grant Line Canal is high, the salts in the shallow ground water are raised back into the root zone of the land, and sometimes back to the surface of the land. This means that most of the salts that leached out of the soils during irrigation are re-introduced back into the root zone where they must again be removed either by flooding the field and discharging that water back to the river or by applying water to force the salts back down out of the root zone. I have seen this and done this many times during my years farming in this area. Some times I can actually see the residue of salt on the surface of the field after high flows pushed it back to the surface.

6. In addition to this attempt to control salts introduced during high flows, the normal occurrence of the tides rising and falling twice daily also raises the shallow ground water and its salts back into the root zone, depending on each area's soil types, crops and tidal stage. This situation requires local farmers to implement good management practices for the control of salt.

7. In our area we also have open drain ditches which too serve as methods of lowering the ground water. As the open ditch drain fills with water (seeping from the neighboring soils) it is pumped out, back into the river. However, because the soils in the area are not uniform in composition, the water does not flow evenly or consistently. This means that as we pump out the deep open drain ditches the water surface in those drains is actually lower than the neighboring ground water.

8. Because the federal Central Valley Project causes hundreds of thousands of tons of salt to enter the San Joaquin River upstream of the Delta, local farmers have been forced to take actions necessary to lessen the effects of that salt through good management practices.

9. In 2005 I submitted testimony and appeared at a hearing to give that testimony and was cross-examined .thereon. That testimony, which SDWA is including with its comments to the draft SED, provided evidence of crop damage ABF experienced in 2002 and before due to

salt. My testimony included lab results which confirmed that the damage to walnuts, grapes and beans was a result of high levels of salt in the plants and in the soils. This salt damage continues, with there being regular damage to the ABF walnuts and grapes. Because of this salt caused damage, I believe the current salinity standards in our area are not protective of agriculture.

I declare under penalty of perjury under the laws of the State of California that the foregoing is true and correct.

Dated: 3/28/13

William "Chip" Salmon

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Attorney for SOUTH DELTA
WATER AGENCY

BEFORE THE

STATE WATER RESOURCES CONTROL BOARD

Potential Changes to the Bay-Delta Water Quality Control Plan; Draft Substitute Environmental Documents in Support thereof

DECLARATION OF JOSEPH RATTO

I, Joseph Ratto, declare as follows:

1. I am 70 years old and have resided on Roberts Island, San Joaquin County all of my life.

2. I have farmed land on Roberts Island, Union Island and other local areas for approximately 54 years on behalf of myself and/or family related farming entities or partnerships.

3. One of my ranches on Upper Roberts Island has a tile drain system installed and operated for the purpose of controlling the shallow ground water. This tile drain system, like the others in the area are for the specific purpose of intercepting (as far as possible) the ground water and to keep it out of the root zone of the crops because that ground water is generally too salty for the crops grown in this area. My tile drain, like the others in this area may also receive excess applied surface water that passed through the root zone, but that excess surface water and the amount of salt it contains is extremely small when compared to the ground water and the salt therein.

4. Local measurements of the ground water under Upper Roberts Island indicate that it has an EC many times higher that then EC of the applied water.

5. The shallow ground water under Upper Roberts Island and the neighboring islands and tracts in the southern Delta is hydraulically connected to the surface water of the rivers and channels such that as the tide rises and falls in the Delta, the ground water also rises and falls. In years when the flow of the San Joaquin River (and thus its distributary Middle River) is high, the salts in the shallow ground water are raised back into the root zone of the land, and sometimes back to the surface of the land. This means that all of the salts that leached out of the soils during irrigation are re-introduced back into the root zone where they must again be removed either by flooding the field and discharging that water back to the river or by applying water to force the salts back down out of the root zone. I have seen this and done this many times during my years farming in this area. Some times I can actually see the residue of salt on the surface of the field after high flows pushed it back to the surface.

6. In addition to this attempt to control salts introduced due to high flows, the normal occurrence of the tides rising and falling twice daily also raises the shallow ground water and its salts back into the root zone, depending on each area's soil types, crops and tidal stage. This situation requires local farmers to implement good management practices for the control of salt.

7. In our area we also have open drain ditches which too serve as methods of lowering the ground water. As the open ditch drain fills with water (seeping from the neighboring soils) it is pumped out, back into the river. However, because the soils in the area are not uniform in composition, the water does not flow evenly or consistently. This means that as we pump out the deep open drain ditches the water surface in those drains is actually lower than the neighboring ground water. I witnessed this near the time of this declaration where an excavation in an alfalfa field on Roberts Island revealed ground water at approximately 3 feet, while the neighboring open drain ditch had a water level one or two feet deeper.

8. Because the federal Central Valley Project causes hundreds of thousands of tons of salt to enter the San Joaquin River upstream of the Delta, local farmers have been forced to take actions necessary to lessen the effects of that salt through good management practices. I do not believe the current salinity standards in our area are protective of agriculture given my experience.

I declare under penalty of perjury under the laws of the State of California that the foregoing is true and correct.

Dated: 3/29/13

Joseph Ratto

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Attorney for SOUTH DELTA
WATER AGENCY

BEFORE THE

STATE WATER RESOURCES CONTROL BOARD

Potential Changes to the Bay-Delta Water Quality Control Plan; Draft Substitute Environmental Documents in Support thereof	DECLARATION OF MARK BACCHETTI

I, Mark Bacchetti, declare as follows:

1. I am 56 years old and reside in, San Joaquin County.

2. For the past approximate 30 years I have been involved farming in San Joaquin County with numerous family related business, including the operation of farms on Fabian Tract.

3. Based on information gathered by our farming operations, I am generally familiar with local water and soil conditions. The source water for Fabian Tract is for the most part Old River. That River experiences water quality problems with summer salinity levels regularly in excess of the 0.7 EC standard. Over the years, I have noticed decreased yields for many years due to what I conclude is the high salt concentration in the supply water. At various times we have investigated this issue and have data on water quality, soil salinity and crop yield fluctuations..

4. The ground water under Fabian Tract is shallow and of poor quality. Measurements of this ground water indicate it has an EC many times higher than the EC of the applied water.

5. The shallow ground water under Fabian Tract and the neighboring islands and

tracts in the southern Delta is hydraulically connected to the surface water of the rivers and channels such that as the tide rises and falls in the Delta, the ground water also rises and falls. In years when the flow of the San Joaquin River, Old River, and Grant Line Canal is high, the salts in the shallow ground water are raised back into the root zone of the land, and sometimes back to the surface of the land. This means that most of the salts that leached out of the soils during irrigation are re-introduced back into the root zone where they must again be removed either by flooding the field and discharging that water back to the river or by applying water to force the salts back down out of the root zone. I have seen this and done this many times during my years farming in this area.

6. In addition to this attempt to control salts introduced during high flows, the normal occurrence of the tides rising and falling twice daily also raises the shallow ground water and its salts back into the root zone, depending on each area's soil types, crops and tidal stage. This situation requires local farmers to implement good management practices for the control of salt.

7. On Fabian Tract, we have open surface drain ditches which serve as methods of lowering the ground water. As the open ditch drain fills with water (seeping from the neighboring soils) it is pumped out, back into the river. However, because the soils in the area are not uniform in composition, the water does not flow evenly or consistently. This means that as we pump out the deep open drain ditches the water elevation in those drains is actually lower than the neighboring ground water.

8. The open surface drains collect a combination of excess applied surface water that runs off the end of the field, and the shallow ground water which consists of the ground water which seeps into the ditches as well as any excess applied surface water which made its way through the root zone into the shallow ground water. Because this drain water is a combination from a few different sources, salinity data of that drain water cannot be used to determine how much salt was leached out of the root zone, unless there were some way to quantify and analyze the amounts and salinities of those sources.

9. Because the federal Central Valley Project causes hundreds of thousands of tons

of salt to enter the San Joaquin River upstream of the Delta, local farmers have been forced to take actions necessary to lessen the effects of that salt through good management practices.

I declare under penalty of perjury under the laws of the State of California that the forcgoing is true and correct.

Dated: 3/28/13

Mark Bacchetti
Mark Bacchetti

Exhibit “B”

DEPARTMENT OF WATER RESOURCES
California Data Exchange Center

OLD RIVER NEAR TRACY *(OLD)*

Elevation: 5' · DELTA basin · Operator: CA Dept of Water Resources/O & M

Provisional data, subject to change.
Query executed Thursday at 12:59:51

ELECTRICAL CONDUCTIVTY MICRO S (13582)

Date / Time	*EL COND* **US/CM**
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07/02/2007	854.58
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07/05/2007	906.00
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07/08/2007	913.92
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07/10/2007	922.92
07/11/2007	871.74
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07/13/2007	846.71
07/14/2007	785.21
07/15/2007	773.13
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07/19/2007	737.92
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07/27/2007	782.08
07/28/2007	761.90
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08/01/2007	737.52
08/02/2007	771.08
08/03/2007	761.21
08/04/2007	783.29
08/05/2007	805.04
08/06/2007	795.96
08/07/2007	806.17

DEPARTMENT OF WATER RESOURCES
California Data Exchange Center

OLD RIVER NEAR TRACY *(OLD)*

Elevation: 5' · DELTA basin · Operator: CA Dept of Water Resources/O & M

Provisional data, subject to change.
Query executed Thursday at 12:59:15

ELECTRICAL CONDUCTIVTY MICRO S (13582)

Date / Time	*EL COND* **US/CM**
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07/07/2008	886.13
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07/11/2008	887.96
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07/21/2008	797.00
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08/03/2008	860.50
08/04/2008	888.82
08/05/2008	935.96
08/06/2008	930.58
08/07/2008	919.08

DEPARTMENT OF WATER RESOURCES
California Data Exchange Center

OLD RIVER NEAR TRACY *(OLD)*

Elevation: 5' · DELTA basin · Operator: CA Dept of Water Resources/O & M

Provisional data, subject to change.
Query executed Thursday at 12:52:33

ELECTRICAL CONDUCTIVTY MICRO S (13582)

Date / Time	*EL COND* **US/CM**
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08/05/2009	981.13
08/06/2009	961.08
08/07/2009	973.04

08/08/2009	984.29
08/09/2009	947.67
08/10/2009	998.29
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08/12/2009	1112.42
08/13/2009	1088.63
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08/28/2009	1119.00
08/29/2009	1064.13
08/30/2009	1069.75
08/31/2009	1045.50

Warning! This data is preliminary and subject to revision.

Download Data Now | Plot OLD Data | Show OLD Map | OLD Info

Station ID	Sensor Number	Duration Code	Start date	End date	
OLD	100	M D H E	07/01/2009 0(	08/31/2009 0(	Get data

Exhibit “C”

BUREAU OF RECLAMATION
Central Valley Operation Office
3310 El Camino Avenue, Suite 300
Sacramento, California 95821

DEPARTMENT OF WATER RESOURCES
Division of Operations and Maintenance
3310 El Camino Avenue, Suite 300
Sacramento, California 95821

FEB 27 2013

IN REPLY REFER TO:
CVO-100
WTR-4.10

VIA ELECTRONIC E-MAIL AND U.S. MAIL

Thomas Howard
Executive Director
State Water Resources Control Board
Post Office Box 100
Sacramento, California 95812

Subject: Report of Exceedance of South Delta Water Quality Agricultural Objective

Dear Mr. Howard:

This letter is to notify you that on January 29, 2013, the 30-day average Electrical Conductivity (EC) at Station P-12 (Old River at Tracy Road Bridge) reached 1.1 millisiemens per centimeter (mS/cm), exceeding the D-1641 objective of 1.0 mS/cm. We maintain that the exceedance at P-12 is largely due to local degradation downstream of Vernalis, as well as the dry conditions in the San Joaquin River watershed and reduced Delta exports. On January 29, the daily and 30-day average EC at Vernalis were 0.97 mS/cm and 0.83 mS/cm respectively. Similarly, the 30-day average EC values at the other two interior south Delta Stations, C-6 (San Joaquin River at Brandt Bridge) and C-8 (Old River near Middle River), measured 0.83 mS/cm and 0.84 mS/cm respectively.

During January, San Joaquin River flows at Vernalis averaged approximately 1,800 cubic feet per second (cfs) with the U.S. Bureau of Reclamation (Reclamation) releasing 275 cfs from Goodwin Dam. These conditions are similar to those experienced in January 2012, which was characterized as Dry by the Department of Water Resources' (DWR) Division of Flood Management. In addition, Reclamation and DWR have been limited in their Delta pumping in January primarily due to actions designed to protect delta smelt consistent with the U.S. Fish and Wildlife Services' Biological Opinion for delta smelt. It should be noted that, even with exports at relatively low levels, the water quality in the south Delta continued to degrade to the point of exceedance.

Beginning on January 30, Reclamation increased its releases from Goodwin Dam to 900 cfs and, after holding this rate for a few days, subsequently 1,500 cfs to target an average monthly flow of 2,280 cfs at Vernalis as required by D-1641. These increased releases have generally improved water quality in the south Delta.

Given these conditions, Reclamation and DWR are not proposing any further corrective actions at this time.

If you have any questions regarding this notification, please contact Mr. Paul Fujitani of Reclamation at 916-979-2197 or Mr. John Leahigh at 916-574-2722.

Sincerely,

Ronald Milligan, Operations Manager
Central Valley Operations Office
Bureau of Reclamation

David H. Roose, Chief
SWP Operations Control Office
Department of Water Resources

cc: Craig M. Wilson, Delta Watermaster
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Exhibit “D”

STATE WATER RESOURCES CONTROL BOARD

Public Hearing on the Adequacy of the
Substitute Environmental Document
March 20/21, 2013

San Joaquin River Flows and Southern Delta Water Quality

SOUTH DELTA WATER AGENCY

John Herrick, Esq.

SDWA OPPOSES THE PROPOSED RELAXATION OF THE FOUR SOUTHERN DETLA SALINITY STANDARDS

…because the conclusions in the Hoffman Report are not supported any, much less substantial evidence.

WATER QUALITY OBJECTIVES FOR AGRICULTURAL BENEFICIAL USES IN THE SOUTHERN DELTA

CURRENT

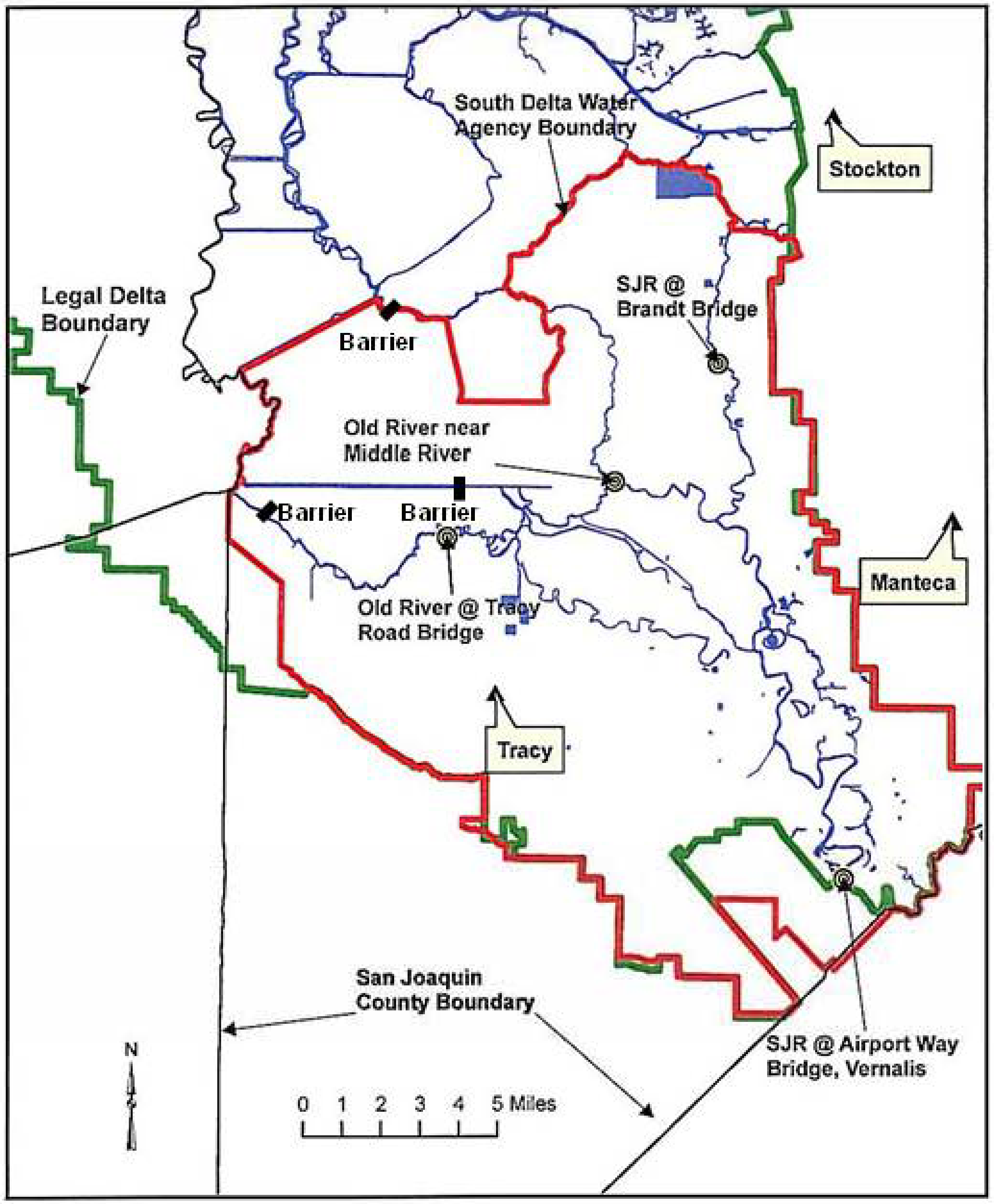
0.7 EC April – August
1.0 EC September - March

PROPOSED

1.0 EC all year

Standards apply throughout the channels but are measured at four locations: Vernalis, Brandt Bridge, Old River at Middle River, and Old River at Tracy Blvd. Bridge

Figure 1.1. Map of southern Delta showing boundary of the South Delta Water Agency and salinity compliance stations.



Recent Violations:

State of California - Department of Water Resources - Division of Operations & Maintenance - Operations Control Office

Delta Water Quality Conditions

South Delta Stations

Date	Vernalis		Brandt Bridge		Old River Near Tracy		Old River Near Middle River	
	md EC	30 day avg	md EC	30 day avg	md EC	30 day avg	md EC	30 day avg
12/31/2012	0.49	0.67	0.44	0.66	0.58	0.89	0.45	0.71
01/01/2013	0.57	0.67	0.49	0.66	0.64	0.88	0.52	0.71
01/02/2013	0.62	0.67	0.58	0.65	0.71	0.88	0.59	0.70
01/03/2013	0.68	0.67	0.63	0.65	0.85	0.88	0.65	0.70
01/04/2013	0.72	0.67	0.68	0.65	0.95	0.89	0.72	0.71
01/05/2013	0.74	0.68	0.73	0.65	1.08	0.90	0.75	0.71
01/06/2013	0.74	0.68	0.76	0.66	1.12	0.90	0.78	0.71
01/07/2013	0.68	0.68	0.80	0.66	1.10	0.91	0.79	0.72
01/08/2013	0.68	0.68	0.80	0.66	1.01	0.92	0.73	0.72
01/09/2013	0.65	0.67	0.75	0.67	0.99	0.92	0.73	0.71
01/10/2013	0.70	0.67	0.75	0.67	0.93	0.92	0.71	0.71
01/11/2013	0.73	0.67	0.70	0.67	0.89	0.92	0.68	0.71
01/12/2013	0.80	0.67	0.70	0.67	0.91	0.92	0.75	0.71
01/13/2013	0.85	0.67	0.75	0.67	0.93	0.92	0.81	0.70
01/14/2013	0.89	0.67	0.83	0.68	1.03	0.92	0.86	0.71
01/15/2013	0.90	0.68	0.87	0.68	1.12	0.93	0.90	0.71
01/16/2013	0.92	0.68	0.92	0.69	1.12	0.93	0.93	0.71
01/17/2013	0.93	0.68	0.94	0.70	1.21	0.94	0.94	0.71
01/18/2013	0.95	0.69	0.95	0.71	1.27	0.94	0.95	0.71
01/19/2013	0.96	0.69	0.96	0.72	1.35	0.95	0.98	0.72
01/20/2013	0.96	0.69	0.98	0.72	1.32	0.96	0.97	0.72
01/21/2013	0.97	0.70	0.99	0.73	1.23	0.96	0.97	0.72
01/22/2013	0.95	0.70	1.01	0.73	1.25	0.97	1.00	0.73
01/23/2013	0.95	0.71	1.01	0.74	1.19	0.97	1.00	0.73
01/24/2013	0.94	0.73	1.02	0.74	1.16	0.98	1.00	0.74
01/25/2013	0.96	0.75	1.01	0.76	1.18	0.99	1.00	0.76
01/26/2013	0.96	0.77	1.00	0.78	1.20	1.00	1.01	0.78
01/27/2013	0.98	0.79	1.00	0.80	1.17	1.02	1.02	0.80
01/28/2013	0.99	0.81	1.01	0.82	1.16	1.04	1.03	0.82
01/29/2013	1.00	0.83	1.01	0.84	1.18	1.06	1.04	0.84

Electrical Conductivity (EC) units: milliSiemens per Centimeter
md : mean daily
NR : No Record
NC : Average not computed due to insufficient data
BR : Below Rating
e : estimated value

State of California - Department of Water Resources - Division of Operations & Maintenance - Operations Control Office

Delta Water Quality Conditions

South Delta Stations

Date	Vernalis		Brandt Bridge		Old River Near Tracy		Old River Near Middle River	
	md EC	30 day avg	md EC	30 day avg	md EC	30 day avg	md EC	30 day avg
01/23/2013	0.95	0.71	1.01	0.74	1.19	0.97	1.00	0.73
01/24/2013	0.94	0.73	1.02	0.74	1.16	0.98	1.00	0.74
01/25/2013	0.96	0.75	1.01	0.76	1.18	0.99	1.00	0.76
01/26/2013	0.96	0.77	1.00	0.78	1.20	1.00	1.01	0.78
01/27/2013	0.98	0.79	1.00	0.80	1.17	1.02	1.02	0.80
01/28/2013	0.99	0.81	1.01	0.82	1.16	1.04	1.03	0.82
01/29/2013	1.00	0.83	1.01	0.84	1.18	1.06	1.04	0.84
01/30/2013	0.99	0.85	1.02	0.85	1.19	1.08	1.06	0.86
01/31/2013	1.01	0.86	1.04	0.87	1.25	1.10	1.03	0.88
02/01/2013	0.85	0.87	1.03	0.89	1.26	1.12	1.03	0.89
02/02/2013	0.82	0.87	1.04	0.90	1.26	1.13	0.90	0.90
02/03/2013	0.81	0.88	0.93	0.91	1.23	1.14	0.83	0.91
02/04/2013	0.81	0.88	0.84	0.91	1.15	1.15	0.82	0.91
02/05/2013	0.81	0.88	0.82	0.92	1.09	1.14	0.82	0.91
02/06/2013	0.78	0.88	0.82	0.92	1.06	1.14	0.81	0.91
02/07/2013	0.75	0.89	0.81	0.92	1.08	1.15	0.79	0.91
02/08/2013	0.70	0.89	0.80	0.92	1.04	1.15	0.76	0.91
02/09/2013	0.69	0.89	0.74	0.92	0.94	1.15	0.68	0.91
02/10/2013	0.68	0.89	0.67	0.92	0.87	1.15	0.65	0.91
02/11/2013	0.68	0.88	0.66	0.92	0.87	1.15	0.64	0.91
02/12/2013	0.66	0.87	0.64	0.91	0.88	1.14	0.63	0.90
02/13/2013	0.65	0.87	0.63	0.91	0.90	1.14	0.61	0.89
02/14/2013	0.65	0.86	0.62	0.90	0.90	1.13	0.61	0.88
02/15/2013	0.66	0.85	0.61	0.89	0.88	1.12	0.60	0.87
02/16/2013	0.64	0.84	0.61	0.88	0.82	1.11	0.61	0.86
02/17/2013	0.61	0.83	0.61	0.86	0.81	1.10	0.59	0.85
02/18/2013	0.62	0.82	0.60	0.85	0.75	1.08	0.58	0.84
02/19/2013	0.60	0.81	0.59	0.84	0.73	1.06	0.59	0.82
02/20/2013	0.57	0.79	0.59	0.83	0.72	1.04	0.57	0.81
02/21/2013	0.58	0.78	0.57	0.81	0.70	1.02	0.55	0.80

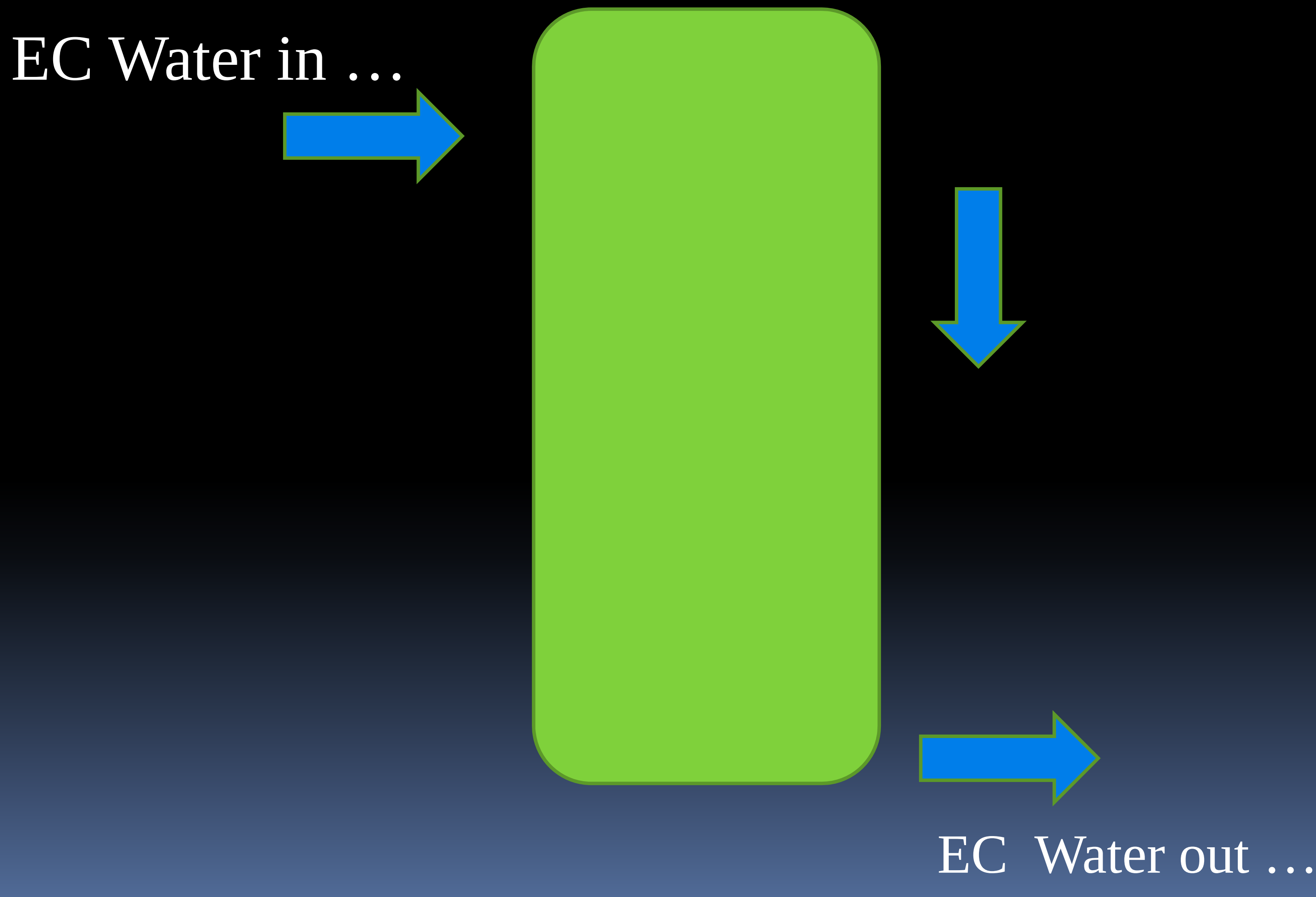
Electrical Conductivity (EC) units: milliSiemens per Centimeter
md : mean daily
NR : No Record
NC : Average not computed due to insufficient data
BR : Below Rating
e : estimated value

The Proposed changes suggest that the southern Delta will be protected even if the salinity standards are relaxed. This conclusion is based upon Dr. Glenn Hoffman's report that calculates a range of leaching fractions for the area. From the leaching fractions he calculated, Dr. Hoffman concluded a worse water quality would adequately protect southern Delta agricultural beneficial uses.

LEACHING REQUIREMENT/LEACHING FRACTION

By definition, leaching requirement (LR) is the fraction of total water applied that must drain below the root zone to restrict salinity to a specified level according to the level of tolerance of the crop.

IN THE LAB:



IN THE REAL WORLD:

Applied water EC varies;

Soil already contains salts;

Difficult to measure amount of water applied;

Impossible to measure amount of water passing through root zone;

Difficult to measure surface runoff;

Difficult to measure subsurface conditions;

Etc ….

HOW TO DETERMINE LEACHING IN THE FIELD:

1. Measure beginning soil salinity

2. Measure applied water EC

3. Measure end soil salinity

SDWA and local U.C. Davis Ag Cooperative Extension are undertaking just such a study.

LAB: SALT *IN* MINUS SALT *OUT* EQUALS SALT LEFT IN ROOT ZONE.

FIELD: SALT AT END EQUALS BEGINNING SALT PLUS APPLIED SALT WHICH WAS NOT LEACHED.

WHAT DID DR. HOFFMAN DO?

Calculated leaching fraction from *applied water* EC and *drain water* EC.

EC of Applied Water:

ASSUMED!

EC of Tile or Surface Drain Water:

SOURCE of WATER?

Paine Slough. The average electrical conductivity of the 26 outlets was 1.5 dS/m. If the salinity of the applied water was 0.7 dS/m then the leaching fraction would be 0.7/1.5 = 0.47. This is a very high leaching fraction and based on these data one would surmise that the irrigation efficiency, on average, is low and/or a great deal of low salinity water was entering the drains without passing through the crop root zone. If the main drains were open surface drains then it is possible that much of the discharge from these drains was irrigation return flow rather than subsurface drainage.

Table 3.10. Electrical conductivity (EC) and calculated leaching fraction (L), assuming EC of applied water is 0.7 dS/m for subsurface tile drains during 1986 and 1987. (Chilcott et al., 1988.).

Drain Location	No. of Samples	EC (dS/m)	L assuming EC_i=0.5 dS/m	L assuming EC_i=0.7 dS/m
3, Grant Line Rd. Sump	3	2.7	0.19	.26
4, Bethany / Lammers	3	2.1	0.24	.33
5, Patterson Pass Rd.	6	2.5	0.20	.28
6, Moitose	3	1.6	0.31	.44
7, Krohn Rd.	4	2.1	0.24	.33
8, Pimentel	2	2.2	0.23	.32
9, Lammers / Corral Hollow	4	4.4	0.11	.16
11, Delta Ave.	6	2.4	0.21	.29
13, Costa Brothers East	2	4.1	0.12	.17
14, Costa Brothers West	4	3.6	0.14	.19
15, Castro	3	2.4	0.21	.29
16, Earp	4	2.8	0.18	.25
17, Freeman	4	3.9	0.13	.18
18, Costa	5	3.4	0.15	.21
19, Moitoso and Castro	4	2.0	0.25	.35
24, Corral Hollow / Bethany	5	6.2	0.08	.11
26, Chrisman Rd.	3	2.0	0.25	.35
36, Kelso Rd. / Byron Hwy.	6	2.4	0.21	.29
37, Spirow Nicholaw	4	3.1	0.16	.23
38, JM Laurence Jr. East	4	3.5	0.14	.20
39, JM Laurence Jr. West	4	2.4	0.21	.29
40, Sequeira	3	3.6	0.14	.19
41, Reeve Rd.	3	3.8	0.13	.18
44, Larch Rd.	4	2.8	0.18	.25
Number of Drains Sampled: 24				
	Average:	3.0	0.18	0.23
	Median:	2.8	0.18	0.25
	Minimum:	1.6	0.08	0.11
	Maximum:	6.2	0.31	0.44

An example of the average leaching fraction for a large area is the New Jerusalem Drainage District. The location of the 12,300 acre District is shown in Figure 3.19. The soils drained are clay and clay loam. The electrical conductivity and the calculated leaching fraction assuming an EC_i of 0.7 dS/m are summarized in Table 3.11. From 1 to 13 samples were analyzed annually from 1977 to 2005. The average EC of the drainage water was 2.6 dS/m with the minimum annual value being 2.4 dS/m and the maximum being 3.2 dS/m. If the EC of the applied water is taken as 0.7 dS/m, the average annual leaching fraction is 0.27 with the minimum and maximum being 0.22 and 0.29, respectively. The measurements over the 17 years of measurements are relatively stable.

Table 3.11. Electrical conductivity (EC) and calculated leaching fraction (L) for applied water of 0.7 dS/m for the New Jerusalem Drainage District (Belden et al., 1989 and D. Westcot, personal communication, 2009)

Year Sampled	No. of Samples	EC of Effluent (dS/m)	L w/ ECi = 0.7 dS/m
1977	1	2.6	0.27
1978	1	3.2	0.22
1979	1	3.0	0.23
1980	1	2.6	0.27
1982	5	2.5	0.28
1983	11	3.0	0.23
1984	13	2.6	0.27
1985	11	2.5	0.28
1986	5	2.5	0.28
1987	2	2.4	0.29
1988	4	2.5	0.28
2000	3	2.4	0.29
2001	12	2.5	0.28
2002	13	2.4	0.29
2003	9	2.4	0.29
2004	6	2.4	0.29
2005	11	2.4	0.29
Number of Years Sampled: 17			
Number of Samples: 109			
	Average:	2.6	0.27
	Median:	2.5	0.28
	Minimum:	2.4	0.22
	Maximum:	3.2	0.29

Another drainage system monitored from 1982 until 1987 is the Tracy Boulevard Tile Drain Sump. This system is labeled in Figure 3.19. As shown in Figure 3.12, the 44 samples taken over the 6-year period had an average EC of 3.4 dS/m with minimum and maximum annual values of 3.1 and 3.6 dS/m. Again, if the EC of the applied water is taken as 0.7 dS/m, the leaching fraction averaged 0.21.

Table 3.12. Electrical conductivity (EC) and calculated leaching fraction (L) for an applied water of 0.7 dS/m for the Tracy Boulevard Tile Drain Sump (Belden et al., 1989).

Year Sampled	No. of Samples	EC of Effluent (dS/m)	L w/ ECi = 0.7 dS/m
1982	3	3.5	0.20
1983	10	3.6	0.19
1984	10	3.4	0.21
1985	12	3.4	0.21
1986	7	3.1	0.23
1987	2	3.1	0.23
Number of Years Sampled: 6			
Number of Samples: 44			
	Average:	3.4	0.21
	Median:	3.4	0.21
	Minimum:	3.1	0.19
	Maximum:	3.6	0.23

The other source of information located for the South Delta is the study by Meyer and colleagues (1976). They measured soil salinity at nine locations in April or May, 1976 and again in August or September, 1976. The locations represented a variety of crops, soil types, and irrigation water sources. They estimated the leaching fraction based upon the irrigation water quality in 1976 and the maximum soil salinity in the lower reaches of the crop root zone. Of the nine locations studied, five had leaching fractions of 0.25 or greater. At three locations the leaching fraction was estimated at 0.15 or greater; one location had an apparent leaching fraction of less than 0.10. The highest soil salinities and lowest apparent leaching fractions occurred at locations where water quality was the best in this study, seasonal average of about 0.7 dS/m. High leaching and low salt accumulations were found at the locations where more saline irrigation water was available, 1.1 dS/m or more.

Hoffman didn’t know:

The amount of salts in the soil at the beginning;

The amount of salt applied;

The amount of water or salt that passed through the root zone;

The amount of salts that left the root zone;

The amount ground water/salts in the drainage;

The amount of salt remaining in the root zone ;

All OF WHICH PREVENTS THE HIM FROM CALCULATING THE LEACHING FRACTION

REPRESENTATION OF TILE DRAINAGE SYSTEM

Tile drains remove **GROUND WATER!**

By adding drain tile, the water table is effectively lowered, and plants can properly develop their roots. The lack of water saturation allows oxygen to exist in the soil around the roots. Drain tile prevents the roots from being under the water table during wet periods that could cause excessive plant stress. By removing excessive water, crops use water they have more effectively. Wikipedia

Per New Jerusalem District manager, the District's tile drains contain mainly ground water!

Supply Water Quality Varies in the South Delta.

Good quality in the cross-Delta flow to the export pumps;

Medium water quality where channels have net flow; and

Poor water quality where null zones collect and concentrate salts.

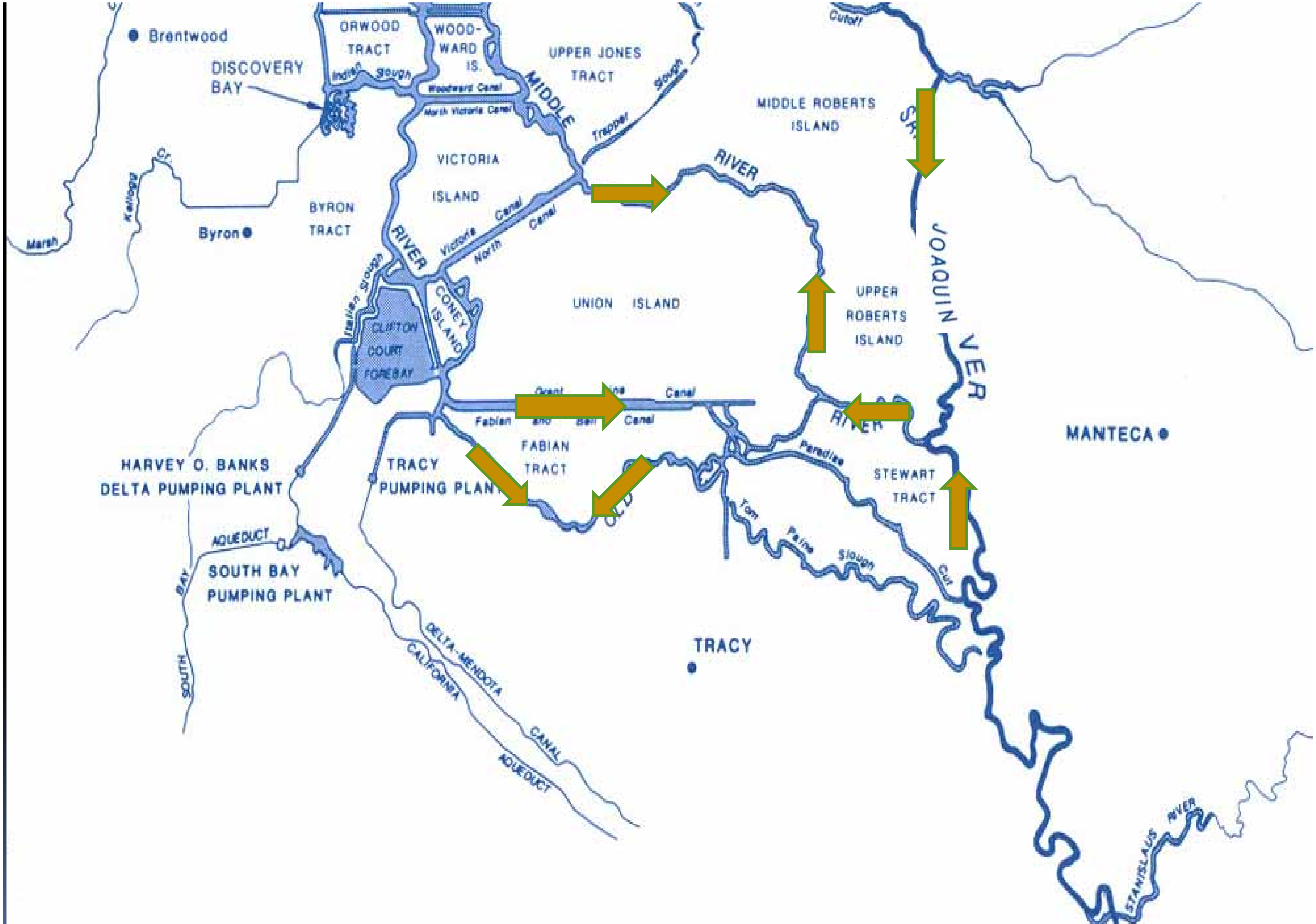
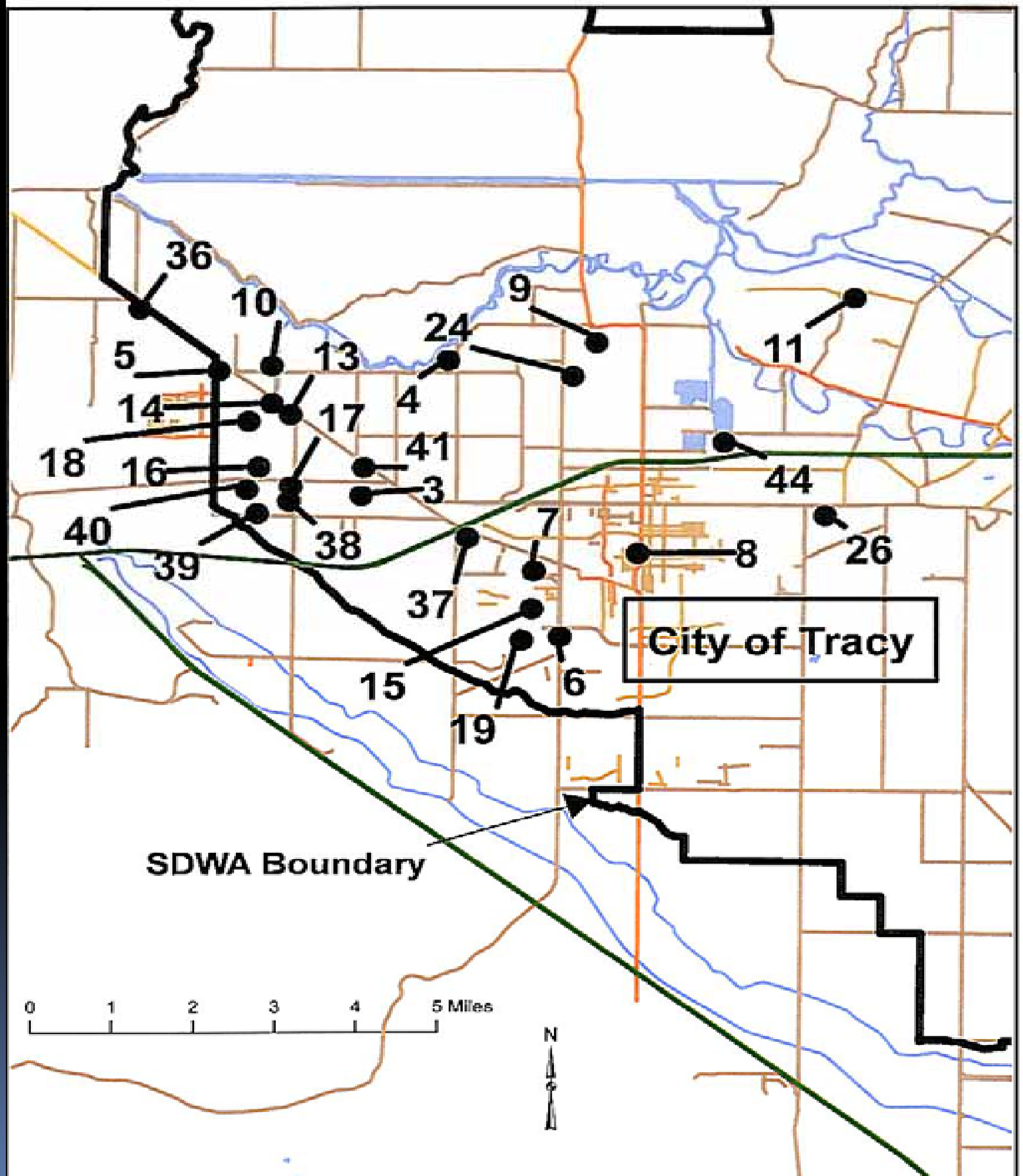
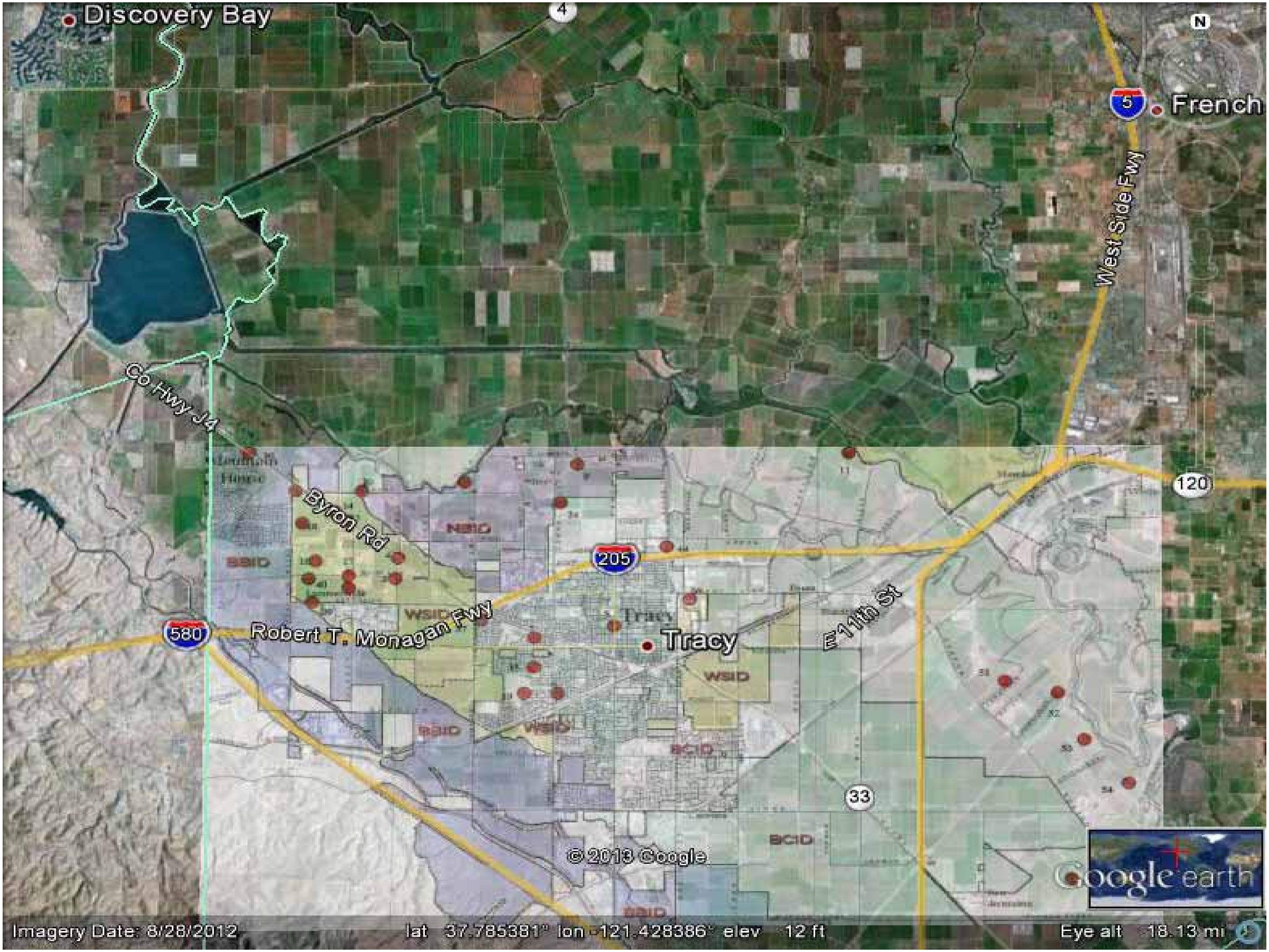

Brentwood
DISCOVERY BAY
ORWOOD TRACT
WOOD-WARD IS.
Indian Slough
Woodward Canal
North Victoria Canal
MIDDLE
UPPER JONES TRACT
Trapper Slough
MIDDLE ROBERTS ISLAND
Cutoff
VICTORIA ISLAND
RIVER
Kellogg
Cr.
Marsh
Byron
BYRON TRACT
RIVER
Victoria Canal
North Canal
Italian Slough
CLIFTON COURT FOREBAY
CONEY ISLAND
UNION ISLAND
UPPER ROBERTS ISLAND
JOAQUIN
VER
Canal
Fabian
Canal
RIVER
MANTECA
FABIAN TRACT
HARVEY O. BANKS DELTA PUMPING PLANT
TRACY PUMPING PLANT
Paradise
STEWART TRACT
Tom Paine Slough
Cut
AQUEDUCT
SOUTH BAY PUMPING PLANT
BAY
SOUTH
DELTA-MENDOTA CANAL
CALIFORNIA AQUEDUCT
TRACY
STANISLAUS RIVER

Figure 3.18. Location of subsurface tile drains sampled on the west side of the SDWA (Chilcott, et al., 1988).




Discovery Bay
4
N
5
French
West Side Fwy
Co Hwy J4
Byron Rd
NSID
BBID
205
120
WSID
580
Robert T. Monagan Fwy
Tracy
E 11th St
WSID
BBID
WSID
BCID
33
BCID
© 2013 Google
Google earth
BBID
Imagery Date: 8/28/2012
lat 37.785381° lon -121.428386° elev 12 ft
Eye alt 18.13 mi

HISTORIC WATER QUALITY WAS VERY GOOD

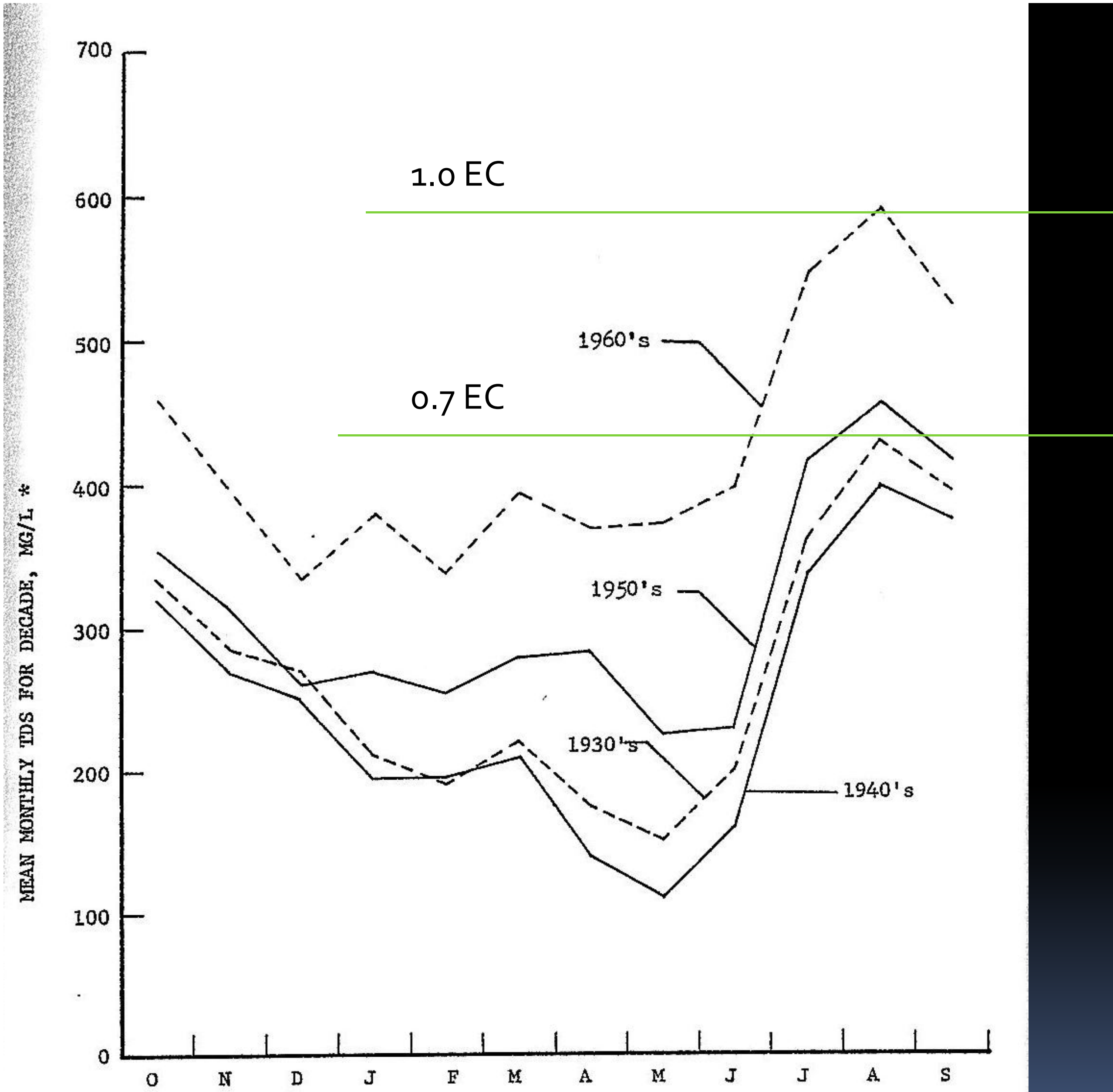


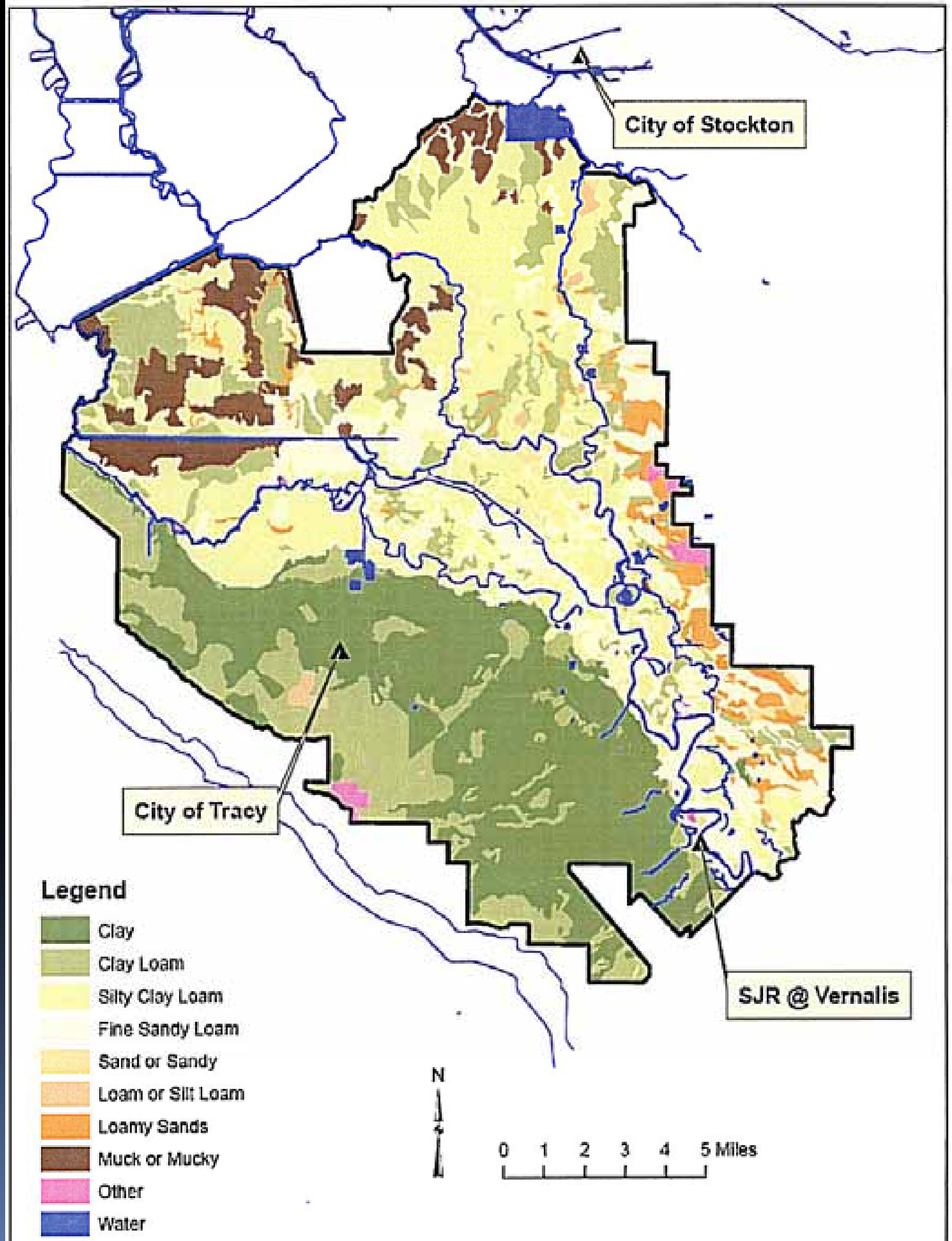
Figure VI-27 MEAN MONTHLY TDS AT VERNALIS BY DECADES 1930-1969

* Estimated by chloride load-flow regressions for 30's and 40's.

Report of the Effects of the CVP Upon the Southern Delta Water Supply Sacramento-San Joaquin River Delta, California, June 1980

VARYING SOIL TYPES IN THE SOUTH DELTA AFFECT ABILITY TO LEACH SALTS

Figure 2.4. Map of soil textures in the southern Delta using GIS data from the NRCS-SSURGO Database.



84 Soil Types in the Southern Delta

Percent of acreage	Type	Permeability in./hr
40%	Slow	<0.2
34%	Moderately slow	0.2 – 0.6
17%	Moderate	0.6 – 2.0
6%	Moderately rapid	2.0 – 6.0
3%	Rapid	>6.0

Water Quality Consideration for the South Delta Water Agency, Hoffman, Prichard, Meyer

SDWA explained to Dr. Hoffman that time restraints for such crops as alfalfa (irrigation, field dries out, cutting, mowing, raking, baling, next irrigation) exacerbated the farmers ability to leach salts from the soil, especially when the low permeability soils were involved.

There simply was not enough time to adequately leach.

DR. GLENN HOFFMAN:

"I can't help it if you have bad management practices."

Local Ground Water is of Very Poor Quality

Hoffman cites three studies regarding drainage and groundwater quality. Per those studies, local ground water ranges from:

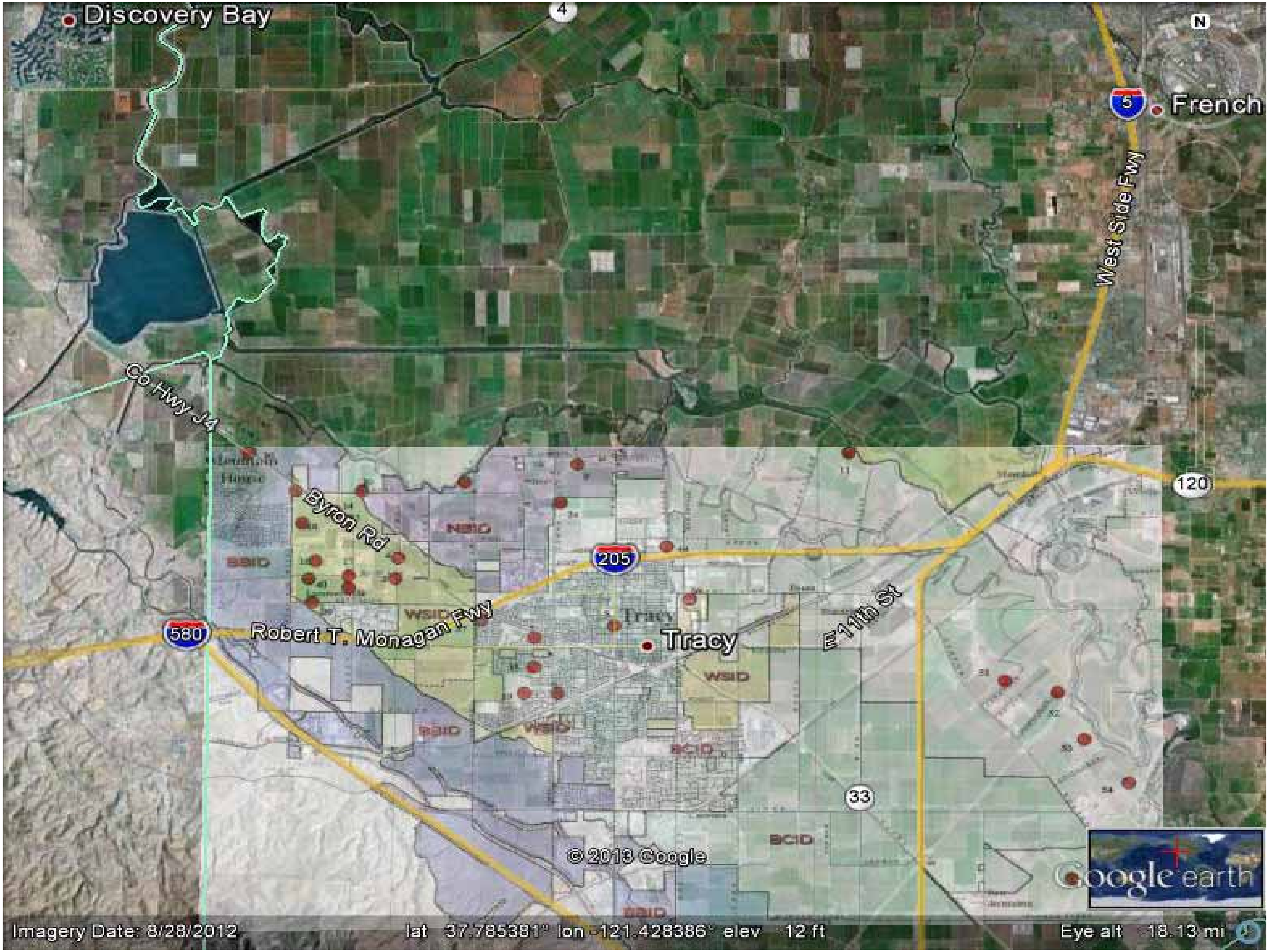
Belden, et.al.	410 – 9400 EC
Chilcott, et.al.	1900 – 4230

Montoya not included; data contains surface water drain data

Most of the Southern Delta ag land is between -5 and +10 feet compared to sea level. The shallow ground water in the area is directly linked to the channel water and thus rises and falls twice daily with the tides.

That shallow ground water contains the accumulation of 50+ years of CVP salts. Thus, when the tides rise and fall, the salty ground water rises and falls entering or approaching the root zone.

This means any salts which are leached do not go anywhere!


Discovery Bay
4
N
5
French
West Side Fwy
Co Hwy J4
Byron Rd
NSID
BBID
205
120
WSID
580
Robert T. Monagan Fwy
E 11th St
Tracy
WSID
BBID
WSID
BCID
33
BCID
© 2013 Google
BBID
Google earth
Imagery Date: 8/28/2012
lat 37.785381° lon -121.428386° elev 12 ft
Eye alt 18.13 mi

Site #	Feet Above Sea Level	Site #	Feet Above Sea Level
3	51	19	68
4	3	24	7
5	37	36	41
6	69	37	44
7	43	38	77
8	41	39	109
9	7	40	90
10	17	41	34
11	12	44	21
13	30	51	24
14	33	52	22
15	56	53	26
16	70	54	23
17	68	55	33
18	49	56	58

Per Google Earth

HOFFMAN REPORT ERRORS:

1. Used assumed applied water EC, and tile drain data from upland areas to calculate leaching fractions; ***wrong area***.

2. Soil permeability not adequately analyzed; ***inability to leach***.

3. Groundwater not adequately understood; ***tides push bad water up into root zone***.

4. Lack of practical knowledge; ***farming alfalfa is "bad management practice."***

OTHER ISSUES:

SALT

Beans, beans, beans …;
Modeling;
How did we get here;
Mitigation of project impacts;
No assimilative capacity;
Implementation plan problems;

River Flows

Zero–sum game;
Upstream obligations.

Exhibit “E”

WATER QUALITY CONSIDERATIONS FOR THE SOUTH DELTA WATER AGENCY

G. J. Hoffman, T. Prichard, and J. Meyer

A mixture of soluble salts is present in all soils. If the concentration of these salts becomes excessive, crop yields will be reduced because of the decrease in osmotic potential of the soil water. To prevent harmful accumulation of salts, the soil profile must be leached periodically with an amount of water in excess of that used by evapotranspiration. Thus, where salinity is a hazard, the concept of efficient water use must be expanded to include an increment of water to meet the leaching requirement (L_r), defined as the minimum fraction of the total amount of applied water that must pass through the soil root zone to prevent a reduction in crop yield from an excess accumulation of salts. Leaching occurs whenever irrigation and rainfall exceed evapotranspiration.

Two quantities establish the leaching requirement: the salt concentration of the applied water and the salt tolerance of the crop. The average salt concentration of the applied water ($\bar{C}$) can be estimated from the mean salt concentration of the irrigation water (C_I) and the amount of rainfall (D_R) and irrigation (D_I) applied. Mathematically,

$$\bar{C} = \frac{C_I \; D_R}{D_I + D_R}$$

because rainfall has an insignificant salt concentration. The amount of water required by the major crops in South Delta, as estimated by both the Bureau of Reclamation and the Extension Service, is summarized in Table 1. Estimates of both evapotranspiration and the total amount of water that must be applied for each crop are in close agreement. We arbitrarily chose to use the average of the values of ET and $D_R + D_I$ in Table 1. Crop salt tolerance data were taken from Maas and Hoffman (1977). They reported salt tolerance by means of two parameters: the threshold (A) and the rate of yield decline as salinity increases beyond the threshold (B). The threshold value is the maximum average salt concentration in the root zone that does not reduce yield. The salt tolerance parameters for the crops of interest are given in Table 2. Relative crop yield (Y_r) as a function of these two parameters is given by

$$Y_r = 100 - B(EC_e - A)$$

where EC_e is the average electrical conductivity of a saturated soil extract from the crop root zone. For example, the relative yield of alfalfa would be 75% at a soil salinity of 5.4 dS/m ($Y_r = 100 - 7.3(5.4 - 2.0)$).

The fraction of the total amount of applied water ($D_R + D_I$) that passes through a crop root zone (D_D) is termed the leaching fraction (L) or

$$L = \frac{D_D}{D_R + D_I} .$$

Because L_r is the minimum leaching fraction needed to prevent yield reduction:

$$L_R = \frac{D_D^*}{D_R + D_I} ,$$

where the superscript * distinguishes required from actual values. Recently, Hoffman and van Genuchten (1981) provided a graphical solution to the relationship between a crop's salt tolerance threshold and the salinity of the applied water as a function of L_r. Such relationships are illustrated in

Fig. 1. As an example, the L_r for alfalfa (threshold value of 2 dS/m from Table 2) would be 0.15 if the salinity of the applied water was 1020 mg/ℓ of total dissolved salts. Fig. 1 presents the leaching requirement of the prominent crops in the South Delta as a function of the salinity of the irrigation water without rainfall. Fig. 2 gives the leaching requirement when rainfall is normal. The amount of rainfall that is effective in meeting each crop's water requirements is given in Table 1 as D_R. The curves in Fig. 2 are displaced to the right by the amount of dilution caused by D_R to the salt concentration of the total amount of water applied to each crop ($D_I + D_R$). This dilution factor is listed in Table 1 and is merely $(D_R + D_I)/D_I$.

After the leaching requirement has been established for a given crop and a given salinity of the irrigation water, the paramount question is whether or not the soil profile has sufficient permeability to pass the required amount of drainage water through and out of the crop root zone. The amount of water that must drain below the root zone (D_D) to prevent yield loss can be estimated from $D_D = L(D_R + D_I)$ when the value of L_R for the irrigation water quality in question is substituted for L. The value of D_D required to prevent yield loss as a function of irrigation water quality and crop is given in Fig. 3 for normal rainfall. For example, alfalfa with normal rainfall has a D_D value of 3.9 in. for a L_R of 0.07. Without rainfall, D_D must increase to ~~account for the higher L_R caused by irrigation water of the same quality~~ applied to compensate for no rainfall. L_R would increase to 0.096 without rainfall and D_D would become 5.3 in. For D_D to remain at 3.9 in. without rainfall, the quality of the irrigation water must improve to 480 mg/ℓ rather than 570 mg/ℓ with rainfall.

Few field measurements have been made of the leaching fractions achieved for various combinations of soils, crops, and water management. One such study was conducted by Jewell Meyer in the South Delta in 1976. His findings are summarized in Table 3. The leaching fractions measured varied from less than 0.05 to 0.25 with a mean of 0.15 for all 11 measurements with a standard deviation of 0.08. If these few measurements are representative then 16% of the soils have a leaching fraction less than 0.07 and 16% have L's above 0.23 with the remaining 68% of the L's between 0.07 and 0.23. A similar study was conducted in the Imperial Valley (Lonkerd et al., 1976). These data are summarized in Table 4. In the Imperial Valley the average L was 0.10 with a standard deviation of 0.09. Considering the fine texture of the soils in the Imperial Valley, these values are not unexpected and perhaps adds credence to the values reported for the South Delta.

With this basic information, the salt concentration of the irrigation water (with and without normal rainfall) that would cause various reductions in yield of the prominent crops in the South Delta are summarized in Table 5 for the mean leaching fraction reported for the South Delta, 0.15, and L's one standard deviation above and below the mean, namely 0.07 and 0.23. The amount of drainage required to prevent yield loss for the same three leaching fractions and crops considered in Table 5 is presented in Table 6.

In addition to the generalized salt tolerance of crops just described, some crops may be more sensitive during emergence than during later stages of growth. Dr. E. V. Maas of the Salinity Laboratory has compiled a list of crops comparing salt tolerance at emergence and for yield. His results for the crops of interest in the South Delta are presented in Table 7; bean is the only crop planted by seed that is lacking. Only sugar beet is more sensitive during emergence than at later growth stages. When comparing growth stages, it is important to separate effects that vary with stage of growth from those that reflect the duration of, or changes in, the saline condition. Plant response is directly related to duration of exposure to salinity. Some crops are salt sensitive at the early seedling stage. Data from the literature indicate that barley, corn, rice, and wheat are most sensitive between emergence and the four-leaf stage.

Another problem specific to crops planted on raised beds is the movement of soluble salts to the top center of the beds. Planting seeds in the center of a single-row, raised bed places the seeds exactly in the area where salts concentrate. Planting either a single or double row near the shoulder of the bed places the seeds away from the greatest salt accumulation. The magnitude of accumulation is site specific and related to soil characteristics, incoming water quality, evaporation rate, and the amount of water applied. Under normal conditions, the maximum salt concentration in the raised bed is no more than 2 to 4 times the average salt concentration of the surface soil.

Soils within the area of the South Delta Water Agency were formed from parent material including metasedimentary, granitic, and organic sources. As a result, the soils vary widely in physical characteristics. Soil textures, for example, range from coarse sand to clay, and in organic matter content, from less than 5% in most mineral soils to more than 50% in the muck soils.

A recent soil survey, conducted by the Soil Conservation Service and provided to us prior to publication, indicates 84 different soil series within the South Delta. A soil series is a group of soils that developed from a particular type of parent material and have soil horizons similar in physical characteristics and arrangement in the soil profile. The soils within a series are nearly homogeneous in all profile characteristics except texture near the surface and such featues as slope, stoniness, degree of erosion, topographic position, and depth to bedrock. Nevertheless, a substantial amount of variation can exist even within a defined soil series. Some fields contain several soil series that differ greatly in soil characteristics. The survey only considers variation on a scale of 10 acres or larger. Variations within a 10-acre block are not included in the survey. A typical soil series description follows.

Grangeville clay loam, drained (GC)

These are very deep, somewhat poorly drained soils, formed in flood plains derived from predominately granitic rock sources. Elevations are 10 to 50 feet, and slopes are 0 to 2 percent. Average annual rainfall is 14 to 16 inches; average annual air temperature is 60°F, and frost-free season is 260 to 280 days. In a typical profile the surface layer is grayish-brown neutral clay loam 16 inches thick. Where mixing with the subsoil and surrounding soils is more pronounced, the surface may be heavy loam or sand clay loam. The subsoil is stratified light grayish-brown mottled loam, fine sandy loam, and sandy loam. Reaction is neutral to mildly alkaline.

Included in this mapping unit are inclusions of other soils too small to delineate separately. About 2 percent of this unit consists of Grangeville fine sandy loam, drained, usually where deep cuts have brought the coarser subsurface material closer to the surface. About 4 percent consists of a similar soil that is underlain at about 40 inches by a clayey substratum, usually on the lower physiographic positions. Two percent consists of Dello loamy sand along old stream channels and there are 5 percent inclusions of Merritt silty clay loam, drained, located at random within the delineation. Two percent of this unit consists of a soil that has a grayish-brown silty clay loam or clay loam surface layer that is 20 to 30 inches thick, underlain by fine sandy loam and loam to 60 inches.

An important soil property in determining if a particular leaching fraction can be achieved is soil hydraulic conductivity, the ability to transmit water through a unit cross section of soil in unit time under specified temperature and hydraulic conditions. In the absence of precise measurements, soils may be placed into relative hydraulic conductivity or permeability classes through studies of structure, texture, porosity, cracking, and other characteristics of the horizons in the soil profile in relation to local experience. The 84 soil series in the South Delta were grouped into five permeability classes by the Soil Conservation Service based upon the percolation rate of the least permeable horizon in the profile. They are as follows:

	Permeability, in./hr
Slow	<0.2
Moderately slow	0.2 to 0.6
Moderate	0.6 to 2.0
Moderately rapid	2.0 to 6.0
Rapid	>6.0

To aid in visualizing how the permeability of soils varies, a generalized soil permeability map was made based on the previously stated soil series permeability ratings. The approximate percent of land in each rating, and the series which comprise each permeability rating are as follows:

Map Symbol	Soil Series
Slow (40%) - less than 0.2 inches per hour	
AD	Finrod clay loam
AO	Archerdale very fine sandy loam, overwash
AR	Archerdale clay loam
CL	Stockton clay
CP	Capay clay, 0 to 2 percent slopes
CPB	Capay clay, 2 to 5 percent slopes
CS	Capay clay, saline alkali
CW	Capay clay, wet
EG	Peltier mucky clay loam, drained
ES	Peltier mucky clay loam, organic substratum
PD	Pescadero clay loam, drained
RM	Rincon clay loam
RW	Rincon clay loam, wet
TC	Colusa variant clay loam, drained
WA	Willows clay, drained
XD	Hollenbeck silty clay
Moderately slow (34%) - 0.2 to 0.6 inches per hour	
BC	Blancho clay loam, drained
BR	Brentwood clay loam
BZ	Bronzan sandy clay loam, drained
CD	Eightmile variant clay loam
CH	Bronzan clay loam, drained
CI	Bronzan clay loam
EA	Egbert mucky clay loam, partially drained
EB	Egbert silty clay loam, partially drained
EF	Egbert silty clay loam, sandy substratum
KI	Kingile muck, drained
KL	Kingile-Ryde complex
LR	Los Robles gravelly clay loam
LS	Los Robles clay loam
ME	Merritt silty clay loam, partially drained
MF	Merritt silty clay loam, flooded
OD	Chualar variant coarse sandy loam
RH	Ryde clay loam, drained
RS	Ryde clay loam, organic substratum
SI	Shinkee muck, drained
VJ	Veritas silty clay loam, overwash
VL	Veritas sandy loam, saline-alkali
VM	Veritas variant sandy loam
VR	Vernalis clay loam
VW	Vernalis clay loam, wet
VY	Vina loam
VZ	Valdes silt loam, drained
WB	Webile muck, drained

Map Symbol	Soil Series
Moderate (17%) - 0.6 to 2.0 inches per hour	
FC	Fluvaquents
GC	Grangeville clay loam, drained
MN	Manteca sandy loam
RF	Ryde clay loam, sandy substratum
RI	Ryde-Peltier complex
SC	Timor loamy sand
SH	Shima muck, drained
XV	Galt clay
Moderately rapid (6%) - 2.0 to 6.0 inches per hour	
CB	Columbia fine sandy loam
CC	Columbia fine sandy loam, clayey substratum
CE	Columbia fine sandy loam, channelled
CF	Columbia fine sandy loam, flooded
CJ	Eightmile loam
CO	Eightmile fine sandy loam, overwash
CT	Cortina gravelly loam
DN	Escalon sandy loam
DV	Devries sandy loam, drained
GV	Grangeville fine sandy loam, drained
GS	Grangeville fine sandy loam, flooded
HA	Honcut fine sandy loam
HG	Escalon sandy loma
HL	Honcut gravelly sandy loam
RK	Reiff loam
VF, VG	Veritas fine sandy loam, very deep
VH	Veritas sandy loam
VK	Devries variant sandy loam
Rapid (3%) - greater than 6.0 inches per hour	
DB	Dello sandy loam, clay substratum
DC	Dello loamy sand, drained
DD	Dello clay loam, overwash
DE	Dello loamy sand, moderately wet
DF	Dello sand, flooded
DH	Delhi loamy coarse sand
RC	Rindge mucky silt loam, overwash
RN	Rindge muck, drained
TG	Tujunga gravelly loamy coarse sand
TS	Tinnin loamy coarse sand, drained
TT	Tinnin loamy coarse sand, loamy substratum
TW	Bisgani loamy coarse sand, partially drained
VC	Venice mucky silt loam, overwash
VE	Venice muck, drained

With this background information, it is hoped that the concerned parties can decide upon an adequate water quality standard for the South Delta. The biggest uncertainty in this information is the leaching fractions which can reasonably be achieved for the various combinations of soils, crops, and management options suitable for the South Delta. Therefore, this committee recommends that the concerned parties sponsor a more extensive field study of the leaching fractions being achieved in the South Delta. The leaching fraction for at least ten sites for soils having an SCS permeability rating of 0 to 0.2 inches per hour and ten for soils with a rating of 0.2 to 0.6 inches per hour should be determined by measuring the soil salinity at the bottom of the root zone in at least five locations at each site. A study of this magnitude would require several months and cost about $15,000.

Table 1. Crop water requirements in the South Delta.

Crop	Area Planted	Effective Rainfall	Bureau of Reclamation			Extension Service			Average		
			Evapotranspiration	Irrigation Water Delivered to Farm	Total Applied	Evapotranspiration	Irrigation Water Delivered to Farm	Total Applied	Evapotranspiration	Total Applied	Rainfall Dilution Factor for $\bar{C}$
		D_R	ET	D_I	$D_R + D_I$	ET	D_I	$D_R + D_I$	ET	$D_R + D_I$	$\frac{D_R + D_I}{D_I}$
	%	in.	in.	in.	in.	in.	in.	in.	in.	in.	
Alfalfa	26	8.4	41.8	44.5	52.9	40.0	48.6	57.0	40.9	55.3	1.18
Tomato	14	3.6	27.4	31.7	35.3	25.5	36.5	40.1	26.4	37.7	1.11
Wheat	16	9.6	16.8	9.6	19.2	15.8	10.4	20.0	16.3	19.6	1.96
Bean	8	2.4	16.2	18.4	20.8	17.5	23.2	25.6	16.8	23.2	1.12
Corn	9	1.2	24.3	30.8	32.0	25.2	40.0	41.2	24.8	36.6	1.03
Sugar Beet	10	7.2	34.4	36.3	43.5	28.0	34.7	41.9	31.2	42.7	1.20
Fruit & Nuts	5	8.4	38.1	39.6	48.0	37.6	38.9	47.3	37.8	47.6	1.21
Asparagus	7	8.8	28.8	26.7	35.5	-	-	-	28.8	35.5	1.33
Grape	-	4.8	27.4	30.1	34.9	20.9	26.8	31.6	24.2	33.2	1.17

$$D_I = \frac{ET - D_R}{eff.}$$

eff. = irrigation efficiency. USBR assumed an eff. of 0.75 for all crops; ES eff. varied from 0.60 to 0.75 depending on crop.

Table 2. Crop salt tolerance parameters (from Maas and Hoffman, 1977).

Crop		Alfalfa	Tomato	Wheat	Bean	Corn	Sugar Beet	Fruit & Nuts	Asparagus	Grape
Threshold, dS/m	(A)	2.0	2.5	6.0	1.0	1.7	7.0	1.5	10	1.5
% Yield decline per unit increase in salinity beyond threshold	(B)	7.3	9.9	7.1	19	12	5.9	20	–	9.6

Table 3. Leaching fractions achieved for various soil types in the South Delta (Meyer, unpublished report, 1976).

SCS Soil Permeability Class in/hr	Crop	No. of Sites Samples	Leaching Fraction Values	Leaching Fraction Mean
0 to 0.2	Alfalfa	2	0.03-0.05; <0.05	0.04
0.2 to 0.6	Alfalfa	2	0.15; 0.15	0.13
	Sugar Beet	1	0.10	
0.6 to 2.0	Walnut	1	0.15	0.18
	Corn	1	0.15	
	Alfalfa	1	0.25	
2.0 to 6.0	Tomato-Cabbage	1	0.25	0.25
	Tomato	1	0.25	
>6.0	–	0	–	–
			Overall Mean =	0.15
			Standard Deviation =	0.08

Table 4. Leaching fractions achieved for various soil types and crops in the Imperial Valley (Lonkerd, Ehlig, and Donovan, unpublished report, 1976).

Soil Series	Crop	No. of Sites Samples	Infiltration Rate, in/hr Range	Leaching Fraction Range	Leaching Fraction Median
Holtsville, stratified fine textures over loamy subsoils	Alfalfa	33	0.30 to 2.0	0.03-0.23	0.09
	Cotton	41		0.01-0.42	0.06
	Lettuce	56		0.02-0.76	0.27
	Sugar Beet	18		0.01-0.49	0.28
	Wheat	37		0.03-0.50	0.12
Imperial, variable surface soil texture but underlain by fine textured subsoil	Alfalfa	21	0.15 to 2.0	0.02-0.11	0.05
	Cotton	11		0.02-0.05	0.03
	Lettuce	26		0.01-0.44	0.07
	Sugar Beet	115		0.01-0.24	0.04
	Wheat	100		0.01-0.42	0.05
Indio, coarse texture over silty flow control subsoil	Alfalfa	71	>2.0	0.02-0.22	0.06
	Cotton	33		0.01-0.26	0.04
	Lettuce	74		0.01-1.00	0.28
	Sugar Beet	7		0.09-0.38	0.15
	Wheat	35		0.03-0.48	0.23
Meloland, coarse loamy surface soils over fine textured subsoils	Alfalfa	14	2.0 to 3.0	0.02-0.05	0.03
	Cotton	17		0.02-0.86	0.05
	Lettuce	10		0.02-0.18	0.04
	Sugar Beet	11		0.01-0.17	0.05
	Wheat	7		0.03-0.16	0.04

Overall Mean = 0.10

Standard Deviation = 0.09

Table 5. Salt concentration of irrigation water, reported as mg/ℓ of total dissolved salts that results in various reductions in crop yield as a function of leaching fraction and rainfall.

	No Rainfall				Normal Effective Rainfall			
Leaching Fraction	Relative Crop Yield 100%	90%	80%	70%	Relative Crop Yield 100%	90%	80%	70%
				ALFALFA				
0.07	480	830	1170	1500	570	980	1380	1770
0.15	1060	1730	2430	3120	1250	2040	2870	3680
0.23	1880	3150			2220	3720		
				TOMATO				
0.07	590	860	1110	1360	650	950	1230	1510
0.15	1290	1800	2320	2840	1430	2000	2580	3150
0.23	2310	3280			2560	3640		
				WHEAT				
0.07	1430	1810			2800	3550		
0.15	3070	3790			6020	7430		
0.23								
				BEAN				
0.07	250	380	510	640	280	430	570	720
0.15	520	790	1060	1330	580	880	1190	1490
0.23	940	1430	1910	2410	1050	1600	2140	2700
				CORN				
0.07	420	630	830	1040	430	650	850	1070
0.15	880	1300	1730	2150	910	1340	1780	2210
0.23	1590	2360	3150		1640	2430	3240	
				SUGAR BEET				
0.07	1660	2120			1990	2540		
0.15	3580				4300			
0.23								
				FRUIT AND NUTS				
0.07	360	500	620	740	440	600	750	900
0.15	780	1040	1290	1550	940	1260	1560	1880
0.23	1400	1870	2340	2800	1690	2260	2830	3390
				GRAPE				
0.07	360	630	880	1140	420	740	1030	1330
0.15	780	1310	1840	2370	910	1530	2150	2770
0.23	1400	2370	3340		1640	2770	3910	

Table 6. The amount of drainage required to prevent yield loss for the leaching fractions and crops considered in Table 5.

Leaching Fraction	No Rainfall: Salinity of Irrigation Water	No Rainfall: Depth of Drainage	Normal Effective Rainfall: Salinity of Irrigation Water	Normal Effective Rainfall: Depth of Drainage
	mg/ℓ	in.	mg/ℓ	in.
		ALFALFA		
0.07	480	3.9	570	3.9
0.15	1060	8.3	1250	8.3
0.23	1880	12.7	2220	12.7
		TOMATO		
0.07	590	2.6	650	2.6
0.15	1290	5.7	1430	5.7
0.23	2310	8.7	2560	8.7
		WHEAT		
0.07	1430	1.4	2800	1.4
0.15	3070	2.9	6020	2.9
		BEAN		
0.07	250	1.6	280	1.6
0.15	520	3.5	580	3.5
0.23	940	5.3	1050	5.3
		CORN		
0.07	420	2.6	430	2.6
0.15	880	5.5	910	5.5
0.23	1590	8.4	1640	8.4
		SUGAR BEET		
0.07	1660	3.0	1990	3.0
0.15	3580	6.4	4300	6.4
		FRUIT AND NUTS		
0.07	360	3.3	440	3.3
0.15	780	7.1	940	7.1
0.23	1400	10.9	1690	10.9
		GRAPE		
0.07	360	2.3	420	2.3
0.15	780	5.0	910	5.0
0.23	1400	7.6	1640	7.6

Table 7. Relative salt tolerance of crops of interest in the South Delta at emergence and later growth of stages.

Crop	Electrical Conductivity of the Soil Saturation Extract (EC_e) that Causes a 50% Reduction in	
	Yield	Emergence
Alfalfa	8.9	8-13
Tomato	7.6	8
Wheat	13	14-16
Corn	5.9	21-24
Sugar Beet	16	6-12

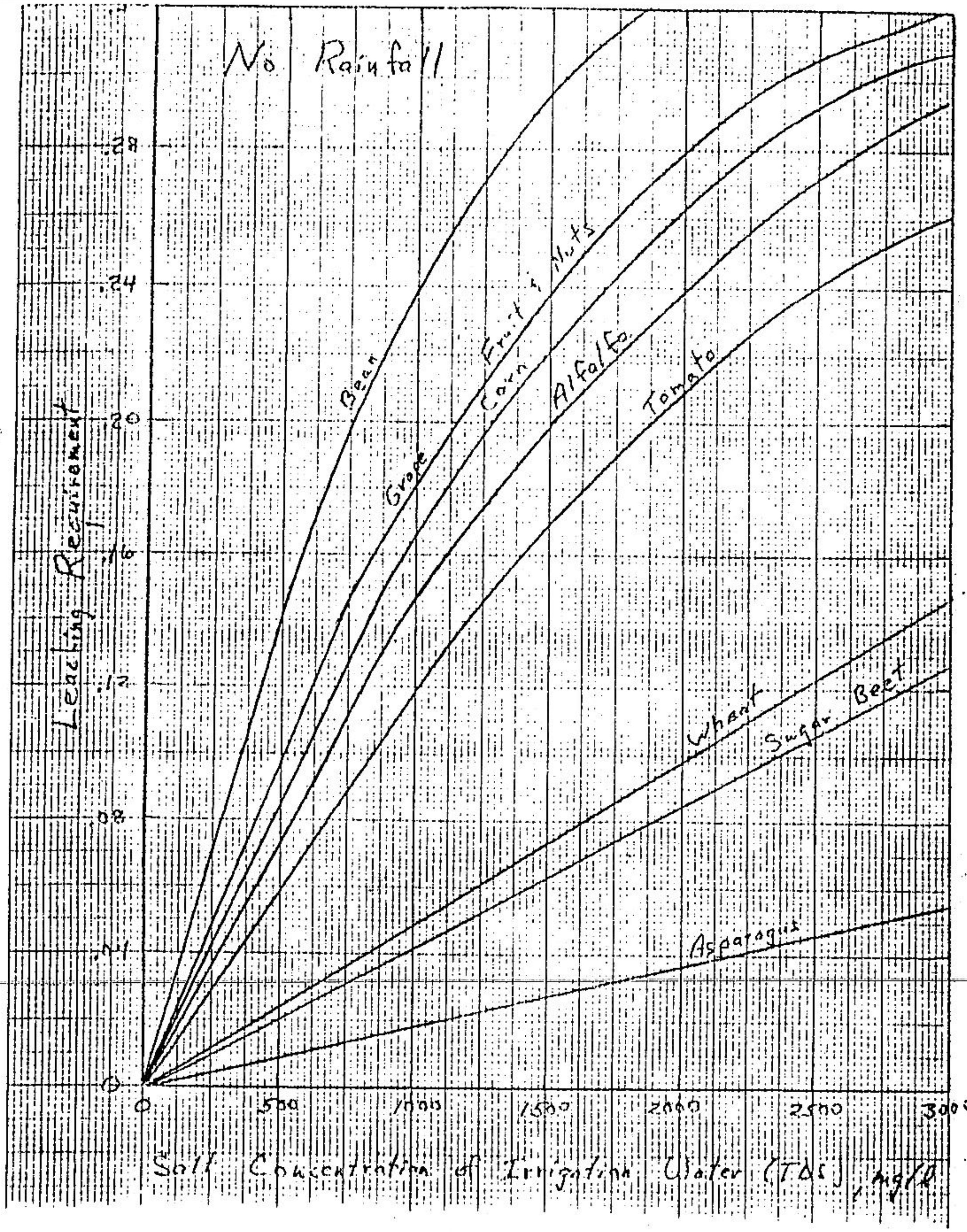


Fig. 1. Leaching requirement of the prominent crops in the South Delta as a function of the salinity of the irrigation water without rainfall.

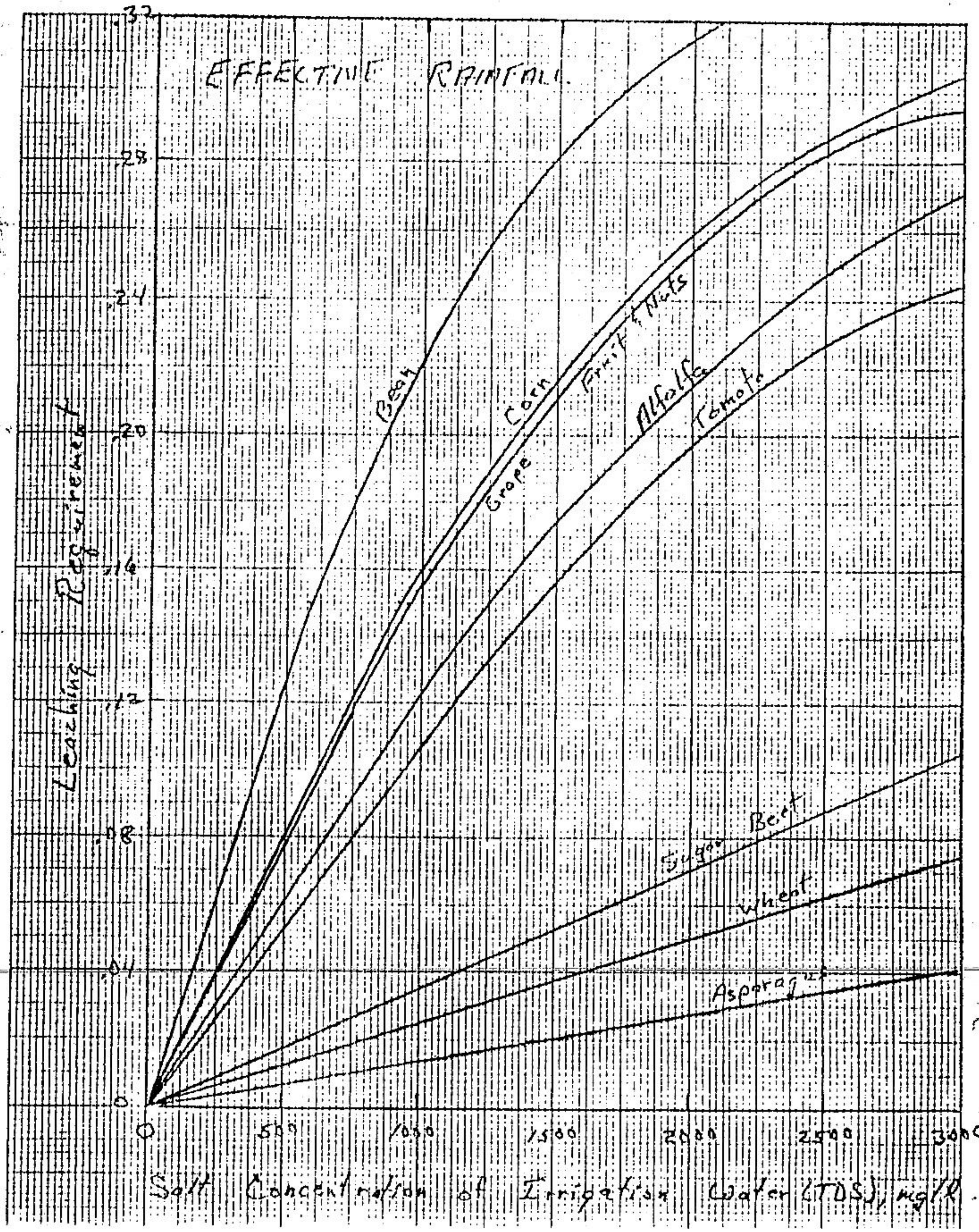


Fig. 2. Leaching requirement of the prominent crops in the South Delta as a function of the salinity of the irrigation water with effective normal rainfall.

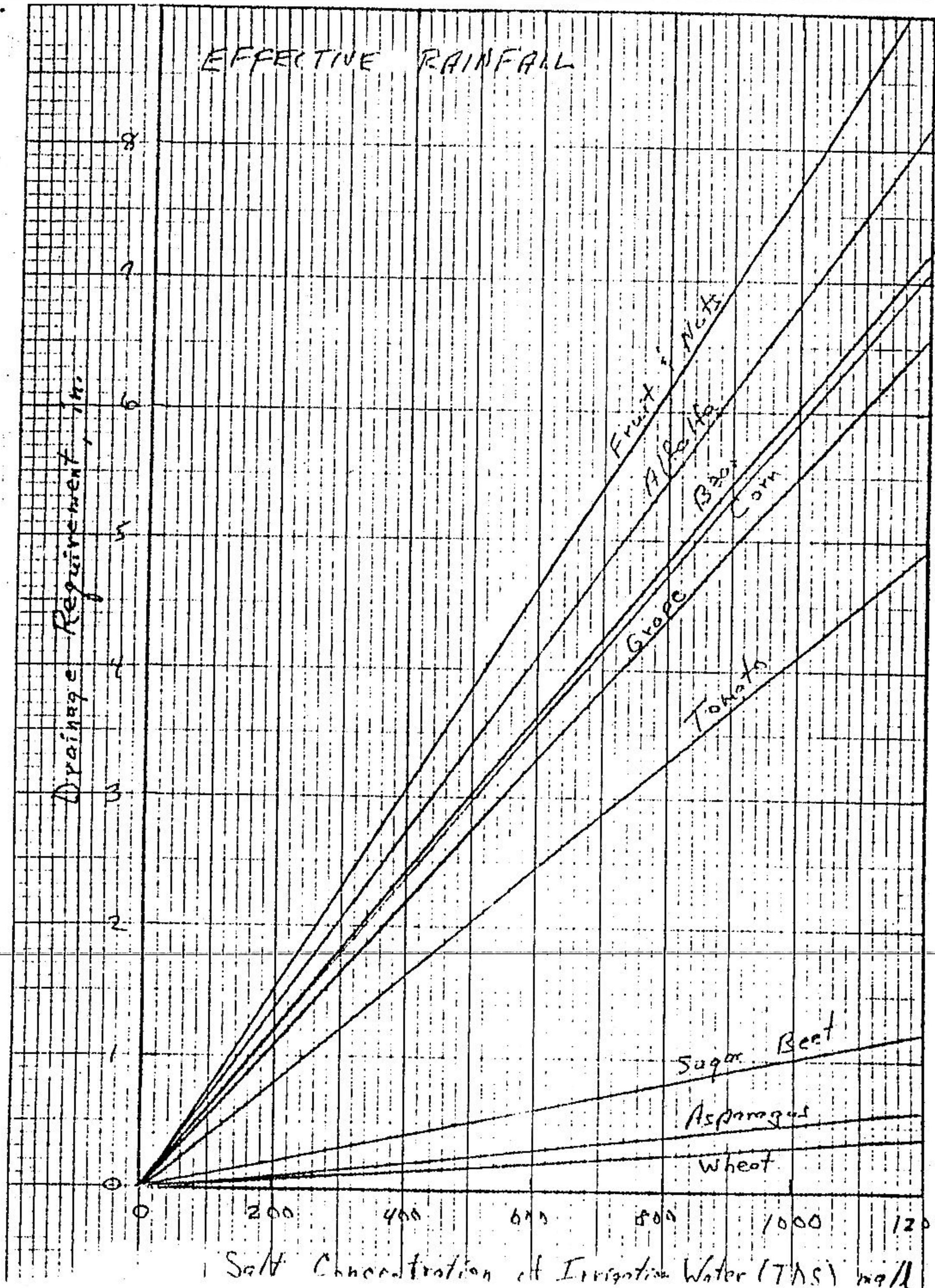


Fig. 3. The amount of drainage required to prevent yield loss as a function of irrigation water quality and crop when rainfall is normal.

Exhibit "F"

EFFECTS OF THE CVP
UPON THE SOUTHERN DELTA WATER SUPPLY
SACRAMENTO-SAN JOAQUIN RIVER DELTA, CALIFORNIA

JUNE 1980

Prepared jointly by the
Water and Power Resources Service
and the South Delta Water Agency

REPORT

ON

EFFECTS OF THE CVP

UPON THE SOUTHERN DELTA WATER SUPPLY

THE PARTICIPATING PARTIES

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I N D E X

APPENDICES

Appendix No.	Title
1	Monthly flow data (KAF) and monthly chloride data (p/m)
2	Chloride load-flow regression curves
3	Salt (chloride) balances by representative months
4	Summary of network analysis of the lower Sacramento-San Joaquin Delta

EFFECTS OF THE FEDERAL CVP UPON THE QUALITY AND VOLUME OF THE INFLOW OF THE SAN JOAQUIN RIVER TO THE SACRAMENTO-SAN JOAQUIN DELTA AND UPON THE IN-CHANNEL WATER SUPPLY IN THE SOUTHERN DELTA

CHAPTER I

INTRODUCTION AND DEFINITIONS

Over the last several years in the course of the discussions between representatives of the South Delta Water Agency (SDWA) and representatives of the United States Water and Power Resources Service (Service), formerly the United States Bureau of Reclamation (USBR), the parties have found that the available technical data relative to the impact of the Federal Central Valley Project (CVP) upon the San Joaquin River inflow to the Sacramento-San Joaquin Delta (Delta) and the effect of the operation of the Federal CVP and California State Water Project (SWP) export pumps near Tracy on the in-channel water supply in the southern Delta was limited and had never been thoroughly studied and evaluated.

At a meeting held in Washington, D.C., on July 17, 1978, attended by representatives of the Department of the Interior, a technical analysis and evaluation of the effect was authorized and undertaken. The State Department of Water Resources of the State of California (DWR) was invited to participate and did so to a limited extent. Since July, 1978, the technical staffs of the SDWA and the Service have engaged in a detailed study of subject matter, and committees representing the participating parties, from time to time, met for the purpose of reviewing progress of the technical advisors and generally directing the areas in which technical research should be conducted.

The purpose of this document is to set forth a report by the SDWA and the Service of the factual technical findings and the conclusions to this date resulting from such research and studies.

For purposes of this report, where substantial areas of disagreement exist between the SDWA and the Service on the interpretation of data, the differences will be noted and the differing views of the parties set forth.

In order to facilitate brevity and to assist in the understanding of this report, the following definitions are intended unless the context or express provision requires otherwise.

1. "South Delta Water Agency" (SDWA) is an agency created by the South Delta Water Agency Act (Cal. Stats. 1973, c. 1089, p. 2207) for the purposes therein described.

2. The "United States Water and Power Resources Service" (Service) is the agency responsible for the operation of the Federal Central Valley Project (CVP). Prior to November 6, 1979, this agency was known as the United States Bureau of Reclamation (USBR).

3. "Southern Delta" is defined as the area within the boundaries of the SDWA as defined in Cal. Stats. 1973, c. 1089, p. 2214, sec. 9.1 (California Water Code Appendix Chapter 116).

4. "Central Valley Project" (CVP) is defined as the Federal Central Valley Project in California.

5. "State Water Project" (SWP) is the State Water Resources Development System as defined in Section 12931 of the California State Water Code.

6. The "Delta Mendota Canal" (DMC) is a conveyance facility of the CVP by means of which water is exported from the Delta near Tracy and delivered on the west side of the San Joaquin Valley and to the Mendota pool in the San Joaquin River.

7. The "State Aqueduct" is a conveyance facility of the SWP by means of which water from the Delta is exported through Clifton Court Forebay near Tracy to the San Joaquin Valley and Southern California.

8. "Export Pumps" are defined as the CVP and SWP pumps located at the diversion point of the DMC and the State Aqueduct. They are operated as part of the CVP and the SWP for the purpose of diverting and exporting from the Delta via the canals.

9. "Delta" or the "Sacramento-San Joaquin Delta" is defined as all of the lands within the boundaries of the Sacramento-San Joaquin Delta as described in Section 12220 of the Water Code of the State of California on January 1, 1974.

10. "New Melones Project" is the Federal project on the Stanislaus River authorized by Public Law 78-534, dated December 22, 1944, as modified by Public Law 87-874, dated October 23, 1962.

11. "Vernalis" is defined as the San Joaquin River gaging station just below the mouth of the Stanislaus River at the Durham Ferry Bridge.

12. "Pre-1944" is defined as the years 1930 to 1943, inclusive, unless otherwise indicated.

13. "Post-1947" is defined as the years 1948 to 1969, inclusive.

14. "Total Dissolved Solids" (TDS) is defined as the concentration in milligrams per liter of a filtered water sample of all inorganic or organic constitutents in solution determined in accordance with procedures set forth in the publication entitled "Standard Methods for the Examination of Water and Waste Water" published jointly by the American Public Health Association, the American Water Works Association and the Water Pollution Control Federation, 13th Edition, 1971.

15. "Cubic Foot Per Second" (ft^3/s) or (CFS) is the flow of 1 cubic foot of water per second past a given point.

16. "p/m" or "ppm" is defined as parts per million, and is used synonomously with mg/L is this report.

17. "mg/L" is defined as milligrams per liter.

18. "KAF" is 1,000 acre-feet.

19. "Mendota Pool" is a small storage reservoir impounded by a diversion dam on the San Joaquin River about 30 miles west of Fresno into which the Delta-Mendota Canal discharges water conveyed from the Tracy Pumping Plant.

20. "Unimpaired Rim Flow" is defined as the sum of gaged flows, adjusted for upstream storage, at four stations on the major tributaries as follows:

SAN JOAQUIN RIVER AT FRIANT DAM
MERCED RIVER AT EXCHEQUER DAM
TUOLUMNE RIVER AT DON PEDRO DAM
STANISLAUS RIVER AT NEW MELONES DAM

The sum of these gaged flows is also used in this report as the Vernalis unimpaired flow.

21. The "Lower San Joaquin River" is defined as that portion of the San Joaquin River downstream of the mouth of the Merced River.

22. The "Upper San Joaquin River" is defined as that portion of the San Joaquin River and basin upstream of the mouth of the Merced River.

CHAPTER II

PURPOSES OF INVESTIGATIONS

The purpose of the investigation was to analyze and prepare a written report upon the following:

(a) The effect of the operation of the CVP upon the San Joaquin River inflow (quality and volume) to the Delta;

(b) The effect of the operation of the CVP export pumps near Tracy upon the in-channel water supply in the Southern Delta.

While all water supply development in the San Joaquin River basin has the effect of reducing the annual flow of the San Joaquin River at Vernalis, this report is directly concerned only with the effects of the CVP on the in-channel water supply in the southern Delta. The available data has been reviewed and analyzed to determine what, if any, changes have occurred affecting the southern Delta in-channel water supply since the CVP began operation in 1947. The two agencies preparing the report have not agreed on the legal obligation of the Federal Government to the southern Delta. In addition, there are several other issues on which agreement has not been reached and further discussion and study will be needed. Therefore, the report does not include consideration of the following:

1. Water rights, priorities, or legal status of any party related to the in-channel water supply in the southern Delta, including water users in the southern Delta.
2. Economic consequences of any impacts discussed on southern Delta agriculture and other uses.

3. Alternative solutions to improve the in-channel water supply in the southern Delta.

4. The impact on the Southern Delta in-channel water supply of the operation of the CVP New Melones Reservoir.

The impacts of developments other than the CVP affecting the in-channel water supply in the southern Delta have been attributed to specific other developments when such impacts are clearly identifiable. The impact of the operation of the SWP export pumps has been specifically included. The impacts other than CVP have been determined incidentally to the principal purposes of this report.

While development other than the CVP has occurred in the upper San Joaquin River basin (as defined in Chapter I) since 1947, it was assumed in the investigation that the impact of other development is negligible. Consequently, for this report, the effects on San Joaquin River inflow to the Delta (both quantity and quality) of all development in the upper San Joaqin River basin since 1947 are considered as effects due to the CVP.

CHAPTER III

DESCRIPTION OF THE SAN JOAQUIN RIVER SYSTEM INCLUDING THE FEDERAL CENTRAL VALLEY PROJECT THE SOUTHERN DELTA, AND DATA SOURCES

A. PRINCIPAL FEATURES

1. General

The San Joaquin River basin lies between the crests of the Sierra Nevada Mountains and the Coast Ranges, and extends north from the northern boundary of the Tulare Lake Basin near Fresno to the Sacramento-San Joaquin Delta (see Figure III-1). It is drained by the San Joaquin River and its tributary system. The basin has an area of about 14,000 square miles extending about 100 miles from the crest of Sierra Nevada Range to the crest of the Coast Ranges and about 120 miles from the northern to the southern boundry. The Sierra Nevada Mountains have an average crest elevation of about 10,000 feet with occasional peaks higher than 14,000 feet. The Coast Ranges crest elevations reach up to about 5,000 feet. The San Joaquin valley area measures about 100 miles by 50 miles and slopes gently from both sides towards a shallow trough somewhat west of the center of the valley. Valley floor elevations range from about 250 feet at the south to near sea level at the north. The trough forms the channel for the Lower San Joaquin River and has an average slope of about 0.8 foot per mile between the Merced River and Paradise Cut.

Major tributary streams, from north to south, are the Cosumnes, Mokelumne, Calaveras, Stanislaus, Tuolumne, and Merced Rivers. These streams, plus the San Joaquin River, contribute the major portion of the surface inflow to the valley. Minor streams on the east side of the valley are the Fresno and Chowchilla Rivers and Burns, Bear, Owens, and Mariposa Creeks. Panoche, Little

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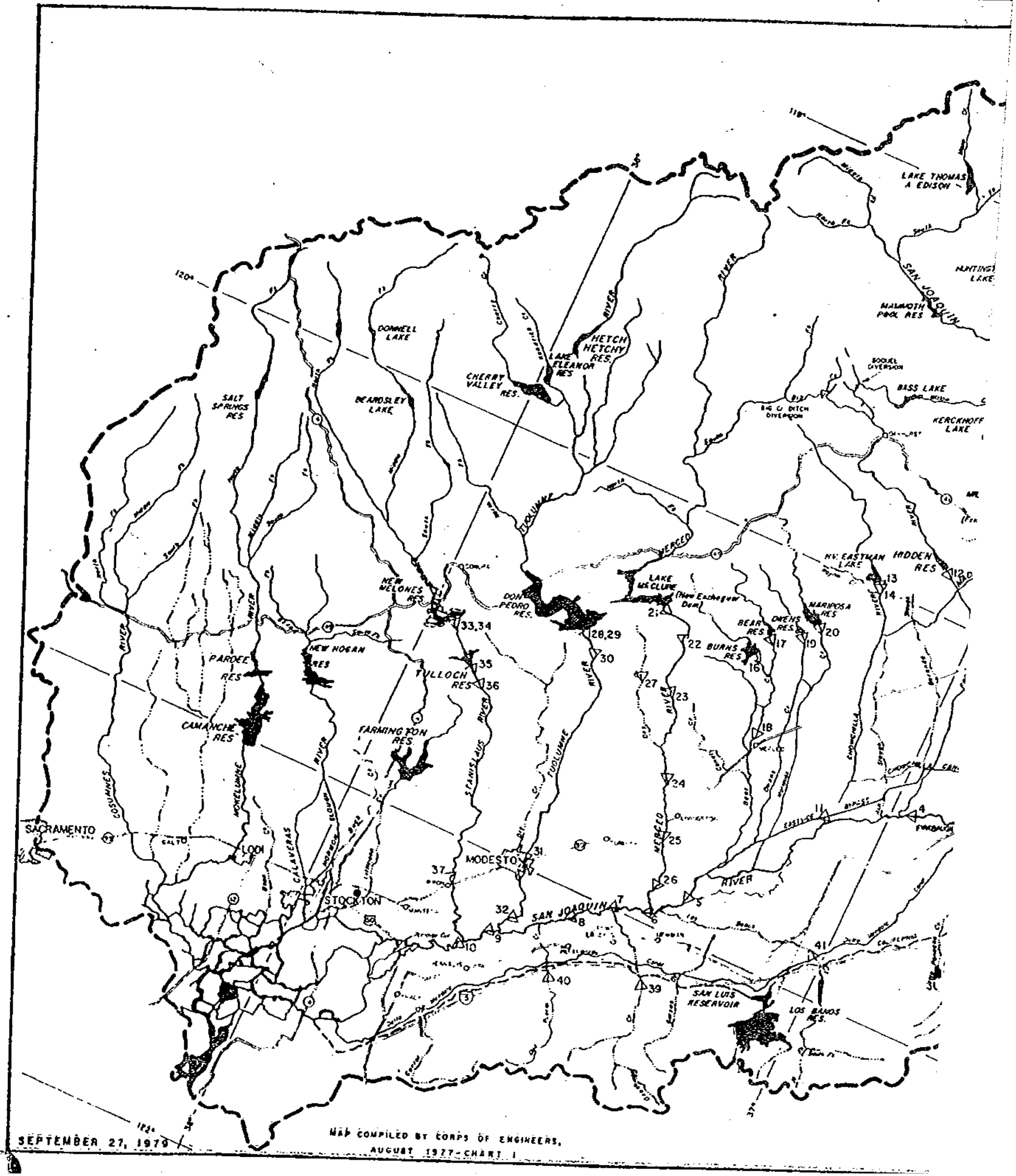
LAKE THOMAS A EDISON
SAN JOAQUIN
MAMMOTH POOL RES
HUNTINGTON LAKE
HETCH HETCHY RES.
LAKE ELEANOR RES
CHERRY VALLEY RES.
DONNELL LAKE
BEARDSLEY LAKE
SALT SPRINGS RES
BASS LAKE
KERCKHOFF LAKE
TUOLUMNE
MERCED
RIVER
NEW MELONES RES.
DON PEDRO RES.
LAKE McCLURE
(New Exchequer Dam)
H.V. EASTMAN LAKE
HIDDEN RES
MARIPOSA RES
OWENS RES
BEAR RES
BURNS RES
PARDEE RES
NEW HOGAN RES
TULLOCH RES
CAMANCHE RES
FARMINGTON RES
STANISLAUS RIVER
TUOLUMNE
CALAVERAS
COSUMNES
MOKELUMNE
SACRAMENTO
LODI
STOCKTON
MODESTO
SAN JOAQUIN
SAN LUIS RESERVOIR
LOS BANOS RES.
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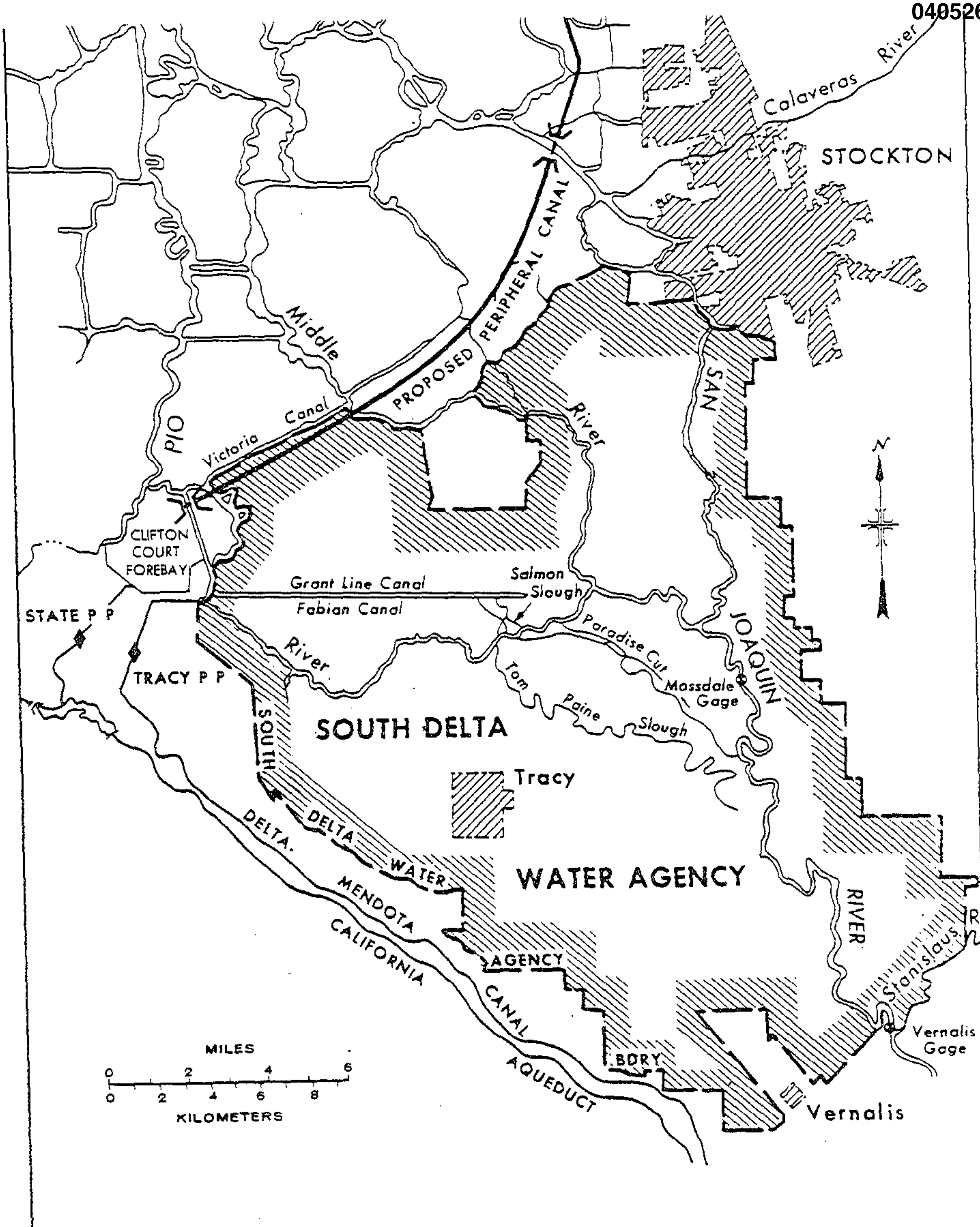
SEPTEMBER 27, 1979
MAP COMPILED BY CORPS OF ENGINEERS,
AUGUST 1977-CHART 1



SOUTH DELTA WATER AGENCY

FIGURE III-2

REVISED MAY 1980

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Panoche, Los Banos, San Luis, Orestimba, and Del Puerto Creeks comprise the minor streams on the west side. These west side streams contribute very little to the runoff of the San Joaquin River. Numerous other small foothill channels carry water only during intense storms. During high runoff periods a distributary channel of Kings River (called James Bypass) discharges water into the San Joaquin River at Mendota. In addition, floodwater is diverted to the San Joaquin River from Big Dry Creek Reservoir near Fresno. Flows from rivers and creeks are significantly reduced by storage, diversions, and channel seepage losses as they cross the valley floor so that only a portion of the water at the foothill line reaches the San Joaquin River.

2. Southern Delta

The boundaries of the South Delta Water Agency (SDWA) are set forth in section 9.1 of the South Delta Water Agency Act (Cal. Stats. 1973, c. 1089, p. 2207). The area encompassed therein is located in the southeastern part of the Sacramento-San Joaquin Delta as illustrated in Figure III-2. It contains approximately 231 square miles or roughly 148,000 acres. Of this area, about 123,000 acres are devoted to agricultural uses and the remainder is comprised of waterways, levees, and lands devoted to residential, industrial and municipal uses. The area within SDWA is generally known as the Southern Delta.

The lands in the southern Delta are generally mineral soils with low permeability. The agricultural lands in the Southern Delta are fully developed, irrigated and highly productive. The agricultural lands are dependent primarily upon the in-channel water supply in the area for irrigation, and for irrigation purposes about 450,000 acre-feet per year are diverted from the channels.

There are about 75 miles of channels in the southern Delta and these are of great importance. They not only serve as water supply sources for irrigation, but also as drainage canals for drainage water, important habitat and migration routes for fish, waterways for commercial shipping and recreational boating, and avenues for the passage of floodwaters.

3. Existing Water Resource Development

a. General

Development of the water resources of the San Joaquin River basin was initiated more than 120 years ago. This development ranges from small local diversions from the rivers and streams to large multiple-purpose reservoirs and extensive levee and channel improvements. Because of this development the flow regime of the San Joaquin River has significantly changed from that which would occur under natural conditions. The major reservoirs in the basin are tabulated below:

Major Reservoirs
San Joaquin River Basin

Name of Reservoir	Operating Agency	Year Completed	Purpose	Capacity (AF)
Stanislaus River				
Union	PG&E	1902	P	2,000
Utica	PG&E	1908	P	2,400
Relief	PG&E	1910	P	15,600
Strawberry	PG&E	1916	P	18,300
Woodward	South San Joaquin I.D.	1918	I	36,000
*Melones	Oakdale & SSJ I.D.	1926	I,P	112,500
Spicer Meadows	PG&E	1929	P	4,100
Lyons	PG&E	1932	P	5,500
Beardsley	Oakdale & SSJ I.D.	1957	I,P	98,300
Donnells	Oakdale & SSJ I.D.	1958	I,P	64,700
Tulloch	Oakdale & SSJ I.D.	1958	I,P	68,200
New Melones	U.S.C.E.	1979	FC,I,P,P,F&W,WQ	2,400,000
Tuolumne River				
Modesto Reservoir	Modesto I.D.	1911	I	27,000
Turlock Lake	Turlock I.D.	1915	I	4,900
Lake Eleanor	City & Co. of S.F.	1918	M&I,P	26,100
Hetch Hetchy	City & Co. of S.F.	1923	M&I,P	360,000
Cherry Valley	City & Co. of S.F.	1956	M&I,P	268,000
**Don Pedro	Modesto & Turlock I.D.	1923	I,P	290,400
New Don Pedro	Modesto & Turlock I.D.	1971	FC,I,P,R	2,030,000

*Inundated by New Melones Reservoir.
**Inundated by New Don Pedro Reservoir.

Major Reservoirs
San Joaquin River Basin
(Cont'd)

Name of Reservoir	Operating Agency	Year Completed	Purpose	Capacity (AF)
Merced County Streams				
Yosemite Lake	Merced I.D.	1888	I	7,000
Mariposa	USCE	1948	FC	15,000
Owens	USCE	1949	FC	3,600
Burns	USCE	1950	FC	6,800
Bear	USCE	1954	FC	7,700
Merced River				
McSwain	Merced I.D.	1966	I,P,R	9,500
***Lake McClure	Merced I.D.	1926	I,P	280,900
New Exchequer	Merced I.D.	1967	FC,I,P,R	1,025,000
Chowchilla & Fresno Rivers				
Madera Lake	Madera Co.	1958	R	4,700
Hensley Lake	USCE	1975	FC,I,R	90,000
H.V. Eastman Lake	USCE	1975	FC,I,R	150,000
San Joaquin River				
Crane Valley	PG&E	1910	P	45,100
Huntington Lake	SCE	1917	P	89,200
Kerckhoff	PG&E	1920	P	4,300
Florence Lake	SCE	1926	P	64,400
Shaver Lake	SCE	1927	P	135,300
Millerton Lake	WPRS	1941	FC,I,M&I	520,500
Big Dry Creek	USCE	1948	FC	16,250
Redinger Lake	SCE	1951	P	35,500
Lake Thomas A. Edison	SCE	1954	P	125,000
Mammoth Pool	SCE	1960	P	123,000
Westside Streams				
Los Banos	WPRS/DWR	1966	I,M&I,P,R	34,600
Little Panoche	WPRS/DWR	1966	I,M&I,P,R	5,600
O'Neill Forebay	WPRS/DWR	1967	FC	56,400
San Luis	WPRS/DWR	1967	FC,R	2,041,000

*** Inundated by New Exchequer Reservoir

b. Irrigation Projects

Major irrigation canals consisting of the Delta-Mendota Canal and the California Aqueduct have been constructed to transport water from the

Sacramento-San Joaquin Delta to water deficient areas in the San Joaquin Valley, Tulare Lake Basin, and Southern California. These canals are located along the west side of the San Joaquin Valley and are shown on Figure III-1. Numerous irrigation distribution systems have been constructed throughout the valley floor area to convey irrigation water to the farms.

c. Delta Export Facilities

Central Valley Project

Tracy Pumping Plant. The Tracy Pumping Plant, located near Tracy at the southern edge of the Delta (Figure III-2) lifts water via an intake channel from Old River some 197 feet into the Delta-Mendota Canal. The six pumps at Tracy are capable of pumping a total of approximately 4,600 ft^3/s. The plant has been operational since 1951. The pumping plant operates on demand and therefore diverts water from the Delta continuously regardless of tidal phase.

Delta-Mendota Canal. The Delta-Mendota Canal is a major canal of the Central Valley Project (CVP). It carries water south from the Tracy Pumping Plant along the west side of the San Joaquin Valley. In addition to water service along the canal, the canal is used both to transport water to the San Luis Unit of the CVP and to partially replace San Joaquin River water stored by Friant Dam and utilized in the Madera and Friant-Kern Canal systems. The canal and pumping plant began operation in 1951. The canal is 117 miles long and terminates at the San Joaquin River in the Mendota Pool near the city of Fresno. The conveyance capacity of the canal varies from 4,600 ft^3/s at the intake to 3,200 ft^3/s at its terminus.

State Water Project

Clifton Court Forebay. The Clifton Court Forebay (Figure III-2) is a 30,000 acre-foot reservoir. The forebay, completed in 1969, buffers the effects of aqueduct pumping on the Delta. It also provides forebay storage for the Delta Pumping Plant to permit a large part of the pumping to be done with offpeak power. Advantage is also taken of the high-tide elevations to admit water into the forebay.

Delta Pumping Plant. The unlined intake channel conveys water from Clifton Court Forebay to the Delta Pumping Plant. The Delta Pumping Plant lifts water from sea level to an elevation of 224 feet where it flows by gravity through the State Aqueduct to the San Luis Division. The pumping plant, completed in 1967, houses seven pumping units, providing an aggregate hydraulic capacity of 6,300 ft^3/s. From the pump discharge lines, the concrete-lined State Aqueduct, with a capacity of 10,300 ft^3/s, conveys water south to the service areas of the State Water Projects.

d. Interbasin Transfers

There are two major diversions from the San Joaquin Basin. The interbasin transfer from the Tuolumne River through the Hetch Hetchy aqueduct to the city of San Francisco began in October 1934. A record of these annual diversions from the Tuolumne Basin was obtained from the files of the city of San Francisco and are presented on Table III-2.

In 1950 diversions from the San Joaquin River through the Friant-Kern Canal to the Tulare Lake Basin were begun by Friant Division of the CVP. A year later, the CVP began to import water into the San Joaquin Basin from the Sacramento-San Joaquin Delta through the Delta-Mendota Canal. Records of these two diversions by the Service are published in the USGS Water Supply Papers.

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TABLE III-2

HETCH HETCHY AQUEDUCT
DIVERSION FROM TUOLUMNE RIVER

CALENDAR YEAR	ACRE-FEET
1934	11,211
1935	38,843
1936	56,814
1937	7,236
1938	1,692
1939	53,233
1940	24,090
1941	18,965
1942	14,087
1943	25,333
1944	47,533
1945	60,241
1946	61,710
1947	69,356
1948	68,812
1949	67,443
1950	75,425
1951	81,450
1952	49,796
1953	94,492
1954	112,850
1955	124,699
1956	80,029
1957	123,619
1958	70,286
1959	167,325
1960	166,623
1961	17,438
1962	158,488
1963	127,020
1964	185,600
1965	164,738
1966	198,425
1967	182,170
1968	223,221
1969	197,844
1970	198,766
1971	213,277
1972	260,359
1973	205,556
1974	215,501
1975	228,551
1976	263,727
1977	222,734
1978	161,304

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INTERBASIN TRANSFERS SAN JOAQUIN RIVER SYSTEM

	San Joaquin River at Friant 1,000 AF		Friant-Kern Canal 1,000 AF		Madera Canal 1,000 AF		Delta-Mendota Canal at Tracy 1,000 AF		Delta-Mendota Canal to Mendota Pool 1,000 AF	
	Annual	Apr-Sept	Annual	Apr-Sept	Annual	Apr-Sept	Annual	Apr-Sept	Annual	Apr-Sept
1938-39	1,077	616								
40	1,829	1,250								
41	2,589	1,255								
42	2,254	1,329								
43	2,068	1,281								
44	1,102	791			48	48				
45	1,885	1,364			110	106				
46	1,662	1,063			119	92				
47	1,155	816			102	76				
48	1,006	802			76	72				
49	1,068	838			152	150				
50	974	743	198	180	118	118				
51	1,216	588	368	345	142	140	164	164	139	139
52	2,084	1,570	462	431	179	179	167	141	122	99
53	351	184	741	592	193	179	784	714	668	615
54	262	138	811	717	212	207	1,004	852	825	720
55	107	57	805	674	219	199	1,131	945	927	780
56	1,225	462	1,322	976	239	226	726	592	519	429
57	149	54	990	793	242	229	1,181	968	920	761
58	1,180	1,067	1,145	952	244	238	663	548	447	367
59	79	57	809	536	208	169	1,341	1,066	1,029	814
60	96	67	582	429	144	124	1,389	1,089	1,009	786
61	100	57	442	324	103	91	1,489	1,189	1,021	817
62	75	46	1,370	1,151	277	268	1,357	1,144	991	837
63	85	58	1,513	1,300	270	262	1,344	1,037	966	744
64	70	48	838	543	228	187	1,667	1,240	1,066	[illegible]7
65	63	40	1,631	1,051	324	285	1,472	1,075	995	736
66	62	45	1,066	628	442	173	1,599	1,259	1,060	819
67	1,269	1,185	1,413	1,047	389	351	1,258	865	572	340
68	58	41	967	503	170	114	1,997	1,476	1,032	787

A portion of the water imported through the Delta-Mendota Canal was delivered to the Mendota Pool in the San Joaquin River near Mendota to replace a portion of the water diverted from the basin at Friant Dam. Records of the amounts of water delivered to Mendota Pool were obtained from the Service files.

A listing of these interbasin transfers is presented on Table III-3.

4. Climate

The climate of the basin is characterized by wet, cool winters, dry, hot summers, and relatively wide variations in relative humidity. In the valley area relative humidity is very low in summer and high in winter. The characteristic of wet winters and dry summers is due principally to a seasonal shift in the location of a high pressure airmass ("Pacific high") that usually exists a thousand or so miles west of the mainland. In the summer the high blocks or deflects storms; in the winter it often moves southward and allows storms to reach the mainland.

a. Precipitation

Normal annual precipitation in the basin varies from 6 inches on the valley floor near Mendota to about 70 inches at the headwaters of the San Joaquin River. Most of the precipitation occurs during the period November through April. Precipitation is negligible during the summer months, particularly on the valley floor. The Sierra Nevada and Coast Ranges have a marked orographic effect on the precipitation. Precipitation increases with altitude, but basins on the east side of the Coast Ranges lie in a rain shadow and receive considerably less precipitation than do basins of similar altitude on the west side of the Sierra Nevada. Mean monthly and annual precipitation at several stations in the basin are tabulated below:

Average Monthly Precipitation (in.)

Station --	Dudleys	Merced FS2	Sonora RS	So. Ent. Yosemite	Stockton WSO
Elev (ft)--	3000	169	1749	5120	22
Jan	7.05	2.24	5.69	8.23	2.91
Feb	5.87	1.92	4.88	7.09	2.11
Mar	5.74	1.74	4.92	6.39	1.96
Apr	3.87	1.41	3.19	4.50	1.37
May	1.28	.45	1.19	1.80	.42
Jun	0.44	.07	.33	.56	.07
Jul	.03	.01	.03	.08	.01
Aug	.05	.02	.05	.07	.03
Sep	.37	.11	.35	.57	.17
Oct	1.65	.55	1.49	2.03	.72
Nov	5.05	1.61	4.21	6.33	1.72
Dec	6.90	2.09	5.61	8.14	2.68
Mean Ann.	38.30	12.22	31.94	45.79	14.17

b. Snowfall

Winter precipitation usually falls as snow above the 5,000-foot elevation and as rain and/or snow at lower elevations. Snow cover below 5,000-feet is generally transient, and may accumulate and melt several times during the winter season. Normally the snow accumulates at higher elevations until about the first of April when the melt rates exceed snowfall. Surveys of the snowpack are conducted by the State of California starting in January of each year. Average April 1 water content at several snow courses is listed in the following tabulation*:

Station	Basin	Elev (ft)	Ave. 1 April Water Content (in)
Soda Cr. Flat	Stanislaus	7,800	22.0
Dana Meadows	Tuolumne	9,850	30.0
Snow Flat	Merced	8,700	42.0
Piute Pass	San Joaquin	11,300	35.0

*SOURCE: "Hydrology, lower San Joaquin River" office report Sacramento District, Corps of Engineers, December 1977.

5. Storm Characteristics

Winter storms affecting the area are cyclonic wave disturbances along the polar front and usually originate in the vicinity of the Aleutian Islands. The normal trajectory of the waves is toward the southeast; however, the storms producing the greatest amount of precipitation have maintained a more easterly trajectory across the Pacific Ocean. The Coast Range Mountains form a barrier that reduces the moisture in the airmass moving inland. Most of the water carried past this barrier is precipitated by orographic effect on the western slope of the Sierra Nevada.

Major storms over the area normally last from 2 to 4 days and consist of two or more waves of relatively intense precipitation with lesser rates between the waves. Warm storms that combine intense precipitation with temperatures above freezing level at high elevations produce major floods from the Sierra Mountains. Rainfall during some of these major storms has occurred up to about the 11,000-foot level.

6. Data Sources

a. Stream Gages

Streamflow and reservoir level records have been maintained by United States Geological Survey (USGS), the California Department of Water Resources (DWR) and others for varying periods dating from 1901. A summary of the principal stations of interest in this investigation is presented in Table III-4 and their locations are indicated in figure III-3.

b. Water Quality Stations

Water quality data for the San Joaquin River system are rather limited.

Although some data are available for tributary streams dating back to 1938, the records are sparse. The most reliable data are those collected by the USGS on a monthly frequency since 1951 (except for the Stanislaus River, on which sampling began in 1956). These generally include analyses for the principal cations and anions and determinations of TDS, EC, pH and Total Hardness. A record of 4-day sampling for chlorides in the San Joaquin River at Mossdale dates from 1929 through mid-1971. In recent years--since about 1959--continuous recordings of electrical conductivity have been made at selected stations in the Delta, including the San Joaquin River at Vernalis.

The locations of the principal water quality stations referenced in this report are indicated in figure III-4.

c. Unimpaired Flow Estimates

Development has affected the flow of all the major streams in the San Joaquin Basin. Estimates of the "unimpaired" flow of the San Joaquin River at Friant have been made by the Water and Power Resources Service for the period 1873-1978. Estimates for the other major streams in the basin were made by the Corps of Engineers (USCE). A list of the stations and the period of record is presented below:

Station	Estimate By	Period of Record
San Joaquin at Friant Dam	SERVICE	1873-1978
Merced River at Exchequer Dam	USCE	1906-1978
Tuolumne River at Don Pedro Dam	USCE	1901-1978
Stanislaus River at New Melones Dam	USCE	1901-1978

For the purposes of this report the unimpaired flow of the San Joaquin River at Vernalis was assumed to be the sum of the unimpaired flows at the four stations above.

Table III-4 STREAM GAGES IN THE SAN JOAQUIN RIVER SYSTEM

Station	Operating 1/ Agency	D.A. (sq.mi.)	Period of record
San Joaquin River			
Millerton Lake	USBR	1638	1941 to date
bel. Friant	USGS	1676	1907 to date
nr. Mendota	USBR	4310 3/	1939 to date
nr. Dos Palos 2/	USBR	5630 3/	1940 to date
at Fremont Ford Bridge	DWR	7615 3/	1937 to date
nr. Newman	USGS	9520 3/	1912 to date
nr. Crows Landing	DWR	-	1965 to 1972
at Patterson Br.	DWR	9760 3/	1938 to 1966 1969 to date
at Maze Rd. Br.	DWR	12400 3/	1943 to date
nr. Vernalis	USGS	13536 3/	1922 to date
Merced River			
Lake McClure	MID	1037	1926 to date
bel. Merced Falls Dam, nr. Snelling	USGS	1061	1901 to date
bel. Snelling	DWR	1096	1958 to date
at Cressey	DWR	1224	1941 to date
nr. Livingston	MID	1245	1922 to 1944
nr. Stevinson	USGS	1273	1940 to date
Tuolumne River			
Don Pedro Reservoir	USGS	1533	1923 to date
abv. LaGrange Dam nr. LaGrange	USGS	1532	1895 to 1970
bel. LaGrange Dam nr. LaGrange	USGS	1538	1970 to date
at Modesto	USGS	1884	1940 to date
at Tuolumne City	DWR	1896	1930 to date
Stanislaus River			
Melones Lake	WPRS	904	1926 to date
bel. Melones Powerhouse	USGS	905	1931 to 1967
Tulloch Reservoir	TRI-DAMS	980	1957 to date
bel. Goodwin Dam	USGS	986	1957 to date
at Ripon	USGS	1075	1940 to date
Westside Streams			
Panoche Cr. bel. Silver Cr.	USGS	293	1949 to 1953 1958 to 1970
Orestimba Cr. nr. Newman	USGS	134	1932 to date
Del Puerto Cr. nr. Patterson	USGS	72.6	1958 to date
Los Banos Cr. nr. Los Banos	USGS	159	1958 to 1966

1/ USGS - United States Geological Survey, USBR - United States Bureau of Reclamation, USCE - United States Corps of Engineers, DWR - State of Calif., Dept. of Water Resources, MID - Merced Irrigation District

2/ Measures most of low flows and only part of flood peaks

3/ Includes Kings River basin

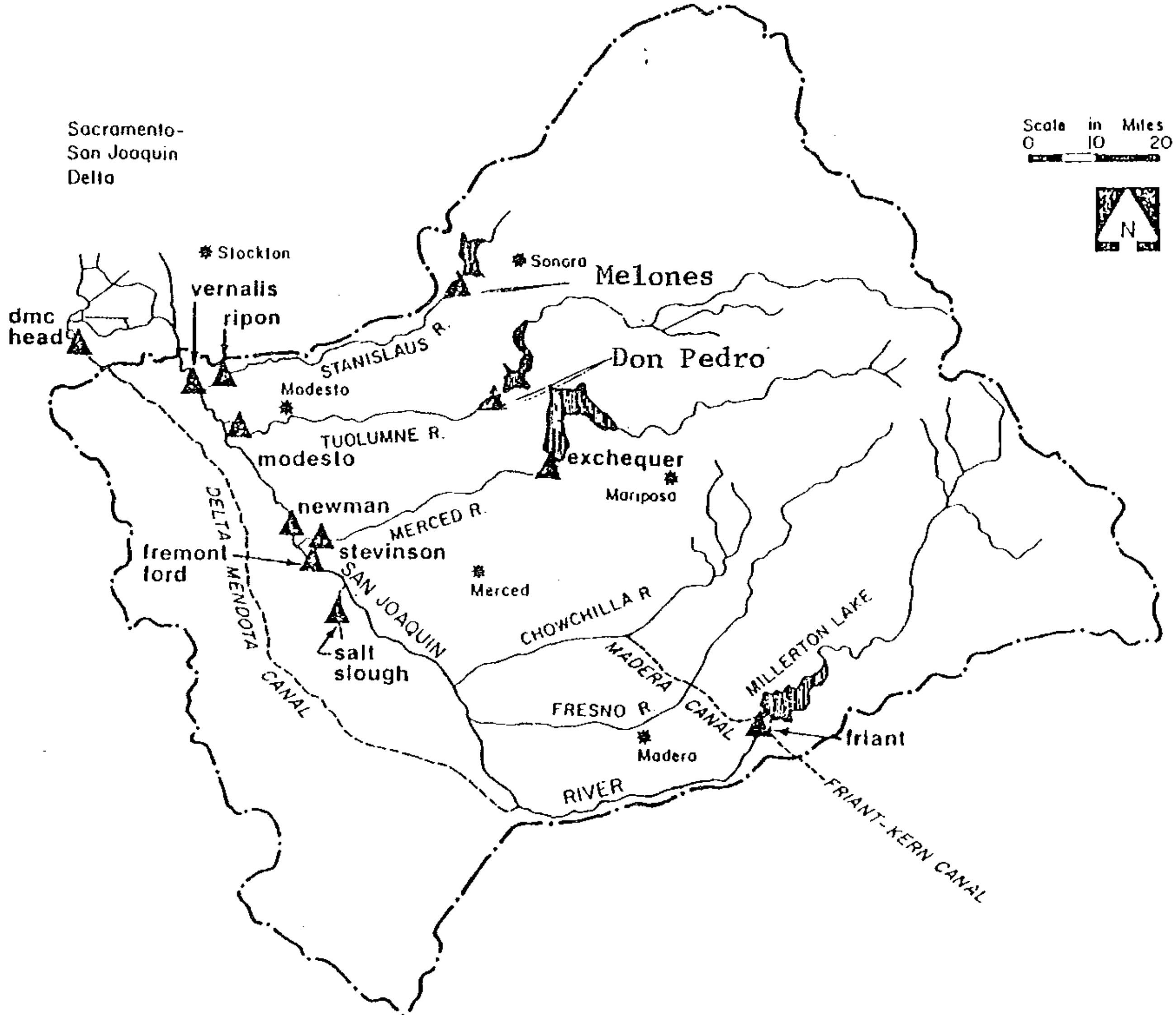


Figure III-3 SAN JOAQUIN RIVER BASIN STREAM FLOW GAGING STATIONS

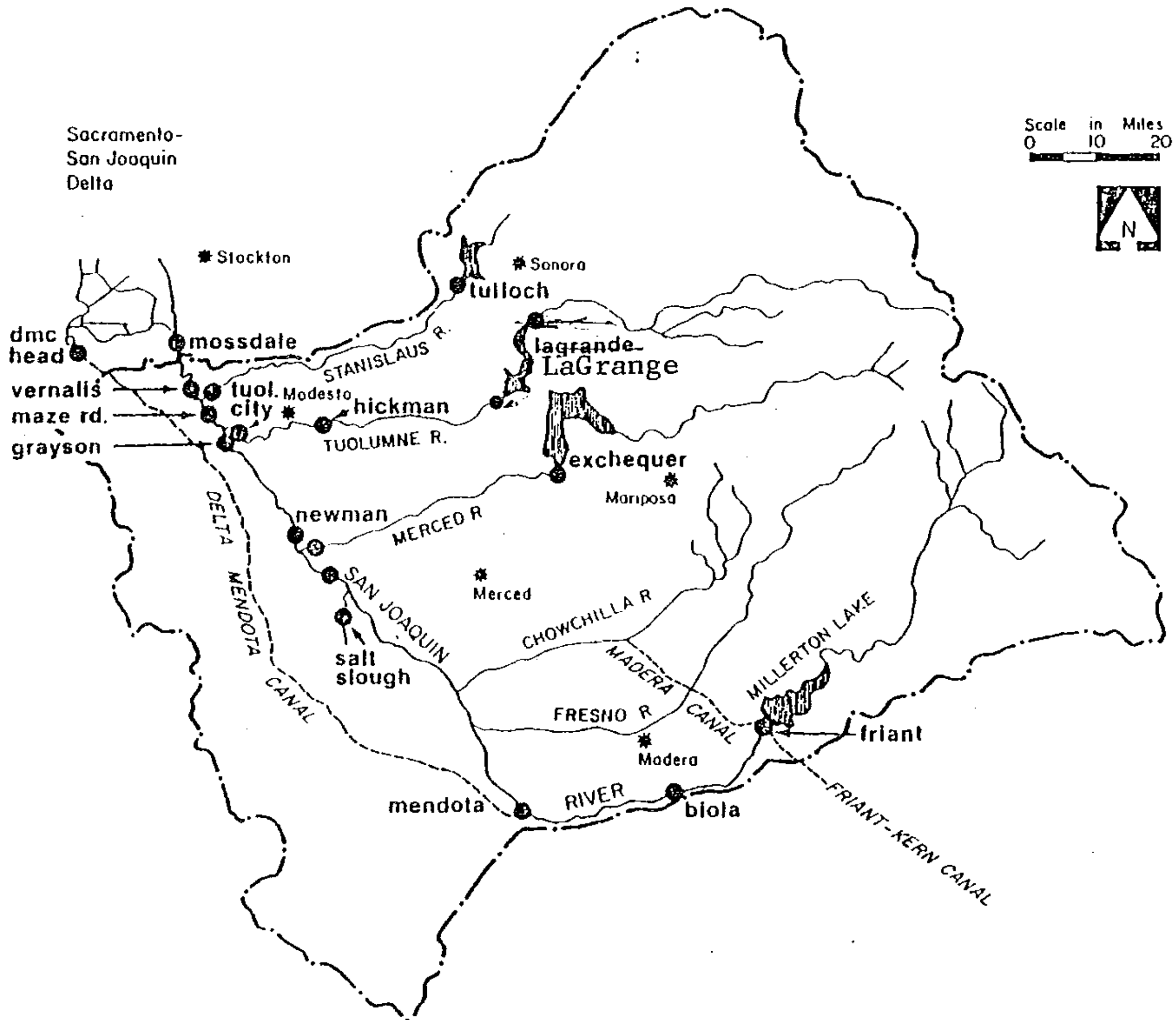


Figure III-4 SAN JOAQUIN RIVER BASIN WATER QUALITY SAMPLING STATIONS

7. Return Flows

There have been few direct measurements of drainage return flows, only occasional gagings associated with special studies. In this report return flows were estimated by water balance calculations between stream gages where the change in flow could be attributed to drainage accretions.

8. Water Levels

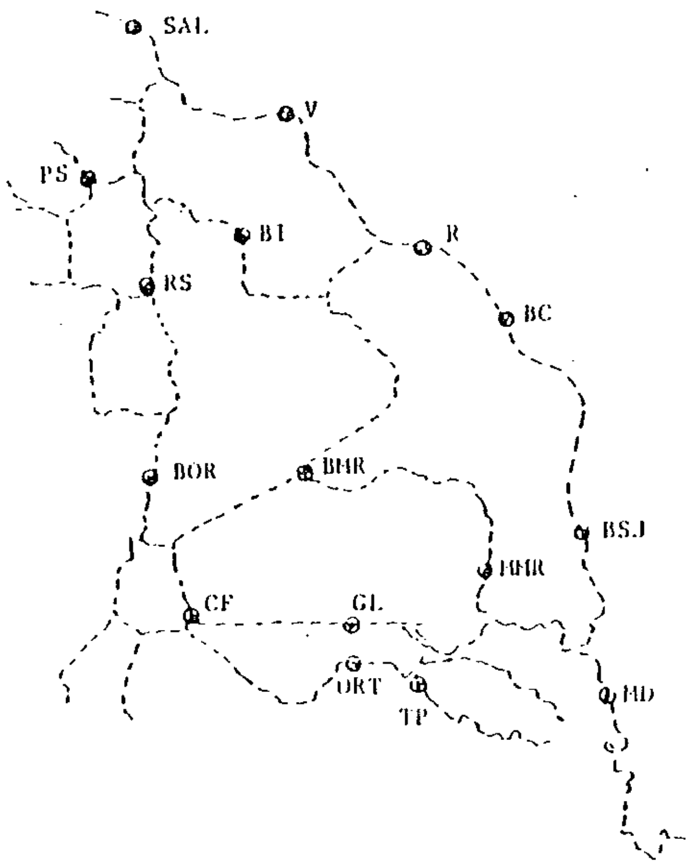
Data on water levels in the Delta channels were derived from continuous recorders operated by the Department of Water Resources. The location of water level stations used in this report are shown in Figure III-5.

9. Channel Depths

Data on channel depths were derived primarily from hydrographic charts of the U.S. Coastal and Geodetic Survey and special surveys conducted in 1974 and 1975 by the Department of Water Resources.

10. Other

Additional data on flows, water quality and water levels were derived from reports of special studies and Service files.



SAL	-	San Andreas Landing
V	-	Venice Island
PS	-	Piper Slough
BI	-	Bacon Island
R	-	Rindge
BC	-	Burns Cutoff
RS	-	Rock Slough
BOR	-	Byron
BHR	-	Borden
CF	-	Clifton Ferry
GL	-	Grant Line
MHR	-	Mowry
BSJ	-	Brandt
ORT	-	Old River Tracy
TP	-	Tom Paine
MD	-	Mossdale

Figure III-5 WATER LEVEL STATIONS IN THE SOUTHERN DELTA

Source: California Department of Water Resources

CHAPTER IV

INVESTIGATION PROCEDURE

A. SELECTION OF HYDROLOGIC AND WATER QUALITY RECORD PERIODS

Since the primary objective of this investigation is to determine the effect of the Central Valley Project on the quantity and quality of the in-channel water supply in the Southern Delta, the period of record was selected to include representative periods both before and after the implementation of CVP operations in the San Joaquin Valley. The pre-1944 spanned 14 years, 1930-1943 inclusive. The post-1947 spanned 22 years, 1948-1969 inclusive. Data records were assembled for the period 1930-1969, although the records for 1944 through 1947, when the CVP was being brought "on-line," were generally excluded from analysis.

B. ESTIMATION OF UNIMPAIRED RUNOFF

For the purposes of this investigation "unimpaired runoff" means the natural runoff of the river basin, absent the influence of man. Generally, this quantity is estimated by determining the aggregate runoff of all gaged streams in the drainage area above the highest point of development and adding an amount estimated to correspond to accretions from precipitation (ungaged) at lower levels if the watershed were entirely undeveloped, i.e., in virgin condition.

However, for reasons of simplicity it was decided to exclude the estimate of valley floor accretions (the ungaged flow from developed lands) and utilize only the gaged runoff of the four principal streams above the major projects. This runoff, which was used to estimate the impact of post-1947 development and operation, is referred to in this report as "unimpaired" rimflow.

Unimpaired runoff at Friant, Exchequer, Don Pedro, and New Melones represent the rim station flows of the San Joaquin, Merced, Tuolumne, and Stanislaus Rivers, respectively. Vernalis unimpaired flow as referred to in this report is the sum of the four unimpaired rim station flows. This definition of Vernalis unimpaired flow is the commonly used form.

C. IDENTIFICATION OF KEY STATIONS FOR WATER BALANCE AND SALT BALANCE

The impacts of upstream development on the inflow to the Delta are measured mainly in the flow and quality of the San Joaquin River at Vernalis, hence data for this location are crucial to the investigation. Development of the CVP has occurred primarily in the upper portion of the San Joaquin River basin, at Friant, near Mendota and along the reach of the San Joaquin River above its confluence with the Merced River. Thus, the gaging station on the San Joaquin River near Newman, situated just below the mouth of the Merced, is important for the information it provides on the changes in runoff that may be attributed to the CVP. This runoff quantity has been corrected for the contribution of the Merced River and Merced Slough to produce a synthetic record of runoff of the upper San Joaquin River basin above the Merced River, which figures prominently in water balance computations. For the purposes of this report changes in runoff from the upper San Joaquin River basin, i.e., above the mouth of the Merced River, that have occurred since 1944 are attributed entirely to the CVP.

Other key stations for both the water quantity and water quality analysis, in addition to Vernalis, include stations on the eastside tributaries just upstream of their confluences with the main stem of the San Joaquin and the major westside tributary, Salt Slough for which good water quality data are available. Several stations along the Tuolumne River, at LaGrange, Hickman, and Tuolumne City serve to assess the contribution of the gas wells to the river's sal. burden. Upstream stations at Friant, Exchequer, LaGra ge, and Tulloch provide water quality data that are useful for comparison w h westside drainage quality and the quality of water in the main stem of the San Joaquin

D. ESTIMATION OF WATER BALANCE

Changes i water balance in the San Joaquin River for the pre-1944 and post-1947 periods h e been assessed by several different techniques as follows:

1. By comparison of average annual, seasonal and monthly runoff at key locations for similar hydrologic periods.

2. By comparison of double mass plots of annual and seasonal runoff for key locations; either in chronological sequence or in order of magnitude sequence. Data for double mass diagrams were fitted with regression equations, that were then used in determining flow reductions.

Since no two-years or other chronological periods are hydrologically identical, an effort was made to classify seasons, years, or groups of years according to the magnitude of unimpaired (rim) runoff. Considering the four-station runoff total** as an estimate of the unimpaired flow of the San Joaquin River at Vernalis, an analysis of the record 1906-1977 (72 years) showed that hydrologic years could be grouped conveniently into four general categories of about equal size as shown on Table IV-1.

Dr	(19 years)	less than 3,500,000 AC/yr
Below normal	(18 years)	3,500,000 to 5,600,000 AC/yr
Above normal	(20 years)	5,600,000 to 7,500,000 AC/yr
Wet	(15 years)	greater than 7,500,000 AC/yr

*During the 1920's a series of gas wells were drilled in the region of the lower Tuolumne River. These wells penetrated water bearing formations, including some with high salinity. When these wells were later abandoned, some that penetrated artesian strata continued to flow, adding significant amounts of salt to the Tuolumne River in the lower section below Hickman. The wells were sealed in 1976-1977 so that the accretions of salt to the Tuolumne River were reduced. Data are not yet available to determine the extent of the salt load reduction and its impact on the San Joaquin River.

**San Joaquin River at Friant, Merced River at Exchequer, Tuolumne River at Excheque and Stanislaus River at Melones.

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TABLE IV-1

UNIMPAIRED FLOW, SAN JOAQUIN RIVER AT VERNALIS, 1906-1979

Year	Flow 1,000 AF	Year	Flow 1,000 AF	Year	Flow 1,000 AF
1977	1,014	1918	4,587	1914	8,692
1924	1,504	1950	4,656	1909	8,971
1931	1,660	1971	4,870	1952	9,312
1976	1,928	1925	5,505	1956	9,679
1961	2,100	1923	5,512	1967	9,993
1934	2,288	1970	5,587	1938	11,248
1929	2,844	1962	5,618	1911	11,480
1939	2,909	1946	5,734	1907	11,824
1968	2,958	1921	5,901	1969	12,295
1960	2,960	1975	6,114	1906	12,427
1959	2,986	1963	6,250		
1913	2,995	1915	6,405		
1964	3,151	1935	6,418		
1930	3,254	1973	6,467		
1908	3,325	1936	6,495		
1933	3,356	1927	6,499		
1947	3,424	1937	6,530		
1912	3,458	1940	6,596		
1926	3,493*	1945	6,612		
1955	3,512	1932	6,622		
1972	3,571	1910	6,645		
1949	3,799	1917	6,662		
1944	3,933	1974	7,146		
1966	3,985	1951	7,262		
1919	4,096	1943	7,283		
1920	4,097	1942	7,370		
1948	4,218	1922	7,681		
1957	4,292	1941	7,945		
1954	4,313	1965	8,108		
1953	4,554	1916	8,229		
1928	4,365	1958	8,367		

* Bars divide the data according to year classifications, dry, below normal, above normal and wet.

This division puts approximately the same number of years during the 1906-1978 period into each category. Each category was not equally represented in the two study periods as the following table illustrates:

	1906-1977	1906-1929	1930-1943	1948-1969	1970-1977
Dry	19	6	5	5	2
Below normal	18	6	0	8	3
Above normal	20	5	7	3	3
Wet	15	7	2	6	0
Total	72	24	14	22	8

A similar breakdown of the runoff of the San Joaquin River at Friant indicated that this year classification system was consistent for the smaller tributary area as well.

Additional relationships were developed comparing flow of a station to flow at an adjacent station. These relationships are used throughout this report when specific dates are not designated. The data, graphs, and mathematical equations that are not included in the body of this report may be found in the files of the CVOCO offices of the Mid-Pacific Region of the Service.

"Other" flows are determined by changes in flow at adjacent stations not contributed by measured tributaries. "Other" flows for several reaches of the main stem of the San Joaquin River have been determined using this water balance method.

E. EVALUATION OF WATER QUALITY EFFECTS

1. Salt Balance

Data is available for the stations studied, to prepare salt load-flow relationships. These relationships are used throughout this report when specific dates are not indicated. The data, graphs, and mathematical equations that are not included in the body of this report may be found in the files of the Offices of the Mid-Pacific Region of the Service.

With the salt load known at key locations, any change in load between stations not caused by measured tributaries can be attributed to "other" sources. "Other" loads are determined using this method for several reaches along the main stem of the San Joaquin River.

2. Chemical Composition

Because the geologic, topographic and hydrologic characteristics of the east and west sides of the San Joaquin Valley are distinctly different, it was expected that detailed water quality analysis of waters derived from the several sources would serve to identify their separate and proportional contributions to the San Joaquin River salt burden. For this purpose USGS data on water quality for selected stations along the main stem of the San Joaquin River were compared to those for the principal tributaries and sources known to contribute drainage water to the system. Comparisons were made on the basis of the proportions of principal cations and anions, especially sulfate ion ($SO_4^{=}$) known to be derived from soils on the westside of the valley and characteristic of both wells and drainage waters from this area. Also, noncarbonate hardness and boron concentration, that tend to distinguish waters from the westside of the valley from those of the major Sierra streams, are used to "fingerprint" the composite drainage water of the San Joaquin River. Comparisons are also made with water imported into the westside of the Valley by the Delta-Mendota Canal.

F. ESTIMATION OF RETURN FLOWS

In the absence of direct measurement of return flows, it was necessary to estimate aggregate returns by either water balance methods or by a combination of water balance and salt balance computation. Details of individual drainage contributions, known to exist along the San Joaquin and the lower reaches of major tributaries (DWR, 1960) are not determinable by either method. The question of the relative contributions of east and westside sources, however, was addressed by considering both chemical composition and water balance.

G. EVALUATION OF EXPORT PUMPING EFFECTS (CVP AND SWP)

1. On Channel Depths

For purposes of evaluating effects of CVP export on South Delta Channels, comparisons were made of channel cross sections and average depths, before the advent of the CVP and after. Data for this purpose were derived from USCGS and DWR sources.

2. On Water Levels

Water level effects were assessed in three ways; from actual records of tidal fluctuation during pumping, from the results of pumping tests designed to determine drawdown due to pumping, and by application of a mathematical model that simulates the hydrodynamic behavior of Delta channels during actual or hypothetical pumping episodes.

3. On Water Quality

Water quality effects of export pumping were not measurable directly, but were assessed in general terms from changes in circulation induced by pumping. Channel discharges, velocities and net circulations were determined from the results of simulations using the mathematical model.

4. Mathematical Modeling

The mathematical model employed as a tool in this investigation is a version of the hydrodynamic simulator developed by Water Resources Engineers, Inc. and employed by DWR and others in a variety of special studies of Delta hydraulics. It was adapted for this investigation, using detailed data on channel geometry and water levels provided by the DWR.

CHAPTER V

WATER QUANTITY EFFECTS OF UPSTREAM DEVELOPMENT

This section of the report discusses the effect of upstream development on lower San Joaquin River flows. It attempts to identify the impact of the CVP by assuming that all development on the upper San Joaquin River (that portion of the San Joaquin River upstream of the mouth of the Merced River) since 1947 is due to the CVP. While some development in addition to the CVP has occurred in the upper San Joaquin basin it is not extensive and for the purpose of this report, is considered negligible.

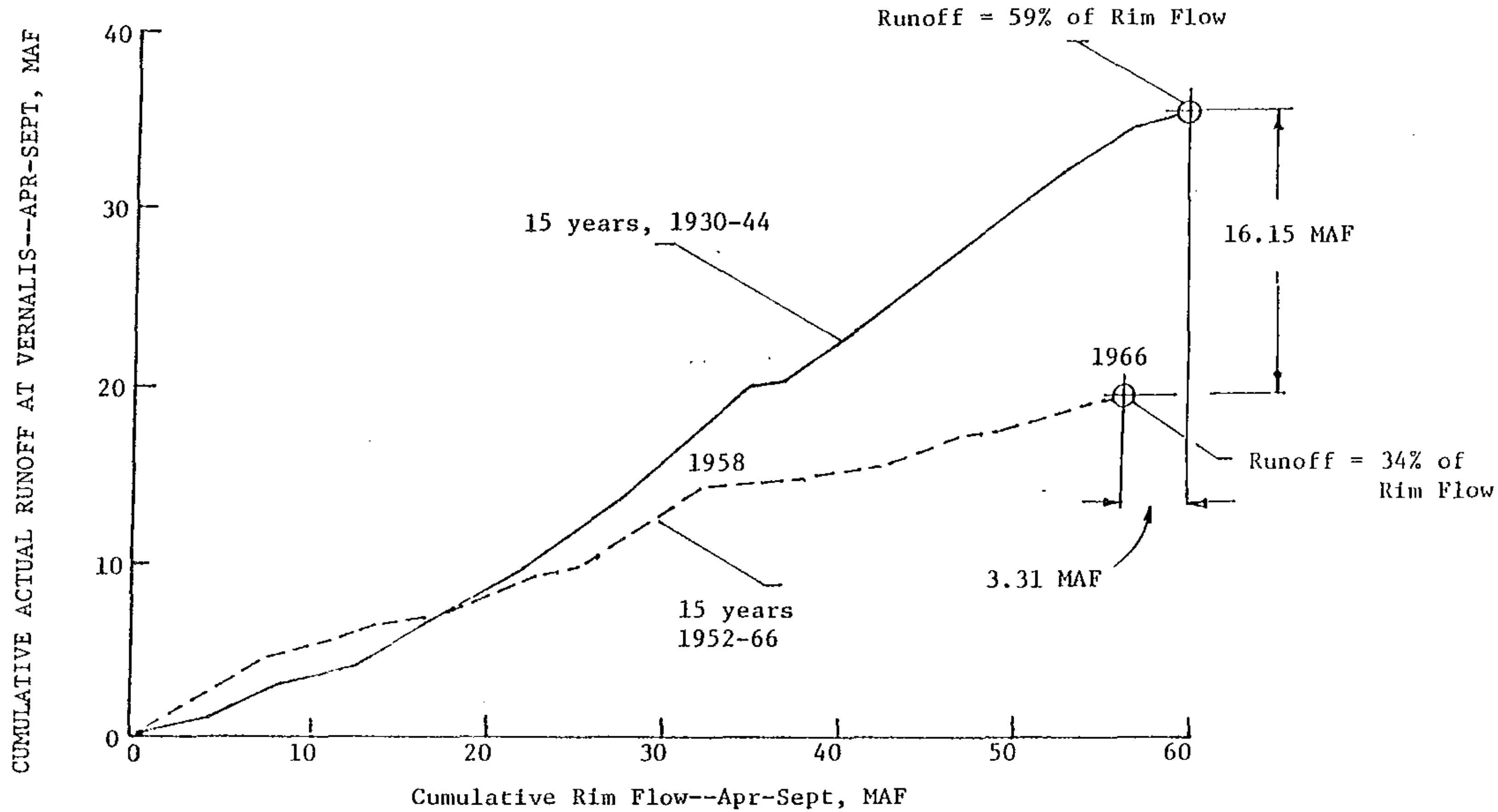
It is obvious from the records of San Joaquin River flows at Vernalis that development of water resources in the basin upstream has decreased the quantity of flow in the lower San Joaquin River. Figure V-1 shows the average reduction in runoff in the April-September period between two historic periods, 1930-1944 and 1952-1966. The figure demonstrates that the flow of the San Joaquin River at the Vernalis gage during the April-September period averaged 1,020,000 acre-feet less in the 1952-1966 period than in the 1930-1944 period when adjusted for the difference in unimpaired rim flow.

Figure V-2 similarly shows the average reduction in flows of the upper San Joaquin River during the April-September period. When adjusted for the difference in unimpaired rim flow, the average flow in the upper San Joaquin River has decreased by 444,600 acre-feet during the April-September period.

Although development has had a significant effect on the average flow in the lower San Joaquin River it is evident from the streamflow records of the San Joaquin basin rivers, that the magnitude of the annual unimpaired flow of the San Joaquin River is important in determining the impact of the CVP on the flow of the river into the southern Delta area.

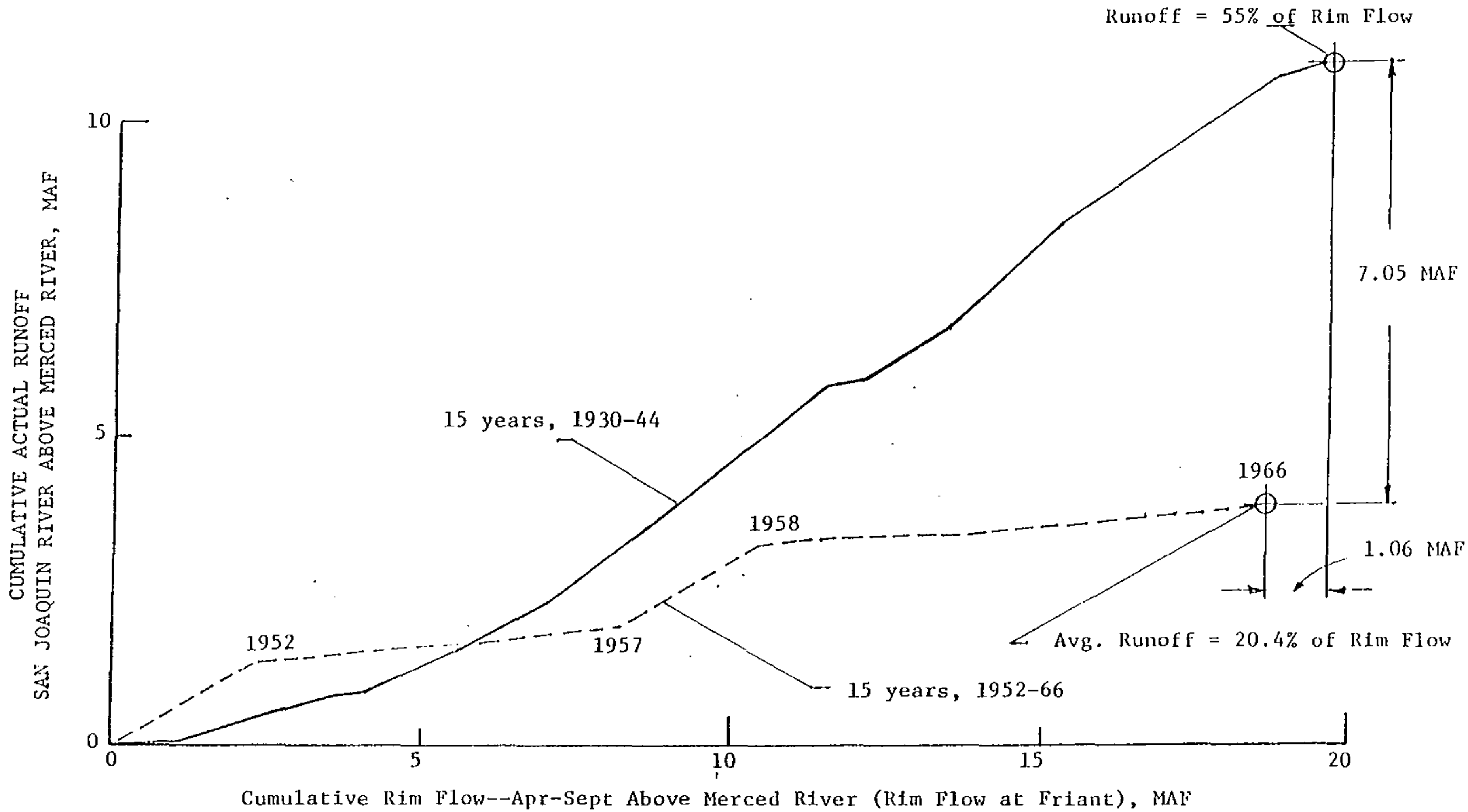
AVG. ANNUAL DECREMENT IN APR-SEPT RUNOFF
BETWEEN TWO HISTORIC PERIODS
(Adjusted for difference in rim flow)

$$= \frac{16.15}{15} \times \frac{56.1}{59.4} \times 10^6 = 1,020,000 \text{ a.f.}$$



CUMULATIVE RUNOFF AT VERNALIS FOR APRIL-SEPTEMBER PERIOD
PRE-CVP (1930-44) AND POST-CVP (1952-66)

AVG. ANNUAL DECREMENT IN APR-SEPT RUNOFF BETWEEN TWO HISTORIC PERIODS (Adjusted for difference in rim flow) $= \frac{7.05}{15} \times \frac{18.57}{19.63} \times 10^6 = 444,600$ a.f.



CUMULATIVE RUNOFF IN SAN JOAQUIN RIVER ABOVE MERCED RIVER DURING THE APRIL-SEPTEMBER PERIOD
PRE-CVP (1930-44) AND POST-CVP (1952-66)

To evaluate more effectively the impact of the CVP in years of differing hydrology runoff, records for the period 1906-1977, inclusive, were studied to determine a logical year classification system. The analysis resulted in classification of hydrologic years into four groupings by magnitude of unimpaired flow as summarized in Table V-1.

Figures V-3 and V-4 show a comparison by year type of actual San Joaquin River flow near Vernalis to the sum of unimpaired rim station flow for the annual and April through September periods, respectively. Figure V-5 presents a comparison by year type of the actual flow of the upper San Joaquin River and the unimpaired flow of the San Joaquin River at Friant Dam for the April through September period. The importance of year type in determining the impact of the CVP can be seen by comparing figures V-3, V-4 and V-5. For example, while figures V-3 and V-4 show that there has been a reduction of flow at Vernalis in dry years, figure V-5 indicates that there has been relatively small changes in the flows of the upper San Joaquin River during the April through September period of dry years.

Since the type of year is important in determining the impact of the CVP on net runoff at Vernalis, the following discussion of impact treats each of the four-year types separately.

DRY YEARS

San Joaquin Basin Above Vernalis

There were five years in each of the pre-1944 and post-1947 periods for which the total rim station unimpaired flow was less than 3,500,000 acre-feet per year. Tables V-2, V-3, V-4, and V-5 summarize the hydrologic conditions for these 10 dry years.

Table V-1
Year Classifications for the San Joaquin River System

Year Class	Unimpaired Flow[1] acre-feet/year
Dry	less than 3,500,000
Below Normal	3,500,000 - 5,600,000
Above Normal	5,600,000 - 7,500,000
Wet	greater than 7,500,000

[1] Sum of runoff of four major tributaries to the San Joaquin Basin.

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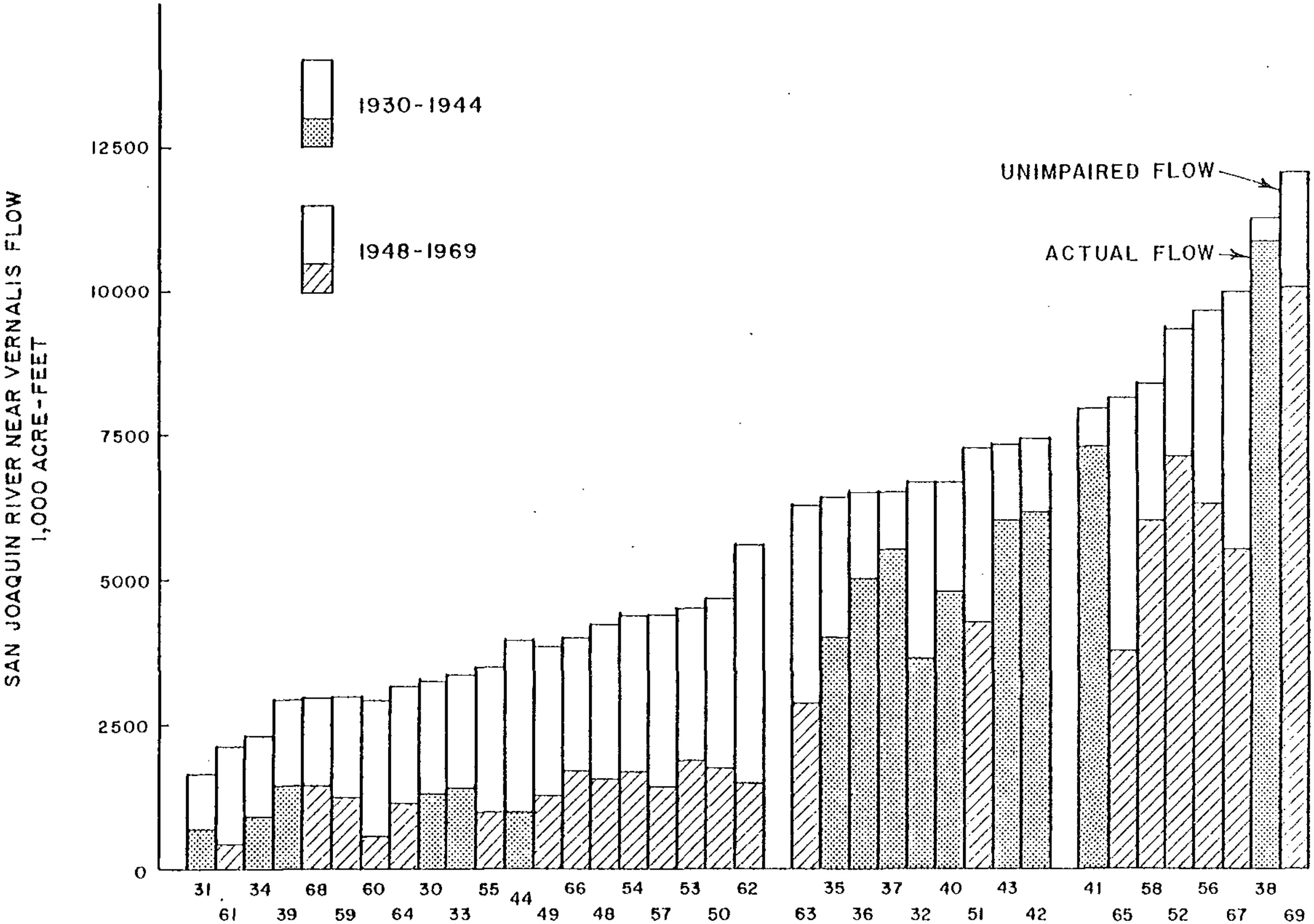
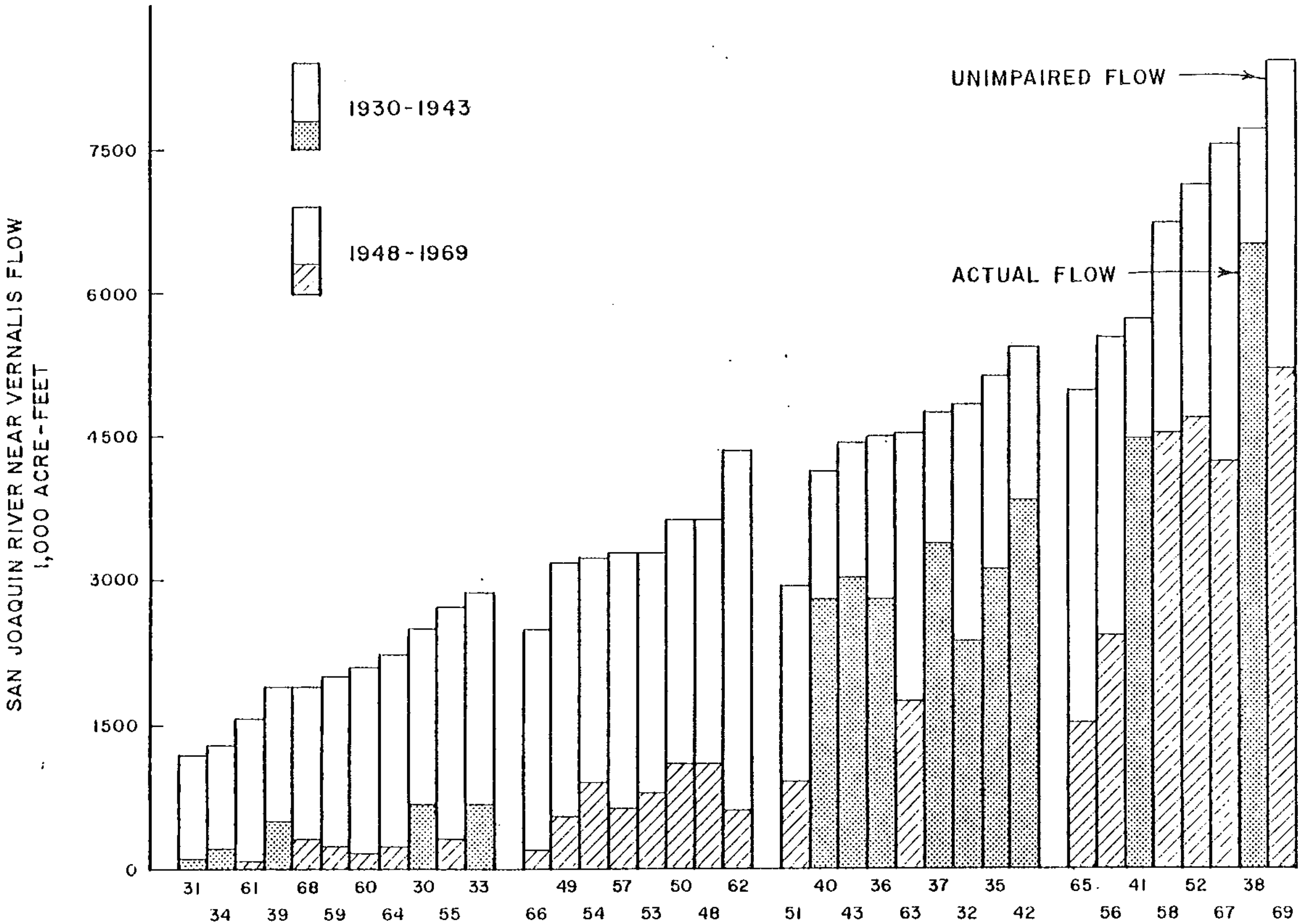


SAN JOAQUIN RIVER NEAR VERNALIS ANNUAL FLOW
PRE-1944 (1930-1944) AND POST 1947 (1948-1969)



SAN JOAQUIN RIVER NEAR VERNALIS, APRIL-SEPT PERIOD
PRE-1944 (1930-1943) AND POST 1947 (1948-1969)

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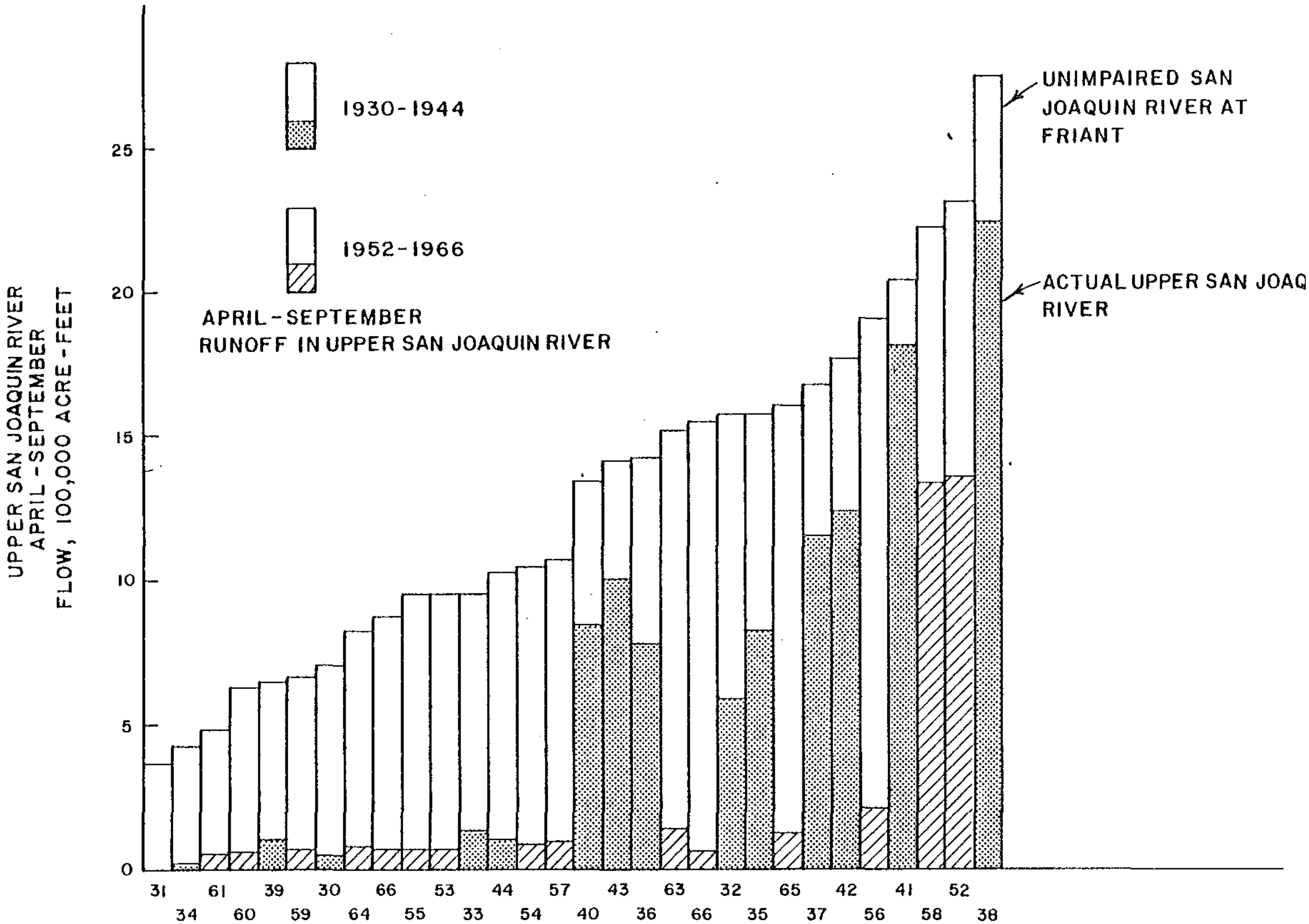


UPPER SAN JOAQUIN RIVER DURING APRIL-SEPT PERIOD
PRE-CVP (1930-44) AND POST-CVP (1952-66)

As the information presented on Table V-2 demonstrates, the annual loss of flow at Vernalis due to post-1947 upstream development as estimated by the double-mass diagram method described on page IV-3, is in the range of 254,000 to 688,000 acre-feet in dry years.

Table V-2 also shows that the city of San Francisco diversion from the Tuolumne River basin through Hetch Hetchy Aqueduct increased from an average of 10,000 acre-feet in pre-1944 dry years (1930, 31, 33, 34 and 39) to an average of 183,000 acre-feet in post-1947 dry years (1959, 60, 61, 64 and 68). CVP operations during post-1947 dry years resulted in importation of an average of 1,031,000 acre-feet through the Delta-Mendota Canal into the Mendota Pool and diversion of an average of 728,000 acre-feet through the Friant-Kern Canal and 171,000 acre-feet through the Madera Canal.

Table V-3 shows that during the April-September period, the estimated flow reduction in the San Joaquin River at Vernalis due to post-1947 development upstream from Vernalis ranged from 149,000 to 594,000 acre-feet in dry years. The table also shows that estimated loss due to the development in the upper San Joaquin basin ranged from 2,000 to 11,000 acre-feet in the April-September period of dry years.

A comparison of the unimpaired flow of the San Joaquin River at Vernalis and the actual flow at the Vernalis station was made as a check on the change in losses* estimated by the double mass diagram method. As shown on Table V-2, in the dry years the average net loss at Vernalis increased from 1,501,000 acre-feet in the pre-1944 years to 1,870,000 acre-feet in the post-1947 years. When the pre-1944 average is adjusted for the difference in average unimpaired flow between pre-1944 and post-1947 periods the average annual increase in

* The terms "loss" or "losses" refer to the difference between the upstream unimpaired flow and the actual flow at the point in question.

TABLE V-2

ESTIMATES OF ANNUAL WATER LOSSES AT VERNALIS IN DRY YEARS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Dry Years	Rim Station Unimpaired KAF	Vernalis Actual KAF	Net Loss @ Vernalis KAF	Estimated Loss @ Vernalis Due to Post 1947 Development Above Vernalis - KAF	Hetch Hetchy KAF	Friant Unimpaired KAF	San Joaquin @ Friant KAF	Actual Upper San Joaquin KAF	Net Loss @ Newman KAF	Estimated Loss at Vernalis Due to Post 1947 Development in Upper San Joaquin - KAF	Madera Canal Diversion KAF	Friant-Kern Canal Diversion KAF	Delta-Mendota Canal Delivery to Mendota Pool KAF	Net Central Valley Project Inter-Basin Transfer
1930	3,254	1,270	1,984		0	859	N.A.	109	750					
1931	1,660	677	983		0	480	N.A.	72	408					
1933	3,356	1,380	1,976		0	1,111	N.A.	295	816					
1934	2,288	927	1,361		0	691	N.A.	195	496					
1939	2,909	1,708	1,201		53	921	1,077	433	488					
Avg.	2,693	1,192	1,501		10	812		221	591					
1959	2,986	1,244	1,742	492	167	949	79	111	838	90	208	809	1,029	+220
1960	2,960	550	2,410	688	167	829	96	105	724	160	144	582	1,009	+427
1961	2,100	437	1,663	254	174	648	100	88	560	111	103	442	1,021	+579
1964	3,151	1,124	2,027	656	186	922	70	164	758	184	228	838	1,066	+220
1968	2,938	1,429	1,509	506	223	862	58	210	652	146	170	967	1,032	+ 65
Avg.	2,827	957	1,870	519	183	842	81	136	706	138	171	728	1,031	+303

Adjusted Loss San Joaquin Basin $= 1870 - \left[1501 \times \frac{2827}{2693}\right] = 294$

Adjusted Loss Upper San Joaquin Basin $= 706 - \left[591 \times \frac{842}{812}\right] = 93$

TABLE V-3

ESTIMATES OF APRIL TO SEPTEMBER WATER LOSSES AT VERNALIS

IN DRY YEARS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Dry Years	Vernalis Unimpaired KAF	Vernalis Actual KAF	Net Loss @ Vernalis KAF	Estimated Loss @ Vernalis Due to Post 1947 Development Above Vernalis - KAF		Friant Unimpaired KAF	San Joaquin @ Friant KAF	Actual Upper San Joaquin KAF	Net Loss Upper San Joaquin-KAF	Estimated Loss @ Vernalis Due to Post 1947 Development Upper San Joaquin - KAF	Madera Canal Diversion KAF	Friant - Kern Canal Diversion KAF	Delta-Mendota Canal Delivery to Mendota Pool KAF	Net Central Valley Project Inter-Basin Transfer KAF
1930	2,490	672	1,818			706	N.A.	45	661					
1931	1,203	121	1,082			368	N.A.	0	368					
1933	2,856	647	2,209			945	N.A.	137	808					
1934	1,303	196	1,107			430	N.A.	16	414					
1939	1,909	483	1,426			641	616	100	541					
Avg.	1,952	424	1,528			618		60	558					
1959	1,995	219	1,776	297		664	57	56	608	11	169	536	814	+278
1960	2,108	138	1,970	535		632	67	39	593	2	124	428	786	+358
1961	1,562	82	1,480	149		487	57	38	449	4	91	324	817	+493
1964	2,216	231	1,985	594		816	48	67	749	10	187	543	817	+274
1968	1,918	309	1,609	510		583	41	77	506	2	114	503	787	+284
Avg.	1,959	196	1,764	417		636		55	581	6	137	467	804	+285

Adjusted Loss = 230* = 7*

*Computed per example in Table V-2

TABLE V-4

ACTUAL AND UNIMPAIRED ANNUAL FLOWS AT RIM STATIONS IN DRY YEARS

	STANISLAUS		TUOLUMNE		MERCED		SAN JOAQUIN	
Dry Years	Unimpaired at Melones KAF	Actual at Ripon KAF	Unimpaired at Don Pedro KAF	Actual at Modesto KAF	Unimpaired at Modesto KAF	Actual at Stevinson KAF	Unimpaired at Friant KAF	Actual Upper San Joaquin KAF
1930	732	474	1,151	527	513	89	859	109
1931	315	611	603	368	262	70	480	72
1933	609	304	1,119	504	516	158	1,111	295
1934	424	134	812	387	361	95	691	195
1939	526	286	985	551	477	224	921	433
AVG.	521	361	934	467	426	127	812	221
1959	584	241	997	627	455	115	949	111
1960	594	92	1,056	293	483	89	829	105
1961	404	81	736	223	312	57	648	88
1964	643	212	1,139	540	447	92	922	164
1968	640	268	1,010	553	426	205	862	210
AVG.	573	179	988	447	425	112	842	136
ADJUSTED LOSS		218*		47*		15*		93*

TOTAL SUB-BASIN LOSS = 373

*Example:

Adjusted loss = Ave. loss in post-1947 years − Average loss in pre-1944 years x $\frac{\text{Average unimpaired flow for post-1947 years}}{\text{Average unimpaired flow for pre-1944 years}}$

(Stanislaus Basin) = $(573-179) - \left[(521-361) \times \frac{573}{521}\right] = 218$

TABLE V-5

ACTUAL AND UNIMPAIRED APRIL TO SEPTEMBER FLOWS AT RIM STATIONS IN DRY YEARS

	STANISLAUS		TUOLUMNE		MERCED		SAN JOAQUIN	
Dry Years	Unimpaired at Melones KAF	Actual at Ripon KAF	Unimpaired at Don Pedro KAF	Actual at Modesto KAF	Unimpaired at Modesto KAF	Actual at Stevinson KAF	Unimpaired at Friant KAF	Upper San Joaquin KAF
1930	524	324	869	246	391	50	706	45
1931	216	38	426	73	193	30	368	0
1933	528	203	953	219	430	58	945	137
1934	222	31	456	97	195	42	430	16
1939	354	[illegible]4	614	142	300	60	641	100
AVG.	369	144	663	155	302	48	618	60
1959	364	52	661	86	307	47	664	56
1960	401	41	731	74	344	37	632	39
1961	301	26	544	53	231	17	487	38
1964	440	46	781	60	312	40	816	67
1968	400	66	652	77	284	51	583	77
AVG.	381	46	673	70	296	38	636	55
ADJUSTED LOSS		103		87		9		7

TOTAL SUB-BASIN LOSS = 206 KAF

* Computed as per example in Table V-4

losses at the Vernalis gage was 294,000 acre-feet with 230,000 acre-feet occurring in the April-September period (see Table V-3).

A further check on change in losses occurring in the San Joaquin River basin was made by analyzing the losses of four subbasins. Tables V-4 and V-5 summarize the hydrologic data for the subbasins during the 10 dry years studied. The sum of the adjusted subbasin losses is 373,000 acre-feet for the annual period. During the April-September period the sum of the adjusted subbasin losses is 206,000 acre-feet (see Table V-5).

The table below summarizes the results of the three methods of analysis.

	Estimated Loss At Vernalis, KAF	
	Annual	April-Sept
Double mass diagram	519	417
Basin comparison	294	230
Subbasin comparison	373	206

Upper San Joaquin Basin

In the upper San Joaquin River basin post-1947 development affected the annual flows in dry years, but had no measurable effect on the flows during the April-September period. In the five pre-1944 dry years the actual annual flow of the upper San Joaquin River ranged from 72,000 to 433,000 acre-feet with an average of 221,000 acre-feet, while the unimpaired annual flows at Friant ranged from 480,000 to 1,110,000 acre-feet. Post-1947 dry-year flows in the upper San Joaquin River ranged from 88,000 to 210,000 acre-feet with an average of 136,000 acre-feet while unimpaired annual flows at Friant ranged from 647,000 to 949,000 acre-feet. There was an average decrease in the annual post-1947 flow in dry years in the upper San Joaquin River of about 138,000 acre-feet as estimated by the double mass diagram method (see Column 11, Table V-2).

With adjustment for the difference in unimpaired annual dry-year flow at Friant, the average decrease in flow from pre-1944 to post-1947 years in the upper San Joaquin River is about 133,000 acre-feet. This is about 60 percent of the pre-1944 flow in the upper San Joaquin River.

During the April-September period there was no significant change from the pre-1944 dry years to the post-1947 dry years in the upper San Joaquin River (see Column 11, Table V-3).

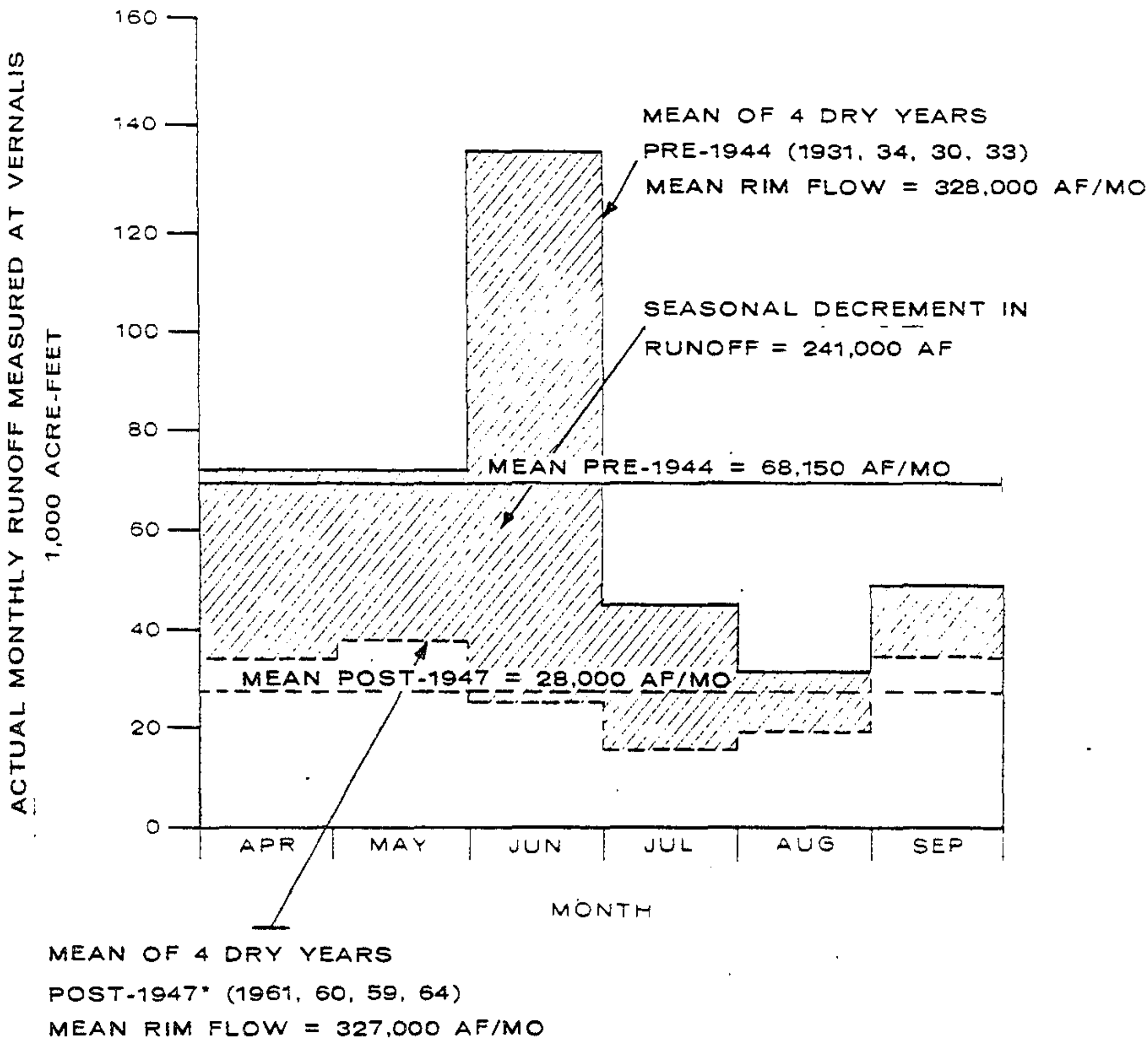
Estimated reduction in flow
in the upper San Joaquin River, KAF

Method	Annual	April-Sept
Double Mass Diagram	133	6
Basin Comparison	93	7

Figure V-6 shows a comparison of actual runoff at Vernalis during the April-September period for dry years in the pre-1944 and post-1947 periods. During four pre-1947 dry years of 1930, 31, 33 and 34 the flow at Vernalis averaged 68,150 acre-feet/month during the April-September period. This was about 40,000 acre-feet/month more than for the same period of the four post-1947 dry years of 1959, 60, 61 and 64.* The April-September decrement in runoff was about 241,000 acre-feet.

The same comparison in the upper San Joaquin River is made on figure V-7. In dry years the average flow in the upper San Joaquin River during the April-September period increased slightly in five of the six months within the period. In June the average flow decreased from 25,000 acre-feet to 8,300 acre-feet. This difference in average flow in June is attributed to an unusually high runoff in June 1933.

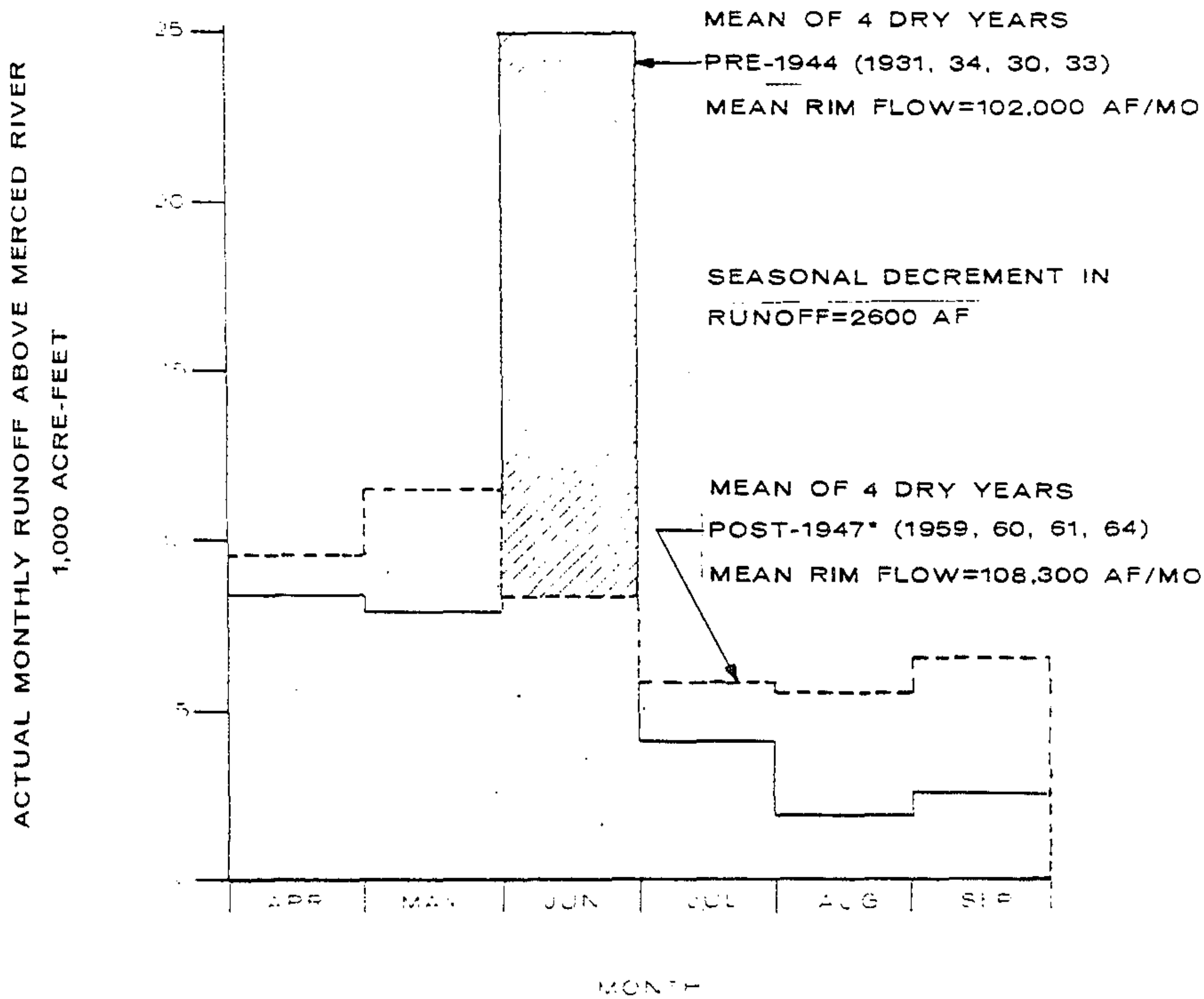
* The two sets of dry years were chosen for comparison so that the average unimpaired rim flows were nearly equal, e.g., 328,000 acre-feet/year for the pre-1944 years v. 327,000 acre-feet/year for the post-1947 years.



ACTUAL RUNOFF AT VERNALIS DURING APRIL-SEPTEMBER PERIOD IN DRY YEARS

PRE-1944 (1931, 34, 30, 33) AND POST-1947 (1961, 60, 59, 64)

* NO ADJUSTMENT



ACTUAL RUNOFF UPPER SAN JOAQUIN RIVER BASIN DURING APRIL-SEPTEMBER PERIOD IN DRY YEARS

PRE-1944 (1930, 31, 33, 34) AND POST-1947 (1959, 60, 61, 64)

* ADJUSTED TO PRE-CVP BASE BY RATIO OF RIM FLOWS

When adjusted for the difference in unimpaired flow at Friant, the April-September period reduction in runoff during the post-1947 period is 2,600 acre-feet or about 400 acre-feet/month in the upper San Joaquin River.

Summary of Impacts - Dry Years

In summary, the data indicates that in dry years the impact of the CVP on the San Joaquin River at Vernalis was as follows:

a. On an annual basis the estimated decrease in flow ranged from 93,000 to 133,000 acre-feet which is about 8 to 11 percent of the pre-1944 average dry-year annual flow at Vernalis.

b. During the April-September period, the reduction in flow attributable to the CVP ranged from 2,600 to 7,000 acre-feet, which is about 0.6 to 1.6 percent of the pre-1944 average dry-year April-September flow at Vernalis.

BELOW NORMAL

The evaluation of the below normal years was the most difficult and probably the least accurate. While the four-year types were almost equally distributed in the 72-year period 1906-1977, there were no below normal years from 1930 through 1943. In contrast, over one-third or eight of the post-1947 years were classified as below normal. When available, information for the below normal years of 1923, 1925, and 1928 were included in Tables V-6, V-7, V-8, and V-9 for comparison purposes.

Based on the double-mass diagram method of calculation, the average annual reduction at Vernalis since 1947 during below normal years is estimated as 1,219,000 acre-feet. Most of the reduction, about 1,064,000 acre-feet, occurred during the April-September period. The average flow reduction due to CVP development on the upper San Joaquin River was about

TABLE V-6

ESTIMATES OF ANNUAL WATER LOSSES AT VERNALIS
IN BELOW NORMAL YEARS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Below Normal Year	Vernalis Unimpaired KAF	Vernalis Actual KAF	Net Loss @ Vernalis KAF	Estimated Loss @ Vernalis Due to Post 1947 Development Above Vernalis - KAF		Friant Unimpaired KAF	San Joaquin @ Friant KAF	Actual Upper San Joaquin KAF	Net Loss Upper San Joaquin KAF	Estimated Loss @ Vernalis Due to Post 1947 Development Upper San Joaquin - KAF	Madera Canal Diversion KAF	Friant-Kern Canal Diversion KAF	Delta-Mendota Canal Delivery to Mendota Pool KAF	Net Central Valley Project Inter-Basin Transfer KAF
1923	5,512	N.A.				1,654	N.A.	N.A.						
1925	5,505	N.A.				1,439	N.A.	N.A.						
1928	4,365	N.A.				1,154	N.A.	228	926					
Avg. *														
1948	4,218	1,553	2,665	1,186		1,215	1,006	103	1,112	473	76	0	0	0
1949	3,799	1,247	2,552	1,044		1,164	1,068	119	1,045	578	152	0	0	0
1950	4,656	1,786	2,870	1,559		1,311	974	108	1,203	699	118	198	0	-198
1953	4,554	1,891	2,663	950		1,227	351	211	1,016	404	193	741	668	- 73
1954	4,315	1,717	2,598	1,370		1,314	262	179	1,135	569	212	811	824	+ 13
1955	3,512	975	2,537	1,195		1,161	107	145	1,016	448	219	805	927	+122
1957	4,292	1,442	2,850	1,400		1,327	149	205	1,122	547	242	990	919	- 71
1966	3,985	1,696	2,289	1,053		1,299	62	247	1,052	628	442	1,066	1,059	- 7
Avg.	4,166	1,538	2,628	1,219		1,252		165	1,088	543	207	833	879	- 3

*Note: Since there were no data for Vernalis flows in 1923, 1925, and 1928 no adjustments were possible for flow restrictions.

TABLE V-7

ESTIMATES OF APRIL TO SEPTEMBER WATER LOSSES AT VERNALIS IN BELOW NORMAL YEARS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Below Normal Year	Vernalis Unimpaired KAF	Vernalis Actual KAF	Net Loss @ Vernalis KAF	Estimated Loss @ Vernalis Due to Post 1947 Development Above Vernalis - KAF		Friant Unimpaired KAF	San Joaquin @ Friant KAF	Actual Upper San Joaquin KAF	Net Loss Upper San Joaquin KAF	Estimated Loss @ Vernalis Due to Post 1947 Development Upper San Joaquin KAF	Madera Canal Diversion KAF	Friant-Kern Canal Diversion KAF	Delta-Mendota Canal Delivery to Mendota Pool KAF	Net Central Valley Project Inter-Basin Transfer KAF
1923	4,123	N.A.				1,303	N.A.	838	465					
1925	4,056	N.A.				1,163	N.A.	N.A.						
1928	2,675	N.A.				801	N.A.	200	601					
Avg.	3,618					1,052		519	533					
1948	3,652	1,093	2,559	1,202		1,077	801	67	1,010	383	72	0	0	0
1949	3,177	573	2,604	947		1,016	838	53	963	491	150	168	0	-168
1950	3,631	1,062	2,569	1,311		1,044	743	42	1,002	511	118	180	0	-180
1953	3,275	780	2,495	898		944	184	67	877	210	179	592	615	+ 23
1954	3,216	902	2,314	1,002		1,045	138	82	963	412	207	717	720	+ 3
1955	2,723	302	2,421	973		941	57	66	875	318	199	674	780	+106
1957	3,269	630	2,639	1,240		1,071	54	94	977	389	229	793	761	- 32
1966	2,492	246	2,246	942		870	45	57	813	373	173	628	819	+191
Avg.	3,180	699	2,481	1,064		1,001	358	66	935	386	166	579	739	- 8

*See note in Table V-6

TABLE V-8

ACTUAL AND UNIMPAIRED APRIL TO SEPTEMBER FLOWS AT RIM STATIONS IN BELOW NORMAL YEARS

	STANISLAUS		TUOLUMNE		MERCED		SAN JOAQUIN	
Below Normal Years	Unimpaired at Melones KAF	Actual at Ripon KAF	Unimpaired at Don Pedro KAF	Actual at Modesto KAF	Unimpaired at Modesto KAF	Actual at Stevinson KAF	Unimpaired at Friant KAF	Actual Upper San Joaquin KAF
1923	820	624	1,310	421	690	520	1,303	838
1925	855	690	1,381	914		N.A.		N.A.
1928	416	394	792	406	391	212	725	200
AVG.	697	569	1,161	580	540	366	1,052	519
1948	781	492	1,192	359	603	211	1,077	67
1949	615	286	1,035	141	511	113	1,016	53
1950	846	535	1,187	361	553	139	1,045	42
1953	736	374	1,141	266	455	67	944	67
1954	650	335	1,037	253	484	185	1,046	82
1955	513	138	851	86	418	48	941	66
1957	661	199	1,038	152	499	169	1,071	94
1966	429	47	784	79	409	39	870	57
AVG.	654	301	1,033	212	491	121	1,001	66
ADJUSTED LOSS*		233		304		212		428

*Computed as per example in Table V-4

TOTAL SUB-BASIN LOSS = 1,177

TABLE V-9

ACTUAL AND UNIMPAIRED ANNUAL FLOWS AT RIM STATIONS IN BELOW NORMAL YEARS

	STANISLAUS		TUOLUMNE		MERCED		UPPER SAN JOAQUIN	
Below Normal Years	Unimpaired at Melones KAF	Actual at Ripon KAF	Unimpaired at Don Pedro KAF	Actual at Modesto KAF	Unimpaired at Modesto KAF	Actual at Stevinson KAF	Unimpaired at Friant KAF	Actual Upper San Joaquin KAF
1923	1,130	947	1,786	833	942	786	1,654	N.A.
1925	1,224	1,111	1,932	1,096	910	N.A.	1,439	N.A.
1928	950	777	1,525	1,028	737	390	1,154	228*
AVG.	1,101	945	1,748	986	840	588		
1948	898	584	1,418	599	688	262	1,215	103
1949	745	433	1,252	1,035	638	195	1,164	119
1950	1,076	706	1,551	696	719	232	1,311	108
1953	967	581	1,534	728	626	243	1,227	211
1954	888	500	1,445	648	668	263	1,314	179
1955	681	311	1,136	369	534	109	1,161	145
1957	894	328	1,424	529	648	255	1,327	205
1966	703	429	1,315	734	669	211	1,299	247
AVG.	856	484	1,384	667	649	221	1,252	165
ADJUSTED LOSS*		273		115		233		

*Note: There is only a single observation for the below normal years (1928) hence it was not feasible to determine an adjusted loss for the Upper San Joaquin River basin.

543,000 acre-feet in below normal years (see Column 11, Table V-6). Approximately 386,000 acre-feet of this reduction occurred during the April-September period (see Column 11, Table V-7).

Although 1923, 1925 and 1928 are not within the study period, information from these years was used to check the results of the double-mass diagram method. The information from these 3 years on an annual basis was inadequate to give a good check. As a result, the annual evaluation of the subbasins gave unreasonable results. However, the data for the April-September period seemed to be reasonable and checked the double-mass diagram method quite well.

The loss at Vernalis during the April through September period due to post-1947 development (see Table V-7), estimated by the double mass diagram method is 1,064,000 acre-feet. The total subbasin reduction in flow was computed to be 1,177,000 acre-feet (Table V-8). Using the subbasin method of evaluation, the estimated reduction in the upper San Joaquin River was about 428,000 acre-feet. The percentage at Vernalis attributed to each subbasin is as follows:*

	Percent of total reduction in flow April through September
Stanislaus	20%
Tuolumne	26%
Merced	18%
San Joaquin River above Merced River (CVP)	36%

* Subbasin riverflows are measured upstream from the actual mouths of the Tuolumne and Stanislaus Rivers. There may be some net accretions or diversions between these gaging stations and the lower San Joaquin River which could affect the proportion of losses attributed to each subbasin.

Summary of Impacts - Below Normal Years

In summary, the data indicate that in below normal years the effect of the CVP on the San Joaquin River at Vernalis has been as follows:

a. On an annual basis the estimated decrease in flow was 543,000 acre-feet, which is 26 percent of the calculated pre-1944 average below normal year flow at Vernalis.

b. During the April-September period, the decrease in flow ranged from 386,000 to 428,000 acre-feet, which corresponds to 35-38 percent of the calculated pre-1944 April-September flow at Vernalis.

ABOVE NORMAL YEARS

Seven of the 14 pre-1944 years were above normal, while only three of the post-1947 years were in this classification. Tables V-10, V-11, V-12, V-13 and Figure V-8 present the hydrologic data for the above normal years.

As indicated in Table V-10 the average Vernalis unimpaired flow during the seven pre-1944 years was 6,763,000 acre-feet, about 485,000 acre-feet greater than the average for the three post-1947 above normal years. The actual flow at Vernalis during the pre-1944 years was 5,021,000 acre-feet for an average loss of 1,742,000 acre-feet or 25.7 percent of rim station unimpaired flow. Losses increased in the post-1947 period to 3,364,000 acre-feet or 47.3 percent of the rim station unimpaired flow. When adjusted for the difference in the unimpaired flows of the two periods, the increase in loss between the two periods is 1,721,000 acre-feet annually. (See column 4 and footnote, Table V-10.)

Using the same type of analysis, the average reduction in flow in the upper San Joaquin River (Table V-11) is estimated at 1,076,000 acre-feet in above normal years. This increase in flow reduction corresponds to 21 percent of the average above normal year flow at pre-1944 Vernalis.

TABLE V-10

ESTIMATES OF ANNUAL WATER LOSSES AT VERNALIS
IN ABOVE NORMAL YEARS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Above Normal Year	Vernalis Unimpaired KAF	Vernalis Actual KAF	Net Loss at Vernalis KAF	Estimated Loss @ Vernalis Due to Post 1947 Development Above Vernalis - KAF		Friant Unimpaired KAF	San Joaquin @ Friant KAF	Actual Upper San Joaquin KAF	Net Loss-Upper San Joaquin KAF	Estimated Loss @ Vernalis Due to Post 1947 Development Upper San Joaquin - KAF	Madera Canal Diversion KAF	Friant-Kern Canal Diversion KAF	Delta-Mendota Canal Delivery to Mendota Pool KAF	Net Central Valley Project Inter-Basin Transfer KAF
1932	6,622	3,660	2,962			2,047	N.A.	989	1,058					
1935	6,418	4,030	2,388			1,923	N.A.	1,076	847					
1936	6,495	4,985	1,510			1,853	N.A.	1,467	386					
1937	6,530	5,484	1,046			2,208	N.A.	2,059	149					
1940	6,596	4,768	1,828			1,881	1,829	1,485	396					
1942	7,398	6,160	1,238			2,254	2,254	2,127	127					
1943	7,283	6,060	1,223			2,054	2,068	2,125	- 71					
Avg.	6,763	5,021	1,742			2,031		1,618	413					
1951	7,262	4,738	2,524	710		1,859	1,216	750	1,109	718	142	368	139	-229
1962	5,618	1,487	4,131	1,891		1,924	75	268	1,656	720	277	1,370	991	-379
1963	6,250	2,813	3,437	1,598		1,945	83	316	1,629	867	271	1,513	966	-547
Avg.	6,377	3,013	3,364	1,400		1,909		445	1,464	768	230	1,084	699	-385

Adjusted Loss = 1,721*   = 1,076*

*Computed as per example in Table V-2

TABLE V-11

ESTIMATES OF APRIL TO SEPTEMBER WATER LOSSES AT VERNALIS

IN ABOVE NORMAL YEARS

Above Normal Years	Vernalis Unimpaired KAF	Vernalis Actual KAF	Net Loss @ Vernalis KAF	Estimated Loss @ Vernalis Due to Post 1947 Development Above Vernalis - KAF	Friant Unimpaired KAF	San Joaquin @ Friant KAF	Actual Upper San Joaquin KAF	Net Loss-Upper San Joaquin KAF	Estimated Loss @ Vernalis Due to Post 1947 Development Upper San Joaquin - KAF	Madera Canal Diversion KAF	Friant-Kern Canal Diversion KAF	Delta-Mendota Canal Delivery to Mendota Pool KAF	Net Central Valley Project Inter-Basin Transfer KAF
1932	4,829	2,388	2,441		1,578	N.A.	588	990					
1935	5,152	3,131	2,021		1,579	N.A.	816	763					
1936	4,489	2,801	1,688		1,410	N.A.	765	645					
1937	4,746	3,372	1,374		1,670	N.A.	1,144	526					
1940	4,107	2,827	1,280		1,336	1,250	836	500					
1942	5,461	3,834	1,627		1,762	1,329	1,222	540					
1943	4,417	3,020	1,397		1,407	1,281	1,011	396					
Avg.	4,743	3,053	1,690		1,534		911	623					
1951	2,909	919	1,990	1,783	960	588	74	886	308	140	345	139	- 206
1962	4,358	647	3,711	1,832	1,558	46	51	1,507	470	268	1,151	837	- 314
1963	4,560	1,753	2,807	1,581	1,515	58	159	1,356	542	262	1,300	744	- 556
Avg.	3,942	1,106	2,836	1,732	1,344		95	1,250	440	223	864	573	359

Adjusted Loss = 1,432*

= 704*

*Computed as per example in Table V-2

TABLE V-12

ACTUAL AND UNIMPAIRED ANNUAL FLOWS AT RIM STATIONS IN ABOVE NORMAL YEARS

	STANISLAUS		TUOLUMNE		MERCED		SAN JOAQUIN	
Above Normal Years	Unimpaired at Melones KAF	Actual at Ripon KAF	Unimpaired at Don Pedro KAF	Actual at Modesto KAF	Unimpaired at Modesto KAF	Actual at Stevinson KAF	Unimpaired at Friant KAF	Actual Upper San Joaquin KAF
1932	1,353	939	2,109	1,097	1,113	549	2,047	989
1935	1,214	974	2,110	1,251	1,171	735	1,923	1,076
1936	1,322	1,075	2,168	1,418	1,152	757	1,853	1,467
1937	1,109	869	1,998	1,383	1,215	828	2,208	2,059
1940	1,400	1,152	2,221	1,322	1,095	706	1,881	1,485
1942	1,485	1,247	2,373	1,786	1,287	965	2,254	2,127
1943	1,566	1,268	2,376	1,712	1,289	973	2,054	2,125
AVG.	1,350	1,075	2,194	1,424	1,189	788	2,031	1,618
1951	1,694	1,436	2,484	1,668	1,225	801	1,859	750
1962	995	407	1,773	365	928	380	1,924	268
1963	1,268	861	2,053	990	984	505	1,945	316
AVG.	1,319	901	2,103	1,008	1,046	562	1,909	445
ADJUSTED LOSS		149*		357*		131*		1,076*

TOTAL SUB-BASIN LOSS = 1,713

*Computed as per example in Table V-4

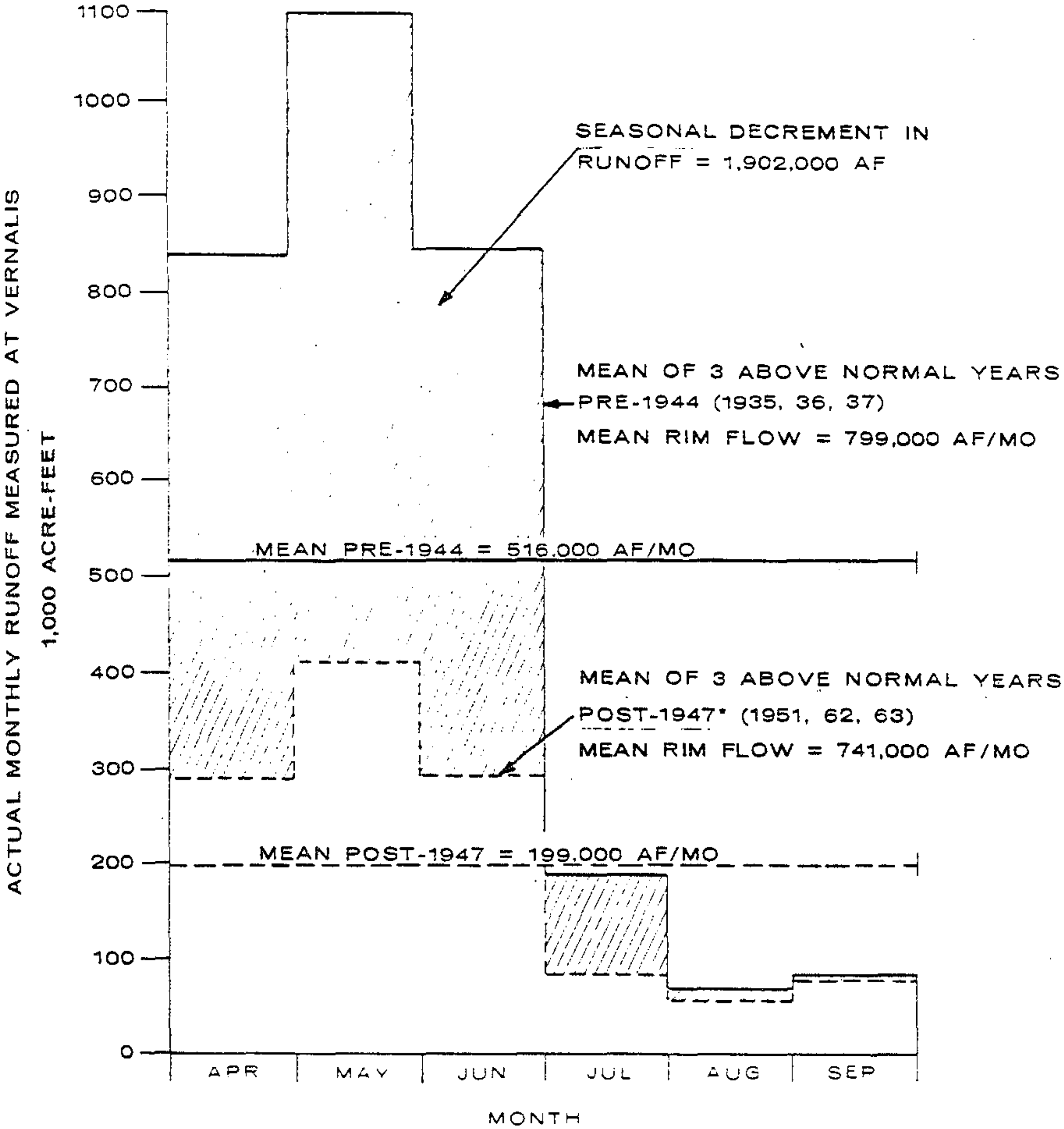
TABLE V-13

ACTUAL AND UNIMPAIRED APRIL TO SEPTEMBER FLOWS AT RIM STATIONS IN ABOVE NORMAL YEARS

	STANISLAUS		TUOLUMNE		MERCED		SAN JOAQUIN	
Above Normal Years	Unimpaired at Melones KAF	Actual at Ripon KAF	Unimpaired at Don Pedro KAF	Actual at Modesto KAF	Unimpaired at Modesto KAF	Actual at Stevinson KAF	Unimpaired at Friant KAF	Actual Upper San Joaquin KAF
1932	996	674	1,515	770	740	310	1,578	588
1935	1,014	791	1,647	1,040	912	580	1,579	816
1936	884	671	1,452	795	743	481	1,410	765
1937	827	622	1,441	868	808	531	1,670	1,144
1940	799	615	1,315	714	657	475	1,336	836
1942	1,063	826	1,705	1,133	931	675	1,762	1,222
1943	872	623	1,400	792	738	498	1,407	1,011
AVG.	922	689	1,496	873	790	507	1,534	911
1951	545	286	957	350	443	193	964	74
1962	794	256	1,337	109	670	202	1,558	51
1963	876	616	1,477	505	692	376	1,515	159
AVG.	738	386	1,257	321	602	257	1,344	95
ADJUSTED LOSS		165*		412*		129*		700*

TOTAL SUB-BASIN LOSS = 1,406

*Computed as per example in Table V-4



ACTUAL RUNOFF AT VERNALIS DURING APRIL-SEPTEMBER
PERIOD IN ABOVE NORMAL YEARS
PRE-1944 (1935, 36, 37) AND POST-1947 (1951, 62, 63)
* ADJUSTED TO PRE-1944 BASE BY RATIO OF RIM FLOWS

Estimation by the double mass diagram method indicates the average annual loss at Vernalis to be 1,400,000 acre-feet in above normal years with the contribution from above the upper San Joaquin River being 768,000 acre-feet.

The subbasin analysis for annual flows, summarized in Table V-12 produced the following results:

	Increased Losses KAF
Stanislaus	149,000
Tuolumne	357,000
Merced	131,000
San Joaquin	1,076,000
Total	1,713,000

In the evaluation of the April through September period of the above normal years (Tables V-11 and V-13), the basin analysis and the subbasin analysis were again in close agreement with the double mass diagram method producing appreciably different results. The table below summarizes results obtained by the three methods of analysis:

	Estimated reduction flow at Vernalis, KAF	
Method	Annual	April-Sept
Double mass diagram	1400	1732*
Basin comparison	1721	1400
Subbasin comparison	1713	1406

	Estimated reduction in flow in the Upper San Joaquin River, KAF	
Method	Annual	April-Sept
Double mass diagram	768	440
Basin comparison	1076	704

* Analysis by the double mass diagram method gives a higher estimate for the April-September period than for the annual period. This anomaly results from the statistical treatment of the data, i.e., fitting data with a regression line.

As the above table indicates, the flow reduction at Vernalis due to post-1947 development averaged from 1,400,000 to 1,721,000 acre-feet with almost all the reduction occurring in the April through September period. The reduction at Vernalis due to development in the upper San Joaquin River basin is estimated to range from 768,000 to 1,076,000 acre-feet in above normal years. About 440,000 to 700,000 acre-feet of the reduction occurs in the April-September period. The following table indicates the percentage of the April-September reduction attributable to the various river basins.

Stanislaus	12 percent
Tuolumne	29 percent
Merced	9 percent
Upper San Joaquin	50 percent

<u>Summary of Impacts</u> - <u>Above Normal Years</u>

In summary, the data indicate that in above normal years the effect of the CVP on the San Joaquin River at Vernalis has been as follows:

a. On an annual basis, the estimated decrease in flow ranged from 768,000 to 1,076,000 acre-feet, which corresponds to 15 - 21 percent of pre-1944 average above normal flows at Vernalis.

b. During the April-September period, the estimated decrease in flow ranged from 440,000 to 704,000 acre-feet, which corresponds to 14 - 23 percent of pre-1944 average above normal flows at Vernalis during the period.

WET YEARS

Six of the post-1947 yea: : and two of the pre- .944 years are classified as ·et. Tables V-14, V-15, V-16, and V-17 present the hydrologic data for these years.

Analysis of wet year hydrologic data is somewhat complicated by the contribution of unmeasured flows to the valley floor. Consequently, the su . of rim station unimpaired flows is not necessarily a good estimate of available water. Nevertheless, for comparison purposes the same procedures were applied as for other year classes.

The unimpaired flow at Vernalis during pre-1944 wet years averaged 9,596,000 acre-feet; in the post-1947 wet years the average was 9,626,000 acre-feet. According to the double mass diagram method, substantial reduction in runoff resulted in the post-1947 period, averaging (after adjustment) about 2,609,000 acre-feet for the full year. In the April-September period the corresponding reduction in flow between pre-1944 and post-1947 years was about 1,74 000 acre-feet. (See Tables 14 and 15, calculation of adjusted losses.)

Analysis of the data for the upper San Joaquin basin by the double mass diagram method indicates average reduction in flow to the valley floor of 1,706,000 acre-feet for the annual period and 965,000 acre-feet during the April-September period.

Analysis by the subbasin comparison methods, as summarized in Tables V-16 and V-17, indicates relatively higher proportions of the reduction in flow attributed to development in the upper San Joaquin basin. On an annual basis the adjusted reduction was 2,916,000 acre-feet for the four subbasins, 2,014,000 acre-feet, or 69 percent of which is attributed to the CVP. In the April-September period the reduction in valley floor runoff was 1,760,000 acre-feet for the four subbasins, and 960,000 acre-feet, or 55 percent of which was attributed to the CVP.

TABLE V-14

ESTIMATES OF ANNUAL WATER LOSSES AT VERNALIS
IN WET YEARS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Wet Year	Vernalis Unimpaired KAF	Vernalis Actual KAF	Net Loss @ Vernalis KAF	Estimated Loss @ Vernalis Due to Post 1947 Development Above Vernalis - KAF		Friant Unimpaired KAF	San Joaquin @ Friant KAF	Actual Upper San Joaquin KAF	Net Loss - Upper San Joaquin KAF	Estimated Loss @ Vernalis Due to Post 1947 Development Upper San Joaquin - KAF	Madera Canal Diversion KAF	Friant-Kern Canal Diversion KAF	Delta-Mendota Canal Delivery to Mendota Pool KAF	Net Central Valley Project Inter-Basin Transfer KAF
1938	11,248	10,840	408			3,688	N.A.	4,992	-1,304					
1941	7,945	7,298	647			2,652	2,589	3,244	- 592					
Avg.	9,596	9,069	527			3,170		4,118	- 622					
1952	9,312	7,144	2,168	215		2,840	2,084	2,090	750	935	179	462	122	-340
1956	9,679	6,305	3,374	840		2,960	1,225	1,319	1,641	551	239	1,322	519	-803
1958	8,367	6,056	2,311	561		2,631	1,180	1,657	974	514	244	1,145	447	-698
1965	8,108	3,795	4,313	1,994		2,272	63	397	1,875	448	324	1,631	995	-636
1967	9,993	5,561	4,432	2,230		3,232	1,269	1,601	1,631	1,250	389	1,422	572	-841
1969	12,295	10,070	2,225			4,040	2,208	4,202	- 162	930	404	1,082	378	-704
Avg.	9,626	6,488	3,138	1,168		2,996		1,878	1,118	771	356	1,177	607	-607

Adjusted Loss = 2,608*

= 1,705*

*Computed as per example in Table V-2

TABLE V-15

ACTUAL AND UNIMPAIRED ANNUAL FLOWS AT RIM STATIONS IN WET YEARS

	STANISLAUS		TUOLUMNE		MERCED		SAN JOAQUIN	
Wet Years	Unimpaired at Melones KAF	Actual at Ripon KAF	Unimpaired at Don Pedro KAF	Actual at Modesto KAF	Unimpaired at Modesto KAF	Actual at Stevinson KAF	Unimpaired at Friant KAF	Actual Upper San Joaquin KAF
1941	1,338	1,176	2,500	1,750	1,454	1,083	2,652	3,244
1938	2,045	1,836	3,435	2,595	2,080	1,690	3,688	4,992
AVG.	1,692	1,506	2,968	2,172	1,767	1,387	3,170	4,118
1952	1,919	1,529	2,989	2,116	1,563	1,141	2,840	2,090
1956	1,883	1,542	3,162	1,999	1,675	1,158	2,960	1,319
1958	1,678	1,180	2,649	1,855	1,409	1,058	2,631	1,657
1965	1,702	1,192	2,748	1,333	1,386	690	2,272	397
1967	1,932	1,355	3,113	1,751	1,716	718	3,232	1,601
1969	2,210	1,707	3,856	2,422	2,188	1,260	4,040	4,202
AVG.	1,887	1,418	3,086	1,913	1,656	1,004	2,996	1,878
ADJUSTED LOSS		261*		345*		296*		2,014*

TOTAL SUB-BASIN LOSS = 2,916

*Computed as per example in Table V-4

TABLE V-16

ESTIMATES OF APRIL TO SEPTEMBER WATER LOSSES AT VERNALIS IN WET YEARS

Wet Years	Vernalis Unimpaired KAF	Vernalis Actual KAF	Net Loss @ Vernalis KAF	Estimated Loss @ Vernalis Due to Post 1947 Development Above Vernalis - KAF	Friant Unimpaired KAF	San Joaquin @ Friant KAF	Actual Upper San Joaquin KAF	Net Loss-Upper San Joaquin KAF	Estimated Loss @ Vernalis Due to Post 1947 Development Upper San Joaquin - KAF	Madera Canal Diversion KAF	Friant-Kern Canal Diversion KAF	Delta-Mendota Canal Delivery to Mendota Pool KAF	Net Central Valley Project Inter-Basin Transfer KAF
1938	7,668	6,494	1,174		2,744	N.A.	N.A.	500[E]					
1941	5,718	4,444	1,274		2,035	1,855	1,810	225					
Avg.	6,693	5,469	1,224		2,389			362					
1952	7,124	4,678	2,446	431	2,315	1,570	1,354	961	416	179	431	99	- 322
1956	5,535	2,404	3,131	925	1,899	462	212	1,687	317	226	976	429	- 547
1958	6,691	4,448	2,243	561	2,216	1,067	1,330	886	379	237	952	367	- 585
1965	4,971	1,545	3,426	2,072	1,594	40	116	1,478	724	285	1,051	735	- 316
1967	7,527	4,192	3,335	1,503	2,548	1,185	1,370	1,178	913	351	1,047	340	- 707
1969	8,421	5,181	3,240	518	3,075	1,250	1,976	1,099	577	356	1,023	280	- 743
Avg.	6,712	3,741	2,970	1,002	2,275		1,060	1,215	554	272	913	375	- 537

Adjusted Loss = 1,742* = 965*

*Computed as per example in Table V-2

TABLE V-17

ACTUAL AND UNIMPAIRED APRIL TO SEPTEMBER FLOWS AT RIM STATIONS IN WET YEARS

	STANISLAUS		TUOLUMNE		MERCED		SAN JOAQUIN	
Wet Years	Unimpaired at Melones KAF	Actual at Ripon KAF	Unimpaired at Don Pedro KAF	Actual at Modesto KAF	Unimpaired at Modesto KAF	Actual at Stevinson KAF	Unimpaired at Friant KAF	Actual Upper San Joaquin KAF
1941	953	804	1,746	1,096	984	750	2,035	1,810
1938	1,387	1,174	2,240	1,594	1,297	974	2,744	N.A.
AVG.	1,170	989	1,993	1,345	1,140	862		
1952	1,481	1,080	2,217	1,264	1,110	830	2,316	1,354
1956	1,007	733	1,727	808	902	536	1,899	212
1958	1,307	897	2,073	1,140	1,095	861	2,216	1,330
1965	977	514	1,593	468	807	331	1,594	116
1967	1,423	971	2,258	1,085	1,298	671	2,548	1,370
1969	1,426	868	2,518	1,225	1,401	718	3,076	1,976
AVG.	1,270	844	2,064	998	1,102	658	2,275	1,060
ADJUSTED LOSS		230*		395*		175*		960*

TOTAL SUB-BASIN LOSS = 1,760

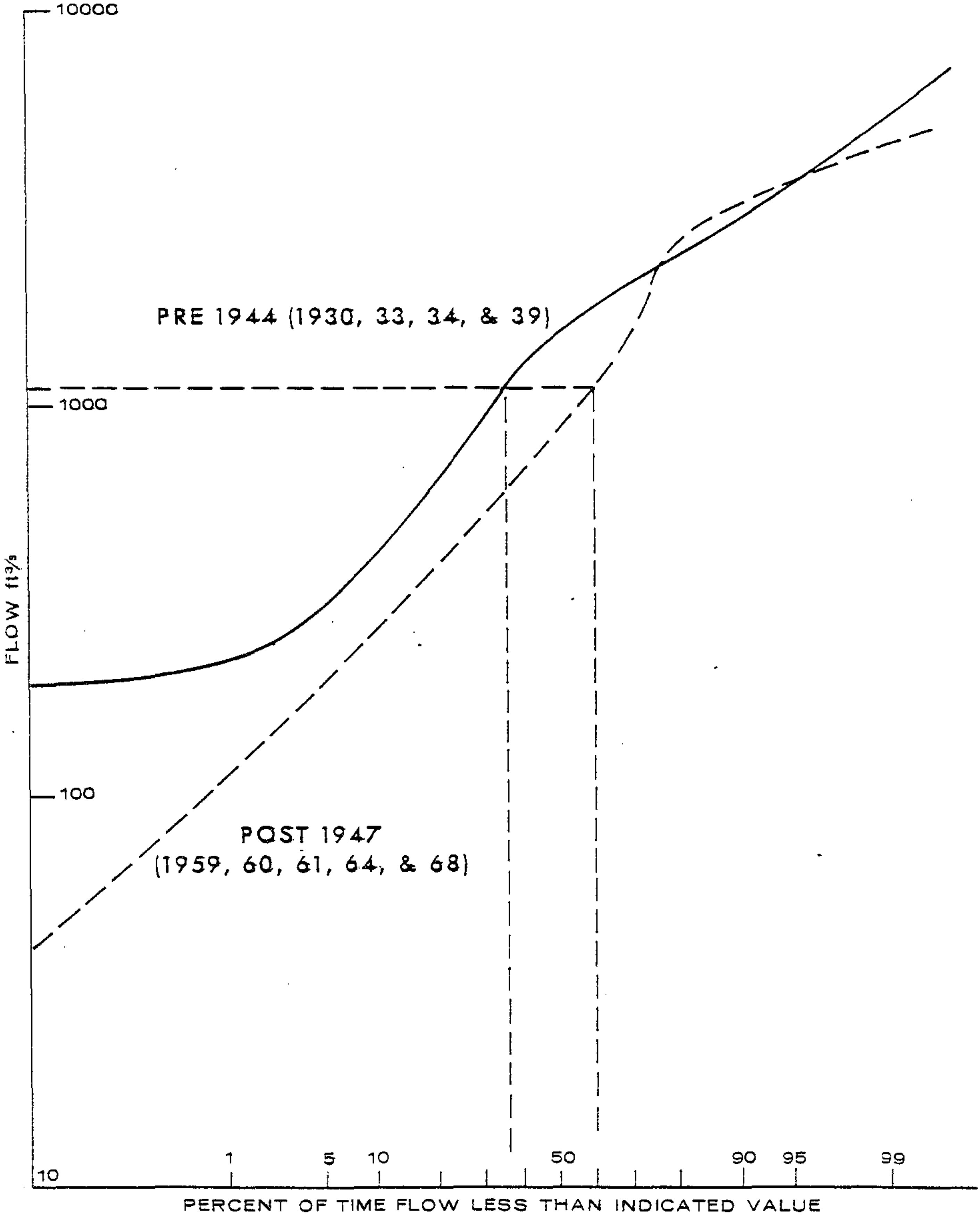
*Computed as per example in Table V-4

FLOW DURATION ANALYSIS

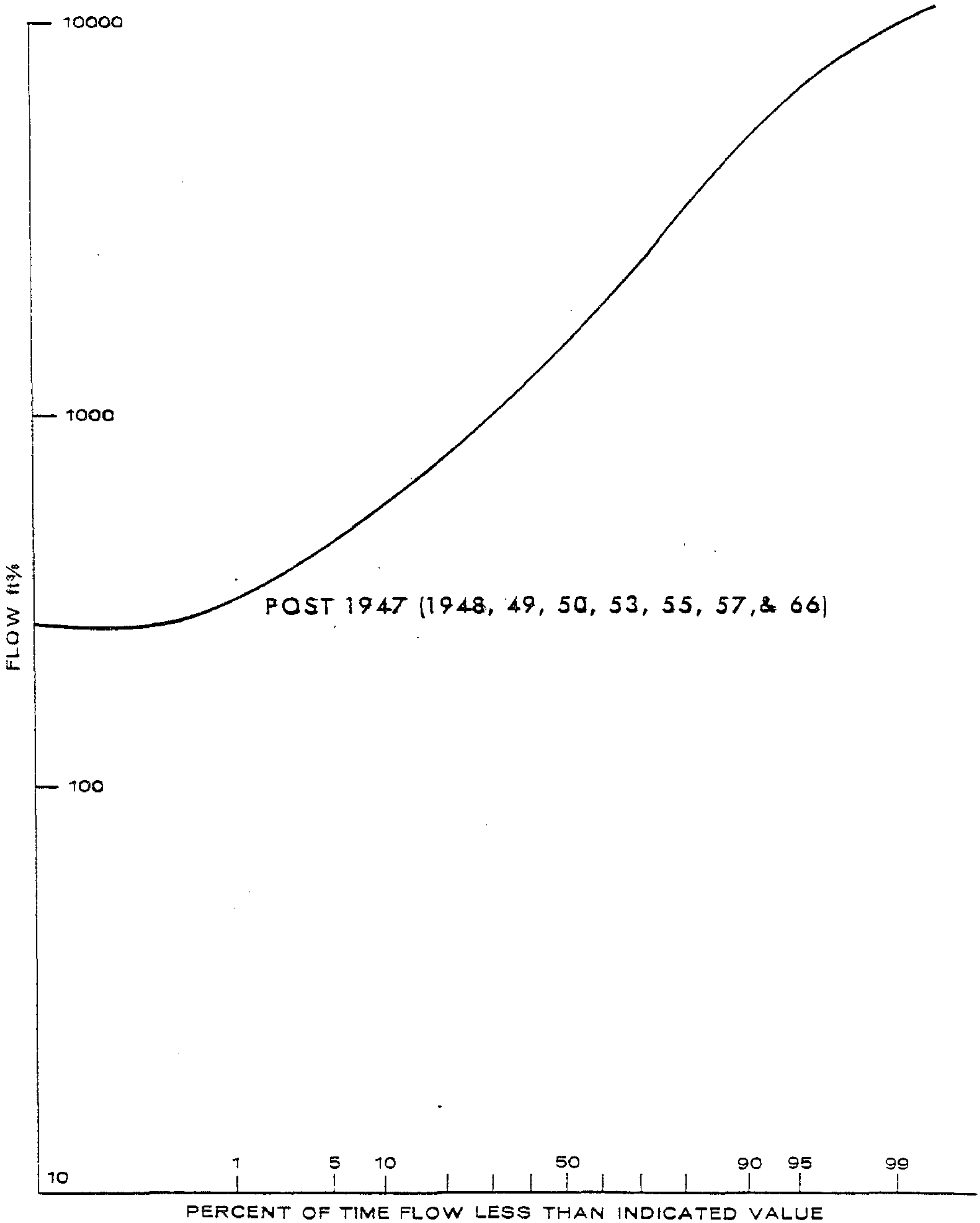
Reductions in the flow of the San Joaquin River at Vernalis do not always of themselves adversely affect the southern Delta. Much of the flow reduction occurred in above normal and wet years, providing a necessary flood control function for the lower San Joaqauin River. Some of the flow reduction occurs at times when the water is not required to maintain a minimum flow requirement at Vernalis. Therefore, it is useful to determine the frequency and duration of flows below certain thresholds. While specific requirements for the San Joaquin River at Vernalis have not been established, flow-duration curves provide useful information for impact assessment. Figures V-9, V-10, V-11, and V-12 graphically illustrate the percentage of the time the San Joaquin River flow at Vernalis is less than any given assumed level of flow. The example in Figure V-9 demonstrates how the flow-duration curves can be used to compare the pre-1944 and post-1947 conditions at Vernalis. For example, during the pre-1944 dry years the flow was less than 1,100 ft^3/s 36 percent of the time. In the post-1947 dry years flow was less than 1,100 ft^3/s 60 percent of the time.

Comparisons can be made for any flow value during all year types except below normal years. There were no pre-1944 below normal years in the study period.

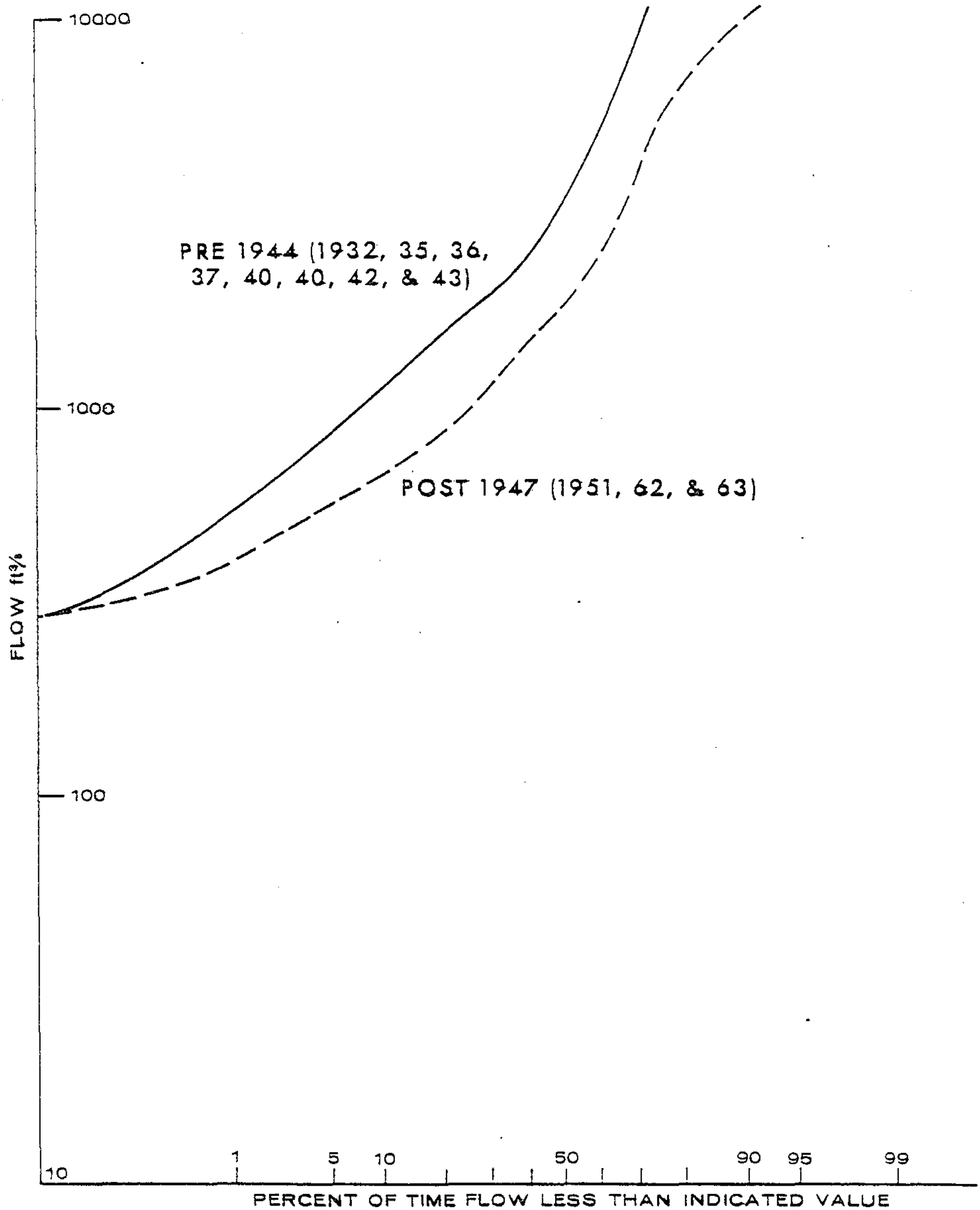
It is not within the scope of this report to determine the level of San Joaquin River flow at Vernalis below which the impact on the southern Delta water supply becomes a damaging impact in relation to adequacy of downstream



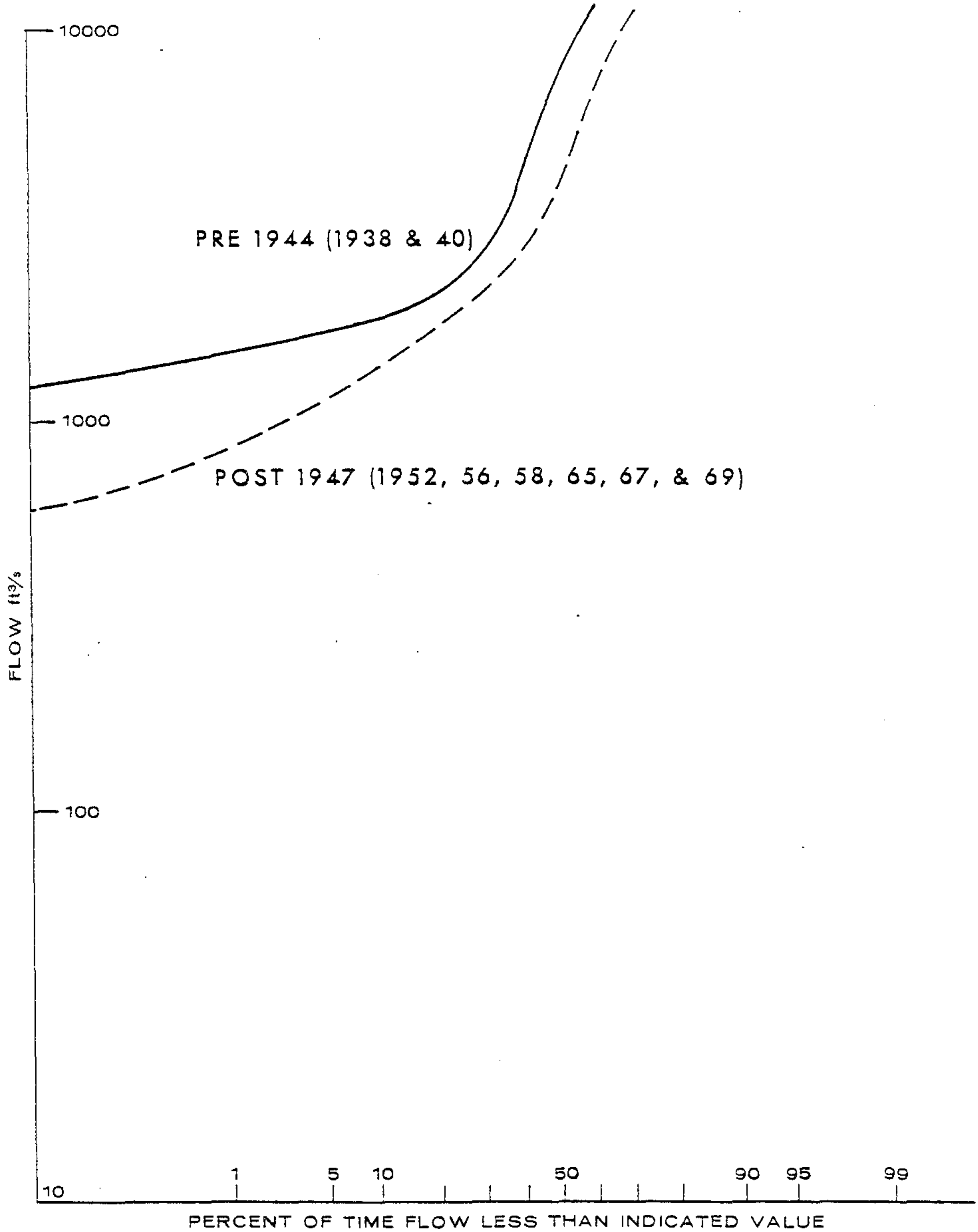
SAN JOAQUIN RIVER NEAR VERNALIS
DRY YEARS FLOW DURATION



SAN JOAQUIN RIVER NEAR VERNALIS
BELOW NORMAL FLOW DURATION



SAN JOAQUIN RIVER NEAR VERNALIS
ABOVE NORMAL YEARS FLOW DURATION



SAN JOAQUIN RIVER NEAR VERNALIS
WET YEARS FLOW DURATION

channel flow for removal of incoming salt load, or in relation to dilution of incoming salts, or in relation to adequate channel water depth for pump draft, etc. The flow required to prevent damage will depend, among other things, on the quality of the water.

However, the Service developed a procedure to estimate the flow reduction attributable to the CVP which might cause the flow of the San Joaquin River near Vernalis to drop below required minimums. Since the minimum flow requirements have not yet been established, the procedure was used to produce curves which relate total loss and minimum flow requirement. Curves representing dry, below normal, above normal and wet years for the October-March period, the April-September period and the annual total, are presented on Figures V-13, V-14 and V-15, respectively.

The procedure utilized generalized equations developed using the double-mass diagram method to estimate the flow at Vernalis at a pre-1944 level of development for the 1948 through 1969 period. A similar method was used to estimate the flow at Vernalis with pre-1944 development in the lower San Joaquin River basin and post-1947 development in the upper San Joaquin River basin for the same 1948 through 1969 period. The values calculated using the procedure were then compared to the actual flows recorded at Vernalis to determine the effect of total post-1944 development and the effect of CVP.

Table V-20 is an example of the results of computation. Column 1 is the actual flow recorded at Vernalis for the month of October of the indicated water year. The corresponding flow estimated for a pre-1944 level of development is listed in column 2. Column 3 is the estimated flow at Vernalis assuming pre-1944 level of development in the lower San Joaquin River basin and a post-1947 level of devlopment in the upper San Joaquin River basin.

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TABLE V-18

SAN JOAQUIN RIVER NEAR VERNALIS

YEAR	(1) ACTUAL HISTORIC FLOW (KAF)	(2) ESTIMATED FLOW PRE 1944 LEVEL OF DEVELOPMENT (KAF)	(3) ESTIMATED FLOW WITH POST 1947 DEVELOPMENT ABOVE NEWMAN ONLY (KAF)	(4) DEVELOPMENT ABOVE MERCED RIVER: POST 1947 IMPACT (KAF)	(5) DEVELOPMENT ABOVE MERCED RIVER: CONTRIBUTION TO VERNALIS FLOW REDUCTION BELOW 1,500 ft^3/s (KAF)
1948	80.8	32.4	22.8	9.6	9.6
1949	95.2	101.0	96.6	4.4	
1950	77.9	117.8	113.7	4.1	1.5
1951	81.4	49.3	42.2	7.2	7.2
1952	109.7	118.0	112.8	5.2	
1953	114.7	123.3	116.2	7.1	
1954	100.2	106.4	102.5	3.9	
1955	32.3	67.8	65.3	2.5	2.5
1956	49.2	82.4	79.9	2.6	2.6
1957	122.9	85.7	74.6	11.0	
1958	126.4	136.8	129.9	6.9	
1959	174.3	183.2	176.4	6.8	
1960	53.9	62.6	54.9	7.7	7.7
1961	43.8	75.2	71.7	3.6	3.6
1962	25.2	61.0	56.9	4.1	4.1
1963	89.4	58.3	50.9	7.4	7.4
1964	164.6	131.7	121.0	10.7	
1965	86.8	48.8	44.5	4.2	4.2
1966	181.0	189.9	182.5	7.3	
1967	67.7	74.5	71.8	2.7	2.7
1968	167.6	139.7	128.4	11.3	
1969	85.1	93.7	87.4	6.3	5.3

COLUMNAR EXPLANATION:

(4)=(2)-(3)

IF (2) GREATER THAN (6): (5)=[(4)/[(2)-(1)]]*[(6)-(1)]

IF (2) LESS THAN (6): (5)=(2)-(3)

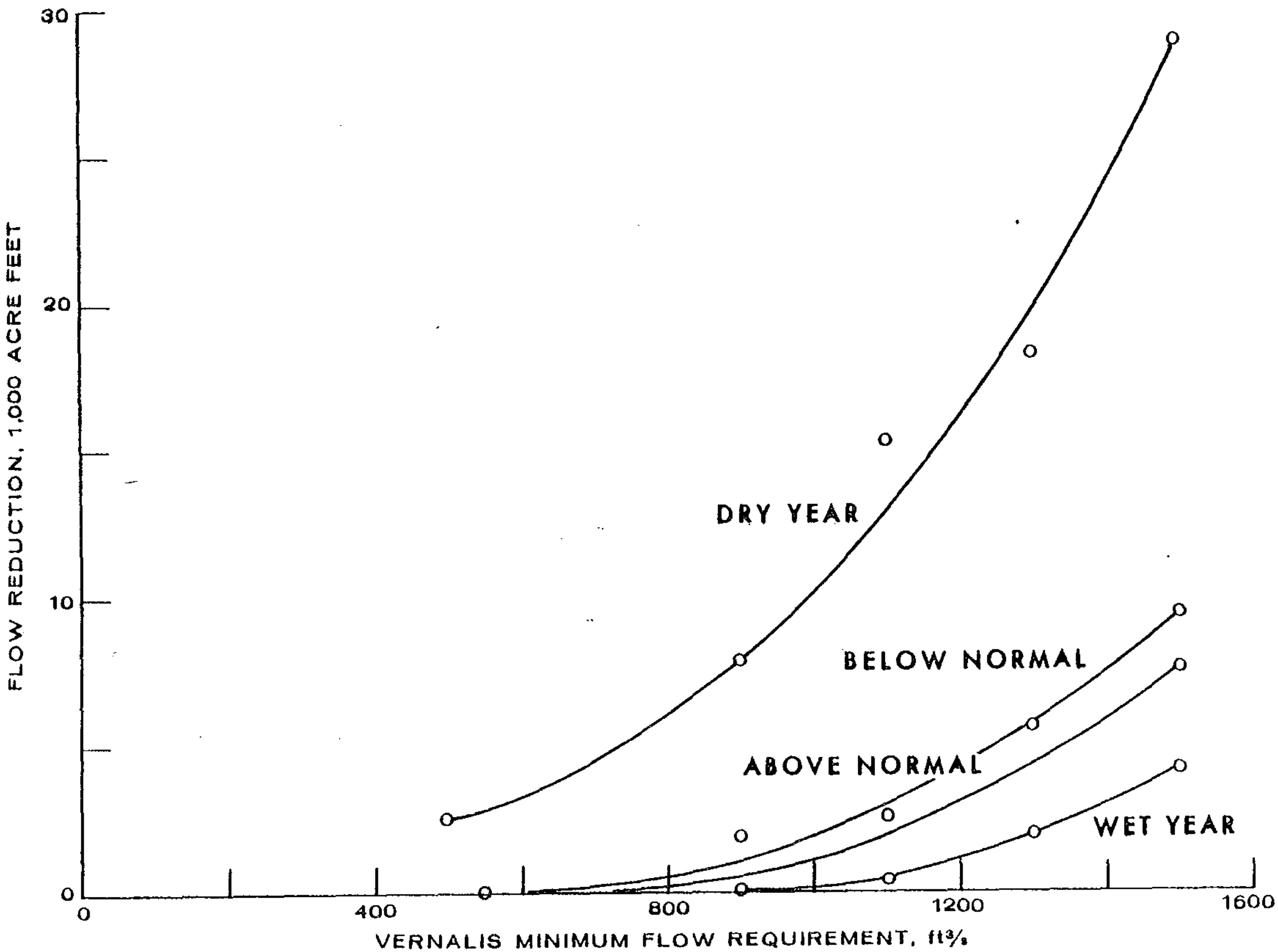
An estimate of the total flow reduction at Vernalis due to development in the upper San Joaquin basin was then made by subtracting column 3 from column 2. The actual historic flow at Vernalis is then compared to the Vernalis target flow, in the case of this example, 1,500 ft^3/s or 92,200 acre-feet for the month. If column 2 is less than the target flow, the contribution to the Vernalis flow reduction by development in the upper San Joaquin River basin is estimated as column 2 - column 3. If column 2 is greater than the target flow, the contribution is computed as a percentage of the total reduction at Vernalis using the equation on table V-18.

The procedure was used to estimate the contribution to flow reduction below various target flows at Vernalis for the 1948-1969 period. Figures V-13, V-14, and V-15 show the curves prepared for the development in the upper San Joaquin River basin average contribution to the reduction of flow at Vernalis below the indicated target flow.

These curves provide a method of estimating CVP impact on flows below a target flow at Vernalis during various year types. For example, if the target flow at Vernalis during April-September was 1,500 ft^3/s, the average CVP contribution to a flow reduction below the target flow as determined from Figure V-14 would be:

In wet years	1,000 acre-feet
In above normal years	20,000 acre-feet
In below normal years	13,000 acre-feet
In dry years	9,000 acre-feet

It is the position of SDWA that the damaging CVP impact on San Joaquin River flow at Vernalis is the difference between the actual flow at Vernalis at



VERNALIS FLOW REQUIREMENT VS ESTIMATED CONTRIBUTION TO VERNALIS REDUCTION
BELOW FLOW REQUIREMENT DUE TO DEVELOPMENT IN UPPER SAN JOAQUIN

FIGURE V-

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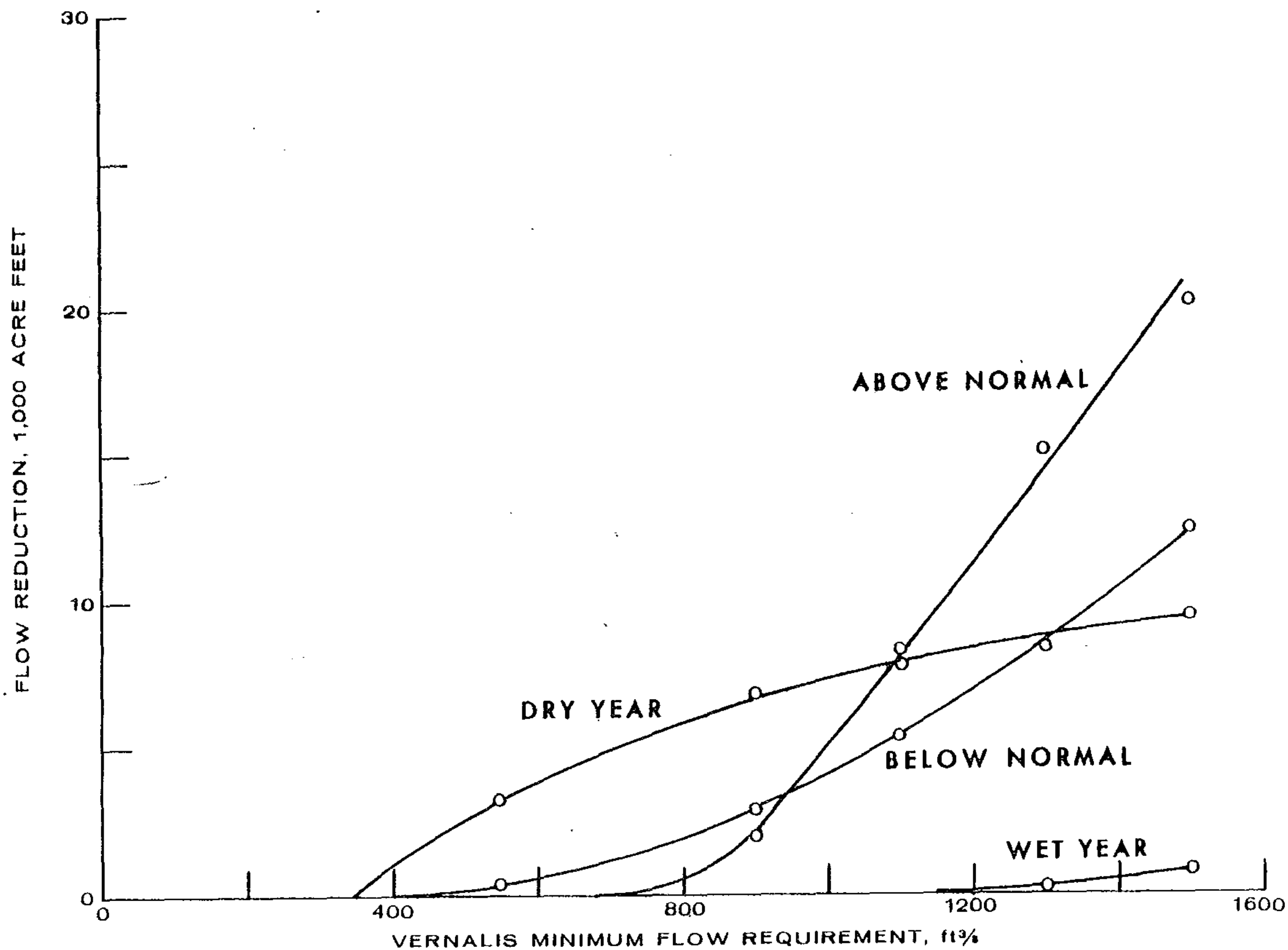
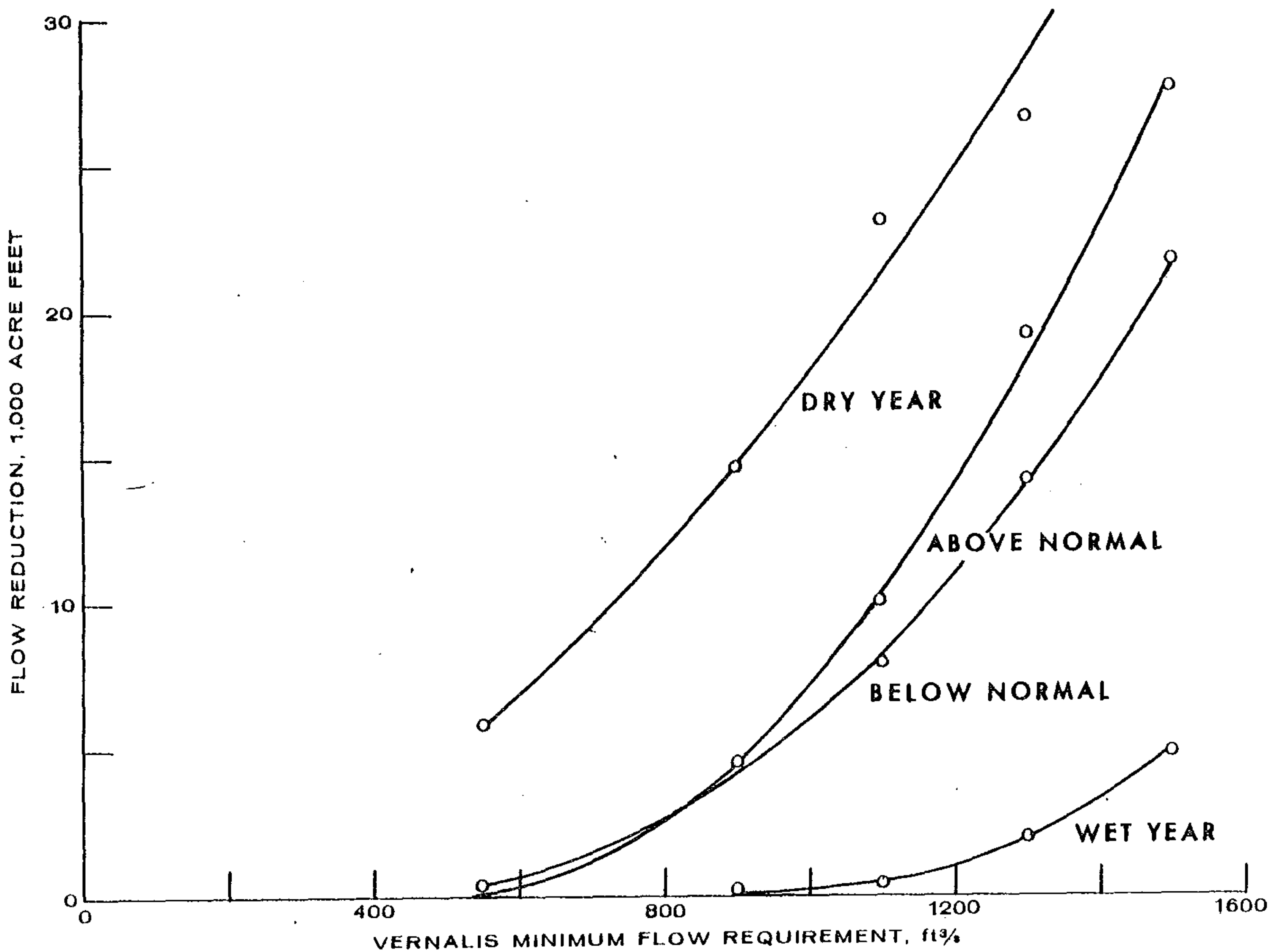


VERNALIS FLOW REQUIREMENT VS ESTIMATED CONTRIBUTION TO VERNALIS REDUCTION BELOW FLOW REQUIREMENT DUE TO DEVELOPMENT IN UPPER SAN JOAQUIN

FIGURE V.1



VERNALIS FLOW REQUIREMENT VS ESTIMATED CONTRIBUTION TO VERNALIS REDUCTION BELOW FLOW REQUIREMENT DUE TO DEVELOPMENT IN UPPER SAN JOAQUIN

FIGURE V-1

any time and the flow which would have occurred if the CVP did not exist in so far as these flows are below needed levels. The Service's analysis does not conform to this definition. There are times when the non-CVP developments actually increase Vernalis flows. At such times the Service's analysis uses part of that enhancement to offset the impact of the CVP flow decreases even when the remaining net flow is inadequate.

SUMMARY OF HYDROLOGIC DATA

Hydrologic data for the San Joaquin River at Vernalis for the periods 1930-1944 and 1947-1969 are summarized in Table V-19. Information presented includes unimparied rim flows, actual flows at Vernalis, and losses, determined as the difference between unimpaired and actual flows. Averages are given for dry, below normal, above normal and wet years. Minima, medians, maxima, and average values are given for all years in each of the two periods, pre-1944 and post-1947. It will be noted that the former period includes 14 years, while the latter includes 22 years of record.

Table V-20 provides an additional summary of flow reduction in the 1948-1969 period that have resulted from development in the entire San Joaquin basin above Vernalis and in the upper San Joaquin basin. Averages of unimpaired and actual flows are given by year type for each basin in each of two calendar periods, annual and April-September. Net losses are also given.

Estimates of flow reduction due to post-1947 development were derived from the several determinations made by the double mass balance, basin comparison and subbasin comparison methods, details of which are given in Tables V-2 through V-17. In general, the values given in Table V-19 are the averages of the highest and lowest values computed by the three methods. For example, for

TABLE V-19

SUMMARY OF HYDROLOGIC DATA, 1930-1944 AND 1947-1969
SAN JOAQUIN RIVER NEAR VERNALIS

Pre-1944

	Unimpaired Rim Annual KAF	Unimpaired Rim Apr-Sept KAF	Actual Annual KAF	Actual Apr-Sept KAF	Losses Annual KAF	Losses Apr-Sept KAF
DRY						
1931	1,660	1,203	677	121	983	1,082
1934	2,288	1,303	927	196	1,361	1,107
1939	2,909	1,909	1,708	483	1,201	1,426
1930	3,254	2,490	1,268	672	1,986	1,818
1933	3,356	2,856	1,376	647	1,980	2,209
AVG.	(2,693)	(1,952)	(1,191)	(424)	(1,502)	(1,528)
BELOW NORMAL						
No Pre-1944 years in the below normal year type.						
ABOVE NORMAL						
1935	6,418	5,152	4,038	3,131	2,380	2,021
1936	6,495	4,489	4,953	2,787	1,543	1,702
1937	6,530	4,746	5,483	3,372	1,047	1,374
1940	6,596	4,107	4,710	2,786	1,886	1,321
1932	6,622	4,829	3,660	2,388	2,962	2,441
1943	7,283	4,417	6,060	3,020	1,223	1,397
1942	7,398	5,461	6,160	3,834	1,238	1,627
AVG.	(6,763)	(4,743)	(5,009)	(3,045)	(1,754)	(1,698)

Post-1947

	Unimpaired Rim Annual KAF	Unimpaired Rim Apr-Sept KAF	Actual Annual KAF	Actual Apr-Sept KAF	Losses Annual KAF	Losses Apr-Sept KAF
DRY						
1961	2,100	1,562	437	82	1,663	1,480
1968	2,938	1,918	1,428	309	1,510	1,609
1960	2,960	2,108	550	139	2,410	1,969
1959	2,986	1,995	1,243	219	1,743	1,776
1964	3,151	2,216	1,124	232	2,027	1,984
AVG.	(2,827)	(1,960)	(957)	(196)	(1,870)	(1,764)
BELOW NORMAL						
1955	3,512	2,723	943	303	2,569	2,420
1949	3,799	3,177	1,247	573	2,552	2,604
1966	3,985	2,492	1,697	246	2,288	2,246
1948	4,218	3,652	1,553	1,094	2,665	2,558
1957	4,292	3,269	1,442	630	2,850	2,639
1954	4,315	3,216	1,717	902	2,598	2,314
1953	4,354	3,275	1,891	780	2,463	2,495
1950	4,656	3,631	1,786	1,062	2,870	2,569
AVG.	(4,141)	(3,179)	(1,534)	(699)	(2,607)	(2,480)
ABOVE NORMAL						
1962	5,618	4,358	1,487	848	4,131	3,510
1963	6,250	4,560	2,812	1,752	3,438	2,808
1951	7,262	2,906	4,738	919	2,524	1,987
AVG.	(6,377)	(3,941)	(3,012)	(1,173)	(3,364)	(2,768)

TABLE V-18

SUMMARY OF HYDROLOGIC DATA, 1930-1944 AND 1947-1969
SAN JOAQUIN RIVER NEAR VERNALIS (Continued)

Pre-1944

	Unimpaired Rim		Actual		Losses	
	Annual KAF	Apr-Sept KAF	Annual KAF	Apr-Sept KAF	Annual KAF	Apr-Sept KAF
WET						
1941	7,945	5,718	7,298	4,444	647	1,274
1938	11,248	7,668	10,837	6,494	411	1,174
AVG.	(9,597)	(6,693)	(9,067)	(5,469)	(529)	(1,224)
ALL YEARS						
Min.	1,660	1,203	677	121	411	1,082
Med.	6,513	4,453	4,374	2,787	1,300	1,412
Max.	11,248	7,668	10,837	6,494	2,962	2,441
Avg.	(5,333)	(3,756)	(3,943)	(2,292)	(1,390)	(1,465)

Post-1947

	Unimpaired Rim		Actual		Losses	
	Annual KAF	Apr-Sept KAF	Annual KAF	Apr-Sept KAF	Annual KAF	Apr-Sept KAF
WET						
1965	8,108	4,971	3,796	1,545	4,312	3,[illegible]
1958	8,367	6,691	6,056	4,449	2,311	2,242
1952	9,312	7,123	7,143	4,685	2,169	2,438
1956	9,679	5,534	6,304	2,404	3,375	3,130
1967	9,993	7,527	5,560	4,192	4,433	3,335
1969	12,295	8,540	10,073	5,181	2,222	3,269
AVG.	(9,626)	(6,716)	(6,489)	(3,743)	(3,137)	(2,973)
ALL YEARS						
Min.	2,100	1,582	437	82	1,510	1,480
Med.	4,335	3,272	1,707	875	2,538	2,467
Max.	12,295	8,540	10,073	5,181	4,433	3,510
Avg.	(5,643)	(3,471)	(2,956)	(1,480)	(2,687)	(2,491)

Table V-20

SUMMARY OF FLOWS, LOSSES AND FLOW REDUCTIONS
SAN JOAQUIN RIVER NEAR VERNALIS
1948-1969

Year Type	ANNUAL: Avg.Rim Station Unimpair KAF	ANNUAL: Actual Flow KAF	ANNUAL: Net Loss KAF	ANNUAL: Estimated Flow Reduction Due to Post-1947 Devel. KAF	ANNUAL: Estimated Flow Reduction Due to Post-1947 Devel. % of Rim Station	ANNUAL: Estimated Flow Reduction Due to Post-1947 Devel. % of Pre-1944	APRIL--SEPTEMBER: Station Unimpair KAF	APRIL--SEPTEMBER: Actual Flow KAF	APRIL--SEPTEMBER: Net Loss KAF	APRIL--SEPTEMBER: Estimated Flow Reduction Due to Post-1947 Devel. KAF	APRIL--SEPTEMBER: Estimated Flow Reduction Due to Post-1947 Devel. % of Rim Station	APRIL--SEPTEMBER: Estimated Flow Reduction Due to Post-1947 Devel. % of Pre-1944
Dry	2,827	957	1,870	410	14	34	1,960	196	1,764	320	16	75
Below Normal	4,141	1,534	2,607	1,220	29	33	3,179	699	2,480	1,060	33	52
Above Normal	6,377	3,012	3,364	1,560	24	31	3,941	1,173	2,768	1,580	40	52
Wet	9,626	6,489	3,137	1,890	20	21	6,716	3,743	2,973	1,370	20	25

UPPER SAN JOAQUIN RIVER BASIN
1948-1969

Year Type	ANNUAL: San Joaquin @ Friant Unimpair KAF	ANNUAL: Actual Flow KAF	ANNUAL: Net Loss KAF	ANNUAL: Estimated Flow Reduction Due to Post-1947 Devel. KAF	ANNUAL: Estimated Flow Reduction Due to Post-1947 Devel. % of Friant	ANNUAL: Estimated Flow Reduction Due to Post-1947 Devel. % of Pre-1944 @ Vern.	APRIL--SEPTEMBER: San Joaquin @ Friant Unimpair KAF	APRIL--SEPTEMBER: Actual Flow KAF	APRIL--SEPTEMBER: Net Loss KAF	APRIL--SEPTEMBER: Estimated Flow Reduction Due to Post-1947 Devel. KAF	APRIL--SEPTEMBER: Estimated Flow Reduction Due to Post-1947 Devel. % of Friant	APRIL--SEPTEMBER: Estimated Flow Reduction Due to Post-1947 Devel. % of Pre-1944 @ Vern.
Dry	842	136	706	120	14	10	636	55	581	7	1.1	1.6
Below Normal	1,252	165	1,088	540	43	24	1,001	66	935	390	39	30
Above Normal	1,909	445	1,464	920	48	18	1,344	95	1,250	570	42	17
Wet	2,996	1,878	1,118	1,240	41	14	2,275	1,060	1,215	760	33	14

dry years at Vernalis an average annual flow reduction of 410,000 acre-feet* was determined from the average of 519,000 acre-feet estimated by the double mass balance method and 294,000 acre-feet estimated by adjustment of average basin losses to a common reference of unimpaired flow. (See table V-2.) Exceptions to this procedure are values given for below normal years which were taken as estimates computed by the double mass diagram method.

Additional information presented in Table V-18 is flow reduction expressed as percentage of the unimpaired rim station flow and the actual Vernalis flow, pre-1944.

SUMMARY

Reductions in runoff that have occurred in the San Joaquin River basin as a result of development subsequent to 1947 are summarized in Table V-21. Data presented in the table are derived from Table V-2 through V-17, which present estimates of water losses for each of the 4-year classifications computed for both the entire San Joaquin River basin and the upper San Joaquin River basin. Reductions in flow are determined as the difference in "losses" between the rim stations and Vernalis. Reductions attributable to the CVP are identified as equivalent to the difference in losses occurring in the upper San Joaquin River basin alone. For purposes of comparison, reductions are expressed both in terms of volumne of runoff in the April-September and annual periods and as percentages of the flow that actually occurred at Vernalis.

The principal conclusions reached from the study of water quantity effects are as follows:

1. For the entire San Joaquin River basin, flows at Vernalis were reduced by post-1947 development,

* Rounded to nearest 10

a. in dry years by amounts ranging from 300,000 to 500,000 acre-feet, about 75 percent of which reduction occurred in the April-September period,

b. in below normal years* by amounts exceeding 1,200,000 acre-feet, about 85 percent of which reduction occurred in the April-September period,

c. in above normal years by amounts exceeding 1,400,000 acre-feet, all of which occurred in the April-September period, and

d. in wet years by amounts ranging from 1,100,000 to 2,900,000 acre-feet, about 60-85 percent of which occurred in the April-September period.

2. For the upper San Joaquin River basin, where the impact is attributable to the CVP, flows at Vernalis were reduced by post-1947 development;

a. in dry years by 90,000 to 130,000 acre-feet, a relatively small proportion of which (about 4 to 8 percent) occurred in the April-September period,

b. in below normal years* by more than 500,000 acre-feet, of which about three-quarters occurred during the April-September period,

c. in above normal years by 750,000 to 1 million acre-feet, about 60 percent of which occurred during the April-September period, and

d. in wet years by 750,000 to 2 million acre-feet, of which about half occurred during the April-September period.

3. The greatest impact of flow reductions at Vernalis occurred during the April-September period of below normal and above normal years when from 14-24

* Data are limited for these years. Refer to analysis below normal years on page V-18.

percent of the flow reduction at Vernalis (on a pre-1944 basis) was attributed to development by the CVP in the upper San Joaquin basin. The impact in dry years was small, less than 2 percent of the pre-1944 flow at Vernalis. In the April-September period of wet years, reductions were in the range of 10-18 percent of the pre-1944 flow at Vernalis.

Table V-21

SUMMARY OF REDUCTIONS IN RUNOFF OF SAN JOAQUIN RIVER AT VERNALIS FROM PRE-CVP TO POST-CVP

YEAR TYPE & PERIOD	EFFECT OF ALL POST-CVP UPSTREAM DEVELOPMENT ON RUNOFF AT VERNALIS		EFFECT OF CVP ON RUNOFF AT VERNALIS		
	Reduction in Runoff KAF[1]	Post 1947 Reduction as Percent of Pre-1944 Actual Runoff	Reduction in Runoff KAF[1]	Reduction at Vernalis as Percent of Pre-1944 Flow	Reduction at Vernalis as Percent of Post-1947 Flow
DRY					
April-Sept	206- 417	49-67[2]	6- 7	1.4- 1.6	3.0- 3.6
Full Year	294- 519	25-44	93- 138	8 - 12	10 - 14
BELOW NORMAL					
April-Sept	1064-1177	60-68[2]	386- 428	22 - 24[2]	55 - 61
Full Year	1219	44[2]	543	- 20[2]	35
ABOVE NORMAL					
April-Sept	1406-1732	47-57	440- 704	14 - 23	40 - 64
Full Year	1400-1721	28-34	768-1076	15 - 21	25 - 36
WET					
April-Sept	1002-1760	19-32	554- 965	10 - 18	15 - 26
Full Year	1168-2916	13-32	771-2014	9 - 22	12 - 31
AVERAGE OF ALL YEARS[3]					
April-Sept	920-1272	44-56	347- 526	12 - 17	28 - 39
Full Year	1020-1594	28-39	544- 943	13 - 19	21 - 29

[1] Range of estimates by all methods of analysis. See Tables V-2 through V-17

[2] Pre-CVP "actual" is assumed to be post-1947 actual plus pre-1944 to post-1947 loss

[3] Assumes that each year class occupies one-quarter of period

CHAPTER VI

WATER QUALITY EFFECTS OF UPSTREAM DEVELOPMENT

INTRODUCTION

There are several complications in analyzing the water quality changes due to upstream development. It is, therefore, necessary that the results of the analysis acknowledge a range of impacts on Southern Delta water quality. Part of the uncertainty in interpretation relates to insufficient and/or unreliable data, and part to differences in approach to the analysis. Each manner of investigation has an aspect of validity, but each must be weighed in light of its assumptions and available data.

Two factors affect water quality, flow and salt load. Chapter V has identified the changes in flow at Vernalis, and this chapter equates these changes in flow with an amount of degradation at Vernalis. This chapter also examines historic salt loads and concentrations at Vernalis to determine changes associated with develoment along the San Joaquin River and its tributaries. Sections A, B, C, and D of this chapter contain the development and results of several studies on different sets of data. Because of the length of the first four sections and the amount of material contained therein, Sections E and F consolidate the results and define the impacts of upstream development. A more detailed explanation of each section follows.

Section A of this chapter presents an analysis of the composition of the salts reaching Vernalis and relates this to composition of salts originating from identifiable sources, e.g., tributary streams, imported water and drainage returns from irrigated lands. These chemical analyses are then used as "fingerprints" in an attempt to identify the principal sources and their relative contributions to the total salts reaching Vernalis. Also included in this section are the results of salt balance computations using this data for a single dry year, 1961.

Section B of this chapter addresses three questions pertaining to water quality at Vernalis. First, has there been a change in salt load at Vernalis? By comparing the TDS salt loads at Vernalis over the period of record, increasing or decreasing trends in loading can be identified. Second, regardless of any change in loading, has a change in TDS concentration occurred? A comparison of the TDS concentrations is used to determine if any degradation has taken place through the period of record. Third, has the source of salt changed? Salt balance computations, utilizing data from identified sources, are employed to judge whether in the years after 1950, the percent of Vernalis salt load contributed by these sources has changed. Section B deals with trends in the data in a qualitative rather than quantitative manner.

Section C of this chapter presents the record of quality degradation in the San Joaquin River as it enters the Delta near Vernalis. Due to limitations of the Vernalis data, two methods of estimating Vernalis quality are developed and used to synthesize an artificial record for periods when none exists. By constructing the complete set of TDS concentrations, similar hydrologic years before and after upstream development can be compared to estimate water quality degradation.

Section D of this chapter is a discussion of the Tuolumne River gas wells and their contribution to the quality problem. Because the Tuolumne River contributes a significant amount of the salt load at Vernalis, and the gas wells are the source of much of the Tuolumne load, Section D deals with the water quality of discharges from these wells.

Section E of this chapter allows the reader who may not be interested in the development of the individual studies, to forego reading Sections A, B, C, and D. Section E summarizes the results of the four preceeding sections and analyzes the impact of upstream development on quality degradation at Vernalis.

Section F of this chapter is a summary of quality impacts at Vernalis resulting from CVP development.

Various methods of analysis utilizing different data sets are presented in this chapter. Due to the type and availability of data, one method of analysis may not use the same chronological division of data as used by another method. For purposes of water quality, generally the period prior to 1950 is considered indicative of conditions in the lower San Joaquin River before CVP development. Each analysis refers to a period preceding a specific year or succeeding a specific year. Although the specific year may vary from analysis to analysis, the implication is that prevalues refer to that period used as a base condition and postvalues refer to that period in which some change has occurred to the lower San Joaquin River basin. Using this assumption, pre- and postvalues calculated by one method can be compared to pre- and postvalues computed by another method, regardless of actual period of record.

SECTION A. IDENTIFICATION OF SOURCES OF SALT BURDEN--CHEMICAL CHARACTERISTICS

Figure VI-1 is a schematic representation of the San Joaquin Valley System showing the location of stream gaging, water quality sampling stations and principal drainage accretions.

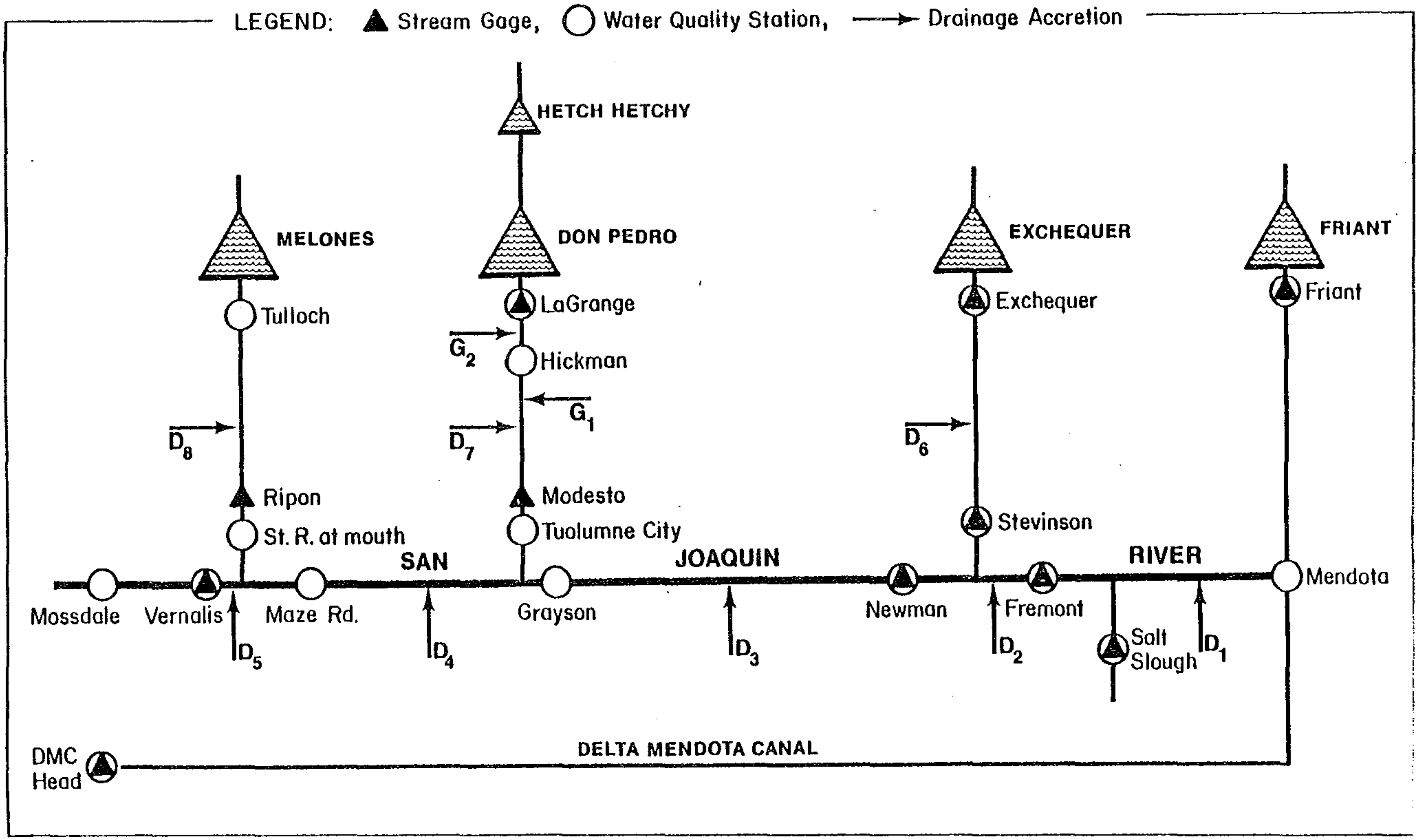


Figure VI-1 SAN JOAQUIN VALLEY SYSTEM

Stream gaging, water quality sampling stations and principal drainage accretions

Characteristics of High Sierra Streams

In order to provide a perspective of quality characteristics of San Joaquin flows, it is necessary to identify the distinguishing chemical properties of the principal sources of runoff. Table VI-1 gives a representative analysis of the four major tributaries at locations corresponding approximately to the location of rim flow gaging stations.

The quality of these high Sierra streams is generally characterized by low levels of total dissolved solids and of each of the principal mineral constituents, low electrical conductivity and a slightly alkaline pH. These waters are very soft, bicarbonate concentrations are relatively high compared to other constituents and sulfates are virtually nil. Carbonate does not occur at the pH of these waters. Chlorides are very low. Traces of iron and fluoride are occasionally noted. Boron is found in measurable concentrations ($\geq$ 0.1 mg/L) in only a few samples. Iron is virtually absent. Distinguishing properties of high Sierra waters are the almost total lack of sulfates and noncarbonate hardness and extremely low boron concentrations.

Characteristics of Sierra Streams at Confluence with San Joaquin Main Stem

Table VI-2 illustrates the quality of the east side tributaries, together with the main stem of the San Joaquin near Mendota during the month of May 1961. Lower in the drainage system the Sierra streams show increased concentrations of most constituents, with relatively larger increases in Na^+, K^+, Cl^- and $SO_4^=$ than of Ca^{++}, Mg^{++} and HCO_3^-. An exception is the Tuolumne River which has picked up an unusually large accretion of saline water from gas wells between Hickman and Modesto. In this case, large increases in Na^+, K^+ and Cl^- are noted, with corresponding changes in TDS, hardness, SAR

Table VI-1. REPRESENTATIVE WATER QUALITY OF HIGH SIERRA STREAMS*

		San Joaquin at Friant	Merced @ Exchequer	Tuolumne @ La Grange	Stanislaus @ Tulloch
1.	Date	6 Sep 61	6 Sep 61	12 Sep 61	8 Sep 61
2.	Mean discharge (cfs)	146	143	2120	
3.	Silica	10	9.3	4.8	8.9
4.	Iron	0.0			
5.	Calcium	3.6	12	2.5	5.6
6.	Magnesium	1.6	2.4	0.5	2.8
7.	Sodium	5.4	3.2	1.2	2.6
8.	Potassium	0.7	0.7	0.4	0.3
9.	Bicarbonate	24	48	12	35
10.	Carbonate				
11.	Sulfate	0.0	3.0	0.2	0.0
12.	Chloride	6.0	3.2	-	1.2
13.	Fluoride	0.1	0.1	0.1	0.1
14.	Nitrate	0.4	0.8	0.4	0.3
15.	Boron	0.1	0.0	0.0	0.0
16.	TDS	40	59	16	39
17.	Ca + Mg hardness	16	40	8	26
18.	Non-carb. "	0	1	0	0
19.	SAR	0.6	0.2	0.2	0.2
20.	EC, µmhos/cm	59	95	22	63
21.	pH	7.3	7.6	6.7	7.3

* mg/L except as noted

Table VI-2. REPRESENTATIVE WATER QUALITY OF TRIBUTARIES AT CONFLUENCE WITH SAN JOAQUIN *

		San Joaquin nr. Mendota	Merced nr. Stevinson	Tuolumne nr. Tuol.City	Stanislaus nr. mouth
1.	Date	4 May 61	4 May 61	9 May 61	4 May 61
2.	Mean discharge (cfs)		71	235	12
3.	Silica	17	26	41	34
4.	Iron	0.1	0.02	0.04	0.01
5.	Calcium	17	22	53	30
6.	Magnesium	9.0	7.1	16	12
7.	Sodium	23	30	102	19
8.	Potassium	0.9	2.0	8.0	2.1
9.	Bicarbonate	84	132	147	182
10.	Carbonate		0	0	
11.	Sulfate	27	15	10	10
12.	Chloride	26	20	207	9.0
13.	Fluoride	0.2	0.1	0.0	0.1
14.	Nitrate	0.9	3.4	3.1	0.6
15.	Boron	0.2	0.1	0.0	0.1
16.	TDS	162	191	512	207
17.	Ca + Mg hardness	80	84	198	126
18.	Non-carb. "	11	0	77	0
19.	SAR	1.1	1.4	3.2	0.7
20.	EC, µmhos/cm	260	294	911	315
21.	pH	7.5	7.8	7.8	7.7

* mg/L except as noted

and EC. However, if these concentrated sources of salinity are eliminated then the quality of the Tuolumne inflow would probably be little different from those of the other major tributaries. Note, for example, that the concentration of sulfate is virtually the same as for the Stanislaus and less than for either the Merced or the San Joaquin at Mendota.

Westside Drainage Water Quality

Drainage waters from the west side of the San Joaquin Valley are characterized by generally high concentrations of total dissolved solids, dominated by Na^+, Cl^- and $SO_4^=$. TDS levels commonly range from 800 to over 1,200 mg/L and EC's may exceed 2,000 umhos/cm in some waters. Some surface drainage is of a quality similar to ground waters that have been used historically as principal sources for irrigation. Surface streams are ephemeral, with few exceptions, so there is a paucity of data on surface accretions from the west side of the valley. However, a fair indication of west side water quality is seen in observations of Salt Slough near Los Banos, some examples of which are described in table VI-3. It is noted that these waters are high in boron and sulfates; noncarbonate hardness is more than 40 percent of total hardness.

Quality Variations Along the Main Stem

A general picture of the pattern of quality along the main stem of the San Joaquin, in relation to the quality of its principal tributaries, is presented in figures VI-2 through VI-6.

Cation-Anion balance. Figure VI-2 shows the cation composition of the river and tributaries during the period May 3-9, 1966, and figure VI-3 shows the corresponding distribution of the principal anicns.

Table VI-3. WATER QUALITY OF SALT SLOUGH*

1.	Date	4 May 61	7 Sep 61	4 May 66
2.	Mean discharge (cfs)	65	73	98
3.	Silica	25	25	17
4.	Iron	0.0		
5.	Calcium	56	52	54
6.	Magnesium	29	32	25
7.	Sodium	146	157	123
8.	Potassium	4.8	5.0	4.6
9.	Bicarbonate	160	174	152
10.	Carbonate	0	0	0
11.	Sulfate	135	129	123
12.	Chloride	220	232	172
13.	Fluoride	0.5	0.3	
14.	Nitrate	2.8	2.4	3.4
15.	Boron	0.4	0.7	0.6
16.	TDS	698	721	628
17.	Ca + Mg hardness	260	260	236
18.	Non-carb. "	129	117	111
19.	SAR	3.9	4.2	3.5
20.	EC, µmhos/cm	1210	1300	1060
21.	pH	7.8	7.4	7.6

* mg/L except as noted

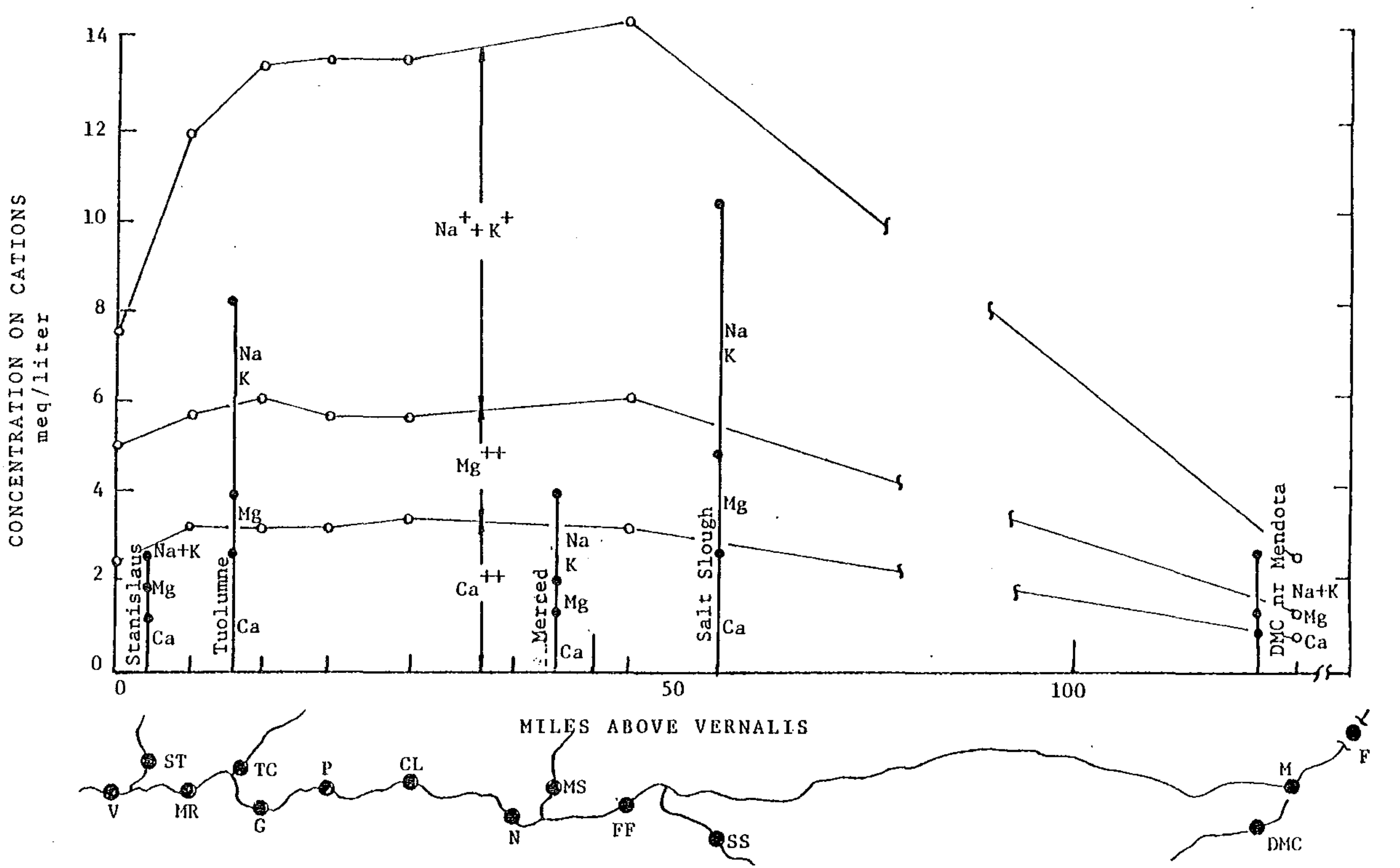


Figure VI- 2 CONCENTRATIONS OF PRINCIPAL CATIONS IN THE SAN JOAQUIN RIVER AND ITS MAJOR TRIBUTARIES. PERIOD: 3-9 MAY 1966

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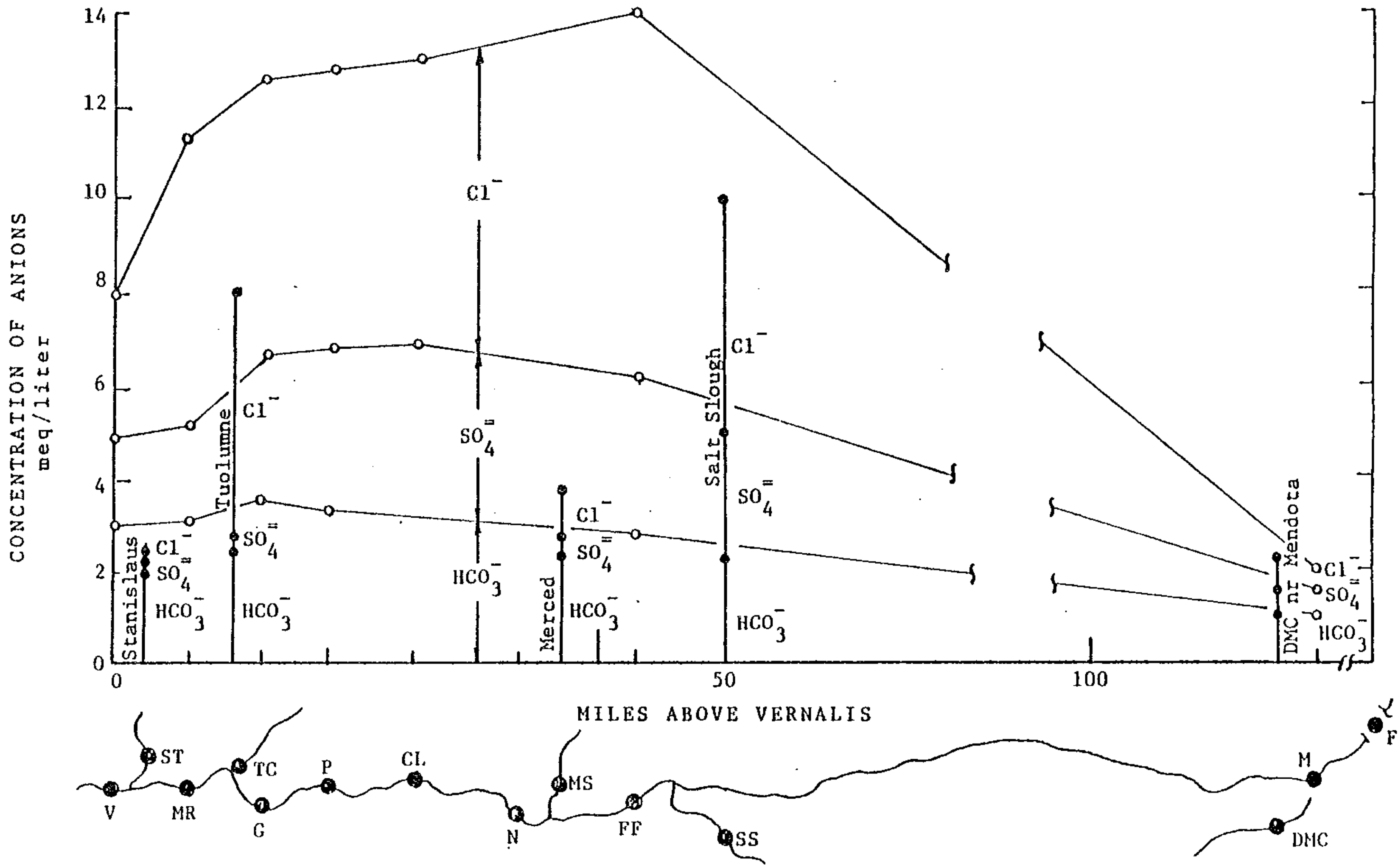


Figure VI- 3 CONCENTRATIONS OF PRINCIPAL ANIONS IN THE SAN JOAQUIN RIVER AND ITS MAJOR TRIBUTARIES. PERIOD: 3-9 MAY 1966

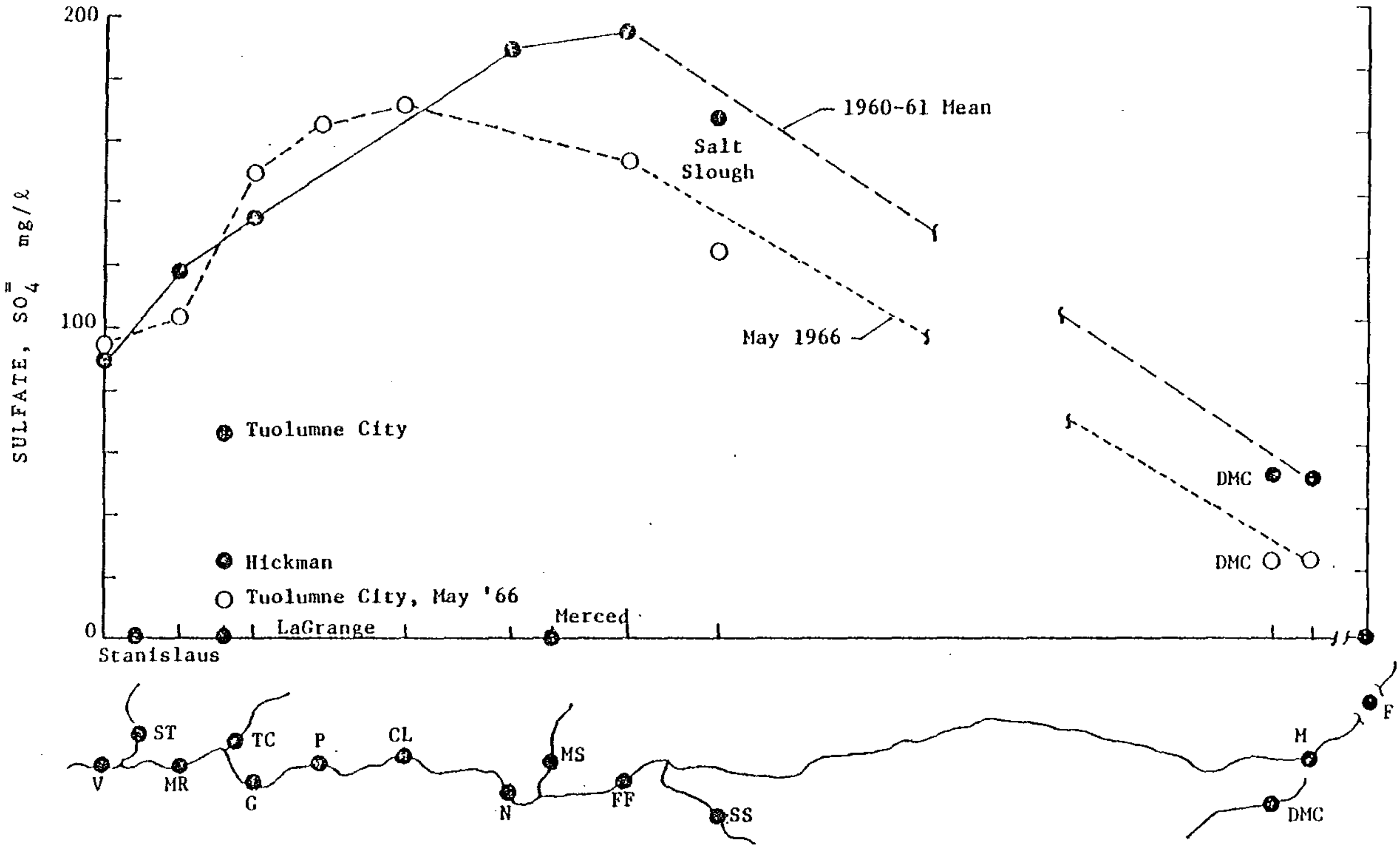


Figure VI- 4 SULFATE CONCENTRATION IN SAN JOAQUIN RIVER SYSTEM 1960-61 AND MAY 1966

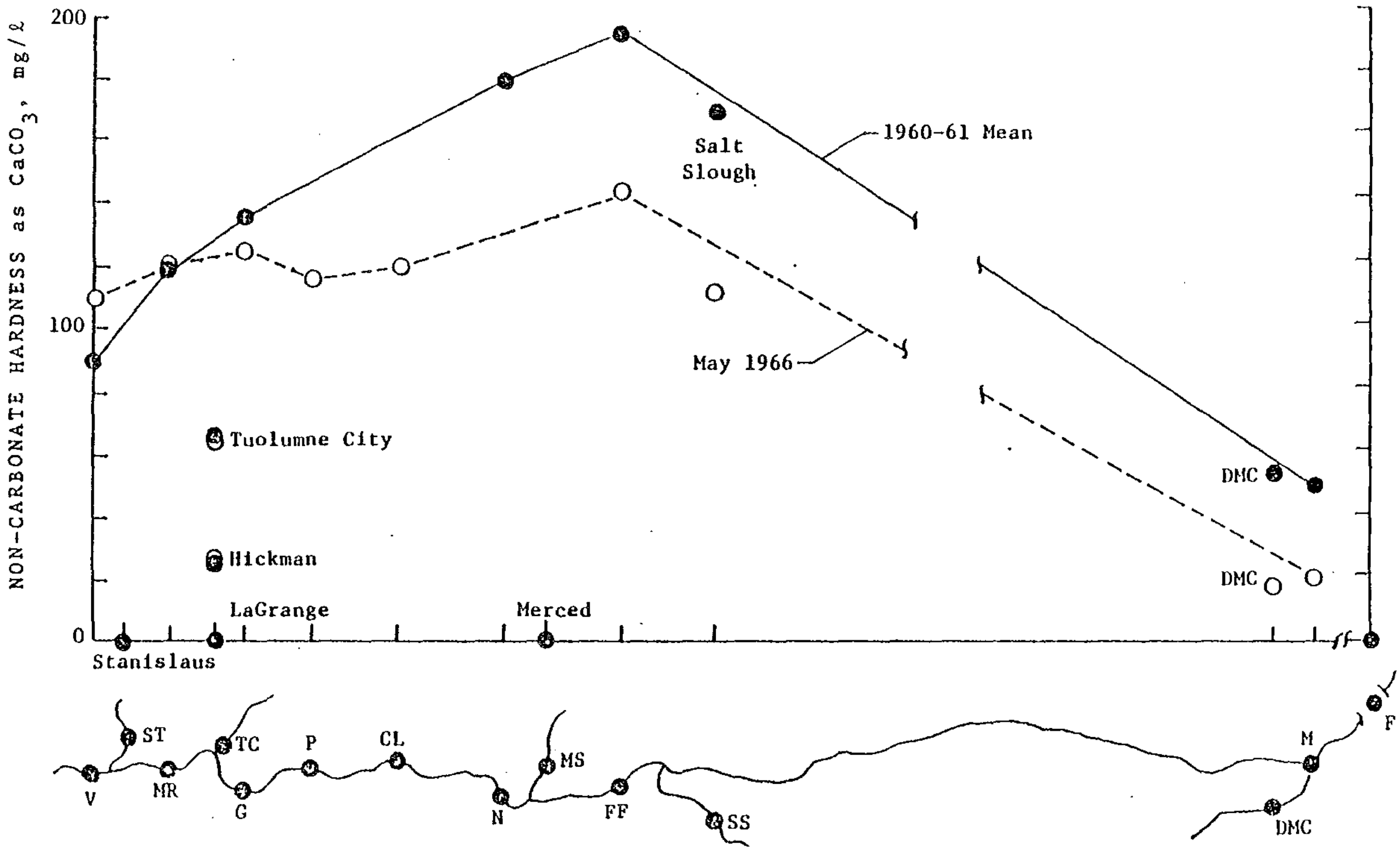


Figure VI- 5. NONCARBONATE HARDNESS IN SAN JOAQUIN RIVER SYSTEM
1960-61 AND MAY 1966

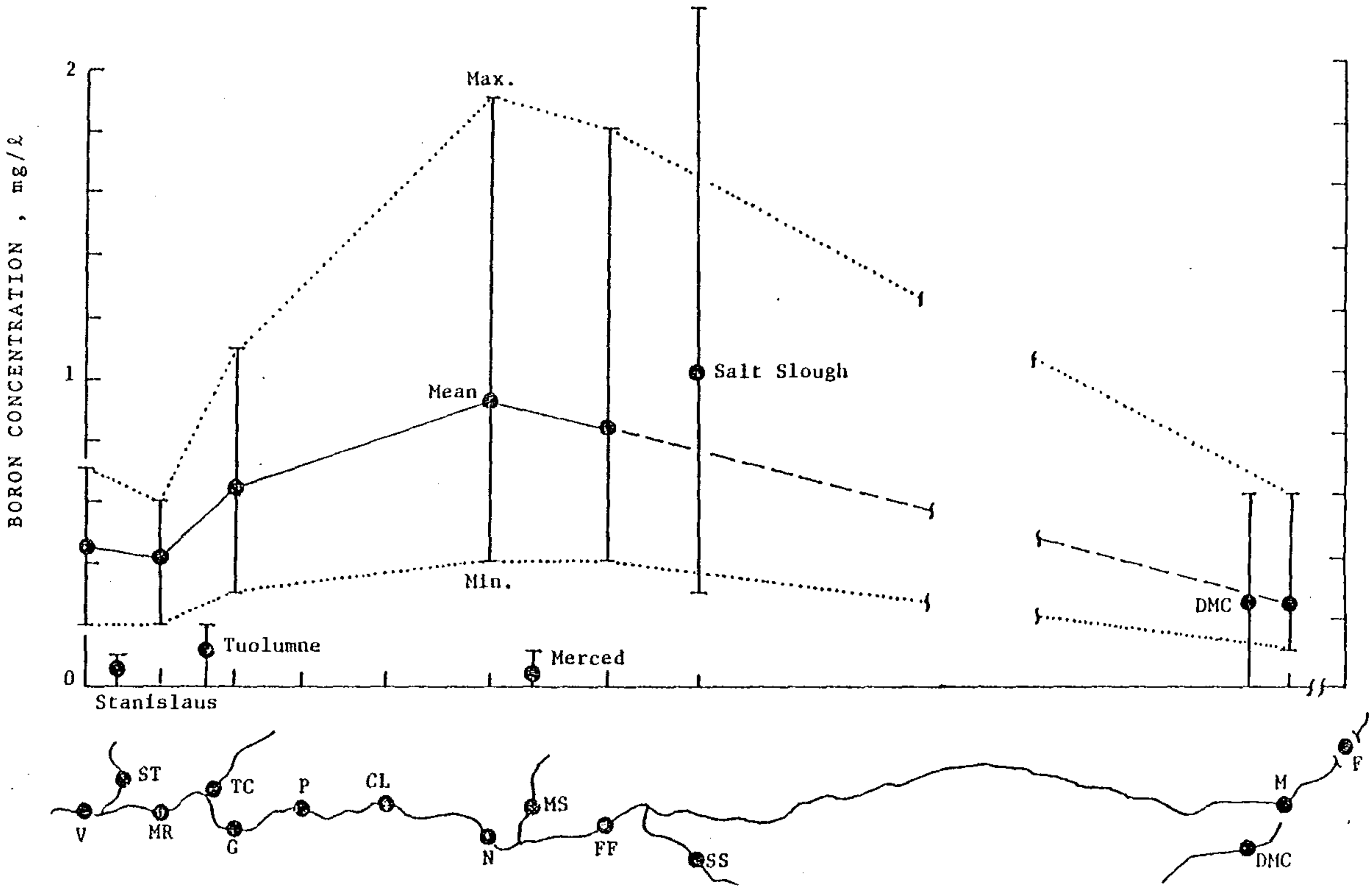


Figure VI-6 BORON CONCENTRATION IN SAN JOAQUIN RIVER SYSTEM 1960-61

Due to the lack of data in the reach between Mendota (Mile 129 above Vernalis) and Fremont Ford Bridge just downstream from the mouth of Salt Slough, it is not clear how the pattern develops over the upper 70 miles or so. Nevertheless, it is clear that the composition of San Joaquin River water at Fremont Ford Bridge (FF) corresponds closely to that of Salt Slough. If principal cations and anions are expressed as percentages of the sum of milliequivalents per liter, then the similarity of these waters becomes even more evident, as can be seen in the following example:

	San Joaquin River @ Fremont Ford 5-5-66 Q = 175 ft^3/s	Salt Slough 5-4-66 Q = 98 ft^3/s
Cations (percent of total)		
Ca^{++}	22.5	26.4
Mg^{++}	19.7	20.2
Na^{+}	56.7	52.2
K^{+}	1.1	1.2
	100.0	100.0
Anions (percent of total)		
HCO_3^-	22.2	25.2
$CO_3^=$	0	0
$SO_4^=$	22.9	25.8
Cl^-	54.9	49.0
	100.0	100.0

It should be noted that the additional drainage accretion to Fremont Ford is about 77 ft^3/s (175 minus 98). The chemical composition of salts in this water must be very similar to that of Salt Slough since the chemical composition of the salts in the blended flows is so little different from that measured in the slough.

Referring once again to figures VI-2 and VI-3, it is noted that downstream of Fremont Ford the pattern remains more or less steady until the flow reaches the vicinity of the mouth of the Tuolumne. At this point an influx of water of superior overall quality, although high in Na^+, K^+ and Cl^-, accelerates a general decline in salt concentration. The proportion of Cl^- to total anions increases notably while the proportion of $SO_4^=$ in the San Joaquin (more or less constant in the Tuolumne) decreases. A further striking improvement in San Joaquin quality is noted between Maze Road and Vernalis with the addition of flow (157 ft^3/s at Ripon) of very high quality.

Sulfates. Table VI-4 summarizes the principal anion composition of the San Joaquin System for the dry year 1960-61. Data shown represent averages of all observations over the year for all USGS stations at which samples were collected.

As noted previously, a distinctive difference in the quality of east side streams and the quality of the main stem below Mendota is the concentration of sulfate ion, $SO_4^=$. East side streams, with the exception of the Tuolumne below the gas wells, contain very little sulfate while the main stem and the principal west side tributary, Salt Slough, are very rich in this anion. The pattern along the river, shown in figure VI-4, highlights these differences, showing clearly that for this period, at least (when flows were generally very low) the river water quality, in terms of chemical composition of salts, was similar to drainage from the west side. Some lowering of $SO_4^=$ concentrations appears to occur below Newman, possibly due to return flows from the irrigated areas on the eastern side of the valley. However, sulfates are sustained at high levels along most of the river from Fremont Ford to Vernalis.

Table VI- 4. CONCENTRATIONS OF PRINCIPAL ANIONS, SAN JOAQUIN RIVER SYSTEM, 1960-61

Station		No. of	Principal Anions, mg/L			
USGS No.	Location	Obs.[1]	HCO_3^-	$SO_4^=$	Cl^-	% SO_4[2]
2510	SJR below Friant	12	22.3	0.5	5.1	1.8
2540	SJR nr Mendota	13	97.7	36.3	98.0	15.7
2580	Fresno R.	8	51.5	0.0	28.4	0.0
2590	Chowchilla R.	7	102.0	3.0	64.4	2.0
2603	Bear Cr.	11	139.4	6.0	5.7	6.9
2610	Salt Slough	12	201.3	242.3	280.5	33.1
2615	SJR, Fremont Fd.	15	208.9	233.8	345.3	31.4
2700	Merced @ Exch.	12	50.1	2.5	4.2	6.7
2725	Merced @ Stev.	11	145.5	13.5	22.1	7.7
2740	SJR nr Newman	13	221.6	252.0	318.4	32.0
2747	SJR nr Grayson	12	229.2	159.3	244.7	26.4
2880	Tuol @ LaGrange	11	14.1	0.6	1.1	4.5
2898	Tuol nr Hickman	11	83.9	2.8	81.1	1.2
2902	Tuol nr Tuol City	11	130.4	9.4	204.0	2.4
2905	SJR @ Maze Rd	12	178.7	87.7	241.6	16.3
2999.98	Stan @ Tulloch	12	35.0	1.0	1.0	1.4
3034	Stan nr mouth	10	151.5	10.0	9.1	5.0
3035	SJR nr Vernalis	39	151.0	81.0	176.0	19.9
3042	SJR nr Mossdale	13	163.2	65.3	192.3	14.0
3048	SJR, Garwood Br.	12	144.6	45.0	145.6	13.1
3127	Old R. nr Tracy	12	167.4	86.5	198.6	17.9
3129.9	DMC above PP	10	101.6	23.5	100.6	12.8
3130.1	DMC below PP	28	94.0	39.0	89.0	17.6
3130.5	DMC nr Mendota	13	110.5	36.0	110.6	15.6
3132	Grantline Canal	12	149.1	65.5	182.2	15.0
3132.5	Old R. @ Cl.Ct.	12	103.5	21.0	103.9	12.3

[1] Corresponds to maximum, usually for HCO_3^- and Cl^-; $SO_4^=$ analyses were made less frequently

[2] Percentage based only on samples analyzed for all three anions, since $SO_4^=$ analyses were made less frequently

A similar pattern is seen for a set of data taken during the period May 3-9, 1966, although in this case the sulfate concentration of the Tuolumne River at Tuolumne City was very much lower than for 1960-61, a fact that probably accounts for the sharp drop in $SO_4^{=}$ between Grayson and Maze Roads.

Noncarbonate hardness. Noncarbonate hardness, a measure of hardness attributed to the chloride and sulfate compounds with calcium and magnesium, also reveals a distinctive difference between east side streams and the main stem plus Salt Slough. This is illustrated in the data of table VI-5 and figure VI-5. Once again the main stem quality, in terms of chemical composition of salts, is closely identified with drainage returns from the west side, i.e., Salt Slough, while the east side streams are virtually devoid of NCH (the exception being the lower reach of the Tuolumne where the gas wells add calcium and magnesium sulfate). Even the DMC carries a relatively high NCH, a condition that is also reflected in the quality of water in the San Joaquin River near Mendota since the DMC is the principal source of water in the main stem at this location.

Boron. Boron concentrations in east side streams are generally very low, while this is a common constituent of west side waters and also of the main stem during periods of low runoff. Data on boron concentrations for 1960-61 are summarized in table VI-6 and figure VI-6.

In these examples, boron concentrations are noted to vary widely with location along the main stem, but at all locations the concentrations are substantially greater than for any of the east side streams. Even the DMC delivers water with more than double the boron concentrations of the highest east side source (Tuolumne River). Maximum boron concentrations in the east side streams are no greater than the least values recorded for the main stem from Fremont Ford to Vernalis.

Table VI-5. TOTAL AND NONCARBONATE HARDNESS
SAN JOAQUIN RIVER SYSTEM, 1960-61

Station USGS No.	Location	No. of Obs.	Hardness as $CaCO_3$, mg/L Ca + Mg	NHC	% @ NHC
2510	SJR below Friant	12	17.0	0.5	2.9
2540	SJR nr Mendota	13	128.1	47.9	37.4
2580	Fresno R.	8	43.8	4.3	9.8
2590	Chowchilla R.	7	101.8	18.3	18.0
2603	Bear Cr.	11	112.2	1.6	1.4
2610	Salt Slough	12	332.9	167.8	50.4
2615	SJR, Fremont Fd.	15	366.3	194.3	53.0
2700	Merced @ Exch.	12	44.4	3.8	8.5
2725	Merced @ Stev.	11	93.6	0.0	0.0
2740	SJR nr Newman	13	370.8	188.6	50.9
2747	SJR nr Grayson	12	327.2	135.5	41.4
2880	Tuol @ LaGrange	11	10.9	0.5	4.8
2898	Tuol nr Hickman	11	94.2	25.5	27.1
2902	Tuol nr Tuol City	11	173.9	66.5	38.2
2905	SJR @ Maze Rd	12	265.9	118.2	44.5
2999.98	Stan @ Tulloch	12	28.2	0.9	3.2
3034	Stan nr mouth	10	110.9	0.0	0.0
3035	SJR nr Vernalis	39	210.0	88.0	41.9
3042	SJR nr Mossdale	13	229.4	95.1	41.5
3048	SJR, Garwood Br.	12	178.1	60.2	33.8
3127	Old R. nr Tracy	12	247.5	110.3	44.6
3129.9	DMC above PP	10	131.8	48.3	36.6
3130.1	DMC below PP	28	115.0	38.0	33.0
3130.5	DMC nr Mendota	13	143.8	52.7	36.6
3132	Grantline Canal	12	206.8	84.3	40.8
3132.5	Old R. @ Cl.Ct.	12	132.2	55.8	42.2

Table VI-6. BORON CONCENTRATION, SAN JOAQUIN RIVER SYSTEM

Station		No. of	Boron Concentration, mg/L			
USGS No.	Location	Obs.	Min.	Max.	Mean	Median
2510	SJR below Friant	12	0.0	0.1	0.03	0.0
2540	SJR nr Mendota	13	0.0	0.6	0.23	0.2
2580	Fresno R.	8	0.0	0.2	0.05	0.0
2590	Chowchilla R.	7	0.0	0.1	0.04	0.0
2603	Bear Cr.	11	0.0	0.1	0.02	0.0
2610	Salt Slough	12	0.3	2.2	1.00	0.75
2615	SJR, Fremont Fd.	15	0.4	1.8	0.83	0.70
2700	Merced @ Exch.	12	0.0	0.1	0.03	0.0
2725	Merced @ Stev.	11	0.0	0.1	0.03	0.0
2740	SJR nr Newman	13	0.4	1.9	0.92	0.8
2747	SJR nr Grayson	12	0.3	1.1	0.63	0.6
2880	Tuol @ LaGrange	11	0.0	0.1	0.04	0.0
2898	Tuol nr Hickman	11	0.0	0.1	0.05	0.0
2902	Tuol nr Tuol City	11	0.0	0.2	0.11	0.1
2905	SJR @ Maze Rd	12	0.2	0.6	0.42	0.4
2999.98	Stan @ Tulloch	12	0.0	0.1	0.02	0.0
3034	Stan nr mouth	10	0.0	0.1	0.04	0.0
3035	SJR nr Vernalis	39	0.2	0.7	0.44	0.4
3042	SJR nr Mossdale	13	0.0	0.5	0.28	0.3
3048	SJR, Garwood Br.	12	0.0	0.5	0.26	0.3
3127	Old R. nr Tracy	12	0.0	0.7	0.39	0.4
3129.9	DMC above PP	10	0.1	0.6	0.21	0.1
3130.1	DMC below PP	28	0.1	0.8	0.22	0.1
3130.5	DMC nr Mendota	13	0.1	0.6	0.22	0.1
3132	Grantline Canal	12	0.0	0.5	0.27	0.4
3132.5	Old R. @ Cl.Ct.	12	0.0	0.5	0.14	0.1

Summary. These data were developed to facilitate identification of the locations and relative strengths of the major contributions to the salt burden carried by the San Joaquin River from the vicinity of the Mendota Pool to Vernalis.

In general, the data on quality constituents show the following:

1. There are distinctive differences between the qualities of east side streams and the quality of water carried by the San Joaquin River along its main stem. East side streams are generally of high quality from source to mouth (an exception being the lower reaches of the Tuolumne River). They are lower in TDS, lower in boron and uniquely deficient in sulfate and noncarbonate hardness compared to the San Joaquin River into which they discharge.
2. In the 1960's there is comparatively little difference between the quality and chemical composition of salts in drainage returns from the west side of the valley and the quality of water carried in the San Joaquin River from Mendota to Vernalis. West side drainage is high in TDS, chlorides, sodium, sulfate, noncarbonate hardness and boron, all of these properties being identified with soils of the area.
3. The quality of water and chemical composition of salts in the San Joaquin from Mendota to Vernalis is similar to the quality of west side accretions to the river. The effect of the flow from east side tributaries has been largely one of dilution of increased salt loads carried by the river.
4. The lower Tuolumne River received substantial accretions of salt (primarily in the form of sodium chloride) during the period studied as a result of drainage from abandoned gas wells. However,

even in 1961, the average annual quality of the Tuolumne at its mouth near Tuolumne City was superior to that in the main stem of the San Joaquin above the confluence of the two rivers (Note: Recently, an attempt to reduce the salt load of the Tuolumne River was initiated by sealing of the wells, although the effectiveness of this control measure has not yet been assessed quantitatively.)

While the properties of the salts carried by the San Joaquin River during periods of low flow appear to be dominated by west side accretions, to a degree that they are hardly indistinguishable, it is not possible on the basis of quality alone to determine the relative contribution of the several sources without considering the flow itself. This leads to the second phase of the quality problem--salt load--the product of flow times concentration.

SECTION B. SALT BALANCE OBSERVATIONS AT VERNALIS

The water quality at Vernalis may be affected by a change in salt load. Generally, an increase in load can be expected to cause quality degradation. (The exception would be an increase in load accompanied by an increase in flow.) An increase in load can be the result of importation of salts, either applied to the soil in the form of fertilizers, soil conditioners, etc., or as in the case of the DMC, with water diverted from the Delta. These salts along with those occurring naturally in the soil are carried in return flows to the San Joaquin River and may increase the total yearly salt load at Vernalis.

A second means of changing the salt load is through a shift of load with time. In such a case, the salt burden may be temporarily detained in the basin during one period but released subsequently with return flow. This mechanism may not change the total annual salt load, merely redistribute it with respect to time, or delay its occurrence at the lower limit of the basin.

This section attempts to determine if additional salts have been introduced into the system, if a change in salt load pattern has occurred, or both.

Historical Trends of Salt Load at Vernalis

In figures VI-7 through VI-10 are presented the monthly average salt loads (tons per month) actually occurring at Vernalis during several decades since the 1940's* plotted as functions of the unimpaired ("rimflow") runoff at Vernalis (1,000's acre-feet) for each of four different months--October, January, April and July. Regression lines of a power funtion form

$$TDS = Constant\ (KAF)^n$$

where

TDS = tons per month

KAF = unimpaired Vernalis runoff, 1,000 acre-feet

n = exponent

that best fit the data are also shown.

In general, the data tend to indicate that the salt load has increased through the decades. It is noted that the lines represent "best fits" for a decade of data (up to 10 data points) and, hence, in some cases the correlations are not very strong, 0.5 or less. The curves do not necessarily describe the cause-effect relationship between salt load at Vernalis and the unimpaired runoff. Apparently, in those cases where correlations are poor

* Data were not considered sufficient to permit computation of monthly averages for the 1930's.

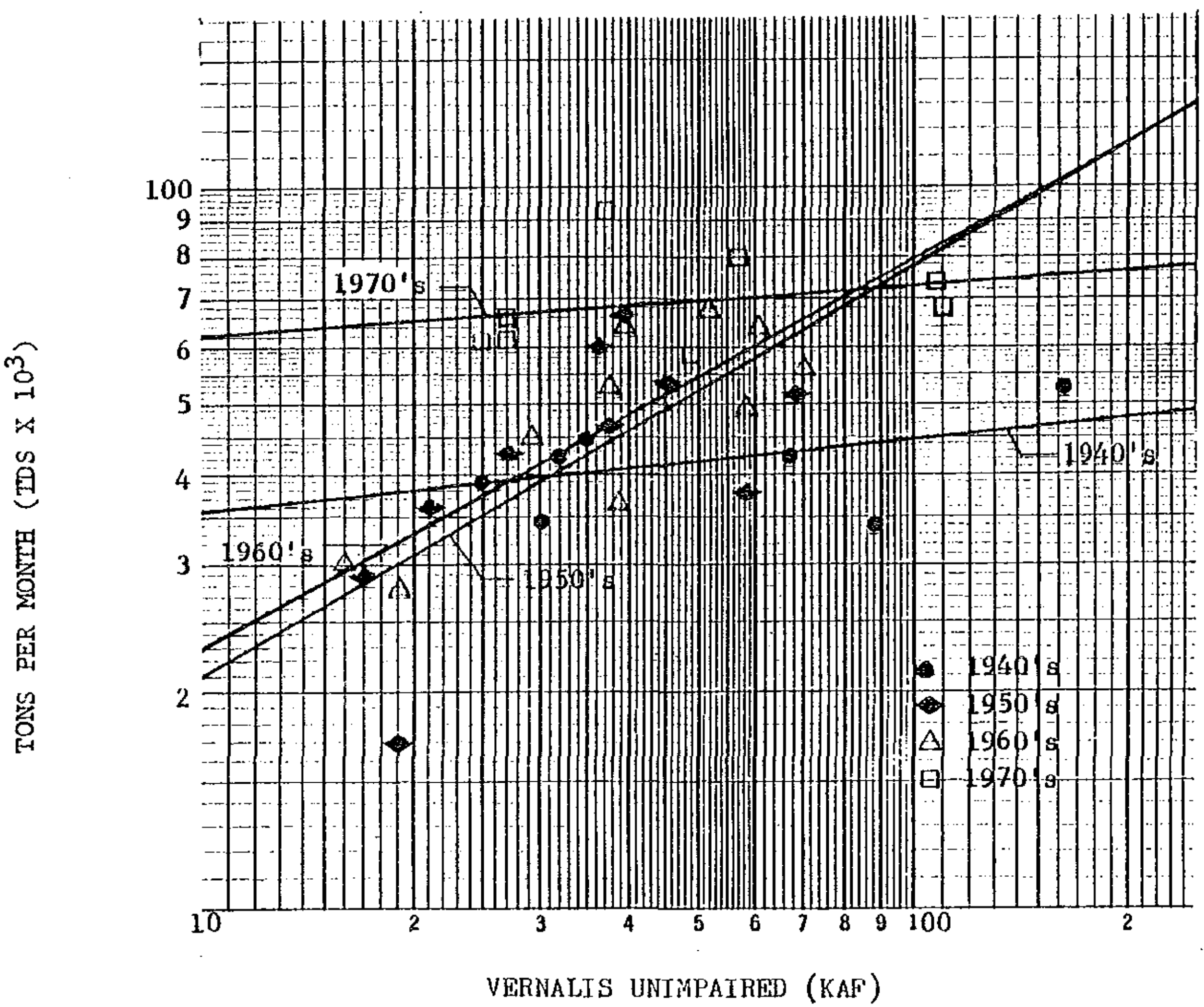


Figure VI-7 AVERAGE MONTHLY SALT LOAD (TDS) AS A FUNCTION OF UNIMPAIRED RUNOFF AT VERNALIS - OCTOBER

040628

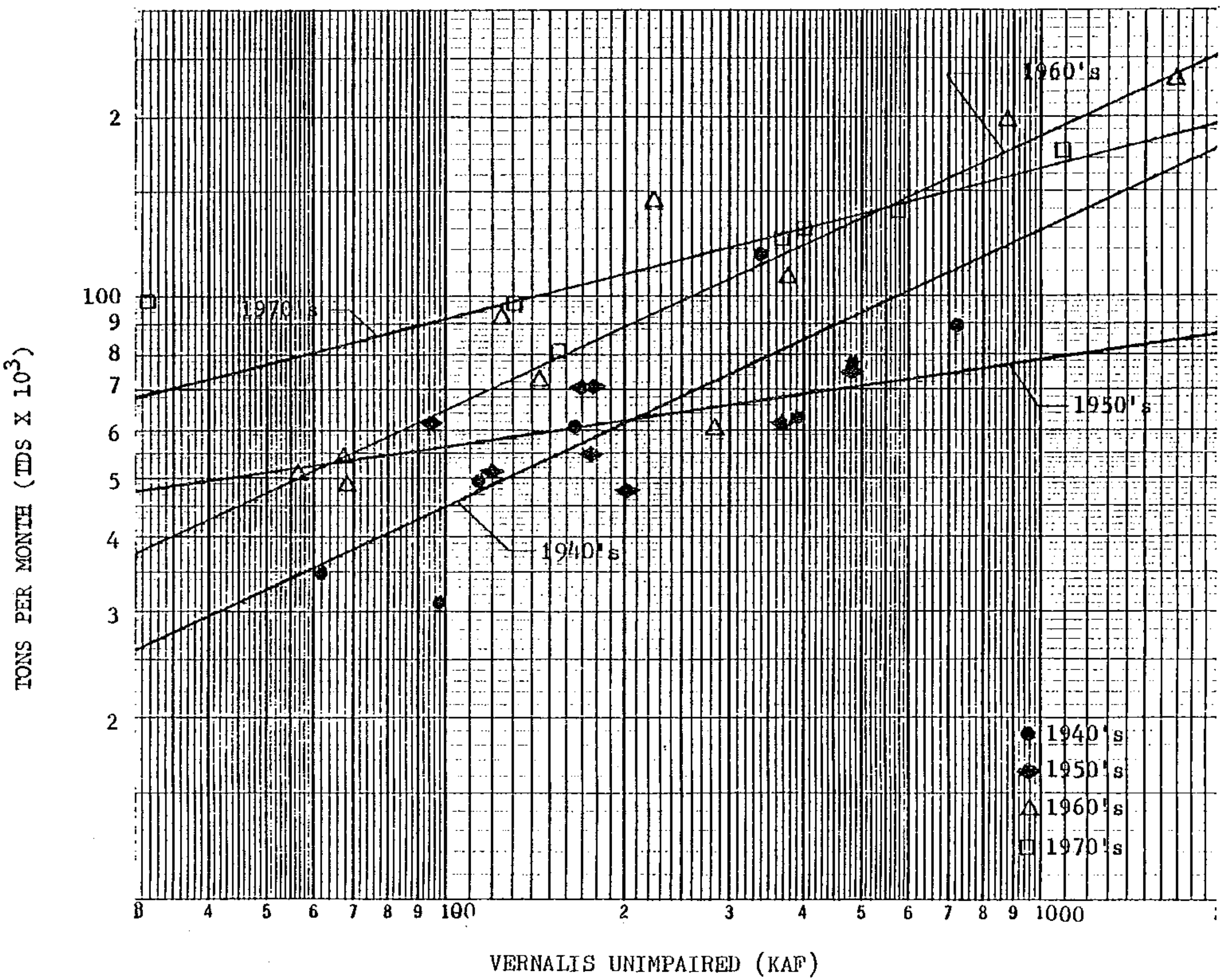


Figure VI-8 AVERAGE MONTHLY SALT LOAD (TDS) AS A FUNCTION OF UNIMPAIRED RUNOFF AT VERNALIS - JANUARY

040629

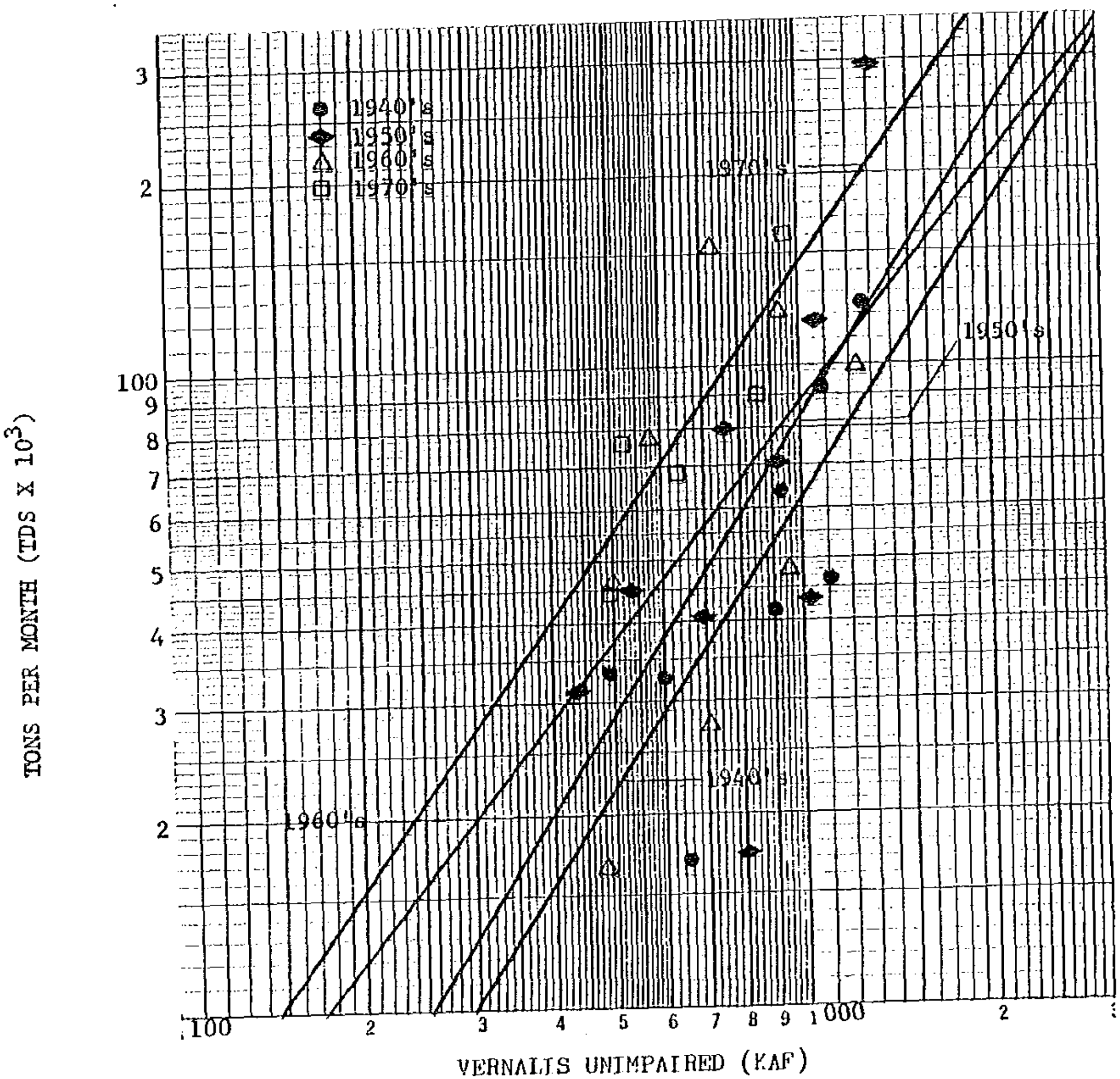


Figure VI-9 AVERAGE MONTHLY SALT LOAD (TDS) AS A FUNCTION OF UNIMPAIRED RUNOFF AT VERNALIS - APRIL

040630

040631

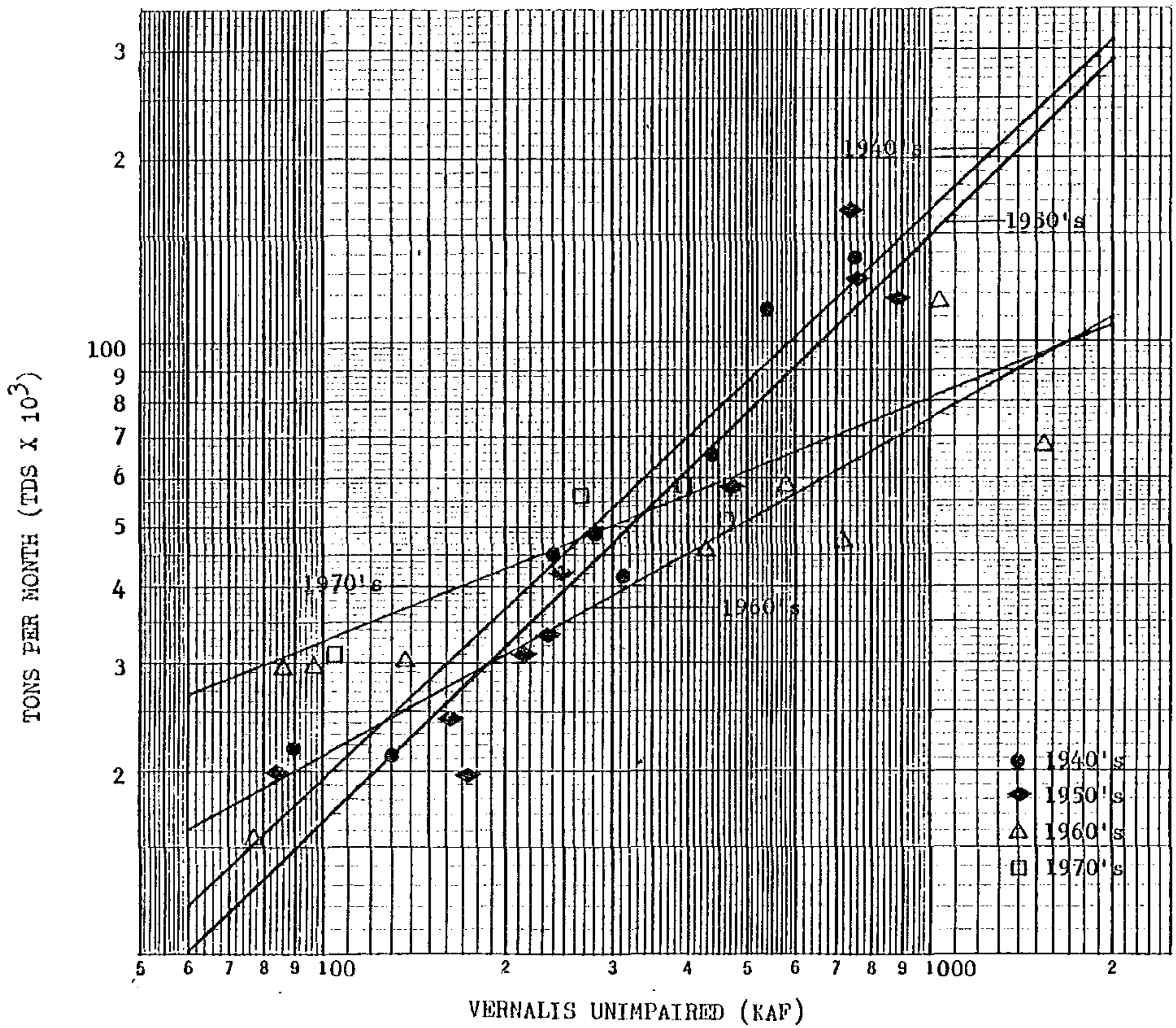


Figure VI-10 AVERAGE MONTHLY SALT LOAD (TDS) AS A FUNCTION OF UNIMPAIRED RUNOFF AT VERNALIS - JULY other mechanisms than those assumed are needed to explain the observed increases in salt load that have occurred at Vernalis over the period since the 1940's.

Historical Trends in Salt Concentration at Vernalis

The Water and Power Resources Service has established a continuous EC recorder at the Vernalis stream gage and records are available, with some minor gaps, almost continuously for the period since September 1952. These are generally in the form of EC measurements from recorders, averaged over the daily cycle and converted to TDS and chlorides by conversion equations periodically updated by comparison of EC measurements with laboratory determinations of TDS and Cl^-. The most recent equations employed by the Water and Power Resources Service for Vernalis are:

$$TDS = 0.62\ EC + 18.0 \qquad 0 < EC < 2000 \tag{1}$$

$$Cl^- = 0.15\ EC - 5.0 \qquad 0 < EC < 500 \tag{2a}$$

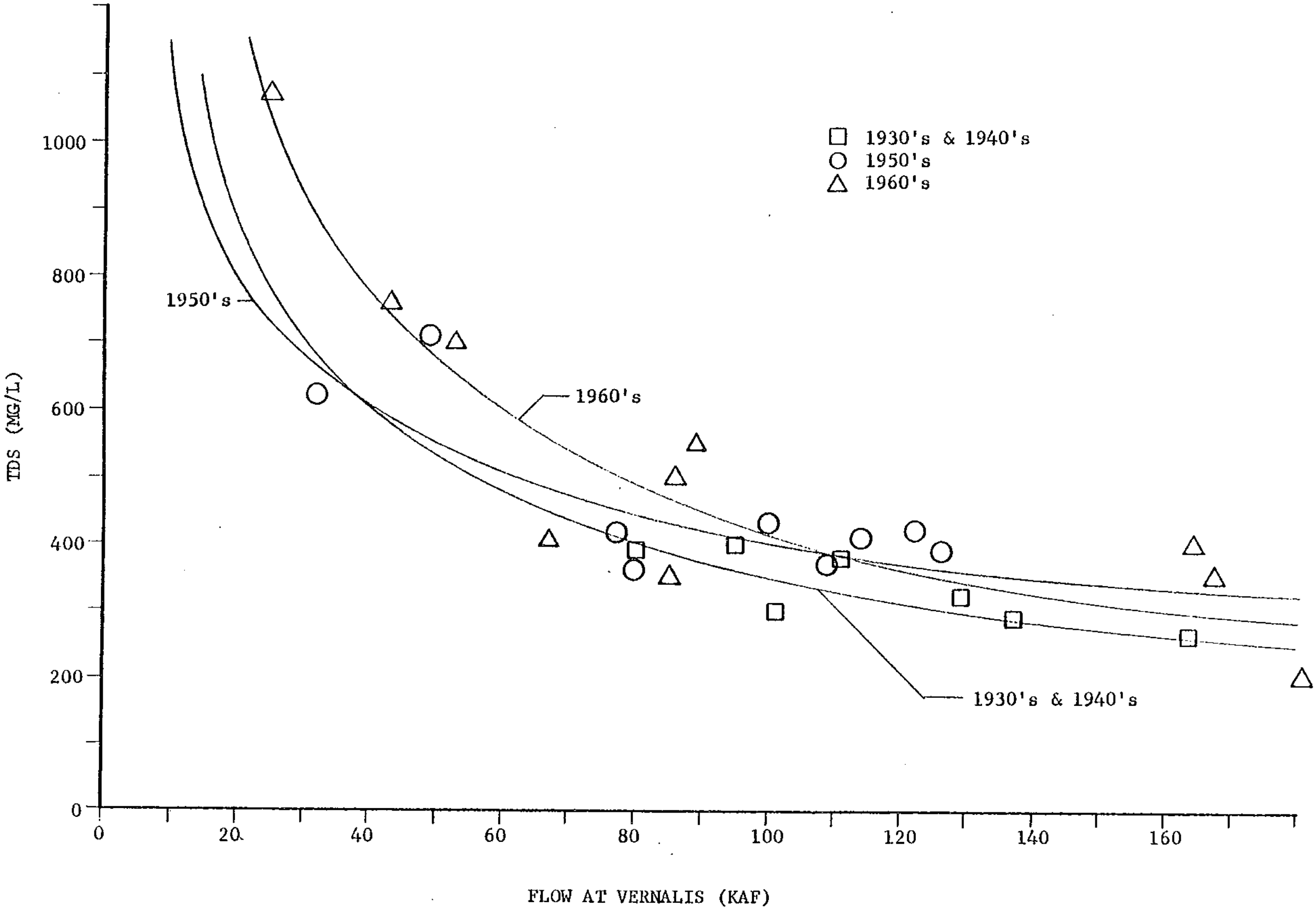
$$Cl^- = 0.202\ EC - 31.0 \qquad 500 < EC < 2000 \tag{2b}$$

By relating TDS to Cl^- for constant EC, there result the following relationships between these two quality constituents:

$$TDS = 3.07\ (Cl^-) + 113 \qquad 70 < Cl^- \tag{3}$$

$$TDS = 4.13\ (Cl^-) + 38.7 \qquad 0 < Cl^- < 70 \tag{4}$$

Using the above equations, and what chloride data are available for the 1930's and 1940's, figures VI-11, VI-12, VI-13, and VI-14 were developed. Also shown in these figures are the actual TDS data for the 1950's and 1960's.


1930's & 1940's
1950's
1960's
1950's
1960's
1930's & 1940's
1000
800
600
400
200
0
TDS (MG/L)
0
20
40
60
80
100
120
140
160
FLOW AT VERNALIS (KAF)

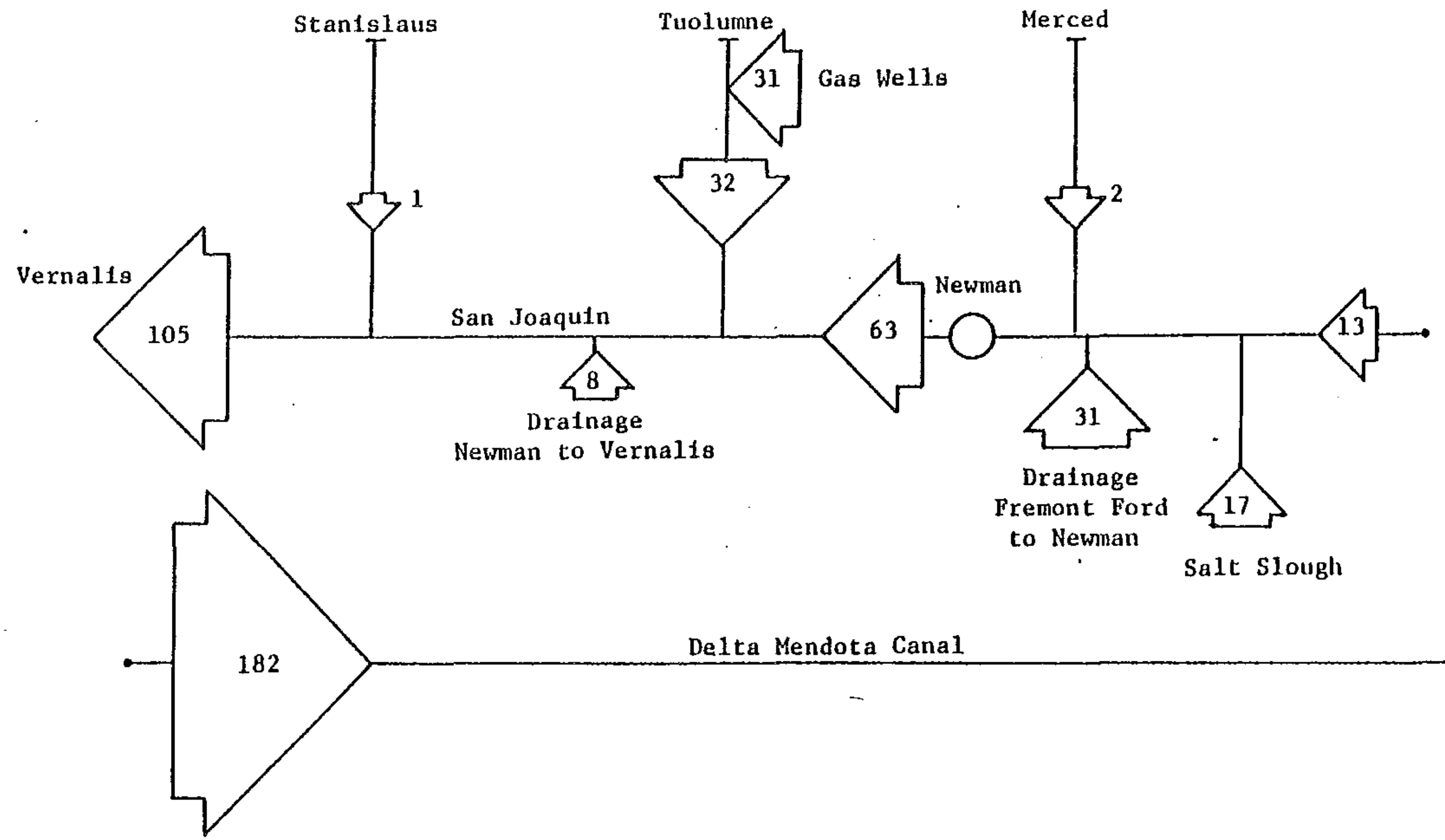


Figure VI-18 CHLORIDE SALT BALANCE--SAN JOAQUIN RIVER SYSTEM, 1960-61

(Numbers indicate salt load in thousand tons per year)

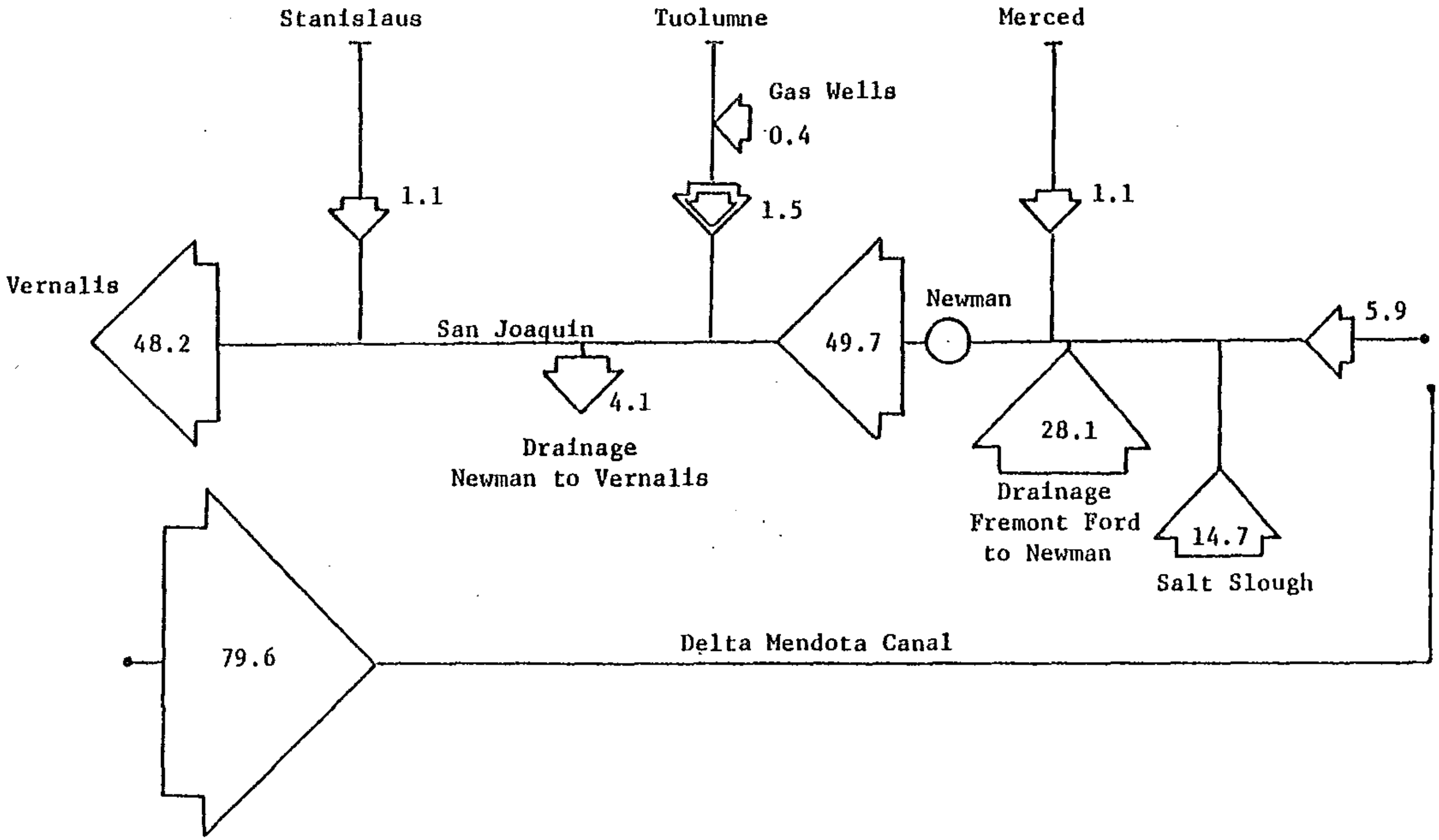


Figure VI-19 SULFATE SALT BALANCE FOR SAN JOAQUIN RIVER SYSTEM, 1960-61

(Numbers indicate salt load in thousand tons per year)

040636

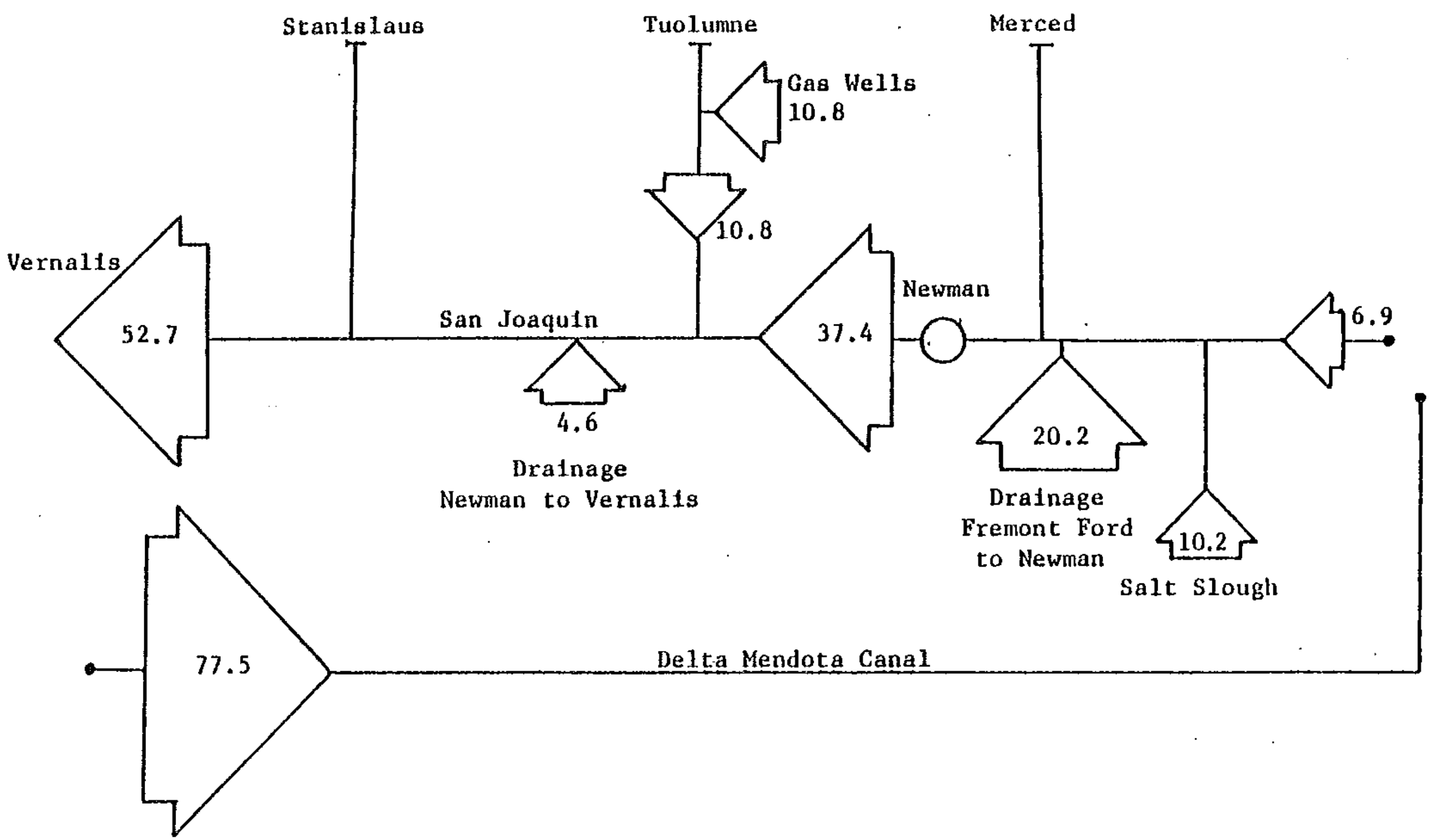


Figure VI-20 NONCARBONATE HARDNESS SALT BALANCE
SAN JOAQUIN RIVER SYSTEM, 1960-61

(Numbers indicate salt load in thousand tons per year)

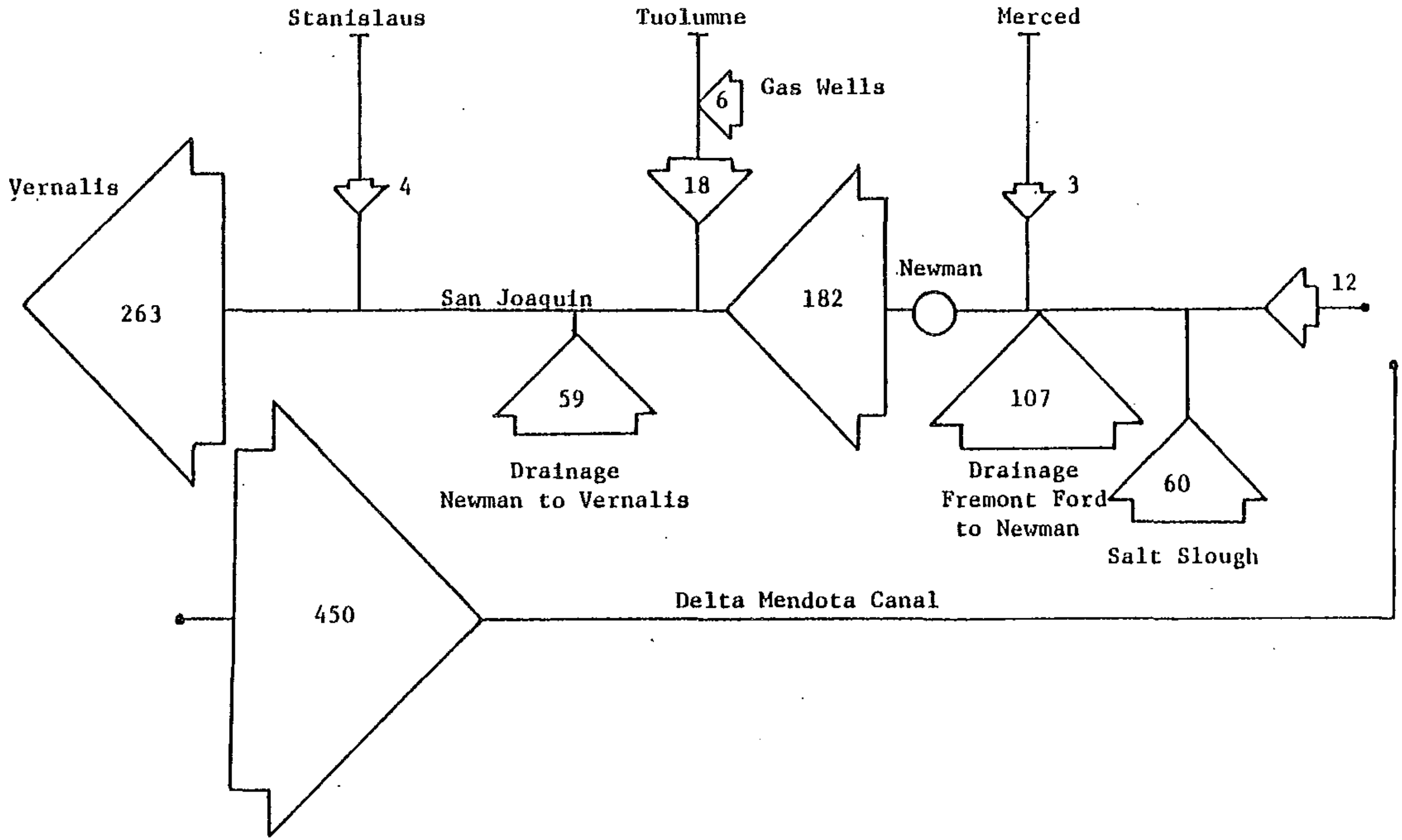


Figure VI- 21 BORON SALT BALANCE--SAN JOAQUIN RIVER SYSTEM, 1960-61

(Numbers indicate salt load in tons per year)

Generally, during periods of lower flows, the 1950's and 1960's have a higher TDS value. These concentration versus flow curves are also of the power function form.

Salt (Chloride) Balances by River Reaches

Like the station at Vernalis, most water quality stations along the San Joaquin River and its tributaries provided only spotty information prior to 1952. Of the data available for earlier years, the record of chloride concentration is the most complete for the greatest number stations. Therefore, these data were used to develop relationships of chloride load versus flow at various water quality stations.

Curves were plotted of total monthly flow at the station versus total monthly chloride load. Preliminary work indicated that seasonal similarities in the data existed, and to simplify the task of verifying data for all months, only October, January, April, and July curves were formulated. Because of the shortage of data prior to 1952, all years prior to 1950 were considered as pre-CVP. Since the Delta-Mendota Canal did not go into operation until after 1950, no major source of imported salt existed to influence the analysis. For Vernalis one additional data point was included to insure that the curves did not exceed known limits. This additional point represented an extreme low flow condition for the San Joaquin River at Vernalis, when the TDS would likely correspond to drainage return flows. For this analysis a flow of 0.5 KAF and a TDS of 1,000 mg/L were assumed. Thus, when used as predictors the curves would not produce estimates of TDS higher than about 1,000 mg/L, the maximum observed during the 1977 drought.

Figures VI-15 and VI-16 are examples of chloride load versus flow curves for the month of July on the Tuolumne River at Tuolumne City. The actual data

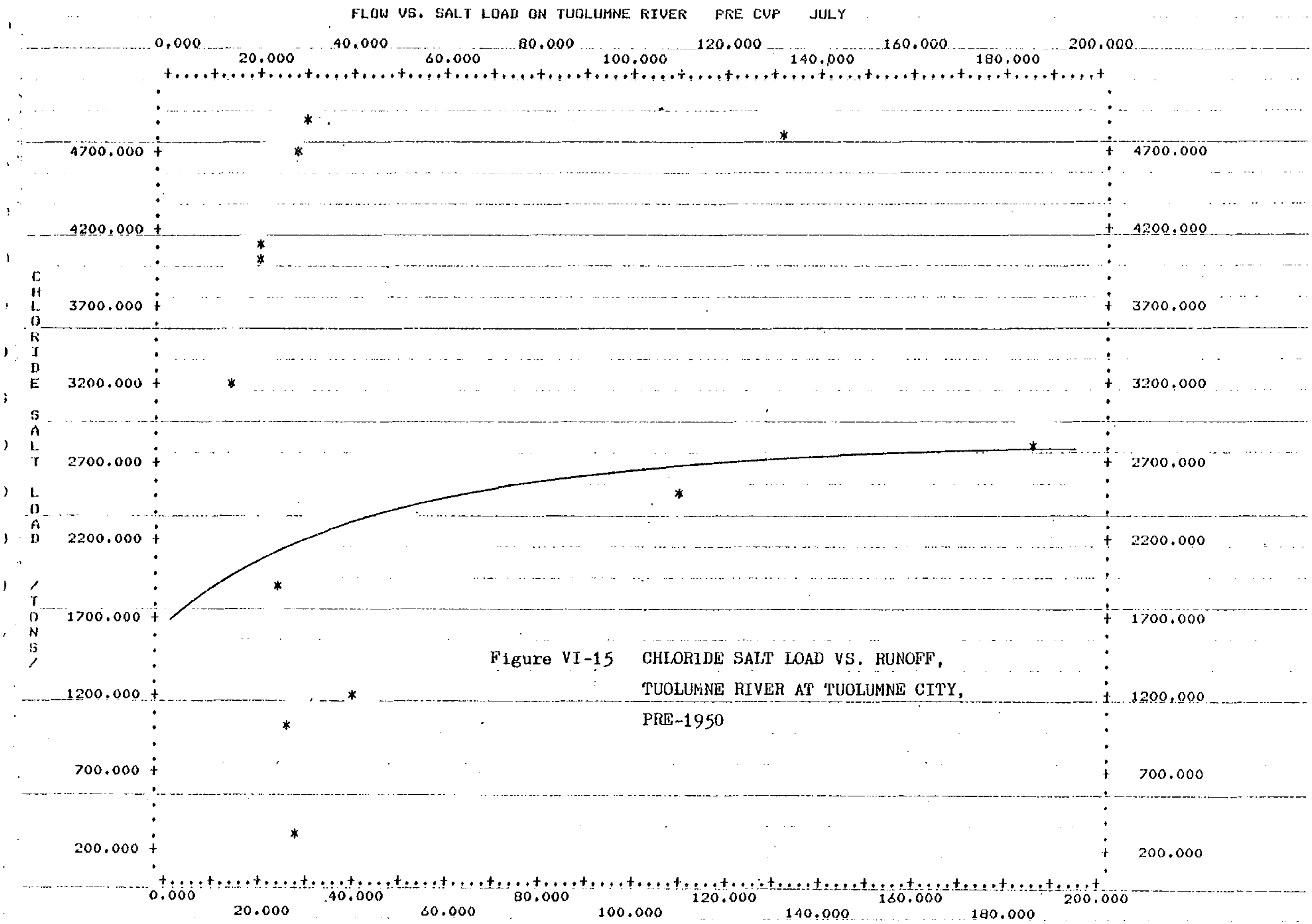


Figure VI-15 CHLORIDE SALT LOAD VS. RUNOFF, TUOLUMNE RIVER AT TUOLUMNE CITY, PRE-1950

FLOW VS. SALT LOAD ON TUOLUMNE RIVER POST CVP JULY

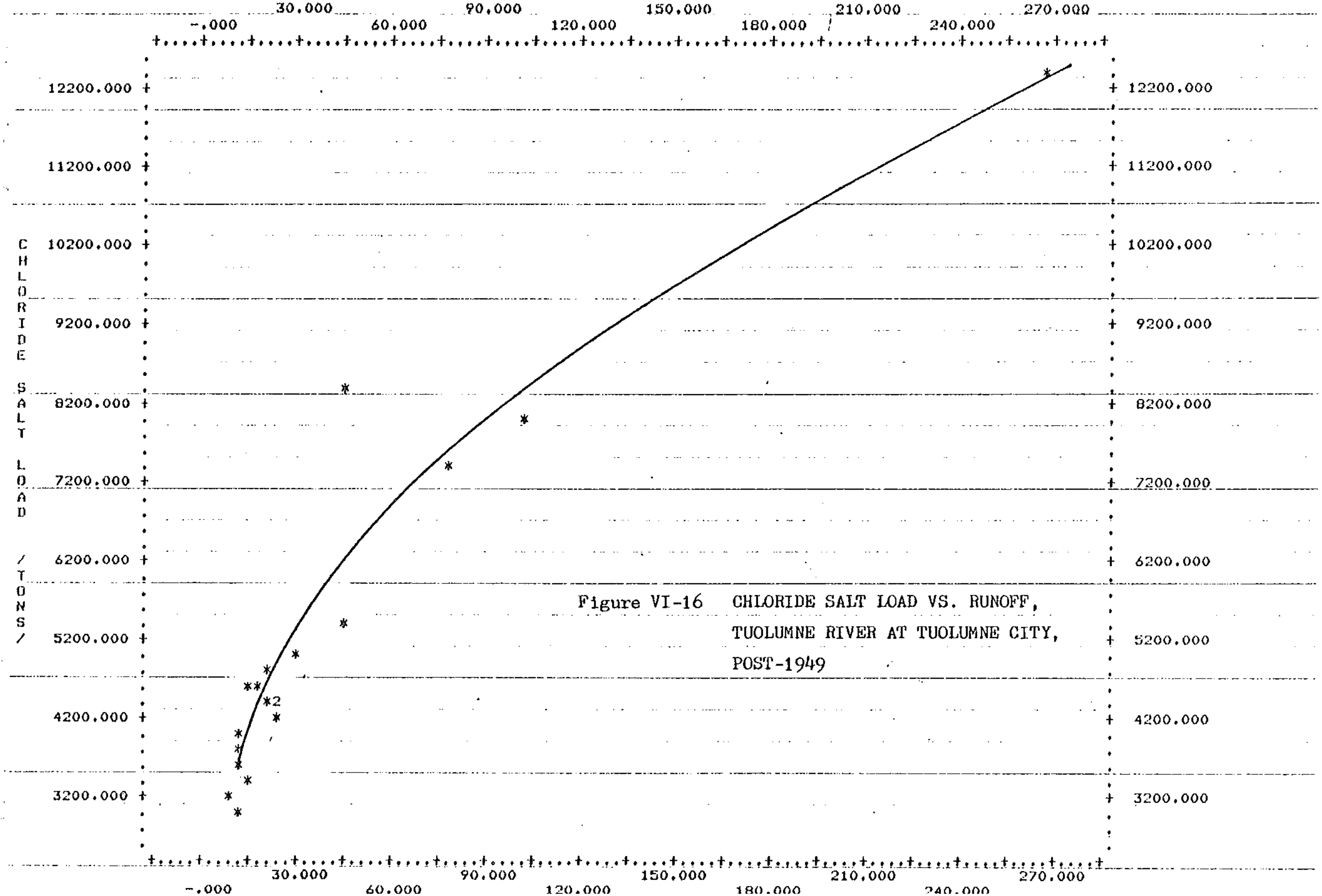


Figure VI-16 CHLORIDE SALT LOAD VS. RUNOFF, TUOLUMNE RIVER AT TUOLUMNE CITY, POST-1949 points used to define the curves are shown on the figures. Additional curves are in appendix 2. Table VI-7 summarizes the characteristics of regression curves of chloride load versus flow for each month of both the pre-1950 and post-1949 periods of analysis for the station at Vernalis.

Using the chloride load-flow curves thus developed, it is possible to perform a salt balance for any given flow at Vernalis.

Salt (Chloride) Balances by Representative Months

Chloride balances (concentration x flow x 1.36), expressed as tons per month, were calculated for the months of October, January, April, and July for a series of river reaches from above Newman to Vernalis. A typical summary of the calculation is presented in figure VI-17 where data are presented for both pre-1950 and post-1949 project periods. The principal tributary streams and stations along the main stem are identified between Newman and Vernalis. "Other" in the figure refers to accretions or subtractions occurring between stations at which both flow and chloride data were sufficient to make the salt balance calculation. Additional calculations are found in appendix 3.

In order to illustrate the changes in salt burden by year type, the data have been grouped, as in the case of water balance calculations, by reference to the Vernalis "unimpaired" flow. Average values of unimpaired flows at Vernalis by year type were calculated. Estimated actual flows at Vernalis were calculated using the average of actual Vernalis flows for a particular period and year type.

As a means of checking the appropriateness of results based on the average of actual flows, and only four representative months, each year of record was evaluated for all months using regression curves and actual flows at Vernalis. An average "actual" load was then calculated for each year type and period. Results for comparison are in table VI-8.

TABLE VI - 7
CHLORIDE LOAD VS. FLOW COEFFICIENTS AT VERNALIS

1930 - 1950

MONTH	C1	C2	# OF PAIRS*	R
OCTOBER	.3416451758E+03	.7238303788	7	.993
NOVEMBER	.3393044927E+03	.6880766404	6	.987
DECEMBER	.3639052910E+03	.6787756342	7	.972
JANUARY	.3928349175E+03	.6231583178	10	.965
FEBRUARY	.5368474514E+03	.5675747831	9	.914
MARCH	.4968879101E+03	.6035477710	10	.951
APRIL	.3866605718E+03	.5624873484	9	.942
MAY	.3805863844E+03	.5399998219	9	.920
JUNE	.6355065225E+03	.5175446121	9	.849
JULY	.6038658134E+03	.6219848451	8	.900
AUGUST	.3874538954E+03	.7410226741	8	.991
SEPTEMBER	.3500905302E+03	.7524035817	8	.989

* # OF PAIRS DOES NOT INCLUDE RESTRICTION POINT (.5,200)

$y = C1*(X)^{C2}$

80/05/16. 11.17.58. OCTOBER 39.7 KAF UNIMPAIRED AT VERNALIS

DRY YEAR

FLOW (KAF) PRE-1950	FLOW (KAF) POST-1949	STATION	CHLORIDES PRE-1950 (TONS)	CHLORIDES PRE-1950 (PCT)	CHLORIDES POST-1949 (TONS)	CHLORIDES POST-1949 (PCT)
24.	20.	NEWMAN	3040.	30.	4170.	29.
16.	16.	OTHER	1960.		2820.	
39.	36.	GRAYSON	5000.	49.	6990.	49.
55.	51.	TUOLUMNE	3830.	37.	5050.	35.
5.	9.	OTHER	1210.		2540.	
99.	96.	MAZE ROAD	10040.	98.	14570.	102.
14.	17.	STANISLAUS	260.	3.	200.	1.
-3.	7.	OTHER	-40.		-470.	
110.	120.	VERNALIS	10260.	100.	14290.	100.
		TOT. OTHERS	3130.	31.	4890.	34.
		NMN. + OTH.	6170.	60.	9060.	63.

QUALITY PPM (CL) / (TDS)

PRE PPM = 69. / 324.
POST PPM = 88. / 383.
DEGRADATION = 19. / 59.

Figure VI-17 SAMPLE OF COMPUTER PRINTOUT, SALT BALANCE COMPUTATION

* NOTE:
PCT COLUMN IS PERCENT OF VERNALIS.

Table VI-8
UNIMPAIRED FLOW OF THE SAN JOAQUIN RIVER
AT VERNALIS

Average Vernalis unimpaired flow	October	January	April	July
Dry year	39.7	110.5	601.4	101.4
Below normal	49.3	167.3	794.9	224.9
Above normal	42.4	352.5	1055.7	425.1
Wet year	29.8	695.7	1169.0	921.0
Estimated actual Vernalis flow				
Pre-years*				
Dry year	110	150	86	46
Below normal	101	119	113	64
Above normal	98	279	805	235
Wet year	107	410	1175	730
Post-years**				
Dry year	120	133	44	18
Below normal	104	202	150	46
Above normal	65	263	264	72
Wet year	87	714	1000	300

* 1930-1949

** 1950-1969

The salt load estimated for Vernalis by month and year classification is summarized in table VI-9. In this summary, the salt load varies with time and year classification. Salt loads tended, of course, to be sensitive both to runoff and concentration. In the pre-1950 period, for example, the greater loads occurred in the wetter years, and generally in the month of July.

In the post-1949 period, salt loads are estimated to be generally higher in all months except July. The average annual salt burden at Vernalis appears to have remained unchanged in wet years and increased by 35 percent in below normal years. The total average annual load in dry years has increased by about 18 percent. In the April-September period, salt loads were unchanged from pre to post dry years; increased in below normal years; decreased in above normal years and decreased slightly in wet years. This can probably be explained by lower flows and loads in the summer months. These estimates are based on "actual loads" as identified in table VI-9.

Salt Balances for a Dry Year

Additional insight to salt balance estimation is provided by an evaluation of the salt load distribution along the San Joaquin River for the dry year 1961, as illustrated by figures VI-18 through VI-21.

In figure VI-18 is shown a schematic representation of the average amounts (thousand tons per year) of chlorides delivered over the year by each of the several discrete sources, previously identified in figure VI-1, "The San Joaquin Valley System." The figure shows the dominance of the salt load at Vernalis by the principal drainage accretions in the upper San Joaquin River. It also shows, in the case of this particular constituent,* the important contribution of the Tuolumne gas wells. According to this analysis of the load

* The principal salt emitted by the gas wells is sodium chloride.

TABLE VI-9. CHLORIDE SALT LOAD AT VERNALIS (TONS)

	Dry years				Below normal years			
	Average flow*		Actual load**		Average flow*		Actual load**	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Oct	10,260	14,290	10,191	12,703	9,650	12,920	9,631	12,663
Jan	8,920	10,420	8,784	10,284	7,720	12,730	7,650	12,320
Apr	4,740	6,030	4,496	5,754	5,520	11,080	5,502	10,329
Jul	6,530	4,540	6,254	4,434	8,020	7,700	7,877	7,500
Apr-Sept	33,810	31,710	33,580	33,106	40,620	56,340	46,482	54,595
Year	91,350	105,840	88,712	104,428	92,730	133,290	98,701	133,617
	Above Normal Years				**Wet Years**			
	Average flow*		Actual load**		Average flow*		Actual load**	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Oct	9,440	9,280	9,238	9,051	10,060	11,400	10,051	11,291
Jan	13,130	14,450	12,926	12,611	16,690	23,320	16,666	21,689
Apr	16,660	14,670	16,434	13,934	20,620	28,410	20,569	27,638
Jul	18,020	9,910	17,498	9,766	36,470	22,130	36,236	21,378
Apr-Sept	104,040	73,740	90,217	71,332	171,270	151,620	136,420	127,626
Year	171,750	144,930	177,146	181,840	251,520	255,780	258,249	258,216

* Load based on regression of average flow for month.

** Load based on average of loads from regression of all flows for month.

NOTE: "Pre" refers to years 1930-1949
"Post" refers to years 1950-1969

of chlorides that reaches Vernalis, about 60 percent of the load originates above the mouth of the Merced River, 30 percent with the gas wells and 10 percent from other sources, including the two east side tributaries and local drainage between Newman and Vernalis. About 30 percent of the total originates upstream of Fremont Ford (Salt Slough plus sources upstream to Mendota) and 30 percent enters in the comparatively short reach between Fremont Ford and Newman (less than 10 miles).

Figures VI-19 through VI-21 give a somewhat clearer picture of the relative contribution of the other drainage sources, exclusive of the unique influence of the Tuolumne gas wells. Since the wells are low in sulfate and the principal irrigated lands on the west side of the valley are high in this constituent, the sulfate balance depicted in figure VI-19 identifies a very large contribution from the drainage above the mouth of the Merced River. Very little sulfate load is contributed by either the east side streams or the gas wells. In this particular example, it appears that there is even a net export of sulfate to irrigated lands below Newman, not an unlikely occurrence in a dry year of max-irrigation water use and reuse. According to these analyses, about 57 percent of the sulfate load of the upper San Joaquin River (that apparently accounts for virtually all that arrives at Vernalis) originates between Fremont Ford and Newman, and about 30 percent comes from Salt Slough.

A very similar picture is presented by figure VI-20, for noncarbonate hardness (the equivalent of hardness originating from such salts as calcium and magnesium sulfate). It is noted in this case, however, that the gas wells do contribute about 20 percent of the total to Vernalis, while 71 percent originates in the upper San Joaquin River. The east side streams have virtually no noncarbonate hardness.

Finally, a boron balance is shown in figure VI-21 (note that values are in tons per year, not thousand tons, as in the previous examples). Again, although some boron is found in most waters tributary to the valley floor, the dominant sources are in the upper San Joaquin River basin about 69 percent of that which eventually passes Vernalis. In this case, local drainage between Newman and Vernalis contributes about 22 percent of the total.

It should be noted that for reference purposes, since it is a part of the valley system, the Delta-Mendota Canal's contribution is indicated in the figures. The imported salt load to the San Joaquin Valley is noted to range from 147 to 173 percent of that leaving at Vernalis for this dry year, 1961.

Summary of Salt Balance Calculations

Salt balances have been performed for two purposes: (1) to identify trends in load that have occurred with time, e.g., between the pre-1944 and post-1947 periods, and (2) to determine the relative contribution of the various sources of salt, including the contribution of the Tuolumne gas wells.

The salt load at Vernalis has changed between the pre-1944 and post-1947 periods, the amount varying with the year classification. Based on chloride data that extend back to the 30's, it appears that loads in the dry years increased 18 percent and below normal year loads increased 35 percent. Little or no load change is apparent in above normal and wet years. In the dry and below normal years the biggest increase in load occurred in April when spring runoff is probably flushing the basin of some accumulated salts. Consistent with this observation, loads in July have also decreased in dry and below normal years apparently due to a reduction in runoff. In general it appears that in drier years, salts are accumulated in the basin during low flow summer and early fall months and then released during the high flow winter and spring months. Because a net increase in load has occurred, it seems likely that sources of salt are adding to the annual burden at Vernalis in dry and below normal years. Without reference to year classification, and comparing the 1950's and 1960's to the average of the 1930-49 period, it is noted further that the greater proportion of the post-1949 increase seems to have occurred in the more recent decade, i.e., the trend toward an increased salt burden is itself increasing, despite an apparent continuing decline in the total runoff at Vernalis.

A summary comparison of relative increase in salt burden at Vernalis by year classification is presented in table VI-10.

The relative contributions of various sources to the salt load at Vernalis were determined by performing water balances and mass balances for selected sections of the San Joaquin River system. Depending on the constituent selected and the particular hydrology used, the relative contribution of each source to the load at Vernalis can be expected to vary somewhat. For the dry year 1960-61 a breakdown in the percentage contribution from the various sources in the San Joaquin system is as shown in table VI-11.

Some highlights of this 1961 salt balance analysis are as follows:

1. About one-half of the salt load carried in the San Joaquin River at Newman originates in the reach between Mendota and Newman. (Based on chloride balance.)
2. About 20 percent of the salt load that passes Newman is contributed between Mendota and Salt Slough.
3. Salt Slough is a major contributor to salt load accounting for one-third to one-half of the load at Newman.
4. The salt load that enters the San Joaquin River above Newman is equivalent to 60 to 100 percent of that observed at Vernalis.

Table VI-10
PERCENTAGE CHANGE IN SALT LOAD (CHLORIDES)
AT VERNALIS BETWEEN PRE-1950 AND POST-1949 AS A
FUNCTION OF TIME OF YEAR AND YEAR CLASSIFICATION

Year Class	PERCENT CHANGE*				
	MONTH				
	October	January	April	July	Year
Dry	25	17	28	-29	18
Below normal	31	61	88	-5	35
Above normal	-2	-2	-15	-44	3
Wet	12	30	34	-41	0

* ((Salt load post-1949/salt load pre-1949)-1) x 100.

TABLE VI-11. PERCENTAGE CONTRIBUTION OF SOURCES TO SALT LOAD ESTIMATES AT VERNALIS

Source	Percent of Total at Vernalis			
	Constituent*			
	Cl	SO_4	NC	B
Mendota to Salt Slough	12.3	12.2	13.0	4.5
Salt Slough	16.2	30.5	19.4	22.8
Merced River	2.0	2.2	0	1.1
Drainage: Fremont Ford to Newman	29.5	58.3	38.4	40.7
San Joaquin at Newman	60.0	103.2	70.8	69.2
Tuolumne River above gas wells	1.0	1.9	0	4.6
Tuolumne River Gas Wells	29.5	1.0	20.5	2.3
Tuolumne River	30.5	2.9	20.5	6.9
Drainage: Newman to Vernalis	7.5	-8.4	8.7	22.4
Stanislaus River	2.0	2.3	0	1.5
San Joaquin River at Vernalis	100.0	100.0	100.0	100.0

* Cl = chlorides; SO_4 = sulfates; NC = noncarbonate hardness; B = boron

5. Of the chloride salt load carried by the river at Vernalis, less than 6 percent was contributed by the three major tributaries--the Merced, the Tuolumne (excluding the gas wells) and the Stanislaus.
6. The Tuolumne gas wells contributed chloride salt load equal to about 30 percent of the total at Vernalis, but only about 1 percent of the sulfates.
7. The sulfates entering the system above Newman exceeded the total load at Vernalis, i.e., the area above Newman accounted for virtually all of the downstream sulfate load.

SECTION C. WATER QUALITY CHANGES AT VERNALIS

This section deals with the effects any changes in flow or load may have had on Vernalis water quality. Due to the sparse data available prior to 1953, two different methods were developed to predict the quality in the years prior to 1953. The first of these methods utilizes a very complete record of chloride values taken at Mossdale, to predict the pre-1953 TDS at Vernalis. The second method utilizes the flow versus load equations developed for salt balance computations and the relationship between chlorides and TDS at Vernalis to estimate TDS for the pre-1950 and post-1949 periods based on Vernalis flow. Results of both methods are discussed and where results are substantially different comparisons are made.

Estimation based on Mossdale Data

Because of the sparse data prior to 1953, one means of determining the Vernalis quality was developed based on chloride observations at Mossdale on the San Joaquin River approximately 16 river miles downstream of Vernalis. These observations, made as a part of the Department of Water Resources' extensive 4-day sampling program, cover a period from June 1929 through March

1971, overlapping for about 17 full years the Service monitoring of EC at Vernalis. The data developed in the DWR program, however, represent grab samples collected a 4-day intervals (about 8 times per month in most months) at or near conditions of slack water (approximately 1.5 hours after high tide). Thus, they tend to reflect the highest levels of chloride that would likely be observed as a result of tidal action at the Mossdale station.

Significant reversals in tide occur at Mossdale where the tidal range is normally about 2.5 to 3 feet. The Vernalis gage, on the other hand, is above tidal influence at most levels of riverflow.

The special value of the Mossdale data which are summarized in table VI-12, is that they cover periods both before and after the construction of the CVP and therefore can be used to predict changes that have occurred from 1930 through 1967, the period selected for the present study of CVP impacts on water quality in the San Joaquin River system.

However, because the station at Vernalis is about 16 miles upstream of Mossdale, it is necessary to demonstrate that there is a relationship between observations taken at the two locations. This is accomplished by correlation of the mean monthly TDS at Vernalis (table VI-13) with the mean monthly slack water chloride values (8 grab samples) at Mossdale (table VI-12), as shown in figure VI-22. Data shown are for the period April through September, as defined for use in this investigation, and cover the period 1953 through 1970, except for a few months for which no data existed.

As may be clearly seen from the array of data in figure VI-22, the correlation between TDS (Vernalis) and chlorides (Mossdale) is strong. This is not unexpected due to the proximity of the two stations and the apparent lack of intervening processes that could lead to a disproportionate balance between

TABLE VI-12. MEAN MONTHLY SHLORIDES AT MOSSDALE[1], MG/LITER
BASED ON DWR 4-DAY GRAB SAMPLE PROGRAM

	O	N	D	J	F	M	A	M	J	J	A	S
1929									74	120	108	56
1930	61	74	84	60	71	67	47	46	40	71	68	58
1931	65	73	61	71	70	124	114	95	93	100	90	80
1932	80	94	71	20	10	34	18	12	10	30	104	80
1933	63	47	58	54	47	89	113	89	19	75	102	77
1934	67	70	-	-	-	-	-	-	128	94	108	138
1935	168	66	49	18	24	29	17	14	18	53	103	78
1936	54	61	39	72	23	14	20	12	15	74	105	81
1937	58	59	47	38	69	14	15	10	12	79	108	78
1938	61	76	34	34	17	28	33	20	21	19	45	106
1939	71	69	55	56	37	33	83	76	84	113	119	100
1940	103	103	93	76	76	38	48	31	32	76	94	108
1941	114	69	86	48	39	48	46	39	36	50	-	-
1942	-	-	-	19	16	29	32	15	9	13	90	68
1943	56	80	38	-	-	-	-	-	-	-	-	-
1944	-	-	-	-	-	-	-	38	49	91	109	103
1945	71	58	58	47	25	21	24	18	15	56	84	69
1946	50	54	45	26	40	63	28	13	50	96	107	97
1947	87	65	42	64	84	74	103	60	115	146	159	101
1948	95	81	93	94	181	186	86	25	21	85	126	103
1949	90	116	106	96	111	37	64	34	78	155	165	149
1950	120	95	100	90	41	79	31	30	44	145	153	129
1951	121	69	15	33	33	51	101	44	64	154	159	133
1952	108	112	66	26	20	23	20	25	12	72	104	90
1953	96	88	51	38	66	143	131	60	32	92	145	122
1954	102	100	101	104	91	59	29	27	135	174	181	172
1955	139	119	100	67	89	126	154	130	93	185	180	175
1956	163	151	70	10	26	57	42	16	13	84	100	96
1957	92	82	76	104	135	87	137	90	62	139	160	134
1958	78	73	74	96	56	35	27	14	16	86	110	88
1959	74	51	68	100	96	136	181	169	212	225	217	183
1960	174	140	129	133	138	245	204	192	220	173	221	247
1961	184	141	121	131	175	258	264	242	261	197	165	278
1962	277	207	207	220	117	56	96	69	57	194	204	169
1963	151	116	84	112	44	120	22	21	36	-	-	-
1964	-	64	61	83	142	212	212	217	182	261	296	179
1965	-	-	-	30	33	45	23	45	60	130	141	-
1966	103	56	-	80	86	140	-	195	229	247	251	218
1967	135	144	65	98	43	65	18	15	12	37	104	97
1968	72	55	57	90	103	76	153	176	214	220	186	166
1969	127	129	79	43	21	24	18	13	12	49	106	61
1970	43	45	55	46	34	63	133	81	70	143	142	126
1971	131	-	50	45	63	81	-	-	-	-	-	-

[1]Average of up to 8 observations taken at roughly 4-day intervals at approximately one and one-half hours after high tide at Mossdale Bridge

TABLE VI-13. MEAN MONTHLY TOTAL DISSOLVED SOLIDS AT VERNALIS *

Year	O	N	D	J	F	M	A	M	J	J	A	S
1953				124	201	400	463	207	128	300	425	373
53-54	317	334	342	365	328	220	124	136	443	539	540	515
54-55	378	354	285	223	254	341	474	388	264	449	464	476
55-56	439	403	302	NR	NR	214	148	69	81	279	295	318
56-57	312	295	254	381	464	330	417	331	203	455	479	451
57-58	316	271	282	346	249	202	149	97	89	289	417	315
58-59	280	198	258	366	331	428	546	538	589	634	620	557
59-60	502	446	428	461	482	654	585	582	673	710	640	682
60-61	520	460	402	447	591	715	846	715	794	936	941	807
61-62	805	661	690	713	440	238	325	237	183	516	565	496
62-63	415	370	267	413	145	395	108	93	125	369	477	405
63-64	287	238	201	301	458	578	562	564	571	756	774	615
64-65	472	340	281	163	189	247	150	194	169	422	494	401
65-66	258	243	243	332	346	NR	NR	598	662	729	727	698
66-67	485	469	260	402	222	264	123	104	86	162	365	354
67-68	299	222	240	367	401	325	486	576	659	665	599	568
68-69	458	481	329	198	129	146	118	86	84	221	363	249

*Average of continuous EC recording converted to TDS by relationships of the form TDS = $C_1 \times EC + C_2$

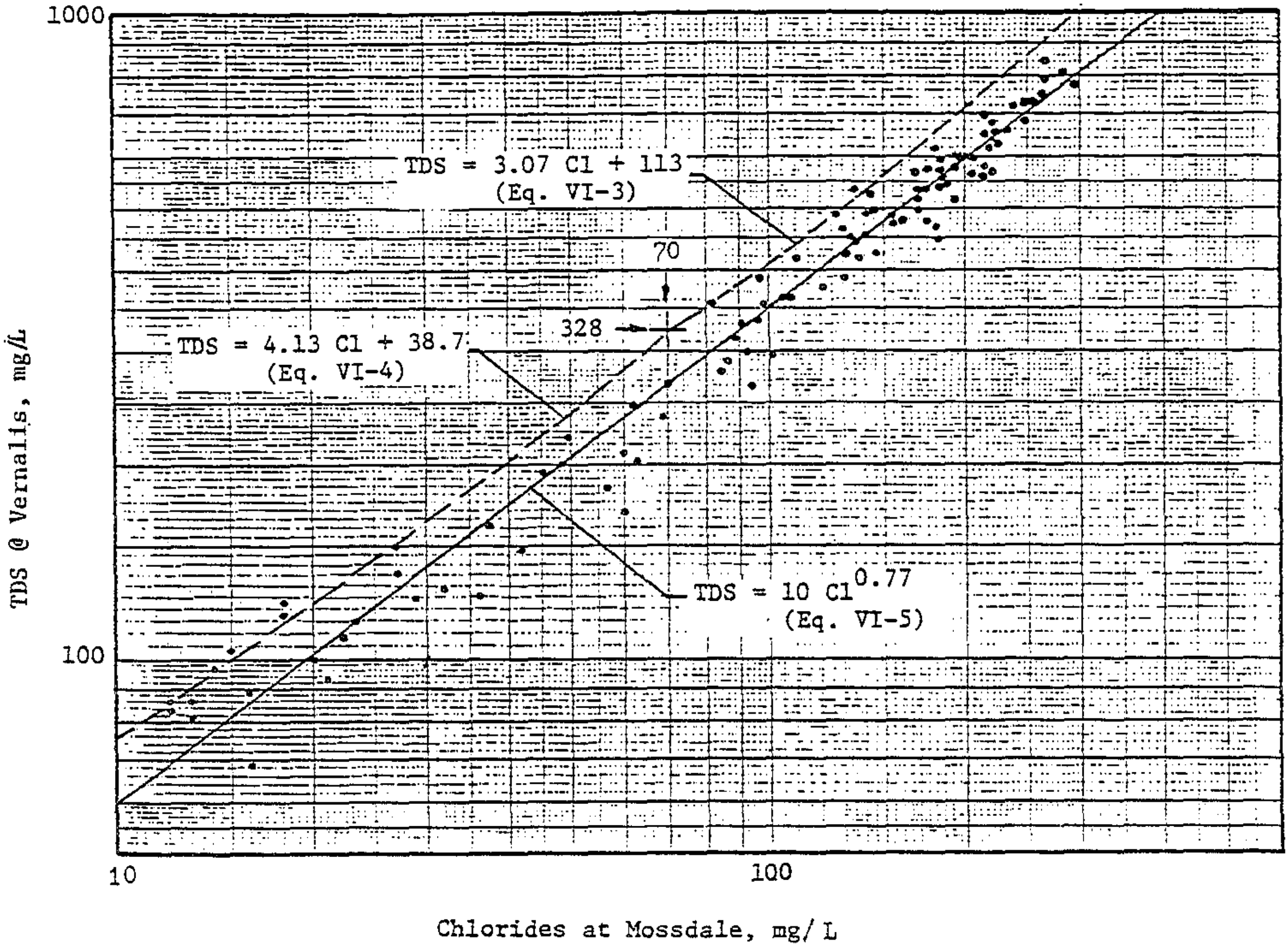


Figure VI-22 RELATIONSHIP BETWEEN TOTAL DISSOLVED SOLIDS AT VERNALIS AND CHLORIDES AT MOSSDALE

Data are for April-Sept, 1953-1970
Monthly mean concentrations, mg/L

chlorides and total salts over the historic period considered. The relationship between these quality constituents is given best by the equation:

$$TDS = 10\ (Cl^{-})^{0.77} \qquad (5)$$

where

TDS = total dissolved solids, mg/L

Cl^{-} = chlorides, mg/L

With the aid of this equation, it is now possible to relate the 4-day chloride data at Mossdale with the corresponding values of TDS at Vernalis and vice versa, recognizing of course that the chloride values are for average high tide, slack water conditions, while the TDS values are averages over the 24-hour daily period.

Historical Changes in TDS at Vernalis

The pattern of TDS change that has occurred at Vernalis is illustrated in figure VI-23 which shows in the lower section the chlorides history actually observed at Mossdale and in the upper section the parallel pattern of TDS at Vernalis estimated by means of Equation 5. To supplement the information on TDS at Vernalis provided in table VI-13, the earlier record of TDS based on the Mossdale experience and the predictor Equation 5 is summarized in table VI-14 covering the hydrologic years 1930 through December 1953. Together, tables VI-13 and VI-14 provide a continuous record of water quality experience at Vernalis from 1930 through 1969.

This water quality experience can be summarized in several ways.

Graphical summary. The graphical history of water quality at Vernalis is illustrated by average monthly TDS in figure VI-23, which shows the long term as well as the seasonal variability. The long-term changes are depicted by the 3-year moving average line presented in the plot of monthly TDS's at Vernalis. The short-term seasonal variations are evident in the month-by-month fluctuations.

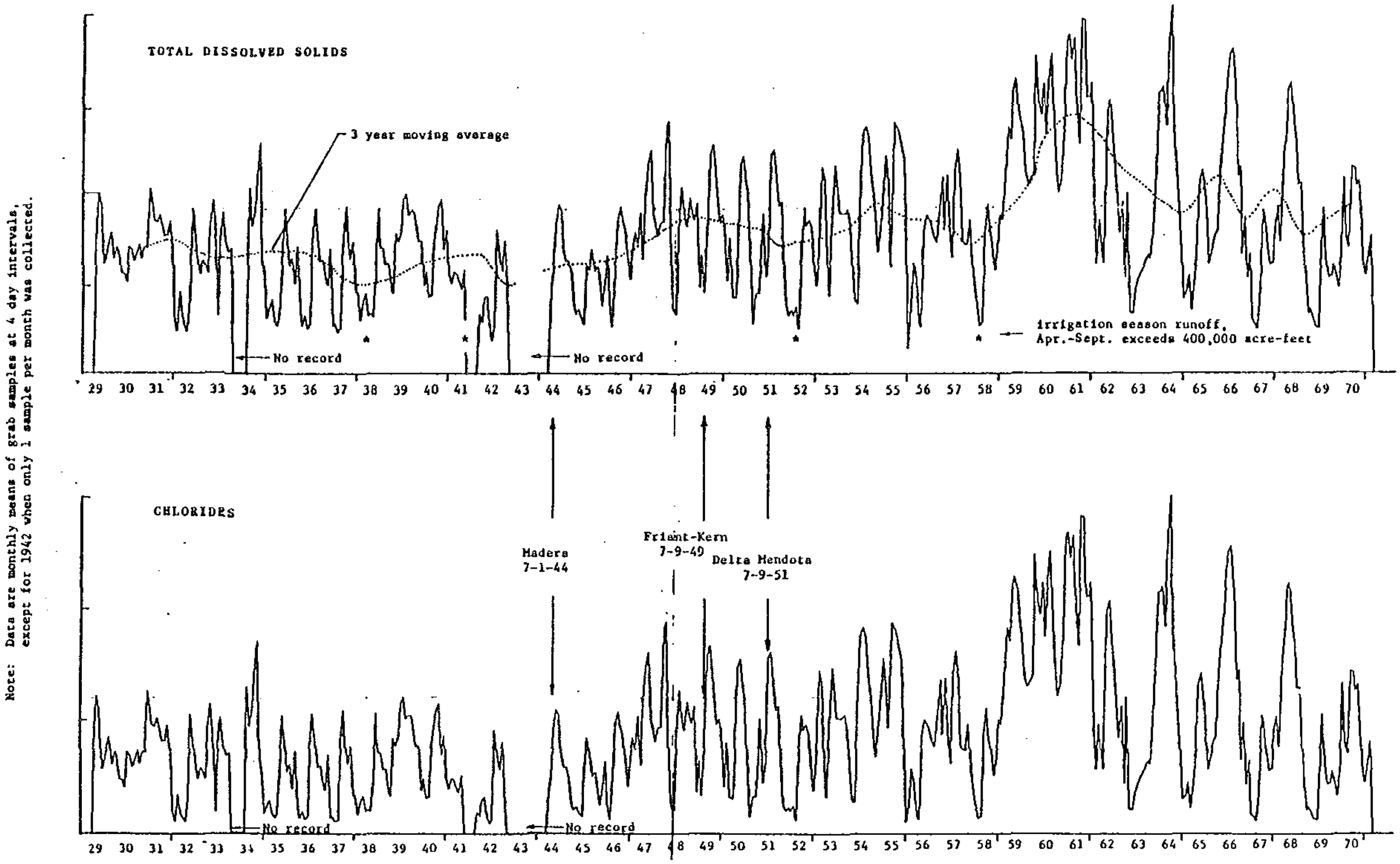


Figure VI-23 OBSERVED CHLORIDES AT MOSSDALE AND ESTIMATED TOTAL DISSOLVED SOLIDS AT VERNALIS 1929-1971

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Table-VI-14. MEAN MONTHLY TOTAL DISSOLVED SOLIDS AT VERNALIS*, mg/liter
Based on TDS (Vernalis): Chloride (Mossdale) Correlation
for period 1953-1970

Year	O	N	D	J	F	M	A	M	J	J	A	S
1929-30	237	275	303	234	266	255	194	191	171	266	258	228
30-31	249	272	234	266	263	409	383	333	328	347	320	292
31-32	292	331	266	100	59	151	93	68	59	137	357	292
32-33	243	194	228	216	194	317	381	317	97	278	352	283
33-34	254	263	-	-	-	-	-	-	419	301	368	444
34-35	517	251	200	93	116	134	89	76	93	213	355	286
35-36	216	237	168	269	112	76	100	68	80	275	360	295
36-37	228	231	194	165	261	76	80	59	68	289	367	286
37-38	237	281	151	151	89	130	148	100	104	97	187	363
38-39	266	260	219	222	158	148	300	280	303	381	396	347
39-40	355	355	328	281	281	165	197	141	144	281	330	368
40-41	384	261	309	197	168	197	191	168	158	203	-	-
41-42	-	-	-	97	85	134	144	80	54	72	320	258
42-43	222	292	165	-	-	-	-	-	-	-	-	-
43-44	-	-	-	-	-	-	-	165	200	322	370	355
44-45	266	228	228	194	119	104	116	93	80	222	303	261
45-46	203	216	187	123	171	243	130	72	203	336	365	338
46-47	311	249	178	246	303	275	355	234	386	464	496	349
47-48	333	295	328	331	548	559	309	119	104	306	414	355
48-49	320	389	362	336	376	161	246	151	286	486	510	471
49-50	399	333	347	320	175	289	141	137	184	462	481	422
50-51	402	261	80	148	148	206	349	184	246	483	496	432
51-52	368	378	252	123	100	112	100	119	68	269	357	310
52-53	336	314	206	165	252	457	426	234	144	325	462	404

*Estimated from the equation: $TDS\ (Vern) = 10[Cl(Moss)]^{0.77}$

Extreme values--maximum monthly TDS. Maximum monthly TDS values by year over the period 1930-1966 are depicted in the graph of figure VI-24. The figure summarizes the extremes in quality and flow during each year of record as tabulated in table VI-15. The triangles in the lower portion of the graph indicate the most critical quality (i.e., maximum TDS) occurrences in each of the indicated years within the period 1930-1944. The solid circles, largely occupying the upper portion of the graph, correspond to the critical occurrences in each of the years, 1952-1966. 1943-1951 are not plotted for reasons of clarity, although they generally are distributed in the region bounded by TDS values of 303 to 510 mg/L as will be seen in table VI-15.

Since a comparison of the pre-1944 and post-1947 conditions is germane, it may be noted further that the means and ranges corresponding to the two data sets* are as given in table VI-16 following.

Mean monthly values of TDS by decades. Using the average monthly values of TDS from tables VI-13 and VI-14 covering the period 1930 through 1969, it is possible to summarize the general trends of changes that have occurred for each month of the year. These trends are given by the mean 10-year values for each of the decades of the 1930's, 1940's, 1950's, and 1960's in table VI-17.

In a few cases, only 8 or 9 observations are included in the averages. These are noted by the asterisks ** and *. Also given in the table for later reference are the corresponding values of the mean monthly runoff by months (KAF) at Vernalis in the San Joaquin River.

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* It will be recalled that the mean annual unimpaired (rimflow) runoffs during the season April through September for these two periods, pre-1944 and post-1947, are comparable, the post-1947 period being slightly drier by approximately 5.6 percent.

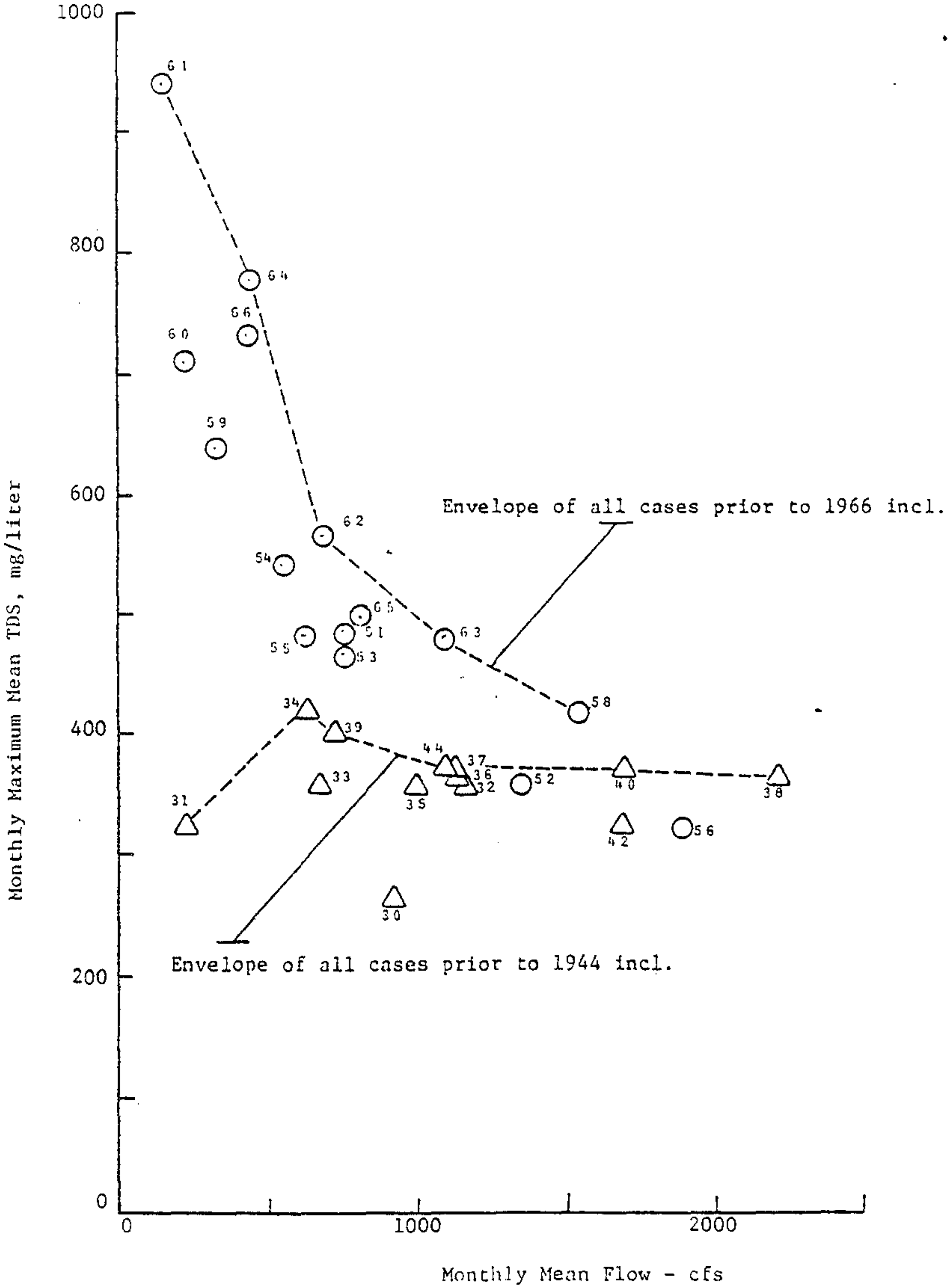


Figure VI- 24 WATER QUALITY AND FLOW EXTREMES AT VERNALIS
1930 - 1966

Table VI-15. EXTREME VALUES OF TDS AND FLOW AT VERNALIS, 1930-1966

Year	Maximum Monthly Mean TDS*	Minimum Monthly Mean Flow	
	MG/L	AF x 1000	CFS
1930	266	56.6	922
1931	320	14.0	228
1932	357	71.3	1161
1933	352	41.0	668
1934	419	37.3	628
1935	355	61.2	996
1936	360	69.0	1124
1937	367	69.4	1130
1938	363	132.0	2222
1939	396	44.0	717
1940	368	100.4	1690
1941	no data	114.0	1919
1942	320	103.6	1687
1943	no data	94.8	1544
1944	370	67.1	1093
1945	303	109.4	1782
1946	365	75.2	1263
1947	496	35.0	570
1948	414	44.6	726
1949	510	37.0	602
1950	481	38.2	622
1951	496	46.7	760
1952	357	83.3	1357
1953	462	46.0	749
1954	540	33.6	547
1955	476	36.3	611
1956	318	112.2	1887
1957	479	46.3	754
1958	417	94.4	1537
1959	634	19.2	313
1960	710	13.7	223
1961	941	9.3	151
1962	565	42.7	695
1963	477	67.4	1098
1964	774	27.1	441
1965	494	75.0	804
1966	729	27.0	439

*Extreme values occurred within the period June-Sept. Flow values correspond to the month in which maximum TDS occurred, 1930-1953 values based on Mossdale data.

TABLE VI-16. SUMMARY OF EXTREME WATER QUALITY CONDITION
APRIL - SEPTEMBER PERIOD

	1930-1944*	1952-1966
CRITICAL WATER QUALITY		
Monthly Mean TDS Mg/L		
Maximum for period	419	941
Mean for period	355	558
Minimum for period	266	318
LOW FLOW CONDITIONS		
Average daily flow ft^3/s corresponding to critical TDS		
Maximum	628	151
Mean	1182	774
Minimum	2222	1887

* Based on Mossdale data.

TABLE VI-17. MEAN MONTHLY RUNOFF AND TDS AT VERNALIS BY DECADES 1930-1969

Month	1930's ***		1940's ***		1950's		1960's	
	R KAF	TDS mg/L	R KAF	TDS mg/L	R KAF	TDS mg/L	R KAF	TDS mg/L
Oct	99	274	110	299**	102	355	98	460
Nov	107	260	129	258**	154	314	117	393
Dec	152	218*	194	261**	344	261	197	334
Jan	200	191*	299	225**	262	271*	294	379
Feb	455	169*	391	256**	280	256*	401	340
Mar	530	188*	505	230**	342	280	385	396*
Apr	503	196*	502	211**	429	287	397	368*
May	678	166*	639	136*	451	223	404	375
Jun	620	172	675	179*	376	231	393	401
Jul	204	258	191	299*	101	418	139	549
Aug	66	332	75	389	56	461	58	595
Sep	70	312	85	344	72	420	76	528
Mean	282.5	228	316.3	257	247.4	315	238.3	427

* Only 9 observations in 10 year period

** Only 8 observations in 10 year period

***Based on Mossdale data

Note: Although 10 runoff observations were recorded for each 10-year period, the values shown are averages for the same series for which TDS values are given.

Figure VI-25 shows graphically the trend of mean monthly TDS at Vernalis on a seasonal basis by decades, from the 1930's through the 1960's.

Relationship Between Mean Runoff and Mean TDS

Data presented in table VI-17 permit illustration of the changes in runoff and corresponding TDS values that have occurred during each of the decades since the 1930's. The relationships between these quantities are shown graphically in figures VI-26A, B, C, and D. The individual data points are identified by a number corresponding to the month of the year. Coordinates for each point were determined as the average monthly TDS and average monthly runoff without regard for year type (i.e., dry, below normal, above normal, wet).

Using figure VI-26A as illustrative of a normal pre-1950 cycle, it is noted that during the year the lowest runoff-highest TDS month is August (which is the case, incidentally, for all four decades). In succeeding months the TDS gradually drops as the average flow increases, although not in a linear fashion. The curve connecting the monthly points follows in a fairly smooth sequence through the winter and into the spring when the best quality is identified with the greatest monthly runoff (point 5 corresponding to May, the month of maximum runoff in the pre-1950 period). Thereafter the flow declines as the TDS level rises gradually, but at generally higher levels through the summer months. A somewhat similar pattern is seen for the 1940's (see figure 26B), although in this case the early spring months seem to reflect somewhat higher TDS levels. The range of flows and TDS are comparable to the 1930's. In the 1950's (see figure 26C) some of the same characteristics are noted although flows are less and TDS values higher. Also, less variation in TDS in relation to flow is noted during the winter and early spring months. In the 1960's (see figure 26D), the pattern is shifted decidedly upward and toward the left,

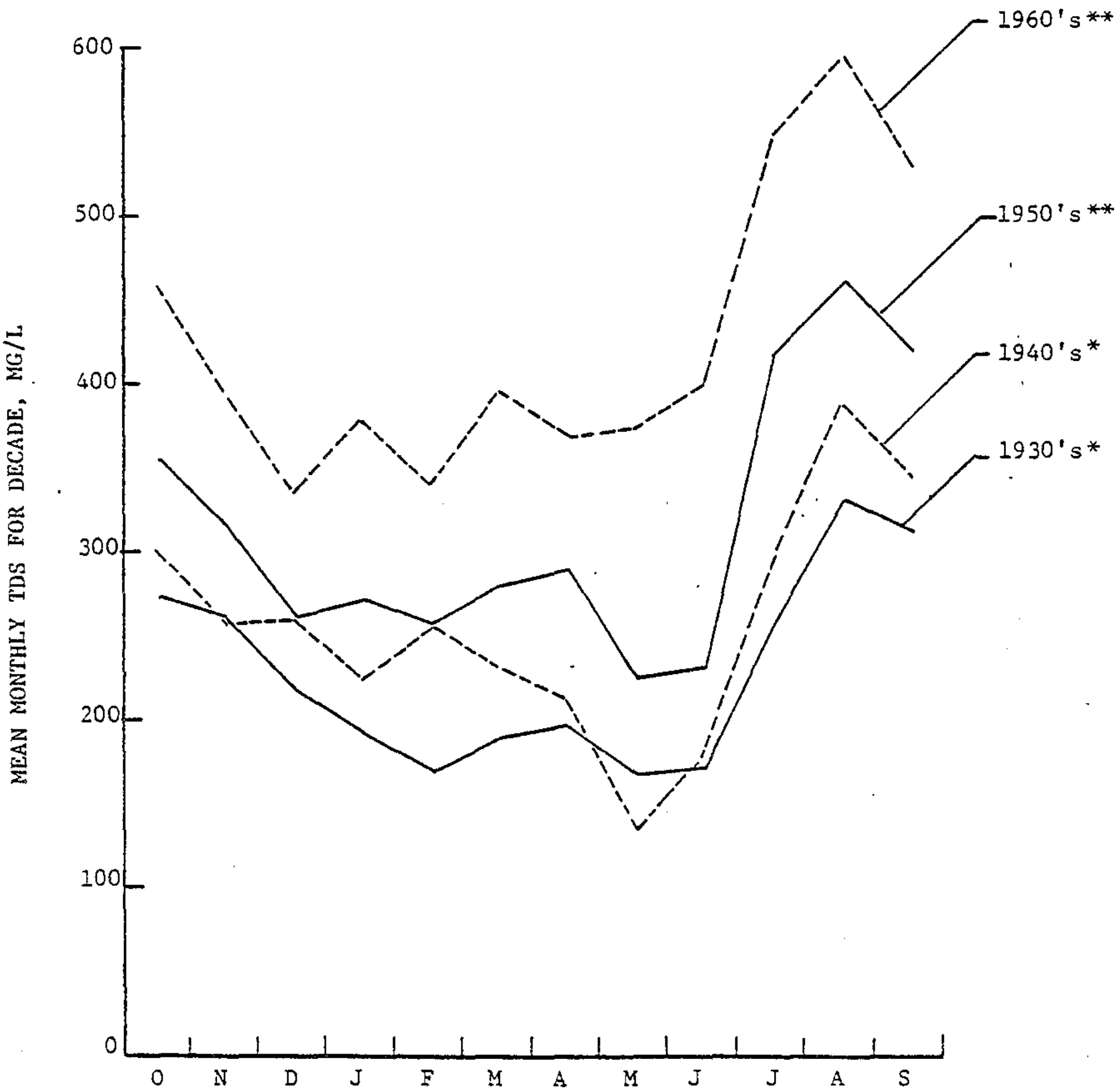


Figure VI-25 MEAN MONTHLY TDS AT VERNALIS BY DECADES 1930-1969
*Based on Mossdale chloride data
**Based on actual observations

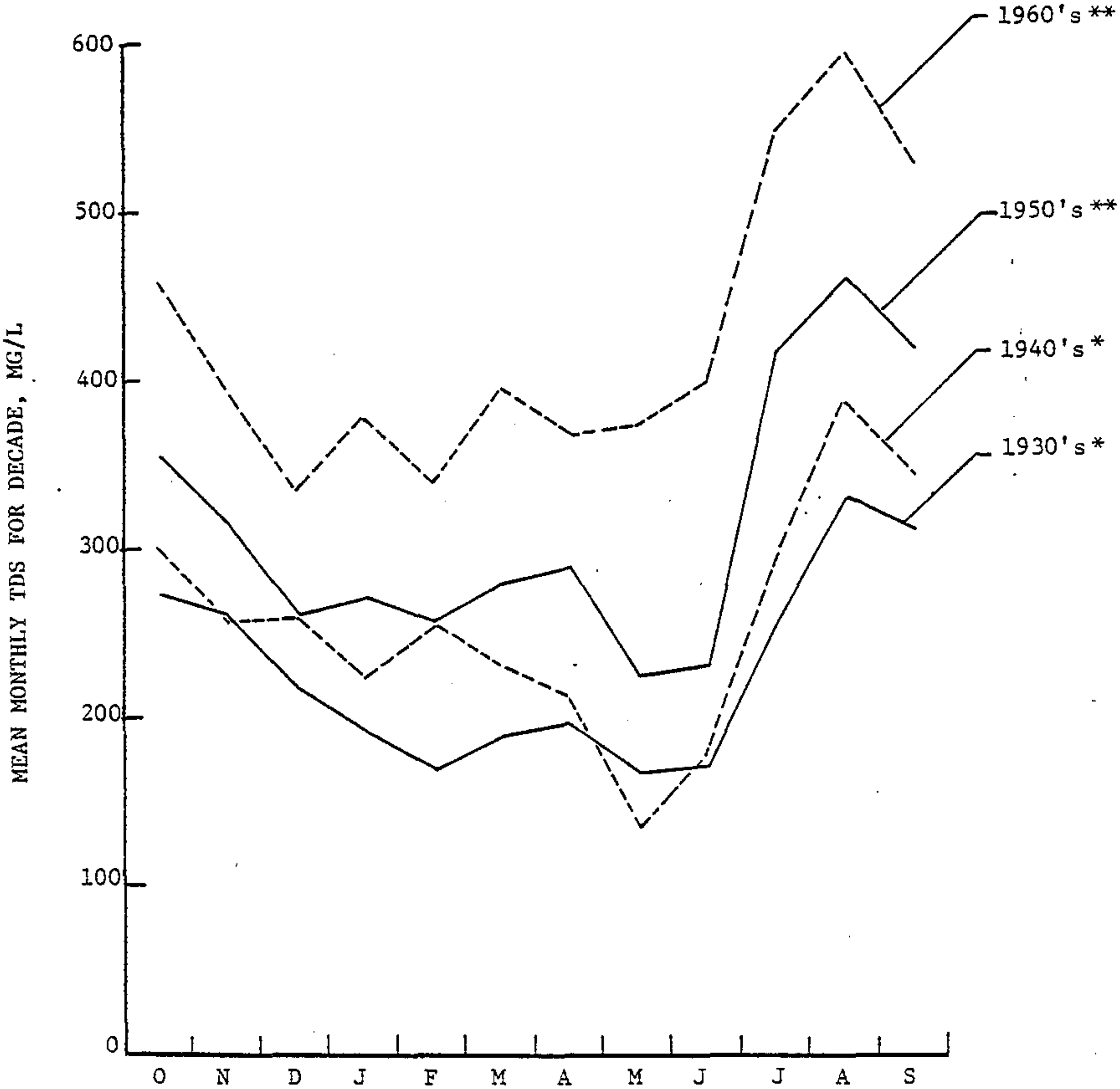


Figure VI-25 MEAN MONTHLY TDS AT VERNALIS BY DECADES
1930-1969
*Based on Mossdale chloride data
**Based on actual observations

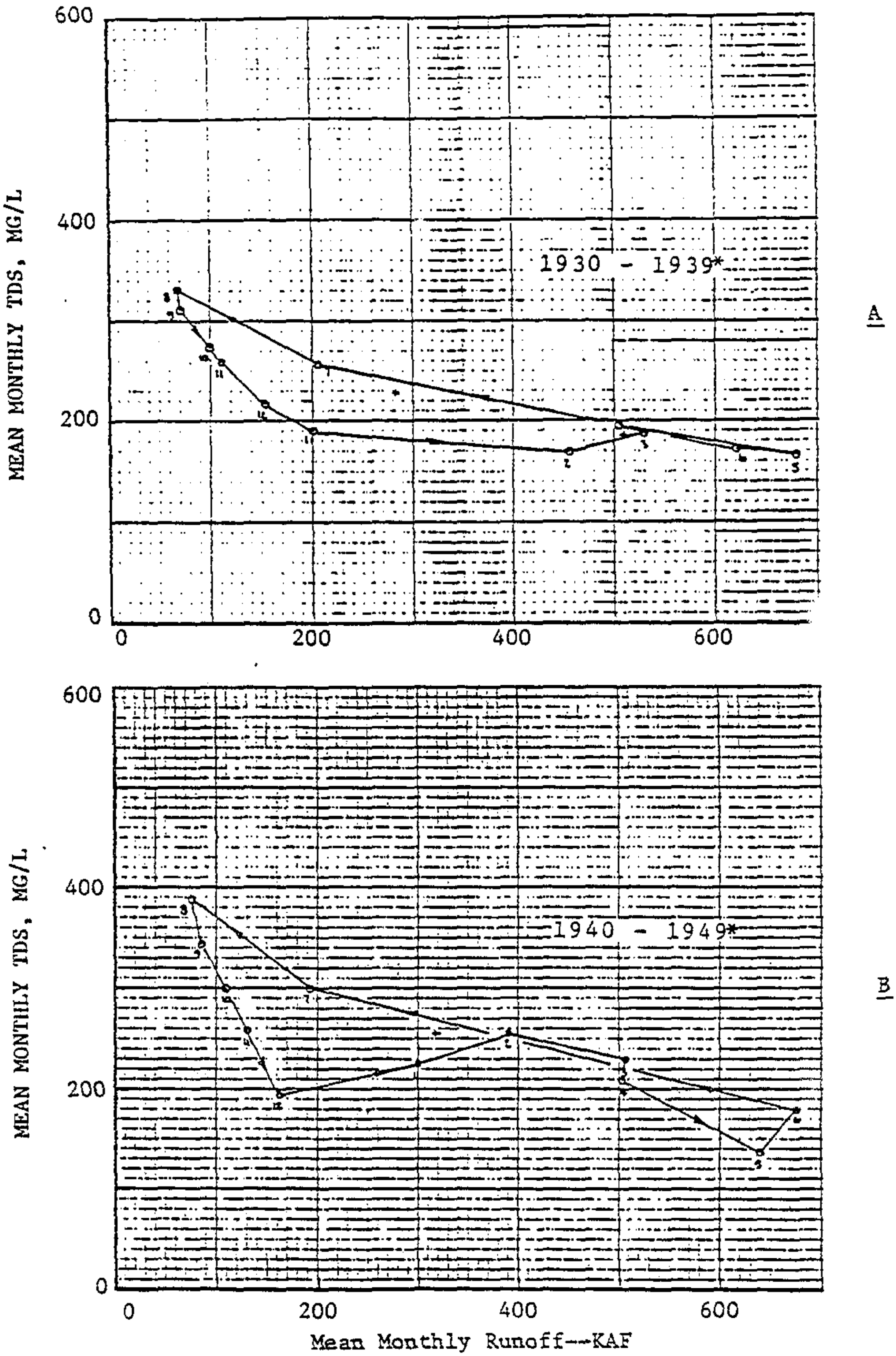
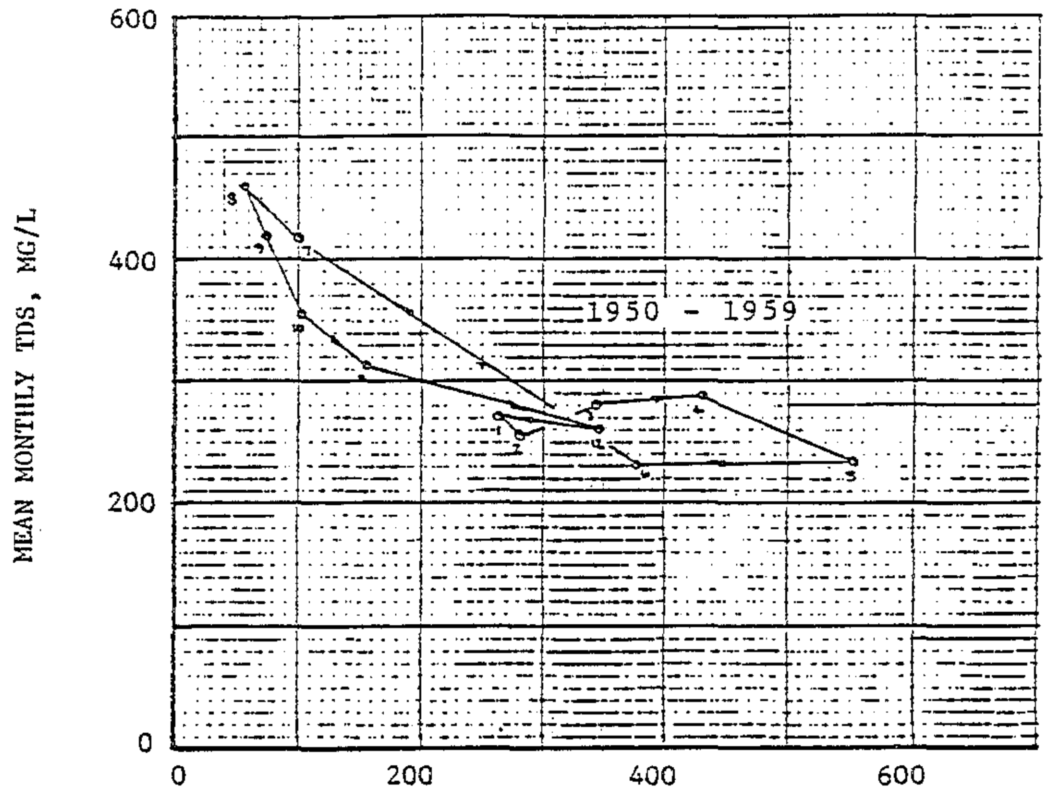
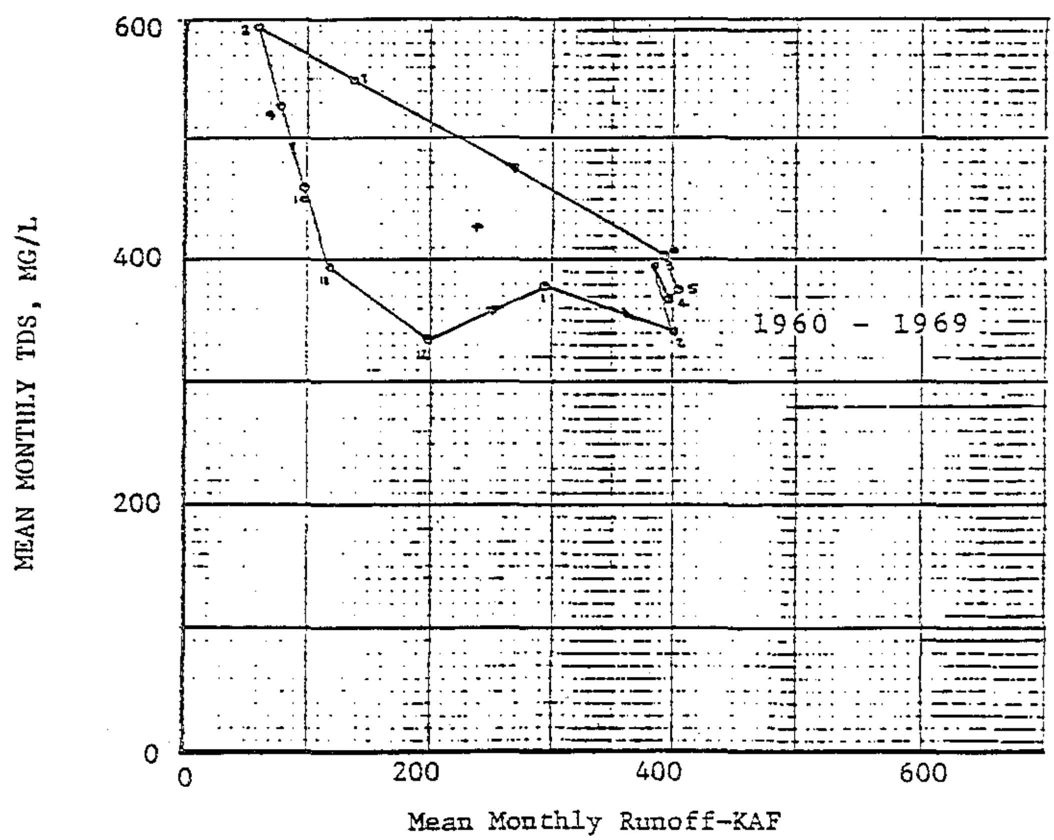


Figure VI-26 MEAN MONTHLY TDS (MG/L) VS. MEAN MONTHLY RUNOFF (KAF) FOR FOUR DECADES, 1930-1969

* Based on Mossdale data.



C



D

Figure VI-26 (Continued)

indicating substantial increases in salt load for the same levels of flow, and a generally decreased runoff, especially during the late winter and spring months (February through June). In all cases it is of interest to note:

1. The lowest runoff and poorest quality occurred in August.
2. The greatest runoff occurred in May or June (three times in May, one time in June).
3. A regular pattern of improving quality with increasing flow is identified with the period September through December.
4. Late spring and early summer months always show a tendency toward increased TDS as the flow decreases approaching the maximum in August.

Estimation Based on Chloride Load-Flow Relationships

To broaden the approach to prediction of pre-1953 water quality conditions at Vernalis on the San Joaquin River, an alternative method of analysis was developed. This method utilized chloride observations derived from monthly grab samplings at Vernalis for the period subsequent to 1938*. These data were combined with mean monthly flows to determine mean monthly chloride loads that, in turn, were correlated with Vernalis runoff to produce linear regressions of the power function form. Correlations were made for each month of record for the periods 1938 through 1949 and 1950 through 1969, respectively. Because these regression lines were fitted to a limited set of data (from six to ten data points in the 1938 to 1949 period) they were generally limited to the range of the data used, e.g., they were not considered reliable for very

* With the exception of some months during World War II when no samplings were made.

low flows, where they tended to give TDS predictions larger than had been observed historically. To correct for this limitation a new set of regression equations, the coefficients for which are summarized in table VI-7 for the Vernalis station, were prepared using an additional hypothetical chloride load-flow point corresponding to a TDS of 1,000 mg/L and a monthly flow of 0.5 KAF. Including this value in the data set had the effect of precluding TDS concentrations in excess of 1,000 mg/L*.

Although plots similar to figures VI-15 and VI-16 express quality in tons of chlorides, the chloride concentration in p/m is given by the following formula:

$$p/m = \frac{\text{Load}}{\text{Flow} \times 1.36}$$

where,

p/m = parts per million Cl^-
Load = chloride load in tons
Flow = 1,000's of acre-feet

Table VI-18 tabulates the mean monthly TDS values for the years 1930-1953 based on the chloride load flow regressions.

The extreme water quality conditions at Vernalis for the years 1930-66 are presented in table VI-19. A comparison of the pre-project years with post-project years is presented in table VI-20. These tables indicate that extreme water quality conditions at Vernalis are poorer for the post-project years, in terms of higher TDS concentrations and lower daily flows.

Applying the regression curves to the pre-1950 and 1950-1952 years and using actual data for the post-1952 years, table VI-21 can be used to compare the mean monthly water quality at Vernalis for the four decades being studied.

* Approximately the maximum mean monthly TDS during the 1977 drought.

TABLE VI-18. MEAN MONTHLY TOTAL DISSOLVED SOLIDS AT VERNALIS, MG/LITER, BASED ON CHLORIDE LOAD-FLOW REGRESSIONS FOR PERIOD 1930-1949

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
1930	338	309	310	241	267	245	168	159	204	378	421	376
1931	327	286	278	253	274	344	334	292	429	616	555	494
1932	417	359	314	199	140	196	138	95	111	238	403	396
1933	327	275	279	233	217	275	224	189	159	390	447	391
1934	333	291	261	211	241	277	270	253	364	523	501	456
1935	372	306	292	194	205	208	99	87	110	305	415	380
1936	312	273	256	200	135	141	103	86	123	293	405	383
1937	318	273	249	200	135	145	100	82	110	286	405	378
1938	318	272	211	166	112	111	89	76	86	179	333	349
1939	293	229	232	187	194	262	171	164	309	434	441	399
1940	335	296	293	187	150	140	97	90	124	335	402	366
1941	330	282	245	159	133	127	95	81	99	206	362	366
1942	306	260	217	152	134	164	102	87	99	217	376	358
1943	305	260	222	170	133	124	94	89	121	326	383	366
1944	310	273	262	213	218	197	176	132	188	378	407	388
1945	329	256	231	191	141	161	114	90	122	270	373	355
1946	290	234	207	147	171	214	128	92	154	362	399	374
1947	321	252	234	211	235	253	204	164	315	481	461	396
1948	343	280	287	262	342	384	209	122	134	372	441	395
1949	332	294	298	244	286	219	182	136	231	472	456	426
1950	420	351	351	288	269	343	192	174	169	506	566	514
1951	415	211	166	144	180	219	258	156	203	468	538	505
1952	390	342	293	153	174	181	117	92	93	298	464	458
1953	386	323	280	179	265	414	329	216	171	385	538	498

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1939	293	229	232	187	194	262	171	164	309	434	441	399
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1941	330	282	245	159	133	127	95	81	99	206	362	366
1942	306	260	217	152	134	164	102	87	99	217	376	358
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1945	329	256	231	191	141	161	114	90	122	270	373	355
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1953	386	323	280	179	265	414	329	216	171	385	538	498

TABLE VI-19. EXTREME VALUES OF TDS AND FLOW AT VERNALIS 1930-1966

Year	Maximum monthly mean TDS* mg/L	Minimum monthly mean flow KAF	ft^3/s
1930	421	56.6	921
1931	616	14.0	228
1932	403	71.3	1160
1933	447	41.0	667
1934	523	23.6	384
1935	415	61.2	995
1936	405	69.0	1122
1937	405	69.4	1129
1938	349	132.4	2225
1939	441	44.0	716
1940	402	72.9	1186
1941	366	100.3	1686
1942	376	103.6	1685
1943	383	94.8	1542
1944	407	67.1	1091
1945	373	109.4	1779
1946	399	75.3	1225
1947	481	32.4	527
1948	441	44.6	725
1949	472	34.6	563
1950	566	38.2	621
1951	538	46.7	760
1952	464	83.3	1355
1953	538	46.0	748
1954	540	33.6	547
1955	476	36.3	611
1956	318	112.2	1887
1957	479	46.3	754
1958	417	94.4	1537
1959	634	19.2	313
1960	710	13.7	223
1961	941	9.3	151
1962	565	42.7	695
1963	477	67.4	1098
1964	774	27.1	441
1965	494	75.0	804
1966	729	27.0	439

*Extreme values occurred within the period June-September. Flow values correspond to the month in which maximum TDS occurred. 1930-53 values based on load-flow regressions.

TABLE VI-18. MEAN MONTHLY TOTAL DISSOLVED SOLIDS AT VERNALIS, MG/LITER, BASED ON CHLORIDE LOAD-FLOW REGRESSIONS FOR PERIOD 1930-1949

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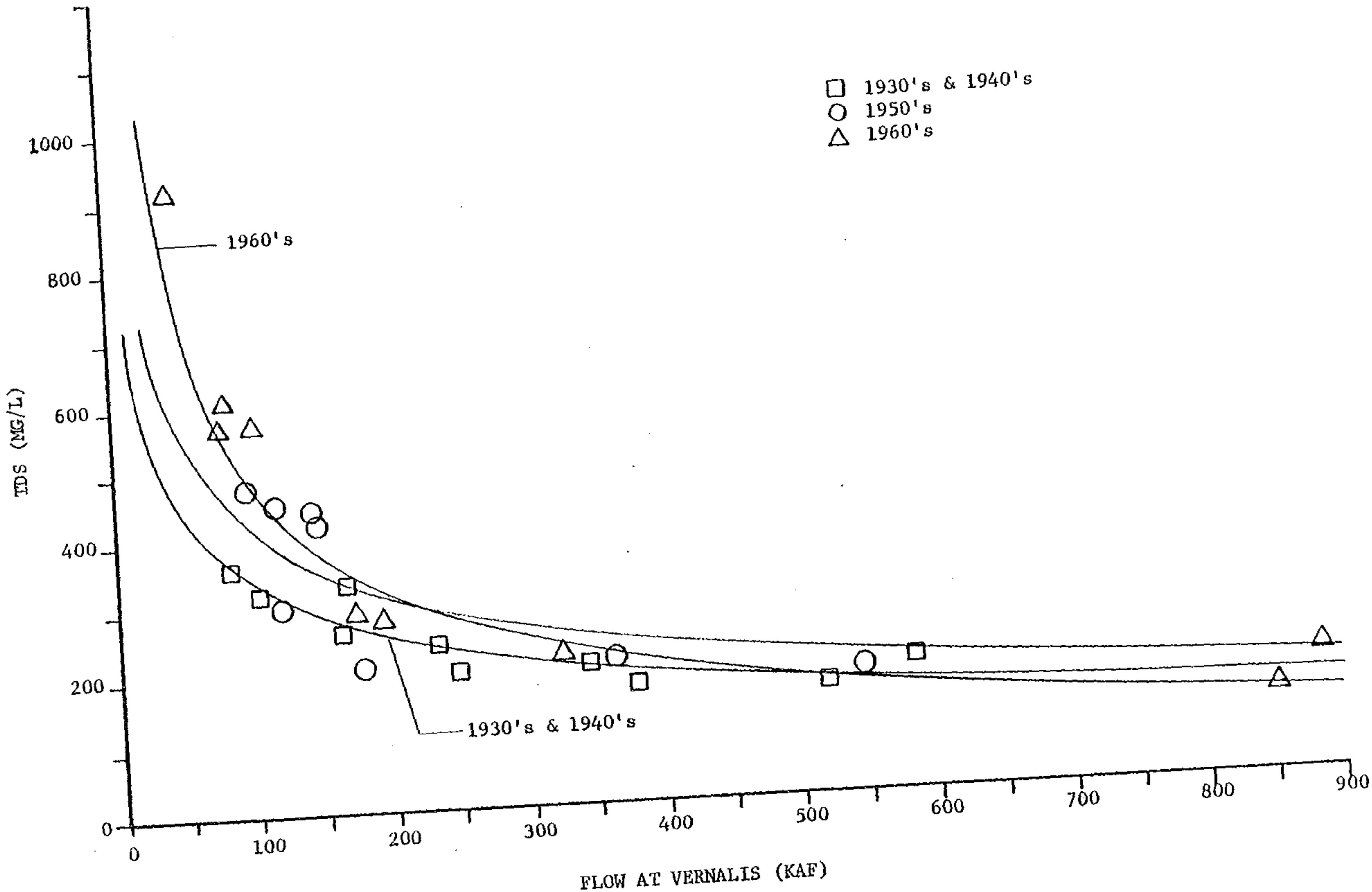
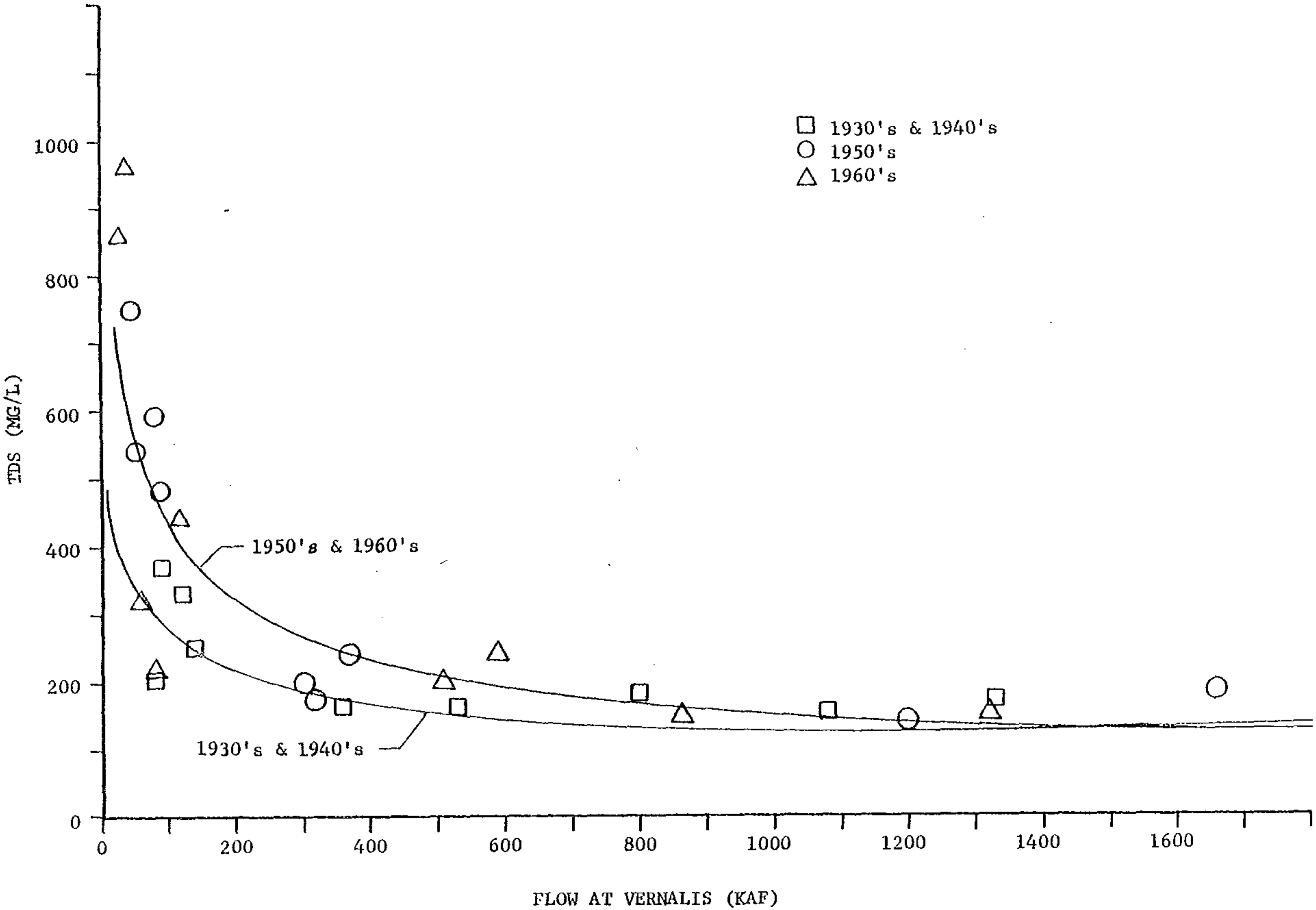
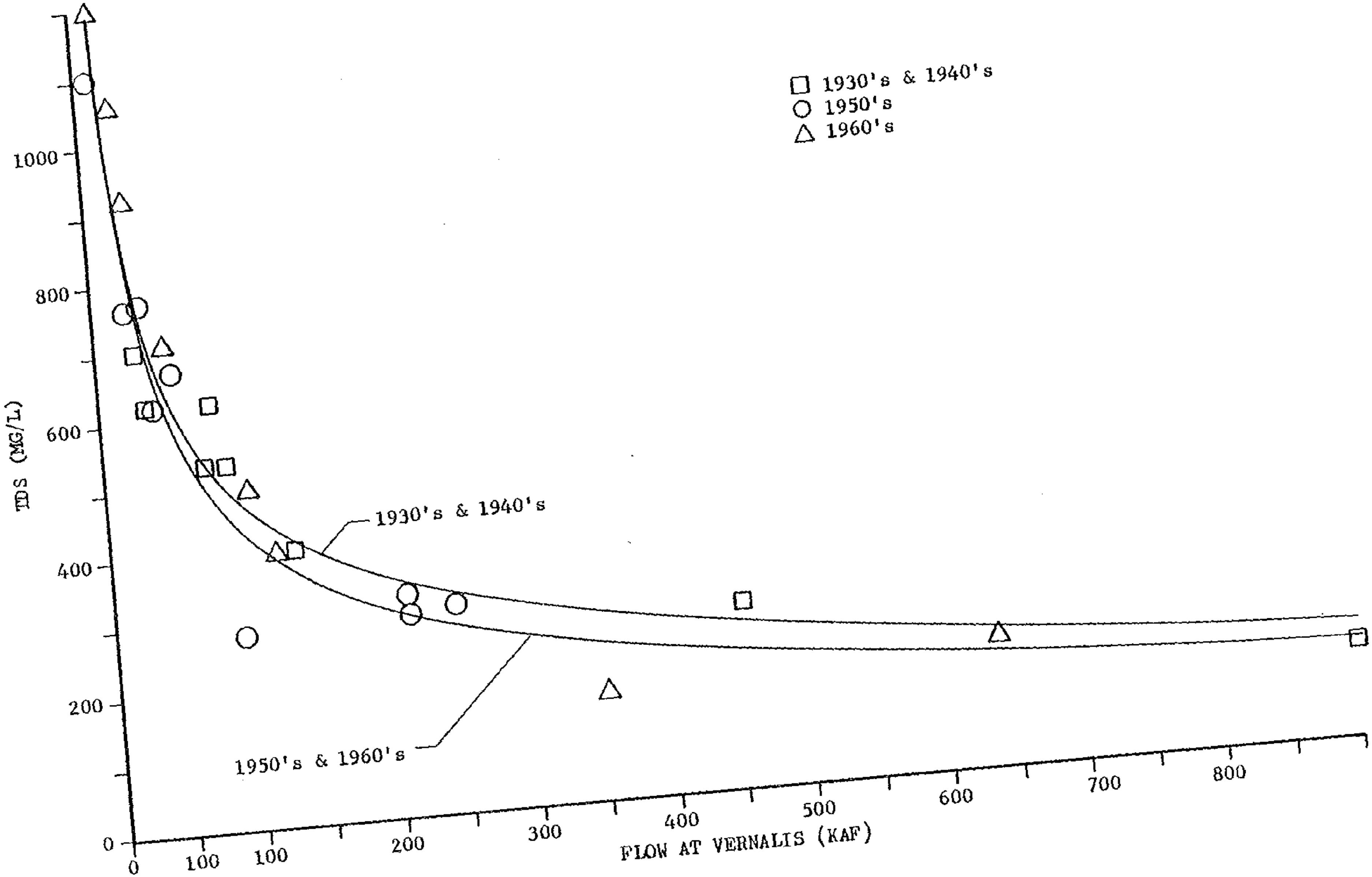


Figure VI-12 QUALITY-FLOW RELATIONSHIPS
SAN JOAQUIN RIVER AT VERNALIS - JANUARY


1930's & 1940's
1950's
1960's
1000
800
600
400
200
0
TDS (MG/L)
1950's & 1960's
1930's & 1940's
0
200
400
600
800
1000
1200
1400
1600
FLOW AT VERNALIS (KAF)



QUALITY-FLOW RELATIONSHIPS
VERNALIS - JULY

TABLE VI-20. SUMMARY OF EXTREME WATER QUALITY CONDITION
APRIL - SEPTEMBER PERIOD

	1930-1944*	1952-1966
CRITICAL WATER QUALITY		
Monthly mean TDS mg/L		
Maximum for period	616	941
Mean for period	424	558
Minimum for period	349	318
LOW FLOW CONDITIONS		
Average daily flow ft^3/s corresponding to critical TDS		
Maximum	228	151
Mean	1107	774
Minimum	2225	1887

* Based on load-flow regression curves.

TABLE VI-21. MEAN MONTHLY RUNOFF AND TDS AT VERNALIS BY DECADES 1930-1969

Month	1930's***		1940's***		1950's		1960's	
	R KAF	TDS mg/L	R KAF	TDS mg/L	R KAF	TDS mg/L	R KAF	TDS mg/L
Oct	99	336	115	320	102	355	98	460
Nov	107	287	129	269	154	314	117	393
Dec	152	268	200	250	344	261	197	334
Jan	197	208	291	194	262	271*	294	379
Feb	420	192	401	194	280	256*	401	340
Mar	488	220	564	209	342	280	385	396*
Apr	457	170	518	140	429	287	397	368*
May	613	148	667	108	451	223	404	375
Jun	620	201	590	159	376	231	393	401
Jul	204	364	185	342	101	418	139	549
Aug	66	433	75	406	56	461	58	595
Sept	70	400	85	379	72	420	76	528
Mean	291	269	318	248	247	315	238	427

* Only 9 observations in 10 year period

** Only 8 observations in 10 year period

*** Based on load-flow regression curves

NOTE: Although 10 runoff observations were recorded for each 10-year period, the values shown are averages for the same series for which TDS values are given.

monthly water quality at Vernalis for the four decades being studied. Figure VI-27 presents graphically the same data. It is apparent that during the 1950's and 1960's water quality at Vernalis has experienced some degradation. Particularly notable is the decade of the 1960's in which mean monthly water quality is poorer in all months to the extent of several hundred mg/L TDS in some months.

Data presented in table VI-21 illustrate the changes in runoff and corresponding TDS values that have occurred during each of the decades since the 1930's. The relationships between these quantities are shown graphically in figures VI-28A and B, for the 1930's and 1940's. The 1950's and 1960's data are the same as those used in the Mossdale discussion (see figures VI-26C & D). Individual data points are identified by a number corresponding to the month of the year. Coordinates for each point were determined as the average monthly TDS and average monthly runoff without regard for year type (i.e., dry, below normal, above normal, wet).

As an illustration of a pre-1950 cycle, figure VI-28A shows that the lowest runoff - highest TDS month is August. With succeeding months the TDS drops as the flow increases until May when the best quality is identified with a high average runoff. In June, runoff is about that of May; however, the TDS concentration begins to increase. July and August both show a reduction of runoff and an increase in TDS concentration with the greatest changes occurring in July. A similar pattern is exhibited in the 1940's with some slight changes in the March through June period. A description of the 1950's and 1960's is contained in the discussion of results based on the Mossdale chloride data. In each of the decades the following statements are valid for average conditions:

1. The lowest runoff and poorest quality occurred in August.
2. The greatest runoff occurred in May or June.

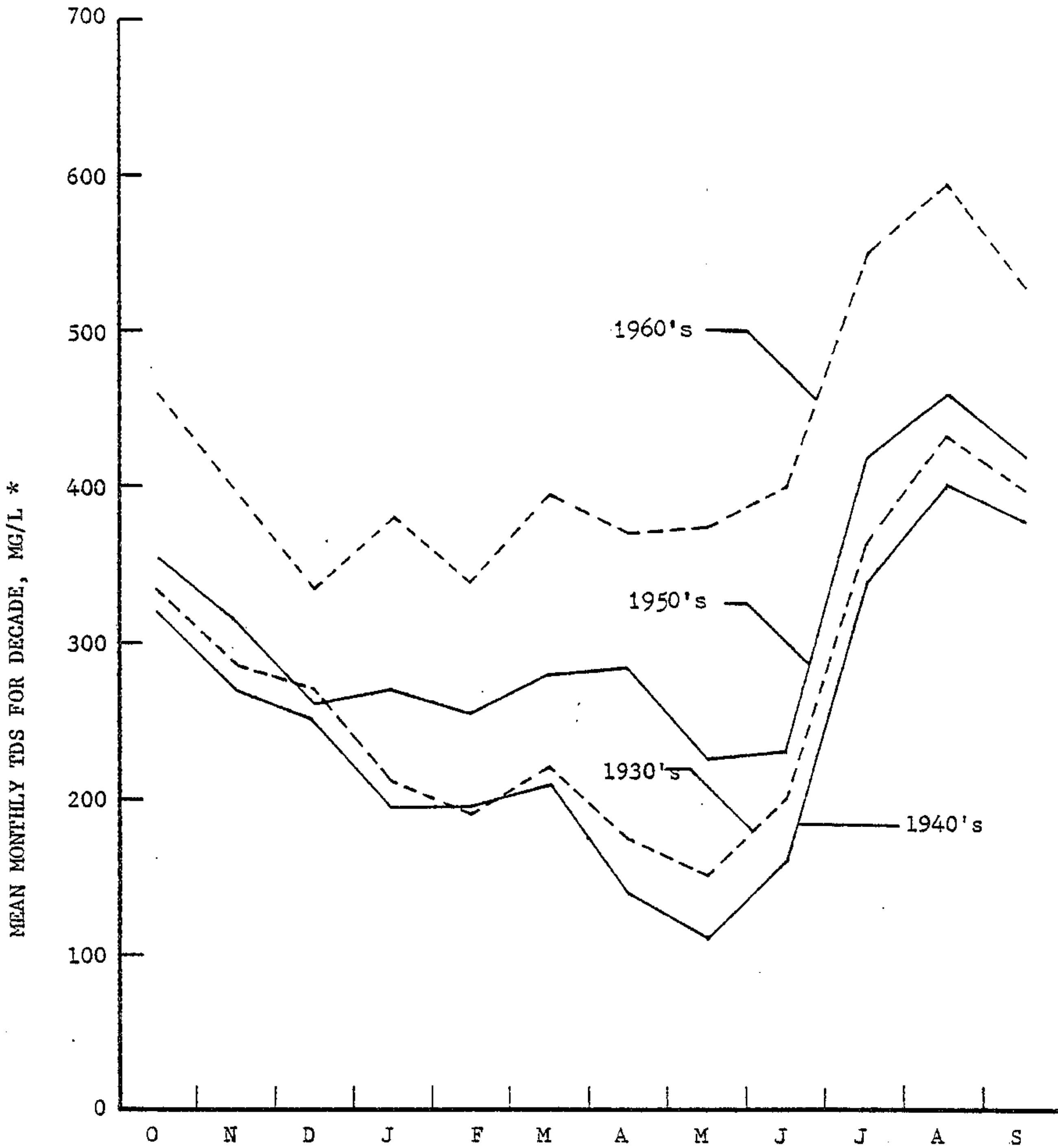
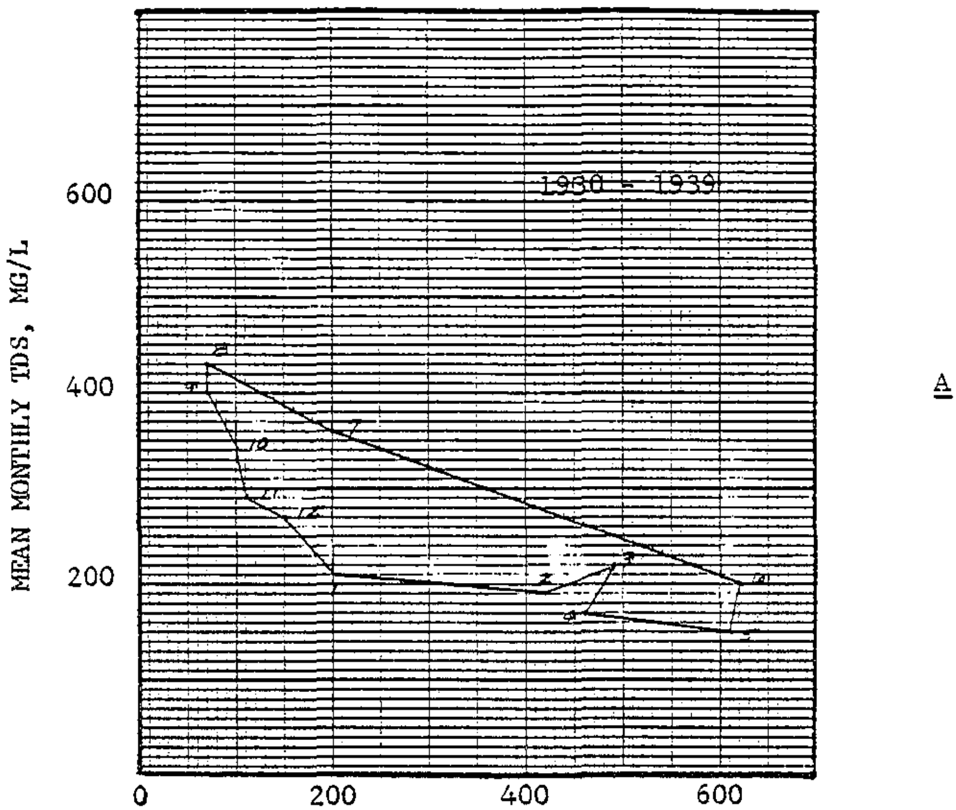


Figure VI-27 MEAN MONTHLY TDS AT VERNALIS BY DECADES 1930-1969

* Estimated by chloride load-flow regressions for 30's and 40's.



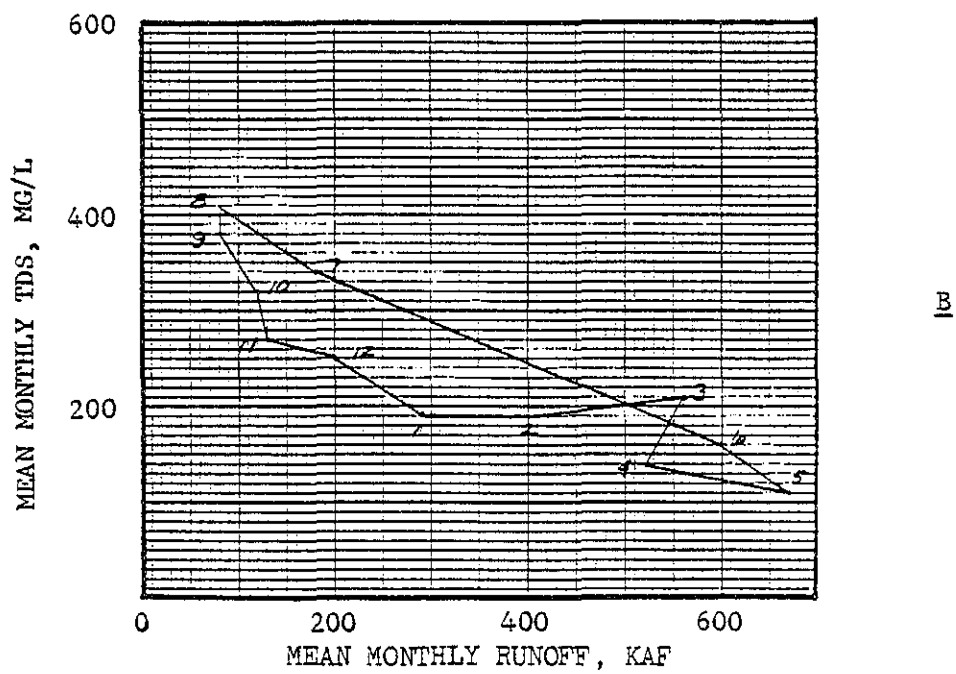


Figure VI-28 MEAN MONTHLY TDS (mg/L) VS. MEAN MONTHLY RUNOFF (KAF) FOR TWO DECADES, 1930-1949, BASED ON CHLORIDE LOAD-FLOW RELATIONSHIPS

3. A regular pattern of improving quality with increasing flow is identified with the period September through December.

4. Late spring and early summer months show a tendency toward increased TDS as the flow decreases approaching a maximum in August.

SECTION D. EFFECT OF TUOLUMNE GAS WELLS

Since the 1920's and until very recently, a group of about 10 exploratory gas wells, located along the Tuolumne River in the reach from Hickman to the mouth, have been contributing flows of very saline water to the river. The salt contribution of these wells, which has been estimated to range from 7,000 to 10,000 tons per month of TDS, is reflected in an overall increase in the salinity of the Tuolumne River, which depends upon the discharge from upstream sources not affected by the wells and to a lesser extent upon local returns of irrigation drainage water. In turn, because the Tuolumne contributes to the San Joaquin flow, there is an impact of these gas wells on the quality of water reaching Vernalis. It is not known whether there has been a significant change in the salt output of the wells over the period studied, i.e., from 1930 through 1966, but in 1977 concerted efforts were made to seal the wells and thus reduce the contribution of salts to the river. The effectiveness of these efforts has not yet been assessed.

The variation in salt concentration (represented by electrical conductivity, EC) in the Tuolumne River in relation to flow is summarized for three different locations in figure VI-29. The actual data shown are for the period 1960-1965, inclusive, and correspond to grab samples collected by the USGS at the several locations (approximately 1 sample per month). Curves of hyperbolic form are plotted to represent the data, indicating generally that as flows in the river increase (the gas wells flows are considered nearly constant over the

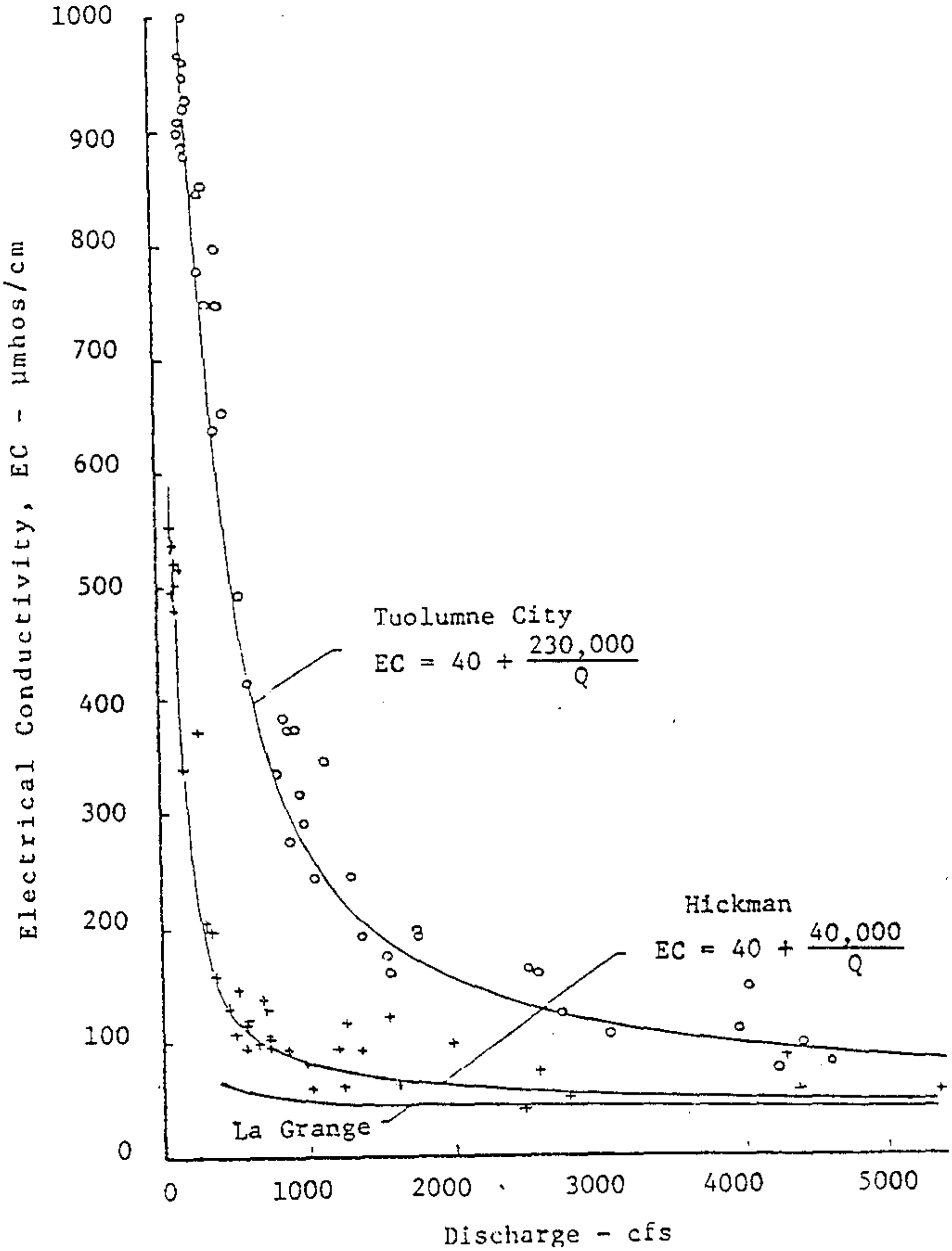


Figure VI- 29 QUALITY-FLOW RELATIONSHIPS
TUOLUMNE RIVER

year) the quality improves, but at very low flows the quality may be dominated by the gas well salt load. Assuming a constant accretion of salt (tons per month), it is estimated that about one-sixth of the salt is contributed by two wells above Hickman and the remaining five-sixths by the several wells between Hickman and Tuolumne City, near the river's mouth. This analysis, which presumes a constant strength of the wells, indicates a total load as high as 10,800 tons TDS per month, although estimates by the Central Valley Regional Water Quality Control Board, based on direct sampling and analysis of the well water, indicate smaller loads--about 6,000 tons per month. Differences between these estimates may be attributed, in part, to the effects of drainage returns in the lower reach of the river. These are reflected, however, by the total salt load estimated at Tuolumne City (see figures VI-18 to 21).

Analysis of chloride data for the period 1938 through 1969, for four seasonal periods (November-January, February- April, May-July, and August-October) indicate similar relationships between chloride concentration and flow in the Tuolumne to those depicted in figure VI-29 for EC versus flow. Results of this analysis, which characterizes C1 versus flow in the form of

$$Cl^- = C_1 \text{ (Flow)}^{C_2} \quad \text{(VI-6)}$$

where

Cl^- = monthly average concentration of chlorides, mg/L

Flow = average monthly runoff, cfs

C_1, C_2 = constants

are summarized in table VI-22.

The coefficients given correspond to the statistical "best fit" lines of the relationship presumed in equation VI-6. The coefficient of correlation, R, indicates the reliability of the equation in predicting the values actually observed, R = 1.0, corresponding to a perfect fit.

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are summarized in table VI-22.

The coefficients given correspond to the statistical "best fit" lines of the relationship presumed in equation VI-6. The coefficient of correlation, R, indicates the reliability of the equation in predicting the values actually observed, R = 1.0, corresponding to a perfect fit.

A summary of predicted values of chlorides for various levels of flow, corresponding to each of the seasonal and chronological periods, studied, is presented in table VI-23. Estimates are also shown for electrical conductivity (EC) based on the relationship

$$EC = 8.82\ (Cl^-)^{0.88} \qquad (VI-7)$$

where

EC = electrical conductivity, umhos/cm @ 25 °C

Cl = chlorides, mg/L

which was derived from USGS data for the period 1960-65. For purposes of graphical comparison, the resulting EC versus flow relationships are shown in figure VI-30, together with the 1960-1965 data for Tuolumne City, shown also in figure VI-29.

SECTION E. IMPACT OF UPSTREAM DEVELOPMENT ON QUALITY DEGRADATION OF THE SAN JOAQUIN RIVER SYSTEM

The preceding sections of this chapter have dealt with the changes that have occurred historically in the San Joaquin River system, dating from about 1930 and extending through the 1960's. Data has been presented to indicate the changes in quality that have been experienced at the lower extremity of the system, near Vernalis and at Mossdale 16 miles downstream and within the South Delta Water Agency. Data on the composition and quantity of salt accretion to the river system from various sources from Mendota downstream to Vernalis have been described. Finally, two methods of estimating the missing quality data for the early years of the study have been developed. For the benefit of the reader who may have elected not to read sections A, B, C, and D, a summary of each section is included here.

Table VI-23. PREDICTED CHLORIDE CONCENTRATIONS IN THE TUOLUMNE RIVER AT TUOLUMNE CITY, AUGUST THROUGH OCTOBER, FOR SEVERAL CHRONOLOGICAL PERIODS .

	CHRONOLOGICAL PERIOD					
Flow	1938-49		1950-59		1960-69	
cfs	Cl*	EC**	Cl	EC	Cl	EC
250	164	784	189	889	194	909
500	87	449	114	570	109	548
1000	46	258	68	361	61	329
2000	25	148	41	232	34	196
3000	17	107	30	176	25	147
5000	11	73	21	129	16	101

* From regression equation, Aug-Oct, Table VI-22, mg/L

** By correlation Cl vs EC, equation VI-7, µmhos/cm @ 25°C

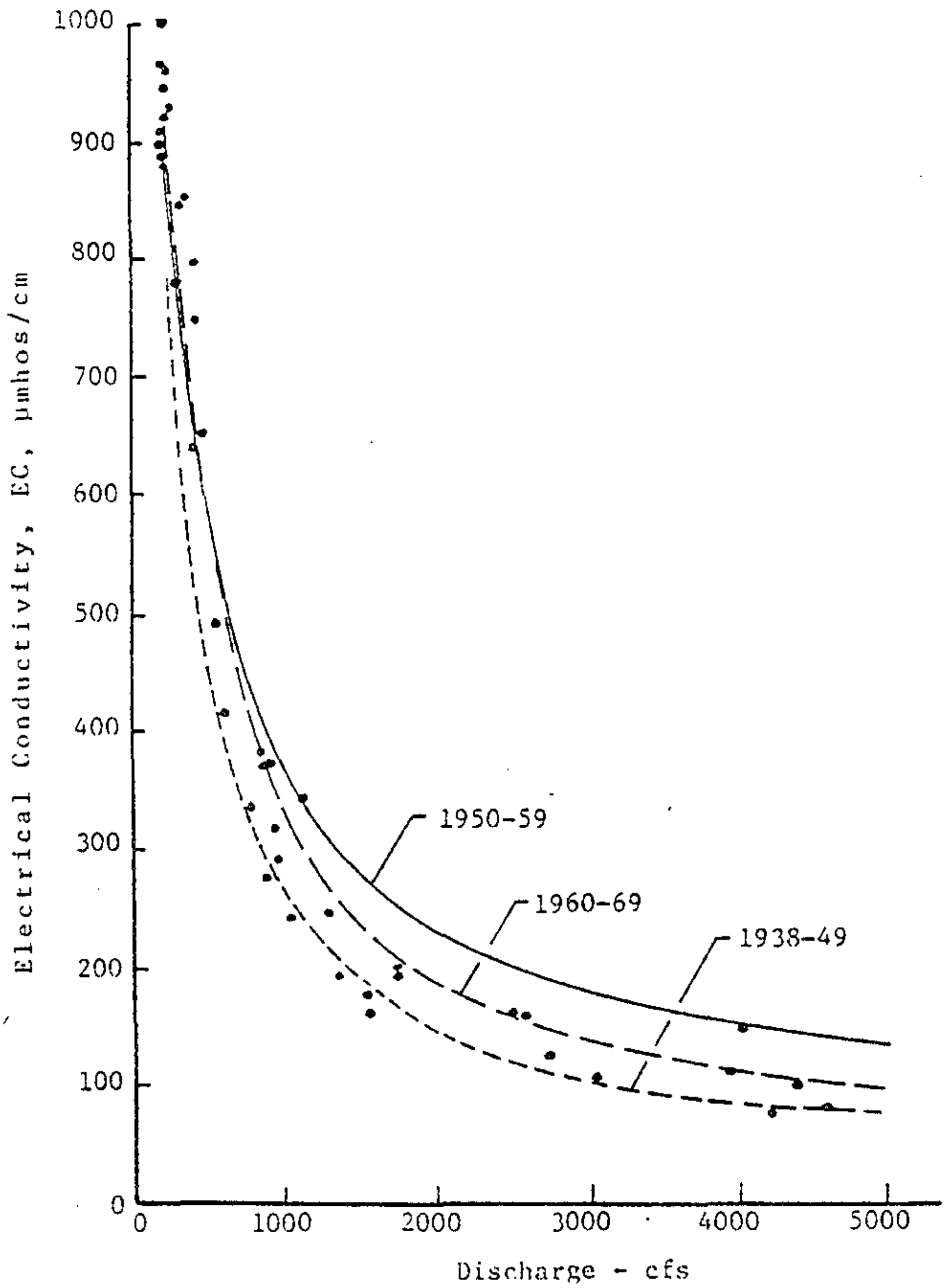

Figure VI-30 QUALITY-FLOW RELATIONSHIPS
TUOLUMNE RIVER, 1938-1969 (August-October)

Data shown are for period 1960-65, regression lines are described in Table VI-22

Data for Section A were developed to facilitate identification of the locations and the relative strengths of major contributions to the salt burden carried by the San Joaqin River from the vicinity of the Mendota Pool to Vernalis. This study of quality constituents was used in an effort to "fingerprint" the waters of various sources. In general, the data on quality constituents show the following:

1. There are distinctive differences between the qualities of eastside streams and the quality of water carried by the San Joaquin River along its main stem.
2. In the 1960's there is comparatively little difference between the quality and chemical composition of salts in drainage returns from the westside of the valley and the quality of water carried in the San Joaquin River from Mendota to Vernalis. Westside drainage is high in TDS, chlorides, sodium, sulfate, noncarbonate hardness, and boron, all of these properties being identified with soils of the area.
3. The effect of the flow from eastside tributaries has been largely one of dilution of salt loads carried by the river.

The properties of the salts carried by the San Joaquin River during periods of low flow appear to be dominated by westside accretions during the 1960's to a degree that they are hardly indistinguishable. To determine the relative contribution of several sources, the salt balance computations of Section B were performed.

Section B data were examined to determine trends in TDS salt load and TDS concentration at Vernalis. A study of monthly TDS load v. monthly Vernalis unimpaired rimflow was performed for the four months of October, January, April, and July. By grouping the data into subsets by decades, the results indicate that in general, the salt load has increased at Vernalis. Lines describing the "best fit" of the data oftentimes do not correlate very strongly but, the indication is that the salt loads have probably increased, while the magnitude of the load is not strongly dependent on unimparied rimflow (see figures VI-7 through VI-10).

A second study contained in Section B compares the TDS concentrations at Vernalis for various actual flows. Again, the data was divided into subsets by decades and "best fit" curves derived (see figures VI-11 through VI-14). Only the four representative months were studied, but the data supports a trend of higher TDS concentrations in the 1950's and 1960's than occurred in the 1940's and 1930's. An exception to this general statement is the month of July although no ready explanation is available for this difference from the other three months. the purpose of these first two studies was not to gain a quantitative description, but merely a qualitative insight to the situation at Vernalis.

The third portion of Section B, the salt balance computations, is used to determine the relative contribution of the several sources by combining the effects of flow and concentration. For comparison purposes, the years were grouped into water year classifications e.g., dry, below normal, above normal, and wet. Post-1947 results were then compared to pre-1944 years of the same type, much the same as was done in the water balance computations of Chapter 5.

The salt load at Vernalis has changed between the pre-1944 and post-1947 periods, the amount varying with the year classification. It appears that annual loads in the dry years increased 18 percent and below normal year annual loads increased 35 percent. Little or no annual load change is evident in above normal and wet years. In the dry and below normal years the biggest increase in load occurred in April when spring runoff is probably flushing the basin of some accumulated salts. Consistent with this observation, loads in July have decreased in dry and below normal years apparently due to a reduction in runoff. In general, it appears that in drier years, salts are accumulated in the basin during low flow summer and early fall months and then released during the high flow winter and spring months. Because a net increase in load has occurred, it seems likely that sources of salt are adding to the annual burden at Vernalis in dry and below normal years.

In order to evaluate the changes in TDS concentration that have occurred at Vernalis, a complete record of monthly values is necessary. Due to gaps in the Vernalis data two methods of estimating the missing values were developed in Section C. The first of these methods estimates Vernalis TDS based on a correlation with Mossdale chloride data. The second method estimates the Vernalis TDS based on actual flow at Vernalis. Results of the two methods vary slightly but generally compare favorably. For average conditions, the following statements are valid:

1. The lowest runoff and poorest quality occurred in August.
2. The greatest runoff occurred in May or June.
3. A regular pattern of improving quality with increasing flow is identified with the period September through December.
4. Late spring and early summer months show a tendency toward increased TDS as the flow decreases approaching a maximum in August.

The Tuolumne gas wells are a significant source of salt. The exploratory wells have been contributing highly saline flows since the 1920's estimated to be as much as 7,000 to 10,000 tons per month of TDS. The study contained in Section D indicates that no significant change has occurred in the contribution of the wells through the 1960's.

An attempt to seal the wells was instituted in 1977 but insufficient data are available to evaluate the effectiveness of the effort.

The remainder of Section E is a discussion of impacts on water quality at Vernalis utilizing the results of the preceeding sections. Because the impacts are based on the 1930's and 1940's period, and two methods were used to estimate the data for those years, two sets of results will be discussed, one based on Mossdale chloride data and one based on Vernalis chloride load-flow data.

The changes in quality that have occurred at Vernalis have been most notable during the drier years of record, especially during the spring and summer months of such years. Using the Mossdale data, extreme values of monthly average TDS followed a more or less regular pattern in the period prior to about 1944, ranging roughly between 300 and 400 mg/L, only slightly affected by the magnitude of runoff during the month (refer to figure VI-24). Since the predictions from regression curves are based on runoff, the magnitude of estimated TDS at Vernalis is affected by the flow and the lower envelope shown in figure VI-24 is modified upward.

The analysis of Mossdale data indicates that if there were any highly saline return flows during the 1930's-1940's period, they diminished in flow during dry periods in comparable degree to the reduction in flow of high quality waters. Chloride load-flow regression data indicate that, in the 1930's and 1940's, the quality of Vernalis water deteriorated with a reduction in flow, more or less as it did in the 1950's and 1960's, however, not as dramatically. For the years prior to 1950, the average difference in maximum monthly TDS estimated by both methods is 17 percent. Load-flow regression TDS values are, in most years, higher than Mossdale values, ranging from -10 percent in 1939, a dry year, to +93 percent in 1931, a dry year.

In the period subsequent to 1951, in distinct contrast, data indicates that a change occurred that was manifested by occasional very high levels of TDS correlatable to a high degree with a diminished flow in the river. Concentrations rose to 700 mg/L and above in several instances and exceeded 900 mg/L in 1961. This phenomenon was most evident in the late summer months--in almost every instance July or August proved to be the critical month--but it can be seen in the data of more recent years to be associated with the late spring and early summer periods when upstream diversions were most likely to influence the runoff reaching Vernalis.

A comparison of the four decades--the 1930's through the 1960's (see table VI-17)--indicates that the quality at Vernalis deteriorated at an accelerating rate relative to the decline in runoff. While the period (1930-1949) produced approximately the same annual average unimpaired runoff as the 1950-1969 period, the quality-flow relationship shifted markedly after the end of the earlier period. The average monthly runoff at Vernalis, which was about 300,000 acre-feet in the 1930's and 1940's, dropped by about 19 percent--to 243,000 acre-feet in the 1950's and 1960's (an average difference of 684,000 acre-feet per year). Over the same time span the average monthly TDS (over the entire year based on Mossdale chlorides for the 1930-1949 period) increased 53 percent--from about 243 mg/L to 371 mg/L. Comparing the 1950's and 1960's to the earlier two decades, the TDS increases are about 30 percent and 76 percent of the 1930-1949 average, respectively.

For a constant salt load it may be expected that a decrease in runoff at Vernalis would result in an increase in TDS. Comparing the average monthly TDS (over the entire year), load-flow regressions show a 1950-1969 increase of 43 percent--from 259 mg/L to 371 mg/L. For the 1950's alone, the percentage increase is about 22 percent and for the 1960's, 65 percent.

From these same data it is possible to estimate the proportionate degradation that occurred as a result of reduction of flow and as a result of added salt load in the system. Using the Mossdale data for the decades of the 1930's and 1940's as a base of reference (mean monthly runoff = 299.4 KAF and mean TDS = 242.5 mg/L), and assuming, first, no change in salt load, we find that due to runoff reduction alone in the 1950's we could expect an increase in TDS of about 40.5 mg/L. The difference in this increase and that which actually occurred, 72.5 mg/L, is 32.0 mg/L and must be attributed to an increase in salt burden carried by the river. Thus, according to this analysis, in this first decade after the CVP went into operation, about 56 percent of the increase in average TDS was caused simply by a reduction in flow from upstream sources; the remaining 44 percent was a result of increased salt burden, perhaps associated with an expansion of irrigated lands in the basin. Similarly, in the 1960's (compared to the 1930's and 1940's) about 27 percent of the average increase in TDS (184.5 x 0.27 = 50.0) can be accounted for by a reduction in flow and 73 percent attributed to increased salt burden. It is of interest to note here that the absolute change apparently caused by reduction in flow changed relatively little from the 1950's to the 1960's (from 41 to 50 mg/L) while that charged to an increase in salt burden increased about four times (from 33 to 134.5 mg/L). This is consistent with other analyses that indicate a progressive buildup in salt load in the San Joaquin system.*

Based on the load-flow regressions data for the 1930's and 1940's, the proportionate degradation that has occurred due to decreased flow and increased load is also calculated.*

1930' & 1940's average load = 747,740 tons**

1950's reduction due to flow = (50) (690) = 34,500 tons

1950's TDS increase due to flow = $\frac{747,740 - 34,500}{2,969}$ - 204 = 36 mg/L TDS

1950's TDS increase due to load = (277 - 36) - (204) = 37 mg/L TDS

1960's reduction due to flow = (50) x (700) = 35,000 tons

1960's TDS increase due to flow = $\frac{747,740 - 35,000}{2,959}$ - 204 = 37 mg/L TDS

1960's TDS increase due to load = (393 - 37) - (204) = 152 mg/L TDS

According to this analysis, in the 1950's a quality degradation of 36 mg/L TDS is due to a reduction in flow. The calculations show a slight degradation of 37 mg/L TDS due to load, or about 50 percent. The degradation due to load change is significantly greater in the 1960's, 152 mg/L TDS, while the degradation due to reduced flow, 37 mg/L TDS, is about the same as for the 1950's.

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* It is assumed in this analysis that water lost from the system would have a TDS of about 50 mg/L.

** Obtained by summation of average monthly saltloads for the period 1930-1949.

The chronological shifts in TDS concentration and salt loads, calculated by the Mossdale method, are depicted graphically in figures VI-31 and VI-32, in which the changes that have occurred (see table VI-17) in the 1950's and 1960's are related to the average of the earlier period. The relative concentration is noted to be greater than unity throughout the year in both decades, the maximum occurring in late spring and early summer. The rate of increase over time, indicated by the spacing between the curves, is seen as increasing in all months from the 1950's through the 1960's, with the greatest rate differences occurring in May and June.

Changes in salt load, i.e., the product of runoff and concentration, are indicated in figure VI-32 to have changed relatively little between the 1950's and the 1930's-1940's period. However, the salt load at Vernalis for the 1960's increased substantially in all months of the year, by amounts 40 percent or greater than for the period of the 1930's and 1940's, despite the fact that flows in this period were substantially reduced by upstream development. The average for the 12-month period of the 1960's was about 152 percent of the 1930's-1940's level. For the 1950's, the average was about 110 percent.

Chronological shifts in TDS concentration and salt loads as determined by the load-flow regressions are presented in figures VI-33 and VI-34. Monthly changes that have occurred in the 1950's and 1960's (see table VI-21) are related to the average of the 1930's and 1940's. Relative concentrations are greater than unity for all months in the 1950's and 1960's. The greatest rate of increase over time for both the 1950's and 1960's is seen in April and May.

The changes in salt load, i.e., the product of runoff and concentration, are indicated in figure VI-34. The 1950's show some change in load over the

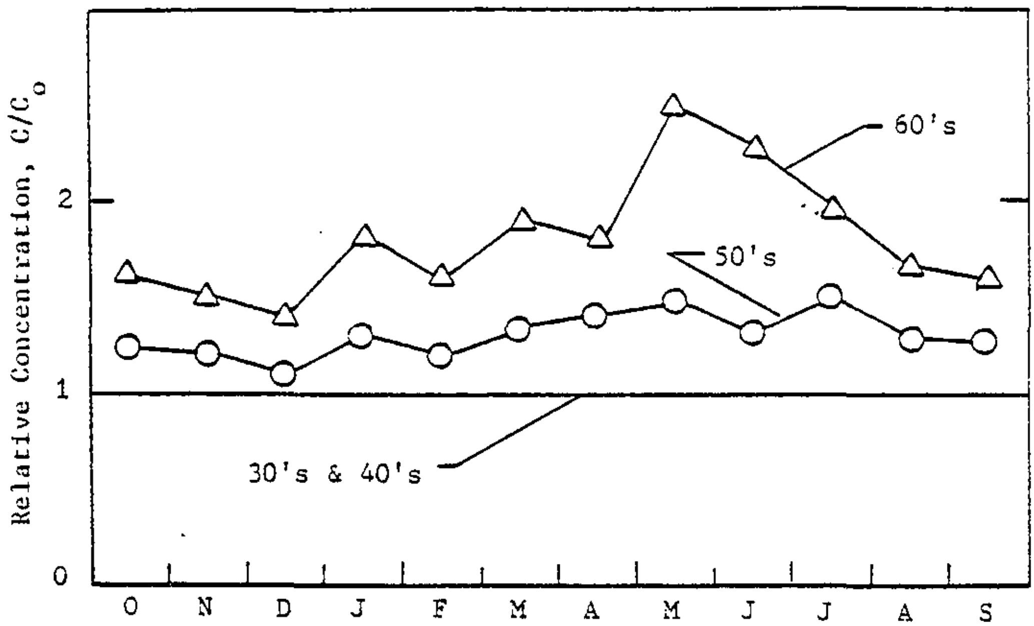

Figure VI-31 RELATIVE TDS CONCENTRATION AT VERNALIS BY DECADES, 1930-1969

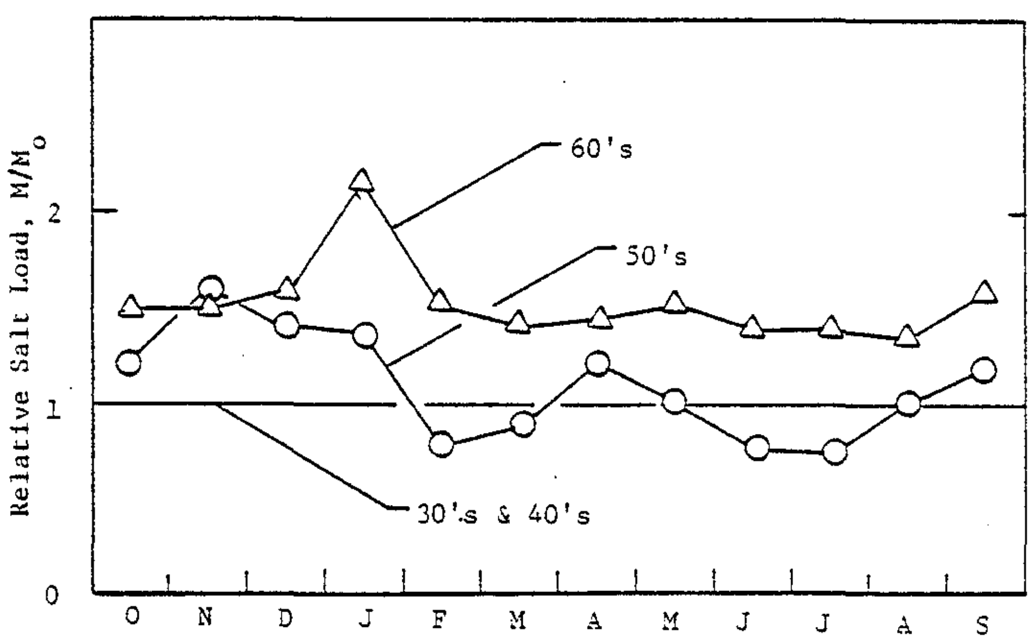

Figure VI- 32 RELATIVE TDS SALT LOAD AT VERNALIS BY DECADES, 1930-1969

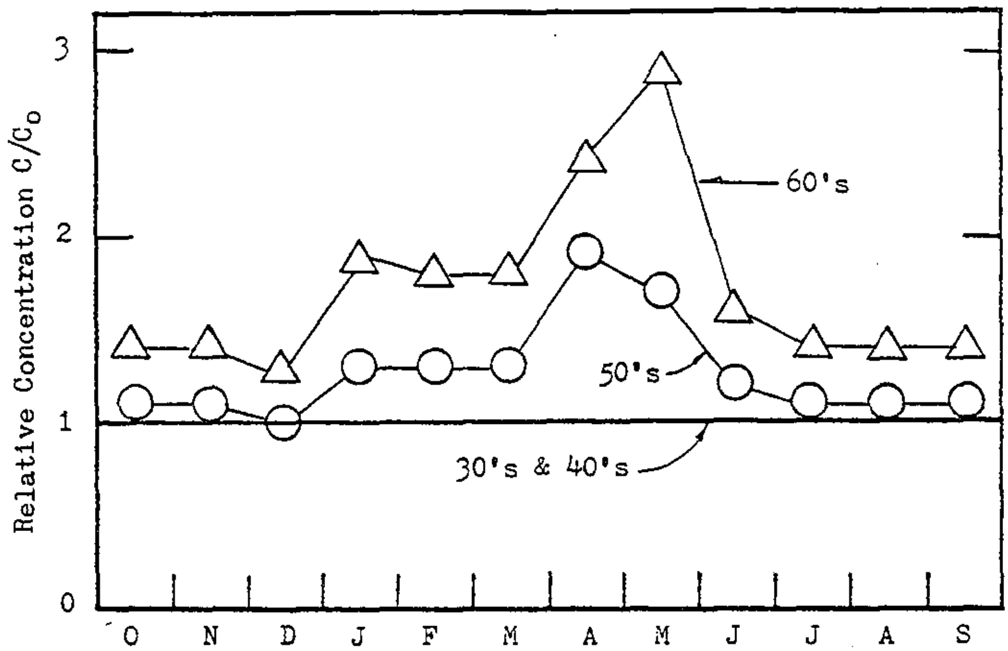

Figure VI-33 RELATIVE TDS CONCENTRATION AT VERNALIS BY DECADES, 1930-1969*

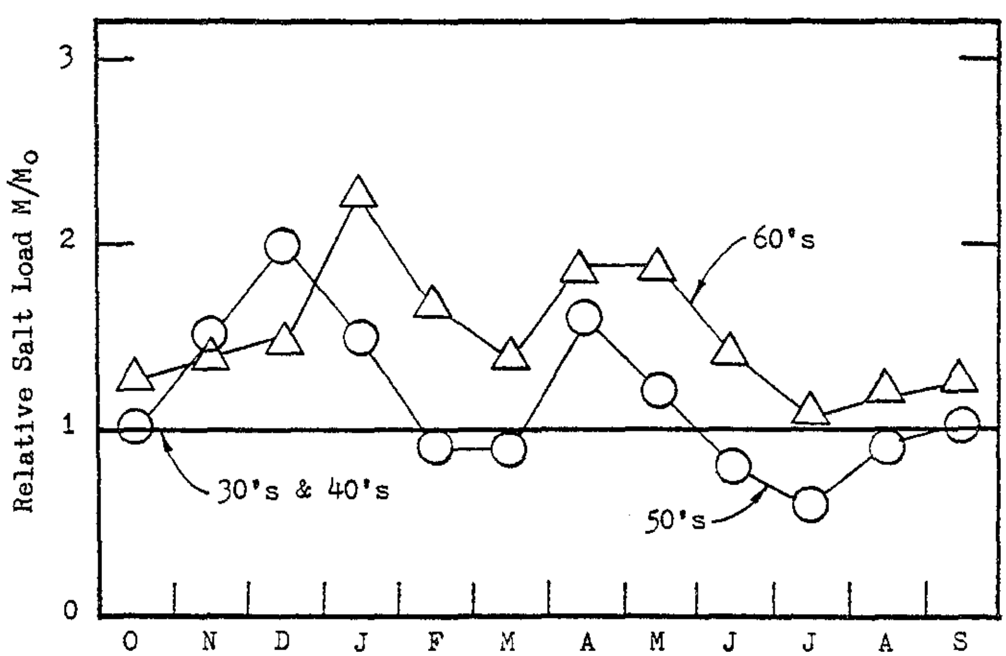

Figure VI-34 RELATIVE SALT LOAD AT VERNALIS BY DECADES, 1930-1969*

*Based on chloride load-flow relationships.

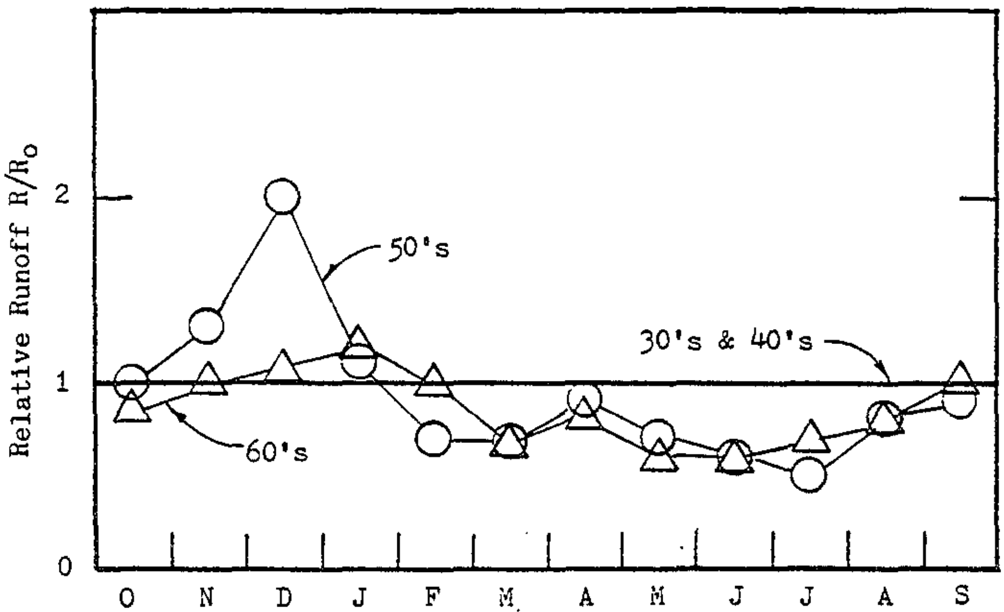

Figure VI-35 RELATIVE RUNOFF AT VERNALIS BY DECADES, 1930-1969 year, and a substantial chronological shift is evident. Loads are greater in the months of November, December, January, and April. The months of February, March, June, July, and August, show relative loads less than unity. For the 12-month period, loads in the 1950's were about 116 percent of the 1930's-1940's period. During the 1960's salt loads were much higher than those of the 1930's and 1940's. For the January through May period the monthly loads were as much as 240 percent of the 1930's and 1940's. Overall the salt loads for the 1960's were about 153 percent of the pre-1950 years. Figure VI-35 depicts the relative runoff at Vernalis in the same manner as figure VI-33 and VI-34. Both the 1950's and 1960's have relative runoffs generally less than unity. Exceptions are the months of November, December, and January; however, these increases are offset by reductions in the remaining months. The 1960's relative flow was about the same as the 1950's, while at the same time the relative load was greater than the 1950's. This supports the calculations indicating that an additional salt burden has been placed on the system.

Comparisons of quality changes by year classification is possible from the Mossdale data presented in tables VI-13, 14 and 15. These are summarized in tables VI-24 and VI-25, for the April through September period, and for the extremes of high TDS and corresponding flows experienced in each of the study years. Data are presented as averages for each of the several year classifications. It is noted that because of the scarcity of "Below Normal" years in the 1930-1944 period and "Above Normal" years in the 1952-1966 period averages are presented also for "Below and Above Normal" year classifications.

The summary of Mossdale results shown in table VI-24 for the April through September period shows clearly the impact of post-1952 upstream development of

TABLE VI-24. MEAN TDS AND RUNOFF AT VERNALIS BY YEAR CLASSIFICATION, APRIL-SEPTEMBER PERIOD,

Year Class	Mean TDS MG/L		Mean Period Runoff AF x 1000	
	Pre*	Post**	Pre	Post
Dry	314	677	424	168
Below Normal	282	419	788	735
Above Normal	190	325	3046	1201
Combined: Below & Above Normal	203	396	2764	851
Wet	180	209	5469	3845
All Years	227	434	2344	1268

* 1930-1944, data from Table VI-14, based on Mossdale chlorides.

** 1952-1966, data from Tables VI-13 and VI- 14.

TABLE VI-25. EXTREME VALUES OF HIGH TDS AND LOW FLOWS AT VERNALIS BY YEAR CLASSIFICATION

Year Class	Maximum Monthly Mean TDS MG/L		Minimum Monthly Mean Flow AF x 1000	
	Pre*	Post**	Pre	Post
Dry	351	765	38.6	17.3
Below Normal	370	530	67.1	44.0
Above Normal	355	521	81.4	55.0
Combined: Below & Above Normal	357	528	79.6	46.8
Wet	363	364	123.0	96.6
All Years	354.8	558.2	71.7	48.9

* 1930-1944, data from Table VI-15, based on Mossdale chlorides

** 1952-1966, data from Table VI-15

the San Joaquin Basin's water resources on both the quantity and quality of water reaching Vernalis. This effect is especially notable in the dry years, where a reduction of about 60 percent in the average April through September runoff corresponds to approximately 115 percent increase in average TDS--from 314 mg/L pre-1944 period to 677 mg/L post-1952 period. In the below and above normal years, the impact is similar, a reduction in average runoff of about 69 percent corresponds to an average increase in TDS of roughly 95 percent. In wet years, although flow reductions were substantial--about 30 percent of pre-1944 levels--the quality changes were minor, as would be expected. Considering all years, a reduction in runoff of 41 percent (959,000 acre-feet for the April-September period) corresponded to a 84 percent increase in TDS concentration in the runoff at Vernalis.

Comparisons of quality changes by year classification for the pre-1944 period and post-1952 period using load-flow regression data are presented in tables VI-26 and VI-27. Data summarized in those tables are found in tables VI-13, 18, and 19. The impact of upstream development is apparent in reduced flows and increased TDS concentration at Vernalis for all year types. Like results from the Mossdale method, the estimated April-September flow reductions are about 60 percent in the drier years and about 30 percent in the wet years. The loadflow regressions give an average TDS increase in dry years of 93 percent, in below and above normal years 69 percent, and in wet years 8 percent. Considering all years together, the degradation of quality amounted to an increase of 63 percent coupled with a 46 percent reduction in flow for the April-September period.

The same comparisons using the extreme TDS month is summarized in table VI-27.

TABLE VI-26. MEAN TDS AND RUNOFF AT VERNALIS BY YEAR CLASSIFICATION, APRIL-SEPTEMBER PERIOD

Year class	Mean TDS mg/L		Mean period runoff, KAF	
	Pre*	Post**	Pre	Post
Dry	350	677	424	168
Below normal	278	419	788	735
Above normal	228	325	3046	1201
Combined Below normal & above normal	234	396	2764	851
Wet	194	209	5469	3845
All years	267	434	2344	1394

* 1930–1944, data from table VI-18 based on flow-load regression data.

** 1952–1966, data from table VI-13 and VI-14.

TABLE VI-27. EXTREME VALUES OF HIGH TDS AND LOW FLOW AT VERNALIS BY YEAR CLASSIFICATION

Year Class	Maximum monthly mean TDS mg/L		Minimum monthly mean flow AF x 1000	
	Pre*	Post**	Pre	Post
Dry	490	765	35.8	17.3
Below normal	407	530	67.1	44.0
Above normal	398	521	77.5	55.0
Combined above & below normal	399	528	76.2	46.8
Wet	358	364	116.4	96.6
All years	424	561	68.1	48.9

* 1930-1944, data from table VI-19, based on load-flow regression data.

** 1952-1966, data from table VI-15.

Exhibit “F”

F. SUMMARY OF QUALITY IMPACTS

Generally, the water quality at Vernalis has deteriorated since the 1930's. How much degradation has occurred and what have been the principal causes, have been the topics of this chapter. In the analysis of data and interpretation of results, several methods have been employed, sometimes with differing results. The discussion that follows attempts to summarize results and reconcile differences wherever possible. In cases where the methods yield disparate results, ranges are given to include all estimates.

Changes that have occurred in the quality of water at Vernalis between the pre-1944 and post-1952 periods are summarized in tables VI-28 and VI-29. The tables present data derived from the records of mean monthly TDS at Vernalis (mg/L) given in tables VI-13, VI-14, and VI-18. Maximum and mean values are given for three periods--the maximum month, the April-September period and the entire water year--and for each type of year--dry, below normal, above normal and wet.

Data presented in the tables indicate that the TDS at Vernalis has increased in almost all categories listed. The greatest effect is shown in the drier years and the least in the wettest years. Table VI-30 is a composite of tables VI-28 and VI-29, showing the range of estimated impacts at Vernalis. Using the April-September period in a dry year as an example, the mean TDS increased somewhere between 327 and 363 mg/L from pre-1944 to post-1952 years. This increase corresponded to 93 to 116 percent of the pre-1944 period TDS.

As noted in previous discussion, the general deterioration in quality at Vernalis is identified both with reductions in flows along the main stem of the San Joaquin and increases in salt burden transferred to the river. When

Table VI-28. SUMMARY OF* IMPACTS ON QUALITY AT VERNALIS PRE-1944 AND POST-1952

YEAR TYPE & PERIOD	Total Dissolved Solids, mg/L PRE-1944		POST-1952		Percent Increase PRE-1944 to POST-1952	
	Max	Mean	Max	Mean	Max	Mean
DRY						
Max.month	444	387	941	765	112	98
April-Sept	383	314	840	677	119	116
Full Year	342	288	651	549	99	91
BELOW NORMAL						
Max.month	370	370	729	544	97	47
April-Sept	282	287	683	419	142	46
Full Year	282	261	502	364	78	40
ABOVE NORMAL						
Max.month	517	382	805	641	56	68
April-Sept	244	260	387	325	59	52
Full Year	269	233	489	394	82	69
WET						
Max.month	384	374	462	439	20	17
April-Sept	180	173	226	209	26	21
Full Year	224	197	252	237	13	20
ALL YEARS						
Max.month	517	381	941	584	82	53
April-Sept	383	239	840	433	119	81
Full Year	342	234	651	392	99	68

*BASED ON MOSSDALE DATA

TABLE VI-29. SUMMARY OF IMPACTS ON QUALITY AT VERNALIS PRE-1944 AND POST-1952

	Total dissolved solids, mg/L				Percent increase	
	PRE-1944		POST-1952		PRE-1944 to POST-1952	
Year type and period	Max	Mean	Max	Mean	Max	Mean
DRY						
Max month	616	490	941	765	53	56
Apr-Sept	453	350	840	677	85	93
Full year	374	310	681	549	82	77
BELOW NORMAL						
Max month	407	407	729	544	79	34
Apr-Sept	278	278	683	419	146	51
Full year	262	262	502	364	92	39
ABOVE NORMAL						
Max month	415	398	805	641	94	61
Apr-Sept	236	228	387	325	64	43
Full year	251	229	489	394	95	72
WET						
Max month	366	358	462	439	26	23
Apr-Sept	202	194	226	209	12	8
Full year	207	200	252	237	22	19
ALL YEARS						
Max month	616	424	941	588	53	39
Apr-Sept	453	267	840	434	85	63
Full year	372	254	681	383	82	51

TABLE VI-30. RANGE OF ESTIMATED IMPACTS* ON QUALITY AT VERNALIS (1930-1944) to (1952-1966)

Year type & period	Total dissolved solids, mg/L		Percent increase	
	Max	Mean	Max	Mean
DRY				
Max month	325 - 497	275 - 378	53 - 112	56 - 98
Apr-Sept	387 - 457	327 - 363	85 - 119	93 - 116
Full year	307 - 339	239 - 261	82 - 99	77 - 91
BELOW NORMAL				
Max month	322 - 359	137 - 174	79 - 97	34 - 47
Apr-Sept	401 - 405	132 - 141	142 - 146	46 - 51
Full year	220 - 240	102 - 103	78 - 92	39 - 40
ABOVE NORMAL				
Max month	288 - 390	243 - 259	56 - 94	61 - 68
Apr-Sept	143 - 151	65 - 97	59 - 64	25 - 43
Full year	220 - 238	161 - 165	82 - 95	69 - 72
WET				
Max month	78 - 96	65 - 81	20 - 26	17 - 23
Apr-Sept	24 - 46	15 - 36	12 - 26	8 - 21
Full year	45 - 59	37 - 40	22 - 31	19 - 20
ALL YEARS				
Max month	325 - 497	164 - 203	53 - 112	39 - 53
Apr-Sept	387 - 457	167 - 194	85 - 119	63 - 81
Full year	307 - 339	129 - 158	82 - 99	51 - 68

* Based on results from Mossdale data and load-flow regression data. See tables VI-28, VI-29.

the total change in quality at Vernalis that has occurred between the two periods is distributed between reduced flow and increased salt load, it is noted that the effect of increased salt load is becoming relatively more important in recent years. Tables VI-31 and VI-32 summarize the changes in total salt load that have occurred in the two decades 1950-59 and 1960-69 in relation to the period of 1930-49.

In the 1950's, the estimated increased in annual TDS load at Vernalis. In the 1960's the load increased 530 to 569 kilotons TDS per year. This increase between the 1950's and 1960's, a 50-56 percent jump, indicates the more recent impact on water quality at Vernalis. During the 1960's the average annual runoff at Vernalis was about 710,000 acre-feet lower than for the 1930-1949 period while the total TDS load actually increased.

In the 1950's the estimated increase in the April-September TDS load at Vernalis ranged from -18 to +21 kilotons TDS. In the 1960's the load increased +251 to 290 kilotons TDS per year. This increase, 44 to 54 percent of 1930-1949 is indicative also of more recent impacts on Vernalis water quality. During the 1960's the average April-September runoff at Vernalis was about 610 thousand acre-feet lower than in the 1930-1949 period.

A similar analysis based on chloride data summarized in table VI-10, indicates an overall increase in salt load (as chlorides) of about 0-35 percent in the post-1949 years depending on year classification, the dry and below normal years showing the greatest change.

Analysis of the sources of salt load contributing to the San Joaquin River, and which account for, in part, the increases noted at Vernalis, indicates that about 45 to 85 percent of the total load, depending somewhat on the

Table VI-31. SUMMARY OF CHANGES IN TDS LOAD AT VERNALIS, 1930-1969

Month of Year	TDS Load, Tons x 10^3		
	1930-49 *	1950-59	1960-69
Oct	41	49	61
Nov	42	66	63
Dec	57	81	90
Jan	71	97	152
Feb	122	98	186
Mar	148	131	208
Apr	140	168	199
May	136	137	207
Jun	155	119	215
Jul	75	58	104
Aug	35	35	47
Sep	35	41	55
Apr-Sep	576	558	827
Percent change from 1930-49	0	-3	44
Year	1057	1080	1587
Percent Change from 1930-49	0	2	50

* Based on Mossdale chloride data

TABLE VI-32. SUMMARY OF CHANGES IN TDS LOAD AT VERNALIS, 1930-1969

Month of year	TDS load, tons x 10^3		
	1930-49*	1950-59	1960-69
Oct	48	49	61
Nov	44	66	63
Dec	62	81	90
Jan	66	97	152
Feb	108	98	186
Mar	153	131	208
Apr	102	168	199
May	111	137	207
Jun	149	119	215
Jul	94	58	104
Aug	40	35	47
Sept	41	41	55
Apr-Sept	537	558	827
% Change from 1930-49	0	4	54
Year	1018	1080	1587
% Change from 1930-49	0	6	56

* Based on load-flow regression data.

quality constituent considered and the year type, enters within upper San Joaquin River basin. The remaining fraction includes the contributions of the Tuolumne gas wells that have been the subject of efforts by the State of California to reduce point source salt accretions to the river, local drainage returns between Newman and Vernalis and runoff from the east side streams.

Table VI-33 is a summary of the results obtained from salt balances using chloride data for the four representative months of October, January, April, and July. The tabulated results show that virtually no change has occurred in the proportion of salt load contributed by the upper San Joaquin River basin. The table shows that the most apparent changes have taken place on the Tuolumne River and in "other" flows, the unidentified sources and sinks of salt load within the San Joaquin River basin.

Table VI-33 summarizes estimated impacts on the water quality of the San Joaquin River at Vernalis as determined by the two methods, one utilizing the Mossdale chloride data and the second based on chloride load-flow regressions. Data presented in the summary table were derived from various tables presented earlier in this chapter; specifically tables VI-9, 30, 31, 32, and 33 were utilized. Footnotes on table VI-34 describe the procedures used in calculation of the values given.

The effects of upstream development, both in the entire San Joaquin River basin and in the upper San Joaquin River basin as given in table VI-34, are outlined briefly for each year classification as follows:

Dry Years

In dry years the average TDS increase at Vernalis, resulting from development upstream after 1947, was estimated at about 350 mg/L for the April-September

Table VI-33 PERCENT OF VERNALIS CHLORIDE LOAD AND THEIR ORIGINS*

	Upper San Joaquin River Basin %		"Others" %		Stanislaus River %		Tuolumne River %		Upper San Joaquin plus "others" %	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
DRY										
Apr-Sep	107	86	-67	-55	4	2	57	69	40	30
Full Year	72	71	-22	-28	3	2	47	56	50	43
BELOW NORMAL										
Apr-Sep	83	81	-28	-49	3	2	43	66	55	32
Full Year	61	67	-1	-21	3	2	38	52	59	46
ABOVE NORMAL										
Apr-Sep	59	63	17	1	2	3	23	35	75	63
Full Year	51	55	22	9	2	2	26	34	72	64
WET										
Apr-Sep	68	56	37	25	2	3	16	21	82	77
Full Year	47	49	31	25	2	2	21	26	78	73
ALL YEARS										
Apr-Sep	78	73	-11	-24	3	2	35	51	63	48
Full Year	58	62	7	-7	2	2	33	44	65	55

*Based on load-flow regression salt balances.
Pre refers to 1930-1944 period with 5-Dry, 1-B.Norm., 7-A.Norm., 2-Wet
Post refers to 1952-1966 period with 4-Dry, 5-B.Norm., 2-A.Norm., 4-Wet

TABLE VI-34. SUMMARY OF ESTIMATED IMPACTS ON THE QUALITY OF THE SAN JOAQUIN RIVER AT VERNALIS

1	2	3	4	5	6	7	8
	Total increase in TDS mg/L at Vernalis	Increase in TDS mg/L due to decreased flow		Increase in total salt load			
				Vernalis total		Increased caused by CVP	
Year Type & Period		Percent of Pre-CVP	Percent due to CVP	Increase Tons x 10^3	% of Pre-CVP	Increase Tons x 10^3	% of Pre-CVP
DRY							
Apr-Sep	327 - 363	84 - 100	1.8 - 2.1	68	49	58	42
Full Year	239 - 261	22 - 26	6.3 - 7.4	143	55	102	39
BELOW NORMAL							
Apr-Sep	132 - 141	100	36	95	57	77	46
Full year	102 - 103	100	45	193	62	129	41
ABOVE NORMAL							
Apr-Sep	65 - 97	100	37	33	39	21	25
Full year	161 - 165	100	59	72	46	40	26
WET							
Apr-Sep	15 - 36	81 - 100	45 - 55	76	46	43	26
Full year	37 - 40	65 - 73	44 - 50	143	46	70	23
ALL YEARS							
Apr-Sep	167 - 194	90 - 100	30 - 33	73	49	54	36
Full year	129 - 158	70 - 73	37 - 39	147	53	91	33

Col. 2 - See Table VI-30.
3 - Obtained by assuming no change in salt load and flow reduction TDS=50 mg/L.
4 - Col 3 x ratio of upper San Joaquin flow reductions to total San Joaquin flow reduction.
5 - Obtained by pro-rating average TDS load increase between 1960's and 1930-49 period (Tables VI-31 and 32) in proportion to salt load increase in each year type (Table VI-9) and number of years of each year type in 1950-69 period.
6 - Col 5 salt load for 1930-49 period x proportion of years in each class.
7 - Col 5 x proportion of total chloride load contributed by upper San Joaquin basin (Table VI-33)
8 - Col 7 x proportion of years in each year class.

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Table VI-33 PERCENT OF VERNALIS CHLORIDE LOAD AND THEIR ORIGINS*

	Upper San Joaquin River Basin %		"Others" %		Stanislaus River %		Tuolumne River %		Upper San Joaquin plus "others" %	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
DRY										
Apr-Sep	107	86	-67	-55	4	2	57	69	40	30
Full Year	72	71	-22	-28	3	2	47	56	50	43
BELOW NORMAL										
Apr-Sep	83	81	-28	-49	3	2	43	66	55	32
Full Year	61	67	-1	-21	3	2	38	52	59	46
ABOVE NORMAL										
Apr-Sep	59	63	17	1	2	3	23	35	75	63
Full Year	51	55	22	9	2	2	26	34	72	64
WET										
Apr-Sep	68	56	37	25	2	3	16	21	82	77
Full Year	47	49	31	25	2	2	21	26	78	73
ALL YEARS										
Apr-Sep	78	73	-11	-24	3	2	35	51	63	48
Full Year	58	62	7	-7	2	2	33	44	65	55

*Based on load-flow regression salt balances.
Pre refers to 1930-1944 period with 5-Dry, 1-B.Norm., 7-A.Norm., 2-Wet
Post refers to 1952-1966 period with 4-Dry, 5-B.Norm., 2-A.Norm., 4-Wet

TABLE VI-34. SUMMARY OF ESTIMATED IMPACTS ON THE QUALITY OF THE SAN JOAQUIN RIVER AT VERNALIS

1	2	3	4	5	6	7	8
		Increase in TDS mg/L due to decreased flow		Increase in total salt load			
				Vernalis total		Increased caused by CVP	
Year Type & Period	Total increase in TDS mg/L at Vernalis	Percent of Pre-CVP	Percent due to CVP	Increase Tons x 10^3	% of Pre-CVP	Increase Tons x 10^3	% of Pre-CVP
DRY							
Apr-Sep	327 - 363	84 - 100	1.8 - 2.1	68	49	58	42
Full Year	239 - 261	22 - 26	6.3 - 7.4	143	55	102	39
BELOW NORMAL							
Apr-Sep	132 - 141	100	36	95	57	77	46
Full year	102 - 103	100	45	193	62	129	41
ABOVE NORMAL							
Apr-Sep	65 - 97	100	37	33	39	21	25
Full year	161 - 165	100	59	72	46	40	26
WET							
Apr-Sep	15 - 36	81 - 100	45 - 55	76	46	43	26
Full year	37 - 40	65 - 73	44 - 50	143	46	70	23
ALL YEARS							
Apr-Sep	167 - 194	90 - 100	30 - 33	73	49	54	36
Full year	129 - 158	70 - 73	37 - 39	147	53	91	33

Col. 2 - See Table VI-30.
3 - Obtained by assuming no change in salt load and flow reduction TDS=50 mg/L.
4 - Col 3 x ratio of upper San Joaquin flow reductions to total San Joaquin flow reduction.
5 - Obtained by pro-rating average TDS load increase between 1960's and 1930-49 period (Tables VI-31 and 32) in proportion to salt load increase in each year type (Table VI-9) and number of years of each year type in 1950-69 period.
6 - Col 5 salt load for 1930-49 period x proportion of years in each class.
7 - Col 5 x proportion of total chloride load contributed by upper San Joaquin basin (Table VI-33)
8 - Col 7 x proportion of years in each year class.

period and 250 mg/L for the full year. Of this increase the proportion due to reduced flow from all sources was 90 percent in the April-September period, but only 25 percent for the entire year. The impact of the CVP on water quality (as expressed by changes in TDS) in dry years, caused by flow reductions in the upper San Joaquin basin, was relatively small, only 2 percent in the April-September period and 7 percent for the entire year.

Salt loads at Vernalis in dry years were estimated to have increased in the period subsequent to 1947, by 68,000 tons in the April-September period and by 143,000 tons for the whole year. These increases corresponded to roughly 49 percent and 55 percent, respectively, of the pre-1944 TDS loads at Vernalis. The CVP salt load impact in dry years was estimated at 58,000 tons in the April-September period and 102,000 tons for the full year, corresponding to 42 percent and 39 percent increases, respectively, of pre-1944 salt loads at Vernalis.

Below Normal Years

In below normal years, the increase in average TDS concentration at Vernalis between the pre- and post-CVP periods was estimated at about 135 mg/L for the April-September period and slightly more than 100 mg/L for the full year. Virtually all of this increase is attributed to reductions in flow from all sources. The impact due to reduced flow attributed to the CVP was about 36 percent in the April-September period and 45 percent for the full year.

TDS load increases in below normal years subsequent to 1947 are estimated at 95,000 tons for the April-September period and 193,000 tons for the year. Of this increase, 77,000 tons and 129,000 tons, respectively, were estimated to have been derived from the upper San Joaquin basin. The proportionate impact of the CVP on salt loads at Vernalis was largest for below normal years, 46 percent of the total increase at Vernalis in the April-September period and 41 percent for the whole year.

Above Normal Years

In above normal years the average TDS increase at Vernalis, resulting from development upstream after 1947, was estimated at about 80 mg/L for the April-September period and 165 mg/L for the full year. Of this increase, the proportion due to reduced flow from all sources was 100 percent in both the April-September and full year periods. The impact of the CVP on water quality (as expressed by changes in TDS) in above normal years, caused by flow reductions in the upper San Joaqin basin, was 37 percent in the April-September period and 59 percent for the entire year.

Salt loads at Vernalis in above normal years were estimated to have increased in the period subsequent to 1947 by 33,000 tons in the April-September period and by 72,000 tons for the entire year. These increases correspond to roughly 39 percent and 46 percent, respectively, of pre-1944 TDS loads at Vernalis. The CVP salt load impact in above normal years was estimated at 21,000 tons in the April-September period and 40,000 tons for the full year, corresponding to 25 and 26 percent increases respectively, in pre-1944 salt loads at Vernalis.

Wet Years

In wet years, the increase in average TDS concentration at Vernalis between the pre- and post-CVP periods was estimated at about 25 mg/L for the April-September period and about 40 mg/L for the full year. Of this increase the proportion due to reduced flow from all sources was 90 percent in the April-September period, and 70 percent for the entire year. The impact due to reduced flow attributed to the CVP was about 50 percent for both the April-September and full year periods.

TDS load increases in wet years subsequent to 1947 are estimated at 76,000 tons for the April-September period and 143,000 tons for the year. Of this increase, 43,000 tons and 70,000 tons, respectively, were estimated to have been derived from the Upper San Joaquin Basin. The proportionate impact of the CVP on salt loads at Vernalis was 26 percent of the total increase at Vernalis in the April-September period and 23 percent for the full year.

CHAPTER VII

EFFECTS OF OPERATION OF CVP AND SWP EXPORTS PUMPS NEAR TRACY

CHANNEL DEPTHS AND CROSS SECTIONS

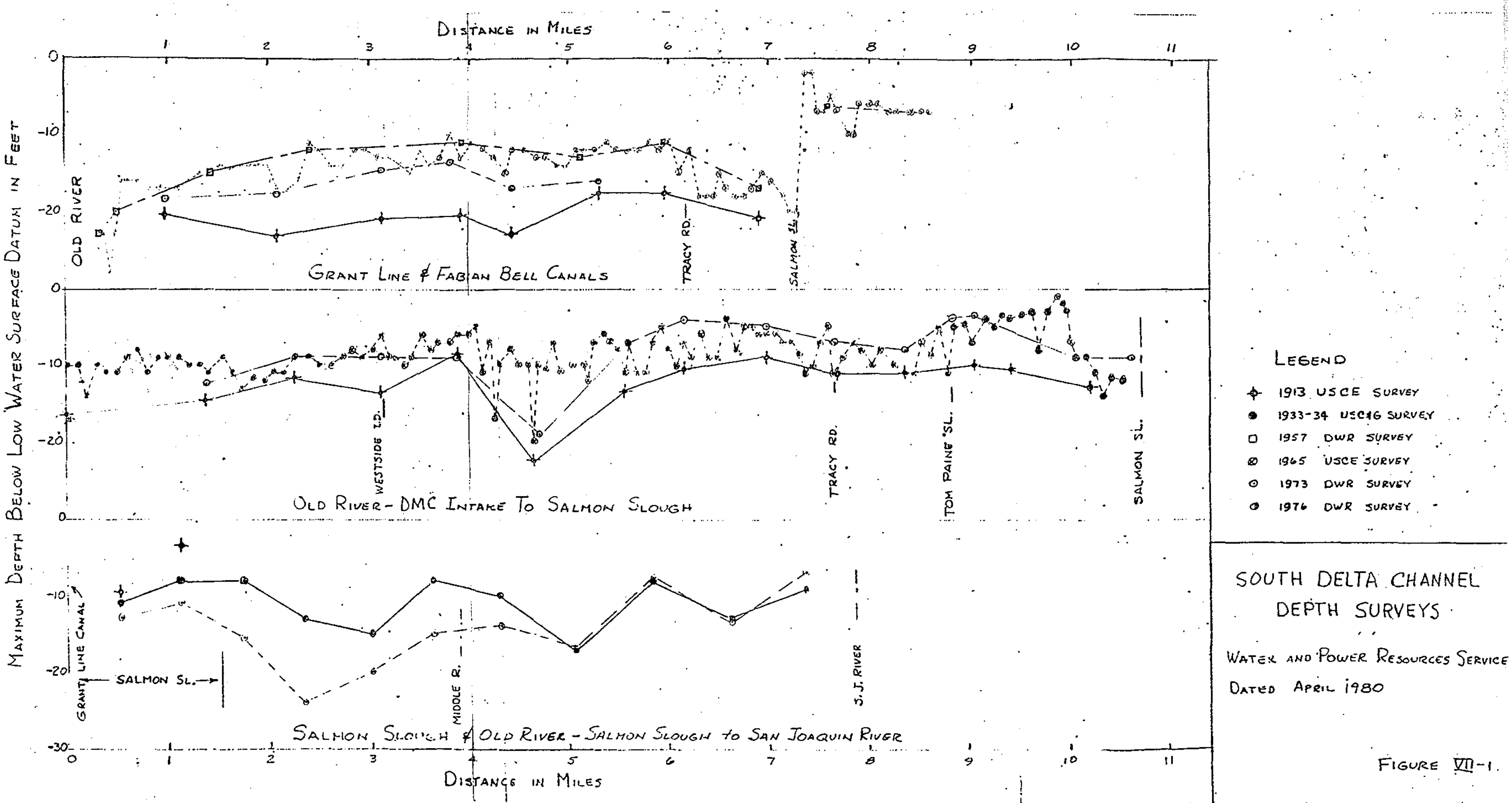
The geometry of the channels within the southern Delta was studied to determine whether the channel cross sections and bottom elevations have changed since the 1930's in such a way as to alter water circulation patterns and water depths to a degree that modifies the southern Delta water supply.

Channel Surveys

Prior to 1913, most existing channels within the South Delta Water Agency were well defined, due in part to the sidedraft clamshell dredge which was used over many years to construct the levee system within the South Delta and to keep channels clean of sediment. Since 1913 most of the channels in the South Delta have been surveyed several times. The results of surveys are summarized if figure VII-1.

Available survey data include:

Date of survey	Channels surveyed	Source of data
1913	Old River - Middle River to Victoria Canal Middle River - Old River to Victoria Canal Grant Line and Fabian Canals	USCE
1933-34	All SDWA channels	USC&GS
1957	Grant Line and Fabian Canals, plus Salmon Slough and Paradise Cut	DWR
1965	Grant Line and Fabian Canals	USCE
1973	Old River-San Joaquin River to Victoria Canal Middle River-Old River to Victoria Canal Grant Line and Fabian Canals	DWR
1976	San Joaquin River-Vernalis to Mossdale	DWR



SOUTH DELTA CHANNEL
DEPTH SURVEYS

Water and Power Resources Service
Dated April 1980

Figure VII-1.

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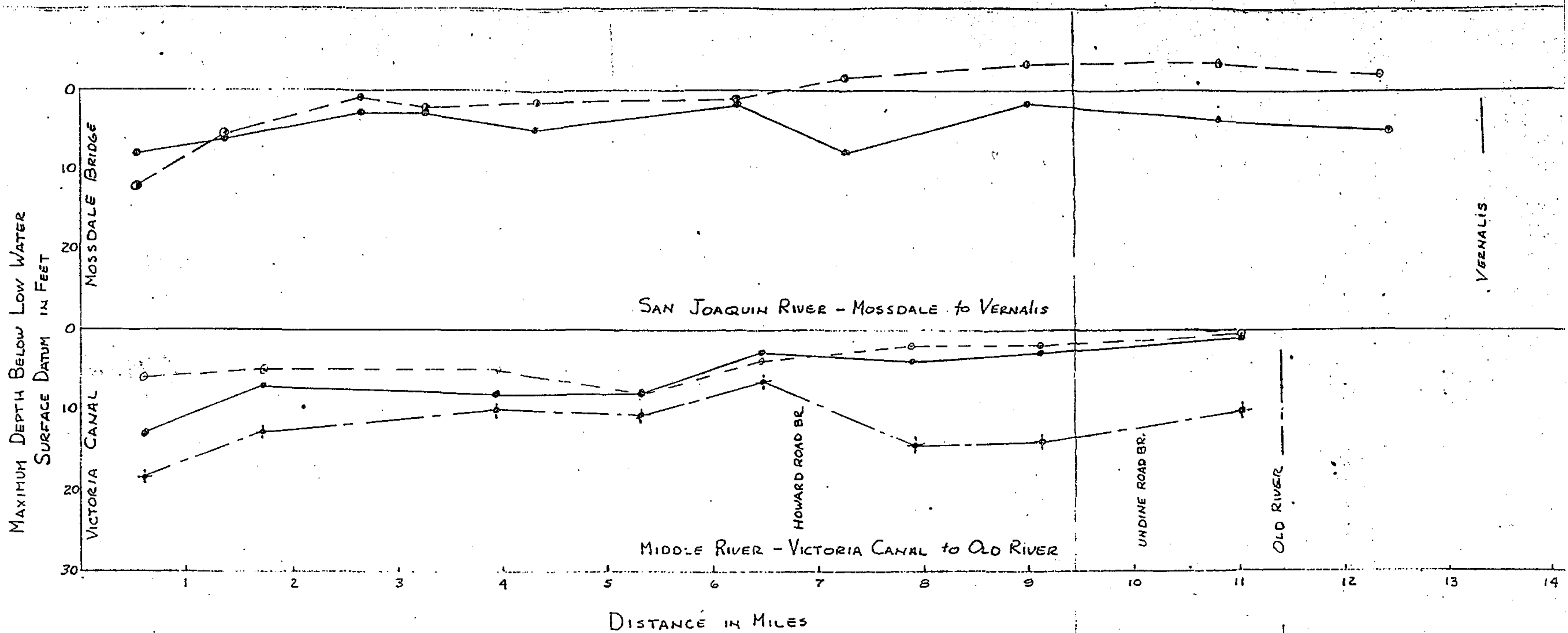


SOUTH DELTA CHANNEL DEPTH SURVEYS

Water and Power Resources Ser

Dated April 1980

Figure (Cont

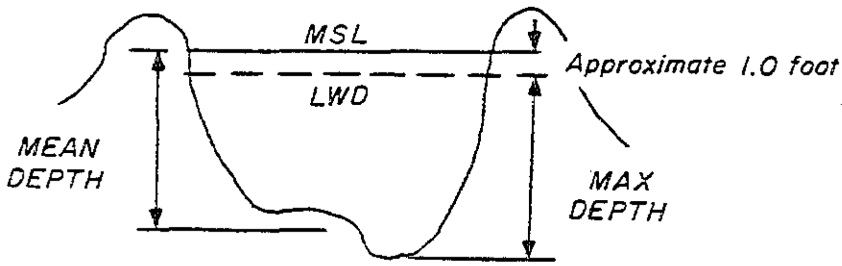
In describing the geometry of the channels, especially the depth, it is appropriate to use a fixed reference plane. For example, navigation charges which need to be site specific use local MLLW. However, this locally oriented datum varies from -0.2 ft MSL to +0.5 ft MSL within the SDWA and is dependent upon the condition of San Joaquin River inflow.

Much of the hydrographic data used in this study was taken from charts used by the Corps of Engineers to build the Sausalito model of the Bay-Delta, the low water datum, (LWD) of 1.0 foot below mean sea level as shown in the etch below, which was used by the Corps to integrate data from diverse ..rces, was also adopted for the present study. It is a conservative datum in that it is lower than the local MLLW levels throughout the SDWA by a foot or more.

Most of the channels, dredged prior to 1913, were 10 to 20 feet below the LWD. By 1933-34, however, most channels surveyed had aggraded significantly. Existing survey data indicate that in some channels, such as the southern reaches of Middle River, little dredging has been done. Data on dredging to maintain the levees and to provide fill for road construction were not available.

In the 1973 and 1976 surveys channel geometry was determined for reaches from Vernalis on the San Joaquin River to the State and Federal pumping plants near Clifton Court Forebay, including Old River and the Grant Line and Fabian-Bell Canals, and for the Middle River between Old River and Victoria Canal. To determine channel bottom profiles, bottom elevations taken at 1/2 to 1-1/2-mile intervals were averaged. The shapes of the channels studied were such that the average water depths approximated the hydraulic radius. An example of the channel mean depths and cross sections observed in the 1973 survey for the reach of Old River between Clifton Court and the San Joaquin River is presented in figure VII-2.

The diagram below illustrates the differences between average and maximum depths and between LWD and MSL.



Bottom elevations of the major channels were further analyzed in relationship to the survey dates and the initial operations of the Federal and State pumping plants.

San Joaquin River--Vernalis to Mossdale Bridge. Most of this reach has aggraded since the 1933-34 surveys. By 1976 the elevation of the stream bottom had risen 0.5 to 9.5 feet above the 1933-34 levels, with an average increase of about 4.0 feet. The bottom elevation of the reach from Vernalis to a point approximately 4.8 miles north of the San Joaquin River club varied from 2 to 7 feet below the LWD in 1933 and varied from 1.5 to 3.5 feet above LWD in 1976. This aggradation generally causes a corresponding reduction in water depth.

Old River, San Joaquin River to and including Salmon Slough. In 1973, streambed elevations of this 7.5-mile reach were equal to or below that measured in the 1933-34 survey. The 1973 elevations ranged from 8 to 24 feet below LWD with an average of about 14 feet; the 1933-34 elevations varied from 8 to 17 feet with an average of about 10 feet. Therefore, during the intervening

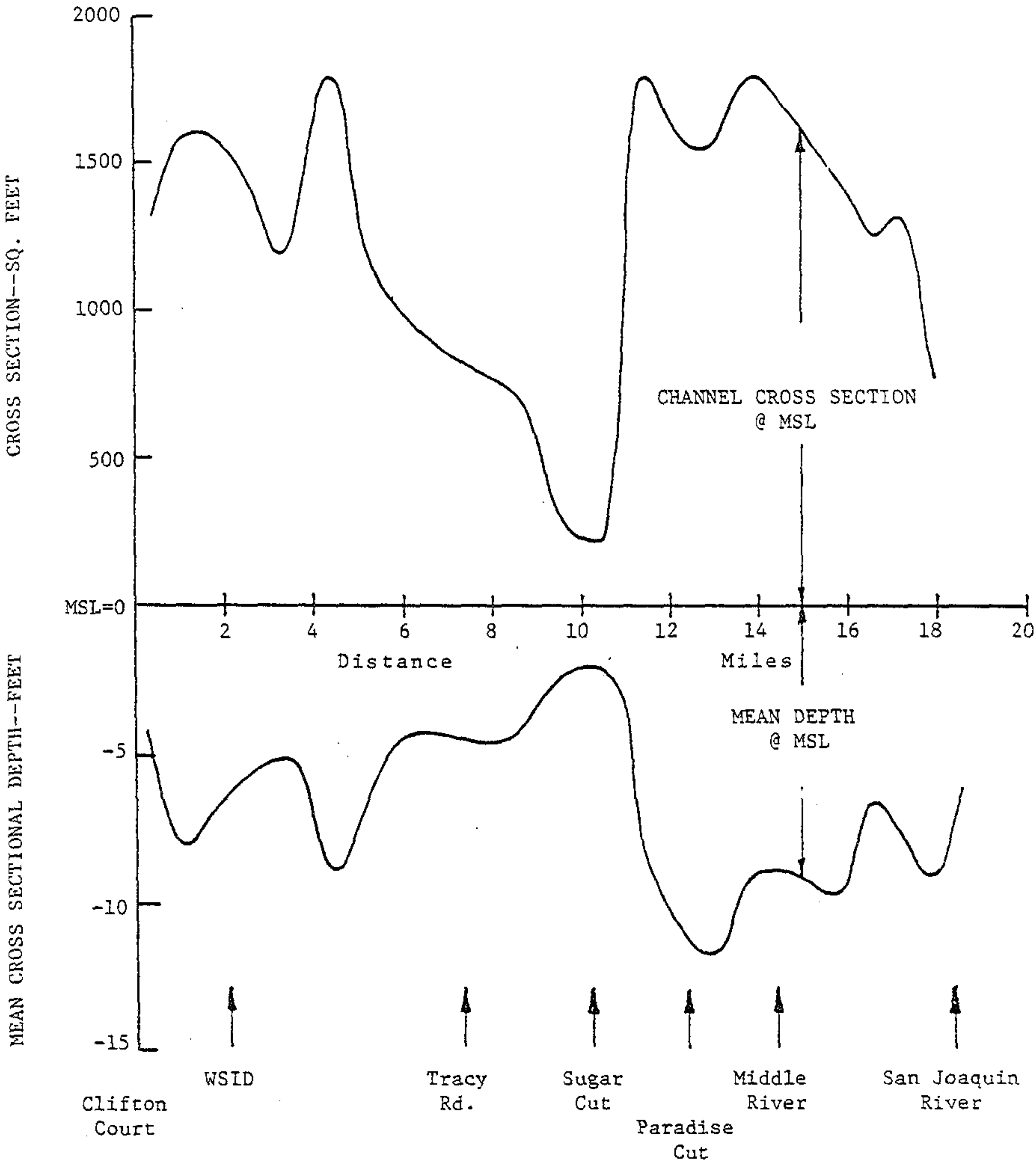


Figure VII-2 CHANNEL PROPERTIES, OLD RIVER, CLIFTON COURT TO SAN JOAQUIN RIVER (Data from 1973 DWR Survey, Datum is Mean Sea Level)

40 years, the channel had degraded an average of 4 feet, but with very little change in the upstream 1/3 of the reach.

Old River, to Salmon Slough to Delta-Mendota Canal Intake Channel. Bottom elevations of this 11-mile channel averaged 12 feet in 1913, with a range of 9 to 22 feet below LWD. The channel had displayed a 3.5-foot aggradation by the 1933-34 survey. However, the channel had not had any further significant change by the 1973 survey. The 1933-34 and the 1973 surveys each indicated a similar channel restriction near the bifurcation of Old River and Tom Paine Slough. Maximum cross sectional depths measured in 1973 through the 4-mile restricted section averaged about 6 feet with a minimum of 4 feet with reference to LWD elevation. The mean elevation of the bottom of the most restricted area is about 2 feet below mean sea level as shown in figure VII-2. Where as the maximum depth below LWD was about 3.7 feet.

Grant Line and Fabian Canals--In 1913 the elevation of these paralleling 7-mile channels averaged more than 20 feet below LWD. By 1957 they had aggraded about 8 feet with an average depth of 12 feet below LWD, remaining at that depth until after the 1965 survey. By the 1973 survey, however, the channels had degraded to an average of about 16 feet below LWD. The channel depths could have been influenced by maintenance dredging and/or increases in channel velocities due to operation of Clifton Court Forebay. Flow restrictions have not been apparent in these channels.

Middle River--Old River to Victoria Canal--In 1913, the channel elevation of this 11.5-mile reach of Middle River varied between 7 and 18 feet below LWD with an average of about 12 feet below LWD. By the 1933-34 survey, channel bed had aggraded to an average of about 6 feet below LWD elevation. Further aggradation was shown by the 1973 survey to an average depth of 4 feet below LWD elevation. However, the 6-mile reach directly north of Old River has only aggraded about 0.5 feet since the 1933-34 survey. Both the 1933-34 and 1973 surveys recorded a restriction 0.4 of a mile north of the head of Middle River with maximum depths of 1.0 in 1933-34 and 0.5 feet in 1973, below LWD elevation.

Calculated Hydraulic Resistance in Old River

The resistance to flow, assuming present channel geometry in Old River, was studied as a basis for examination of the effect of reduced water levels on water circulation through this channel.

Using channel cross section data obtained by the DWR in 1973, the hydraulic resistance characteristics were estimated for some 22 channel segments of Old River between Clifton Court and the main stem of the San Joaquin River. It can be shown by open channel flow hydraulics that resistance, the relationship between head loss and channel discharge, is proportional to the square of channel width and the 10/3 power of the mean depth. In essence, this means that a narrow, shallow channel greatly restricts flow--much more dramatically than might at first appear to be the case by inspection in the field. For example, simply reducing channel width and depth by one-half each, thereby reducing the effective area to one-quarter, increases hydraulic resistance for the same length and roughness more than 40 times. These effects are especially evident in the central section of Old River in the vicinity of Tom Paine Slough where mean channel depths below mean sea level average less than 3 feet and widths are less than 100 feet.

The channel cross sections and depths along Old River are illustrated graphically in figure VII-2. In figure VII-3 the cumulative hydraulic resistance

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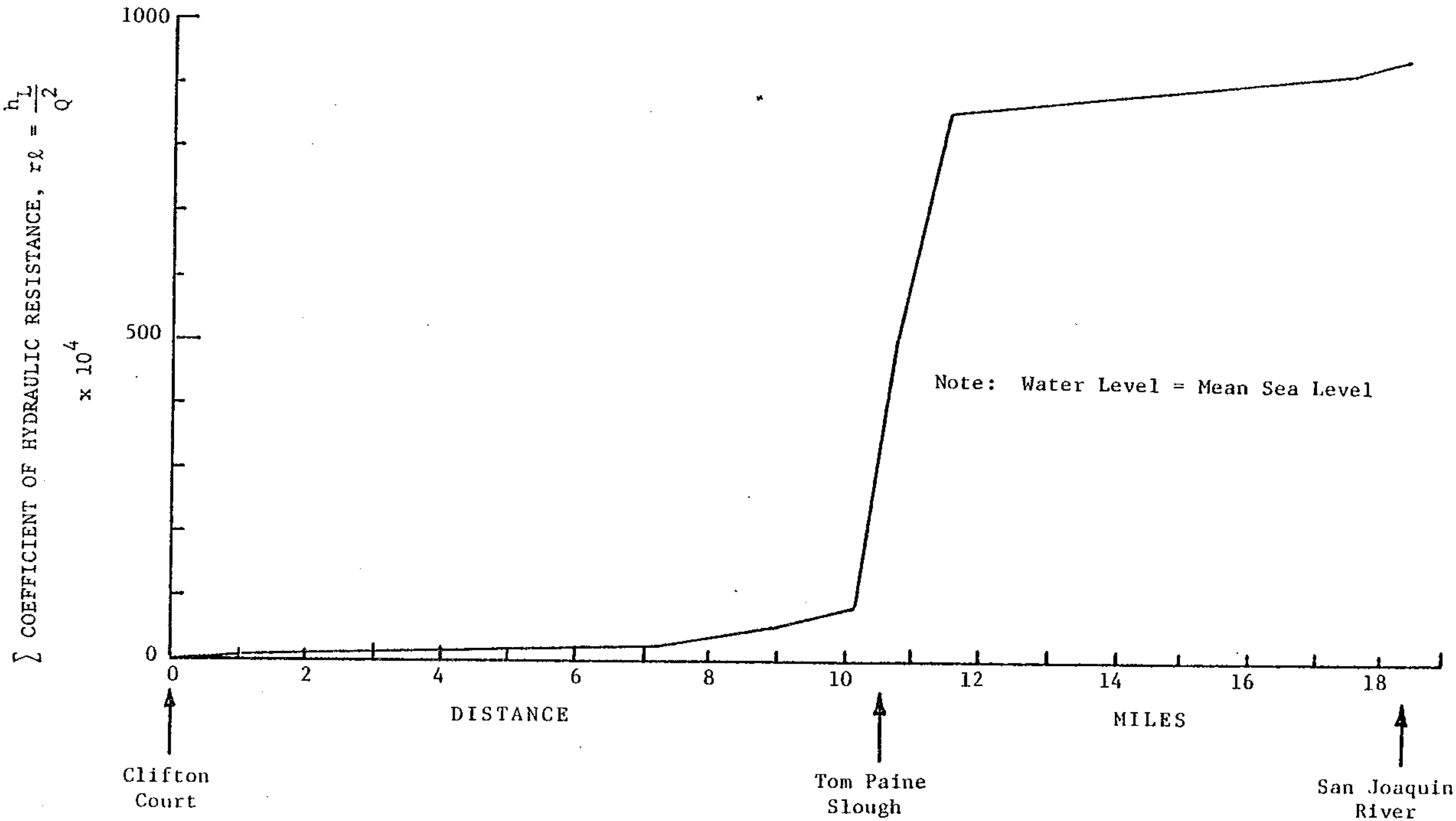


Figure VII-3 CUMULATIVE HYDRAULIC RESISTANCE IN OLD RIVER, CLIFTON COURT TO SAN JOAQUIN RIVER to flow is plotted for the entire channel from Clifton Court to the San Joaquin River. The same data are visually keyed to a partial map of Old River in figure VII-4. It is noted that most of the effect, about 90 percent of the total, is concentrated in a short section about 2 miles long in the vicinity of Tom Paine Slough. This restriction was evident during the 1933-34 channel survey. Obviously, this area controls the rate of flow in an east-west direction through Old River. Actually, it forces the largest proportion of the east to west flow through Grant Line and Fabian-Bell Canals rather than through the westerly section of Old River.

Sediment Movement

In 1950, the USBR improved the operation of the Delta-Mendota Canal intake channel by dredging the Old River Channel to a minus 17-foot elevation from the Delta-Mendota Canal headworks downstream to approximately Grant Line Canal. By 1969 the dredged channel was nearly obliterated by sediment which continued to move into the Delta-Mendota Canal Intake Channel. The Old River Channel was dredged again in 1969 and in 1974. Another example of sediment movement is the accumulation of 60,000 cubic yards of sediment in Clifton Court Forebay during the first 4 years of its operation.

During the same period a large but unestimated amount of sediment was pumped into the Delta-Mendota Canal as suspended load and deposited within the canal, O'Neill Forebay and Mendota Pool. The available suspended solids data for both the DMC and State Aqueduct and vicinity are located in STORET, a Federal data storage system, and summarized below for the period of record:

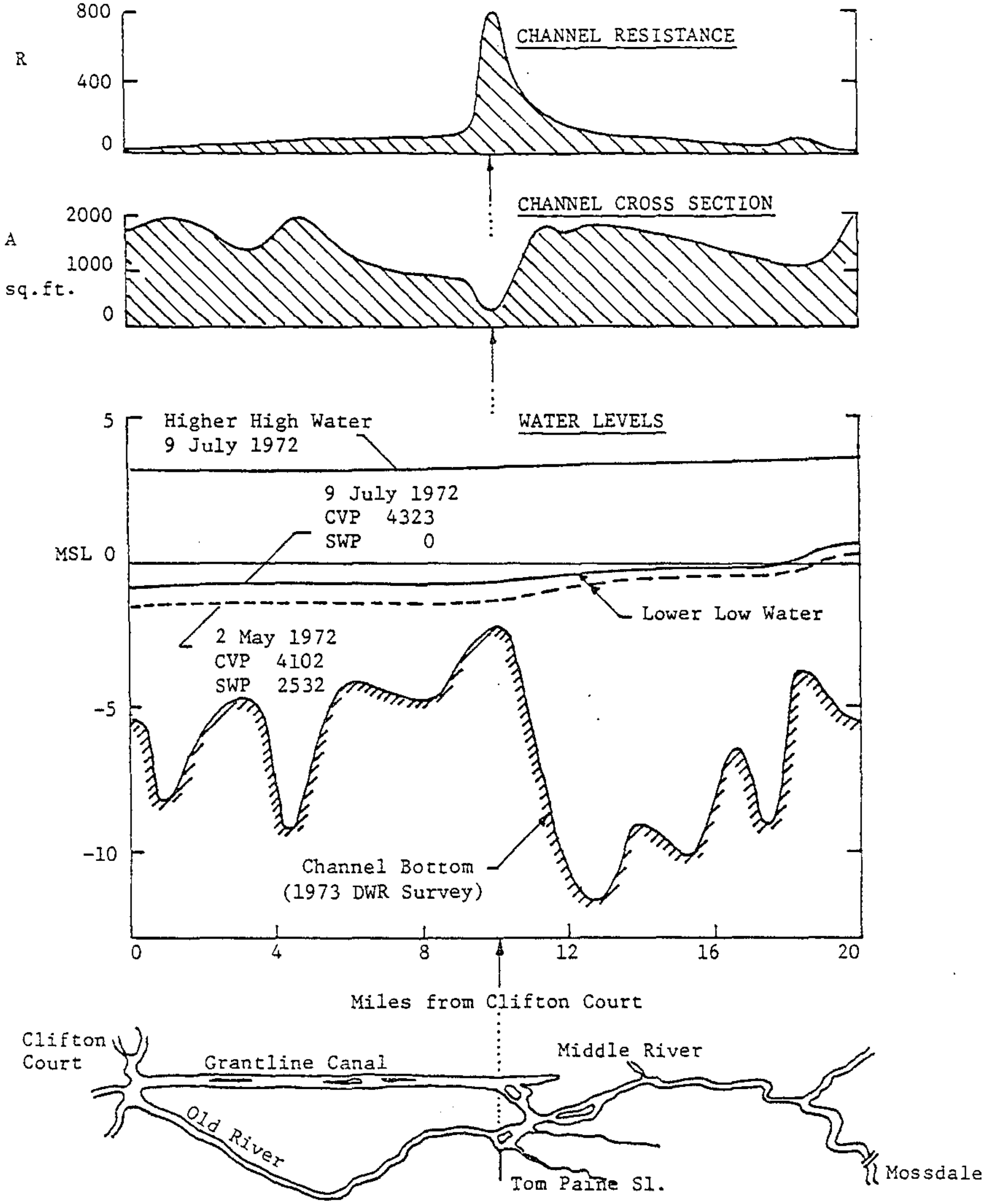


Figure VII-4 WATER LEVELS AND CHANNEL CHARACTERISTICS
OLD RIVER--SOUTH DELTA

Stations	Period of record	Average total suspended solids mg/L	pounds/acre-foot
DMC near Head	1973 - 1974	42.0	115
Delta Pumping Plant Headworks	1973 - 1979	21.3	58
Clifton Court	1973 - 1979	41.6	114
Old River at Mouth of Clifton Court Intake	1973 - 1974	44.1	120
Old River at Mossdale Bridge	1973 - 1978	48.0	123
Old River opposite Rancho Del Rio (near Rock Slough)	1973 - 1979	23.0	63

The Service and the Department of Water Resources established a Scour Monitoring Program primarily in Old and Middle Rivers north of the pumps to identify any channel scouring. The Department makes soundings repetitively at selected cross sections and the Service makes an annual aerophotographic survey of channels contiguous to the export pumps. Results indicate some degradation and aggradation at the selected cross sections north of the pumping plants, but no overall erosion or scour patterns. There are no stations east of Tracy Road in the South Delta Water Agency in the program.

IMPACT OF EXPORT PUMPS ON SOUTHERN DELTA WATER LEVELS, WATER DEPTHS, AND WATER QUALITY

Impact of Export Pumping on Water Levels and Water Depths

Any diversion from the Delta, including export pumping, lowers the water levels to some distance from the point of diversion, and the lowering of level is superimposed on whatever level would otherwise result from the combination of tides and net advective or downstream flows. The effect of large diversions from Delta channels is a depression in channel water surface which provides the gradient for the movement of water in all connecting channels toward the pumps. The distribution of flow and the water level drawdown among connecting channels is a function of channel geometry, roughness, pumping rate and in the instance of the SDWA channels, the flows in the San Joaquin River. A generalized impact of operating the CVP and SWP export pumps is a reduction of water levels and a modification of channel flows in the southern Delta.

The Clifton Court Forebay was incorporated into the SWP primarily to allow the use of offpeak power to pump water into the State Aqueduct and to prevent channel scouring prior to the creation of a Delta transfer facility.

Water level data are available in considerable detail at a number of stations throughout the Delta, including nine stations within the southern Delta. Since the drawdown of water level by the export pumps is superimposed on the water level fluctuations that would otherwise occur, two approaches have been used to determine the degree and spatial extent of the drawdown caused by the export pumps. These methods of determination include field tests and mathematical modeling.

Field tests--Steady export pumping field tests were made in May and August of 1968 wherein levels were measured at high and low export pumping rates with other conditions substantially the same. These tests were precipitated by concerns that export pumping was a contributing cause of reductions in water level such that the operation of agricultural pumps in Tom Paine Slough and in the southern portion of Middle River was restricted during low tide, and siphons around Victoria Island were losing prime. Reductions in pump capacity due to low water levels were also reported at the Westside Irrigation

District intake on Old River south of Fabian Tract. The test evaluations were limited to low tide levels which were considered by the project operators to represent the periods when steady export pumping has the maximum effect on southern Delta water supply. However, the reduction in channel water supply is also influenced by the reduction in tidal prism upstream from the export pumps and this is related to water level reductions at all levels of tide.

The flows in the San Joaquin River near Vernalis were about 700 and 900 ft^3/s for the May and August testing period, respectively.

These 1968 tests are described and the results summarized in two cooperative reports by DWR and the USBR, both titled "Summary of Effect of Export Pumping on Water Levels in the Southern Delta." One report describes the May 25-30, 1968 tests and was issued in July 1968. The other report describes the August 29 to September 9, 1968 tests and was issued in December 1968. Results of these tests indicated that steady export pumping at the rates observed in the tests lowered the lower low tide level at Clifton Court by 0.07 to 0.08 foot for each 1,000 ft^3/s of export pumping.

The effects of water level depression due to State and Federal export pumping extends northward and eastward from the points of diversion. The 1968 test results in vicinity of Clifton Court, after correction by a constant amount for the normal tidal fluctuation at Antioch (assumed to be outside of the influence of the pumps), are presented in table VII-1.

The general effect of export pumping is to reduce local water levels, creating a gradient toward the point of diversion and redistributing flows in the principal channels of the southern Delta. Depending on the level of export and rate of inflow to the Delta near Vernalis, the effect is sometimes to

TABLE VII-1

1968 PUMP TESTS RESULTS

Stations	1 May Test 6725 to 1950 ft^3/s Differential (4775 ft^3/s) Water Level Depression Feet	Ft/1000 ft^3/s	2 Aug/Sep Test 6934 to 800 ft^3/s Differential (6134 ft^3/s) Water Level Depression Feet	Ft/1000 ft^3/s	3 Difference in water level depression between pump tests[1/] Col.1 Col. 2 Feet
Old River at Clifton Court	0.33	0.07	0.47	0.08	0.13
Old River at Tracy Road	0.30	0.063	0.40	0.065	0.10
Tom Paine Slough above Mouth	0.29	0.06	0.35	0.06	0.06
Grant Line at Tracy Road	0.30	0.06	0.38	0.06	0.08
Middle River at Bacon Island	0.12	0.03	0.10	0.02	-0.02
San Joaquin River at Mossdale	0.14	0.03	--	--	--
San Joaquin River at Brant Bridge	0.16	0.03	0.12	0.02	-0.04
Old River near Byron	0.29	0.06	0.32	0.05	0.03
Old River near Rock Slough	0.08	0.02	0.12	0.02	0.04
Middle River at Borden Hwy.	0.29	0.06	0.30	0.05	0.01
Rock Slough at CCC Intake	0.15	0.03	0.14	0.02	-0.01

[1/] This column illustrates that with an increase in diversion rate of about 1,400 ft^3/s the water level depression either decreased or increased only slightly at stations beyond Tom Paine Slough. This is indicative of the significance of pumping impact during the tests at these outlying stations.

reverse the net flow downstream of the bifurcation of the San Joaquin and Old Rivers.

Another examination of recorded water levels was made for the June 14-30, 1972 period. Dr. G. T. Orlob's November 15, 1978 memorandum to the SDWA Board examined the hydraulic depression created by the export pumps and the gradient toward the export pumps along various channels during this period. Table VII-2 and figure VII-5 are taken from pages 8 and 10 of that memorandum. Table VII-2 shows the drawdown of HHW indicated for various dates and export rates. The period of June 22-25 was used to develop figure VII-5. During this period only the CVP steady export pumping was being made. Figure VII-5 shows the difference between Bacon Island tide levels and Clifton ferry tide levels as a function of CVP export rates. The figure also indicates a high tide level depression at Clifton Court of 0.1 foot for each 1,000 ft^3/s of steady export pumping.

Data collected in 1977 was used by the DWR to compare two 15-day periods with markedly different export rates and with other pertinent conditions only moderately different (see table VII-3). The period October 17-31, 1977 included an average export of about 300 ft^3/s and a San Joaquin River flow at Vernalis of about 250 ft^3/s. The period December 17-31, 1977 included an average export rate of about 9,400 ft^3/s and a San Joaquin River flow at Vernalis of 470 to 600 ft^3/s. Table VII-4 compares the differences in the 15 day means of each tidal phase between the selected control station at Rock Slough and stations in the South Delta for the two periods. About 5,800 ft^3/s of this average export rate was by the SWP which diverted at high tide. Therefore, the differences in water level depression near Clifton Court was greatest during the high tidal phase. The comparison between the October and December

TABLE VII-2

EXAMPLE OF TIDAL ELEVATION DATA
FOR SOUTH DELTA - JUNE 1972

Date	Export, ft^3/s		HHW, feet MSL		ΔH, feet
	SWP	CVP	Bacon Island	Clifton Ferry	
6-16-72	2109	4191	2.79	1.67	-1.12
6-17-72	2090	4196	2.34	1.18	-1.16
6-18-72	2382	4204	2.81	1.56	-1.25
6-19-72	2331	4180	3.45	2.28	-1.17
6-20-72	2411	4233	3.42	2.22	-1.20
6-21-72 1/	2362	3561	3.39	1.85	-1.54
6-22-72	0	2558	2.93	2.51	-0.42
6-23-72	0	1173	3.46	3.25	-0.21
6-24-72	0	923	3.25	3.07	-0.18
6-25-72	0	926	3.45	3.28	-0.17
6-26-72	487	947	3.69	3.52	-0.17
6-27-72	911	968	3.68	3.37	-0.31
6-28-72	945	965	3.52	3.17	-0.35
6-29-72	1564	963	3.35	2.98	-0.37
6-30-72	1682	1041	2.98	2.34	-0.64
6-30-72	1682	1041	3.10	2.38	-0.72

1/ Andrus and Brannon Islands were filling due to a levee failure June 21 at about 0030. The effect on the tidal elevation at Bacon Island is indicated in figure VII-6, where a small depression in the water level curve is noted for about an hour following the break. It may be expected that this effect would have had only a minor influence in the water levels in the Southern Delta.

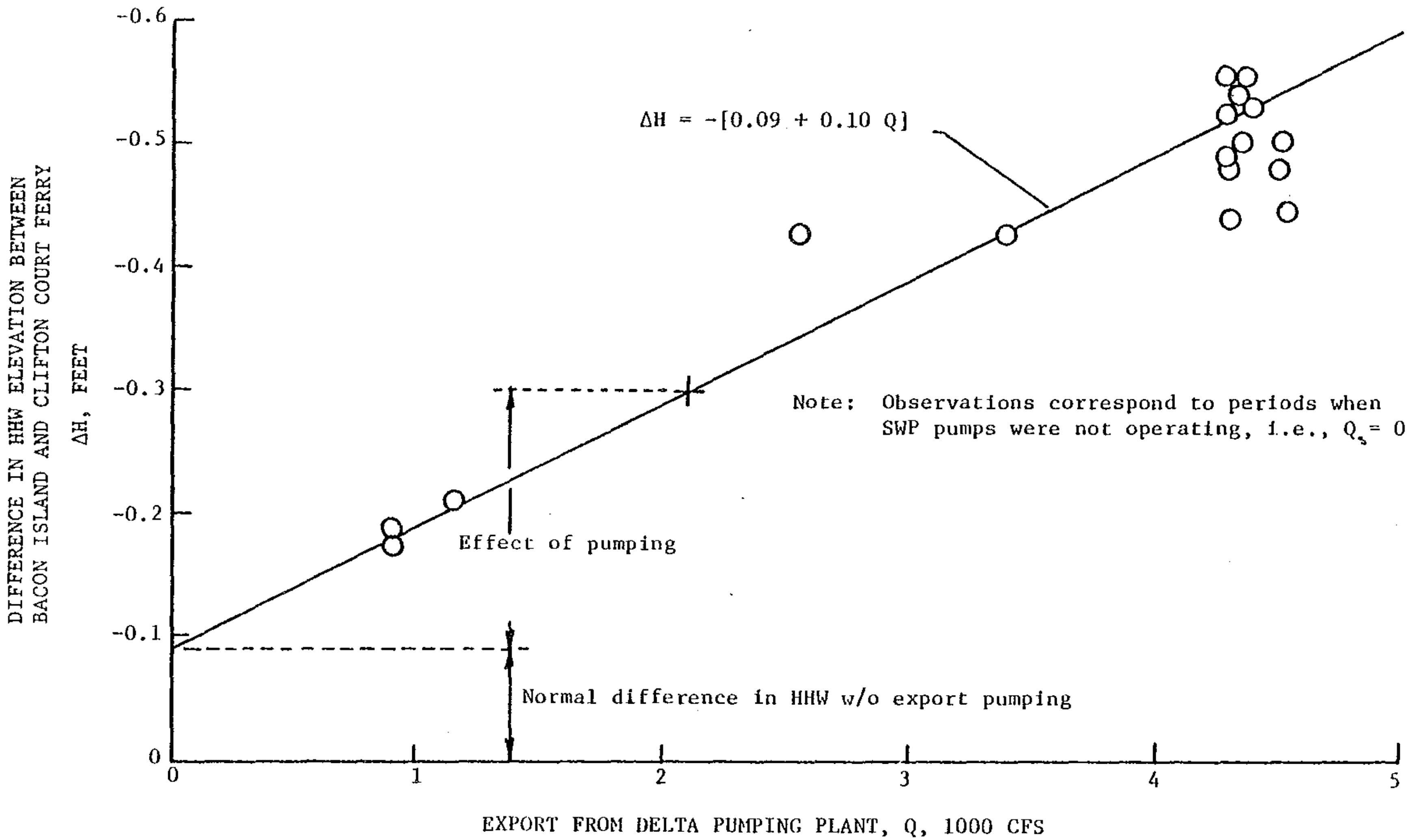


Figure VII-5 DEPRESSION IN HWL AT CLIFTON COURT RELATIVE TO MIDDLE RIVER AT BACON ISLAND AS A RESULT OF CVP EXPORT PUMPING AT TRACY

TABLE VII-3

CLIFTON COURT FOREBAY

Daily Operation of Gates

Month October, 1977

DATE	TIME OPENED	TIME CLOSED	DAILY AMOUNT OF INFLOW IN ACRE-FEET
17			0
18	1010	1325	198
19	1800	1848	99
20	2000	2050	99
21	1311	1625	595
22	1733	2000	595
23			0
24			0
25	1041	1217	298
26			0
27			0
28	0842	1000	298
29	0855	0945	298
30	0853	1012	298
31	1015	1250	1,388

Month December, 19 77

DATE	TIME OPENED	TIME CLOSED	DAILY AMOUNT OF INFLOW IN ACRE-FEET
17	0016		13,231
18	0807 2204	0430 1845	10,468
19	0840 2325	0617 1836	10,168
20		2007	11,615
21	0005	2050	8,866
22	0015 1120	0740 1645	9,332
23	0723	1640	7,735
24	0219 0910	0710 1905	10,897
25	0300	2153	13,095
26	0330	2200	12,473
27	0330	2200	11,974
28	0445		11,931
29	0517	0005	12,083
30	0530	0042	11,382
31	0555	0021	10,963

TABLE VII-4

EXPORT EFFECTS ON TIDE STAGES[1/]

Delta Tide Stations	Tidal Stage	15 Day Mean Tidal Differences between Old River at Rock Slough and indicated locations, 1977, Oct. 17-31, 296 ft^3/s [2/]	1977, Dec. 17-31, 9,368 ft^3/s [2/]
	HH	0.10	0.55
	LH	0.10	0.49
	HL	0.16	0.41
1. Old River near Byron	LL	0.10	0.23
	HH	0.02	0.52
	LH	0.03	0.44
	HL	0.10	0.36
2. Middle River at Borden Hwy.	LL	0.06	0.18
	HH	0.04	1.08
	LH	0.06	0.95
	HL	0.17	0.47
3. Old River at Clifton Court Ferry	LL	0.09	0.32
	HH	0.12	1.04
	LH	0.12	0.88
	HL	-0.04	0.30
4. Grantline Canal at Tracy Road Bridge	LL	-0.30	-0.07
	HH	-0.13	0.55
	LH	-0.11	0.42
	HL	-0.31	0.00
5. Middle River at Mowry Bridge	LL	-0.67	-0.60
	HH	0.25	1.20
	LH	0.62	0.99
	HL	-0.55	0.08
6. Old River near Tracy Road Bridge	LL	-0.93	-0.61
	HH	0.13	1.05
	LH	0.13	0.88
	HL	-0.12	-0.30
7. Tom Paine Slough above Mouth	LL	-0.32	-0.13
	HH	0.02	0.57
	LH	-0.10	0.37
	HL	-0.18	-0.42
8. San Joaquin River at Mossdale	LL	-1.35	-1.01

1/ Range of San Joaquin River flows near Vernalis was 232-268 ft^3/s and 470-600 ft^3/s during the Oct 17-31 period, and the Dec 17-31 period, respectively.

2/ Tracy Pumping Plant and Clifton Court Intake combined 15 day mean diversion rate.

periods demonstrates, in general, that reductions in 15 day average water levels due to an increase in export as measured in the prototype are of the same order as those obtained in mathematical model studies to be discussed later in the text. The reduction in 15 day average water level at high tide at Clifton Court is a composite effect of high tide diversion into Clifton Court Forebay and steady diversion into the Delta-Mendota Canal. The impact of steady pumping is estimated to be about an average of 0.08 foot depression at Clifton Court Ferry per 1,000 ft^3/s based on the analysis of the 1977 data. The impact of intermittent diversion into Clifton Court Forebay at high tide is approximately 0.14 foot per 1,000 ft^3/s of average daily diversion. The combined effect of steady and intermittent pumping was to depress the high tide level by about 1.1 feet. Table VII-5 discusses the data and describes the procedures used to calculate these estimates.

The above tests showed that water level drawdown was about the same in Old River near Tracy Road and at Clifton Court. A depression in water level was evident as far away as Mossdale. However, an exact effect at Mossdale cannot be determined by tests in which San Joaquin River flows and agricultural diversions upstream from the export pumps vary between test periods. For example, in December 1977 the San Joaquin River flow was two to three times greater, and the agricultural diversions were presumably less than in October 1977.

A graphic presentation of the effect of intermittent export pumping on water levels at high tide is shown in figure VII-6. This figure shows the tide levels during the upper portion of the tide at Clifton Court and at Old River at Tracy Road on June 20-21, 1972, and compares them to the Bacon Island tide level. During this period, the average daily export rates were 2,362 ft^3/s

Table VII-5. Impact of CVP and SWP export on water levels in Old River at Clifton Court Forebay[1]

Observation period	CVP-SWP mean daily diversion rate in ft^3/s		Mean 15-day tidal elevation difference between Old River at Rock Slough and Clifton Court Forebay in feet			
	CVP	SWP	HH	LH	HL	LL
October 17-31, 1977	180	140	0.04	0.06	0.17	0.09
December 17-31, 1977	3,600	5,800	1.08	0.95	0.47	0.32
Differential	3,420	5,660	1.04	0.89	0.30	0.23

$$\text{Steady pumping impact} = \frac{\dfrac{\text{HL Diff.} + \text{LL Diff.}}{2}}{\text{average DMC Diversion in } 1{,}000\ ft^3/s}$$

$$= \frac{\dfrac{0.30 + 0.23}{2}}{3.42} = 0.08\ ft/1{,}000\ ft^3/s$$

$$\text{Intermittent pumping impact} = \frac{\text{HH Diff.} - \text{steady pumping impact}}{\text{average daily diversion to CCFB in } 1{,}000\ ft^3/s}$$

$$= \frac{1.04 - \dfrac{0.08 \times 3{,}420}{1{,}000}}{5.66} = 0.14 \text{ ft per } 1{,}000\ ft^3/s \text{ of average daily diversion}$$

$$\text{Intermittent pumping impact} = \frac{\text{HH} - \text{Steady pumping impact}}{\text{Average daily diversion to CCFB} \times \dfrac{24 \text{ hours}}{\text{Diversion period}}}$$

$= \text{feet per } 1{,}000\ ft^3/s$ of intermittent diversion.

$$= \frac{1.04 - 0.08 \times 3.42}{5.66 \times \dfrac{24}{17}} = \frac{1.04 - 0.27}{7.99} = 0.096 \text{ or } 0.10 \text{ feet per } 1{,}000\ ft^3/s$$

Total impact at high high tide $= 0.08 \times 3.42 + 0.14 \times 5.66 = 0.27 + 0.79$

$= 1.06$ feet as compared to the measured value of 1.04 feet.

[1]The rates of impacts identified in this analysis are approximations only.

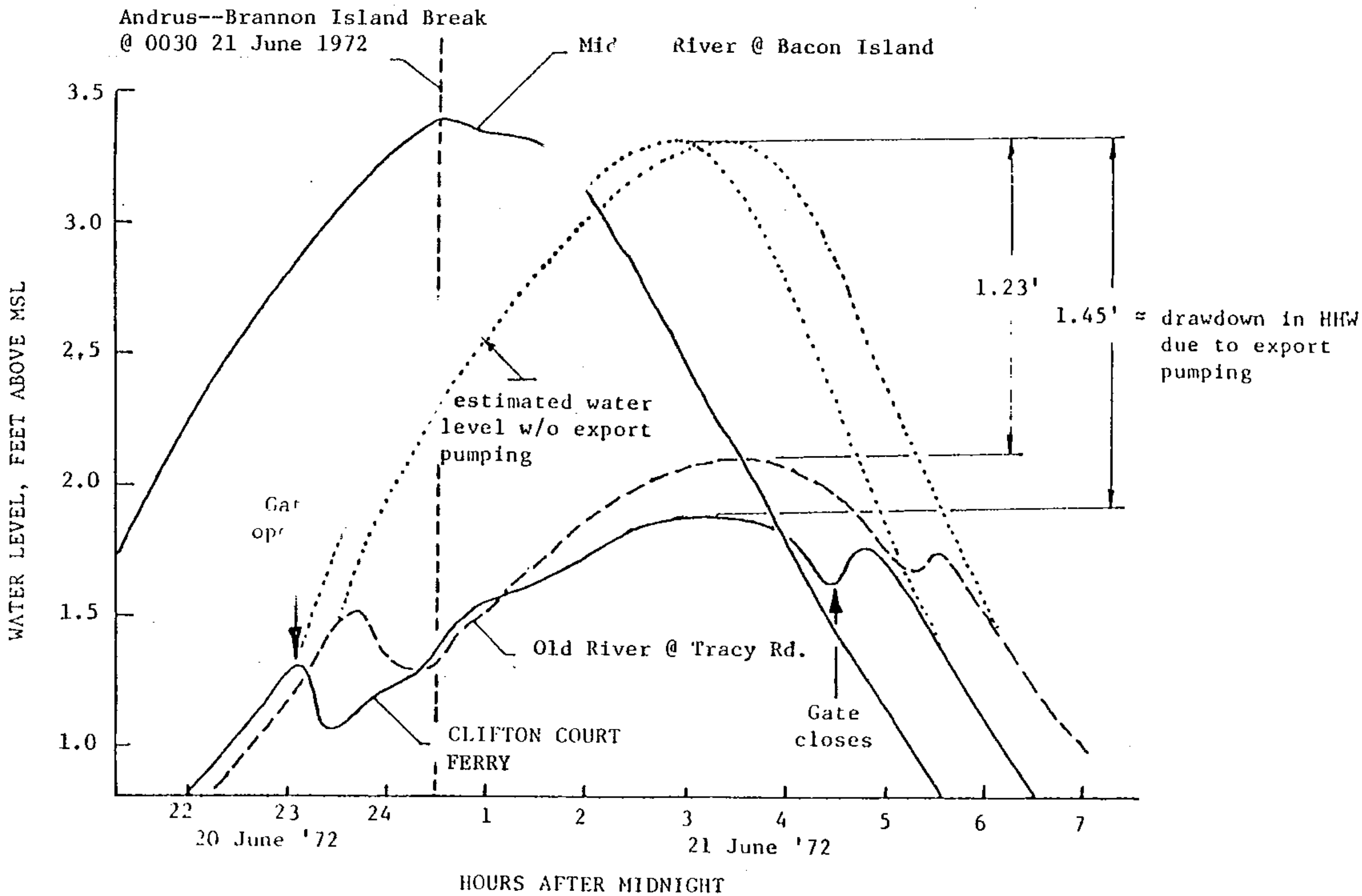


Figure VII-6 WATER LEVELS IN SOUTHERN DELTA, 20-21 JUNE 1972

CVP Export = 4233 cfs SWP Export (Avg) = 2411 cfs for the SWP and 3,561 ft^3/s for the CVP. The southern Delta tide levels would probably have been about the same height as the Bacon Island tide in the absence of pumping. Using the indicated difference between HH water at Bacon Island and Clifton Court as the effect of pumping and the procedure outined in table VII-5, it is estimated that the intermittent pumping impact was about 0.5 feet per 1,000 ft^3/s of average daily diversion and 0.122 feet per 1,000 ft^3/s of actual intermittent diversion rate. The total impact was a reduction in water level at high tide of about 1.5 feet, extending as far upstream on Old River to Tom Paine Slough.

The comparison of the impact of intermittent pumping rates on the water levels near Clifton Court in feet per 1,000 ft^3/s of average daily diversion is appropriate when the periods of diversion are approximately the same. Comparing the impact of intermittent pumping during the June 20-21, 1972 period with the October 17-31, 1977 and December 17-31, 1977 periods, in feet per 1,000 ft^3/s of average daily diversion will give a distorted result. During the 1972 period the actual diversion of 10,300 ft^3/s occurred over a period of 5.5 hours whereas during the 1977 period the actual diversion of 7,990 ft^3/s was sustained for 17 hours. The maximum pumping water level drawdown on June 21, 1972, between Bacon Island and Clifton Court was 1.26 feet; during the 1977 period between Rock Slough and Clifton Court the drawdown was 0.77 foot. Expressing these drawdowns in terms of actual rates of diversion for each period results in 0.122 foot per 1,000 ft^3/s and 0.10 foot per 1,000 ft^3/s, respectively.

The impact of export pumping on water levels in the vicinity of Clifton Court Forebay is relatively insensitive to the flows in the San Joaquin River at Vernalis. However, the effects of export pumping on the hydraulic gradient between Clifton Court Ferry and the San Joaquin River does vary with the riverflows. The project impact on net flow rates and water levels in this reach are greatest at low rates of inflow.

A mathematic procedure (Hardy Cross network analysis) was used to describe the relationship between head loss within individual channels and the average exports and flows in the San Joaquin River. A memorandum dated February 16, 1951, summarized the network analyses of the Lower Sacramento-San Joaquin Delta that were made in connection with the design of the Delta Cross Channel. Copy of this memorandum is included in Appendix 4. A simplified technique, based on the assumption of steady flow with no tidal fluctuation was used to demonstrate the effect of San Joaquin River inflow on the distribution of drawdown related to a constant export. This procedure assumes no agriculture diversion within the southern Delta. (During periods of low flow this is seldom a realistic assumption.)

For the semi-quantitative use the various channels were combined into four equivalent channels as shown. The ship channel because of its relatively large cross-section was assumed to act as a manifold at a constant level. The resistance values represent channel resistance coefficients such that head loss (h) = $5.543 \times 10^{-8} rQ^2$ where the constant was derived from the Manning equation.

Flow distributions were developed: Case A with 4,600 ft^3/s export and a downstream flow at Mossdale of 1,000 ft^3/s, and Case B with the same export (4,600 ft^3/s), but a downstream flow of 300 ft^3/s.

Case A

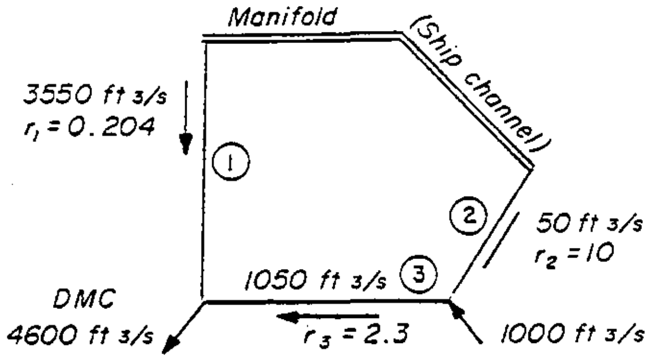
Q_1 in channel 1 = 3,550 ft^3/s

Q_2 in channel 2 = 50 ft^3/s

Q_3 in channel 3 = 1,050 ft^3/s

$\Delta h_1 = 0.145$, $\Delta h_2 = 0.00014$

and $\Delta h_3 = 0.1405$



The junction of channel 2 and 3 which represents Mossdale approximately is subject to negligible drawdown (1 percent of drawdown at Tracy).

Case B

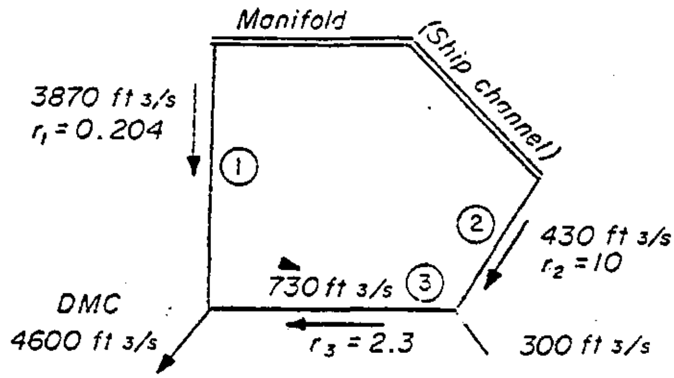
Q_1 = 3,870 ft^3/s

Q_2 = 430 ft^3/s

Q_3 = 730 ft^3/s

$\Delta h_1 = 0.169$, $\Delta h_2 = 0.102$

and $h_3 = 0.068$



At Mossdale the drawdown (Δh_2) is 0.102 or 60 percent of the drawdown at the DMC intake.

The analysis indicated that when the flows at Mossdale are less than 500 ft^3/s and the pumping is approximately 4,600 ft^3/s, the gradient between the pumps and the bifurcation was very flat. Therefore, depression of the water levels at Clifton Court would be felt as far away as the bifurcation and even upstream beyond Mossdale. However, with riverflows at Mossdale of a magnitude of about 1,000 ft^3/s, the gradient is much steeper and, therefore, the pumping impact is less at the bifurcation.

Model studies--Tests such as those just described in 1968 and 1977 are difficult to arrange. They are, therefore, limited in the range of conditions tested. Furthermore, conditions of tide, riverflow, and agricultural diversions vary during the tests, thereby modifying results, particularly for points far upstream of the export pumps. Therefore, it was necessary to develop a mathematical model in order to examine a wider range of conditions and to avoid the uncertainties of test data wherein conditions other than export rates vary during the tests. A mathematical model for this purpose was developed for SDWA by Dr. G. T. Orlob per his report entitled "Investigation of Water Level Problems in the Southern Delta - Model Studies" and dated May 14, 1979. The model is a refinement of an earlier Delta-wide model which was developed under Dr. Orlob's direction and commonly referred to as the WRE model.

It was first necessary to establish a reference station for southern Delta tides. Delta tides do not correlate reliably with ocean tides for various reasons. (See DWR-USBR report dated September 1970 and titled "Sacramento--San Joaquin River Delta Low Tides of April--May 1970.") The Bacon Island tide station was, therefore, chosen as being reliably related to the southern Delta tide levels which would occur in the absence of all pumping.

The model was calibrated so as to obtain a close a match as possible between model results and the measured data from southern Delta tide gages during various conditions of tide, export diversion, and riverflow. Comparison of the model's predictions and actual tidal curves for conditions of steady diversion indicate that the model is a useful tool for water level studies. The model still requires verification for some special cases . However it improves understanding of the interrelationships between water level changes and export pumping under the dynamic conditions induced by tides in the southern Delta.

Table VII-6 shows the model's predicted change in water level due to export pumping at various southern Delta points and for various export rates. With a CVP export rate of 4,323 ft^3/s and no SWP export and a 550 ft^3/s riverflow rate at Vernalis, the drawdown of water levels by the export pumps is calculated to be 0.52 foot at HHW and 0.40 foot at LLW at the CVP intake channel; 0.51 at HHW and 0.47 at LLW at the Westside Irrigation District intake channel on Old River; 0.41 foot at HHW and 0.37 foot at LLW at Old River and Tom Paine Slough; 0.35 foot at HHW and 0.31 foot at LLW at Old River and Middle River; and 0.34 foot at HHW and 0.13 at LLW at Mossdale. Steady pumping impacts predicted by the mathematical model presented in table VII-6 is compared to the LLW value calculated using the 1968 pumping test rated of depression presented on table VII-1.

	Model Run	May 1968 Test[1,2] Results
Old River at Clifton Court Ferry	-.40	-.30
Old River at Tracy Road	-.39	-.27
Grant Line at Tracy Road	-.44	-.27
Tom Paine Slough	-.37	-.27
San Joaquin River at Mossdale	-.13	-.13

[1]The May 1968 test results were adjusted to reflect the same rate of diversion as simulated in the model run, i.e., the 1968 test results were multiplied by the factor of $\frac{4,323}{4,775}=0.90$.

[2]During the 1968 test 10 to 31 percent of the flows diverted from the Delta by the SWP were withdrawn from Italian Slough not Clifton Court Forebay as simulated in the model study.

With the same CVP export rate and the same riverflow rate at Vernalis, but with a 4,800 ft^3/s average daily SWP export rate (drawn off the high

TABLE VII-6

SUMMARY OF WATER LEVEL CHANGES IN THE SOUTHERN DELTA DUE TO EXPORT PUMPING BY THE CVP AND SWP 1/

Node	Location	RUN SD-29A Q_e 2/ (DMC) = 4323, Q_e (SWP) = 0			RUN SD-29B Q_e (DMC) = 4323, Q_e (SWP) = 1600, Q_{ep} 3/ (SWP) = 2000			RUN SD-30 Q_e (DMC) = 4323, Q_e (SWP) = 2800, Q_{ep} (SWP) = 7000			RUN SD-32 Q_e (DMC) = 4323, Q_e (SWP) = 4800, Q_{ep} (SWP) = 12,000		
		HHW	HTL	LLW	HHW	HTL	LLW	HHW	HTL	LLW	HHW	HTL	LLW
1	Bacon Isl. (Input)	0	0	0	0	0	0	0	0	0	0	0	0
20	Clifton Ct.	-0.36	-0.35	-0.34	-0.89	-0.47	-0.36	-1.08	-0.58	-0.34	-1.74	-0.77	-0.26
22	Old R. @ DMC	-0.52	-0.49	-0.40	-1.01	-0.59	-0.40	-1.17	-0.70	-0.39	-1.83	-0.89	-0.32
26	WSID	-0.51	-0.47	-0.47	-1.01	-0.58	-0.49	-1.17	-0.68	-0.46	-1.84	-0.87	-0.38
32	Old R. @ Tracy Rd.	-0.43	-0.43	-0.39	-0.97	-0.54	-0.40	-1.12	-0.64	-0.37	-1.81	-0.83	-0.29
115	Grantline @ Tracy Rd.	-0.44	-0.40	-0.44	-0.93	-0.60	-0.46	-1.09	-0.61	-0.43	-1.76	-0.80	-0.36
34	Tom Paine Sl.	-0.41	-0.42	-0.37	-0.92	-0.53	-0.40	-1.11	-0.62	-0.39	-1.78	-0.81	-0.34
35	Salmon Sl.	-0.40	-0.39	-0.33	-0.90	-0.50	-0.37	-1.06	-0.59	-0.36	-1.73	-0.79	-0.31
39	Old R. @ Middle R.	-0.35	-0.33	-0.31	-0.81	-0.46	-0.35	-1.00	-0.56	-0.34	-1.63	-0.74	-0.31
44	Old R. @ San Joaquin	-0.31	-0.27	-0.18	-0.65	-0.38	-0.24	-0.89	-0.46	-0.26	-1.32	-0.61	-0.29
139	San Joaquin @ Mossdale	-0.34	-0.26	-0.13	-0.66	-0.38	-0.22	-0.87	-0.46	-0.27	-1.33	-0.65	-0.37

1/ Based on mathematical model analysis using a version of the WRE Model
2/ Q_e is the average daily diversion
3/ Q_{ep} is the actual diversion during HHW
Note: Vernalis flow rate 550 rfs.

tide at about 12,000 ft^3/s), the drawdown at the CVP intake channel is increased to 1.83 feet at HHW and 0.32 foot at LLW; at Old River and Tom Paine Slough it is 1.78 feet at HHW and 0.34 foot at LLW; and at Mossdale it is 1.33 feet at HHW and 0.37 foot at LLW. The intermittent pumping impact at Clifton Court was calculated at 0.127 foot per 1,000 ft^3/s at HHW, which compares favorably with the rate calculated using the June 21-22, 1972 data (0.122 ft/1,000 ft^3/s).

Impact of Export Pumping and Channel Configuration on Water Circulation and Water Quality

Circulation of water in southern Delta channels and the related water quality in those channels is influenced by tidal activity, export and local pumping, inflow and channel configuration. Tidal activity is the dominant factor [illegible]fluencing circulation for short time periods. For longer periods, net flow direction [illegible]d primarily by export pumping and inflows becomes the major influence. The [illegible] circulation is determined by the excursion and the volume of displacement duri[illegible] idal cycle, which are related to the tidal prism upstream from any given st[illegible] taken together with the cross sectional area at that station. Values of exc[illegible] from a low slack to a high slack tide range to as much as 3 miles in the s[illegible] Delta.

Net flow direction is markedly changed by v[illegible] physical works such as pumps, siphons, and tidal gates. Circulation chan[illegible]s have been studied in the field and by models, both physical and mathematical. A relationship between the division of flow at the head of Old River and export pumping has been developed per figure VII-7. This figure is a modification of plate 11 of the appendix to DWR Bulletin 76. This plot depicts the flow split at the

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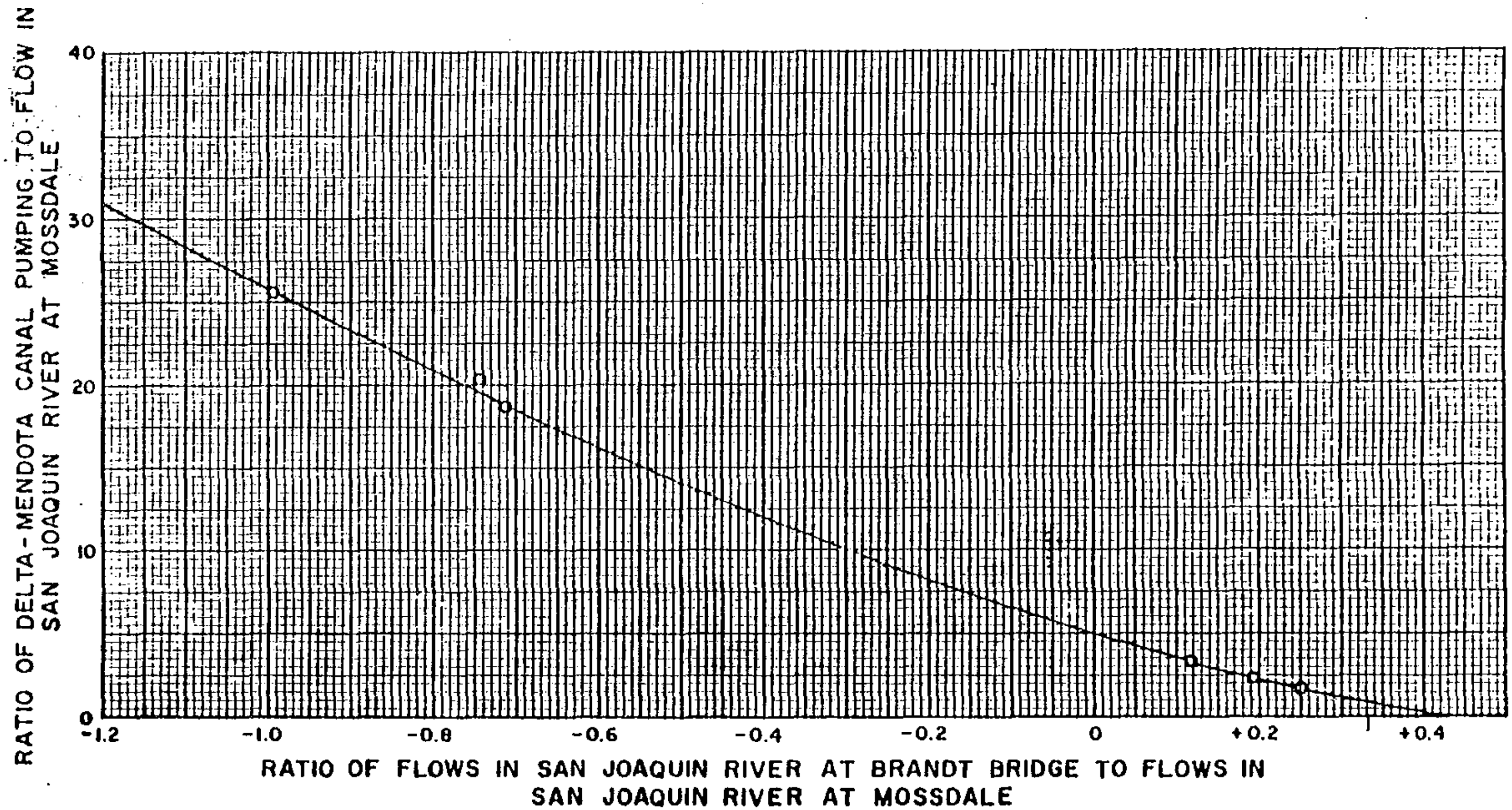


NOTE: **Flows in northwesterly direction in San Joaquin River at Brant Bridge positive and in opposite direction negative.**

This is plate 11 from the California Department of Water Resources' Report entitled Salinity Incursion and Water Resources Bulletin No. 76 Appendix on Delta Water Facilities dated April 1962.

RATIO OF FLOW AT TWO LOCATIONS ON SAN JOAQUIN RIVER AS INFLUENCED BY DELTA-MENDOTA CANAL PUMPING

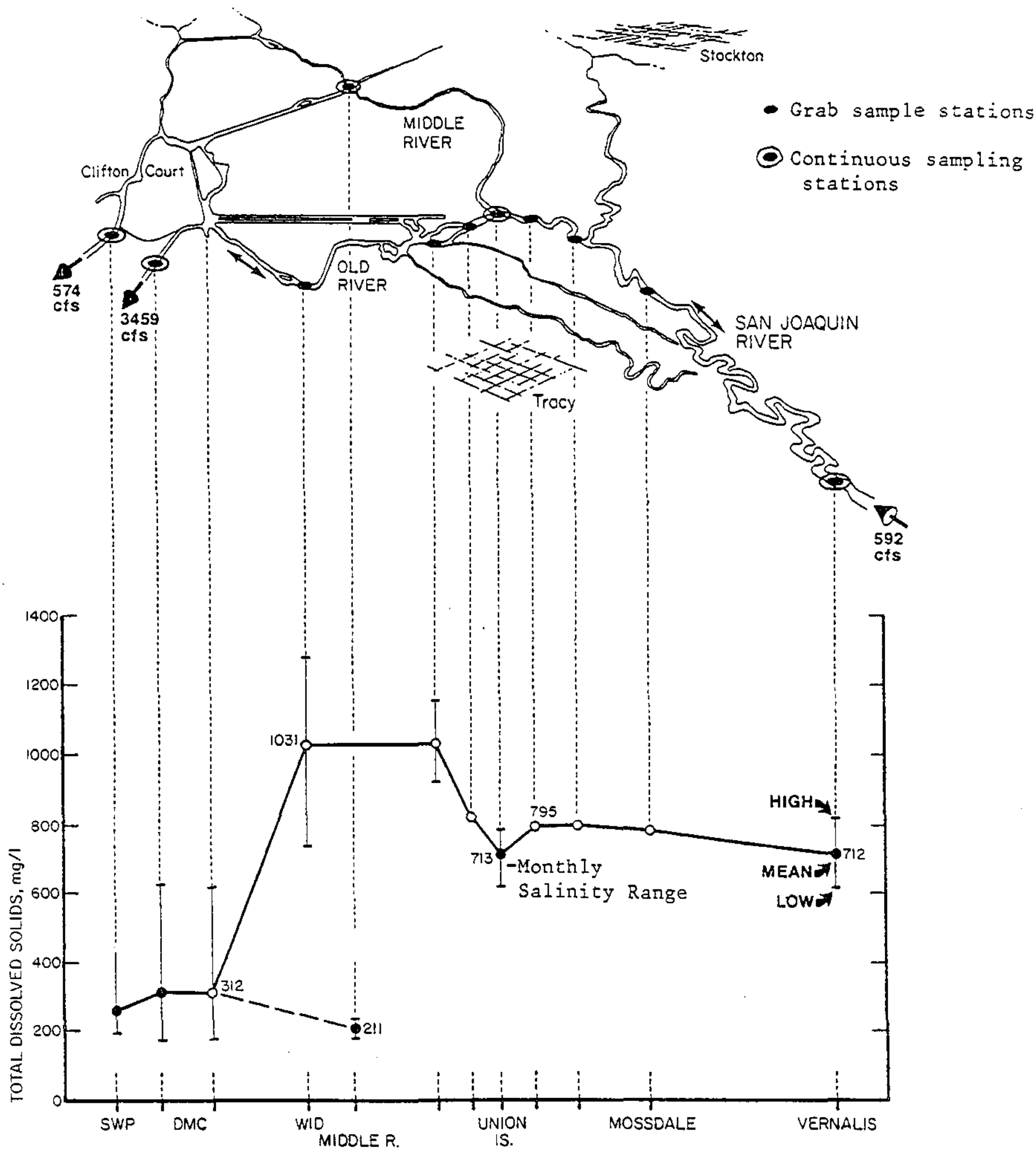
APRIL 1962

bifurcation of Old River and the San Joaquin River in relationship to the rate of export pumping. This determination of the relationship is an approximation because it does not account for the seasonally varying channel depletions between Vernalis and the head of Old River and because net flows are difficult to determine in tidal channels. However, the approximation is useful in analyses of the circulation and water quality. Depending upon the rate of export and local pumping, varying percentages of the San Joaquin inflow are drawn toward the export pumps even to the extent of reversing the normal downstream flow of the San Joaquin River below its bifurcation with Old River.

The induced flow toward the export pumps is carried mainly by Salmon Slough and Grant Line and Fabian Canals. Downstream flows in Middle River and Old River west of Salmon Slough have serious impediments to flow in the form of width and/or depth constrictions as previously discussed. These limitations are exacerbated to some degree by the lowering of water levels at the entrance of these channels.

Hydraulic restrictions in Middle River and portions of Old River tend to limit circulation and increase the likelihood of stagnation and poor water quality. These conditions may be aggravated further by reductions in water level, depth and/or tidal prism. Such occurrences are illustrated by the behavior of Old River between Salmon Slough and the DMC intake channel during July 1976, as shown in figure VII-8. The average monthly TDS concentration in Old River between Salmon Slough and the Westside Irrigation District intake generally exceeded 1,000 mg/L, while at the DMC intake the TDS averaged 312 mg/L. The rather large gradient of TDS between these two locations indicates that the effects of tidal mixing, and any available advective flow is not

Figure VII-8 TOTAL DISSOLVED SOLIDS IN THE SOUTH DELTA CHANNELS*
JULY 1976



Sources: WPRS continuous EC recorders, grab samples by Westside Irrigation District, Reclaimed Islands Land Co., Piscadero Reclamation District and Nelson Laboratories.

*Where ranges are indicated, they represent extreme values of daily observation or continuous records during the month. Where no range is indicated, data correspond to a very small number of samples.

sufficient to offset the effect of salt accumulation in this channel. Such circulation as did exist may have been aided by the Westside Irrigation District diversion since there are no other significant diversions between the district's intake and the DMC intake.

The operation of the export pumps draws water from all contributing channels, including the Old River--Salmon Slough--Grantline Canal principal channel through which water from the San Joaquin River enters the zone affected by export. Data derived from the Service's continuous EC monitors show that at low tide following a downstream tidal excursion the EC near Clifton Court is generally higher than at high tide when cross Delta flows from the Sacramento River are most likely to be dominant. As an illustration the quality of water in San Joaquin River at Vernalis between July 9 and July 18, 1978, averaged about 635 umhos EC with no tidal variation whereas the quality in the Delta-Mendota Canal intake channel varied about threefold between the high and low tidal stages. The 10-day average qualities in each tidal phase in umhos at the various tidal phases between July 9 through July 18, 1978 were as follows:

Tidal phase	Water quality (micromhos)
HH	323
LH	212
LL	631
HL	385

SUMMARY AND CONCLUSIONS

CHANNEL DEPTHS AND CROSS SECTIONS

Changes in channel geometry were assessed by comparison of surveys made in 1913 and 1965 by the Corp of Engineers and in 1933-34 by the United States Coast and Geodetic Survey and at various times during the period 1957 through 1976 by the Department of Water Resources. Results of the analysis for each principal channel is summarized below:

San Joaquin River--Vernalis to Mossdale Bridge

The bottom elevation increased from 0.5 to 9.5 feet, with an average increase of about 4 feet. This aggradation raised the bottom elevation of about 45 percent of this reach to an elevation of 1.5 to 3.5 feet above LWD whereas it was 2 to 7 feet below LWD in 1933. This probably has occurred due to reduced floodflows, a normal supply of river sediment load, and the fact that this reach is where the river enters the tidal zone. Sediments tend to deposit at the entry to a tidal zone.

Old River--San Joaquin River to Salmon Slough

The bottom elevation dropped an average of 4 feet, i.e., the channel degraded. This degradation is unexplained.

Grant Line and Fabian Canals

These channels degraded between 1957 and 1973 by an average of 4 feet. This period corresponds to an increase in Delta export pumping. Channel degradation could have been due to maintenance dredging of the channels performed by the local reclamation districts and the Corps of Engineers.

Middle River--Old River to Victoria Canal

This channel has aggraded since the 1933 survey from an average maximum bottom elevation of 6 feet below LWD to an average maximum bottom elevation of 4 feet below LWD. About 55 percent of the reach, that immediately north of Old River, has aggraded an average of 0.5 foot since 1933-34. The most restrictive section is now about 0.5 foot below LWD as compared to the previous 1 foot below LWD. The channel conveyance capacity is quite low and often less than the agricultural diversion rate. There is no evidence of recent channel maintenance dredging (access to 55 percent of the most restrictive sections is hampered by two fixed span bridges).

Old River--Salmon Slough to DMC Intake Channel

This channel also has restrictive cross sections with maximum depths of about 3.5 feet below LWD and a minimum mean depth of about 2 feet below LWD. There has been little change since the 1933-34 survey.

Changes in channel cross sections that have been observed since 1933-34 are a consequence of modifications in the hydraulic regimen of the southern Delta: export pumping by the CVP initiated in 1951, intermittent diversions by the SWP commencing in 1968, and reduced San Joaquin River inflows at Vernalis. The analysis of channel depths within the South Delta Water Agency does not establish whether or not export pumping has caused appreciable siltation or scour within the SDWA channels. Channel degradation in the reach of Old River between Salmon Slough and the San Joaquin River is unexplainable. The channel degradation within Grant Line--Fabian Canals could be attributed to export pumping and/or dredging. This channel carries the largest proportion of San Joaquin River flows which are drawn to the export pumps. The decrease in channel resistance in this channel modifies the proportion of flows carried by this channel and the proportion carried by the reach of Old River between Salmon Slough and the export pumps.

The control of siltation in some South Delta channels requires periodic channel maintenance. No routine channel maintenance program exists in this area of the Delta at this time.

IMPACT OF EXPORT PUMPS ON WATER LEVELS

Steady diversion of flows by the CVP reduces the water level at Clifton Court and adjacent channels by a range of 0.07 to 0.10 foot per 1,000 ft^3/s, or about 0.32 to 0.46 foot at full capacity of 4,600 ft^3/s. This impact influences the water levels in Old River and Grant Line Canal upsteam to Salmon Slough, at about the same magnitude, thereby directly impacting the entrance to Tom Paine Slough, which relies on tidal elevation differences to produce the gradient for flow into the Slough.

The intermittent diversions into Clifton Court Forebay by the SWP reduce the HHW levels by about 0.10 to 0.127 per 1,000 ft^3/s of water diverted. At full capacity of the CVP, operating at 4,600 ft^3/s on a steady basis, and the SWP, operating only on the high tide, with a 10,000 ft^3/s diversion rate,[1] the water level depression at HHT may be expected to be in the range of 1.34 to 1.76 feet.

Reductions in water level also are evident at Mossdale Bridge on the San Joaquin River. However, the water level depression at this point is related to the portion of the inflow from the San Joaquin River which reaches

[1] The maximum SWP pumping rate of 6,000 ft^3/s into the aqueduct corresponding to this 10,000 ft^3/s high tide diversion to Clifton Court Forebay over a period of approximately 14 hours.

the bifurcation with Old River. When the riverflows at the bifurcation are less than 1,000 ft^3/s, the gradient between the pumps and the bifurcation flattens and the pumping effect is increased whereas at 1,000 ft^3/s the effect is relatively insignificant.

IMPACT OF EXPORT PUMPING ON WATER CIRCULATION AND QUALITY

During most summer periods, the San Joaquin River flows are now less than the net rate of channel depletion within the SDWA. The induced flow toward the export pumps which is caused by the drawdown of levels, is carried mainly by Salmon Slough and Grant Line and Fabian Canals. Downstream advective flows into the reach of Middle River between Old River and Victoria Canal and in the reach of Old River west of Tom Paine Slough are generally less than the agricultural diversions from those channels during dry seasons, thereby causing water to flow into these reaches from both ends permitting accumulation of salts from local return flows as illustrated in figure VII-8. Both of these channels have serious impediments to flow in the form of width and/or depth constrictions as previously discussed. However, it is apparent that substantial portions of low summer San Joaquin River flows pass through the upstream end of Old River and Grant Line and Fabian Canals and are diverted with the export.

The increase in net unidirectional flow from the San Joaquin River toward the pumps reduces the accumulation of drainage salts in the upper end of Old River and in Grant Line and Fabian Canals. However, the drawdown which causes this increase in flow does not necessarily induce net daily unidirectional flows through Middle River in the southern Delta, or in Old River from Tom Paine Slough west toward the DMC intake channel as discussed above.

Tidal circulation is reduced by the lowering of water levels. However tidal exchange of salts is dependent both on circulation and the difference in salt concentration between any two points in a channel. For example in the restricted reach of Old River even with the reduced tidal prism in the vicinity of the DMC intake channel, there is some flushing resulting from tidal exchange with better quality of water available.

Quality in dead end sloughs such as Paradise Cut and Old Oxbows rely e[illegible]irely on tidal exchange. When San Joaquin River flows at Vernalis are less [illegible] the agricultural diversions south of Mossdale, the reach of San Joaquin Rive[illegible] [illegible]nnel south of the bifurcation of Old River functions also functions like a b[illegible] [illegible]lough and tidal flushing becomes important for water quality as well as for [illegible] [illegible]epth in that reach of channel.

The overall [illegible] [illegible]f export pumping on the South Delta channels includes:

1. Reduction in [illegible] [illegible]raulic capacity of channels with consequent reduced water availability [illegible] [illegible] local diversion points.

2. Increase in gradient to[illegible] the Delta export pumps which results in increased downstream advec[illegible] circulation from the San Joaquin River through the east end of Old River to C[illegible] Court via Grant Line Canal.

3. Availability of Sacramento River w[illegible] [illegible] the northern boundary of the southern Delta which is drawn into portions [illegible] [illegible]e southern Delta channels through tidal mixing.

4. Increase in suction lift required of pumps of local diverters.

5. Increase in frequency of loss of prime (due to inadequate water depth) by pumps of local diverters.

6. Reduction in tidal prism with resultant decrease of tidal flows and of tidal flushing of salts, particularly in shallow, or stagnant, or blind channels.

This report does not attempt to quantify all of these export pump impacts or to determine the water levels, hydraulic capacities, and salinity levels needed in southern Delta channels. Water level drawndown, of the magnitude indicated, obviously has an impact on water availability in the shallowest channels, but determining the net effect on salinity due to changes in advective and tidal flow would require additional study of the net effect in each channel. Furthermore, the impact of export pumping also varies with the degree to which San Joaquin River flow and salinity at Vernalis are altered.

APPENDIX 1

MONTHLY FLOW DATA (KAF) AND

MONTHLY CHLORIDE DATA (P/M)

THIS IS THE DATA FILE OF ACTUAL SAN JOAQUIN RIVER FLOWS (KAF) AT VERNALIS.

		OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1930	VN	86.70	73.20	79.30	111.00	94.40	151.00	154.00	136.00	164.00	76.20	56.60	85.10
1931	VN	103.00	97.60	117.00	95.30	88.90	54.20	23.10	27.30	23.30	14.30	14.00	19.00
1932	VN	29.40	38.30	76.90	205.00	621.00	301.00	286.00	713.00	898.00	356.00	71.30	63.70
1933	VN	103.00	113.00	115.00	124.00	167.00	107.00	68.40	84.80	316.00	68.20	41.00	68.40
1934	VN	94.10	91.00	148.00	169.00	124.00	105.00	41.80	39.30	37.30	24.30	23.60	29.80
1935	VN	52.20	76.80	98.80	223.70	196.30	250.60	878.20	1007.00	938.80	165.90	61.20	80.30
1936	VN	125.10	115.40	155.90	203.20	688.00	878.10	773.10	1020.00	661.60	187.40	69.00	76.20
1937	VN	116.20	116.60	175.60	202.40	688.30	812.20	860.60	1233.00	925.70	200.50	69.40	83.10
1938	VN	116.70	117.80	326.40	381.20	1301.00	2100.00	1333.00	1743.00	2181.00	898.30	206.60	132.40
1939	VN	163.90	226.00	227.50	251.50	231.60	124.60	146.80	125.20	59.00	46.50	44.00	61.50
1940	VN	91.30	85.40	97.60	254.00	493.10	902.30	965.20	879.30	645.60	122.70	72.90	100.40
1941	VN	98.60	102.00	185.20	438.60	727.90	1302.00	1017.00	1309.00	1327.00	562.10	128.80	100.30
1942	VN	135.20	138.60	293.70	518.40	706.90	533.40	798.20	1017.00	1323.00	478.20	103.60	114.00
1943	VN	137.50	138.80	268.40	347.20	725.80	1422.00	1075.00	920.60	693.40	135.80	94.80	100.50
1944	VN	129.60	116.20	146.80	165.40	164.60	294.70	136.90	235.30	201.40	76.60	67.10	71.40
1945	VN	101.40	147.20	232.90	237.60	604.30	566.70	534.80	855.60	673.80	238.60	109.40	120.90
1946	VN	169.60	207.30	352.50	584.80	330.70	229.60	357.90	802.90	344.10	90.10	75.30	88.30
1947	VN	111.60	155.70	222.40	171.10	133.70	138.90	88.50	125.80	56.10	32.40	35.00	63.90
1948	VN	80.80	105.50	104.20	85.10	47.50	36.80	82.90	307.50	512.10	81.70	44.60	64.70
1949	VN	95.20	88.80	91.40	107.00	78.60	213.30	122.40	217.00	119.20	34.60	37.00	42.50
1950	VN	77.90	94.10	96.60	122.90	196.70	135.60	319.30	308.20	298.30	42.30	38.20	56.30
1951	VN	81.40	482.10	1545.00	632.10	600.50	477.70	157.80	401.20	198.60	53.50	46.70	61.60
1952	VN	109.70	104.90	192.80	544.20	661.90	845.30	1202.00	1699.00	1389.00	215.10	83.30	96.40
1953	VN	114.70	129.50	225.00	365.70	204.00	71.50	90.40	188.10	292.40	98.60	46.00	65.00
1954	VN	100.20	98.90	108.30	101.90	131.00	274.30	301.00	412.90	76.50	33.30	33.60	44.90
1955	VN	32.30	82.50	111.50	182.30	136.10	96.00	54.60	70.70	89.00	25.60	26.50	36.30
1956	VN	49.20	63.70	670.60	1663.00	993.90	460.30	372.60	859.30	729.00	214.20	116.90	112.20
1957	VN	122.90	131.60	154.00	118.10	97.90	187.80	78.90	158.70	223.70	53.80	46.30	68.30
1958	VN	126.40	133.80	153.30	148.80	301.80	743.60	1661.00	1379.00	929.30	251.60	94.40	133.40
1959	VN	174.30	216.10	181.70	143.40	181.50	127.20	48.30	48.60	31.70	19.20	24.70	46.70
1960	VN	53.90	62.60	72.80	85.80	99.10	36.60	30.80	38.00	17.40	13.70	16.50	22.90
1961	VN	43.80	60.30	79.10	82.30	62.10	27.30	11.90	23.40	12.30	6.40	9.30	19.10
1962	VN	25.20	35.30	43.80	49.50	320.90	364.80	124.10	161.20	208.10	52.60	42.70	59.10
1963	VN	89.40	97.80	149.70	107.80	454.60	160.30	512.70	574.20	396.50	112.00	67.40	90.20
1964	VN	164.60	179.80	217.20	176.60	97.60	57.10	45.50	43.20	38.70	23.60	27.10	53.50
1965	VN	86.80	140.20	371.20	894.80	440.30	327.50	586.70	325.60	336.20	121.30	75.10	99.90
1966	VN	181.00	216.80	383.80	323.90	227.20	117.70	58.40	53.10	33.90	27.00	30.70	43.20
1967	VN	67.70	79.10	269.00	197.30	353.40	401.90	862.50	1252.00	1190.00	642.50	124.20	120.70
1968	VN	167.60	206.70	223.50	130.80	150.50	190.20	85.40	54.80	35.20	30.90	47.20	55.80
1969	VN	85.10	95.50	155.70	849.40	1808.00	1898.00	1316.00	1513.00	1659.00	356.80	142.90	193.70
1970	VN	274.40	275.40	246.70	683.50	510.50	441.50	99.53	147.20	160.90	81.79	64.22	78.51

THIS IS THE DATA FILE FOR STANISLAUS RIVER FLOW AT RIPON.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1930 RP	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
1931 RP	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
1932 RP	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
1933 RP	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
1934 RP	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
1935 RP	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
1936 RP	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
1937 RP	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
1938 RP	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
1939 RP	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
1940 RP	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
1941 RP	15.19	18.40	28.29	52.11	72.00	186.10	178.90	386.50	173.90	36.34	14.73	13.63
1942 RP	15.46	27.82	53.31	77.20	175.90	71.01	215.00	294.30	232.10	56.69	13.33	14.70
1943 RP	16.51	27.44	52.74	113.80	122.20	313.20	265.30	203.30	108.20	17.13	14.71	13.87
1944 RP	16.51	17.46	26.32	31.60	17.42	81.66	31.01	104.40	51.71	14.11	11.97	11.69
1945 RP	13.40	31.88	60.44	55.84	105.40	111.40	125.80	265.20	152.00	25.57	14.42	13.41
1946 RP	16.30	30.36	74.98	146.90	50.39	64.93	155.20	234.30	61.95	15.50	13.59	12.54
1947 RP	11.83	21.40	38.42	11.56	11.15	37.56	52.60	82.53	15.35	9.70	9.37	9.59
1948 RP	10.72	16.19	25.94	17.35	12.07	10.46	53.08	216.70	180.30	21.01	10.90	9.76
1949 RP	12.14	14.62	14.11	24.34	12.62	68.69	44.82	158.70	52.26	10.85	9.86	9.80
1950 RP	11.78	11.38	13.60	37.55	53.77	42.70	152.40	235.50	112.30	13.36	11.36	10.38
1951 RP	11.39	268.90	467.40	152.90	122.10	127.60	81.59	130.90	38.28	13.55	11.01	10.18
1952 RP	23.12	21.25	54.38	78.75	116.60	155.00	224.90	473.60	294.80	57.17	15.56	14.01
1953 RP	15.91	20.93	35.03	84.12	39.03	12.43	56.38	109.50	153.60	30.36	12.19	11.73
1954 RP	15.30	21.20	21.35	13.62	22.92	70.90	146.00	147.50	13.96	9.62	9.99	8.93
1955 RP	11.97	15.36	33.63	47.53	28.22	35.62	13.14	37.40	63.93	8.67	7.98	7.14
1956 RP	8.32	9.77	275.70	317.50	117.40	80.34	147.90	312.30	187.90	62.18	12.01	10.71
1957 RP	23.82	27.18	21.32	17.86	7.96	30.62	11.10	73.48	81.53	12.04	10.30	10.69
1958 RP	14.07	10.43	10.46	32.43	78.41	136.90	242.80	362.20	217.00	36.62	18.55	20.04
1959 RP	19.91	29.56	49.61	28.05	23.29	38.99	9.97	9.16	7.85	6.98	7.96	9.71
1960 RP	9.17	8.69	9.00	8.24	9.70	6.83	7.21	8.64	6.66	5.96	6.09	6.10
1961 RP	7.65	9.66	11.02	11.18	8.71	6.50	5.58	5.38	3.84	3.15	3.74	4.56
1962 RP	5.61	6.34	6.87	6.63	54.76	70.77	49.61	73.72	103.40	11.44	8.73	9.24
1963 RP	13.48	14.84	19.22	11.40	133.50	42.46	177.80	288.80	118.10	16.34	11.24	13.74
1964 RP	24.04	17.54	32.15	54.94	24.78	12.03	10.23	8.16	7.15	6.37	6.53	7.98
1965 RP	9.99	13.12	189.30	254.40	109.30	102.40	202.00	131.20	124.20	25.84	13.72	16.75
1966 RP	24.47	47.96	86.83	90.41	65.17	16.00	11.39	9.95	7.82	6.11	5.54	6.07
1967 RP	8.26	9.35	60.27	70.59	97.84	137.00	225.40	267.20	329.10	107.20	19.36	23.00
1968 RP	29.79	36.09	52.79	38.72	15.90	28.53	28.00	9.38	7.68	6.29	7.01	7.44
1969 RP	11.59	11.70	13.34	309.90	266.70	225.70	187.10	359.40	233.60	41.12	17.09	29.64

END OF FILE

lnh

THIS IS THE DATA FILE FOR THE ACTUAL FLOW AT MAZE ROAD BRIDGE (KAF).

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1930	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1931	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1932	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1933	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1934	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1935	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1936	0.00	0.00	0.00	162.20	564.30	668.20	574.60	767.60	503.80	150.60	55.10	64.10
1937	102.50	106.60	161.00	176.70	617.40	722.80	708.90	970.30	818.80	177.60	52.30	71.80
1938	110.50	100.80	0.00	341.20	1268.00	2077.00	1092.00	1265.00	1798.00	776.40	185.20	123.00
1939	140.70	206.70	206.80	216.00	212.40	114.60	90.20	84.70	43.10	34.10	36.20	51.50
1940	84.20	76.40	83.80	194.70	394.30	707.20	727.90	643.40	527.20	99.80	57.90	91.20
1941	87.80	88.70	166.60	388.00	660.50	1094.00	819.20	990.00	1202.00	510.10	116.30	93.40
1942	118.70	113.10	241.60	464.30	547.30	468.20	572.00	737.20	1113.40	427.50	88.80	101.50
1943	124.10	115.90	210.10	247.20	578.00	1088.20	773.60	683.60	565.20	113.80	79.10	85.70
1944	110.70	101.20	127.70	135.80	144.20	218.60	100.50	140.20	146.20	58.10	49.20	58.40
1945	96.40	117.10	169.20	166.20	496.00	466.90	400.00	600.80	538.90	214.80	95.90	104.40
1946	150.50	177.60	288.60	451.60	278.00	171.60	217.50	557.40	282.70	79.50	62.10	74.20
1947	97.60	131.40	178.80	162.00	118.40	106.60	37.30	52.10	40.30	26.10	27.30	60.60
1948	71.30	89.00	80.40	65.90	34.70	25.40	29.30	123.90	323.80	61.10	36.20	56.20
1949	88.80	73.20	77.20	82.40	61.60	154.50	83.50	83.90	75.30	24.80	30.80	35.90
1950	66.50	82.40	84.20	88.90	145.60	88.70	172.50	99.00	178.70	33.00	30.60	46.00
1951	73.40	341.40	1003.00	455.90	474.60	351.30	93.20	271.90	159.50	41.80	35.40	50.80
1952	82.20	74.80	140.60	445.40	546.00	698.40	942.50	1402.50	1006.30	171.80	76.50	79.20
1953	88.40	94.00	175.30	279.70	158.40	59.90	48.70	66.90	161.10	73.70	35.00	51.20
1954	80.20	73.20	81.90	84.10	104.00	201.60	179.60	270.20	60.70	33.20	31.40	38.20
1955	51.60	59.30	72.70	131.70	102.20	61.00	43.30	42.20	37.30	23.50	23.10	30.40
1956	37.90	47.40	394.60	1303.00	768.60	342.90	244.20	609.00	555.20	148.60	103.30	97.00
1957	94.90	96.00	116.30	100.10	85.00	149.80	70.20	103.30	154.90	43.80	43.40	53.40
1958	101.90	114.20	130.20	103.50	239.40	668.00	1583.00	1121.00	719.60	236.70	87.20	112.90
1959	149.40	209.60	134.20	116.30	137.70	89.80	42.80	43.80	29.00	19.90	22.80	39.20
1960	45.50	52.50	61.40	81.40	90.10	37.00	29.30	32.20	17.90	16.00	17.40	20.80
1961	37.90	52.10	69.70	76.10	55.60	25.30	15.00	24.40	13.50	9.60	12.00	20.00
1962	22.40	30.60	39.20	43.60	271.10	255.40	72.90	87.90	109.00	41.20	36.00	46.70
1963	64.30	70.30	101.80	83.50	374.70	110.40	384.70	410.40	293.40	77.90	48.80	65.30
1964	136.10	155.60	173.80	120.20	70.30	40.90	37.00	38.60	33.80	24.40	27.70	45.00
1965	0.00	0.00	240.60	555.70	324.90	236.90	400.90	227.20	233.90	91.20	63.20	80.40
1966	151.90	173.80	297.00	245.60	169.30	100.10	48.90	42.80	26.90	22.30	24.60	35.40
1967	57.40	67.40	220.60	146.30	267.90	279.40	685.10	970.30	906.60	485.50	101.50	86.80
1968	120.90	162.10	157.10	123.40	122.30	149.30	56.10	45.10	29.10	27.80	42.80	48.10
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

THIS IS DATA FILE FOR THE TUOLUMNE RIVER FLOW AT TUOLUMNE CITY.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1930 TC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	69.20	47.00	37.00	58.70
1931 TC	59.30	0.00	0.00	0.00	0.00	0.00	0.00	16.50	15.70	15.50	15.40	15.40
1932 TC	19.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23.60	23.40
1933 TC	60.80	0.00	0.00	0.00	0.00	0.00	0.00	19.80	90.80	25.70	19.70	39.50
1934 TC	62.50	0.00	0.00	0.00	0.00	0.00	0.00	19.00	17.90	17.70	18.00	17.10
1935 TC	33.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	41.60	23.80	40.90
1936 TC	49.70	0.00	0.00	72.90	231.10	247.60	199.20	328.10	258.60	56.30	25.00	30.60
1937 TC	55.90	54.70	79.30	59.80	161.30	210.30	222.30	388.50	222.20	34.00	23.40	36.00
1938 TC	59.50	70.30	0.00	88.10	402.10	444.10	342.70	398.40	620.00	186.10	45.80	56.60
1939 TC	67.30	125.90	88.40	70.90	58.00	38.40	23.90	28.90	20.10	27.50	27.10	29.50
1940 TC	50.50	52.00	50.40	58.60	159.00	293.20	264.20	213.20	184.10	26.70	27.70	52.80
1941 TC	47.90	64.10	83.30	88.30	132.90	270.90	225.90	319.90	390.40	109.00	47.30	45.70
1942 TC	63.50	68.30	107.60	144.80	118.90	141.10	172.80	255.30	445.90	131.80	42.30	52.80
1943 TC	63.40	54.40	132.60	95.30	179.20	378.80	231.70	251.90	214.30	39.40	33.70	44.20
1944 TC	59.10	61.70	78.70	55.20	48.50	74.80	35.20	63.60	40.90	23.20	22.00	21.80
1945 TC	46.50	71.00	118.10	70.20	183.00	167.90	119.90	127.90	238.20	83.00	29.60	35.90
1946 TC	53.50	85.90	121.60	145.50	85.90	58.10	118.80	282.50	119.30	30.10	28.20	24.60
1947 TC	51.10	93.50	86.20	55.30	48.30	49.00	20.60	18.10	16.50	15.20	17.30	39.80
1948 TC	48.40	67.60	53.10	41.90	17.80	18.10	20.90	79.30	174.20	37.40	21.50	24.20
1949 TC	48.30	47.50	52.40	43.70	32.10	80.50	51.10	31.00	23.00	20.60	20.80	19.50
1950 TC	45.60	63.90	63.70	51.80	79.70	51.30	148.70	69.10	113.40	24.00	21.90	21.30
1951 TC	41.80	250.00	522.20	205.70	160.10	181.20	39.70	164.20	108.40	25.10	23.20	21.70
1952 TC	54.30	48.80	98.00	209.90	168.20	277.50	390.70	481.50	302.30	50.00	26.10	26.50
1953 TC	41.70	67.30	132.20	128.20	93.90	30.30	29.70	36.00	120.20	68.50	22.80	20.10
1954 TC	49.10	48.10	52.70	54.10	47.30	134.00	85.00	125.90	24.60	20.50	18.80	18.50
1955 TC	31.40	38.90	46.40	72.10	69.60	37.90	20.40	19.00	17.20	16.30	16.20	22.00
1956 TC	22.00	34.80	294.80	507.00	236.10	145.20	108.80	204.30	190.80	69.50	59.40	52.30
1957 TC	51.30	64.10	80.40	58.60	37.60	70.30	29.30	33.40	51.10	21.90	20.70	21.40
1958 TC	60.60	88.90	96.80	55.60	95.10	288.10	530.50	444.30	305.00	106.00	28.60	46.90
1959 TC	93.90	162.00	96.10	66.70	92.60	46.10	21.40	20.50	17.40	16.40	15.60	16.80
1960 TC	26.20	34.20	42.20	48.50	39.60	21.70	16.40	15.40	13.40	13.40	13.20	14.10
1961 TC	27.40	35.80	52.10	43.20	23.90	14.80	11.00	10.90	9.90	8.80	10.50	13.60
1962 TC	14.60	20.30	16.60	12.60	102.20	120.20	37.90	22.30	18.60	17.90	19.20	23.00
1963 TC	42.50	60.10	105.50	54.10	0.00	0.00	155.20	125.20	122.10	44.60	25.10	23.40
1964 TC	69.30	131.10	147.30	73.10	37.80	19.30	16.50	15.50	14.30	12.50	12.60	14.40
1965 TC	21.90	82.80	189.40	378.40	209.80	97.70	240.10	89.00	107.50	45.80	25.90	0.00
1966 TC	115.60	120.00	159.40	113.00	96.60	56.70	21.10	18.30	14.40	13.50	13.10	13.10
1967 TC	34.40	40.10	164.70	80.90	144.80	201.50	341.10	238.40	326.80	218.50	25.00	23.10
1968 TC	49.70	116.60	94.70	63.70	59.80	92.10	20.80	14.90	12.00	12.40	15.30	15.20
1969 TC	23.50	30.00	98.10	359.20	437.60	289.70	285.10	376.80	458.20	88.60	16.50	35.20

END OF FILE

THIS IS THE DATA FILE FOR SAN JOAQUIN RIVER FLOW AT NEWMAN.

		OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1930	NM	8.90	8.50	9.70	26.30	19.70	29.80	19.00	20.10	18.90	12.70	12.40	12.30
1931	NM	11.10	10.90	14.60	28.80	28.70	17.10	7.30	7.10	6.80	3.60	2.60	3.10
1932	NM	4.50	5.10	24.80	151.00	309.00	141.00	96.40	223.00	339.00	164.00	21.20	19.60
1933	NM	19.70	13.80	24.60	62.10	98.90	38.90	24.30	27.40	94.60	21.60	12.90	14.50
1934	NM	11.70	9.90	21.00	86.10	62.20	40.90	15.80	12.10	10.90	8.20	5.60	5.60
1935	NM	7.10	8.40	18.50	110.40	118.80	152.60	368.30	430.00	375.30	78.80	22.80	20.50
1936	NM	31.80	38.00	58.40	79.20	388.90	349.50	368.80	451.40	222.90	77.40	26.90	26.30
1937	NM	28.20	36.40	77.60	104.60	499.10	439.10	413.00	528.50	479.10	109.60	26.30	26.30
1938	NM	28.60	21.00	174.10	233.80	797.00	1445.00	683.00	941.20	1250.00	530.30	107.30	45.70
1939	NM	43.50	63.30	89.30	120.90	135.60	41.80	57.10	38.60	19.80	14.40	13.80	16.50
1940	NM	13.90	11.30	26.00	135.10	260.80	411.70	394.80	426.40	324.30	55.50	22.80	23.00
1941	NM	20.10	12.80	79.50	278.60	538.90	769.90	548.20	689.50	755.90	345.50	44.40	29.60
1942	NM	25.20	25.00	126.00	314.30	389.60	285.70	370.90	427.80	657.10	249.70	37.30	30.40
1943	NM	33.60	43.00	79.80	163.70	405.10	762.90	555.00	437.30	325.20	52.80	27.50	26.80
1944	NM	29.50	19.70	37.80	74.10	87.20	129.00	51.90	61.10	88.40	31.40	25.60	25.80
1945	NM	31.10	35.00	45.10	82.80	311.80	274.30	257.70	414.80	301.50	107.70	51.80	47.20
1946	NM	67.00	74.30	155.60	278.10	178.10	83.30	93.90	259.80	128.90	40.80	29.00	34.30
1947	NM	26.90	30.30	81.80	92.00	60.70	54.00	25.60	40.00	28.80	20.10	17.40	19.80
1948	NM	14.10	14.70	16.10	18.00	11.80	13.10	21.90	35.70	136.60	20.00	29.10	28.40
1949	NM	20.70	13.20	13.20	21.90	19.80	59.80	29.20	38.90	49.80	14.60	15.60	15.70
1950	NM	10.60	11.00	12.50	29.40	60.60	34.00	33.90	34.10	60.90	13.70	14.20	18.40
1951	NM	12.60	61.10	408.70	253.40	295.30	142.30	47.40	110.00	42.80	20.60	18.60	23.00
1952	NM	16.90	14.80	30.60	250.60	316.80	386.80	525.60	687.00	625.30	71.20	34.50	36.40
1953	NM	28.10	17.00	58.70	149.90	45.70	21.00	22.80	31.40	28.10	14.30	14.80	22.30
1954	NM	15.60	12.40	14.70	23.60	54.50	54.90	58.40	121.20	32.60	17.80	17.30	17.50
1955	NM	10.80	12.40	16.10	50.10	29.30	21.40	22.40	26.50	20.50	15.20	14.50	14.40
1956	NM	10.10	9.70	198.20	711.40	508.40	186.10	78.90	284.50	261.10	46.70	26.70	30.60
1957	NM	26.70	15.60	15.10	26.40	37.10	75.70	45.40	48.50	104.20	21.00	21.70	22.50
1958	NM	19.40	12.60	17.70	43.90	111.70	318.70	827.30	659.40	426.10	84.60	31.50	37.00
1959	NM	25.90	13.10	16.90	35.00	42.90	28.90	24.90	26.80	16.20	11.00	11.40	12.90
1960	NM	9.80	9.90	12.80	24.30	42.50	18.50	16.40	19.70	12.00	9.80	10.40	7.80
1961	NM	6.40	9.50	13.40	24.60	21.80	13.80	11.20	14.50	10.40	6.00	6.30	6.60
1962	NM	5.60	8.30	17.60	28.30	193.90	141.10	33.20	64.90	94.40	22.30	19.30	18.90
1963	NM	15.40	15.90	19.10	25.80	156.40	53.50	133.40	200.40	126.20	27.50	22.60	25.10
1964	NM	37.20	23.40	23.30	31.20	18.70	15.70	18.30	21.60	19.90	13.00	13.40	20.50
1965	NM	38.50	41.10	61.40	247.70	91.10	129.20	155.70	118.50	113.30	32.00	27.40	31.00
1966	NM	19.50	52.80	130.10	97.70	37.00	24.40	23.10	21.60	16.60	12.60	11.10	11.30
1967	NM	10.30	17.00	52.00	38.80	96.40	62.90	376.50	716.00	539.10	277.50	63.70	44.50
1968	NM	48.90	33.80	58.80	55.10	52.20	38.20	27.10	25.90	14.70	13.80	22.30	23.70
1969	NM	29.30	35.20	38.90	332.40	979.40	1129.00	750.00	758.30	830.70	149.40	63.10	89.00

END OF FILE

THIS IS THE DATA FILE FOR SAN JOAQUIN RIVER FLOW AT NEWMAN.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1930 NM	8.90	8.50	9.70	26.30	19.70	29.80	19.00	20.10	18.90	12.70	12.40	12.30
1931 NM	11.10	10.90	14.60	28.80	28.70	17.10	7.30	7.10	6.80	3.60	2.60	3.10
1932 NM	4.50	5.10	24.80	151.00	309.00	141.00	96.40	223.00	339.00	164.00	21.20	19.60
1933 NM	19.70	13.80	24.60	62.10	98.90	38.90	24.30	27.40	94.60	21.60	12.90	14.50
1934 NM	11.70	9.90	21.00	86.10	62.20	40.90	15.80	12.10	10.90	8.20	5.60	5.60
1935 NM	7.10	8.40	18.50	110.40	118.80	152.60	368.30	430.00	375.30	78.80	22.80	20.50
1936 NM	31.80	38.00	58.40	79.20	388.90	349.50	368.80	451.40	222.90	77.40	26.90	26.30
1937 NM	28.20	36.40	77.60	104.60	499.10	439.10	413.00	528.50	479.10	109.60	26.30	26.30
1938 NM	28.60	21.00	174.10	233.80	797.00	1445.00	683.00	941.20	1250.00	530.30	107.30	45.70
1939 NM	43.50	63.30	89.30	120.90	135.60	41.80	57.10	38.60	19.80	14.40	13.80	16.50
1940 NM	13.90	11.30	26.00	135.10	260.80	411.70	394.80	426.40	324.30	55.50	22.80	23.00
1941 NM	20.10	12.80	79.50	278.60	538.90	769.90	548.20	689.50	755.90	345.50	44.40	29.60
1942 NM	25.20	25.00	126.00	314.30	389.60	285.70	370.90	427.80	657.10	249.70	37.30	30.40
1943 NM	33.60	43.00	79.80	163.70	405.10	762.90	555.00	437.30	325.20	52.80	27.50	26.80
1944 NM	29.50	19.70	37.80	74.10	87.20	129.00	51.90	61.10	88.40	31.40	25.60	25.80
1945 NM	31.10	35.00	45.10	82.80	311.80	274.30	257.70	414.80	301.50	107.70	51.80	47.20
1946 NM	67.00	74.30	155.60	278.10	178.10	83.30	93.90	259.80	128.90	40.80	29.00	34.30
1947 NM	26.90	30.30	81.80	92.00	60.70	54.00	25.60	40.00	28.80	20.10	17.40	19.80
1948 NM	14.10	14.70	16.10	18.00	11.80	13.10	21.90	35.70	136.60	20.00	20.10	28.40
1949 NM	20.70	13.20	13.20	21.90	19.80	59.80	29.20	38.90	49.80	14.60	15.60	15.70
1950 NM	10.60	11.00	12.50	29.40	60.60	34.00	33.90	34.10	60.90	13.70	14.20	18.40
1951 NM	12.60	61.10	408.70	253.40	295.30	142.30	47.40	110.00	42.80	20.60	18.60	23.00
1952 NM	16.90	14.80	30.60	250.60	316.80	386.80	525.60	687.00	625.30	71.20	34.50	36.40
1953 NM	28.10	17.00	58.70	149.90	45.70	21.00	22.80	31.40	28.10	14.30	14.80	22.30
1954 NM	15.60	12.40	14.70	23.60	54.50	54.90	58.40	121.20	32.60	17.80	17.30	17.50
1955 NM	10.80	12.40	16.10	50.10	29.30	21.40	22.40	26.50	20.50	15.20	14.50	14.40
1956 NM	10.10	9.70	198.20	711.40	508.40	186.10	78.90	284.50	261.10	46.70	26.70	30.60
1957 NM	26.70	15.60	15.10	26.40	37.10	75.70	45.40	48.50	104.20	21.00	21.70	22.50
1958 NM	19.40	12.60	17.70	43.90	111.70	318.70	827.30	659.40	426.10	84.60	31.50	37.00
1959 NM	25.90	13.10	16.90	35.00	42.90	28.90	24.90	26.80	16.20	11.00	11.40	12.90
1960 NM	9.80	9.90	12.80	24.30	42.50	18.50	16.40	19.70	12.00	9.80	10.40	7.80
1961 NM	6.40	9.50	13.40	24.60	21.80	13.80	11.20	14.50	10.40	6.00	6.30	6.60
1962 NM	5.60	8.30	17.60	28.30	193.90	141.10	33.20	64.90	94.40	22.30	19.30	18.90
1963 NM	15.40	15.90	19.10	25.80	156.40	53.50	133.40	200.40	126.20	27.50	22.60	25.10
1964 NM	37.20	23.40	23.30	31.20	18.70	15.70	18.30	21.60	19.90	13.00	13.40	20.50
1965 NM	38.50	41.10	61.40	247.70	91.10	129.20	155.70	118.50	113.30	32.00	27.40	31.00
1966 NM	19.50	52.80	130.10	97.70	37.00	24.40	23.10	21.60	16.60	12.60	11.10	11.30
1967 NM	10.30	17.00	52.00	38.80	96.40	62.90	376.50	716.00	539.10	277.50	63.70	44.50
1968 NM	48.90	33.80	58.80	55.10	52.20	38.20	27.10	25.90	14.70	13.80	22.30	23.70
1969 NM	29.30	35.20	38.90	332.40	979.40	1129.00	750.00	758.30	830.70	149.40	63.10	89.00

END OF FILE

JOB ACTIVE.
list,f=vufile
THIS IS THE DATA FILE OF UNIMPAIRED FLOW AT VERNALIS.

		OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1930	VU	9.70	12.20	57.20	102.10	182.50	400.50	713.70	796.30	773.60	152.50	34.04	20.46
1931	VU	27.36	51.51	33.67	70.02	107.90	167.30	422.95	563.45	151.50	36.70	17.60	10.19
1932	VU	12.00	24.20	316.80	236.00	680.60	524.40	817.60	1673.20	1628.70	561.60	112.10	35.40
1933	VU	29.60	22.80	38.30	81.40	91.40	237.10	535.20	794.20	1200.30	245.70	54.50	25.70
1934	VU	12.10	28.90	125.70	163.90	230.60	425.00	544.90	420.40	239.70	56.20	24.20	16.80
1935	VU	33.30	108.50	130.40	300.40	290.10	404.30	1414.60	1728.90	1538.80	348.80	91.30	28.90
1936	VU	34.90	52.20	50.40	234.90	1009.00	625.40	1250.40	1662.00	1096.00	376.40	82.00	21.90
1937	VU	26.30	33.20	94.00	112.00	863.50	655.90	956.30	2149.40	1212.80	335.00	70.10	21.60
1938	VU	27.30	47.00	844.40	291.00	945.80	1425.20	1389.00	2498.80	2459.60	990.10	243.20	86.60
1939	VU	119.87	117.63	97.90	118.67	152.39	393.74	850.90	638.68	253.55	83.48	36.58	45.47
1940	VU	111.58	47.24	50.10	614.27	698.75	967.46	1055.72	1780.52	1005.96	206.31	45.40	13.40
1941	VU	32.20	39.90	361.60	348.00	659.20	785.50	866.60	2202.30	1705.30	745.50	156.20	42.70
1942	VU	47.20	97.50	409.60	478.10	431.20	473.70	1075.90	1577.10	1890.70	749.60	133.50	34.70
1943	VU	31.56	209.75	236.59	715.74	490.72	1181.94	1254.17	1591.95	997.98	434.53	106.38	32.44
1944	VU	34.92	47.17	62.51	113.60	215.08	406.96	487.09	1372.99	803.72	313.03	61.72	20.05
1945	VU	30.02	232.17	214.58	162.62	911.63	524.49	926.16	1529.06	1387.33	533.99	120.24	39.28
1946	VU	162.65	257.53	555.41	339.16	206.58	479.22	1091.18	1521.44	793.04	239.60	60.20	28.08
1947	VU	67.02	197.81	241.00	138.66	229.90	392.55	604.57	1055.02	370.13	89.69	22.12	16.44
1948	VU	88.06	67.42	50.83	96.56	74.83	188.55	649.70	1380.41	1271.07	285.30	46.27	19.42
1949	VU	25.05	33.85	57.56	61.96	107.02	336.65	890.61	1359.82	736.33	130.67	38.89	20.83
1950	VU	20.80	43.23	45.12	200.66	348.87	366.58	1037.36	1419.17	901.25	215.82	38.69	19.14
1951	VU	58.29	1395.26	1494.97	478.82	429.31	501.43	763.11	1080.94	753.76	235.20	54.14	16.88
1952	VU	35.92	78.22	322.04	617.42	418.42	716.58	1393.43	2647.17	1910.71	885.42	218.67	67.97
1953	VU	37.20	49.17	151.67	367.88	180.56	292.57	798.35	785.41	1124.88	479.18	65.00	22.44
1954	VU	27.02	50.33	60.65	116.59	258.36	585.84	1063.52	1371.46	569.67	163.93	31.12	16.19
1955	VU	18.50	49.04	124.84	176.51	169.95	249.94	439.02	1128.28	925.17	177.11	36.61	16.96
1956	VU	17.30	40.00	1831.30	1207.30	494.10	555.00	923.60	1846.70	1761.00	759.90	176.70	66.90
1957	VU	67.70	75.60	69.00	94.70	294.00	422.30	540.30	1188.10	1209.10	250.70	55.20	25.80
1958	VU	45.14	61.08	133.25	169.38	491.84	774.83	1319.13	2535.83	1822.49	722.78	217.41	73.65
1959	VU	38.65	37.69	33.39	174.57	330.68	375.87	694.22	667.98	410.46	82.76	21.29	118.67
1960	VU	37.82	26.55	30.64	68.38	291.52	398.28	703.09	847.07	443.46	77.27	23.20	13.63
1961	VU	16.37	57.31	92.03	56.44	119.50	195.99	481.55	606.47	353.92	57.17	43.76	19.51
1962	VU	18.65	32.64	66.90	68.87	673.90	399.52	1240.79	1217.04	1362.56	427.62	81.69	28.67
1963	VU	56.49	31.68	66.20	285.40	907.54	343.03	728.87	1683.95	1386.11	575.68	128.36	56.85
1964	VU	59.85	256.78	134.83	143.59	133.16	206.91	495.68	903.16	612.32	135.85	45.18	23.77
1965	VU	69.12	153.05	1143.86	877.22	437.81	455.60	964.37	1381.29	1423.25	710.37	353.72	138.32
1966	VU	38.66	350.81	238.94	223.72	202.78	438.75	940.10	1066.90	322.48	96.33	41.29	24.95
1967	VU	29.44	132.56	663.70	377.93	349.53	912.80	930.90	2165.70	2487.10	1517.20	309.30	116.57
1968	VU	50.70	53.60	94.00	125.90	352.60	343.90	572.30	801.80	392.20	86.40	43.40	21.70
1969	VU	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

THIS IS THE DATA FILE FOR UNIMPAIRED SAN JOAQUIN RIVER FLOW (KAF) AT FRIANT.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1930 FR	5.00	6.20	8.30	18.20	35.60	80.00	165.10	213.50	243.60	60.80	16.90	5.90
1931 FR	10.60	13.40	10.20	16.00	23.40	38.90	100.20	173.50	59.70	16.00	11.10	7.20
1932 FR	5.90	8.40	71.80	58.90	167.70	156.60	238.10	491.50	543.60	238.80	51.40	14.70
1933 FR	12.60	8.90	14.60	26.50	30.00	73.40	159.00	213.40	410.10	118.90	29.30	14.70
1934 FR	6.80	10.30	38.10	46.80	50.30	109.40	166.10	146.20	68.90	27.30	13.40	7.90
1935 FR	12.60	26.60	36.20	72.50	85.20	110.90	356.60	496.80	519.20	144.20	43.80	18.60
1936 FR	13.60	15.80	16.40	38.30	195.90	163.50	348.60	510.00	347.70	150.50	42.10	10.90
1937 FR	10.90	12.60	36.40	34.90	252.70	190.60	303.80	704.80	456.80	159.70	34.00	10.80
1938 FR	9.80	12.30	210.70	70.90	207.30	433.80	434.20	795.00	912.70	431.20	127.90	42.60
1939 FR	38.90	33.10	28.70	32.70	43.30	102.80	239.90	208.80	110.30	43.40	24.80	14.10
1940 FR	34.80	14.20	11.40	134.10	139.80	210.00	290.00	558.60	362.90	96.60	21.20	7.00
1941 FR	10.10	11.70	98.40	105.80	182.80	208.60	242.40	711.20	641.50	330.90	85.80	23.30
1942 FR	21.50	30.30	96.00	113.10	102.60	128.50	298.50	465.40	632.60	284.00	64.70	16.70
1943 FR	10.10	42.50	43.40	169.70	113.30	267.70	335.10	502.50	325.10	178.80	49.90	15.60
1944 FR	10.50	15.10	19.80	31.20	55.40	111.60	140.80	408.20	279.50	142.60	35.00	15.70
1945 FR	12.70	58.40	56.10	44.10	237.70	147.90	275.90	476.80	487.60	240.20	73.90	26.80
1946 FR	59.10	65.60	118.30	78.90	53.80	125.80	310.40	463.90	279.90	117.80	36.90	19.10
1947 FR	28.50	64.90	84.50	47.70	64.00	100.30	171.00	347.70	145.80	42.70	16.80	11.60
1948 FR	22.80	18.20	15.40	18.90	20.20	42.60	164.60	390.60	372.60	107.90	26.00	15.00
1949 FR	10.50	7.90	14.60	16.20	25.90	73.00	234.50	409.50	268.30	63.20	25.60	14.90
1950 FR	9.80	16.10	17.20	43.20	90.10	89.60	280.10	379.00	262.90	87.00	21.70	13.80
1951 FR	17.10	247.00	300.40	111.20	104.20	119.20	201.90	321.90	278.00	114.70	31.70	11.70
1952 FR	12.30	20.40	83.40	133.00	98.70	176.70	385.20	819.90	640.80	335.30	101.40	33.00
1953 FR	16.90	18.70	42.90	85.00	48.00	71.50	197.20	211.30	320.20	171.60	30.20	13.20
1954 FR	9.40	16.60	16.60	33.40	65.40	127.20	278.40	439.50	217.60	80.40	20.20	9.10
1955 FR	6.00	17.80	31.20	41.60	48.90	74.10	126.50	337.80	348.20	87.90	29.60	11.40
1956 FR	6.10	13.20	460.50	271.20	140.80	169.50	278.30	568.00	613.80	317.80	86.50	34.40
1957 FR	26.30	21.70	20.70	29.50	66.90	90.10	142.20	326.70	439.90	115.00	31.70	15.90
1958 FR	16.40	18.50	43.30	42.60	112.50	181.40	362.60	795.50	622.30	287.50	107.90	40.50
1959 FR	16.10	14.60	14.60	37.00	89.60	113.60	203.10	208.10	153.00	41.50	16.80	41.40
1960 FR	18.40	9.70	9.50	18.00	55.00	86.10	177.90	240.70	146.90	42.60	16.40	7.50
1961 FR	8.50	22.30	31.20	19.00	30.80	48.90	124.60	171.60	128.00	27.40	24.80	10.40
1962 FR	9.80	14.90	23.10	23.50	184.80	109.90	381.00	396.90	505.20	202.60	51.70	20.20
1963 FR	17.60	10.80	10.70	81.90	207.90	101.40	191.90	464.20	492.40	264.20	70.70	31.40
1964 FR	25.50	64.30	36.40	31.20	30.80	51.80	126.70	256.90	200.00	59.30	28.70	10.50
1965 FR	10.10	34.00	203.90	187.80	114.10	128.20	250.80	431.20	472.20	266.70	137.80	35.10
1966 FR	17.50	101.10	66.50	61.90	55.50	125.80	276.90	361.60	147.70	50.40	25.00	8.80
1967 FR	6.40	29.70	212.70	92.50	100.70	243.00	249.60	659.90	823.50	594.30	154.20	66.80
1968 FR	26.90	22.90	34.30	36.90	75.40	82.90	146.10	231.10	131.20	43.80	22.10	8.40
1969 FR	15.10	40.00	52.20	396.60	233.60	227.20	464.50	1096.40	874.20	462.80	137.10	40.50
1970 FR	32.60	31.70	47.10	159.40	83.30	136.90	146.00	375.80	278.50	106.60	36.70	11.00

list,f ernali
THIS IS THE DATA FILE CHLORIDES (PPM) AT VERNALIS

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1930	0	0	0	0	0	0	0	0	0	0	0	0
1931	0	0	0	0	0	0	0	0	0	0	0	0
1932	0	0	0	0	0	0	0	0	0	0	0	0
1933	0	0	0	0	0	0	0	0	0	0	0	0
1934	0	0	0	0	0	0	0	0	0	0	0	0
1935	0	0	0	0	0	0	0	0	0	0	0	0
1936	0	0	0	0	0	0	0	0	0	0	0	0
1937	0	0	0	0	0	0	0	0	0	0	0	0
1938	0	0	0	20	0	18	18	10	7	8	53	82
1939	47	32	41	30	31	84	0	0	0	0	0	0
1940	0	0	0	0	0	0	0	0	0	0	0	0
1941	0	0	0	0	0	0	0	0	0	0	0	0
1942	0	0	0	17	21	23	9	8	8	52	78	72
1943	59	43	26	27	11	13	10	7	24	88	80	64
1944	66	66	48	49	35	49	42	23	86	120	98	78
1945	61	52	37	43	19	17	14	18	7	0	0	0
1946	0	0	0	26	31	66	16	10	62	120	100	110
1947	83	59	62	71	77	78	80	63	140	160	150	76
1948	85	84	94	77	180	160	29	10	14	140	120	100
1949	88	0	96	68	130	30	70	60	110	140	130	140
1950	93	100	100	62	37	63	18	16	76	140	140	110
1951	78	10	0	0	0	0	0	0	0	0	0	0
1952	80	86	52	21	15	18	10	9	10	58	106	83
1953	89	78	48	32	72	147	108	66	23	54	134	123
1954	94	97	94	107	80	45	28	23	132	177	167	160
1955	140	113	94	33	79	106	121	142	71	174	170	159
1956	163	143	63	13	25	57	40	14	14	68	92	89
1957	93	84	64	100	124	61	133	100	39	152	151	135
1958	84	72	70	93	52	34	21	16	16	62	125	100
1959	0	0	50	97	83	109	172	178	201	256	240	172
1960	161	138	124	138	125	236	199	193	263	281	272	263
1961	175	140	110	129	168	252	348	253	315	407	401	286
1962	250	194	196	213	110	49	96	55	67	162	186	154
1963	124	101	67	129	44	97	27	15	36	109	167	130
1964	87	70	50	58	95	209	223	171	146	248	259	182
1965	112	108	92	21	35	46	42	32	21	88	153	122
1966	28	32	11	36	37	112	66	52	90	0	110	112
1967	89	37	31	53	25	35	12	12	9	26	34	101
1968	75	56	50	32	108	35	32	82	0	214	188	179
1969	75	42	94	2	6	15	13	8	4	17	49	35

READY.

list,f=graflow

THIS IS THE DATA FILE OF CHLORIDES (PPM) AT GRAYSON

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1930	0	0	0	0	0	0	0	0	0	0	0	0
1931	0	0	0	0	0	0	0	0	0	0	0	0
1932	0	0	0	0	0	0	0	0	0	0	0	0
1933	0	0	0	0	0	0	0	0	0	0	0	0
1934	0	0	0	0	0	0	195	199	213	240	202	0
1935	0	0	0	0	0	0	0	0	0	0	159	0
1936	0	0	0	[illegible]	0	0	0	0	0	0	189	0
1937	0	0	0		0	0	0	0	0	0	0	100
1938	112	0	0		0	22	0	12	8	9	54	99
1939	89	54	57	[illegible]	50	180	50	31	88	135	124	111
1940	97	184	110	[illegible]	22	24	13	3	9	80	131	87
1941	113	187	117	26	20	23	20	9	6	40	153	100
1942	98	137	52	19	28	19	16	11	7	38	130	112
1943	93	130	66	69	19	14	10	16	16	118	91	94
1944	0	0	[illegible]	52	34	49	66	56	73	130	84	69
1945	78	100	[illegible]	62	17	18	29	13	9	0	0	0
1946	0	0	[illegible]	0	0	0	0	0	0	0	0	0
1947	66	168	0	56	0	206	0	148	127	185	0	0
1948	0	207	0	175	0	0	246	0	0	0	0	0
1949	0	0	0	0	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0	0	0	0	0
1951	0	0	0	0	0	0	123	35	148	146	184	95
1952	169	205	97	16	22	35	13	6	8	116	127	76
1953	153	168	130	36	161	232	180	103	134	190	159	91
1954	106	192	212	250	119	174	41	21	96	168	155	170
1955	210	224	209	116	174	218	177	114	176	191	159	184
1956	234	222	191	17	25	78	120	28	12	132	154	122
1957	118	192	198	191	170	102	179	131	36	159	146	128
1958	162	218	192	66	65	100	0	18	12	111	165	100
1959	112	216	240	160	250	277	218	220	228	235	0	0
1960	181	225	280	250	205	306	248	213	248	210	191	238
1961	270	239	225	235	0	318	288	180	175	200	256	257
1962	295	298	205	233	292	53	220	232	39	158	161	158
1963	208	0	282	309	42	210	0	70	37	114	168	148
1964	115	231	225	186	238	343	240	155	162	216	0	154
1965	115	204	208	57	127	21	118	0	65	126	156	116
1966	122	245	30	96	228	305	0	0	0	0	0	0
1967	0	0	0	0	0	0	0	0	0	0	0	0
1968	0	0	0	0	0	0	0	0	0	0	0	0
1969	0	0	0	0	0	0	0	0	0	0	0	0

THIS IS THE DATA FILE OF CHLORIDES (PPM) AT MAZE ROAD BRIDGE.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1930	0	0	0	0	0	0	0	0	0	0	0	0
1931	0	0	0	0	0	0	0	0	0	0	0	0
1932	0	0	0	0	0	0	0	0	0	0	0	0
1933	0	0	0	0	0	0	0		0	0	0	0
1934	0	0	0	0	0	0	0	[illegible]	0	0	0	0
1935	0	0	0	0	0	0	[illegible]	0	0	0	0	0
1936	0	0	0	0	0	0		0	0	0	0	0
1937	0	0	0	0	0	[illegible]	0	0	0	0	0	0
1938	0	0	0	0	0		0	0	0	0	0	0
1939	0	0	0	0	0	[illegible]	90	56	146	108	106	94
1940	78	82	72	35	15	24	11	10	9	54	126	66
1941	73	85	74	24	0	15	21	13	7	46	79	79
1942	67	75	49	0	17	0	0	0	0	50	0	90
1943	62	0	39	0		0	0	0	0	120	0	99
1944	0	0	0	0		0	68	0	0	0	107	0
1945	0	0	0	0	[illegible]	0	0	0	0	0	0	0
1946	0	0	0	0	0	0	0	0	0	0	0	0
1947	91	74	0	[illegible]	0	211	0	187	170	162	0	0
1948	0	87	0	[illegible]	0	0	213	0	0	0	0	0
1949	0	0	0	[illegible]	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0	0	0	0	0
1951	0	0	0	0	0	0	75	13	37	92	60	46
1952	0	58	[illegible]	8	11	9	0	0	0	116	136	65
1953	0	70	[illegible]	34	73	0	0	72	69	33	166	0
1954	0	117	20	0	0	230	31	31	95	196	194	194
1955	188	[illegible]	137	0	0	0	213	216	199	198	191	187
1956	206	[illegible]	124	18	23	0	0	19	20	154	127	91
1957	103	[illegible]	84	142	150	45	205	154	42	172	165	140
1958	82	74	88	67	24	60	23	17	16	80	164	81
1959	110	55	109	119	120	146	195	210	240	295	0	262
1960	227	132	104	135	175	190	280	250	285	278	246	269
1961	260	144	132	122	0	287	325	206	258	344	0	0
1962	0	0	0	0	0	0	0	0	0	0	0	0
1963	0	0	0	0	0	0	0	0	0	0	0	0
1964	89	80	60	89	151	271	218	0	0	265	0	180
1965	139	132	98	49	42	25	52	0	76	117	0	25
1966	66	82	22	74	67	126	220	222	190	244	0	245
1967	0	0	0	0	0	0	0	0	0	0	0	0
1968	0	0	0	0	0	0	0	0	0	0	0	0
1969	0	0	0	0	0	0	0	0	0	0	0	0

END OF FILE

list,f=tuoflow

THIS IS THE DATA FILE OF CHLORIDES (PPM) FROM THE TUOLUMNE

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1930	0	0	0	0	0	0	0	0	0	0	0	0
1931	0	0	0	0	0	0	0	0	0	0	0	0
1932	0	0	0	0	0	0	0	0	0	0	0	0
1933	0	0	0	0	0	0	0	0	0	0	0	0
1934	0	0	0	0	0	0	0	0	0	0	0	0
1935	0	0	0	0	0	0	0	0	0	0	0	0
1936	0	0	0	0	0	0	0	0	0	0	0	0
1937	0	0	0	0	0	0	0	0	0	0	0	0
1938	0	30	0	18	0	7	13	8	3	11	35	41
1939	31	16	28	37	37	41	46	23	12	9	13	12
1940	7	9	14	11	4	5	5	2	5	27	36	13
1941	25	20	22	20	5	7	7	6	2	17	40	17
1942	25	13	12	10	16	9	9	7	9	27	49	30
1943	25	52	11	33	10	12	17	41	24	22	42	27
1944	49	37	34	52	60	83	20	31	110	60	60	110
1945	51	32	26	38	35	14	21	77	6	0	0	0
1946	0	0	0	0	0	0	0	0	0	0	0	0
1947	0	0	0	0	0	0	0	0	0	0	0	0
1948	0	0	0	0	0	0	0	0	0	0	0	0
1949	0	0	0	0	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0	0	0	0	0
1951	0	0	0	0	0	0	0	9	15	62	48	79
1952	29	30	17	0	7	0	0	0	0	13	38	27
1953	0	10	13	10	20	0	0	88	54	24	114	122
1954	0	0	74	34	34	90	13	7	61	130	62	0
1955	69	45	37	63	62	72	195	186	151	150	146	151
1956	155	121	74	7	20	28	38	11	79	56	95	73
1957	74	63	46	70	108	20	166	170	74	178	183	153
1958	54	38	44	63	10	25	9	13	18	42	176	68
1959	85	23	66	75	54	67	171	169	210	206	0	222
1960	238	86	62	73	107	112	223	236	235	238	210	218
1961	232	94	70	65	0	218	0	207	255	298	283	179
1962	189	196	162	170	190	9	45	136	135	138	184	164
1963	0	0	39	61	11	66	24	24	34	0	168	181
1964	69	31	21	38	70	185	192	172	0	222	0	202
1965	152	66	48	21	12	27	21	0	76	76	134	30
1966	38	36	20	35	17	38	143	198	185	216	0	209
1967	0	0	0	0	0	0	0	0	0	0	0	0
1968	0	0	0	0	0	0	0	0	0	0	0	0
1969	174	0	0	0	0	0	0	0	0	0	0	0

list,f=graflow

THIS IS THE DATA FILE OF CHLORIDES (PPM) AT GRAYSON

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1930	0	0	0	0	0	0	0	0	0	0	0	0
1931	0	0	0	0	0	0	0	0	0	0	0	0
1932	0	0	0	0	0	0	0	0	0	0	0	0
1933	0	0	0	0	0	0	0	0	0	0	0	0
1934	0	0	0	0	0	0	195	199	213	240	202	0
1935	0	0	0	0	0	0	0	0	0	0	159	0
1936	0	0	0	0	0	0	0	0	0	0	189	0
1937	0	0	0	0	0	0	0	0	0	0	0	100
1938	112	0	0	23	0	22	0	12	8	9	54	99
1939	89	54	57	73	50	180	50	31	88	135	124	111
1940	97	184	110	39	22	24	13	3	9	80	131	87
1941	113	187	117	26	20	23	20	9	6	40	153	100
1942	98	137	52	19	28	19	16	11	7	38	130	112
1943	93	130	66	69	19	14	10	16	16	118	91	94
1944	0	0	88	52	34	49	66	56	73	130	84	69
1945	78	100	110	62	17	18	29	13	9	0	0	0
1946	0	0	0	0	0	0	0	0	0	0	0	0
1947	66	168	0	56	0	206	0	148	127	185	0	0
1948	0	207	0	175	0	0	246	0	0	0	0	0
1949	0	0	0	0	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0	0	0	0	0
1951	0	0	0	0	0	0	123	35	148	146	184	95
1952	169	205	97	16	22	35	13	6	8	116	127	76
1953	153	168	130	36	161	232	180	103	134	190	159	91
1954	106	192	212	250	119	174	41	21	96	168	155	170
1955	210	224	209	116	174	218	177	114	176	191	159	184
1956	234	222	191	17	25	78	120	28	12	132	154	122
1957	118	192	198	191	170	102	179	131	36	159	146	128
1958	162	218	192	66	65	100	0	18	12	111	165	100
1959	112	216	240	160	250	277	218	220	228	235	0	0
1960	181	225	280	250	205	306	248	213	248	210	191	238
1961	270	239	225	235	0	318	288	180	175	200	256	257
1962	295	298	205	233	292	53	220	232	39	158	161	158
1963	208	0	282	309	42	210	0	70	37	114	168	148
1964	115	231	225	186	238	343	240	155	162	216	0	154
1965	115	204	208	57	127	21	118	0	65	126	156	116
1966	122	245	30	96	228	305	0	0	0	0	0	0
1967	0	0	0	0	0	0	0	0	0	0	0	0
1968	0	0	0	0	0	0	0	0	0	0	0	0
1969	0	0	0	0	0	0	0	0	0	0	0	0

READY

040777

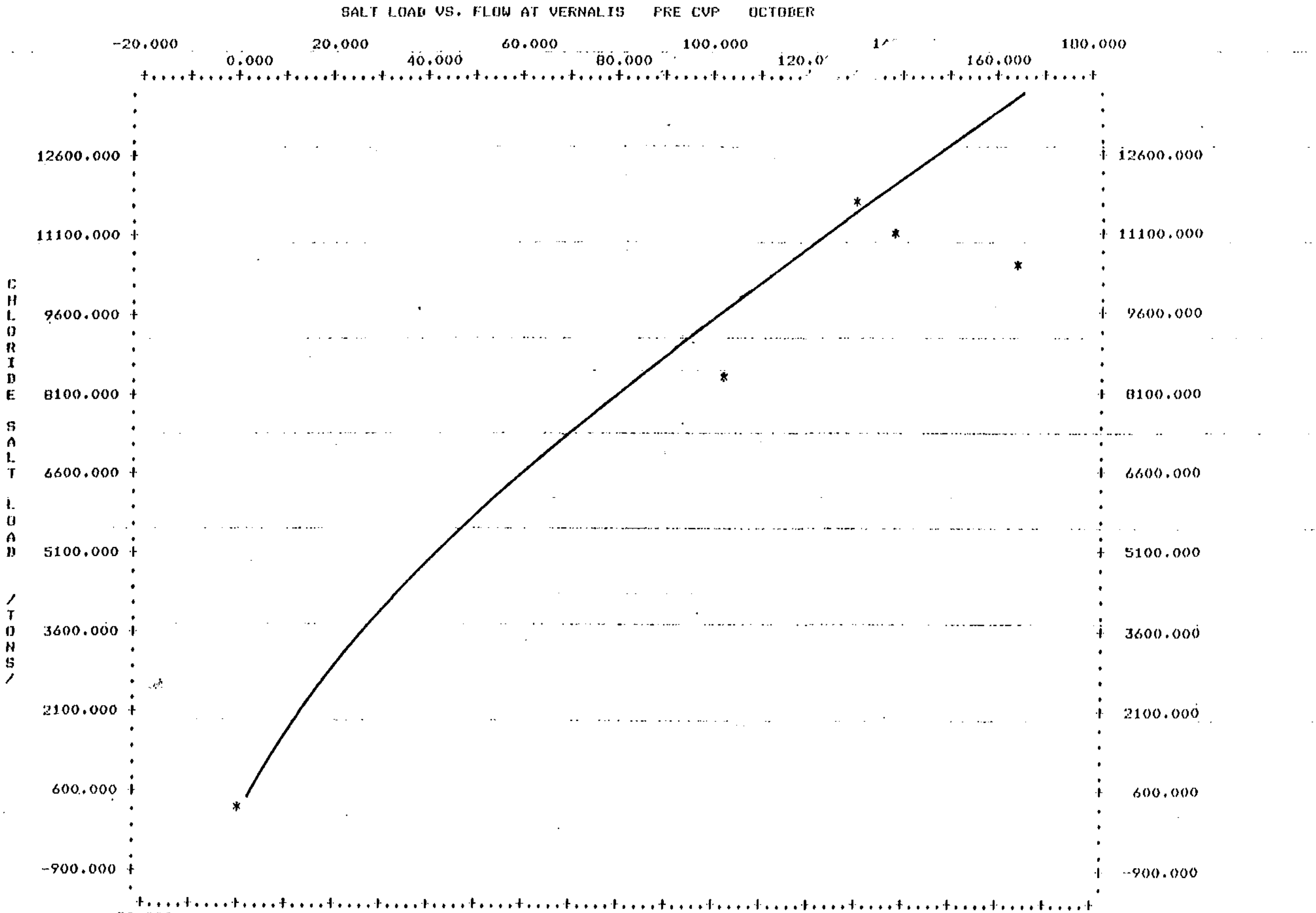
list,f-newman

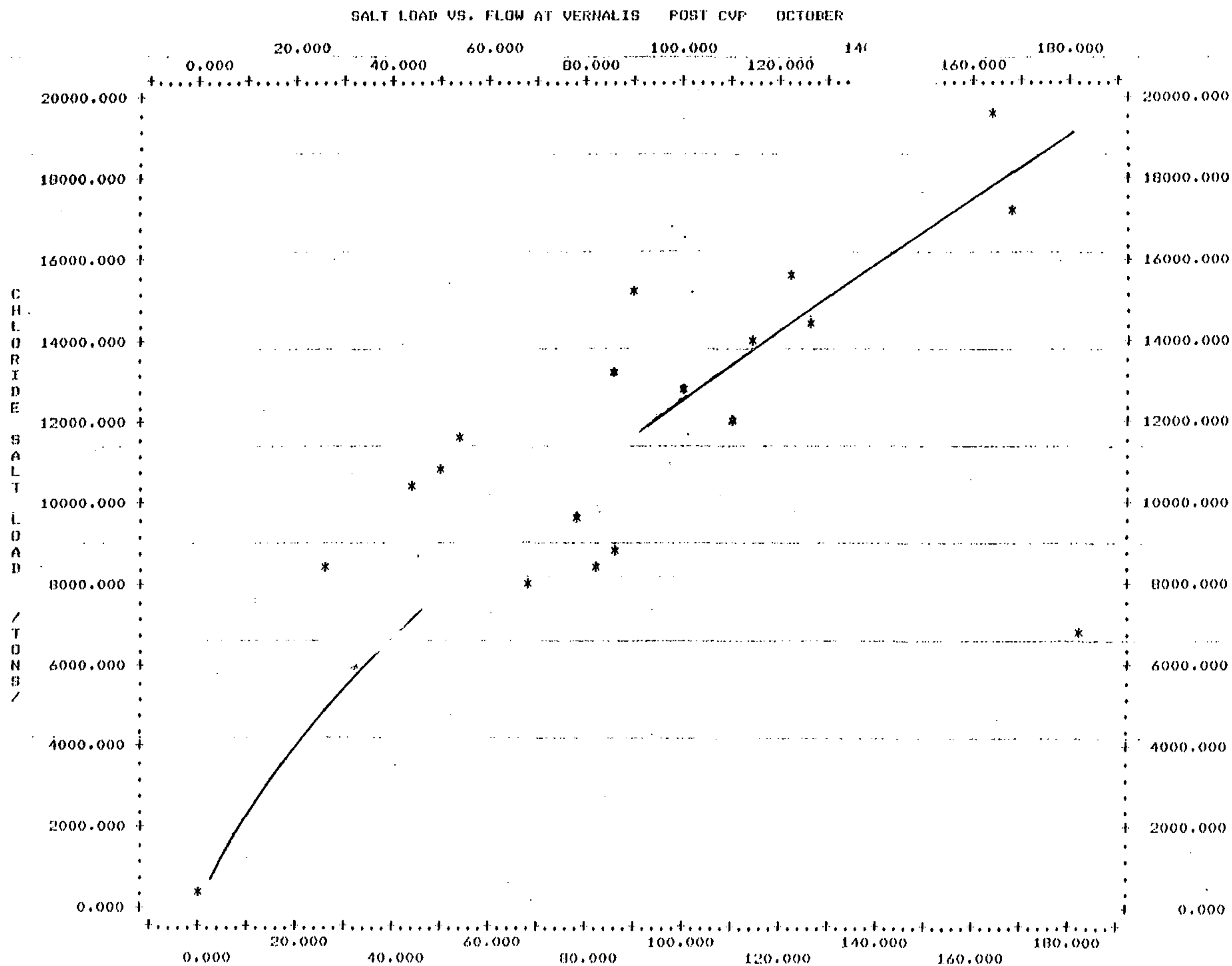
THIS IS THE DATA FILE OF CHLORIDES (PPM) AT NEWMAN

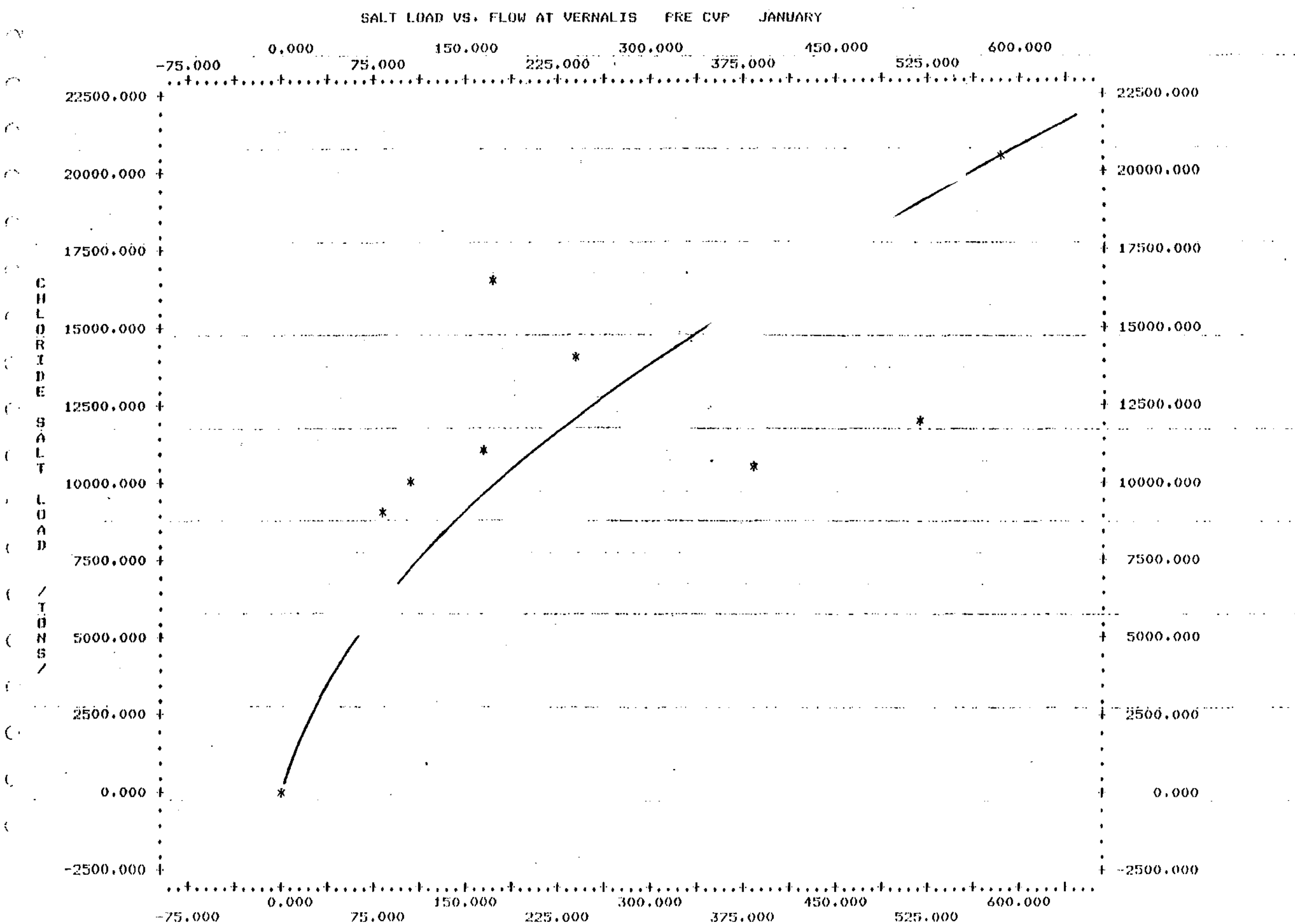
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1930	0	0	0	0	0	0	0	0	0	0	0	0
1931	0	0	0	0	0	0	0	0	0	0	0	0
1932	0	0	0	0	0	0	0	0	0	0	0	0
1933	0	0	0	0	0	0	0	0	0	0	0	0
1934	0	0	0	0	0	0	0	0	0	0	0	0
1935	0	0	0	0	0	0	0	0	0	0	0	0
1936	0	0	0	0	0	0	0	0	0	119	171	92
1937	73	0	45	0	0	0	0	0	0	73	168	95
1938	77	0	0	23	33	14	0	9	8	4	86	70
1939	59	43	44	50	44	110	56	76	130	160	120	78
1940	160	170	51	39	24	40	22	6	8	52	150	88
1941	120	140	0	34	29	28	20	10	6	39	140	77
1942	82	66	31	26	11	10	22	8	4	27	120	80
1943	77	29	25	63	29	28	14	19	11	100	77	57
1944	88	46	92	51	66	74	86	68	80	220	110	56
1945	53	78	74	36	12	14	39	8	8	0	0	0
1946	0	0	0	23	34	150	84	13	24	200	71	70
1947	120	200	47	48	84	190	170	130	110	130	110	110
1948	140	170	200	0	280	0	195	75	12	1100	47	40
1949	110	0	0	0	0	33	0	0	84	0	78	81
1950	120	150	134	100	150	84	130	180	83	89	190	61
1951	300	17	13	0	25	100	240	54	150	200	140	130
1952	320	260	150	27	24	23	14	10	10	150	140	81
1953	130	180	84	0	0	0	0	0	0	0	0	0
1954	0	0	0	0	0	0	0	0	0	0	0	0
1955	0	0	0	0	0	0	0	0	0	0	0	187
1956	237	281	257	25	30	104	132	58	15	143	180	98
1957	98	190	217	0	0	0	0	0	0	0	0	0
1958	0	0	0	0	0	44	0	9	33	137	121	178
1959	135	222	232	161	349	197	213	205	163	235	209	304
1960	277	388	445	490	165	280	214	0	223	219	222	290
1961	262	325	420	238	390	449	436	234	235	302	318	212
1962	280	365	230	198	233	165	351	194	52	124	150	162
1963	143	226	274	240	120	422	133	202	62	0	0	0
1964	0	0	0	0	0	0	0	0	0	0	0	0
1965	0	0	0	0	0	0	0	0	0	0	0	0
1966	0	0	0	0	0	0	0	0	0	0	0	0
1967	0	0	0	0	0	0	0	0	0	0	0	0
1968	0	0	0	0	0	0	0	0	0	0	0	0
1969	0	0	0	0	0	0	0	0	0	0	0	0

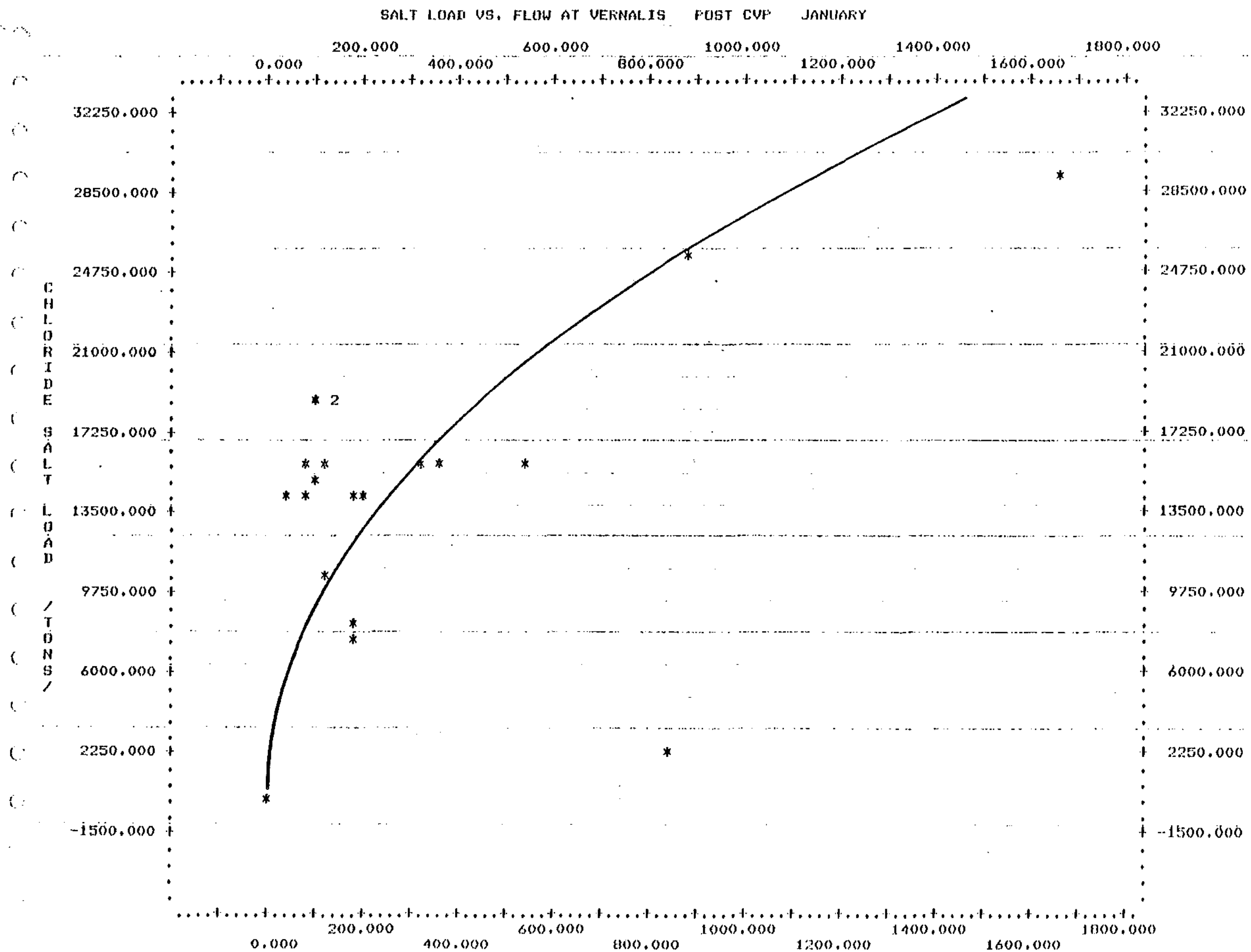
APPENDIX 2

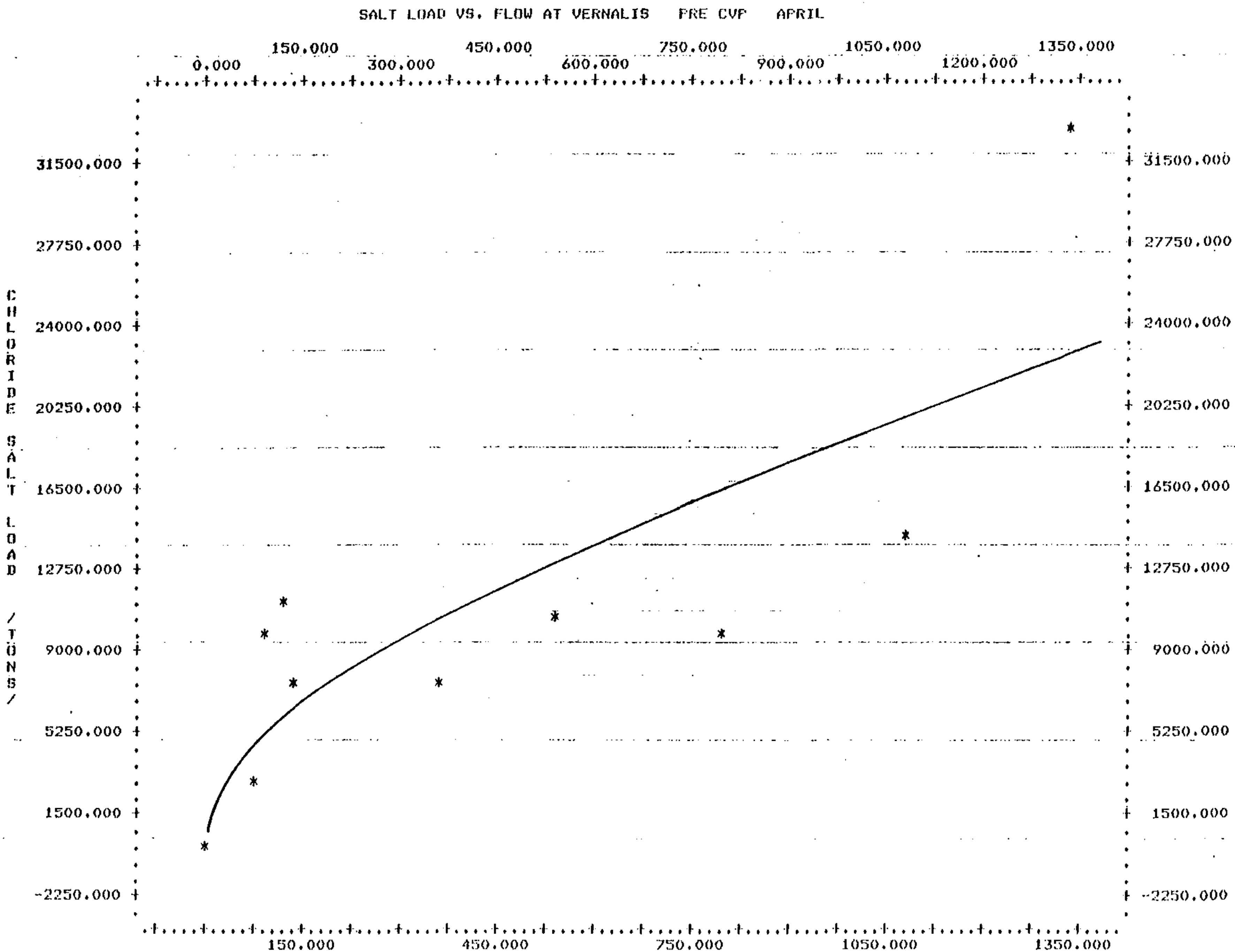
CHLORIDE LOAD-FLOW REGRESSION CURVES


SALT LOAD VS. FLOW AT VERNALIS PRE CVP OCTOBER
-20.000
0.000
20.000
40.000
60.000
80.000
100.000
120.0
160.000
180.000
12600.000
11100.000
9600.000
8100.000
6600.000
5100.000
3600.000
2100.000
600.000
-900.000
CHLORIDE SALT LOAD /TONS/

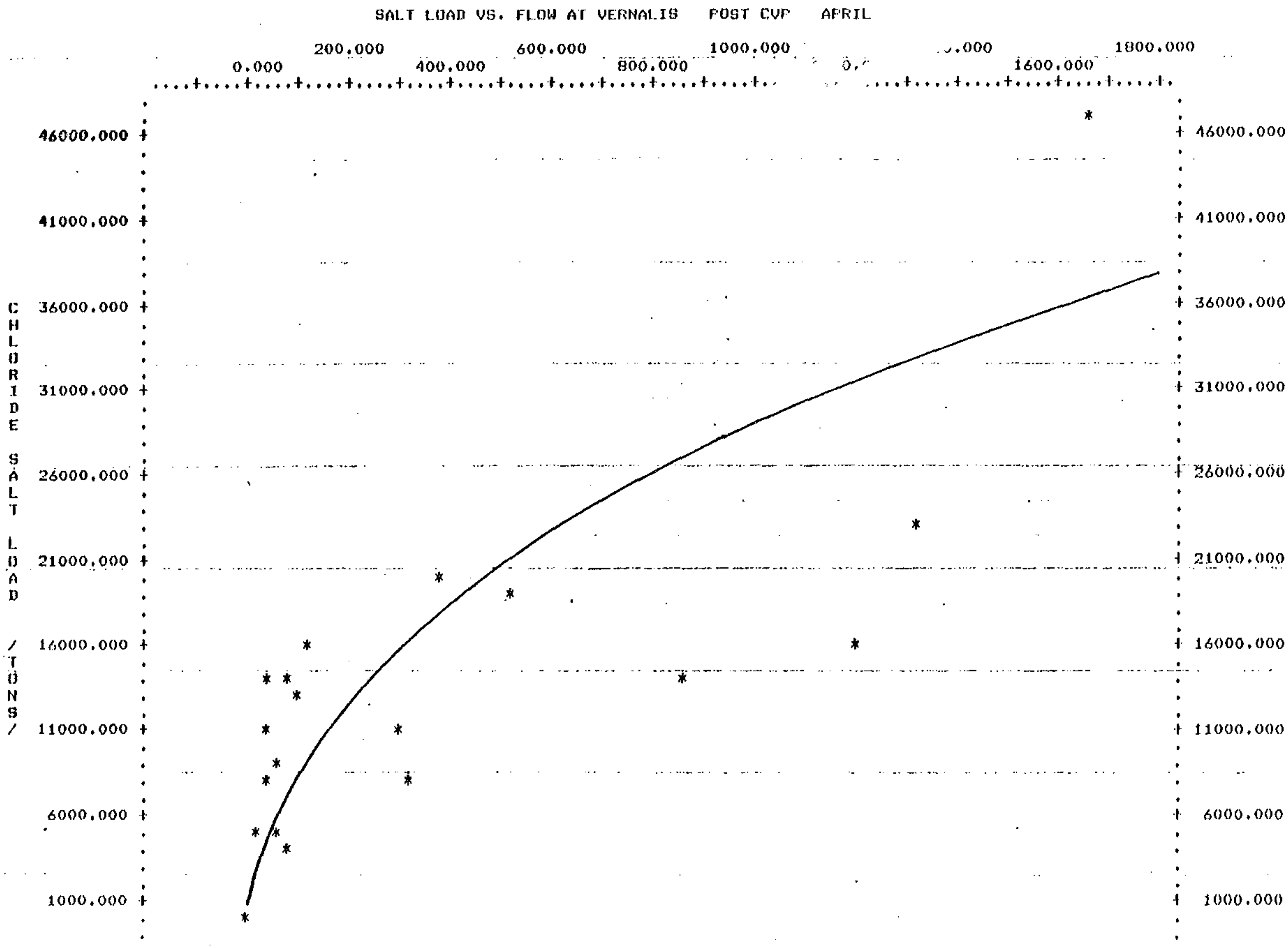

SALT LOAD VS. FLOW AT VERNALIS POST CVP OCTOBER
CHLORIDE SALT LOAD /TONS/
0.000
20.000
40.000
60.000
80.000
100.000
120.000
140.000
160.000
180.000
0.000
2000.000
4000.000
6000.000
8000.000
10000.000
12000.000
14000.000
16000.000
18000.000
20000.000


SALT LOAD VS. FLOW AT VERNALIS PRE CVP JANUARY
-75.000
0.000
75.000
150.000
225.000
300.000
375.000
450.000
525.000
600.000
22500.000
20000.000
17500.000
15000.000
12500.000
10000.000
7500.000
5000.000
2500.000
0.000
-2500.000
CHLORIDE SALT LOAD /TONS/

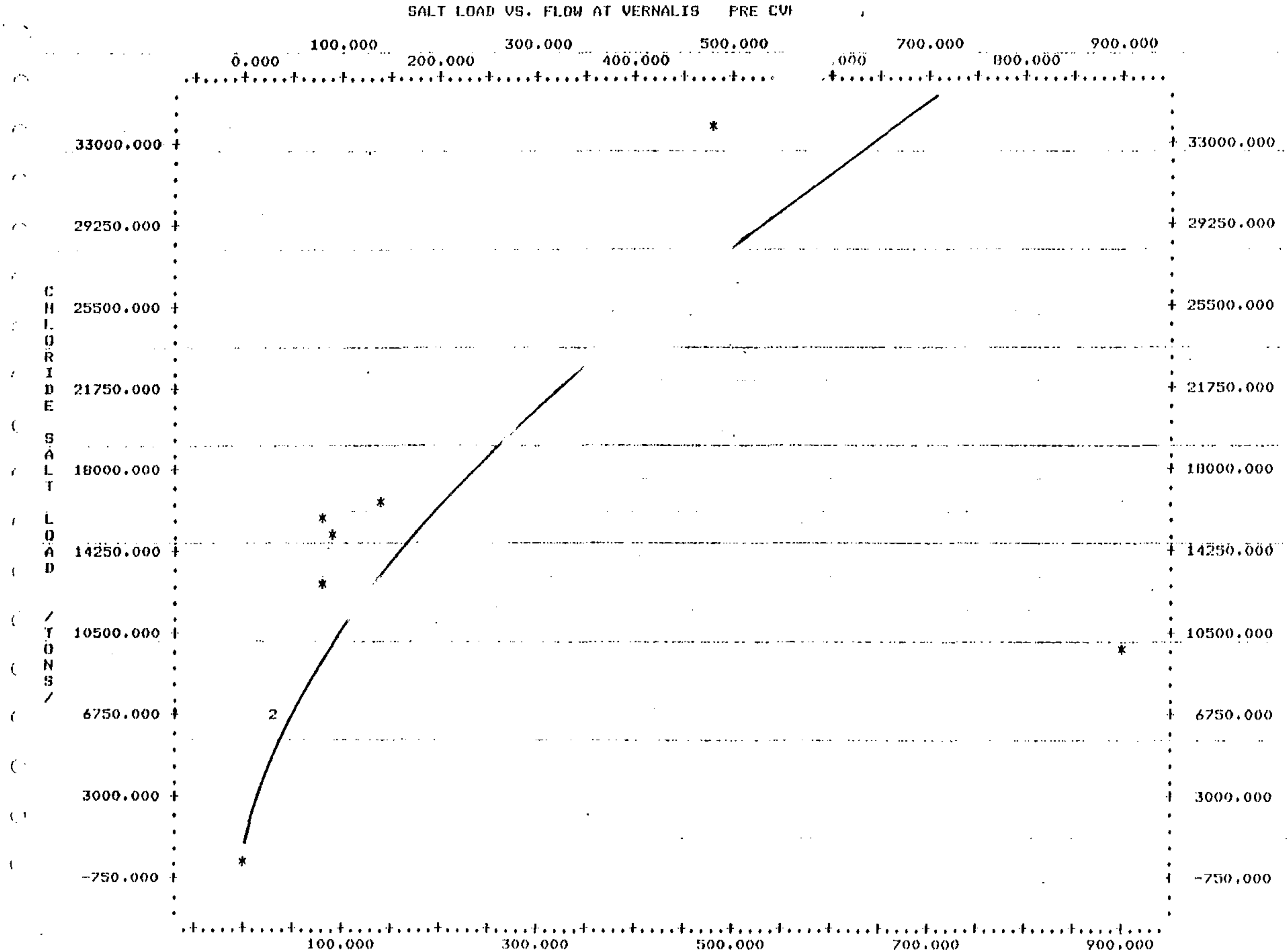

SALT LOAD VS. FLOW AT VERNALIS POST CVP JANUARY
CHLORIDE SALT LOAD /TONS/
32250.000
28500.000
24750.000
21000.000
17250.000
13500.000
9750.000
6000.000
2250.000
-1500.000
0.000
200.000
400.000
600.000
800.000
1000.000
1200.000
1400.000
1600.000
1800.000
2



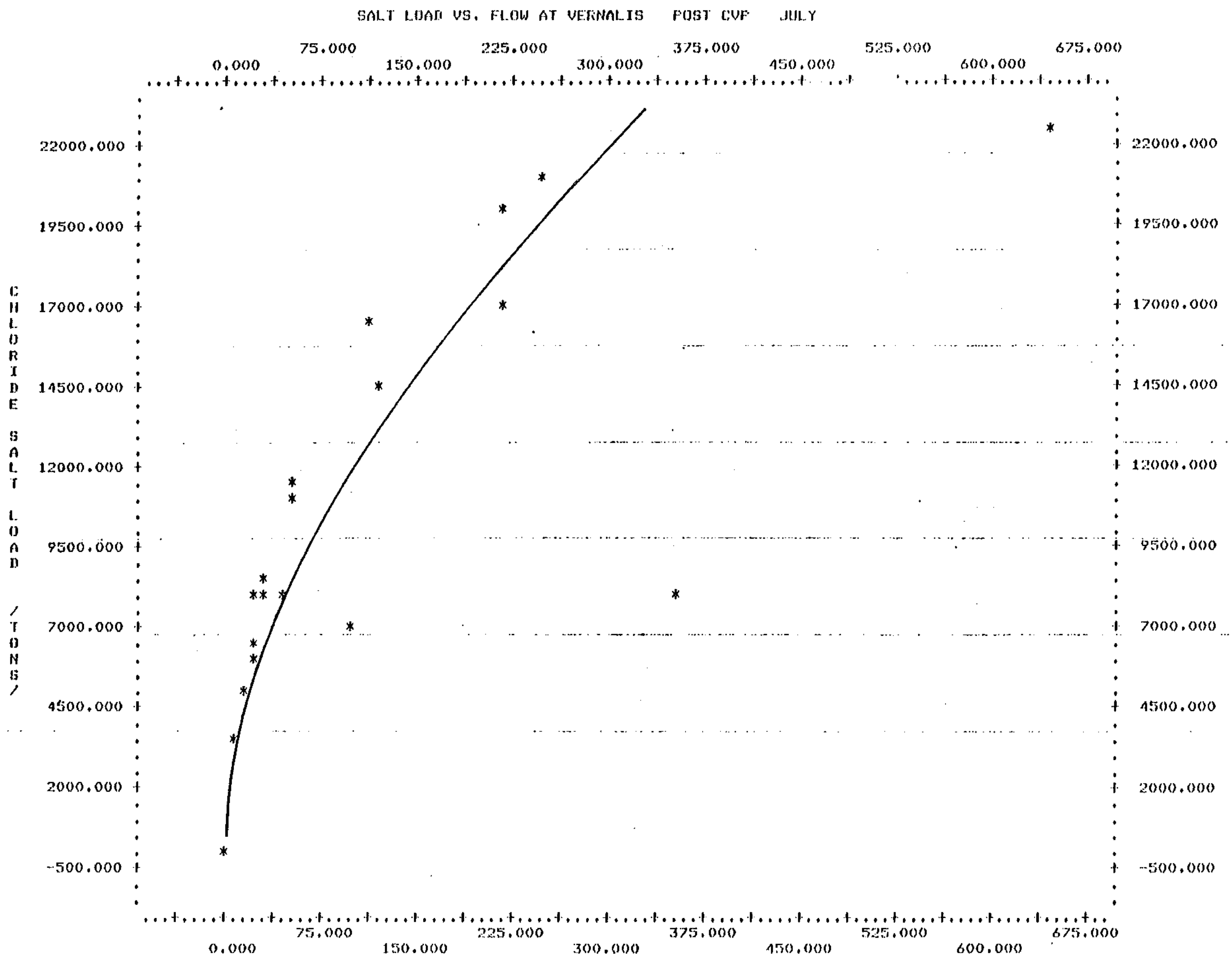
SALT LOAD VS. FLOW AT VERNALIS PRE CVP APRIL
0.000
150.000
300.000
450.000
600.000
750.000
900.000
1050.000
1200.000
1350.000
CHLORIDE SALT LOAD /TONS/
31500.000
27750.000
24000.000
20250.000
16500.000
12750.000
9000.000
5250.000
1500.000
-2250.000


SALT LOAD VS. FLOW AT VERNALIS POST CVP APRIL
0.000
200.000
400.000
600.000
800.000
1000.000
1600.000
1800.000
46000.000
41000.000
36000.000
31000.000
26000.000
21000.000
16000.000
11000.000
6000.000
1000.000
CHLORIDE SALT LOAD /TONS/

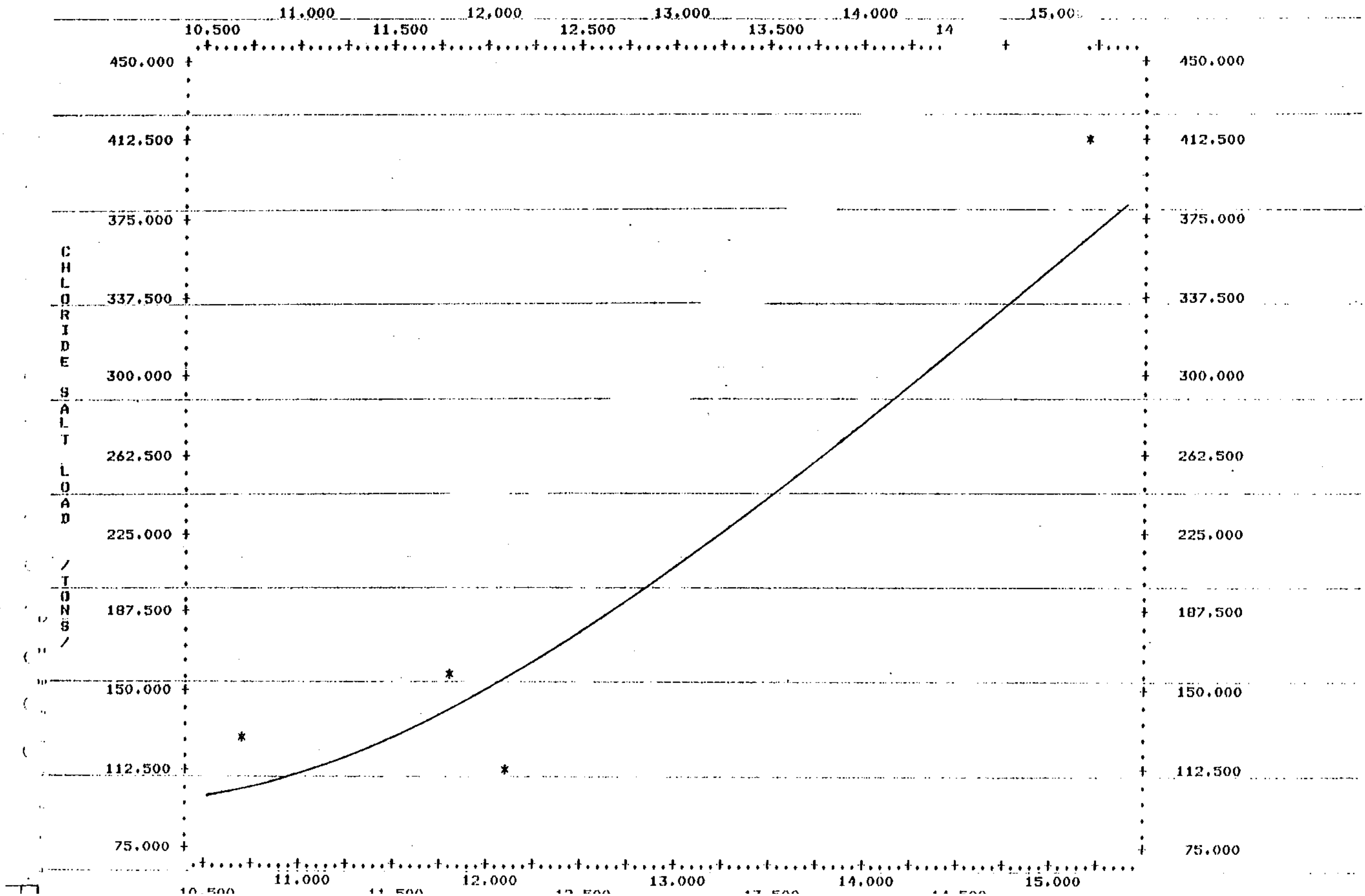
040786

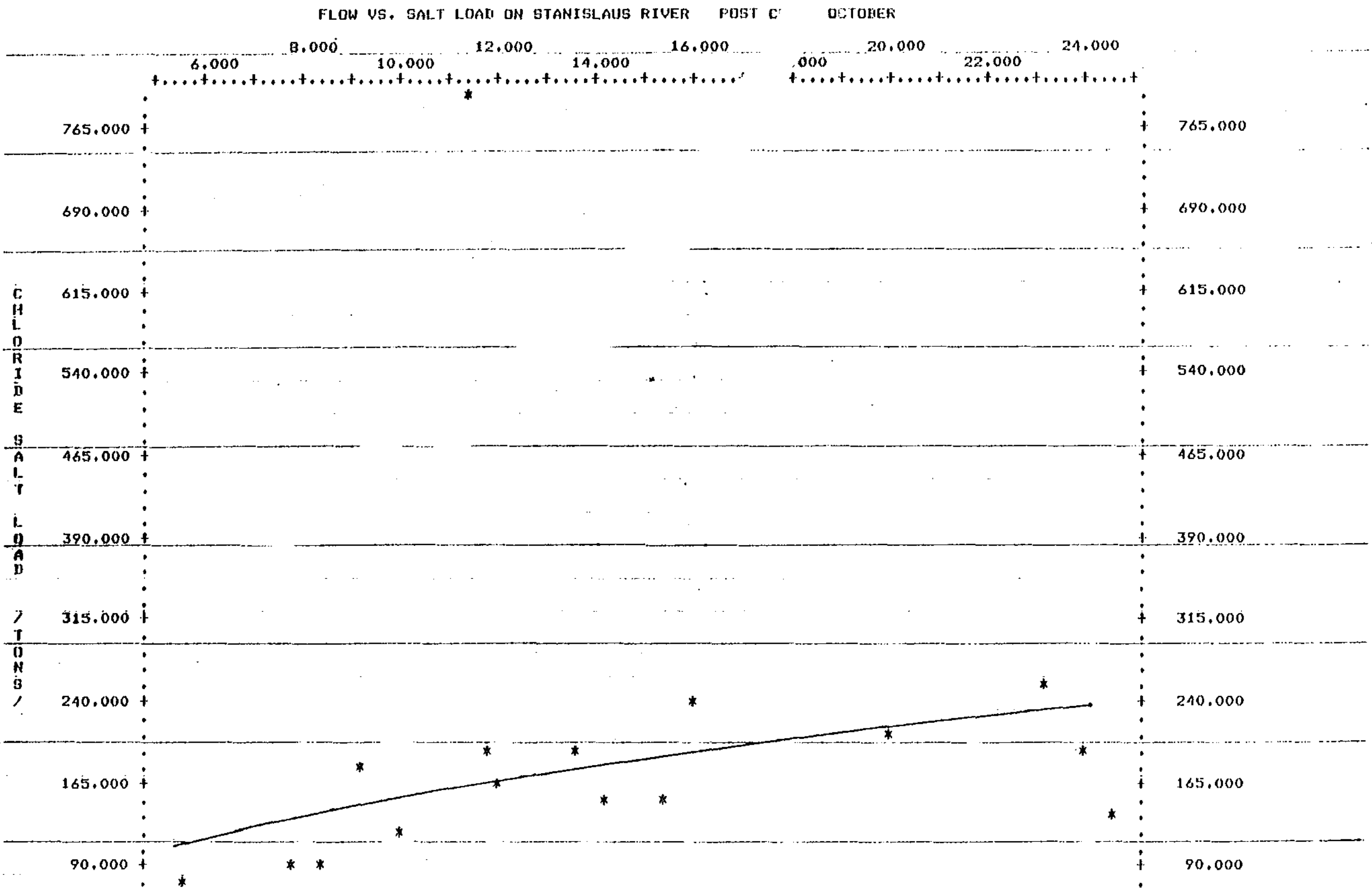


SALT LOAD VS. FLOW AT VERNALIS PRE CVI
0.000
100.000
200.000
300.000
400.000
500.000
700.000
800.000
900.000
33000.000
29250.000
25500.000
21750.000
18000.000
14250.000
10500.000
6750.000
3000.000
-750.000
CHLORIDE SALT LOAD /TONS/
2

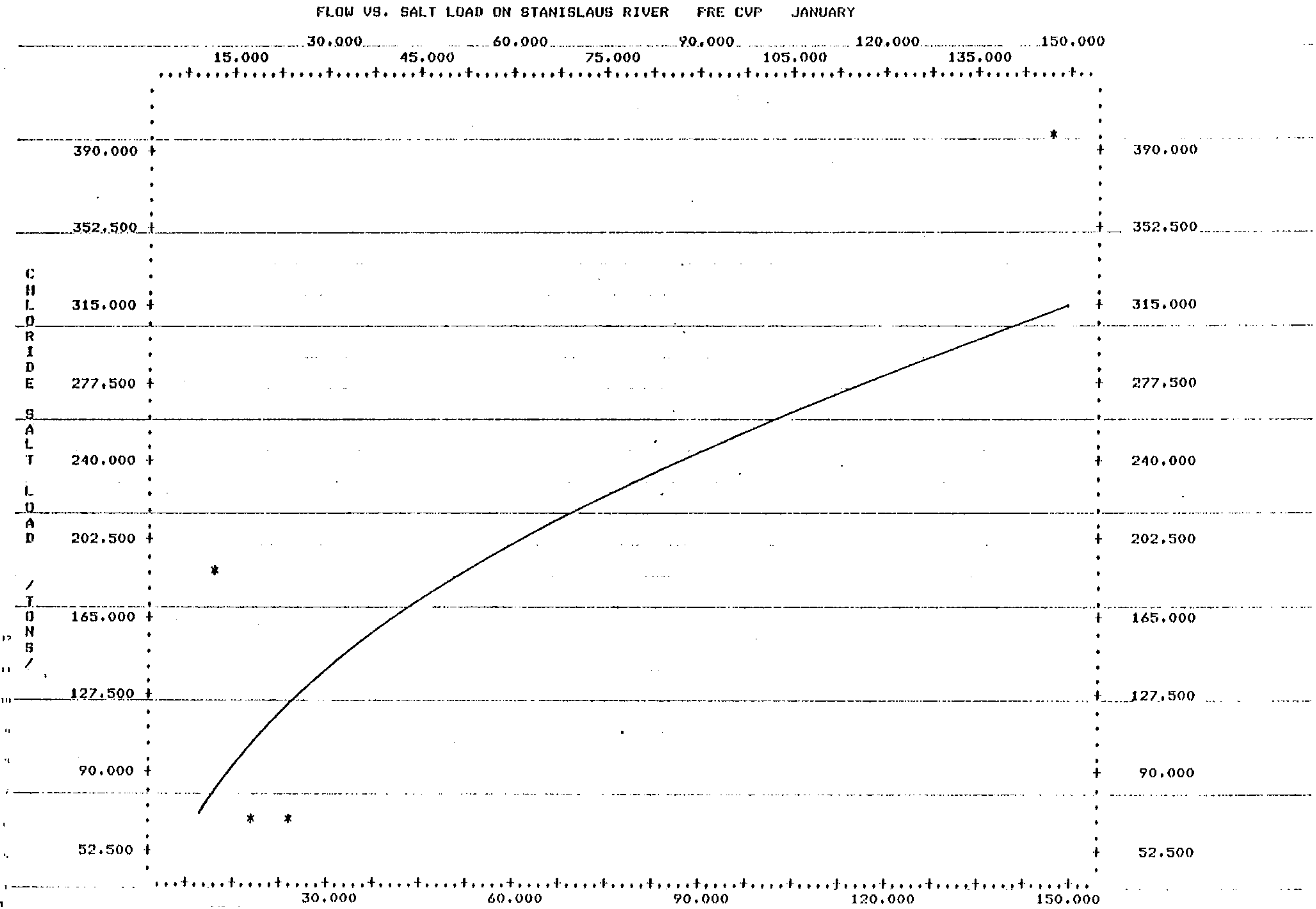

SALT LOAD VS. FLOW AT VERNALIS POST CVP JULY
0.000
75.000
150.000
225.000
300.000
375.000
450.000
525.000
600.000
675.000
CHLORIDE SALT LOAD /TONS/
22000.000
19500.000
17000.000
14500.000
12000.000
9500.000
7000.000
4500.000
2000.000
-500.000

FLOW VS. SALT LOAD TANISLAUS RIVER PRE CVP OCTOBER



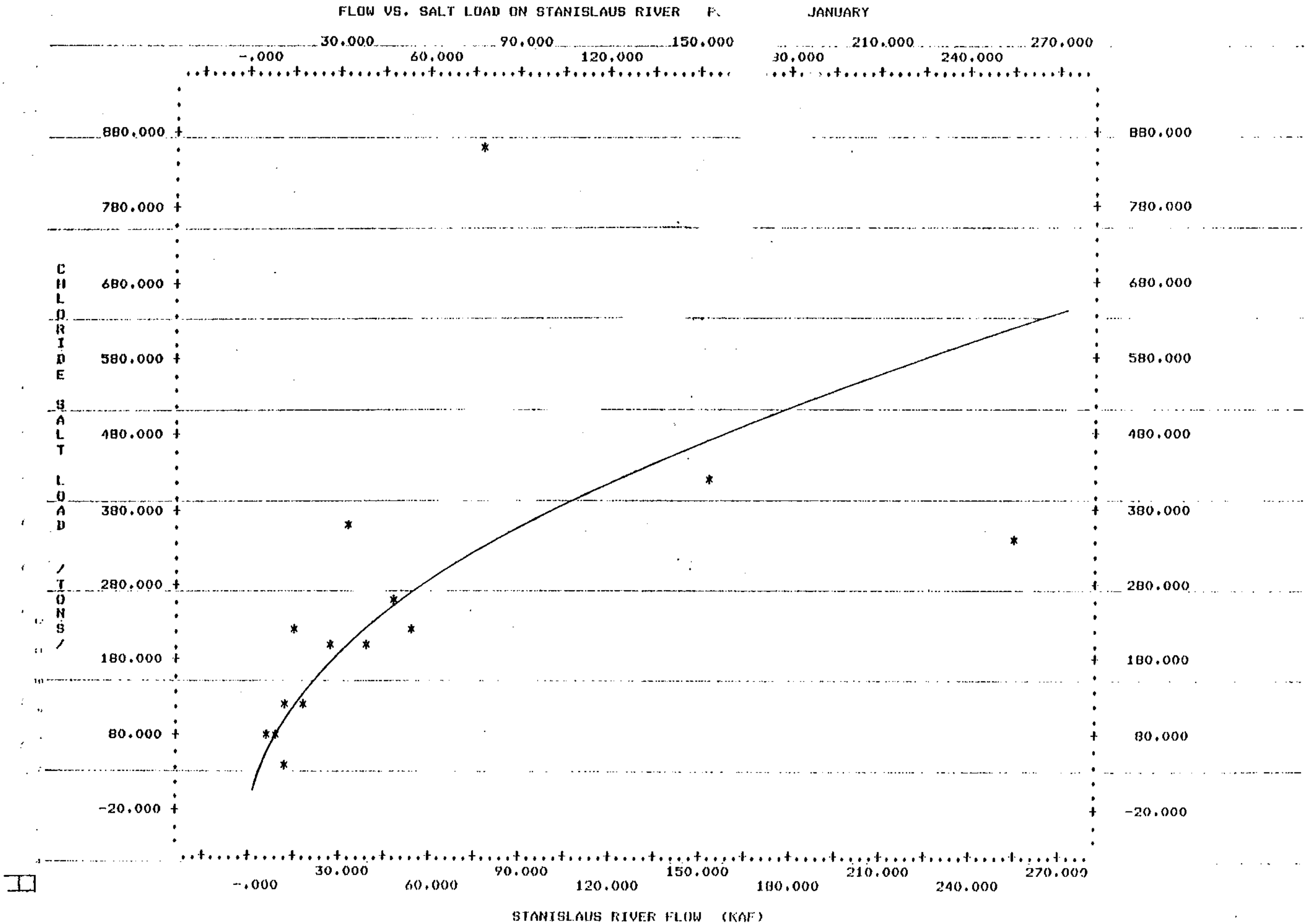

FLOW VS. SALT LOAD ON STANISLAUS RIVER POST C OCTOBER
6,000
8,000
10,000
12,000
14,000
16,000
,000
20,000
22,000
24,000
CHLORIDE SALT LOAD /TONS/
765,000
690,000
615,000
540,000
465,000
390,000
315,000
240,000
165,000
90,000

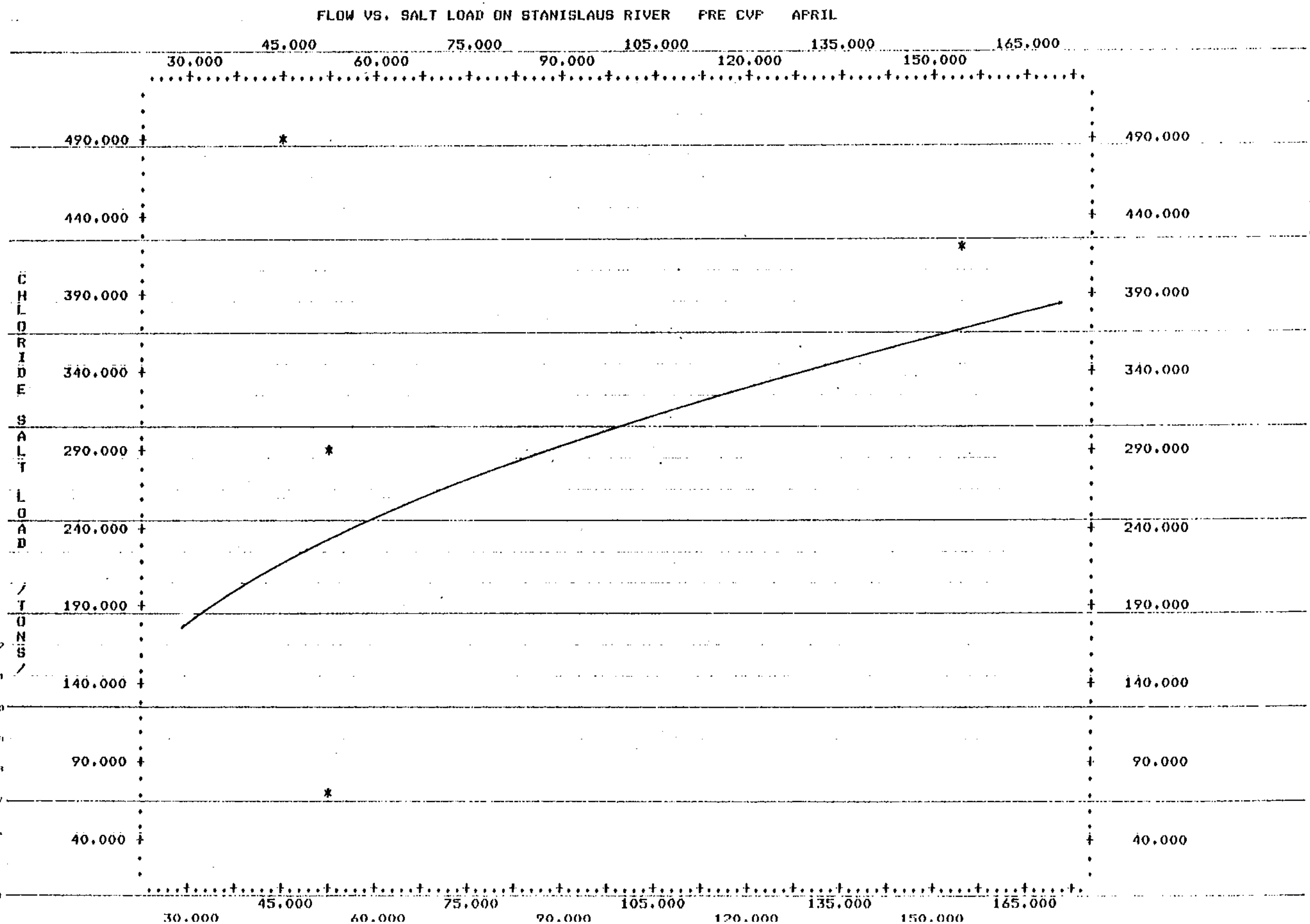
040790

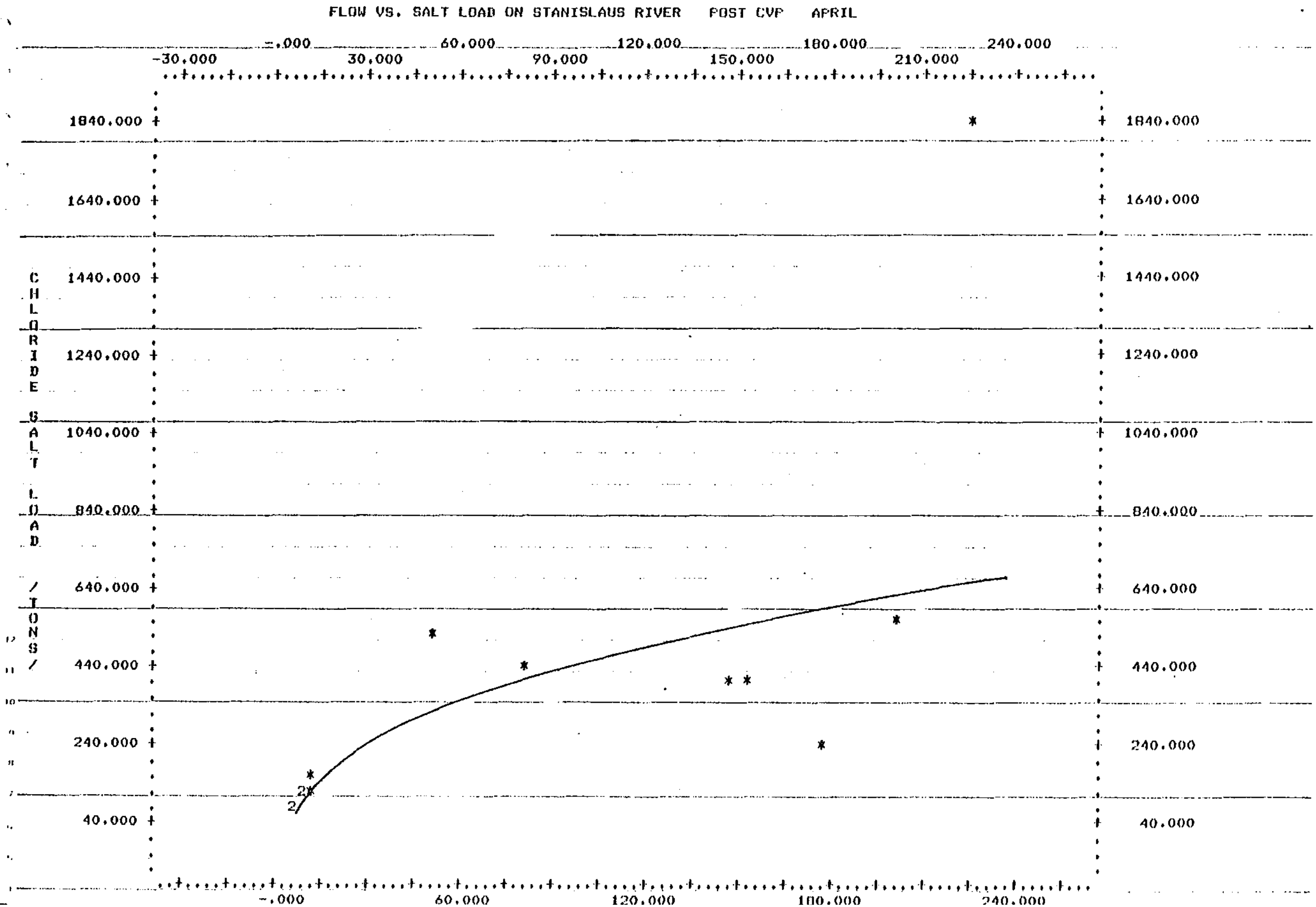


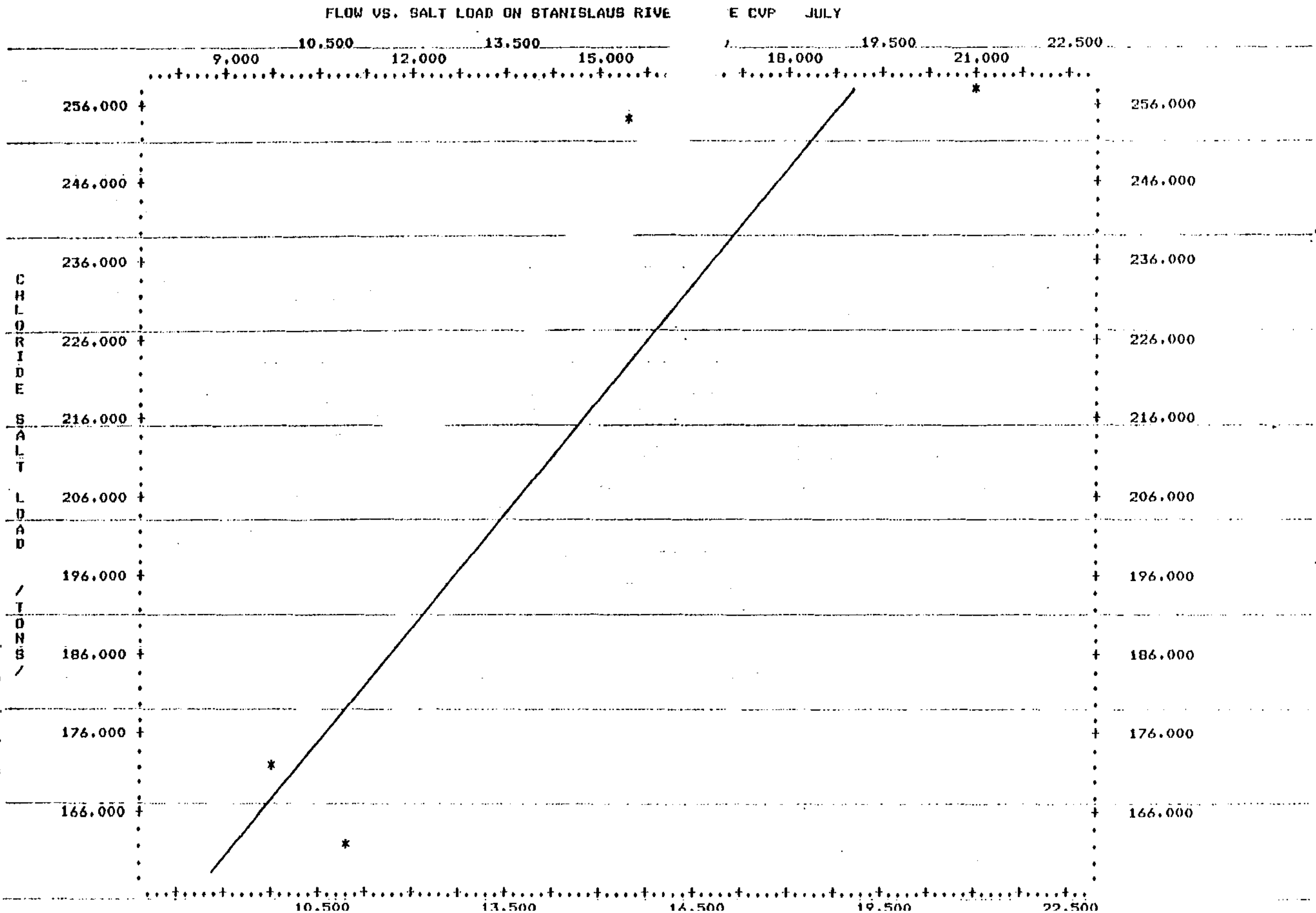
FLOW VS. SALT LOAD ON STANISLAUS RIVER PRE CVP JANUARY
15,000
30,000
45,000
60,000
75,000
90,000
105,000
120,000
135,000
150,000
390,000
352,500
315,000
277,500
240,000
202,500
165,000
127,500
90,000
52,500
CHLORIDE SALT LOAD /TONS/
30,000
60,000
90,000
120,000
150,000

040791

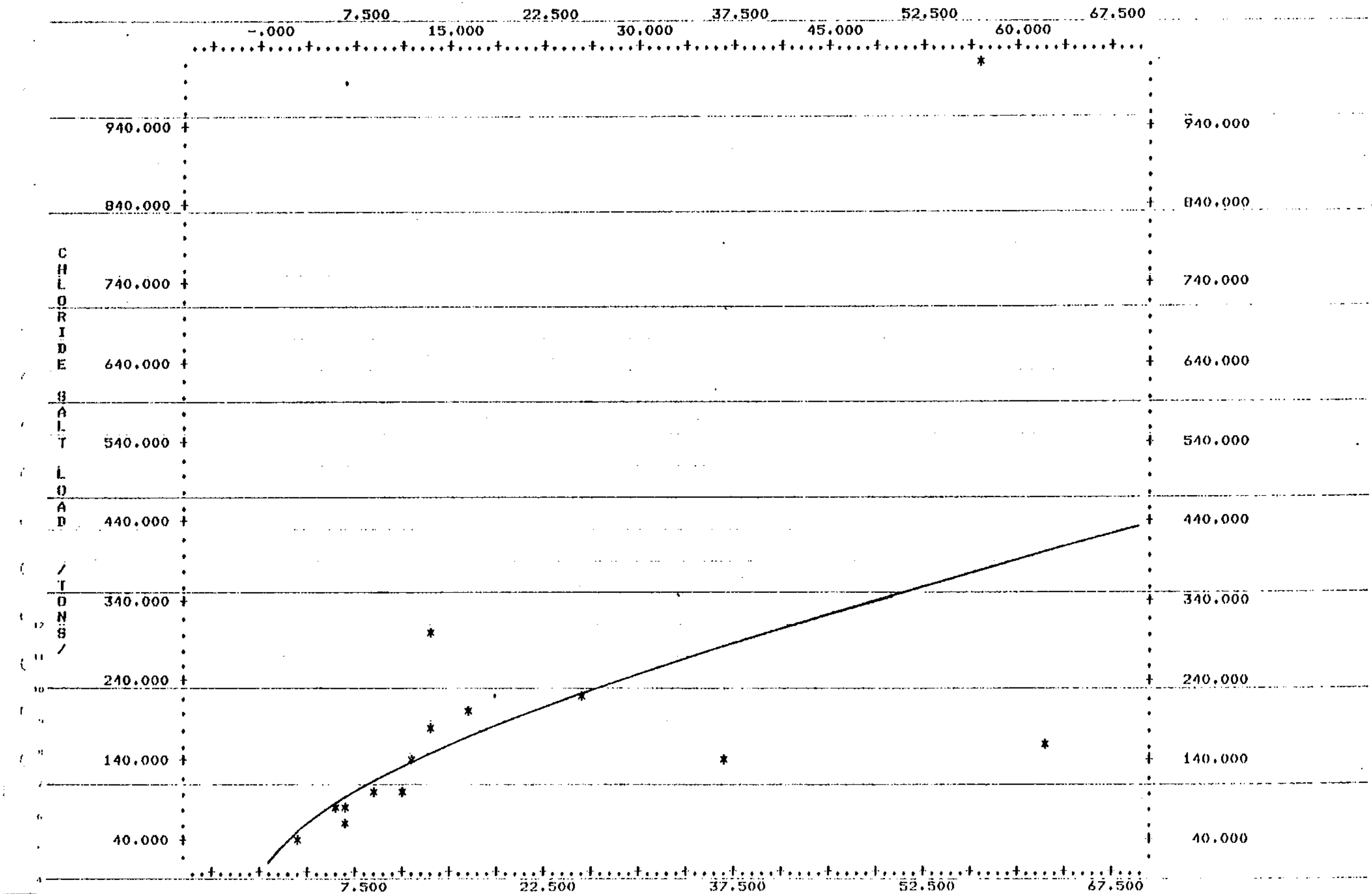

FLOW VS. SALT LOAD ON STANISLAUS RIVER
JANUARY
CHLORIDE SALT LOAD /TONS/
STANISLAUS RIVER FLOW (KAF)
-20.000
80.000
180.000
280.000
380.000
480.000
580.000
680.000
780.000
880.000
-.000
30.000
60.000
90.000
120.000
150.000
180.000
210.000
240.000
270.000

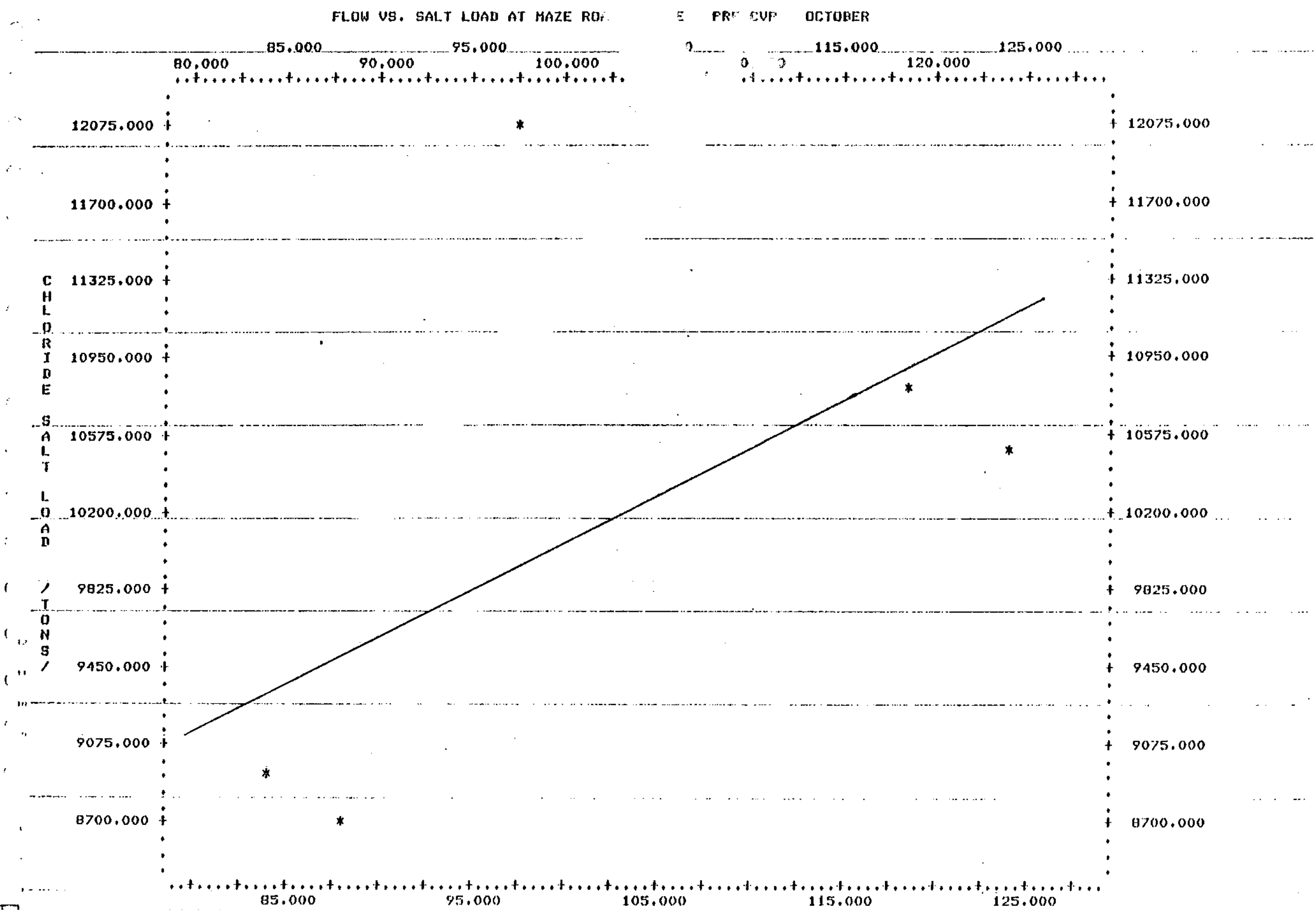

FLOW VS. SALT LOAD ON STANISLAUS RIVER PRE CVP APRIL
30,000
45,000
60,000
75,000
90,000
105,000
120,000
135,000
150,000
165,000
CHLORIDE SALT LOAD /TONS/
490,000
440,000
390,000
340,000
290,000
240,000
190,000
140,000
90,000
40,000


FLOW VS. SALT LOAD ON STANISLAUS RIVER POST CVP APRIL
-.000
60.000
120.000
180.000
240.000
-30.000
30.000
90.000
150.000
210.000
1840.000
1640.000
1440.000
1240.000
1040.000
840.000
640.000
440.000
240.000
40.000
CHLORIDE SALT LOAD /TONS/
2

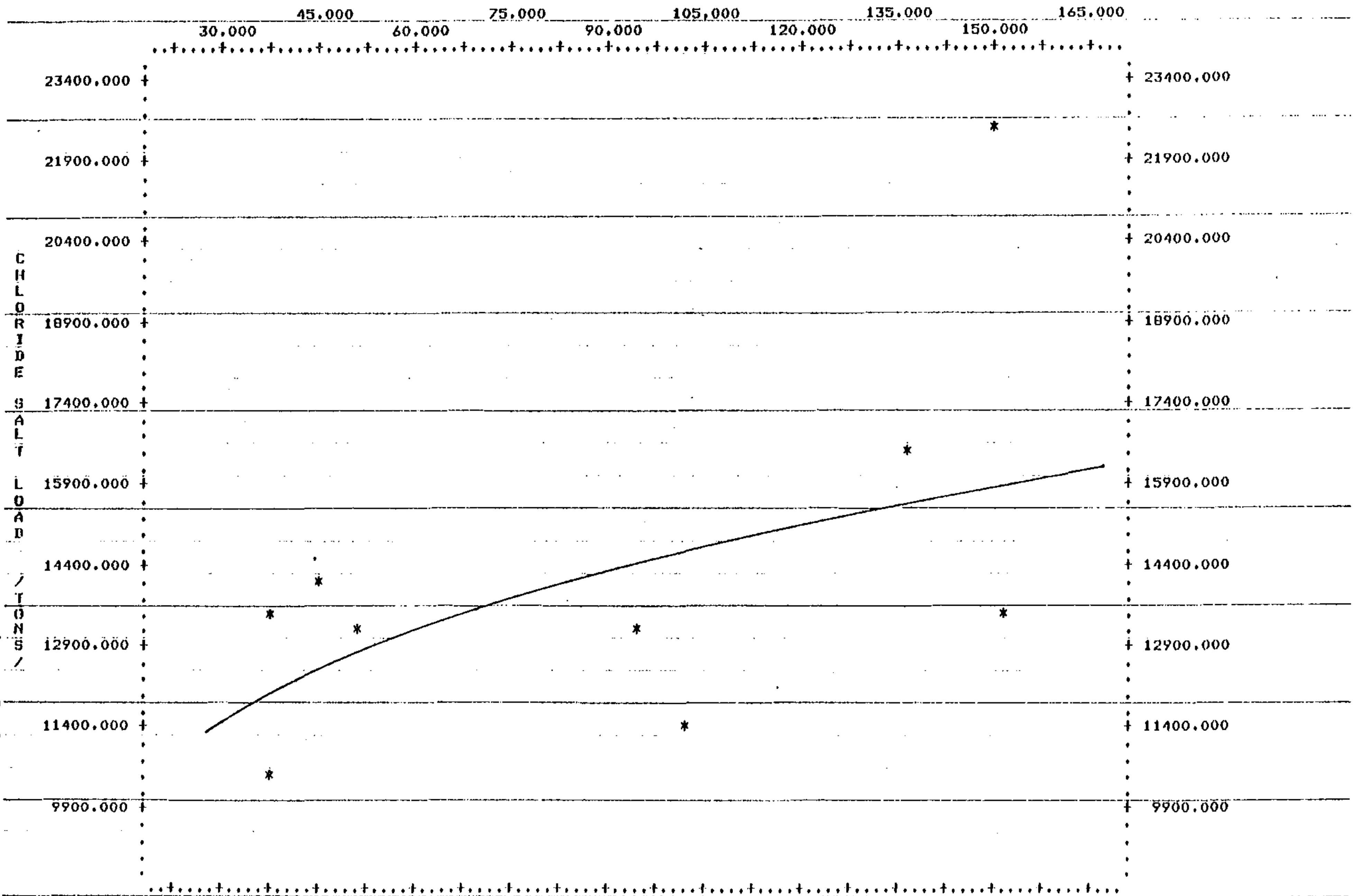

FLOW VS. SALT LOAD ON STANISLAUS RIVE E CVP JULY
9,000
10,500
12,000
13,500
15,000
18,000
19,500
21,000
22,500
256,000
246,000
236,000
226,000
216,000
206,000
196,000
186,000
176,000
166,000
CHLORIDE SALT LOAD /TONS/
10,500
13,500
16,500
19,500
22,500

FLOW VS. SALT LOAD ON STANISLAUS RIVER POST CVP JULY

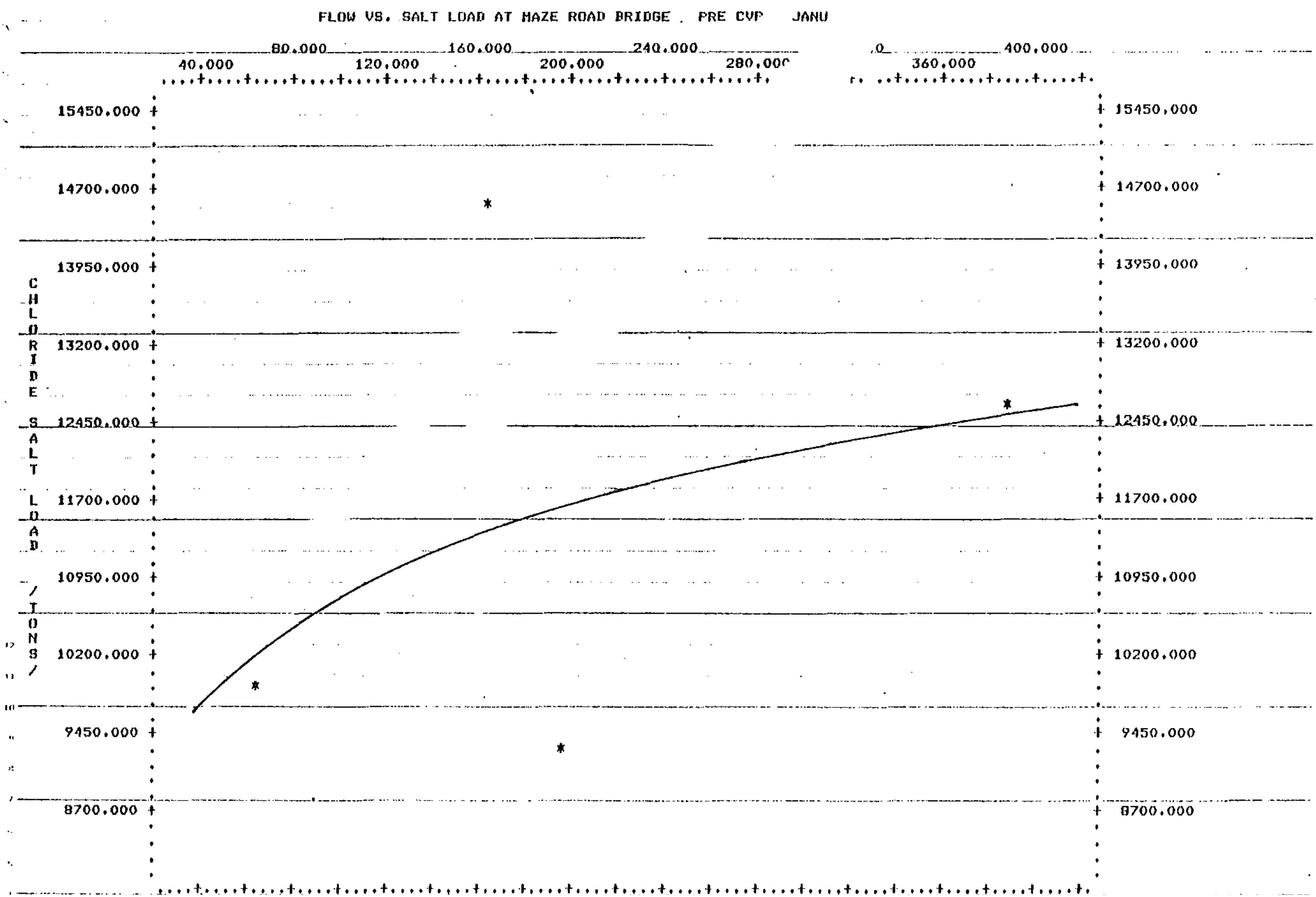



FLOW VS. SALT LOAD AT MAZE ROA E FR CVP OCTOBER
85.000 95.000 115.000 125.000
80.000 90.000 100.000 120.000
12075.000
11700.000
11325.000
10950.000
10575.000
10200.000
9825.000
9450.000
9075.000
8700.000
CHLORIDE SALT LOAD /TONS/
85.000 95.000 105.000 115.000 125.000

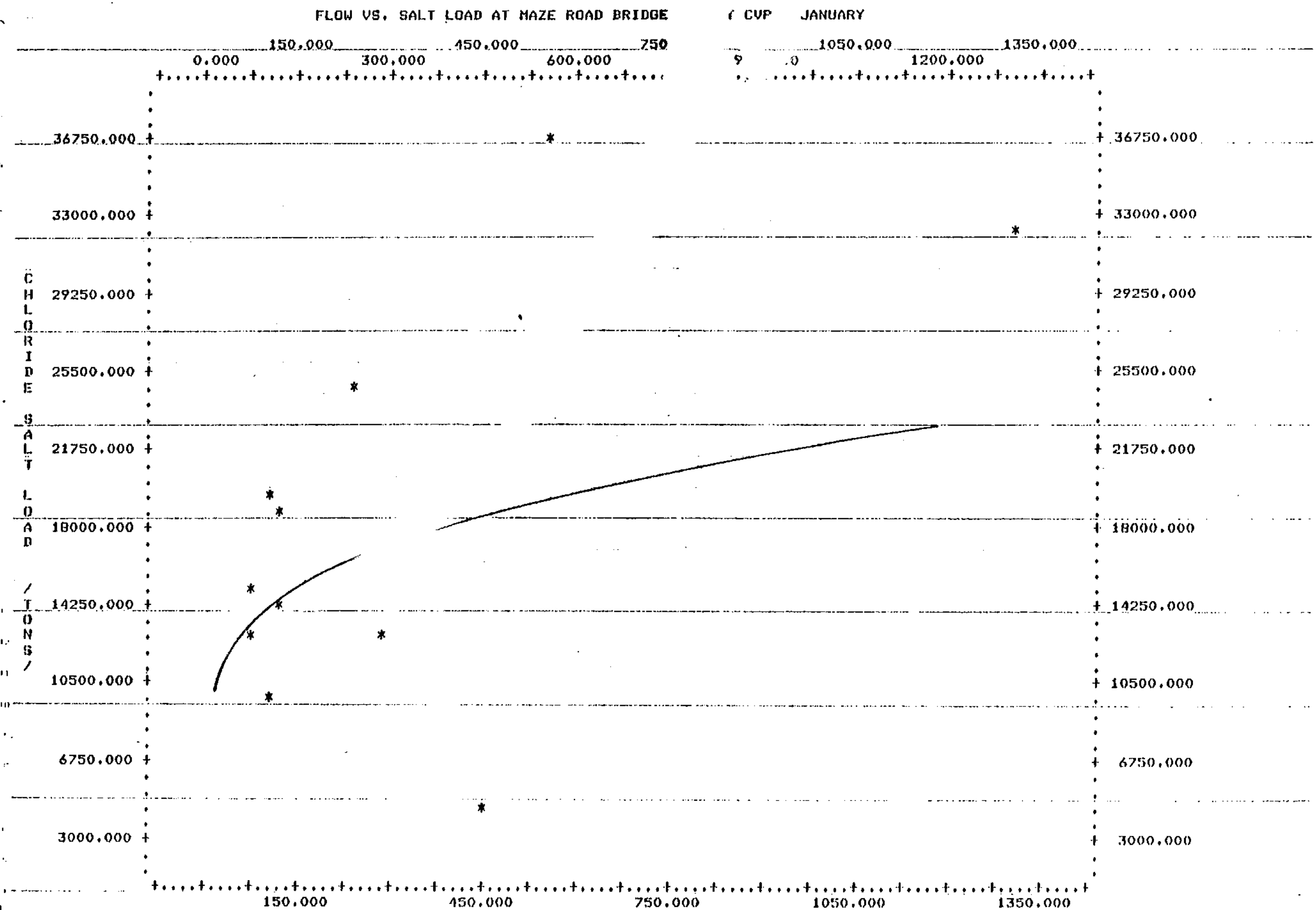
FLOW VS. SALT LOAD AT MAZE ROAD BRIDGE POST CVP OCTOBER



040798



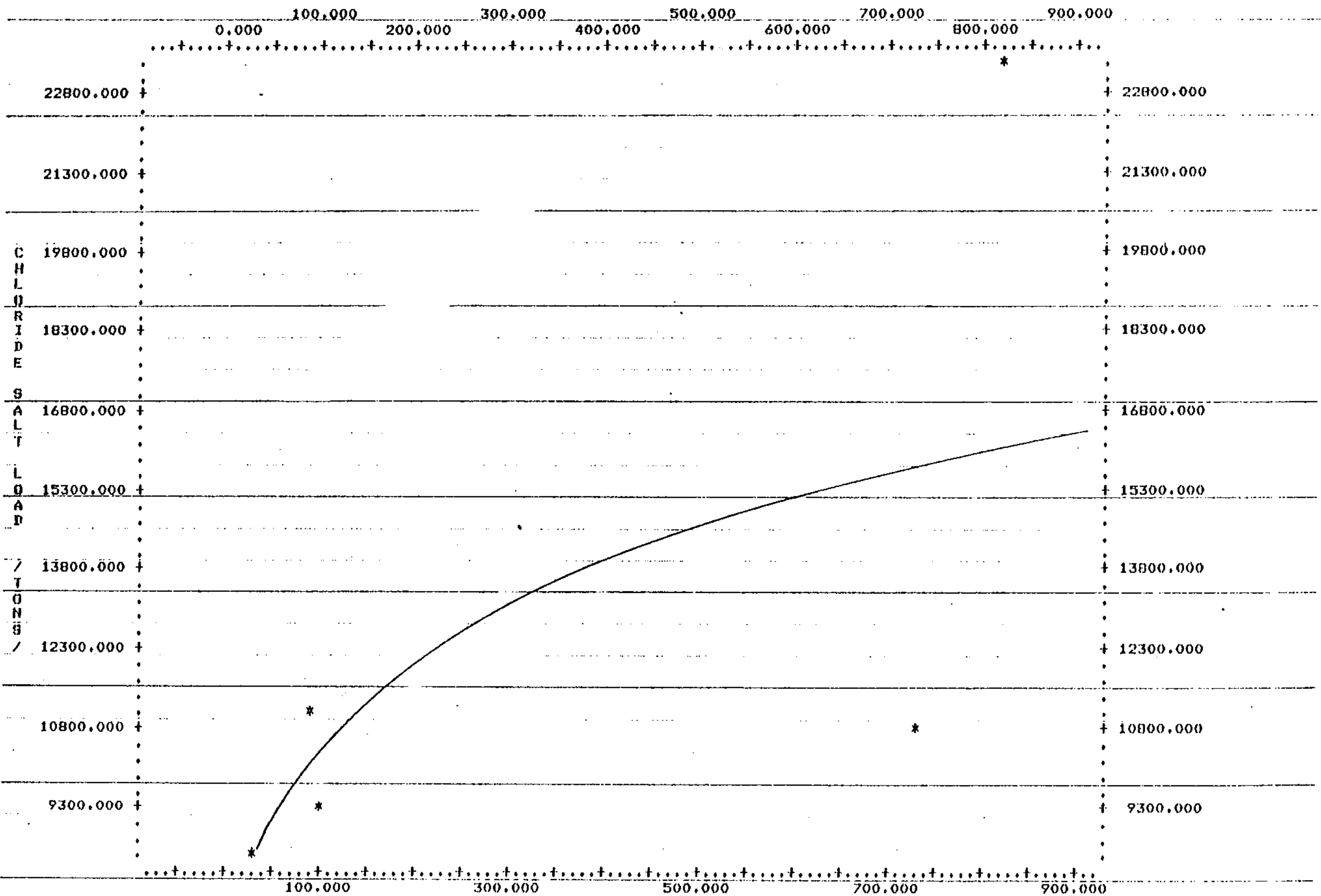
FLOW VS. SALT LOAD AT MAZE ROAD BRIDGE . PRE CVP JANU
80.000
160.000
240.000
0
400.000
40.000
120.000
200.000
280.000
360.000
15450.000
14700.000
13950.000
13200.000
12450.000
11700.000
10950.000
10200.000
9450.000
8700.000
CHLORIDE SALT LOAD /TONS/

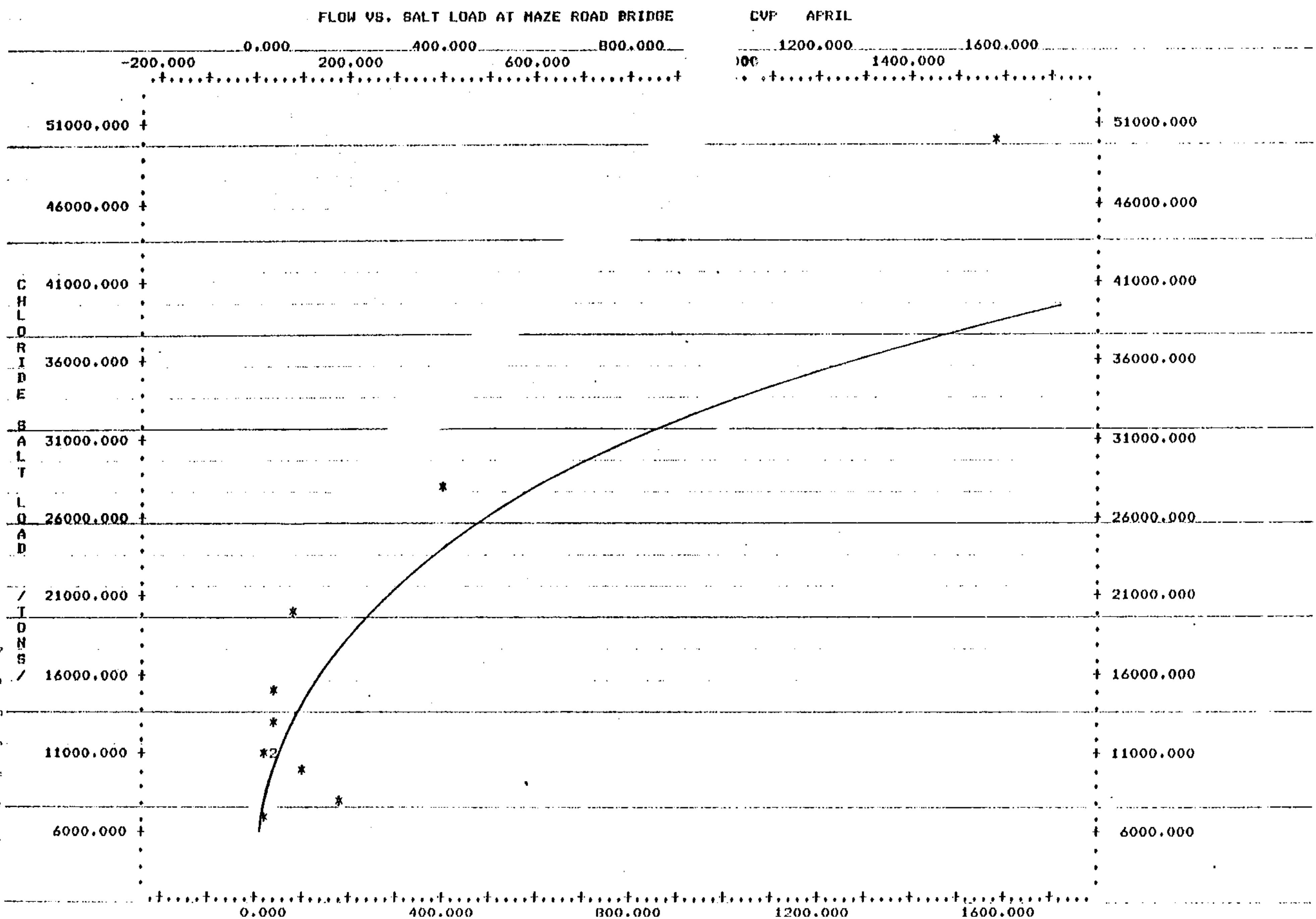


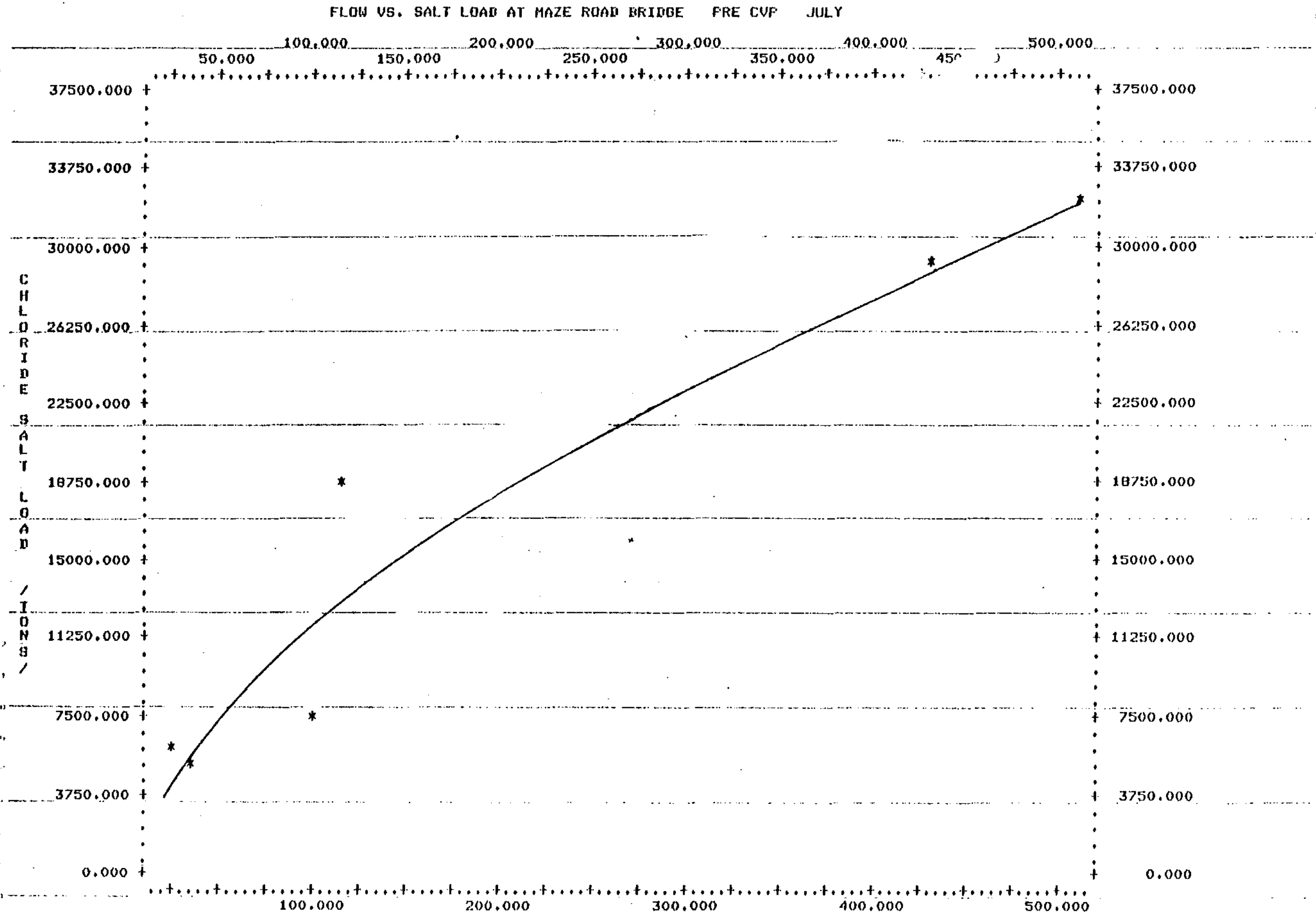
FLOW VS. SALT LOAD AT MAZE ROAD BRIDGE (CVP JANUARY
0.000
150.000
300.000
450.000
600.000
750
1050.000
1200.000
1350.000
36750.000
33000.000
29250.000
25500.000
21750.000
18000.000
14250.000
10500.000
6750.000
3000.000
CHLORIDE SALT LOAD /TONS/
150.000
450.000
750.000
1050.000
1350.000

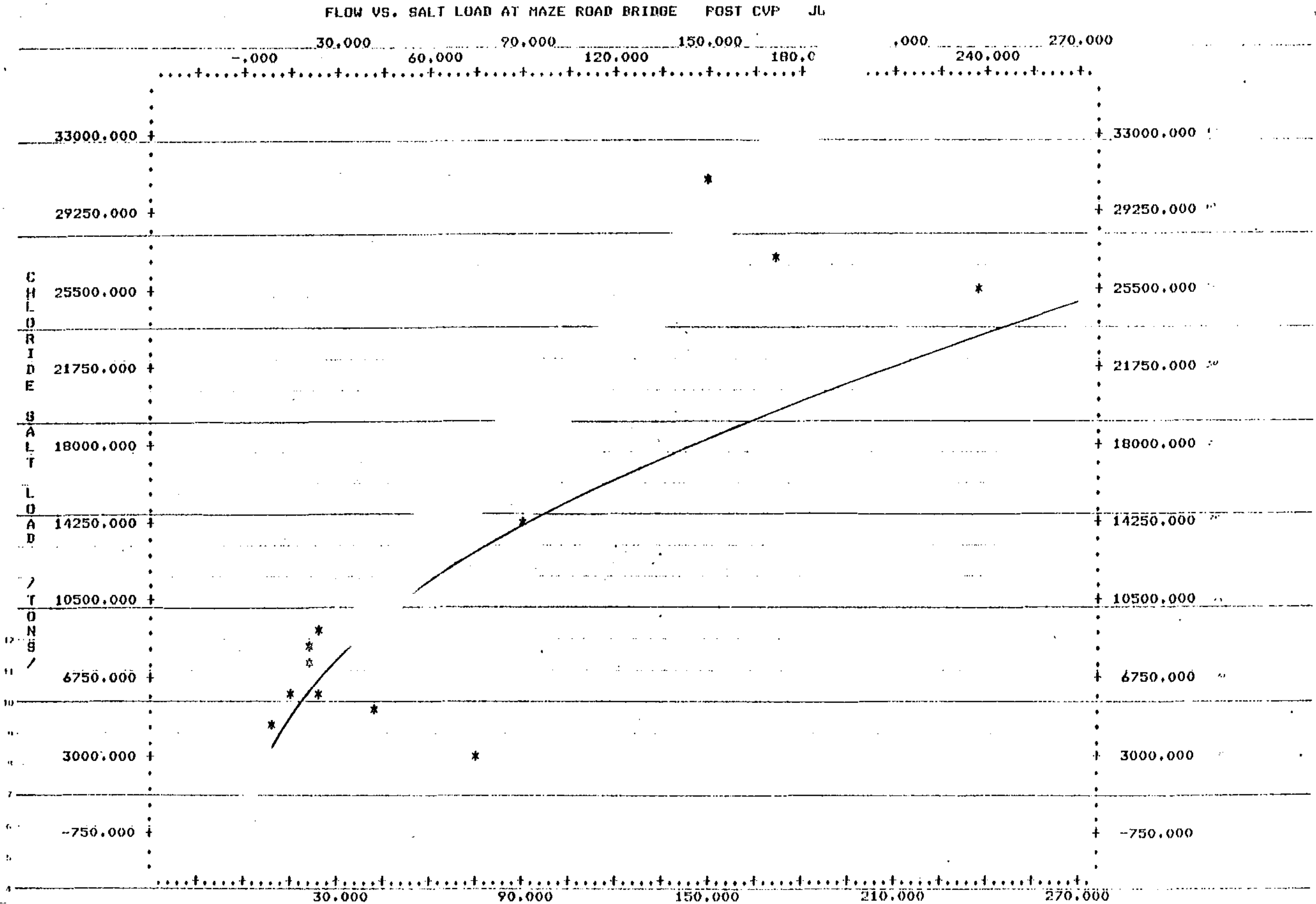
040800

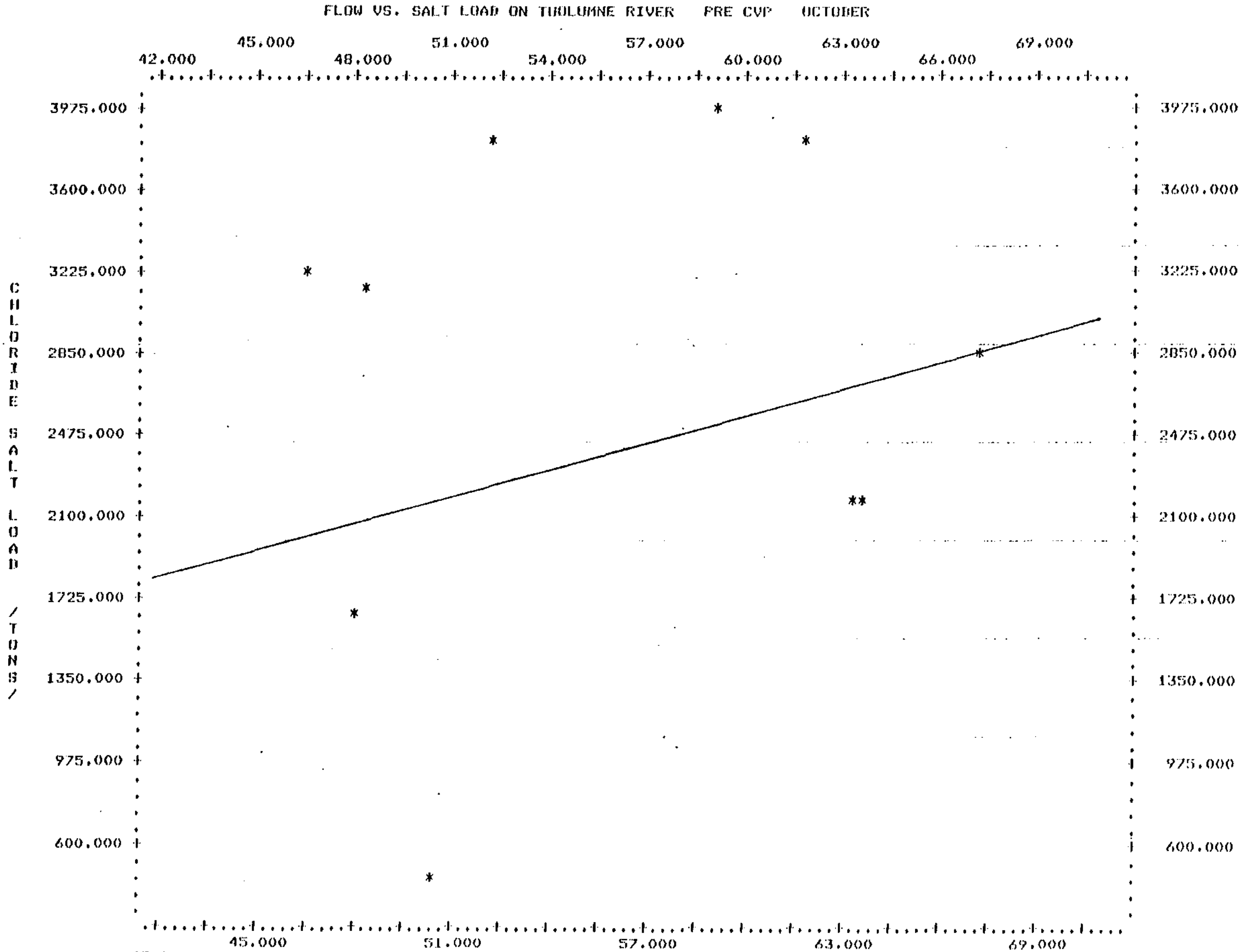
FLOW VS. SALT LOAD AT MAZE ROAD BRIDGE PRE CVP APRIL



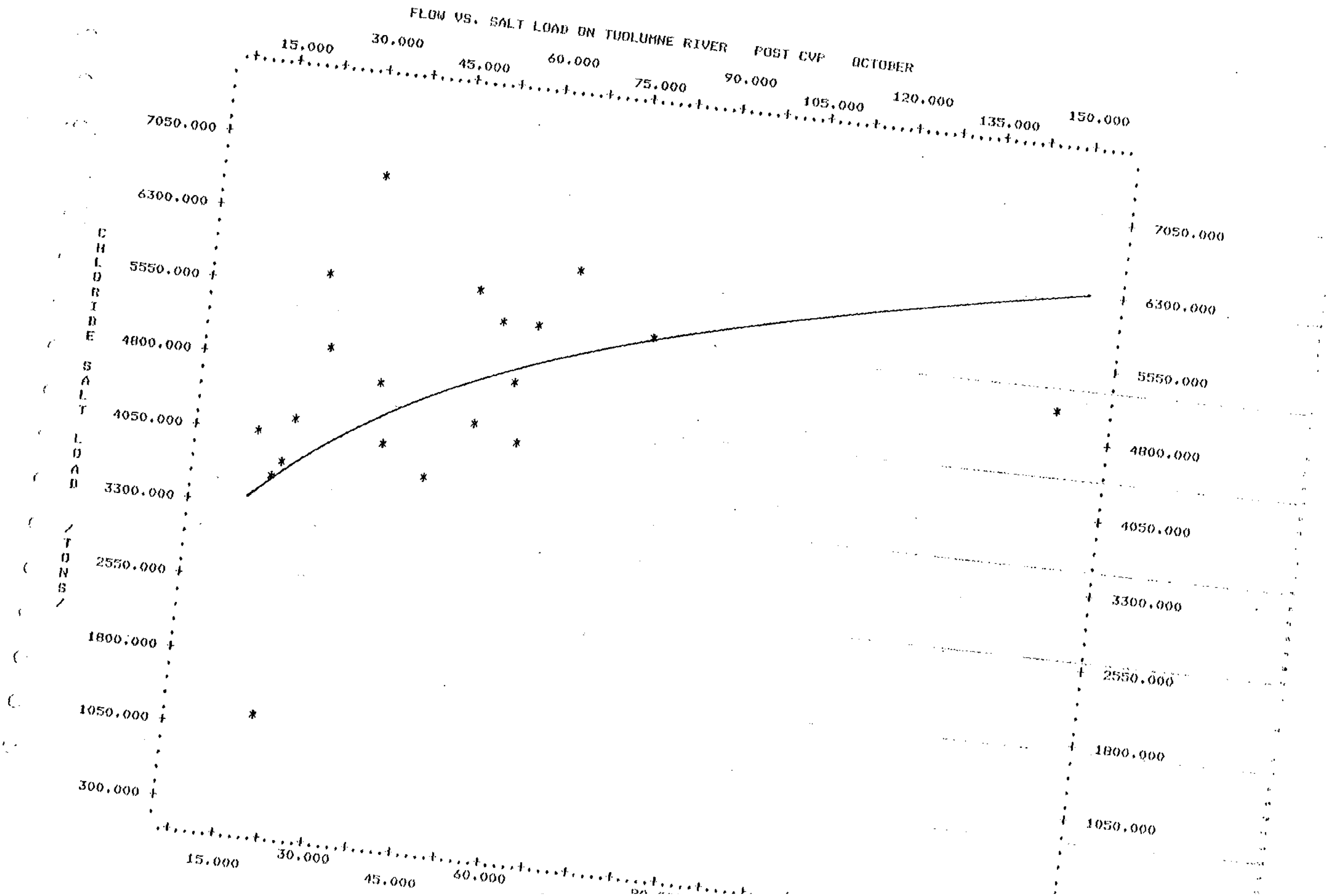

FLOW VS. SALT LOAD AT MAZE ROAD BRIDGE CVP APRIL
CHLORIDE SALT LOAD /TONS/
-200.000
0.000
200.000
400.000
600.000
800.000
1200.000
1400.000
1600.000
51000.000
46000.000
41000.000
36000.000
31000.000
26000.000
21000.000
16000.000
11000.000
6000.000
2


FLOW VS. SALT LOAD AT MAZE ROAD BRIDGE PRE CVP JULY
50.000
100.000
150.000
200.000
250.000
300.000
350.000
400.000
500.000
37500.000
33750.000
30000.000
26250.000
22500.000
18750.000
15000.000
11250.000
7500.000
3750.000
0.000
CHLORIDE SALT LOAD /TONS/
100.000
200.000
300.000
400.000
500.000

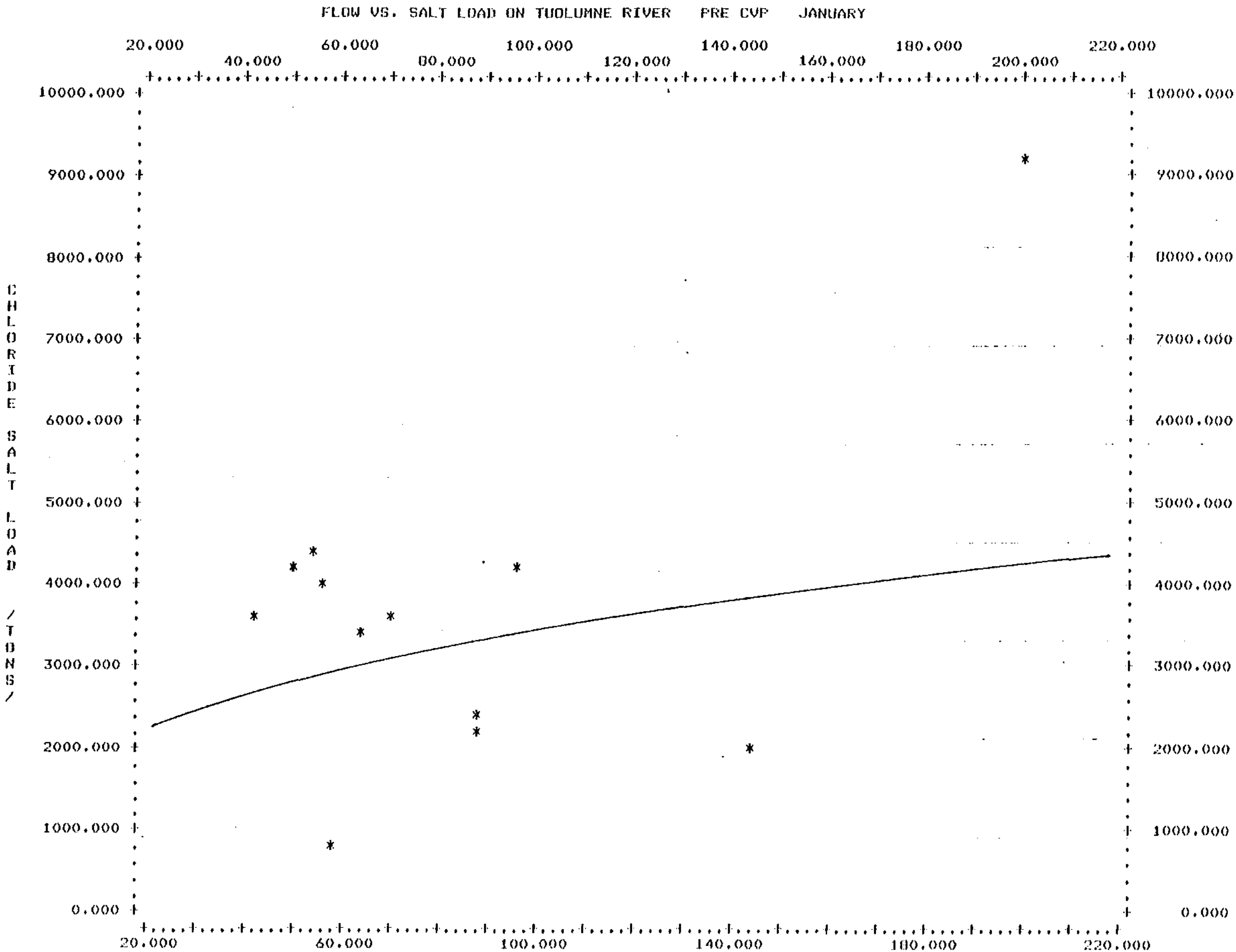

FLOW VS. SALT LOAD AT MAZE ROAD BRIDGE POST CVP JL
-.000
30,000
60,000
90,000
120,000
150,000
180,0
,000
240,000
270,000
33000.000
29250.000
25500.000
21750.000
18000.000
14250.000
10500.000
6750.000
3000.000
-750.000
CHLORIDE SALT LOAD / TONS /
30.000
90.000
150.000
210.000
270.000



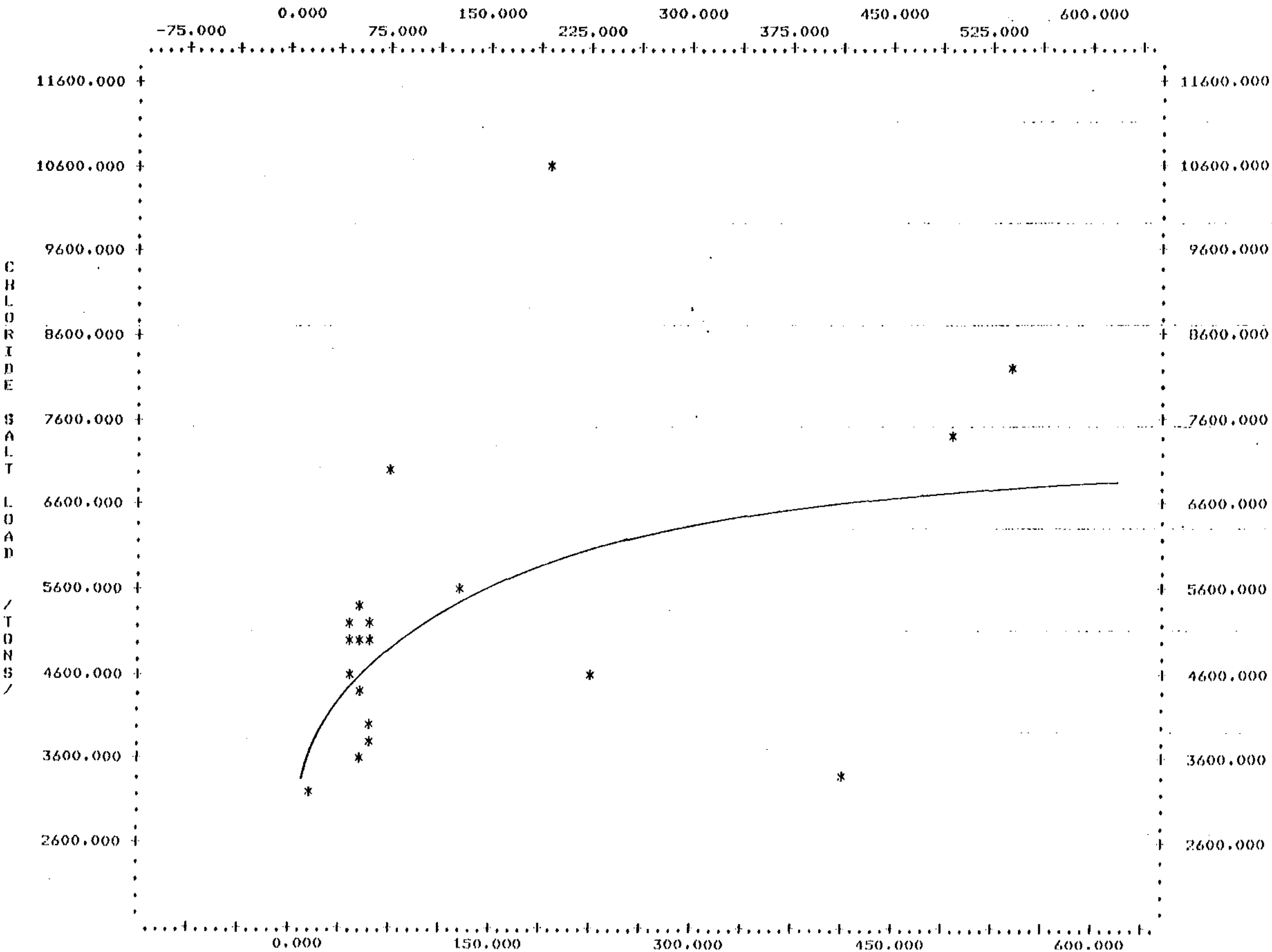
FLOW VS. SALT LOAD ON TUOLUMNE RIVER PRE CVP OCTOBER
42.000
45.000
48.000
51.000
54.000
57.000
60.000
63.000
66.000
69.000
3975.000
3600.000
3225.000
2850.000
2475.000
2100.000
1725.000
1350.000
975.000
600.000
CHLORIDE SALT LOAD /TONS/


FLOW VS. SALT LOAD ON TUOLUMNE RIVER POST CVP OCTOBER
15.000
30.000
45.000
60.000
75.000
90.000
105.000
120.000
135.000
150.000
7050.000
6300.000
5550.000
4800.000
4050.000
3300.000
2550.000
1800.000
1050.000
300.000
CHLORIDE SALT LOAD /TONS/

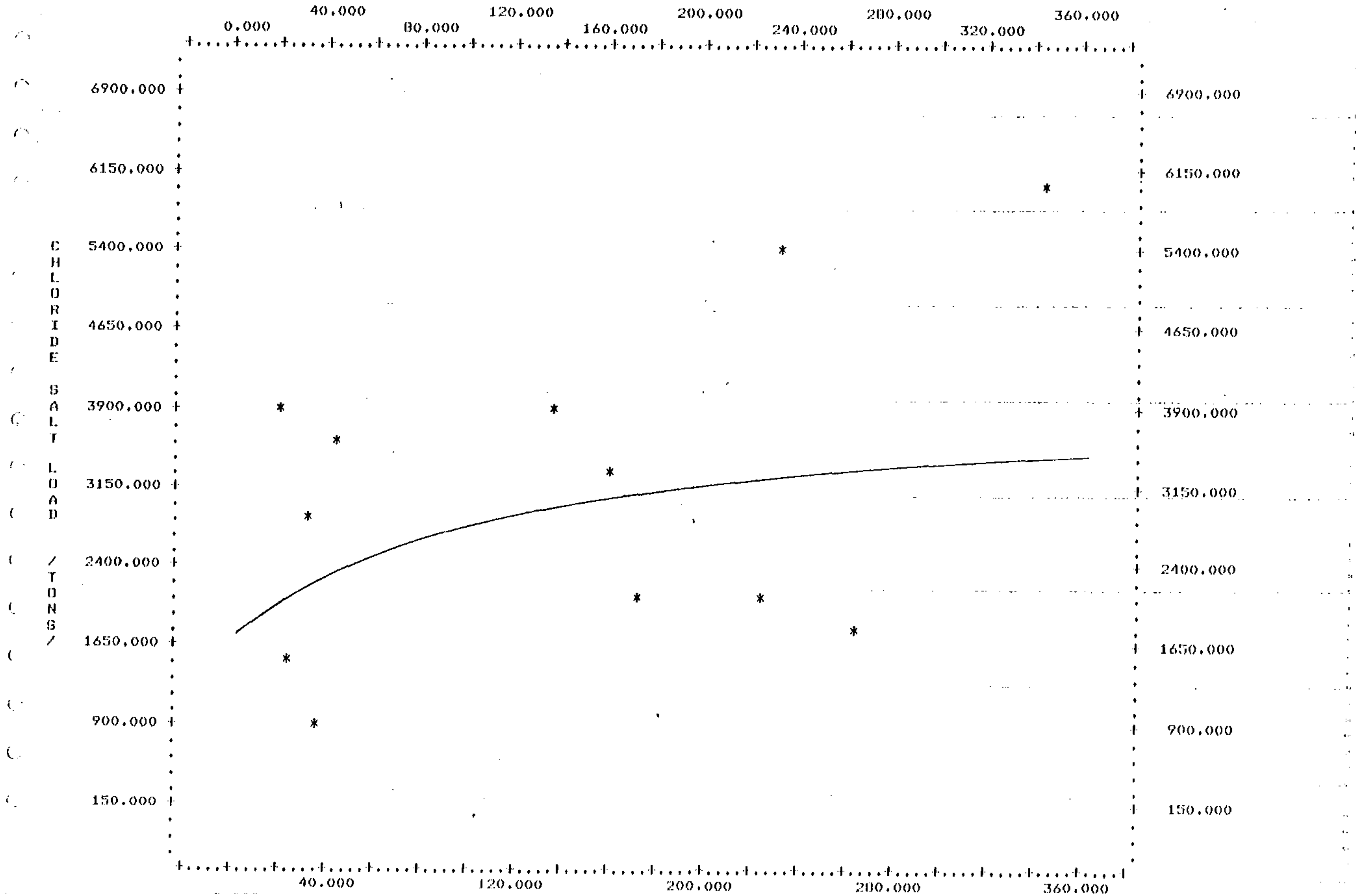
040806

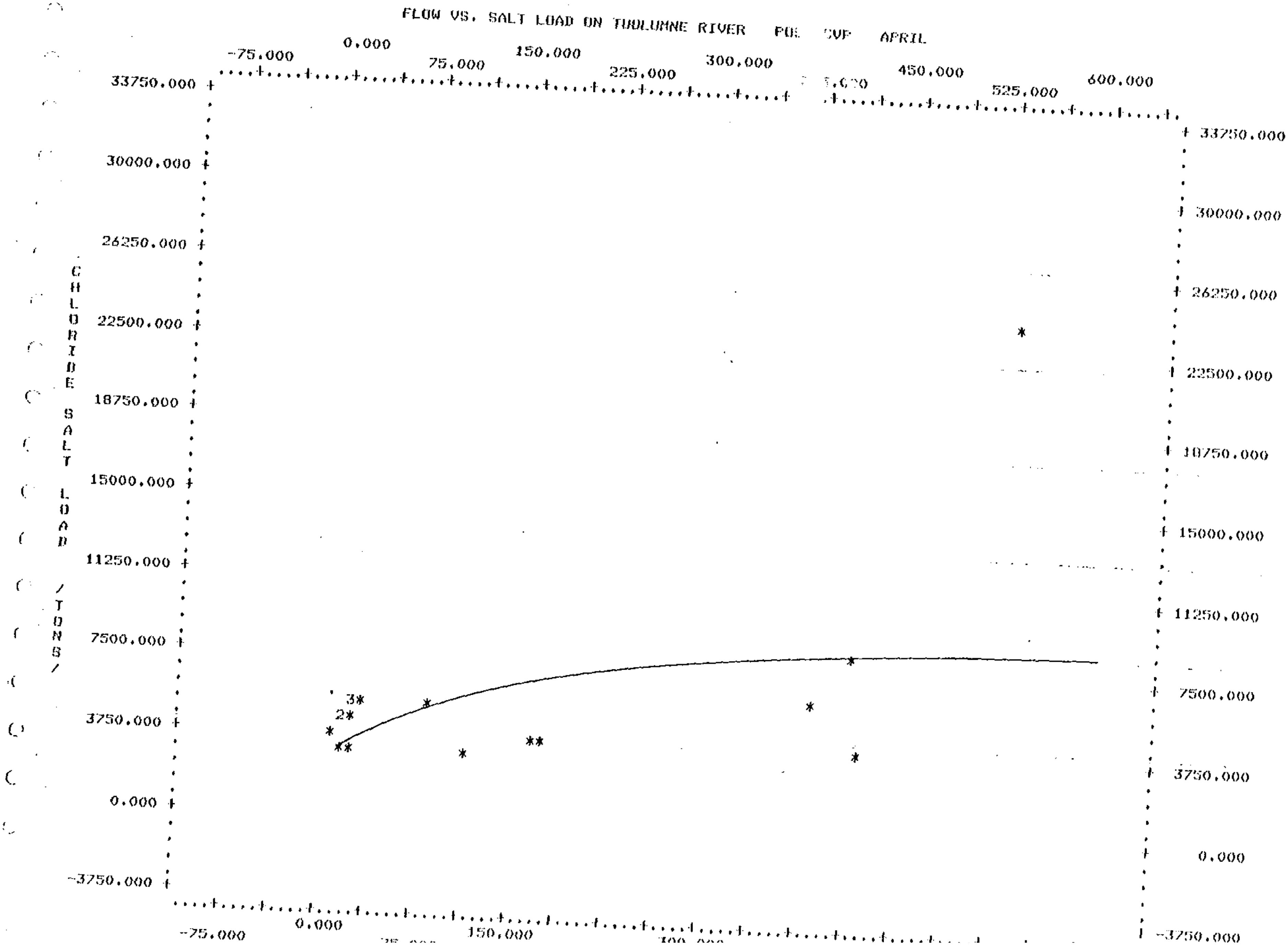

FLOW VS. SALT LOAD ON TUOLUMNE RIVER PRE CVP JANUARY
20.000
40.000
60.000
80.000
100.000
120.000
140.000
160.000
180.000
200.000
220.000
10000.000
9000.000
8000.000
7000.000
6000.000
5000.000
4000.000
3000.000
2000.000
1000.000
0.000
CHLORIDE SALT LOAD /TONS/

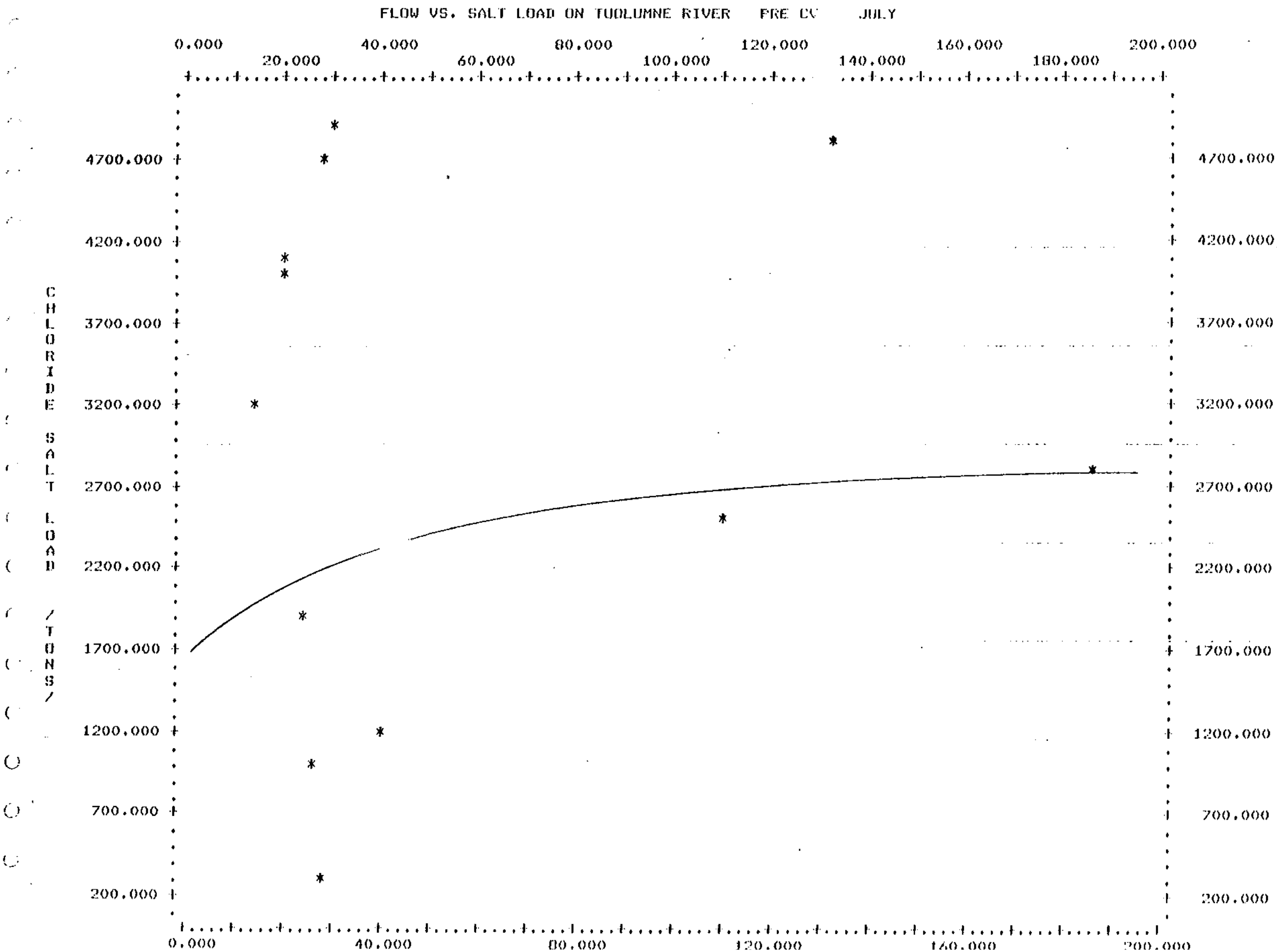
FLOW VS. SALT LOAD ON TUOLUMNE RIVER POST CVP JANUARY



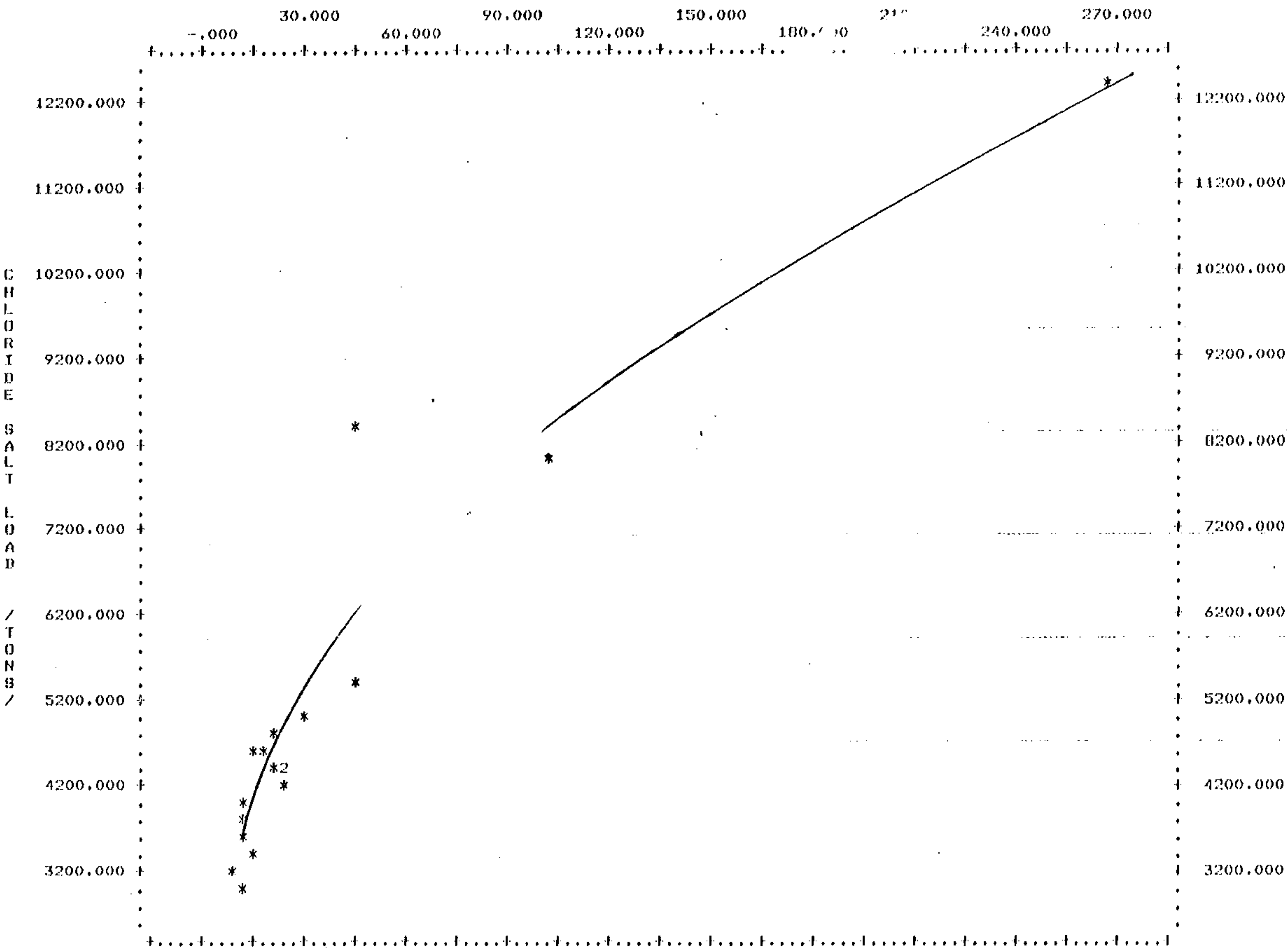
FLOW VS. SALT LOAD ON TUOLUMNE RIVER PRE CVP APRIL

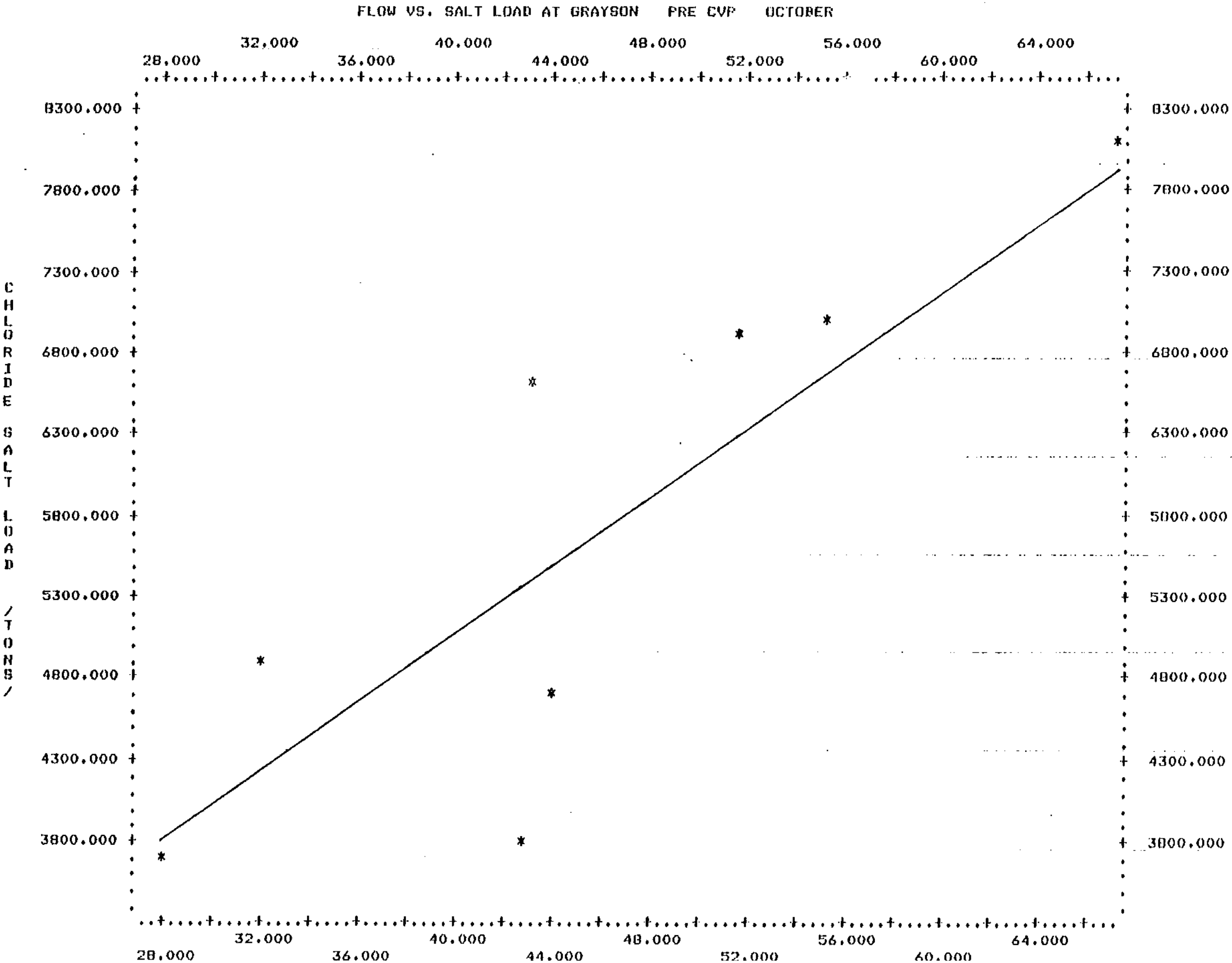



FLOW VS. SALT LOAD ON TUOLUMNE RIVER POE CVP APRIL
CHLORIDE SALT LOAD /TONS/
-75.000
0.000
75.000
150.000
225.000
300.000
450.000
525.000
600.000
33750.000
30000.000
26250.000
22500.000
18750.000
15000.000
11250.000
7500.000
3750.000
0.000
-3750.000

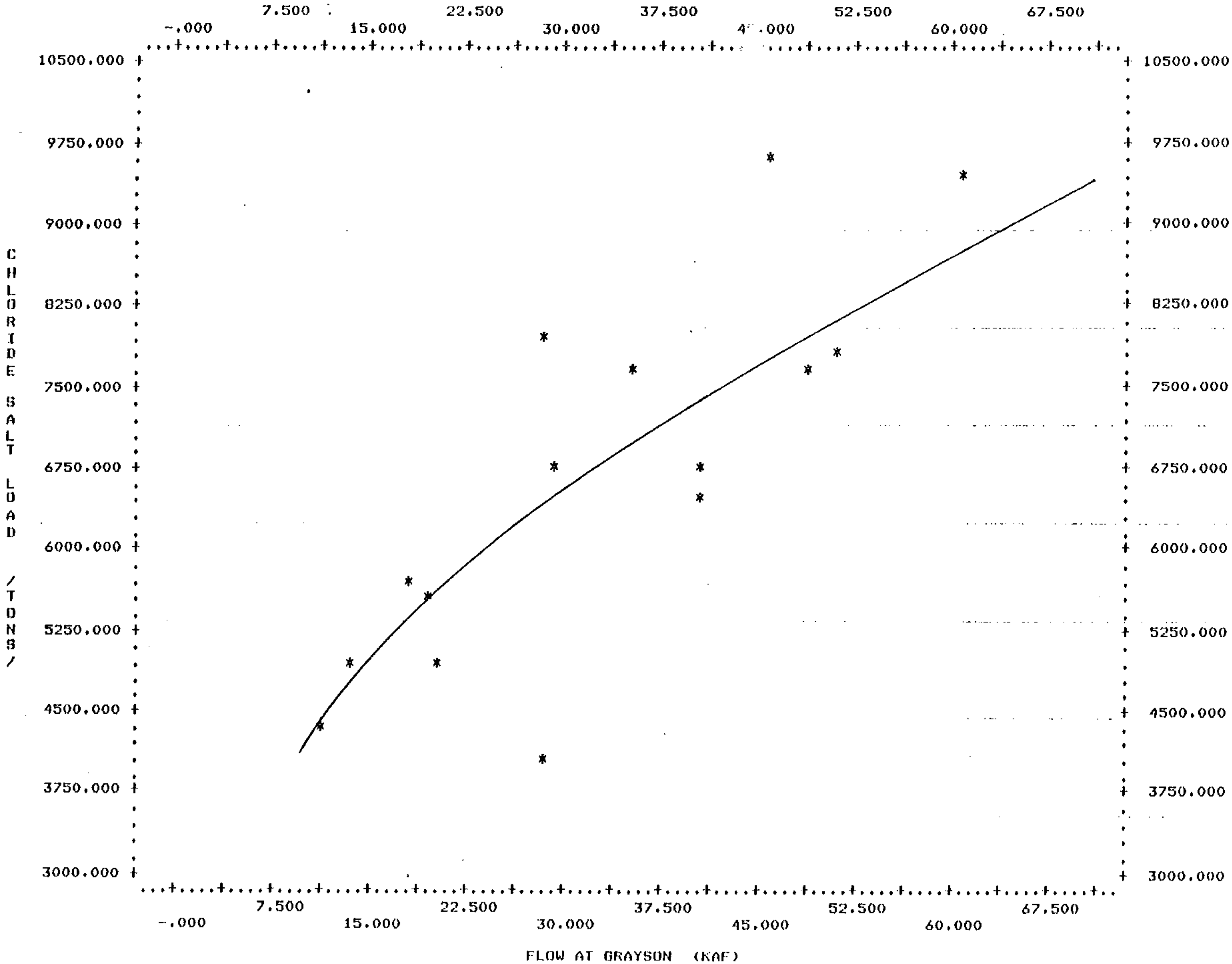

FLOW VS. SALT LOAD ON TUOLUMNE RIVER PRE CV JULY
0.000
20.000
40.000
60.000
80.000
100.000
120.000
140.000
160.000
180.000
200.000
CHLORIDE SALT LOAD /TONS/
4700.000
4200.000
3700.000
3200.000
2700.000
2200.000
1700.000
1200.000
700.000
200.000
0.000
40.000
80.000
120.000
160.000
200.000

FLOW VS. SALT LOAD ON TUOLUMNE RIVER POST CVP JULY

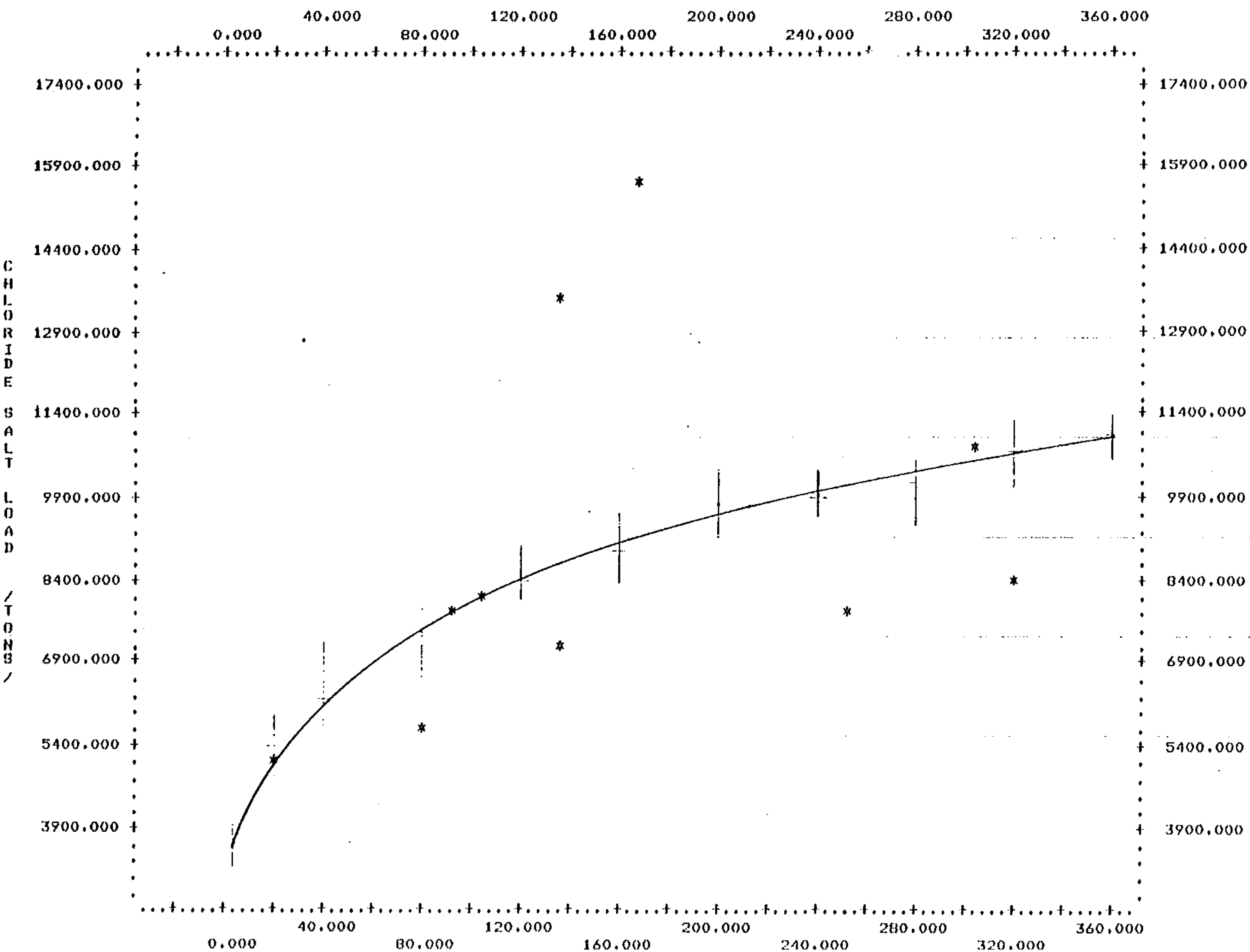



FLOW VS. SALT LOAD AT GRAYSON PRE CVP OCTOBER
28,000
32,000
36,000
40,000
44,000
48,000
52,000
56,000
60,000
64,000
8300.000
7800.000
7300.000
6800.000
6300.000
5800.000
5300.000
4800.000
4300.000
3800.000
CHLORIDE SALT LOAD /TONS/

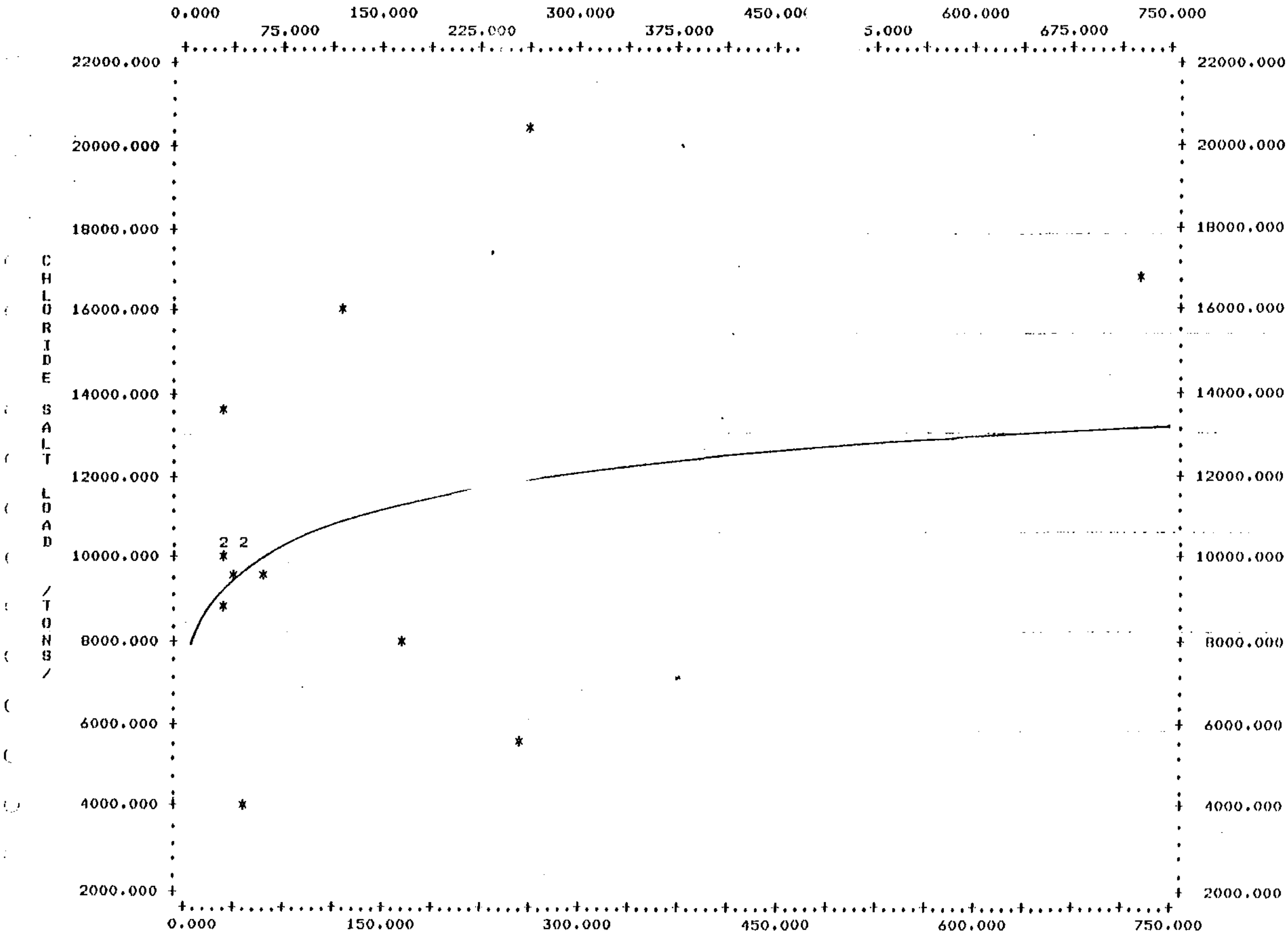
FLOW VS. SALT LOAD AT GRAYSON POST CVP OBER



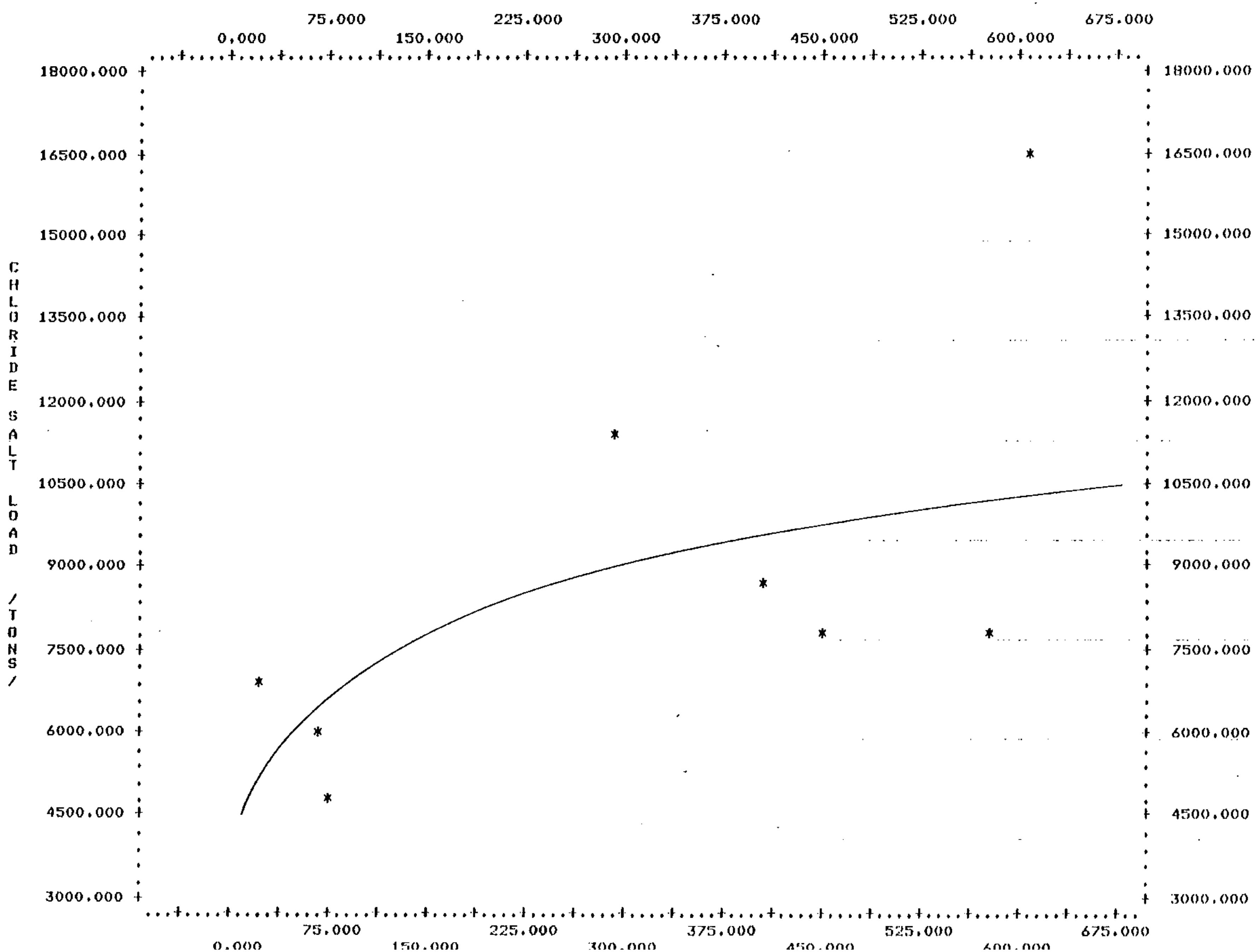
FLOW VS. SALT LOAD AT GRAYSON PRE CVP JANUARY

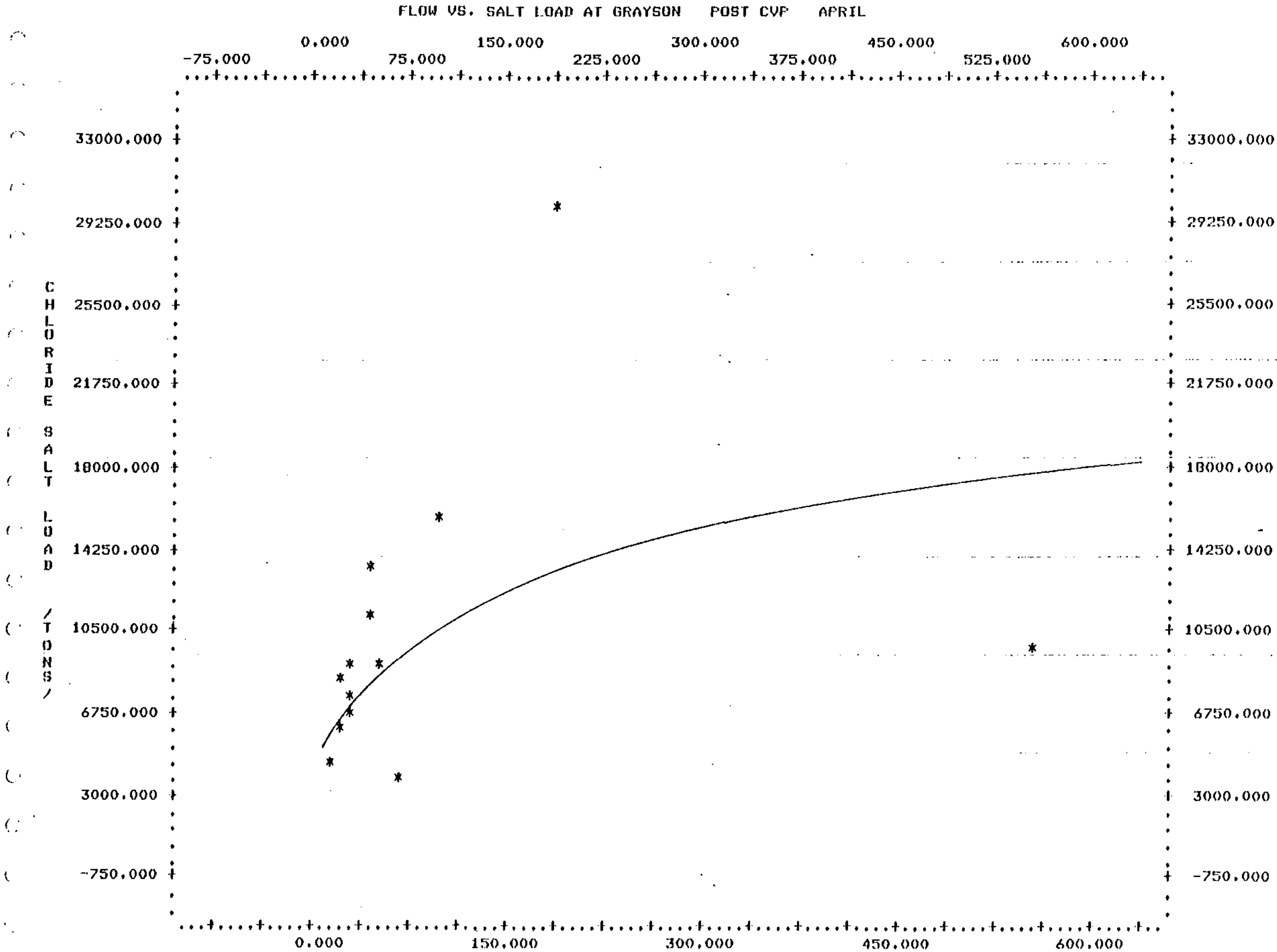


FLOW VS. SALT LOAD AT GRAYSON POST CVP

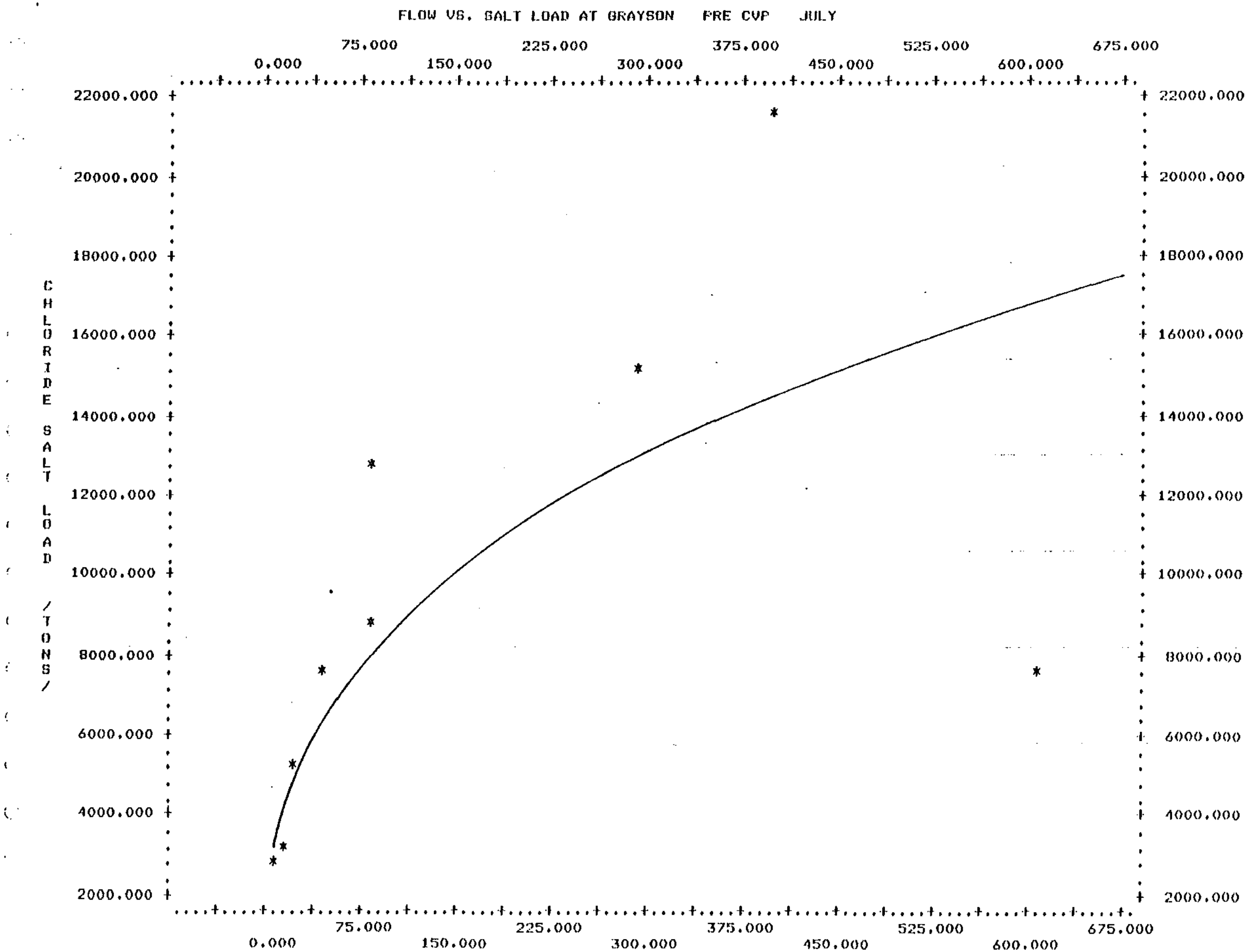


FLOW VS. SALT LOAD AT GRAYSON PRE CVP APRIL

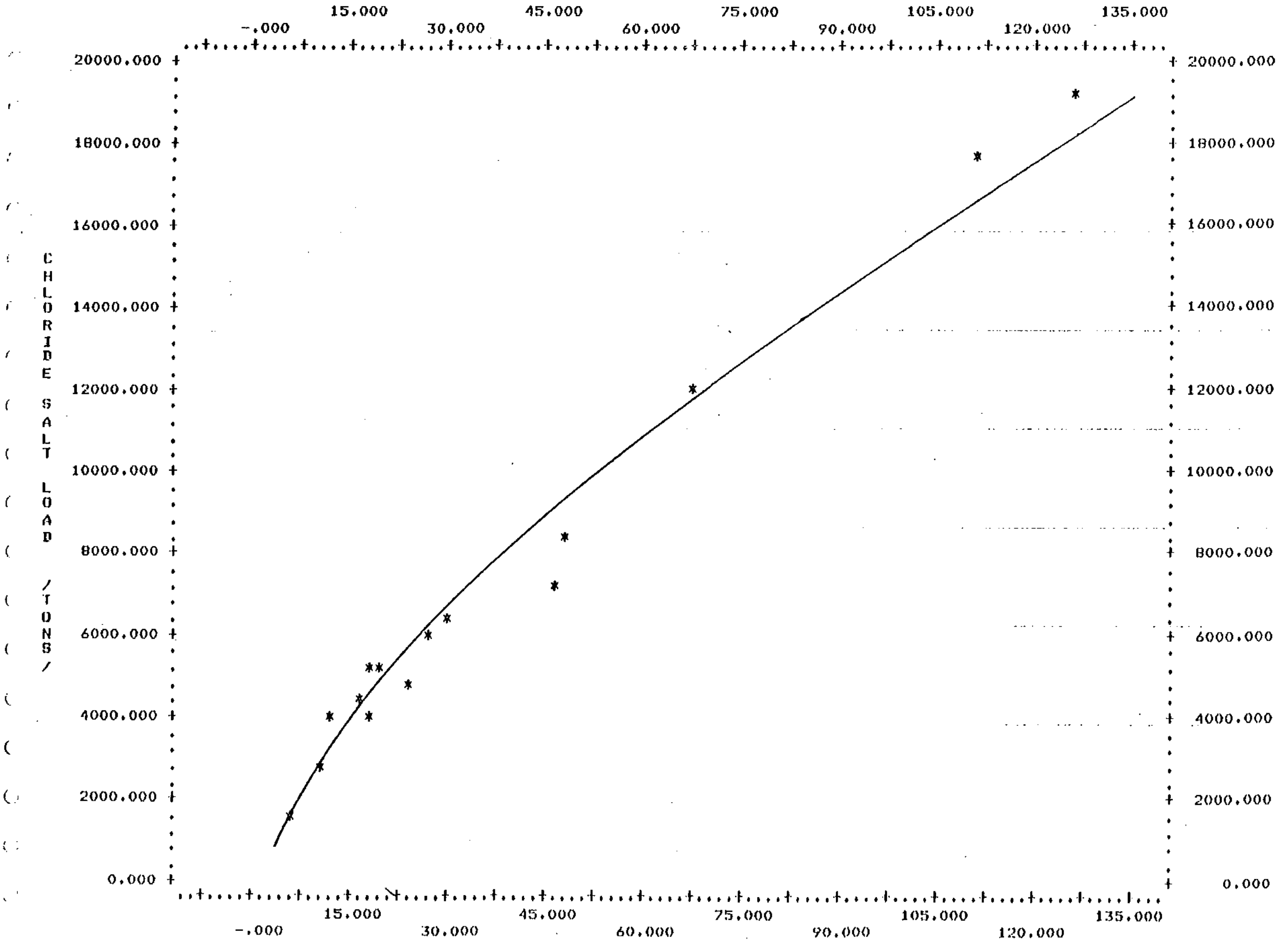


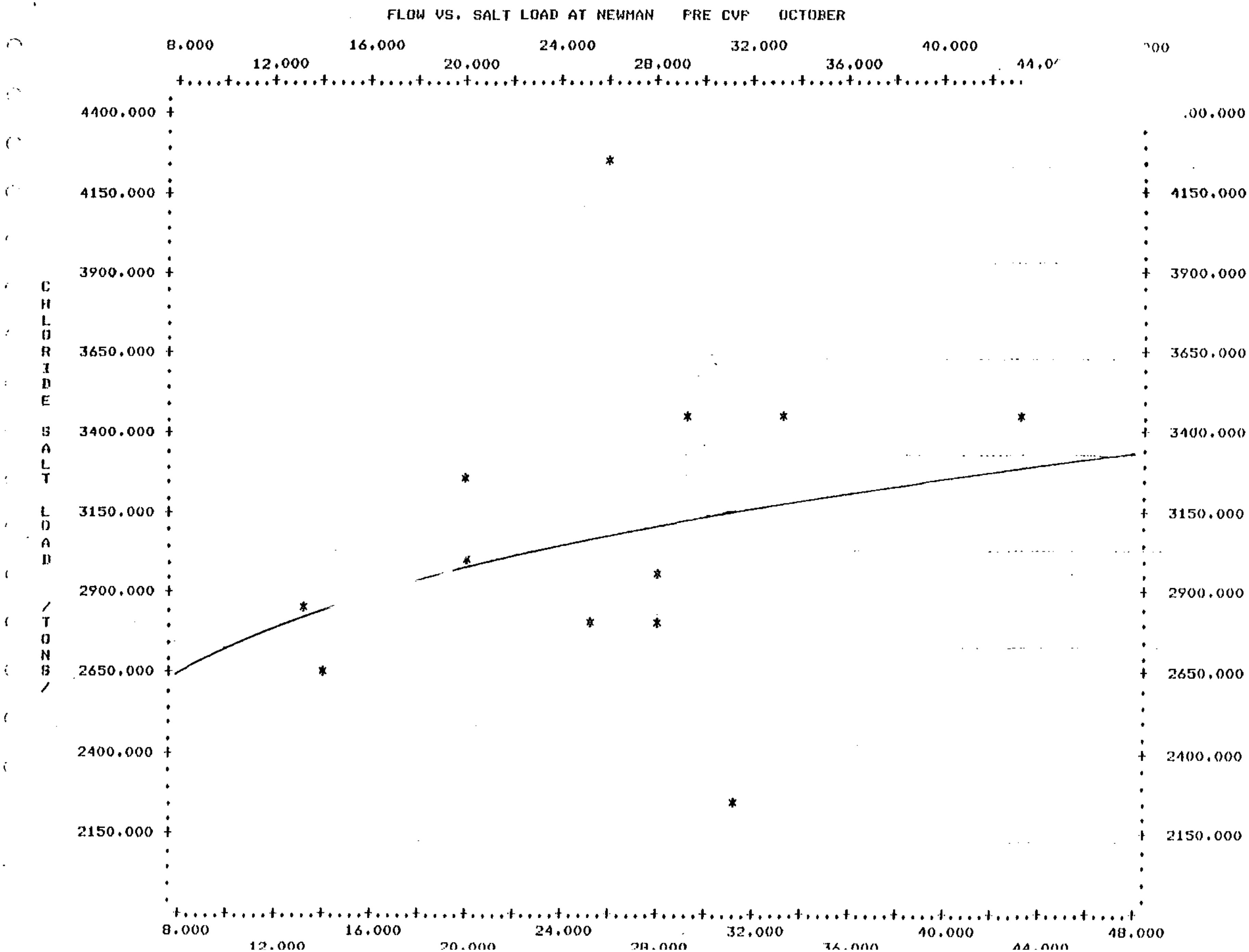

FLOW VS. SALT LOAD AT GRAYSON POST CVP APRIL
0.000
150.000
300.000
450.000
600.000
-75.000
75.000
225.000
375.000
525.000
33000.000
29250.000
25500.000
21750.000
18000.000
14250.000
10500.000
6750.000
3000.000
-750.000
CHLORIDE SALT LOAD /TONS/

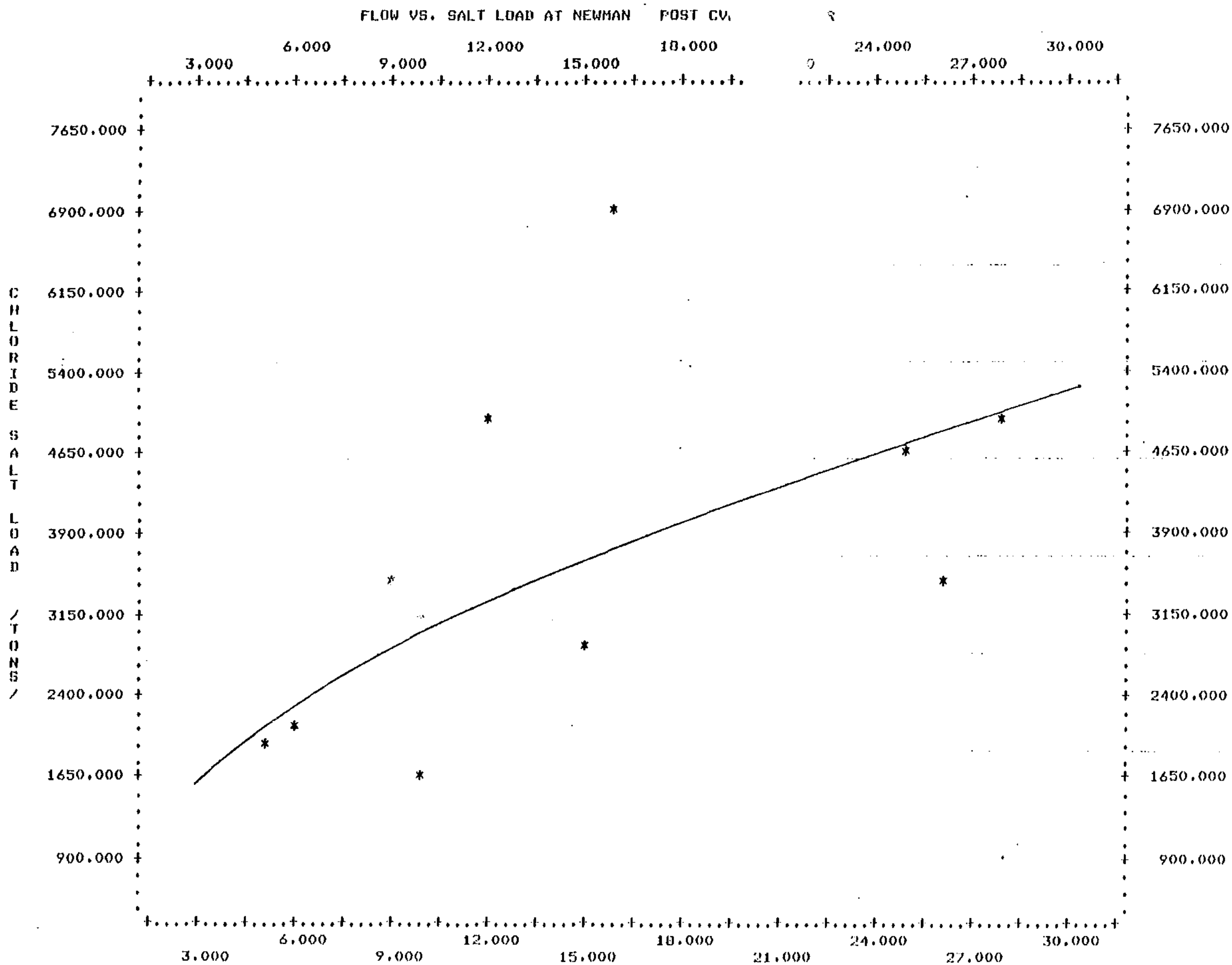
040818

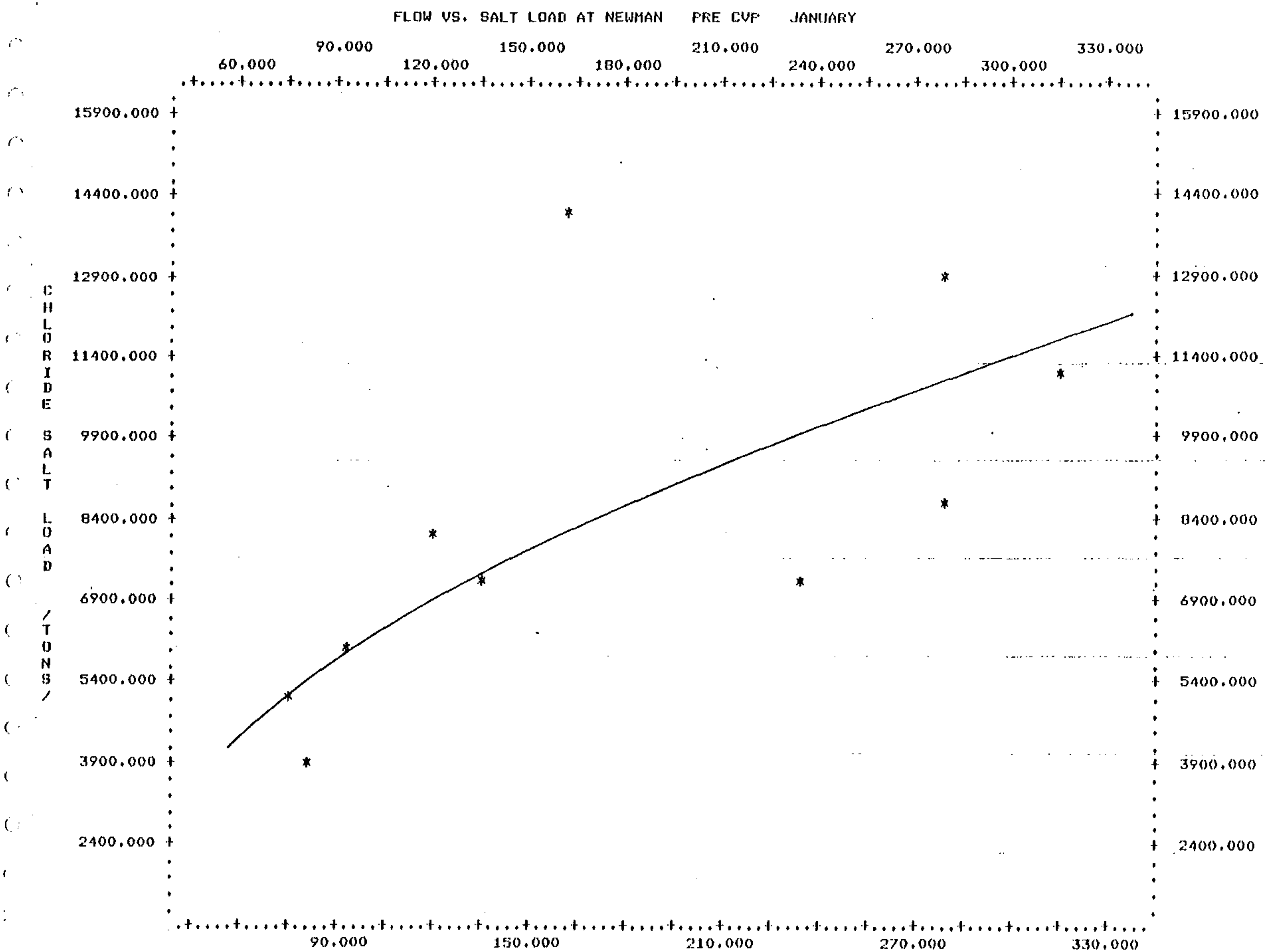

FLOW VS. SALT LOAD AT GRAYSON PRE CVP JULY
0.000
75.000
150.000
225.000
300.000
375.000
450.000
525.000
600.000
675.000
22000.000
20000.000
18000.000
16000.000
14000.000
12000.000
10000.000
8000.000
6000.000
4000.000
2000.000
CHLORIDE SALT LOAD /TONS/

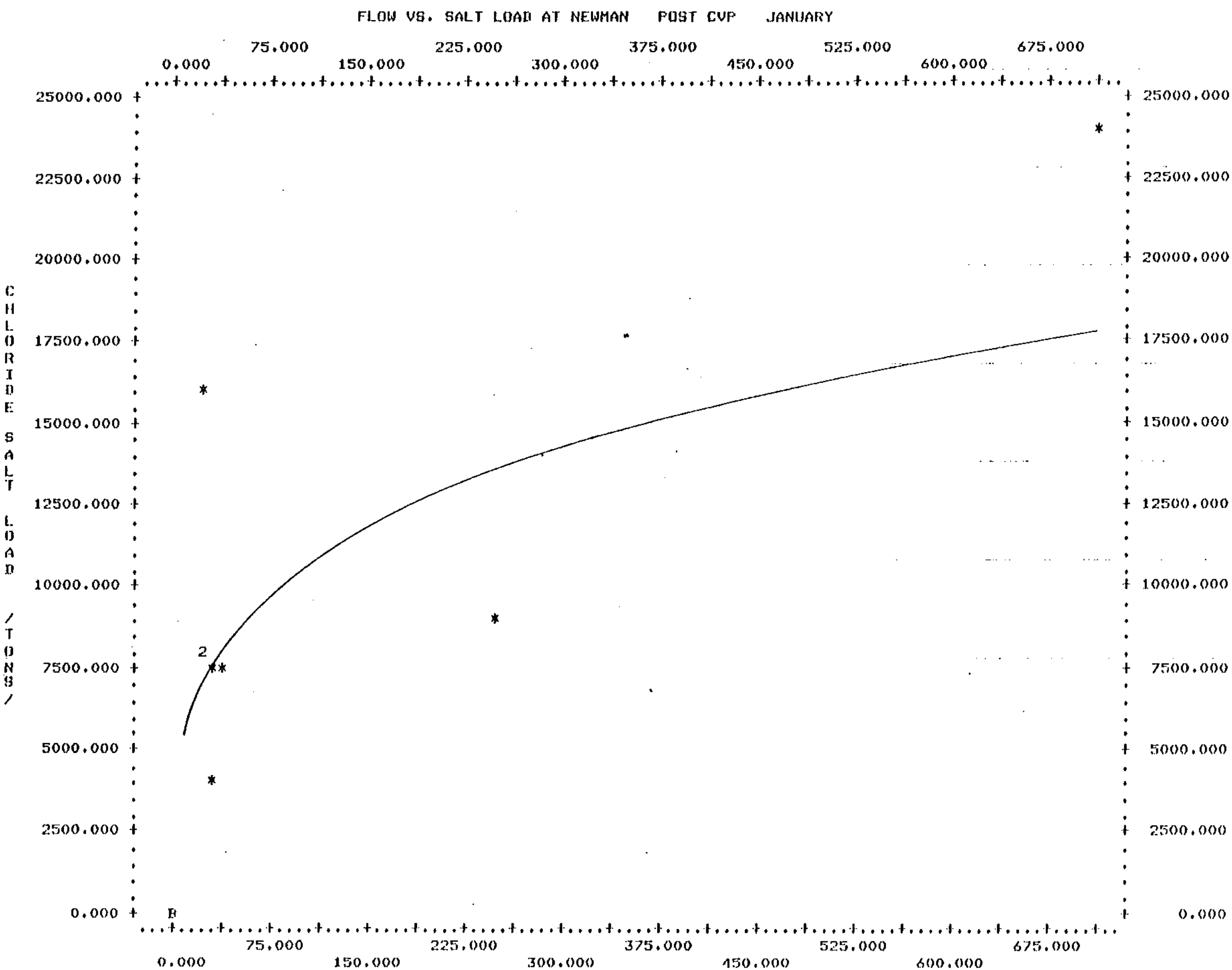
FLOW VS. SALT LOAD AT GRAYSON POST CVP JULY



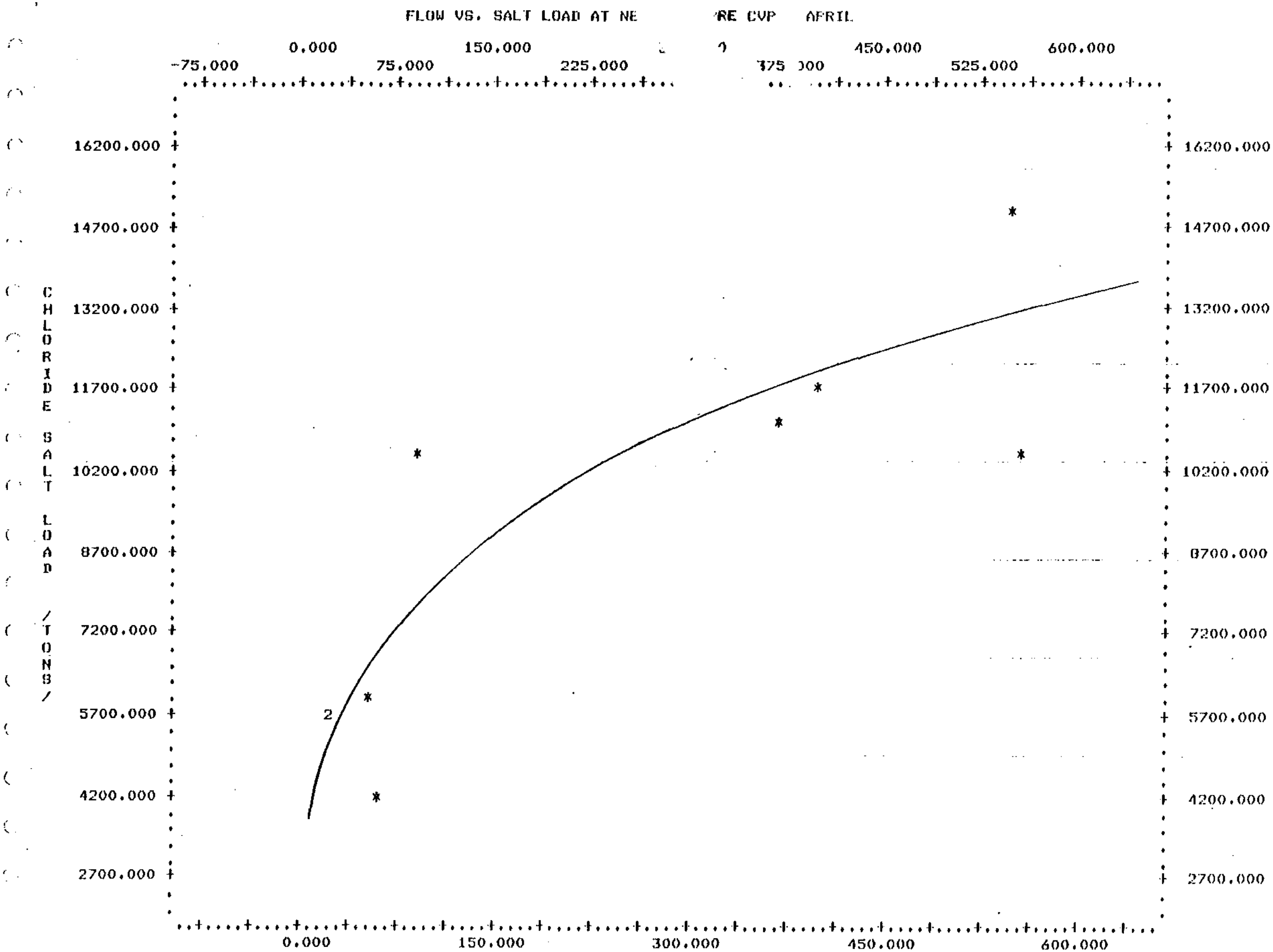

FLOW VS. SALT LOAD AT NEWMAN PRE CVP OCTOBER
8.000
12.000
16.000
20.000
24.000
28.000
32.000
36.000
40.000
44.000
48.000
CHLORIDE SALT LOAD /TONS/
4400.000
4150.000
3900.000
3650.000
3400.000
3150.000
2900.000
2650.000
2400.000
2150.000


FLOW VS. SALT LOAD AT NEWMAN POST CV
3.000
6.000
9.000
12.000
15.000
18.000
21.000
24.000
27.000
30.000
CHLORIDE SALT LOAD /TONS/
7650.000
6900.000
6150.000
5400.000
4650.000
3900.000
3150.000
2400.000
1650.000
900.000

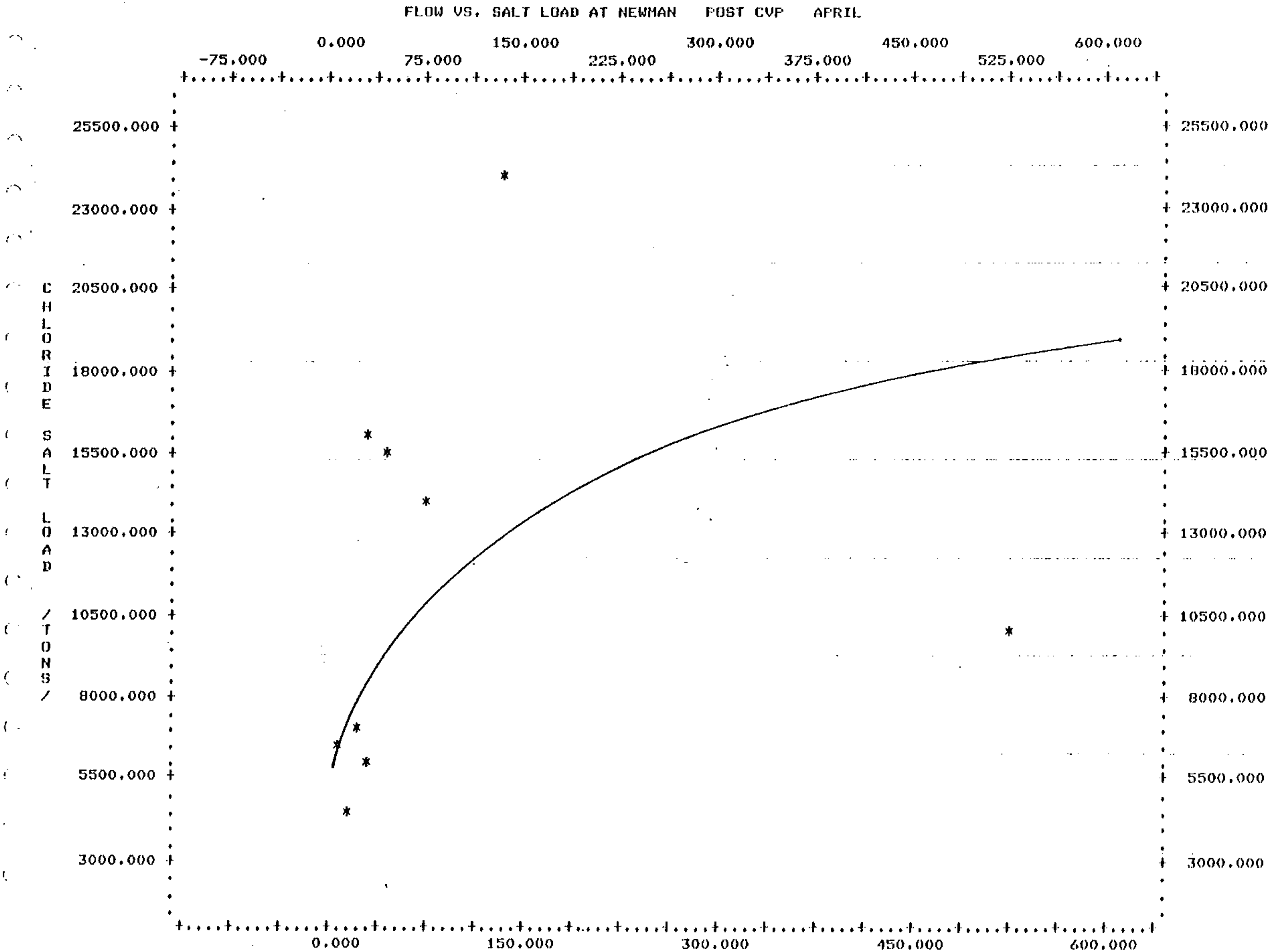

FLOW VS. SALT LOAD AT NEWMAN PRE CVP JANUARY
60,000
90,000
120,000
150,000
180,000
210,000
240,000
270,000
300,000
330,000
15900.000
14400.000
12900.000
11400.000
9900.000
8400.000
6900.000
5400.000
3900.000
2400.000
CHLORIDE SALT LOAD /TONS/

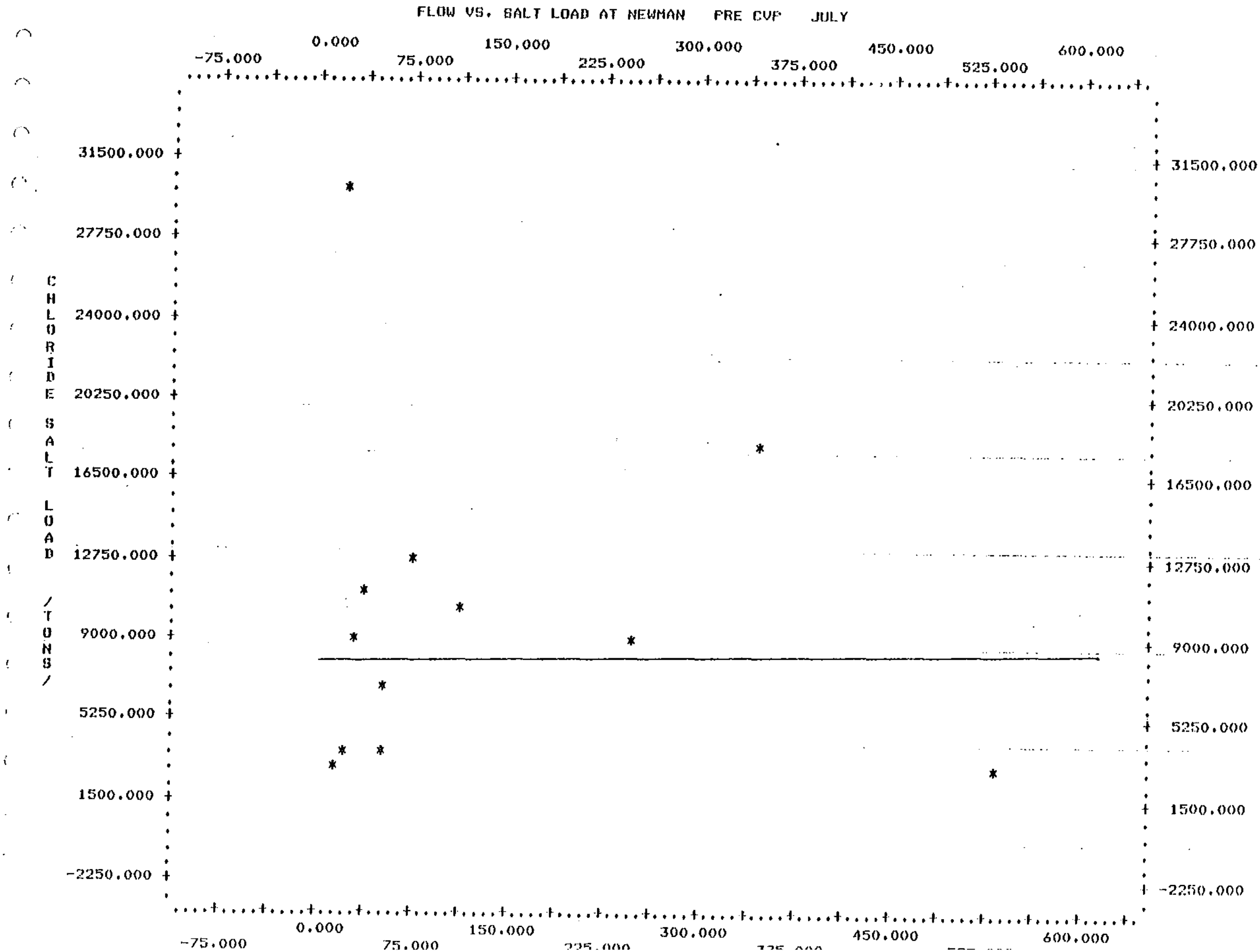


FLOW VS. SALT LOAD AT NEWMAN POST CVP JANUARY
0.000
75.000
150.000
225.000
300.000
375.000
450.000
525.000
600.000
675.000
25000.000
22500.000
20000.000
17500.000
15000.000
12500.000
10000.000
7500.000
5000.000
2500.000
0.000
CHLORIDE SALT LOAD /TONS/
2
B

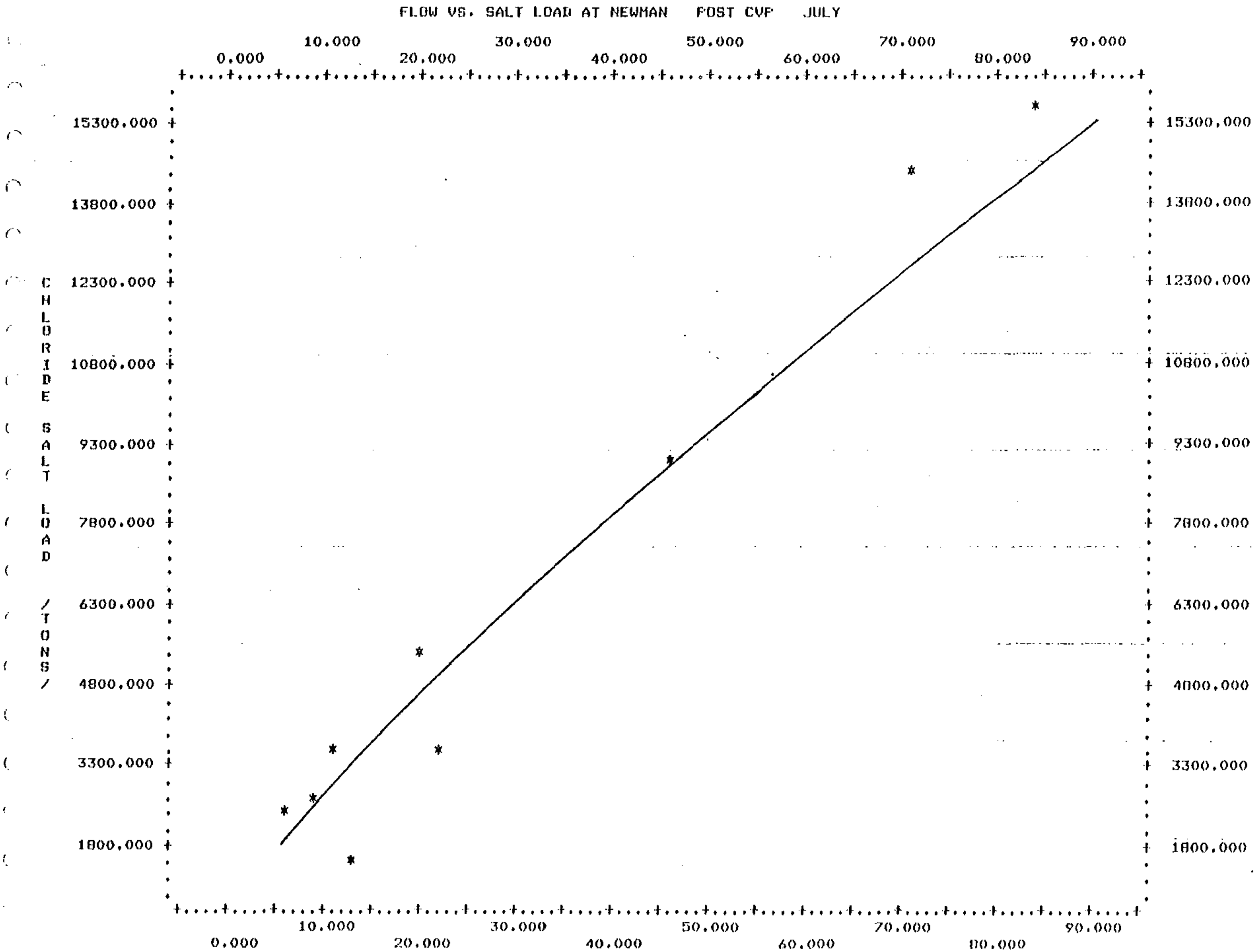


FLOW VS. SALT LOAD AT NE RE CVP APRIL
CHLORIDE SALT LOAD /TONS/
-75.000
0.000
75.000
150.000
225.000
300.000
375.000
450.000
525.000
600.000
16200.000
14700.000
13200.000
11700.000
10200.000
8700.000
7200.000
5700.000
4200.000
2700.000
2


FLOW VS. SALT LOAD AT NEWMAN POST CVP APRIL
0.000
150.000
300.000
450.000
600.000
-75.000
75.000
225.000
375.000
525.000
25500.000
23000.000
20500.000
18000.000
15500.000
13000.000
10500.000
8000.000
5500.000
3000.000
CHLORIDE SALT LOAD /TONS/


FLOW VS. SALT LOAD AT NEWMAN PRE CVP JULY
CHLORIDE SALT LOAD /TONS/
-75.000
0.000
75.000
150.000
225.000
300.000
375.000
450.000
525.000
600.000
31500.000
27750.000
24000.000
20250.000
16500.000
12750.000
9000.000
5250.000
1500.000
-2250.000

040827



FLOW VS. SALT LOAD AT NEWMAN POST CVP JULY
0.000
10.000
20.000
30.000
40.000
50.000
60.000
70.000
80.000
90.000
15300.000
13800.000
12300.000
10800.000
9300.000
7800.000
6300.000
4800.000
3300.000
1800.000
CHLORIDE SALT LOAD /TONS/

040828

APPENDIX 3

SALT (CHLORIDE) BALANCES BY

REPRESENTATIVE MONTHS

80/05/12. 13.40.05. OCTOBER 39 AF UNIMPAIRED AT VERNALIS

DRY YEAR

FLOW (KAF) PRE	POST	STATION	CHLORIDES PRE (TONS)	(PCT)	POST (TONS)	(PCT)
24.	20.	NEWMAN	3040.	30.	4170.	29.
16.	16.	OTHF	1960.		2820.	
39.	36.	N	5000.	49.	6990.	49.
55.	51.	LUMNE	3830.	37.	5050.	35.
5.	9	OTHER	1210.		2540.	
99.		MAZE ROAD	10040.	98.	14570.	102.
14.	17.	STANISLAUS	260.	3.	200.	1.
-3.	7.	OTHER	-40.		-470.	
110.	120.	VERNALIS	10260.	100.	14290.	100.
		TOT. OTHERS	3130.	31.	4890.	34.
		NMN. + OTH.	6170.	60.	9060.	63.

QUALITY PPM (CL) / (TDS)

PRE PPM = 69. / 324.
POST PPM = 88. / 383.
DEGRADATION = 19. / 59.

80/05/12. 13.50.38. JANUARY 110.5 KAF UNIMPAIRED AT VERNALIS

DRY YEAR

FLOW (KAF) PRE	FLOW (KAF) POST	STATION	CHLORIDES PRE (TONS)	CHLORIDES PRE (PCT)	CHLORIDES POST (TONS)	CHLORIDES POST (PCT)
51.	37.	NEWMA	4240.	48.	8380.	80.
7.	9.	OT	2690.		1310.	
58.	46.	YSON	6930.	78.	9690.	93.
54.	55.	TUOLUMNE	3490.	39.	4740.	45.
9.	4.	OTHER	580.		-330.	
121.	106.	MAZE ROAD	11010.	123.	14100.	135.
27.	24.	STANISLAUS	130.	1.	170.	2.
2.	3.	OTHER	-2220.		-3850.	
150.	133.	VERNALIS	8920.	100.	10420.	100.
		TOT. OTHERS	1050.	12.	-2870.	-27.
		NMN. + OTH.	5290.	59.	5510.	53.

QUALITY PPM (CL) / (TDS)

PRE PPM = 44. / 221.
POST PPM = 58. / 291.
DEGRADATION = 14. / 71.

80/05/12.   14.01.24.   APRIL   601.[illegible]   AF UNIMPAIRED AT VERNALIS

DRY YEAR

FLOW (KAF) PRE	FLOW (KAF) POST	STATION	CHLORIDES PRE (TONS)	CHLORIDES PRE (PCT)	CHLORIDES POST (TONS)	CHLORIDES POST (PCT)
23.	18.	NEWMAN	5210.	110.	7830.	130.
5.	4.	OTHER	410.		-580.	
28.	22.	GRAYSL	5630.	119.	7250.	120.
26.	21.	MNE	3410.	72.	4420.	73.
-9.	-7.	HER	-190.		-1340.	
43.	3[illegible]	MAZE ROAD	8830.	186.	10310.	171.
41.	[illegible]4.	STANISLAUS	210.	4.	150.	2.
1.	-6.	OTHER	-4300.		-4430.	
86.	44.	VERNALIS	4740.	100.	6030.	100.
		TOT. OTHERS	-4080.	-86.	-6350.	-105.
		NMN. + OTH.	1130.	24.	1480.	25.

QUALITY PPM   (CL) / (TDS)

PRE PPM = 41. / 208.
POST PPM = 101. / 423.
DEGRADATION = 60. / 215.

040832

80/05/12. 14.12.25. JULY 101.4 KAF UNIMPAIRED AT VERNALIS

DRY YEAR

FLOW (KAF) PRE	FLOW (KAF) POST	STATION	CHLORIDES PRE (TONS)	CHLORIDES PRE (PCT)	CHLORIDES POST (TONS)	CHLORIDES POST (PCT)
19.	10.	NEWM	7610.	117.	2670.	59.
4.	2.	[illegible]	-2540.		490.	
23.	12.	,YSON	5070.	78.	3160.	70.
18.	12.	(UOLUMNE	3690.	57.	3810.	84.
-5.	-[illegible]	OTHER	-2800.		-1020.	
36.	[illegible].	MAZE ROAD	5950.	91.	5940.	131.
12.	6.	STANISLAUS	190.	3.	80.	2.
-1.	-6.	OTHER	390.		-1480.	
46.	18.	VERNALIS	6530.	100.	4540.	100.
		TOT. OTHERS	-4950.	-75.	-2010.	-44.
		NMN. + OTH.	2660.	41.	660.	15.

QUALITY PPM (CL) / (TDS)

PRE PPM = 104. / 432.
POST PPM = 185. / 681.
DEGRADATION = 81. / 249.

80/05/12. 13.42.33. OCTOBER 49.3 KAF UNIMPAIRED AT VERNALIS

BELOW NORMAL YEAR

FLOW (KAF) PRE	FLOW (KAF) POST	STATION	CHLORIDES PRE (TONS)	CHLORIDES PRE (PCT)	CHLORIDES POST (TONS)	CHLORIDES POST (PCT)
20.	17.	NEF	2980.	31.	3920.	30.
14.	15.	ER	1470.		2780.	
34.	32.	GRAYSON	4450.	46.	6700.	52.
53.	46	TUOLUMNE	3820.	40.	4930.	38.
5.	7.	OTHER	1420.		2580.	
92.	85.	MAZE ROAD	9690.	100.	14220.	110.
13.	16.	STANISLAUS	220.	2.	190.	1.
-3.	3.	OTHER	-260.		-1480.	
101.	104.	VERNALIS	9650.	100.	12920.	100.
		TOT. OTHERS	2630.	27.	3880.	30.
		NMN. + OTH.	5610.	58.	7800.	60.

QUALITY PPM (CL) / (TDS)

PRE PPM = 70. / 328.
POST PPM = 91. / 392.
DEGRADATION = 21. / 64.

* NOTE:
PCT COLUMN IS PERCENT OF VERNALIS.

040833

80/05/12.   13.53.13.   JANUARY   167.3 KAF UNIMPAIRED AT VERNALIS

BELOW NORMAL YEAR

FLOW (KAF) PRE	FLOW (KAF) POST	STATION	CHLORIDES PRE (TONS)	CHLORIDES PRE (PCT)	CHLORIDES POST (TONS)	CHLORIDES POST (PCT)
36.	60.	NEWMAN	3500.	45.	9430.	74.
6.	12.	OTHER	2880.		750.	
42.	71.	GRAYSON	6370.	83.	10190.	80.
46.	85.	TUOLUMNE	3400.	44.	4950.	39.
7.	0.	OTHER	950.		100.	
95.	157.	MAZE ROAD	10720.	139.	15230.	120.
21.	40.	STANISLAUS	120.	2.	230.	2.
2.	5.	OTHER	-3110.		-2730.	
119.	202.	VERNALIS	7720.	100.	12730.	100.
		TOT. OTHERS	720.	9.	-1880.	-14.
		NMN. + OTH.	4220.	55.	7550.	59.

QUALITY PPM   (CL) / (TDS)

PRE PPM   =   48. /   237.
POST PPM   =   46. /   254.
DEGRADATION =   -2. /   17.

040834 * NOTE:
PCT COLUMN IS PERCENT OF VERNALIS

80/05/12. 14.03.58. APRIL 794.9 KAF UNIMPAIRED AT VERNALIS

BELOW NORMAL YEAR

FLOW (KAF) PRE	POST	STATION	CHLORIDES PRE (TONS)	PRE (PCT)	POST (TONS)	POST (PCT)
32.	52.	NEWMAN	5760.	104.	10230.	92.
6.	11.	OTHER	250.		-520.	
38.	63.	GRAYSON	6000.	109.	9710.	88.
33.	61.	TUOLUMNE	3460.	63.	4770.	43.
-11.	-8.	OTHER	-20.		1000.	
60.	115.	MAZE ROAD	9440.	171.	15490.	140.
50.	44.	STANISLAUS	230.	4.	270.	2.
3.	-8.	OTHER	-4130.		-4670.	
113.	150.	VERNALIS	5520.	100.	11080.	100.
		TOT. OTHERS	-3900.	-70.	-4190.	-37.
		NMN. + OTH.	1860.	34.	6040.	55.

QUALITY PPM (CL) / (TDS)

PRE PPM = 36. / 187.
POST PPM = 54. / 279.
DEGRADATION = 18. / 91.

040836

80/05/12. 14.15.13. JULY 224.9 KAF UNIMPAIRED AT VERNALIS

BELOW NORMAL YEAR

FLOW (KAF) PRE	POST	STATION	CHLORIDES PRE (TONS)	PRE (PCT)	POST (TONS)	POST (PCT)
27.	19.	.WMAN	7690.	96.	4370.	57.
7.	5.	OTHER	-1890.		1060.	
34.	24.	GRAYSON	5790.	72.	5430.	71.
23.	23.	TUOLUMNE	3720.	46.	4260.	55.
-5.	-5.	OTHER	-2090.		-480.	
51.	42.	MAZE ROAD	7420.	93.	9210.	120.
14.	12.	STANISLAUS	210.	3.	140.	2.
0.	-8.	OTHER	390.		-1640.	
64.	46.	VERNALIS	8020.	100.	7700.	100.
		TOT. OTHERS	-3590.	-44.	-1060.	-13.
		NMN. + OTH.	4100.	51.	3310.	43.

QUALITY PPM (CL) / (TDS)

PRE PPM = 92. / 396.
POST PPM = 123. / 491.
DEGRADATION = 31. / 95.

80/05/12.   13.45.43.   OCTOBER   42.4 KAF UNIMPAIRED AT VERNALIS

ABOVE NORMAL YEAR

FLOW (KAF) PRE	FLOW (KAF) POST	STATION	CHLORIDES PRE (TONS)	CHLORIDES PRE (PCT)	CHLORIDES POST (TONS)	CHLORIDES POST (PCT)
19.	12.	NEWMAN	2960.	31.	3190.	34.
13.	11.	OTHER	1310.		2650.	
33.	23.	GRAYSON	4270.	45.	5840.	63.
52.	32.	TUOLUMNE	3820.	40.	4580.	49.
4.	2.	OTHER	1480.		2700.	
89.	57.	MAZE ROAD	9570.	101.	13120.	141.
13.	11.	STANISLAUS	210.	2.	160.	2.
-4.	-3.	OTHER	-330.		-3990.	
98.	65.	VERNALIS	9440.	100.	9280.	100.
		TOT. OTHERS	2460.	26.	1360.	15.
		NMN. + OTH.	5420.	57.	4550.	49.

QUALITY PPM   (CL) / (TDS)

PRE PPM   =   71. /   331.
POST PPM   = 105. /   435.
DEGRADATION =   34. /   104.

80/05/12. 13.56.03. JANUARY 352.5 KAF UNIMPAIRED AT VERNALIS

ABOVE NORMAL YEAR

FLOW (KAF) PRE	FLOW (KAF) POST	STATION	CHLORIDES PRE (TONS)	CHLORIDES PRE (PCT)	CHLORIDES POST (TONS)	CHLORIDES POST (PCT)
130.	80.	NEWMAN	7130.	54.	10160.	70.
11.	14.	OTHER	1560.		350.	
141.	94.	GRAYSON	8700.	66.	10510.	73.
81.	111.	TUOLUMNE	3750.	29.	5080.	35.
6.	-4.	OTHER	-630.		400.	
229.	201.	MAZE ROAD	11810.	90.	16000.	111.
51.	56.	STANISLAUS	180.	1.	270.	2.
0.	6.	OTHER	1140.		-1820.	
279.	263.	VERNALIS	13130.	100.	14450.	100.
		TOT. OTHERS	2070.	16.	-1070.	-7.
		NMN. + OTH.	9200.	70.	9090.	63.

QUALITY PPM (CL) / (TDS)

PRE PPM = 35. / 183.
POST PPM = 40. / 236.
DEGRADATION = 5. / 53.

80/05/12.   14.06.23.   APRIL   1055.7 KAF UNIMPAIRED AT VERNALIS

ABOVE NORMAL YEAR

FLOW (KAF)		STATION	CHLORIDES			
PRE	POST		PRE		POST	
			(TONS)	(PCT)	(TONS)	(PCT)
366.	84.	NEWMAN	11730.	70.	11570.	79.
46.	17.	OTHER	-2170.		-450.	
413.	102.	GRAYSON	9550.	57.	11110.	76.
199.	98.	TUOLUMNE	3880.	23.	4950.	34.
-2.	-3.	OTHER	1730.		2610.	
609.	196.	MAZE ROAD	15160.	91.	18680.	127.
190.	74.	STANISLAUS	400.	2.	370.	3.
5.	-6.	OTHER	1100.		-4370.	
805.	264.	VERNALIS	16660.	100.	14670.	100.
		TOT. OTHERS	660.	4.	-2210.	-15.
		NMN. + OTH.	12390.	74.	9360.	64.

QUALITY PPM (CL) / (TDS)

PRE PPM = 15. / 101.
POST PPM = 41. / 239.
DEGRADATION = 26. / 138.

80/05/12. 14.17.48. JULY 425.1 KAF UNIMPAIRED AT VERNALIS

ABOVE NORMAL YEAR

FLOW (KAF) PRE	FLOW (KAF) POST	STATION	CHLORIDES PRE (TONS)	PRE (PCT)	POST (TONS)	POST (PCT)
108.	25.	NEWMA'	8000.	44.	5540.	56.
33.	9.	OTF'	1830.		1510.	
141.	34.	' SON	9830.	55.	7040.	71.
55.	31.	OLUMNE	3860.	21.	4490.	45.
3.	--	OTHER	4010.		-170.	
200.	62.	MAZE ROAD	17710.	98.	11360.	115.
28.	17.	STANISLAUS	330.	2.	170.	2.
7.	-7.	OTHER	-10.		-1620.	
235.	72.	VERNALIS	18020.	100.	9910.	100.
		TOT. OTHERS	5830.	32.	-280.	-2.
		NMN. + OTH.	13830.	77.	5260.	53.

QUALITY PPM (CL) / (TDS)

PRE PPM = 56. / 270.
POST PPM = 101. / 423.
DEGRADATION = 45. / 153.

80/05/12.   13.48.12.   OCTOBER   29.8 KAF UNIMPAIRED AT VERNALIS

WET YEAR

FLOW (KAF) PRE	FLOW (KAF) POST	STATION	CHLORIDES PRE (TONS)	CHLORIDES PRE (PCT)	CHLORIDES POST (TONS)	CHLORIDES POST (PCT)
22.	15.	NEWMAN	3020.	30.	3620.	32.
15.	13.	OTHER	1800.		2740.	
38.	28.	GRAYSON	4820.	48.	6360.	56.
54.	40.	TUOLUMNE	3830.	38.	4800.	42.
5.	5.	OTHER	1280.		2630.	
97.	73.	MAZE ROAD	9930.	99.	13790.	121.
14.	14.	STANISLAUS	240.	2.	180.	2.
-3.	0.	OTHER	-110.		-2570.	
107.	87.	VERNALIS	10060.	100.	11400.	100.
		TOT. OTHERS	2970.	30.	2800.	25.
		NMN. + OTH.	5990.	60.	6420.	56.

QUALITY PPM   (CL) / (TDS)

PRE PPM = 69. / 324.
POST PPM = 96. / 408.
DEGRADATION = 27. / 84.

80/05/12.   13.58.57.   JANUARY   695.7 KAF UNIMPAIRED AT VERNALIS

WET YEAR

FLOW (KAF) PRE	FLOW (KAF) POST	STATION	CHLORIDES PRE (TONS)	CHLORIDES PRE (PCT)	CHLORIDES POST (TONS)	CHLORIDES POST (PCT)
233.	246.	NEWMAN	9850.	59.	13480.	58.
13.	2[illegible].	OTHER	160.		-1630.	
246.	268.	GRAYSON	10010.	60.	11850.	51.
104.	310.	TUOLUMNE	3910.	23.	5630.	24.
-10.	-61.	OTHER	-1590.		1770.	
339.	516.	MAZE ROAD	12330.	74.	19250.	83.
75.	185.	STANISLAUS	220.	1.	530.	2.
-4.	13.	OTHER	4140.		3540.	
410.	714.	VERNALIS	16690.	100.	23320.	100.
		TOT. OTHERS	2710.	16.	3680.	16.
		NMN. + OTH.	12560.	75.	17160.	74.

QUALITY PPM   (CL) / (TDS)

PRE PPM = 30. / 163.
POST PPM = 24. / 187.
DEGRADATION = -6. / 24.

040842 * NOTE:
PCT COLUMN IS PERCENT OF VERNALIS.

80/05/12.   14.09.13.   APRIL   1169.0 KAF UNIMPAIRED AT VERNALIS

WET YEAR

FLOW (KAF) PRE	FLOW (KAF) POST	STATION	CHLORIDES PRE (TONS)	CHLORIDES PRE (PCT)	CHLORIDES POST (TONS)	CHLORIDES POST (PCT)
585.	267.	NEWMAN	13450.	65.	15470.	54.
67.	47.	OTHER	-3000.		-190.	
652.	314.	GRAYSON	10450.	51.	15270.	54.
281.	306.	TUOLUMNE	3960.	19.	5390.	19.
19.	73.	OTHER	2190.		8380.	
952.	693.	MAZE ROAD	16600.	81.	29040.	102.
246.	256.	STANISLAUS	450.	2.	720.	3.
-23.	51.	OTHER	3560.		-1340.	
1175.	1000.	VERNALIS	20620.	100.	28410.	100.
		TOT. OTHERS	2750.	13.	6850.	24.
		NMN. + OTH.	16200.	79.	22320.	79.

QUALITY PPM   (CL) / (TDS)

PRE PPM = 13. / 92.
POST PPM = 21. / 178.
DEGRADATION = 8. / 85.

80/05/12. 14.20.10. JULY 921.0 KAF UNIMPAIRED AT VERNALIS

WET YEAR

FLOW (KAF) PRE	FLOW (KAF) POST	STATION	CHLORIDES PRE (TONS)	CHLORIDES PRE (PCT)	CHLORIDES POST (TONS)	CHLORIDES POST (PCT)
365.	65.	NEWMAN	8280.	23.	11740.	53.
129.	40.	OTHER	7300.		4360.	
494.	105.	GRAYSON	15580.	43.	16100.	73.
119.	80.	TUOLUMNE	3980.	11.	5320.	24.
49.	29.	OTHER	18210.		720.	
662.	214.	MAZE ROAD	37780.	104.	22140.	100.
50.	51.	STANISLAUS	480.	1.	360.	2.
17.	34.	OTHER	-1780.		-360.	
730.	300.	VERNALIS	36470.	100.	22130.	100.
		TOT. OTHERS	23730.	65.	4720.	21.
		NMN. + OTH.	32010.	88.	16460.	74.

QUALITY PPM (CL) / (TDS)

PRE PPM = 37. / 192.
POST PPM = 54. / 279.
DEGRADATION = 17. / 87.

APPENDIX 4

SUMMARY OF NETWORK ANALYSES OF THE LOWER SACRAMENTO-SAN JOAQUIN DELTA

R. F. Blanks February 16, 1951

D. J. Hebert and W. B. McBirney

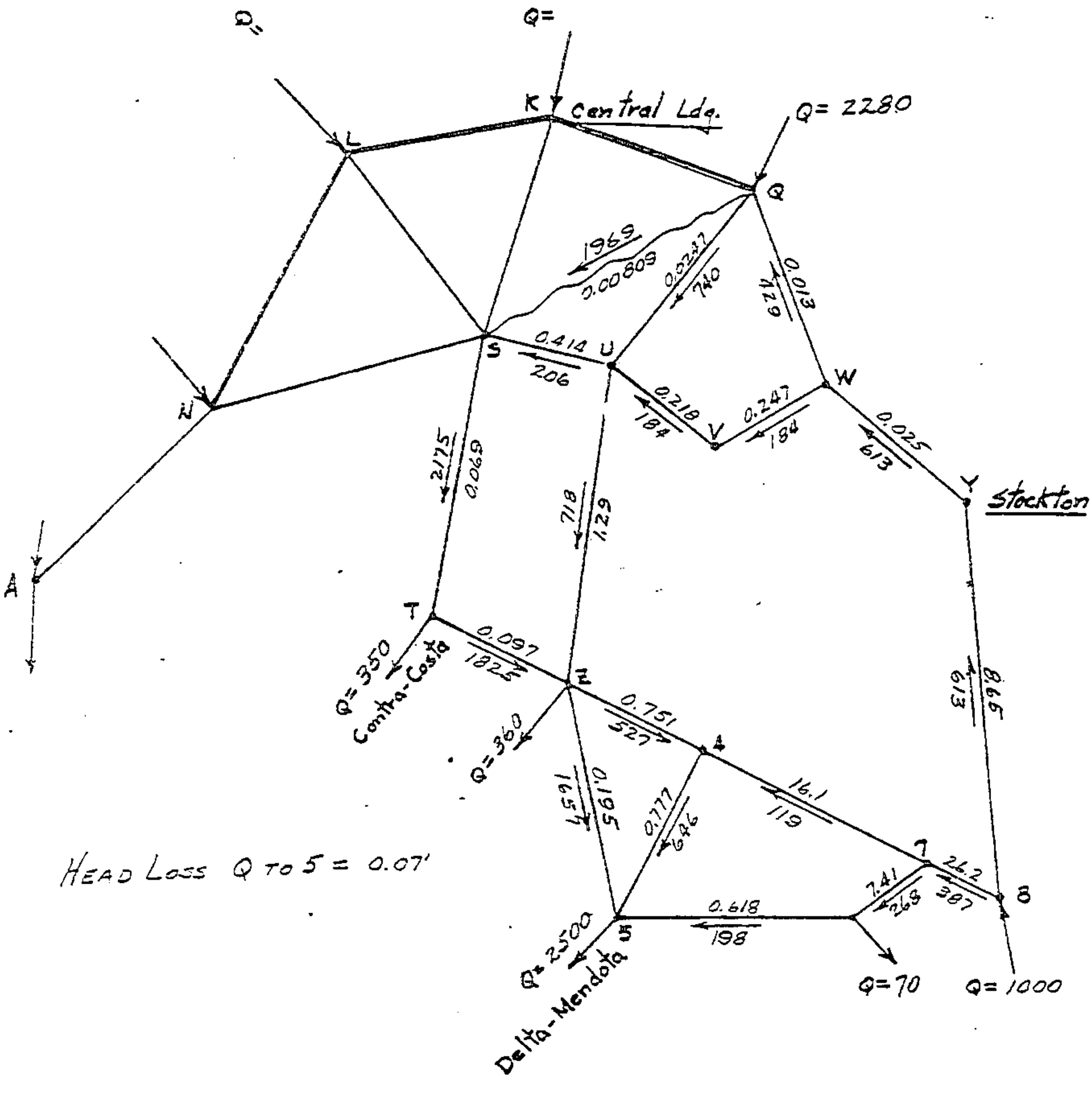
Summary of network analyses of lower Sacramento-San Joaquin Delta

1. The results of all network analyses of the lower Sacramento-San Joaquin Delta have been summarized on the six diagrams attached. Rate and direction of flow are shown on one side of a channel, and a resistance value based on channel characteristics is given on the other side. Resistances were computed from $r = \frac{L \times 10^4}{b^2 d^{10/3}}$. Three channels NL, LK, and KQ, are very large and have been assumed at constant level regardless of discharge. Computations made to test this premise show that a large increase in discharge can be accommodated by a negligible increase in slope. The wavy connection shown from S to Q represents channels NS, LS, and KS, and the resistance value used is the hydraulic equivalent of the three channels having S as a common point and terminating at N, L, K, or Q.

2. The first few schemes tried made use of resistance values which were derived from channel cross-sections as shown on available maps. It became evident they gave a division of flow which was contrary to that actually prevailing, and therefore at points such as 7 and 8, the resistances of connecting channels were arbitrarily adjusted until the division was more nearly correct. Thus, in channel (7-8) the resistance was changed to 26.2 and to 0.832 from 239.0, and in channel 8-Y, the resistance was increased to 10.0 from 8.65. Resistance in channel 6-7 was decreased to 2.0 from 7.41.

3. The results of the network analysis can be used to estimate the drop in water surface from Central Landing to Tracy Pumping Plant when the pumps are working at design capacity of 4,600 cubic feet per second. For mean tide height in the lower Delta this drop has been estimated to be 0.25 foot. Were the levels to be at mean low tide height an increase to approximately 0.34 foot may be expected. Making allowance for indeterminate factors, it is thought the maximum head loss, or draw-down, to Tracy Pumping Plant will be about 0.5 foot.

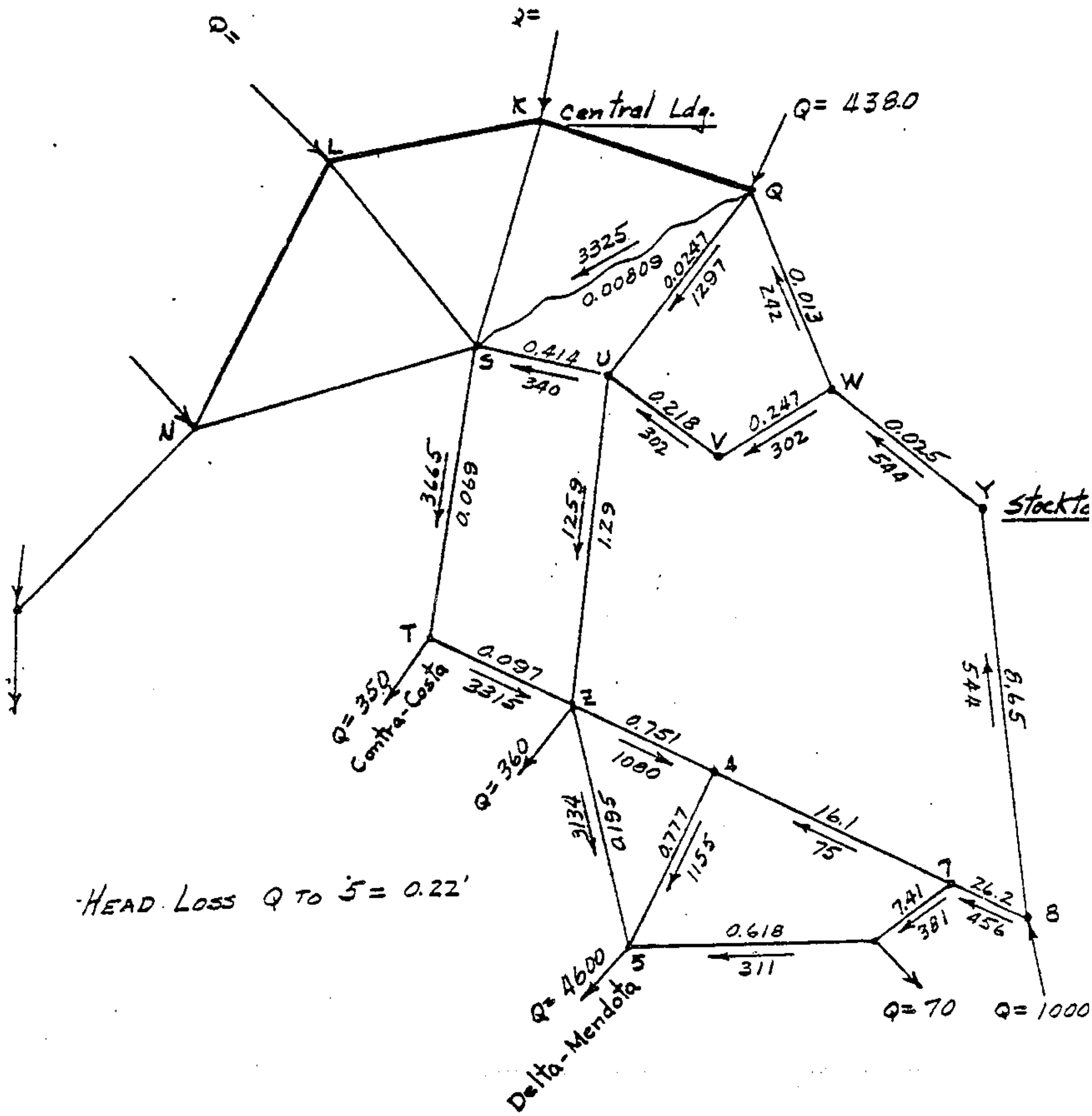
DELTA NETWORK ANALYSIS



SCHEME 7 TRIAL *FINAL*

040848

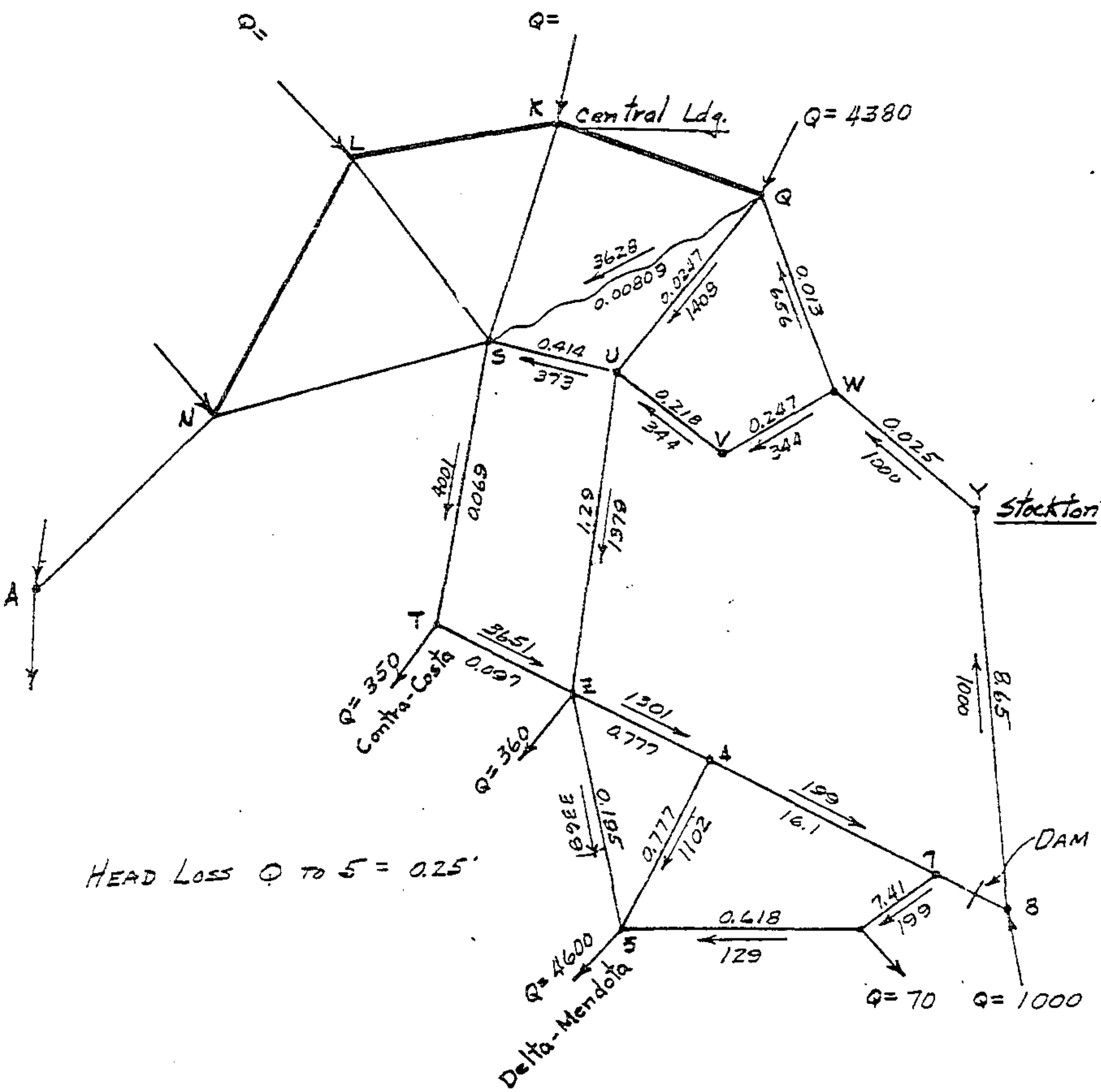
DELTA NETWORK ANALYSIS



HEAD LOSS Q TO 5 = 0.22'

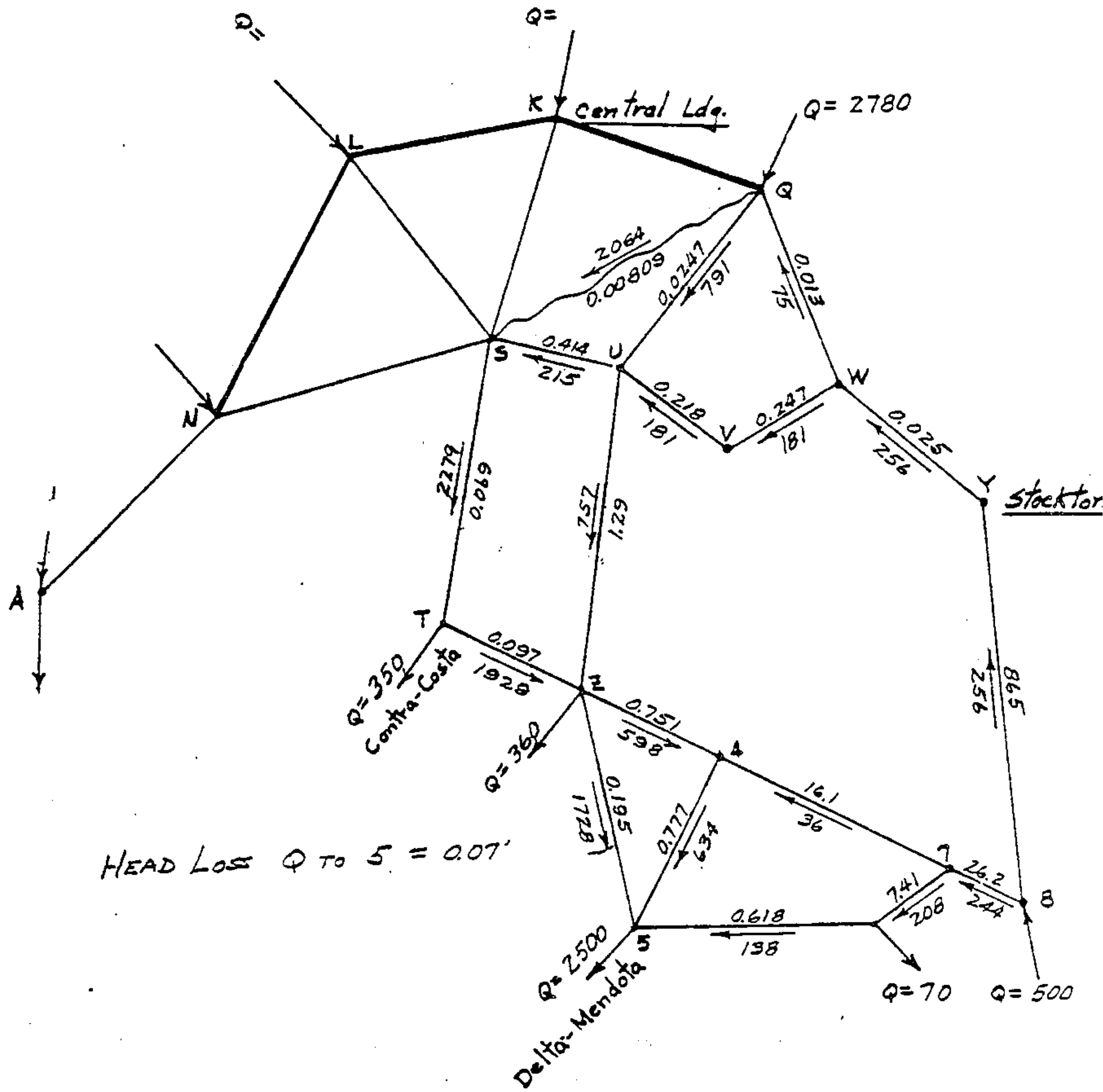
SCHEME 8 TRIAL FINAL

DELTA NETWORK ANALYSIS



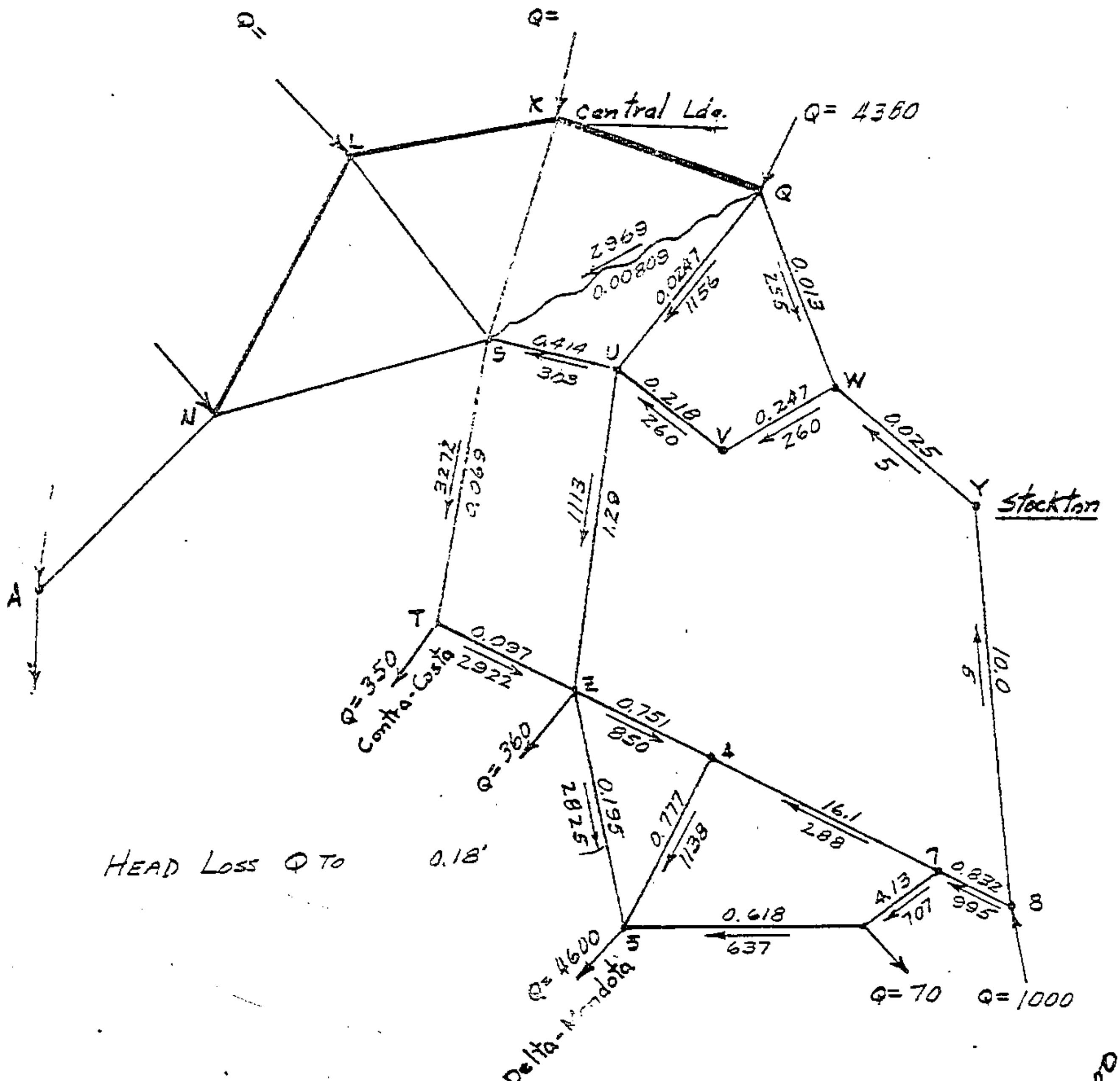
SCHEME 9 TRIAL *FINAL*

DELTA NETWORK ANALYSIS



SCHEME 11 TRIAL FINAL

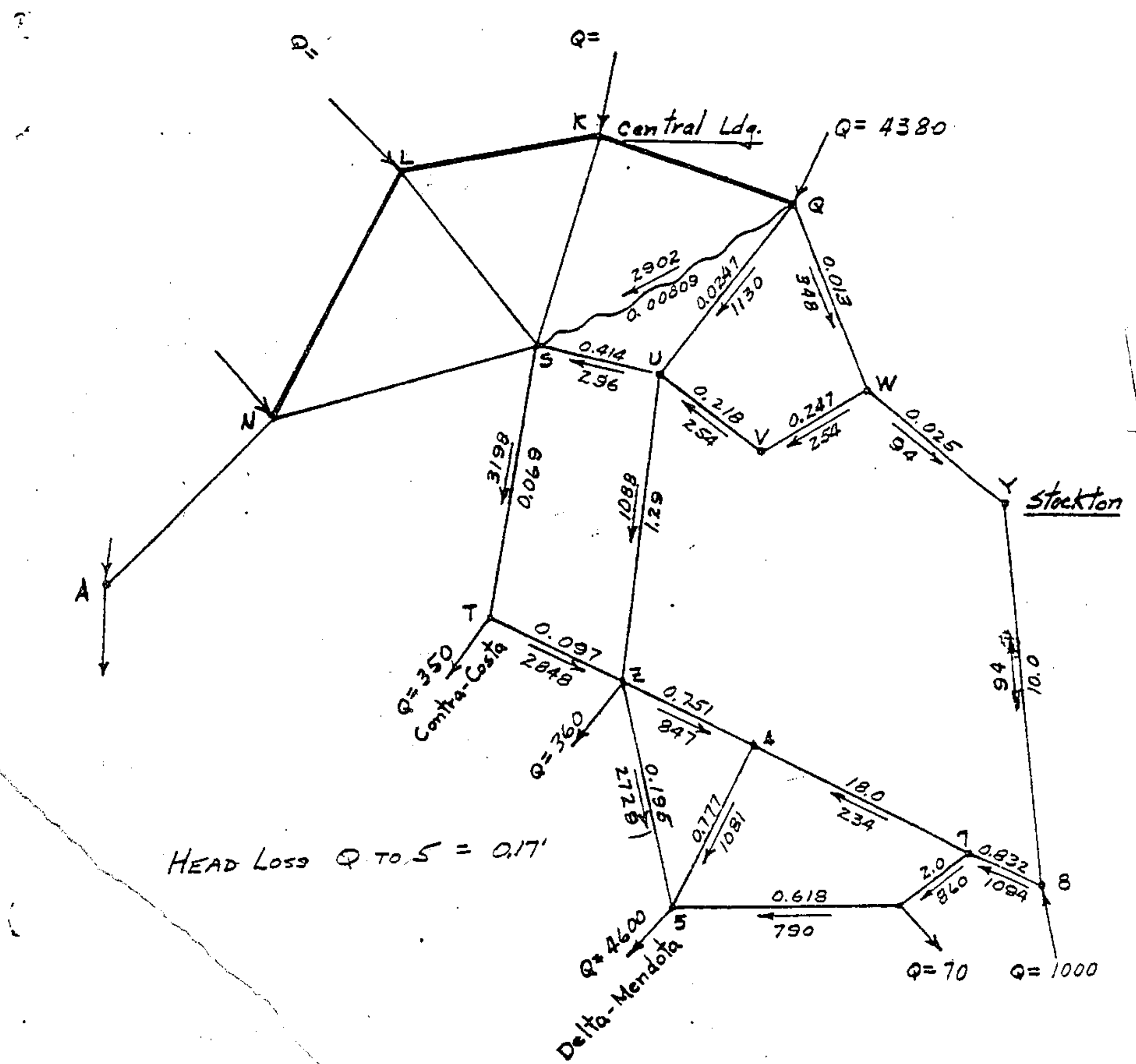
DELTA NETWORK ANALYSIS



SCHEME 13 TRIAL FINAL

B-100

DELTA NETWORK ANALYSIS



SCHEME 14 TRIAL FINAL

Exhibit “G”

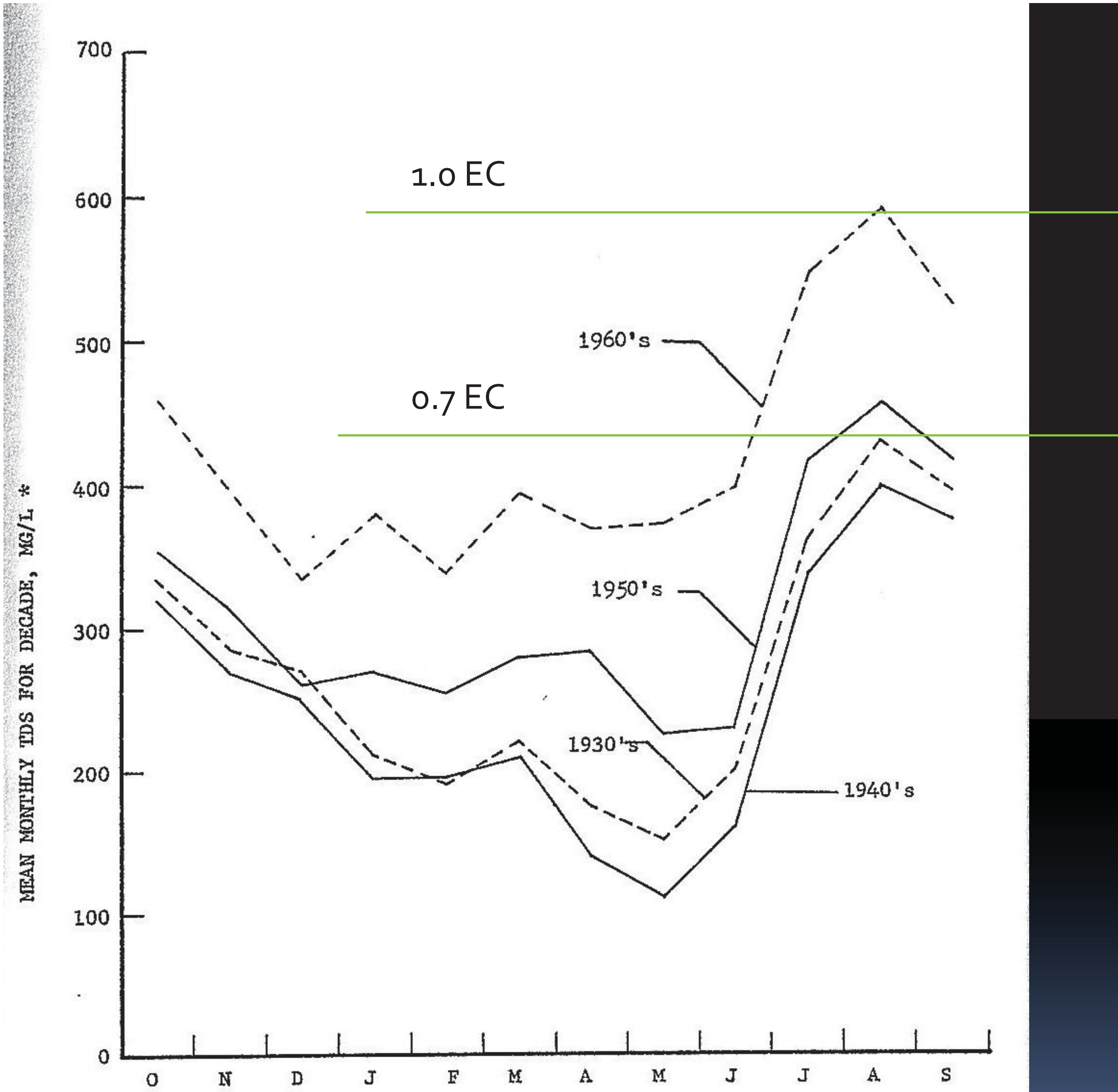


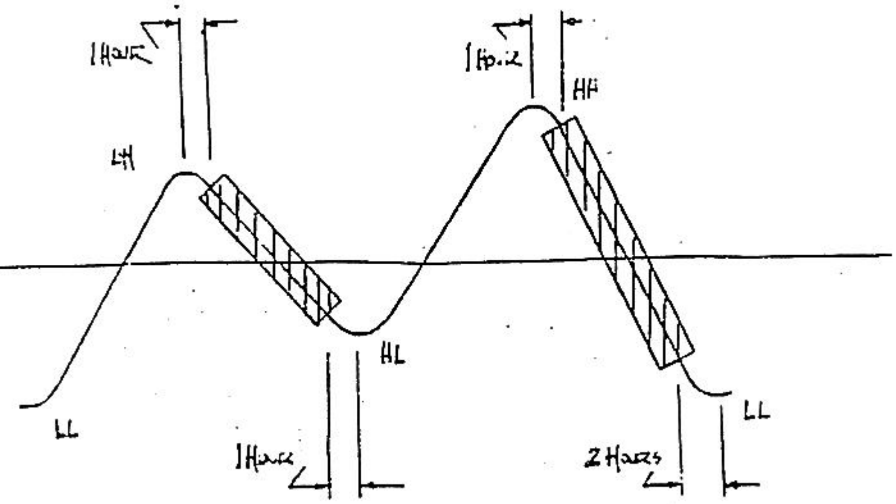
Figure VI-27 MEAN MONTHLY TDS AT VERNALIS BY DECADES 1930-1969

* Estimated by chloride load-flow regressions for 30's and 40's.

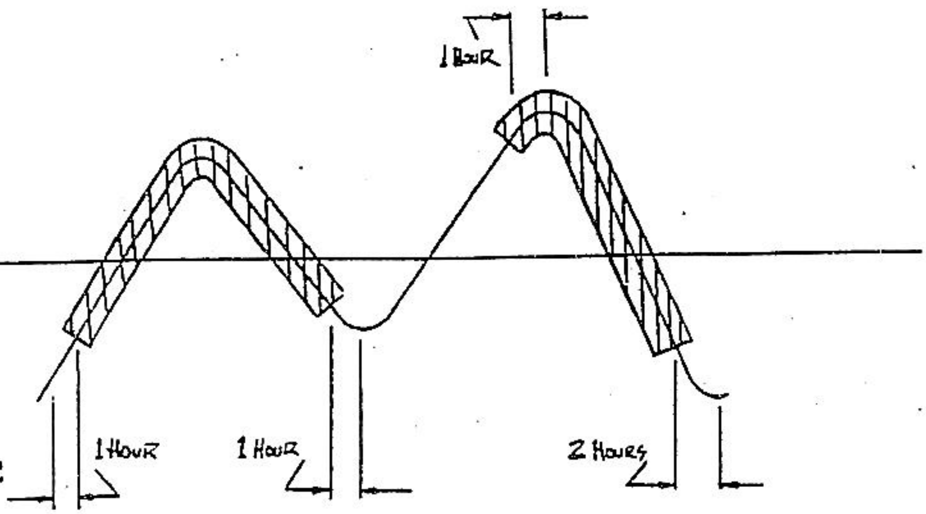
Report of the Effects of the CVP Upon the Southern Delta Water Supply Sacramento-San Joaquin River Delta, California, June 1980

Exhibit "H"

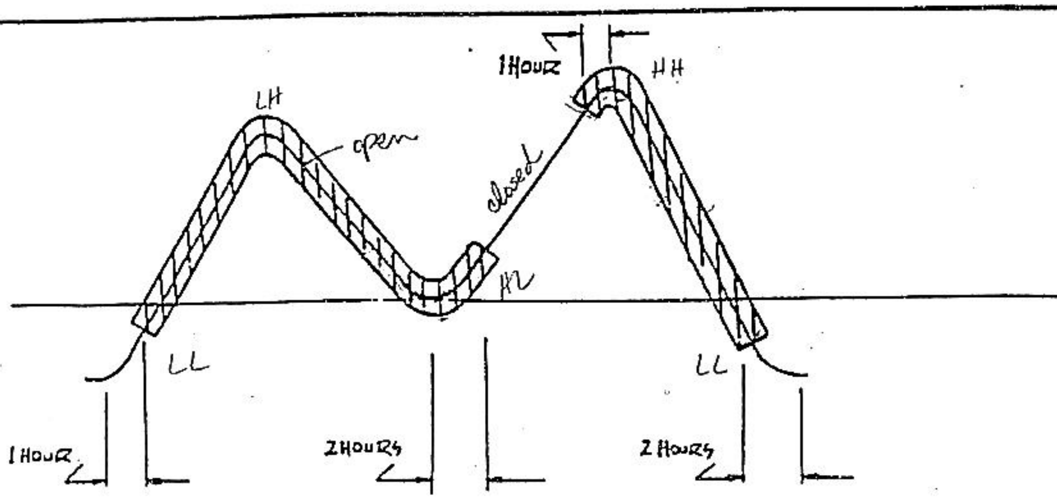
Proposed Clifton Court Gate Operation
(derived from Planning)



PRIORITY #1

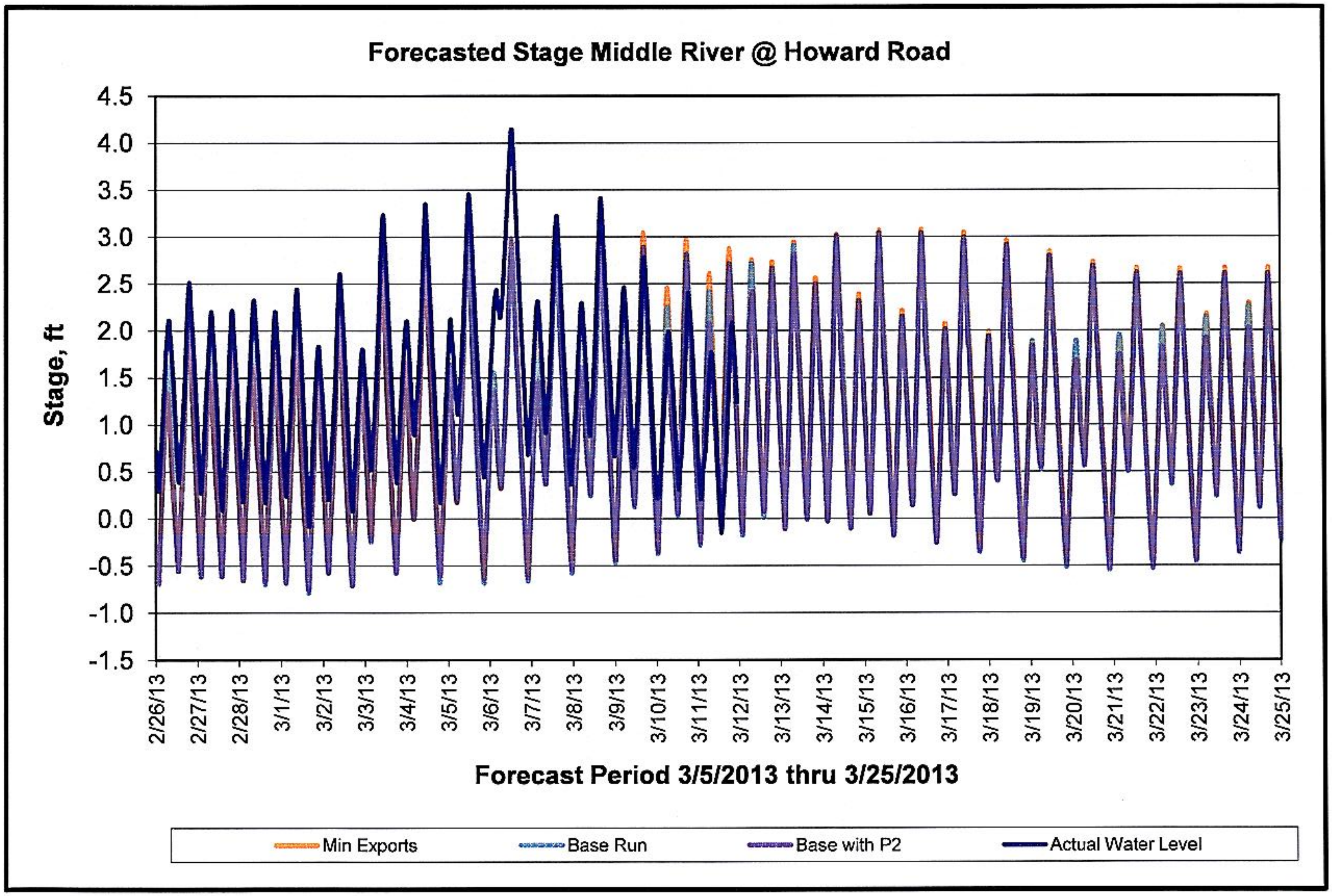


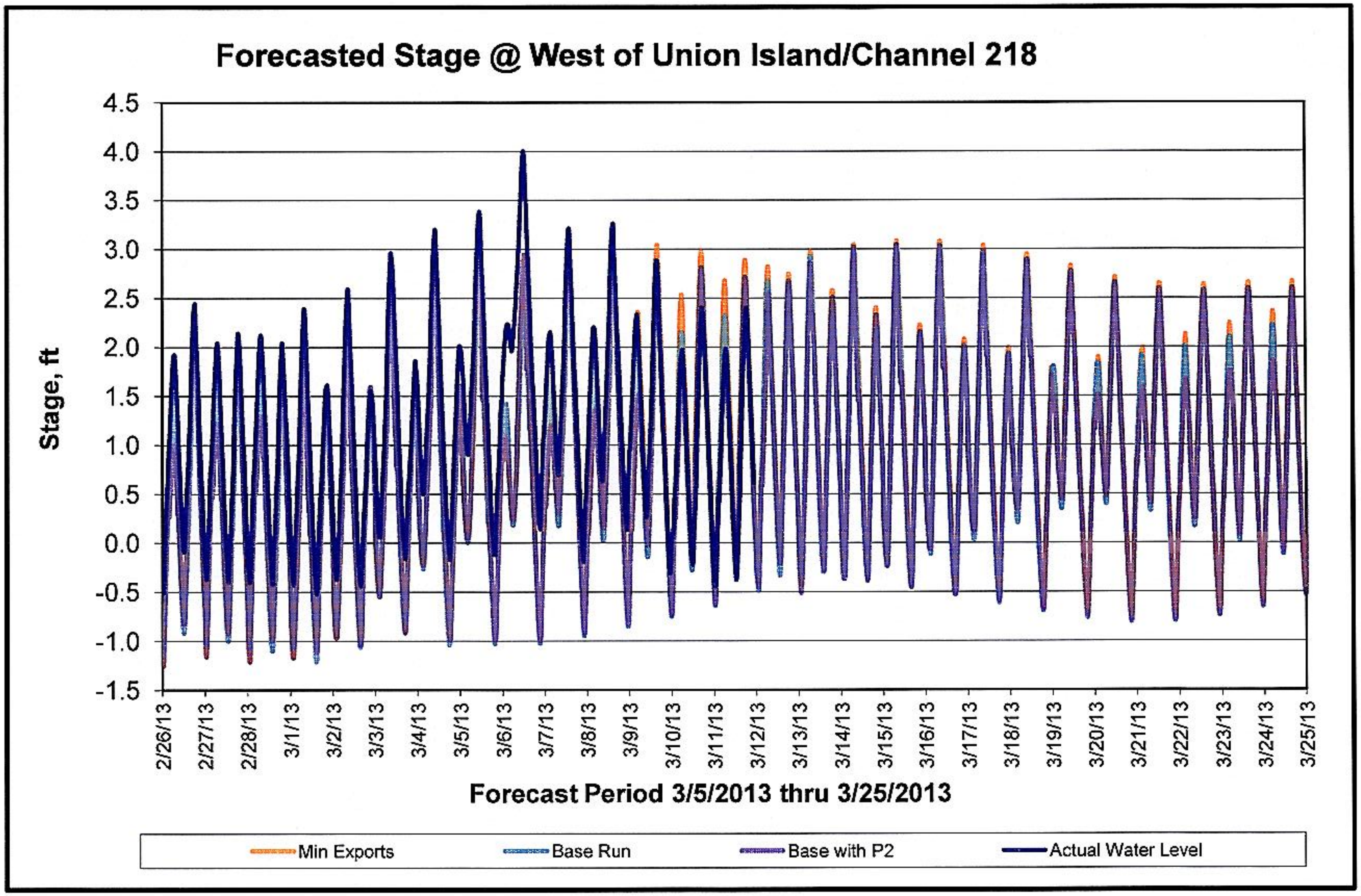
PRIORITY #2



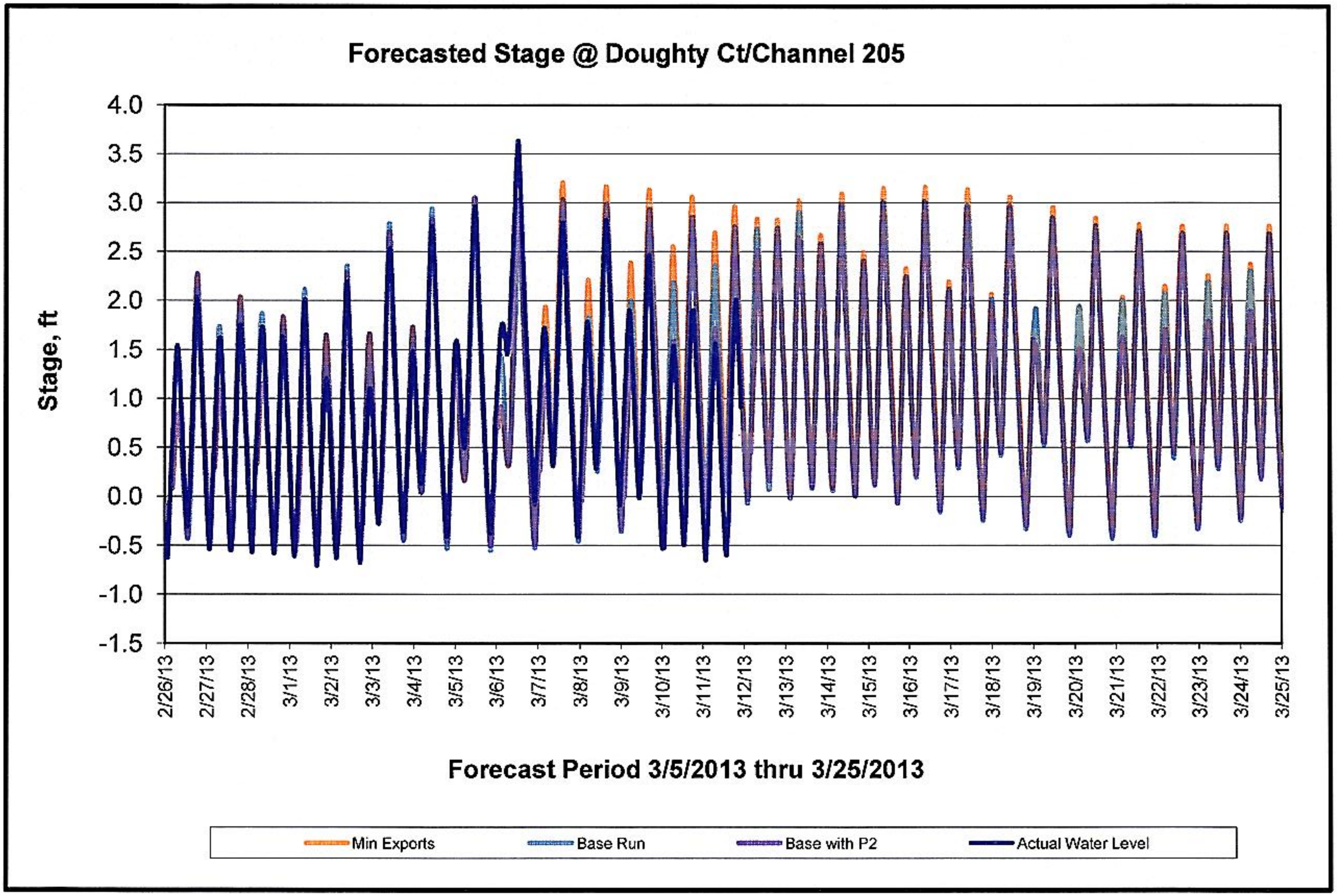
PRIORITY #3

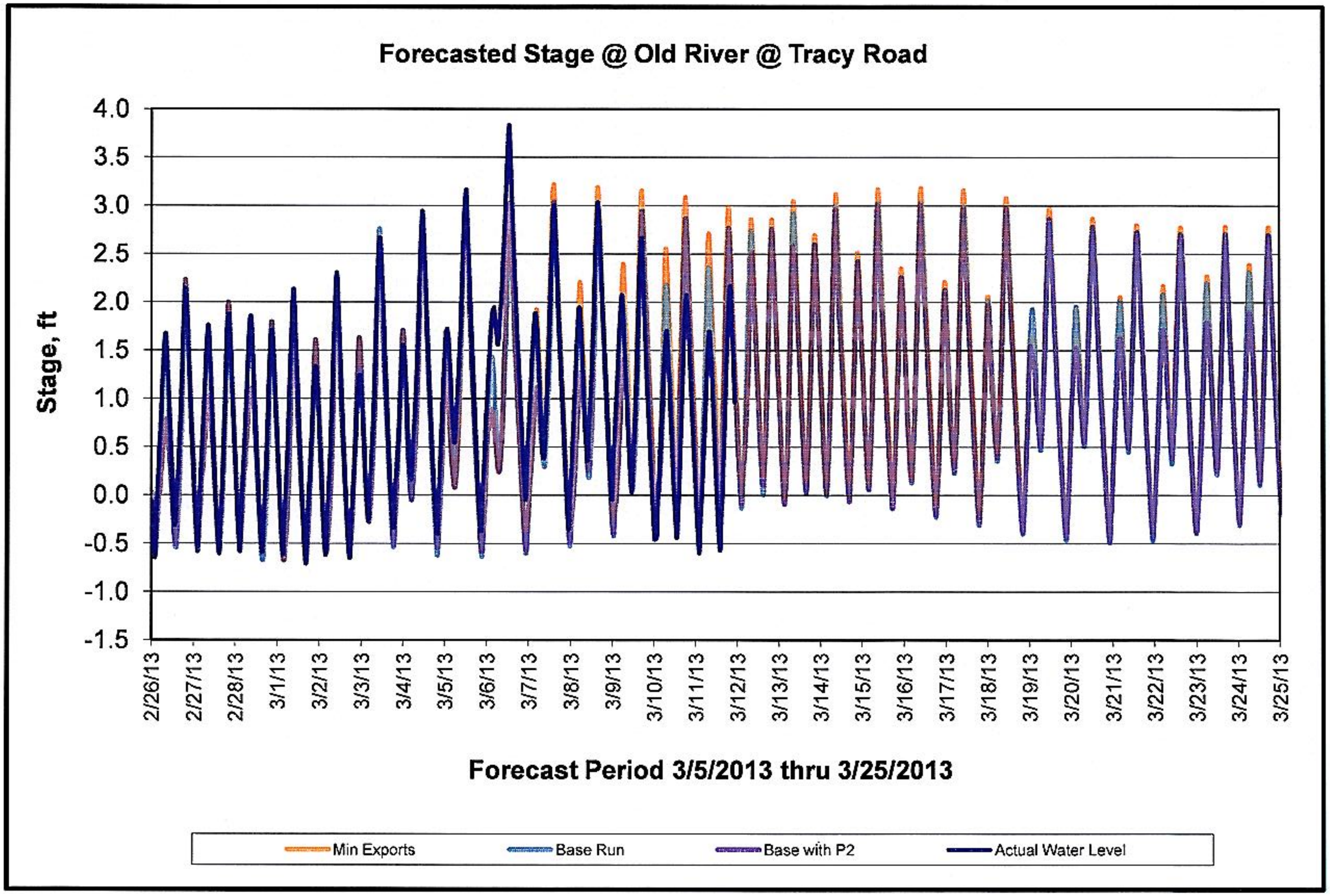
Exhibit “I”

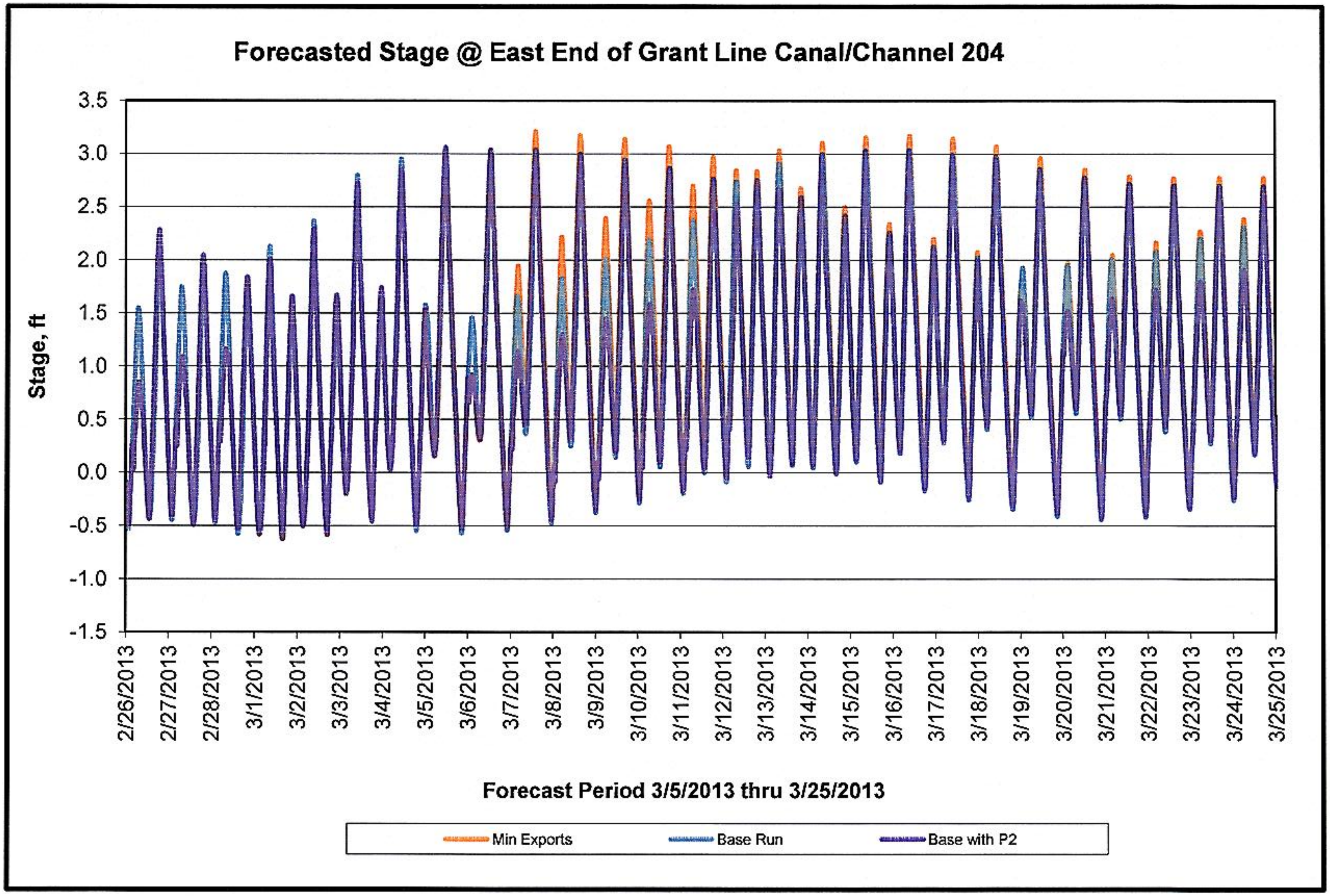

Forecasted Stage Middle River @ Howard Road
Stage, ft
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
2/26/13
2/27/13
2/28/13
3/1/13
3/2/13
3/3/13
3/4/13
3/5/13
3/6/13
3/7/13
3/8/13
3/9/13
3/10/13
3/11/13
3/12/13
3/13/13
3/14/13
3/15/13
3/16/13
3/17/13
3/18/13
3/19/13
3/20/13
3/21/13
3/22/13
3/23/13
3/24/13
3/25/13
Forecast Period 3/5/2013 thru 3/25/2013
Min Exports
Base Run
Base with P2
Actual Water Level

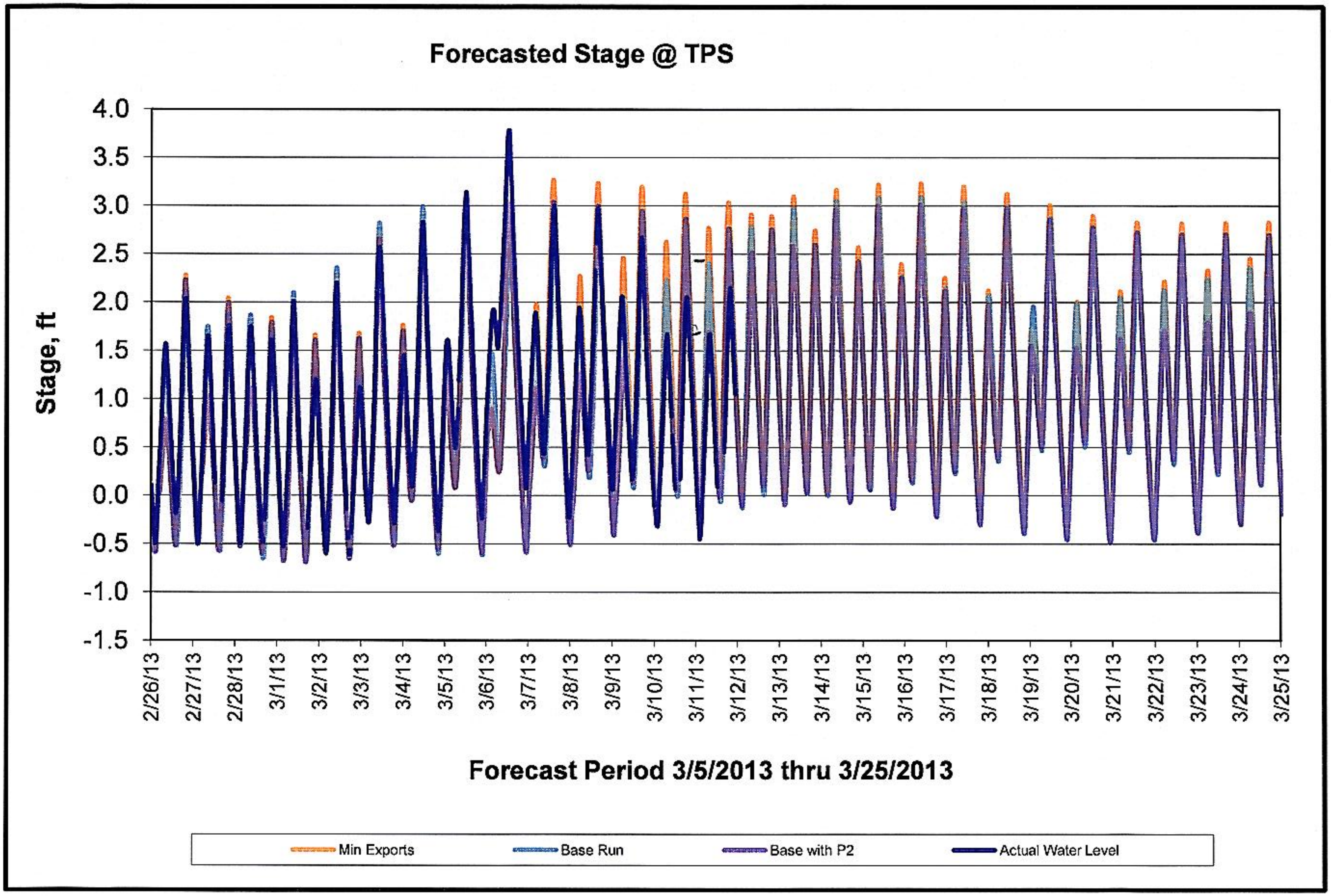


Forecasted Stage @ West of Union Island/Channel 218
Stage, ft
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
2/26/13
2/27/13
2/28/13
3/1/13
3/2/13
3/3/13
3/4/13
3/5/13
3/6/13
3/7/13
3/8/13
3/9/13
3/10/13
3/11/13
3/12/13
3/13/13
3/14/13
3/15/13
3/16/13
3/17/13
3/18/13
3/19/13
3/20/13
3/21/13
3/22/13
3/23/13
3/24/13
3/25/13
Forecast Period 3/5/2013 thru 3/25/2013
Min Exports
Base Run
Base with P2
Actual Water Level


Forecasted Stage @ Doughty Ct/Channel 205
Stage, ft
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
2/26/13
2/27/13
2/28/13
3/1/13
3/2/13
3/3/13
3/4/13
3/5/13
3/6/13
3/7/13
3/8/13
3/9/13
3/10/13
3/11/13
3/12/13
3/13/13
3/14/13
3/15/13
3/16/13
3/17/13
3/18/13
3/19/13
3/20/13
3/21/13
3/22/13
3/23/13
3/24/13
3/25/13
Forecast Period 3/5/2013 thru 3/25/2013
Min Exports
Base Run
Base with P2
Actual Water Level


Forecasted Stage @ Old River @ Tracy Road
Stage, ft
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
2/26/13
2/27/13
2/28/13
3/1/13
3/2/13
3/3/13
3/4/13
3/5/13
3/6/13
3/7/13
3/8/13
3/9/13
3/10/13
3/11/13
3/12/13
3/13/13
3/14/13
3/15/13
3/16/13
3/17/13
3/18/13
3/19/13
3/20/13
3/21/13
3/22/13
3/23/13
3/24/13
3/25/13
Forecast Period 3/5/2013 thru 3/25/2013
Min Exports
Base Run
Base with P2
Actual Water Level


Forecasted Stage @ East End of Grant Line Canal/Channel 204
Stage, ft
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
2/26/2013
2/27/2013
2/28/2013
3/1/2013
3/2/2013
3/3/2013
3/4/2013
3/5/2013
3/6/2013
3/7/2013
3/8/2013
3/9/2013
3/10/2013
3/11/2013
3/12/2013
3/13/2013
3/14/2013
3/15/2013
3/16/2013
3/17/2013
3/18/2013
3/19/2013
3/20/2013
3/21/2013
3/22/2013
3/23/2013
3/24/2013
3/25/2013
Forecast Period 3/5/2013 thru 3/25/2013
Min Exports
Base Run
Base with P2



Forecasted Stage @ TPS
Stage, ft
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
2/26/13
2/27/13
2/28/13
3/1/13
3/2/13
3/3/13
3/4/13
3/5/13
3/6/13
3/7/13
3/8/13
3/9/13
3/10/13
3/11/13
3/12/13
3/13/13
3/14/13
3/15/13
3/16/13
3/17/13
3/18/13
3/19/13
3/20/13
3/21/13
3/22/13
3/23/13
3/24/13
3/25/13
Forecast Period 3/5/2013 thru 3/25/2013
Min Exports
Base Run
Base with P2
Actual Water Level

Exhibit "J"

Delta Hydrology Conditions

Date	Sacramento River at Freeport + SRWTP cfs	Yolo Bypass cfs	East Side Streams cfs	San Joaquin River at Vernalis cfs	Rainfall inches	Clifton Court Forebay Intake cfs	Tracy Pumping Plant cfs	CCWD Pumping Plants cfs	Barker Slough Pumping Plant cfs	BBID Diversion cfs
2/17/2013	14,713	64	409	2,407	0.00	1,499	2,401	127	26	0
2/18/2013	14,269	64	401	2,410	0.00	1,495	2,383	105	26	18
2/19/2013	14,448	64	390	2,414	0.20	1,493	2,387	103	24	5
2/20/2013	14,907	65	410	2,452	0.00	1,492	2,562	115	18	2
2/21/2013	14,751	63	359	2,461	0.00	2,488	2,788	129	23	5
2/22/2013	14,374	61	344	2,458	0.00	2,055	3,065	121	29	5
2/23/2013	14,408	58	338	2,479	0.00	2,956	3,458	116	18	0
2/24/2013	14,248	58	351	2,501	0.00	2,494	3,458	103	27	0
2/25/2013	13,826	57	354	2,498	0.00	2,498	3,454	101	27	20
2/26/2013	13,571	56	322	2,437	0.00	2,498	3,456	108	24	13
2/27/2013	13,522	55	347	2,397	0.00	2,494	3,464	115	30	16
2/28/2013	13,397	55	342	2,272	0.00	2,491	3,056	120	24	25
3/1/2013	13,207	53	348	2,054	0.00	2,497	2,872	285	27	31
3/2/2013	12,915	52	331	1,940	0.00	2,998	2,867	273	23	0
3/3/2013	12,655	53	338	1,938	0.00	2,992	2,873	281	29	31
3/4/2013	12,901	52	378	1,944	0.00	2,491	2,877	298	27	0
3/5/2013	12,454	52	397	1,833	0.00	2,696	2,882	300	14	46
3/6/2013	12,121	74	433	1,917	0.04	2,989	2,899	294	23	43
3/7/2013	12,644	82	476	1,789	0.00	2,696	2,633	275	15	46
3/8/2013	12,119	65	438	1,745	0.00	2,897	2,529	290	23	65
3/9/2013	13,053	59	413	1,745	0.00	2,691	2,684	307	23	0
3/10/2013	12,373	54	402	1,853	0.00	2,692	2,562	300	28	45
3/11/2013	12,934	51	401	1,832	0.00	2,498	2,648	333	21	44
3/12/2013	14,972	50	424	1,563	0.00	2,491	2,661	341	11	52
3/13/2013	15,647	50	445	1,495	0.00	1,489	1,762	337	8	57
3/14/2013	15,516	114	453	1,418	0.00	999	1,703	325	8	68
3/15/2013	15,347	224	456	1,485	0.00	2,493	1,728	160	11	66
3/16/2013	15,367	283	460	1,506	0.00	2,496	1,719	170	8	0
3/17/2013	15,844	320	446	1,541	0.00	2,492	1,702	165	16	50
3/18/2013	15,969	342	405	1,542	0.00	2,997	1,693	171	6	54

SRWTP : Sacramento Regional Water Treatment Plant effluent.
Yolo Bypass : combined measurements of Cache Creek at Rumsey and Freemont Weir.
East Side Streams : combined stream flows of Cosumnes River at Michigan Bar, Mokelumne River at Woodbridge, miscellaneous streams estimated from Dry Creek at Galt (discontinued since Dec. 1997), and Calaveras River based on releases from New Hogan Dam.
Rainfall : incremental daily precipitation measured at Stockton Fire Station #4.
CCWD Pumpling Plants : combined pumping at the Old River, Rock Slough and Middle River Plants.

Delta Hydrology Conditions

Date	Banks Pumping Plant cfs	Delta Gross Channel Depletions cfs	Rio Vista Flow cfs	QWEST cfs	Net Delta Ouflow Index cfs	Percent of Inflow Diverted 3 day	Percent of Inflow Diverted 14 day	Delta Status
2/17/2013	1,499	850	11,951	1,039	12,904	21.3%	19.4%	f
2/18/2013	1,499	850	11,753	1,083	12,750	21.7%	19.7%	f
2/19/2013	1,499	850	11,368	1,007	12,292	22.1%	19.9%	f
2/20/2013	1,512	850	11,843	1,577	13,422	22.6%	20.4%	f
2/21/2013	2,549	900	12,228	430	12,652	25.2%	23.1%	f
2/22/2013	1,184	900	12,091	531	12,610	27.4%	25.6%	f
2/23/2013	2,967	900	11,762	-831	10,930	31.9%	30.2%	f
2/24/2013	2,883	900	11,788	-336	11,443	33.5%	31.8%	f
2/25/2013	2,965	900	11,330	-1,041	10,199	35.4%	33.8%	f
2/26/2013	1,738	900	10,963	-1,114	9,763	34.8%	33.3%	f
2/27/2013	2,889	900	10,741	-1,250	9,398	35.4%	33.8%	f
2/28/2013	2,541	900	10,698	-855	9,755	35.2%	33.4%	f
3/1/2013	2,411	950	10,575	-1,015	9,467	34.4%	32.6%	f
3/2/2013	2,565	1,000	10,394	-1,799	8,502	34.8%	32.8%	f
3/3/2013	2,939	1,000	10,140	-1,947	8,094	36.3%	33.7%	f
3/4/2013	3,108	1,000	9,916	-1,529	8,290	37.2%	34.2%	f
3/5/2013	2,737	1,050	10,114	-1,648	8,378	36.8%	33.8%	f
3/6/2013	2,783	1,050	9,727	-2,106	7,524	37.2%	34.2%	f
3/7/2013	2,986	1,050	9,524	-1,302	8,150	37.4%	34.5%	f
3/8/2013	2,551	1,100	9,971	-1,443	8,444	37.2%	34.6%	f
3/9/2013	2,767	1,100	9,499	-1,625	7,790	36.5%	34.0%	f
3/10/2013	2,906	1,100	10,303	-1,352	8,862	35.7%	34.2%	f
3/11/2013	2,508	1,150	9,694	-1,305	8,304	35.4%	34.0%	f
3/12/2013	2,471	1,150	10,114	-1,406	8,616	34.1%	33.6%	f
3/13/2013	1,496	1,200	11,866	496	12,271	28.6%	29.2%	b
3/14/2013	1,450	1,250	12,437	1,079	13,421	21.9%	23.6%	b
3/15/2013	1,496	1,250	12,387	-363	11,926	19.1%	21.5%	b
3/16/2013	1,955	1,300	12,337	-419	11,819	20.9%	23.4%	b
3/17/2013	2,452	1,350	12,399	-347	11,942	23.8%	26.4%	b
3/18/2013	2,878	1,350	12,850	-761	11,989	24.4%	27.0%	b

Delta Gross Channel Depletions from Dayflow Table 3.
Rio Vista Flow calculated from Dayflow equation.
QWEST calculated from Dayflow equation.
Net Delta Ouflow Index calculated from equation as specified in D-1641, revised June 1995.

Coordinated Operation Agreement Delta Status:
- c = excess Delta conditions
- b = balanced Delta cond. w/ no storage withdrawal
- s = balanced Delta cond. w/ storage withdrawal
- Excess Delta conditions with restrictions:
  - f = fish concerns
  - r = E/I ratio concerns

Exhibit “K”

DEPARTMENT OF WATER RESOURCES
1416 NINTH STREET, P.O. BOX 942836
SACRAMENTO, CA 94236-0001
(916) 653-5791

April 16, 2008

Ms. Dorothy R. Rice
Executive Director
State Water Resources Control Board
1001 I Street
Sacramento, California 95814

Dear Ms. Rice:

Report of Exceedence of South Delta Water Quality Agricultural Objective

This letter reports on the exceedence of the electrical conductivity objective at Old River at Tracy Road Bridge station (P-12), as required under Condition A.5 of the State Water Resources Control Board's Order WR-2006-0006 (Order) to the Department of Water Resources (DWR) and the U.S. Bureau of Reclamation (Reclamation). Condition A.5 requires that DWR and Reclamation report to the Executive Director within 30 days of an exceedence of water quality objectives in the South Delta, including (1) the length of time over which the exceedence occurred and (2) any corrective actions taken to curtail the exceedence.

For a seven-day period between March 16 and March 22, 2008, the 30-day running-average of electrical conductivity at Old River near Tracy Road Bridge reached 1.1 EC, exceeding the 1.0 EC objective. (Reclamation notified the SWRCB of the exceedence in a letter dated March 25, 2008.)

DWR did not take corrective actions, as salinity at this station was not within DWR's control. Local degradation is believed to have been a key factor in the exceedence. Table 1 (attached) presents the observed daily and 30-day average EC values at all four south Delta salinity stations in March, and Figure 1 (also attached) is a plot of the 30-day EC values at those four stations. As the figure shows, the 30-day average EC at Old River near Tracy Road Bridge was consistently 0.1 mmhos/cm higher than at Vernalis, Brandt Bridge, and Old River near Middle River (Union Island), all of which remained below the 1.0 EC objective.

Furthermore, DWR has modeled three operational scenarios, and the results of those model runs (presented in Figures 2-4) demonstrate the Projects' inability to influence water quality at the compliance station at Old River near Tracy Road Bridge.

As you know, the Projects have been operating to maintain Old and Middle River flow targets since December 28, as required in a Remedy Order issued by Judge Oliver Wanger of the U.S. District Court on December 14, 2007. The base case run simulated electrical conductivity under Project operations as they *would have been* absent Judge Wanger's OMR flow targets. The second run simulated EC for *actual* operations under the OMR-restricted case. A third model run explored whether reductions in Project exports to minimum levels would improve south Delta EC. Exports were cut to 350 cfs at the SWP and 800 cfs at the CVP beginning on March 6, the first day that daily EC values rose above 1.0 EC, and continuing through the end of the simulation period. (Observed historical daily and 30-day averages are also plotted in all three figures.)

As shown by the model results, the daily and 30-day EC values at San Joaquin River at Brandt Bridge and at Old River near Middle River are identical under all three scenarios. At the Old River at Tracy Road location, the three alternatives produced only the slightest changes to daily EC. Specifically, the modeling suggests that daily EC would have been about 0.005 mmhos/cm lower in the minimum export case than in the actual case on March 10; however, daily EC would have been about 0.006 mmhos/cm higher beginning March 19. On the other hand, daily EC would have been about 0.002 mmhos/cm higher in the (higher-export) base case beginning on March 10, then about 0.014 mmhos/cm lower beginning March 19. The 30-day EC values would be virtually identical under all three scenarios, with a maximum difference of 0.003 mmhos/cm.

The Projects could not have implemented the higher-export base case scenario in light of Judge Wanger's remedy order, and cutting exports to minimum levels would only have reduced the 30-day EC by 0.003 mmhos, which was not enough to avoid, or even shorten, the exceedence period.

In conclusion, the model runs continue to support DWR's position that Project operations either do not effectively control salinity in south Delta or cannot reasonably be used for such purposes.

If you have any questions regarding this report, please contact me at (916) 574-2656 or your staff may contact Tracy Hinojosa at (916) 574-2655.

Sincerely,

For D. Roose

David H. Roose, Chief
SWP Operations Control Office
Division of Operations and Maintenance

Attachments (5)

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Operations Manager
US Bureau of Reclamation
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Sacramento, California 95821

Table 1

Electrical Conductivity at the Four Southern Delta Salinity Stations

March 2008

	Vernalis		Brandt Bridge		Old River Tracy		Union Island	
Date	Daily	30-day avg	Daily	30-day avg	Daily	30-day avg	Daily	30-day avg
01-Mar-08	0.67	0.75	0.58	0.79	0.66	0.90	0.59	0.77
02-Mar-08	0.75	0.76	0.68	0.80	0.66	0.90	0.70	0.78
03-Mar-08	0.81	0.77	0.78	0.81	0.72	0.90	0.78	0.79
04-Mar-08	0.94	0.78	0.85	0.81	0.83	0.91	0.86	0.80
05-Mar-08	0.99	0.79	0.91	0.82	0.94	0.92	0.91	0.81
06-Mar-08	1.06	0.80	0.96	0.83	1.01	0.93	0.96	0.82
07-Mar-08	1.03	0.82	1.00	0.85	1.14	0.94	1.02	0.83
08-Mar-08	1.07	0.84	1.05	0.86	1.27	0.96	1.01	0.84
09-Mar-08	1.06	0.86	1.04	0.88	1.26	0.97	1.03	0.86
10-Mar-08	1.07	0.87	1.06	0.89	1.20	0.99	1.05	0.88
11-Mar-08	1.10	0.88	1.05	0.91	1.21	1.01	1.03	0.89
12-Mar-08	1.05	0.89	1.06	0.92	1.19	1.02	1.07	0.90
13-Mar-08	1.09	0.90	1.08	0.93	1.18	1.03	1.04	0.91
14-Mar-08	1.08	0.91	1.06	0.93	1.17	1.04	1.11	0.92
15-Mar-08	1.03	0.91	1.09	0.94	1.12	1.04	1.11	0.92
16-Mar-08	0.99	0.92	1.07	0.94	1.13	1.05	1.08	0.93
17-Mar-08	0.96	0.92	1.02	0.95	1.13	1.05	1.04	0.93
18-Mar-08	0.93	0.92	1.00	0.95	1.12	1.06	0.99	0.93
19-Mar-08	0.83	0.91	0.97	0.95	1.10	1.06	0.98	0.93
20-Mar-08	0.77	0.90	0.93	0.95	1.07	1.06	0.88	0.93
21-Mar-08	0.75	0.89	0.83	0.94	1.03	1.06	0.81	0.92
22-Mar-08	0.73	0.88	0.78	0.93	0.98	1.05	0.79	0.91
23-Mar-08	0.69	0.88	0.76	0.92	0.92	1.04	0.76	0.90
24-Mar-08	0.72	0.87	0.72	0.90	0.87	1.03	0.72	0.89
25-Mar-08	0.66	0.86	0.72	0.89	0.82	1.02	0.75	0.88
26-Mar-08	0.60	0.86	0.72	0.88	0.79	1.01	0.71	0.88
27-Mar-08	0.58	0.86	0.66	0.88	0.78	1.00	0.64	0.87
28-Mar-08	0.57	0.86	0.62	0.87	0.77	0.99	0.63	0.87
29-Mar-08	0.55	0.86	0.59	0.87	0.73	0.98	0.61	0.87
30-Mar-08	0.58	0.86	0.58	0.87	0.67	0.98	0.59	0.88
31-Mar-08	0.57	0.85	0.58	0.87	0.68	0.98	0.61	0.88

FIGURE 1

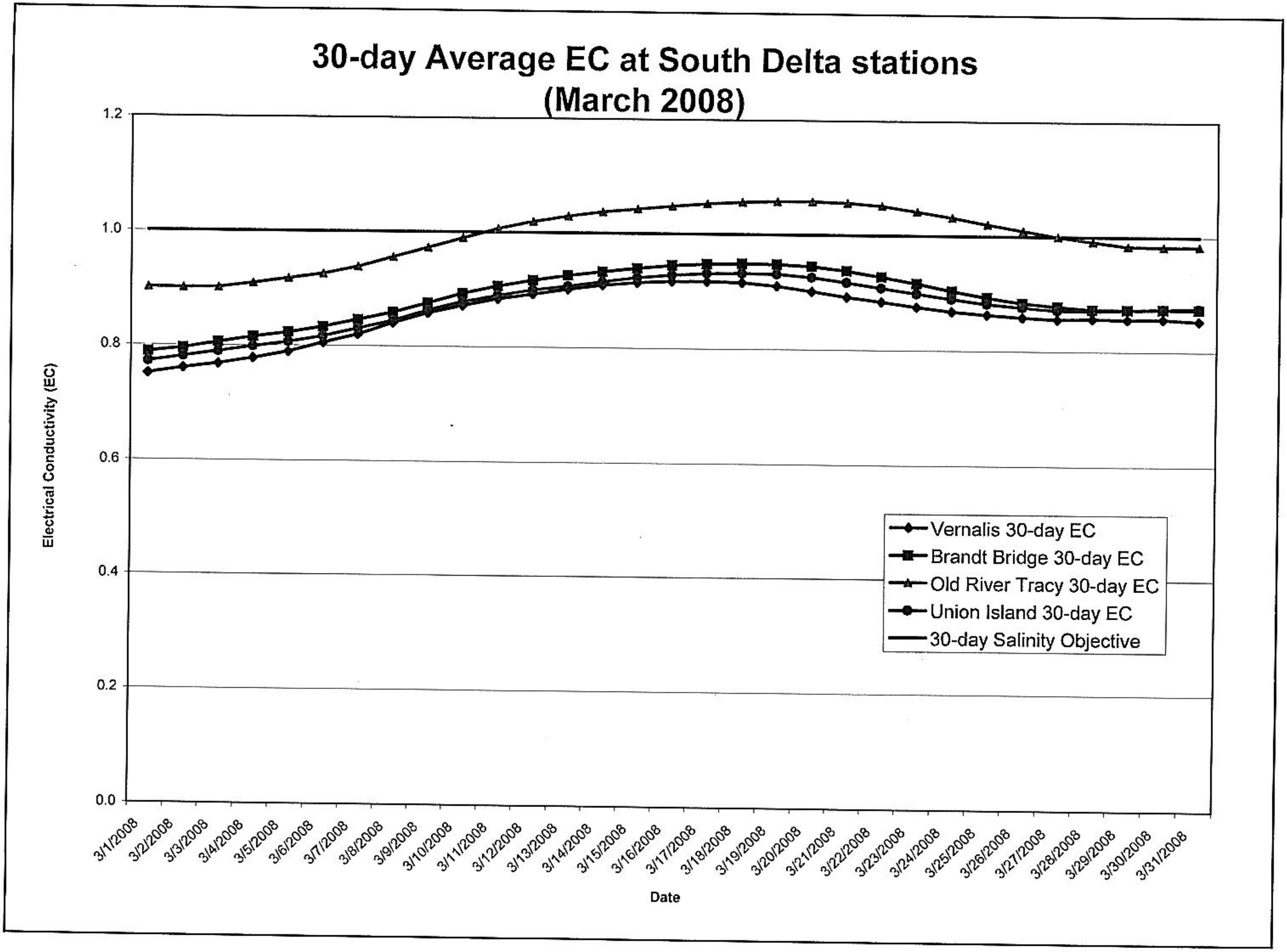

30-day Average EC at South Delta stations
(March 2008)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Electrical Conductivity (EC)
Vernalis 30-day EC
Brandt Bridge 30-day EC
Old River Tracy 30-day EC
Union Island 30-day EC
30-day Salinity Objective
3/1/2008
3/2/2008
3/3/2008
3/4/2008
3/5/2008
3/6/2008
3/7/2008
3/8/2008
3/9/2008
3/10/2008
3/11/2008
3/12/2008
3/13/2008
3/14/2008
3/15/2008
3/16/2008
3/17/2008
3/18/2008
3/19/2008
3/20/2008
3/21/2008
3/22/2008
3/23/2008
3/24/2008
3/25/2008
3/26/2008
3/27/2008
3/28/2008
3/29/2008
3/30/2008
3/31/2008
Date

FIGURE 2

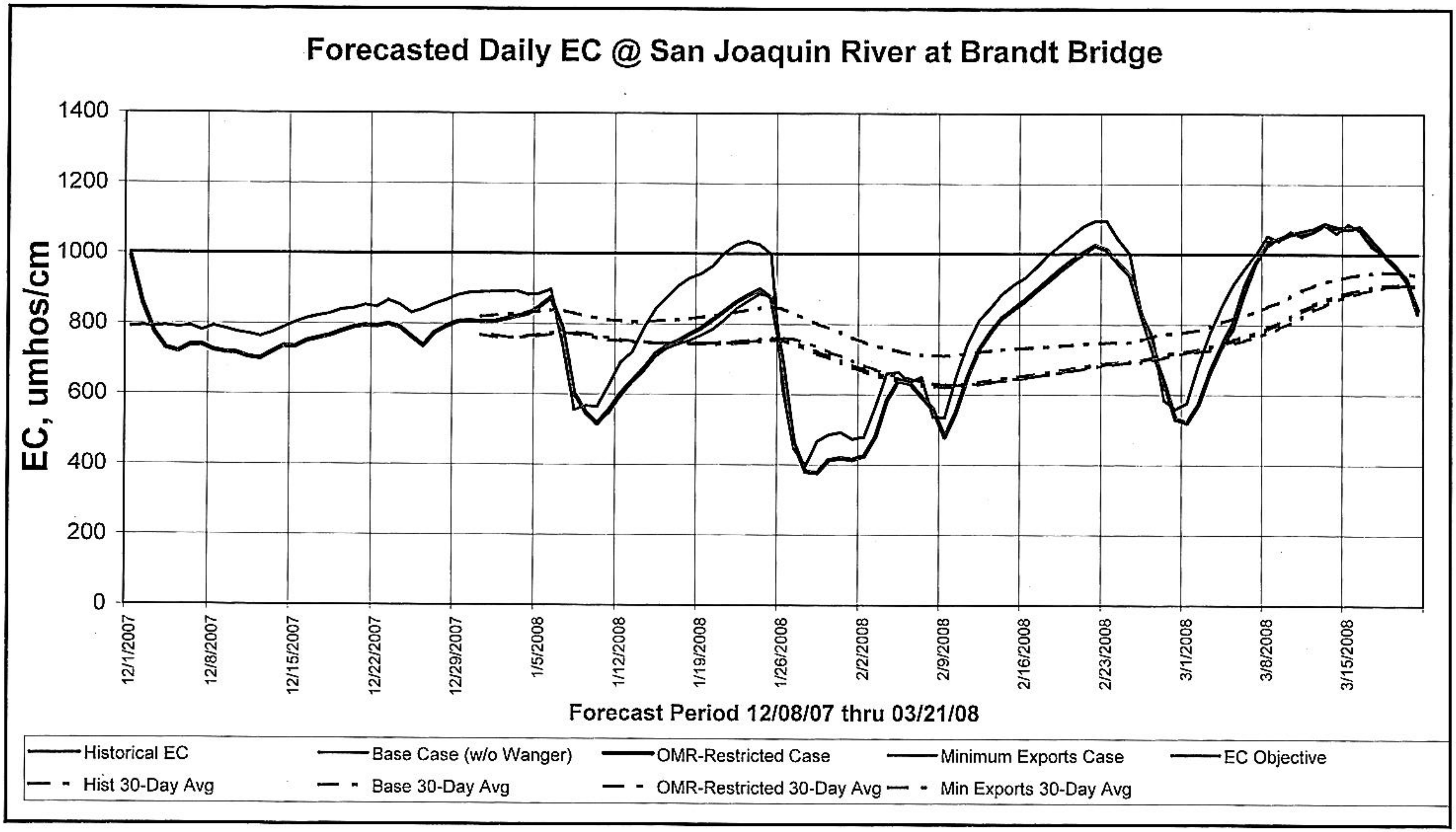

Forecasted Daily EC @ San Joaquin River at Brandt Bridge
EC, umhos/cm
1400
1200
1000
800
600
400
200
0
12/1/2007
12/8/2007
12/15/2007
12/22/2007
12/29/2007
1/5/2008
1/12/2008
1/19/2008
1/26/2008
2/2/2008
2/9/2008
2/16/2008
2/23/2008
3/1/2008
3/8/2008
3/15/2008
Forecast Period 12/08/07 thru 03/21/08
Historical EC
Base Case (w/o Wanger)
OMR-Restricted Case
Minimum Exports Case
EC Objective
Hist 30-Day Avg
Base 30-Day Avg
OMR-Restricted 30-Day Avg
Min Exports 30-Day Avg

FIGURE 3

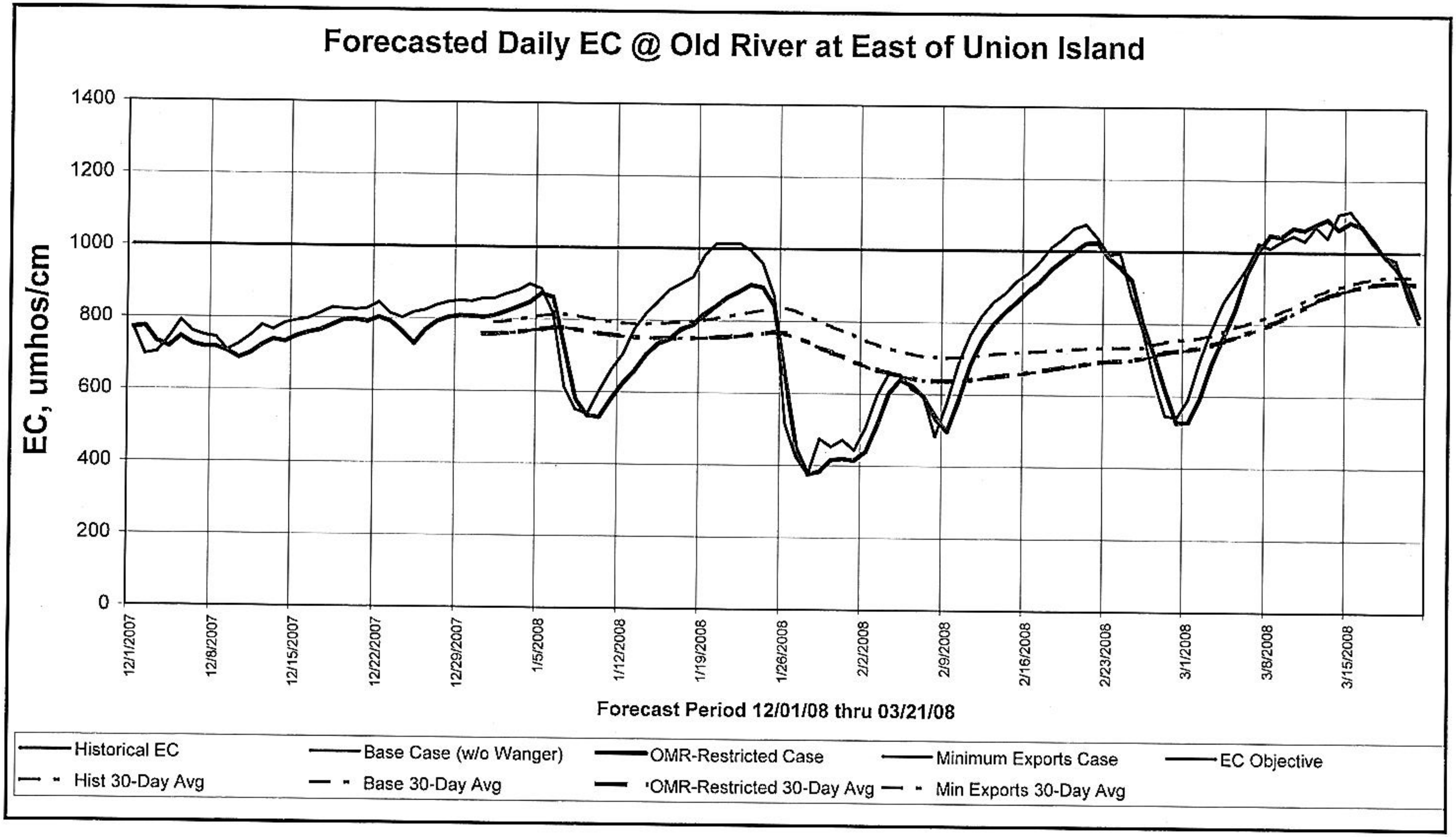
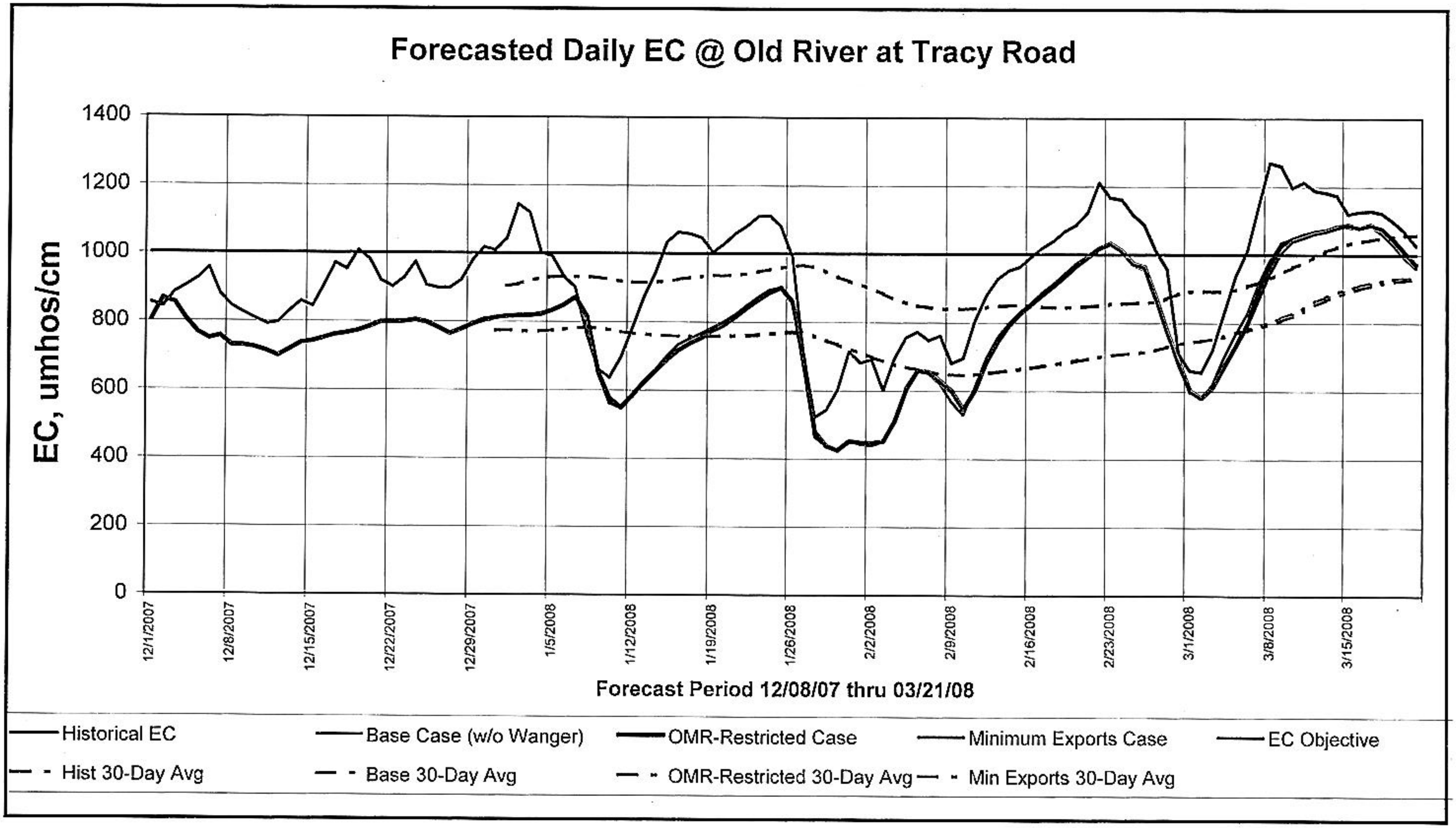

Forecasted Daily EC @ Old River at East of Union Island
EC, umhos/cm
1400
1200
1000
800
600
400
200
0
12/1/2007
12/8/2007
12/15/2007
12/22/2007
12/29/2007
1/5/2008
1/12/2008
1/19/2008
1/26/2008
2/2/2008
2/9/2008
2/16/2008
2/23/2008
3/1/2008
3/8/2008
3/15/2008
Forecast Period 12/01/08 thru 03/21/08
Historical EC
Base Case (w/o Wanger)
OMR-Restricted Case
Minimum Exports Case
EC Objective
Hist 30-Day Avg
Base 30-Day Avg
OMR-Restricted 30-Day Avg
Min Exports 30-Day Avg

FIGURE 4



Forecasted Daily EC @ Old River at Tracy Road
EC, umhos/cm
1400
1200
1000
800
600
400
200
0
12/1/2007
12/8/2007
12/15/2007
12/22/2007
12/29/2007
1/5/2008
1/12/2008
1/19/2008
1/26/2008
2/2/2008
2/9/2008
2/16/2008
2/23/2008
3/1/2008
3/8/2008
3/15/2008
Forecast Period 12/08/07 thru 03/21/08
Historical EC
Base Case (w/o Wanger)
OMR-Restricted Case
Minimum Exports Case
EC Objective
Hist 30-Day Avg
Base 30-Day Avg
OMR-Restricted 30-Day Avg
Min Exports 30-Day Avg

State of California The Resources Agency

Memorandum

Date: May 22, 2007

To: Dorothy R. Rice
Executive Director
State Water Resources Control Board
1001 I Street
Sacramento, California 95814

From: **Department of Water Resources**

Subject: Report of Exceedance of South Delta Water Quality Agricultural Objective

This memorandum reports on the exceedance of water quality objectives in the South Delta as required under Condition A.5 of the State Water Resources Control Board's Order WR-2006-0006 (Order) to the Department of Water Resources (DWR) and the U.S. Bureau of Reclamation (USBR). In addition, this memorandum responds to the May 11, 2007, letter sent to DWR and USBR requesting information regarding increased flows on the San Joaquin River to improve southern Delta salinity.

Condition A.5 requires that DWR and USBR report to the Executive Director within 30 days of an exceedance of water quality objectives in the South Delta, including (1) the length of time over which the exceedance occurred and (2) any corrective actions taken to curtail the exceedance.

On April 24, 2007 DWR sent a letter to the SWRCB reporting that the 30-day running-average salinity objective at Old River near Tracy Road Bridge of 0.7 EC was likely to be exceeded on April 30, 2007 and continue for some time thereafter. We also noted the possibility of additional exceedances at Old River near Middle River and the San Joaquin River near Brandt Bridge during May through August of 2007. DWR noted that modeling of SWP operations demonstrate that additional storage releases from Lake Oroville and reductions in SWP exports at Clifton Court Forebay/Banks Pumping Plant will not effectively control the increasing salinity, nor can DWR control the actions that appear to be causing the increasing salinity at the compliance station near Tracy Road Bridge.

On April 30, 2007, the 30-day running average value for the south Delta water quality of 0.7 EC was exceeded. Figure 1 (attached) shows the information on water quality at the four southern Delta salinity objective locations. The data shows that the 30-day running average salinity at Vernalis, Brandt Bridge and Old River near Middle River (Union Island) has remained well below the 0.7 EC objective level since April 30 and is continuing to decrease. In contrast, salinity at Old River near Tracy Road Bridge has remained stable and unaffected at the 0.86 level (approximately) since April 30. It appears that salinity conditions at Old River near Tracy Road Bridge have not improved during the VAMP period when San Joaquin flows have been increased.

This is sharply contrasted by the conditions at the other three salinity stations, as Figure 1 shows. One possibility is that local agricultural drainages in the vicinity of Old River near Tracy Road Bridge are being "trapped" in this area and are not being circulated away from the station. DWR did not take any corrective actions as the increasing salinity was not within its control.

On May 11, 2007, the SWRCB sent a reply to DWR's April 24 notice of the potential exceedance. The SWRCB stated that it "agrees with DWR's assertion that making releases from Lake Oroville or shutting down Banks Pumping Plant will do little, if anything, to improve salinity at the three southern Delta stations". As discussed above, DWR has no control over the increasing salinity in the south delta. However, the State Water Board requested additional information be submitted on alternatives that it believes could improve south delta salinity, including: 1) releases of water from New Melones Reservoir, 2) recirculation of water through the Delta Mendota Canal, or 3) other water releases in the San Joaquin basin. The SWRCB requested a feasibility analysis of these three alternatives that included the sources, quantity and quality of water available, the costs of this water, and the rationale for excluding full consideration of any action. DWR has no facilities to provide increased flows on the San Joaquin River. DWR understands, however, that the USBR is preparing its response to State Water Board's request. Hence, DWR defers to the USBR's study and additional information to respond to the Boards request regarding augmenting San Joaquin River flows.

If you have any further questions please contact me at (916) 574-2656, or your staff may contact Mike Ford at (916) 574-2654.

David Roose, Chief
SWP Operations Control Office
Division of Operations and Maintenance

Attachment

cc: See Attached List

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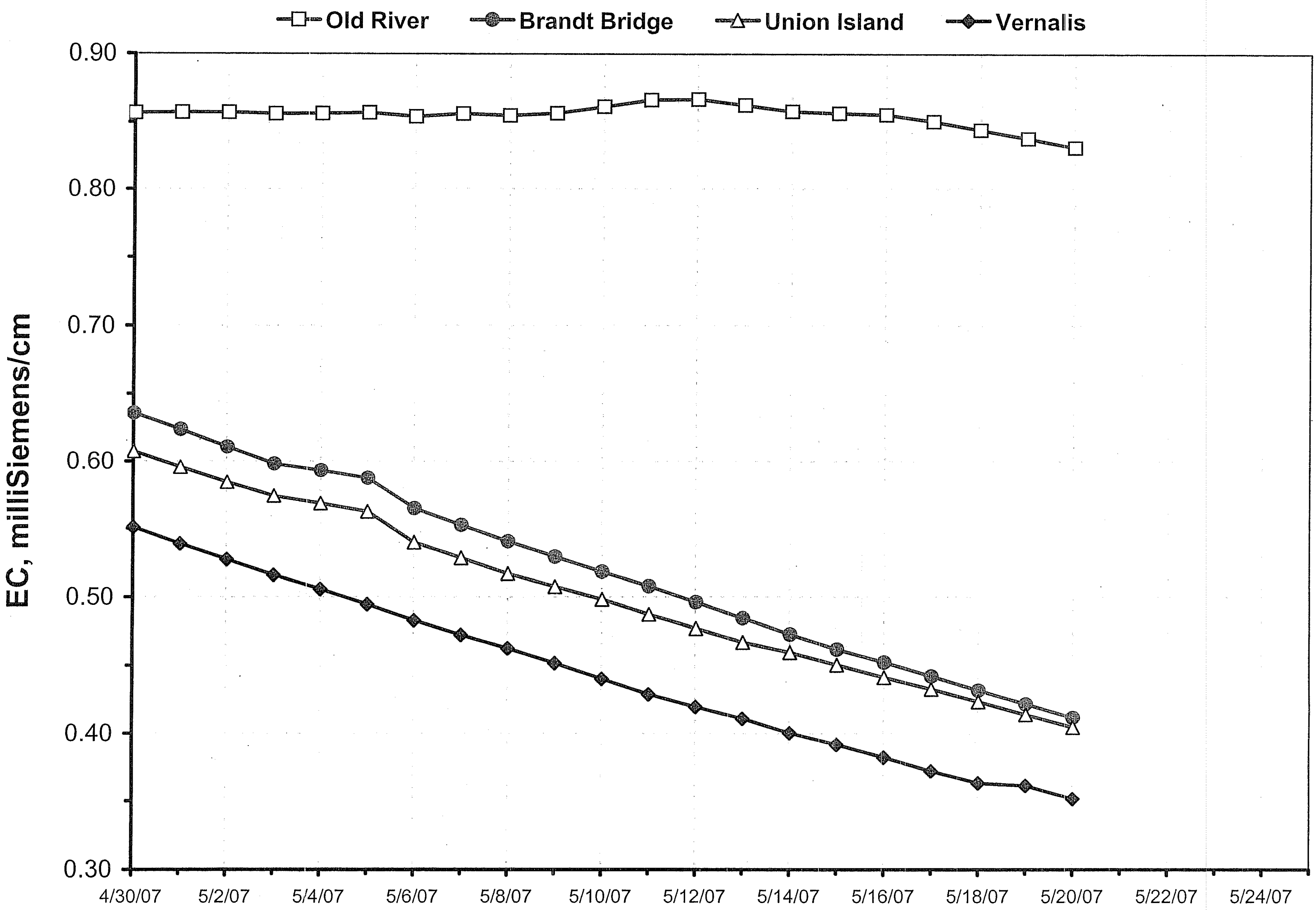
Rep: Calif. Sportfishing Protection Alliance

Ron Milligan
US Bureau of Reclamation
Central Valley Operations Office
3310 El Camino Avenue
Sacramento, California 95821

Figure 1.   30 Day Average EC



PROOF OF SERVICE

I, the undersigned, hereby certify that I am over the age of eighteen (18) years of age and an employee of the State of California Department of Water Resources, 1416 Ninth Street, Sacramento, California 95814.

On May 22, 2007, I served true and correct copies of the attached Department of Water Resources "Report of Exceedence of South Delta Water Quality Agricultural Objective" by electronic-mail to "vwhitney@waterboards.ca.gov", and by U.S. Mail to the Executive Director of the State Water Resources Control Board at 1001 'I' Street, Sacramento, California 95814. I also served true and correct copies of this document by U.S. Mail and by electronically transmitting the report to the parties listed on the attached Mailing List.

Date: May 22, 2007

By: Carol A. Rahner
(insert name of DWR person who mails the letter)

MAILING LIST

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December 22, 2008

RECEIVED
DEC 30 2008

Ms. Dorothy R. Rice
Executive Director
State Water Resources Control Board
1001 I Street
Sacramento, California 95814

Report of Exceedence of South Delta Water Quality Agricultural Objective

Dear Ms. Rice:

As required by Decision 1641, this memorandum is to notify you that the 30-day running average electrical conductivity at Old River at Tracy Road Bridge station (P-12) is exceeding the 1.0 mmhos/cm objective as of December 19, 2008.

The electrical conductivity at Vernalis is currently 0.84 EC, and is not anticipated to exceed the 1.0 EC objective.

We believe that the exceedence at Old River at Tracy Road Bridge is due to local salinity accumulation and poor circulation in south delta channels, which are beyond the control of the Projects.

If you have any questions regarding this matter, please contact Tracy Hinojosa at (916) 574-2655 or Paul Fujitani at (916) 979-2197.

Sincerely,

David Roose, Chief
SWP Operations Control Office
Department of Water Resources
3310 El Camino Avenue, Suite 300
Sacramento, California 95821

for Ron Milligan, Operations Manager
Central Valley Operations Office
U.S. Bureau of Reclamation
3310 El Camino Avenue, Suite 300
Sacramento, California 95821

cc: (See distribution list.)

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Sacramento, California 95821

DEPARTMENT OF WATER RESOURCES
Division of Operations and Maintenance
3310 El Camino Avenue, Suite 300
Sacramento, California 95821

IN REPLY REFER TO:
CVO-400
WTR-4.00

NOV 27 2012

Thomas Howard
Executive Director
State Water Resources Control Board
1001 I Street
Sacramento, California 95814

Subject: Exceedance of the Percent of Inflow Diverted Standard

Dear Mr. Howard:

This is to inform you of an inadvertent exceedance of the Percent of Inflow Diverted (E/I Ratio) using a 3-day average inflow, as set forth in Table 3, Water Quality Objectives for Fish and Wildlife Beneficial Uses, Footnote 20, of the Water Rights Decision 1641. On October 28, 2012, the E/I Ratio reached 68 percent. (Please see Attachment 1.) The standard to which the project operators target is 65 percent.

The exceedance resulted from the difficulties we encounter having to base our real-time water project operations and scheduling on forecasted future conditions with only provisional operational data available at the time. Unfortunately in this instance, the Sacramento River depletions responded differently than predicted going into our weekend operations, and we also found some preliminary export data from Jones Pumping Plant to be in error. The erroneous export data spanned a day when Jones Pumping Plant was out of operation for part of the day for maintenance, and the data was corrected immediately after it was discovered. Once all the hydrological data was updated and the export data was corrected on Monday, October 29, exports were immediately reduced to get the E/I ratio into compliance with an additional buffer to compensate for the additional water exported on October 28.

We strive to use the best information available for our project operations and to make any necessary adjustments as soon as possible to ensure compliance with our water rights permits and conditions. We will continue to work towards improving our forecasting and reporting techniques and expect that this exceedance is only an isolated occurrence.

If you have any questions or would like more information regarding the above notification, please contact Mr. Paul Fujitani of Reclamation at (916) 979-2197, or Mr. John Leahigh at (916) 574-2722.

Sincerely,

Ronald Milligan, Operations Manager
Central Valley Operations Office
Bureau of Reclamation

David H. Roose, Chief
SWP Operations Control Office
Department of Water Resources

Attachments

cc: Craig M. Wilson, Delta Watermaster
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Tracy, California 95376

Patricia D. Fernandez
Division of Water Rights
1001 I Street, 14th Floor
Sacramento, California 95814

Attachment 1:
Operational Data for October 2012

Date	Delta Inflows [cfs]								Delta Exports [cfs]				Flow Req'mts	
	Sac. River @ Freeport (prev. day)	Yolo Bypass (prev. day)	Sacto Treatment Plant (prev. day)	San Joaquin River @ Vernalis (prev. day)	Cosumnes River @ Michigan Bar	Mokelumne River @ Woodbridge (prev. day)	Calaveras River @ New Hogan (prev. day)	Net accretions / depletions above Freeport	Clifton Court Forebay Intake	Jones Pumping Plant	Contra Costa Pumps	Byron Bethany Diversions	Daily Net Delta Outflow Index (cfs)	% of Inflow Diverted 3-day Avg E/I Ratio
01-Oct-12	12,509	398	200	1,038	11	44	145	-528	3,494	4,356	184	65	4,150	53.3
02-Oct-12	12,369	398	190	1,054	11	111	124	-521	3,495	4,286	197	64	4,183	53.6
03-Oct-12	12,332	400	190	960	10	107	113	-803	3,488	4,285	192	61	4,077	54.3
04-Oct-12	12,045	392	190	1,002	10	107	107	-869	3,491	4,267	175	62	3,834	54.8
05-Oct-12	12,511	396	190	977	10	105	107	-427	3,993	4,276	172	60	3,803	55.9
06-Oct-12	13,952	399	190	1,051	10	115	117	-865	4,996	4,272	169	59	4,355	57.1
07-Oct-12	14,003	400	190	1,101	10	110	120	-970	4,994	4,267	162	53	4,511	57.8
08-Oct-12	13,893	379	190	1,155	10	110	101	-690	4,990	4,260	174	56	4,426	58.0
09-Oct-12	13,918	338	190	1,256	11	136	96	-488	5,499	4,309	179	58	3,979	59.0
10-Oct-12	13,999	301	190	1,228	12	381	94	-874	5,489	4,404	179	61	4,193	60.0
11-Oct-12	13,461	261	190	1,265	12	284	71	-1,334	5,492	4,412	164	56	3,545	61.7
12-Oct-12	12,998	252	190	1,424	14	250	61	-700	4,994	4,402	161	54	3,692	62.0
13-Oct-12	13,404	251	190	1,496	13	164	91	-1,163	3,990	4,398	159	51	5,126	59.6
14-Oct-12	12,424	133	190	1,466	14	114	109	-1,411	2,997	4,404	158	52	5,005	55.5
15-Oct-12	11,196	74	190	1,559	15	112	109	-1,455	2,498	4,409	185	44	4,267	52.1
16-Oct-12	10,204	38	190	1,830	15	128	109	-1,321	2,483	4,422	182	46	3,536	52.2
17-Oct-12	9,468	16	190	2,080	15	261	109	-1,150	1,996	4,426	179	54	3,656	52.8
18-Oct-12	9,348	10	190	2,145	15	242	109	-1,492	1,999	4,425	169	55	3,631	53.3
19-Oct-12	9,262	9	190	2,150	16	202	109	-1,684	1,995	3,794	122	57	4,196	51.2
20-Oct-12	9,091	8	190	2,148	16	161	110	-1,912	1,994	3,486	151	56	4,265	49.2
21-Oct-12	8,884	7	190	2,198	16	110	111	-1,628	1,993	3,501	137	53	4,047	47.3
22-Oct-12	9,179	7	190	2,411	15	111	111	-925	1,996	3,454	135	49	4,604	46.2
23-Oct-12	9,888	11	190	2,776	18	171	73	-254	1,993	3,529	118	48	7,769	44.5
24-Oct-12	10,810	13	190	2,705	23	271	31	-394	2,499	3,519	97	46	8,900	43.0
25-Oct-12	10,684	14	190	2,590	52	242	32	-83	3,499	3,519	96	45	7,674	45.0
26-Oct-12	11,000	12	190	2,788	54	195	33	-513	6,486	3,508	134	45	5,124	54.4
27-Oct-12	10,510	10	190	2,647	40	160	33	-706	6,674	3,254	51	0	4,542	64.4
28-Oct-12	10,351	9	190	2,398	33	120	33	-894	6,673	1,419	28	10	3,889	68.2
29-Oct-12	10,174	9	190	2,110	28	122	33	-882	3,590	3,431	82	11	3,806	63.5
30-Oct-12	10,175	8	190	1,834	27	117	33	-1,008	2,717	3,505	94	16	4,324	55.8
31-Oct-12	10,024	8	190	1,585	27	222	33	-1,197	2,988	3,381	93	6	3,865	52.7

Linda S. Adams
Secretary for Environmental Protection

State Water Resources Control Board

Executive Office
Tam M. Doduc, Board Chair
1001 I Street • Sacramento, California • 95814 • 916.341.5615
P.O. Box 100 • Sacramento, California • 95812-0100
Fax 916.341.5621 • www.waterboards.ca.gov

Arnold Schwarzenegger
Governor

APR 24 2008

RECE[illegible]
APR [illegible]

Mr. David Roose, Chief
State Water Project Operations Control Office
Department of Water Resources
3310 El Camino Avenue, Suite 300
Sacramento, CA 95821

Mr. Ronald Milligan, Operations Manager
Central Valley Operations
Bureau of Reclamation
3310 El Camino Avenue, Suite 300
Sacramento, CA 95821

Dear Messrs. Roose and Milligan:

EXCEEDANCE OF SWRCB D-1641 SALINITY WATER QUALITY OBJECTIVE AT OLD RIVER AT TRACY ROAD BRIDGE STATION (P-12) IN MARCH 2008

This memorandum acknowledges receipt of your letter dated March 25, 2008 regarding the exceedance of the SWRCB D-1641 salinity water quality objective at Old River at Tracy Road Bridge (station P-12) in March 2008. The letter was received at the State Water Resources Control Board (State Water Board) on March 28, 2008.

During a subsequent telephone conversation (April 4, 2008) between Tom Kimball, Chief of the Bay-Delta Unit of the Division of Water Rights and Paul Fujitani with the Bureau of Reclamation, Mr. Fujitani clarified that the April 1, 2008 deliverable date for the exceedance report was incorrect, and that the correct deliverable date is April 15, 2008.

When sending this report and any further correspondence regarding this matter, please copy the parties on the following "cc" list.

If you have questions, please contact Tom Kimball, Chief of the Bay-Delta Unit in the Division of Water Rights, at (916) 341-5289.

Sincerely,

Dorothy Rice
Executive Director

cc: See next page.

cc:

Mr. Gerald E. Johns
Deputy Director
Department of Water Resources
1416 9th Street
Sacramento, CA 95814

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Division of Operations and Maintenance
Department of Water Resources
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State of California

The Resources Agency

Memorandum

Date: April 28, 2009

To: Dorothy Rice
Executive Director
State Water Resources Control Board
1001 I Street
Sacramento, California 95814

RECEIVED
APR 30 2009
BY:________

From: **Department of Water Resources**

Subject: Report of Potential Exceedence of South Delta Water Quality Agricultural Objective

This memorandum, prepared in coordination with the U.S. Bureau of Reclamation (Reclamation), is written pursuant to the State Water Resources Control Board's (Board) Order WR 2006-0006 to the Department of Water Resources (DWR) and Reclamation ("Order," February 15, 2006). The Order requires that DWR and Reclamation notify the Board Executive Director if they project there will be an exceedence of the South Delta water quality objectives. In addition, DWR and Reclamation must submit a report demonstrating that the potential exceedence is caused by actions beyond their reasonable control or they should initiate corrective actions.

By this memo, DWR and Reclamation are reporting that the 30-day average electrical conductivity at the three interior south Delta stations is expected to exceed the agricultural water quality objective in the south Delta at the end of the month. As of April 20, the 30-day average EC values were 0.7 mmhos/cm at Brandt Bridge, 0.9 mmhos/cm at Old River near Tracy Road Bridge, and 0.8 mmhos/cm at Old River near Middle River. (Daily EC values for the three stations are lower--0.36 mmhos/cm at Brandt Bridge, 0.57 mmhos/cm at Old River Tracy, and as of April 23, 0.41 mmhos/cm at Old River near Middle River.) Based on current trends in electrical conductivity, the 30-day objective of 0.7 EC at the interior south Delta stations is expected to be exceeded April 30.

DWR and Reclamation are not required to initiate corrective actions when actions causing the exceedence are beyond their reasonable control and, as such, we are not proposing any corrective actions at this time. DWR and Reclamation are providing information on current water quality conditions in the South Delta, and on factors increasing salinity in the interior south Delta during the irrigation season. DWR and Reclamation will continue to monitor the water quality conditions in the South Delta and report to the Board as conditions change.

Current Conditions

Current projections are that water year 2009 will be "dry" in both the Sacramento and San Joaquin River basins. Furthermore, it is a San Joaquin River Agreement (SJRA) off ramp year, thus San Joaquin River flows may not be supplemented with releases from SJR tributaries per the agreement.

Reclamation anticipates meeting the 0.7 EC water quality objective at Vernalis through operation of New Melones Reservoir. Reclamation believes storage releases from New Melones Reservoir on the Stanislaus River beyond the levels needed to meet the south Delta water quality objective at Vernalis are beyond their reasonable control, and the interior south delta compliance stations are not flow-based water quality objectives.

DWR provided a report of the effects of local drainage and diversions to the Board during the January 2007 workshop on South Delta Salinity Objectives for Agriculture. (See "Sources of Salinity in South Sacramento-San Joaquin Delta" by Barry Montoya, ("Montoya Report") updated on April 19, 2007, and sent to you on April 24, 2007 and again as a final report for the Board's April 22, 2009 workshop.) Information in the report shows that local municipal and agricultural drainages occurring in the south Delta and on the San Joaquin River between Vernalis and Brandt Bridge are factors increasing the mean salinity in the south Delta during the irrigation season and contributing to exceedence of the 0.7 EC objective. DWR and Reclamation do not control these drainages.

In the Order, the Board listed recirculation as a possible corrective action to improve South Delta water quality if DWR or Reclamation causes exceedence of the objectives. As noted above, DWR and Reclamation are not proposing any corrective actions at this time. However, DWR and Reclamation will coordinate with South Delta Water Agency to consider a combination of re-circulation and operation of the temporary barrier flap gates during the summer months if Vernalis flows and water levels are very low. This is not a commitment by DWR and Reclamation, but a good-faith coordination with South Delta Water Agency to address adverse circumstances.

DWR and Reclamation will provide additional information and keep the Board apprised of salinity conditions in the South Delta as the irrigation season progresses, as well as providing the regular quarterly reports pursuant to the Order. The real-time salinity data at the South Delta stations can also be obtained by your staff at http://wwwoco.water.ca.gov/cmplmon/reports/DeltaWaterQuality.pdf.

If you have any questions regarding the above, please contact me at (916) 574-2656 or your staff may contact Mike Ford at (916) 574-2654, or Paul Fujitani of Reclamation at (916) 979-2197.

Sincerely,

David H. Roose, Chief
SWP Operations Control Office
Division of Operations and Maintenance

cc: (See distribution list)

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PROOF OF SERVICES

I, the undersigned, hereby certify that I am over the age of eighteen (18) years of age and an employee of the State of California Department of Water Resources, 1416 Ninth Street, Sacramento, California 95814.

On April 29, 2009, I served true and correct copies of the attached Department of Water Resources "Report of Exceedence of South Delta Water Quality Agricultural Objective" by electronic mail to vwhitney@waterboards.ca.gov, and hand delivered to the Executive Director of the State Water Resources Control Board at 1001 I Street, Sacramento, California 95814. I also served true and correct copies of this document by U.S. Mail and by electronically transmitting the report to the parties on the attached Mailing List.

Date: April 29, 2009

By: ______________________________
(insert name of DWR person who mails the letter)

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May 28, 2009

Ms. Dorothy Rice
Executive Director
State Water Resources Control Board
1011 I Street
Sacramento, California 95814

Report of Exceedence of South Delta Water Quality Agricultural Objective

Dear Ms. Rice:

This memorandum reports the exceedence of the 0.7 EC salinity objective at Station P-12 (Old River near Tracy Road Bridge) from April 30, 2009 through May 5, 2009 as required under Condition A.5 of the State Water Resources Control Board's (SWRCB) Order WR-2006-0006 (Order) to the Department of Water Resources (DWR) and the United States Bureau of Reclamation (USBR).

The 30-day running average EC at Old River near Tracy Road Bridge was greater than 1.0 EC beginning on December 19, 2008 through March 10, 2009 and from March 23, 2009 through April 20, 2009. This exceedence was largely due to the continuation of extremely dry conditions in the Sacramento-San Joaquin Delta basin through early 2009. The SWRCB was notified of this situation in an earlier letter to the SWRCB dated December 22, 2008 (Attachment 1) as part of the reporting requirements of Decision 1641 (D-1641); it is not a specific part of Order WR-2006-0006.

D-1641 specifies that the 30-day running average 0.7 EC objective applies from April through August of each calendar year at the three interior south Delta stations C-6 (San Joaquin River at Brandt Bridge), C-8 (Old River near Middle River, and P-12 (Old River near Tracy Road Bridge). All of the applicable salinity objectives at stations C-6 and C-8 have been met for this year at the current time.

The salinity objective from April through August is 0.7 EC and the determination of compliance begins on the last day of the 30-day averaging period, April 30. The mean daily EC readings at the station P-12 began dropping steeply with the onset of the 31-day pulse flow period for salmon protection beginning on April 17, 2009. On April 30, 2009, the 30-day running average EC at Stations C-6 and C-8 were in compliance with the 0.7 objective but the 30-day running average EC at Station P-12 was 0.9. The mean daily salinities at Station P-12 continued to decline and on May 6, 2009, the 30-day running average EC at Station P-12 was in compliance with the 0.7 EC objective level. Since that time, 30-day running average EC's at all three interior south Delta stations have remained in compliance with objective levels in D-1641.

2009 has been the third consecutive dry year in a row, precipitation in November and December was below average and in January, it was only 1/3 of average for the month. Project pumping has been at low levels due to dry hydrology and restrictions imposed by U.S. Fish and Wildlife Service to protect Delta smelt. 2009 has remained very dry and the Governor has declared a drought emergency.

Condition A.5 also requires that the Projects inform you of any corrective actions that were taken to avoid a potential or actual exccedence of an interior south Delta salinity objective. No corrective actions were taken other than to comply with the objective at Station C-10 (San Joaquin River at Airport Way Bridge, Vernalis). DWR and Reclamation are not required to initiate corrective actions when no additional reasonable control measures exist that the SWP or CVP could take to meet the objectives.

As noted above, all of the salinity objectives at stations C-6 and C-8 have been met so far this year. This further indicates there is significant salinity degradation occurring in the south Delta in the vicinity of Tracy Road Bridge. DWR has provided significant evidence of the degradation of water quality in the south Delta through previous communications, hearings and workshops with the SWRCB.

We appreciate the cooperation and understanding that the SWRCB and its staff has demonstrated in coping with the considerable challenges imposed by the continuation of dry conditions in 2009.

If you have any questions, please contact us at the numbers shown below.

Sincerely,

David H. Roose, Chief
SWP Operations Control Office
Department of Water Resources
(916) 574-2656

Ronald Milligan, Operations Manger
Central Valley Operations Office
U.S. Bureau of Reclamation
(916) 979-2199

Attachments

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Mr. Carl. P.A. Nelson
Bold, Polisner, Maddow, Nelson and Judson
500 Ygnacio Valley Road, Suite 325
Walnut Creek, California 94596-3840

Mr. Thomas J. Shepherd, Sr.
San Joaquin County
Post Office Box 20
Stockton, California 95201

Mr. Michael Jackson
California Sportfishing Protection Alliance
Post Office Box 207
429 West Main Street
Quincy, California 95971

Ralph Torres, DWR
Carl Torgersen, DWR
Jerry Johns, DWR
John Leahigh, DWR
Cathy Crothers, DWR
Erick Soderlund, DWR
Kathy Kelly, DWR

attachment 1

December 22, 2008

Ms. Dorothy R. Rice
Executive Director
State Water Resources Control Board
1001 I Street
Sacramento, California 95814

Report of Exceedence of South Delta Water Quality Agricultural Objective

Dear Ms. Rice:

As required by Decision 1641, this memorandum is to notify you that the 30-day running average electrical conductivity at Old River at Tracy Road Bridge station (P-12) is exceeding the 1.0 mmhos/cm objective as of December 19, 2008.

The electrical conductivity at Vernalis is currently 0.84 EC, and is not anticipated to exceed the 1.0 EC objective.

We believe that the exceedence at Old River at Tracy Road Bridge is due to local salinity accumulation and poor circulation in south delta channels, which are beyond the control of the Projects.

If you have any questions regarding this matter, please contact Tracy Hinojosa at (916) 574-2655 or Paul Fujitani at (916) 979-2197.

Sincerely,

Original Signed By

David Roose, Chief
SWP Operations Control Office
Department of Water Resources
3310 El Camino Avenue, Suite 300
Sacramento, California 95821

Original Signed By

Ron Milligan, Operations Manager
Central Valley Operations Office
U.S. Bureau of Reclamation
3310 El Camino Avenue, Suite 300
Sacramento, California 95821

cc: (See distribution list.)

Distribution List:

Mr. Dante John Nomelini, Esq.
Nomellini, Grilli and McDaniel
Central Delta Water Agency
Post Office Box 1461
235 East Weber Avenue
Stockton, California 95201

Mr. John Herrick, Esq.
South Delta Water Agency
4255 Pacific Avenue, Suite 2
Stockton, California 95207

Mr. Gregory Gartrell,
Contra Cost Water District
Post Office Box H20
131 Concord Avenue
Concord, California 94524

Mr. Thomas J. Shepherd, Sr.
San Joaquin County
Post Office Box 20
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Mr. Michael Jackson
California Sportfishing Alliance
Post Office Box 207
429 West Main Street
Quincy, California 95971

THINOJOSA:Erma Ash
G:LtrSWRCBrsoDeltaECExceedence(Dec 08) simplerversionTH
Spell check: December 22, 2008

State of California

The Resources Agency

Memorandum

Date: August 19, 2010

To: Thomas Howard
Executive Director
State Water Resources Control Board
1001 I Street
Sacramento, California 95814

RECEIVED
AUG 20 2010
BY:

From: **Department of Water Resources**

Subject: Report of Potential Exceedence of South Delta Water Quality Agricultural Objective

This letter is written pursuant to Condition A.9 of the State Water Resources Control Board's (SWRCB) Order WR 2010-0002 (Order) to the Department of Water Resources (DWR) and the United State Bureau of Reclamation (USBR) and is to advice SWRCB of a potential exceedance of the south Delta water quality objective at Station P-12.

Condition A.9 requires DWR and/or USBR to inform the SWRCB of a potential exceedence of the 0.7 EC South Delta Water Quality Objective at Interagency Stations C-6 (San Joaquin river at Brandt Bridge), C-8 (Old River near Middle River), and P-12 (Old River at Tracy Road Bridge). By this memo, DWR and USBR are reporting that the 30-day running average EC at Interagency Station P-12 is expected to exceed the agricultural water quality objective in the south Delta by the end of the month.

The attached table (Attachment 1) shows both the mean daily EC at each station and the corresponding 30-day running average at all three stations since July 17, 2010. On or about August 12, daily water quality, particularly at Station P-12, has begun to degrade as shown by the increasing salinity values in Attachment 1.

DWR wishes to emphasize a key point here. The daily salinity at station C-10 (San Joaquin River at Airport Way Bridge, Vernalis) has been running at approximately the 0.6 EC range in early August, below the standard of 0.7 EC at this location. In spite of daily EC's at Vernalis in the 0.6 EC range, the corresponding daily EC at Station P-12 is running at approximately 0.8 EC. Thus there is a salinity degradation from Venalis to Tracy Road Bridge of approximately 0.2 EC that is not attributable to Vernalis water quality or water project pumping operations.

DWR and USBR have provided extensive evidence in the past of the significant salinity degradation that occurs in the south Delta that is beyond the control of, and not attributable to, water project operations. The "real-time" situation that is occurring now provides further evidence that our concerns are well-founded and reasonable. We sincerely hope the SWRCB and its staff will take this into consideration in future hearings and proceedings related to the appropriateness of current and proposed south Delta water quality objectives and responsibility for implementation of such objectives.

Condition A.9 also requires DWR and USBR to describe any corrective actions they are initiating to avoid the exceedance. There are two actions planned which may help improve south Delta water quality conditions this month.

Construction of all three temporary agricultural barriers (Middle River barrier, Old River barrier, and Grant Line Canal barrier) was completed July 7, 2010. As we have done in the past three years, the flap gates at the Old River near Tracy barrier are periodically tied open to provide additional water quality benefits.

Also, up to 15,000 acre-feet of water is being planned for a transfer from the San Joaquin River (primarily from the Merced River) to south of Delta exporters during late August and September. The increased flow at Vernalis that would occur as a result of this transfer may help improve south delta water quality conditions.

Although these actions should benefit salinity conditions, it is highly unlikely that these efforts will be sufficient to avoid exceedance of the 0.7 EC objective given the level of observed degradation. Other than these actions, no further corrective actions are being contemplated b DWR and/or USBR.

If you have any questions regarding the above, please contact me at (916) 574-2656 or your staff may contact Tracy Pettit at (916) 574-2662 or Paul Fujitani of Reclamation at (916) 979-2197.

Sincerely,

David H. Roose, Chief
SWP Operations Control Office
Division of Operations and Maintenance

Attachments

cc: (See distribution list)

Delta Water Quality Conditions*

July-Aug 2010

Date	Vernalis		Brandt Bridge		Old River Near Tracy		Old River Near Middle	
	VERec	VER30ec	BDTec	BDT30ec	OLDec	OLD30ec	UNIec	UNI30ec
17-Jul-10	0.46	0.40	0.57	0.39	0.67	0.49	0.59	0.37
18-Jul-10	0.48	0.42	0.57	0.40	0.66	0.50	0.56	0.38
19-Jul-10	0.44	0.43	0.56	0.41	0.67	0.50	0.55	0.39
20-Jul-10	0.47	0.44	0.56	0.42	0.64	0.51	0.53	0.39
21-Jul-10	0.50	0.45	0.54	0.42	0.64	0.51	0.52	0.40
22-Jul-10	0.50	0.46	0.54	0.43	0.59	0.52	0.55	0.40
23-Jul-10	0.47	0.46	0.55	0.43	0.62	0.52	0.58	0.41
24-Jul-10	0.48	0.46	0.56	0.44	0.63	0.53	0.57	0.41
25-Jul-10	0.50	0.46	0.57	0.44	0.65	0.53	0.56	0.42
26-Jul-10	0.52	0.47	0.57	0.45	0.61	0.53	0.57	0.42
27-Jul-10	0.48	0.47	0.58	0.45	0.62	0.54	0.56	0.43
28-Jul-10	0.49	0.47	0.58	0.46	0.62	0.54	0.59	0.44
29-Jul-10	0.48	0.47	0.58	0.47	0.67	0.55	0.55	0.44
30-Jul-10	0.48	0.47	0.58	0.48	0.65	0.55	0.58	0.45
31-Jul-10	0.51	0.47	0.58	0.49	0.66	0.56	0.57	0.46
01-Aug-10	0.52	0.47	0.58	0.50	0.68	0.57	0.57	0.47
02-Aug-10	0.53	0.47	0.58	0.51	0.70	0.58	0.60	0.49
03-Aug-10	0.58	0.48	0.58	0.52	0.68	0.59	0.60	0.50
04-Aug-10	0.60	0.48	0.58	0.53	0.67	0.60	0.62	0.51
05-Aug-10	0.56	0.49	0.56	0.54	0.64	0.61	0.65	0.53
06-Aug-10	0.55	0.49	0.55	0.55	0.67	0.62	0.68	0.56
07-Aug-10	0.55	0.50	0.54	0.55	0.71	0.63	0.66	0.57
08-Aug-10	0.54	0.50	0.54	0.56	0.69	0.64	0.66	0.58
09-Aug-10	0.57	0.51	0.56	0.56	0.69	0.64	0.64	0.58
10-Aug-10	0.58	0.51	0.56	0.56	0.70	0.65	0.63	0.59
11-Aug-10	0.60	0.51	0.56	0.56	0.69	0.66	0.65	0.59
12-Aug-10	0.63	0.52	0.57	0.57	0.71	0.66	0.66	0.59
13-Aug-10	0.63	0.52	0.54	0.56	0.74	0.66	0.70	0.60
14-Aug-10	0.59	0.53	0.51	0.56	0.75	0.67	0.71	0.60
15-Aug-10	0.58	0.53	0.53	0.56	0.78	0.67	0.72	0.61
16-Aug-10	0.60	0.53	0.57	0.56	0.82	0.68	0.68	0.61
17-Aug-10	0.58	0.54	0.59	0.56	0.80	0.68	0.67	0.61
18-Aug-10	0.55	0.54	0.58	0.56	0.74	0.68	0.68	0.62

* Salinity reported as electrical conductivity in milliSiemens per centimeter (mS/cm)

XXXec	XXX30ec	Daily average and 30-day running average electrical conductivity

State of California | The Resources Agency

Memorandum

CDO

RECEIVED
JUN 24 2009
BY:________

Date : June 19, 2009

To : Ms. Dorothy Rice
Executive Director
State Water Resources Control Board
1001 I Street
Sacramento, California 95814

From : Department of Water Resources

Subject : Report of Potential Exceedance of South Delta Water Quality Objectives

This letter is written pursuant to Condition A.4 of the State Water Resource Control Board's (SWRCB) Order WR-2006-0006 (Order) to the Department of Water Resources (DWR) and the United States Bureau of Reclamation (USBR) and is to advise the SWRCB of a potential exceedance of the south Delta water quality objective at Station P-12.

Condition A.4 requires DWR and/or USBR to inform the SWRCB of a potential exceedance of the 0.7 EC South Delta Water Quality Objective at Interagency Stations C-6 (San Joaquin River at Brandt Bridge), C-8 (Old River near Middle River), and P-12 (Old River at Tracy Road Bridge), prior to July 1, 2009.

The June 1, 2009 Quarterly Report that was sent to you (part of the reporting requirements in the Order) states that "The Department is not projecting any further exceedances of south Delta objectives for June through August..." This conclusion was based on modeling (DSM2) projections of south Delta water quality. The report, however, also notes on Page 2 that "These modeling projections do not account for any salinity degradation which may occur downstream of Vernalis and include simplifying assumptions regarding local discharges within the south Delta".

The attached table (Attachment 1) shows both the mean daily EC at each station and the corresponding 30 day running average at all three stations since May 1, 2009. In our May 28, 2009 exceedance letter, we noted that the 0.7 EC objective has been met at all three stations since May 6, 2009. However, on or about May 24, daily water quality, particularly at Station P-12, has begun to steadily degrade as shown by the increasing salinity values in Attachment 1.

DWR wishes to emphasize two key points here. First, combined State Water Project/Central Valley Project exports at Banks and Jones Pumping Plants have been very low over the last two months, averaging 2026 cfs for the entire month of May and

1529 cfs to date in June. The low export rates have occurred due to a combination of extremely dry conditions in the watershed and export restrictions imposed to protect San Joaquin River salmon and delta smelt. Therefore, high export pumping rates are not attributable causes to the current water quality degradation that is being experienced at Station P-12.

Second, and perhaps more importantly, the daily salinity at Station C-10 (San Joaquin River at Airport Way Bridge, Vernalis) has been running at approximately the 0.5 EC range in mid-June, well below the standard of 0.7 EC at this location. In spite of daily EC's at Vernalis in the 0.5 EC range, the corresponding daily EC at Station P-12 (Old River near Tracy Road Bridge) is running at approximately 0.8 EC. Thus, there is a salinity degradation from Vernalis to Tracy Road Bridge of approximately 0.3 EC that is *not* attributable to Vernalis water quality or water project pumping operations.

DWR and Reclamation have provided extensive evidence in the past of the significant salinity degradation that occurs in the south Delta that is beyond the control of, and not attributable to, water project operations. The "real-time" situation that is occurring now provides further and, we believe, conclusive evidence that our concerns are well-founded and reasonable. We sincerely hope the SWRCB and its staff will take this into consideration in future hearings and proceedings related to the appropriateness of current and proposed south Delta water quality objectives and responsibility for implementation of such objectives.

Condition A.4 also requires DWR and USBR to describe any corrective actions they are initiating to avoid the exceedance. There are three actions planned which may help improve south Delta water quality conditions this summer.

Consultation with the U.S. Fish and Wildlife Service on the construction and removal of temporary agricultural barriers for 2009 was only recently concluded. Construction of the barriers began in late May. The Middle River barrier has been completed and it is anticipated that the Old River and Grant Line Canal barriers will be completed and fully operational by June 25, 2009. As we have done in the last two years, the flap gates at the Old River near Tracy barrier will be periodically tied open during the summer to provide additional water quality benefits.

DWR has also applied to the U.S. Army Corps of Engineers and the Department of Fish and Game for a permit modification to allow DWR to raise the weir height of the

Middle River barrier by one foot. Modeling has shown that in combination with tying open culverts at the Old River near Tracy barrier, this modification can improve water circulation and water quality in Old River. DWR hopes to make this modification later this summer after receiving regulatory agency approval.

Lastly, up to 60,000 acre-feet of water is being planned for transfer from the San Joaquin River (primarily from the Stanislaus River) to south of Delta exporters during this summer. The increased flow at Vernalis that would occur as a result of the transfers may help improve south Delta water quality conditions.

Although these actions should benefit salinity conditions, it is highly unlikely that these efforts will be sufficient to avoid exceedances of the 0.7 EC objective given the level of observed degradation.

Other than these actions, no further corrective actions are being contemplated by DWR and/or USBR.

If you have any questions, please contact me at (916) 574-2656 or your staff may contact Mike Ford at (916) 574-2654.

Sincerely,

David H. Roose, Chief
SWP Operations Control Office
Division of Operations and Maintenance

Attachments

cc: (See distribution list.)

Distribution List:

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California Sportfishing Protection Alliance
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Ralph Torres, DWR-1115-9
Carl Torgersen, DWR-605-1
Jerry Johns, DWR-1115-9
John Leahigh, DWR-JOC
Cathy Crothers, DWR-1118
Erick Soderlund, DWR-1118
Kathy Kelly, DWR-215-37
Ron Milligan, USBR
Paul Fujitani, USBR
Jeff Sandberg, USBR
Amy Aufdemberge USBR

PROOF OF SERVICE

I, the undersigned, hereby certify that I am over the age of eighteen (18) years of age and an employee of the State of California Department of Water Resources, 1416 Ninth Street, Sacramento, California 95814

On June 19, 2009, I served true and correct copies of the attached letter to the persons listed on the cc list.

Date: June 19, 2009

Attachment 1

Delta Water Quality Conditions

South Delta Stations

Date	Vernalis		Brandt Bridge		Old River Near Tracy		Old River Near Mid	
ST Date	VERec	VER30ec	BDTec	BDT30ec	OLDec	OLD30ec	UNIec	UNI30ec
01-May-09	0.30	0.5	0.36	0.6	0.59	0.8	0.36	0.7
02-May-09	0.32	0.5	0.35	0.6	0.60	0.8	0.36	0.7
03-May-09	0.33	0.5	0.35	0.6	0.58	0.8	0.38	0.6
04-May-09	0.34	0.5	0.37	0.6	0.58	0.8	0.40	0.6
05-May-09	0.34	0.5	0.38	0.6	0.57	0.8	0.41	0.6
06-May-09	0.32	0.5	0.39	0.5	0.56	0.7	0.41	0.6
07-May-09	0.32	0.4	0.39	0.5	0.54	0.7	0.39	0.6
08-May-09	0.32	0.4	0.37	0.5	0.52	0.7	0.38	0.5
09-May-09	0.32	0.4	0.36	0.5	0.50	0.7	0.37	0.5
10-May-09	0.30	0.4	0.36	0.5	0.49	0.7	0.39	0.5
11-May-09	0.27	0.4	0.36	0.5	0.49	0.7	0.36	0.5
12-May-09	0.26	0.4	0.33	0.5	0.50	0.6	0.33	0.5
13-May-09	0.26	0.4	0.30	0.4	0.46	0.6	0.31	0.5
14-May-09	0.25	0.4	0.30	0.4	0.45	0.6	0.31	0.4
15-May-09	0.26	0.3	0.30	0.4	0.43	0.6	0.31	0.4
16-May-09	0.26	0.3	0.30	0.4	0.46	0.6	0.32	0.4
17-May-09	0.27	0.3	0.31	0.4	0.47	0.6	0.33	0.4
18-May-09	0.28	0.3	0.32	0.4	0.50	0.6	0.33	0.4
19-May-09	0.29	0.3	0.32	0.4	0.50	0.6	0.34	0.4
20-May-09	0.28	0.3	0.32	0.4	0.52	0.5	0.34	0.4
21-May-09	0.26	0.3	0.33	0.4	0.48	0.5	0.36	0.4
22-May-09	0.27	0.3	0.34	0.4	0.48	0.5	0.33	0.4
23-May-09	0.29	0.3	0.33	0.3	0.49	0.5	0.33	0.4
24-May-09	0.30	0.3	0.32	0.3	0.50	0.5	0.34	0.4
25-May-09	0.32	0.3	0.32	0.3	0.57	0.5	0.37	0.4
26-May-09	0.31	0.3	0.33	0.3	0.61	0.5	0.39	0.4
27-May-09	0.32	0.3	0.35	0.3	0.56	0.5	0.42	0.4
28-May-09	0.34	0.3	0.36	0.3	0.61	0.5	0.41	0.4
29-May-09	0.34	0.3	0.38	0.3	0.68	0.5	0.42	0.4
30-May-09	0.35	0.3	0.39	0.3	0.59	0.5	0.44	0.4
31-May-09	0.34	0.3	0.40	0.3	0.60	0.5	0.44	0.4
01-Jun-09	0.34	0.3	0.41	0.3	0.61	0.5	0.44	0.4
02-Jun-09	0.36	0.3	0.42	0.3	0.62	0.5	0.44	0.4
03-Jun-09	0.38	0.3	0.42	0.4	0.61	0.5	0.44	0.4
04-Jun-09	0.42	0.3	0.43	0.4	0.64	0.5	0.46	0.4
05-Jun-09	0.43	0.3	0.43	0.4	0.69	0.5	0.47	0.4
06-Jun-09	0.46	0.3	0.44	0.4	0.71	0.5	0.52	0.4
07-Jun-09	0.45	0.3	0.45	0.4	0.74	0.6	0.55	0.4
08-Jun-09	0.45	0.3	0.47	0.4	0.77	0.6	0.58	0.4
09-Jun-09	0.45	0.3	0.51	0.4	0.76	0.6	0.57	0.4
10-Jun-09	0.46	0.3	0.53	0.4	0.73	0.6	0.55	0.4
11-Jun-09	0.47	0.3	0.54	0.4	0.74	0.6	0.58	0.4
12-Jun-09	0.48	0.4	0.54	0.4	0.75	0.6	0.58	0.4
13-Jun-09	0.49	0.4	0.55	0.4	0.77	0.6	0.60	0.4
14-Jun-09	0.49	0.4	0.56	0.4	0.81	0.6	0.61	0.4

15-Jun-09	0.52	0.4	0.57	0.4	0.82	0.6	0.64	0.5
16-Jun-09	0.55	0.4	0.59	0.4	0.87	0.6	0.64	0.5
17-Jun-09	0.56	0.4	0.60	0.4	0.88	0.7	0.64	0.5
18-Jun-09	0.56	0.4	0.60	0.4	0.85	0.7	0.68	0.5

United States Department of the Interior

BUREAU OF RECLAMATION
Central Valley Operation Office
3310 El Camino Avenue, Suite 300
Sacramento, California 95821

DEPARTMENT OF WATER RESOURCES
Division of Operations and Maintenance
3310 El Camino Avenue, Suite 300
Sacramento, California 95821

AUG 20 2012

IN REPLY REFER TO:
CVO-100
WTR-4.10

Thomas Howard
Executive Director
State Water Resources Control Board
1001 I Street
Sacramento, California 95814

Subject: Report of Exceedance of South Delta Water Quality Agricultural Objective at Old River at Tracy Road Bridge Station

Dear Mr. Howard:

Pursuant to Condition A.10 of the State Water Resources Control Board's (SWRCB) Order WR 2010-0002 (Order) to the Department of Water Resources (DWR) and the United States Bureau of Reclamation (Reclamation), DWR and Reclamation advise SWRCB of an exceedance of the 30-day average 0.7 millimhos per centimeter (mmhos/cm) electrical conductivity (EC) South Delta Water Quality Objective at Old River at Tracy Road Bridge (Station P-12) on August 6, 2012.

The attached table (Attachment 1) shows that the 30 day running average EC at Station P-12 was 0.8 on August 6, exceeding the 0.7 objective. The date of exceedance was determined by rounding the 30-day average values to the nearest one-tenth EC value. The objective continues to be exceeded at the present time. In contrast the EC readings at the other two Interagency Stations, San Joaquin River at Brandt Bridge (Station C-6) and Old River near Middle River (Station C-8), are 0.6 EC and continue to be below the objective salinity level. The Vernalis station (C-10) also has been reading low salinity levels on par with Stations C-6 and C-8. This anomaly at Station P-12 has been noted in several correspondences in the past and continues to be a problem for all agencies involved.

In April 2008, DWR and Reclamation provided evidence demonstrating that the significant salinity degradation that occurs in the south Delta is beyond the control of, and not attributable to, water project operations. DWR and Reclamation have also demonstrated that the response of the water quality at Station P-12, in particular, to improved flow conditions is much different than the response at the other interior south Delta stations. In the exceedance letter provided earlier this year (dated April 23, 2012), DWR and Reclamation further demonstrated that there is a severe degradation in water quality from Vernalis to the south Delta stations. As such, we concluded that additional actions, other than those already in place and described below, would not be implemented as they would unlikely be sufficient to avoid continued exceedance of the water quality objective at Station P-12.

As you know, DWR and Reclamation continue to coordinate several actions to help improve overall salinity conditions in the south Delta. The actions being implemented are as follows:

1. Continued operation of the temporary agricultural barriers, which includes intermittently tying open the flapgates at the Old River near Tracy barrier from time to time during the summer to provide additional water quality benefits while balancing the effect upon water levels. Attached modeling (Attachment 2) shows the effect of flapgate operations on water levels and water quality in graphical form.

2. Tidally operating the flapgates on the Grant Line Canal barrier and raising the weir of the Middle River Barrier by one foot to improve circulation in the south Delta. These actions were completed on June 29 and July 3, respectively.

Lastly, Condition A.10 requires DWR and Reclamation to identify the amount of water project supplies remaining for beneficial uses following corrective actions. Since no additional corrective actions are being contemplated by DWR or Reclamation, project supplies are estimated as those needed to meet applicable D-1641 requirements, Endangered Species Act needs for 2012, requirements of the NMFS and U.S. Fish and Wildlife Service Biological Opinions and the Department of Fish and Game's Incidental Take Permit, and contractual obligations to water project users.

If you have any questions or would like more information regarding the above notification, please contact Mr. Paul Fujitani of Reclamation at 916-979-2197 or Mr. John Leahigh at 916-574-2722.

Sincerely,

for Ronald Milligan, Operations Manager
Central Valley Operations Office
Bureau of Reclamation

David H. Roose, Chief
SWP Operations Control Office
Department of Water Resources

Attachments - 2

cc: See next page.

cc: John Herrick, Esq.
South Delta Water Agency
4255 Pacific Avenue, Suite 2
Stockton, California 95207

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Delta Watermaster
State Water Resources Control Board
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Sacramento, California 95812

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Attachment 1

Delta Water Quality Conditions

(Daily and 30-day Averages)

Delta Water Quality Conditions*

Date	Vernalis		Brandt Bridge		Old River Near Tracy		Old River Near Middle	
	VERec	VER30ec	BDTec	BDT30ec	OLDec	OLD30ec	UNIec	UNI30ec
14-Jul-12	0.6	0.4	0.5	0.5	0.8	0.6	0.7	0.5
15-Jul-12	0.6	0.4	0.5	0.5	0.8	0.6	0.6	0.5
16-Jul-12	0.5	0.4	0.6	0.5	0.8	0.6	0.7	0.5
17-Jul-12	0.6	0.4	0.6	0.5	0.7	0.6	0.7	0.5
18-Jul-12	0.6	0.4	0.6	0.5	0.8	0.6	0.6	0.5
19-Jul-12	0.5	0.5	0.6	0.5	0.8	0.6	0.7	0.5
20-Jul-12	0.6	0.5	0.6	0.5	0.8	0.6	0.7	0.5
21-Jul-12	0.5	0.5	0.6	0.5	0.8	0.6	0.6	0.5
22-Jul-12	0.5	0.5	0.6	0.5	0.8	0.7	0.7	0.5
23-Jul-12	0.5	0.5	0.6	0.5	0.8	0.7	0.7	0.5
24-Jul-12	0.6	0.5	0.6	0.5	0.7	0.7	0.6	0.6
25-Jul-12	0.5	0.5	0.6	0.5	0.8	0.7	0.6	0.6
26-Jul-12	0.5	0.5	0.6	0.5	0.8	0.7	0.6	0.6
27-Jul-12	0.5	0.5	0.6	0.5	0.8	0.7	0.7	0.6
28-Jul-12	0.5	0.5	0.6	0.5	0.8	0.7	0.6	0.6
29-Jul-12	0.5	0.5	0.6	0.6	0.8	0.7	0.6	0.6
30-Jul-12	0.5	0.5	0.6	0.6	0.8	0.7	0.6	0.6
31-Jul-12	0.5	0.5	0.6	0.6	0.7	0.7	0.6	0.6
01-Aug-12	0.5	0.5	0.6	0.6	0.7	0.7	0.6	0.6
02-Aug-12	0.5	0.5	0.6	0.6	0.7	0.7	0.6	0.6
03-Aug-12	0.6	0.5	0.6	0.6	0.7	0.7	0.6	0.6
04-Aug-12	0.6	0.5	0.6	0.6	0.7	0.7	0.6	0.6
05-Aug-12	0.5	0.5	0.7	0.6	0.7	0.7	0.6	0.6
06-Aug-12	0.5	0.5	0.7	0.6	0.8	0.8	0.7	0.6
07-Aug-12	0.5	0.5	0.7	0.6	0.8	0.8	0.7	0.6
08-Aug-12	0.5	0.5	0.7	0.6	0.8	0.8	0.6	0.6
09-Aug-12	0.5	0.5	0.6	0.6	0.8	0.8	0.6	0.6
10-Aug-12	0.5	0.5	0.6	0.6	0.8	0.8	0.6	0.6
11-Aug-12	0.6	0.5	0.6	0.6	0.7	0.8	0.6	0.6
12-Aug-12	0.6	0.5	0.6	0.6	0.7	0.8	0.6	0.6
13-Aug-12	0.5	0.5	0.6	0.6	0.7	0.8	0.6	0.6

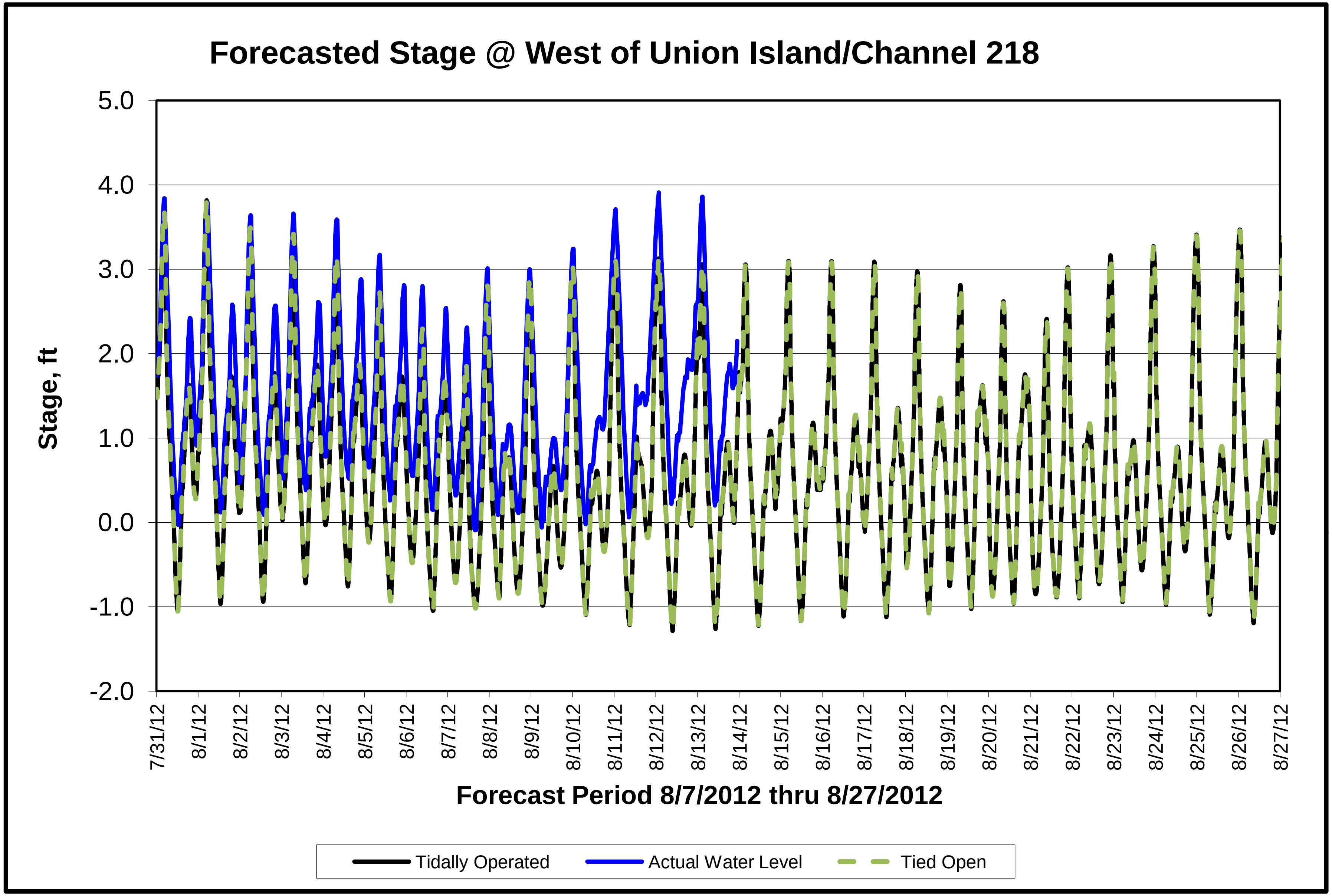
* Salinity reported as electrical conductivity in milliSiemens per centimeter (mS/cm)

XXXec	XXX30ec	Daily average and 30-day running average electrical conductivity

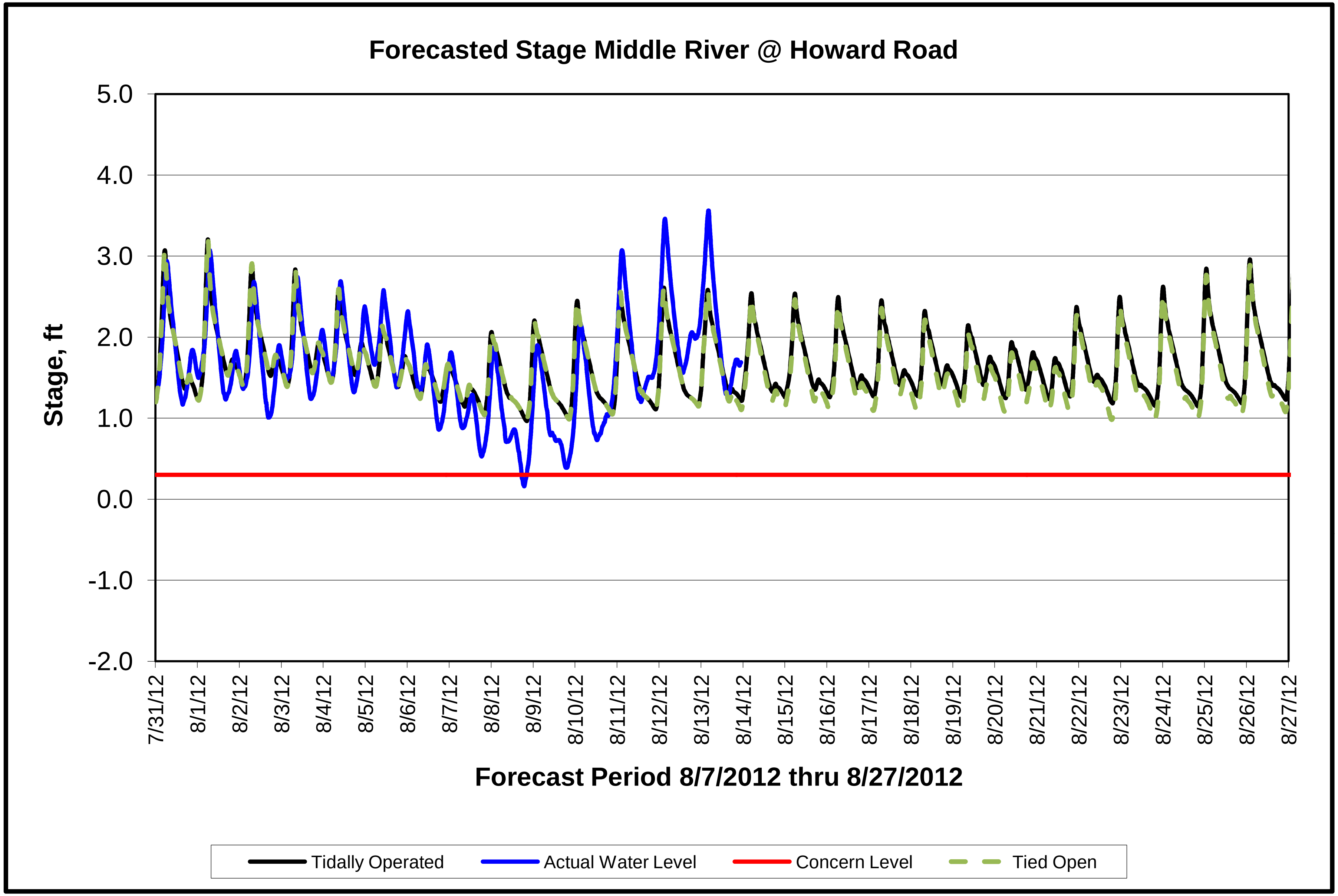
Attachment 2

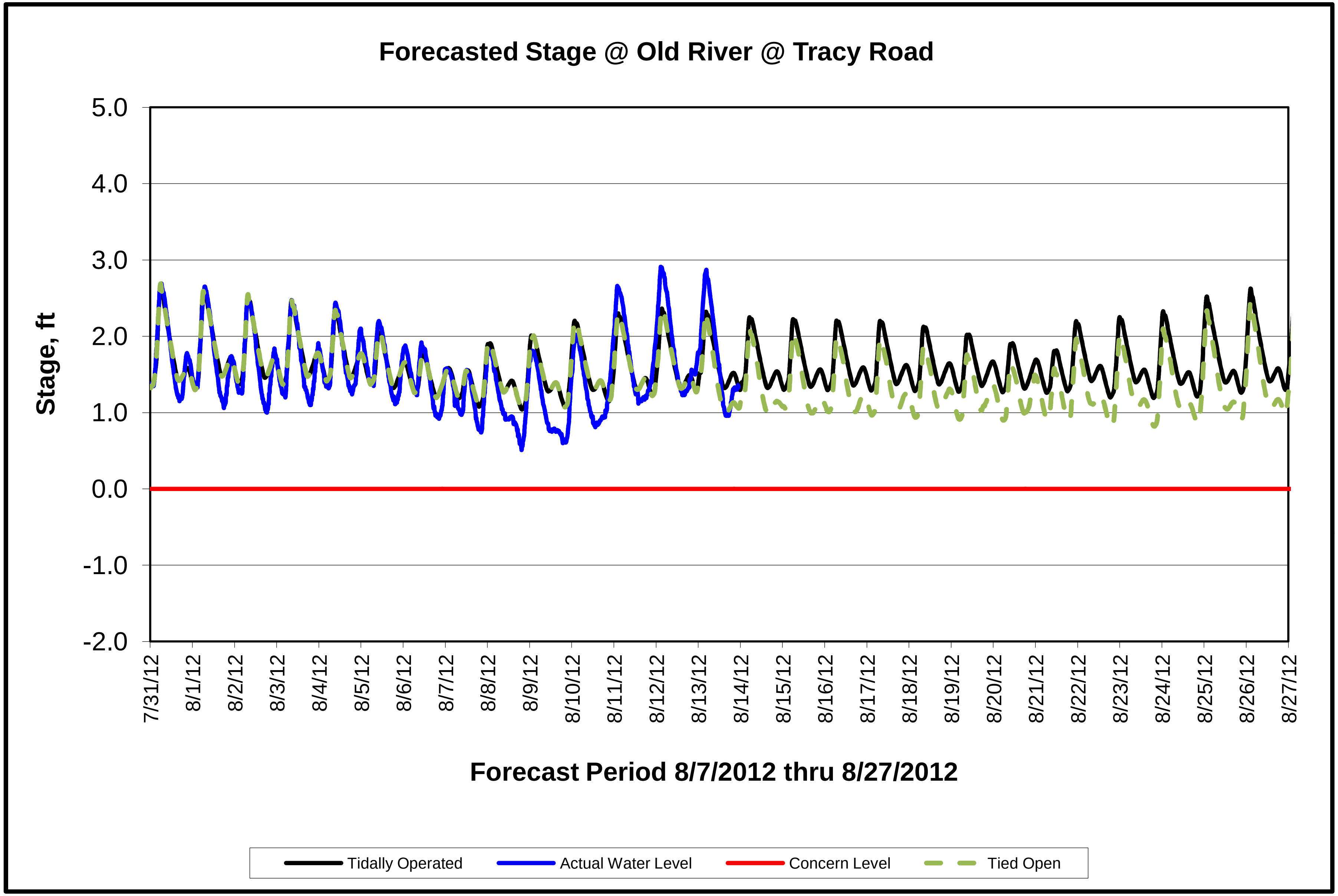
DSM2 Modeling Results
of
Water Quality and Water Levels

(July 31 - August 27)

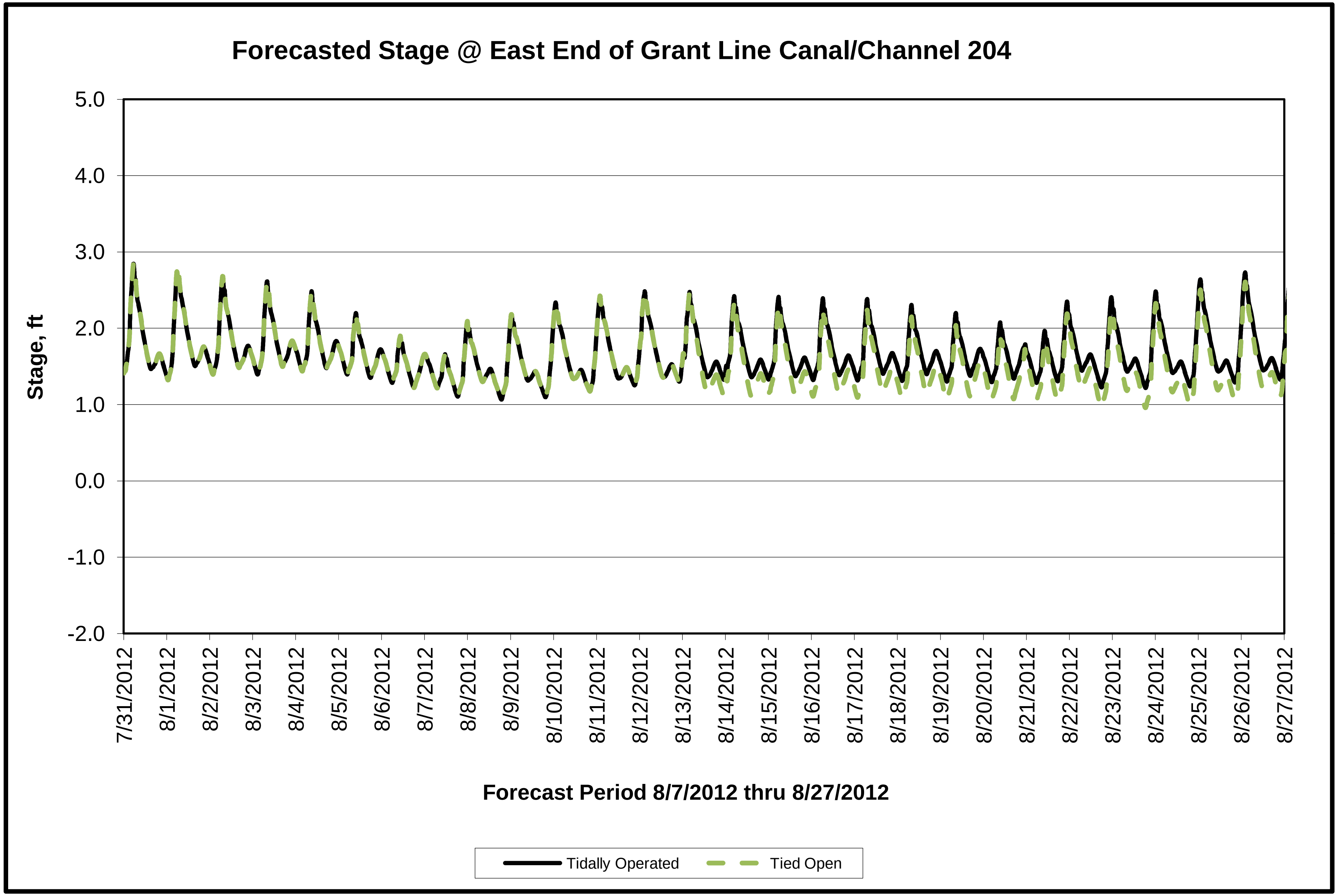


Forecasted Stage @ West of Union Island/Channel 218
Stage, ft
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
7/31/12
8/1/12
8/2/12
8/3/12
8/4/12
8/5/12
8/6/12
8/7/12
8/8/12
8/9/12
8/10/12
8/11/12
8/12/12
8/13/12
8/14/12
8/15/12
8/16/12
8/17/12
8/18/12
8/19/12
8/20/12
8/21/12
8/22/12
8/23/12
8/24/12
8/25/12
8/26/12
8/27/12
Forecast Period 8/7/2012 thru 8/27/2012
Tidally Operated
Actual Water Level
Tied Open

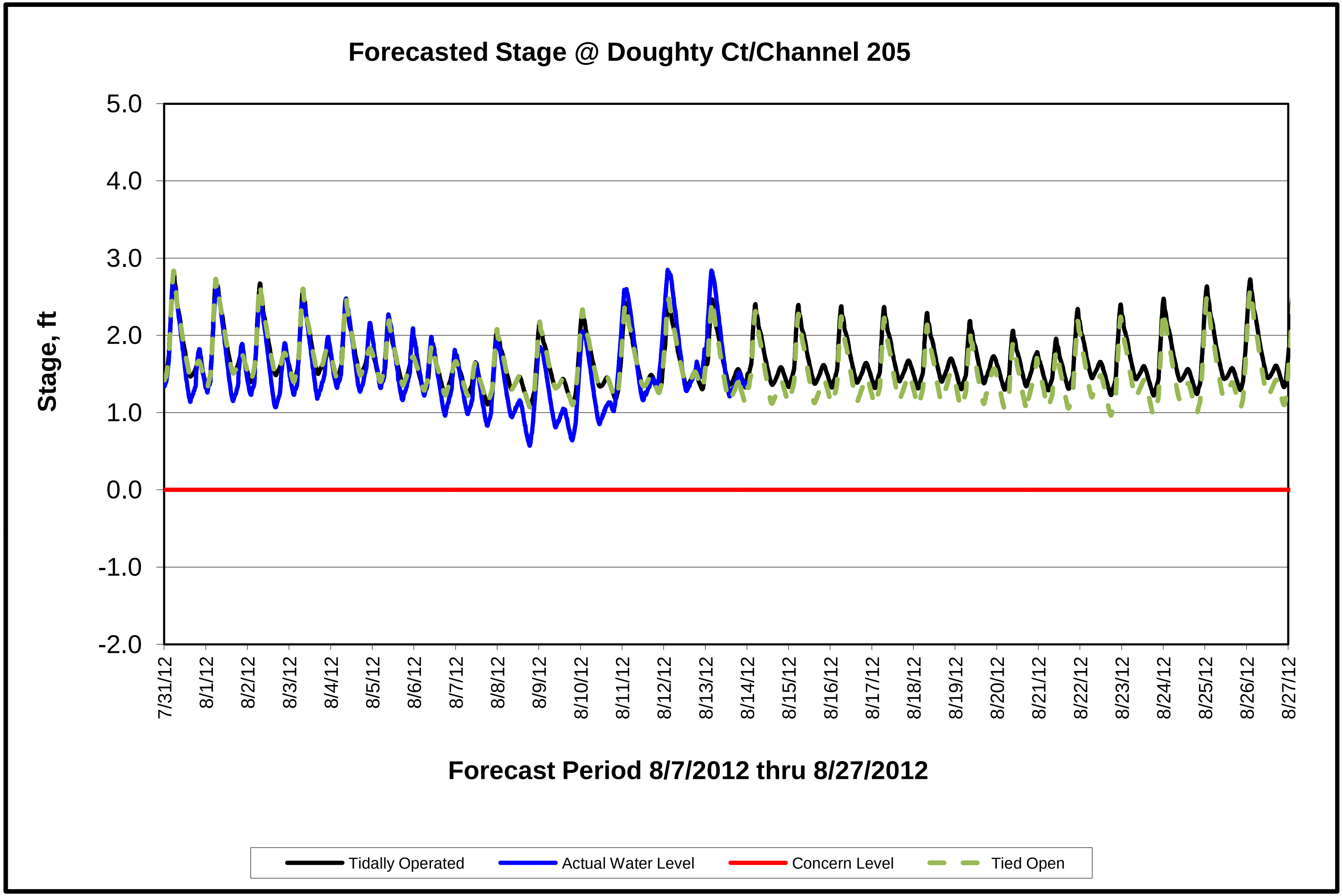

Forecasted Stage Middle River @ Howard Road
Stage, ft
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
7/31/12
8/1/12
8/2/12
8/3/12
8/4/12
8/5/12
8/6/12
8/7/12
8/8/12
8/9/12
8/10/12
8/11/12
8/12/12
8/13/12
8/14/12
8/15/12
8/16/12
8/17/12
8/18/12
8/19/12
8/20/12
8/21/12
8/22/12
8/23/12
8/24/12
8/25/12
8/26/12
8/27/12
Forecast Period 8/7/2012 thru 8/27/2012
Tidally Operated
Actual Water Level
Concern Level
Tied Open



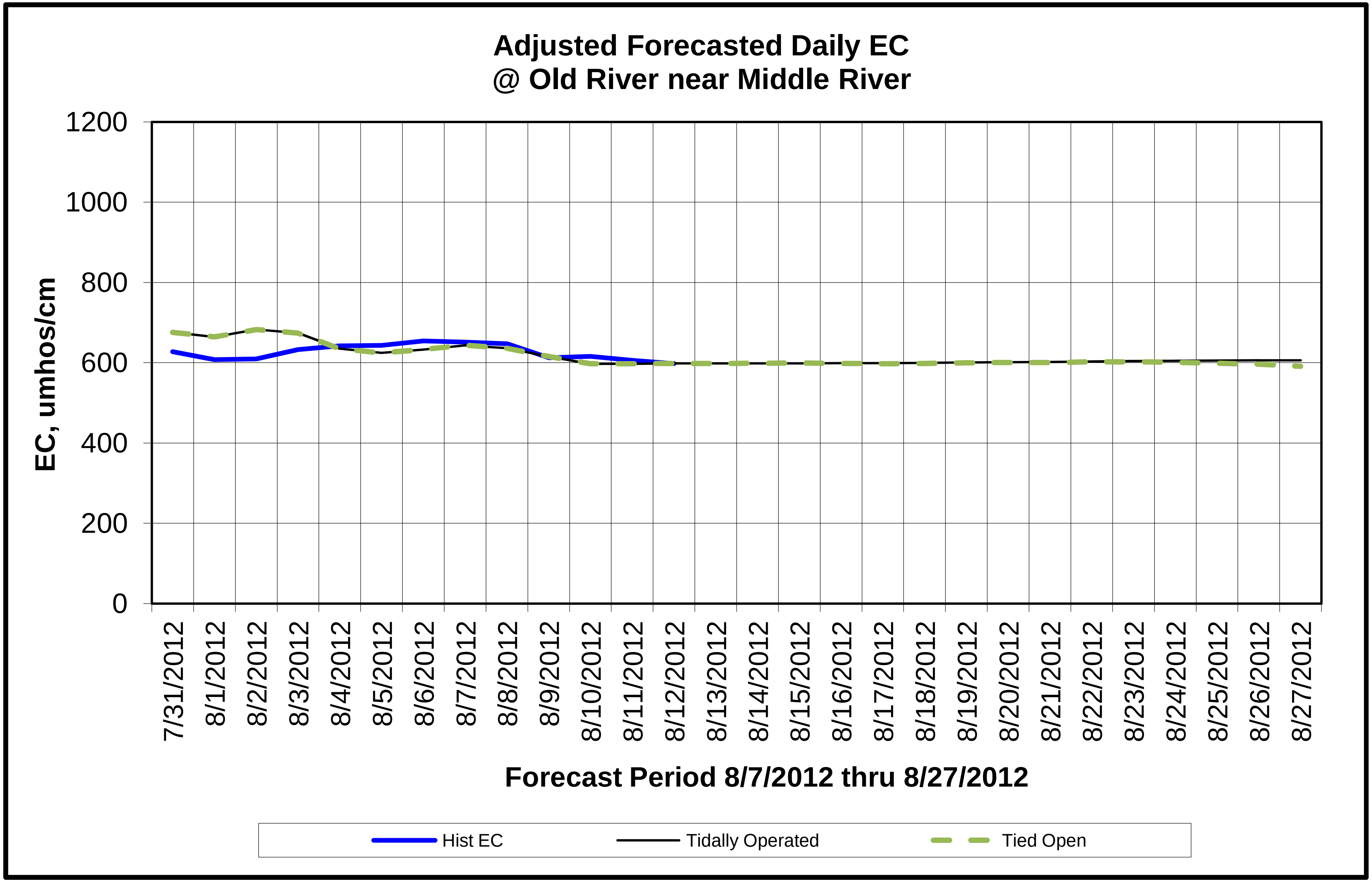
Forecasted Stage @ Old River @ Tracy Road
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
Stage, ft
7/31/12
8/1/12
8/2/12
8/3/12
8/4/12
8/5/12
8/6/12
8/7/12
8/8/12
8/9/12
8/10/12
8/11/12
8/12/12
8/13/12
8/14/12
8/15/12
8/16/12
8/17/12
8/18/12
8/19/12
8/20/12
8/21/12
8/22/12
8/23/12
8/24/12
8/25/12
8/26/12
8/27/12
Forecast Period 8/7/2012 thru 8/27/2012
Tidally Operated
Actual Water Level
Concern Level
Tied Open



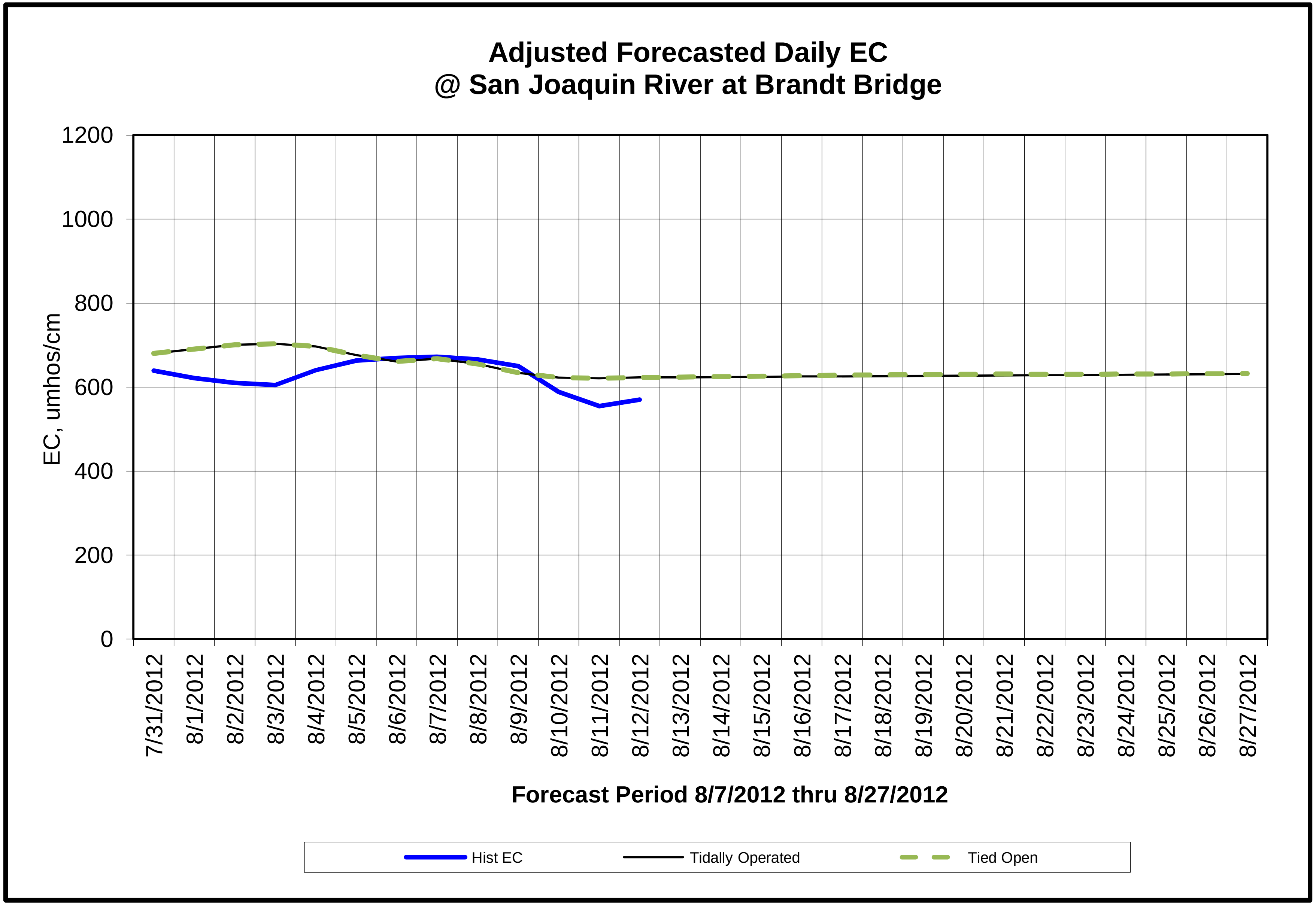
Forecasted Stage @ East End of Grant Line Canal/Channel 204
Stage, ft
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
7/31/2012
8/1/2012
8/2/2012
8/3/2012
8/4/2012
8/5/2012
8/6/2012
8/7/2012
8/8/2012
8/9/2012
8/10/2012
8/11/2012
8/12/2012
8/13/2012
8/14/2012
8/15/2012
8/16/2012
8/17/2012
8/18/2012
8/19/2012
8/20/2012
8/21/2012
8/22/2012
8/23/2012
8/24/2012
8/25/2012
8/26/2012
8/27/2012
Forecast Period 8/7/2012 thru 8/27/2012
Tidally Operated
Tied Open



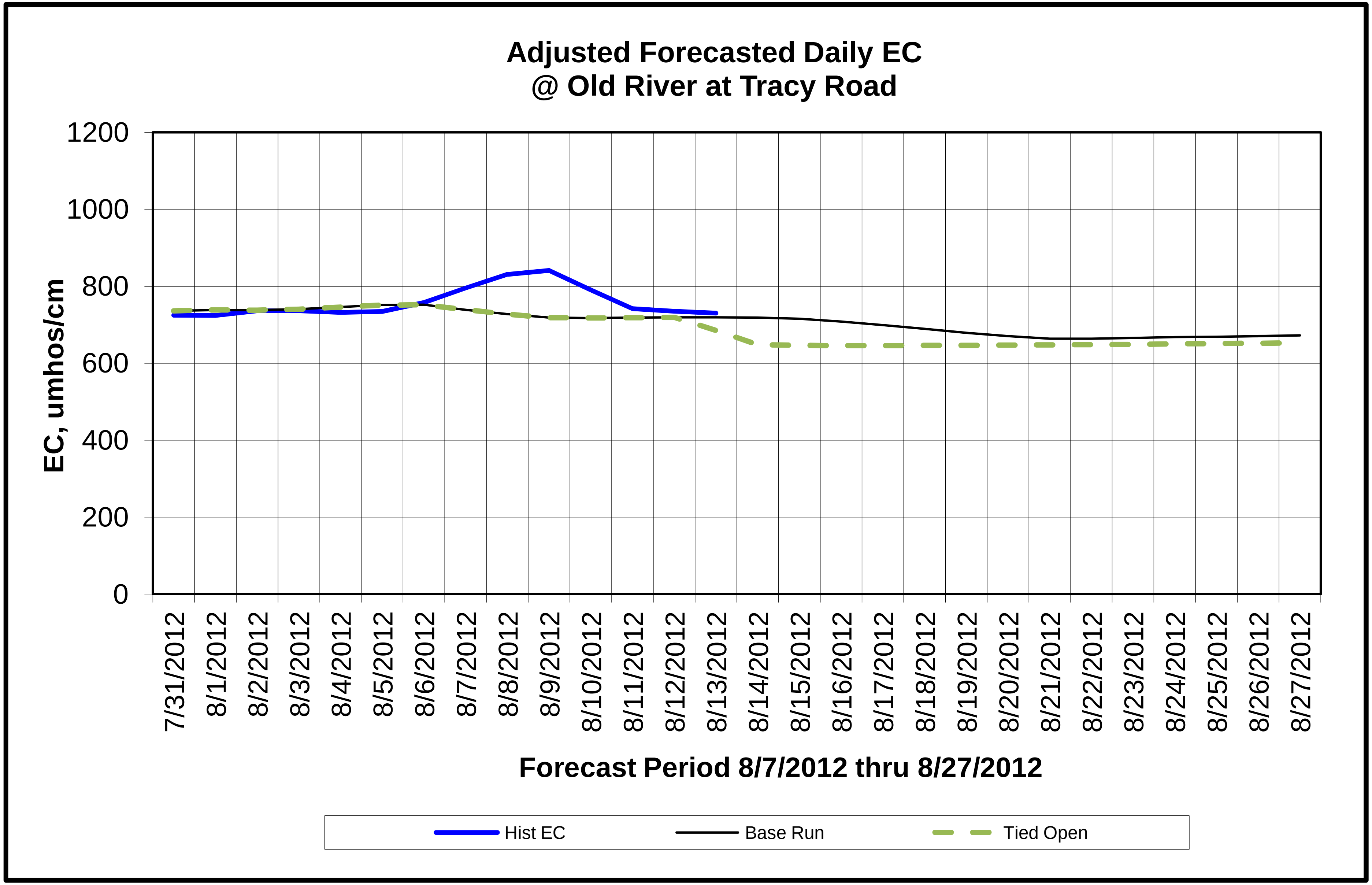
Forecasted Stage @ Doughty Ct/Channel 205
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
Stage, ft
7/31/12
8/1/12
8/2/12
8/3/12
8/4/12
8/5/12
8/6/12
8/7/12
8/8/12
8/9/12
8/10/12
8/11/12
8/12/12
8/13/12
8/14/12
8/15/12
8/16/12
8/17/12
8/18/12
8/19/12
8/20/12
8/21/12
8/22/12
8/23/12
8/24/12
8/25/12
8/26/12
8/27/12
Forecast Period 8/7/2012 thru 8/27/2012
Tidally Operated
Actual Water Level
Concern Level
Tied Open



Adjusted Forecasted Daily EC
@ Old River near Middle River
EC, umhos/cm
1200
1000
800
600
400
200
0
7/31/2012
8/1/2012
8/2/2012
8/3/2012
8/4/2012
8/5/2012
8/6/2012
8/7/2012
8/8/2012
8/9/2012
8/10/2012
8/11/2012
8/12/2012
8/13/2012
8/14/2012
8/15/2012
8/16/2012
8/17/2012
8/18/2012
8/19/2012
8/20/2012
8/21/2012
8/22/2012
8/23/2012
8/24/2012
8/25/2012
8/26/2012
8/27/2012
Forecast Period 8/7/2012 thru 8/27/2012
Hist EC
Tidally Operated
Tied Open



Adjusted Forecasted Daily EC
@ San Joaquin River at Brandt Bridge
EC, umhos/cm
1200
1000
800
600
400
200
0
7/31/2012
8/1/2012
8/2/2012
8/3/2012
8/4/2012
8/5/2012
8/6/2012
8/7/2012
8/8/2012
8/9/2012
8/10/2012
8/11/2012
8/12/2012
8/13/2012
8/14/2012
8/15/2012
8/16/2012
8/17/2012
8/18/2012
8/19/2012
8/20/2012
8/21/2012
8/22/2012
8/23/2012
8/24/2012
8/25/2012
8/26/2012
8/27/2012
Forecast Period 8/7/2012 thru 8/27/2012
Hist EC
Tidally Operated
Tied Open


Adjusted Forecasted Daily EC
@ Old River at Tracy Road
EC, umhos/cm
1200
1000
800
600
400
200
0
7/31/2012
8/1/2012
8/2/2012
8/3/2012
8/4/2012
8/5/2012
8/6/2012
8/7/2012
8/8/2012
8/9/2012
8/10/2012
8/11/2012
8/12/2012
8/13/2012
8/14/2012
8/15/2012
8/16/2012
8/17/2012
8/18/2012
8/19/2012
8/20/2012
8/21/2012
8/22/2012
8/23/2012
8/24/2012
8/25/2012
8/26/2012
8/27/2012
Forecast Period 8/7/2012 thru 8/27/2012
Hist EC
Base Run
Tied Open

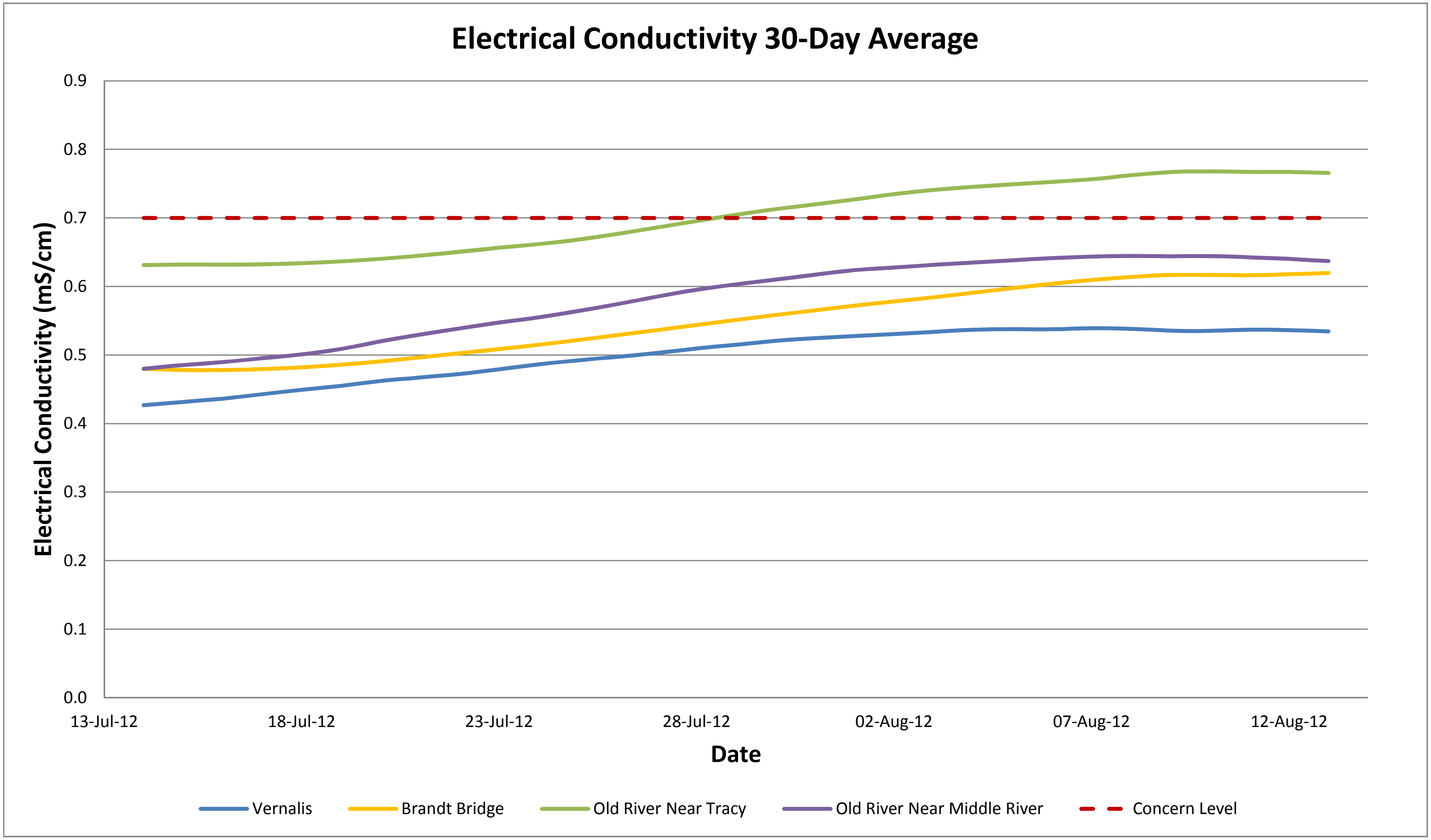

Electrical Conductivity 30-Day Average
Electrical Conductivity (mS/cm)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
13-Jul-12
18-Jul-12
23-Jul-12
28-Jul-12
02-Aug-12
07-Aug-12
12-Aug-12
Date
Vernalis
Brandt Bridge
Old River Near Tracy
Old River Near Middle River
Concern Level

Exhibit “L”

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
GOODWIN J. KNIGHT, Governor
HARVEY O. BANKS, Director of Water Resources

INVESTIGATION OF THE SACRAMENTO-SAN JOAQUIN DELTA

Report No. 4

QUANTITY AND QUALITY OF WATERS APPLIED TO AND DRAINED FROM THE DELTA LOWLANDS

JULY 1956

TABLE OF CONTENTS

Table of Contents - Continued

TABLES

(Following Text)

Tables - Continued

Table No.

PLATES

(Following Tables)

Plate No.

ACKNOWLEDGMENT

Valuable assistance and data used in this investigation were contributed by many individuals and by public and private agencies. Their cooperation is gratefully acknowledged; it greatly facilitated the collection and compilation of data contained in this report.

ORGANIZATION

Water Project Authority

of the

State of California

Frank B. Durkee, Director of Public Works
Chairman

Edmund G. Brown
Attorney General

Charles G. Johnson
State Treasurer

John M. Peirce
Director of Finance

Robert C. Kirkwood
State Controller

Harvey O. Banks, State Engineer
Executive Officer

Isabel C. Nessler
Acting Secretary

- - - - -

Effective July 5, 1956, the Water Project Authority was abolished and its functions, duties and responsibilities assigned to the Department of Water Resources by Chapter 52, Statutes of 1956.

Harvey O. Banks	Director of Water Resources
W. J. Shelton	Deputy Director of Water Resources
William L. Berry	Chief, Division of Water Resources Planning

Activities covered by this report were conducted by the staff of the Water Project Authority under the direction of

Irvin M. Ingerson	Principal Hydraulic Engineer

assisted by

Wayne MacRostie	Supervising Hydraulic Engineer

- - - -

The field and office work for this investigation were supervised by and this report was prepared by

Sam Kabakov	Senior Hydraulic Engineer

Field and Office Assistants

William G. Brigance	Assistant Civil Engineer
George W. Deatherage	Assistant Hydraulic Engineer
Walter Fisher	Assistant Hydraulic Engineer
Roger R. Lindholm	Assistant Hydraulic Engineer

INVESTIGATION

of the

SACRAMENTO-SAN JOAQUIN DELTA

Report No. 4

QUANTITY AND QUALITY OF WATERS APPLIED TO AND DRAINED FROM THE DELTA LOWLANDS

* * *

PART I - INTRODUCTION

This series of five reports is designed to furnish new and additional factual data collected during the past three years, with analyses thereof, that are germane to those hydrologic problems in the State's water development programs which involve the use of Delta channels as conveyance conduits and as sources of diversion.

The Sacramento-San Joaquin Delta lies in the Central Valley of California and embraces the confluent channels and tributaries of the Sacramento River entering from the north, the Mokelumne and Calaveras Rivers entering from the east, and of the San Joaquin River entering from the south. The Delta is comprised of a block of nearly 400,000 acres of irrigated agricultural land interlaced by more than 600 miles of tidal channels which in turn surround more than 50 islands lying at or below sea-level and which are protected by levees.

The strategic geographic location of the Delta makes it the pivotal conveyance link across which the surplus water supplies of the northern portion of the State must be transported to the water-deficient areas of the central and southern portion to permit the continued agricultural, industrial, and municipal growth of those areas. The Central Valley Project has been designed, constructed, and put into operation to take advantage of the Delta channels to convey some 5,000 second-feet of the surplus Sacramento Valley waters to the south into the San Joaquin Valley. The plans of the Feather River Project call for the transfer and conveyance of an additional 11,000 second-feet through these same tidal Delta channels.

Despite the recognized importance of the pivotal position the Delta plays, or will play, in major programs of water development in California, there has been a dearth of geologic, hydraulic, hydrologic, and salinic information of the physical phenomena present. Such information is essential for intelligent planning of water transfer across the Delta area. On the other hand, the fruition of such water transfer plans must include solutions to problems of flood control, water utilization, and water disposal within the Delta area itself. The solutions will involve plans for optimum fresh-water distribution, saline-water drainage disposal, and degrees of channel salinity control to satisfy agricultural and industrial needs. The data and their analyses as presented in this series of reports are germane and essential to solutions of these Delta problems.

An investigation so comprehensive as to cover and report upon all of the facets of pertinent knowledge concerning the Delta area would be prohibitive in cost at this time. This series of reports perforce is limited to some of these facets, namely, ground water geology, water source and water utilization phenomena on two of the Delta islands, quantities and qualities of applied water and of drainage water in the Delta, and the extent of sea-water incursion in Delta channels.

This report is the fourth in this series and deals with some of the hydrographic and salinic aspects of water supply and water disposal in the Delta.

Purpose of This Investigation

One purpose of this investigation was to determine the monthly and seasonal quantities of water applied to the irrigated crops in the Delta Lowlands. This investigation was initiated in 1954 prior to, but in anticipation of, the "Sacramento River and Delta Trial Water Distribution Agreement for 1955" in which the State agreed to undertake "studies to ascertain the quantity of water required by water users diverting in and from the Delta".

Another purpose of this investigation was to determine the extent and sources of degradation in quality of the channel waters as they move from the Sacramento River to the Tracy Pumping Plant.

Area Under Investigation

For purposes of this report, the area under investigation, as delineated on Plate 1, will be called the "Delta Lowlands" and includes lands bordering the Sacramento and San Joaquin Rivers and their distributaries within the Delta area. The Delta Lowlands refer to those areas in the Sacramento-San Joaquin Delta consisting generally of the lands lying below an elevation of plus five, mean sea-level datum, and which, for the most part, consume water not susceptible to direct measurement since such water is largely derived from Delta channels by percolation or by numerous unratable siphons.

The Delta Lowlands comprise a land and water area of approximately 469,000 acres of which about 374,000 acres are developed for agricultural purposes and of which approximately 292,000 acres were irrigated in 1955.

The surface soils in the area embrace a large number of soil classes. The sedimentary mineral soil classes range from loamy sand to clay while the organic soil classes range from mucky loam to peat. Generally the organic soils are concentrated in the central part of the Delta. The purest organic soils (peats) vary in thickness from zero to over 30 feet and overlie mineral soils. Sedimentary soils generally lie along the Delta channels and cover the island areas lying above sea level.

Related Investigations and Reports

The following investigations and reports covering the Sacramento-San Joaquin Delta and adjacent areas were reviewed in connection with the current investigation:

California State Department of Public Works, Division of Water Resources. "Variation and Control of Salinity in Sacramento-San Joaquin Delta and Upper San Francisco Bay", Bulletin No. 27, 1931.

- - -"Putah Creek Cone Investigation", December 1955.

- - -"Sacramento River and Sacramento-San Joaquin Delta, Trial Water Distribution 1955, Summary Report of Data", January 1956.

- - -Water Quality Investigations, Report No. 7 "Quality of Ground Water in the Stockton Area, San Joaquin County", March 1955.

California State Water Resources Board. "San Joaquin County Investigation" Bulletin No. 11, June 1955.

United States Department of Agriculture, Bureau of Plant Industry. "Soil Survey, Dixon Area, California".

- - -"Soil Survey, Tracy Area, California".

- - -"Soil Survey, Sacramento-San Joaquin Delta Area California".

University of California, College of Agriculture. "Soils of Sacramento County". Weir, Walter W., April 1950.

Scope of This Investigation and Report

The period of field investigation covered by this report extended from May, 1954, through October, 1955.

Field observations covered the following activities: (1) determining the amount of water applied on sample fields for the six major irrigated crops of the Delta Lowlands; (2) collecting surface water samples from drains and from Delta channels for mineral analyses; and (3) observing specific conductance of surface waters in drains and in Delta channels. Office studies included: (1) determining the quantity of waters applied to the Delta Lowlands; (2) determining from specific conductance observations the concentration of dissolved minerals in surface waters in drains and in Delta channels; and (4) the quantitative net degradation of water in Delta channels by saline drainage water from the Delta lands was determined from observed data giving both the quality and the quantity of water applied to and drained from those lands.

This report is divided into six parts: (1) Introduction, (2) Water Applied to Irrigated Crops of the Delta Lowlands, (3) Water Drained from the Delta Lowlands, (4) Water Supply and Disposal, (5) Quality of Water, and (6) Summary and Conclusions.

PART II - WATER APPLIED TO IRRIGATED CROPS OF THE DELTA LOWLANDS

This section deals with the determination of the amounts of water applied on the six major irrigated crops of the Delta Lowlands. The term "applied water" as used in this report refers only to that water which is diverted from channels by pumps or siphons and generally delivered for irrigation use in the immediate vicinity.

Irrigation Practices

Irrigation practices throughout the Delta Lowlands vary with the crop, soil type, depth to water table, quality of channel water available, and the irrigator's past experience and judgment.

In the areas of highly organic soil, subirrigation is used extensively. In this method temporary ditches, spaced about 30 feet apart and approximately 6 inches wide and 12 to 18 inches deep, are used to distribute the water through the fields. Raising the water level in the ditches by means of control structures causes horizontal movement of water through the soil resulting in subirrigation of the crops.

In the moderately organic and in the mineral soils, row crops are generally irrigated by the use of furrow-type irrigation. Alfalfa and pasture are generally irrigated by the use of strip-check irrigation. Sprinkler irrigation is used on many higher-elevation mineral and organic soil areas in the Delta both for its beneficial leaching effects as well as for the better control over the water than can be achieved in furrow irrigation.

Most irrigation takes place in the late Spring and Summer. However, some irrigators apply a large quantity of water in the early Spring before planting to increase the moisture content of the soil in the expectation of early seed germination.

The increase in salinity of the channel waters during the summer period causes some farm operators in the western portion of the Delta to cease irrigation during that period because of the deleterious effects of applying highly-saline water to crops. Waters are applied in the fall and winter seasons primarily to leach accumulated salts from the soils.

Some irrigators divert waters to their lands during the summer in excess of their requirements because ample water is available at practically no additional cost to them. Water conservation would be enhanced if more careful use of water were practiced.

Soil Types

A division of the Delta by soil types was estimated from data on soil maps embracing the Delta area compiled jointly by the United States Department of Agriculture and University of California. For purposes of this investigation the agricultural lands in the Delta area were divided, as shown on Plate 1, into three soil types: (1) north mineral, (2) middle organic, and (3) south mineral. These types cover approximately 121,000 acres, 192,000 acres, and 61,000 acres respectively. These acreages comprise, respectively, about 33 per cent, 51 per cent, and 16 per cent of the total Delta Lowlands area developed for agricultural purposes.

Land Use

A comprehensive land-use survey was made in 1955 by the State Division of Water Resources, the results of which are detailed in that Division's report titled "Sacramento River and Sacramento-San Joaquin Delta, Trial Water Distribution 1955, Summary Report of Data". A summary from that report is shown in Table 1. For purposes of this investigation the areas of the exterior water surface and of the islands in the channels were excluded, leaving an area of 419,439 acres considered as the "Delta Lowlands".

Crops Investigated

As shown in Table 1 the seven major crops grown in 1955 on the Delta Lowlands were: (1) asparagus, (2) field corn, (3) alfalfa, (4) sugar beets, (5) tomatoes, (6) pasture, and (7) milo. Table 2 herein shows the irrigated acreages and the percentage of total irrigated area for each of the seven major crops and for all other crops as a single value.

Unit Application of Water

Quantities of water applied were estimated by measurements on six of the seven irrigated major crops in the Delta area in 38 sample fields totaling 3,369 acres. Locations of these fields are shown on Plate 1. Each of these 38 sample fields was investigated separately and records of applied-water quantities were obtained. The fields were selected as typifying the soil, irrigation practices, and crops grown on each of the three soil types in the Delta Lowlands. As expected, irrigation practices, soil types in the Delta, and varying amounts of seepage, resulted in varying amounts of water applied to the irrigated crops. The length of the irrigation season also varied, for different crops, from one to eight months.

Although this investigation started in May, 1954, quantities of water applied to the sample fields earlier in the year were estimated from data on power consumption and/or from water users' records.

The unit applied-water factor for the seventh major crop, milo, was estimated from other available data. The estimated applied water during the irrigation season for milo, as determined from experiments by the University of California at Davis, is 1.0 acre-foot per acre. Data in the Division of Water Resources report "San Joaquin County Investigation" indicates that 0.7 acre-foot per acre was applied to an 80-acre test plot of milo. For purposes of this present report, 1.0 acre-foot per acre was used as the applied-water factor for milo for the entire Delta area. No measurements were made for certain major crops in each of the three soil-type areas because of (1) lack of cooperation by farmers in granting permission to make the measurements or in keeping the necessary records and (2) inability to find an area encompassing only the one crop and containing a distribution system that would permit determination of the quantity of water applied to that crop. Therefore, values for such major crops were assumed to approximate the values for those crops in comparable areas for which actual applied water measurements were made.

The subdivision unit numbers referred to in tables described subsequently in this report designate subdivisions of the Sacramento-San Joaquin Delta of which the Delta Lowlands encompass all or part of all of the units except numbers 1, 4 and 5. The locations of the units are shown on Plate 2.

Major Crops on North Mineral Soils. Monthly and seasonal applications of water to crops of the north mineral soils area are shown in Table 3. The depths of applied-water during the irrigation season for five of the major crops were: field corn, 1.5 feet; alfalfa, 2.3 feet; sugar beets, 1.9 feet; tomatoes, 2.5 feet; and pasture, 2.2 feet.

The Division of Water Resources in its report "Putah Creek Cone Investigation, December 1955", determined certain applied-water factors on areas at the northern edge of the Delta. The weighted mean value of applied water for pasture reported therein was 3.9 acre-feet per acre, based upon a 430-acre area. This value was considered a reasonable applied-water factor for pasture and it was used in this report because the sample field for pasture in the present investigation, due to its small size of only five acres, was not considered representative of that crop

A value of 0.7 acre-foot per acre for asparagus as determined for the south mineral soils area, was also used for the north mineral soils area.

Major Crops on Middle Organic Soils. Monthly and seasonal applications of water to crops of the middle organic soils area are shown in Table 4. The depths of applied-water during the irrigation season for four of the major crops were: asparagus, 1.4 feet; field corn, 3.6 feet; sugar beets, 3.3 feet; and tomatoes, 3.4 feet.

A value of 2.3 acre-feet per acre for alfalfa, as determined for the north mineral soils area, was assumed to approximate the unit quantity of water applied to alfalfa in the middle organic soils area.

A value of 3.9 acre-feet per acre for pasture, as determined for the north mineral soils area, was assumed as the unit quantity of water applied to pasture in the middle organic soils area.

Major Crops on South Mineral Soils. Monthly and seasonal applications of water to crops of the south mineral soils area are shown in Table 5. The depths of applied-water during the irrigation season for the six major crops were: asparagus, 0.7 foot; field corn, 1.5 feet; alfalfa, 4.2 feet; sugar beets, 3.7 feet; tomatoes, 2.6 feet; and pasture, 8.2 feet.

The applied-water values for two sample plots for pasture indicated an excessive annual use of water (over 10 acre-feet per acre) as compared to the other two plots. The Division of Water Resources in its report "San Joaquin County Investigation, June 1955", determined the weighted mean applied-water value for pasture on areas at the southeast edge of the Delta to be 4.5 acre-feet per acre as based upon a 240-acre area. However, for purposes of this report, the weighted average of 4.8 acre-feet per acre for the remaining two sample plots of pasture in Unit 27, as shown in Table 5, was used as the applied-water factor for pasture in the south mineral soils area.

Minor Crops. To determine the total quantity of irrigation water applied to the Delta Lowlands during the irrigation season, it was necessary to estimate unit applied-water values for the minor irrigated crops. This was done by calculating the weighted average unit depth of water applied to the major irrigated crops in each of the soil-type areas. These values for the north mineral, middle organic, and south mineral soils areas are 2.1, 2.3 and 2.4 acre-feet per acre, respectively. These weighted averages were multiplied by their respective soil-type areas; these quantities were then used as the estimated amount of water applied to the minor crops for inclusion in the evaluation of total water applied to the Lowlands.

Total Applied Water

The total seasonal amounts of applied water on irrigated crops of the Delta Lowlands were determined from the 1955 land-use survey data and the unit applied-water values described heretofore.

The total seasonal applications by soil type and by crop and the totals for the Delta Lowlands are shown in Table 6. The total irrigation seasonal use of applied water for the Delta Lowlands amounted to about 656,000 acre-feet or an average of 2.25 acre-feet per irrigated acre.

The monthly distribution of applied irrigation water was calculated for each of the aforesaid subdivisions from its crop pattern and applicable monthly applied-water values. Table 7 shows the monthly distribution of applied irrigation water by units, monthly percentages of seasonal totals, and monthly average unit applied-water values in acre-feet per acre. The monthly distribution of seasonal applied-water values varied from one per cent each in March and October to a maximum of 33 per cent (about 216,000 acre-feet) in July.

Waters Applied for Leaching Purposes

Water is applied to the Delta Lowlands for leaching excess salts from the soil, thereby lowering the salinity of the soil solution in the root zone. As will be shown hereinafter, evidence indicates that the concentration of salts in the soil increases during the summer season. These salts must subsequently be removed from the soils, otherwise the increasing saline concentration would accumulate and adversely affect plant growth.

Leaching waters are usually applied during the fall and winter months. No attempt was made during this investigation to determine the quantity of water applied for leaching purposes because of the wide variations in leaching practices and because of the relative unimportance on channel demands of leaching water requirements since ample water of good quality is usually available during the late fall and winter seasons.

Precipitation

Precipitation, although not part of the "applied water" as considered in this report, does affect month by month the irrigation and leaching practices, and the quantities and qualities of drainage water as will be discussed later.

Data shown in Table 8 from the United States Weather Bureau Reports titled "Climatological Data, California" for the seven weather stations in and near the Delta, are considered representative of precipitation on the Delta. The average rainfall for the Delta Lowlands is assumed to be the arithmetic average of precipitation at those seven stations. Table 8 also shows the monthly rainfall at these stations for the period May, 1954, through October, 1955, and the monthly average for the Delta.

Monthly total quantities of precipitation on the Delta Lowlands, estimated by multiplying the aforesaid average depths of precipitation by the 419,439 acres of the Delta Lowlands are given in Table 9. The total precipitation for the March through October irrigation season in 1955 amounted to about 150,000 acre-feet.

PART III - WATERS DRAINED FROM THE DELTA LOWLANDS

Concurrent with the observations of water applied for irrigation in the Delta Lowlands, observations were made to determine the quantities of waters drained from those lands. Permission was secured from property owners to test and rate their drainage pumping plants and to secure their power consumption records. These data were used to calculate the water quantities pumped from the interior drain canals into the tidal channels.

Drainage Practices

In general, each island or tract in the Delta Lowlands has one or more drainage systems wherein the drainage waters first enter small drainage ditches leading to larger main drains and then terminate at the pumping plants. These plants, usually float-actuated between predetermined water levels in the main drains, pump water intermittently from the main drains into the contiguous channels.

Drainage pumps used in the Delta vary in combinations of the following types and sizes: 3- to 50-inch discharge pipe, 3- to 500-horsepower motor, horizontally or vertically mounted, double or single suction centrifugal type, mixed-flow or axial-flow propeller type, direct or belt connected to gasoline or diesel internal combustion engine or to an electric motor. The most common drainage-pump installation in the Delta area is a 30 to 75 horsepower, direct connected, electric-motor driven, axial-flow propeller-type pump.

Quantity of Drainage Water Pumped

The quantity of drainage water pumped from 82 per cent of the area in the Delta Lowlands for the period May, 1954, through October, 1955, by means of 162 pumping plants involving 255 pumps, was determined from pump test data and power consumption records. For the same period, drainage pumped by 64 pumps at 44 pumping plants servicing 16 per cent of the Delta Lowlands, was estimated by assuming that the plant rating factors were similar to comparable measured installations or by correlation with drainage-per-acre values in adjacent areas. The remaining 2 per cent of the area covers lands either drained by gravity or urbanized, and their drainage contributions were estimated by correlation with drainage-per-acre values in adjacent areas.

Table 10 shows the combined measured and estimated monthly total drainage from each subdivision unit within the Delta Lowlands and the monthly average unit drainage in acre-feet per acre. During the period of investigation the monthly total drainage varied from a low of about 30,000 acre-feet in October, 1955, to a maximum of approximately 96,000 acre-feet in January, 1955.

The average monthly unit drainage values in acre-feet per acre are shown graphically on Plates 3, 4 and 5 for three periods: May through October, 1954; November, 1954, through February, 1955; and March through October, 1955. A comparison of these three plates indicates that the average monthly drainage in the Delta during the winter is greater than during the other seasons as indicated by the small area during the winter from which drainage was between zero and 0.10 acre-feet per acre per month. This increase is due to a combination of greater precipitation and lower consumptive use demands at that time. Also during the winter a noticeable increase occurred in the area from which drainage was between 0.31 and 0.60 acre-foot per acre per month. It may also be noted that certain areas in the northern and southern parts of the Delta show the results of high irrigation efficiency and minor seepage problems since the drainage from those areas remained in the zero to 0.10 acre-foot per acre per month category throughout the entire period of investigation. The higher elevation of those lands compared to lands in the central portion of the Delta probably accounts for the lesser seepage.

PART IV - WATER SUPPLY AND DISPOSAL

The water supply to islands of the Delta Lowlands consists of (1) applied irrigation water, (2) subsurface inflow, and (3) precipitation. Water disposal consists of (1) drainage water, and (2) consumptive use. Ground water storage changes account for any imbalance between supply and disposal. Of the foregoing items, applied irrigation water, precipitation, and drainage have been discussed and evaluated heretofore. This chapter presents an evaluation of consumptive use and a derivation of subsurface inflow under assumptions as to ground water storage changes.

Consumptive Use

The monthly total quantities of consumptive use of water were taken from the Division of Water Resources report titled "Sacramento River and Sacramento-San Joaquin Delta Trial Water Distribution 1955, Summary Report of Data". These quantities were derived by multiplying 1955 crop acreages by appropriate unit consumptive use values. Monthly consumptive use quantities within the Delta Lowlands are shown in Table 11 of this report. It will be noted that these values varied from about 22,000 acre-feet in January, 1955, to about 211,000 acre-feet in August, 1955. Of the annual consumptive use requirements of 1,160,000 acre-feet, about 1,036,000 acre-feet were consumed during the March through October irrigation season.

Subsurface Inflow

Subsurface inflow to islands of the Delta Lowlands was derived by means of the hydrologic equation. This equation provides that inflow to an area must equal disposal therefrom plus or minus changes in ground water storage. The measurable and estimable sources of water supply are the applied irrigation water and precipitation. The measurable and estimable water disposal consists of return drainage water and consumptive use. The unknown and practically unmeasurable terms in the hydrologic equations pertaining to Delta islands are (1) ground water storage changes, (2) contribution to the islands by seepage from contiguous channels, and/or (3) rising water from deep-seated and remote sources. Items 2 and 3 are discussed together herein as subsurface inflow.

The measurable and estimable values of water supply and disposal in the Delta Lowlands are presented in Table 12, which summarizes data presented heretofore. As shown, the partial water supply during the March through October, 1955, period consisted of about 805,000 acre-feet of applied irrigation water and of precipitation. During that period, water disposal consisted of approximately 1,453,000 acre-feet of drainage and of consumptive use. Therefore, during this period the excess of water disposal over the measurable water supply was approximately 648,000 acre-feet. Because of the irrigation and drainage practices in the Delta area, it properly may be assumed that the ground-water storage change during the March through October period is comparatively insignificant. Therefore, it is concluded that the 648,000 acre-feet is indicative, during that period, of the magnitude of subsurface inflow.

The data presented in Table 12 are shown graphically on Plate 6. In this plate, for each month, the total measurable water supply is shown on the right side of the double column and the water disposal on the left side of the double column. It is to be noted that no applied irrigation water values were determined for the months of November, 1954, through February, 1955. In spite of this omission, an inspection of the plate shows that, except for the month of December, 1954, the water disposal exceeded the measurable and estimable water supply in every month during the 18-month period from May, 1954, through October, 1955, indicating subsurface inflow.

PART V - QUALITY OF WATER

An inspection of water analyses from the files of the Division of Water Resources shows that generally the quality of Delta channel water becomes progressively poorer as the water moves from the northern to the southern part of the Delta, that is, from the Sacramento River toward the Tracy Pumping Plant of the Central Valley Project. One possible cause of this degradation is the effect of sea-water intrusion, which effect is discussed in Report No. 5 in this series of reports on the Sacramento-San Joaquin Delta.

Another possible source of the degradation is the salt contributed to the channels by the drainage waters from the Delta islands. To evaluate this possibility the salt contribution to the Delta channels was determined from observations and computations involving the qualities and quantities of waters applied to and drained from the Delta Lowlands. The quantities of those waters have been discussed and presented heretofore.

Quality of Applied Water

The quality of applied water was determined in the field from specific-conductance data collected at random tide phases at 62 sampling points in the Delta channels at approximately six-week intervals during 18 continuous months of 1954 and 1955. At 22 of these sampling points, water samples were also collected at 3-month intervals, and subjected to complete mineral analyses. Correlations were determined between specific conductance of the water and the sum of concentrations of mineral constituents in parts per million (ppm). By interpolation; a monthly average concentration was determined for the water at each sampling point. These monthly concentrations and the monthly applied-water quantities for each subdivision unit were used to determine the monthly tons of salt in the irrigation water applied to each unit of the Delta Lowlands. These monthly quantities, as well as values for tons-per-irrigated acre, are shown in Table 13. The monthly total salts in applied irrigation water varied from a minimum of about 2,100 tons in March, 1955, to a maximum of approximately 70,000 tons during August, 1954. Since no applied-water values were determined for the period November, 1954, through February, 1955, no salt tonnages are shown for those months. However, it is to be noted that water applied for leaching during this period of winter runoff from the Central Valley, would have been of generally good quality.

The monthly average quality of applied irrigation water within each subdivision unit was determined as an arithmetical average of the monthly water qualities at all of the sampling points within that unit. Table 14 shows that these values ranged from 70 ppm in Unit 27 during May, 1954, to about 1,800 ppm in Unit 14 during August, 1955. Also shown in this table are the weighted monthly averages for the entire Delta as computed from data in Table 13. These averages ranged from 86 ppm in May, 1954, to 300 ppm in August, 1954. Since applied-water values were not determined for the period November, 1954, through February, 1955, no weighted averages for that period could be calculated.

The data in Tables 13 and 14 involve only the salt content of applied surface water. They do not concern the salt in water entering the islands by seepage from channels or from other sources. Although the quality of such additional supplies is uncertain, it is indicated in Reports No. 2 and 3 that the ground water inflow to Medford and McDonald Islands was largely channel water. Available data are not sufficient at this time to indicate whether or not this is true for the Delta Lowlands as a whole. However, if for purposes of a rough approximation, it is hypothesized that the rate of ground water inflow to the islands of the Delta Lowlands is constant, and that the quality of such inflow equals the approximate Delta-wide average annual quality of channel waters of about 260 ppm, about 33,000 tons of salt per month in addition to those amounts shown in Table 13 would enter such islands.

An inspection of the average concentrations of applied water in Table 14 indicates that peak concentrations of salts in the channels occur in the late summer months. Evidence presented in Report No. 5 shows that this condition is due largely to sea-water incursion caused by a combination of high consumptive use, including high water-surface evaporation losses, and by the relatively low fresh-water inflow to the Delta at that time.

Quality of Drainage Waters

The quality of water drained from the Delta Lowlands was determined in a manner similar to that described in preceding section under the heading, "Quality of Applied Water". Specific conductance field measurements at approximately six-week intervals were made of the drainage water at 196 sampling points. Water samples were also collected at 24 of these points at approximately three-month intervals and subjected to complete mineral analyses. The estimated quantities of drainage water, presented heretofore, and the drainage-water qualities were used to determine the amount of salt discharged at pumping plants in each unit. Table 15 shows the estimated monthly salt tonnage discharged to the channels within each unit and the monthly total discharge in tons-per-acre for the Delta Lowlands as a whole. The total salt tonnage discharged in the drainage water during the 18-month period varied from a minimum of about 19,000 tons in October, 1955, to a maximum of approximately 113,000 tons in January, 1955.

The data in Table 15 were converted to show, in Table 16, the weighted average concentration of drainage water in each subdivision unit and for the entire Delta Lowlands area. Total dissolved solids in drainage water varied from about 120 ppm in June, 1955, in Unit 3 to about 1,600 ppm in February, 1955, in Unit 17. The Delta average ranged between about 300 ppm in June, 1954, to 865 ppm in January, 1955. An inspection of Table 16 indicates that the average concentration of the drainage water remains comparatively constant between May and October. During this period in each year, the concentration increased from about 300 to approximately 475 ppm.

Values of average monthly salt discharge in tons-per-acre from the Delta Lowlands are shown graphically on Plates 7, 8, and 9 for three periods: May through October, 1954; November, 1954, through February, 1955; and March through October, 1955. An inspection of these plates indicates that there was a larger area contributing high tonnages of salt per-acre-per-month during the winter than during other seasons. This is shown by the large areas in the categories of 0.21 to 0.50, and 0.51 to 0.80 tons-per-acre-per-month of salt removed during the winter months.

Channel-Water Degradation by Drainage Water. An inspection of the data shown in Tables 13 and 15 reveals that during summer months salt inflow to Delta Lowlands islands exceeds salt drainage therefrom. This is true even without taking into account the relatively large amounts of salt carried by subsurface inflow to the islands mentioned heretofore, and salts introduced by fertilization and other agricultural practices. In other months of the year, salt removal exceeds salt inflow. Thus the Delta lands act as a salt reservoir by first storing some of the salts that enter the islands during the summer and then by releasing those salts during the winter through leaching and/or drainage of precipitation. This indicates that agricultural practices within the Delta Lowlands during the summer, when the problem of water quality there is most critical, do not degrade good quality Sacramento River water as it moves through the Delta to the Tracy Pumping Plant but rather enhances its quality by removing a portion of its salt content. In the winter months, when the accumulated surplus salts are discharged to the channels, there is usually sufficient surplus flow through the Delta to dilute and to carry out to the ocean the leached salts. However, it should be noted that the preceding statement applied to conditions as of 1954-55. Any additional upstream regulation or a "dry" year, such as 1924 or 1931, will decrease the winter flows through the Delta to the extent that leached salts may not be completely removed from the area. These findings are important and are the first available demonstrated conclusions relating to Delta channel water degradation by drainage waters.

PART VI - SUMMARY AND CONCLUSION

As a result of field investigation and analysis of other available data and on the basis of the estimates and assumptions discussed hereinbefore, the following summary and conclusion are presented:

Summary

1. The Delta Lowlands comprises the major portion of the Sacramento-San Joaquin Delta. The area, as shown on Plate 1, covers about 469,000 acres of which about 374,000 acres are developed for agricultural purposes and of which about 292,000 acres were irrigated in 1955.

2. Approximately 62 per cent of the Delta Lowlands was irrigated during the period of investigation, May, 1954, through October, 1955. The March through October seasonal demand for water applied to irrigated crops was approximately 656,000 acre-feet, with the maximum monthly demand of about 216,000 acre-feet occurring in July. These quantities were determined (a) from detailed investigations for the six irrigated major crops on 38 sample fields totalling 3,369 acres, and (b) from estimates for the other crops.

3. Monthly precipitation on the Delta Lowlands during the period of investigation varied from zero in summer months to about 128,000 acre-feet in December, 1954. The total precipitation during the period March through October, 1955, amounted to approximately 150,000 acre-feet.

4. Drainage water, returned monthly to the channels from the Delta Lowlands during the period of investigation, varied between approximately 30,000 acre-feet in October, 1955, and 96,000 acre-feet in January, 1955. During the irrigation season the maximum drainage pumping occurred during July, 1954, and amounted to about 81,000 acre-feet. During the period of March through October, 1955, the drainage amounted to approximately 417,000 acre-feet.

5. The estimated consumptive use in the Delta Lowlands during the period of investigation, based on the 1955 crop pattern, varied from approximately 22,000 acre-feet in January to about 211,000 acre-feet in August. On that basis the annual consumptive-use requirements are approximately 1,160,000 acre-feet, of which 1,036,000 acre-feet are consumed during the March through October irrigation season.

6. During the March through October, 1955, irrigation season, the difference between the approximately 805,000 acre-feet of water supply and the 1,453,000 acre-feet of water disposal, amounting to about 648,000 acre-feet of water must come from a combination of ground water storage changes (considered herein to be comparatively insignificant because of irrigation and drainage practices in the Delta) and from subsurface inflow comprising seepage from contiguous channels and/or rising water from deep-seated and remote sources.

7. The estimated quantity of salt in the irrigation water applied to the Delta Lowlands during the irrigation season

varied from approximately 2,100 tons in March, 1955, to about 70,000 tons in August, 1954, with a total of about 187,000 tons for the March-through-October season. The average concentration of total dissolved solids in applied irrigation water varied from about 100 to 300 ppm during that period.

8. Under the hypothesis that subsurface inflow to the Delta Lowlands is constant and that the quality of such inflow equals the average annual quality of channel waters, roughly 33,000 tons of salt per month would be introduced by subsurface inflow.

9. The estimated amount of salt discharged in the drainage waters from the Delta Lowlands during the period of investigation varied from approximately 19,000 tons in October to about 113,000 tons in January, 1955, with a total of about 248,000 tons for the March-through-October period. The average concentration of total dissolved solids in the drainage water varied from about 300 ppm in June, 1954, to 865 ppm in January, 1955

Conclusion

The Delta Lowlands act as a salt reservoir, storing salts obtained largely from the channels during the summer, when water quality in such channels is most critical and returning such accumulated salts to the channels during the winter when water quality there is least important. Therefore agricultural practices in that area enhanced rather than degraded the good quality Sacramento River water enroute to the Tracy Pumping Plant.

TABLE 1

LAND USE - DELTA LOWLANDS - 1955

In acres

Crop		Crop	
Pasture		Fruit & Nuts	5,141
Sudan	522	Grapes	110
Miscellaneous	22,475	Native Vegetation	
Alfalfa	34,481	Lush	897
Rice	2,103	Medium	7,891
Field Crops		Dry	3,116
Beans	420	Fallow & Bare	1,360
Field Corn	47,557	Idle Crop Land	1,103
Milo	20,972	Duck Ponds	203
Grain & Hay	79,709	Urban	6,914
Peas	97	Tule & Swamp	4,581
Safflower	770	Levee & Berm	16,616
Sunflower	2,204	Interior Water Surface	5,585
Sugar Beets	30,181	Subtotal	419,439
Truck Crops		Exterior Water Surface	42,168
Asparagus	80,325	Islands in Channels	7,027
Celery	1,083	Total	468,634
Onions	1,193		
Potatoes	8,539		
Tomatoes	30,099		
Seed & Miscellaneous	3,192		

TABLE 2

IRRIGATED CROPS
DELTA LOWLANDS, 1955

Crop	Area in acres	Per cent of total irrigated area
Asparagus	80,325	28
Field Corn	47,557	16
Alfalfa	34,481	12
Sugar Beets	30,181	10
Tomatoes	30,099	10
Pasture	22,997	8
Milo	20,972	7
All others	25,055	9
Total	291,667	100

TABLE 3

WATER APPLIED TO CERTAIN IRRIGATED CROPS DURING 1954
DELTA LOWLANDS – NORTH MINERAL SOIL

Crop	Unit	Sample field acreage	Depth per month – in inches							
			April	May	June	July	August	September	October	Total
Field corn	19	14				11.8	5.8			17.6
					Weighted mean depth: 17.6" (1.5')					
Alfalfa	6	87	1.9	3.9	3.8	5.5	4.5	1.4	0.6	21.6
	6	55			8.4	8.0	6.5	9.4	10.0	42.3
	19	14		1.5	3.7	3.5	3.5	2.0		14.2
Total		156								
					Weighted mean depth: 28.2" (2.3')					
Sugar Beets	6	45		4.7	11.2	16.5				32.4
	6	44		2.7	7.5	7.0	2.2			19.4
	7	32			6.1	5.1	1.9			13.1
Total		121								
					Weighted mean depth: 22.6" (1.9')					
Tomatoes	6	45		19.0	8.1	15.5	5.0			47.6
	6	37		2.3	2.4	2.5	3.5			10.7
	7	20			10.7	8.8	3.4			22.9
Total		102								
					Weighted mean depth: 29.4" (2.5')					
Pasture	19	5	11.8		5.0	5.3	3.8			25.9
					Weighted mean depth: 25.9" (2.2')					

TABLE 4

WATER APPLIED TO CERTAIN IRRIGATED CROPS DURING 1954
DELTA LOWLANDS - MIDDLE ORGANIC SOIL

Crop	Unit	Sample field acreage	Depth per month - in inches					
			May	June	July	August	September	Total
Asparagus	25	774	4.7	4.7	5.8	6.4	2.7	24.3
	16	728		0.7	0.9	1.1	5.7	8.4
Total		1,502		Weighted mean depth: 16.6" (1.4')				
Field Corn	20	85			16.9			16.9
	24	75			30.9	30.9		61.8
	24	90			34.7	29.3		64.0
	16	78		10.5	6.2	7.6	6.0	30.3
Total		328		Weighted mean depth: 43.3" (3.6')				
Sugar Beets	20	115.5	5.2	10.2	12.6	8.7	3.9	40.6
	22	35.3			25.7	7.9		33.6
Total		150.8		Weighted mean depth: 39.0" (3.3')				
Tomatoes	20	54.5		1.2	4.1			5.3
	18	102.0		25.9	19.8	14.2		59.9
Total		156.5		Weighted mean depth: 40.9" (3.4')				

TABLE 5

WATER APPLIED TO CERTAIN IRRIGATED CROPS DURING 1954
DELTA LOWLANDS - SOUTH MINERAL SOIL

Crop	Unit	Sample field acreage	Depth per month - in inches										
			Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Total
Asparagus	24	68								7.9			7.9
					Weighted mean depth: 7.9" (0.7')								
Field Corn	24	75						4.2	7.0	4.6	1.8		17.6
					Weighted mean depth: 17.6" (1.5')								
Alfalfa	24	22.0				10.1		5.8	18.6	6.3	6.0		46.8
	24	53.0					11.0	9.7	14.5	6.1	6.4		47.7
	25	88.5					4.0	1.4	10.4	4.7	0.3		20.8
	26	32.0						28.9	34.1	26.2	33.0		122.2
	27	31.0				11.2		10.6	6.9	5.7	9.5	8.8	52.7
	27	31.0			5.0	5.1	5.8	9.0	5.2	10.2	5.3	6.3	51.9
	27	32.8				8.5	11.4	9.2	13.0	10.2	11.5	0.4	64.2
	27	32.5		1.0		7.1	5.6	8.0	13.3	12.3	2.5		49.8
Total		322.8											
					Weighted mean depth: 50.4" (4.2')								
Sugar Beets	24	76				4.4	4.4	7.7	10.6	13.2	4.7		45.0
					Weighted mean depth: 45.0" (3.7')								
Tomatoes	24	55						2.3	11.8	16.8	2.5		33.4
	24	68						6.4	4.3	7.2	11.1		29.0
Total		123											
					Weighted mean depth: 31.0" (2.6')								
Pasture	26	40.0						28.8	34.2	26.1	33.0		122.1
	27	62.3	5.6		5.1	18.4	21.2	17.0	26.7	12.6	16.5	4.3	127.4
	27	32.8				8.5	11.4	9.2	13.0	10.2	11.5	0.4	64.2
	27	32.5		1.0		7.1	5.6	8.0	13.3	12.3	2.5		49.8
Total		167.6											
					Weighted mean depth: 98.7" (8.2')								

TABLE 6

IRRIGATION SEASONAL USE OF APPLIED WATER - DELTA LOWLANDS - 1954

Crop	Irrigated Area in Acres				Seasonal Applied Water Acre-feet/acre			Seasonal Applied Water Acre-feet			
	North Mineral Soils	Middle Organic Soils	South Mineral Soils	Total	North Mineral Soils	Middle Organic Soils	South Mineral Soils	North Mineral Soils	Middle Organic Soils	South Mineral Soils	Total for Delta Lowlands
Asparagus	6,878	53,096	20,351	80,325	0.7	1.4	0.7	4,820	74,330	14,250	93,400
Corn	13,681	30,342	3,534	47,557	1.5	3.6	1.5	20,520	109,230	5,300	135,050
Alfalfa	14,081	9,478	10,922	34,481	2.3	2.3	4.2	32,390	21,800	45.870	100,060
Sugar Beets	20,514	8,573	1,094	30,181	1.9	3.3	3.7	38,980	28,290	4,050	71,320
Tomatoes	13,284	9,899	6,916	30,099	2.5	3.4	2.6	33,210	33,660	17,980	84,850
Pasture	13,266	2,887	6,844	22,997	3.9	3.9	4.8	51,740	11,260	32,850	95,850
Milo	8,189	10,194	2,589	20,972	1.0	1.0	1.0	8,190	10,190	2,590	20,970
All other crops	17,403	5,041	2,611	25,055	2.1	2.3	2.4	36,550	11,590	6,270	54,410
Total	107,296	129,510	54,861	291,667				226,400	300,350	129,160	655,910
Weighted average acre-feet per acre								2.11	2.32	2.35	2.25

TABLE 7

MONTHLY DISTRIBUTION OF APPLIED WATER TO IRRIGATED CROPS
DELTA LOWLANDS
1954
In acre-feet

Unit	Irrigated acreage	March	April	May	June	July	Aug.	Sept.	Oct.	Seasonal Total
2	5394	110	460	790	2040	3730	2940	1130	110	11310
3	4074	80	320	560	1430	2630	2070	790	80	7960
6	24900	510	2040	3570	9180	16820	13250	5100	510	50980
7	6025	130	500	870	2240	4090	3230	1240	130	12430
8	16518	360	1450	2550	6540	11990	9450	3640	360	36340
9	7779	190	760	1330	3430	6290	4960	1910	190	19060
10	8447	150	600	1060	2710	4980	3920	1510	150	15080
11	11142	280	1110	1940	5000	9170	7220	2780	280	27780
12	12916	320	1290	2260	5810	10660	8400	3230	320	32290
13	10413	290	1150	2010	5160	9460	7450	2870	290	28680
14	4319	90	370	650	1670	3070	2420	930	90	9290
15	13445	400	1580	2770	7130	13070	10300	3960	400	39610
16	13598	330	1340	2330	6000	11000	8660	3330	330	33320
17	6130	110	430	760	1950	3580	2820	1080	110	10840
18	12792	350	1410	2480	6370	11680	9200	3540	350	35380
19	12943	330	1300	2280	5860	10740	8470	3250	330	32560
20	16534	400	1610	2810	7230	13260	10440	4020	400	40170
21	10666	210	820	1440	3690	6770	5340	2050	210	20530
22	14465	270	1080	1890	4860	8910	7020	2700	270	27000
23	19812	350	1410	2460	6330	11610	9150	3520	350	35180
24	24156	500	2010	3520	9060	16600	13080	5030	500	50300
25	25912	530	2120	3700	9530	17460	13760	5290	530	52920
26	651	20	90	150	400	730	570	220	20	2200
27	8636	250	990	1730	4440	8150	6420	2470	250	24700
Total	291667	6560	26240	45910	118060	216450	170540	65590	6560	655910
Per cent of seasonal total		1.0	4.0	7.0	18.0	33.0	26.0	10.0	1.0	100
Average acre-feet per acre		0.02	0.09	0.16	0.41	0.74	0.58	0.23	0.02	2.25

TABLE 8

AVERAGE PRECIPITATION IN SACRAMENTO-SAN JOAQUIN DELTA

In inches

Station	1954								1955									
	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
Antioch	0.39	0.05	0	0	0	0.02	1.53	3.44	2.59	1.26	0.92	1.40	0.74	0	0	0	0.03	0.15
Benson's Ferry	0.46	0.01	0	0.02	0	0.01	2.43	3.92	2.28	1.14	0.40	2.24	0.47	0	0	0	0.44	0.33
Davis	0.16	0.16	0	0.08	0	0	2.98	3.91	2.68	1.24	0.40	2.17	0.64	0	0	0	0.92	0.44
Lodi	0.26	0.08	0	0.04	0	0.01	2.34	4.32	3.40	1.39	0.17	3.09	0.51	0	0	0	1.10	0.13
Sacra-mento	0.21	0	0	0.35	0	0.02	3.35	4.93	3.14	1.33	0.37	2.75	0.67	0.01	0	0	0.95	0.57
Stock-ton	0.28	0.40	0	0	0	0	2.23	3.19	3.84	1.03	0.57	2.38	1.02	0	0	0	0.01	0.12
Tracy	0.37	0.42	0	0	0	0	1.45	1.85	2.94	0.77	1.91	1.12	0.83	0	0	0	0	0.03
AVERAGE	0.30	0.16	0	0.07	0	0.01	2.33	3.65	2.98	1.17	0.68	2.16	0.70	0	0	0	0.49	0.25

TABLE 9

PRECIPITATION ON DELTA LOWLANDS

In acre-feet

1954		1955	
May	10486	January	104161
June	5593	February	40895
July	0	March	23768
August	2447	April	75499
September	0	May	24467
October	350	June	0
November	81441	July	0
December	127579	August	0
		September	17127
		October	8738

TABLE 10

DRAINAGE FROM DELTA LOWLANDS

In acre-feet

Unit	Acreage	1954 May	1954 June	1954 July	1954 Aug.	1954 Sept.	1954 Oct.	1954 Nov.	1954 Dec.	1955 Jan.	1955 Feb.	1955 Mar.	1955 Apr.	1955 May	1955 June	1955 July	1955 Aug.	1955 Sept.	1955 Oct.
2	11202	45	0	0	0	0	179	0	672	582	90	0	90	0	0	0	0	0	134
3	5465	639	552	662	526	234	147	225	387	594	558	475	403	541	401	667	573	299	43
6	33027	617	388	339	299	359	358	1480	2541	2944	2159	771	401	293	235	314	269	227	320
7	7510	510	117	104	60	64	44	183	379	669	367	221	229	259	189	214	120	122	59
8	22103	4126	2984	2227	2935	2997	3932	2867	1917	1046	1086	1752	2018	2354	3267	3817	2830	2411	1577
9	16085	1238	1628	2074	2081	1495	952	696	979	841	252	401	1057	742	1301	1408	1647	1067	710
10	11067	395	865	1057	975	350	261	313	486	637	352	245	443	535	757	874	860	624	450
11	14365	1620	1697	1337	1350	770	530	753	1383	1516	865	637	889	792	1349	1433	1411	591	417
12	16877	2408	3144	3559	2971	1450	1029	1481	2916	3105	1689	1690	2582	2171	3921	3927	3690	971	621
13	16641	886	1529	2022	1602	357	459	529	1288	1303	777	767	1081	964	1575	2356	2022	1049	435
14	14671	1730	2131	2053	926	648	1227	1483	2166	1961	1645	1983	2307	1614	1773	2264	846	545	891
15	26424	2583	2463	3005	2879	2055	2957	3425	4851	5721	2871	2782	2544	1801	2425	2805	3398	2079	2021
16	18343	2114	2434	2321	3181	2147	1521	1076	2804	4008	1470	1041	1854	1707	2457	2336	2044	1811	1511
17	10191	992	955	1379	1013	739	1159	1185	3597	3198	1039	1291	1823	1585	1613	2000	1499	1153	603
18	18504	4710	8676	11051	8210	6748	6994	4025	5759	4836	2425	1942	1439	3509	5603	10156	8081	3432	2884
19	17917	2507	3570	4636	4307	2688	1516	1268	2753	2454	1221	826	1301	2618	3160	3759	3282	1963	1275
20	21302	5456	9197	10223	10410	4627	4582	5639	10209	14637	3840	2016	3533	6521	10456	11726	11870	8521	3505
21	14846	3154	4000	5245	4705	2698	2691	3792	7388	7472	2765	1935	2350	3873	5340	5398	4576	3392	2175
22	19357	12368	15756	15252	12942	8629	9306	8637	10635	12773	7385	5127	3949	10734	16862	15557	12826	6142	5302
23	24493	2396	3032	3917	3259	1974	3790	3514	9308	11828	3229	2103	1843	2018	2481	2056	2818	1663	1981
24	32879	2125	2500	2964	2839	1849	2103	2795	8907	9189	3410	2053	2135	2355	2649	2862	2929	2285	1974
25	33212	2335	2197	3773	2289	1237	892	971	3812	3678	2188	1958	2540	2233	2553	3574	3217	2068	922
26	2810	96	131	144	149	99	88	140	399	412	150	92	95	107	133	155	153	113	93
27	10148	669	627	1231	949	343	100	60	195	264	127	311	722	487	584	948	1209	588	114
Total	419439	55719	70573	80575	70857	44557	46817	46537	85731	95668	41960	32419	37628	49813	71084	80606	72170	43116	30017
Acre-feet per acre		0.13	0.17	0.19	0.17	0.11	0.11	0.11	0.20	0.23	0.10	0.08	0.09	0.12	0.17	0.19	0.17	0.10	0.07

TABLE 11

CONSUMPTIVE USE REQUIREMENTS, DELTA LOWLANDS

1955

In acre-feet

January	22,371	July.	191,744
February.	26,108	August.	211,339
March	35,001	September	156,805
April	84,015	October	91,609
May	129,609	November.	42,593
June.	136,679	December.	32,915
		Total	1,160,323

WATER SUPPLY AND DISPOSAL
DELTA LOWLANDS
In acre-feet

	1954							
	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Water Supply								
Applied Water	45910	118060	216450	170540	65590	6560	-	-
Precipitation	10486	5593	0	2447	0	350	81441	127579
Total Water Supply	56396	123653	216450	172987	65590	6910	-	-
Water Disposal								
Drainage	55719	70573	80575	70857	44557	46817	46537	85731
Consumptive Use	129609	136679	191744	211339	156805	91164	42573	32915
Total Water Disposal	185328	207252	272319	282196	201362	137981	89110	118646

	1955									
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
Water Supply										
Applied Water	-	-	6560	26240	45910	118060	216450	170540	65590	6560
Precipitation	104161	40895	23768	75499	24467	0	0	0	17127	8738
Total Water Supply	-	-	30328	101739	70377	118060	216450	170540	82717	15298
Water Disposal										
Drainage	95668	41960	32419	37628	49813	71084	80606	72170	43116	30017
Consumptive Use	22371	26108	35001	84015	129609	136679	191744	211339	156805	91164
Total Water Disposal	118039	68068	67420	121643	179422	207763	272350	283509	199921	121181

TABLE 13

WEIGHT OF SALTS IN APPLIED IRRIGATION WATER
DELTA LOWLANDS

In tons

Unit	Irri-gated acreage	1954 May	1954 June	1954 July	1954 Aug.	1954 Sept.	1954 Oct.	1955 Mar.	1955 Apr.	1955 May	1955 June	1955 July	1955 Aug.	1955 Sept.	1955 Oct.
2	5394	97	433	721	628	275	16	14	43	118	311	650	616	268	15
3	4074	64	292	501	456	184	12	10	33	81	214	440	394	176	12
66	24900	408	1824	3044	2956	1180	82	67	241	466	1324	2700	2380	985	94
7	6025	91	439	718	721	275	22	17	62	110	323	645	554	272	26
8	16518	250	1032	2219	1851	797	71	48	195	375	819	1860	1710	718	60
9	7779	166	957	1292	1134	499	39	57	185	284	443	1061	918	439	39
10	8447	133	553	840	896	427	34	49	158	212	391	820	725	333	33
11	11142	243	1041	1634	1611	707	46	42	148	230	721	1447	1248	609	59
12	12916	228	1130	1943	1840	760	52	42	156	283	814	1769	1463	725	58
13	10413	183	885	1725	1804	687	49	40	142	222	737	1647	1500	679	58
14	4319	74	643	6249	4880	553	24	19	150	96	868	3225	6137	1002	42
15	13445	290	1416	5050	7287	2031	121	126	374	471	1057	4143	5115	1864	142
16	13598	488	1069	3981	6527	1817	137	171	352	526	980	3068	4795	1767	141
17	6130	121	329	935	1558	523	61	66	150	249	366	818	1189	494	49
18	12792	256	1049	2320	2666	891	67	70	224	307	936	2225	2015	915	81
19	12943	236	733	2133	1809	641	59	52	168	236	726	1739	1694	690	61
20	16534	291	1426	3067	3096	1116	102	120	381	505	1279	2868	2500	1187	112
21	10666	172	763	1796	1925	742	80	88	300	460	884	1363	1482	725	81
22	14465	278	860	2170	2970	973	85	119	332	406	926	1915	2092	860	83
23	19812	328	1257	3001	3797	1480	152	180	574	870	1507	2827	2813	1178	119
24	24156	393	3143	6843	6068	2607	252	244	963	1710	3069	6098	4698	2190	263
25	25912	428	3306	8409	7844	3325	304	224	998	1782	3423	7459	6047	2893	293
26	651	15	184	339	287	131	12	7	37	74	132	298	250	117	14
27	8636	165	2767	6221	5031	2403	248	245	955	1368	3063	6709	4830	2302	251
Total		5398	27531	67151	69642	25024	2127	2117	7321	11441	25313	57794	57165	23388	2186
Tons/Ac		0.02	0.09	0.23	0.24	0.09	0.01	0.01	0.03	0.04	0.09	0.20	0.20	0.08	0.01

TABLE 14

AVERAGE QUALITY OF APPLIED WATER
DELTA LOWLANDS

Sum of the mineral constituents in parts per million

Unit	1954 May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	1955 Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.
2	90	156	142	157	179	105	65	109	99	111	91	68	110	112	128	154	174	100	119
3	84	150	140	162	171	106	82	87	89	113	88	75	106	110	123	140	164	109	106
6	84	146	133	164	170	118	96	91	85	100	96	87	96	106	118	132	142	136	130
7	77	144	129	164	163	122	103	86	80	96	95	91	93	106	116	126	161	146	134
8	72	116	136	144	161	144	94	80	85	113	98	99	108	92	114	133	145	123	113
9	92	205	151	168	192	149	152	185	202	219	220	179	157	95	124	136	169	152	160
10	92	150	124	168	208	169	176	183	190	216	242	194	147	106	121	136	162	163	165
11	92	153	131	164	187	122	108	102	95	102	109	98	87	106	116	127	161	155	148
12	74	143	134	161	173	119	98	83	79	111	96	89	92	103	122	128	165	133	122
13	67	126	134	178	176	124	99	114	132	126	102	91	81	105	128	148	174	148	129
14	84	283	1496	1482	437	200	212	124	150	171	156	298	108	382	772	1864	792	344	343
15	77	146	284	520	377	222	197	247	284	266	231	174	125	109	233	365	346	261	189
16	154	131	266	554	401	306	330	409	432	453	380	193	166	120	205	407	390	313	367
17	117	124	192	406	356	406	504	480	458	509	443	257	241	138	168	310	336	329	523
18	76	121	146	213	185	141	128	139	168	164	146	117	91	108	140	161	190	170	159
19	76	92	146	157	145	132	56	75	94	104	115	95	76	91	119	147	156	136	116
20	76	145	170	218	204	187	197	168	158	195	221	174	132	130	159	176	217	206	203
21	88	152	195	265	266	281	341	275	227	283	308	269	235	176	148	204	260	284	323
22	108	130	179	311	265	231	299	299	297	321	324	226	158	140	158	219	234	225	261
23	98	146	190	305	309	319	384	389	399	395	377	299	260	175	179	226	246	250	332
24	82	255	303	341	381	370	367	311	265	335	359	352	357	249	270	264	320	387	439
25	85	255	354	419	462	422	391	332	255	307	310	346	354	264	314	323	402	406	438
26	75	339	341	370	436	449	336	227	104	228	275	302	364	242	300	323	392	500	522
27	70	458	561	576	715	730	810	728	613	688	721	709	581	507	605	553	685	739	772
Wtd. Avg.	86	171	228	300	280	238					237	205	183	158	196	246	262	245	

TABLE 15

WEIGHT OF SALTS IN DRAINAGE WATER
DELTA LOWLANDS

In tons

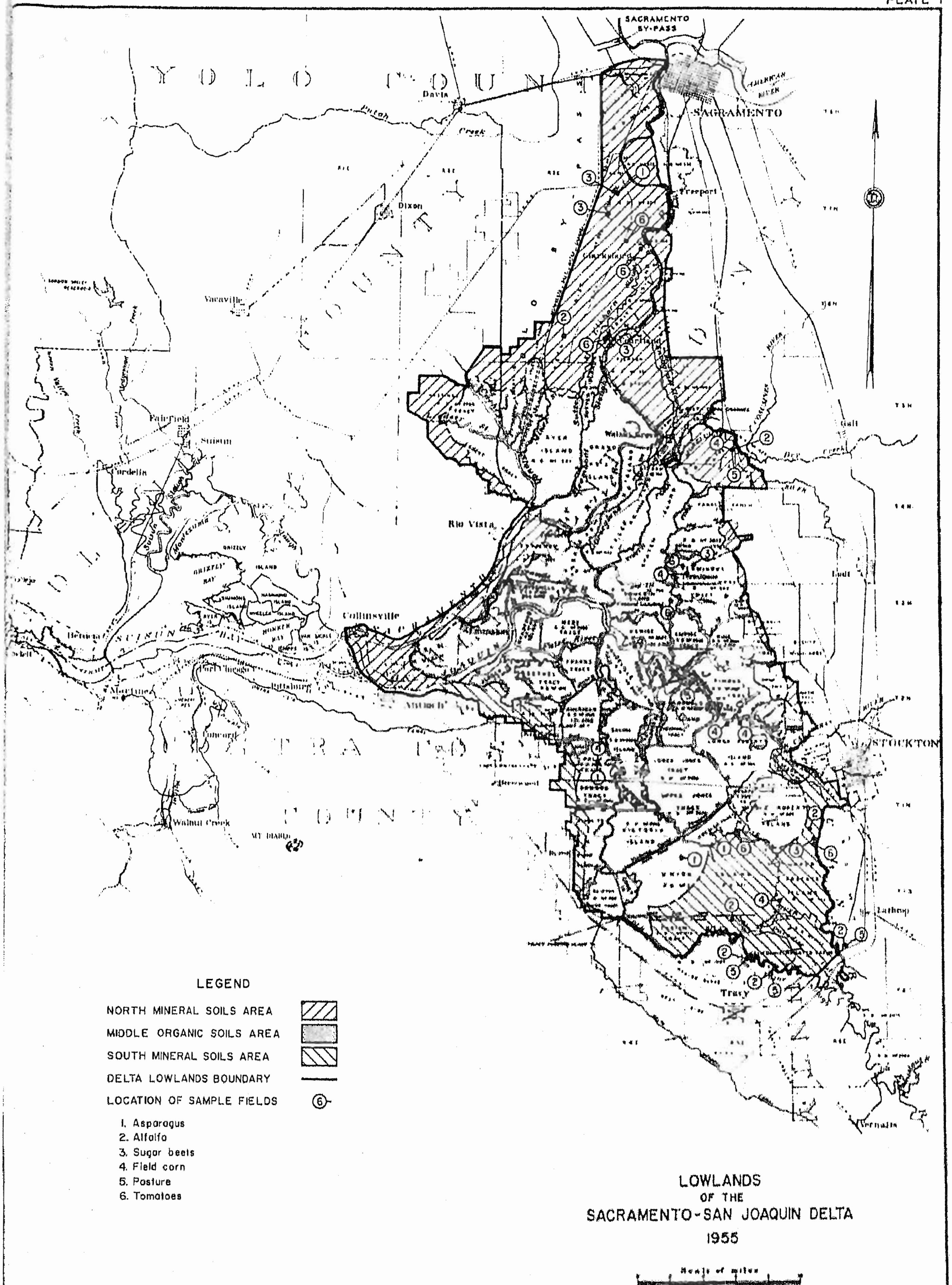
Unit	Acreage	1954								1955									
		May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
2	11202	47	0	0	0	0	195	0	782	677	96	0	82	0	0	0	0	0	112
3	5465	210	199	201	129	73	59	69	138	210	183	126	108	95	65	132	125	74	8
6	33027	194	108	60	67	99	143	794	2023	2286	2076	786	301	104	72	50	52	49	116
7	7510	157	52	37	24	26	20	102	248	439	263	170	160	147	83	85	42	46	30
8	22103	1074	842	640	936	921	1097	769	819	409	580	913	926	688	813	916	828	802	559
9	16085	556	731	772	1012	734	482	512	824	724	297	482	992	365	537	498	647	427	340
10	11067	192	411	397	271	110	92	115	241	399	237	170	299	286	410	236	208	153	135
11	14365	381	385	301	377	236	157	367	966	1067	578	404	497	269	460	286	357	167	129
12	16877	708	923	900	966	480	346	498	1540	2112	1045	906	1245	864	1565	1275	1135	314	235
13	16641	362	798	542	555	155	208	311	1106	1138	585	495	593	408	512	696	724	489	214
14	14671	1124	1656	2590	1435	798	1098	1582	2981	3188	2675	3029	2941	1514	1685	2634	1177	616	1190
15	26424	1645	1489	1748	2610	1999	2844	3737	6457	7708	4201	3741	3131	1294	1769	1731	2589	2089	1878
16	18343	1121	1343	1406	3112	2129	1452	1391	4408	5800	2510	1966	2026	1243	1574	1503	1555	1433	1203
17	10191	883	814	1162	960	781	1286	1572	6423	5662	2284	2159	3500	2293	1307	1436	1148	1014	615
18	18504	1347	2503	2946	3442	2621	2603	2557	4768	4086	2218	1710	1026	1217	2182	2676	2526	1362	1206
19	17917	940	1374	2410	2094	1169	979	1146	2774	3263	1515	862	1026	906	1198	1319	1314	852	646
20	21302	3264	4998	4823	6347	3491	3531	5150	12081	19485	5251	2751	4732	5523	8032	6505	7016	7544	3138
21	14846	1288	1596	2070	2233	1657	2028	2778	7489	9865	2750	1362	1651	2235	2343	2195	1801	1566	1320
22	19357	3025	3727	4708	6408	3815	3663	4251	7863	11986	6086	3447	2109	3753	5317	5385	4816	2304	2365
23	24493	1144	1192	1647	1730	907	1796	1865	6754	15843	3542	1647	1274	1153	1200	1175	1033	612	846
24	32879	1365	1548	1878	1852	1329	1591	2690	10325	11369	4393	2590	2569	2507	1907	1676	1765	1351	2128
25	33212	1501	1451	2337	1602	894	658	691	3789	4086	2234	1758	2295	2109	2288	2839	2525	1784	763
26	2810	63	80	96	98	66	73	121	456	513	192	118	120	119	95	83	86	66	91
27	10148	538	534	1253	1075	383	112	41	138	243	115	290	826	523	632	935	1342	709	131
Total	419439	23129	28754	34924	39335	24873	26513	33109	85393	112558	45906	31882	34429	29615	36046	36266	34811	25823	19398
Tons/Ac.		0.06	0.07	0.08	0.09	0.06	0.06	0.08	0.20	0.27	0.11	0.08	0.08	0.07	0.09	0.09	0.08	0.06	0.05

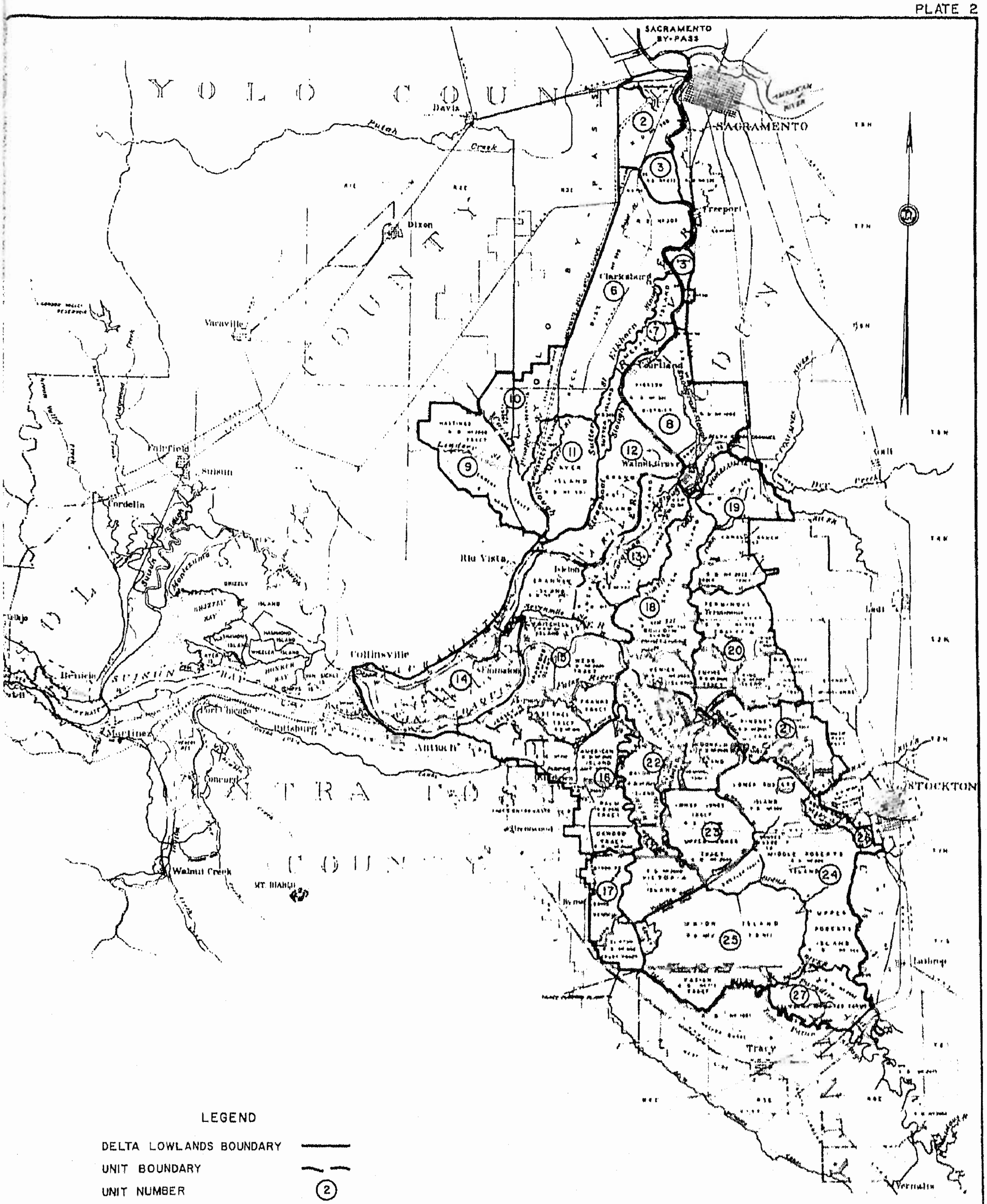
TABLE 16

AVERAGE QUALITY OF DRAINAGE WATER
DELTA LOWLANDS

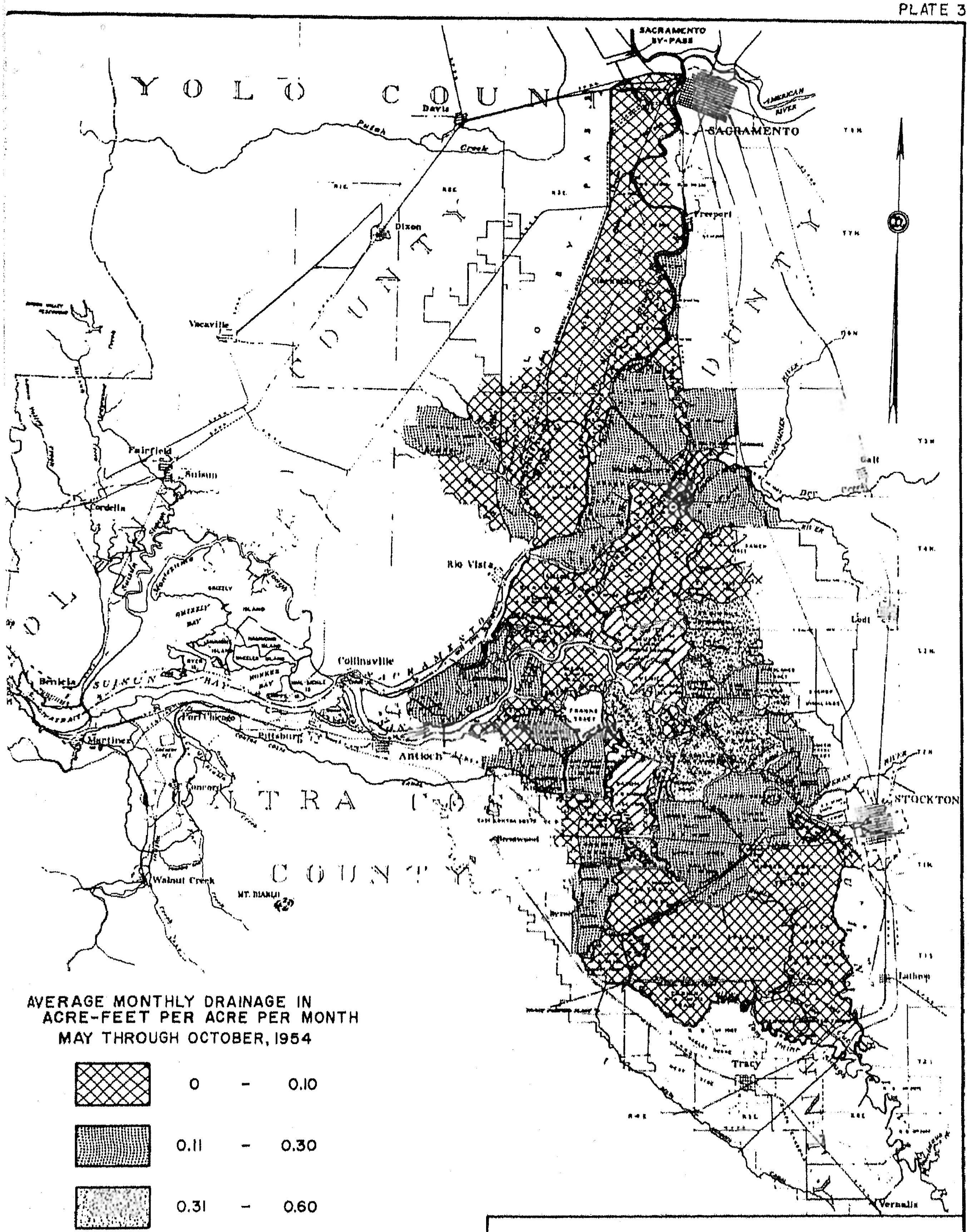
Sum of mineral constituents in parts per million

Unit	1954								1955									
	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
2	768	0	0	0	0	801	0	855	855	784	0	670	0	0	0	0	0	614
3	242	265	223	180	229	295	225	262	260	241	195	197	129	119	145	160	182	137
6	231	205	130	165	203	294	394	585	571	707	749	552	261	225	117	142	159	266
7	226	327	261	294	299	334	410	481	482	527	565	514	417	323	292	257	277	374
8	191	207	211	234	226	205	197	314	287	393	383	337	215	183	176	215	244	261
9	330	330	274	357	361	372	541	619	633	866	883	690	362	303	260	289	294	352
10	357	349	276	204	231	259	270	364	460	495	510	496	393	398	198	178	180	220
11	173	167	165	205	225	218	358	513	517	491	466	411	250	251	147	186	208	227
12	216	216	186	239	243	247	247	388	500	455	394	354	293	293	239	226	238	278
13	300	384	197	255	319	333	432	631	642	553	474	403	311	239	217	263	343	362
14	478	571	927	1139	905	658	784	1012	1195	1195	1123	937	689	699	855	1023	831	982
15	468	444	428	666	715	707	802	978	990	1075	988	905	528	536	454	560	739	683
16	390	406	445	719	729	702	950	1155	1064	1255	1388	803	535	471	473	559	582	585
17	654	626	619	697	777	816	975	1312	1301	1616	1229	1411	1063	596	528	563	646	750
18	210	212	196	308	285	274	467	609	621	672	647	524	255	286	194	230	292	307
19	276	283	382	357	320	475	664	741	977	912	767	580	254	279	258	294	319	372
20	440	399	347	448	555	566	671	870	978	1005	1003	984	623	565	408	434	651	658
21	300	293	290	349	451	554	538	745	970	731	517	516	424	322	299	289	339	446
22	180	174	227	364	325	289	362	543	690	606	494	393	257	232	254	276	276	328
23	351	289	309	390	338	348	390	533	984	806	576	508	420	356	420	269	270	314
24	472	455	466	479	528	556	707	852	909	947	927	884	782	529	430	443	435	792
25	472	485	455	514	531	542	523	731	817	750	660	664	694	659	584	577	634	608
26	482	449	490	483	490	610	635	840	915	941	943	928	817	525	394	413	429	719
27	591	626	748	833	821	823	502	520	677	666	685	841	789	795	725	816	886	845
Wtd. Avg.	305	299	319	408	410	416	523	732	865	804	723	673	437	373	331	355	440	475


SACRAMENTO BY-PASS
SACRAMENTO
Davis
Dixon
Vacaville
Fairfield
Suisun
Cordelia
Freeport
Clarksburg
Courtland
Walnut Grove
Galt
Rio Vista
Lodi
Collinsville
Benicia
Martinez
Pittsburg
Antioch
Concord
Walnut Creek
STOCKTON
Lathrop
Tracy
Vernalis
LEGEND
NORTH MINERAL SOILS AREA
MIDDLE ORGANIC SOILS AREA
SOUTH MINERAL SOILS AREA
DELTA LOWLANDS BOUNDARY
LOCATION OF SAMPLE FIELDS
1. Asparagus
2. Alfalfa
3. Sugar beets
4. Field corn
5. Pasture
6. Tomatoes
LOWLANDS
OF THE
SACRAMENTO-SAN JOAQUIN DELTA
1955
Scale of miles



SUBDIVISION UNITS
OF THE
SACRAMENTO - SAN JOAQUIN DELTA
1955



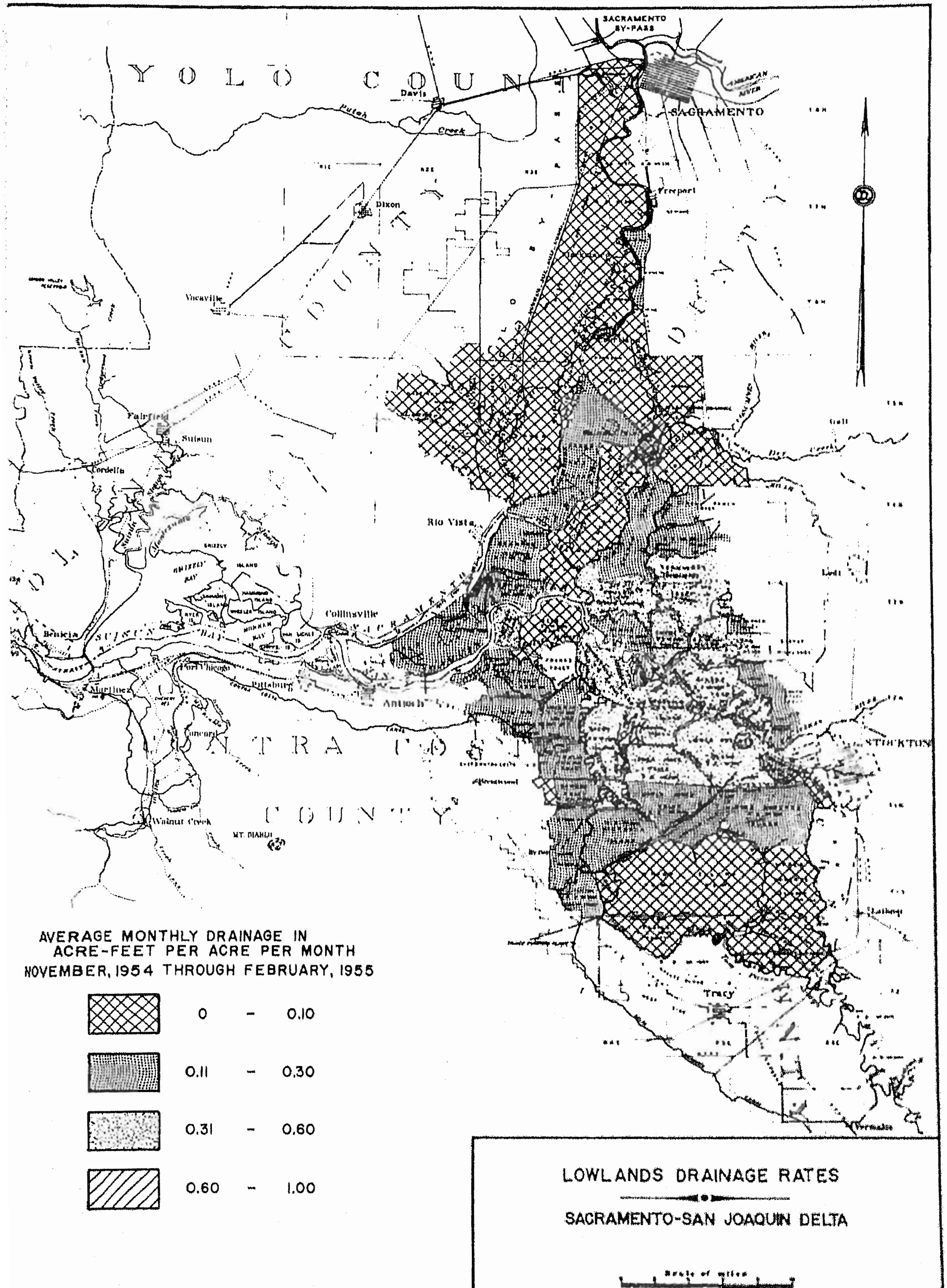
AVERAGE MONTHLY DRAINAGE IN ACRE-FEET PER ACRE PER MONTH MAY THROUGH OCTOBER, 1954

Cross-hatched	0 - 0.10
Fine stipple	0.11 - 0.30
Light stipple	0.31 - 0.60
Diagonal lines	0.60 - 1.00

LOWLANDS DRAINAGE RATES

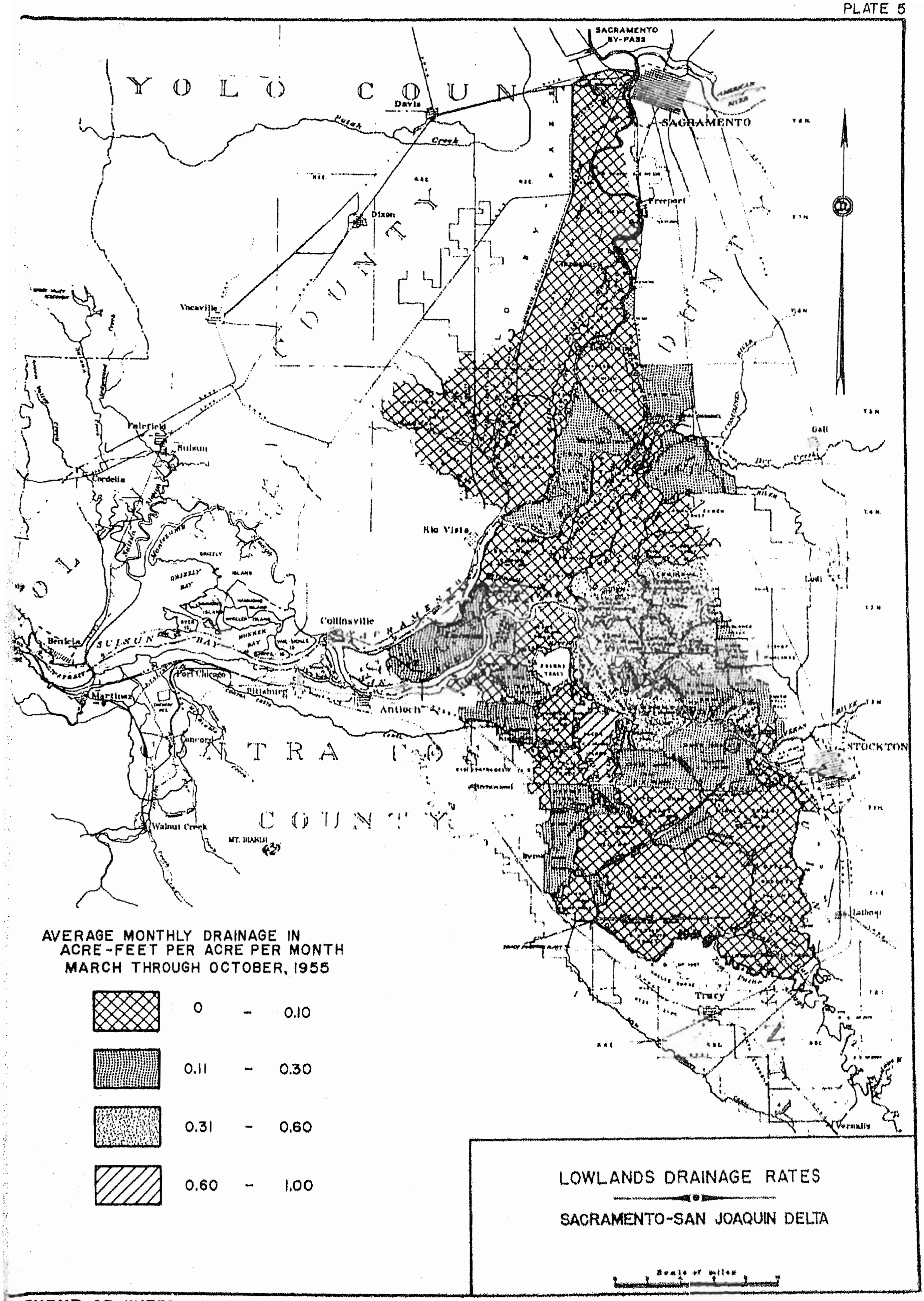
SACRAMENTO-SAN JOAQUIN DELTA

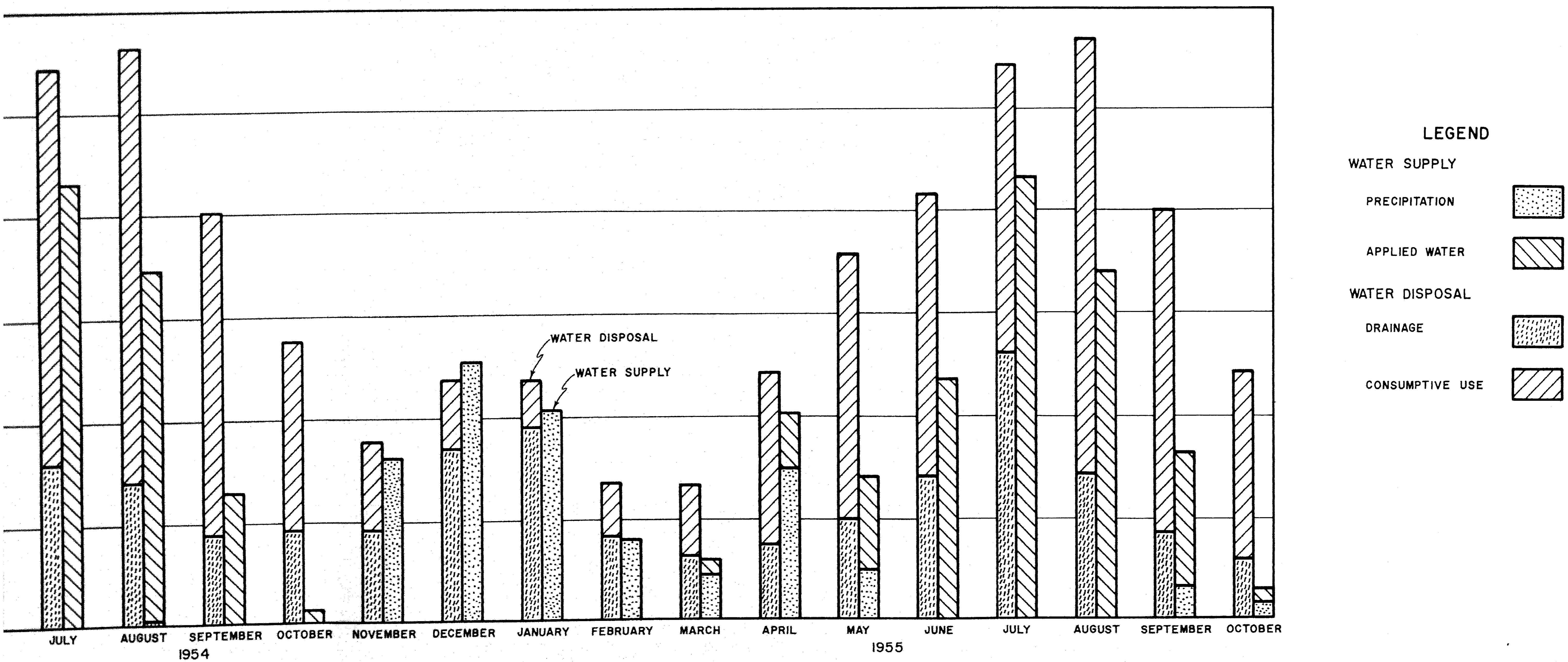
Scale of miles



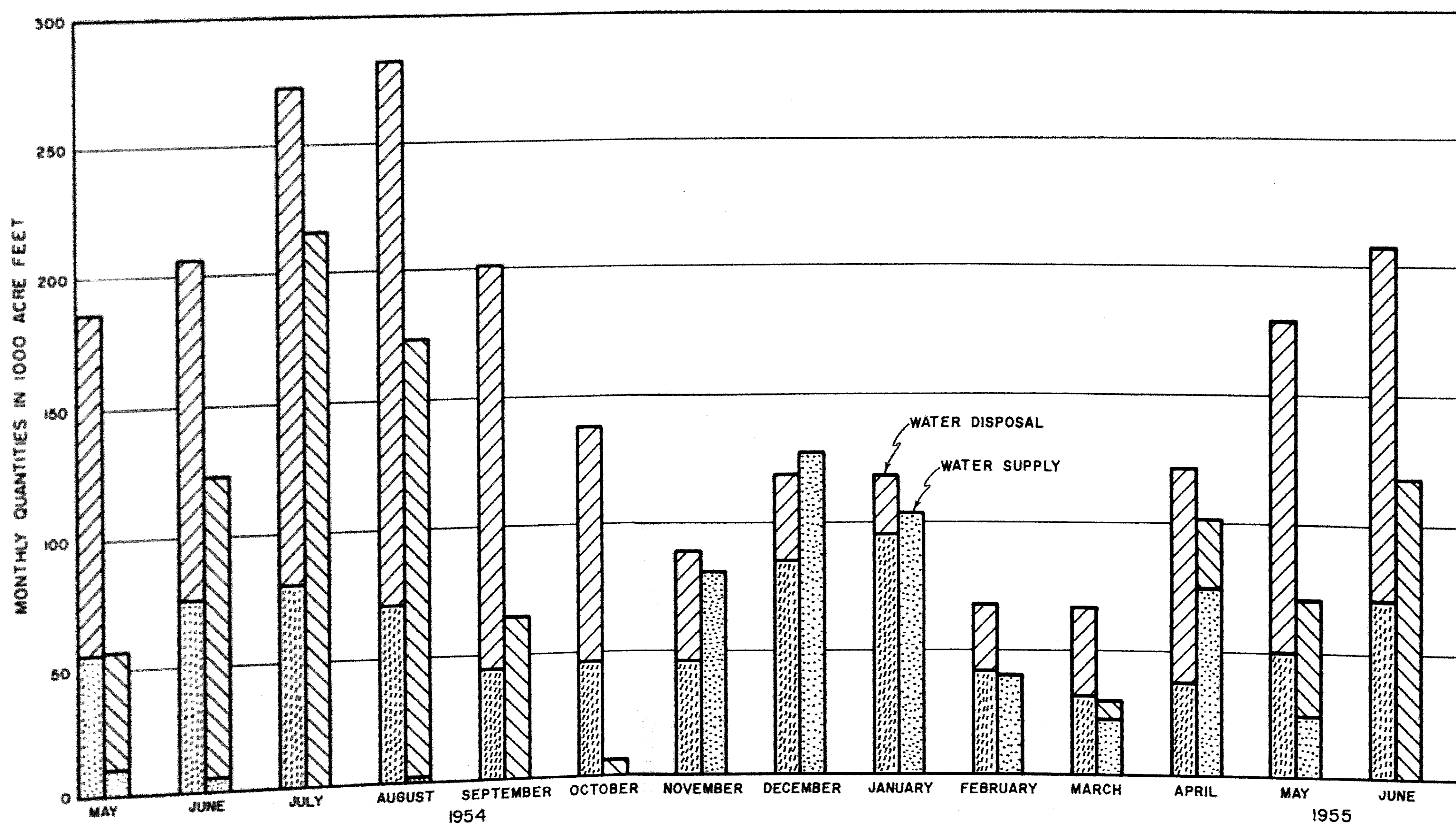
LOWLANDS DRAINAGE RATES

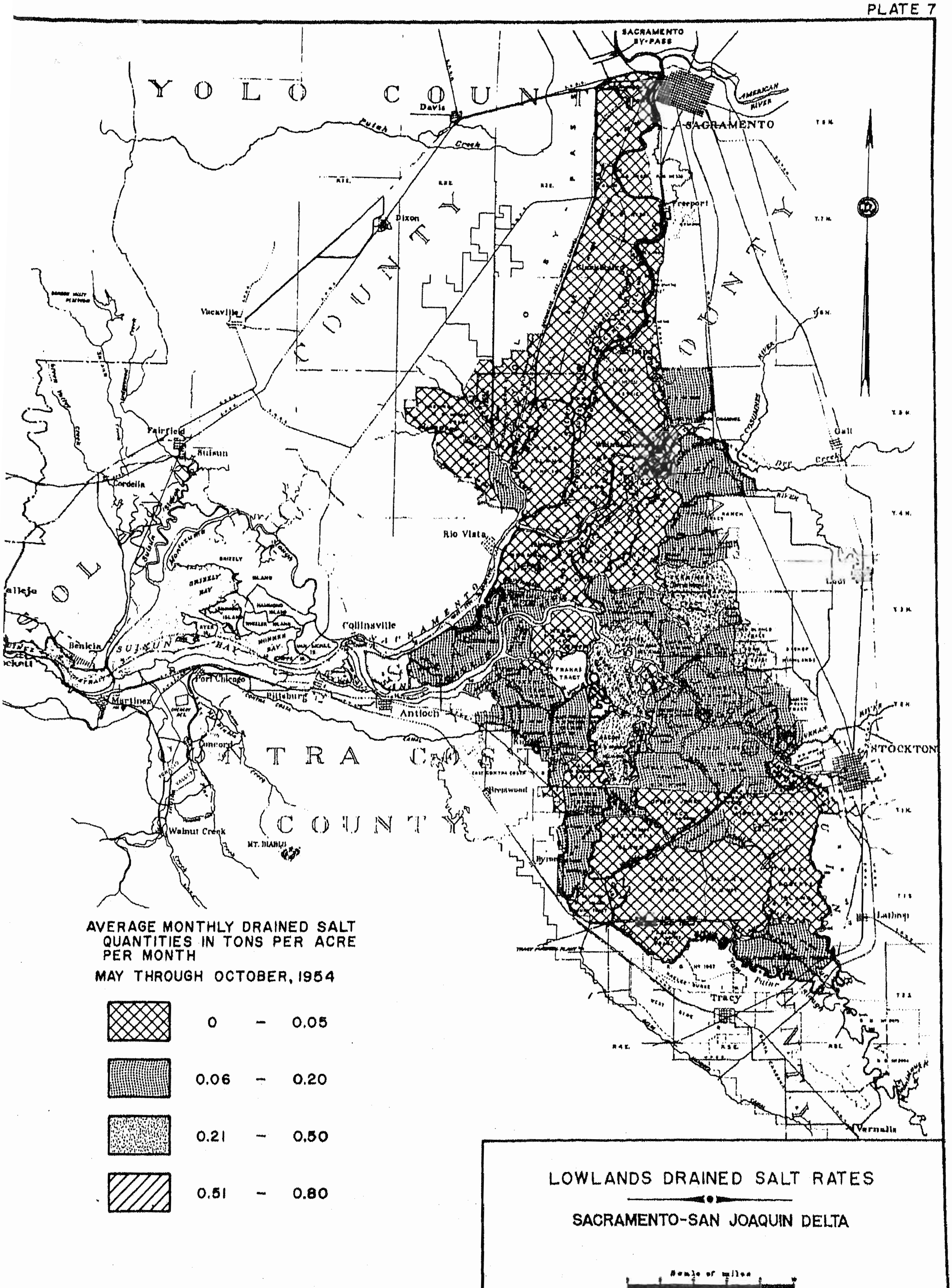
SACRAMENTO-SAN JOAQUIN DELTA

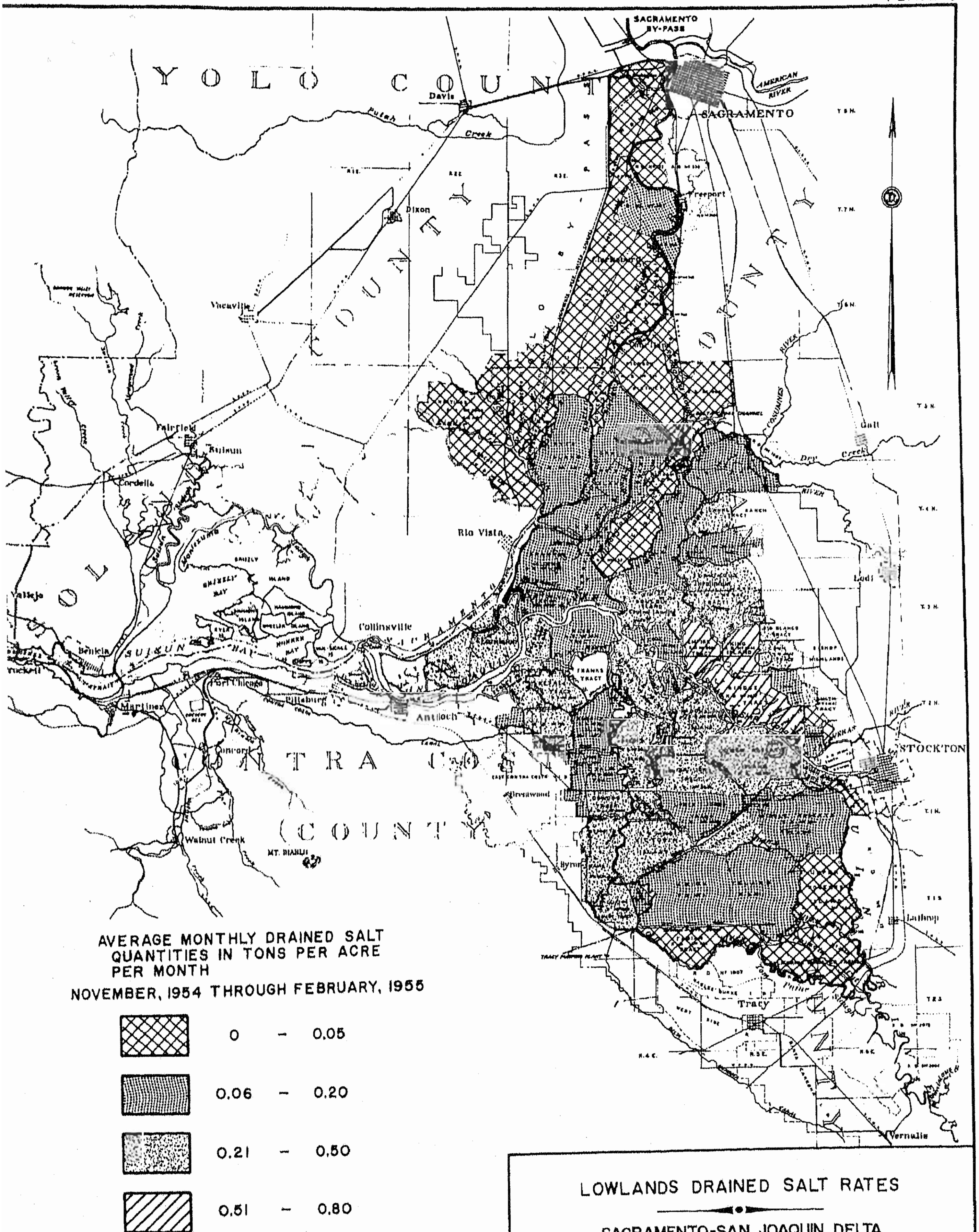

SACRAMENTO BY-PASS
AMERICAN RIVER
SACRAMENTO
YOLO COUNTY
Davis
Putah Creek
Dixon
Vacaville
Freeport
Fairfield
Suisun
Cordelia
Rio Vista
Collinsville
Benicia
SUISUN BAY
Martinez
Port Chicago
Pittsburg
Antioch
Concord
Walnut Creek
MT. DIABLO
CONTRA COSTA COUNTY
Galt
Dry Creek
Lodi
STOCKTON
Byron
Tracy
Lathrop
Vernalis
AVERAGE MONTHLY DRAINAGE IN
ACRE-FEET PER ACRE PER MONTH
MARCH THROUGH OCTOBER, 1955
0 - 0.10
0.11 - 0.30
0.31 - 0.60
0.60 - 1.00
LOWLANDS DRAINAGE RATES
SACRAMENTO-SAN JOAQUIN DELTA
Scale of miles



COMPARISON OF WATER SUPPLY AND DISPOSAL
DELTA LOWLANDS
1954-55

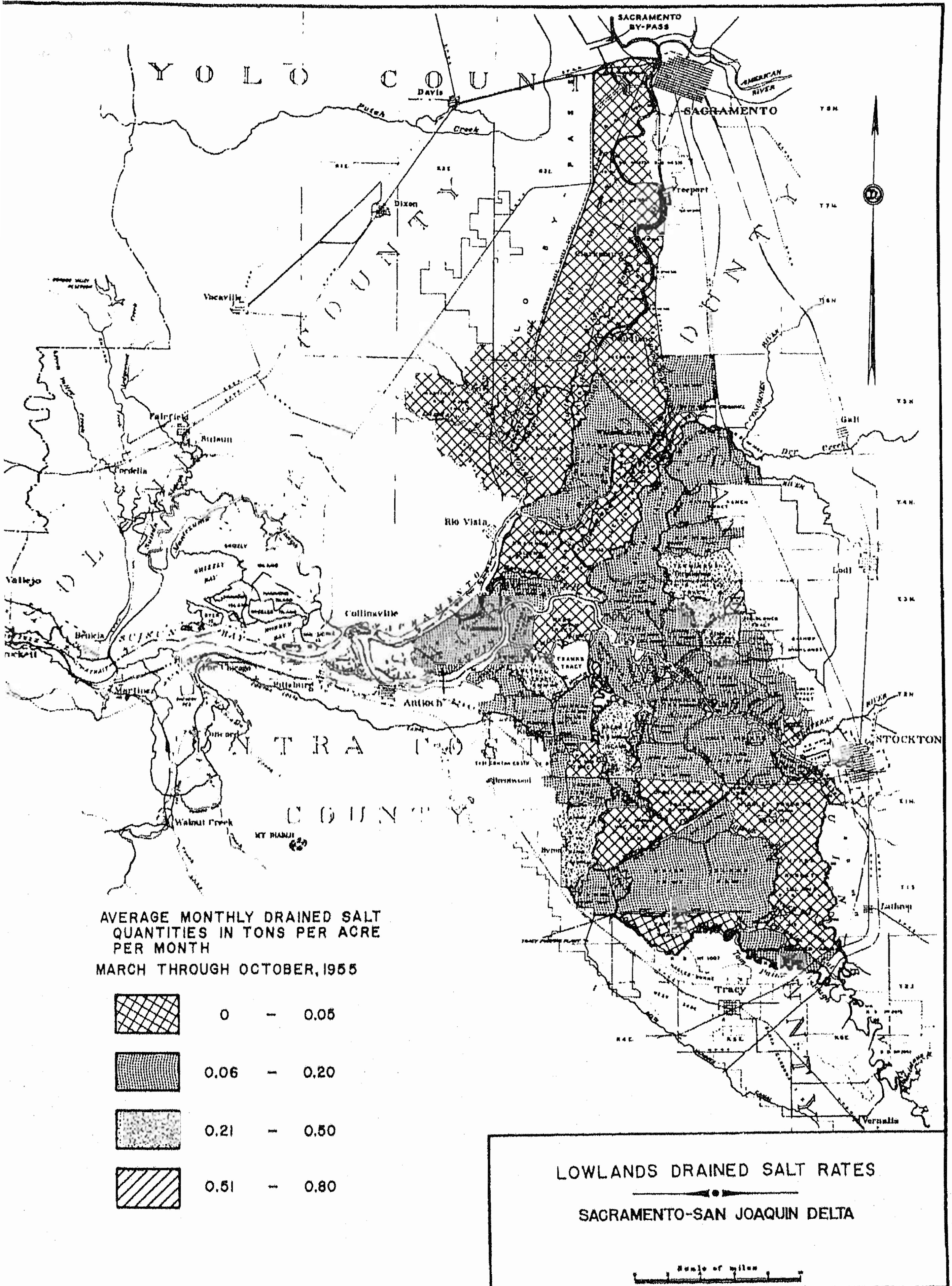

MONTHLY QUANTITIES IN 1000 ACRE FEET
300
250
200
150
100
50
0
WATER DISPOSAL
WATER SUPPLY
MAY
JUNE
JULY
AUGUST
SEPTEMBER
1954
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
MAY
1955
JUNE

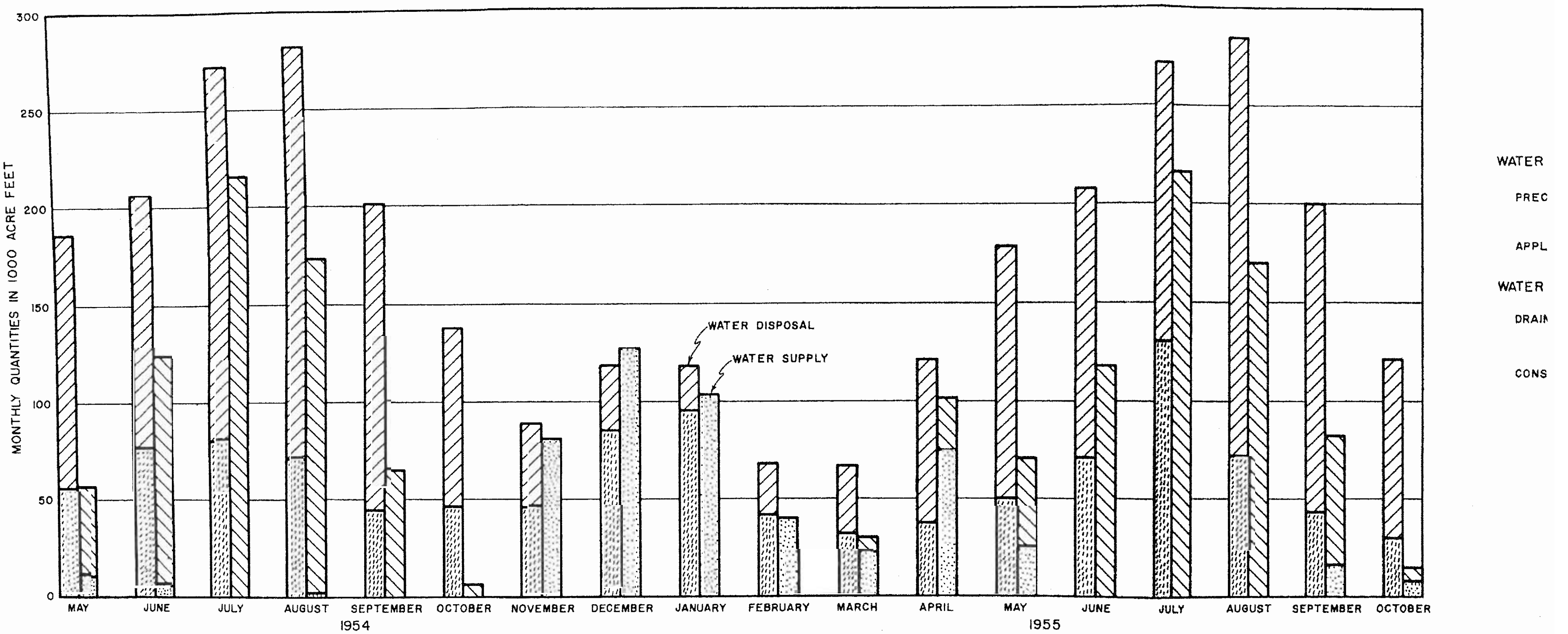

SACRAMENTO BY-PASS
YOLO COUNTY
SOLANO COUNTY
CONTRA COSTA COUNTY
SAN JOAQUIN COUNTY
SACRAMENTO COUNTY
AMERICAN RIVER
SACRAMENTO
Davis
Putah Creek
Dixon
Freeport
Vacaville
Fairfield
Suisun
Cordelia
Rio Vista
Galt
Dry Creek
Lodi
Collinsville
Benicia
Martinez
Port Chicago
Pittsburg
Antioch
Concord
Walnut Creek
MT. DIABLO
Brentwood
STOCKTON
Lathrop
Tracy
Vernalis
SUISUN BAY
GRIZZLY BAY
FRANKS TRACT
SACRAMENTO RIVER
AVERAGE MONTHLY DRAINED SALT QUANTITIES IN TONS PER ACRE PER MONTH
MAY THROUGH OCTOBER, 1954
0 – 0.05
0.06 – 0.20
0.21 – 0.50
0.51 – 0.80
LOWLANDS DRAINED SALT RATES
SACRAMENTO-SAN JOAQUIN DELTA
Scale of miles



LOWLANDS DRAINED SALT RATES

SACRAMENTO-SAN JOAQUIN DELTA


AVERAGE MONTHLY DRAINED SALT QUANTITIES IN TONS PER ACRE PER MONTH
MARCH THROUGH OCTOBER, 1955
0 - 0.05
0.06 - 0.20
0.21 - 0.50
0.51 - 0.80
LOWLANDS DRAINED SALT RATES
SACRAMENTO-SAN JOAQUIN DELTA
Scale of Miles
YOLO COUNTY
SACRAMENTO BY-PASS
AMERICAN RIVER
SACRAMENTO
Davis
Putah Creek
Dixon
Freeport
Vacaville
Fairfield
Suisun
Cordelia
Rio Vista
Vallejo
Benicia
Collinsville
Martinez
Port Chicago
Pittsburg
Antioch
Concord
Walnut Creek
MT DIABLO
CONTRA COSTA COUNTY
Brentwood
Byron
Lodi
Galt
Dry Creek
STOCKTON
Lathrop
Tracy
Vernalis



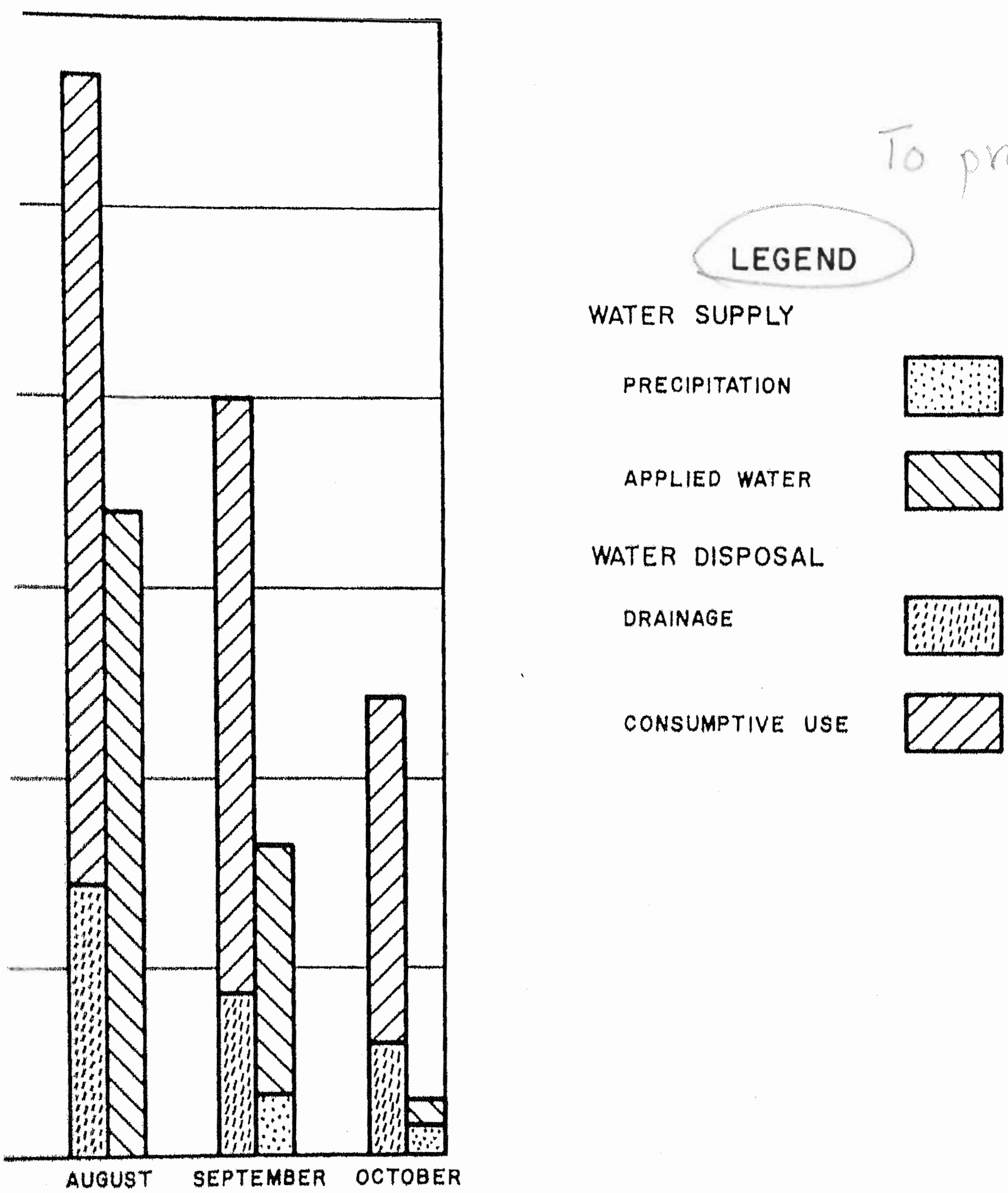
Legend attached

COMPARISON OF WATER SUPP

DELTA LOWLAN

1954-55

DEPARTMENT OF WATER RESOURCES



To previous page

Exhibit “M”

DEPARTMENT OF WATER RESOURCES
California Data Exchange Center

SAN JOAQUIN RIVER NEAR VERNALIS *(VNS)*

Elevation: 35' · SAN JOAQUIN R basin · Operator: USGS and DWR

Provisional data, subject to change.
Query executed Friday at 9:55:32

FLOW, MEAN DAILY (6272)

Date / Time	*M FLOW* **CFS**
07/01/2007	1288
07/02/2007	1297
07/03/2007	987
07/04/2007	960
07/05/2007	983
07/06/2007	991
07/07/2007	928
07/08/2007	949
07/09/2007	1045
07/10/2007	928
07/11/2007	992
07/12/2007	1013
07/13/2007	1011
07/14/2007	1053
07/15/2007	1071
07/16/2007	1100
07/17/2007	997
07/18/2007	946
07/19/2007	989
07/20/2007	968
07/21/2007	942
07/22/2007	1030
07/23/2007	1036
07/24/2007	991
07/25/2007	988
07/26/2007	768
07/27/2007	795
07/28/2007	1019 r
07/29/2007	1071 r
07/30/2007	1082 r
07/31/2007	1013 r
08/01/2007	963
08/02/2007	981
08/03/2007	973
08/04/2007	1056
08/05/2007	1117
08/06/2007	1088
08/07/2007	1069

08/08/2007	1077
08/09/2007	1110
08/10/2007	1068
08/11/2007	971
08/12/2007	999
08/13/2007	1056
08/14/2007	1002
08/15/2007	919
08/16/2007	878
08/17/2007	909
08/18/2007	975
08/19/2007	1004
08/20/2007	1069
08/21/2007	1054
08/22/2007	972
08/23/2007	1009
08/24/2007	1040
08/25/2007	1029
08/26/2007	1074
08/27/2007	1066
08/28/2007	933
08/29/2007	915
08/30/2007	919
08/31/2007	905

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Station ID	Sensor Number	Duration Code	Start date	End date	
VNS	41	M ◉D H E	07/01/2007 0(	08/31/2007 0(	Get data

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DEPARTMENT OF WATER RESOURCES
California Data Exchange Center

SAN JOAQUIN RIVER NEAR VERNALIS *(VNS)*

Elevation: 35' · SAN JOAQUIN R basin · Operator: USGS and DWR

Provisional data, subject to change.
Query executed Friday at 9:57:03

FLOW, MEAN DAILY (6272)

Date / Time	*M FLOW* **CFS**
07/01/2008	1003
07/02/2008	993
07/03/2008	922
07/04/2008	923
07/05/2008	987
07/06/2008	1035
07/07/2008	946
07/08/2008	882
07/09/2008	877
07/10/2008	887
07/11/2008	898
07/12/2008	897
07/13/2008	955
07/14/2008	998
07/15/2008	951
07/16/2008	912
07/17/2008	904
07/18/2008	919
07/19/2008	925
07/20/2008	949
07/21/2008	975
07/22/2008	854
07/23/2008	803
07/24/2008	778
07/25/2008	775
07/26/2008	816
07/27/2008	825
07/28/2008	862
07/29/2008	786
07/30/2008	737
07/31/2008	803
08/01/2008	865
08/02/2008	854
08/03/2008	819
08/04/2008	855
08/05/2008	857
08/06/2008	835
08/07/2008	782

DEPARTMENT OF WATER RESOURCES
California Data Exchange Center

SAN JOAQUIN RIVER NEAR VERNALIS *(VNS)*

Elevation: 35' · SAN JOAQUIN R basin · Operator: USGS and DWR

Provisional data, subject to change.
Query executed Friday at 9:57:53

FLOW, MEAN DAILY (6272)

Date / Time	*M FLOW* **CFS**
07/01/2009	1140
07/02/2009	988
07/03/2009	893
07/04/2009	874
07/05/2009	912
07/06/2009	963
07/07/2009	867
07/08/2009	803
07/09/2009	814
07/10/2009	773
07/11/2009	734
07/12/2009	776
07/13/2009	787
07/14/2009	730
07/15/2009	704
07/16/2009	527
07/17/2009	525
07/18/2009	561
07/19/2009	581
07/20/2009	582
07/21/2009	526
07/22/2009	542
07/23/2009	586
07/24/2009	572
07/25/2009	598
07/26/2009	610
07/27/2009	604
07/28/2009	552
07/29/2009	580
07/30/2009	581
07/31/2009	573
08/01/2009	583
08/02/2009	624
08/03/2009	675
08/04/2009	643
08/05/2009	562
08/06/2009	561
08/07/2009	498

Exhibit “N”

DEPARTMENT OF WATER RESOURCES
California Data Exchange Center

VERNALIS (USBR) *(VER)*

Elevation: 0' · SAN JOAQUIN R basin · Operator: US Bureau of Reclamation

Provisional data, subject to change.
Query executed Tuesday at 14:16:57

Select a sensor type for a plot of data.

Earlier

Date	EL COND uS/cm	TEMP W DEG F
06/11/2010	210.50	64.2
06/12/2010	172.53	62.5
06/13/2010	173.75	63.3
06/14/2010	169.33	63.7
06/15/2010	172.92	63.0
06/16/2010	198.38	63.5
06/17/2010	216.04	63.4
06/18/2010	257.75	64.6
06/19/2010	290.46	65.6
06/20/2010	307.79	66.0
06/21/2010	318.67	67.1
06/22/2010	344.65	68.5
06/23/2010	--	--
06/24/2010	--	--
06/25/2010	--	--
06/26/2010	--	--
06/27/2010	--	--
06/28/2010	--	--
06/29/2010	--	--
06/30/2010	--	--
07/01/2010	--	--
07/02/2010	--	--
07/03/2010	--	--
07/04/2010	--	--
07/05/2010	--	--
07/06/2010	--	--
07/07/2010	--	--
07/08/2010	331.44	72.9
07/09/2010	326.39	73.6
07/10/2010	449.80	73.5

Later | Latest

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DEPARTMENT OF WATER RESOURCES
California Data Exchange Center

VERNALIS (USBR) *(VER)*

Elevation: 0' · SAN JOAQUIN R basin · Operator: US Bureau of Reclamation

Provisional data, subject to change.
Query executed Tuesday at 14:17:22

Select a sensor type for a plot of data.

Earlier

Date	EL COND	TEMP W
	uS/cm	DEG F
07/11/2010	493.37	75.1
07/12/2010	494.50	76.0
07/13/2010	488.63	76.2
07/14/2010	472.72	76.0
07/15/2010	488.00	76.4
07/16/2010	490.00	77.3
07/17/2010	460.53	77.9
07/18/2010	476.20	78.0
07/19/2010	441.25	77.4
07/20/2010	472.13	77.0
07/21/2010	495.21	76.3
07/22/2010	495.00	75.2
07/23/2010	474.67	75.6
07/24/2010	483.76	75.9
07/25/2010	497.12	76.1
07/26/2010	520.71	75.5
07/27/2010	479.38	74.8
07/28/2010	489.75	74.3
07/29/2010	479.82	74.0
07/30/2010	476.27	74.3
07/31/2010	509.14	74.5
08/01/2010	520.33	74.4
08/02/2010	531.73	75.2
08/03/2010	578.80	76.0
08/04/2010	604.45	76.3
08/05/2010	562.38	75.5
08/06/2010	554.42	75.4
08/07/2010	554.17	76.1
08/08/2010	541.42	76.3
08/09/2010	573.21	76.3

Later | Latest

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DEPARTMENT OF WATER RESOURCES
California Data Exchange Center

VERNALIS (USBR) *(VER)*

Elevation: 0' · SAN JOAQUIN R basin · Operator: US Bureau of Reclamation

Provisional data, subject to change.
Query executed Tuesday at 14:17:45

Select a sensor type for a plot of data.

Earlier

Date	EL COND uS/cm	TEMP W DEG F
08/10/2010	575.67	76.2
08/11/2010	604.75	75.4
08/12/2010	627.29	75.1
08/13/2010	630.88	76.0
08/14/2010	593.13	75.8
08/15/2010	575.04	75.4
08/16/2010	602.17	75.8
08/17/2010	577.79	76.3
08/18/2010	552.04	75.7
08/19/2010	568.25	75.5
08/20/2010	559.42	75.8
08/21/2010	545.08	75.2
08/22/2010	582.46	73.7
08/23/2010	578.08	73.8
08/24/2010	579.75	75.7
08/25/2010	589.71	77.8
08/26/2010	576.13	77.9
08/27/2010	565.25	76.1
08/28/2010	562.58	73.6
08/29/2010	527.71	71.6
08/30/2010	516.38	71.1
08/31/2010	493.38	71.6
09/01/2010	498.13	72.8
09/02/2010	523.04	74.7
09/03/2010	506.79	76.0
09/04/2010	530.42	76.0
09/05/2010	544.46	75.2
09/06/2010	502.08	73.9
09/07/2010	504.79	73.2
09/08/2010	507.21	71.0

Later | Latest

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DEPARTMENT OF WATER RESOURCES
California Data Exchange Center

VERNALIS (USBR) *(VER)*

Elevation: 0' · SAN JOAQUIN R basin · Operator: US Bureau of Reclamation

Provisional data, subject to change.
Query executed Tuesday at 14:16:13

Select a sensor type for a plot of data.

Earlier

Date	EL COND	TEMP W
	uS/cm	**DEG F**
06/06/2011	172.67	58.2
06/07/2011	180.29	59.1
06/08/2011	183.38	60.8
06/09/2011	186.75	62.0
06/10/2011	180.54	62.8
06/11/2011	175.83	62.9
06/12/2011	168.25	62.2
06/13/2011	169.33	62.2
06/14/2011	167.67	62.6
06/15/2011	162.42	63.2
06/16/2011	165.38	63.4
06/17/2011	164.38	63.5
06/18/2011	152.25	63.7
06/19/2011	158.54	63.7
06/20/2011	161.08	64.0
06/21/2011	147.92	64.9
06/22/2011	146.54	66.2
06/23/2011	144.58	67.2
06/24/2011	136.79	67.3
06/25/2011	137.13	67.5
06/26/2011	139.92	67.8
06/27/2011	137.33	68.4
06/28/2011	142.04	68.5
06/29/2011	139.79	68.1
06/30/2011	138.58	67.8
07/01/2011	124.08	66.5
07/02/2011	117.67	66.9
07/03/2011	123.29	68.1
07/04/2011	149.83	69.3
07/05/2011	169.63	71.3

Later | Latest

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VERNALIS (USBR) *(VER)*

Elevation: 0' · SAN JOAQUIN R basin · Operator: US Bureau of Reclamation

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Query executed Tuesday at 14:15:42

Select a sensor type for a plot of data.

Earlier

Date	EL COND uS/cm	TEMP W DEG F
07/06/2011	171.38	71.9
07/07/2011	150.38	70.8
07/08/2011	132.92	69.0
07/09/2011	127.71	67.6
07/10/2011	128.50	66.7
07/11/2011	120.21	66.6
07/12/2011	129.71	67.9
07/13/2011	131.75	68.8
07/14/2011	125.92	69.0
07/15/2011	126.17	68.9
07/16/2011	141.96	68.9
07/17/2011	174.58	68.2
07/18/2011	191.88	66.5
07/19/2011	180.29	65.0
07/20/2011	174.21	64.6
07/21/2011	200.63	66.2
07/22/2011	226.50	67.0
07/23/2011	245.58	67.6
07/24/2011	269.96	68.0
07/25/2011	284.17	68.0
07/26/2011	288.04	67.6
07/27/2011	309.54	67.9
07/28/2011	312.38	68.3
07/29/2011	309.96	68.7
07/30/2011	325.42	68.6
07/31/2011	331.00	68.3
08/01/2011	329.46	68.1
08/02/2011	321.46	68.2
08/03/2011	245.92	66.1
08/04/2011	218.96	64.4

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VERNALIS (USBR) *(VER)*

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Query executed Tuesday at 14:14:56

Select a sensor type for a plot of data.

Earlier

Date	EL COND	TEMP W
	uS/cm	DEG F
08/05/2011	218.04	64.6
08/06/2011	222.17	65.1
08/07/2011	221.25	65.4
08/08/2011	229.38	65.5
08/09/2011	232.54	65.3
08/10/2011	235.63	65.5
08/11/2011	218.67	65.3
08/12/2011	219.17	65.0
08/13/2011	219.25	65.1
08/14/2011	215.63	65.1
08/15/2011	217.83	65.3
08/16/2011	218.46	65.1
08/17/2011	215.92	65.0
08/18/2011	217.92	64.9
08/19/2011	206.63	64.6
08/20/2011	205.25	64.2
08/21/2011	209.46	63.9
08/22/2011	206.17	64.2
08/23/2011	202.92	64.1
08/24/2011	201.33	64.8
08/25/2011	202.00	65.9
08/26/2011	163.83	65.7
08/27/2011	158.33	65.7
08/28/2011	160.50	65.4
08/29/2011	155.83	65.0
08/30/2011	167.67	65.1
08/31/2011	187.83	65.7
09/01/2011	168.08	65.5
09/02/2011	167.00	65.4
09/03/2011	194.38	65.5

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Earlier

Date	EL COND	TEMP W
	uS/cm	**DEG F**
06/30/2012	322.79	68.5
07/01/2012	403.08	70.9
07/02/2012	439.33	73.0
07/03/2012	458.42	73.7
07/04/2012	465.13	74.5
07/05/2012	461.00	73.7
07/06/2012	507.65	74.0
07/07/2012	512.21	75.0
07/08/2012	490.83	75.5
07/09/2012	544.91	75.9
07/10/2012	589.04	76.3
07/11/2012	--	--
07/12/2012	0.00	--
07/13/2012	346.33	80.2
07/14/2012	596.58	77.3
07/15/2012	566.79	77.3
07/16/2012	544.71	76.9
07/17/2012	589.42	74.9
07/18/2012	565.83	74.1
07/19/2012	524.79	74.3
07/20/2012	572.54	74.8
07/21/2012	516.42	76.7
07/22/2012	532.46	78.3
07/23/2012	539.92	79.3
07/24/2012	560.75	78.6
07/25/2012	507.46	77.3
07/26/2012	482.83	76.0
07/27/2012	498.71	75.0
07/28/2012	525.29	75.4
07/29/2012	504.46	75.6

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VERNALIS (USBR) *(VER)*

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Query executed Tuesday at 14:05:29

Select a sensor type for a plot of data.

Earlier

Date	EL COND	TEMP W
	uS/cm	**DEG F**
07/30/2012	491.17	76.4
07/31/2012	524.00	77.8
08/01/2012	527.83	78.0
08/02/2012	547.17	77.9
08/03/2012	561.46	77.6
08/04/2012	554.42	75.8
08/05/2012	530.54	75.0
08/06/2012	508.46	75.4
08/07/2012	535.33	76.0
08/08/2012	518.42	76.0
08/09/2012	511.38	77.4
08/10/2012	532.42	78.5
08/11/2012	557.79	79.1
08/12/2012	561.50	79.7
08/13/2012	546.38	80.3
08/14/2012	565.04	80.6
08/15/2012	564.46	80.1
08/16/2012	510.50	78.8
08/17/2012	513.25	77.9
08/18/2012	503.08	77.2
08/19/2012	472.17	76.3
08/20/2012	430.38	76.3
08/21/2012	498.04	76.0
08/22/2012	506.50	75.9
08/23/2012	529.58	76.5
08/24/2012	543.88	76.3
08/25/2012	541.04	75.5
08/26/2012	574.21	74.5
08/27/2012	614.38	73.4
08/28/2012	599.96	74.3

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VERNALIS (USBR) *(VER)*

Elevation: 0' · SAN JOAQUIN R basin · Operator: US Bureau of Reclamation

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Query executed Tuesday at 14:05:59

Select a sensor type for a plot of data.

Earlier

Date	EL COND uS/cm	TEMP W DEG F
08/29/2012	565.46	74.4
08/30/2012	549.25	75.0
08/31/2012	564.38	73.8
09/01/2012	574.04	72.3
09/02/2012	564.79	72.8
09/03/2012	599.54	73.9
09/04/2012	610.54	74.5
09/05/2012	593.96	73.2
09/06/2012	626.21	73.1
09/07/2012	652.63	73.0
09/08/2012	659.58	73.4
09/09/2012	588.42	72.9
09/10/2012	584.83	72.2
09/11/2012	617.25	72.6
09/12/2012	602.29	73.2
09/13/2012	621.00	74.0
09/14/2012	610.42	74.6
09/15/2012	566.88	74.4
09/16/2012	572.29	73.8
09/17/2012	559.29	72.7
09/18/2012	609.17	71.5
09/19/2012	578.48	70.5
09/20/2012	589.21	70.2
09/21/2012	625.50	70.4
09/22/2012	610.58	71.5
09/23/2012	575.96	71.8
09/24/2012	557.67	71.1
09/25/2012	591.29	70.6
09/26/2012	630.21	70.8
09/27/2012	663.79	71.3

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Exhibit “O”

federal register

Tuesday
January 24, 1995

Part II

Environmental Protection Agency

40 CFR Part 131

Water Quality Standards for Surface Waters of the Sacramento and San Joaquin Rivers, and San Francisco Bay and Delta, California; Final Rule

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Part 131

[OW–FRL–5084–4]

Water Quality Standards for Surface Waters of the Sacramento River, San Joaquin River, and San Francisco Bay and Delta of the State of California

AGENCY: Environmental Protection Agency.

ACTION: Final rule.

SUMMARY: This final rule, required under Section 303 of the Clean Water Act, is part of an interagency effort designed to ensure that the fish and wildlife resources of the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Bay/Delta) are protected and to minimize the likelihood of future listings of Bay/Delta species under the Endangered Species Act. The Bay/Delta is the West Coast's largest estuary, supplying habitat for over 120 fish species and large populations of waterfowl. Over the past two years, the U.S. Environmental Protection Agency (EPA) has worked closely with the Departments of the Interior and Commerce, as well as the State of California, to address the severe and continuing decline of Bay/Delta fish and wildlife resources. This decline has been so severe that a number of fish species, including the winter-run chinook salmon are considered threatened or endangered under the Endangered Species Act. In coordinating their respective actions in the Bay/Delta, the Federal agencies endorsed an ecosystem (as opposed to a species-by-species) approach. EPA's final rule establishes four sets of water quality criteria protecting habitat conditions in the estuary.

EFFECTIVE DATE: This rule shall be effective February 23, 1995.

ADDRESSES: The public may inspect the administrative record for this rulemaking, including documentation supporting the criteria, and all public comments received on the proposed rule at the Environmental Protection Agency, Water Management Division, 11th Floor, 75 Hawthorne Street, San Francisco, California 94105 (Telephone Sara Hedrick at 415–744–2200) on weekdays during the Agency's normal business hours of 9 a.m. to 5 p.m. A reasonable fee will be charged for photocopies. Inquiries can be made by calling Sara Hedrick at 415–744–2200.

FOR FURTHER INFORMATION CONTACT: Judy Kelly, Bay/Delta Program Manager, Water Management Division, W–2–4, Environmental Protection Agency, 75 Hawthorne Street, San Francisco, California 94105, 415/744–1162.

SUPPLEMENTARY INFORMATION: This preamble is organized according to the following outline:

A. Background

1. Introduction

This section of the Preamble introduces the topics which are addressed subsequently, provides a brief description of the environmental issues at stake in the San Francisco Bay/Sacramento-San Joaquin River Delta Estuary (Bay/Delta), and reviews the U.S. Environmental Protection Agency's (EPA or the Agency) recent involvement in these issues. Section B of this Preamble describes the statutory framework of section 303 of the Federal Water Pollution Control Act (33 U.S.C. 1251 to 1387) (CWA or the Clean Water Act), as well as the regulatory process for developing and revising water quality standards. In addition, Section B summarizes the recent actions of the State of California (State) and EPA under section 303 of the CWA. Section C describes the Final Rule, focusing especially on the changes from the criteria proposed at 59 FR 810, January 6, 1994 (Proposed Rule). Sections D, E, F, G, and H discuss the public comments, the requirements of Executive Order 12866, the Regulatory Flexibility Act, Executive Order 12875, and the Paperwork Reduction Act, respectively.

In addition to publishing the Proposed Rule, EPA, on August 26, 1994, at 59 FR 44095, published a Notice of Availability announcing the availability of two documents prepared since the close of the comment period. The first of these documents was a summary of a series of scientific workshops on EPA's proposed Fish Migration criteria that were sponsored and facilitated by the California Urban Water Users (CUWA) and four environmental organizations. The second document was an internal EPA staff paper presenting a reformulation of the Fish Migration criteria based upon the comments at the workshops. EPA accepted public comments on the issues raised in these two documents until September 30, 1994. EPA received two written comments in response to the Notice of Availability.

This final rule satisfies EPA's obligations under a settlement agreement approved and entered as an order in *Golden Gate Audubon Society et al.* v. *Browner* (E.D. Cal. Civ. No. 93–646 (LKK)).

2. Background

a. Environmental Concerns

The Bay/Delta is the West Coast's largest estuary, encompassing nearly 1600 square miles, and draining over 40 percent of California. The Bay/Delta is the point of convergence of California's two major river systems—the Sacramento River system flowing southward and draining a large part of northern California, and the San Joaquin River system flowing northward and draining a large part of central California. These two river systems come together at the western tip of the Delta, forming an estuary as fresh water mixes with marine water through a series of bays, channels, shoals and marshes and ultimately flowing into San Francisco Bay and then to the Pacific Ocean.

The Bay/Delta constitutes one of the largest systems for fish production in the country, supplying habitat for over 120 fish species. It also comprises one of the largest areas of waterfowl habitat in the United States, providing a vital stopover for rest and feeding for more than one-half of the waterfowl and shorebirds migrating on the Pacific Flyway. Within the boundaries of the Bay/Delta is the Suisun Marsh, the largest contiguous brackish water marsh in the United States.

The Bay/Delta is also the hub of California's two major water distribution systems—the Central Valley Project (CVP) built and operated by the U.S. Bureau of Reclamation (USBR) and the State of California's State Water Project (SWP). These two projects account for approximately 60% of the watershed's diversions (San Francisco Estuary Project (SFEP) 1992). In addition, at least 7,000 other permitted water diverters, some large and some small, have developed water supplies from the watershed feeding the Bay/Delta estuary (California State Lands Commission 1991). Together, these water development projects divert, on average, 50% of the natural flow in the Bay/Delta estuary (SFEP 1992). Most of the State's developed water—75 to 85 percent—is used for irrigation purposes by agriculture, irrigating over 4.5 million acres throughout the State. The Bay/Delta watershed also provides part or all of the drinking water supply for over 18 million people.

In large part due to the effects of these water diversions, and as discussed in more detail in the preamble to the Proposed Rule, the fish and wildlife resources in the Bay/Delta estuary have deteriorated drastically over the past twenty years. One common measure used to quantify this deterioration is the Striped Bass Index (SBI) (a measure of the relative abundance of young striped bass in the estuary). The SBI measures the relative health of an indicator species for the Bay/Delta, the striped bass. In its 1978 Water Quality Control Plan (1978 Delta Plan), the California State Water Resources Control Board (State Board) committed to maintaining an SBI value of 79. Since that time the SBI has never attained its targeted value of 79, but instead has plummeted to unprecedented low values.[1]

The precipitous decline in striped bass is indicative of the poor health of other aquatic resources in the Bay/Delta estuary. Several species have experienced similar declines, including chinook salmon (the winter-run of chinook salmon has recently been reclassified as an endangered species under the Federal Endangered Species Act, 16 U.S.C. 1531 to 1540 (ESA)), Delta smelt (listed as a threatened species under the ESA), and the Sacramento splittail (recently proposed for listing as a threatened species under the ESA). The California Department of Fish and Game (California DFG) recently testified that virtually all of the estuary's major fish species are in clear decline. (CDFG 1992b, WRINT–DFG–8)[2] Another recent report suggests that at least three more of the Bay/Delta estuary's fish species (spring-run Chinook salmon, green sturgeon, and Red Hills roach) qualify for immediate listing under the ESA (Moyle and Yoshiyama 1992). Furthermore, the decline in aquatic resources is not limited to fishes. One recent workshop noted that the available data ''indicate clearly that species at every trophic level are now at, or near, record low levels in the Delta and in Suisun Bay.''[3] (SFEP 1993) The ecological communities under stress include the plant and animal communities in the tidal portions of the brackish water marshes adjacent to Suisun Bay (Collins, J.N. and T.C. Foin, 1993).

b. State Designation of Uses in the Bay/Delta

Under section 303(c) of the CWA, states review their water quality standards every three years and submit any new or revised standards to EPA for approval or disapproval (the ''triennial review''). A water quality standard for a waterbody consists of two components: (1) Designated uses for the waterbody and (2) water quality criteria which support such designated uses.[4] In California, designated uses are equivalent to state law ''beneficial uses'' and criteria are equivalent to state law ''water quality objectives.'' Thus, the water quality objectives and beneficial use designations adopted under the California Water Code serve as water quality standards for purposes of section 303 of the CWA.

Pursuant to state and federal law, the State Board, on May 1, 1991, adopted State Board Resolution No. 91–34, formally approving the 1991 Bay/Delta Plan. The Plan restated the specific designated uses that had been included in the 1978 Delta Plan and related regional board basin plans. As restated in the 1991 Bay/Delta Plan and submitted to EPA for review under the Clean Water Act, the designated uses for waters of the Bay/Delta included the following: Agricultural Supply, Cold and Warm Fresh-Water Habitat, Estuarine Habitat, Fish Migration, Fish Spawning, Groundwater Recharge, Industrial Process Supply, Industrial Service Supply, Municipal and Domestic Supply, Navigation, Contact and Non-Contact Water Recreation, Ocean Commercial and Sport Fishing, Preservation of Rare and Endangered Species, Shellfish Harvesting, and Wildlife Habitat.[5]

c. EPA Activity Under CWA Section 303

As explained in detail in the preamble of the Proposed Rule, the serious environmental crisis for fish and wildlife resources in the Bay/Delta has been the source of an ongoing dialogue between EPA and the State for many years. Pursuant to section 303(c)(3) of the CWA, EPA reviewed the 1978 Delta Plan in 1980. While EPA approved the Plan, it was concerned that the 1978 Delta Plan standards would not provide adequate protection of striped bass and the estuary's fishery resources. EPA therefore sought and received assurances from the State Board as to the interpretation of the standards, and secured the State Board's commitment to review and revise the 1978 Delta Plan standards immediately if there were measurable adverse impacts on striped bass spawning, or if necessary to attain ''without project'' levels of protection for the striped bass as defined by an SBI value of 79. The ''without projects'' level of protection is the level of protection that would have resulted in the absence of the state and Federal water projects (the SWP and the CVP). EPA also conditioned its approval on the State Board's commitment to develop additional criteria to protect aquatic life and tidal wetlands in and surrounding the Suisun Marsh. The State Board concurred with these

[1] During the 1980's, the SBI averaged approximately 23.5, and in 1985 reached an all-time low of 4.3. Some of the decline in the SBI may be attributable to drought conditions in the late 1970's and again in the late 1980's. In all but two years since the 1978 Delta Plan was adopted, the SBI has ranged from 4.3 to 29.1, a substantial shortfall from the stated goal of 79.

[2] If a reference was presented to the State Board during one of its hearings, this preamble will present citations in both the standard scientific form and in the State Board hearing record form. Accordingly, the eighth exhibit submitted by California DFG at the Board's interim water rights hearings in the summer of 1992 is cited as indicated.

[3] The workshop report went on to state that this low level of biological diversity was ''not surprising considering the recent drought, the introduction of exotic species, and the increased diversion of water.''

[4] In addition, a state's criteria must be consistent with the state's antidegradation policy. The federal regulations provide that, at a minimum, the state's policy must maintain ''[e]xisting instream water uses [those existing in the waterbody at any time on or after November 28, 1975] and the level of water quality necessary to protect the existing uses. * * *'' 40 CFR 131.12(a)(1).

[5] As explained in more detail below, under certain circumstances a state may revise or even remove designated uses. However, in the Bay/Delta context, the State Board has made no effort to revise the designated uses adopted and restated in the 1991 Bay/Delta Plan.

interpretations in its letter to EPA dated November 21, 1980.

As fish and wildlife resources in the Bay/Delta continued to decline, EPA on several occasions expressed its continuing concern to the State Board about the need to develop standards that would adequately protect these resources. Throughout the first and second triennial reviews ending in 1981 and 1985, EPA urged the State Board to review and revise the 1978 Delta Plan in accordance with EPA's 1980 approval letter. After its second triennial review, in a letter to EPA dated June 23, 1986, the State Board acknowledged that the 1978 Delta Plan standards were not adequate to protect the estuary's fishery resources. It then outlined the hearing process it was planning for revising the standards. In response, and as part of its consideration of the State Board's second triennial review, EPA, on June 29, 1987, sent a letter to the State Board stating that EPA could no longer approve the striped bass survival standards (or the related provision allowing relaxation of the spawning standard in drier years) because these standards did not adequately protect the designated fish and wildlife uses. EPA recognized, however, that the State Board had initiated new hearings to revise the 1978 Delta Plan standards. EPA therefore indicated that it would await the results of the new hearings and approve or disapprove the revised standards after the State Board's submission to EPA of a complete set of revised standards. Following the first phase of the new hearings, the State Board in November 1988 issued a draft Plan that included revised salinity and flow standards to protect the fisheries and other designated uses (SWRCB 1988). The State Board subsequently withdrew that draft Plan, however, and issued a revised workplan that served as the basis for the State Board's present Water Quality Control Plan for Salinity for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (1991 Bay/Delta Plan).

The 1991 Bay/Delta Plan, which the State Board submitted to EPA for review on May 29, 1991, amended certain salinity criteria and adopted new temperature and dissolved oxygen criteria for specified locations in the estuary. The 1991 Bay/Delta Plan did not, however, revise the earlier 1978 Delta Plan to address EPA's longstanding concerns about adequate protection for the designated fish and wildlife uses of the Bay/Delta.

On September 3, 1991, EPA approved in part and disapproved in part the provisions of the 1991 Bay/Delta Plan. EPA's letter found that ''[t]he record * * * does not support the conclusion that the State has adopted criteria sufficient to protect the designated uses'' of the estuary. The designated uses at risk, as defined by the State Board, include Estuarine Habitat, and also Cold and Warm Water Habitat, Fish Migration, Fish Spawning, Ocean Commercial and Sport Fishing, Preservation of Rare and Endangered Species, Shellfish Harvesting, and Wildlife Habitat. In addition to its general finding that the 1991 Bay/Delta Plan did not contain sufficient criteria to protect the designated uses, EPA also disapproved the absence of salinity standards to protect the Estuarine Habitat and other fish and wildlife uses in the Suisun, San Pablo, and San Francisco Bays and Suisun Marsh, the absence of scientifically supportable salinity standards (measured by electrical conductivity) to protect the Fish Spawning uses of the lower San Joaquin River, and the absence of scientifically supportable temperature standards on the San Joaquin and Sacramento Rivers to support the Fish Migration and Cold Fresh Water Habitat uses, including the fall-run and winter-run chinook salmon.

In the summer of 1992, the State Board held hearings for the purpose of establishing interim measures to protect the natural resources in the Bay/Delta estuary. EPA participated in these hearings—rather than proposing federal standards at that time—in the hope that the hearings would result in state adoption of approvable standards and preclude the need for a federal rulemaking. EPA submitted its own recommendations to the State Board and joined with the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) in submitting an Interagency Statement of Principles. These statements specifically recommended that the State Board adopt a habitat and ecosystem-based approach to standards that would satisfy CWA requirements and meet the State Board's goal of reversing the decline of the estuary's fish and wildlife resources.

At the conclusion of these hearings, the State Board, on December 10, 1992, issued its recommended interim measures in Draft Water Rights Decision D–1630 (hereinafter D–1630). After the close of the comment period for D–1630, however, the State Board declined to adopt D–1630. Accordingly, the State criteria EPA disapproved on September 3, 1991, are still in effect. In response to the State Board's failure to revise these criteria, EPA, pursuant to section 303 (c)(3) and (c)(4) of the Act, published a Proposed Rule that would establish Federal water quality criteria for the Bay/Delta which would in effect supersede and supplement the disapproved State criteria for purposes of the CWA. EPA's Proposed Rule also satisfied its obligations under a partial settlement agreement approved and entered as an order in *Golden Gate Audubon Society et al.* v. *Browner,* (E.D. Ca. Civ. No. 93–646 (LKK)).

EPA's Proposed Rule was one component of a coordinated initiative by the several Federal agencies having regulatory or operational responsibilities in the Bay/Delta. In early 1993, these four agencies—EPA, USFWS, NMFS, and USBR—formed the Federal Environmental Directorate (now known almost exclusively as ''Club FED'') for the purpose of assuring that the Federal agencies worked in a coordinated manner in taking actions under their respective statutory authorities that would affect the estuary. The Federal initiative announced in December 1993 included the EPA Proposed Rule, the USFWS proposal to list the Sacramento splittail as a threatened species under the ESA, the USFWS proposal for critical habitat for the threatened Delta smelt, and the NMFS reclassification of the winter-run chinook salmon as endangered. This initiative also coincided with the USBR's preliminary water allocation forecast for CVP deliveries for the 1994 water year.

d. Post-Proposal Activities

Since the publication of the Proposed Rule, EPA has moved towards final promulgation of protective criteria in an expeditious and open manner. EPA held several public hearings throughout the state in late February, 1994, to hear comments on the Proposed Rule. In addition, EPA met with a number of interested parties to discuss the economic analysis prepared in conjunction with the Proposed Rule. The purpose of these meetings was to solicit recommendations as to how to improve the analysis of potential economic impacts resulting from the State's implementation of the Federal criteria.

EPA also participated in a series of scientific workshops arranged and facilitated by California Urban Water Agencies (CUWA), the Bay Institute, the Natural Heritage Institute, Save San Francisco Bay Association, and the Environmental Defense Fund. These workshops were designed to discuss the extensive scientific comments submitted by CUWA on the criteria proposed in the Proposed Rule. Dr. Wim Kimmerer, the reporter for these workshops, prepared written summaries of the discussions on the Estuarine

Habitat criteria and the Fish Migration Criteria (Kimmerer 1994b). As discussed above, the summary of the workshops on the Fish Migration criteria and EPA's alternative formulation of the Fish Migration criteria were made available to the public in EPA's Notice of Availability published on August 26, 1994, 59 FR 44095.

The Federal interagency cooperation effort begun before the publication of the Proposed Rule has continued during the past year. The most formal aspects of this cooperation effort have been the consultations under Section 7 of the ESA between EPA and the USFWS and NMFS on the potential effects of EPA's criteria on threatened and endangered species and their critical habitat.[6] EPA and the Services began consulting informally in December 1991. Formal consultations were initiated in August 1993. In recognition of the tentative nature of a proposed rule, the Services deferred preparing a formal biological opinion for the Proposed Rule and instead, on November 24, 1993, submitted formal comments to EPA on the Proposed Rule. These formal comments raised the major concerns of the respective Services about potential effects of the proposed criteria on threatened and endangered species. Since publication of the Proposed Rule, the Services have worked closely with EPA to assure that the final rule complies with the ESA. The Services have been actively involved in reviewing comments received from the public, and participated in the CUWA scientific workshops on EPA's Proposed Rule.

In early November 1994, after discussing the probable final criteria with EPA, NMFS and USFWS concluded their reviews of the final criteria and issued their respective final conclusions as to the anticipated effects of the implementation of these criteria on threatened and endangered species. The USFWS issued a ''no jeopardy'' biological opinion under Section 7 of the ESA, finding that implementation of these criteria would not likely jeopardize the continued existence of any listed species or result in adverse modification of habitat deemed critical to the survival of listed species. In recognition of the fact that the final EPA criteria may be implemented only when the State Board adopts final implementation plans, the USFWS biological opinion also called for the reinitiation of consultations when the implementation plans are finalized by the State Board so that any possible problems for endangered or threatened species caused by implementing the criteria can be addressed.

NMFS concluded its review by making a finding that implementation of these criteria would not adversely affect the threatened and endangered species or result in adverse modification of critical habitat of those species (anadromous fishes) under its jurisdiction. The NMFS findings also called for reinitiation of consultation when implementation plans are developed by the State Board, so that any possible problems for threatened or endangered species caused by implementing the criteria can be addressed.

In addition to the formal ESA consultation process, the four Club Fed agencies have again coordinated several of their regulatory and operational duties and are announcing two Federal actions simultaneously. In addition to EPA's final promulgation of water quality criteria under the CWA, the USFWS is making it's final designation of critical habitat for the Delta smelt under the ESA. These coordinated Federal actions serve as the underlying basis for the long-term solution to fish and wildlife protection in the Bay/Delta estuary.

Finally, in an effort to facilitate the long-term resolution of Bay/Delta issues, the Club Fed agencies and their counterpart agencies in the State of California executed, as of July 1994, a Framework Agreement laying out the Federal and State intentions as to how these agencies would work together cooperatively on a range of issues in the estuary. One key element of this Framework Agreement was EPA's agreement to sign a final rule regarding these water quality criteria by the end of 1994. At the same time, the State Board agreed to prepare a draft revision to its water quality plan by the end of 1994, and to finalize that plan in early 1995. The Framework Agreement envisions that, if EPA finds that the revised State plan submitted to EPA meets the requirements of the CWA, EPA will initiate action to withdraw this rule.

Consistent with its commitment in the Framework Agreement, the State Board conducted a series of workshops on Bay/Delta issues throughout the spring, summer and fall of 1994. EPA participated in these workshops, and has continued to work with the State Board to assure that the revisions adopted by the State Board will meet the requirements of the CWA. It is EPA's hope that the cooperative process outlined in the Framework Agreement will lead to approvable state standards for protecting the designated uses in the Bay/Delta estuary.

EPA is aware of efforts by urban and agricultural users, in cooperation with environmental groups, to identify alternative standards that may meet the requirements of the CWA. EPA encourages affected parties to continue to work with EPA and the State to develop proposals that meet the requirements of the CWA. EPA would welcome the adoption by the State of a revised plan based in whole or in part on such private proposals provided that it complies with the requirements of the CWA.

B. Statutory and Regulatory Background

Section 303(c) of the Act requires that state water quality standards ''* * * be such as to protect the public health or welfare, enhance the quality of water and serve the purposes of this [Act]. Such standards shall be established taking into consideration their use and value for propagation of fish and wildlife, recreational purposes, and agricultural, industrial, and other purposes. * * *'' Key concerns of this statutory provision are the enhancement of water quality for the protection of the propagation of fish and other aquatic life. The ultimate purpose of water quality standards, as with the other provisions of the CWA, is ''to restore and maintain the chemical, physical, and biological integrity of the Nation's waters.'' CWA section 101(a).

Under section 303(c) of the Act, a water quality standard for a specific waterbody consists of two components: designated uses for which a waterbody is to be protected (such as recreation in and on the water, protection and propagation of fish and wildlife, or agricultural uses) and the water quality criteria which support those designated uses.[7]

The Act gives primary responsibility for the adoption of water quality standards to the states. After adopting its initial water quality standards, a state is required, no less than every three years, to review those standards, and, if necessary, modify them. Under section 303(c)(1) of the Act, if a state revises or adopts a new standard, it must submit such a standard to EPA for approval or disapproval.

[6] As stated above, the species of concern include primarily the winter-run chinook salmon (a listed endangered species under the jurisdiction of NMFS) and the Delta smelt (a listed threatened species under the jurisdiction of the USFWS). The USFWS has also formally proposed that the Sacramento splittail be listed as threatened.

[7] As discussed below, a state's water quality standards must also contain an antidegradation policy.

EPA's Water Quality Standards regulations at 40 CFR part 131 specify the requirements for designated uses. ''Designated Uses'' are those uses specified in water quality standards for each water body or segment whether or not they are being attained. 40 CFR 131.3(f). Examples of designated uses are listed in section 303(c)(2)(A) of the CWA. They include: public water supplies, protection and propagation of fish, shellfish, and wildlife, recreation, agricultural and industrial, and navigation. Other uses have been adopted as well (e.g. aquifer protection, coral reef preservation).

Under certain circumstances, States may remove a designated use which is not an existing use. 40 CFR 131.10(g). ''Existing Uses'' are those uses actually attained in the water body on or after November 28, 1975, whether or not they are included in the water quality standards. 40 CFR 131.3(f). Generally, existing uses, whether or not they are ''designated uses,'' may not be removed. 40 CFR 131.3(g) and (h). A state must conduct a ''use attainability analysis'' as defined in 40 CFR 131.3(g) whenever (1) the State designates uses that do not include the uses specified in section 101(a)(2) of the CWA, or (2) the State wishes to remove a designated use that is specified in section 101(a)(2) of the CWA or to adopt subcategories of uses which require less stringent criteria. 40 CFR 131.3(j). The state may take economics into account when it designates uses, as, for example, in a use attainability analysis. 40 CFR 131.3(g)(6).

EPA's Water Quality Standards regulations at 40 CFR part 131 specify the requirements for water quality criteria.

> States must adopt those water quality criteria that protect the designated use. Such criteria must be based on sound scientific rationale and must contain sufficient parameters or constituents to protect the designated use. For waters with multiple use designations, the criteria shall support the most sensitive use. 40 CFR 131.11(a).

Thus, once designated uses are established, the water quality criteria are based on what is necessary scientifically to protect the most sensitive designated use.

In addition, a state's criteria must be consistent with the state's antidegradation policy. The federal regulations provide that, at a minimum, the state must have an antidegradation policy that maintains ''[e]xisting instream water uses [those existing in the waterbody at any time on or after November 28, 1975] and the level of water quality necessary to protect the existing uses. * * *'' 40 CFR 131.12(a)(1).

In order to approve a state's water quality criteria, EPA must determine that the state has adopted ''water quality criteria [that are] sufficient to protect the designated uses.'' 40 CFR 131.6(c).

Section 303(c)(4) of the Act provides that the Administrator shall promptly prepare and publish proposed regulations establishing a new or revised standard in either of two situations: first, when the Administrator has disapproved a state standard under section 303(c)(3) and the state has not taken corrective action within 90 days; and, second, in any case where the Administrator determines that a revised or new standard is necessary to meet the requirements of the Act. Once promulgated, the federal regulations are applicable to the state's waters, and, if they are more stringent, have the effect of supplanting and supplementing the state's standards for all purposes under the CWA. However, it is EPA's longstanding policy that the federal water quality standards will be withdrawn if a state adopts and submits standards that in the Agency's judgment meet the requirements of the Act.

The chronology of State and EPA actions under the CWA in the Bay/Delta estuary over the past two decades were described in more detail in the preamble to the Proposed Rule, and in paragraph A.1.c. herein. Briefly stated, the State Board's adoption of the 1978 Delta Plan, and of the revised Bay/Delta Plan in 1991, were intended to meet the State's obligations to establish water quality standards under the CWA. Pursuant to its mandate under section 303(c)(3) of the Act, on September 3, 1991, EPA disapproved several of the criteria contained in the State Board's plan. EPA's letter found that ''[t]he record * * * does not support the conclusion that the State has adopted criteria sufficient to protect the designated uses'' of the estuary. The designated uses at risk, as defined by the State Board, include Estuarine Habitat, and also Cold and Warm Water Habitat, Fish Migration, Fish Spawning, Ocean Commercial and Sport Fishing, Preservation of Rare and Endangered Species, Shellfish Harvesting, and Wildlife Habitat. In addition to its general finding that the 1991 Bay/Delta Plan did not contain sufficient criteria to protect the designated uses, EPA also disapproved the absence of salinity criteria to protect fish and wildlife uses in the Suisun, San Pablo, and San Francisco Bays and Suisun Marsh, the absence of scientifically supportable salinity criteria (measured by electrical conductivity) to protect the Fish Spawning uses of the lower San Joaquin River, and the absence of scientifically supportable temperature standards on the San Joaquin and Sacramento Rivers to protect the Fish Migration and Cold Fresh Water Habitat Uses.

For the reasons outlined herein, in the Proposed Rule, and in EPA's letter of September 3, 1991, the Agency finds that the water quality criteria adopted by the State fail to protect the designated uses and that the criteria below meet the requirements of the Act. Accordingly, pursuant to sections 303(c)(3) and 303(c)(4) of the Act, the Administrator is promulgating the following water quality criteria applicable to the Bay/Delta's waters.

C. Description of the Final Rule and Changes From Proposal

1. Estuarine Habitat Criteria

a. Overview

(1) Importance of the Estuarine Habitat Designated Use. The State's 1991 Bay/Delta Plan included ''Estuarine Habitat'' as a designated use for the Bay/Delta estuary. This Estuarine Habitat designated use is intended to provide ''an essential and unique habitat that serves to acclimate anadromous fishes (salmon, striped bass) migrating into fresh or marine conditions. This habitat also provides for the propagation and sustenance of a variety of fish and shellfish, numerous waterfowl and shore birds, and marine mammals.'' *See* Water Quality Control Plan, San Francisco Bay Basin [2], December 1986, at II–4.

EPA considers protection of the Estuarine Habitat designated use to be important for a number of important reasons. As described in detail in the Preamble to the Proposed Rule, conditions in the estuary are of critical importance because the estuary's particular characteristics provide a unique food source, spawning habitat or nursery habitat for a whole range of aquatic and aquatic-dependent species. The Estuarine Habitat designated use protects this vital ecosystem, an ecosystem that has a crucial role in restoring and protecting the fish and wildlife populations of the Bay/Delta. EPA and the other Federal agencies are committed to multispecies or ecosystem protection approaches, rather than focusing on the peculiar needs of individual species. In addition, the resource values benefitting from the protection of the Estuarine Habitat use include resources described in other state-designated uses, including Ocean Commercial and Sport Fishing, Preservation of Rare and Endangered Species, Fish Migration, and Wildlife

Habitat.[8] Indeed, many of the resources targeted for protection by these related uses would not be fully protected without adequate protection of the Estuarine Habitat designated use. In developing criteria protective of the Estuarine Habitat use, EPA has been mindful of the overlapping designated uses and of the range of natural resources affected by the broad Estuarine Habitat.

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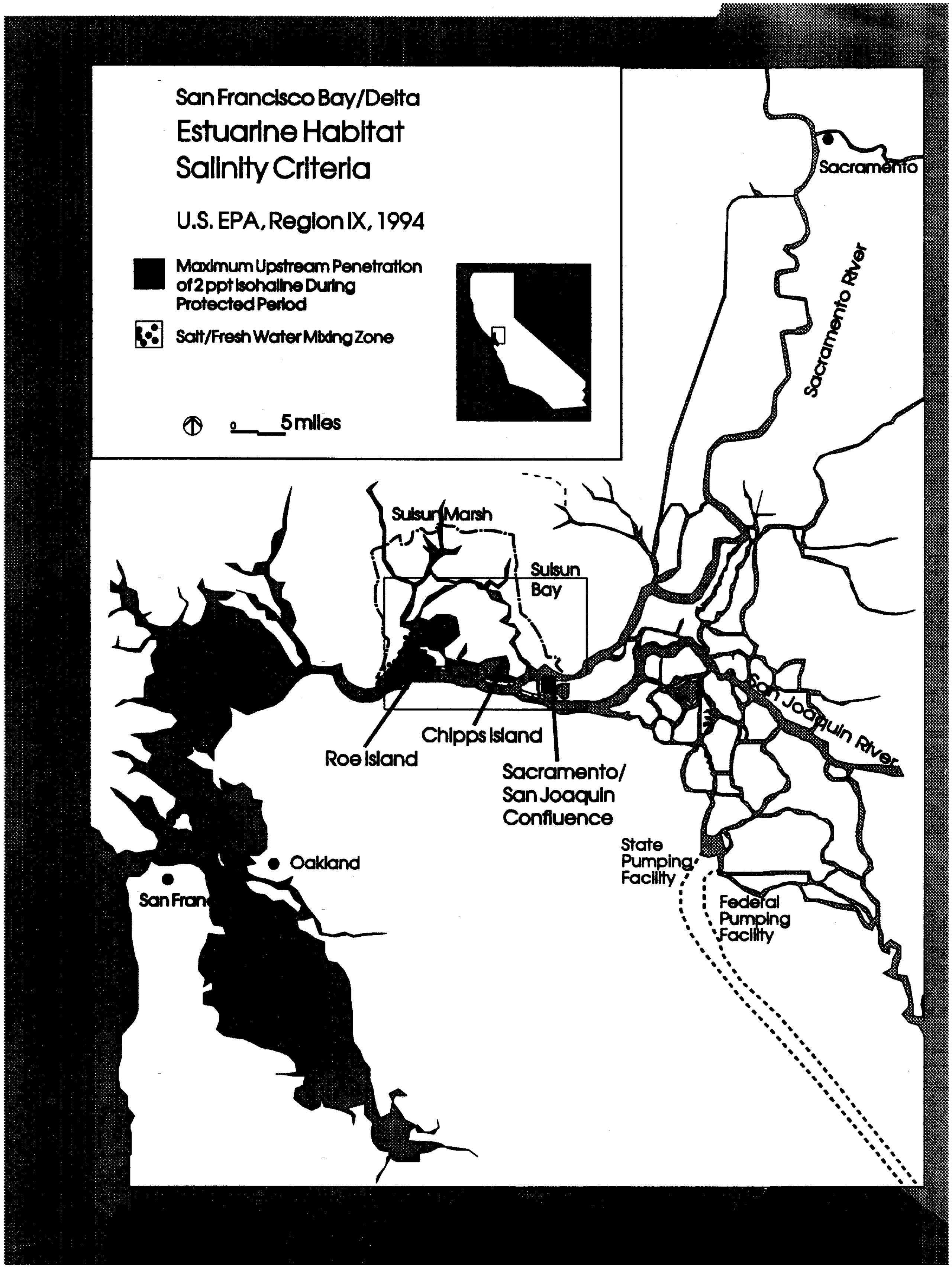
[8] As described by the State Board, the Ocean Commercial and Sport Fishing designated use protects the ''commercial fishing and collection of various types of fish and shellfish, including those taken for bait purposes, and sport fishing in ocean, bays, estuaries and similar non-freshwater areas.'' The Preservation of Rare and Endangered Species use ''[p]rovides an aquatic habitat necessary, at least in part, for the survival of certain species established as being rare and endangered species.'' As described below, the Fish Migration use ''[p]rovides a migration route and temporary aquatic environment for anadromous or other fish species.'' Finally, the Wildlife Habitat ''[p]rovides a water supply and vegetative habitat for the maintenance of wildlife.''


San Francisco Bay/Delta
Estuarine Habitat
Salinity Criteria
U.S. EPA, Region IX, 1994
Maximum Upstream Penetration of 2 ppt Isohaline During Protected Period
Salt/Fresh Water Mixing Zone
0 5 miles
Sacramento
Sacramento River
Suisun Marsh
Suisun Bay
Roe Island
Chipps Island
Sacramento/
San Joaquin
Confluence
San Joaquin River
State
Pumping
Facility
Federal
Pumping
Facility
Oakland
San Fran

(2) Proposed Criteria. As stated in the Proposed Rule, the Estuarine Habitat criteria consisted of three interrelated components:

(i) A salinity requirement of 2 parts per thousand (2 ppt);

(ii) Maintained at one or more of three monitoring locations in the Suisun Bay;

(iii) For a specified number of days during the critical spring months.

These criteria were designed to reflect the conditions in the estuary at a time when it attained protection of the designated Estuarine Habitat use.

As a preliminary matter, EPA determined the ''reference period,'' the historical time period during which the salinity regime in the estuary was sufficient to protect the designated uses. To determine the reference period, EPA was guided by the Interagency Statement of Principles signed by EPA, USFWS and NMFS, which called for estuarine conditions similar to the late 1960's to early 1970's as necessary to protect the Estuarine Habitat. However, the decade from 1965 to 1974 did not include water years types from each of the five water year type categories.[9] Therefore, in order to estimate those conditions over the entire range of possible hydrological conditions that may occur in the future, EPA used data from the years 1940 to 1975 to represent the conditions in the reference period of the late 1960's to early 1970's, and used this larger set of historical data to determine the minimum number of days of compliance.

As explained in more detail below and in the preamble to the Proposed Rule, EPA then focused on the salinity regime in the estuary to develop criteria that protect the Estuarine Habitat. Salinity was selected for several reasons: it is closely associated with the abundance and distribution of species at all trophic levels, it can be measured accurately and easily, and it integrates a number of important estuarine properties and processes.

Salinity conditions in the estuary vary dramatically from month to month and year to year, primarily in response to natural factors such as precipitation and snowmelt upstream, and to man-made factors such as reservoir operations, upstream diversions and export rates. EPA concluded that maintaining salinity conditions reflecting the natural hydrology in the Bay/Delta during the reference period would provide estuarine habitat conditions that protect the fish and wildlife resources dependent on that habitat. In other words, because precipitation varies naturally from year to year and within each year, salinity conditions reflecting this natural variability at a time period when the Bay/Delta attained its designated uses would protect the natural resources dependent upon estuarine habitat. While it may seem counterintuitive to provide *less* fresh water to the estuary in a dry year, and *more* water in a wet year, the natural resources in the Bay/Delta ecosystem have adapted to the cycle of both within-year hydrological fluctuations and substantial year-to-year fluctuations in hydrology. The intent of the proposed criteria was to restore a pattern and magnitude of those hydrological fluctuations that reflected the historical period during which the designated uses were fully protected.

To provide these conditions, EPA proposed maintaining the low salinity[10] 2 ppt isohaline (an isohaline is simply a line joining all points of equal salinity) in Suisun Bay during the critical wet season months of February to June. This particular time period is important because many different species use the low salinity habitat in the spring for spawning, as nursery habitat, for transportation through the Delta, or for a combination of these three purposes. To take account of the variation in natural hydrological conditions, EPA proposed criteria that varied according to the water year type. In all water years, the 2 ppt salinity criteria would be met at the furthest upstream monitoring site (the confluence of the Sacramento and San Joaquin Rivers at the upstream end of Suisun Bay). In wetter years, the 2 ppt salinity criteria would also be met at one or both of two downstream monitoring sites (Chipps Island and Roe Island, in the middle and downstream end of Suisun Bay, respectively).

The proposal was stated as requiring attainment of the 2 ppt salinity criteria at or below one of the three monitoring sites for a specified number of days during the February to June period, depending on the water year type. For example, under the Proposed Rule, in a ''below normal'' water year, the 2 ppt isohaline would have been required at or downstream of Chipps Island for a total of 119 days during the February to June period. This ''number of days'' approach allowed the criteria to be responsive and replicative of the varying natural hydrology during February to June. That is, if February or March were particularly wet, the criteria's ''number of days'' could be met at that time using those natural storm flows, rather than requiring reservoir releases later in the February to June period.

Finally, again in an attempt to match the criteria with the natural hydrology, the Proposed Criteria included a ''trigger'' for compliance with the farthest downstream monitoring site (Roe Island). Compliance at that site would not be required unless and until the 2 ppt isohaline had been pushed that far downstream through natural storm events.

(3) Final Criteria. The Estuarine Habitat criteria in the final rule have been revised to address many of the technical issues raised in the public comments. The fundamental structure of the Estuarine Habitat criteria is unchanged: The criteria require maintenance of the 2 ppt[11] isohaline at or downstream of one of three monitoring sites in Suisun Bay during a specified portion of the February through June period. The final criteria continue to require a 2 ppt salinity value at the Confluence of the Sacramento and San Joaquin rivers each day between February through June in all years. The 2 ppt salinity value is to be met at Chipps Island for a specified number of days, depending on the amount of precipitation. The greater the precipitation, the higher the number of days the criteria must be attained. The 2 ppt salinity value must be met at Roe Island only if it is triggered by precipitation sufficient to push the 2 ppt salinity value downstream to Roe Island during the last half of the previous month. Once triggered, the 2 ppt salinity value is to be met at Roe Island for a specified number of days, depending on precipitation.

The changes to the final criteria are primarily refinements to how the rule determines the number of days the salinity standard must be met at Chipps and Roe Islands. The primary revisions include:

[9] ''Water year'' type categories in California refer to precipitation patterns for the year. The standard water year categories are wet, above normal, below normal, dry, and critically dry years.

[10] Low salinity in the 2 ppt range is being used to describe salinity conditions in the ''mixing zone'' between freshwater coming downstream and marine water moving inland from the ocean in response to tidal influences and fluctuations in freshwater outflow. This mixing zone generally contains low surface salinity of 1 to 6 ppt, whereas ocean salinity is over 30 ppt and freshwater salinity is generally less than 1 ppt (Arthur and Ball 1979).

[11] The Proposed Rule stated the criteria as a requirement for 2 ppt salinity. As discussed more fully below, in order to state the requirement more precisely, the final rule language will define the criteria in terms of micromhos per centimeter specific conductance at 25 °C instead of parts per thousand salinity. Accordingly, the final rule will state the criteria value as ''2640 micromhos/cm,'' which is equivalent to 2 ppt salinity. Although EPA is restating the actual rule language in the more precise specific conductance language, it will continue to refer to this criteria value as 2 ppt in this discussion of the final rule.

(i) *Shift from water year categories to a ''sliding scale''.* Rather than basing the number of days on data reflecting average salinity for each of the five water year types, EPA is basing the number of days on a ''sliding scale'' or ''smooth function'' that more precisely states the correlation between precipitation and the number of days of the 2 ppt value. For example, whereas the previous approach would require the same number of days of the 2 ppt value for all ''above normal'' years, the sliding scale requires fewer number of days for a *dry* ''above normal'' year than for a *wet* ''above normal'' year. In other words, rather than stating the criteria as five discrete points representing water year types, the sliding scale uses all the data underlying those five points to construct a continuous function or line reflecting salinity as a function of flow. The sliding scale is a more realistic description of the relationship between salinity and flow as it existed at the time during which the estuary attained its designated uses.

(ii) *Shift from yearly hydrology to monthly hydrology.* Instead of basing the number of compliance days at Chipps and Roe Islands on the expected hydrological conditions for the entire year, the final criteria base the current month's requirements only on the previous month's hydrological conditions. This change requires that these criteria specify a ''sliding scale'' for each month, but allows a much more accurate reflection of variations in natural hydrology.

(iii) *Revising the data used to reflect more accurately conditions in the estuary during the reference period.* As explained above, the reference period is the historical time period when the estuary attained its designated uses. In the Proposed Rule, EPA used the late 1960's to early 1970's as the reference period because the available information about the fish and wildlife resources in the Bay/Delta suggests that this time period encompasses the most recent time period during which the designated uses were attained. To describe hydrological and salinity conditions in this late 1960's to early 1970's reference period, the Proposed Rule used data from 1940 to 1975. This longer period was used because the actual conditions in the late 1960's to early 1970's did not provide representative samples of the possible broad range of hydrological conditions in the estuary. The Proposed Rule suggested that the period 1940–1975 could be considered representative of the late 1960's to early 1970's because the longer period was one of fairly consistent hydrological conditions bracketed by the completion of Shasta Dam on the Sacramento in the early 1940's and by the severe drought of the mid-1970's.

EPA received much comment on the approach in the Proposed Rule, with some commenters arguing convincingly that the 1940 to 1975 was in fact not one of consistent hydrological conditions, since the ''level of development''—the change in the facilities used for water diversion and storage—changed over time during this period due to additional construction activities at the state, federal, and local levels. EPA agrees with these comments and has reevaluated the historical data to account for the effects of the level of development on the salinity regime in Suisun Bay. As discussed below, EPA has determined that it is appropriate to use the level of development—and corresponding salinity regime—represented by calendar year 1968 as a surrogate for the late 1960's to early 1970's reference period when the estuary attained its designated uses.

(iv) *Alternative measures of attainment.* Under the CWA, the State Board has the responsibility for developing an implementation plan, including the methodology for measuring attainment. Based on the comments received as discussed below, EPA believes that attainment could be measured at the Roe Island and Chipps Island monitoring sites by any of (1) the daily salinity value, (2) the 14-day average salinity, or (3) the ''flow equivalence'' of the salinity value, as predicted in the recent Contra Costa Water District (CCWD) model described below. For reasons that are peculiar to that model, attainment at the Confluence monitoring site could be measured by either of the first two of these approaches only.

b. Detailed Discussion

(1) Proposed Estuarine Habitat Criteria

The Estuarine Habitat criteria included in the Proposed Rule specified the location and number of days that the 2 ppt salinity value would need to be met to protect the designated use. EPA's proposed criteria are shown in Table 1. They consisted of 2 ppt salinity criteria [12] to be attained for a specified number of days at Roe Island, Chipps Island, and at the Sacramento/San Joaquin River confluence during the period of February through June. The Proposed Rule provided that the 2 ppt salinity value must be met at the Sacramento/San Joaquin River confluence monitoring station for the entire 150 day period from February through June. The number of days of compliance with the 2 ppt value at Chipps and Roe Islands were based on the late 1960's to early 1970's ''reference period'' representing a time in which the conditions in the estuary were adequate to protect the designated uses. To represent this reference period, the criteria replicated the average number of days in each of the five water year types during which the 2 ppt salinity value occurred at or downstream from each of these locations during the historical period 1940–1975. Because no critically dry years occurred in the period from 1940 to 1975, the required number of days for critically dry years was based on an extrapolation of the data. In addition, in a number of years in the 1940–1975 period, data existed for flow conditions in the estuary but not for salinity. For these years, the Kimmerer-Monismith model (SFEP 1993) was used to estimate the salinity regime based on the existing flow data.

The proposed criteria were to be measured using a 14-day moving average.[13] The use of a 14-day moving average allowed the mean location to be achieved despite the varying strength of tidal currents during the lunar cycle, because any 14 day period would include the full range of spring and neap tidal conditions.[14]

[12] EPA's proposed Estuarine Habitat criteria were stated as a certain number of days when the average daily near-bottom salinity at each of three locations in the estuary is less than 2 parts per thousand. This salinity is approximately equivalent to electrical conductivity less than 2.640 mmhos/cm EC when corrected to a temperature of 25°C.

[13] A 14 day moving average would compute the salinity for a given day by taking the overall average of daily averages of salinity values for the measurement day and each of the previous 13 days. At the monitoring sites used in the Estuarine Habitat criteria, salinity is generally measured at least hourly, thereby facilitating computation of daily averages.

[14] Spring and neap tides refer to the times during the 28 day lunar cycle when tides are strongest and weakest, respectively.

TABLE 1.—PROPOSED 2 PPT ESTUARINE HABITAT CRITERIA [1]

Year type	Roe Island [km 64]	Chipps Island [km 74]	Confluence [km 81]
Wet	133 days	148 days	150 days.
Above normal	105 days	144 days	150 days.
Below normal	78 days	119 days	150 days.
Dry	33 days	116 days	150 days.
Critically dry	0 days	90 days	150 days.

[1] Numbers indicate the required number of days (based on a 14-day moving average) at or downstream from each location for the 5-month period from February through June. The water year classifications are identical to those included in the 1991 Bay/Delta Plan for the Sacramento River Basin. Roe Island salinity shall be measured at the salinity measuring station maintained by the USBR at Port Chicago (km 64). Chipps Island salinity shall be measured at the Mallard Slough station, and salinity at the Confluence shall be measured at the Collinsville station, both of which are maintained by the California Department of Water Resources. The Roe Island number represents the maximum number of days of compliance, based on the adjustment described in the text.

As explained in more detail in the Proposed Rule, the proposed Estuarine Habitat criteria also included a ‘‘trigger’’ that limited the applicability of the Roe Island criteria to wetter years. This trigger provided that the Roe Island criteria would not apply in a particular year unless and until the average daily salinity at Roe Island attained the 2 ppt level through natural uncontrolled flows. If that occurred, the 2 ppt salinity value would have to be met at Roe Island for the number of days specified in Table 1 (or the number of days left in the February to June period, if that number was less). In effect, this ‘‘trigger’’ provided that the additional water needed to move the 2 ppt isohaline downstream to Roe Island would come from natural storms rather than from reservoir releases or export restrictions. This approach helped the criteria reproduce the natural variability in timing and quantity of runoff that existed during the reference period.

In the Proposed Rule, EPA requested public comment on a number of issues, including the desirability of stating the criteria as a ‘‘sliding scale’’ rather than by water year categories, the appropriate compliance measurement period, and the appropriate reference period for criteria target levels. EPA has incorporated many of the comments received on these and other issues in its revisions to the Proposed Rule.

(2) Technical Changes to the Estuarine Habitat Criteria

The fundamental structure of the Estuarine Habitat criteria in the final rule is unchanged from the Proposed Rule: The criteria require maintenance of the 2 ppt isohaline at or downstream of one of three monitoring sites in Suisun Bay during a specified portion of the February through June period. The final criteria continue to require a 2 ppt salinity value at the Confluence of the Sacramento and San Joaquin rivers each day between February through June in all years.

Virtually all of the changes to the final Estuarine Habitat criteria involve refinements for determining the number of days the salinity standard must be met at Chipps and Roe Islands. In general, these changes either make certain measurements more accurate or provide a closer approximation of the natural hydrological cycles. The changes, which are highly technical, can be grouped into four broad categories: (i) underlying computational revisions, (ii) using a sliding scale, (iii) using monthly rather than annual compliance, and (iv) alternative measurement of attainment of the criteria. These changes to the final rule are reflected in the final criteria at 40 CFR 131.37(a)(1).

(i) *Underlying Computational Revisions.*

The first group of changes in the final criteria are slight refinements to the methodology of some of the computations used in the rule. These include:

(I) *Updated model correlating salinity and flows.* As described above, the Proposed Rule used data from the historical period 1940 to 1975 to approximate conditions in the targeted late 1960's to early 1970's reference period. For years during that historical period when actual salinity data was unavailable, the Proposed Rule used the Kimmerer-Monismith model to estimate salinity conditions based on the available flow data. This earlier model, which was used by the San Francisco Estuary Project (SFEP) (SFEP 1993), was considered at that time to be the most accurate available for this purpose. Since the Proposed Rule was published, a revised model correlating salinity and flow has been developed by the CCWD (Denton, R.A. 1993, and Denton, R.A. 1994). EPA concluded, and the participants at the CUWA scientific workshops generally agreed (Kimmerer 1994b), that the CCWD model is a more appropriate model to use in developing the Estuarine Habitat criteria.[15] The final rule will use this new CCWD model to estimate the number of days that salinities have been less than 2 ppt historically at each of the compliance monitoring stations.

The earlier model used for the Proposed Rule measured salinity one meter above the bottom. The new CCWD model measures salinity measured at the surface. There is substantial evidence that at salinities near 2 ppt there is little variability in stratification so that bottom salinities are accurately predicted from surface salinities (CCWD 1994; Monismith 1993). Therefore, bottom salinities of 2 ppt as modeled by the Kimmerer-Monismith model correspond to surface conductivities described, as discussed below, in terms of electroconductivity of 2.640 mmhos/cm EC in the CCWD model.

(II) *Use of entire basin unimpaired flow.* In calculating the applicable Estuarine Habitat criteria value, the Proposed Rule measured flow by reference to the Sacramento Basin Water Year Type classification. EPA did this primarily to simplify calculations and to reflect the dominant role of Sacramento River flows in the Bay/Delta estuary.[16] Nevertheless, as commenters noted, in some circumstances the omission of the San Joaquin River basin flows from the calculation could significantly overstate

[15] The CCWD model developed by Denton and Sullivan models salinity at a particular location, whereas the Kimmerer-Monismith model models the location of a particular salinity. Thus, the Kimmerer-Monismith model can predict whether the 2 ppt salinity value is upstream or downstream of a given location whereas the CCWD model can predict if the salinity at the same point is greater or lesser than 2 ppt. The CCWD model is more accurate because it predicts salinity based not only on flow (as in the Kimmerer-Monismith model) but also based on the location being modeled. For example, the relationship between flow and salinity is slightly different at Roe Island than at the Confluence, and only the CCWD model reflects that difference in the relationship.

[16] The Sacramento River basin usually accounts for about 80% of net Delta outflow, with the remainder coming primarily from the San Joaquin River basin.

or understate the actual hydrological conditions in the estuary because precipitation patterns in the two river basins are not identical. Further, one of the reasons EPA chose the three locations for compliance (all at or downstream of the confluence of the Sacramento and San Joaquin Rivers) was to give the State Board maximum flexibility in determining the source of flows to meet the Estuarine Habitat criteria. To reflect the importance of the San Joaquin River basin, the final criteria have been revised to measure unimpaired flow by reference to both the Sacramento River basin (Sacramento, Feather, Yuba, and American rivers) and the San Joaquin River basin (Stanislaus, Tuolumne, Merced, and San Joaquin rivers). EPA believes that the Sacramento/San Joaquin Unimpaired Flow Index described by CUWA is the best statement of how this unimpaired flow should be computed, and will generally refer to this index as the ''8–River Index.'' [17]

(III) *''Parts per thousand'' versus ''electroconductivity''*. The Proposed Rule stated the criteria as a requirement for 2 ppt salinity at the three compliance stations for varying numbers of days. In order to state the requirement more precisely, the final rule language will define the criteria in terms of millimhos per centimeter electroconductivity or ''mmhos/cm EC'' instead of parts per thousand salinity. This change is being made to conform the final rule to the more traditional methodology for measuring fresh water salinity. Accordingly, the final rule will state the criteria value as ''2.640 mmhos/cm EC,'' which is equivalent to 2 ppt salinity.

Although EPA is restating the actual rule language in the more precise electroconductivity language, it will continue to refer to this criteria value as 2 ppt in this discussion of the final rule. To do otherwise would unnecessarily confuse the interested scientific and policy community, which for a number of years has been using the 2 ppt language in its discussion of estuarine habitat criteria.

These revisions to the underlying computational methodology apply to the Estuarine Habitat at all three monitoring sites (the Confluence, Chipps, and Roe Islands). The remaining revisions to the final criteria pertain primarily to the methodology used in defining the number of days of compliance to be met at Chipps and Roe Islands.

(ii) *Using a Sliding Scale.*

In the final Estuarine Habitat criteria, EPA is restating the number of days that the 2 ppt salinity value must be met as a sliding scale correlating the number of days of compliance with unimpaired flow. The sliding scale approach has also been called the ''continuous function'' or ''smooth function'' approach. This approach replaces the Proposed Rule's statement of the criteria as a single fixed number of days of compliance for each of the five water year categories. The previous approach did not account for the substantial differences in hydrological conditions *within* water year types. For example, an ''above normal'' water year type could range from a *wet* ''above normal'' year to a *dry* ''above normal'' year. Given the extreme variation of hydrological conditions in the Bay/Delta, these variations within each of the five standard water years types are substantial, and should be factored into the calculation of the number of days of compliance with the 2 ppt salinity criteria.

The sliding scale approach addresses this problem by transforming the average salinity values for the five discrete water year categories into a more precise equation (graphically, a single line or curve) correlating the number of days of compliance with the specific observed hydrological conditions. This sliding scale approach would result in the same *average* number of days of compliance for each year type, and therefore represents the same level of protection for the Estuarine Habitat use as the Proposed Rule. The new approach, however, more accurately reflects differences *within* water year categories, thereby allowing a more accurate reflection of the natural hydrological cycles representative of the reference period necessary for protection of the use.

In addition, while the sliding scale approach equally represents the conditions under which the estuary attains its designated uses, the sliding scale results in lower water costs and, for operational reasons, may actually enhance protection of the uses. Testimony at recent State Board hearings criticized the use of water year type categories. Because water year types can change as the year progresses, criteria based on the historical mean for each water year type can cause major changes in project operations and habitat conditions if a given year shifts from one water year type to another over the course of the winter months. For example, a later season storm could cause the water year type to be reclassified from the below normal category to the above normal category. This shift would increase the number of days the criteria must be met at one of the monitoring sites. Such large and sudden changes are inefficient for water resource management and may harm aquatic resources by dewatering or washing away newly spawned eggs. Incorporating a sliding scale definition of the criteria would likely ease the actual operational procedures necessary to meet the criteria and would avoid the relatively sudden, large scale changes in operations that might come from a sudden shift in the determination of year type as spring progresses.

The comments EPA received on the Proposed Rule were generally supportive of this change in approach (CUWA 1994a, California DWR 1994, NHI 1994, and Kimmerer 1994a). Both written comments and the discussions at the CUWA scientific workshops offered several suggestions as to how the sliding scale function should be formulated.

There are two major components to the sliding scale approach. First, the shape of the scale must be determined. Second, the actual scaled values must be determined.

(I) *Defining the sliding scale.* There are a number of possible mathematical definitions of a sliding scale, including (a) a straight line, (b) a quadratic equation, or (c) a logistic equation.[18]

In the Proposed Rule, EPA suggested that a quadratic equation could be used to define the sliding scale. After reviewing the public comments, EPA has concluded that the Estuarine Habitat criteria should be stated as a logistic equation defining the sliding scale. Dr. Wim Kimmerer, in his comments on the Proposed Rule (Kimmerer 1994a), noted that the logistic model is ''appropriate

[17] As stated on page 3 of Appendix 1 to the California Urban Water Agencies ''Recommendations to the State Water Resources Control Board for a Coordinated Estuarine Protection Program for the San Francisco Bay-Sacramento and San Joaquin River Delta Estuary'' dated August 25, 1994, the Sacramento/San Joaquin Unimpaired Flow Index ''shall be computed as the sum of flows at the following stations:

1. Sacramento River at Band Bridge, near Red Bluff
2. Feather River, total inflow to Oroville Reservoir
3. Yuba River at Smartville
4. American River, total inflow to Folsom Reservoir
5. Stanislaus River, total inflow to New Melones Reservoir
6. Tuolumne River, total inflow to Don Pedro Reservoir
7. Merced River, total inflow to Exchequer Reservoir
8. San Joaquin River, total inflow to Millerton Lake.''

[18] The standard forms of these types of equations are (a) a straight line (y=a+b*x), (b) a quadratic equation (y=a+b*x+c*x2) or (c) a logistic equation ($y=1/(1+e^{3(a+b*x)})$).

for a relationship between a dichotomous variable (i.e. compliance or no compliance) and a continuous variable.'' A logistic model cannot require fewer than 0 or more than the number of days available in the month, whereas linear equations (such as one included in written comments of CCWD (CCWD 1994) or quadratic equations (such as the one EPA suggested in the Proposed Rule) can result in unrealistic extrapolations (e.g., resulting in the criteria having to be met less than zero days or more than the number of possible days each month).[19]

Kimmerer suggested a sliding scale based on logistic equations that stated the percentage number of days of compliance during the February to June period as a function of the unimpaired flow for those five months. An example of graphic representations of these equations for Roe Island is shown in Figure 1. EPA has adopted this basic approach; however, as discussed below, EPA has revised the logistic equations to reflect monthly computations of compliance.

[19] While uncommon in some fields, the logistic equation is the basis of many ecological models, especially for population dynamics and epidemiology. In these ecological applications, the logistic model is useful because of the nature of the dichotomous variables (such as how many individuals are alive or dead in population dynamics, or how many individuals are infected or healthy in epidemiological studies). In each case, the dichotomous variables are arrayed along time as the continuous variable. In both cases, also, the function is constrained between 0 and the total population size, which is biologically realistic. EPA is using the logistic equation to model the number of days of attainment of the 2 ppt value (the dichotomous variable) against unimpaired flow (as the continuous variable). The logistic model also provides that no less than 0 and no more than the total number of days in the month can be required for attainment.

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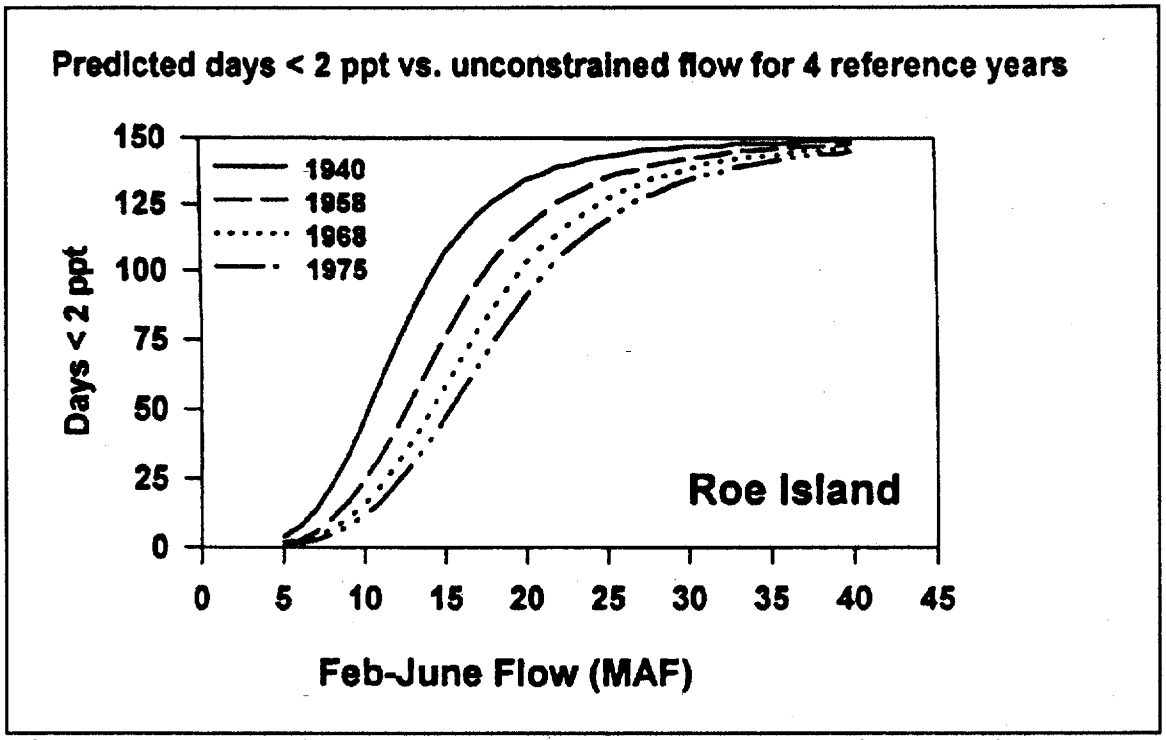

Figure 1. Predicted number of days of compliance with 2 ppt criteria during February to June at four levels of development across a range of unimpaired flows.

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(II) *Selecting sliding scale values: the reference period that would reflect protection of the designated uses.* Having concluded that the logistic equation is the best form of sliding scale for the Estuarine Habitat criteria, EPA still needed to determine the appropriate reference period reflected in that logistic equation.

In the Proposed Rule, EPA chose as the reference period the late 1960's to early 1970's. Available information suggested that during this period the estuarine conditions were able to support the designated uses. To describe the conditions in this late 1960's to early 1970's reference period, the Proposed Rule used hydrological and salinity data from 1940 to 1975. This longer period was used because the actual conditions in the late 1960's to early 1970's did not provide representative samples of the possible broad range of precipitation conditions in the estuary.[20] The Proposed Rule suggested that the period 1940–1975 could be considered representative of the late 1960's to early 1970's because the longer period was one of fairly consistent hydrological conditions bracketed by the completion of Shasta Dam on the Sacramento in the early 1940's and by the severe drought of the mid-1970's.

EPA received substantial comment about its choice of an historical reference period to define the targeted level of protection for the Estuarine Habitat criteria. One group of comments criticized the choice of the years included in the reference period. Various other historical periods were discussed by different commenters as alternatives. (Bay Institute 1994, California DWR 1994, and NHI 1994). EPA's specific responses to these comments are in the comment response document included in the record to this rule.

A second set of comments raised a more fundamental problem with the use of an historical reference period. These comments argued that the choice of any particular historical reference period was inherently suspect if it could not account for the changing ''level of development'' (that is, the changing system of dams, diversion facilities, storage reservoirs, etc.) during the 1940 to 1970 period (California DWR 1994). For example, if exactly the same amount of precipitation had fallen in each of 1940 and 1970, the different ''level of development'' in each year would affect how much water actually made its way down the rivers into Suisun Bay. In other words, the level of development, independent of the amount of rainfall, would affect the number of days that the 2 ppt salinity value was attained in Suisun Bay. Without accounting for the level of development, it would be hard to use rainfall data from the 1940's to represent conditions in the late 1960's to early 1970's.

EPA is persuaded that addressing these concerns about the effects of the level of development on resulting salinity criteria is, to a certain extent, appropriate. EPA and others (notably, the CUWA scientific workshops) have presented and discussed methods for accounting for the level of development. The Final Rule includes a straightforward approach to this issue. Standard statistical regression analysis was used to isolate the effects on the number of days of 2 ppt salinity of (1) the level of development, represented by calendar year,[21] and (2) precipitation (Kimmerer 1994b; Ferreira and Meyer

[20] In fact, no dry or critically dry years, and only one above normal year occurred during the late 1960's to early 1970's.

[21] The use of the calendar year as a surrogate for the level of development is reasonable up until the late 1970's, because up until that time there was a fairly consistent increase year-by-year in the number and capacity of diversion and storage facilities, and the significant changes to the salinity regime imposed by the 1978 Delta Plan had not yet taken effect.

1994). This statistical procedure allowed EPA to separate the effects of year-to-year variability in precipitation from the effects of increased levels of upstream development.[22]

The results of these recomputations are shown graphically in Figures 1 and 2. The response surface or curved plane in Figure 2 shows how the number of days of 2 ppt salinity at Roe Island changes with both the precipitation (flow) and the changing level of development over time. Figure 1 shows several ''slices'' of the curved plane in Figure 2. Each of these different slices corresponds to a particular year's level of development (1940, 1958, 1968, and 1975), and show how the number of 2 ppt days would have varied over different hydrological conditions at that year's level of development. Historically, of course, each year experienced only one hydrological scenario; the purpose of the regression equations for these four different years is to show how that particular level of development would have influenced the position of the 2 ppt isohaline over the entire range of possible hydrological conditions.

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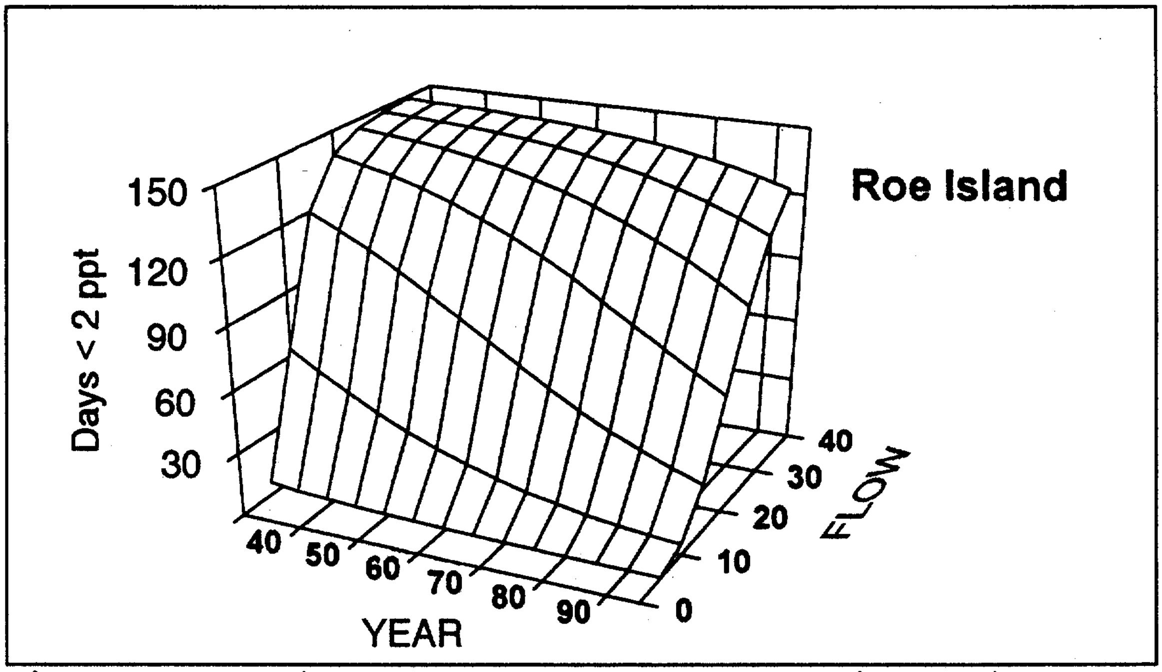

Figure 2. Predicted number of days of compliance with 2 ppt criteria during Feb-Jun period, showing relationship to (1) increasing level of development represented by calendar year and (2) unimpaired flow.

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Having adjusted the historical data to account for the effects of the level of development, EPA must still determine the appropriate reference period for defining the final criteria. The final criteria must adequately reflect conditions in the estuary at a time period during which the estuary attained the designated uses, regardless of the causes of degradation to the waterbody.

In the final rule, EPA is establishing Estuarine Habitat criteria that replicate the ''level of development'' existing in 1968. The intent of these criteria is to protect the Estuarine Habitat designated use to the same degree that these uses would have been protected under the level of development present in 1968.

EPA chose the 1968 level of development because the best available information indicates that at that time, salinity conditions in the Bay/Delta were adequate to protect the estuarine habitat. As explained in the Proposed Rule, EPA, NMFS, and USFWS have called for a level of protection equal to that which existed in the late 1960's and early 1970's. EPA believes that the fish population data summarized in the San Francisco Estuary Project's Status and Trends Report document the precipitous and unreversed decline of the most abundant species beginning in 1970. (Herbold et al. 1992). This downward trend is also apparent in the population data for winter run Chinook salmon. (Herbold et al. 1992).

In choosing a particular year, EPA is not suggesting that the particular hydrological conditions in 1968 are being replicated. Instead, the use of an individual calendar year appears to be a reasonable surrogate for the level of development for that period. As the graph in Figure 2 suggests, there would not be a substantial difference between number of days of meeting the 2 ppt salinity value in 1968 versus 1967 or 1969. EPA has chosen the 1968 value as a reasonable representation of the period in which the estuary was attaining its designated uses.

If the Estuarine Habitat criteria were stated on an annual basis as it was in

[22] In that this statistical procedure allowed the effect of the changing level of development to be controlled, the issue of the proper data set (i.e., group of reference years) to be included in the description of historical hydrological conditions essentially disappears. To take advantage of all appropriate historical data, in performing these computations EPA used data from the years 1930 (when accurate records were first available) to 1978 (when the hydrological conditions in the Delta were first substantially affected by the regulatory measures adopted by the State Board).

the Proposed Rule, the logistic equation corresponding to the 1968 line in Figure 1 would serve as the criteria's sliding scale correlating the number of days of meeting the 2 ppt salinity value with annual unimpaired flow. As described below, however, this annual sliding scale must still be transformed into monthly sliding scales.

(iii) *Moving to Monthly Compliance.* EPA has also refined the final rule to restate the Estuarine Habitat criteria on a month-by-month basis, rather than as a single number of days of compliance covering the entire February to June period.

EPA received comments suggesting that the number of days of meeting the 2 ppt salinity value at Chipps and Roe Islands should be stated solely, or largely, in reference to the patterns of precipitation that could directly affect estuarine habitat during the period intended for protection. For example, criteria that are designed to protect conditions in the February–June period should reference only the unimpaired flows of February–June (or, possibly, January–June). Including precipitation in months outside of this February–June period could lead to inaccuracies in the criteria for February–June that could unnecessarily affect water project operations or inadequately protect the designated uses. This same problem could exist *within* the February–June period. For example, if in a given year the precipitation in February is substantial, but the following months are very dry, the overall period of February–June would be considered very dry and, using the sliding scale for the entire February–June period, the number of days of compliance with the 2 ppt salinity value at Chipps or Roe Island would be very low. This result may contradict the actual natural hydrological cycle, which under this scenario would have provided at least one high water period for the estuarine habitat uses.

A related issue raised by the comments and in the CUWA scientific workshops was the problem of how to develop compliance strategies for a given year based on a forecast of hydrological conditions expected during the following months. EPA agrees that this forecasting is unreliable, especially for the critical February and March months which are typically the months of most variable precipitation. Sliding scales such as Figure 1 (for Roe Island), which apply to the entire February to June period of protection, still require the project operators to forecast future hydrological conditions to meet the expected number of days of attainment with the 2 ppt criteria. For example, if February and March are wet, project operators have to forecast weather patterns for April to June to determine whether they should operate their projects to meet a substantial number of days of attaining the 2 ppt salinity value at Chipps or Roe Island (forecasting that the whole period will continue to be wet) or a lesser number of days (forecasting that the remaining months will be dry). Thus, the annual or five month approach described above and shown for Roe Island in Figure 1 would not address the issue of unreliable forecasts.

To address this uncertainty in forecasting long range hydrology, and to provide criteria that more closely reflect the natural hydrology actually affecting the estuarine habitat, EPA is in the final rule restating the Estuarine Habitat criteria on a month-by-month basis. That is, the final criteria define the required number of days of compliance for a particular month solely by reference to the hydrological conditions of the previous month. This approach more precisely ties the salinity conditions affecting Estuarine Habitat with natural hydrological cycles reflecting the time when the estuary attained its designated uses, and is therefore consistent with EPA's overall approach to protecting the Estuarine Habitat designated use.

Developing monthly sliding scales. EPA's analysis indicated that the required number of days of compliance with the 2 ppt criteria in a given month could be quite accurately predicted from logistic models using unimpaired flows of any of (a) the current month, (b) the previous month, (c) the previous two months, or (d) the previous and current month. Including the actual unimpaired flows of the current month, however, did not improve model performance and, in practice, the actual unimpaired flow of the current month cannot be known accurately until the month is over. EPA has, therefore, restated the criteria using the logistic equations described above, but only for one month at a time based on the preceding month's unimpaired flow.

For example, the measured unimpaired flow in January would be used to set the number of days of compliance with the 2 ppt criteria at the Chipps and Roe Island locations. Similarly, measured unimpaired flow in February is used to set March's requirement. This approach has been labeled the ''Previous Month's 8-River Index'' (PMI) approach. To make this approach work, the sliding scales exemplified (for Roe Island) in Figure 1 have been transformed into monthly sliding scales. These monthly logistic equations for both Chipps and Roe islands are shown graphically in Figure 3.

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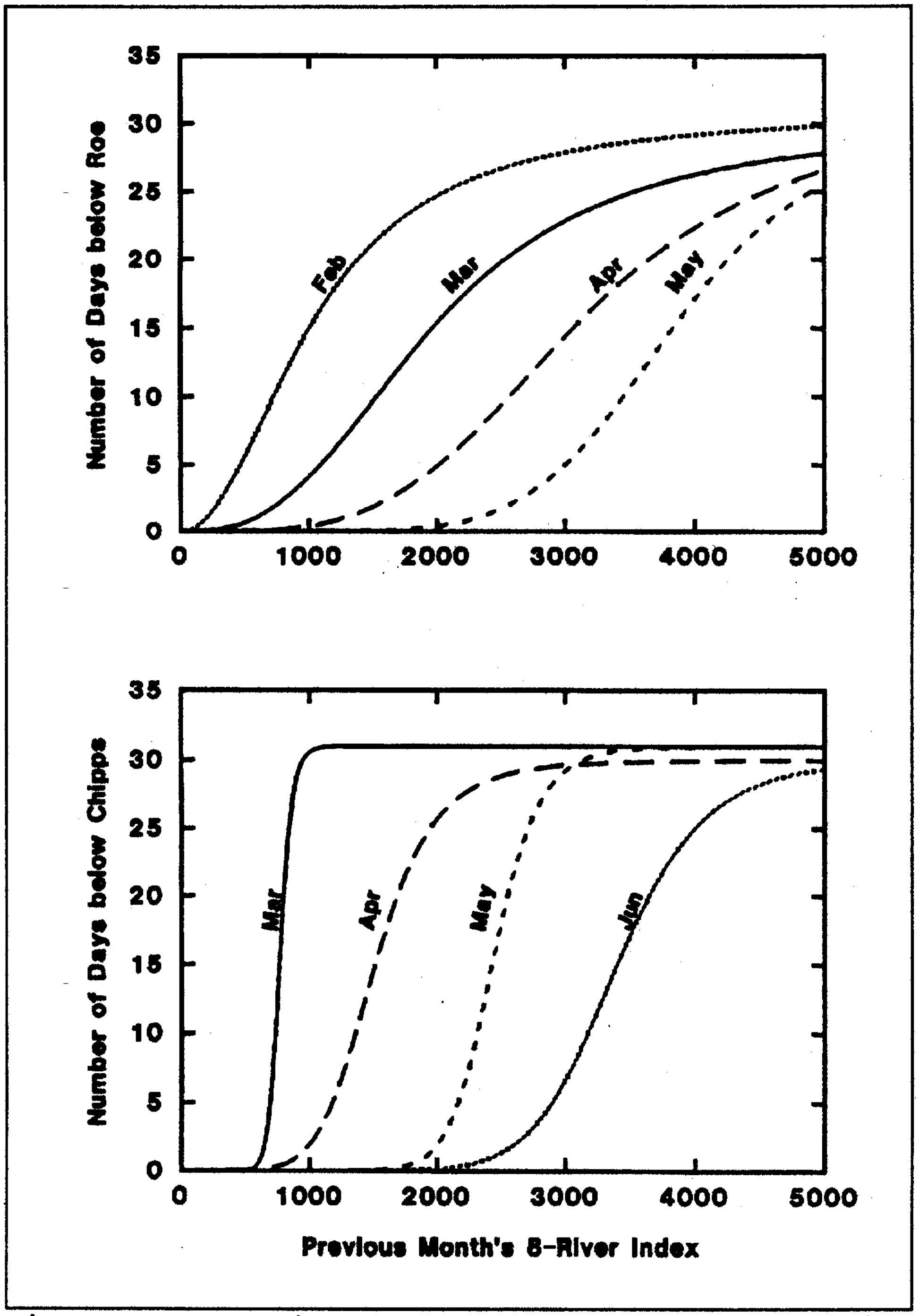

Figure 3 Equations for separate months relating previous month's unimpaired flow to current month requirement.

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Two technical revisions are being made to the criteria values generated by these monthly sliding scale equations. First, to facilitate compliance, the number of days resulting from the monthly equations will be rounded up or down to the nearest whole number. Second, at extremely low flows, the monthly equations include unjustified extrapolations beyond the existing data. For that reason, when the previous month's index is less than 500,000 acre-feet, the number of days of compliance required for the current month shall be zero.

Revising the Roe Island ''trigger'' for monthly compliance. As a result of the above changes to the Estuarine Habitat criteria, the ''trigger'' for the Roe Island location must be restated as a month-to-month trigger. The Proposed Rule stated, in effect, that if the salinity dropped below 2 ppt at Roe Island at any time during the February to June period due to uncontrolled hydrologic conditions, the Roe Island requirements were ''triggered'' for the remainder of the February to June compliance period. In the final rule, the ''trigger'' is evaluated on a monthly basis. If the 14-day moving average salinity at Roe Island falls below 2 ppt on any day during the last 14 days of a month, compliance with the Roe Island criteria would be ''triggered'' for the following month.

For example, assume that the sliding scale of unimpaired flow (PMI) for January indicates that the 2 ppt salinity value shall be attained for 18 days at Roe Island in February, *if* the Roe Island criteria is ''triggered.'' If the 14-day moving average salinity in the last part of January is below 2 ppt at Roe Island, the Roe Island criteria would in fact be triggered for 18 days in February. Assume then that the system is operated to meet the 18 days in February, but that a large storm in mid-February results in the salinities of less than 2 ppt at Roe Island for the entire month of February. This would ''trigger'' the Roe Island criteria in March. If the sliding scale, PMI-based calculation required 31 days of compliance at Roe Island in March in this scenario, compliance for April (for 13 days, for example) would also be triggered, since the 2 ppt would be met during the last 14 days of March. If April is a dry month, the 2 ppt criteria could be met for the required 13 days early in the month, the 14-day moving average salinity in the last half of April would never go below 2 ppt at Roe Island, and the Roe Island criteria would not be triggered for May at all.

Although somewhat complicated, this monthly triggering mechanism is essential to assure that the criteria applicable in a given month reflect the actual distribution of storm events throughout the February to June compliance period. As explained in more detail above, accounting for the natural hydrologic cycles in a manner reflecting the reference period assures protection of the designated uses without unnecessarily affecting water project operations.

(iv) *Alternative Measures of Attaining the Criteria.*

In the Proposed Rule, EPA indicated that it believed a State Board implementation plan that relied on the salinity-flow models, without making additional allowances for ''confidence intervals'', would adequately protect the designated uses. EPA's further review of the comments and continued discussions with the project operators has confirmed this belief.

In addition, EPA believes that the Estuarine Habitat use would be protected if the Estuarine Habitat criteria are directly measured as either a daily salinity value or as a 14-day moving average salinity value. Further, EPA's review of the new CCWD model correlating flow and salinity suggests that the Estuarine Habitat use would be protected at the Chipps and Roe Island monitoring sites if the modeled ''flow equivalent'' of the applicable 2 ppt criteria is provided. According to the CCWD model, the steady state flows that would satisfy these flow equivalent requirements are 29,220 cubic feet per second (cfs) for the Roe Island monitoring site and 11,400 cfs for the Chipps Island monitoring site (Denton, pers. comm.). This ''flow equivalence'' measure of attainment with the criteria would not be available at the Confluence monitoring site because of assumptions in the CCWD model about antecedent conditions in Suisun Bay.[23]

Accordingly, the State Board could adopt an implementation plan providing that project operators would attain the criteria in any one of three ways: (1) the daily salinity value meets the requirement, (2) the 14-day moving average salinity meets the requirement, or (3) at the Chipps and Roe Island monitoring sites, the system is operated on that day so as to meet the ''flow equivalent,'' using the CCWD model, of the stated salinity criteria. EPA notes that the available modeling data indicate that under most circumstances, the most efficient approach (in terms of water usage) to meeting the criteria would be to attain the specified salinity value rather than the alternative flow equivalent.

c. Revised Estuarine Habitat Criteria

Final estuarine habitat criteria reflecting the changes discussed above are shown below at 40 CFR 131.37(a)(1). These revised criteria provide the many equations necessary to define month-by-month sliding scales and, thereby, the applicable criteria.

For illustration purposes only, Table 2 presents representative examples of the required number of days of compliance in different months across a range of possible values of the PMI index of unimpaired flow.

PMI	Chipps Island					Roe Island (if triggered)			
	Feb	Mar	Apr	May	Jun	Feb	Mar	Apr	May
1000	....	31	2	0	0	13	4	2	0
1250	....	....	7	0	0	17	7	4	0
1500	....	....	15	0	0	19	10	8	0
1750	....	....	21	0	0	21	13	11	0
2000	....	....	26	1	0	22	16	15	0
2500	....	....	29	16	1	24	20	21	2
3000	....	....	29	29	7	25	24	25	5
4000	....	....	30	31	25	26	27	28	18
5000	....	....	....	....	29	27	29	29	26

[23] That is, to make this finding that the ''flow equivalence'' would protect the designated use at the Chipps and Roe Island locations, EPA had to make assumptions in the CCWD model that the 2 ppt salinity value was actually being attained at the Confluence. Given that assumption, EPA cannot find that the ''flow equivalence'' at the Confluence is protective.

PMI	Chipps Island					Roe Island (if triggered)			
	Feb	Mar	Apr	May	Jun	Feb	Mar	Apr	May
6000	....	....	....	....	30	28	30	30	29

Table 2. Examples of required number of days of compliance for each month across a range of possible values of the 8–River Index for the prior month (PMI).

2. Fish Migration Criteria

a. Overview

(1) Importance of the Fish Migration and Cold Freshwater Habitat Criteria. The State's designated uses for the Bay/Delta include Cold Fresh-Water Habitat ''to sustain aquatic resources associated with a coldwater environment,'' and Fish Migration to ''[p]rovide[ ] a migration route and temporary aquatic environment for anadromous or other fish species.'' (1991 Bay/Delta Plan at 4–1). The migratory fish species associated with the cold fresh-water environment in the Bay/Delta are chinook salmon (Oncorhynchus tshawytscha) and steelhead trout (Oncorhynchus mykiss).[24]

[24] The State Board has designated both of these uses for the Bay/Delta estuary. However, in practice there is substantial overlap between them because many of the factors affecting the Cold Fresh-Water Habitat use also affect those anadromous fishes migrating through the Delta to the ocean. Because of this overlap, this rule will, in protecting Fish Migration, benefit the Cold Fresh-Water Habitat use as well.

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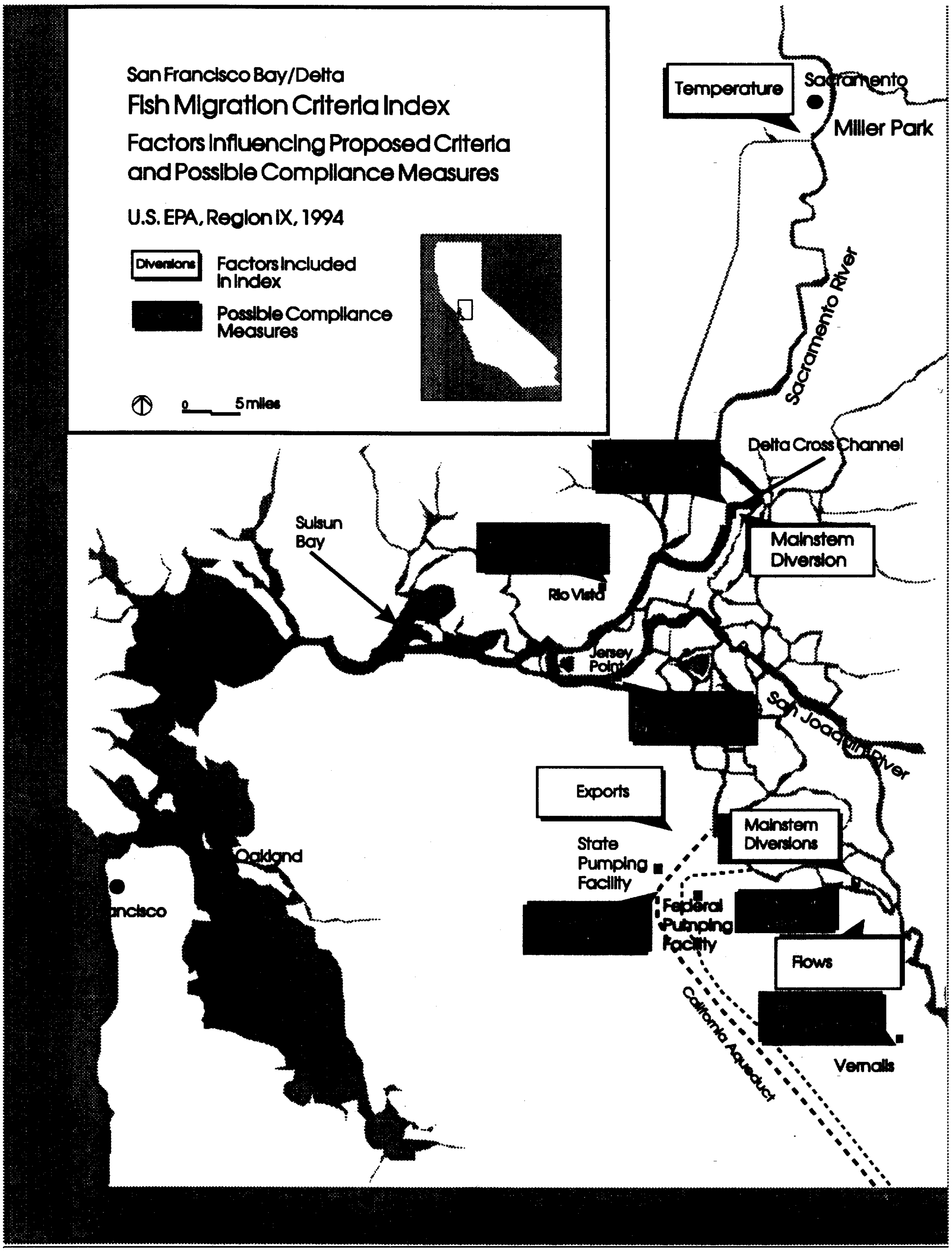

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Currently there are four distinct populations of salmon in the Sacramento/San Joaquin river systems, each named for the season of their migration upstream as adults. The fall-run population is now the most numerous. The San Joaquin River system supports only a fall-run population; the San Joaquin River spring-run became extirpated in the 1940's. The Sacramento River system still supports small winter-run, spring-run and late fall-run populations, but these populations have all declined dramatically in recent years (USFWS 1992a, WRINT–USFWS–7; California DFG 1992a, WRINT–DFG–14). The winter-run population is now listed as threatened under the ESA. The spring-run population has recently reached low enough levels to be recognized as a species of special concern by the State of California, and NMFS has recently included the spring-run in its status review of salmon on the northwest coast of the United States (59 FR 46808 (09/12/94)).

Steelhead trout are also cold fresh-water migratory fish within the Sacramento River System. They have suffered a 90 percent decline since the late 1960's, and are supported largely by hatchery production (CDFG 1992a, WRINT–DFG–14).

Salmon and steelhead migrating through the Delta to the ocean are subject to increased mortality when exposed to high temperatures and low flows and when diverted out of the main channels of the Sacramento and San Joaquin Rivers into less suitable habitat. Those fish diverted from the main river channels into the central and south Delta are also subject to increased mortality because of several factors including higher temperatures, increased predation and increased entrainment at the State and Federal pumping plants in the south Delta (USFWS 1992a).

State and federal legislators have recognized the serious threat to the continued existence of migratory fishes in the Bay/Delta. In 1988, the California State legislature mandated a restoration goal of doubling natural salmon and steelhead production by the year 2000, and required development of a plan to meet this goal. Salmon, Steelhead Trout, and Anadromous Fisheries Program Act; codified at Cal. Fish & Game Code § 6900 et seq. (West 1991). Also, the United States Congress recently enacted the Central Valley Project Improvement Act (CVPIA), which requires that a program be developed and implemented to make ''all reasonable efforts to ensure that * * * natural production of anadromous fish in Central Valley rivers and streams will be sustainable, on a long-term basis, at levels not less than twice the average levels attained during the period 1967–1991. * * *'' Central Valley Project Improvement Act § 3406(b)(1), P.L. 102–575.

(2) Proposed Rule. Many different factors affect the ability of salmon and steelhead to successfully migrate through the Delta to the ocean. These include water temperature, flow rates, diversions, operation of pumping facilities, and gate closures regulating the direction of water flows through the myriad channels and sloughs in the Delta. Clearly, any number of beneficial combinations of these factors could result in conditions that provide for successful migration and protection of the designated use. Accordingly, in formulating its Proposed Rule, EPA concluded that it would state its criteria generally, measuring the success of salmon in migrating through the Delta. That is, EPA would state goals that (1) called for a certain percentage of salmon to be able to survive their passage through the Delta, and (2) that could be achieved by any of a number of different management measures. In this way, the State Board would have maximum latitude to find combinations of management measures that would attain the salmon survival goal.

In order to quantify the success of migrating salmon in passing through the Delta, EPA relied on ''salmon smolt survival models'' developed by the USFWS, one for the Sacramento River and one for the San Joaquin River.[25] These salmon smolt survival models are mathematical equations stating the relationship between specific variables in the Delta (water flow rates, diversions into the central Delta, etc.) and salmon smolt survival.[26] To predict the effect of a particular set of management measures (for example, a specified minimum flow and a specified maximum export flow), EPA inserts the management measures into the model equation. The model equation then generates an ''index value'' representing the relative success of salmon migrating through the Delta while that set of management measures is being implemented.[27]

As its criteria, EPA proposed a set of index values representing successful salmon migration sufficient to protect the designated use. EPA established these target criteria index values by taking a set of USFWS recommendations of management measures that would protect the salmon resource, and translated (using the USFWS model equations) those protective management measures into index values. In other words, the criteria index values represented the level of salmon migration survival through the Delta that would occur if this particular set of protective management measures were adopted. The intent was not to mandate those particular management measures. Rather, it was to set a performance standard—measured by the criteria index value—for salmon survival. To attain the goal, the State Board would use either the specific management measures recommended by USFWS, or any other combination of measures that would yield the same level of survival of migrating salmon.

The Proposed Rule named its criteria index values ''salmon smolt survival index criteria.'' For each of the Sacramento and San Joaquin River systems, the criteria provided a salmon smolt survival index equation (*i.e.* a USFWS model equation) and a set of index values to be attained. The index equation for each river quantified and predicted the survival of salmon smolt migrating through the Delta.

The USFWS equations and EPA's Proposed Rule both ''scaled'' the index values to a scale of 0 to 1. This was done by dividing experimental release results by a constant of 1.8 (the highest release result). In the final rule, EPA is not ''scaling'' its criteria values. It is important to realize that criteria index values in the final rule are not actual survival estimates (such as a percentage of smolt surviving), but indices showing survival relative to other index values.[28]

In the Proposed Rule, the index values contained in the criteria varied according to the standard five water year types—each water year type had a

[25] A ''smolt'' is a salmon in the process of acclimating to the change from a fresh water to a salt water environment. This occurs when young salmon migrate downstream through the Delta to the ocean.

[26] These salmon smolt survival index equations were based in large part on the results of tagged-fish release and recapture experiments designed to measure and compare salmon smolt survival under a number of different physical conditions of varying migration pathways, water temperatures, flow rates, and rates of water exports from the Delta.

[27] There was some disagreement among the commenters on the Proposed Rule as to whether these USFWS models yield index values that are literally ''percentages'' of the salmon smolts surviving through the Delta. All parties appear to agree, however, that these index values do in fact represent the relative survival compared to other index values. This preamble and accompanying rule will generally refer to these values as index values rather than as percentages.

[28] For example, historically, the San Joaquin River index value has reached a number as high as 1.5 (which was attained in an experimental release at Jersey Point). For comparison, the average San Joaquin survival index value during low flow years is 0.09. This 0.09 index value represents approximately 5 smolt recoveries from a release of 50,000 fish at Mossdale, 55 miles upstream of the recovery site at Chipps Island.

particular index value to be attained.[29] The index values were to be attained by implementing management measures affecting the variables included in the index equations. For the Sacramento River, the index equation described a relationship between smolt survival and three variables: water temperature, water diversion out of the mainstem Sacramento River, and water export rates. For the San Joaquin, the variables were river flow rates, water diversion into the Upper Old River, and export rates.

The Proposed Rule included index values generally representing the modeled results of the management measures developed by the USFWS based on the work of the Delta Team of the Five Agency Chinook Salmon Committee.[30] These management measures consist of export limits, minimum flows, channel gate closures, etc., during critical periods in the year. The estimated effects of these management measures on smolt survival were calculated using the criteria index equations.[31] EPA concluded that these management measures, and the associated criteria index values, would lead to the protection of the designated Fish Migration use.

The resulting criteria index values were also consistent with the recommendations of the Interagency Statement of Principles signed by EPA, NMFS, and USFWS, which called for a level of protection for aquatic resources equivalent to the level existing in the late 1960's to early 1970's. To make this comparison, EPA compared its proposed criteria index values with the index values attained historically on the two river systems. See generally the discussion in the preamble to the Proposed Rule at 59 FR 824. The proposed Sacramento River criteria index values represented overall protection for the Fish Migration use at approximately the 1956–1970 historical level, whereas the proposed San Joaquin River criteria index values represented slightly better protection than the 1956–1970 historical level.

The Proposed Rule also relied on the criteria index equations to determine whether the criteria were being attained. In effect, attainment would be assumed if the State adopted an implementation plan with a set of measures (export restrictions, flow requirements, etc.) that, when computed in the index equations, resulted in the criteria index value.

(3) Final Criteria. EPA received substantial comment on its Proposed Fish Migration criteria. In addition, CUWA sponsored a number of scientific workshops to discuss the Proposed Rule, and EPA participated in these discussions. In response to the comments and scientific workshops, EPA developed a revised approach to the Fish Migration criteria, which was summarized in the documents made available to the public in EPA's Notice of Availability published in the **Federal Register** on August 26, 1994 (59 FR 44095).

The final rule maintains the fundamental approach of the Proposed Rule, but it has been revised in a number of ways to address several concerns. The major changes are:

(i) The methodology for establishing the criteria index values has been revised. Consistent with the discussion in the materials made available in the Notice of Availability, the criteria values on the Sacramento and San Joaquin River systems are described separately and the index values have been derived in different ways.

(a) On the Sacramento River, the criteria index values vary according to the water temperature at Miller Park. ''Ceiling'' and ''floor'' criteria index values are included to reflect the fact that at very high water temperatures, the Fish Migration use needs additional protection, and at very low water temperatures, temperature is unlikely to affect fish migration. The actual index values have been set to replicate the survival values that would be attained if the Delta Cross-Channel[32] were closed during the critical migration period. The Sacramento River tagged-fish release results indicate that, except in very high temperature periods, those periods in which the Delta Cross-Channel is closed provide aquatic conditions allowing for the protection of the Fish Migration designated use.

(b) On the San Joaquin River, the criteria index values vary according to unimpaired San Joaquin river flow. The actual index values have been set to approximately replicate the survival values that would be attained if a series of management measures (flow requirements, export restrictions, barriers, etc.) recommended by the USFWS based on the work of the Delta Team of the Five Agency Chinook Salmon Committee were implemented. The tagged-fish release results indicate that these or equivalent management measures are necessary to protect the Fish Migration designated use on the San Joaquin.

(ii) The criteria have been restated as sliding scales or continuous functions. As described in EPA's alternative formulation of the Fish Migration criteria referenced in the Notice of Availability, 59 FR 44095, and as in the case of the Estuarine Habitat criteria discussed above, stating the criteria index values with reference to the five water year types may create problems[33] in protecting the Fish Migration use. Accordingly, the final criteria index values are expressed as a continuous function.

(iii) Direct experimental measurements of salmon survival through the Delta will be used to estimate attainment of the criteria, instead of relying on estimates of attainment generated by the criteria index equations. This change allows the State Board more flexibility to develop implementation measures because it does not tie attainment of the criteria to the particular variables (exports, flows, etc.) included in the criteria index equations. This also transforms the final criteria into an explicit ''performance standard'', in which the criteria index values serve as the statement of desired protection for the Fish Migration use.

b. Detailed Discussion

(1) Proposed Rule

To protect the Fish Migration designated use, the Proposed Rule included ''salmon smolt survival index criteria.'' For each of the Sacramento and San Joaquin River systems, the criteria provided a salmon smolt survival index equation and a set of index values to be attained. The index equation for each river quantified and predicted the survival of salmon migrating through the Delta.

These index equations were developed by the USFWS (Kjelson, et al. 1989; USFWS 1992a, 1992b), and were based on the results of tagged-fish

[29] As stated above, the standard water year categories are wet, above normal, below normal, dry, and critically dry years.

[30] This interagency group consists of representatives from the USFWS, California DFG, California DWR, NMFS, and USBR. Its reports (Five Agency Delta Salmon Team, 1991a; 1991b) represent a consensus on the most effective and feasible implementation measures to protect downstream migrant salmon smolts in the Delta.

[31] That is, management measures were evaluated as to their effect on the variables included in the index equations, and the index equations were then computed to derive criteria index values. The result was criteria index values that reflect the effects on survival of the recommended management measures.

[32] The Delta Cross Channel is a controlled diversion channel between the Sacramento River and Snodgrass Slough. Water is diverted from the River through the Slough and then through natural channels for almost 50 miles southward to the State and Federal pumping plants.

[33] For example, if a mid-year change in water year types occurs, the Proposed Rule may have called for drastic changes in the flow regime, potentially leading to dewatering or washing away newly-spawned eggs.

release and recapture experiments measuring and comparing salmon smolt survival under a number of different physical conditions of varying migration pathways, water temperatures, flow rates, and rates of water exports from the Delta. On the Sacramento River, over the past 14 years, USFWS has performed a series of studies, releasing coded-wire tagged smolts at Sacramento and using recapture data to estimate an index of their survival to Chipps Island. Similarly, on the San Joaquin River, between 1982 and the present, the USFWS has conducted a series of experimental releases and captures of tagged salmon smolts in the San Joaquin River system, and has used the data collected in these experiments to develop a smolt survival index model for that basin (Brandes 1994).[34] EPA believes that the smolt survival indices from these releases do in fact represent the pattern of smolt survival through the Delta, and this belief was generally confirmed by the scientific workshops sponsored by CUWA (Kimmerer 1994b). As noted above, USFWS and the EPA Proposed Rule both ''scaled'' the index values by dividing experimental release results by 1.8.

In the Proposed Rule, the index values contained in the criteria varied according to the standard five water year types. The proposed criteria index values were stated in tabular form as in Table 3, below. The index values were to be attained by implementing management measures affecting the variables included in the index equations. For the Sacramento River, the index equation stated a relationship between smolt survival and three variables: water temperature, water diversion out of the mainstem Sacramento River, and water export rates. For the San Joaquin, the variables were river flows rates, water diversion into the Upper Old River, and export rates.

The Preamble to the Proposed Rule discussed in detail how the actual criteria index values in Table 3 were determined. To protect the designated uses, the Proposed Rule included index values representing the modeled results of the management measures proposed by USFWS based on the work of the Delta Team of the Five Agency Chinook Salmon Committee, with the exception of certain recommendations regarding the Georgiana Slough. The management measures consisted of export limits, minimum flows, channel gate closures, etc., during critical periods in the year. As explained in the preamble to the Proposed Rule (59 FR 825), EPA was concerned that the Delta Team recommendation to close the Georgiana Slough would have deleterious effects on the Delta smelt and other aquatic life in the central Delta, and possibly on adult salmon returning upstream. Thus, the management measures underlying the recommended criteria index values did not assume that the Slough would be closed. EPA concluded that these management measures, if implemented by the State, would lead to the protection of the designated Fish Migration use.

EPA then evaluated the effects of these management measures on the variables contained in the models, and calculated the criteria index values using the model's equations. The result was criteria index values that reflect effects on survival as a result of implementing the recommended management measures.

Although the criteria index values were set by reference to the protective management measures, the resulting criteria index values were also consistent with the recommendations of the Interagency Statement of Principles signed by EPA, NMFS, and USFWS, which called for a level of protection for aquatic resources equivalent to the level existing in the late 1960's to early 1970's. To make this comparison, EPA compared its proposed criteria index values with the index values attained historically on the two river systems. The historical index values were developed by the USFWS. *See* USFWS, 1992c (WRINT-USFWS–8); also 59 FR 824. The proposed Sacramento River criteria index values represented overall protection for the Fish Migration use at approximately the 1956–1970 historical level, whereas the proposed San Joaquin River criteria index values represented slightly better protection than the 1956–1970 historical level. Both sets of criteria index values represented better protection than the 1956–1970 historical period in drier years, and less protection in wetter years. These proposed criteria index values were intended to reflect more consistent smolt survival and help avoid situations where extraordinary measures would be necessary to preserve runs, particularly in the San Joaquin River tributaries.

TABLE 3.—PROPOSED SALMON SMOLT CRITERIA

Sacramento River		San Joaquin River	
Water year type	Criteria value	Water year type	Criteria value
Wet	.45	Wet	.46
Above Normal.	.38	Above Normal.	.30
Below Normal.	.36	Below Normal.	.26
Dry	.32	Dry	.23
Critical	.29	Critical	.20

Finally, the Proposed Rule also relied on the criteria index equations to determine whether the criteria were being attained. In effect, attainment would be assumed if the State adopted an implementation plan with a set of measures (export restrictions, flow requirements, etc.) that, when computed in the index equations, resulted in the criteria index value. This approach assumed that the criteria index equations included all of the important variables determining smolt survival and correctly stated the interrelationship of those variables, so that actual measurement of attainment would be unnecessary.

The final Fish Migration criteria reflect the following changes from the Proposed Rule: (i) the methodology for establishing the criteria index values has been revised, (ii) the criteria have been restated as sliding scales or continuous functions, and (iii) direct experimental measurements of salmon survival will be used to measure attainment of the criteria.

(i) Revised Method of Selecting Criteria Index Values

As discussed in the materials referenced in EPA's Notice of Availability (59 FR 44095), EPA has revised its approach to stating and developing the criteria index values used in the final criteria. The primary change in the final rule is that EPA has revised the underlying management measures used to generate the criteria index values. On the Sacramento River, available information indicates that closing the Delta Cross Channel during the spring migration period is the most important factor in the protection of the Fish Migration designated use, primarily because closing the Channel prevents migrating fish from being pulled into the inner Delta where survival is significantly lower. Accordingly, the criteria index values were based on tagged-fish release results for migration periods when the Delta Cross Channel was closed. Similarly,

[34] Since the Proposed Rule was published, and as described in the alternative formulation of the Fish Migration criteria made available in EPA's Notice of Availability (59 FR 44095), USFWS has developed a revised version of the San Joaquin River model. This model relates the survival of San Joaquin basin smolts migrating through the Delta to: (1) San Joaquin River flow at Vernalis, (2) proportion of flow diverted from the mainstem San Joaquin River, (3) exports, and (4) temperature at Jersey Point. The revised San Joaquin model structure overall is very similar to that of the Sacramento basin model. This revised model should be more useful than the previous version for analyzing alternative implementation measures.

EPA believes that on the San Joaquin River the management measures recommended by USFWS (with the minor adjustments described below) will protect the designated uses. Accordingly, the criteria index values for the San Joaquin were derived from the modeled values associated with these management measures.

(a) Sacramento River Fish Migration Criteria

On the Sacramento River, the criteria index values vary according to the water temperature at Miller Park at the time of the tagged fish release. ''Ceiling'' and ''floor'' criteria index values are included to reflect the fact that at very high water temperatures, the Fish Migration use needs additional protection, and at very low water temperatures, temperature is unlikely to affect fish migration. The actual index values have been set to replicate the survival values that would be attained if the Delta Cross-Channel were closed during the critical spring migration period. The Sacramento River tagged-fish release results indicate that, except in very high temperature periods, those periods in which the Delta Cross-Channel is closed provide aquatic conditions allowing for the protection of the Fish Migration designated use.

(I) *Using Temperature as the Independent Variable for the Criteria.* In the Proposed Rule, Sacramento River criteria varied according to water year types reflecting precipitation in the Sacramento River Basin. Using water year type as the ''independent variable'' in the criteria allowed EPA to match criteria index values with the natural variation in precipitation. Further analysis of the USFWS tagged-fish release studies suggests that temperature is a dominant factor influencing salmon smolt survival in the Sacramento River. Temperature at release alone is significantly related to salmon smolt survival (Letter from P. Fox to L. Hoag, California Urban Water Agencies, dated July 13th, 1994).

Because water temperature in the Delta is largely independent of management measures in the Delta (in that it varies naturally with ambient weather conditions), EPA will adopt final Fish Migration criteria that vary based on water temperature. That is, the criteria index values will call for higher smolt survival at lower water temperatures, and lower smolt survival at higher water temperatures. This variation in the criteria index values with temperature follows the pattern of the natural variability of temperature and survival existing on the Sacramento River during periods in which the Fish Migration designated use is attained.

Although it is generally adopting water temperature as the independent variable for the Sacramento River Fish Migration criteria, EPA is modifying the approach in two ways in order to better protect the designated use. First, at very high water temperatures (those above 72° F), measured smolt survival index values approach zero. These high temperature conditions are clearly not consistent with protection of the Fish Migration use. Protective measures should therefore be used to increase survival of smolts throughout this period, even at times of high temperature. To this end, USFWS has recommended additional management measures (primarily export restrictions) to restrict passage of fish into the warm waters of the central Delta and, thus, lower mortality of smolts as they pass through the Delta (USFWS 1992a). It is EPA's judgment that these measures should be used to reduce the serious degradation in migration conditions occurring during high temperature periods. EPA believes, therefore, that a ''floor'' to the Fish Migration criteria is appropriate so as to encourage efforts to protect salmon during these periods of high temperature. EPA has included such a ''floor'' at the 72° F temperature level in its final Sacramento River Fish Migration criteria.

Similarly, at lower temperatures, the smolt survival index values likely approach a maximum at some point. The highest survival index recorded (1.48) coincided with the lowest temperature at release recorded during salmon smolt survival experiments (61°F). Below this temperature, it is unlikely that lower water temperatures would lead to a substantially increased survival. In other words, once water temperature reaches the lower temperatures beneficial to smolt survival, additional decreases in the temperature would not be expected to significantly increase survival. This suggests that the Fish Migration criteria should include a ''ceiling'' value associated with those low temperatures. Otherwise, the criteria would state that continued lowering of water temperature should yield higher and higher survival. This result is unlikely to be valid. EPA is therefore placing a ''ceiling'' on the criteria index values corresponding to the 61°F level.

(II) *Establishing criteria values.* To set the actual criteria values, the final rule relies on the recommendation by USFWS that the Delta Cross Channel be closed at critical times during the spring salmon migration period (USFWS 1992a). Recent investigations by USFWS indicate that closing the Delta Cross Channel is the most important factor in the protection of smolts on the Sacramento River (USFWS 1992b). The historical experimental release results support this hypothesis, in that data points derived from periods when the Cross Channel was closed show a significant and consistent improvement in survival compared to periods when it is open (USFWS 1992b).[35]

Based on this beneficial relationship between survival and the closure of the Delta Cross Channel, EPA has concluded that criteria index values corresponding to a closed Delta Cross Channel (adjusted to provide a floor for high temperature periods) would reflect conditions protecting the Fish Migration designated use on the Sacramento River. Accordingly, the final rule adopts criteria index values, stated (as explained below) as a continuous function or line, to approximate[36] the experimental survival index values observed for Sacramento releases during periods in which the Channel is closed. The continuous function or line for these criteria index values can be stated as a simple linear equation (Index value $= 6.96 - .092$ * Fahrenheit temperature).

This approach to developing criteria index values addresses some of the concerns about the criteria index equations raised in the public comments and at the CUWA scientific workshops. Some commenters believed that the complexity and structure of the equations resulted in too much uncertainty about their statistical reliability. The revised approach used in the final rule reduces this problem because it sets the criteria index values using observed tagged-fish release results instead of modeled or computed values.

The final criteria index value line described above very closely approximates the line created by doubling the historical survival data measured at times that the Delta Cross Channel is open. These different lines, and the underlying data, are summarized in Figure 4. Although not intentional, the near-coincidence of the final criteria index value line and the doubling line provides an independent policy rationale for adopting this target index, in that the Central Valley Project

[35] This is particularly true for release studies at Sacramento. Release studies at Courtland (downstream of Sacramento) showed less dramatic improvement with the Cross Channel closed, suggesting that other factors such as those included in the USFWS model are also at work.

[36] Approximating this line was done through a standard least squares ''best fit'' computation.

Improvement Act mandates a ''doubling'' goal for anadromous fish.

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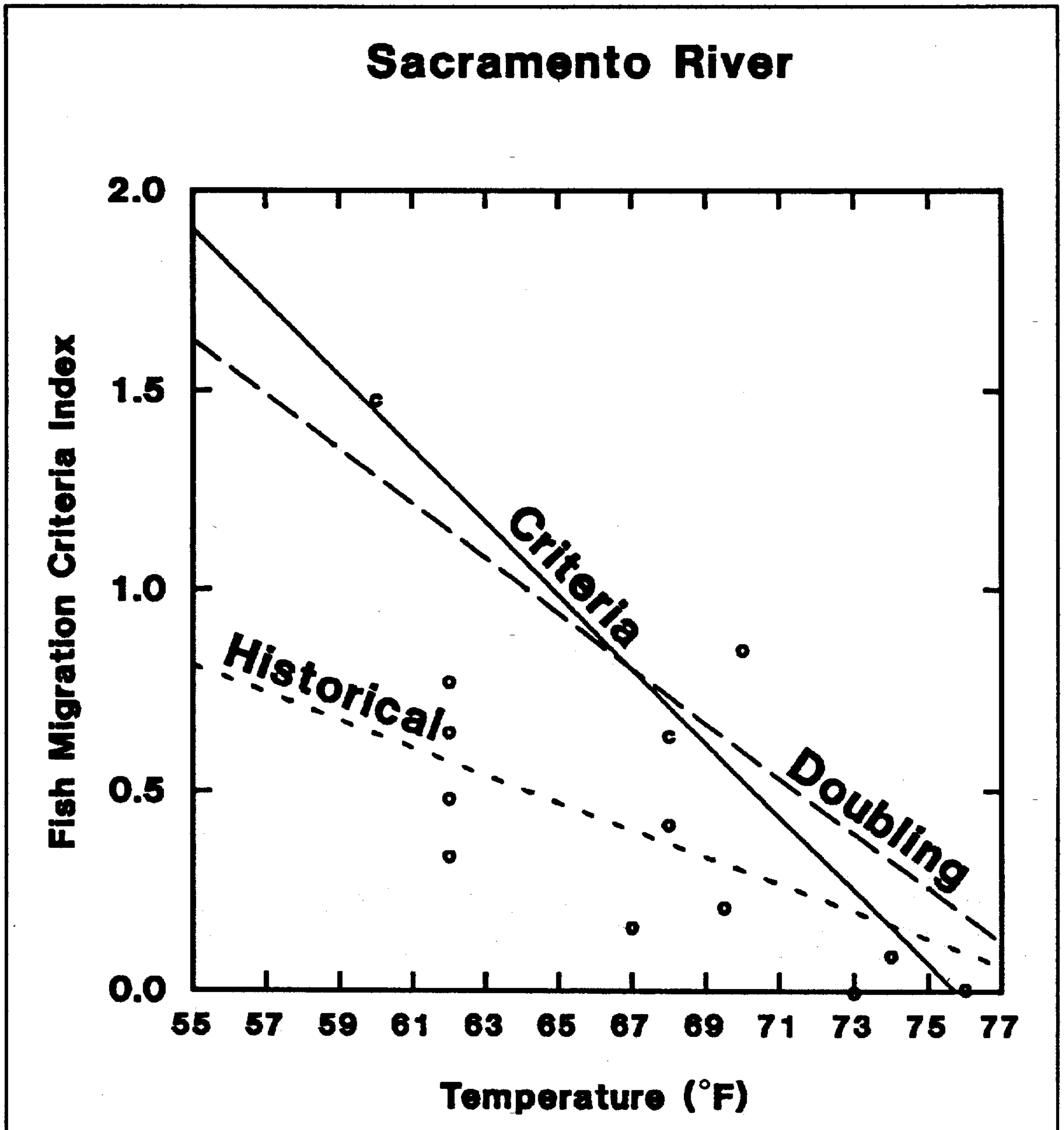

Figure 4: Comparison of Sacramento River Fish Migration Criteria Line with Historical Survival and Doubling of Historical Survival Lines

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Historical information confirms the validity of the final Sacramento River Fish Migration criteria, in that the criteria index values developed in this final rule are consistent with the modeled index values representing conditions in the late 1960's to early 1970's. As stated by EPA in the Proposed Rule, the level of protection on the Sacramento River during this historical period was consistent with the protection of the Fish Migration designated use.

(III) *Revised Sacramento Fish Migration Criteria.* The revised criteria (Sacramento River Fish Migration Criteria or SRFMC) are stated in reference to water temperature. As explained above, use of this linear equation appears inappropriate at both very high and very low temperatures, so the criteria must specify a ceiling on the index values at low temperatures and a floor for high temperatures. Incorporation of these conclusions and comments leads to the following Fish Migration criteria:

At temperatures below 61°F:
SRFMC=1.35
At temperatures between 61°F and 72°F:
SRFMC=6.96 − .092 * Fahrenheit temperature
At temperatures above 72°F:
SRFMC=0.34

In all cases, water temperature is the temperature at release of tagged salmon smolts into the Sacramento River at Miller Park.

These final criteria are shown in Figure 5. Note that the ''ceiling'' and ''floor'' values in the final rule differ somewhat from those included in the documents made available in EPA's Notice of Availability (59 FR 44095). The changes were made to correct computational errors in evaluating the applicable ''continuous function'' values for the 61°F and 72°F ceiling and floor levels.

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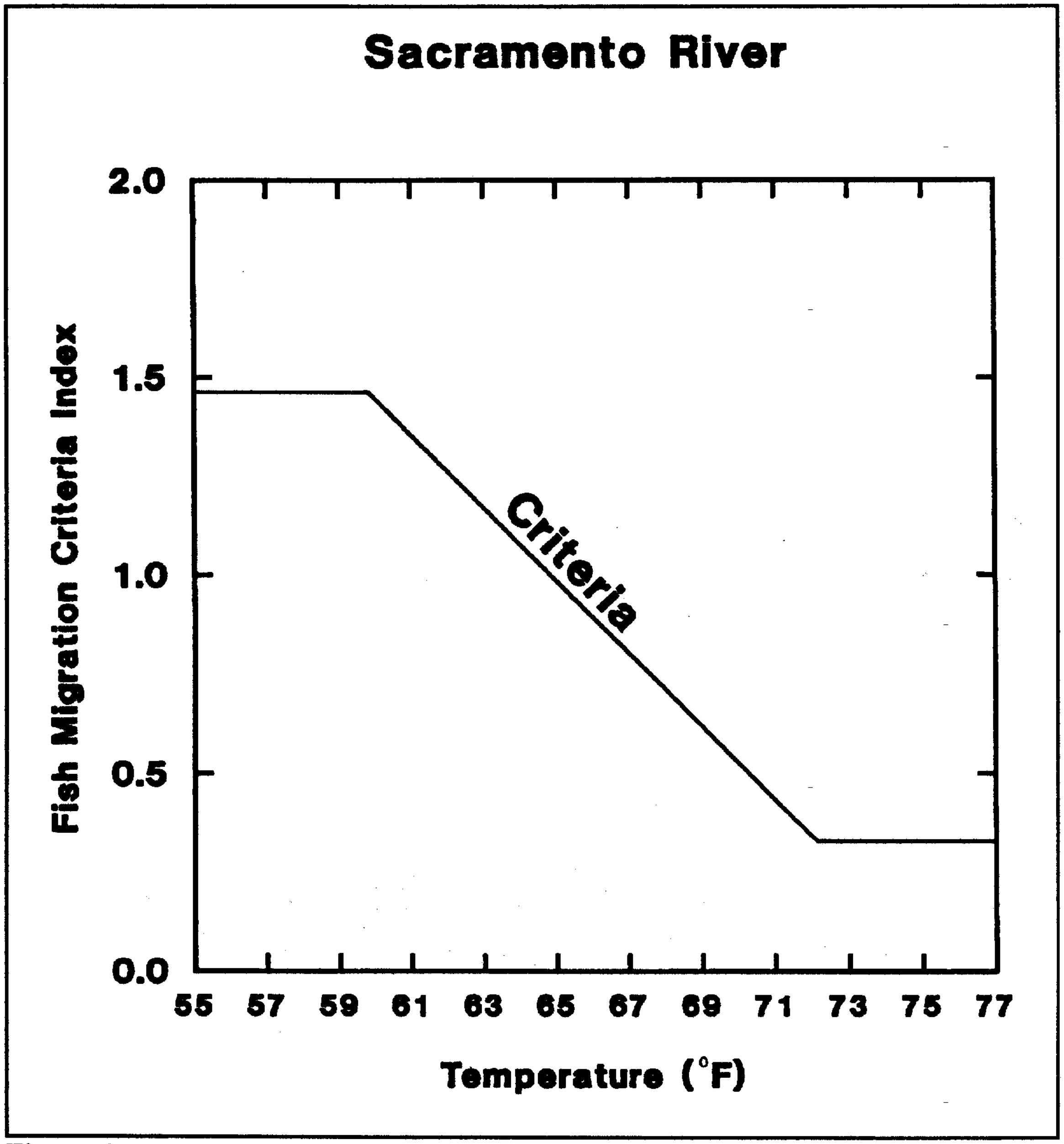

Figure 5: Sacramento River Fish Migration Criteria

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(IV) *Implementation.* On the Sacramento River, the criteria provide survival goals that vary based on the water temperature at the time of release of the tagged salmon smolts. EPA believes that the implementation plan developed by the State Board should provide for a sufficient number of fish releases each year to determine whether the criteria are being attained over a representative range of temperature conditions. EPA recognizes that there may be substantial variation in fish migration criteria values resulting from these experimental releases. Accordingly, the final rule provides that attainment can be measured using a three-year moving average (the current year and two preceding years). Three year periods should provide time to complete sufficient releases to determine whether the implementation measures are, on average, attaining the stated criteria values.

The State Board may consider using the USFWS Sacramento smolt survival model (that is, the model underlying the criteria index equations) to predict measures necessary to attain the criteria. There are a number of base conditions underlying both the tagged-fish release experiments and the USFWS models. For example, USFWS recommended a base Sacramento River flow to ensure that overall conditions do not deteriorate. The State should protect these base conditions as it develops an implementation plan.

Monitoring attainment of these criteria should focus on both within-year measures and across-year comparisons. During each year monitoring of salmon smolt survival should occur throughout the months of April, May and June with particular emphasis during times of temperature change or at times of change in water project operation. It is likely that this monitoring will reveal a large variability in survival at different times and under different conditions within each year. EPA anticipates that at the time of the next triennial review enough monitoring data over a range of temperatures will be available for a preliminary determination of whether the State's implementation actions attain the criteria.

(b) San Joaquin River Fish Migration Criteria

On the San Joaquin River, the criteria index values vary according to unimpaired San Joaquin river flow. The actual index values have been set to approximately replicate the survival values that would be attained if a series of management measures (flow requirements, export restrictions, barriers, etc.) recommended by the USFWS were implemented. The tagged-fish release results indicate that these or equivalent management measures are necessary to protect the Fish Migration designated use on the San Joaquin.

(I) *Using Unimpaired Flow at Vernalis as the Independent Variable for the Criteria.* In the Proposed Rule, San Joaquin River criteria varied according to water year types reflecting precipitation in the San Joaquin River basin. Using the water year type as the ''independent variable'' allowed EPA to match the criteria index values with the natural variation in precipitation. Further analysis has confirmed that water flow at Vernalis shows a significant correlation with survival indices representing total survival through the Delta,[37] suggesting that criteria index values should vary with the natural hydrology. That is, the criteria index values should reflect higher survival during wetter years with more precipitation and lower survival during drier years. This variation replicates the natural hydrological cycles affecting Fish Migration through the estuary.

The Proposed Rule varied criteria index values according to the five water year types, and in that way reflected natural hydrological cycles. In the final rule, however, EPA is using the 60–20–20 unimpaired San Joaquin flow index[38] as a readily-available estimate of natural hydrology. When used in a continuous function (as described below), the 60–20–20 index allows a much more precise statement of the natural hydrology than the five water year categories.

(II) *Establishing Criteria Index Values.* To establish the actual values included in the San Joaquin River Fish Migration criteria, EPA first developed survival values associated with the implementation of management measures proposed by USFWS (USFWS 1992a). These USFWS measures include export limits at certain times, a barrier at Old River during April and May, and minimum flows at Vernalis, and are summarized in Table 5.[39] As indicated in the Proposed Rule, EPA believes that implementation of these management measures would provide conditions protecting the designated Fish Migration use.

Modifying management measures. As explained below, EPA has revised its assessment of some of the USFWS management measures (notably, those involving the Upper Old River barrier). Accordingly, the final rule used the following management measures: (1) A one month (April 15 to May 15), instead of USFWS's two month (April 1 to May 31), requirement for the Upper Old River barrier placement, (2) increased export restrictions (to 1500 cfs) during the time the Old River barrier is in place, (3) increased flow (to an average of 4000 cfs rather than USFWS's 2000 cfs) in critical years when the barrier is in place, and (4) flows and exports varying each year according to the 60–20–20 water year index, rather than using the USFWS proposal to vary measures by water year type. EPA's measures (stated as averages for each water year type) are also shown in Table 4.

EPA revised the management measures recommended by USFWS because recent discussions with USFWS and others, as well as information developed in hydrological modeling for the South Delta Barriers Project (California DWR 1993), raised concerns that an Upper Old River barrier might increase reverse flows in the central Delta. Such an increase has the potential to draw fish into poor habitat and to increase entrainment of fish at the project pumps. This is of particular concern for the threatened Delta smelt. Because the barrier is expected to provide greatly increased protection for migrating salmon smolts, EPA continues to believe, as it expressed in the Proposed Rule, that an Upper Old River barrier is an important implementation measure. However, in order to prevent an increase in detrimental central Delta reverse flows, EPA is revising the USFWS management measures to include only one month with the barrier in place, rather than the two months initially recommended by USFWS.[40]

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[37] EPA considered water temperature at release, smolt size at release, and water flow at Vernalis as potential independent variables affecting survival. Based on the studies done to date, it appears that neither water temperature at release nor smolt size show a significant correlation with the smolt survival indices representing smolt survival through the San Joaquin Delta (P. Fox, Data summary presented at CUWA workshop on June 29, 1994). Note that results from upstream site releases (at Snelling and on the lower Stanislaus and Tuolumne Rivers) were included in this correlation between flow and survival index values in order to supplement data from wetter years. This approach assumed that the mortality between the upstream release sites and the downstream Mossdale, Dos Reis and Upper Old River release sites (all close together) is negligible. If incorrect, this assumption may bias the correlation downward, and survival through the Delta may have been better than the index indicates for those releases.

[38] The San Joaquin water year index (denoted the San Joaquin Valley Index in the final rule language) is the commonly-accepted method for assessing the hydrological conditions in the San Joaquin basin. It is also frequently referred to as the 60–20–20 index, reflecting the relative weighting given to the three terms (current year April to July runoff, current year October to March runoff, and the previous year's index) that make up the index.

[39] As explained above, the index values shown in Table 6 (both USFWS and EPA values) have been ''scaled'' by dividing by 1.8. This scaling allows a direct comparison with the Proposed Rule index values, which were also scaled. EPA's final criteria index values have not been scaled, to facilitate measurement of attainment through actual experiments as discussed below.

[40] As in the Proposed Rule, EPA assumed that exports would be reduced to no more than 1500 cfs while the barrier is in place, to help alleviate hydrological problems caused by the barrier. Minimum flows during the time the barrier is in place are assumed to be an average of approximately 4000 cfs during dry and critically dry years to provide an increased ratio of flows to exports in the lower San Joaquin, thereby further reducing potential problems caused by reverse flows. Management measures assumed in developing the criteria values also included export restrictions during the times in April and May when the barrier is not in place. These maximum export rates are: in critically dry years, 2000 cfs; dry years, 3000 cfs; below normal years, 4000 cfs; above normal years, 5000 cfs; and wet years, 6000 cfs.

TABLE 4.—SAN JOAQUIN MANAGEMENT MEASURES COMPARED

Alternative	Max Total CVP/SWP Exports in cfs	Barrier Upper Old River	Vernalis Flow	Index Values on San Joaquin
EPA	4/15 to 5/15 1500 4/1 to 4/15 & 5/16 to 5/31 W[1] 6000 AN 5000 BN 4000 D 3000 C 2000	4/15 to 5/15 All Year Types	4/15 to 5/5 Minimum CFS W 10000 AN 8000 BN 6000 D 4000 C 4000 Other flows from 4/1 to 5/31 same as DWRSIM run used by USFWS for D–1630	 W .49[2] AN .35 BN .28 D .22 C .22 Avg = .33
USFWS	4/15 to 5/15 W 6000 AN 5000 BN 4000 D 3000 C 2000	4/1 to 5/31 All Year Types	4/15 to 5/15 Minimum CFS W 10000 AN 8000 BN 6000 D 4000 C 2000 Other flows from 4/1 to 5/31 same as DWRSIM run used by USFWS for D–1630	 W .49 AN .41 BN .40 D .35 C .32 Avg = .41

[1] Many of the management measures in Table 4 vary by the water year category. Those categories are wet (W), above normal (AN), below normal (BN), dry (D) and critically dry (C).

[2] For comparison purposes, both EPA and USFWS index values have been scaled by dividing by 1.8. The final EPA criteria have not been scaled.

Criteria index values. Having arrived at this set of management measures that would protect the Fish Migration designated use (and not adversely affect the Delta smelt), EPA used the USFWS survival index equations to develop criteria index values across the potential range of hydrological conditions.[41] Note that, as distinguished from the Proposed Rule, EPA is including only the criteria index *values* as its final Fish Migration criteria. The Proposed Rule had also included the criteria index value *equations* in the criteria. By including only the goal or target index values in the final criteria, EPA is providing greater latitude to the State Board to develop a mix of management measures that attain the stated salmon survival.

Means of these modeled values for each water year type are shown in Table 4. To translate these discrete values into a continuous function (as discussed below), two lines of ''best-fit'' were created, one for the drier years (dry and critically dry) and one for the wetter years (wet, above normal, and below normal). By connecting these two lines, EPA created a continuous function to serve as the criteria index value line on the San Joaquin. This criteria index value line is shown in Figure 6.

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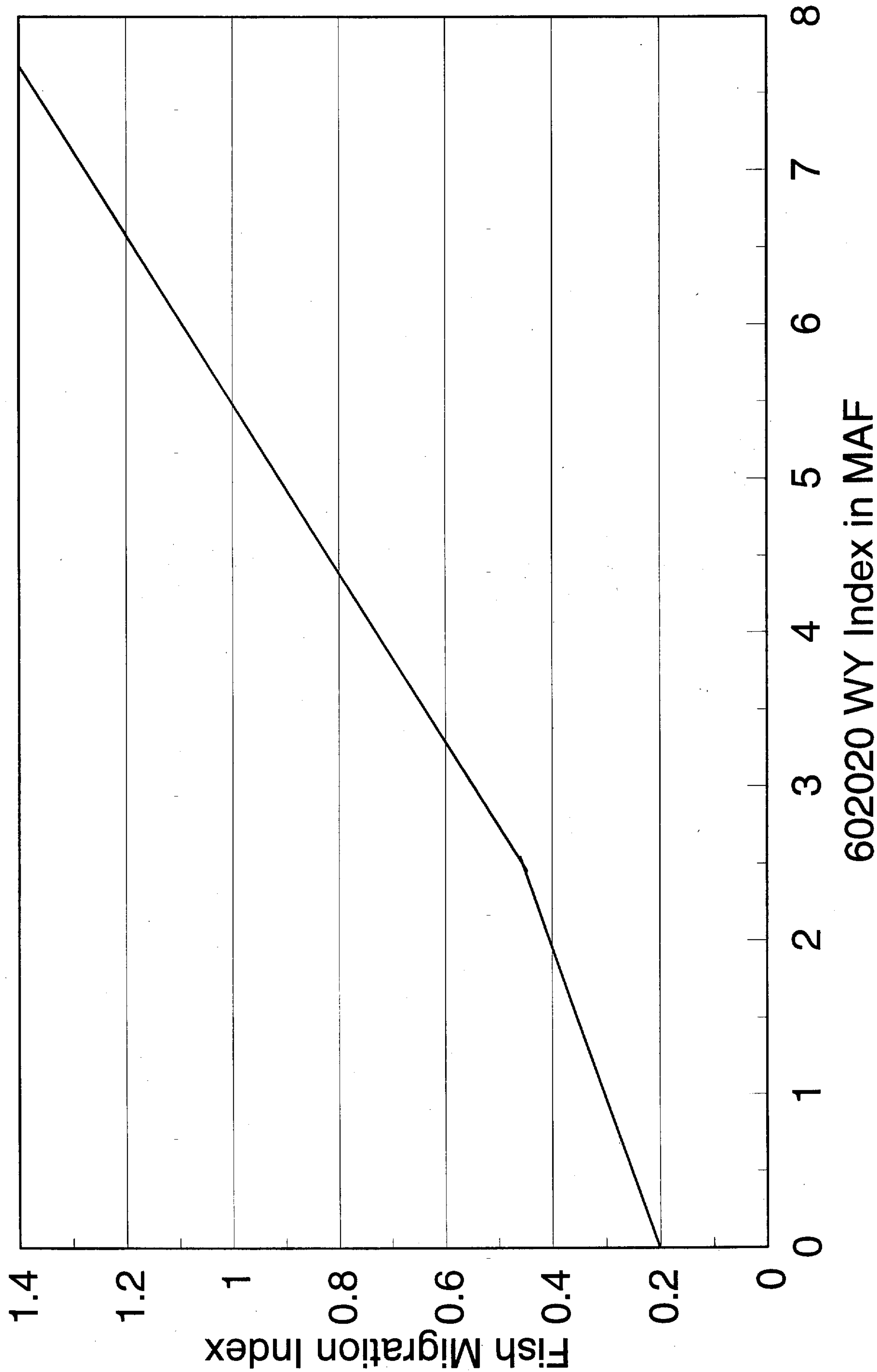
[41] The final Fish Migration criteria on the San Joaquin River do not vary by temperature (as they do for the Sacramento River) because experimental data from releases near the upstream edge of the Delta did not show a significant statistical relationship between survival and temperature at release (P. Fox, Data summary presented at CUWA workshop on June 29, 1994). In other words, on the San Joaquin River, temperature should not be used as the *independent* variable in the criteria. Nevertheless, temperature at Jersey Point is one of the factors included in the revised USFWS San Joaquin River model, and, as described above, that model was used in developing EPA's final criteria to gauge the probable effect of implementation measures on smolt survival. When computing modeled smolt survival, EPA assumed average water temperatures of 60 °F in April and 65 °F in May. These assumed values are averages from a set of temperature data at Jersey Point taken during the late 1950's and 1960's. The recent experimental release temperatures are within the range of this data.

Figure 6. San Joaquin Fish Migration Criteria



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Dry year v. wet year protection. These final criteria index values represent a larger relative increase in survival over current survival rates in dry and critical years (compared to wetter years) so as to protect salmon populations from declining to the critically low levels of recent years. The results from tagged-fish releases on the San Joaquin River show significantly different survival at high versus low flow conditions (USFWS 1992b; Brandes 1994). Most of the release studies have been performed at flows below 5,000 cfs, and it is clear from the relation between survival indices and experimental flow conditions that these conditions are very poor for smolt survival and are inadequate to protect the Fish Migration designated uses. The average survival index for these low flow conditions is 0.09, whereas these index values have attained values as high as 1.5 on the San Joaquin (a Jersey Point release).[42] Although there is less information at higher flows, the experimental results do indicate that survival has been substantially higher under these conditions. The average survival index at these higher flows is 0.48.

To address this relative difference in survival during high and low flow periods, EPA is adopting criteria index values reflecting a relatively larger improvement in survival in low flow years than in high flow years. That is, conditions for migrating fish in drier periods have been relatively worse, so the criteria index values applicable to the drier periods must reflect conditions that are relatively more improved in order to protect the Fish Migration designated use.

Although the final criteria call for relatively higher protection in drier years, it is also particularly important in the San Joaquin basin to protect salmon during periods of higher flow conditions. The years of higher flows have been the only times recently when the Fish Migration use has come close to being attained, and protection in these productive years is important for buffering the salmon population against permanent loss of salmon runs when conditions are poor. To address these special concerns across the spectrum of hydrological conditions, these final criteria index values, on average, increase wet year survival by a factor of 1.8 and critically dry year survival by a factor of 4.

EPA has considered the concerns expressed by some CUWA workshop participants about using the USFWS models to establish criteria index values. The CUWA workshop participants developed a consensus, based not on the USFWS-modeled values but on their independent scientific judgment, that an increase in measured survival index values of two to three times recently observed values would be appropriate in critical years (Kimmerer 1994b). As stated above, the CUWA workshop participants also endorsed relatively higher protection in drier years as opposed to wetter years (Kimmerer 1994b). EPA agrees with these scientific judgments, and believes that measured criteria index values in these ranges must be attained to protect the designated uses on the San Joaquin.

The criteria index values shown as a continuous function in Figure 6, even though developed with the assistance of the USFWS model, are wholly consistent with the findings of the CUWA workshop participants (Kimmerer 1994b). In addition, these target values are, on average, consistent with the historical 1956–70 average survival index for the more protective wetter years of that period (wet, above normal, and below normal water years) as calculated using the USFWS model (Brandes 1994). The target values are also consistent with the CVPIA goal of doubling anadromous fish populations. For comparison, the final criteria index value line is displayed in Figure 7 with the recent historical survival line (based on the tagged fish release results) and a line representing twice the recent historical survival line.

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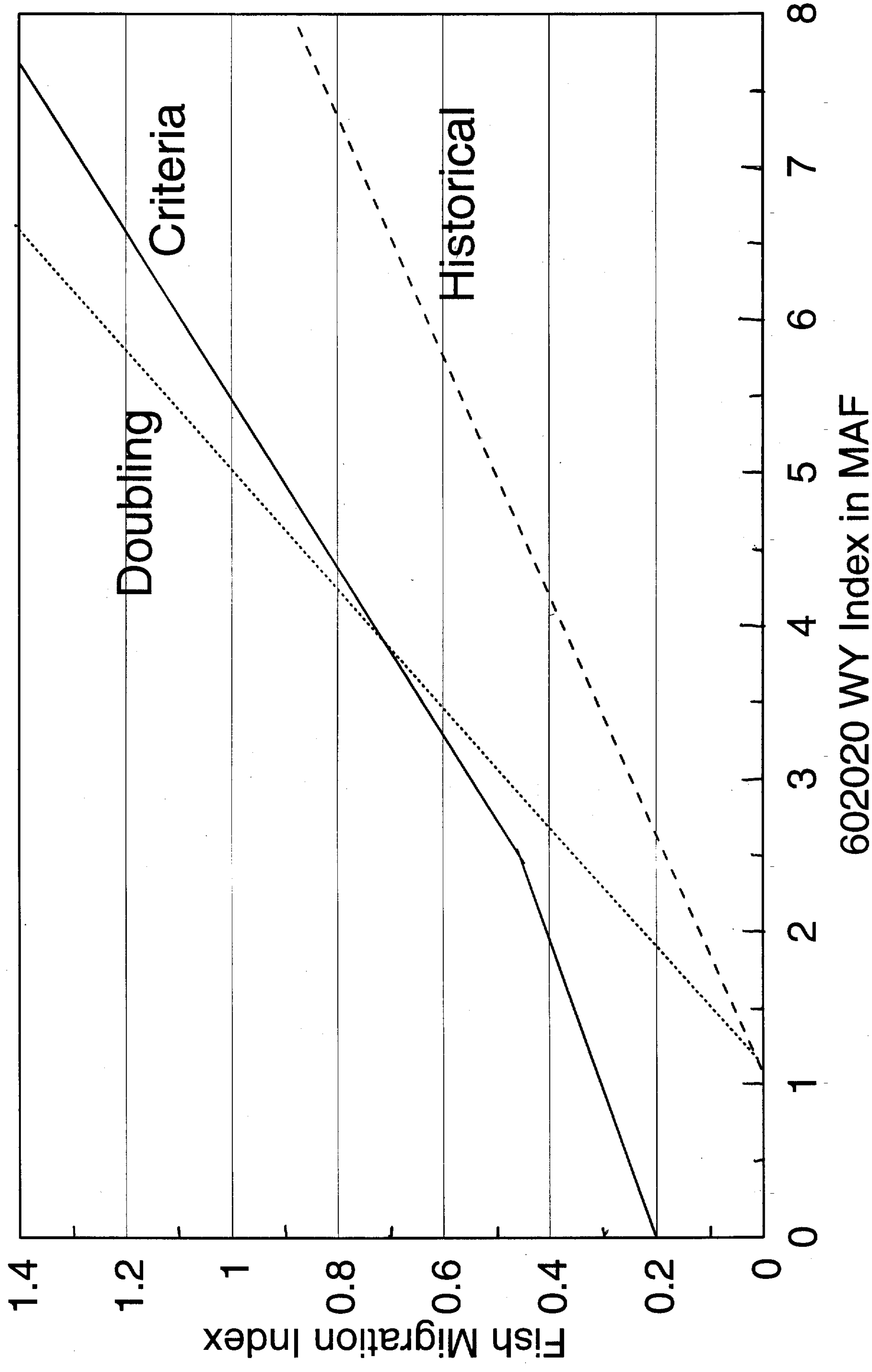
[42] These numbers are not ''scaled'', and are thus indices showing survival relative to other index values. The 0.09 average index value represents approximately 5 recoveries from a release of 50,000 fish at Mossdale, 55 miles upstream of the smolt recovery site at Chipps Island.

Figure 7. San Joaquin Fish Migration Criteria Compared with Historical Experimental Release Results and Release Results Doubled



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(III) Revised San Joaquin Fish Migration Criteria. The criteria index value line is being stated in the final rule as follows:

For years in which the SJVIndex is > 2.5:

SJFMI = (−0.012) + 0.184*SJVIndex

In other years:

SJFMI = 0.205 + 0.0975*SJVIndex

where SJFMI is the San Joaquin Fish Migration index, and SJVIndex is the 60–20–20 San Joaquin water year index in million acre feet (MAF).

These criteria are displayed graphically in Figure 6.

(IV) *Implementation of San Joaquin River Fish Migration Criteria.*

The following discussion is intended to assist the State Board's consideration of the issues involved in implementing these or similar, equally protective, criteria.

The San Joaquin River Fish Migration criteria provide an annual survival goal that varies depending on the 60–20–20 San Joaquin water year index. EPA anticipates that the State Board implementation plan would provide for a sufficient number of tagged fish releases to verify that the applicable criterion is being met in each year. EPA recognizes that there may be substantial variation in fish migration criteria values resulting from these experimental releases. Accordingly, the final rule provides that attainment can be measured using a three-year moving average (the current year and two preceding years). Three year periods should provide time to complete sufficient releases to determine whether the implementation measures are, on average, attaining the stated criteria values.

As stated above, the USFWS model is the best available model of salmon smolt survival through the Delta, and EPA encourages the State Board to use the recently revised USFWS San Joaquin model as guidance for setting implementation measures. Nevertheless, it is important to recognize that there may be constraints on the model's use. Further monitoring and experimental releases under the chosen implementation regime are essential to verify and refine the model, and will ensure that the smolts are actually surviving at the expected level. In addition, it will be particularly important to protect the base conditions assumed in the model, such as flows during the time the Upper Old River barrier is not in place, flows at Jersey Point, and temperature.

The expected criteria index values are unlikely to be achieved if these base conditions deteriorate.

One additional refinement to the implementation measures should be considered on the San Joaquin River. As discussed above, the Sacramento River criteria include a ceiling value on the maximum salmon smolt survival. This was included because there appears to be a point where incrementally lower temperatures do not significantly increase salmon smolt survival. In theory, there may be a similar point on the San Joaquin River where incrementally higher flows in very wet years do not yield significantly higher salmon smolt survival. Nevertheless, the existing data do not allow quantification of what those flow levels are. EPA is supportive of another mechanism for dealing with this issue. It is EPA's judgment that in very wet years (those in which the flows exceed 10,000 cfs during the relevant period) it may be appropriate to meet the flow requirements associated with the targeted Fish Migration criteria index solely through natural storm events and restricted diversions, and not by upstream reservoir releases. In other words, the implementation flows could be provided at these higher flow periods by natural hydrology rather than by reservoir releases. In this way, the natural ''flood events'' that appear to be so beneficial to the salmon would be protected, but the water supply system would not have to bear the water costs of generating artificial flood events through reservoir releases.

(ii) Use of Continuous Function

The second principal difference in the final criteria is to state the criteria as a ''continuous function'' or ''sliding scale.'' As discussed in EPA's alternative formulation of the Fish Migration criteria made available in the Notice of Availability, this approach replaces the Proposed Rule's statement of the criteria as single fixed index values for each of the five water year categories (59 FR 44095). The proposed approach did not account for the substantial differences in hydrological conditions *within* water year types. For example, an ''above normal'' water year type could range from a *wet* ''above normal'' year to a *dry* ''above normal'' year. Given the extreme variation of hydrological conditions in the Bay/Delta, these variations within each of the five standard water year types are substantial, and should be factored into the calculation of the applicable Fish Migration criteria index value. The continuous function approach addresses this problem by transforming the five discrete water year categories into a more precise equation (graphically, a single line or curve) correlating the Fish Migration criteria index value with each year's specific observed hydrological conditions. The continuous function approach provides the same degree of protection for the designated uses as the proposed approach using average survival values. However, the continuous function approach provides a more precise approximation of hydrological conditions and facilitates implementation and compliance. EPA explained the rationale for using the continuous function approach in more detail in the technical documents referenced in the Notice of Availability (59 FR 44095). The derivations of the actual continuous functions for the Sacramento and San Joaquin River systems are explained above.

(iii) Measuring Attainment Through Actual Test Results

The Proposed Rule relied on the criteria index equations to determine whether the criteria were being attained. In effect, attainment would be assumed if the State adopted an implementation plan with a set of measures (export restrictions, flow requirements, etc.) that, when computed in the index equations, resulted in the criteria index value.

Many commenters believed that reliance on the criteria index equations for this purpose was inappropriate because factors other than those implementation measures included in the model may affect smolt survival. To address this concern, in the final criteria, direct experimental measurements of smolt survival through the Delta will be used to estimate attainment of the criteria, instead of relying on modeled estimates. Survival is to be measured through tagged smolt release and recapture studies. This approach assures that factors significantly affecting survival will be reflected in survival measurements, even if they are not well described by the criteria index equations. This more direct approach gives the State greater latitude to develop implementation measures outside of the equation parameters. It also ensures that the implementation measures are actually providing the intended protection for the Fish Migration designated use.

(3) Fish Migration Criteria as Multispecies Protection

The Fish Migration criteria outlined above are based on protection measures required for a single run of salmon, the fall-run Chinook salmon. Some commenters questioned whether this approach conflicts with the habitat or multispecies approach recommended by the Club FED agencies in their

Agreement for Coordination on California Bay/Delta Issues signed September 20, 1993. As noted in the preamble to the Proposed Rule, EPA believes that the implementation measures likely to be adopted to meet the target criteria values in these Fish Migration criteria, when combined with the other Federal actions in the Delta protecting the endangered winter-run Chinook salmon, are fully consistent with the protection of a broad range of anadromous and migratory fishes in the Bay/Delta.

Juvenile spring-run salmon and steelhead move through the Delta during the same period as winter-run and fall-run salmon, and are expected to be protected in the Delta by measures protecting these other runs (CDFG 1990a). Species other than salmon and steelhead seasonally migrate into and out of the Delta for spawning and as juveniles. These species include striped bass, Delta smelt, longfin smelt, white and green sturgeon, American shad and Sacramento splittail. With the exception of temperature, the factors that lead to successful migration of salmon and steelhead smolts are also important for successful migration of the juveniles of these species into the lower embayments. Therefore, EPA's proposed Fish Migration criteria, although specifically addressing fall-run Chinook salmon, will also help protect migration of these other migratory species.

3. Fish Spawning Criteria

a. Proposed Rule

In California, striped bass spawn primarily in the warmer freshwater segments of the Sacramento and San Joaquin Rivers. Protection of spawning in both river systems is important to ensure the genetic diversity of the population as well as to increase the size of the overall striped bass population. The precise location and time of spawning appear to be controlled by temperature and salinity (Turner 1972a; Turner and Chadwick 1972). According to the California DFG, striped bass spawn successfully only in freshwater with electrical conductivities less than 0.44 millimhos[43] per centimeter electroconductivity (mmhos/cm EC), and prefer to spawn in waters with conductivities below 0.33 mmhos/cm. Conductivities greater than 0.55 mmhos/cm appear to block the upstream migration of adult spawners (Radtke and Turner 1967; SWRCB 1988; SWRCB 1991; CDFG 1990b, WQCP–DFG–4). As explained in more detail in the Preamble to the Proposed Rule, salinity does not appear to be a serious limitation on spawning on the Sacramento River. However, in the smaller and shallower San Joaquin River, migrating bass seeking the warmer waters encounter excessive upstream salinity caused primarily by runoff. This salinity can block migration up the San Joaquin River, thereby reducing spawning, and can also reduce survival of eggs (Farley 1966; Radtke 1966; Radtke and Turner 1967; Turner and Farley 1971; Turner 1972a, 1972b).

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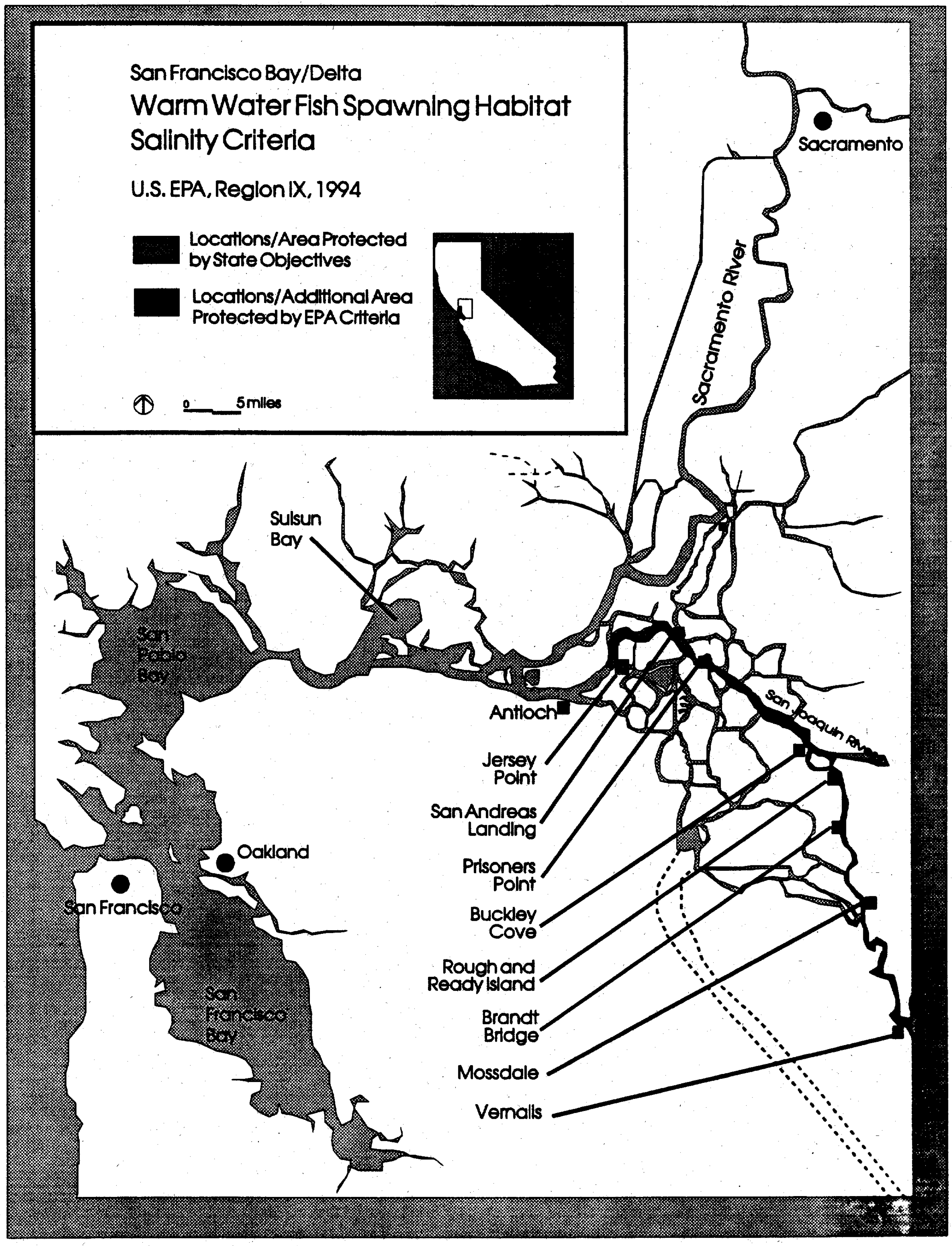
[43] Salinity conditions upstream in freshwater are generally affected by dissolved salts from upstream water runoff. The salinity content of freshwater is traditionally measured by its electroconductivity or specific conductance standardized to 25°C, and is expressed in terms of millimhos per centimeter electroconductivity (''mmhos/cm EC'') or micromhos per centimeter specific conductance. The Proposed Rule stated the Fish Spawning criteria in terms of mmhos/cm EC. In the final rule, EPA will state the criteria in terms of micromhos/cm specific conductance, so as to be consistent with EPA's published guidance. *See* 40 CFR Part 136, Table 1B—List of Approved Inorganic Test Procedures, Parameter 64. The Proposed Rule's term ''0.44 mmhos/cm EC'' is equivalent to the final rule's term ''440 micromhos/cm specific conductance''. EPA will continue using the ''0.44 mmhos/cm EC'' term in this preamble, so as not to confuse the interested public.



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The State Board's 1991 Bay/Delta Plan established objectives of 1.5 mmhos/cm EC at Antioch and 0.44 mmhos/cm EC at Prisoners Point in April and May. EPA disapproved these objectives, in part, because they are not adequate to protect spawning habitat in the reach farther upstream between Prisoners Point and Vernalis. EPA also disapproved the 1991 Bay/Delta Plan spawning criteria because they were not based on sound science. The State Board explained that the 1.5 mmhos/cm EC criteria at Antioch was intended to protect spawning habitat upstream of Antioch (near Jersey Point), not at the Antioch location itself. The State Board acknowledged that ''the use of 1.5 [mmhos/cm] EC at Antioch appears not to be generally appropriate, and proposed that a thorough review of this [criterion] be undertaken at the next triennial review'' (1991 Bay/Delta Plan, p. 5–32). EPA found this unproven approach of setting criteria downstream in hopes of attaining different criteria upstream deficient, and disapproved it.

In the Proposed Rule (40 CFR 131.37(b)), EPA proposed salinity criteria of 0.44 mmhos/cm EC in the lower San Joaquin River in the reach from Jersey Point to Vernalis in wet, above normal, and below normal water years. In dry and critical water years, EPA proposed the 0.44 mmhos/cm criteria for only the reach from Jersey Point to Prisoners Point.

b. Comments on Proposal and Final Criteria

EPA received a number of comments on its proposed Fish Spawning criteria. California DFG was generally supportive of the proposed criteria, but believed that the criteria would need to be supplemented by a range of additional management techniques in order to have any substantial benefit for spawning (California DFG 1994). Several parties noted that striped bass are an introduced predatory species, and that efforts to increase striped bass populations would work at cross-purposes with efforts to enhance other species such as salmon and Delta smelt (City and County of San Francisco Public Utilities Commission 1994; Bay/Delta Urban Coalition 1994; California Farm Bureau Federation 1994). Other commenters raised the possibility that extending the acceptable spawning habitat upstream could result in more striped bass being entrained at the State and Federal water project pumps in the southern Delta. (California DWR 1994). Finally, some commenters believed that emphasizing the striped bass as an individual species was inconsistent with the multiple species approach to habitat protection. (CUWA 1994a).

Although EPA believes there is some merit to each of these comments, EPA is not making any changes to the Fish Spawning criteria in the final rule stated at 40 CFR § 131.37(b). EPA believes there is substantial scientific evidence indicating that increased salinities in the designated reaches of the San Joaquin River do in fact have an adverse effect on fish spawning. This problem of increased salt loadings has been recognized by virtually all the parties (CUWA 1994b; ACWA 1994) and recommendations on how to address it have been developed by, among others, the San Joaquin Valley Drainage Program (SJVDP 1990).

The possibility that healthier populations of predatory fishes such as striped bass would adversely affect other species of concern needs to be considered in the context of the whole range of protective measures being developed for the fishery. The package of project management measures, water quality standards, and implementation programs being developed under the CWA, ESA, CVPIA, and counterpart State authorities are intended to address the entire Bay/Delta ecosystem. For that reason, EPA believes that healthier predatory species populations should not interfere with the protection of other species of concern. EPA further believes that, if the State Board adopts and/or implements these criteria, the State Board can address the impact of entrainment at the pumps in its implementation measures. Finally, EPA believes that salinity problems in the lower San Joaquin affect aquatic species other than the striped bass. Recent research findings of USFWS (Meng 1994) suggest that the spawning habitat for the Sacramento splittail (currently proposed for listing as threatened under the ESA) is also being adversely affected by increased salt loadings in the lower San Joaquin. Accordingly, these criteria are consistent with a multiple species approach.

EPA believes that clearly stating the salinity conditions necessary for protection of the designated fish spawning uses on the lower San Joaquin provides the foundation for implementation plans by the State Board and other regulatory agencies. EPA believes that these implementation plans should build upon the recommendations of the San Joaquin Drainage Program, to the end that compliance with these criteria can be effectively and efficiently achieved.

One change has been made to the final Fish Spawning criteria. In the Proposed Rule, the Fish Spawning criteria were stated with reference to the five standard water year types, with one criterion required for dry and critical dry water years and another criterion required for the remaining water year types. In the final rule, reliance on water year types is eliminated. Instead, deciding which of the two different criteria applies is made by reference to the San Joaquin Valley Index, the standard index of San Joaquin Valley flows. This change merely eliminates the unnecessary middle step of translating the San Joaquin Valley Index into the five water year types.

4. Suisun Marsh Criteria

The tidal wetlands bordering Suisun Bay are characterized as brackish marsh because of their unique combination of species typical of both freshwater wetlands and more saline wetlands. Suisun Marsh itself, bordering Suisun Bay on the north, is the largest contiguous brackish water marsh in the United States. These large tidal marshes are distinct from the approximately 44,000 acres of ''managed'' marshes in the Suisun Bay, which are currently diked and managed for waterfowl use and hunting. Approximately 10,000 acres of marshes, both along channels within Suisun Marsh and bordering Suisun Bay, are still fully tidal (Meiorin et al. 1991).

These tidal marshes provide habitat for a large, highly diverse, and increasingly rare ecological community. The recent ''Status and Trends'' reports published by the SFEP listed 154 wildlife species associated with the brackish marshes surrounding Suisun Bay (Harvey, et al. 1992), including a number of candidates for listing under the ESA. These include the Suisun song sparrow (*Melospiza melodia maxillaris*) and the Suisun ornate shrew (*Sorex ornatus sinuosus*), as well as the plants Suisun slough thistle (*Cirsium hydrophilum* var. *hydrophilum*), Suisun aster (*Aster chilensis* var. *lentus*), delta tule pea (*Lathyrus jepsonii*), Mason's lilaeopsis (*Lilaeopsis masonii*), and soft-haired bird's beak (*Cordylanthus mollis mollis*). These rare species are all found exclusively in tidally inundated marsh.

Recent studies indicate that increases in salinity caused by a combination of upstream diversions and drought have adversely affected the tidal marsh communities (Collins and Foin 1993). As salinity has intruded, brackish marsh plants which depend on soils low in salt content (especially the tules *Scirpus californicus* and *S. acutus*) have died back in both the shoreline marshes and in some interior marsh channel margins of the western half of Suisun Bay. These plants have been replaced by plants typically growing in saline soils, especially cordgrass (*Spartina foliosa*). This has been associated with erosion of the marsh margins. In addition, tules in the upper intertidal zone have been replaced by the smaller and more salt tolerant alkali bulrush (*Scirpus robustus*). These changes have significantly affected available habitat for a variety of wildlife that nest and feed in these areas, including the Suisun song sparrow, marsh wren, common yellowthroat, black-crowned night heron, and snowy egret (Collins and Foin 1993; Granholm 1987a; 1987b). The loss of habitat for the Suisun song sparrow is of particular concern, since individuals of this species are found only in the already fragmented marshes bordering Suisun Bay, occupy an established territory for their lifetime, and depend on tall tules for successful reproduction and cover from predators (Marshall 1948).

There are currently no salinity criteria protecting the brackish tidal marshes of Suisun Bay, although there is some incidental protection provided by salinity criteria protecting the managed non-tidal marshes. EPA's approval of the 1978 Delta Plan criteria explicitly sought and received assurances from the State Board to develop additional criteria for the brackish tidal marshes and to protect aquatic life in the Suisun Marsh channels and open waters. Because these assurances have not been met, EPA, in its September 3, 1991 letter on the 1991 Bay/Delta Plan, disapproved the standards for Suisun Marsh and stated that the State Board should immediately develop salinity objectives sufficient to protect aquatic life and the brackish tidal wetlands surrounding Suisun Marsh.

In its Proposed Rule, EPA relied on the Estuarine Habitat criteria to protect the tidal wetlands bordering Suisun Bay, and did not propose separate standards in the Suisun Marsh. EPA's proposed criteria were developed to protect aquatic species and to provide salinity conditions similar to those in the late 1960's to early 1970's. Therefore, many of the aquatic species that inhabit the marsh channels would receive increased protection once the Estuarine Habitat criteria are implemented. In addition, the Estuarine Habitat criteria were designed to provide substantially better dry and critically dry year springtime conditions than the recent conditions that have caused adverse effects on the tidal marsh communities bordering Suisun Bay. EPA therefore concluded that these Estuarine Habitat criteria would lead to substantially improved conditions in the marshes.

In its Proposed Rule, EPA solicited comment as to whether the Estuarine Habitat criteria should be supplemented by additional criteria to fully protect the tidal marsh resources. For illustrative purposes, EPA included two possible narrative criteria in the Proposed Rule:

(1) ''water quality conditions sufficient to support high plant diversity and diverse wildlife habitat throughout all elevations of the tidal marshes bordering Suisun Bay''

(2) ''water quality conditions sufficient to assure survival and growth of brackish marsh plants dependent on soils low in salt content (especially *Scirpus californicus* and *Scirpus acutus*) in sufficient numbers to support Suisun song sparrow habitat in shoreline marshes and interior marsh channel margins bordering Suisun Bay.''

EPA received a number of substantive comments on this issue. The State Board and the California DWR opposed additional criteria, believing that any such criteria would be premature pending completion of a biological assessment in the marsh (SWRCB 1994; California DWR 1994). The California DFG recommended adoption of the numeric salinity criteria included in the Suisun Marsh Preservation Agreement signed by California DFG, California DWR, the USBR, and the Suisun Resource Conservation District in 1987 (California DFG 1994). Two environmental organizations, Natural Heritage Institute and the Bay Institute, recommended that additional standards be developed for the Suisun Marsh. Relying primarily on scientific studies that had been prepared and submitted to the State Board's D–1630 hearings (Jocelyn 1992, WRINT–NHI–12; Williams 1992, WRINT–NHI–18), these groups raised questions about whether the EPA Estuarine Habitat criteria would adequately protect the brackish marshes during January and February, or during a multiple year drought, and whether the Estuarine Habitat criteria would adequately protect the interior tidal channels of Suisun Marsh. In its comments, NHI recommended the adoption of numeric salinity criteria (NHI 1994). The Bay Institute recommended adoption of narrative criteria for the Marsh, and offered a detailed suggestion.

EPA believes that the available scientific information points strongly to the need for numeric criteria in the tidal marshes. Nevertheless, EPA does not believe there exists a sufficient scientific basis at this time to support Federal promulgation of numeric criteria for these marshes. EPA is hopeful that the biological studies being prepared at the request of the State Board will be completed soon, and that the State Board will expedite its review of this issue. Given the substantial delays in the completion of these studies, however, EPA does not believe it advisable to delay addressing the serious possibility of adverse impacts to the brackish tidal marshes. For these reasons, EPA is incorporating a narrative criterion applicable to the tidal (i.e., unmanaged) areas of the Suisun Marsh in the final rule.

To be consistent with EPA guidance, narrative criteria should include specific language about conditions that must exist to protect a designated use, and may include specific classes and species of organisms that will occur in waters for a given designation (USEPA 1990). The narrative criterion promulgated below by EPA includes language about important measures of biological integrity specific to Suisun Bay tidal marshes. Specific reference conditions are not included in the criterion; however, it is the intent of this criterion to reflect conditions equalling the level of protection existing in the Suisun Marsh in the late 1960's to early 1970's. As a result of the recent drought and continued high level of freshwater diversion from the estuary, recent conditions have deteriorated in the Suisun Marsh, as indicated by decreased habitat for the Suisun song sparrow and replacement of tules with *Spartina foliosa.*

In implementing this narrative criterion, the State Board should take care to protect the specific classes and species of organisms that are vulnerable to increasing salinity in the Suisun Marsh. Vulnerable species include those species that are presently listed under the Federal Endangered Species Act, including the salt-marsh harvest mouse *(Reithrodontomys raviventris)* and the California clapper rail *(Rallus longirostris obsoletus).* Vulnerable species also include both those rare plants that are candidates for listing under the Federal Endangered Species Act (including Mason's *lilaeopsis (Lilaeopsis masonii),* delta tule pea *(Lathyrus jepsonii),* Suisun slough thistle *(Cirsium hydrophilum var. hydrophilum),* Suisun aster *(Aster chilensis var. lentus),* soft-haired bird's beak *(Cordylanthus mollis ssp mollis)*) and dominant plant species such as the tules *Scirpus acutus* and *S. californicus,* and the bulrush S. robustus. Animal species include Federal candidate species Suisun song sparrow *(Melospiza melodia maxillaris),* California black rail *(Laterallus jamaicensis coturniculus),* tri-colored blackbird *(Agelaius tricolor),* saltmarsh common yellowthroat *(Geothylpis trichos sinuosa),* Suisun ornate shrew *(Sorex ornatus sinuosus)* and southwestern pond turtle *(Clemmys marmorata pallida).* Other vulnerable species include river otter *(Lutra canadensis),* beaver *(Castor canadensis),* nesting snowy egret *(Egretta thula),* nesting black-crowned night-heron *(Nycticorax ncyticorax),* ducklings of breeding ducks such as mallard *(Anas platyrhynchos),* gadwall *(Anas strepera)* and cinnamon teal *(Anas cyanoptera),* marsh wren *(Cistothorus palustris),* American bittern *(Botaurus lentiginosus),* Virginia rail *(Rallus limicola),* sora *(Porzana carolina),* and common moorhen *(Gallinula chloropus).*

EPA hopes that the measures taken to implement the Estuarine Habitat criteria will be sufficient to protect the fish and wildlife designated uses targeted by this narrative criterion. Nevertheless, in the event that continuing substantial adverse impacts on the brackish marsh habitat become evident before any possible revisions to the State's numeric criteria, this narrative criterion will provide a basis for State Board measures to address those adverse impacts.

D. Public Comments

Public hearings on the Proposed Rule were held in Fresno, California on February 23, 1994; in Sacramento, California on February 24, 1994; in San Francisco, California on February 25, 1994; and in Los Angeles, California on February 28, 1994. Over 120 people spoke at these four hearings. The public comment period closed on March 11, 1994. EPA received over 225 written comments on the Proposed Rule.[44]

Responses to the public comments have been prepared and are a part of the administrative record to this rulemaking. The public may inspect this administrative record at the place and time described above.

E. Executive Order 12866

Under Executive Order 12866 (58 FR 51735, October 4, 1993), the Agency must determine whether the regulatory action is ''significant'' and therefore subject to Office of Management and Budget (OMB) review and the requirements of the Executive Order. The Order defines ''significant regulatory action'' as one that is likely to result in a rule that may:

(1) Have an annual effect on the economy of $100 million or more or adversely affect in a material way the economy, a sector of the economy, productivity, competition, jobs, the environment, public health or safety, or State, local, or tribal governments or communities;

(2) Create a serious inconsistency or otherwise interfere with an action taken or planned by another agency;

(3) Materially alter the budgetary impact of entitlements, grants, user fees, or loan programs or the rights and obligations of recipients thereof; or

(4) Raise novel legal or policy issues arising out of legal mandates, the President's priorities, or the principles set forth in the Executive Order.

Pursuant to the terms of Executive Order 12866, it has been determined that this rule is a ''significant regulatory action'' because it raises novel policy issues arising out of the Federal coordination effort described above. This coordination effort, which calls for the integration of several Federal agencies and several different Federal statutes, is a unique and precedential approach to the implementation of Federal natural resources policy. As such, this action was submitted to OMB for review. Changes made in response to OMB suggestions or recommendations will be documented in the public record.

The following is a summary of the regulatory impact assessment (RIA) that has been prepared in compliance with Executive Order 12866. The full RIA is part of the administrative record to this rule, and is available for public review as described above.

Executive Order 12866 requires Federal agencies to assess the costs and benefits of each significant regulatory action they promulgate. The RIA addresses two interrelated regulatory actions. The first is the promulgation by EPA of water quality criteria for the Bay/Delta estuary under the CWA. The second is the USFWS designation of critical habitat for the Delta smelt under the ESA.

Need for Regulation

The Bay/Delta is the largest estuarine environment on the west coast of the Americas, encompassing 1,600 square miles and draining more than 40% of the water in California.

- The Bay/Delta estuary supports more than 120 species of fish and is a waterfowl migration and wintering area of international significance.
- The estuary supports 108 known species of fish, birds, mammals, reptiles, amphibians, invertebrates, and plants imperiled by habitat loss, including 25 species that are listed or are candidates for listing under the Endangered Species Act (ESA).
- The estuary is composed of numerous habitats valued for their recreational, scientific, educational, aesthetic, and ecological aspects; designated uses defined by the California State Water Resources Control Board include estuarine habitat, coldwater and warmwater habitat, fish migration, fish spawning, ocean commercial and sport fishing, preservation of rare and endangered species, shellfish harvesting, and wildlife habitat.
- As a result of habitat change and other human-induced impacts, the estuary's ability to support a diverse ecosystem with large populations of important commercial, recreational, and heritage species has declined. The 1980's and 1990's brought the number of indigenous species to extremely low levels. Declines in aquatic resources have led to curtailed fishing seasons, petitions for listing species under the ESA, and general concern about the health of the estuarine ecosystem.
- The principal benefit expected to result from this rulemaking is an increase in ecosystem health. A healthy Bay/Delta ecosystem will maintain aquatic species in populations of sufficient sizes to sustain recreational and commercial fisheries, as well as the uniqueness and diversity still present in the estuary.

The Bay/Delta estuary is also the hub of California's two major water distribution systems, the SWP operated by California DWR and the CVP operated by the USBR. Most of the water stored and transported by the CVP is used for agriculture; the CVP also supplies municipal and industrial water to portions of the Central Valley and San Francisco Bay Area. SWP water is primarily used for municipal and industrial uses and the production of agricultural crops. Development and operation of the water projects have contributed to losses in biological productivity in the Bay/Delta estuary by substantially altering the flow and salinity conditions to which the indigenous organisms are adapted.

The Bay/Delta estuary is subject to the water quality control jurisdiction of the State Board and two regional boards. Pursuant to requirements of the CWA, the State Board in 1991 adopted and submitted to EPA the 1991 Bay/Delta Plan containing water quality standards for the Bay/Delta estuary. EPA, finding that the 1991 plan did not provide for adequate protection of the designated fish and wildlife uses of the Bay/Delta estuary, disapproved provisions of the plan. In response to State Board's failure to revise the disapproved criteria, EPA published the proposed rule for

[44] The Bay Institute submitted identical comment letters generally supporting adoption of protective standards in the Bay/Delta from approximately 1,500 people. The total number of comments stated in the text counts these comments as a single comment.

establishing revised water quality criteria; these EPA criteria are the primary subject of the RIA.

Approach

The RIA analyzes a final rule that establishes four sets of federal criteria to protect the designated uses of the Bay/Delta estuary. The analysis focuses on the two sets of criteria with measurable water costs to Delta exporters:

- Salinity criteria protecting the estuarine habitat, and
- Fish migration criteria to protect fish migration in the estuary.

The other two criteria; salinity criteria to protect fish-spawning habitat on the lower San Joaquin river and narrative criteria to protect tidal wetlands surrounding Suisun Marsh, are not expected to result in actions that generate additional economic costs.

The primary method for implementing the criteria is to increase Delta outflow, and the analysis focuses on the effects of this approach. EPA recognizes that the State of California has sole authority to reallocate water rights in implementing these criteria. However, because the State has not yet developed a plan for implementation of the criteria, EPA considered the water supply and delivery impacts of the criteria using the following three implementation approaches that represent the range of options available to the State:

- Project Exporters-Only Approach:

—Generally represents implementation of D–1485, under which the SWP and CVP exporters are solely responsible for providing sufficient water supplies to attain the water quality criteria.

—Because of priority systems within the SWP and CVP, would concentrate responsibility for meeting the standards on water districts with junior water rights, which also bear responsibility for meeting requirements associated with the ESA. Municipal and industrial (M&I) users are priority users within the SWP system. In the CVP priority system, users of 27% of diversions are responsible for meeting 100% of the ESA requirements and water quality standards.

—Could result in effects on San Joaquin Valley agricultural water users, primarily in western Fresno and portions of Kern County and the urban areas supplied by Metropolitan Water District of Southern California (MWD) and Santa Clara Valley Water District (SCVWD).

- Sharing Approach:

—Would spread water supply impacts to more or potentially all of the water districts that divert water from the Sacramento and San Joaquin River systems, including areas of the Sacramento Valley, eastside San Joaquin Valley and urban areas of San Francisco and East Bay.

—Could be based on formulas using many criteria in assigning responsibility, such as diversions, depletions, damage caused by diversions, seniority and priority of water rights, beneficial and reasonable use, and economics.

—For the analysis, an illustrative formula was used where nonproject diverters and non-exporter CVP users share 20% of responsibility for meeting flow requirements necessary to achieve compliance with the criteria.

- Other Innovative Approaches:

—Could include combining shared implementation responsibility with a system of mitigation credits, a water supply cap, and a fund or fee system for purchasing water for environmental uses; policies for promoting a water market and/or a water bank are crucial.

Water Supply and Delivery Impacts

Short-term (1995) and longer term (2010) impacts of the Project Exporters-Only and Sharing Approaches were analyzed through comparison with baseline conditions consisting of current conditions that exist in the absence of the criteria, estimated for a range of hydrological conditions represented in the 71-year hydrologic record for the Delta. Water supply costs are commonly reported using two conventions: the average of 71 years and the ‘‘critical period’’, which represents conditions experienced in the drought period of the 1930s.

The analysis estimated the incremental (i.e. new) water supply and delivery impacts of the criteria over those associated with D–1485 and the recent (1992–1994) winter-run salmon requirements. These impacts reflect the effects of a package of federal actions under several laws designed to comprehensively protect the Bay/Delta ecosystem. The entire package of actions and requirements have been extensively coordinated to achieve significant improvements in the Bay/Delta ecosystem.

Both the incremental water supply impacts, as well as the recent Endangered Species Act impacts can be illustrated in the following table:

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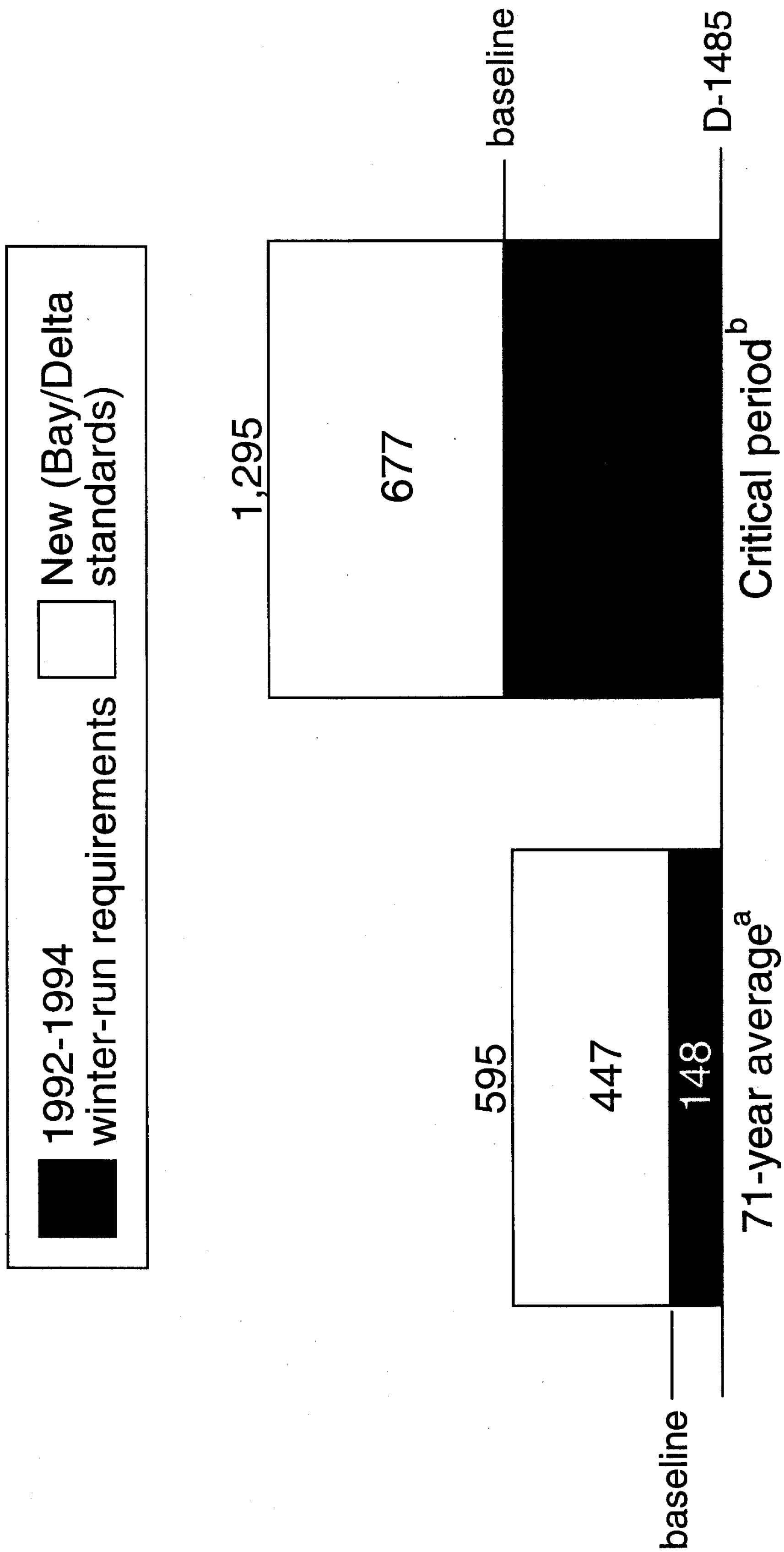
RIA TABLE 1

Water Supply (TAF)



a Includes exports only.

b Includes exports and storage.

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Water delivery impacts are the changes in water volumes available to different users and depend on seniority of water rights and priority systems within affected water delivery systems, such as the SWP and the CVP.

Costs

The State's implementation plan will substantially affect the magnitude and distribution of the costs of regulatory actions. In the agricultural sector, economic welfare costs would consist primarily of changes in producers' surplus (net operating revenues accruing to farmers). In the urban sector, economic welfare costs would take the form of consumers' surplus losses to the residential sector resulting from developing higher cost replacement supplies and consumer costs of water supply shortages. The following are key results of the cost analysis:

• Water transfers can greatly reduce impacts on affected agricultural and urban areas. Water transfers to urban areas through waterbank programs are common and considered likely in the short-run. Although, increased agriculture-to-agriculture water transfers are not expected in the short-run, they can theoretically decrease impacts considerably.

• Urban project contractors water supplies would not be affected in most years, even without sharing.

—MWD's supplies are affected in 11% of years, SCVWD supplies are affected in 25% of years.

• With water transfers available in dry years, the cost associated with the regulations is estimated to be $4.3 million on average and $15.8 million during dry water years for the Project-Exporters Only scenario. Without water transfers or waterbanks, costs increase significantly; the combined cost of water shortages and replacement water supplies to project users is estimated to be $28.3 million on average years and $165.3 million during dry years.

• Agricultural impacts would be small relative to agricultural value in the Central Valley but would be concentrated in agricultural areas with low-seniority water rights in portions of Fresno and Kern counties.

—Under the Project-Exporters Only scenario and assuming no increase in water transfers, economic welfare losses to agriculture are estimated to average $27 million annually, weighted over all hydrological conditions. However, impacts in the driest 10% of years account for economic costs of $43 million.

—If the State's implementation plan is based solely on seniority of water rights and existing contractual arrangements, impacts will be concentrated in geographic subareas of Fresno and Kern counties. Cumulative impacts are an important consideration in these areas—the impacts of environmental requirements associated with the ESA and the CVPIA are already concentrated in these subareas. However, the State's implementation plan may be based on many criteria, including economics.

• The Sharing Approach would have an important cost-reducing effect, especially in dry years if transfers are limited, in comparison with the Project Exporters-Only Approach.

—Economic welfare costs to agriculture would be reduced by sharing the responsibility of environmental requirements with all diverters. Overall, economic welfare losses would be reduced by approximately $0.5 million for average years and more than $5.5 million in dry years.

—A net gain in economic welfare to urban areas would also result from sharing. Overall economic losses would be reduced by approximately $10.5 million in average years and $54.0 million in dry years when transfers are limited.

• Over the long term, costs are not estimated to substantially increase, even with increasing demand resulting from population growth and decreased groundwater availability.

A summary of these costs is shown below in RIA Table 2.

RIA TABLE 2.—SUMMARY OF ECONOMIC WELFARE COSTS

[In millions of dollars]

	Average expected value	Dry Years
Agriculture: [1]		
• No increase in water transfers	28	43
• Sharing/no increase in transfers	27	37
• Increased transfers	10–18	NA
Urban: [2]		
• Dry year transfer	4	16
• No dry year transfer	28	165
• Sharing/no dry year transfer	18	111

Note: Total impacts are less than the sum of agricultural and urban impacts in the case of agricultural-to-urban transfers. In cases in which there are no agricultural-to-urban transfer, total impacts equal the sum of agricultural and urban impacts.

[1] Transfers are from agriculture to agriculture.

[2] Transfers are from agriculture to urban users.

Benefits

Important benefits of the water quality regulations include the following:

• Biological productivity and health for many estuarine species are expected to increase.

• The decline of species is expected to be reversed and the existence of species unique to the Bay/Delta, such as Delta smelt, winter-run chinook salmon, longfin smelt, and Sacramento splittail, will be protected.

• Populations of a variety of estuarine species are expected to increase; although the extent of the population increases has not been determined for all species, the increases are anticipated to benefit the recreational and commercial fisheries.

• Costs associated with further declines in the estuary will be avoided. The most important avoided cost is associated with further declines in the recreational and commercial fisheries industry including further closures affecting the 200 million dollar industry, with possible future actions needed to protect species from extinction. Other avoided costs include government costs associated with crop deficiency payments; agricultural drainage costs; and costs associated with potential reductions in property values.

The ecological benefits of improved Bay/Delta estuary conditions are expected to generate approximately $2–21 million annually in net economic benefits to commercial and recreational fisheries and have associated employment gains of an estimated 145–1,585 full-time equivalent jobs annually. The federal package of actions to protect the estuary, of which EPA's criteria are a part, will also produce the benefit of increased certainty regarding water supplies from the delta; this allows for more informed water management planning and investments.

Conclusions

The following general conclusions can be drawn regarding the results of the RIA:

• Although urban water supplies are are not affected in most years, however, minimizing urban costs largely depend on the availability of water through transfers and a drought water bank.

• Under the Project-Exporters Only approach to implementation (i.e., status-quo), agricultural impacts are concentrated only in certain areas of Fresno and Kern Counties. This concentration of impacts is magnified by these areas bearing the responsibility for Endangered Species requirements. This concentration of impacts is the result of historic water rights arrangements and may be attenuated through the water rights phase.

- Benefits of ecosystem protection, which could not be estimated in the analysis, are expected to substantially exceed the use benefits to commercial and recreational fisheries. These nonuse or intrinsic values, which include benefits to the public for improved ecosystem health and for avoiding the extinction of species and closures of fisheries, are difficult to estimate accurately because they are nonmarginal.
- Substantial reductions in economic costs—for the same level of benefits—resulted from the sharing scenario analysis, particularly when transfers are limited. For urban areas, the economic benefits of dry year transfers are large, even when compared to the benefits of sharing.
- Although a fully developed water market is not likely, it could theoretically reduce economic costs to very low levels. Innovative implementation plans (purchase funds, fees, tradeable responsibility) that take advantage of these potential efficiencies may be the most cost-effective solution.

Given both the monetary estimates and the information on ecological benefits that is not calculated in monetary terms, EPA believes that the benefits are commensurate with the costs. Cost-effective implementation of the criteria will result in a healthy ecosystem and fisheries resources coexisting with a strong agricultural sector.

F. Regulatory Flexibility Act

Under the Regulatory Flexibility Act (5 U.S.C. 601 et seq.) (RFA) EPA generally is required to conduct a final regulatory flexibility analysis (FRFA) describing the impact of the regulatory action on small entities as part of a final rulemaking. However, under section 605(b) of the RFA, if EPA certifies that the rule will not have a significant economic impact on a substantial number of small entities, EPA is not required to prepare a FRFA. Although EPA is providing the certification here, it is nevertheless including a discussion for public information of possible effects to small entities that could result from State Board implementation of today's rule.

Today's rule establishes ambient water quality criteria that are unique in that implementation of these criteria is solely dependent upon actions by agencies other than EPA. Until actions are taken to implement today's criteria (or equally protective state criteria meeting the requirements of the CWA), there will be no economic effect of this rule on any entities—large or small. For that reason, and pursuant to section 605(b) of the Regulatory Flexibility Act, 5 U.S.C. 605(b), I hereby certify that this rule itself will not have a significant economic impact on a substantial number of small entities.

Discussion

Although EPA is certifying that this rule will not have a significant economic impact on a substantial number of small entities, and therefore is not required to prepare a FRFA, it is nevertheless presenting this discussion to inform the public of possible economic effects of state implementation of the criteria promulgated today on small entities. By so doing, EPA intends to inform the public about how such entities might be affected by the State's implementation. The focus of the discussion is on small farms, and our analysis shows that there will be no significant economic effect on a substantial number of them. Additionally, as described elsewhere in the RIA, impacts on the urban sector, while speculative, are expected to be limited. Accordingly, EPA believes there will be no significant economic impact on a substantial number of small entities as a result of the State's implementation of these criteria.

This discussion first provides a profile of small entities—in this case small farms—to determine whether or not they will be affected by State Board actions designed to attain the criteria set forth in this rulemaking. EPA investigated information by geographic area using the U.S. Small Business Administration's definition. Information used includes acreage and gross value per acre.

Small entities that may be primarily affected by the State's implementation of EPA's rule are small farms (as discussed in the RIA, the primary economic impacts of implementation of these criteria are expected to fall on the agricultural sector; impacts on the urban sector are expected to be limited). Small farms are defined by the U.S. Small Business Administration as farms with annual sales of less than $500,000. Small farms account for 93% of all farms and 53% of all cropland (including unharvested pastureland) in California. The remaining 7% of California farms, which have annual sales of more than $500,000, account for 74% of the value of farm products sold (Jolly 1993). Unfortunately, no survey information is available by subgeographic area and value per operator to assist in determining whether or not State Board action implementing this rulemaking could affect small farms. As discussed in the RIA, impacts may be concentrated in the subgeographic areas of the San Joaquin Valley—particularly the westside of Fresno County, including Westlands Water District and Kern County. This analysis uses the worst case scenarios from the RIA in assuming concentrated and, possibly, not insignificant impacts in these areas. These assumptions include: no increase in water transfers and the most status-quo implementation plan selected by the State of California. As discussed in the RIA, innovative implementation plans could reduce all agricultural impacts.

Due to the lack of survey information, two commonly reported measures—gross value per acre and acreage per farm—were used to develop an indication of whether or not these subgeographic areas contain small farms, by the SBA definition. The first commonly reported indicator of farm size is acreage.

EPA used two measures of farm size by acreage in the San Joaquin Valley, derived from the 1987 Census of Agriculture. The first measure, average farmland per operator, includes the average amounts of cropland; rangeland; wooded lands; and lands in buildings, roads, and ponds managed by each farm operator in the San Joaquin Valley. The average amount of farmland per operator in the San Joaquin Valley is 341 acres, varying from 266 acres in non-westside areas to 1,834 acres in the Westlands Water District. The second measure of farm size, irrigated land per operator, includes the average amount of cropland, excluding rangelands and wooded lands, managed by each farm operator. The average amount of irrigated land per operator in the San Joaquin Valley is 165 acres, ranging from 114 acres in non-westside areas to 1,113 acres in the Westlands Water District. These data suggest that some agricultural districts contain very few small farms, while others are largely composed of smaller farms.

These measures of farm size may be distorted by characteristics of the data compiled in the 1987 Census of Agriculture. Because of the way farm operators are defined and counted within the census, the number of truly separate farm operations within the San Joaquin Valley may be lower than the census reports. Thus, the amount of farmland and irrigated land per separate farm operation is probably higher than reported. Additionally, farming is not the principal occupation for many farm operators. In the San Joaquin Valley, 44% of the operators included in the census reported that farming was not their principal occupation (Archibald 1990). These operations, which could include hobby farms, are probably much smaller than commercial operations. Therefore, the average size of commercial operations is likely much larger than reported. These data limitations make it difficult to assess the true proportion of the farm industry represented by small commercial farms.

The other measure used to develop an indication of whether or not small farms are affected is average gross revenue per acre. This information was obtained from the USBR and the same data is used in the RIA. As discussed previously, the areas where impacts may be concentrated are primarily the westside of the San Joaquin Valley, especially Westlands Water District and Kern County. Values of $1100–$2300 an acre are indicated by this data. These estimates are further confirmed by the average value of $1413 an acre found in a recent University of California report (Carter 1992.) Thus using the range of values for gross revenue per acre and the more conservative definition of irrigated land per acre for the Westside, farms average approximately $600,000 –$1,120,000. This does not meet the SBA definition. In addition, average farm size in the Westlands Water District is much larger, leading to average estimates over $1 million per operator. In Kern County, however, gross revenue per acre averages $1863 and therefore to meet the SBA definition a farm would have to be unusually small (under 270 acres.) These estimates indicate that a substantial number of small entities would not be substantially affected.

The farms in the CVP area (westside Fresno County) are subject to the U.S. Department of Interior 960-acre limitation on farm size for the receipt of subsidized water. Although the degree of compliance with this limitation is in question, a recent legal settlement by the U.S. Department of Interior will increase the enforcement of this acreage limitation. Using the measures of average gross revenue per acre, farms that approach the acreage limitation are not considered small farms using the SBA definition.

Type of small farm by crop type was also investigated to provide another indication of farms potentially affected by State Board action. As discussed in the RIA, State Board action consistent with this rulemaking would likely result primarily in field and forage crop displacement. In 1987, small farms produced 40% of all irrigated hay and field crops harvested and 30% of all nonfeedlot cattle sales in the state (U.S. Dept. of Commerce 1989). Approximately 80% of the irrigated hay and field crops and 50% of nonfeedlot cattle are raised in the Sacramento Valley and San Joaquin Valley counties (U.S. Dept. of Commerce 1989). Such cattle production is the principal use of irrigated pasture in California. These percentages are substantially lower than the overall percentage of cropland in small farms. In other words, large farms (i.e., farms with annual sales exceeding $500,000) account for a disproportionate share of the production of the crops and livestock that might be displaced by the projected water supply reductions.

While these measures indicate that the State's implementation of the criteria in this rule will not affect a substantial number of small farms, given that the measure was developed from averages, there will exist in every irrigation district some small farms. Westlands Water District reports that 125 farms are 320 acres or less (a 320 acre farm grossing $1400-$1500 an acre would meet the SBA definition of a small farm.) Thus, without survey information, we cannot completely conclude that all small farms would not be affected by State Board action.

The RIA conducted for this rulemaking indicates that if previous implementation procedures are followed, impacts may be concentrated in geographic subareas. The State does have implementation flexibility to spread the impacts to a greater geographic area. This would have two offsetting impacts in relationship to farm size. First, the impacts overall will be decreased so that impacts would be less concentrated in subregions, possibly to insignificant levels. Second, however, in spreading the impacts more broadly, the State will be spreading it to areas with small farms.

Within irrigation districts with project water, junior water rights and little access to groundwater, even the State may have little implementation authority to assess or minimize impacts by farm size. A Stanford University study explains:

Most farmers receive their water from a local district (generally an irrigation, water, or water storage district) or from a mutual water company * * * local districts have considerable discretion over the acquisition, allocation and pricing of water. The nature and limits of the discretion, however, vary among districts depending on the laws under which the district was formed, any special legislation unique to a district, and a district's local rules and regulations. (Center for Economic Policy Research 1992.)

G. Enhancing the Intergovernmental Partnership Under Executive Order 12875

In compliance with Executive Order 12875, 58 FR 58093 (October 28, 1993), we have involved state, local, and tribal governments in the development of this rule. In addition to the substantial participation by state and local governments and local agricultural and municipal water districts in the public commenting process, several activities have been carried out since the publication of the Proposed Rule. These include:

(1) The State of California and the Federal government (represented by the EPA, the Department of the Interior, and the Department of Commerce) have negotiated and this past summer signed a Framework Agreement laying out the institutional processes and mechanisms to be used to coordinate state and Federal activities affecting water quality and water development in the Bay/Delta. The Framework Agreement specifically included (a) a process for Federal and state adoption of water quality standards meeting the requirements of state and Federal law, (b) a structure and process for technical coordination of the state and Federal regulatory activities affecting operation of the state and Federal water projects in the Bay/Delta (the SWP and the CVP), and (c) a process for developing a Federal-state partnership for long term planning for water resources in California. Many of the steps envisioned in the Framework Agreement have already been accomplished. The Framework Agreement explicitly called for the final Federal promulgation of a water quality rule, which is being accomplished in this rulemaking.

(2) EPA has held a number of workshops with representatives of the municipal and agricultural water districts to discuss the Proposed Rule and the accompanying draft economic analysis. Further, EPA has participated in additional workshops sponsored by the California Urban Water Agencies (CUWA) to discuss CUWA's scientific comments on the Proposed Rule.

(3) As envisioned by the Framework Agreement, the State Board has held a series of workshops to assist in developing revised State water quality standards meeting the requirements of the CWA. EPA has participated in these workshops and, in accordance with the State Board's processes, has presented the State Board options for possible standards that would meet the requirements of the CWA.

(4) EPA has worked closely with the California DWR to ascertain the

probable water supply impacts of its Proposed Rule, and has continued to work with California DWR to explore mechanisms for reducing water supply impacts of protective standards. As explained in the Preamble to the final rule, many of these mechanisms have been incorporated into EPA's final rule.

(5) EPA has worked closely with representatives of a coalition of CUWA and of agricultural water agencies to consider alternative standards and measures that would meet the requirements of the CWA.

(6) EPA has continued to meet with the State Board and other State officials, both at the staff and policy levels, to discuss ways to attain protection of the Bay/Delta resources in a way that meets the requirements of the CWA and is consistent with the State's roles in water quality and water development planning.

H. Paperwork Reduction Act

This rule places no information collection activities on the State of California and, therefore, no information collection request (ICR) will be submitted to the Office of Management and Budget (OMB) for review in compliance with the Paperwork Reduction Act, 44 U.S.C. 3501 et seq.

References in the Preamble

Archibald, S. 1990. Economic profile of agriculture in the west side of the San Joaquin Valley.

Arthur, J.F., and M.D. Ball, 1979. Factors influencing the entrapment of suspended materials in the San Francisco Bay/Delta Estuary. In: San Francisco Bay: The Urbanized Estuary, R.J. Conomos (ed.). Pacific Div., American Assoc. for the Advancement of Science, San Francisco, California, pp. 143–174.

Association of California Water Agencies, 1994. Comments of the Association of California Water Agencies on water quality standards for the Bay/Delta dated July 13, 1994. 22 pp.

Bay Institute, 1994. Comments on the proposed Rule for Water Quality Standards in the Bay/Delta, 1 p., plus three appendices and three enclosures.

Bay/Delta Urban Coalition, 1994. Letter from Steering Committee to P. Wright dated March 4, 1994. 4 pp., plus large comment book.

Brandes, P., 1994. Development of a Refined San Joaquin Delta Salmon Smolt Model. Draft Report, May 31, 1994. 7 pp. plus attachments.

California Department of Fish and Game, 1990a. Central Valley Salmon and Steelhead Restoration and Enhancement Plan. 115 pp.

California Department of Fish and Game, 1990b. Testimony of Department for Fish and Game. WQCP–DFG–4.

California Department of Fish and Game, 1992a. Water quality and water quantity needs for chinook salmon production in the Upper Sacramento River. Prepared for the California SWRCB Interim Water Rights Decision on the San Francisco Bay/ Sacramento-San Joaquin Delta Estuary. WRINT–DFG–14.

California Department of Fish and Game, 1992b. Summary and Recommendations for the Department of Fish and Game's Testimony on the Sacramento-San Joaquin Estuary. WRINT–DFG–8.

California Department of Fish and Game, 1994. Comments on the Water Quality Standards for the Bay and Delta, 6 pp., plus 1 p. comment attachment.

California Department of Water Resources, 1993. Biological Assessment for South Delta Temporary Barriers Project for USFWS Section 7 Endangered Species Permit. Amendment 1. Office of Environmental Services. March 1993. 35 pp.

California Department of Water Resources, 1994. Comments on the Water Quality Standards for the Bay and Delta, 2 pp., plus 88+ pp. comment booklet and 7 appendices.

California Farm Bureau Federation, 1994. Letter from B. Vice to C. Browner dated April 8, 1994. 2 pp., plus attachments.

California State Lands Commission, 1991. Delta-Estuary: California's Inland Coast, A Public Trust Report, 208 pp.

California Urban Water Agencies, 1994a. Comments on the Water Quality Standards for the Bay and Delta dated March 9, 1994. 3 pp., plus 5 pp. supplementary comments and 12 draft technical appendices.

California Urban Water Agencies, 1994b. Recommendations to the State Water Resources Control Board for a coordinated estuarine protection program for the San Francisco Bay-Sacramento and San Joaquin River Delta Estuary, August 25, 1994. 46 pp. plus 2 appendices.

Carter, H., and G. Goldman, 1992. The Measure of California Agriculture. University of California. Oakland, California.

Center for Economic Policy Research, 1992. An Economic Analysis of Water Availability in California Central Valley Agriculture, Phase III Draft Report. Stanford, California.

City & County of San Francisco Public Utilities Commission, 1994. Letter from A. Moran to P. Wright dated March 11, 1994. 2 pp., plus attachments.

Collins, J.N. and T.C. Foin, 1993. Evaluations of the Impacts of Aqueous Salinity on the Shoreline Vegetation of Tidal Marshlands in the San Francisco Estuary. In: SFEP, Managing Freshwater Discharge to the San Francisco Bay-Delta Estuary: The Scientific Basis for an Estuarine Standard. Appendix C.

Contra Costa Water District, 1994. Comments on the Water Quality Standards for the Bay and Delta, 5 pp., plus 2 attachments.

Denton, R.A., 1993. Accounting for Antecedent Conditions in Seawater Intrusion Modeling—Applications for the San Francisco Bay/Delta Hydraulic Engineering 93, vol. 1, pp. 448–453.

Denton, R.A., 1994. Minor Modifications to the G-Model Fit of Electrical Conductivity Versus Antecedent Outflow. Internal CCWD report, 8 pp.

Five Agency Delta Salmon Team, 1991a. Evaluation of the Feasibility of Protecting Downstream Migrant Chinook Salmon Smolts in the Sacramento River and San Joaquin River with Physical Facilities, July 15, 1991.

Five Agency Delta Salmon Team, 1991b. Benefit/Cost Evaluations of Alternative Salmon Protective Measures in the Sacramento-San Joaquin Delta. Draft Report. March 13, 1991. 101 pp.

Farley, T.C., 1966. Striped bass, Roccus saxatilis, spawning in the Sacramento San Joaquin River systems during 1963 and 1964. DFG Fish Bull. 136 pages 28–43.

Ferriera, I. and H. Meyer, 1994. WRMI Presentation at the Sliding Scale Workshop, April 14, 1994, 1 p.

Granholm, S.L., 1987a. Special-status wildlife species of the Suisun Bay tidal marshes, and expected impacts of reduced freshwater inflows. Sierra Club Legal Defense Fund Exhibit 4, SWRCB San Francisco Bay/ Delta Hearings.

Granholm, S.L., 1987b. Expected impacts of reduced freshwater inflows on representative birds and mammals of the Suisun Bay tidal marshes. Sierra Club Legal Defense Fund Exhibit 5, SWRCB San Francisco Bay/Delta Hearings.

Harvey, T.E., K.J. Miller, R.L. Hothem, M.J. Rauzon, G.W. Page, R.A. Keck, 1992. Status and Trends Report on Wildlife of the San Francisco Estuary. January 1992.

Herbold, B., A.D. Jassby, P.B. Moyle, 1992. San Francisco Estuary Project Status and Trends Report on Aquatic Resources in the San Francisco Estuary. March 1992. 257 pp.

Jocelyn, M., 1992. Adverse effects of increased salinity in the Suisun Marsh Brackish wetlands. WRINT–NHI–12. 6 pp.

Jolly, 1993. ''The small farm: It's innovative and persistent in a changing world'', 47 California Agriculture No. 2. University of California, Oakland, California.

Kimmerer, W., 1994a. A sliding scale for the EPA salinity standard. 12 p.

Kimmerer, W., 1994b. Setting Goals for Salmon Smolt Survival in the Delta and Discussions on the Proposed EPA Salinity Standard. August 10, 1994. 28 pp.

Kjelson, M., S. Green & P. Brandes, 1989. A Model for Estimating Mortality and Survival of Fall-run Chinook Salmon Smolts in the Sacramento River Delta between Sacramento and Chipps Island.

Marshall, J.T., Jr., 1948. Ecologic races of song sparrows in the San Francisco Bay region, Part I. Habitat and abundance. Condor 50(5) 193–215.

Meiorin, E.C., M.N. Josselyn, R. Crawford, J. Calloway, K. Miller, R. Pratt, T. Richardson and R. Leidy, 1991. Status and Trends Report on Wetlands and Related Habitats in the San Francisco Estuary. San Francisco Estuary Project, December 1991.

Meng, L., 1994. Status Report on Sacramento splittail and longfin smelt. Unpublished report submitted to USFWS August 25, 1994. 15 pp. plus attachments.

Monismith, S.J., 1993. A note on the physical significance of X2. IESP Newsletter, June 1993.

Moyle, P.B. and R.M. Yoshiyama, 1992. Fishes, Aquatic Diversity Management Areas, and Endangered Species: A Plan to Protect California's Native Aquatic Biota. University of California. California Policy Seminar Report. 222 pp.

Natural Heritage Institute, 1994. Comments on the proposed rule for water quality standards in the Bay/Delta, 1 p., plus 42+ pp. of comments and Attachments A–F.

Radtke, L.D., 1966. Distribution and abundance of adult and subadult striped bass Roccus saxatilis, in the Sacramento-San Joaquin Delta. DFG Fish Bulletin 136 pages 15–27.

Radtke, L.D. and J.L. Turner, 1967. High concentrations of total dissolved solids block spawning migration of striped bass, Roccus saxatilis, in the San Joaquin River, California. Transactions of the American Fisheries Society 96:405–407.

San Francisco Estuary Project, 1992. State of the Estuary: A Report on Conditions and Problems in the San Francisco Bay/ Sacramento-San Joaquin Delta Estuary. 270 pp.

San Francisco Estuary Project, 1993. Managing Freshwater Discharge to the San Francisco Bay/Sacramento-San Joaquin Delta Estuary: The Scientific Basis for an Estuarine Standard. 17 pp. + appendices.

San Joaquin Valley Drainage Program, 1990. A Management Plan for Agricultural Subsurface Drainage and Related Problems on the Westside San Joaquin Valley. 183 pp.

SWRCB, 1987. Phase I Hearing Transcript, Volume XLI, 68:1–69:10. December 22, 1987.

SWRCB, 1988. Draft Water Quality Control Plan for Salinity, San Francisco Bay/ Sacramento-San Joaquin Delta Estuary. October 1988.

SWRCB, 1991. Water Quality Control Plan for Salinity, San Francisco Bay/Sacramento-San Joaquin Delta Estuary. 91–15WR, May 1991.

SWRCB, 1994. Comments on the Water Quality Standards for the Bay and Delta, 2 pp., plus 63+ pp. comments attachment.

Turner, J.L., 1972a. Striped bass spawning in the Sacramento and San Joaquin Rivers in Central California. Calif. Fish Game 62:106–118.

Turner, J.L., 1972b. Striped Bass in Ecological Studies of the Sacramento-San Joaquin Delta Estuary, DFG Delta Fish and Wildlife Protection Report 8 pages 36–43.

Turner, J.L. and H.K. Chadwick, 1972. Distribution and abundance of young-of-year striped bass (Morone saxatilis) in relation to river flow in the Sacramento-San Joaquin Estuary. Transactions American Fisheries Society 101(3):442–452.

Turner, J.L. and T.C. Farley, 1971. Effects of temperature, salinity, and dissolved oxygen on the survival of striped bass eggs and larvae. Calif. Fish and Game 57:268–273.

U.S. Department of Commerce, 1989. 1987 Census of Agriculture, Volume 1, Geographic Area Series, Part 5, California State and County Data.

USEPA, 1990. Biological Criteria: National Program Guidance for Surface Waters. EPA–440/5–90–004, April 1990.

USFWS, 1992a. Measures to improve the protection of chinook salmon in the Sacramento/San Joaquin River Delta. WRINT–USFWS–7. Expert testimony of U.S. Fish and Wildlife Service on chinook salmon technical information for State Water Resources Control Board Water Rights Phase of the Bay/Delta Proceedings, July 6, 1992.

USFWS, 1992b. Abundance and survival of juvenile chinook salmon in the Sacramento-San Joaquin Estuary. WRINT–USFWS–9. 1991 Annual Progress Report. Sacramento-San Joaquin Estuary Fishery Resource Office, U.S. Fish and Wildlife Service, Stockton, Calif. June, 1992.

USFWS, 1992c. Expert testimony of United States Fish and Wildlife Service on recommendations for interim protection and response to hearing notice key issues for State Water Resources Control Board Water Rights Phase of the Bay-Delta Estuary Proceedings, July 6, 1992. WRINT–USFWS–8.

Williams, P., 1992. Management of Salinity in Suisun Bay. WRINT–NHI–18. 3+ pp.

List of Subjects in 40 CFR Part 131

Environmental protection, Indians—lands, Intergovernmental relations, Reporting and recordkeeping requirements, Water pollution control, Water quality standards, Water quality criteria.

Dated: December 14, 1994.

Carol M. Browner,

Administrator.

40 CFR part 131 is amended as follows:

PART 131—[AMENDED]

1. The authority citation for part 131 continues to read as follows:

Authority: 33 U.S.C. 1251 *et seq.*

2. Section 131.37 is added to read as follows:

§ 131.37 California.

(a) *Additional criteria.* The following criteria are applicable to waters specified in the Water Quality Control Plan for Salinity for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary, adopted by the California State Water Resources Control Board in State Board Resolution No. 91–34 on May 1, 1991:

(1) *Estuarine habitat criteria.* (i) *General rule.* (A) Salinity (measured at the surface) shall not exceed 2640 micromhos/centimeter specific conductance at 25 °C (measured as a 14-day moving average) at the Confluence of the Sacramento and San Joaquin Rivers throughout the period each year from February 1 through June 30, and shall not exceed 2640 micromhos/ centimeter specific conductance at 25 °C (measured as a 14-day moving average) at the specific locations noted in Table 1 near Roe Island and Chipps Island for the number of days each month in the February 1 to June 30 period computed by reference to the following formula:

Number of days required in Month X = Total number of days in Month X * $(1-1/(1+e^{K})$

where K = A + (B*natural logarithm of the previous month's 8-River Index);

A and B are determined by reference to Table 1 for the Roe Island and Chipps Island locations;

x is the calendar month in the February 1 to June 30 period;

and e is the base of the natural (or Napierian) logarithm.

Where the number of days computed in this equation in paragraph (a)(1)(i)(A) of this section shall be rounded to the nearest whole number of days. When the previous month's 8-River Index is less than 500,000 acre-feet, the number of days required for the current month shall be zero.

Table 1. Constants applicable to each of the monthly equations to determine monthly requirements described.

Month X	Chipps Island		Roe Island (if triggered)	
	A	B	A	B
Feb	−[1]	−[1]	−14.36	+2.068
Mar	−105.16	+15.943	−20.79	+2.741
Apr	−47.17	+6.441	−28.73	+3.783
May	−94.93	+13.662	−54.22	+6.571
June	−81.00	+9.961	−92.584	+10.699

[1] Coefficients for A and B are not provided at Chipps Island for February, because the 2640 micromhos/cm specific conductance criteria must be maintained at Chipps Island throughout February under all historical 8-River Index values for January.

(B) The Roe Island criteria apply at the salinity measuring station maintained by the U.S. Bureau of Reclamation at Port Chicago (km 64). The Chipps Island criteria apply at the Mallard Slough Monitoring Site, Station

D–10 (RKI RSAC–075) maintained by the California Department of Water Resources. The Confluence criteria apply at the Collinsville Continuous Monitoring Station C–2 (RKI RSAC–081) maintained by the California Department of Water Resources.

(ii) *Exception.* The criteria at Roe Island shall be required for any given month only if the 14-day moving average salinity at Roe Island falls below 2640 micromhos/centimeter specific conductance on any of the last 14 days of the previous month.

(2) *Fish migration criteria.* (i) *General rule.*

(A) *Sacramento River.* Measured Fish Migration criteria values for the Sacramento River shall be at least the following:

At temperatures less than below 61°F: SRFMC = 1.35
At temperatures between 61°F and 72 °F: SRFMC = 6.96–.092 * Fahrenheit temperature
At temperatures greater than 72 °F: SRFMC = 0.34

where SRFMC is the Sacramento River Fish Migration criteria value. Temperature shall be the water temperature at release of tagged salmon smolts into the Sacramento River at Miller Park.

(B) *San Joaquin River.* Measured Fish Migration criteria values on the San Joaquin River shall be at least the following:

For years in which the SJVIndex is > 2.5: SJFMC = (−0.012) + 0.184*SJVIndex
In other years: SJFMC = 0.205 + 0.0975*SJVIndex

where SJFMC is the San Joaquin River Fish Migration criteria value, and SJVIndex is the San Joaquin Valley Index in million acre feet (MAF)

(ii) *Computing fish migration criteria values for Sacramento River.* In order to assess fish migration criteria values for the Sacramento River, tagged fall-run salmon smolts will be released into the Sacramento River at Miller Park and captured at Chipps Island, or alternatively released at Miller Park and Port Chicago and recovered from the ocean fishery, using the methodology described in this paragraph (a)(2)(ii). An alternative methodology for computing fish migration criteria values can be used so long as the revised methodology is calibrated with the methodology described in this paragraph (a)(2)(ii) so as to maintain the validity of the relative index values. Sufficient releases shall be made each year to provide a statistically reliable verification of compliance with the criteria. These criteria will be considered attained when the sum of the differences between the measured experimental value and the stated criteria value (i.e., measured value minus stated value) for each experimental release conducted over a three year period (the current year and the previous two years) shall be greater than or equal to zero. Fish for release are to be tagged at the hatchery with coded-wire tags, and fin clipped. Approximately 50,000 to 100,000 fish of smolt size (size greater than 75 mm) are released for each survival index estimate, depending on expected mortality. As a control for the ocean recovery survival index, one or two groups per season are released at Benecia or Pt. Chicago. From each upstream release of tagged fish, fish are to be caught over a period of one to two weeks at Chipps Island. Daylight sampling at Chipps Island with a 9.1 by 7.9 m, 3.2 mm cod end, midwater trawl is begun 2 to 3 days after release. When the first fish is caught, full-time trawling 7 days a week should begin. Each day's trawling consists of ten 20 minute tows generally made against the current, and distributed equally across the channel.

(A) The Chipps Island smolt survival index is calculated as:

SSI=R÷MT(0.007692)

where R=number of recaptures of tagged fish
M=number of marked (tagged) fish released
T=proportion of time sampled vs total time tagged fish were passing the site (i.e. time between first and last tagged fish recovery)

Where the value 0.007692 is the proportion of the channel width fished by the trawl, and is calculated as trawl width/channel width.

(B) Recoveries of tagged fish from the ocean salmon fishery two to four years after release are also used to calculate a survival index for each release. Smolt survival indices from ocean recoveries are calculated as:

$OSI=R_1/M_1 \div R_2/M_2$

where R_1=number of tagged adults recovered from the upstream release
M_1=number released upstream
R_2=number of tagged adults recovered from the Port Chicago release
M_2=number released at Port Chicago

(*1*) The number of tagged adults recovered from the ocean fishery is provided by the Pacific States Marine Fisheries Commission, which maintains a port sampling program.

(*2*) [*Reserved*]

(iii) *Computing fish migration criteria values for San Joaquin River.* In order to assess annual fish migration criteria values for the San Joaquin River, tagged salmon smolts will be released into the San Joaquin River at Mossdale and captured at Chipps Island, or alternatively released at Mossdale and Port Chicago and recovered from the ocean fishery, using the methodology described in paragraph (a)(2)(iii). An alternative methodology for computing fish migration criteria values can be used so long as the revised methodology is calibrated with the methodology described below so as to maintain the validity of the relative index values. Sufficient releases shall be made each year to provide a statistically reliable estimate of the SJFMC for the year. These criteria will be considered attained when the sum of the differences between the measured experimental value and the stated criteria value (i.e., measured value minus stated value) for each experimental release conducted over a three year period (the current year and the previous two years) shall be greater than or equal to zero.

(A) Fish for release are to be tagged at the hatchery with coded-wire tags, and fin clipped. Approximately 50,000 to 100,000 fish of smolt size (size greater than 75 mm) are released for each survival index estimate, depending on expected mortality. As a control for the ocean recovery survival index, one or two groups per season are released at Benicia or Pt. Chicago. From each upstream release of tagged fish, fish are to be caught over a period of one to two weeks at Chipps Island. Daylight sampling at Chipps Island with a 9.1 by 7.9 m, 3.2 mm cod end, midwater trawl is begun 2 to 3 days after release. When the first fish is caught, full-time trawling 7 days a week should begin. Each day's trawling consists of ten 20 minute tows generally made against the current, and distributed equally across the channel.

(B) The Chipps Island smolt survival index is calculated as:

SSI=R÷MT(0.007692)

where R=number of recaptures of tagged fish
M=number of marked (tagged) fish released
T=proportion of time sampled vs total time tagged fish were passing the site (i.e. time between first and last tagged fish recovery)

Where the value 0.007692 is the proportion of the channel width fished by the trawl, and is calculated as trawl width/channel width.

(C) Recoveries of tagged fish from the ocean salmon fishery two to four years after release are also used to calculate a survival index for each release. Smolt survival indices from ocean recoveries are calculated as:

$OSI = R_1/M_1 \div R_2/M_2$

where R_1=number of tagged adults recovered from the upstream release

M_1=number released upstream

R_2=number of tagged adults recovered from the Port Chicago release

M_2=number released at Port Chicago

(*1*) The number of tagged adults recovered from the ocean fishery is provided by the Pacific States Marine Fisheries Commission, which maintains a port sampling program.

(*2*) [*Reserved*]

(3) *Suisun marsh criteria.* (i) Water quality conditions sufficient to support a natural gradient in species composition and wildlife habitat characteristic of a brackish marsh throughout all elevations of the tidal marshes bordering Suisun Bay shall be maintained. Water quality conditions shall be maintained so that none of the following occurs: Loss of diversity; conversion of brackish marsh to salt marsh; for animals, decreased population abundance of those species vulnerable to increased mortality and loss of habitat from increased water salinity; or for plants, significant reduction in stature or percent cover from increased water or soil salinity or other water quality parameters.

(ii) [Reserved]

(b) *Revised criteria.* The following criteria are applicable to state waters specified in Table 1–1, at Section (C)(3) (''Striped Bass—Salinity : 3. Prisoners Point—Spawning) of the Water Quality Control Plan for Salinity for the San Francisco Bay—Sacramento/San Joaquin Delta Estuary, adopted by the California State Water Resources Control Board in State Board Resolution No. 91–34 on May 1, 1991:

Location	Sampling site Nos (I--A/RKI)	Parameter	Description	Index type	San Joaquin Valley Index	Dates	Values
San Joaquin River at Jersey Point, San Andreas Landing, Prisoners Point, Buckley Cove, Rough and Ready Island, Brandt Bridge, Mossdale, and Vernalis.	D15/RSAN018, C4/RSAN032, D29/RSAN038, P8/RSAN056, -/RSAN062, C6/RSAN073, C7/RSAN087, C10/RSAN112	Specific Conductance @ 25 °C	14-day running average of mean daily for the period not more than value shown, in mmhos.	Not Applicable	>2.5 MAF	April 1 to May 31.	0.44 micromhos.
San Joaquin River at Jersey Point, San Andreas Landing and Prisoners Point.	D15/RSAN018, C4/RSAN032, D29/RSAN038	Specific Conductance.	14-day running average of mean daily for the period not more than value shown, in mmhos.	Not Applicable	≤2.5 MAF	April 1 to May 31.	0.44 micromhos.

(c) *Definitions.* Terms used in paragraphs (a) and (b) of this section, shall be defined as follows:

(1) *Water year.* A water year is the twelve calendar months beginning October 1.

(2) *8-River Index.* The flow determinations are made and are published by the California Department of Water Resources in Bulletin 120. The 8-River Index shall be computed as the sum of flows at the following stations:

(i) Sacramento River at Band Bridge, near Red Bluff;

(ii) Feather River, total inflow to Oroville Reservoir;

(iii) Yuba River at Smartville;

(iv) American River, total inflow to Folsom Reservoir;

(v) Stanislaus River, total inflow to New Melones Reservoir;

(vi) Tuolumne River, total inflow to Don Pedro Reservoir;

(vii) Merced River, total inflow to Exchequer Reservoir; and

(viii) San Joaquin River, total inflow to Millerton Lake.

(3) *San Joaquin Valley Index.* (i) The San Joaquin Valley Index is computed according to the following formula:

$I_{SJ}=0.6X+0.2Y$ and $0.2Z$

where I_{SJ}=San Joaquin Valley Index

X=Current year's April–July San Joaquin Valley unimpaired runoff

Y=Current year's October–March San Joaquin Valley unimpaired runoff

Z=Previous year's index in MAF, not to exceed 0.9 MAF

(ii) *Measuring San Joaquin Valley unimpaired runoff.* San Joaquin Valley unimpaired runoff for the current water year is a forecast of the sum of the following locations: Stanislaus River, total flow to New Melones Reservoir; Tuolumne River, total inflow to Don Pedro Reservoir; Merced River, total flow to Exchequer Reservoir; San Joaquin River, total inflow to Millerton Lake.

(4) *Salinity.* Salinity is the total concentration of dissolved ions in water. It shall be measured by specific conductance in accordance with the procedures set forth in 40 CFR 136.3, Table 1B, Parameter 64.

[FR Doc. 95–817 Filed 1–23–95; 8:45 am]

BILLING CODE 6560–50–P

Exhibit “P”

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF FISH AND GAME

FISH BULLETIN 136

Ecological Studies of The Sacramento-San Joaquin Delta Part II: Fishes of The Delta

Compiled by

JERRY L. TURNER

D. W. KELLEY

1966

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FOREWORD

In July 1961 the Delta Fish and Wildlife Protection Study began an investigation of the ecology of the Sacramento-San Joaquin estuary in California. Our investigations were designed to answer specific questions raised by water development plans proposed for the estuary, and to provide a background of information that could be used to evaluate these plans.

We have annually prepared a progress report, and more recently published the first volume of our ecological studies; a series of eight papers on fishes of San Pablo and Suisun bays, and of zooplankton and zoobenthos of the Delta and San Pablo and Suisun bays.

This is the second volume of our ecological studies. It consists of 12 individual papers about the distribution, relative abundance, food and spawning habits of fishes in the Sacramento-San Joaquin Delta.

All investigations of the Delta Fish and Wildlife Protection Study have been financed with funds made available through the California Department of Water Resources by the California Water Bond Act. The practical result is that those who will profit by water development have paid for investigations needed to protect fish and wildlife resources dependent upon that water.

In 1965, after evaluation of four alternative Delta water transfer concepts, the peripheral canal plan was selected as the only plan with the opportunity to both protect and enhance these resources. Our present studies are being directed toward learning how to operate the peripheral canal to use these opportunities.

Acknowledgments

The success of any undertaking of this size is dependent on the cooperation, advice, and participation of many people.

The Delta Studies Section of the California Department of Water Resources provided us with much of the information regarding physical conditions in the Delta. Special thanks are expressed to Cyril McRae, Glenn Twitchell, Roy Nelson, and August Mueller.

Clarkson E. Blunt, Jr., helped to organize the fish study and directed the first year of the investigation.

David Ganssle organized and conducted the 1963 survey of striped bass eggs and larvae distribution.

Vincent Catania made many helpful suggestions concerning our operations and captained the trawl-netting boat at all times. Elvn Gunderson kept our gill-net boat in operation and spent many unrewarded hours in the field. Ratzi Mercurio made and repaired most of our nets.

John Pierce assisted in our field program and did the laboratory analysis of food habits of threadfin shad. Numerous others assisted in

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our field work. Armand Croft, Dennis Knowles, and Brad Wood deserve special acknowledgment.

Mrs. Janet Boranian and Mrs. Marlene Oehler handled our office work and typed the manuscripts of this bulletin.

Credit for drafting and lettering the illustrations goes to Don Wolf.

Special thanks go to Robert L. Jones, former Leader of the Delta Fish and Wildlife Study, who solved our administrative problems and gave much encouragement and advice.

To all of the above and the many others who helped in so many ways, go our appreciation and thanks.

JERRY L. TURNER
D. W. KELLEY

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INTRODUCTION TO FISHERIES STUDIES IN THE SACRAMENTO-SAN JOAQUIN DELTA

JERRY L. TURNER

DESCRIPTION OF THE DELTA

The Sacramento-San Joaquin Delta is at the confluence of the Sacramento and San Joaquin rivers and receives all the flows draining the 26,000 square miles of the Central Valley of California. It is a reclaimed tidal marsh which consists of some 30 large farmed islands protected by high earthen levees and surrounded by 700 miles of sloughs and river channels. Most of these channels are subject to tidal action twice a day with a mean fluctuation of from 2 to 3 feet. Controlled river flows from upstream storage usually maintain the saline water below the Delta. During late summer and early fall, brackish water sometimes intrudes into the extreme western portion of the Delta. Kelley (1966) described the geography and physical-chemical environment of the Delta in detail.

Striped bass, Roccus saxatilis, king salmon, Oncorhynchus tshawytscha, white sturgeon, Acipenser transmontanus, green sturgeon, A. medirostris, steelhead trout, Salmo gairdnerii, American shad, Alosa sapidissima, white catfish, Ictalurus catus, black crappie, Pomoxis nigromaculatus, and a number of other species depend upon the Sacramento-San Joaquin Delta for part or all of their life cycle. The extent of both commercial and recreational fishing has been reported by Pelgen (1955), Skinner (1955, 1962), Wendler (1960), and Chadwick (1962).

PURPOSE OF STUDY

Development of the California Water Plan will create considerable environmental changes in the Sacramento-San Joaquin Delta. Major changes will occur in amount and pattern of water flow, water quality and salinity incursion. A knowledge of the major factors affecting fish distribution and abundance is essential if we are to protect and enhance, if possible, the fishery resources of the Delta with the development of the California Water Plan. The purpose of this study was to add to our understanding of the factors affecting the present distribution, relative abundance, spawning and food habits of fishes in the Delta. This bulletin is a report of our investigations on fish during the past several years.

The methods used and manner of presenting the data are included in this introductory paper so that authors of individual papers will not have to repeat descriptions of their own. The one exception is the paper on striped bass spawning by Timothy C. Farley. The sampling techniques were quite different and have been reported in his paper.

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METHODS

Fish collections were made each month over a 12-month period from September 1963 to August 1964 in order to obtain a seasonal picture of fish abundance and distribution. As a result of some preliminary sampling, a total of 16 stations were located throughout the Delta on the Sacramento, San Joaquin, and Mokelumne rivers as well as some adjacent sloughs (Figure 1). One day each month was spent at each sampling station.

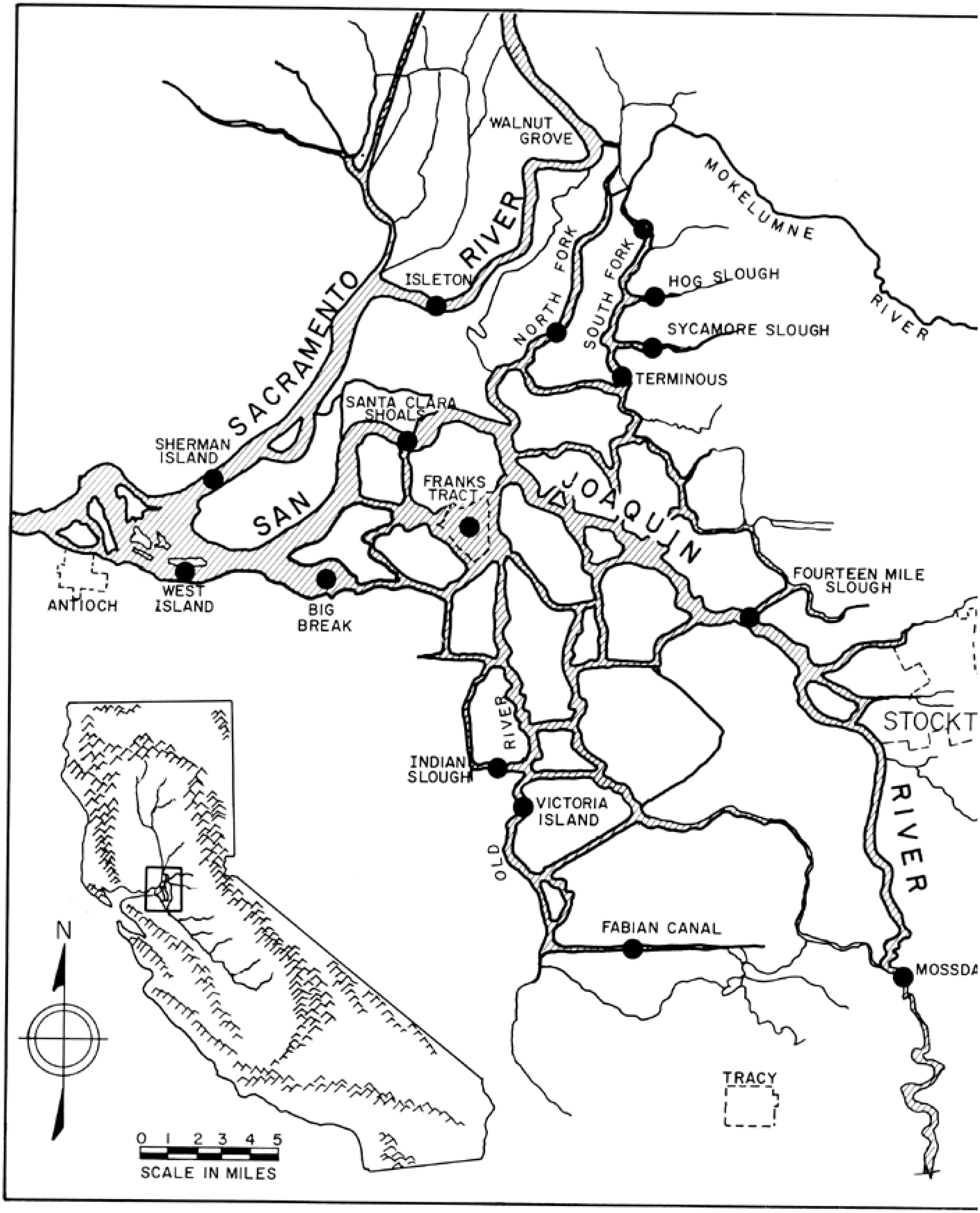

FIGURE 1. Location of sampling stations in the Sacramento-San Joaquin Delta.

FIGURE 1. Location of sampling stations in the Sacramento-San Joaquin Delta

Sampling Gear

Some exploratory sampling with various types of fishing gear was made prior to commencing a regular sampling program. We wanted to find a fishing gear that would (i) sample all sizes of fish present in

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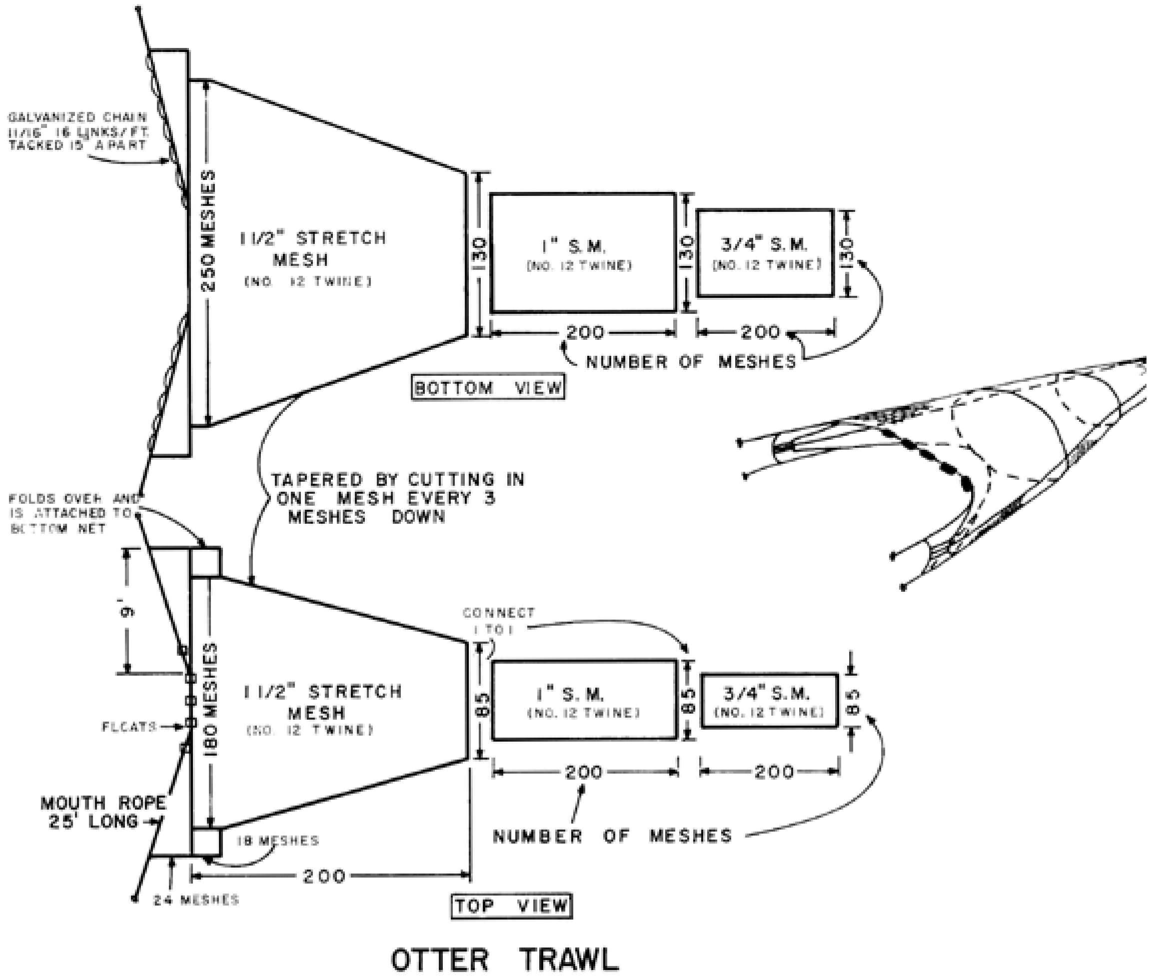

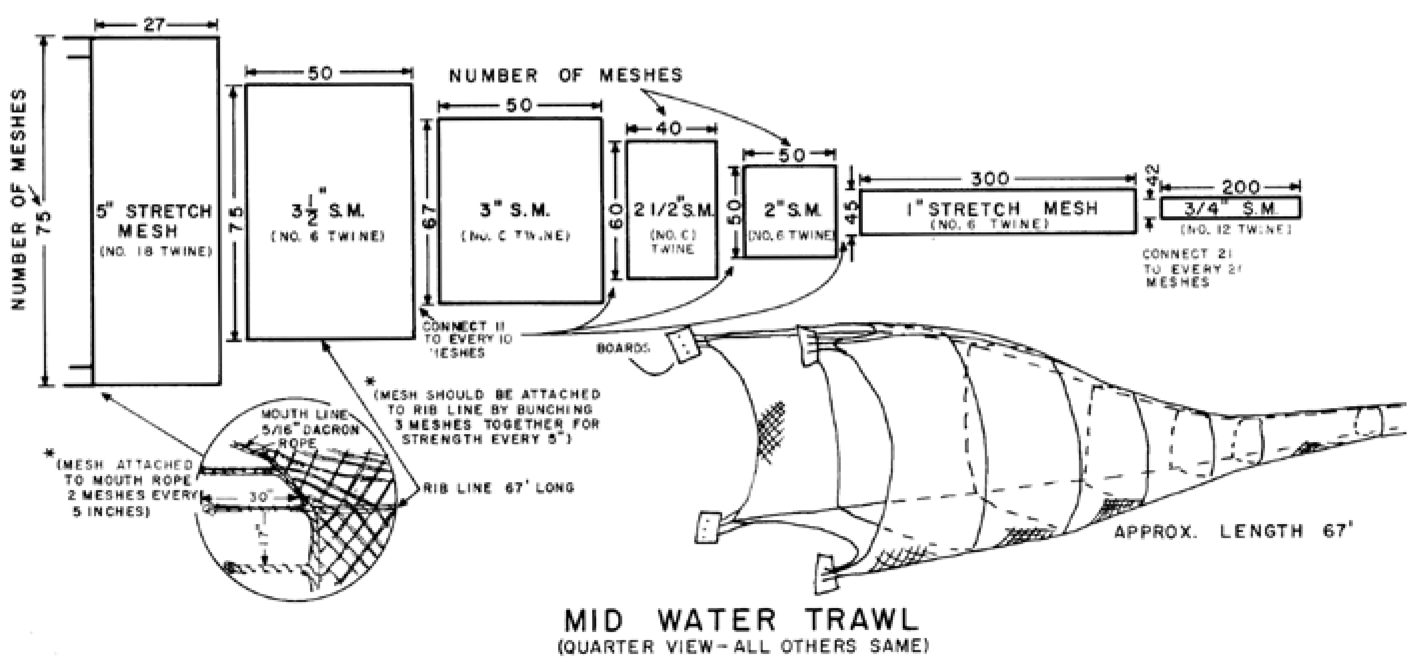

FIGURE 2. Diagram showing construction of otter trawl and midwater trawl used i study.

FIGURE 2. Diagram showing construction of otter trawl and midwater trawl used in this study

the Delta, (ii) sample in the complete range of water flows and depths, and (iii) be easy to operate under most field conditions. We were unable to find one gear that met all the requirements but a combination of several did fulfill our needs.

The fishing gears tested were the lampara net, beam trawl, midwater trawl, otter trawl, and set gill net. Two sizes of lampara nets, 360 and 650 feet long, were fished in the Delta. These nets caught small fish but required extensive open areas of quiet waters, free from snags and obstructions. The beam and otter trawl both caught small fish on the bottom in all ranges of water flows, but the beam trawl was much more difficult to handle. The midwater trawl caught small fish in the mid-depths, was easy to use, and sampled in both swift and slow currents.

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The set gill net caught large fish at all depths, was relatively simple to manage but was difficult to set in swift water.

We finally decided to use gill nets to sample large fish, an otter trawl to sample small fish on the bottom, and a midwater trawl to sample small fish in the mid-depths.

Our otter trawl was a semi-balloon trawl that sampled a cross sectional area of water on the bottom approximately 15 feet wide and 5 feet deep. The midwater trawl sampled a cross sectional area of water near the surface approximately 10 feet by 10 feet. Varying sizes of leading mesh in both nets guided the fish to a ¾-inch-stretch mesh in the cod end of the nets (Figure 2).

All trawling tows were 10 minutes long, not including time to retrieve the trawl. When possible, six otter and four midwater trawls were made at each station. The otter and midwater trawls were made over the same area at each station except in the shoal areas at the West Island and Santa Clara stations, where only otter trawl tows could be made. All samples were taken towing with the current at a velocity through the water of approximately 2.9 feet per second.

Each "gill net unit" was composed of two nets: one 250 feet long, 12 feet deep, and made up of five 50-foot sections of webbing, the meshes of which (stretched measure, inches) were 2½, 3, 3½, 4 and 4½; and one 200 feet long, 12 feet deep, and made up of four 50-foot sections of webbing, the meshes of which were 5, 5½, 6 and 7. Two "gill net units" were set overnight at each station except on the North and South Fork of the Mokelumne River and at Isleton on the Sacramento River where only one set was made. Each net was set in a stationary position on the bottom by anchors. Nets were set as near perpendicular to the current as possible. In narrow channels the nets had to be laid out at an angle. The shallow as well as deep areas were sampled.

Each overnight gill net set was considered to be a standard fishing unit even though actual fishing times varied somewhat. Van Oosten, Hile and Jobes (1946) found while netting in the Great Lakes that small differences in time in overnight gill net sets had little effect on the total catch.

Fish Analysis

All fish caught in each unit of gear were identified, counted, and recorded. All were measured in centimeters from the tip of the snout to the notch in the tail fin of fork-tailed fish or to the center of fin when the tail was not forked (fork length). Subsamples were measured when unusually large numbers of a particular species were caught.

The stomach contents of most species were examined whenever possible. All food organisms were counted and identified on the boat at the time of collection. Unknown food organisms taken were preserved and placed in jars for later analysis in the laboratory.

Gonads were examined when time permitted. Since there are difficulties in field determination of male sexual maturity, it was assumed that the male breeding cycle paralleled that of the female, and no attempt was made to distinguish the stages in male sexual maturity other than by noting the presence of obviously ripe males. The stages

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of sexual maturity of the female were determined by gross examination and the following criteria:

A. Immature (I): No eggs visible macroscopically in the ovary: ovary generally small.
B. Developing (D): The eggs are visible in the ovary but not loose and free flowing.
C. Ripe (R): The eggs are large and loose and flow from the fish when the abdomen is squeezed. The ovaries are soft and greatly enlarged.

D. Spent (S): The ovaries are flabby and only a few large eggs remain, scattered through the ovaries.

Environmental Measurements

A series of environmental measurements were made at the same time that the fish population was being sampled. Surface water temperature was measured with a bucket thermometer, turbidity with a Secchi disc, surface salinity with a hydrometer, and water depth with the depth finder aboard the boat. A sample of water was obtained for a measurement of its specific conductance.

From September 1963 to February 1964, information was obtained from Turner (1966) and Turner and Heubach (1966) on the concentration of zooplankton at each sampling station. From March to August 1964, a zooplankton sample was taken each month at each station during our regular fish sampling program in the same manner as described by Turner (1966). The Department of Water Resources furnished us with a monthly average of net flow and cross sectional area at each of our sampling stations.

PRESENTATION OF RESULTS

The first five papers of this bulletin are devoted to striped bass. There is one paper on adults, one on their spawning areas, one on young-of-the-year, one on juveniles, and one on the food habits of all age groups. American shad and king salmon are each described in individual papers. All reports of other anadromous fish are combined into one paper.

There are three papers on the resident families, Centrarchidae, Cyprinidae and Ictaluridae. All resident fish not in these three families and some limited information on crayfish have been combined into the final paper.

Catches of fish by otter and midwater trawl are expressed as the daily mean number of each species of fish per 10 minutes of towing. All counts of gill net catches are expressed as the mean number of each species per overnight "gill net unit". Monthly catches are an average of all the tows or sets made at one station in a particular month. Season catches are an average of the mean monthly tows or sets at one station over a 3-month period. Seasons are defined as fall (September through November), winter (December through February), spring (March through May), and summer (June through August).

Most types of fishing gear are selective for one or more kinds of fish and for various sizes of the same species of fish. To minimize this problem, our comparison of catches between stations and between seasons

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was usually limited to a single fishing gear and to individual age groups of a single species or for all age groups of a species when we were unable to separate age groups based on the length frequency of catch.

We have assumed that the catch of each species of fish per unit of effort is a rough estimate of the concentration of the fish at that station for that month. The dangers of such assumptions are well known. Anything that changes the ability of the fish to sense or avoid the oncoming trawl will affect the catch even though the population remains the same. All we really know about this is that large fishes are more successful in avoiding the trawl than small ones. We therefore do not use trawl catches to quantitatively compare fish of different year-classes.

Our gill nets were anchored in place so that the catches depended upon the movement of fish. Thus anything that affects movement must greatly affect the catch. We suspect that rate of movement is much less during the winter than at other times, but we have no measure of this. The only solution to this problem is to use the catch data with caution, recognizing that errors exist even though they are seldom definable.

LITERATURE CITED

Chadwick, Harold K. 1962. Catch records from the striped bass sportfishery in California. Calif. Fish and Game, *48* (1) : 153–177. Kelley, D. W. 1966. Description of the Sacramento-San Joaquin Estuary, p. 8–17. *In* D. W. Kelley, (ed), Ecological studies of the Sacramento-San Joaquin Estuary. Calif. Fish and Game, Fish Bull., (133) : 1–133. Pelgen, David E. 1955. Economic values of striped bass, salmon, and steelhead sport fishing in California. Calif. Fish and Game, *41* (1) : 5–17. Skinner, John E. 1955. California state-wide angling estimates for 1953. Calif. Fish and Game, *41* (1) : 19–32. Skinner, John E. 1962. An historical review of the fish and wildlife resources of the San Francisco Bay area. Calif. Fish and Game, Water Projects Branch Rept., (1) : 1–225. Turner, Jerry L. 1966. The seasonal distribution of crustacean plankters in the Sacramento-San Joaquin Delta, p. 95–104, *In* D. W. Kelley, (ed), Ecological studies of the Sacramento-San Joaquin Estuary. Calif. Fish and Game, Fish Bull., (133) : 1–133.

Turner, Jerry L., and William Heubach. 1966. Distribution and concentration of Neomysis awatschensis in the Sacramento-San Joaquin Delta, p. 105–112, *In* D. W. Kelley, (ed), Ecological studies of the Sacramento-San Joaquin Estuary. Calif. Fish and Game, Fish Bull., (133) : 1–133. Van Oosten, John, Ralph Hile and Frank W. Jobes. 1946. The whitefish fishery of Lakes Huron and Michigan with special reference to the deep-trap-net fishery. U. S. Fish and Wildl. Serv., Fish Bull. *50* (40) : 295–394. Wendler, Henry O. 1960. The importance of the ocean sport fishery to the ocean catch of salmon in the states of Washington, Oregon, and California. Calif. Fish and Game, *46* (3) : 291–300.

DISTRIBUTION OF ADULT AND SUBADULT STRIPED BASS, ROCCUS SAXATILIS, IN THE SACRAMENTO-SAN JOAQUIN DELTA

LARRY D. RADTKE

The number of adult striped bass in the Sacramento-San Joaquin Delta varies widely throughout the year for, being anadromous fish, they spend a large part of their lives in San Francisco, San Pablo, and Suisun bays or in the Pacific Ocean.

This report describes the distribution of adult (1960 and earlier year-classes) and subadult (1961 year-class) striped bass in the Delta for the period of September 1963 through August 1964. It is based on an analysis of gill net catches made once a month at 16 stations. Roughly 6,000 bass were caught.

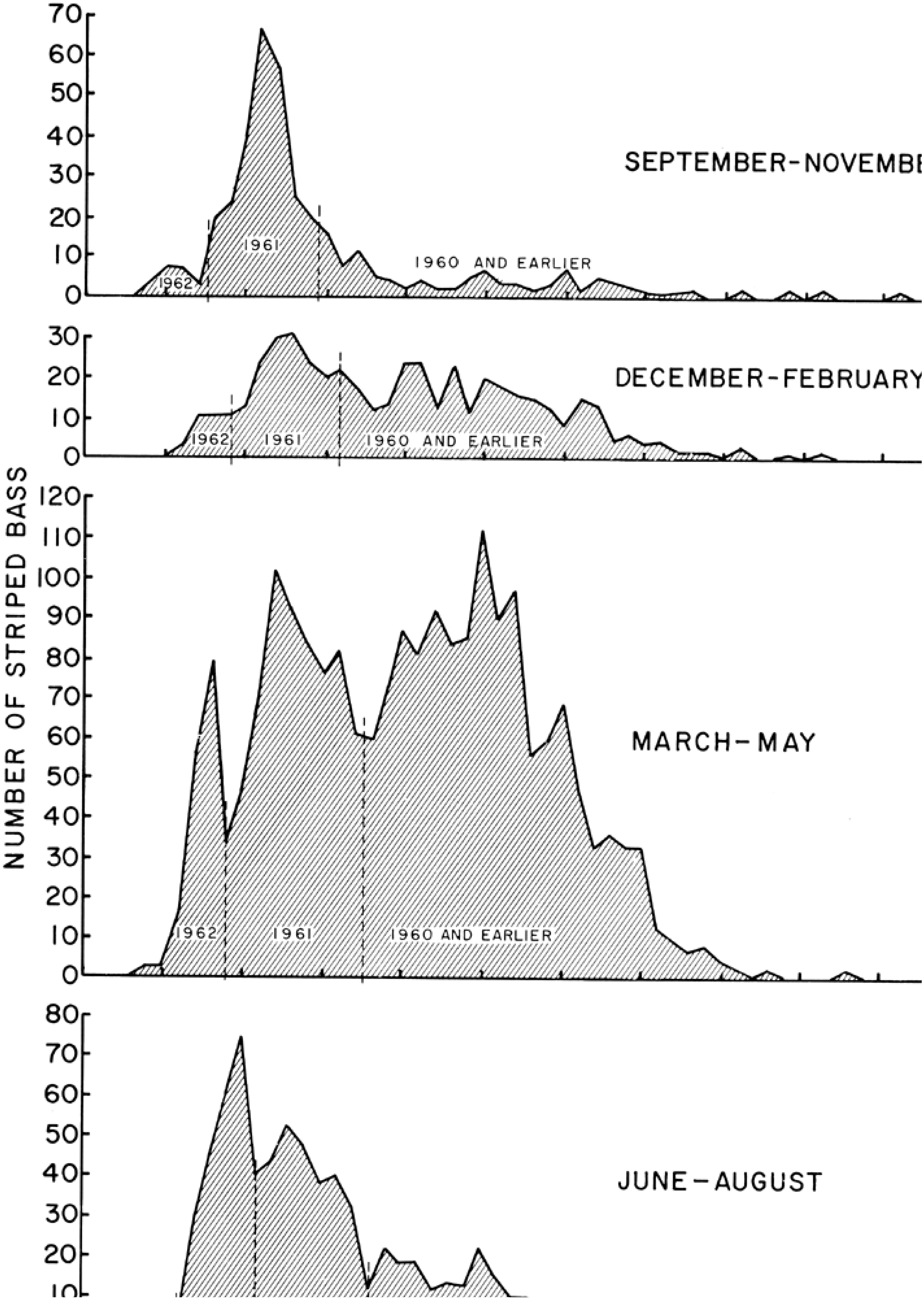
Relatively few striped bass were found in the Delta during the fall and winter. Large numbers of mature adults entered the Delta in the spring, a large run of males preceding the females. Bass in the northern Delta migrated rapidly up the Sacramento River, while those in the central Delta concentrated in the lower San Joaquin River during the spawning period. High concentrations of total dissolved solids at and upstream from Stockton appear to have blocked the spawning migration up the San Joaquin River.

METHODS

The sampling techniques and the location of sampling stations are described in the introductory paper of this bulletin. The interpretation of gill net catches and determination of sexual maturity are also described there.

The year-classes of striped bass were identified by length-frequency analysis of the gill net catch (Figure 1). Fish of the 1960 or earlier year-classes are called *adults* in this paper. Gonad examination revealed that most were capable of spawning in 1964. Only a portion of the 1961 year-class was capable of spawning in 1964. Members of this group are referred to as *subadults*.

Gonads were examined to determine how sex and maturity were related to distribution. When possible at least 10 adults and 10 subadults were examined at each station each month. Sample sizes were too small to estimate sex ratios reliably for each station each month. The ratios used in the analysis were obtained by combining the samples of fish sexed at similar and nearby stations and calculating the sex ratio for the group. The groups included stations in (i) the Sacramento River, (ii) the Mokelumne River, (iii) Hog and Sycamore sloughs, (iv) Franks Tract and Big Break, (v) San Joaquin River below the City of Stockton, (vi) the San Joaquin River above Stockton (Mossdale), Old River, Fabian and Bell Canal, and Indian Slough (Figure 2A).


NUMBER OF STRIPED BASS
SEPTEMBER-NOVEMBE
1962
1961
1960 AND EARLIER
DECEMBER-FEBRUARY
1962
1961
1960 AND EARLIER
MARCH-MAY
1962
1961
1960 AND EARLIER
JUNE-AUGUST

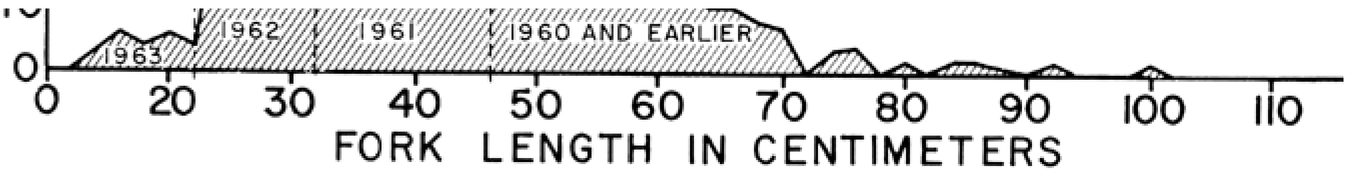


FIGURE 1. Length-frequency distribution of striped bass caught in gill nets. Year-class sions are indicated by dotted lines.

FIGURE 1. Length-frequency distribution of striped bass caught in gill nets. Year-class divisions are indicated by dotted lines

DISTRIBUTION OF ADULTS IN FALL AND WINTER

Catches of adult striped bass were low at nearly all stations from September through February (Figure 2B, C, D). The only exception

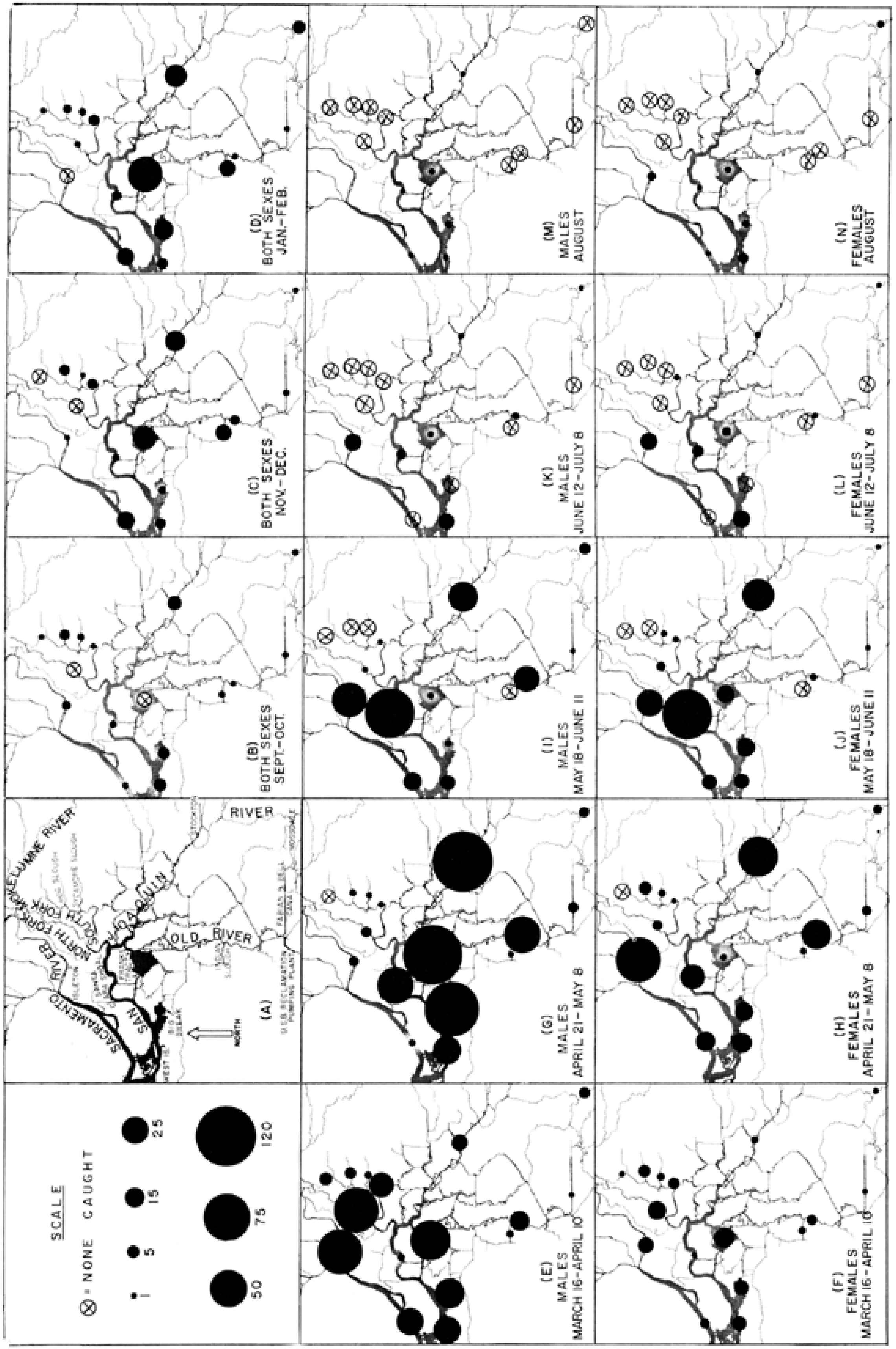


FIGURE 2. Distribution of adult striped bass in the Delta. The area of each circle is proportional to the catch per gill net unit. (A) shows locations mentioned in the text. Circles

portional to the catch per gill net unit. (A) shows locations mentioned in the text. Circles in (B) through (D) represent averages of two monthly samples at each station. Circles in (E) through (N) represent one sample at each station during each period.

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was Franks Tract where catches increased from zero in September and October to 24.5 fish per gill net unit on January 22 and 57.5 per unit on February 19. The generally low catches probably indicate that there were few adults in the Delta during this period.

The higher catches at Franks Tract in January and February may be the result of a population increase there, although why this would happen is unknown. Temperature was essentially the same there as in the surrounding waterways. A food habits investigation in the Delta concurrent with the present study indicates that the percentage of adult bass stomachs containing food was higher in fall and winter than during spring (see stevens, p. 76). But other areas of the Delta had higher concentrations of forage fish than Franks Tract during this time (see Sasaki, p. 48; see Turner, p. 160). Therefore, it is doubtful that food alone attracted adult bass to Franks Tract. Perhaps the relative stillness of the water, with only tidal currents, attracted them.

DISTRIBUTION OF ADULTS IN SPRING AND SUMMER

Catches during late March and early April suggest a migration primarily of males up the Sacramento River and into the western San Joaquin Delta (Figure 2E, F).

Catches during late April and early May indicate that most males in the Sacramento River had migrated upstream (Figure 2G). There were many males in the San Joaquin River below Stockton, in the central Delta, and in part of the southern Delta.

Females migrated into the Sacramento River during late April and early May (Figure 2H). Females were also present in the San Joaquin River below Stockton and in part of the southern Delta.

During late May and early June, the heaviest concentration of males in the San Joaquin Delta was in the Santa Clara Shoal area of the San Joaquin River (Figure 2I). Catches declined in most other areas of the San Joaquin Delta. Virtually all males were ripe.

Calhoun (1946) reported high numbers of ripe male bass caught by anglers in Franks Tract in mid April 1946. He found that in the latter half of April, the catch in Franks Tract dropped sharply, while catches of ripe males in the main San Joaquin increased and remained high through most of May. This pattern of movement is similar to that indicated by the present study.

Females in the Sacramento River migrated upstream during late May and early June (Figure 2J). Those in the San Joaquin River concentrated mainly in the Santa Clara Shoal area. Farley (see p. 34) found evidence of heavy spawning in the lower portion of the San Joaquin River, including Santa Clara Shoal, in mid May 1964. He found little evidence of spawning in other areas of the San Joaquin Delta.

Although adult males and females entered the San Joaquin River in large numbers during the spring, few migrated upstream beyond Stockton or into Fabian and Bell Canal.

Catches of both sexes were low from early June to early July (Figure 2K, L). Eighty percent of the females caught were spent. Most bass had spawned and left the Delta by this time. By August, very few remained (Figure 2M, N).

DISTRIBUTION OF SUBADULTS

Few subadults were caught, compared to adults. This may be partly explained by the fact that several year-classes were included in the adult classification while only the 1961 year-class made up the subadults.

Few subadults were caught from September through February (Figure 3A, B, C). From mid March to early June, the distribution pattern of subadult males resembled that of adult males; i.e., those in the Sacramento River migrated upstream, while those in the San Joaquin remained in the central and western Delta (Figure 3D, F, H). Approximately 65 percent of the subadult males caught from mid May to early June were ripe; they probably spawned with the adults. During the summer they migrated into the bay (Figure 3J, L).

The few subadult females caught during spring and summer (Figure 3E, G, I, K, M) were immature. Few female striped bass mature before their fourth year (Scofield, 1931), and few migrate from the bay into the Delta before this time (Chadwick, 1967).

GEOGRAPHICAL POPULATION DIFFERENCES

The Delta is a maze of channels that vary in width from a few hundred feet to a mile. While gill net catches are comparable expressions of *concentration,* they are not comparable expressions of the *relative numbers* or *abundance* of fish in different parts of the Delta. The entire fish population could be contained in the wide channels of the western Delta with a concentration (and therefore a net catch) only a fraction of that which would result from containing the same population in the smaller channels of the eastern Delta. To achieve an index of relative abundance in various parts of the Delta, stations were grouped on the basis of river system and flow and delineated into zones. Sasaki, (see p. 52) illustrates these geographical areas and the stations in them. The mean seasonal catch of bass in each zone (*index of concentration*) was multiplied by the percent of the Delta's surface area represented by each zone. The resulting figures are *population indices* for each zone, which I converted to percent of total bass in the Delta (Tables [1] and [2]). The population indices of the zones were totaled to obtain population indices for the entire Delta each season *(quarterly population indices)*.

The quarterly population indices suggest that the number of adult bass in the Delta increased greatly from fall to spring and decreased from spring to summer (Table 1). While these changes in the index are probably due primarily to migration, the magnitude of change was undoubtedly influenced by the effects of various factors on the gill net catches. For instance, from fall to winter the actual population of adult bass in the Delta may have increased by much more than is indicated. Low temperatures probably caused a decrease in fish activity, resulting in disproportionately low catches and an underestimate of the increase. The increase in the index from winter to spring is probably disproportionately large due to increased fish activity caused by rising temperature and approaching sexual maturity.

During the fall, winter, and spring, most adult bass in the Delta were located in the flooded islands, the Sacramento River, and the lower and

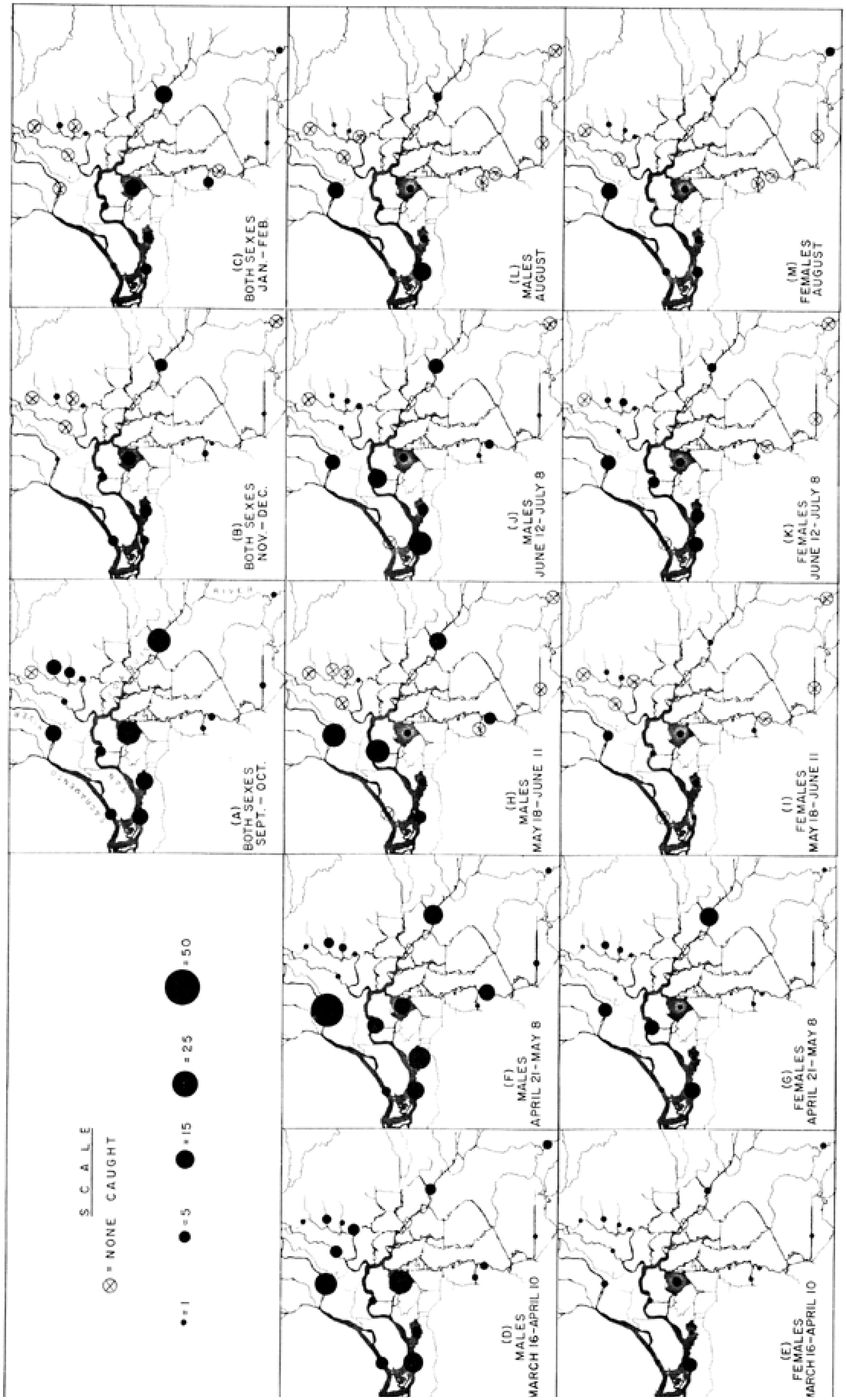
(C) BOTH SEXES JAN.-FEB.
(L) MALES AUGUST
(M) FEMALES AUGUST
(B) BOTH SEXES NOV.-DEC.
(J) MALES JUNE 12-JULY 8
(K) FEMALES JUNE 12-JULY 8
(A) BOTH SEXES SEPT.-OCT.
(H) MALES MAY 18-JUNE 11
(I) FEMALES MAY 18-JUNE 11
(F) MALES APRIL 21-MAY 8
(G) FEMALES APRIL 21-MAY 8
(D) MALES MARCH 16-APRIL 10
(E) FEMALES MARCH 16-APRIL 10
SCALE
⊗ = NONE CAUGHT
= 1
= 5
= 15
= 25
= 50

FIGURE 3. Distribution of subadult striped bass in the Delta. The area of each circle is proportional to the catch per gill net unit. Circles in (A) through (C) represent averages of two monthly samples at each station. Circles in (D) through (M) represent one sample at each station during each period.

FIGURE 3. Distribution of subadult striped bass in the Delta. The area of each circle is proportional to the catch per gill net unit. Circles in (A) through (C) represent averages of two monthly samples at each station. Circles in (D) through (M) represent one sample at each station during each period

TABLE 1

Relative Abundance of Adult Striped Bass in Zones of

Zones	Percent of Delta Area	Fall			Winter			
		Index of concen-tration	Pop. index	Percent of pop. in zone	Index of concen-tration	Pop. index	Percent of pop. in zone	In cc tr
Lower San Joaquin River	24.6	3.4	83.4	16.3	6.2	153.3	10.6	
Middle San Joaquin River	12.4	9.3	115.3	22.5	15.5	192.2	13.2	
Upper San Joaquin River	2.1	1.3	2.7	0.5	3.8	8.0	0.5	
Sacramento River	15.3	4.5	68.9	13.5	12.2	186.7	12.8	
Mokelumne River	5.4	2.0	10.8	2.1	4.8	25.9	1.8	
South Delta	15.7	2.2	34.5	6.7	3.0	47.1	3.2	
Flooded Islands	17.6	7.8	137.3	26.8	43.2	760.3	52.3	
Dead-end Sloughs	6.9	8.5	58.7	11.5	11.7	80.7	5.5	
Quarterly population indices	----------	----------	511.6	----------	----------	1,454.2	----------	---

TABLE 1

Relative Abundance of Adult Striped Bass in Zones of the Delta

TABLE 2

Relative Abundance of Subadult Striped Bass in Zones c

Zones	Percent of Delta Area	Fall			Winter			
		Index of concen-tration	Pop. index	Percent of pop. in zone	Index of concen-tration	Pop. index	Percent of pop. in zone	In co tr
Lower San Joaquin River	24.6	6.9	170.7	16.1	6.8	168.2	25.6	
Middle San Joaquin River	12.4	16.5	204.6	19.2	12.5	155.0	23.5	
Upper San Joaquin River	2.1	0.7	1.5	0.1	1.3	2.7	0.4	
Sacramento River	15.3	11.7	179.0	16.8	3.2	49.0	7.4	
Mokelumne River	5.4	2.3	12.4	1.1	0.5	2.7	0.4	
South Delta	15.7	2.8	44.0	4.3	0.3	4.7	0.7	
Flooded Islands	17.6	21.2	373.1	35.1	13.8	242.9	36.7	
Dead-end Sloughs	6.9	11.3	78.0	7.3	5.0	34.5	5.3	
Quarterly population indices			1,063.3			659.7		

TABLE 2

Relative Abundance of Subadult Striped Bass in Zones of the Delta

middle San Joaquin River. During the summer approximately half the Delta population was in the Sacramento River.

Quarterly population indices for subadults suggest an overall decrease in numbers in the Delta from fall to winter, followed by a large increase in spring and a decrease in summer (Table 2). Again, these indices undoubtedly reflect, in part, the influences of temperature and spawning activity. The distribution of the subadult population among the various zones of the Delta was similar to that of the adults. The most notable exception was in summer when a substantially higher percentage of subadults was in the lower San Joaquin River and a lower percentage was in the Sacramento River.

WHY DO STRIPED BASS AVOID THE UPPER SAN JOAQUIN RIVER?

Although large numbers of adult and subadult striped bass were caught in all other areas of the Delta in the spring, few were taken in the San Joaquin River above Stockton or in the extreme south Delta. In attempting to explain this, various environmental factors such as food, temperature, flow, and total dissolved solids were considered.

Food

An extensive study of their food habits indicates that few adult bass fed during the spawning migration (see Stevens, p. 76), and because of this, it is doubtful that food availability had much influence on their distribution during this time.

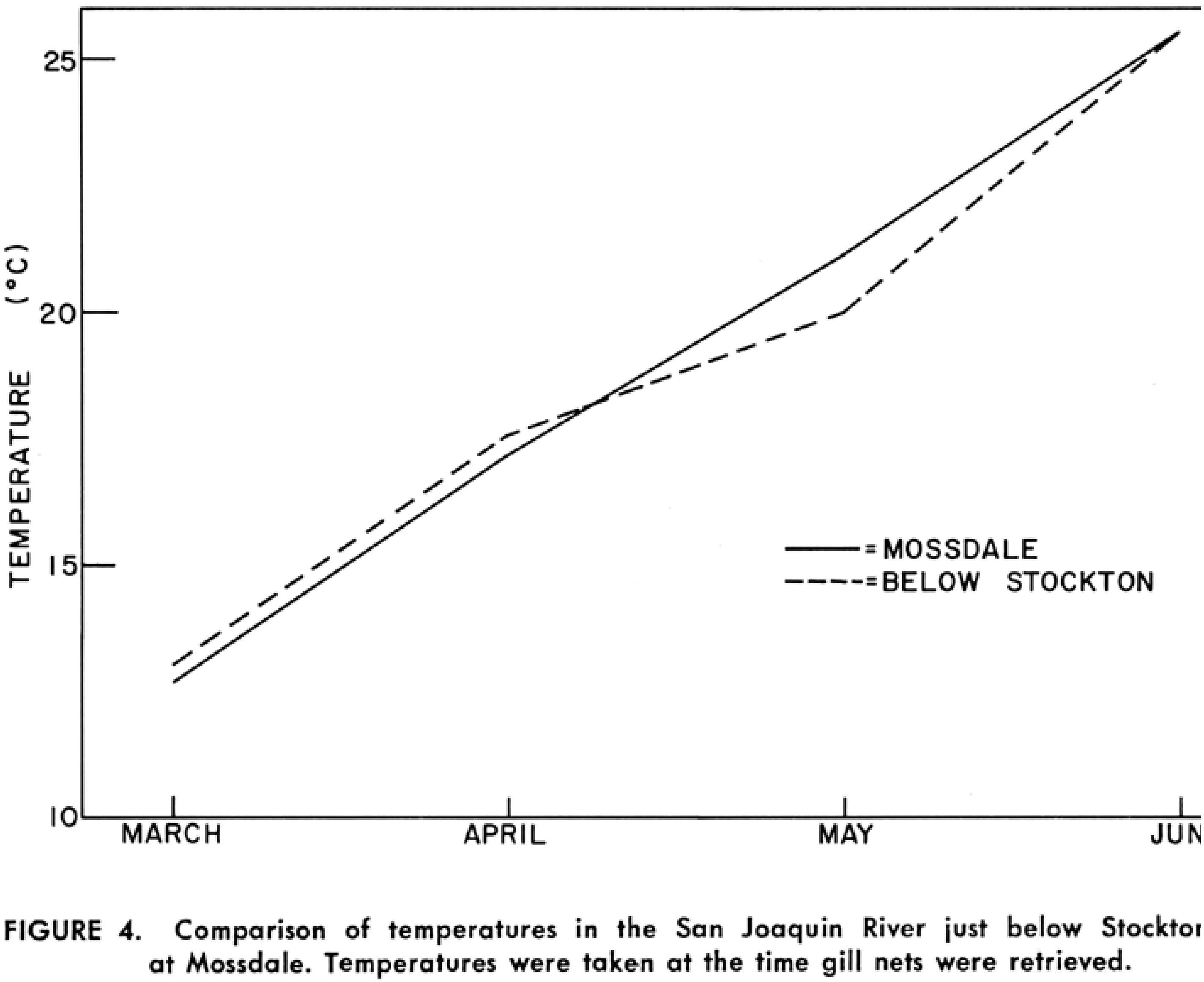

FIGURE 4. Comparison of temperatures in the San Joaquin River just below Stockton and at Mossdale. Temperatures were taken at the time gill nets were retrieved

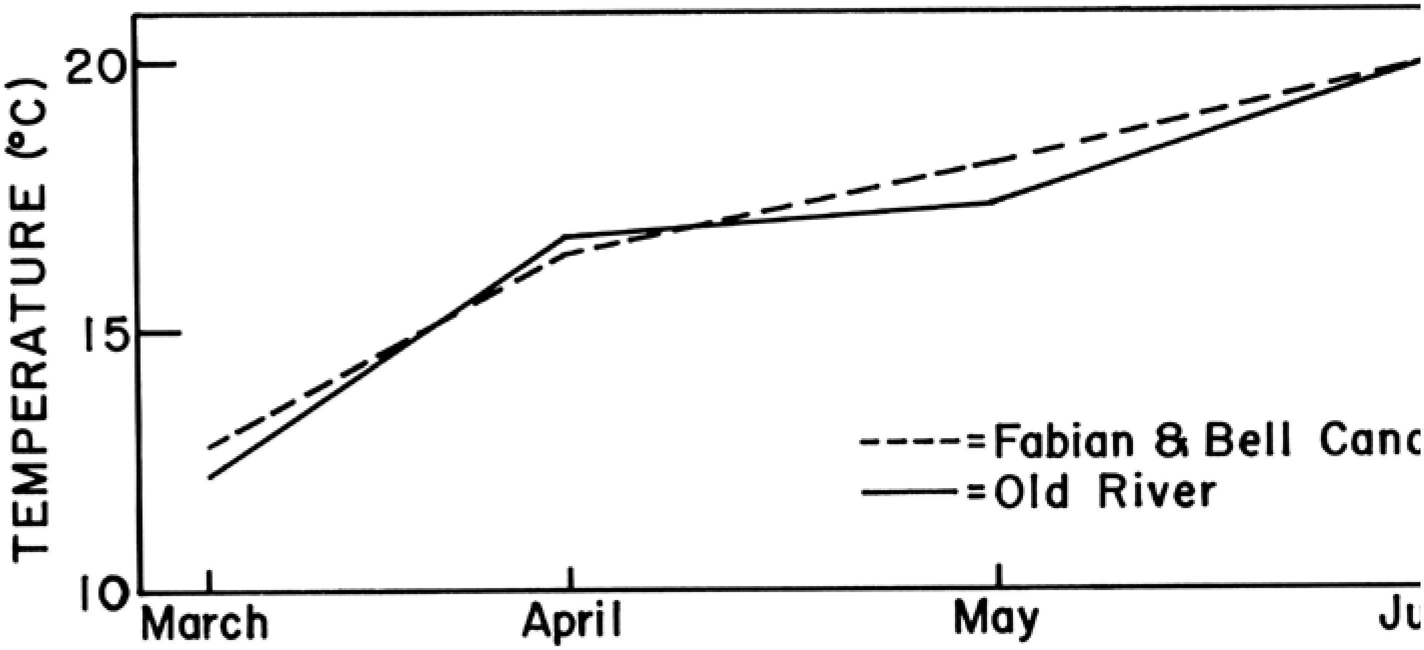

FIGURE 5. Comparison of temperatures in Old River and Fabian and Bell Canal. Te
atures were taken at the time gill nets were retrieved.

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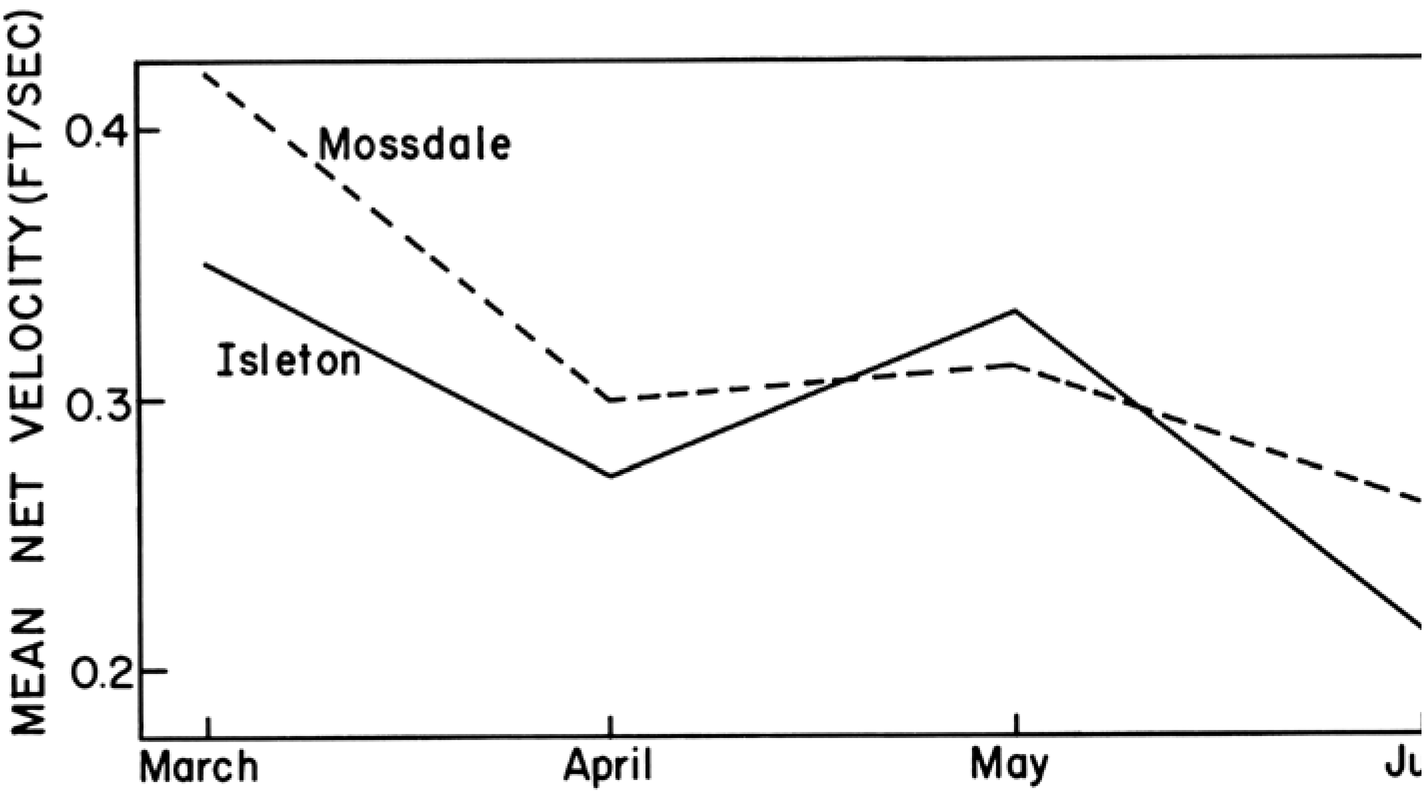

FIGURE 6. Comparison of mean net velocity of flow in the Sacramento River at Is
and in the San Joaquin River at Mossdale, based on monthly net flows estimated by
California Dept. of Water Resources.

FIGURE 6. Comparison of mean net velocity of flow in the Sacramento River at Isleton and in the San Joaquin River at Mossdale, based on monthly net flows estimated by the California Dept. of Water Resources

Temperature

Temperature does not appear to have prevented the migration up the San Joaquin River. Just below Stockton, where many bass were caught, temperatures taken during the spawning migration were similar to those taken at Mossdale, where few bass were caught (Figure 4).

In Old River, where large numbers of bass were taken, temperatures differed little from those in the adjacent Fabian and Bell Canal, where very few bass were caught (Figure 5).

Flow

Current velocity in the upper San Joaquin River was not unfavorable for striped bass migration. Mean net velocities[1] at Isleton on the Sacramento

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River and at Mossdale on the San Joaquin River were similar during the spring of 1964 (Figure 6). Although this does not mean that actual velocities at these stations were necessarily similar, it does indicate that at both places water moved toward the ocean at about the same rate. If this were the controlling factor, comparable concentrations of striped bass would be expected at both stations during the spawning migration. However, catches indicate that in the spring of 1964, very few went up the San Joaquin, while many went up the Sacramento River.

Dissolved Solids

In the spring of 1964 adult striped bass passed through a 50-mile long section of decreasing salinities in the bays before they reached the fresh water of the Delta. Those that entered the San Joaquin River continued upstream until confronted with increasing total dissolved solids just below Stockton (Figure 7). The bass that migrated into Old River encountered a similar situation at Fabian and Bell Canal in the south Delta. In both instances, migration appeared to cease.

In years of low natural runoff, such as 1964, the San Joaquin River contains relatively high concentrations of sodium chloride during the spring and summer, due to the influence of irrigation water returned to the river from farmlands in the San Joaquin Valley (Calif. Dept. of Water Resources, 1961). A *reverse salinity gradient* is caused by the mixture of San Joaquin and Sacramento RIver waters as they are drawn to the Delta-Mendota Canal by the U. S. Bureau of Reclamation pumping plant.

During the journey from salt to fresh water, adult striped bass necessarily undergo certain osmoregulatory changes, as do all anadromous fishes during their spawning migrations. Changes in endocrine activity usually accompany or precede changes in osmoregulatory mechanisms, indicating hormonal control. The pituitary, the thyroid, and the gonads are concerned with physiological changes prior to and during migrations. Their secretions may initiate osmoregulatory processes. Lagler, Bardach, and Miller (1962) mention that pituitary and gonadal changes often lead to appetitive behavior, such as the stickleback's, Gasterosteus, preference for fresh water when preparing to spawn.

Black (1957) reviewed the literature dealing with osmoregulation in anadromous fishes and cited evidence than anadromous fishes are adjusted to either the freshwater or the saltwater phase of their life cycles and cannot change abruptly from one to the other. For example, the sea lamprey, Petromyzon marinus, after having entered fresh water, cannot tolerate even half sea water salinities. It can regulate body fluids until this time but becomes stenohaline upon beginning its anadromous migration.

The physiological effects of the salinity gradient in the San Joaquin River near Stockton and in the south Delta on striped bass are not known. But it seems reasonable to hypothesize that, having been in fresh water for several weeks, their osmoregulatory systems had thoroughly adapted to the freshwater environment. They were probably sensitive to increases in salinity and were able to detect the relatively high salinity of the water from the upper San Joaquin River. When they encountered it, they did not continue upstream.

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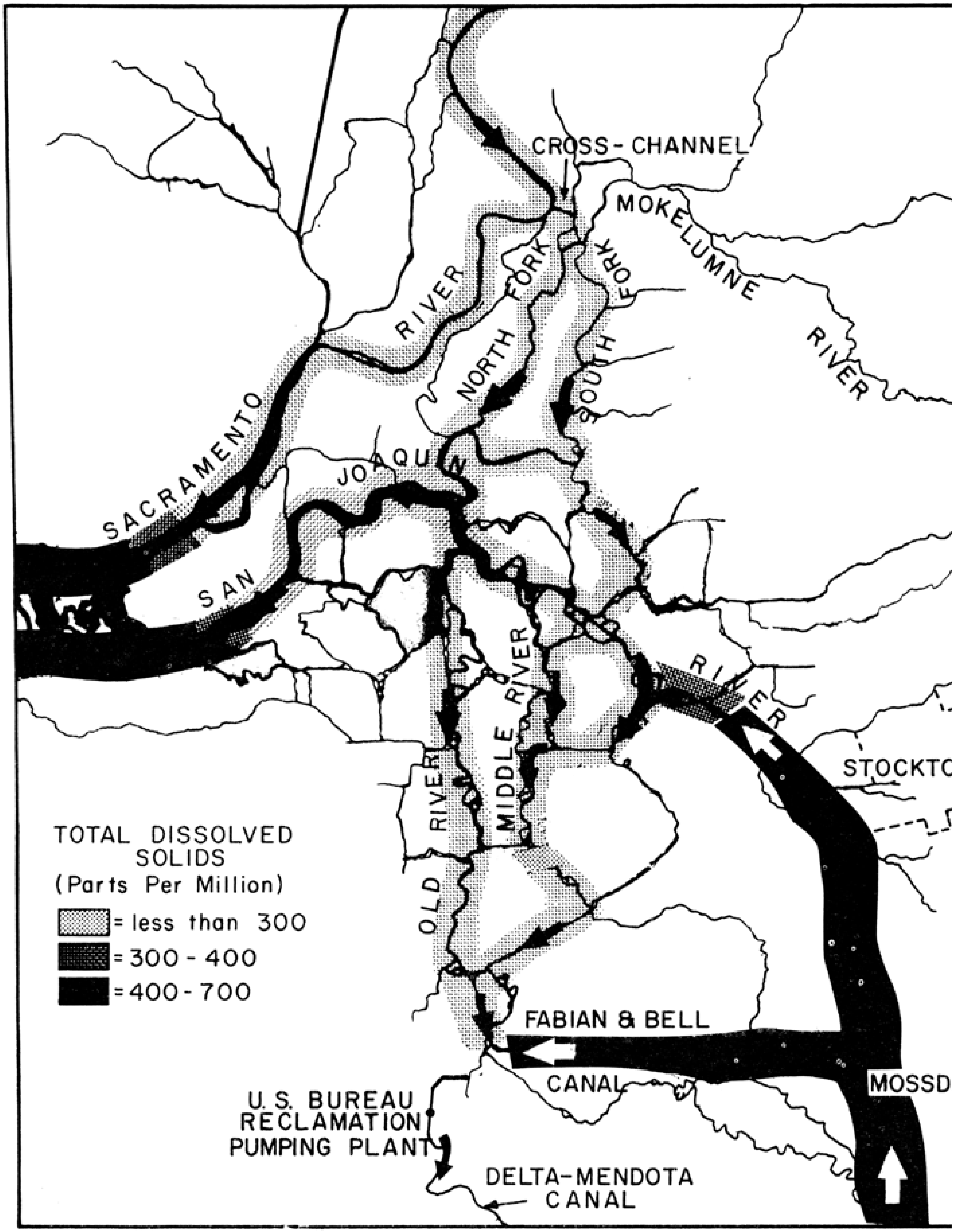

FIGURE 7. Flow pattern and total dissolved solids concentrations in the Delta from
through June 1964. Arrows indicate the direction of net flow, based on monthly flows esti
by the California Dept. of Water Resources. Shaded areas represent ranges of total dis

solids, based on water samples collected during fish sampling.

FIGURE 7. Flow pattern and total dissolved solids concentrations in the Delta from March through June 1964. Arrows indicate the direction of net flow, based on monthly flows estimated by the California Dept. of Water Resources. Shaded areas represent ranges of total dissolved solids, based on water samples collected during fish sampling

Striped bass apparently always spawn in fresh water and, except for a few isolated populations located entirely in fresh water, they migrate from essentially sea water through a salinity gradient to do so (Morgan and Gerlach, 1950; Tresselt, 1952; Rathjen and Miller, 1957). I believe that when the San Joaquin River above Stockton has a high concentration of dissolved solids, striped bass will not migrate upstream to spawn. In years when high flows occur in the San Joaquin River due to natural runoff, the dissolved solids concentration is much lower and striped bass probably migrate upstream. Farley (see p. 37) reviewed the literature on striped bass spawning in the Delta and

found that in years when there was evidence of spawning in the upper San Joaquin River, the dissolved solids concentration was low. According to his data, bass spawned there in the spring of 1963 but not in 1964.

SUMMARY

From September 1963 through August 1964, gill nets were set in the Sacramento-San Joaquin Delta to obtain information on the distribution and abundance of adult and subadult striped bass. Few adult or subadult striped bass were caught in the Delta during fall and winter except in the flooded island, Franks Tract. The major spawning migration of adult striped bass occurred during the spring, with a large run of males preceding the females. The bass that entered the northern Delta migrated upstream in the Sacramento River, while those in the central Delta concentrated in the lower San Joaquin River. Few migrated into the upper San Joaquin River or the extreme south Delta.

Most of the subadult males (3 years old) were mature in the spring and their migration pattern resembled that of adult males. Female subadults were not mature at that time and very few migrated into the Delta.

Relatively high concentrations of total dissolved solids apparently blocked the spawning migration of striped bass into the upper San Joaquin River.

LITERATURE CITED

Black, Virginia Safford. 1957. Excretion and osmoregulation. p. 163–205, *In* M. C. Brown, (ed.), The physiology of fishes, vol. 1. Academic Press, Inc., New York. Calhoun, A. J. 1946. Observations of the striped bass fishery in the Sacramento Delta area during April and May 1946. Calif. Dept. Fish and Game, Inland Fish. Admin. Rept., (46–12) : 1–36 p. California Department of Water Resources. 1961. Quality of surface waters in California, 1959. Pt. 1. Northern and central California. Calif. Dept. Water Resources, Bull., (65–59) : 1–432. Chadwick, Harold K. 1967. Recent migrations of the Sacramento-San Joaquin River striped bass population. Ms. Lagler, Karl F., John E. Bardach, and Robert R. Miller. 1962. Excretion and osmotic regulation, p. 262–278, *In* Karl F. Lagler, et al., Ichthyology. John Wiley and Sons, Inc., New York. Morgan, A. R., and A. R. Gerlach. 1950. Striped bass studies in Coos Bay in 1949 and 1950. Oregon Fish Comm., Contrib., (14) : 1–31. Rathjen, Warren F., and L. C. Miller. 1957. Aspects of the early life history of the striped bass in the Hudson River. N.Y. Fish and Game J., 4(1) : 43–60. Scofield, Eugene C. 1931. The striped bass of California (Roccus lineatus) . Calif. Dept. Fish and Game, Fish Bull., (29) : 1–82. Tresselt, Ernest F. 1952. Spawning grounds of the striped bass, Roccus saxatilis (Walbaum) in Virginia. Bingham Oceanog. Coll., Bull., 14(1) : 98–110. Turner, Jerry L. 1966. Seasonal distribution of crustacean plankters in the Sacramento-San Joaquin Delta, p. 95–104, *In* D. W. Kelley (ed.), Ecological studies of the Sacramento-San Joaquin estuary. Calif. Dept. Fish and Game, Fish Bull., (133) : 1–133.

STRIPED BASS, ROCCUS SAXATILIS, SPAWNING IN THE SACRAMENTO-SAN JOAQUIN RIVER SYSTEMS DURING 1963 AND 1964

TIMOTHY C. FARLEY

This paper is the result of 2 years' work to determine where striped bass spawn in the Sacramento and San Joaquin River systems and why they spawn where they do. Plankton nets were used to collect striped bass eggs and larvae from various locations in the Delta and its tributaries. The geographic origins of eggs and larvae were estimated by determining the ages of individuals and calculating how far, and from where, they could have been carried by the river currents since they were spawned. Some eggs and larvae were traced back to or found newly spawned in almost every area in the Delta and tributaries, but there were three areas in 1963 and two areas in 1964 where most eggs and larvae originated. These are defined as the main spawning areas.

The onset of spawning in the spring was correlated with spring warming of the water to about 15°C. There is evidence to support the hypothesis that the later the water reaches this temperature, the farther up the Sacramento River bass will migrate to spawn.

No significant amount of spawning occurred in areas where the total dissolved solids content of the water was above 180 parts per million; in 1964 TDS values above that level prevented bass from migrating above Stockton in the San Joaquin River.

EGG SAMPLING

In 1963 eggs and larvae were sampled at 26 stations every 2 to 5 days from April 2 to June 28 (Figure 1). In 1964, 33 stations were sampled from April 13 to June 12; all the stations south of Courtland on the Sacramento River were covered each Monday, Wednesday, and Friday and those north of Courtland on Tuesdays and Thursdays.

Eggs were collected in plankton nets, 18 inches in diameter at the mouth, made of a 40-inch cone of 23 mesh per inch bolting cloth. The eggs and larvae were concentrated in a small screen bucket attached to the small end of the net. In 1964 pygmy-type flow meters were mounted in the mouths of the nets to measure the amount of water strained during each tow.

At most stations two nets were towed behind a power boat at a speed of 3.0 to 3.5 feet per second relative to the water current. One net was fished at the surface. A 10-pound weight was attached to the towing line on the other net to make it fish 15 to 25 feet deep. In 1964 only surface tows were made in the San Joaquin River above Stockton and in Old River near Bacon Island due to the shallowness of those areas.

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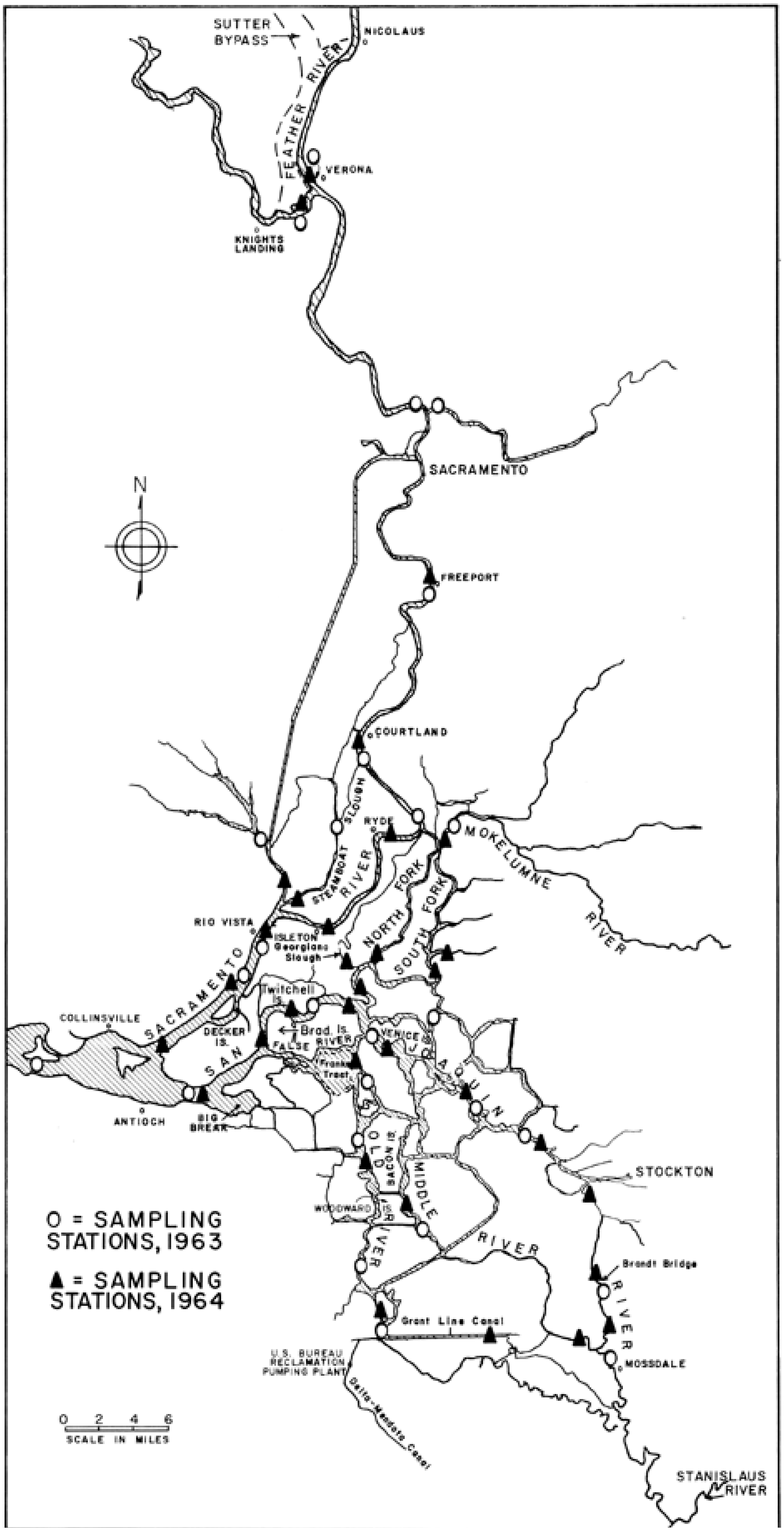
SUTTER BYPASS
NICOLAUS
FEATHER RIVER
VERONA
KNIGHTS LANDING
SACRAMENTO
N
FREEPORT
COURTLAND
STEAMBOAT SLOUGH
RYDE
MOKELUMNE RIVER
NORTH FORK
SOUTH FORK
RIVER
RIO VISTA
ISLETON
Georgiana Slough
SACRAMENTO
Twitchell Is.
COLLINSVILLE
DECKER IS.
Brad. Is.
FALSE RIVER
VENICE
Franks Tract
SAN JOAQUIN
ANTIOCH
BIG BREAK
OLD
MIDDLE
RIVER
STOCKTON
WOODWARD IS.
O = SAMPLING STATIONS, 1963
▲ = SAMPLING STATIONS, 1964
RIVER
Brandt Bridge
RIVER
Grant Line Canal
U.S. BUREAU RECLAMATION PUMPING PLANT
MOSSDALE
Delta-Mendota Canal
0 2 4 6
SCALE IN MILES
STANISLAUS RIVER

FIGURE 1. Striped bass egg and larva sampling stations.

FIGURE 1. Striped bass egg and larva sampling stations

In both years surface samples were collected from the highway bridges at Courtland and Freeport. The stations above Sacramento were sampled from an anchored skiff.

In all cases 10-minute tows were made.

During each tow, physical and chemical measurements of the water were made (e.g., bottom and surface temperatures, turbidity, water velocity, tidal stage). In 1964 a water sample was collected at each station for analysis of total dissolved solids (TDS) in the laboratory.

The contents of each tow were preserved in 5 to 7 percent formalin to which rose bengal dye had been added. When the sample was emptied into a white enamel laboratory pan, the stained eggs and larvae were easily seen.

1963 Collections

Few eggs and no larvae were collected during April (Figure 2). In the first half of May the numbers of eggs and larvae increased in the collections in both the Sacramento and San Joaquin rivers. From May 16 to May 31 the catches (numbers of eggs and larvae in the samples) in the San Joaquin River from Antioch to Venice Island and above Stockton increased to their highest values there for the sampling period. Catches in the Sacramento River continued to increase in the latter part of May, but did not reach a peak until the first half of June. San Joaquin River catches declined greatly by mid June. During the latter half of June, most catches had declined and consisted almost entirely of larvae.

Although some eggs were collected at almost every station, the areas of highest egg and larvae catches were in the San Joaquin River from Antioch to Venice Island and above Stockton, and in the Sacramento River above Sacramento.

1964 Collections

Low to moderate numbers of eggs and larvae were caught from April 13 to May 1 in 1964 (Figure 3). From May 4 to May 8 no eggs and only a few larvae were caught; this cessation of spawning followed a storm which caused a drop in water temperature of 1.1 to 3.3°C. in most areas of the Delta. From May 11 to May 29 high numbers of eggs were caught in the lower San Joaquin River and the upper Sacramento River. High numbers of larvae were caught in the lower Sacramento and San Joaquin rivers from May 11 until June 12, the end of the survey.

LOCATING THE SPAWNING AREAS

The ages of eggs and larvae were determined by examining each individual under a dissecting microscope and comparing the stage of development with those described by Mansueti (1958). The geographic origin of each egg and larva collected in the Sacramento River was then estimated by multiplying its age by the average river velocity upstream from the collection site; for example, a 36-hour old egg collected below a stretch of river with a 2-mile per hour mean velocity was estimated to have been spawned 72 miles upstream. Such a calculation assumes that striped bass eggs travel at the same rate as the river flow. Since bass eggs are pelagic, this assumption was reasonable for a rough estimation of the location of spawning.

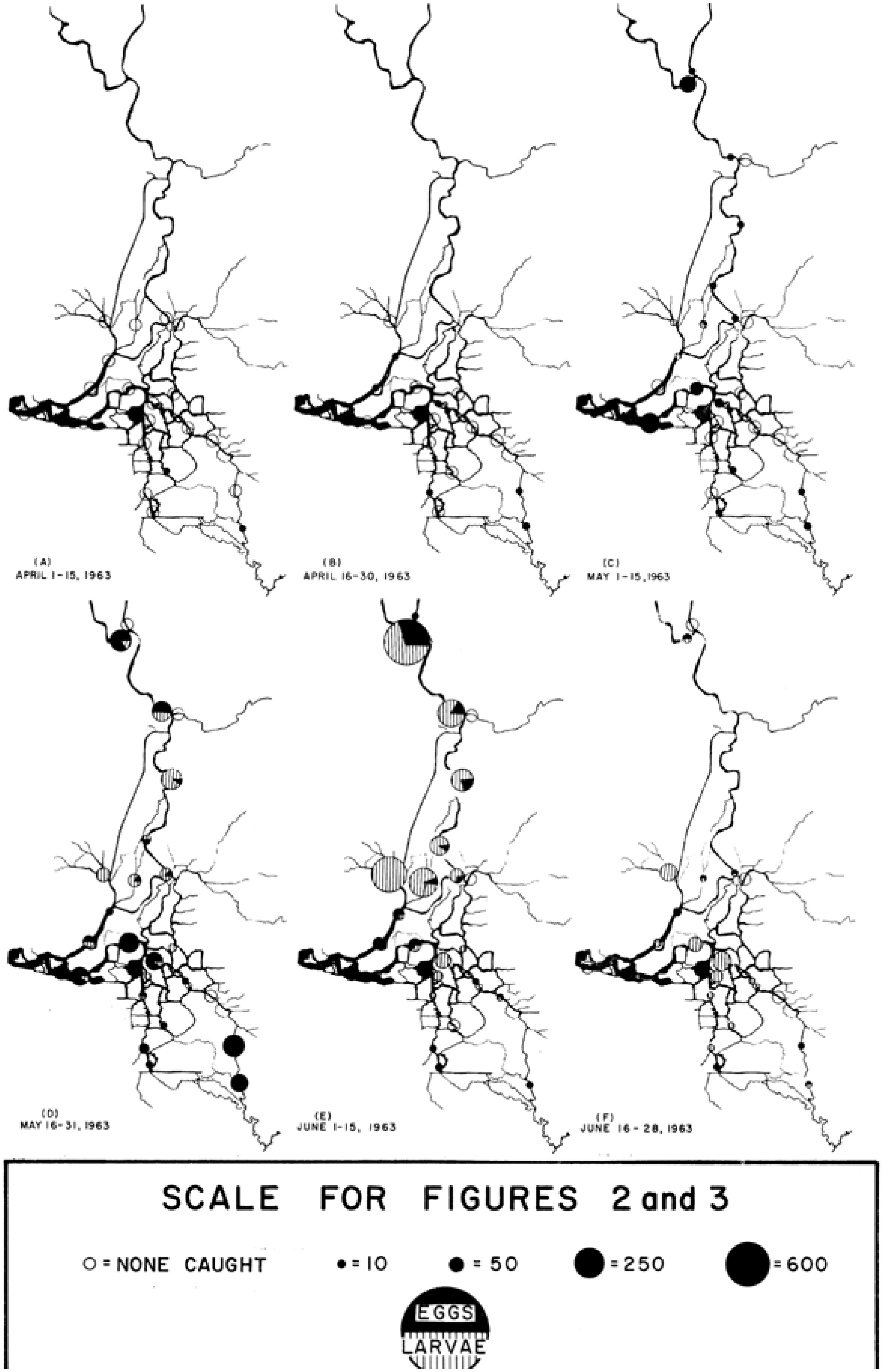
(A)
APRIL 1-15, 1963
(B)
APRIL 16-30, 1963
(C)
MAY 1-15, 1963
(D)
MAY 16-31, 1963
(E)
JUNE 1-15, 1963
(F)
JUNE 16-28, 1963
SCALE FOR FIGURES 2 and 3
○ = NONE CAUGHT
• = 10
= 50
= 250
= 600
EGGS
LARVAE

FIGURE 2. Semi-monthly mean eggs and larvae per tow in 1963.

FIGURE 2. Semi-monthly mean eggs and larvae per tow in 1963

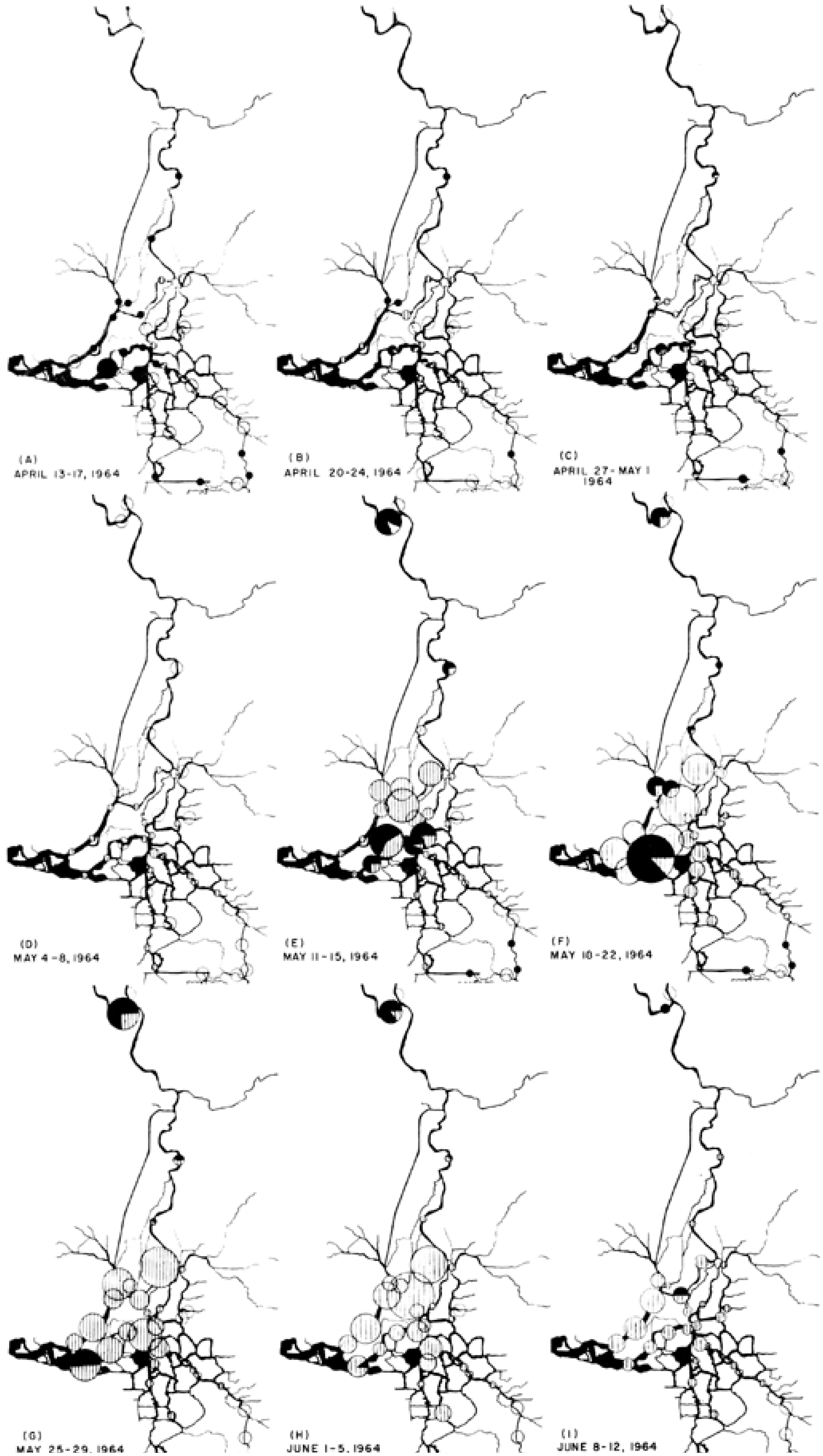
(A)
APRIL 13-17, 1964
(B)
APRIL 20-24, 1964
(C)
APRIL 27-MAY 1
1964
(D)
MAY 4-8, 1964
(E)
MAY 11-15, 1964
(F)
MAY 10-22, 1964
(G)
MAY 25-29, 1964
(H)
JUNE 1-5, 1964
(I)
JUNE 8-12, 1964

FIGURE 3. Weekly mean eggs and larvae per tow in 1964. For scale and legend see Figure 2.

FIGURE 3. Weekly mean eggs and larvae per tow in 1964. For scale and legend see Figure 2

— 33 —

Mansueti (op. cit.) described the growth rate and development of striped bass eggs and larvae in temperatures from 17.2 to 17.8°C.; at this range of temperature, the eggs hatch in from 36 to 48 hours. We collected eggs and larvae in temperatures from 14.4 to 22.2°C. Because egg development and larval growth rate vary with temperature, there was some error in some of the estimates of the ages of eggs and larvae. In many instances it was necessary to assign broad age estimates to eggs and larvae; e.g., 12 to 20 hours old, 3 to 5 days old. This increased the possible area from which such individuals could have originated.

Back-tracking eggs and larvae collected in the confined channel of the Sacramento River above the Delta was relatively easy since travel time down stretches of that river had already been calculated for various levels of outflow (Calif. Dept. Water Resources, 1962).

Because of the complex current pattern in the San Joaquin River and in the Delta, it was impossible to determine accurately the origin of older eggs and larvae collected there. Therefore, eggs from there were not back-tracked and the spawning areas in the San Joaquin River and Delta are defined as those areas where eggs less than 24 hours old were consistently caught. This is reasonable since water there moves back and forth with the tide, and net flows were low throughout the spawning season [(Table 1)].

TABLE 1

Net Flows and Net Velocities in the Lower San Joaquin River in 1963 and 196

Location and Month	Cross Section (ft²)	Net Flow (ft³/sec)	Net Velocity (ft/sec)	Net Downs Movemen Hours (in
1963				
San Joaquin River—Between Bradford and Twitchell Islands				
April	71,000	12,100	0.17	2.8
May	71,000	11,000	0.15	2.5
June	71,000	6,860	0.10	1.6
San Joaquin River—at Antioch				
April	85,800	31,380	0.37	6.1
May	84,200	23,340	0.28	4.6
June	82,000	11,430	0.14	2.3
1964				
San Joaquin River—Between Bradford and Twitchell Islands				
April	71,000	1,700	0.02	0.3
May	71,000	1,660	0.02	0.3
June	71,000	230	0.003	0.1
San Joaquin River—at Antioch				
April	81,125	3,390	0.04	0.7
May	81,100	3,580	0.04	0.7
June	81,050	940	0.01	0.2

[1] Cross-section and net flow information supplied by California Department of Water Resources, Delta St Section.

TABLE 1

Net Flows and Net Velocities in the Lower San Joaquin River in 1963 and 1964

1963 Spawning Areas

Most eggs caught in the Sacramento River were spawned in the stretch of river from 70 to 160 miles above the junction of the Sacramento and San Joaquin rivers at Collinsville (Figure 4). This section of the river is from 200 to 300 feet wide and 10 to 15 feet deep. Tidal action affected water levels as far upstream as Verona (mile 80), but did not cause flow reversal above Freeport during the spawning period.

— 34 —

During the peak spawning period the flow in the river above Verona was from 8,000 to 9,000 cubic feet per second (Calif. Dept. Water Resources, August 1963). This amount of outflow causes the water to flow 2 to 3 feet per second (Calif. Dept. Water Resources, 1962).

In the Delta the main spawning areas were in the San Joaquin River from Antioch to Venice Island and from Stockton to above Mossdale (Figure 4). Between Antioch and Venice Island, the river is from 1,500 to 4,500 feet wide. Thirty percent of the total water area is made up of shoals less than 10 feet deep (see Sasaki, p. 54). In a few places the water is up to 75 feet deep, but most of the river is maintained as a deep-water ship channel averaging 30 to 40 feet deep. This area is directly affected by tides; the current reverses direction with each ebb and flood of the tide. The river narrows at Venice Island and again at Stockton, so that above Stockton it is only 200 to 300 feet wide. The average depth of the river above Stockton was about 15 feet during the spawning season. Although the water level rose and fell due to tidal action, the flow above Stockton was always downstream during the spawning period.

1964 Spawning Areas

In the Sacramento River most eggs and larvae were spawned from 10 to 60 miles above Collinsville (Figure 4). This is considerably downstream from where the major spawning occurred in 1963. The width of the river below

Sacramento varies from 250 to 800 feet, generally becoming wider as it flows downstream. This section of the river was influenced by tidal action. On several occasions the river was observed flowing upstream with the flood tide at Freeport. The flow ranged from 9,000 to 15,000 cubic feet per second from April to June, and the average river velocity was probably near 1 foot per second during the spawning season. At a flow of 10,000 cubic feet per second at Sacramento, the river velocity averages slightly less than 1 foot per second (Calif. Dept. Water Resources, 1962).

Again large numbers of eggs were spawned in the lower San Joaquin River, but the upper San Joaquin River was not a major spawning area as it had been in 1963. The apparent reason for this is discussed in a later section of this paper describing the effect of total dissolved solids on spawning.

THE EFFECT OF WATER TEMPERATURE ON SPAWNING

In both years the onset of bass spawning occurred when the water temperature reached 14.4 to 15.0°C. In 1963 the first egg was collected in Middle River opposite Woodward Island on April 11, 9 days after the survey began; the water temperature was 14.4°C. In 1964 the first eggs were collected on April 13 at Antioch and near the mouth of False River, where the water temperatures were 15.0 and 14.4°C respectively. Although April 13 was the first day of regular sampling, I believe very little spawning took place before that time because we caught only a very small number of larvae during the entire first week of the survey.

In both years the greatest numbers of eggs were collected near the spawning areas when the water temperature was between 16.1 and 20.6°C [(Table 2)].

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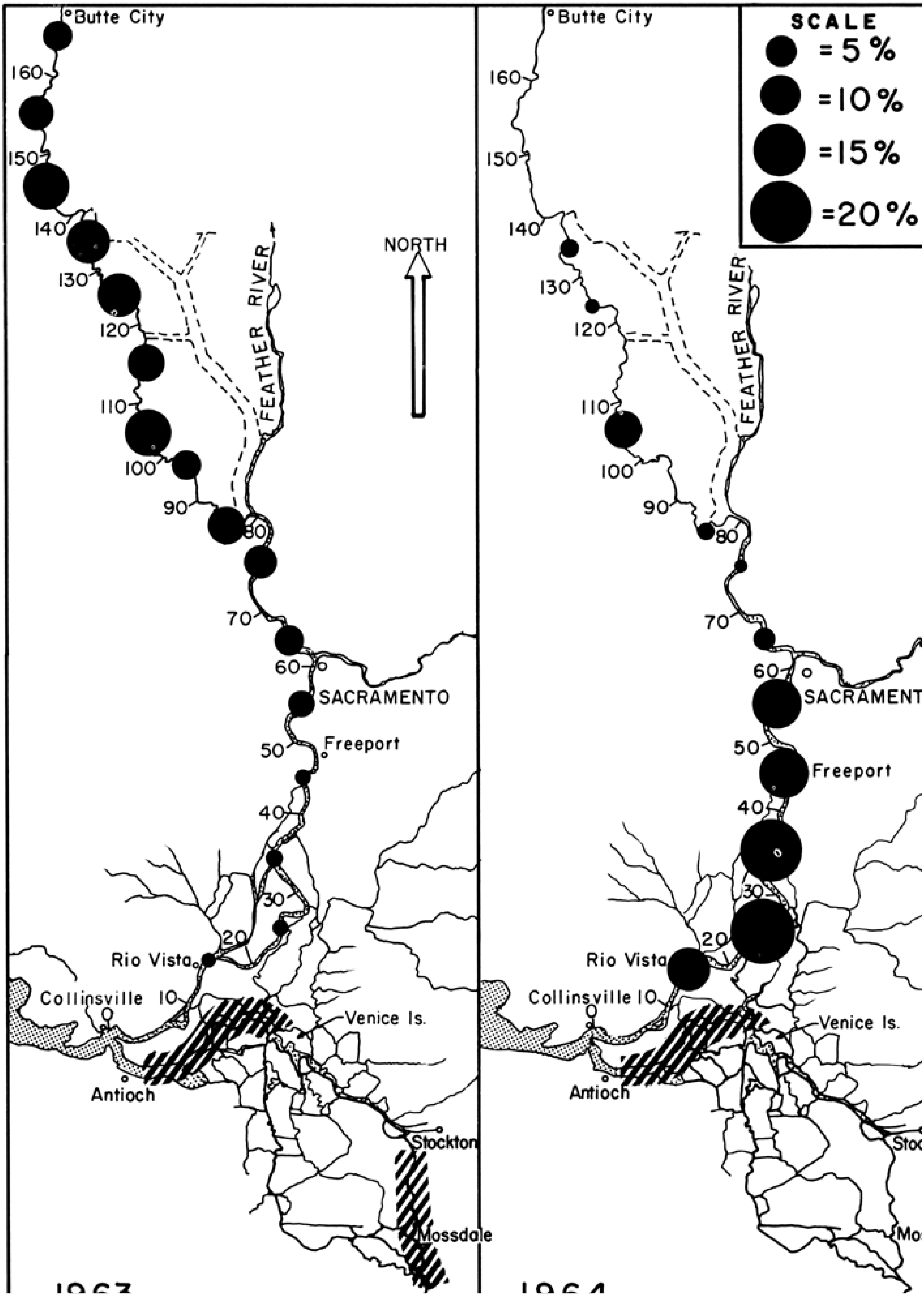
Butte City
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
NORTH
FEATHER RIVER
SACRAMENTO
Freeport
Rio Vista
Collinsville
Venice Is.
Antioch
Stockton
Mossdale
SCALE
=5%
=10%
=15%
=20%

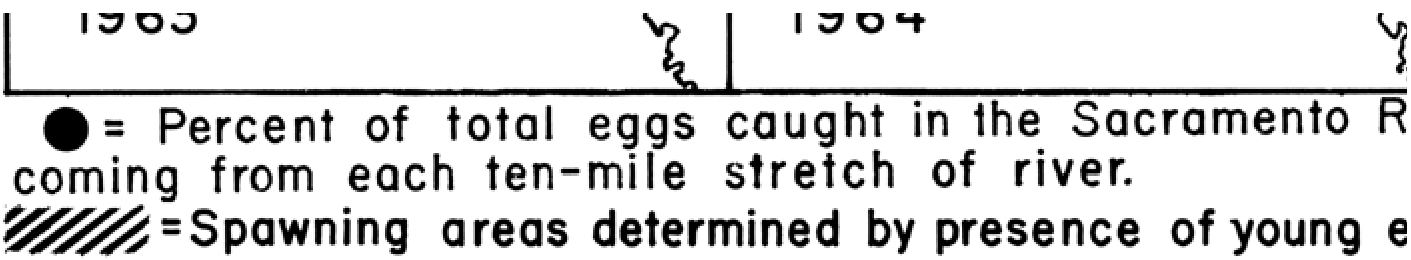

FIGURE 4. Major striped bass spawning areas in 1963 and 1964.

FIGURE 4. Major striped bass spawning areas in 1963 and 1964

Bass ceased spawning temporarily when the water temperature fell below 15.6°C, or when there was a sudden drop in water temperature even though it remained above 15.6°C. This was clearly demonstrated

TABLE 2

Mean Eggs Per Tow and Water Temperature Near the Spawning Areas in 1963 and 1964

		April			May			June	
		1–10	11–20	21–30	1–10	11–20	21–30	31–9	10–19
1963									
San Joaquin River above Stockton	C°	13.9	13.3	15.0	15.6	17.8	—	17.8	20.0
	Eggs/Tow	0	0.5	8.5	11.0	81.0	—	9.0	2.5
San Joaquin River from Webb Tract to Venice Island	C°	13.3	13.3	13.5	16.7	17.2	17.8	18.3	19.4
	Eggs/Tow	0	0	0	45.0	70.0	4.0	3.0	9.0
Sacramento River above Verona	C°	—	—	—	16.1	16.7	18.9	19.4	20.6
	Eggs/Tow	—	—	—	84.0	50.0	90.0	95.0	250.0
1964									
San Joaquin River at the Mouth of False River	C°	—	16.1	16.1	15.0	16.7	18.3	18.3	18.3
	Eggs/Tow	—	57.0	27.0	14.0	374.0	160.0	83.0	42.0
Sacramento River above Verona[1]	C°	—	16.1	16.1	15.0	18.3	18.9	20.0	18.3
	Eggs/Tow	—	4.0	4.0	1.5	163.0	426.0	312.0	6.0

[1] Most spawning in the Sacramento River took place below this point. However, the catches above Verona composed primarily of eggs 16–20 hours old, and the catches delimiting the lower spawning area were comp primarily of larvae. Since the catches above Verona were closer in time to the actual spawning events, the w temperature that they were caught in was considered more representative of the water temperature when spaw occurred.

TABLE 2

Mean Eggs Per Tow and Water Temperature Near the Spawning Areas in 1963 and 1964

in 1964 in the Sacramento River above the mouth of the Feather River when the water temperature dropped following cold weather from May 1 to May 5 and from June 4 to June 11 (Figure 5). The drop in water temperature in the first week of May was widespread and caused spawning to cease throughout the Delta (see Figure 3d).

Previous studies of striped bass spawning have shown a close relationship between water temperature and spawning. Although eggs have been found in a range of temperature from 10.0 to 23.9°C, the onset of spawning usually occurs at 14.4 to 15.6°C (May and Fuller, 1962; Chadwick, 1958), and the peak of spawning has usually been at about 18.3°C (Mansueti and Hollis, 1963). The cessation of spawning due to a sudden drop in temperature has been observed in several instances (Calhoun, Woodhull and Johnson, 1950; Chadwick, 1958; Mansueti and Hollis, 1963).

In addition to the relationship of certain temperatures to the onset and peak of spawning and the starting and stopping effect caused by fluctuating temperatures, some biologists believe that temperature may affect the location of spawning. Calhoun, Woodhull and Johnson (1950) theorized that bass continue to migrate up the river until the water becomes warm enough for spawning, so in years when the Delta and rivers remain cool in spring (years of heavy runoff), bass migrate farther up river than they do in years when the water is relatively warm in spring (years of low runoff).

The results of my sampling in the Sacramento River in 1963 and 1964 support this theory. In 1963 (a wet spring), the water temperature did not reach 15.6°C at Rio Vista until May 17; most spawning in the Sacramento River was between river mile 50 and river mile 170. In 1964, a relatively dry spring, the water reached 15.6°C on April 13 and most spawning took place below river mile 60.

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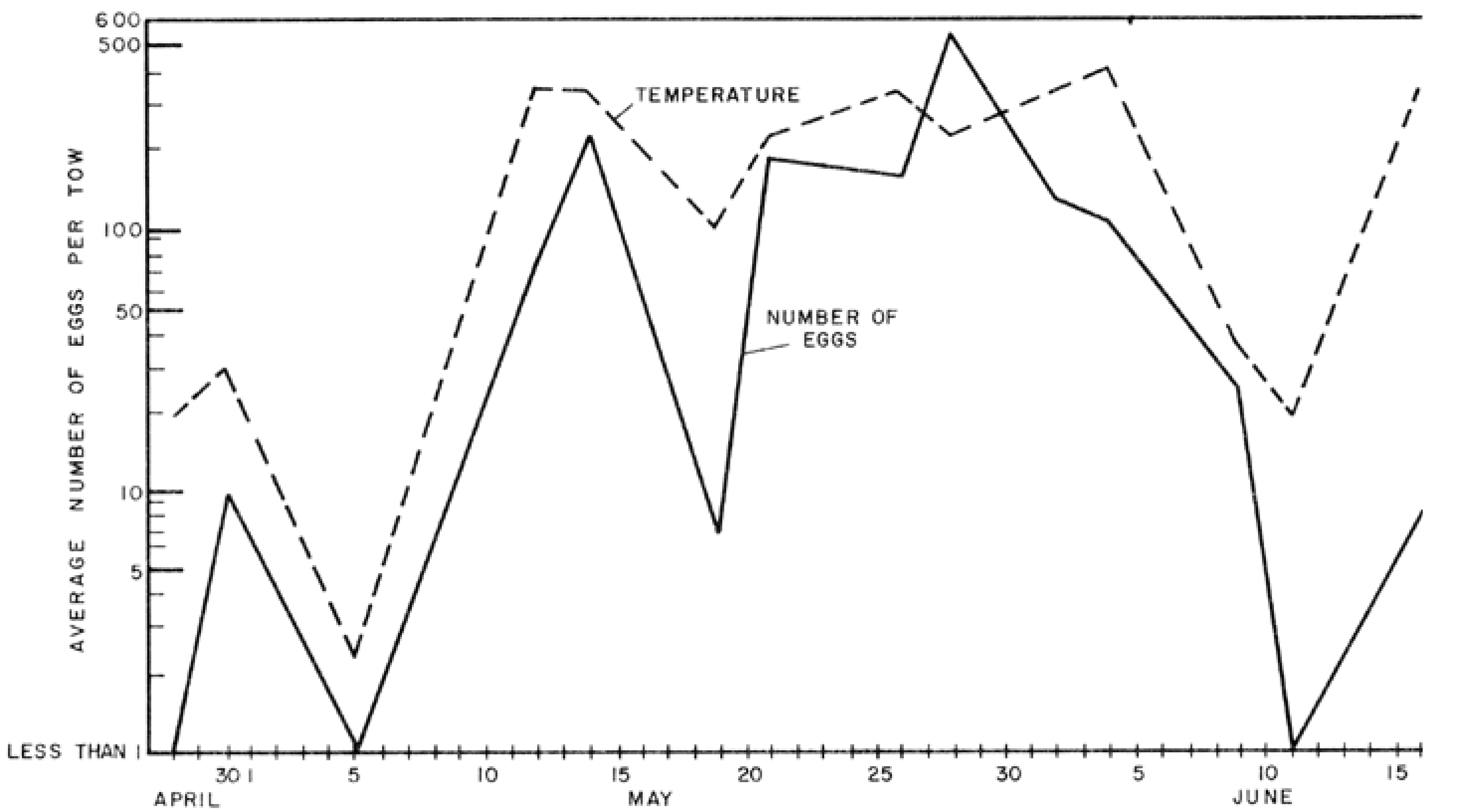


FIGURE 5. The relationship of water temperature to spawning activity in the Sacra River above the mouth of the Feather River in 1964.

FIGURE 5. The relationship of water temperature to spawning activity in the Sacramento River above the mouth of the Feather River in 1964

THE EFFECT OF TOTAL DISSOLVED SOLIDS ON SPAWNING

I know of no documented case of striped bass spawning in brackish or saline water, although eggs have been collected there. In California, Chadwick (1958) collected three eggs in Suisun Slough, a tributary to Suisun Bay, in 1957. The salinity was 1.3%. In some short Chesapeake Bay tributaries, striped bass eggs have been found in salinities greater than 3%; in 1959 eggs were collected in the Blackwater River in salinities from 4.72 to 11.28% (Edgar Hollis, pers. commun.). In both of these instances, it is possible that spawning took place in fresh water upstream from the collection site.

TABLE 3

Concentration of Total Dissolved Solids at or Near Striped Bass Spawning Areas in 1963 and 1964 [1]

Location	April	May
1963		
San Joaquin River at Mossdale	171	73
San Joaquin River at Antioch	179	113
Sacramento River at Freeport	56	73
1964		
San Joaquin River at the Mouth of False River	153	120
Sacramento River at Ryde	96	112

[1] 1963 TDS information from Calif. Dept. of Water Resources (June 1963, July 1963). 1964 TDS information obt directly from water samples collected when sampling for eggs and larvae.

TABLE 3

Concentration of Total Dissolved Solids at or Near Striped Bass Spawning Areas in 1963 and 1964

In both 1963 and 1964 most spawning in the Sacramento-SanJoaquin River system occurred in water with a total dissolved solids (TDS) content below 180 ppm [(Table 3)]. In 1963 water throughout the Delta and tributaries was relatively fresh during the spawning period due to a heavy spring runoff, and bass migrated far up the Sacramento and San Joaquin rivers to spawn. In 1964 the San Joaquin River at and above Stockton averaged between 650 and 1,000 ppm TDS concentration,

and very little spawning took place there. Radtke (see p. 17) found a heavy concentration of adult bass 5 miles below Stockton in April. He concludes (see p. 26) that these fish did not migrate farther up the river because of the high TDS concentration there.

In three previous studies [(Table 4)], bass eggs were found to have originated in the San Joaquin River above Stockton. The TDS concentration was less than 250 ppm during May in each of those years.

TABLE 4

Presence or Absence of Spawning in the San Joaquin River Above Stockto Years When Spawning Surveys Were Made There. TDS Measurements Taken at Mossdale

Year	Spawning	TDS in May (ppm)
1948	Yes[1]	120[4]
1949	Yes[1]	250[5]
1952	Yes[2]	61[6]
1963	Yes[3]	73[7]
1964	No[3]	661[3]

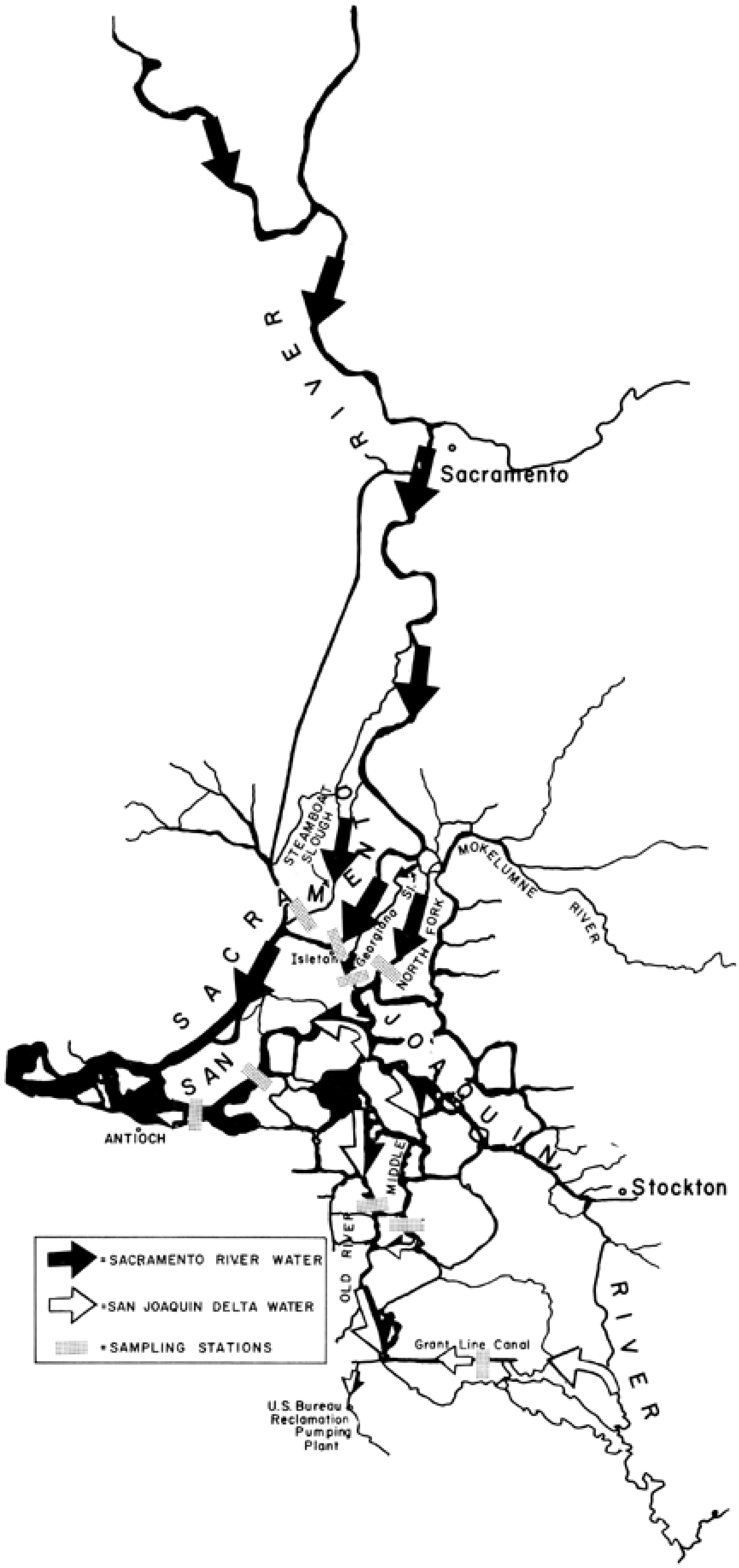
[1] Erkkila, et al (1950).
[2] U.S. Dept. of the Interior (1957).
[3] Results of this Survey.
[4] Calif. Div. of Water Resources (1949).
[5] Calif. Div. of Water Resources (1950).
[6] Calif. Div. of Water Resources (1953).
[7] Calif. Dept. of Water Resources (June, 1963).

TABLE 4

Presence or Absence of Spawning in the San Joaquin River Above Stockton in Years When Spawning Surveys Were Made There. TDS Measurements Taken at Mossdale

THE RELATIVE AMOUNT OF SPAWNING IN THE SACRAMENTO AND SAN JOAQUIN RIVER SYSTEMS

Measurement of the amount of water strained during each tow in 1964 allowed an estimation of the relative importance of the Sacramento and San Joaquin rivers as spawning areas. The mean weekly catch of eggs and larvae per tow at Steamboat Slough, Isleton, Georgiana Slough and the North Fork of the Mokelumne River was used to estimate the total amount of eggs and larvae from the Sacramento River. These stations represent all major locations where Sacramento River water enters the Delta (Figure 6), and my estimates assume that all eggs spawned in the Sacramento River in 1964 passed these points. For a comparable estimate of eggs spawned in the San Joaquin River and Delta, the stations at Grant Line Canal, Old River near Bacon Island, Middle River, and an average of the catch at Antioch and the mouth of False River stations in the San Joaquin River were used (Figure 6). The Grant Line Canal station provided a measure of the few eggs and larvae originating there and also any eggs or larvae present in the upper San Joaquin River water as it was drawn across to the U. S. Bureau of Reclamation pumping plant. The other three stations represented the possible directions that eggs and larvae could have been transported from the lower San Joaquin River spawning area. The Antioch and mouth of False River stations were averaged because the Antioch station was always sampled early in the morning and the False River station was sampled in mid afternoon; averaging the catches gave a better estimate of the eggs passing through that stretch of river throughout the day. It is assumed that all eggs and larvae spawned in the San Joaquin River system passed these points; although due to low net flows in the river at the time, it is possible



Sacramento
SACRAMENTO RIVER
STEAMBOAT SLOUGH
Georgiana Sl.
NORTH FORK
MOKELUMNE RIVER
Isleton
SAN JOAQUIN RIVER
ANTIOCH
MIDDLE
OLD RIVER
Stockton
Grant Line Canal
U.S. Bureau Reclamation Pumping Plant
= SACRAMENTO RIVER WATER
= SAN JOAQUIN DELTA WATER
= SAMPLING STATIONS

FIGURE 6. Direction of water flow from the major spawning areas in 1964.

FIGURE 6. Direction of water flow from the major spawning areas in 1964

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that some eggs and larvae were retained upstream from the sampling stations.

The estimate of eggs produced was made by applying the following formula to the 1964 egg catches for each of the nine index stations during each week of the survey:

$$E = \frac{e}{w} \times f \quad \text{where}$$

EQUATION

E = number of eggs and larvae flowing past the station in a week e = mean number of eggs and larvae per tow at the station during the week w = mean volume of water strained during each tow f = net volume of water flow past the station during the week

The sum of the estimates of the total number of eggs passing the index stations each week is an estimate of the total eggs surviving to these points. Some bias could be introduced into the calculations if the average age of eggs and larvae caught at the index stations of one system differed significantly from the average age of eggs and larvae caught at the index stations of the other system. All other things being equal, the oldest eggs and larvae probably would have suffered a higher natural mortality than the younger ones; this could result in an underestimate of the relative number of eggs produced in the system where the average age was highest. Detailed knowledge of the survival rate versus age of striped bass eggs and larvae is needed before this factor can be accounted for in future calculations.

Assuming that egg survival is equal in both rivers, the Sacramento River contributed approximately 66 percent of the total and those from the San Joaquin Delta made up 34 percent of the total [(Table 5)].

HYPOTHESES ABOUT THE LOCATION OF BASS SPAWNING

A hypothesis of what causes striped bass to spawn where they do brings together some of the important results of this paper. Some adults spend the winter in the Delta, but most of the spawning population migrates upstream from the bay in the spring (see Radtke, p. 18). As the bass reach the confluence of the Sacramento and San Joaquin rivers, they can go up either river. What causes them to choose one river or the other is a matter of conjecture although there is some evidence that bass tend to return to the river where they spawned the previous year (Chadwick, 1967). Fish that choose the Sacramento River keep migrating upstream until the water temperature approaches that necessary for the onset of spawning (14.4 to 15.6°C). When water temperatures remain cool in spring, as they did in 1963, bass migrate farther up the river to spawn than when the water warms early in the spring, as it did in 1964.

In some years bass spawn in the Feather River. In 1948 Calhoun, Woodhull, and Johnson (1950) found many eggs in the Feather River when they sampled off the highway bridge at Nicolaus. I found no evidence of spawning in the Feather River in either 1963 or 1964. In 1963, when many bass migrated past the mouth of the Feather River

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TABLE 5

The Relative Amount of Striped Bass Spawning in the Sacramento and San Joaquin River Systems in 1964 [1]

	Sacramento River System				San Joaquin River System			
	Steam-boat Slough	Sacra-mento River at Isleton	Georgiana Slough	North Fork of the Mokel-umne River	Grantline Canal	Middle River	Old River at Bacon Island	S Joa Ri a Ant
April 12-18	2.8	5.0	0.0	0.0	0.4	0.1	0.4	
April 19-25	1.0	27.3	0.2	0.8	0.0	0.0	0.5	
April 26–May 2	4.7	0.6	0.2	0.3	3.5	1.8	1.3	
May 3-9	0.5	6.1	1.7	1.1	0.0	1.6	0.2	
May 10-16	239.9	685.0	123.6	81.5	1.1	2.5	0.7	
May 17-23	150.0	1,156.2	42.6	19.1	2.0	7.9	52.3	9
May 24-30	102.2	199.8	20.0	27.7	1.1	3.6	31.8	5
May 31–June 6	65.7	582.1	63.0	11.3	0.2	16.8	5.1	
June 7-13	13.6	116.1	42.9	4.9	0.0	6.9	36.7	
Station totals	580.4	2,778.2	294.2	146.7	8.3	41.2	129.0	1,8

Sacramento River System total = 3,799.5 San Joaquin Delta total = 1,97

Total for Both Areas = 5,778.4

$$\text{Sacramento River System} = \frac{3{,}799.5}{5{,}778.4} = 66\% \text{ of all Spawning}$$

$$\text{San Joaquin River System} = \frac{1{,}978.9}{5{,}778.4} = 34\% \text{ of all Spawning}$$

[1] All values are in millions of eggs and larvae.
[2] An average of the Antioch and False River stations.

TABLE 5

The Relative Amount of Striped Bass Spawning in the Sacramento and San Joaquin River Systems in 1964

to spawn in the upper Sacramento River, flow and temperature characteristics in the Feather River and Sacramento River were similar to the conditions existing there in 1948. Therefore, bass avoided the Feather River for some other reason.

The behavior of fish that choose to move up the San Joaquin River depends on the amount of runoff in the spring season, which in turn affects the total dissolved solid concentration of the water in the river. In wet springs, the TDS is low (below 250 ppm), and some fish migrate upstream past Stockton. In dry springs, the TDS is high and bass are blocked by a TDS "barrier" some place below Stockton; these fish then return to the lower San Joaquin River area to spawn. Radtke (see p. 24) concludes that current velocity conditions alone did not prevent bass from moving into the upper San Joaquin River in 1964 since the mean net velocities at Isleton and Mossdale were similar and bass moved past Isleton but not Mossdale.

In both wet and dry springs some spawning occurs in the lower San Joaquin River. Some bass that spawn there may consist of fish which have over-wintered in the nearby flooded islands. Large concentrations of bass over-winter in Big Break and Franks Tract (see Radtke, p. 17), and both Radtke and Calhoun (1946) have demonstrated a movement of ripe fish out of Franks Tract in April and May into the San Joaquin River nearby. The extensive shoals in that area of the river may be somehow attractive to bass waiting to spawn. I have no evidence that this is or is not true, except that I know bass do not necessarily select shallow water for spawning. I observed a large school

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of bass spawning in the San Joaquin River near False River on May 11, 1964. There is a shallow area near the north shore, but these fish were spawning throughout the full width of the river.

SUMMARY

Striped bass eggs and larvae were collected from 26 stations in 1963 and 33 stations in 1964 in the Sacramento-San Joaquin Delta and its tributaries. In the Sacramento River spawning areas were determined by back-tracking eggs and larvae to the place where they were spawned. This was accomplished by multiplying the age of an egg or larva by the river velocity upstream from the sampling stations. In the San Joaquin Delta the spawning areas were defined as those areas where young eggs were consistently caught.

In 1963 the main spawning areas in the San Joaquin River were from Antioch to Venice Island and upstream from Stockton. In the Sacramento River most spawning occurred above Sacramento.

In 1964 the main areas were the Sacramento River below Sacramento and the San Joaquin River from Antioch to Venice Island. No spawning took place in the upper San Joaquin River.

No significant amount of spawning occurred in water with a TDS content greater than 180 ppm, and in 1964 the migration up the San Joaquin River was blocked by a concentration exceeding that level. In both 1963 and 1964, spawning began when the water temperature reached 14.4 to 15.0°C.

Most spawning occurred when water temperatures were between 16.1 and 20.6°C.

A sudden drop in water temperature caused bass to cease spawning until the temperature rose again.

There is evidence that water temperature affects the location of spawning in the Sacramento River. In 1963 the river warmed up slowly and bass spawned from river mile 50 to river mile 170. In 1964 the river warmed up quickly and most bass spawned below river mile 60.

In general no evidence was found that bass prefer a particular type of environment for spawning other than it be flowing, fresh water. The location of spawning appears to depend upon water temperature and water quality conditions, which in turn depend upon the weather and the amount of spring runoff.

LITERATURE CITED

Calhoun, Alex J. 1946. Observations of the striped bass fishery in the Sacramento Delta area during April and May 1946. Calif. Fish and Game, Inland Fish. Admin. Rept., (46–12) : 1–36. Calhoun, A. J., C. A. Woodhull and Wm. C. Johnson. 1950. Striped bass reproduction in the Sacramento River system in 1948. Calif. Fish and Game, *36*(2) : 135–145. California Department of Water Resources. 1962. Sacramento River water pollution survey. Bull. 111. California Department of Water Resources. 1963. Quality of California surface waters in April 1963, 24 p. California Department of Water Resources. 1963. Quality of California surface waters in May 1963, 27 p. California Department of Water Resources. 1963. Quality of California surface waters in June 1963, 24 p. California Division of Water Resources. 1949. Report of Sacramento-San Joaquin water supervision for 1948, 158 p. California Division of Water Resources. 1950. Report of Sacramento-San Joaquin water supervision for 1949, 193 p.

— 43 —

California Division of Water Resources. 1953. Report of Sacramento-San Joaquin water supervision for 1952, 209 p. Chadwick, Harold K. 1958. A study of the planktonic fish eggs and larvae of the Sacramento-San Joaquin Delta with special reference to striped bass. Calif. Dept. Fish and Game, Inland Fish. Admin. Rept. (58-5) : 1–23.

(typewritten). Chadwick, Harold K. 1967. Recent migrations of the Sacramento-San Joaquin River striped bass population. Ms. Erkkila, L. F., J. W. Moffett, O. B. Cope, B. R. Smith, and R. S. Nielson. 1950. Sacramento-San Joaquin Delta fishery resources: Effect of Tracy pumping plant and Delta cross channel. U. S. Fish and Wildl Serv., Spec. Sci. Rept., Fish., (56) : 1–109. Mansueti, Romeo. 1958. Eggs, larvae and young-of-the-year striped bass, Roccus saxatilis. Maryland Dept. Res. and Educ., Contrib. (112) : 1–35. Mansueti, Romeo J., and Edgar H. Hollis. 1963. Striped bass in Maryland tidewater. Univ. Maryland, Nat. Res. Inst., Educ. Ser. (61) : 1–23. May, Otho D., Jr., and J. C. Fuller, Jr. 1962. A study on striped bass egg production in the Congaree and Wateree Rivers. South Carolina Wildl. Res. Dept., Division of Game, 39 p. U. S. Department of the Interior. 1957. Fish protection at the Tracy pumping plant, Central Valley Project, California. Bureau of Reclamation, Reg. 2, Sacramento, Calif. and Fish and Wildlife Service Reg. 1, Portland, Ore., 96 p.

DISTRIBUTION OF YOUNG STRIPED BASS, ROCCUS SAXATILIS, IN THE SACRAMENTOSAN JOAQUIN DELTA

SHOKEN SASAKI

Young striped bass (1963 year-class) were sampled in the Sacramento-San Joaquin Delta with a midwater trawl and an otter trawl from September 1963 to August 1964. They were most abundant in the Delta during the fall. There was evidence that large numbers of young bass migrated from the Delta downstream to San Pablo Bay area during the fall and winter of 1963. Concentrations of young bass in the Delta remained low through the following spring and summer. The concentrations were almost always greatest over the shoals in the lower San Joaquin River. This region was the most important nursery area in the Delta for young bass.

DEFINITION OF "YOUNG" STRIPED BASS

In this paper the term "young" striped bass applies to the 1963 year-class. Members of this year-class were identified by analyzing the length frequencies of the bass caught in both the otter and midwater trawls (Figure 1). These bass grew from a range of 5 to 12 cm (*FL*) in September 1963 to a range of 12 to 23 cm in August 1964.

THE INDEX OF CONCENTRATION

The description of the distribution of young striped bass in this paper is based on an "index" of concentration. This index is an approximation which considers the catch of bass by both the otter and midwater trawls and the relative volume of the Delta channel represented by the catch of each.

In the channels, the otter trawl sampled the water within 5 feet of the bottom. The midwater trawl sampled the water within 10 feet of the surface. Large numbers of young striped bass were caught in both the otter trawl and the midwater trawl. Neither gear was adequate by itself. Concentrations of bass near the bottom were missed with the midwater trawl and concentrations near the surface were missed by the otter trawl.

A valid index of concentration of young striped bass must therefore be based on the catch of both gears so that all depths and levels in the channel are represented. Since the vertical distribution of the bass can be expected to change with the season and to be different in different areas, and since the two nets could not be expected to catch fish equally well, the catch data of the two gears could not simply be added or averaged. These catch data were adjusted (i) with an estimate of the efficiency of the two nets and (ii) by weighting the mean catch of each gear according to the relative amount of "midwater" and "bottom" water at the sampling station. Only after this adjustment

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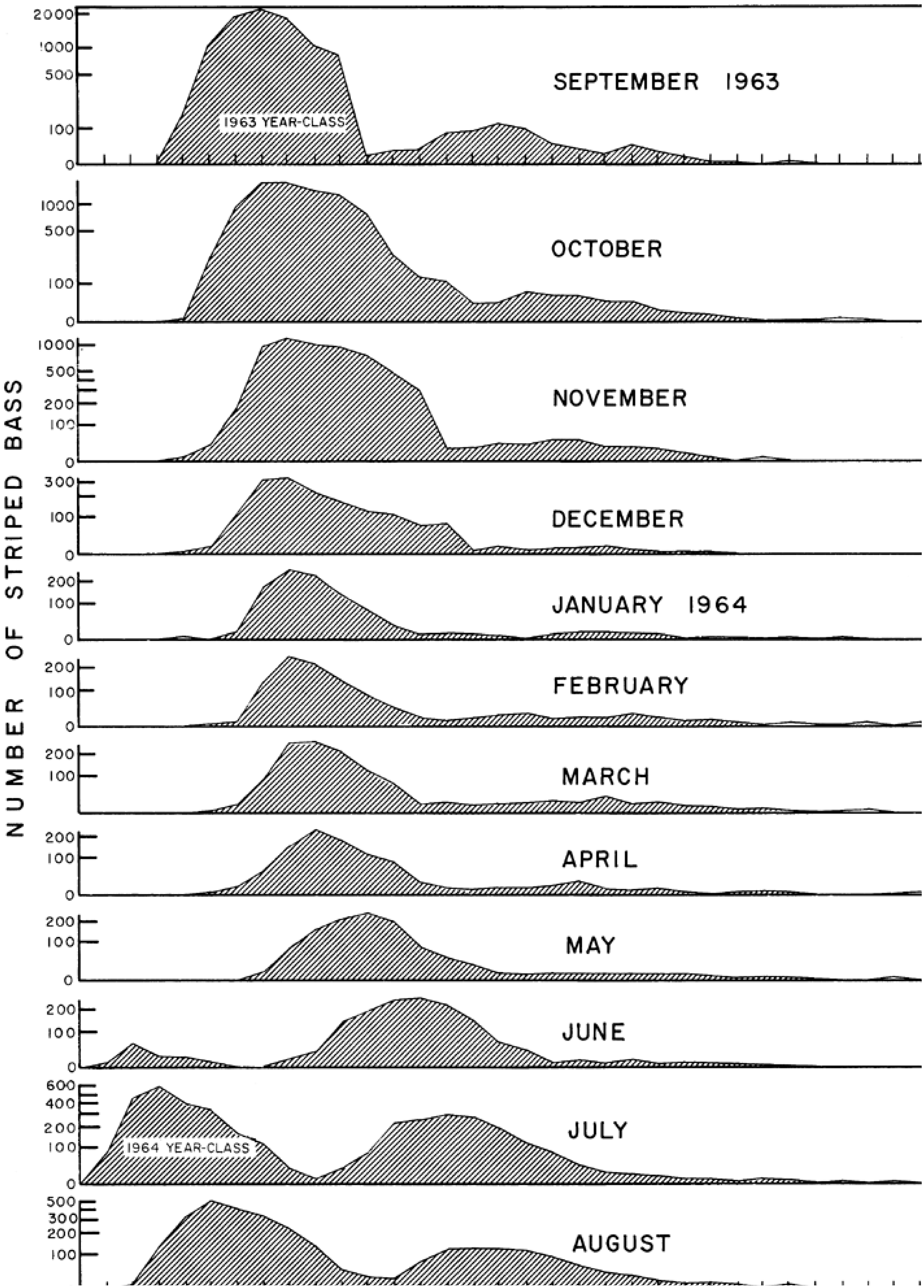
NUMBER OF STRIPED BASS
SEPTEMBER 1963
1963 YEAR-CLASS
OCTOBER
NOVEMBER
DECEMBER
JANUARY 1964
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
1964 YEAR-CLASS
AUGUST

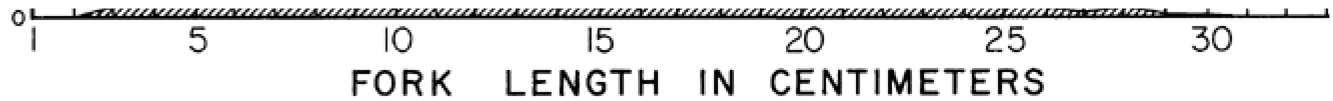

FIGURE 1. Length frequency of striped bass taken with the otter and midwater from September 1963 to August 1964.

FIGURE 1. Length frequency of striped bass taken with the otter and midwater trawls from September 1963 to August 1964

could the catch data be combined and valid comparisons made of indices of concentration from one station or time to another.

Relative Efficiency of Otter Trawl and Midwater Trawl

The relative efficiency of the otter trawl and the midwater trawl was estimated by fishing each trawl along with a third kind of gear,

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a floating gill net that collected the same size striped bass as the trawls.

On November 17, 1964, three 1-hour drifts were made with a 150 foot by 10 foot gill net with a stretch mesh of ⅝ inch. The net was floated at the surface in deep water in the San Joaquin River near West Island. At the same time, nine 10-minute tows were made with the midwater trawl in the path of the gill net. The mean gill net catch was 19.7 bass per hour drift while the mean midwater trawl catch was 13.6 bass per tow [(Table 1)]. Since the midwater trawl strains an area of 100 square feet (see Turner, p. 12), the mean midwater trawl catch was 0.136 bass per square foot.

TABLE 1

Comparison of the Efficiency of the Otter and Midwater Trawls. Figures are Numbers of Young Striped Bass Per Trawl Tow or Per Hour Drift

Midwater trawl	Gill net drifting near surface in deep water	Gill net drifting at bottom in shallow water	Otter trawl
35	23.2	136.0	279
11	18	86.6	275
10	18		166
16			421
11			222
16			
9			
4			
11			
Sample mean...13.6	19.7	111.3	272.4

TABLE 1

Comparison of the Efficiency of the Otter and Midwater Trawls. Figures are Numbers of Young Striped Bass Per Trawl Tow or Per Hour Drift

On November 20, 1964, two 1-hour drifts were made with the gill net on the shoals near West Island in water where the lead line dragged on the bottom. The depth was about 4 to 10 feet. While these drifts were being made, five 10-minute hauls of the otter trawl were made in the path of the gill net. The mean catch of young striped bass in the otter trawl was 272.4 per tow while the mean gill net catch was 111.3 per hour drift (Table 1). The otter trawl strains an area of 75 square feet (see Turner, p. 12), so the mean otter trawl catch was 3.632 bass per square foot.

It was assumed that the drifting gill net fished in the deep water with the same efficiency that it did while fishing over the shoal area. Therefore, we increased the gill net catch in the deep area by a factor of 5.65 to equal that of the gill net catch in the shoal area and increased the midwater trawl catch proportionately. The adjusted midwater trawl catch was 0.768 bass per square foot, therefore the otter trawl was 3.632/0.768 or roughly 4.7 times more efficient than the midwater trawl. Accordingly, for the analysis in this paper, the midwater trawl catches were multiplied by a factor of 4.7.

Vertical Distribution of Young Striped Bass

A comparison of otter trawl catches with adjusted midwater trawl (x 4.7) catches demonstrated that the vertical distribution of young bass varied considerably from station to station during fall and winter but there was a tendency for young bass to be concentrated on the

— 47 —

bottom at most stations [(Table 2)]. During the spring, more bass were found in the midwaters. In the summer, young bass were definitely more concentrated in the midwaters.

TABLE 2

Seasonal Comparison of Mean Otter Trawl Catches with Mean 4.7 Midw Trawl Catches of the 1963 and 1964 Year-Class of Striped Bass at Various Stations from September 1963 to August 1964

Stations	Mean Otter Trawl Catch/Mean 4.7 Midwater Trawl Ca				
	1963 year class				1[illegible] year
	Fall	Winter	Spring	Summer	Sur
Sacramento River—Isleton	34.3	1.0	5.7	1.0	[illegible]
Sacramento River—Sherman Island	0.2	1.2	0.09	0.4	[illegible]
San Joaquin River—Mossdale	34.9	27.5	3.2	0.1	[illegible]
San Joaquin River—Fourteen Mile Slough	0.3	2.4	0.9	0.1	[illegible]
San Joaquin River—Santa Clara Shoal—Deep	0.01	0.8	0.06	0.08	[illegible]
San Joaquin River—West Island—Deep	0.1	0.8	0.6	0.1	[illegible]
Mokelumne River—North Fork	7.5	----	0.9	0.5	[illegible]
Mokelumne River—South Fork	12.1	----	2.5	2.0	[illegible]
Mokelumne River—Terminous	14.9	4.2	7.7	1.1	1[illegible]
Old River—Fabian and Bell Canal	2.1	4.2	2.3	0.2	[illegible]
Old River—Victoria Island	5.5	3.3	0.6	0.3	[illegible]
Dead-end Slough—Sycamore Slough	36.6	2.2	0.6	0.03	[illegible]
Dead-end Slough—Hog Slough	32.8	----	0.2	0.1	[illegible]
Dead-end Slough—Indian Slough	0.4	0.5	0.1	0.1	[illegible]

TABLE 2

Seasonal Comparison of Mean Otter Trawl Catches with Mean 4.7 Midwater Trawl Catches of the 1963 and 1964 Year-Class of Striped Bass at Various Stations from September 1963 to August 1964

The 1964 year-class of striped bass appeared in the catch in large numbers in July and August of 1964. These bass were most concentrated in the midwaters at most stations (Table 2).

Because of these differences in the vertical distribution, the numbers of bass caught in the otter trawl could not simply be averaged with the numbers caught in the midwater trawl (x 4.7) for an index of the concentration of bass at each station. Each adjusted catch of bass in the midwater trawl was weighted by the proportion of the channel

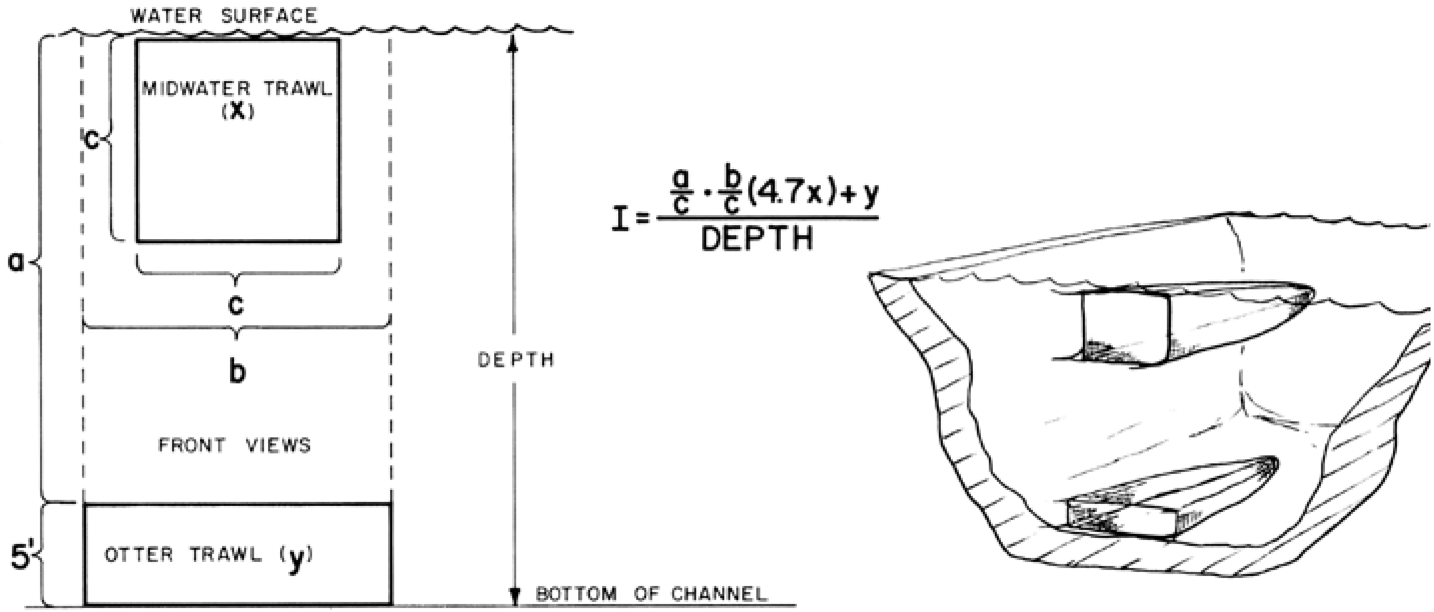

FIGURE 2. Index of concentration "I" where:
- a = the depth of water represented by the midwater trawl.
- b = the width of water represented by the midwater trawl. This width is equal to width of otter trawl.
- x = the mean catch of bass in the midwater trawl.
- c = the depth and width of water actually sampled by the midwater trawl.
- y = the mean catch of bass in the otter trawl in a constant 5-foot depth from the bot

FIGURE 2. Index of concentration "I" where:

a = the depth of water represented by the midwater trawl.

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x = the mean catch of bass in the midwater trawl.

c = the depth and width of water actually sampled by the midwater trawl.

y = the mean catch of bass in the otter trawl in a constant 5-foot depth from the bottom.

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from 5 feet off the bottom to the surface before adding it to the otter trawl catch. This total catch was then divided by the station water depth to derive the index of concentration of bass for each station (Figure 2).

GEOGRAPHICAL DIFFERENCES IN POPULATION DENSITY

Striped bass spawned in and above the Delta during late May and early June 1963 (see Farley, p. 30), and personnel of the California Department of Fish and Game started to collect large numbers of 1.8–5.0 cm long young striped bass in late June with a tow net having a bobbinet cod end with 2.5 mm diameter openings.

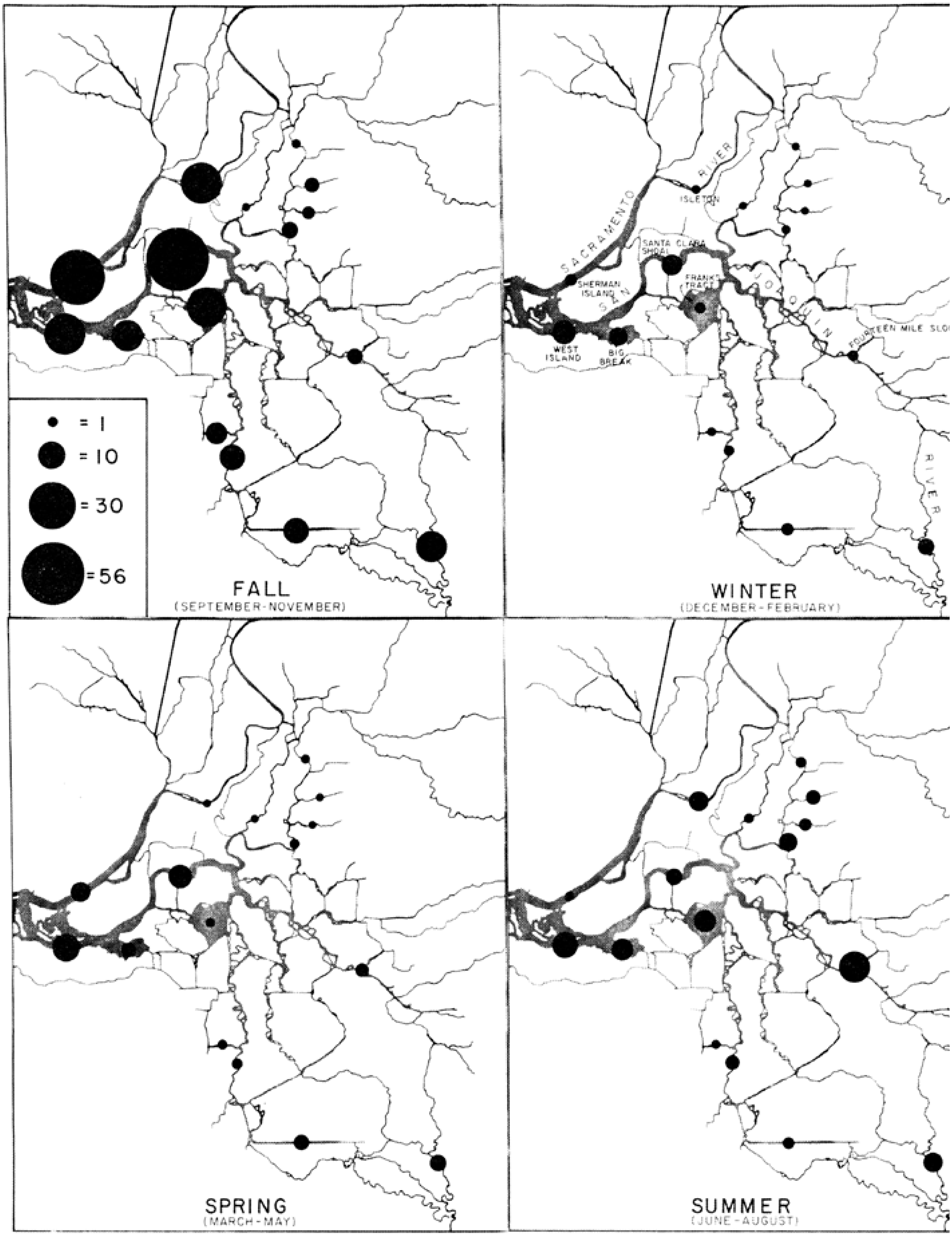

FIGURE 3. Distribution of 1963 year-class striped bass, September 1963 to August
The area of each circle represents the index of concentration (see text, page 44).

FIGURE 3. Distribution of 1963 year-class striped bass, September 1963 to August 1964. The area of each circle represents the index of

concentration (see text, page 44)

These young bass were abundant in the Delta when we started sampling in September 1963 (Figure 3). They were most concentrated in the western Delta. Concentrations were especially high in the San Joaquin River at West Island and Santa Clara Shoal, in the Sacramento River at Sherman Island and Isleton, and in flooded islands (Big Break and Franks Tract).

By winter the concentrations of young bass in the Delta had declined. A sudden and large drop in catches occurred between November and December (Figure 4). Ganssle (1966) reported that catches in San Pablo Bay increased from almost nothing in September to almost 150 bass per tow in November (Figure 4). Since striped bass do not spawn in San Pablo Bay (see Farley, p. 33), these young bass must have emigrated from the Delta to San Pablo Bay in the fall. Fall catches of young bass in San Pablo Bay were very low in 1964 suggesting a possible difference in emigration pattern that year (Ganssle, 1966).

Other biologists have also suggested that young bass migrate toward the ocean when they are a few months old. Scofield and Bryant (1926) based their belief on age and growth studies which showed a large "sea growth" in the second year and also in the high catches of young striped bass in the fall and winter by shrimp nets fishing on the ebb tide between San Pablo and San Francisco bays. Erkkila, *et al.* (1950), sampling in the Sacramento-San Joaquin Delta, found increasing numbers of young bass in the lower San Joaquin River and Sacramento River along with a decreasing number of bass in the central and southern Delta during late summer. On the East Coast, Mansueti (1954) based his belief on finding young bass farther downstream toward the lower rivers and bay as time progressed after the spawning period.

Concentrations of young bass in the Delta were never high after the fall migration (Figure 3).

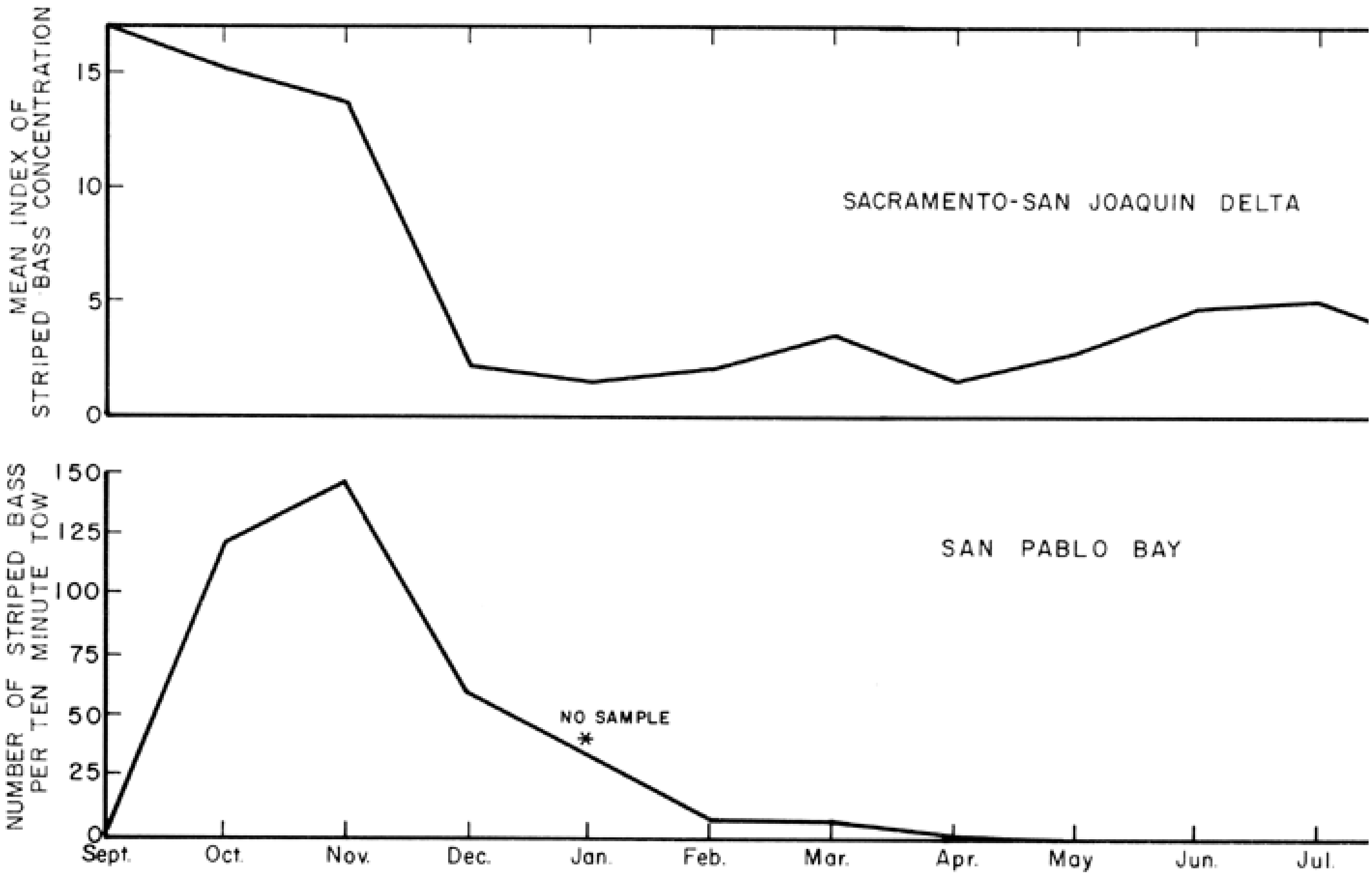

FIGURE 4. Comparison of the monthly mean index of concentration (see text, p. 44) Delta and the monthly average otter trawl catches in San Pablo Bay (Ganssle, 1966) 1963 year-class striped bass, September 1963 to August 1964.

FIGURE 4. Comparison of the monthly mean index of concentration (see text, p. 44) in the Delta and the monthly average otter trawl catches in San Pablo Bay (Ganssle, 1966) of the 1963 year-class striped bass, September 1963 to August 1964

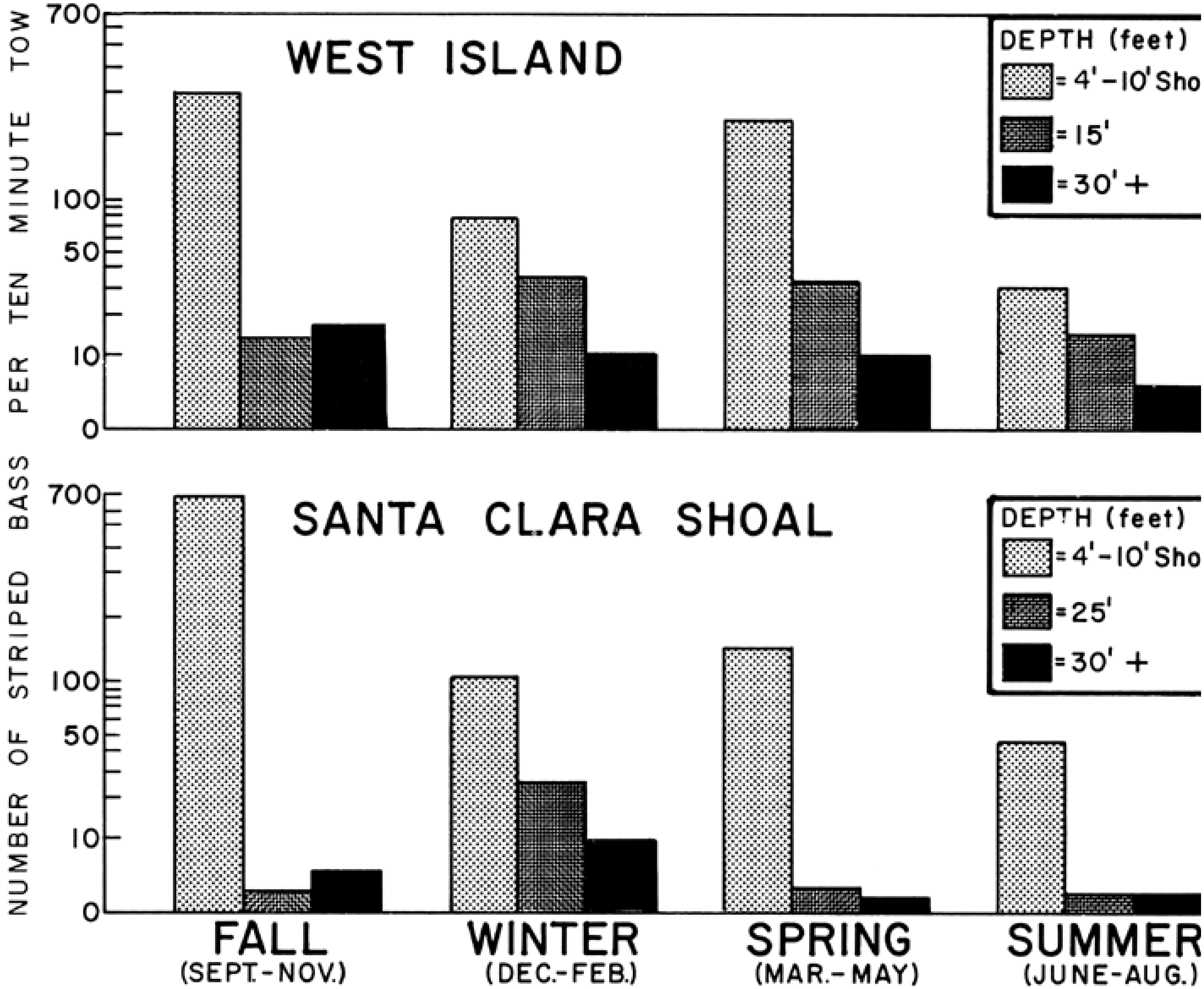

FIGURE 5. Average catch by season of the 1963 year-class striped bass taken at v bottom depths by otter trawl at West Island and Santa Clara Shoal on the San Jo River during 1963–1964.

FIGURE 5. Average catch by season of the 1963 year-class striped bass taken at various bottom depths by otter trawl at West Island and Santa Clara Shoal on the San Joaquin River during 1963–1964

The concentration of young striped bass did increase in the San Joaquin River near Fourteen Mile Slough during the summer of 1964. Stevens (see p. 93) believes that this increase may have been caused by young bass moving down into the Delta from the upper river areas.

Young bass in the lower San Joaquin River were always more concentrated over the shoal areas than in the deeper water (Figure 5).

Large numbers of the new (1964) year-class of striped bass were collected in July and August 1964 (Figure 1). These bass were too small to be trapped by the ¾ inch stretch mesh on the cod end of the trawls before July. The largest concentrations were in the flooded islands, in the lower San Joaquin River at West Island and in the Sacramento River at Sherman Island (Figure 6).

GEOGRAPHICAL DIFFERENCES IN TOTAL POPULATION

Delta channels vary a great deal in size so the index of concentration (Figure 2), a measure of population *density*, does not indicate (i) what proportion of the population of young bass in the Delta is in different areas of the Delta or (ii) the *changes* in *total* numbers of young striped bass in the Delta from season to season. To do this the weighted catch in a column of water at each station (the numerator of the index of concentration formula, Figure 2) must be adjusted by the surface area of that portion of the Delta it represents. The Delta was divided into eight environmental zones based largely on river systems and flow.

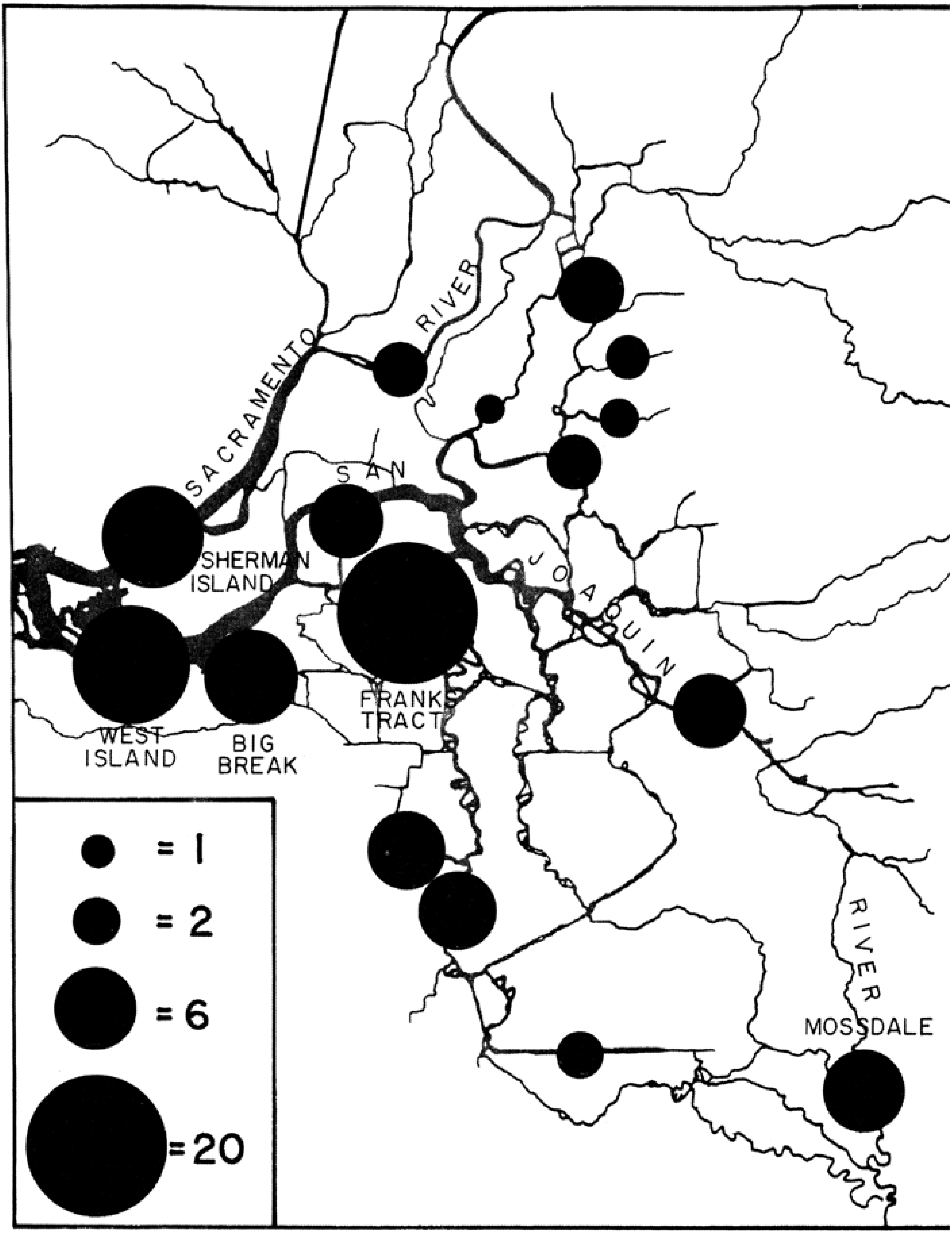

FIGURE 6. Distribution of 1964 year-class striped bass in summer (June, July, and Au 1964. The area of each circle represents the index of concentration (see text, p. 44).

FIGURE 6. Distribution of 1964 year-class striped bass in summer (June, July, and August) 1964. The area of each circle represents the index

of concentration (see text, p. 44)

These zones are the Sacramento River, Mokelumne River, the upper, middle, and lower San Joaquin River, south Delta, flooded islands, and dead-end sloughs (Figure 7). The mean weighted catch of bass in each zone was multiplied by the percent of the Delta area represented by each zone [(Table 3)]. The products are population indices useful to compare the proportion of the Delta population in different parts of the Delta and to describe changes in the relative abundance of young striped bass from season to season (Figure 8).

In the fall of 1963, 79 percent of the young striped bass in the Delta were in the lower San Joaquin (I) and Sacramento River (II) environmental zones (Table 3). About 10 percent were in the flooded islands (III).

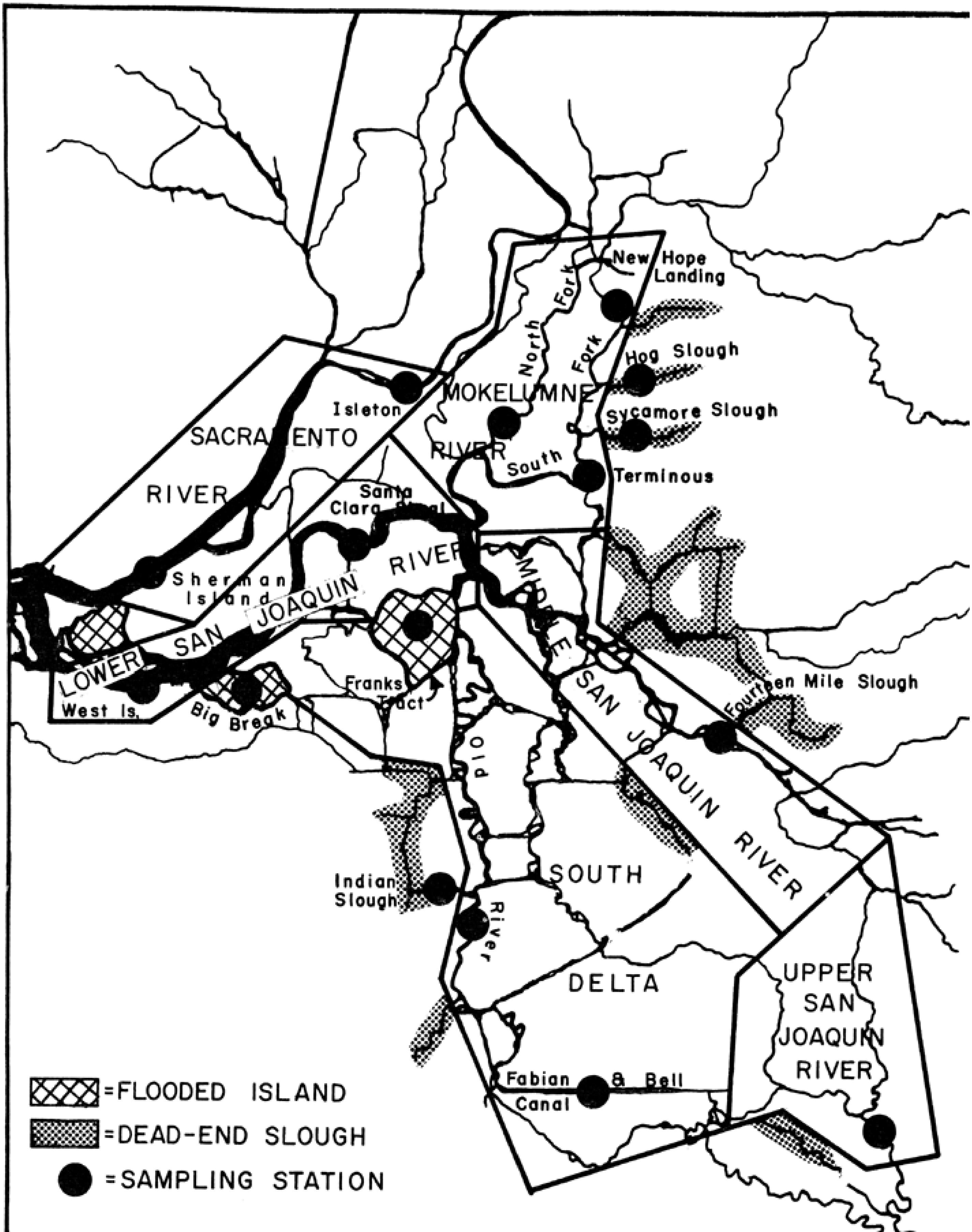

FIGURE 7. Location of sampling stations and areas of similar environments in the Sacran San Joaquin Delta.

FIGURE 7. Location of sampling stations and areas of similar environments in the Sacramento-San Joaquin Delta

During the winter, the population of young striped bass in the Delta was reduced to about one-ninth of what it was in the fall. Evidence has already been presented that leads me to believe most of these young striped bass migrated downstream into the bay portion of this estuary.

The population of young striped bass in the Delta remained low until the following summer when it about doubled. This increase was almost entirely due to a build-up in the concentration of young bass in the middle San Joaquin River zone (V) and to a lesser extent in the flooded island zone (III). The increase in population in the middle San Joaquin River may have been a result of some young bass over-wintering above the Delta in the San Joaquin River and migrating

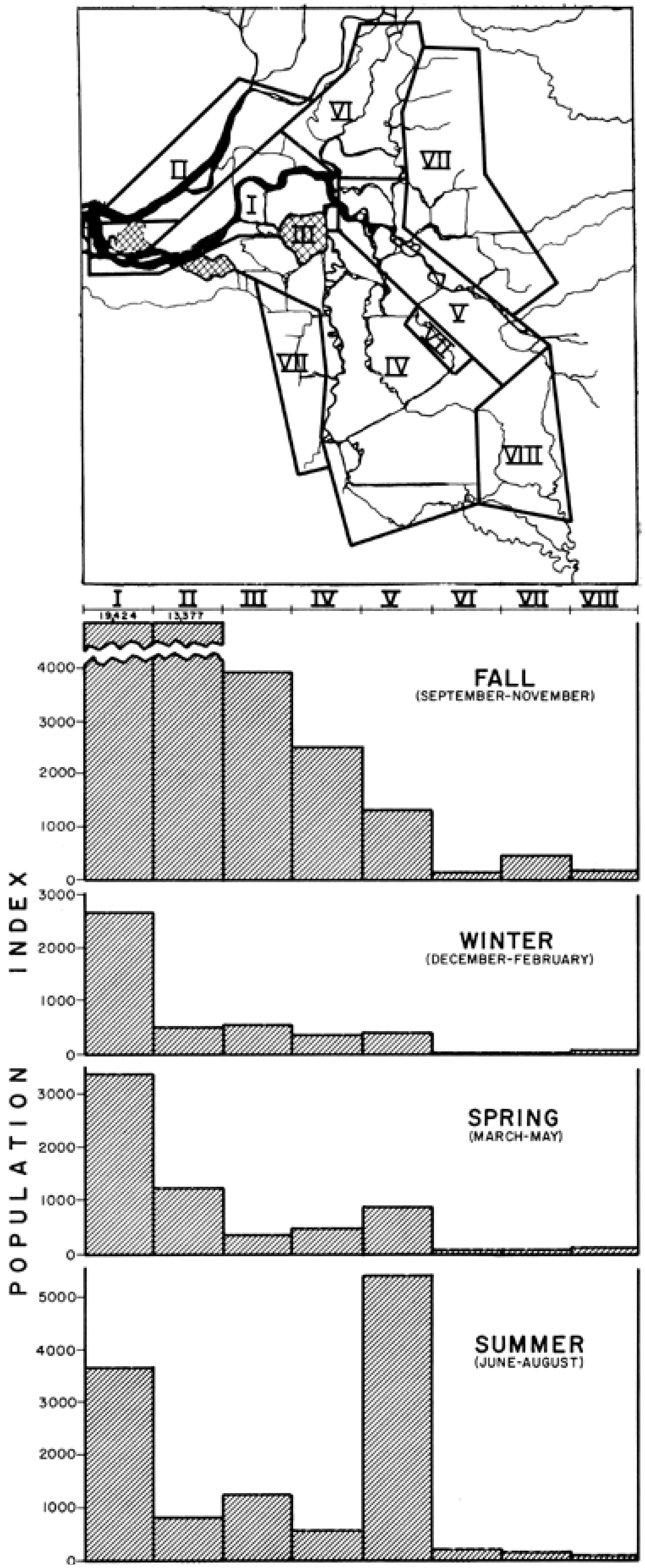
I
II
III
IV
V
VI
VII
VIII
19,424
13,377
FALL
(SEPTEMBER-NOVEMBER)
WINTER
(DECEMBER-FEBRUARY)
SPRING
(MARCH-MAY)
SUMMER
(JUNE-AUGUST)
POPULATION INDEX
0
1000
2000
3000
4000
5000

FIGURE 8. Population indices of 1963 year-class striped bass, 1963–1964.

FIGURE 8. Population indices of 1963 year-class striped bass, 1963–1964

TABLE 3

Relative Abundance of Young Striped Bass in the Environmental Zones

Environmental zones	Percent of Delta Area	Fall: Mean weighted catch	Fall: Pop. index	Fall: Percent of pop. in zone	Winter: Mean weighted catch	Winter: Pop. index	Winter: Percent of pop. in zone
I Lower San Joaquin River—Deep	18.9	871.1	16,464	46.9	117.7	2,224	58.2
I Lower San Joaquin River—Shoals	5.7	519.0	2,960		89.9	512	
V Middle San Joaquin River	12.4	104.6	1,297	3.1	32.0	397	8.4
VIII Upper San Joaquin River	2.1	124.7	262	0.6	36.7	77	1.6
II Sacramento River	15.3	874.3	13,377	32.3	33.7	515	11.0
VI Mokelumne River	5.4	24.9	134	0.3	3.5	19	0.4
IV South Delta	15.7	164.7	2,586	6.2	24.5	385	8.2
III Flooded Islands	17.6	223.0	3,925	9.5	30.5	537	11.4
VII Dead-end Sloughs	6.9	63.5	438	1.1	5.4	37	0.8
Quarterly population indices			41,443			4,703	

TABLE 3

Relative Abundance of Young Striped Bass in the Environmental Zones of the Delta During 1963–1964 down to the Delta during their second summer (see p. 50 and Stevens, p. 93).

Population indices were also calculated for the 1964 year-class striped bass in the Delta [(Table 4)] during the summer of 1964. Eighty-seven percent of these bass were in the middle San Joaquin River, the lower San Joaquin River, the flooded islands, and the Sacramento River environmental zones (Figure 9).

TABLE 4

Relative Abundance of 1964 Year-Class Striped Bass in the Environmental Zo of the Delta During Summer 1964

Environmental Zones	Percent of Delta Area	Mean Weighted Catch	Pop. Index	Pe of in
I Lower San Joaquin River—Deep	18.9	245.6	4,642 }	[illegible]
I Lower San Joaquin River—Shoals	5.7	58.9	336 }	
V Middle San Joaquin River	12.4	134.7	1,670	
VIII Upper San Joaquin River	2.1	67.2	141	
II Sacramento River	15.3	123.5	2,598	
VI Mokelumne River	5.4	39.5	213	
IV South Delta	15.7	70.7	1,110	
III Flooded Islands	17.6	168.4	2,964	[illegible]
VII Dead-end Sloughs	6.9	46.0	317	

TABLE 4

Relative Abundance of 1964 Year-Class Striped Bass in the Environmental Zones of the Delta During Summer 1964

EFFECT OF ENVIRONMENT ON CONDITION AND GROWTH OF YOUNG STRIPED BASS

To determine whether environment might have some effect on condition of young striped bass, the coefficient of condition (*K f1*) was calculated for 113 young striped bass collected over a 6-day period with the otter trawl from the three zones in the San Joaquin River during August 1964.

The young bass were selected from a small size range (16.6 cm to 19.1 cm) to minimize the effects of fish length on condition. The bass from the lower San Joaquin River were in better condition than those from the middle San Joaquin at Fourteen Mile Slough and the upper San Joaquin River at Mossdale [(Table 5)]. Differences in the mean coefficients of condition were significant at the one percent level.

TABLE 5

Comparison of Mean Coefficients of Condition of 1963 Year-Class Striped Ba Caught in August 1964 from Three Environmental Zones of the San Joaquin R

Environmental zones and mean coefficients of conditions	t Value	Degrees of freedom	Le signi
Lower River vs. Middle River 1.19 1.12	4.79	81	(
Lower River vs. Upper River 1.19 1.13	3.75	80	(

TABLE 5

Comparison of Mean Coefficients of Condition of 1963 Year-Class Striped Bass Caught in August 1964 from Three Environmental Zones of the San Joaquin River

Mean fork lengths were also calculated for 532 young striped bass similarly collected from the same three zones. The mean fork length of young bass from the lower San Joaquin River was 20.2 cm and that of bass collected from middle and upper San Joaquin River was

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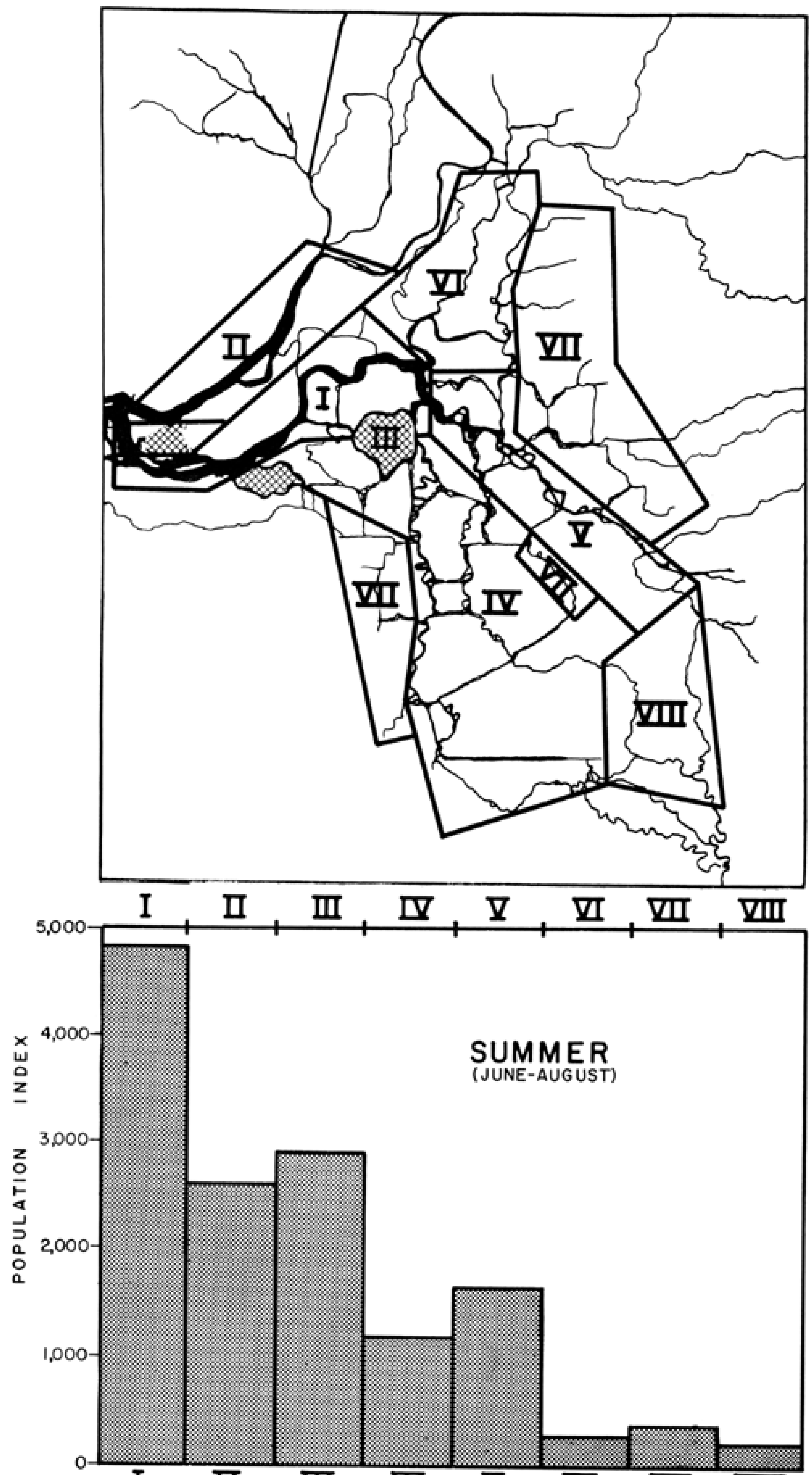
I
II
III
IV
V
VI
VII
VII
VII
VIII
I
II
III
IV
V
VI
VII
VIII
5,000
4,000
3,000
2,000
1,000
0
POPULATION INDEX
SUMMER
(JUNE-AUGUST)

FIGURE 9. Population indices of 1964 year-class striped bass, summer 1964.

FIGURE 9. Population indices of 1964 year-class striped bass, summer 1964

16.9 cm. The differences were statistically significant at the one percent level [(Table 6)]. Also, throughout most of the year young bass from the upper and middle San Joaquin River were consistently shorter than those from the lower San Joaquin River.

TABLE 6

Comparison of Mean Fork Lengths of 1963 Year-Class Striped Bass Caught i August 1964 From Three Environmental Zones of the San Joaquin River and From Suisun Bay

Environmental zones and mean fork lengths	t Value	Degrees of freedom	Lev signifi
Suisun Bay 20.6 vs. Lower River 20.2	0.8	345	N signif
Lower River 20.2 vs. Middle River 16.9	10.38	409	(
Lower River 20.2 vs. Upper River 16.9	9.27	386	(
Suisun Bay 20.6 vs. Middle River 16.9	8.73	142	(
Suisun Bay 20.6 vs. Upper River 16.9	8.28	119	(

TABLE 6

Comparison of Mean Fork Lengths of 1963 Year-Class Striped Bass Caught in August 1964 From Three Environmental Zones of the San Joaquin River and From Suisun Bay

The mean fork length of young striped bass collected by Ganssle (1966) in Suisun Bay during August 1964 was 20.6 cm. This length was not significantly greater than the mean length of those bass I collected from the lower San Joaquin River at the same time, but it was significantly greater than the mean length of bass collected from the middle and upper San Joaquin River.

Stevens (see p. 92) has related these differences in condition and mean length to food supply.

SUMMARY AND DISCUSSION

Young striped bass were abundant in the Delta when we started sampling in September 1963. The data suggest that in October and November, large numbers of these bass migrated downstream from the Delta. A small part of the population remained in the Delta throughout the year.

It is not known why these young bass migrated seaward. Mansueti (1954) suggested that endocrine changes may force the young striped bass to seek water with a higher salt content.

Young striped bass were most concentrated over the shoal areas in the lower San Joaquin River. They may prefer shoal areas because of the lower water velocities there. Kerr (1953) observed that fish (striped bass included) invariably sensed and sought lower uniform current velocities.

A large percentage of those young bass in the Delta were usually in the western portion (lower and middle San Joaquin River, Sacramento River, and flooded islands). Under existing environmental conditions this region is the most important nursery for young bass in the Delta.

Young bass of the 1963 and 1964 year-classes were never abundant in either fork of the Mokelumne River, the south Delta, the upper San Joaquin River, or the dead-end sloughs. Farley (see p. 32) collected few eggs or larvae in the south Delta and in Sycamore Slough, a dead-end

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slough. He believed that in these areas the flows, or water quality, or both, were not conducive for spawning by adult bass. He found that a number of adults spawned in the upper San Joaquin River in 1963. Most of the young bass produced in this area were probably swept downstream to the more "quiet" western Delta before they were large enough to control their distribution. Farley also collected a number of eggs and larvae in the Mokelumne River which were probably washed to the western Delta. These areas did not attract young bass after they were able to control their distribution probably because concentrations of their primary food Neomysis awatschensis (see Stevens, p. 72) were low there (Turner and Heubach, 1966).

Although the Mokelumne River and upper San Joaquin River are not important nursery areas, their importance as migration routes for young bass should not be overlooked.

During August 1964, young bass were longer and in better condition in the lower San Joaquin River than they were in the middle and upper San Joaquin River. Stevens (see p. 92) has related this to differences in the intensity of feeding by bass from the same zones.

LITERATURE CITED

Erkkila, Leo F., James W. Moffett, Oliver B. Cope, Bernard R. Smith, and Reed S. Nielson. 1950. Sacramento-San Joaquin Delta fishery resources: Effects of Tracy pumping plant and Delta cross channel. U. S. Fish and Wildl. Serv., Spec. Sci. Rept., Fish. (56): 1–109. Ganssle, David. 1966. Fishes and decapods of the San Pablo and Suisun Bays, p. 64–94. *In* D. W. Kelley (ed.), Ecological studies of the Sacramento-San Joaquin Estuary. Calif. Dept. Fish and Game, Fish Bull., (133): 1–133. Kerr, James E. 1953. Studies on fish preservation at the Contra Costa steam plant of the Pacific Gas and Electric Company. Calif. Dept. Fish and Game, Fish Bull., (92): 1–66. Mansueti, Romeo J. 1954. Mysterious movements of young striped bass studied. Maryland Tidewater News, 11 (5): 1–3. Scofield, N. B., and H. C. Bryant. 1926. The striped bass in California. Calif. Fish and Game, 12(2): 55–74. Turner, Jerry L., and William Heubach. 1966. Distribution and concentration of Neomysis awatschensis in the Sacramento-San Joaquin Delta, p. 105–112. *In* D. W. Kelley (ed.), Ecological studies of the Sacramento-San Joaquin Estuary. Calif. Dept. Fish and Game, Fish Bull., (133): 1–133.

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DISTRIBUTION OF JUVENILE STRIPED BASS, ROCCUS SAXATILIS, IN THE SACRAMENTOSAN JOAQUIN DELTA

SHOKEN SASAKI

Juvenile striped bass (1962 year-class) were collected from the Sacramento-San Joaquin Delta with an otter trawl, a midwater trawl, and gill nets from September 1963 to August 1964. They were found in relatively high concentrations in many areas of the Delta during the fall. There was also evidence that they were migrating from the Delta to the bays below the Delta during this same season. The population of juvenile bass in the Delta was relatively low through the winter, but it appeared to increase in late spring and summer.

Usually these bass were most concentrated in the shoal areas in the western Delta. Many of the males were sexually mature in the spring while all of the females were immature.

The lower San Joaquin River appeared to be the most important nursery area in the Delta for juvenile striped bass.

METHODS

The term "juvenile" striped bass is applied throughout this paper to the 1962 year-class. Striped bass of this year-class were identified by length frequency analysis (Figure 1). These bass grew from a range

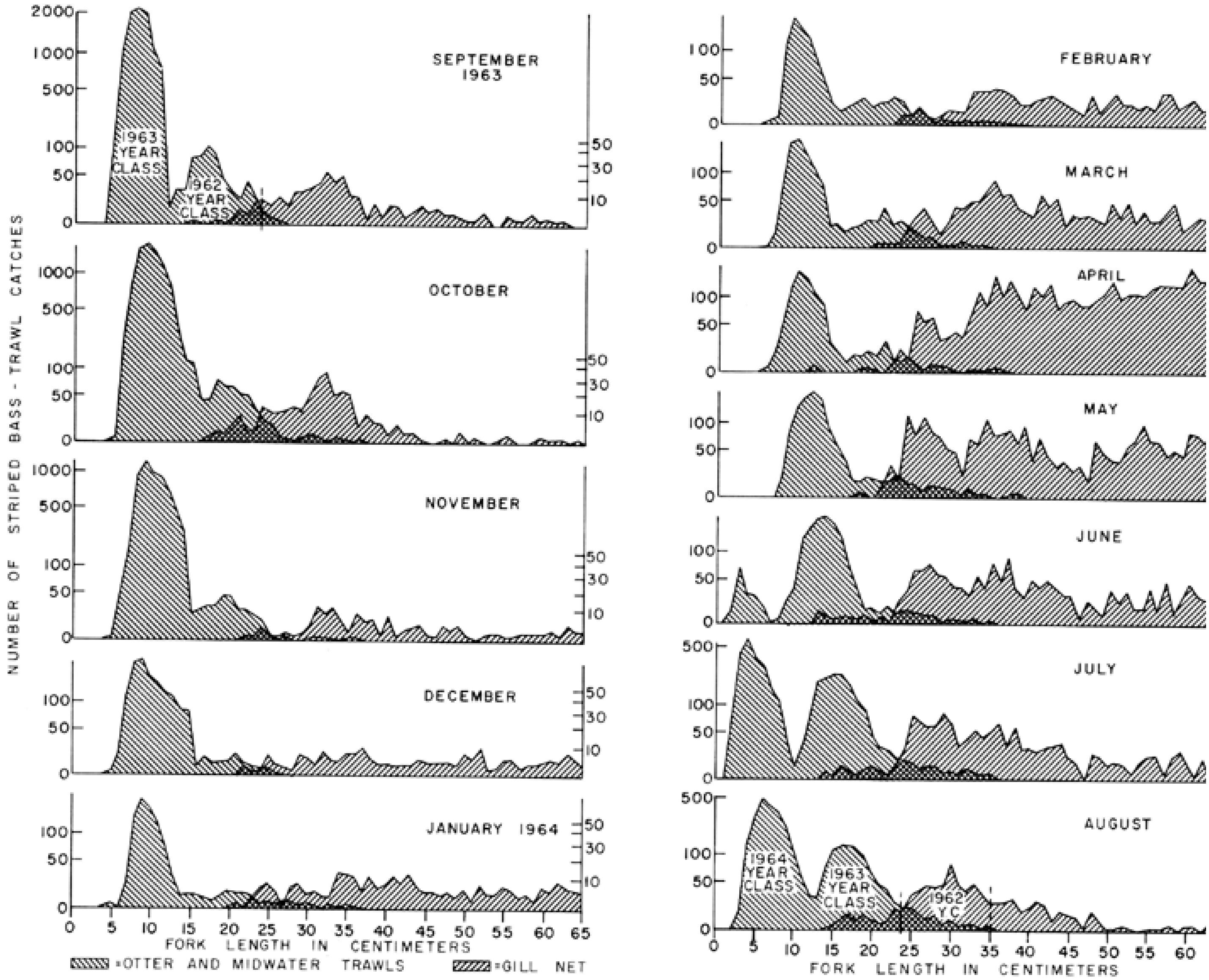


FIGURE 1. The length frequency of striped bass taken with the otter and midwater and with the gill net from September 1963 to August 1964.

FIGURE 1. The length frequency of striped bass taken with the otter and midwater trawls and with the gill net from September 1963 to August 1964

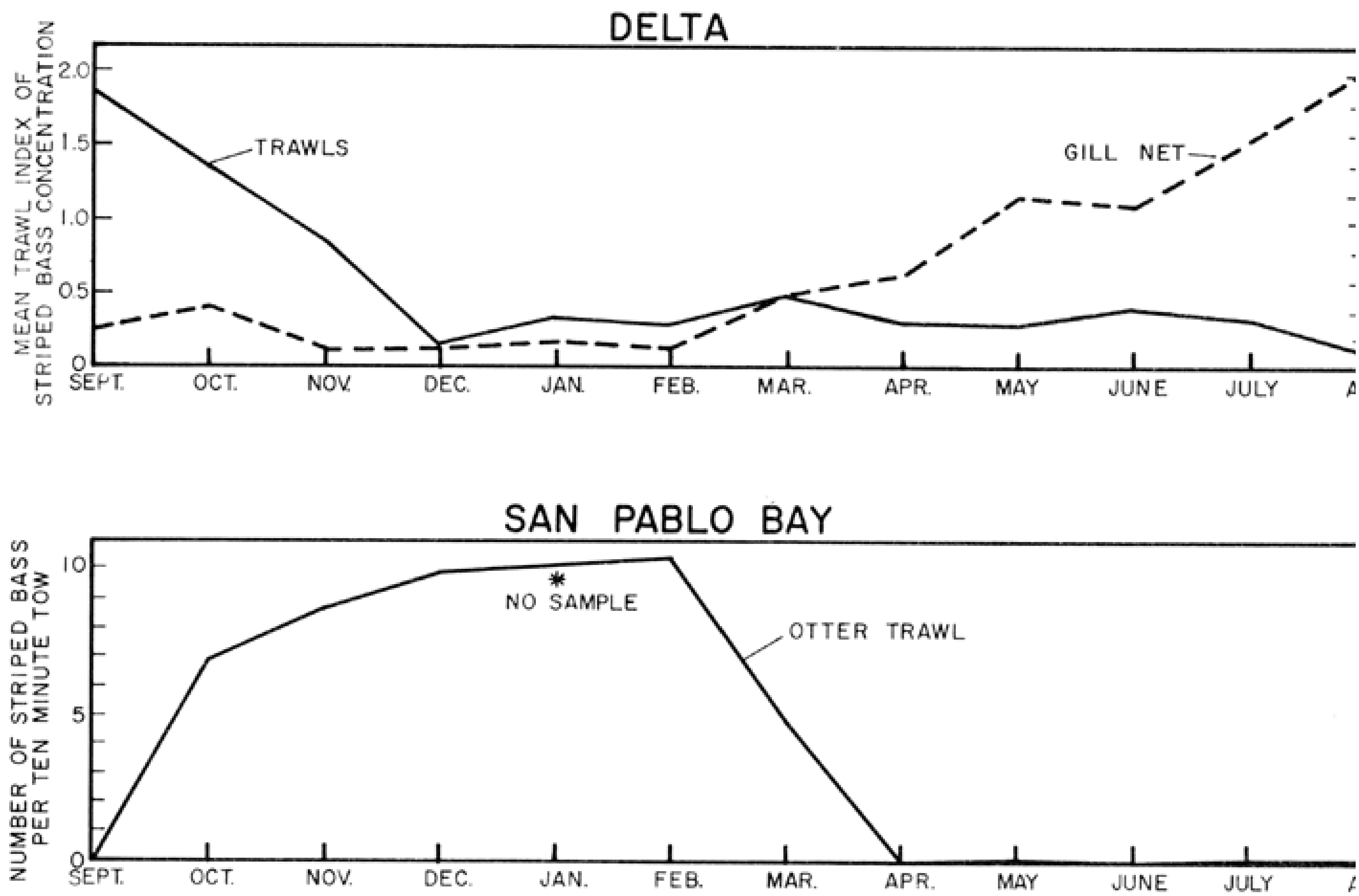


FIGURE 2. Comparison of the mean index of concentration (see Sasaki, p. 44) in Delta, the mean gill net catch in the Delta and the mean otter trawl catch in San Bay (Ganssle, 1966) of the 1962 year-class striped bass, September 1963 to August

FIGURE 2. Comparison of the mean index of concentration (see Sasaki, p. 44) in the Delta, the mean gill net catch in the Delta and the mean otter trawl catch in San Pablo Bay (Ganssle, 1966) of the 1962 year-class striped bass, September 1963 to August 1964

of 13 to 25 cm (*FL*) in September 1963 to a range of 24 to 35 cm in August 1964.

In the fall of 1963 large numbers of juvenile striped bass were captured in the trawls but few were caught in the gill nets because the mesh was too large. As the juveniles grew larger, they became less vulnerable to the trawls and more vulnerable to the gill net (Figure 2). A switch was made from the trawl data to the gill net data for analysis of their distribution after February 1964.

The otter trawl and midwater trawl catch data was combined for the purpose of analysis in the manner and for the reasons described for the young striped bass (see Sasaki, p. 44).

The population index, a figure representing the relative abundance of fish, was used to compare the numbers of juveniles in the various environmental zones of the Delta. These environmental zones and the method used to compute the population index figures have been explained in the paper on young striped bass (see Sasaki, p. 50).

DISTRIBUTION OF JUVENILE STRIPED BASS

In September 1963 the catches of juvenile striped bass in the trawls were high (Figure 2). These catches were highest in the middle and lower San Joaquin River areas (Figure 3). The catches in the Delta steadily decreased in the fall while Ganssle (1966) reported that trawl catches of juveniles in San Pablo Bay increased during this same period (Figure 2). This suggests that a downstream movement of juvenile bass from the Delta occurred at this time. The concentration of juveniles remained low in the Delta through the winter but they were still high in San Pablo Bay (Figure 2). Concentration in the Delta was highest in the lower San Joaquin River area (Figure 3).

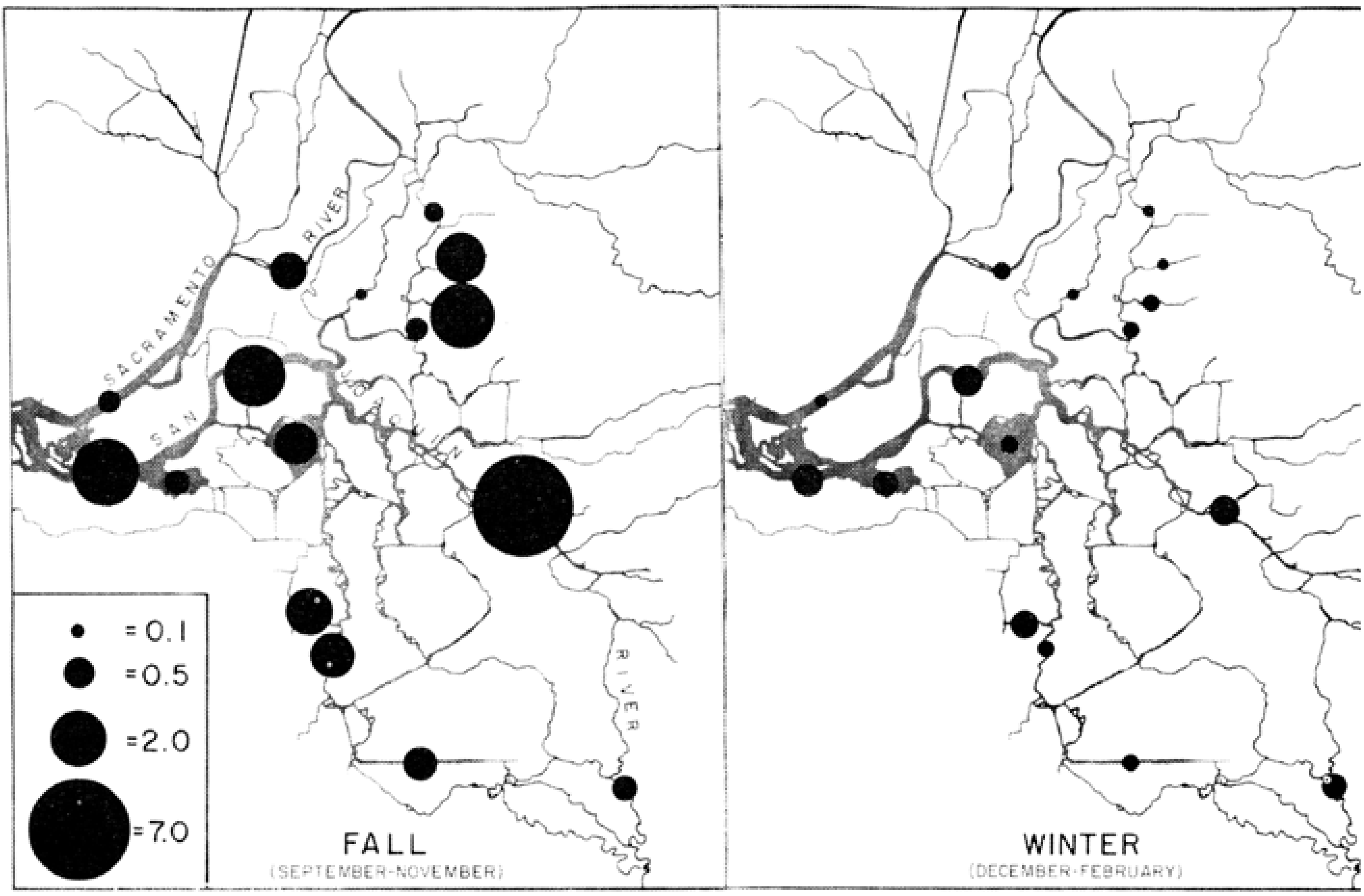


FIGURE 3. Distribution of 1962 year-class striped bass, September 1963–February The area of each circle represents the index of concentration (see Sasaki, p. 44).

FIGURE 3. Distribution of 1962 year-class striped bass, September 1963–February 1964. The area of each circle represents the index of concentration (see Sasaki, p. 44)

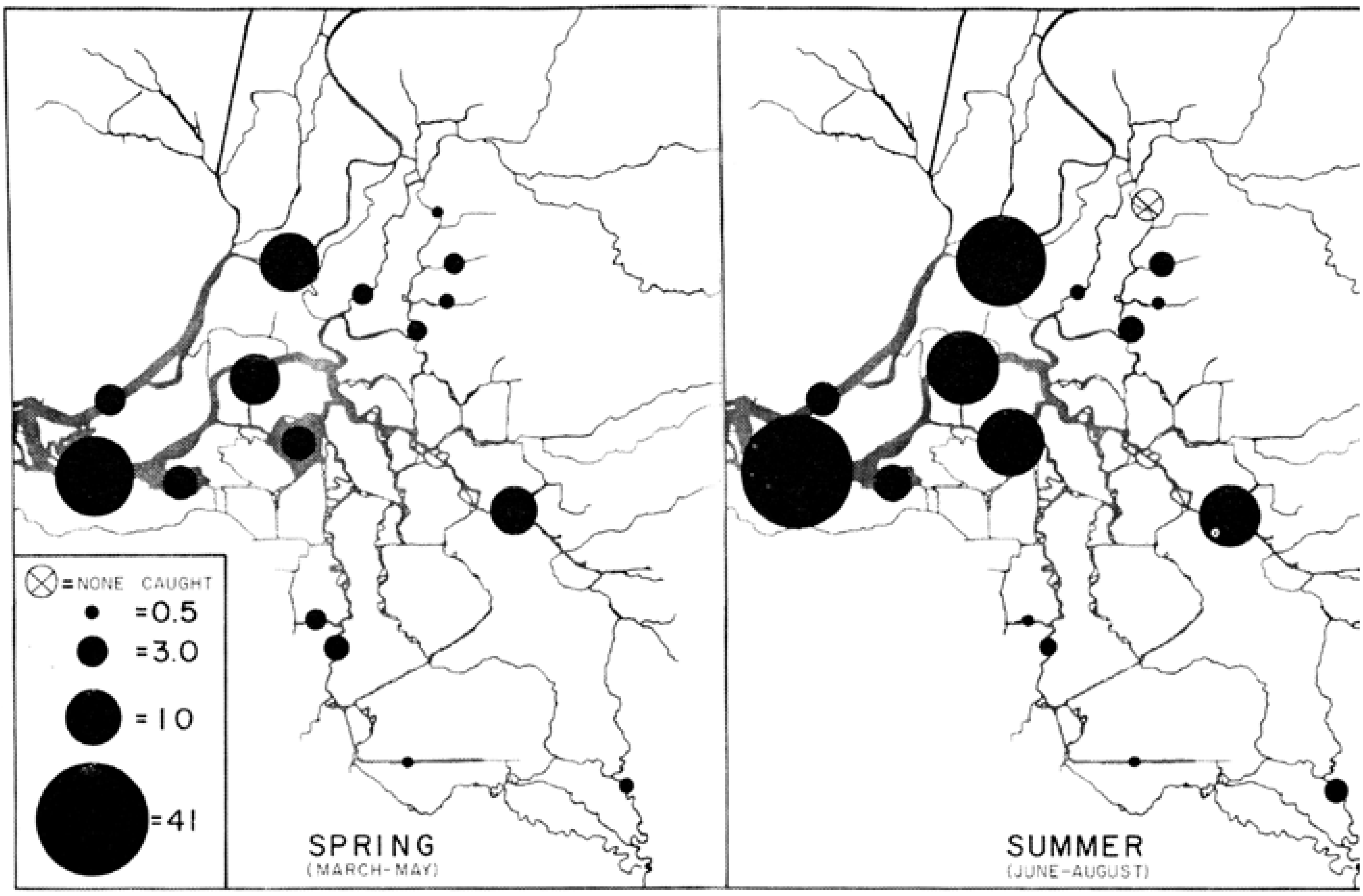


FIGURE 4. Distribution of 1962 year-class striped bass, March 1964–August 1964. The of each circle represents the average gill net catch.

FIGURE 4. Distribution of 1962 year-class striped bass, March 1964–August 1964. The area of each circle represents the average gill net catch

What happened to the juveniles in the Delta from winter to spring cannot be determined because the trawl catch data were used for analysis in winter, and gill net catch data were used for analysis in spring.

The numbers of juvenile striped bass caught in the gill nets increased in the late spring and summer especially in the western Delta (Figure 4). This increase could be a direct result of an increasing number of juveniles growing large enough to be caught, an increase in their activity

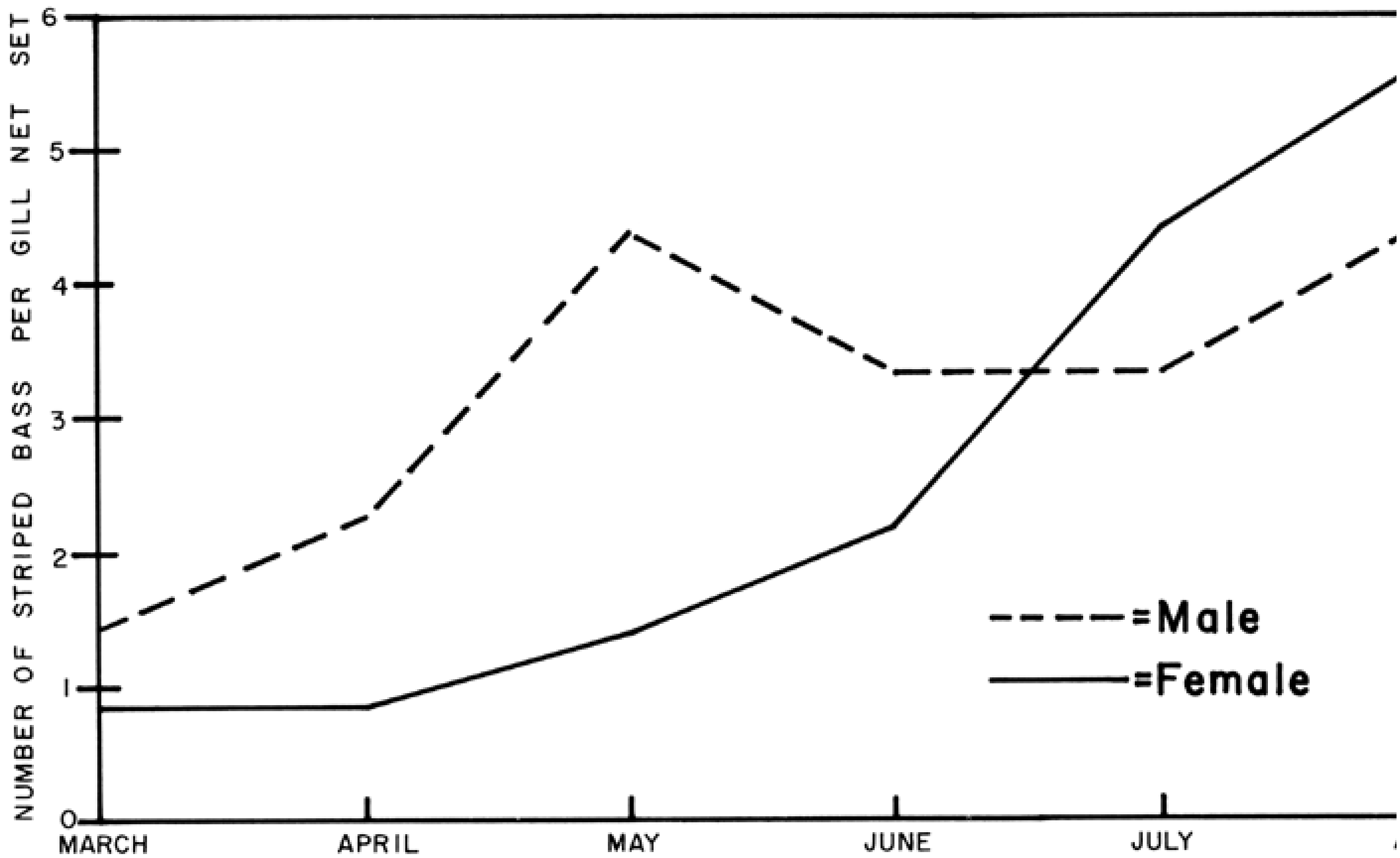


FIGURE 5. Comparison of the average catch of male and female 1962 year-class stri bass from March to August 1964.

FIGURE 5. Comparison of the average catch of male and female 1962 year-class striped bass from March to August 1964

due to the warming water, or an increase in their population in the Delta.

Undoubtedly some increase in the gill net catches resulted from an increase in the size or activity of the juvenile bass but I also believe that some bass moved into the Delta. I base this belief on the changing ratio of male to female juvenile bass in the catch (Figure 5). If the increase in catch from spring to summer was only caused by the bass increasing in size and becoming more active, then the ratio of males to females should have remained the same assuming that both sexes grew and increased their activity at about the same rate. Robinson (1960) found that male and female striped bass grow at the same rate for the first 3 years of life. Since the ratio changed as the catch increased, some of this increase must have been caused by an increase in the numbers of juveniles in the Delta.

Like the young striped bass, the juveniles in the western Delta were usually more concentrated over the shoals than in deep areas (Figure 6).

Most of the juvenile striped bass in the Delta during the spring were males (Figure 5). The number of females in the Delta increased with the approach of summer and by July there were more females than males.

SEXUAL MATURITY

The testes of many of the juvenile males were ripe in the spring, but all of the females examined had immature ovaries [(Table 1)]. Other biologists have also found that males mature younger than females. On the Atlantic Coast, Merriman (1941) found that most male striped bass matured at 2 years and all had matured at 3. He also examined hundreds of females from 1 to 3 years old in the spring and all had immature ovaries. Morgan and Gerlach (1950) found that in Coos Bay, Oregon, some male striped bass as young as 1 year were mature. They did not find any mature 1- or 2-year-old females.

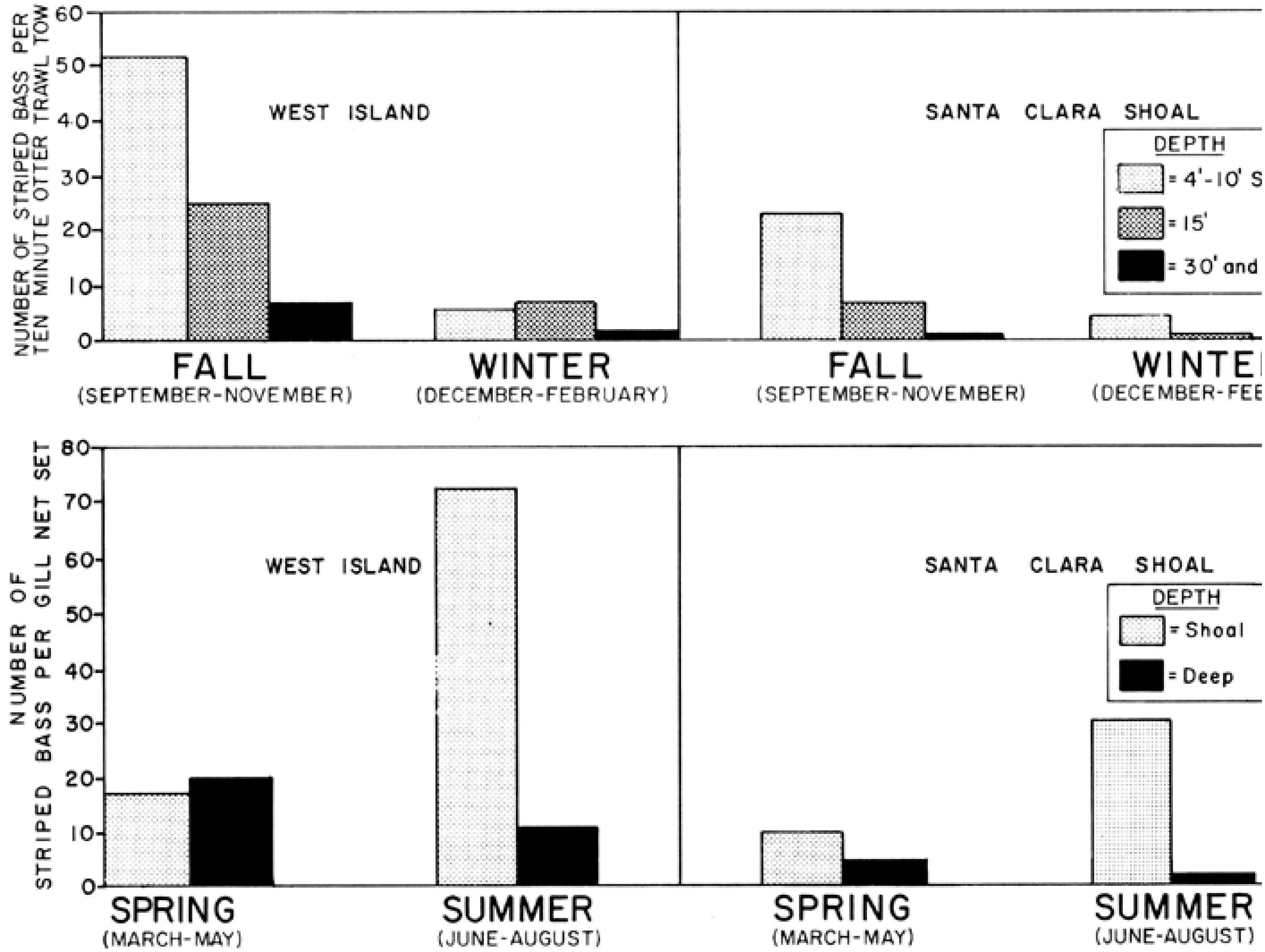


FIGURE 6. Average catch by season of the 1962 year-class striped bass taken at va depths at West Island and Santa Clara Shoal on the San Joaquin River during 1963–1

FIGURE 6. Average catch by season of the 1962 year-class striped bass taken at various depths at West Island and Santa Clara Shoal on the San Joaquin River during 1963–1964

TABLE 1

Percentage of Sexually Mature Striped Bass of the 1962 Year-Class Observed in 1964

Month	Number of males examined	Number of males with ripe testes	Percent of ripe males	Number of females examined	Numb females ripe ov
March	29	0	0	15	0
April	49	18	36.7	18	0
May	67	51	74.6	23	0
June	53	15	28.3	33	0
July	48	1	2.1	62	0
August	69	0	0	86	0

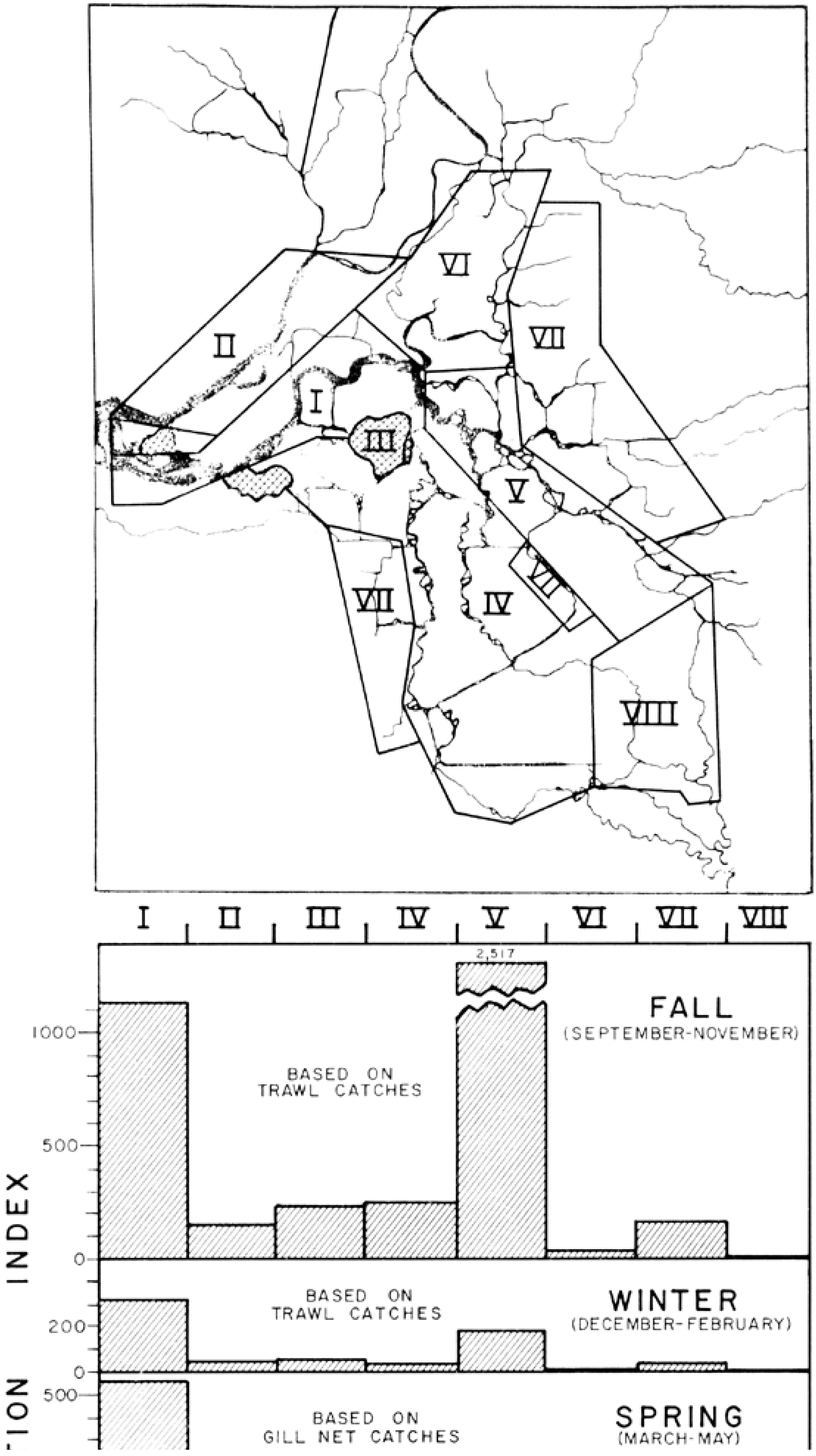
TABLE 1
Percentage of Sexually Mature Striped Bass of the 1962 Year-Class Observed in 1964

GEOGRAPHICAL DIFFERENCES IN TOTAL POPULATION

Population indices (see Sasaki, p. 50) were computed for each environmental zone of the Delta in order to compare the numbers of juvenile striped bass in these different zones (Figure 7).

These indices were also used to compare the number of juveniles in the Delta from fall to winter and from spring to summer. Fall and winter indices were not compared with spring and summer indices because they were based on samples collected with different types of nets.

In the fall, 56 percent of the juvenile striped bass in the Delta were in the middle San Joaquin River, and 25 percent were in the lower San Joaquin River [(Table 2)]. In the winter the number of juveniles in the Delta was about one seventh of what it was in the fall. The evidence already presented leads me to believe that most of these juveniles



I
II
III
IV
V
VI
VII
VIII
2,517
FALL
(SEPTEMBER-NOVEMBER)
BASED ON TRAWL CATCHES
1000
500
0
INDEX
WINTER
(DECEMBER-FEBRUARY)
200
SPRING
(MARCH-MAY)
BASED ON GILL NET CATCHES
TION

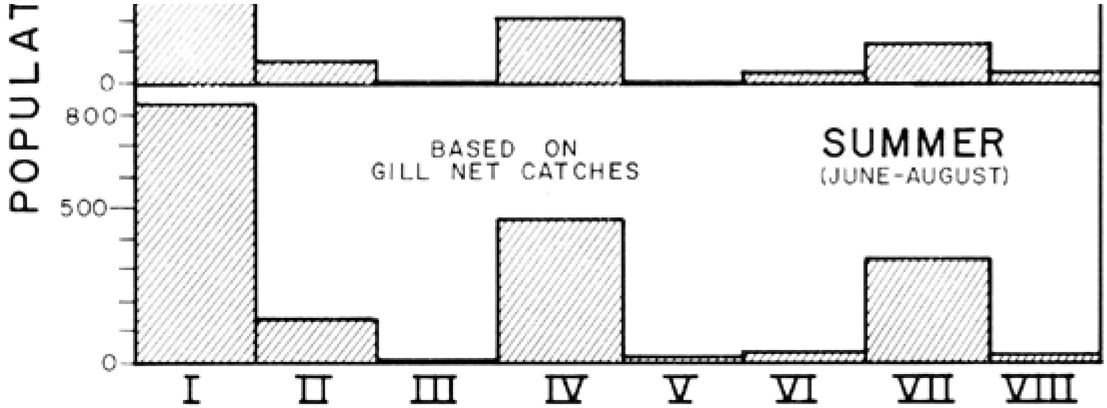


FIGURE 7. Population indices of 1962 year-class striped bass, 1963--1

FIGURE 7. Population indices of 1962 year-class striped bass, 1963–1964

migrated from the Delta to the San Pablo Bay area. Forty-eight percent of those bass left in the Delta during the winter were in the lower San Joaquin River.

In the spring, about 85 percent of the juveniles in the Delta were in the western portion (lower San Joaquin River, Sacramento River, flooded islands). The number of juveniles in the Delta almost doubled from spring to summer. As in the spring, most of these juveniles were in the western Delta.

The lower San Joaquin River is considered to be the most important nursery area in the Delta for juvenile striped bass because the lower San Joaquin River generally had the highest numbers of bass throughout

TABLE 2

Relative Abundance of Juvenile Striped Bass in the Environmental Zones of

Environmental zones	Percent of Delta Area	Indices based on trawl catches					
		Fall			Winter		
		Mean weighted catch	Pop. index	Percent of pop. in zone	Mean weighted catch	Pop. index	Percent of pop. in zone
I Lower San Joaquin River—Deep	18.9	46.9	886	25.4	15.1	285	47.8
I Lower San Joaquin River—Shoals	5.7	44.2	252		4.6	26	
V Middle San Joaquin River	12.4	203.0	2,517	56.2	14.7	182	28.0
VIII Upper San Joaquin River	2.1	1.2	2	0.1	1.5	3	0.5
II Sacramento River	15.3	9.2	141	3.1	2.9	44	6.8
VI Mokelumne River	5.4	2.6	14	0.3	0.9	5	0.8
IV South Delta	15.7	16.3	256	5.7	2.5	39	6.0
III Flooded Islands	17.6	12.6	222	5.0	2.6	46	7.0
VII Dead-end Sloughs	6.9	27.4	189	4.2	2.9	20	3.1
Quarterly population indices			4,479			650	

TABLE 2

Relative Abundance of Juvenile Striped Bass in the Environmental Zones of the Delta During 1963–1964

most of the year. Juvenile bass were never abundant in the Mokelumne River, upper San Joaquin River, south Delta, or dead-end sloughs so these environmental zones may not be important to them as nursery areas now.

SUMMARY AND DISCUSSION

The collections of juvenile striped bass lead me to believe there was a migration of juvenile striped bass from the Delta to San Pablo Bay area during the fall. Sexually maturing male juveniles moved into the Delta during the spring. They were followed by immature females in the summer. Usually the juveniles in the lower San Joaquin

River were most concentrated over the shoal areas. This region also was the most important nursery in the Delta for juvenile bass.

Why the juvenile striped bass moved out of the Delta in the fall is not known. Perhaps the juveniles were seeking warmer water, or were following their food supply, or both. In the winter, water in the lower bays (San Pablo Bay) and the ocean was warmer than water in the Delta, and the center of abundance of Neomysis awatschensis, their primary food source, (see Stevens, p. 73) shifted toward the bay (Turner and Heubach, 1966).

In the spring, sexually mature juvenile males migrate into the Delta to spawn. The juvenile females are not sexually mature. They migrated into the Delta in late spring and summer, perhaps in response to a warming of the water in the Delta, to the upstream movement of N. awatschensis (Turner and Heubach, 1966), or to other stimuli that have not yet been defined.

The observations of juvenile striped bass migrations do not agree with published reports from other areas. Vladykov and Wallace (1938) tagged striped bass in Chesapeake Bay; they concluded that striped bass under 2 years of age were not migratory. Massmann and Pacheco (1961) working in the Chesapeake Bay region stated that almost all striped bass shorter than 12 inches in length remained in the river system in which they were tagged. Mansueti (1961) thought that bass hatched in the Potomac River remain there during the first 3 or 4 years of their life. He also believed that the exchange between bay and river populations of Maryland striped bass was not very great. Merriman (1941) found little evidence that striped bass younger than 2 years undertook migrations along the Atlantic Coast.

Clark (1936) tagged more than 1,500 striped bass in the Sacramento-San Joaquin Delta. Most of these bass were juveniles (shorter than 13 inches). The tag returns revealed that the bass simply diffused away from the tagging site; no distinct migration patterns were evident.

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LITERATURE CITED

Clark, G. H. 1936. A second report on striped bass tagging. Calif. Fish and Game, 22(4) : 272–283. Ganssle, David. 1966. Fishes and decapods of the San Pablo and Suisun Bays, p. 64–94. *In* D.W. Kelley (ed.), Ecological studies of the Sacramento-San Joaquin Estuary. Calif. Dept. Fish and Game, Fish Bull. (133) : 1–133. Mansueti, Romeo J. 1961. Age, growth and movements of the striped bass taken in size, selective fishing gear in Maryland. Chesapeake Sci.; 2(1) : 9–36. Massmann, William H., and Anthony L. Pacheco, 1961. Movements of striped bass tagged in Virginia waters of Chesapeake Bay. Chesapeake Sci., 2(1) : 37–44. Merriman, Daniel. 1941. Studies of the striped bass, Roccus saxatilis, of the Atlantic Coast. U.S. Fish and Wildl. Serv. Fish Bull., 50(35) : 1–77. Morgan, Alfred R., and Arthur R. Gerlach. 1950. Striped bass studies on Coos Bay, Oregon in 1949 and 1950. Oregon Fish Comm. Contrib., (14) : 1–31. Robinson, John B. 1960. The age and growth of striped bass (Roccus saxatilis) in California. Calif. Fish and Game, 46(3) : 279–290. Turner, Jerry L., and William Heubach. 1966. Distribution and concentration of Neomysis awatschensis in the Sacramento-San Joaquin Delta, p. 105–112. *In* D. W. Kelley (ed.), Ecological studies of the Sacramento-San Joaquin Estuary. Calif. Dept. Fish and Game, Fish Bull., (133) : 1–133. Vladykov, Vadim D., and David H. Wallace. 1938. Is the striped bass (Roccus lineatus) of Chesapeake Bay a migratory fish? Trans. Amer. Fish. Soc., 67 : 67–86.

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FOOD HABITS OF STRIPED BASS, ROCCUS SAXATILIS, IN THE SACRAMENTO-SAN JOAQUIN DELTA

DONALD E. STEVENS

This paper describes the food habits of striped bass older than three months, in the Delta of the Sacramento and San Joaquin rivers. Most of the older descriptions (Smith, 1896; Scofield, 1910; Scofield and Coleman, 1910; Scofield and Bryant, 1926; Scofield, 1928, 1931; Shapovalov, 1936; Hatton, 1940; Johnson and Calhoun, 1952) of striped bass food habits in the Sacramento-San Joaquin estuary are merely qualitative or fragmentary. More recently, Heubach, Toth, and McCready (1963) examined a large number of stomachs of bass younger than 6 months from the Delta, but they examined few stomachs of older bass. Ganssle (1966) has described striped bass food habits in the estuary between the Delta and the lower end of San Pablo Bay, and Thomas (1967) has studied the diet of striped bass from the Sacramento and San Joaquin rivers above the Delta down to San Francisco Bay. To avoid duplication of my work, Thomas did not attempt Delta-wide coverage.

This paper is based on an analysis of stomach contents of 8,628 striped bass from eight types of Delta environments. The stomachs were collected from September 1963 through August 1964. The mysid shrimp, Neomysis awatschensis, and the amphipods, Corophium stimpsoni and Corophium spinicorne, were the most important foods of young bass. As bass grew their diet shifted to forage fishes, primarily small striped bass and the threadfin shad, Dorosoma petenense. The composition of the diet varied by season and area.

There is some evidence that N. awatschensis was a preferred food of young bass. Stomach contents differed for bass collected by different sampling gear. The amount of food in stomachs of year-old bass decreased significantly from the lower to the middle to the upper San Joaquin River. Differences in the length and coefficient of condition of bass from these same zones may be a direct result of the differences in food intake.

METHODS

Collecting methods are described by Turner (see p. 12). Stomachs were examined on the boat as the fish were removed from the nets. Most food organisms were counted and measured at this time. Only those food organisms that could not be identified on the boat were taken to the laboratory for analysis.

The data were analyzed by percent frequency of occurrence in the stomachs and percent of diet by volume. Volumes of the food organisms were not measured directly. For the most common foods, mean volumes were determined and they were multiplied by the number of organisms eaten [(Table 1)]. These means were determined from the volume of water displaced by a known number of each food organism freshly collected from the Delta. Volumes of foods eaten infrequently were visually estimated.

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Variations in the digestion rates of food organisms were not compensated for in the analysis. In their study of young-of-the-year striped bass food habits, Heubach, *et al.* (1963) found under controlled conditions that Neomysis mercedis (now N. awatschensis) was recognizable 6 hours after ingestion whereas Corophium spinicorne could be identified after 8 hours. Large organisms, such as forage fishes, are probably recognizable longer after consumption than most small invertebrates, so the value of invertebrates as compared with forage fishes may be underestimated in the analysis by frequency of occurrence. This error was probably reduced in the volume analysis, since when making that analysis, each food item was considered to be at pre-ingestion size.

TABLE 1

Mean Volume Displacement (cc) of Food Organisms of Striped Bass

Food Organisms	
Invertebrates	
Cladocerans and Copepods	0.0005
Amphipods, *Corophium stimpsoni and Corophium spinicorne*	0.0034
Tendipedids	0.0030

Mysid Shrimp, *Neomysis awatschensis* (Length mm)	1–5	6–8	9–11	11–14	15–20
	0.0010	0.0028	0.0079	0.0152	0.0332

Fishes (Length cm)	2	3	4	5	6	7	8	9	10
Threadfin shad, *Dorosoma petenense*	—	0.25	0.8	1.5	2.8	4.4	7.2	10.5	14.0
American shad, *Alosa sapidissima*	—	0.25	0.5	1.1	2.4	3.6	5.1	7.3	9.9
Pond smelt, *Hypomesus transpacificus*	0.1	0.25	0.4	0.8	1.4	2.4	4.0	—	—
Striped bass, *Roccus saxatilis*	0.3	0.5	0.9	1.4	2.3	3.7	6.0	9.1	12.4

TABLE 1

Mean Volume Displacement (cc) of Food Organisms of Striped Bass

To be considered important, a food must be eaten by a significantly large proportion of the bass in significantly large amounts. No objective limits to what is and what is not "significantly large" were set, so my classification of a food as important is a matter of my own judgment after reviewing its frequency of occurrence in bass stomachs and the volume with which it was found.

In this paper, the diet of bass of different sizes during each season of the year is described first. Then local variations in diet that are essential to an understanding of the ecology of the Delta are described. After these seasonal and geographic differences in food habits are documented, this information is reviewed and conclusions are drawn about the individual important foods of striped bass. These sections are followed by sections on food selectivity, differences in stomach contents of bass caught by different sampling gear, and the growth of bass as related to their food intake.

GENERAL DELTA-WIDE FOOD HABITS

To obtain Delta-wide coverage of the food habits of each of four age-groups of bass, an attempt was made to examine 20 stomachs from bass of each age-group collected with each of three types of net at each

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station each month. Most of the time, that many bass of each age-group were not caught with each type of net at each station, so the sample was somewhat smaller. Yet, the sample was still stratified, so to portray the diet with reasonable accuracy, the result from each stratum was weighted by the proportion of the total Delta bass population that it represented.

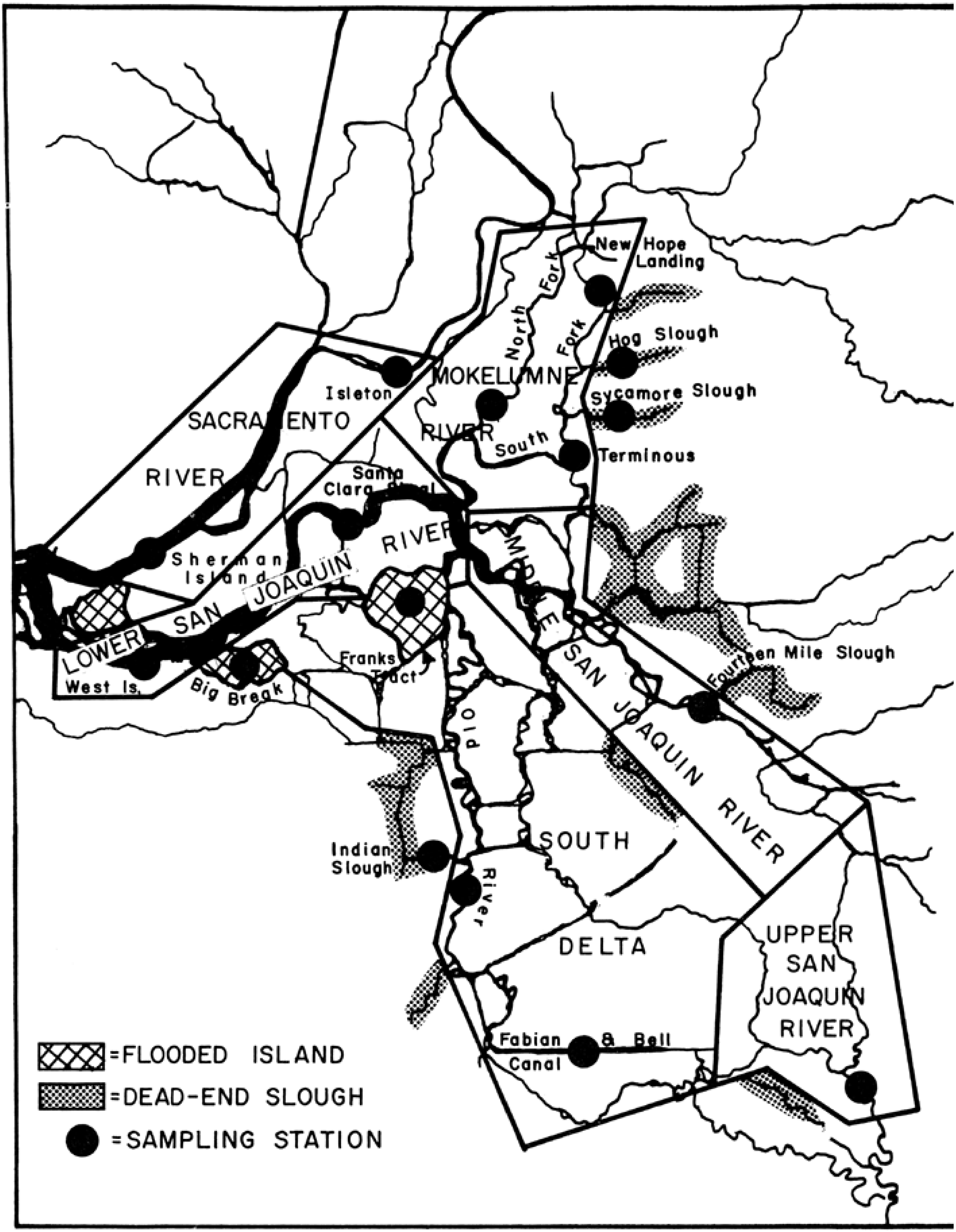

FIGURE 1. Location of sampling stations and areas of similar environments.

FIGURE 1. Location of sampling stations and areas of similar environments

Sasaki (see p. 50) has divided the Delta into eight environmental zones based on river systems and flow (Figure 1). From his catches of young bass and the area of each of these zones, he has estimated the percentage of the total population of young bass in the Delta in each zone during each season (see p. 54). He has done the same for juvenile

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bass (see p. 65), and Radtke has done it for subadult and adult bass (see pp. 22 and 21). My analysis of the Delta-wide food habits of each age-group of striped bass is based on food habit data from each of these zones weighted by the percent of the total population found there.

The percentage of the population of bass in the Delta utilizing a food item was estimated by multiplying the percentage of the total Delta population of bass in each zone by the percent occurrence of the food item in the stomachs of bass in the appropriate zones and summing the products of these calculations [(Table 2)].

TABLE 2

Method of Estimating Percentage of Bass Population Utilizing a Food Organi

Environmental Zone	Percentage of Population		Percent Frequency of Occurrence of Food Item in Stomach		
Lower San Joaquin River	42.7	×	96.3	=	41.1
Middle San Joaquin River	3.0	×	50.0	=	1.5
Upper San Joaquin River	1.0	×	0.0	=	0.0
Sacramento River	31.8	×	88.2	=	28.0
Mokelumne River	0.5	×	8.3	=	0.0
South Delta	6.2	×	42.9	=	2.7
Flooded Islands	13.1	×	66.7	=	8.7
Dead-end Sloughs	1.7	×	75.0	=	1.2
	Percentage of Population Utilizing Food Item			=	83.2

TABLE 2

Method of Estimating Percentage of Bass Population Utilizing a Food Organism

The percentage of the total diet volume formed by a food item was estimated in a similar manner. First the percentage of the total Delta population of bass in each zone was multiplied by the mean volume of that food item in the stomachs of bass from the appropriate zone, and the products were summed to obtain a total weighted mean volume

TABLE 3

Method of Estimating the Total Weighted Mean Volume of a Food Item

Environmental Zone	Percentage of Population		Mean Volume (cc) of Food Item A in Stomachs		Weighted M Volumes Food A
Lower San Joaquin River	42.7	×	0.0317	=	0.135
Middle San Joaquin River	3.0	×	0.0171	=	0.005
Upper San Joaquin River	1.0	×	0.0000	=	0.000
Sacramento River	31.8	×	0.0444	=	0.141
Mokelumne River	0.5	×	0.0042	=	0.000
South Delta	6.2	×	0.0067	=	0.004
Flooded Islands	13.1	×	0.0198	=	0.026
Dead-end Sloughs	1.7	×	0.0701	=	0.012
	Total of Weighted Mean Volumes of Food A			=	0.323

TABLE 3

Method of Estimating the Total Weighted Mean Volume of a Food Item

[(Table 3)]. Then, to obtain the percentage of total volume formed by that food item, the total weighted mean volume was divided by the sum of the total weighted mean volumes of all food items [(Table 4)].

The estimates resulting from these calculations are presented in Tables 5 through 8 for all food organisms.

TABLE 4

Method of Estimating the Percentage of Total Diet Volume Formed by a Food I

Food Item	Total of Weighted Mean Volume of Food Items[1]				Percent o Total Volu
Food A	0.323	÷	.855	=	38
Food B	0.129				15
Food C	0.403				47
Sum	0.855				

[1] See Table 3 for method of estimating total of weighted mean volumes.

TABLE 4

Method of Estimating the Percentage of Total Diet Volume Formed by a Food Item

Diet of Young Bass

Young bass are defined by Sasaki (see p. 44) as the 1963 year-class. They were hatched about 3 months before this study started in the fall of 1963 and were a few months past 1-year old when the study terminated in the summer of 1964. During this period, they grew from a range of 5 to 12 cm in September 1963 to a range of 12 to 23 cm in August 1964.

N. awatschensis was their most important food [(Table 5)]. This mysid was the only organism consumed in quantity by a large percentage of the young bass during every season.

Significant amounts of the amphipods, C. stimpsoni and C. spinicorne, were eaten by about a third to a half of the young bass. I judge Corophium to be the second most important food of young bass.

A very few of the young bass ate small threadfin shad as early as the fall of 1963 when threadfins were abundant (see Turner p. 160), and the bass themselves were only a few months old. During the winter and spring, the bass were larger, but small fish were not abundant and were rarely eaten. In the summer, the bass were even larger, and they fed occasionally on the new crops of threadfin shad and small striped bass.

During the winter, a few young bass fed extensively on pieces of sardine and anchovy bait discarded by anglers or stolen from their hooks.

In the fall, cladocerans and copepods were eaten by less than one percent of the young bass. In contrast, Heubach, *et al.* (1963) found that these plankton were eaten quite frequently by young bass during this season. The difference in my results could be due to differences in food availability from one year to another, but I believe the difference really reflects differences in food selection by bass of different sizes. The bass collected by Heubach, *et al.*, were all shorter than 11 cm (2.0–4.5 in). Because stomachs of bass shorter than 11 cm are too small to handle expediently in the field, most of the bass in my samples were longer than that length.

TABLE 5

Stomach Contents of Young Striped Bass in the Delta [1]

Food Items	Fall		Winter		Spring		Summer		Ave
	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ
Annelids									
Polychaete (*Neanthes limnicola*)	--	--	--	--	--	--	Tr	Tr	Tr
Unidentified Annelid	--	--	--	--	Tr	Tr	--	--	Tr
Crustaceans									
Cladocerans and/or Copepods	Tr	Tr	3	Tr	2	Tr	1	Tr	2
Mysid shrimp (*Neomysis awatschensis*)	85	36	84	44	86	81	65	30	80
Isopod (*Exosphaeroma oregonensis*)	--	--	Tr	1	--	--	--	--	Tr
Unidentified Isopod	--	--	--	--	--	--	Tr	Tr	Tr
Amphipods (*Corophium*)	39	13	30	5	37	7	56	7	40
Crayfish (*Pacifastacus leniusculus*)	--	--	--	--	Tr	Tr	Tr	Tr	Tr
Unidentifiable shrimp	--	--	--	--	Tr	2	Tr	Tr	Tr
Insects									
Tendipedids	2	Tr	2	Tr	2	Tr	8	Tr	4
Other insects	--	--	Tr	Tr	--	--	--	--	Tr
Molluscs									
Asiatic clam (*Corbicula fluminea*)	Tr	1	Tr	1	--	--	Tr	Tr	Tr
Fishes									
Threadfin shad (*Dorosoma petenense*)	1	45	--	--	--	--	6	41	2
American shad (*Alosa sapidissima*)	--	--	--	--	1	2	Tr	2	Tr
Unidentifiable Clupeids	--	--	--	--	--	--	Tr	Tr	Tr
Pond smelt (*Hypomesus transpacificus*)	--	--	--	--	--	--	Tr	Tr	Tr
White catfish (*Ictalurus catus*)	--	--	--	--	--	--	Tr	Tr	Tr
Striped bass (*Roccus saxatilis*)	--	--	--	--	--	--	7	19	2
Starry flounder (*Platichthys stellatus*)	--	--	--	--	Tr	Tr	--	--	Tr
Unidentifiable fishes	--	--	--	--	Tr	3	Tr	1	Tr
Fish eggs	--	--	--	--	Tr	Tr	--	--	Tr
Sardine and anchovy bait	1	6	3	49	Tr	4	Tr	Tr	1
Stomachs examined	320		946		1,303		1,274		
Percent containing food	85		73		84		81		

[1] Stomach content data for young bass in each of the eight environmental zones in the Delta were weighted b percent of the total Delta population of young bass found there and summed (see text, p. 71).

TABLE 5

Stomach Contents of Young Striped Bass in the Delta

Diet of Juvenile Bass

Juvenile bass are the 1962 year-class (see Sasaki, p. 59). They were slightly more than 1 year old at the start of the study and had passed the end of their second year at the end of the study. Their lengths varied from 13 to 25 cm in September 1963 to 24 to 35 cm in August 1964.

N. awatschensis was a very important food each season [(Table 6)]. It was especially important in the winter and spring.

Juvenile bass often fed on fishes. In the fall, the distribution of the juveniles was such that a large percentage were in areas where threadfin shad were abundant; as a result threadfins were eaten by about one quarter of the population and by volume made up most of the diet. In the winter and spring, small fishes were scarce in the Delta and only a few were eaten. Large numbers of small striped bass of the new year-class became available in the summer (see Sasaki, p. 47); they were preyed upon by about one-quarter of the juveniles.

About one-quarter to one-third of the juveniles fed on some Corophium each season, but they consumed relatively small quantities, so Corophium were not really too important.

In the winter and spring, about 10 percent of the juveniles ate portions of sardine and anchovies which had been used for bait by anglers.

TABLE 6

Stomach Contents of Juvenile Bass in the Delta [1]

Food Items	Fall		Winter		Spring		Summer		Av
	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ
Annelids									
Polychaete (*Neanthes limnicola*)	Tr	Tr	--	--	--	--	--	--	Tr
Crustaceans									
Cladocerans and/or Copepods	--	--	Tr	Tr	Tr	Tr	--	--	Tr
Mysid shrimp (*Neomysis awatschensis*)	39	2	84	11	79	29	64	11	66
Isopod (*Exosphaeroma oregonensis*)	--	--	--	--	Tr	Tr	--	--	Tr
Amphipods (*Corophium*)	22	Tr	27	Tr	31	Tr	31	2	28
Crayfish (*Pacifastacus leniusculus*)	Tr	Tr	--	--	Tr	1	Tr	Tr	Tr
Crab (*Rhithropanopeus harrisii*)	1	1	--	--	--	--	--	--	Tr
Unidentifiable shrimp	--	--	1	Tr	--	--	1	1	Tr
Insects									
Tendipedids	9	Tr	--	--	1	Tr	3	Tr	3
Other insects	--	--	1	Tr	--	--	--	--	Tr
Molluscs									
Asiatic clam (*Corbicula fluminea*)	Tr	Tr	--	--	--	--	Tr	Tr	Tr
Fishes									
Unidentified Ammocoete	--	--	--	--	Tr	Tr	Tr	Tr	Tr
Threadfin shad (*Dorosoma petenense*)	27	72	3	38	1	11	2	4	8
American shad (*Alosa sapidissima*)	2	3	--	--	--	--	1	4	1
King salmon (*Oncorhynchus tshawytscha*)	--	--	--	--	1	1	1	3	Tr
Pond smelt (*Hypomesus transpacificus*)	--	--	--	--	1	3	2	8	1
White catfish (*Ictalurus catus*)	--	--	--	--	--	--	Tr	Tr	Tr
Striped bass (*Roccus saxatilis*)	4	7	1	8	Tr	1	26	55	8
Unidentifiable fishes	15	14	1	7	5	29	6	11	7
Sardine and anchovy bait	2	1	13	36	9	24	Tr	Tr	6
Stomachs examined	655		365		544		473		
Percent containing food	69		71		70		61		

[1] Stomach content data for juvenile bass in each of the eight environmental zones in the Delta were weighted b percent of the total Delta population of juvenile bass found there and summed (see text, p. 71).

TABLE 6

Stomach Contents of Juvenile Bass in the Delta

Diet of Subadult Bass

Subadult bass are defined by Radtke (see p. 15) as the 1961 year-class. These bass were 2 years old several months before the start of the study; they were 3 years of age shortly before the study terminated. In September, subadults were 26 to 37 cm long; by August they were 36 to 47 cm long.

Subadults fed primarily on fishes [(Table 7)]. In the fall, threadfin shad and small striped bass were abundant in the Delta and both were consumed by more than one-third of the subadult bass. In the winter, even though numbers of threadfin shad and small striped bass in the Delta decreased, they still made up most of the diet. The percentage of the subadults that ate small bass did decrease somewhat; however, the percentage of the subadults that fed on threadfins increased slightly. By spring, there were few threadfin shad and striped bass of a size suitable for food in the Delta. Correspondingly, the occurrence of these fishes in stomachs of subadults decreased appreciably. In the summer, when the new year-classes of striped bass and threadfin shad became available, they were preyed upon more frequently. Small bass were especially prevalent in the summer diet of the subadults.

A significant percentage of the subadults fed on N. awatschensis in the winter, spring, and summer, and on Corphium in the spring; but

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because the amounts that were consumed were relatively small, I consider these crustaceans to be of minor importance.

TABLE 7

Stomach Contents of Sub-Adult Bass in the Delta [1]

Food Items	Fall % Freq Occ	Fall % by Vol	Winter % Freq Occ	Winter % by Vol	Spring % Freq Occ	Spring % by Vol	Summer % Freq Occ	Summer % by Vol	Ave % Freq Occ
Crustaceans									
Mysid shrimp (*Neomysis awatschensis*)	6	Tr	22	Tr	37	2	34	2	25
Amphipods (*Corophium*)	2	Tr	5	Tr	21	Tr	13	Tr	10
Crayfish (*Pacifastacus leniusculus*)	1	Tr	Tr	Tr	2	6	Tr	Tr	1
Unidentifiable shrimp	Tr	Tr	2	Tr	--	--	--	--	1
Insects									
Other insects	--	--	--	--	--	--	1	--	Tr
Fishes									
Unidentified Ammocoete	--	--	--	--	Tr	Tr	--	--	Tr
Threadfin shad (*Dorosoma petenense*)	36	67	39	68	5	13	12	25	23
American shad (*Alosa sapidissima*)	3	2	1	1	--	--	--	--	1
Pacific herring (*Clupea pallasi*)	--	--	--	--	1	Tr	--	--	Tr
Unidentifiable Clupeids	Tr	Tr	6	2	--	--	3	4	2
King salmon (*Oncorhynchus tshawytscha*)	Tr	1	--	--	4	10	--	--	1
Pond smelt (*Hypomesus transpacificus*)	1	Tr	1	1	2	4	--	--	1
Carp (*Cyprinus carpio*)	Tr	Tr	--	--	--	--	--	--	Tr
White catfish (*Ictalurus catus*)	Tr	Tr	--	--	--	--	--	--	Tr
Striped bass (*Roccus saxatilis*)	39	23	20	22	14	41	42	54	29
Unidentifiable Centrarchids	--	--	--	--	--	--	Tr	Tr	Tr
Unidentifiable fishes	21	4	6	3	15	20	12	15	14
Sardine and anchovy bait	4	1	9	3	7	5	--	--	5
Stomachs examined	455		234		312		241		
Percent containing food	47		58		29		36		

[1] Stomach content data for sub-adult bass in each of the eight environmental zones in the Delta were weighte the percent of the total Delta population of sub-adult bass found there and summed (see text, p. 71).

TABLE 7

Stomach Contents of Sub-Adult Bass in the Delta

Diet of Adult Bass

All bass older than 3 years in the fall of 1963 were classified as adult bass (see Radtke, p. 15). In the summer of 1964, at the end of the study, they were all older than 4 years. In September 1963, these bass were 38 cm or longer; in August 1964 they were 48 cm or longer.

The diet of adults was almost entirely fishes, especially small bass and threadfin shad [(Table 8)]. In the fall, small bass were eaten by almost one-half of the adults and threadfin shad were eaten by about one-quarter of the adults. In the winter, the percentage of the adults that fed on small bass decreased somewhat, but the percentage of adults that preyed upon threadfin shad increased; so both of these fishes were eaten by about one-third of the adults.

In the spring, when few threadfin shad and small bass were in the Delta, they were each eaten by about one-quarter of the adult bass. The occurrence of threadfin shad in the stomachs of adults decreased to 6 percent and that of small bass increased to 50 percent in the summer; however, only 21 stomachs with food were examined so these percentages may not be very meaningful.

Sardine and anchovy bait occurred in about one-sixth of the stomachs during the fall, winter, and summer. Bait did not occur in any stomachs in the spring sample.

TABLE 8

Stomach Contents of Adult Bass in the Delta [1]

Food Items	Fall		Winter		Spring		Summer		Ave
	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ
Crustaceans									
Mysid shrimp (*Neomysis awatschensis*)	--	--	--	--	16	Tr	--	--	4
Amphipods (*Corophium*)	--	--	--	--	7	Tr	--	--	2
Crayfish (*Pacifastacus leniusculus*)	Tr	Tr	--	--	Tr	Tr	--	--	Tr
Crab (*Rhithropanopeus harrisii*)	--	--	1	Tr	--	--	--	--	Tr
Unidentifiable shrimp	--	--	1	Tr	--	--	10	1	3
Fishes									
Unidentified Ammocoete	--	--	Tr	Tr	1	Tr	--	--	Tr
Threadfin shad (*Dorosoma petenense*)	24	15	34	56	24	27	6	4	22
American shad (*Alosa sapidissima*)	8	12	4	6	--	--	--	--	3
Unidentifiable Clupeids	--	--	14	2	--	--	--	--	4
King salmon (*Oncorhynchus tshawytscha*)	--	--	--	--	6	3	5	1	3
Pond smelt (*Hypomesus transpacificus*)	--	--	Tr	Tr	2	Tr	--	--	1
Carp (*Cyprinus carpio*)	--	--	Tr	1	--	--	--	--	Tr
Goldfish (*Carassius auratus*)	--	--	Tr	Tr	--	--	--	--	Tr
Sacramento blackfish (*Orthodon microlepidotus*)	--	--	--	--	Tr	Tr	--	--	Tr
Sacramento hitch (*Lavinia exilicauda*)	--	--	--	--	Tr	Tr	--	--	Tr
Striped bass (*Roccus saxatilis*)	44	56	32	26	25	56	50	43	38
Bluegill (*Lepomis macrochirus*)	Tr	1	--	--	1	5	--	--	Tr
Black crappie (*Pomoxis nigromaculatus*)	--	--	Tr	Tr	Tr	Tr	--	--	Tr
Three-spined stickleback (*Gasterosteus aculeatus*)	--	--	Tr	Tr	--	--	--	--	Tr
Unidentifiable fishes	30	9	8	4	18	9	12	3	17
Sardine and anchovy bait	18	7	17	5	--	--	16	49	13
Stomachs examined	223		574		531		174		
Percent containing food	41		37		12		12		

[1] Stomach content data for adult bass in each of the eight environmental zones in the Delta were weighted b percent of the total Delta population of adult bass found there and summed (see text, p. 71).

TABLE 8

Stomach Contents of Adult Bass in the Delta

In both the spring and early summer, only a very small percentage of the stomachs contained food. Although few small fishes were available at this time, I do not believe that the scarcity of food in the stomachs was a result of poor forage conditions. If it was merely a lack of suitable forage that caused the reduced food intake, angler catches should be rather large in the Delta in the spring since adult bass are so abundant in the Delta during that season (see Radtke, p. 17; Calhoun, 1952). However, catches by anglers are actually quite small. The mean catch of bass on sport-fishing party boats in the Delta was not above 0.14 per angler hour during any spring between 1961 and 1964, and a creel census conducted by the California Department of Fish and Game, indicated that the catch on many days was as low as 0.05 bass per angler hour (Thomas Doyle, pers. commun.). A suggestion (Hollis, 1952) that striped bass do not feed heavily when they near spawning is relevant. Bass spawn in the Delta during April, May, and June (see Farley, p. 30), and most of the stomachs examined during the spring and summer were collected during these months.

GEOGRAPHICAL VARIATIONS IN DIET

In this section, the diet and abundance of bass and the abundance of their food organisms in each environmental zone of the Delta are reviewed.

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Lower San Joaquin River [(Table 9)]

This zone was one of the most important nursery areas in the Delta for young bass (see Sasaki, p. 57); it was also a very important nursery for juvenile bass (see Sasaki, p. 64). The large quantities of N. awatschensis that were consumed by these bass reflected the large concentrations of N. awatschensis that were present (Turner and Heubach, 1966). Stomachs of the young bass contained as many as 100 or 150 individual N. awatschensis. Stomachs of the juvenile bass often held 200 to 300 N. awatschensis. Corophium were of some importance to young bass in the fall, but only small amounts were consumed by young bass during the rest of the year. The abundant young bass provided most of the forage for large bass.

Middle San Joaquin River [(Table 10)]

During the fall, winter, and spring, N. awatschensis was the most important invertebrate eaten by bass in this zone; however, only a small percentage of the young bass in the Delta were here until the summer (see Sasaki, p. 52) when concentrations of N. awatschensis in the environment (Turner and Heubach, 1966) had decreased from the relatively high winter and spring levels, and Corophium had become a more important food.

The large numbers of threadfin shad which were eaten here in the fall and winter reflected the extreme concentrations of this species in the environment (see Turner, p. 161). Stomachs of adult bass contained as many as 24 threadfins averaging 10 cm *FL.* In the fall, the threadfin shad was the most important food of juvenile bass, and in that season about one-half of the juveniles in the Delta were in this zone (Sasaki, p. 63). The bass in this area also ate a few of their own young.

Upper San Joaquin River [(Table 11)]

The upper San Joaquin River was not an important zone for bass of any age-group. Each season only a very small percentage of the bass in the Delta were here (see Sasaki, pp. 54 and 65; Radtke, pp. 21 and 22). The few young bass inhabiting this area fed primarily on Corophium. A significant percentage of these bass also fed on the tendipedid larvae and pupae which were fairly abundant in the bottom sediments (Hazel and Kelley, 1966). N. awatschensis was scarce (Turner and Heubach, 1966), and was consumed in quantity only by juvenile bass in the fall. Much of the diet of juveniles was formed by Corophium and sardine and anchovy bait. The threadfin shad was the most common forage fish in stomachs of large bass. It was consumed most frequently in the winter and spring.

South Delta [(Table 12)]

Relatively few bass of any size inhabited the south Delta (see Sasaki, pp. 54 and 55; Radtke, pp. 21 and 22). The young bass in this area usually fed on Corophium, although in the winter N. awatschensis was a more important food. N. awatschensis was never particularly abundant in the environment (Turner and Heubach, 1966), but it was still the most important food of juvenile bass.

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TABLE 9

Stomach Contents of Striped Bass in the Lower San Jo

Food Items	Young Bass								Juvenile Bass									
	Fall		Winter		Spring		Summer		Fall		Winter		Spring		Summer		Fall	
	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol
Crustaceans																		
Cladocerans and Copepods	--	--	--	--	1	Tr	--	--	--	--	--	--	1	Tr	--	--	--	--
Mysid shrimp (*Neomysis awatschensis*)	96	82	89	94	95	89	98	80	95	34	82	12	93	58	83	16	30	2
Unidentified Isopod	--	--	--	--	--	--	1	Tr	--	--	--	--	--	--	--	--	--	--
Amphipods (*Corophium*)	30	18	28	6	29	4	32	2	21	1	24	Tr	34	Tr	23	Tr	6	Tr
Unidentifiable shrimp	--	--	--	--	Tr	2	--	--	--	--	1	Tr	--	--	--	--	2	Tr
Insects																		
Tendipedids	--	--	--	--	--	--	1	Tr	--	--	--	--	--	--	--	--	--	--
Molluscs																		
Asiatic clam (*Corbicula fluminea*)	--	--	--	--	--	--	--	--	1	1	--	--	--	--	--	--	--	--
Fishes																		
Unidentified Ammocoete	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	1	--	--
Threadfin shad (*Dorosoma petenense*)	--	--	--	--	--	--	--	--	1	8	1	35	--	--	--	--	--	--
American shad (*Alosa sapidissima*)	--	--	--	--	1	2	--	--	--	--	--	--	--	--	--	--	11	12
Pacific herring (*Clupea pallasi*)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
King salmon (*Oncorhynchus tshawytscha*)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2	10
Carp (*Cyprinus carpio*)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2	1
Striped bass (*Roccus saxatilis*)	--	--	--	--	--	--	7	18	1	24	1	16	--	--	21	68	53	70
Unidentifiable fishes	--	--	--	--	Tr	1	Tr	1	2	22	--	--	4	32	8	14	6	5
Sardine and anchovy bait	--	--	--	--	Tr	2	--	--	2	11	12	38	4	9	--	--	2	1
Stomachs examined	105		292		279		211		174		132		164		185		82	
Percent containing food	75		63		78		85		87		70		79		66		57	

TABLE 9

Stomach Contents of Striped Bass in the Lower San Joaquin River

TABLE 10

Stomach Contents of Striped Bass in the Middle San Jo

Food Items	Young Bass								Juvenile Bass									
	Fall		Winter		Spring		Summer		Fall		Winter		Spring		Summer		Fall	
	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol
Crustaceans																		
Cladocerans and Copepods	--	--	--	--	5	Tr	2	Tr	--	--	--	--	--		--	--	--	--
Mysid shrimp (*Neomysis awatschensis*)	50	1	94	14	81	69	40	5	14	Tr	82	12	56	3	21	2	--	--
Isopod (*Exosphaeroma oregonensis*)	--	--	--	--	--	--	--	--	--	--	--	--	5	2	--	--	--	--
Amphipods (*Corophium*)	50	1	33	1	53	19	68	9	17	Tr	37	Tr	46	1	29	3	--	--
Crayfish (*Pacifastacus leniusculus*)	--	--	--	--	--	--	--	--	--	--	--	--	2	6	--	--	--	--
Crab (*Rhithropanopeus harrisii*)	--	--	--	--	--	--	--	--	2	1	--	--	--	--	--	--	--	--
Insects																		
Tendipedids	--	--	--	--	1	Tr	14	Tr	12	Tr	--	--	--	--	12	Tr	5	T[illegible]
Fishes																		
Threadfin shad (*Dorosoma petenense*)	25	98	--	--	--	--	14	75	43	76	4	36	5	22	21	30	84	9[illegible]
American shad (*Alosa sapidissima*)	--	--	--	--	--	--	--	--	2	3	--	--	--	--	--	--	--	--
Unidentifiable Clupeids	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pond smelt (*Hypomesus transpacificus*)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
White catfish (*Ictalurus catus*)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	4	3	--	--
Striped bass (*Roccus saxatilis*)	--	--	--	--	--	--	5	11	5	5	--	--	2	4	4	42	6	[illegible]
Unidentifiable fishes	--	--	--	--	--	--	--	--	24	14	2	14	7	33	12	21	26	[illegible]
Sardine and anchovy bait	--	--	27	85	1	12	--	--	--	--	12	37	26	30	--	--	--	--
Stomachs examined	14		37		92		143		98		64		61		64		90	
Percent containing food	57		89		86		78		43		77		70		38		54	

TABLE 10

Stomach Contents of Striped Bass in the Middle San Joaquin River

TABLE 11

Stomach Contents of Striped Bass in the Upper San J

Food Items	Young Bass								Juvenile Bass								
	Fall		Winter		Spring		Summer		Fall		Winter		Spring		Summer		Fall
	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ
Annelids																	
Unidentified Annelid	--	--	--	--	1	2	--	--	--	--	--	--	--	--	--	--	--
Crustaceans																	
Cladocerans and Copepods	--	--	20	2	2	Tr	--	--	--	--	20	Tr	5	Tr	--	--	--
Mysid shrimp (*Neomysis awatschensis*)	--	--	8	1	36	10	5	Tr	85	49	40	2	16	4	12	Tr	--
Amphipods (*Corophium*)	86	3	92	43	89	38	87	9	8	Tr	20	Tr	84	5	88	4	33 T
Insects																	
Tendipedids	14	Tr	23	2	39	8	52	1	54	5	10	Tr	10	Tr	25	Tr	--
Molluscs																	
Asiatic clam (*Corbicula fluminea*)	--	--	--	--	--	--	--	--	8	Tr	--	--	--	--	--	--	--
Fishes																	
Threadfin shad (*Dorosoma petenense*)	--	--	--	--	--	--	7	42	--	--	10	20	5	34	12	62	--
Carp (*Cyprinus carpio*)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Striped bass (*Roccus saxatilis*)	--	--	--	--	--	--	7	42	--	--	--	--	--	--	--	--	67 10
Unidentifiable fishes	--	--	--	--	1	39	--	--	--	--	--	--	--	--	--	--	--
Fish eggs	--	--	--	--	1	2	--	--	--	--	--	--	--	--	--	--	--
Sardine and anchovy bait	29	97	3	52	--	--	1	6	8	46	60	77	16	57	12	33	--
Stomachs examined	7		63		113		105		13		17		38		11		9
Percent containing food	100		97		94		72		100		59		50		73		33

TABLE 11

Stomach Contents of Striped Bass in the Upper San Joaquin River

TABLE 12

Stomach Contents of Striped Bass in the South

Food Items	Young Bass								Juvenile Bass									
	Fall		Winter		Spring		Summer		Fall		Winter		Spring		Summer		Fall	
	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol
Annelids																		
Polychaete (*Neanthes limnicola*)	--	--	--	--	--	--	1	Tr	2	Tr	--	--	--	--	--	--	--	--
Crustaceans																		
Cladocerans and Copepods	--	--	10	2	Tr	Tr	--	--	--	--	--	--	--	--	--	--	--	--
Mysid shrimp (*Neomysis awatschensis*)	43	6	75	31	58	20	58	12	39	6	83	49	59	24	80	62	--	--
Isopod (*Exosphaeroma oregonensis*)	--	--	1	4	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Amphipods (*Corophium*)	99	26	51	17	78	23	81	18	46	1	44	3	59	2	80	9	--	--
Crayfish (*Pacifastacus leniusculus*)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Insects																		
Tendipedids	14	1	3	Tr	14	1	18	1	32	2	--	--	19	Tr	--	--	--	--
Molluscs																		
Asiatic clam (*Corbicula fluminea*)	--	--	1	23	--	--	2	1	2	2	--	--	--	--	--	--	--	--
Fishes																		
Unidentified Ammocoete	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Threadfin shad (*Dorosoma petenense*)	--	--	--	--	--	--	1	1	--	--	--	--	--	--	--	--	17	57
Unidentifiable Clupeids	--	--	--	--	--	--	1	6	--	--	--	--	--	--	--	--	--	--
Pond smelt (*Hypomesus transpacificus*)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Striped bass (*Roccus saxatilis*)	--	--	--	--	--	--	6	37	2	40	--	--	--	--	20	29	50	27
Bluegill (*Lepomis macrochirus*)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Unidentifiable fishes	--	--	--	--	1	28	3	22	2	16	--	--	3	9	--	--	33	16
Sardine and anchovy bait	7	66	1	23	Tr	28	1	4	11	33	6	48	12	64	--	--	--	--
Stomachs examined	17		128		210		157		59		23		50		8		10	
Percent containing food	82		88		87		74		75		78		64		62		60	

TABLE 12

Stomach Contents of Striped Bass in the South Delta

Few stomachs of the older bass had food. Threadfin shad were the most important forage fish. They were present in 11 of the 22 stomachs of adult bass, and 2 of the 13 stomachs of subadult bass that contained food. All except one were eaten during the winter. In the fall, winter, and summer, a few of the stomachs contained small bass.

Sacramento River [(Table 13)]

In the fall, about one-third of the young bass in the Delta were in the Sacramento River, but during the rest of the year this proportion was much smaller (See Sasaki, p. 54). The proportion of the juvenile bass in this area was quite small in the fall, but it increased each season until the summer when it peaked at about one-quarter of the population in the Delta (see Sasaki, p. 65). N. awatschensis was quite abundant in the environment (Turner and Heubach, 1966) and was the most important food of these age-groups. These bass also consumed a fair number of Corophium. Young striped bass were the predominant forage fish.

Mokelumne River [(Table 14)]

The Mokelumne River was of small importance as a nursery area for young and juvenile bass (see Sasaki, pp. 58 and 66). Turner and Heubach (1966) found that N. awatschensis was scarce here in all seasons, but this mysid was the most important food of the juveniles from this area and of those young bass here in the winter and spring. In the fall and summer, young bass fed more often on Corophium.

Only a few stomachs from the older bass contained food. The threadfin shad was the most common of the forage fishes in them.

Flooded Islands [(Table 15)]

The proportion of the Delta population of young and juvenile bass in flooded islands varied seasonally from 5 to 18 percent. These bass fed largely on N. awatschensis in the winter and spring. In the fall and summer, Corophium were a more important food source. In contrast, Turner and Heubach (1966) did not collect any N. awatschensis in these areas during the winter, but they did collect a few in the other seasons.

Depending on season, from 20 to 52 percent of the subadult and adult bass in the Delta inhabited the flooded islands (see Radtke, pp. 21 and 22). These bass preyed primarily on small striped bass and threadfin shad.

Dead-end Sloughs [(Table 16)]

Few bass of any size populated the dead-end sloughs (see Sasaki, pp. 54 and 65; Radtke, pp. 21 and 22). N. awatschensis was the most important invertebrate utilized as food, although it was never abundant in the environment (Turner and Heubach, 1966). Corophium were only of small importance as a food. The threadfin shad, which was so abundant in these sloughs (see Turner, p. 161) was, by far, the most important forage fish. Stomachs of adult and subadult bass often contained more than 10 threadfins. Juvenile bass in these sloughs also consumed a substantial number of threadfins. A few individuals of many other species of fishes were also eaten by the larger bass.

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TABLE 13

Stomach Contents of Striped Bass in the Sacrament

	Young Bass								Juvenile Bass									
	Fall		Winter		Spring		Summer		Fall		Winter		Spring		Summer		Fall	
Food Items	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol
Annelids																		
Unidentified Annelid	--	--	--	--	1	6	--	--	--	--	--	--	--	--	--	--	--	--
Crustaceans																		
Cladocerans and Copepods	--	--	--	--	18	Tr	--	--	--	--	--	--	--	--	--	--	--	--
Mysid shrimp (*Neomysis awatschensis*)	88	79	51	54	75	70	86	55	53	13	36	7	53	4	57	10	--	--
Isopod (*Exosphaeroma oregonensis*)	--	--	3	6	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Amphipods (*Corophium*)	31	21	38	6	30	10	33	2	38	5	27	Tr	18	Tr	17	Tr	--	--
Crayfish (*Pacifastacus leniusculus*)	--	--	--	--	1	7	--	--	--	--	--	--	--	--	--	--	5	5
Unidentifiable shrimp	--	--	--	--	--	--	1	Tr	--	--	--	--	--	--	2	2	--	--
Insects																		
Tendipedids	3	Tr	14	2	4	Tr	--	--	9	Tr	--	--	--	--	5	Tr	--	--
Other Insects	--	--	1	2	--	--	1	Tr	--	--	9	2	--	--	--	--	--	--
Fishes																		
Threadfin shad (*Dorosoma petenense*)	--	--	--	--	--	--	--	--	2	31	--	--	3	25	--	--	--	--
American shad (*Alosa sapidissima*)	--	--	--	--	1	7	4	10	--	--	--	--	--	--	2	7	5	6
King salmon (*Oncorhynchus tshawytscha*)	--	--	--	--	--	--	--	--	--	--	--	--	3	3	2	10	--	--
Pond smelt (*Hypomesus transpacificus*)	--	--	--	--	--	--	1	2	--	--	--	--	3	11	7	23	5	1
Striped bass (*Roccus saxatilis*)	--	--	--	--	--	--	12	30	6	30	--	--	--	--	38	42	65	75
Unidentifiable fishes	--	--	--	--	--	--	1	1	2	5	9	30	9	24	5	7	20	4
Sardine and anchovy bait	--	--	1	31	--	--	--	--	6	16	27	60	18	34	--	--	10	9
Stomachs examined	75		129		145		140		64		27		60		62		52	
Percent containing food	91		57		77		89		83		41		57		68		38	

TABLE 13

Stomach Contents of Striped Bass in the Sacramento River

TABLE 14

Stomach Contents of Striped Bass in the Mokelumn

Food Items	Young Bass								Juvenile Bass									
	Fall		Winter		Spring		Summer		Fall		Winter		Spring		Summer		Fall	
	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol
Crustaceans																		
Cladocerans and Copepods	--	--	--	--	--	--	5	1	--	--	--	--	--	--	--	--	--	--
Mysid shrimp (*Neomysis awatschensis*)	8	2	98	55	74	43	47	13	76	46	88	41	71	5	41	3	--	--
Isopod (*Exosphaeroma oregonensis*)	--	--	--	--	--	--	1	Tr	--	--	--	--	--	--	--	--	--	--
Amphipods (*Corophium*)	92	18	12	1	54	19	70	11	24	3	4	Tr	32	Tr	35	1	17	Tr
Crayfish (*Pacifastacus leniusculus*)	--	--	--	--	--	--	2	8	--	--	--	--	3	Tr	6	9	--	--
Insects																		
Tendipedids	4	Tr	--	--	3	Tr	17	Tr	--	--	--	--	--	--	12	Tr	--	--
Molluscs																		
Asiatic clam (*Corbicula fluminea*)	8	80	--	--	--	--	--	--	--	--	--	--	--	--	6	6	--	--
Fishes																		
Unidentified Ammocoete	--	--	--	--	--	--	--	--	--	--	--	--	3	3	--	--	--	--
Threadfin shad (*Dorosoma petenense*)	--	--	--	--	--	--	1	7	--	--	--	--	3	25	--	--	17	14
American shad (*Alosa sapidissima*)	--	--	--	--	--	--	6	40	--	--	--	--	--	--	6	3	--	--
King salmon (*Oncorhynchus tshawytscha*)	--	--	--	--	--	--	--	--	--	--	--	--	3	24	--	--	--	--
White catfish (*Ictalurus catus*)	--	--	--	--	--	--	2	2	--	--	--	--	--	--	--	--	--	--
Striped bass (*Roccus saxatilis*)	--	--	--	--	--	--	2	18	--	--	--	--	--	--	24	49	17	18
Black crappie (*Pomoxis nigromaculatus*)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Starry flounder (*Platichthys stellatus*)	--	--	--	--	1	6	--	--	--	--	--	--	--	--	--	--	--	--
Unidentifiable fishes	--	--	--	--	--	--	--	--	--	--	--	--	--	--	12	30	50	68
Sardine and anchovy bait	--	--	2	44	1	31	--	--	6	51	12	59	21	42	--	--	--	--
Stomachs examined	28		70		120		153		35		34		47		19		16	
Percent containing food	86		83		80		80		49		74		70		90		38	

TABLE 14

Stomach Contents of Striped Bass in the Mokelumne River

TABLE 15

Stomach Contents of Striped Bass in Flooded Isla

Food Items	Young Bass								Juvenile Bass									
	Fall		Winter		Spring		Summer		Fall		Winter		Spring		Summer		Fall	
	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol
Crustaceans																		
Cladocerans and Copepods	5	Tr	--	--	6	4	--	--	--	--	--	--	2	Tr	--	--	--	--
Mysid shrimp (*Neomysis awatschensis*)	67	40	99	58	96	83	71	17	29	1	69	11	89	35	47	6	2	Tr
Amphipods (*Corophium*)	87	59	8	2	23	3	76	11	61	5	8	Tr	24	2	70	16	2	Tr
Crab (*Rhithropanopeus harrisii*)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Unidentifiable shrimp	--	--	--	--	--	--	--	--	--	--	4	3	--	--	--	--	--	--
Insects																		
Tendipedids	--	--	1	Tr	--	--	3	Tr	--	--	--	--	--	--	6	Tr	--	--
Fishes																		
Threadfin shad (*Dorosoma petenense*)	--	--	--	--	--	--	--	--	10	36	--	--	--	--	--	--	33	51
American shad (*Alosa sapidissima*)	--	--	--	--	--	--	Tr	8	3	11	--	--	--	--	2	11	--	--
Unidentifiable Clupeids	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Striped bass (*Roccus saxatilis*)	--	--	--	--	--	--	11	64	3	14	4	25	--	--	32	66	44	41
Unidentifiable fishes	--	--	--	--	1	10	Tr	Tr	5	20	--	--	4	54	2	Tr	24	6
Sardine and anchovy bait	--	--	2	40	--	--	--	--	10	13	23	61	2	9	--	--	5	2
Stomachs examined	63		148		188		200		124		33		63		87		128	
Percent containing food	100		78		94		92		75		79		86		61		43	

TABLE 15

Stomach Contents of Striped Bass in Flooded Islands

TABLE 16

Stomach Contents of Striped Bass in Dead-End Slo

Food Items	Young Bass								Juvenile Bass									
	Fall		Winter		Spring		Summer		Fall		Winter		Spring		Summer		Fall	
	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol	% Freq Occ	% by Vol
Crustaceans																		
Cladocerans and Copepods	--	--	--	--	2	Tr	--	--	--	--	--	--	--	--	--	--	--	--
Mysid shrimp (*Neomysis awatschensis*)	75	39	93	95	88	97	82	8	16	Tr	68	2	54	7	38	2	4	Tr
Amphipods (*Corophium*)	12	6	26	5	24	3	19	Tr	13	Tr	4	Tr	20	Tr	6	Tr	4	Tr
Crayfish (*Pacifastacus leniusculus*)	--	--	--	--	--	--	--	--	3	1	--	--	--	--	--	--	--	--
Insects																		
Tendipedids	--	--	--	--	2	Tr	6	Tr	--	--	--	--	--	--	--	--	--	--
Molluscs																		
Asiatic clam (*Corbicula fluminea*)	--	--	--	--	--	--	--	--	3	2	--	--	--	--	--	--	--	--
Fishes																		
Unidentified Ammocoete	--	--	--	--	--	--	--	--	--	--	--	--	5	8	--	--	--	--
Threadfin shad (*Dorosoma petenense*)	12	55	--	--	--	--	13	78	50	70	36	98	3	21	44	57	71	83
American shad (*Alosa sapidissima*)	--	--	--	--	--	--	3	3	--	--	--	--	--	--	--	--	--	--
Unidentifiable Clupeids	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7	2
Pond smelt (*Hypomesus transpacificus*)	--	--	--	--	--	--	1	2	--	--	--	--	--	--	6	25	--	--
Carp (*Cyprinus carpio*)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Goldfish (*Carassius auratus*)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Hitch (*Lavinia exilicauda*)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Sacramento blackfish (*Orthodon microlepidotus*)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
White catfish (*Ictalurus catus*)	--	--	--	--	--	--	1	1	--	--	--	--	--	--	--	--	4	1
Striped bass (*Roccus saxatilis*)	--	--	--	--	--	--	7	6	5	9	--	--	3	10	--	--	7	7
Bluegill (*Lepomis macrochirus*)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Black crappie (*Pomoxis nigromaculatus*)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Unidentifiable Centrarchids	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Three-spined stickleback (*Gasterosteus aculeatus*)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Unidentifiable fishes	--	--	--	--	--	--	2	2	18	17	--	--	13	40	19	13	18	8
Sardine and anchovy bait	--	--	--	--	--	--	--	--	3	1	--	--	8	14	6	3	--	--
Stomachs examined	11		79		156		169		88		35		61		37		68	
Percent containing food	73		87		78		62		43		80		62		43		41	

TABLE 16

Stomach Contents of Striped Bass in Dead-End Sloughs

IMPORTANCE OF INDIVIDUAL FOODS

In any season, only five items ever occurred in more than 10 percent of the stomachs of bass of any age. These items were N. awatschensis, Corophium, small striped bass, threadfin shad, and discarded or stolen sardine and anchovy bait. In this section their importance to each of the four age groups of bass is reviewed.

Neomysis awatschensis

N. awatschensis was by far the most important food of young bass. During the fall, winter and spring, it was consumed by more than 84 percent of the young bass. In the summer, even though concentrations of N. awatschensis peaked in the environment (Turner and Heubach, 1966), its occurrence in the stomachs of young bass decreased to 65 percent. This decrease reflected a change in the relative abundance and distribution of the young bass. In the fall, winter and spring, a large percentage of the young bass in the Delta inhabited the lower San Joaquin River where concentrations of N. awatschensis were high. In the summer, the percentage of the bass in this area decreased considerably and the percentage increased in the middle San Joaquin River (see Sasaki, p. 54) where N. awatschensis was not as available.

N. awatschensis was also a very important food of juvenile bass. In the winter and spring, more than 79 percent of the juveniles consumed N. awatschensis. During the fall and summer, when forage fishes were readily available, fewer juveniles fed on N. awatschensis.

N. awatschensis was eaten by a few subadult and adult bass, but it was not an important part of their diet.

Corophium

Corophium were eaten by large numbers of young and juvenile bass, especially by young bass in those areas of the Delta where N. awatschensis was scarce. They were consumed by a few subadult and adult bass also. These amphipods are too small to be a very important food of any but the young bass.

Small Striped Bass

Young striped bass were one of the important foods of adult and subadult bass. In the fall, they were eaten by about two-fifths of the subadults and adults. In the winter and spring, as the young bass became less abundant and larger (see Sasaki, p. 49), they were eaten less frequently. In the summer, when the new year-class of young bass became available, there was a sharp increase in the percentage of the subadults and adults that had eaten small bass. These new young-of-the-year bass were also of importance as a food of juvenile bass.

Threadfin Shad

Threadfin shad were also a very important food source for subadult and adult bass. They were especially important in the fall when they were extremely abundant in the middle San Joaquin River and the dead-end sloughs, and in the winter when their numbers were decreasing (see Turner, p. 164). In the winter, numbers of small bass also decreased (see Sasaki, p. 49), so the threadfins were still one of the more available forage species. In the fall, the threadfins were also

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quite prominent in the diet of juvenile bass. They were eaten by only a very few young bass.

Sardine and Anchovy Bait

A surprisingly large percentage of the adult bass had eaten quantities of sardine and anchovy bait which had either been discarded by anglers or stolen from their hooks. In the winter and spring, bait was also consumed by a small but significant percentage of the juvenile bass. It was eaten by relatively few young or subadult bass.

FOOD SELECTIVITY

Some organisms in the Delta that were of a size suitable for food were seldom eaten. For example, small American shad were very abundant during the summer and fall (see Stevens, p. 101), but few were consumed by bass. Similarly, Hazel and Kelley (1966) collected zoobenthos from the Delta belonging to 35 taxa; they found that the two species of Corophium, tendipedids, Corbicula fluminea, and oligochaetes were abundant; however, bass stomachs contained benthic organisms belonging to only 8 taxa and Corophium were the only benthos utilized in appreciable quantity.

Young bass seem to prefer N. awatschensis over Corophium [(Table 17)]. Indices of concentrations of N. awatschensis and Corophium in the environment when compared with the frequency of occurrence of these organisms in the stomachs of young bass, show that young bass fed primarily on Corophium only if Corophium were abundant and N. awatschensis was scarce. If N. awatschensis and Corophium were abundant, if N. awatschensis was abundant and Corophium were not, and if N. awatschensis and Corophium were scarce, young bass fed primarily on N. awatschensis.

TABLE 17

Occurrence of *Neomysis awatschensis* and *Corophium* in Stomachs of Young Striped Bass Compared with the Abundance of *N. awatschensis* [1] and *Corophium* [2] in the Environment

Area	Mean Seasonal Percent Frequency of Occurrence of N. *awatschensis* in Stomachs of Young Bass	Mean Seasonal Percent Frequency of Occurrence of *Corophium* in Stomachs of Young Bass	Abundance of N. *awatschensis* in Environment	Abundanc *Corophi* in Environ
Lower San Joaquin River	94.8	29.5	A	A
Dead-End Sloughs	84.3	20.4	S	S
Sacramento River	75.2	32.8	A	A
Franks Tract	73.3	55.5	S	S
Middle San Joaquin River	66.1	51.3	A	S
North Fork of Mokelumne River and South Fork of Mokelumne River at New Hope Landing	59.7	45.1	S	S
Old River-Fabian and Bell Canal	58.4	72.0	S	A
Mokelumne River at Terminous	52.3	65.2	S	A
Upper San Joaquin River	12.3	88.2	S	A

[1] Based on mean season catch of N. *awatschensis* with a Clarke-Bumpus plankton net (Turner and Heubach, 1
A = abundant (28–75 N. *awatschensis* per cubic meter of water).
S = scarce (0– 6 N. *awatschensis* per cubic meter of water).

[2] Based on mean numbers of *Corophium* caught with a Peterson dredge by Hazel and Kelley (1966).
A = abundant (30–57 *Corophium* per square foot).
S = scarce (6–20 *Corophium* per square foot).

TABLE 17

Occurrence of Neomysis awatschensis and Corophium in Stomachs of Young Striped Bass Compared with the Abundance of N. awatschensis and Corophium in the Environment

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Small bass and threadfin shad were eaten at a rate more directly related to their density in the environment. Turner (see p. 161) indicates that threadfin were most concentrated in the middle San Joaquin River and dead-end sloughs, and in these areas large bass preyed on them heaviest. Sasaki (see p. 49) has shown that the greatest concentrations of small bass occurred in the lower San Joaquin River, Sacramento River, and flooded islands, and they were utilized by large bass more frequently in these areas than in the rest of the Delta.

EFFECT OF SAMPLING GEAR ON RESULTS

It has been shown in this paper that bass stomach contents differed in the various environmental zones of the Delta. These differences are probably an effect of differences in the availability of foods in the different zones, and food preferences.

There were also differences in the availability of different kinds of food organisms within each zone, particularly at different depths of the channels. N. awatschensis (Turner and Heubach, 1966) and Corophium are generally most abundant near the bottom of the channels, the vertical distribution of small striped bass is quite variable (Chadwick, 1964; see Sasaki, p. 46), and threadfin shad are most abundant at the surface (see Turner, p. 160). Because the otter trawl collected bass from near the bottom of the channels and the midwater trawl collected bass from near the surface, it was possible to compare the stomach contents of bass collected at different depths, and consequently determine if the results of this study might have been influenced by the proportion of the sample collected by each type of trawl. Chi square, two-way classification tests were used to determine if in the summer of

1964 the proportion of young bass utilizing each of the important food organisms was significantly different from each type of trawl.

The tests indicated three major differences in stomach contents [(Table 18)]. The proportion of the stomachs that contained threadfin shad was significantly larger in the sample from the midwater trawl than in the sample from the otter trawl, and the proportions of the stomachs that contained N. awatschensis and Corophium were significantly larger in the sample from the otter trawl than in the sample from the midwater trawl.

TABLE 18

Frequency of Important Foods Compared for Stomachs of Young Striped Ba Collected in the Midwater and Otter Trawls in Summer, 1964 in All Environmental Zones

Food Item	Midwater Trawl		Otter Trawl			
	Obs. Freq.	Exp. Freq.	Obs. Freq.	Exp. Freq.	X^2	Perc (1
N. awatschensis	213	236	433	410	10.13	0.
Corophium	183	211	393	365	13.38	0.
Threadfin Shad	31	13	5	22	37.32	0.
Striped Bass	25	27	48	46	0.09	
Stomachs Containing Food	360		624			

TABLE 18

Frequency of Important Foods Compared for Stomachs of Young Striped Bass Collected in the Midwater and Otter Trawls in Summer, 1964 in All Environmental Zones

— 90 —

These differences in stomach contents could have resulted directly (i) from bass caught at different depths having fed on different organisms or (ii) from bass caught in the midwater trawl having formed a larger than normal proportion of the sample from zones where threadfin shad were most available and/or from bass caught in the otter trawl having formed a larger than normal proportion of the sample from zones where N. awatschensis and Corophium were most available.

Further inspection of the data revealed that in the two zones, (middle San Joaquin River and dead-end sloughs) where threadfin shad were most densely distributed, the proportion of the sample formed by bass caught in the midwater trawl was, in fact, large. Bass caught in the midwater trawl formed 47 percent of the trawl-caught sample in these two zones; whereas they made up only 37 percent of the trawlcaught sample for all zones combined. Therefore, the proportion of bass utilizing each food organism was also compared for the midwater and otter trawl samples from the middle San Joaquin River and dead-end sloughs only. Chi square tests indicated that the same three differences in stomach contents were significant [(Table 19)].

TABLE 19

Frequency of Important Foods Compared for Stomachs of Young Striped Bas[illegible] Collected in the Midwater and Otter Trawls in Summer, 1964 in Middle San Joaquin River and Dead-end Sloughs

Food Item	Midwater Trawl		Otter Trawl		X^2	Perce[illegible] (1 d[illegible]
	Obs. Freq.	Exp. Freq.	Obs. Freq.	Exp. Freq.		
N. awatschensis	50	60	80	70	6.42	0.[illegible]
Corophium	22	44	74	52	34.91	0.[illegible]
Threadfin Shad	26	13	3	16	23.91	0.[illegible]
Striped Bass	8	6	5	7	0.78	
Stomachs Containing Food	99		117			

TABLE 19

Frequency of Important Foods Compared for Stomachs of Young Striped Bass Collected in the Midwater and Otter Trawls in Summer, 1964 in Middle San Joaquin River and Dead-end Sloughs

On the basis of the chi square tests, I have concluded that the results of this food habits study were influenced by the proportion of the sample collected with each type of trawl. The validity of the results of this study might have been increased if it were possible to weight accurately the sample from each trawl according to the proportion of the population in the strata of water that it represented. However, the catch data indicate that the vertical distribution of young bass varied considerably over time and between sampling stations (see Sasaki, Table 2, p. 47), and only fragmentary data were available on the vertical distribution of other age groups; therefore, it was not possible to estimate meaningful weight factors.

The proportion of the stomachs that contained food also varied with the sampling gear (Figure 2). To demonstrate this point it was necessary to compare proportions representing each gear for only one age-group of bass because the proportion of the stomachs containing food varied with the age of the bass (Tables 5–8) and each gear caught a different proportion of the total sample of each age-group. Large numbers of individuals from only the juvenile age-group were caught by all three types of gear so this group was selected.

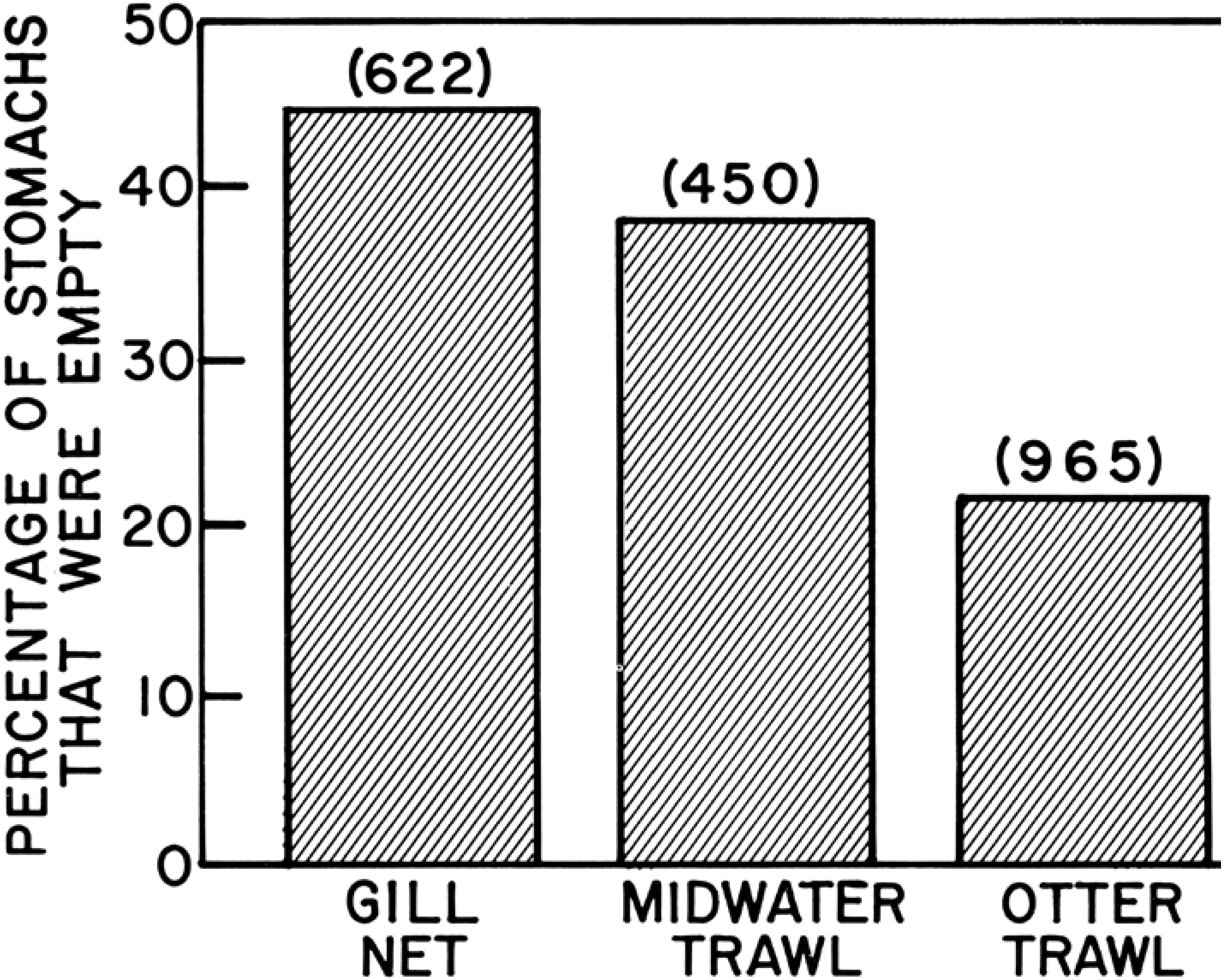

FIGURE 2. Percentage of juvenile bass stomachs that were empty compared to m
by which the bass were collected. Numbers of stomachs examined are in parent

FIGURE 2. *Percentage of juvenile bass stomachs that were empty compared to method by which the bass were collected. Numbers of stomachs examined are in parentheses.*

Two-way classification chi square tests indicated that the proportion of bass stomachs that contained food for each type of gear was significantly different from the proportion for each of the other two types of gear [(Table 20)]. The proportion of the bass with empty stomachs that were caught in the midwater trawl was larger than the proportion of the bass with empty stomachs from the otter trawl, and the proportion of bass with empty stomachs that were caught in the gill net was larger than that proportion for both the otter trawl and midwater trawl samples. The former difference probably reflected a greater abundance of food near the bottom, and the latter difference probably resulted from some of the stomachs' content being digested while the bass were in the net and unable to feed.

TABLE 20

Frequency of Empty Stomachs Compared for Juvenile Bass Collected by Three Types of Sampling Gear

Comparison	Midwater Trawl		Otter Trawl		Gill Net		X²	Per (1
	Tot. Stomachs = 450		Tot. Stomachs = 965		Tot. Stomachs = 622			
	Obs. No. Empty Stomachs	Exp. No. Empty Stomachs	Obs. No. Empty Stomachs	Exp. No. Empty Stomachs	Obs. No. Empty Stomachs	Exp. No. Empty Stomachs		
Midwater Trawl vs. Otter Trawl	173	120	204	257	—	—	46.14	(
Midwater Trawl vs. Gill Net	173	189	—	—	278	261	3.93	(
Otter Trawl vs. Gill Net	—	—	204	293	278	189	98.12	(

TABLE 20

Frequency of Empty Stomachs Compared for Juvenile Bass Collected by Three Types of Sampling Gear

FOOD INTAKE AND BASS GROWTH

In the summer of 1964 there was a progressive change in the composition of the stomach contents of year-old bass from the lower to the middle to the upper San Joaquin River. In the lower river (Table 9), N. awatschensis occurred in almost all stomachs, Corophium were in about one-third of the stomachs, and tendipedids occurred in almost no stomachs. In the middle river (Table 10), only two-fifths of the stomachs contained N. awatschensis, Corophium occurred in more than two-thirds of the stomachs and were the most common food item, and tendipedids were in 14 percent of the stomachs. In the upper river (Table 11), N. awatschensis was in almost no stomachs, but seven-eights of the stomachs contained Corophium, and more than one-half contained tendipedids. These changes in diet almost certainly reflected a change in the kinds of food available (see p. 88).

There was not only the progressive change in diet composition, but there was also a corresponding progressive change in the intensity of food consumption. The amount of food in bass stomachs decreased significantly from the lower to the middle to the upper river [(Table 21)]. This decrease suggests that the total food availability decreased from the lowermost to the uppermost zone. In regard to this hypothesis, Ellis and Gowing (1957) found that the amount of food in stomachs of brown trout, Salmo trutta, was directly related to the amount of food in the section of the stream from which the trout were collected; and in a series of experiments, Ivlev (1961, pp. 19–40) found that the amount of food consumed by fishes depended on the mean concentration and degree of aggregation of food in the environment.

TABLE 21

Comparison of Mean Volumes of Food in Stomachs of Striped Bass from Thre Environmental Zones of the San Joaquin River [1]

Environmental Zones and Mean Volumes of Food (cc)	t Value	Degrees of Freedom	Percen
Lower River vs. Upper River 0.1875 0.0172	3.61	82	0.9[illegible]
Lower River vs. Middle River 0.1875 0.0845	2.47	98	0.9[illegible]
Middle River vs. Upper River 0.0845 0.0172	3.28	80	0.9[illegible]

[1] Bass were 14.5 to 16.5 cm FL and were collected during August 1964. Bass were selected from this size ran minimize variations in stomach capacities and to maximize the sample size without using effort additional t regular sampling program.

TABLE 21

Comparison of Mean Volumes of Food in Stomachs of Striped Bass from Three Environmental Zones of the San Joaquin River

Sasaki (see p. 55) describes differences in the mean length and mean coefficient of condition of year-old bass from the same three environmental zones. It seems reasonable to expect that these differences were related to the food intake. In support of this theory the mean length and mean coefficient of condition of the bass from the lower river was greater than that of the bass from the middle and upper river (Figure 3). However, the trends in food intake, fork length, and coefficient of condition of bass from the middle to the upper river do not agree. The mean fork length of bass from the middle river was the same as that of bass from the upper river, and the mean coefficient

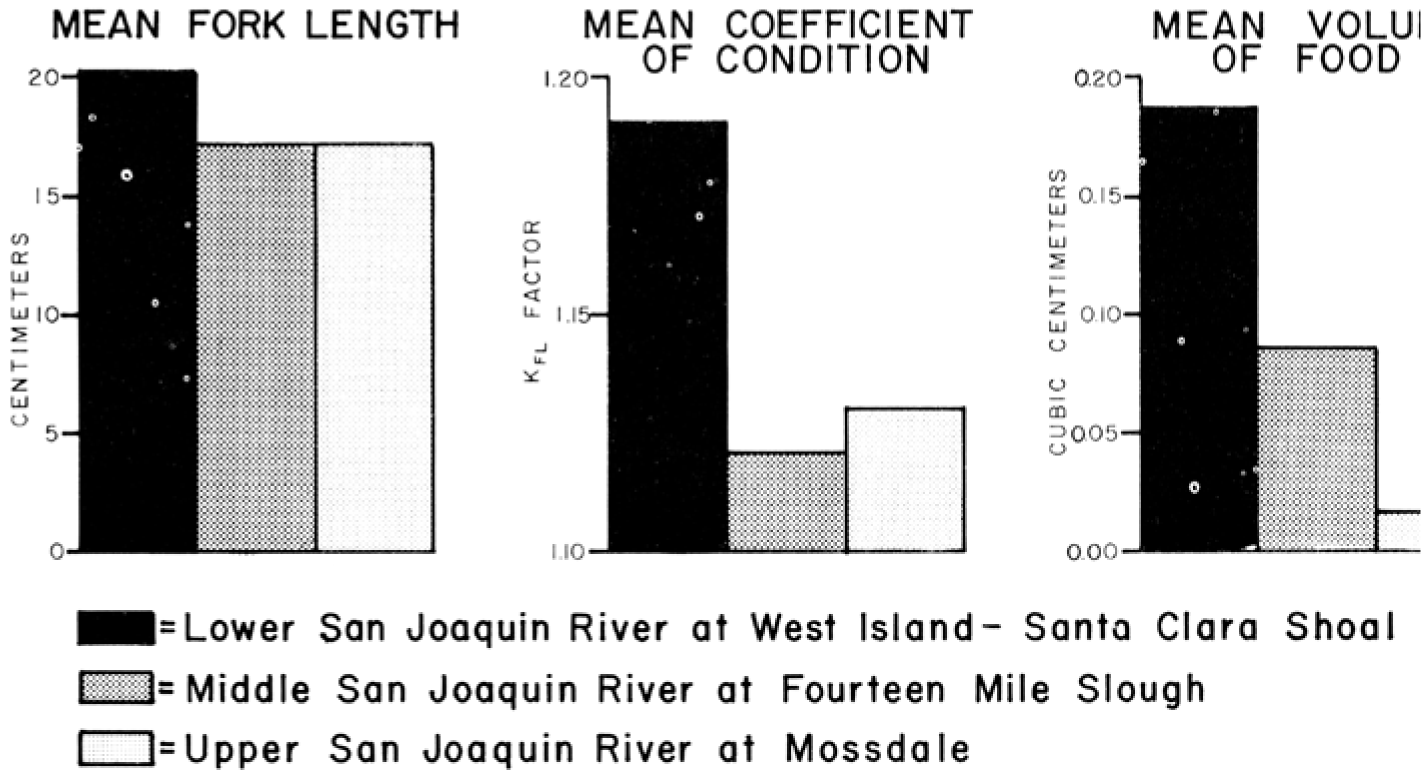

FIGURE 3. Mean volume of food per stomach, mean length, and mean coefficient of tion of year-old bass from the three environmental zones of the San Joaquin River the summer of 1964.

FIGURE 3. *Mean volume of food per stomach, mean length, and mean coefficient of condition of year-old bass from the three environmental zones of the San Joaquin River during the summer of 1964.*

of condition of bass from the middle river was smaller, although not significantly smaller, than bass from the upper river; whereas the food intake was higher in the middle river than in the upper river. However, it should be noted here that there was a large increase in Sasaki's catches of year-old bass in the middle river from spring to summer (see p. 52); therefore, bass must have migrated there from another area. They may have come from upstream too recently to have put on growth consistent with their increased food intake. It is relevant that in the study by Ellis and Gowing (1957) the coefficient of condition of brown trout was highest in the section of the stream in which the food supply and food intake was highest.

DISCUSSION AND SUMMARY

The bass stomachs contained more than 30 different foods, but only 5 of these foods, N. awatschensis, Corophium, small striped bass, threadfin shad, and bait, were eaten by an appreciable percentage of bass during any season.

Young bass entered their first fall, feeding almost entirely on invertebrates (Figure 4). They continued to do so through the winter and spring. In their second summer of life, they began feeding on small fish, primarily new young-of-the-year striped bass and threadfin shad.

In the second fall of their life, the bass, now juveniles, fed nearly half on fish and half on invertebrates. During this period, threadfin shad and small striped bass were abundant and at the proper size. In the winter and spring when many of the small bass had moved

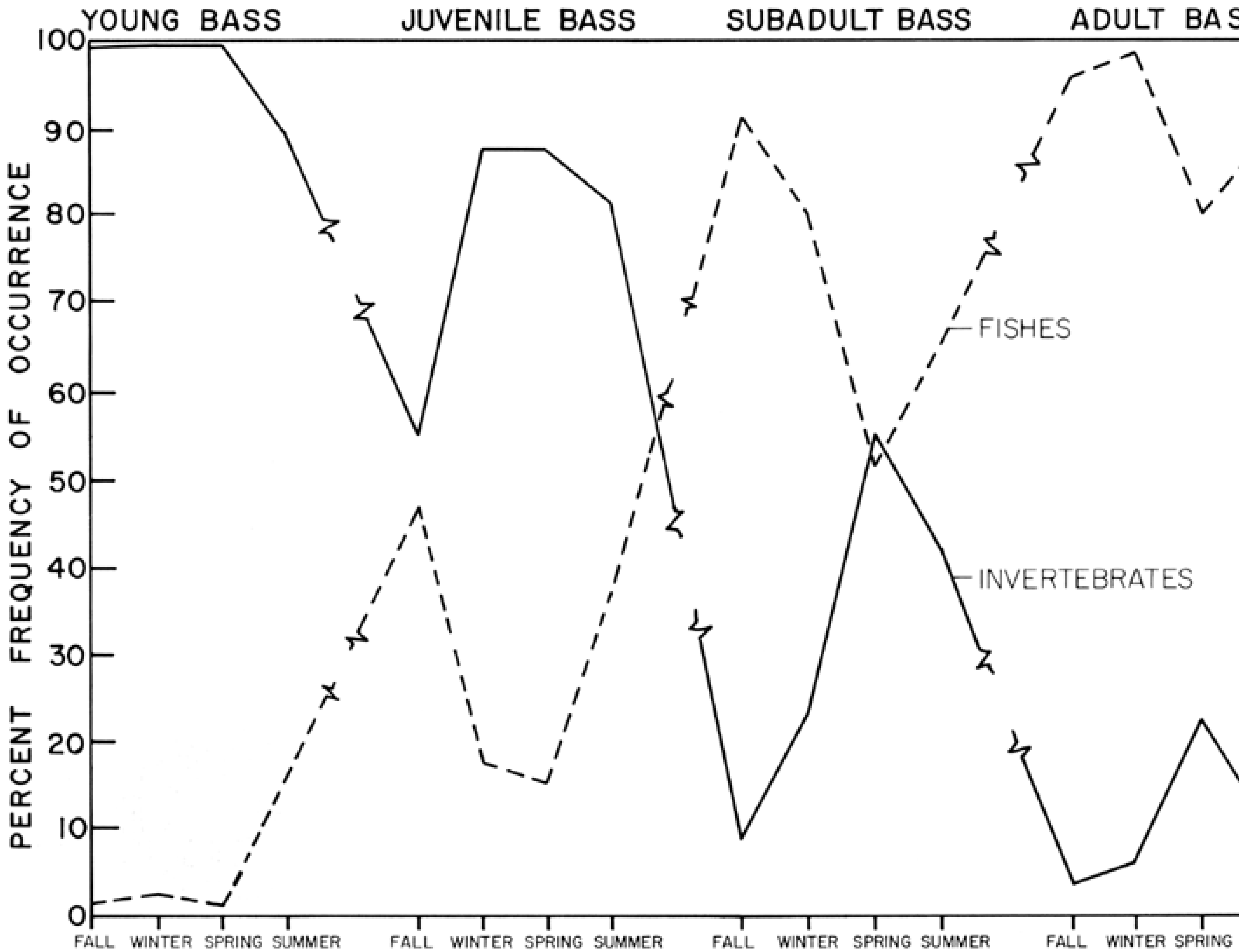

FIGURE 4. Percent frequency of occurrence of fishes and invertebrates in stomac striped bass of different ages from fall 1963 through summer 1964.

FIGURE 4. *Percent frequency of occurrence of fishes and invertebrates in stomachs of striped bass of different ages from fall 1963 through summer 1964.*

down into the bays below the Delta (see Sasaki, p. 49; and Ganssle, 1966), and the threadfin shad had died out (see Turner, p. 164), the juvenile bass returned to a diet formed largely by invertebrates. When the new crop of young-of-the-year bass and threadfin shad became available in the summer, the juveniles turned again toward a diet of small fish.

In the fall, the abundant small striped bass and threadfin shad comprised nearly the entire diet of the subadult bass. Like the juveniles, the subadults consumed less fish and more invertebrates in the winter and spring when small fishes were less numerous. The subadults returned to an almost exclusive fish diet when the new crops of small bass and threadfin shad arrived in the summer.

Adult bass fed primarily on small bass and threadfin shad. In the spring and early summer the adults reduced their food intake. This reduction was probably related to their spawning activities.

The shift from the diet of young bass which consisted primarily of invertebrates to the diet of the adult bass which was formed predominately by fishes was obviously a result of selective feeding by bass of different sizes. This shift in diet was not unexpected in view of findings of many other studies and conforms with the results of Ivlev's (1961, pp. 82–91) experiments showing that predators prefer to devour victims of the largest possible size.

Corophium were the only zoobenthos that bass utilized in significant amounts. These amphipods were the most abundant of the macro-organisms collected from the bottom of the Delta channels by Hazel and Kelley (1966). Corophium also are often found on the substrate

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rather than in it, so are probably more available than those less abundant benthic animals which live in the substrate.

Few bass stomachs contained small king salmon. Oncorhynchus tshawytscha. Several biologists (Scofield, 1931; Shapovalov, 1936; Hatton, 1940) have speculated on how much striped bass prey upon seaward migrating salmon. Hatton (1940) analyzed stomach contents of 224 adult bass from the Delta during the salmon migration primarily to determine the extent of this predation. He found no salmon in the stomachs and concluded that they were not an important food source. Adult bass are spawning during the salmon migration; therefore, they would not be serious predators because they do not feed heavily then.

Recently, Thomas (1966) reported that juvenile bass consumed quantities of small salmon in the spring and summer in the Sacramento River above the Delta. This suggests that salmon are more available there than in the Delta. This availability may be a direct result of the greater clarity and/or small width of the river. The small salmon are necessarily more concentrated when in the relatively narrow river than when in the broad and diverging channels of the Delta. The availability of small salmon to striped bass in the Delta during the summer might also be low because other forage fishes, particularly young-of-the-year striped bass, act as a buffer against predation on the salmon.

Relatively few small American shad were eaten by striped bass, even during the summer when small shad were quite abundant. Thomas (1966) did not find many American shad in the stomachs of striped bass either. Why more bass did not prey upon this species is unknown.

Sardine and anchovy bait were consumed with surprising frequency by juvenile and adult bass. These baits may have either been discarded by anglers or stolen from their hooks.

Young bass grew best in the lower San Joaquin River where the mysid, N. awatschensis, was extremely abundant. A decrease in the concentration of N. awatschensis here would almost certainly reduce the rate of growth and perhaps the survival of these bass. Since this zone is the most important nursery area in the Delta for young bass (see Sasaki, p. 44), such a reduction would probably seriously affect the structure of the entire bass population.

Suitable forage fishes for striped bass were scarce in the Delta during the winter and spring. Both juvenile and subadult bass fed on invertebrates during this period. The rate of growth and survival of these bass might be improved if small forage fishes were more available at this time.

Because the availability of food organisms varied with depth, bass stomach contents varied with the depth at which the bass were collected. Different sampling gear was used to collect bass at different depths; therefore, the results of this study were influenced to some extent by the proportion of the sample collected by each type of gear.

LITERATURE CITED

Calhoun, Alex J. 1952. Annual migrations of California striped bass. Calif. Fish and Game, *38*(3) : 391–403. Chadwick, Harold K. 1964. Annual abundance of young striped bass, Roccus saxatilis, in the Sacramento-San Joaquin Delta, California. Calif. Fish and Game, *50*(2) : 69–99.

— 96 —

Ellis, Robert J., and Howard Gowing. 1957. Relationship between food supply and condition of wild brown trout. Salmo trutta Linnaeus, in a Michigan stream. Limnol. and Oceanog., *2*(4) : 299–308. Ganssle, David. 1966. Fishes and decapods of San Pablo and Suisun Bays, p. 64–94. *In* D. W. Kelley, (ed.), Ecological studies of the Sacramento-San Joaquin Estuary. Calif. Fish and Game, Fish Bull., (133) : 1–133. Hatton, S. Ross. 1940. Progress report on Central Valley fisheries investigation, 1939. Calif. Fish and Game, *26*(4) : 335–373. Hazel, Charles R., and D. W. Kelley. 1966. Zoobenthos of the Sacramento-San Joaquin Delta, p. 113–133. *In* D. W. Kelley, (ed.), Ecological studies of the Sacramento-San Joaquin Estuary. Calif. Fish and Game, Fish Bull., (133) : 1–133. Heubach, William, Robert J. Toth and Alan M. McCready. 1963. Food of young-of-the-year striped bass (Roccus saxatilis) in the Sacramento-San Joaquin River system. Calif. Fish and Game, *49*(4) : 224–239. Hollis, Edgar Harrison. 1952. Variations in the feeding habits of the striped bass, Roccus saxatilis (Walbaum) in Chesapeake Bay. Bingham Oceanogr. Coll., Bull., *14*(1) : 111–131. Ivlev, V. S. 1961. Experimental ecology of the feeding of fishes. Yale Univ. Press, New Haven, 302 p. Johnson, W. C., and A. J. Calhoun. 1952. Food habits of California striped bass. Calif. Fish and Game, *38*(4) : 531–534. Scofield, E. C. 1928. Striped bass studies. Calif. Fish and Game, *14*(1) : 29–37. Scofield, E. C. 1931. The striped bass of California. Calif. Div. Fish and Game, Fish

Bull., (29) : 1–82. Scofield, N. B. 1910. Notes on the striped bass in California. Calif. Fish and Game Comm., Bien. Rept., (21) : 104–109. Scofield, N. B., and H. C. Bryant. 1926. The striped bass in California. Calif. Fish and Game, *12*(2) : 55–74. Scofield, N. B., and G. A. Coleman. 1910. Notes on the spawning and hatching of striped bass eggs at Bouldin Island Hatchery. Calif. Fish and Game Comm., Bien. Rept., (21) : 109–117. Shapovalov, Leo. 1936. Food of the striped bass. Calif. Fish and Game, *22*(4) : 261–271. Smith, H. M. 1896. A review of the history and results of attempts to acclimatize fish and other water animals in the Pacific states. U. S. Fish Comm., Bull., *15* : 449–458. Thomas, John L. 1967. The diet of juvenile and adult striped bass, Roccus saxatilis, in the Sacramento-San Joaquin River system. Calif. Fish and Game, *53*(1) : 49–62. Turner, Jerry L., and William Heubach. 1966. Distribution and concentration of Neomysis awatschensis in the Sacramento-San Joaquin Delta, p. 105–112. *In* D. W. Kelley, (ed.), Ecological studies of the Sacramento-San Joaquin Estuary. Calif. Fish and Game, Fish Bull., (133) : 1–133.

DISTRIBUTION AND FOOD HABITS OF THE AMERICAN SHAD, ALOSA SAPIDISSIMA, IN THE SACRAMENTOSAN JOAQUIN DELTA

DONALD E. STEVENS

This paper describes the distribution, migrations and food habits of the American shad in the Sacramento-San Joaquin Delta. The description is based on catches of shad in gill nets and trawls, on the estimation of gonad maturation in adult shad, and on the examination of contents of 269 stomachs of adult shad.

Adult shad were abundant in the Delta only during their spawning migration. The Sacramento and Mokelumne River systems supported larger runs than the San Joaquin River. There is evidence that while most shad spawned far upstream, some spawned in several areas in the Delta itself. The catch and gonad maturation data suggest that a large percentage of the adults die shortly after spawning, although there is also evidence that some spent shad do migrate seaward. Adult shad fed primarily on a mysid, Neomysis awatschensis, and copepods and cladocerans. Percentages of stomachs containing food were directly related to concentrations of food organisms in the environment.

Young shad were abundant in the Delta from July through November. Greatest concentrations occurred in the Sacramento River, Mokelumne River, dead-ends sloughs tributary to the Mokelumne River, and the San Joaquin River below the mouth of the Mokelumne River. Most of the young shad in the latter area probably originated in the Sacramento and Mokelumne rivers.

Some migrations of young shad within the Delta appeared to be related to the food supply.

METHODS

The trawling and gill netting procedures, locations of the sampling stations, and the method of estimating gonad maturation are described by Turner (see p. 12). Procedures used in the food habits analysis are the same as those described for striped bass by Stevens (see p. 68).

ADULT SHAD

Catch Analysis

Adult shad ranging in size from 20 to 55 cm *FL* were collected with gill nets from September 1963 through August 1964. They were abundant in the Delta only in the spring during their spawning migration (Figure 1). Catches at most stations, but especially at those stations in the Sacramento River, Mokelumne River and tributary sloughs, and Fabian and Bell Canal, increased very significantly during April and May. The catches generally decreased during June and were at prespawning season level after June.

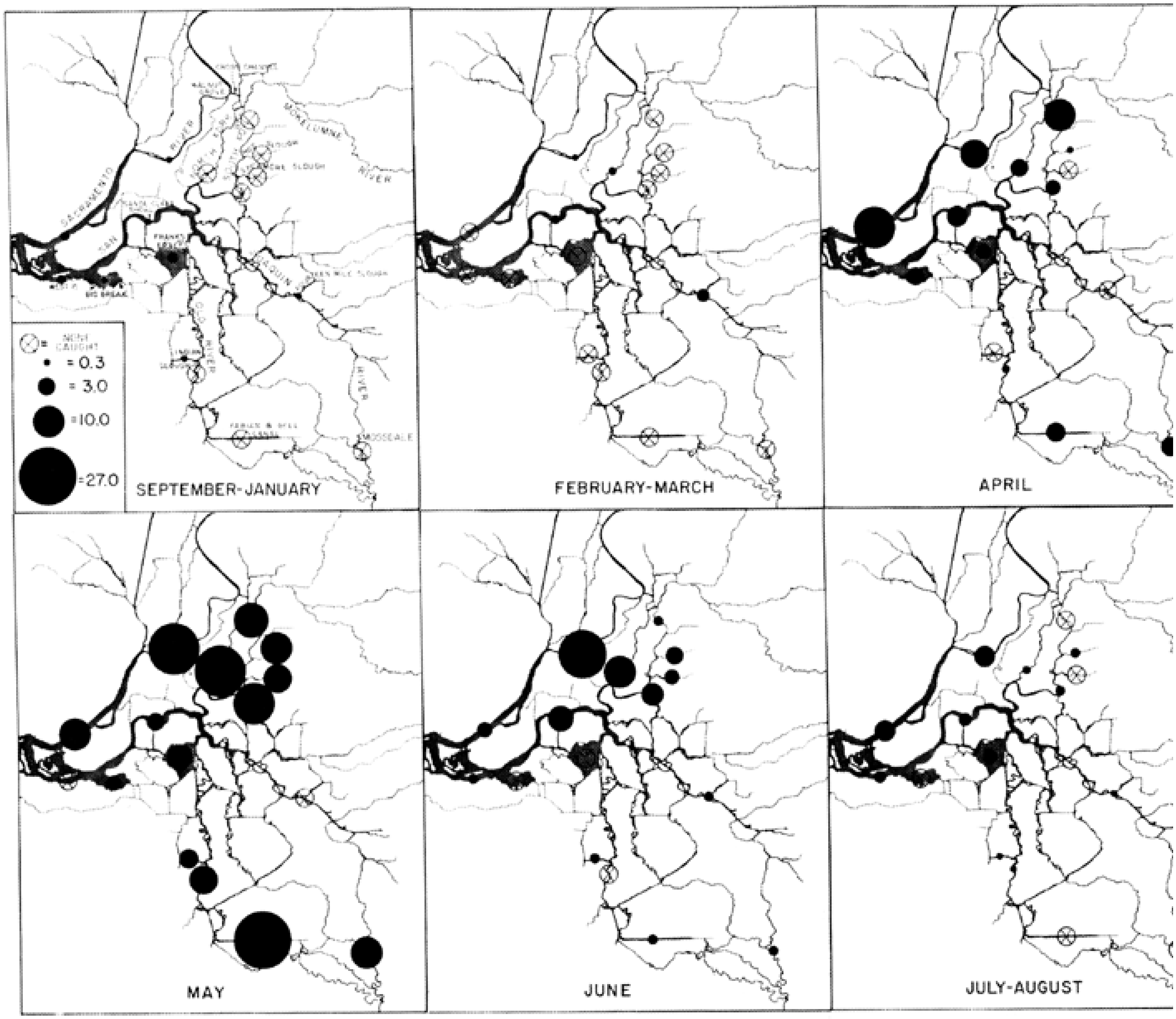

FIGURE 1. Concentrations of adult American shad in the Sacramento-San Joaquin from September 1963 to August 1964. The area of each circle represents the mean n of shad caught in an overnight gill net set.

FIGURE 1. Concentrations of adult American shad in the Sacramento-San Joaquin Delta from September 1963 to August 1964. The area of each circle represents the mean number of shad caught in an overnight gill net set

Between April and July, gonads of many adult shad were ripe and discharging eggs and milt [(Table 1)]. Generally, a higher percentage of males than females were ripe. Even though the largest catches of adult shad were from the lower Sacramento River, no ripe females were caught there until August. Since no females were ripe during or before

TABLE 1

Sexual Maturity of Adult American Shad by Area from April to July, 1964[1]

Area	Stage of Maturity							
	Females					Males		
	Immature	Developing	Ripe	Spent	Sample Size	Not Ripe	Ripe	S
Sacramento River	--	90.0	--	10.0	20	48.3	51.7	
Mokelumne River	--	69.2	28.2	2.6	39	51.7	48.3	
Old River	--	75.0	25.0	--	8	--	100.0	
Fabian and Bell Canal	--	21.4	78.6	--	14	60.0	40.0	
Franks Tract and Big Break	--	100.0	--	--	5	71.4	28.6	
Hog, Sycamore and Indian Sloughs	15.0	50.0	35.0	--	20	16.0	84.0	
San Joaquin River at Mossdale	--	33.3	66.7	--	9	25.0	75.0	
San Joaquin River at West Island, Santa Clara Shoal, and Fourteen Mile Slough	--	50.0	--	50.0	8	100.0	--	

[1] Values for stage of maturity are percentages.

TABLE 1

Sexual Maturity of Adult American Shad by Area from April to July, 1964[1]

the peak of this run, I believe that the shad caught in the lower Sacramento River were on their way to spawning areas upstream. Many shad spawn in the rivers tributary to the Sacramento River above the Delta. In the Feather, Yuba, and American rivers there is an excellent sport fishery on the spawning grounds. Conversely, a large percentage of the female shad caught in Fabian and Bell Canal and in the upper San Joaquin River at Mossdale were ripe, and I believe that these shad were spawning in the Delta proper. A significant but not large percentage of the female shad in the Mokelumne River and adjacent dead-end sloughs were also ripe. I believe that some of these shad spawned in the vicinity of these sampling stations, but most were on their way to the Mokelumne River above the Delta or to the Sacramento River via the cross channel at Walnut Grove.

The large catches of adult shad in Fabian and Bell Canal suggest that the south Delta may be an important producer of shad; however, few young shad were caught in this region (Figures 4 and 5). My analysis of the differences in adult shad gonad maturation between areas as related to their migrations and spawning helps to explain this disagreement. If most of the adult shad caught at the Sacramento and Mokelumne River stations were on their way upstream, a much larger percentage of the shad entering the Delta would have ascended the Sacramento and Mokelumne rivers than is indicated merely by the numbers caught there. The catches of adults in the Sacramento River, and to a lesser extent the catches of adults in the Mokelumne River, would primarily be indices of the concentrations passing by the sampling stations each night; whereas, the numbers of adults caught in the south Delta would reflect the size of the concentrations accumulating there for spawning.

The small catches of adult shad during July and August (Figure 1) suggest that a large percentage of those adults that spawn in the upper rivers succumb shortly after spawning. This suggestion is supported by the large numbers of dead, spent shad present in Sacramento River tributaries during July (Calif. Dept. of Fish and Game, unpublished). However, there is also evidence that some shad do migrate seaward after spawning. During August, I caught 5 spent female shad in the Sacramento River at Sherman Island; and in Suisun Bay in September 1963, Ganssle (1966) caught 11 spent adults. These areas are below all known spawning grounds.

Food Habits

Adult shad fed primarily on zooplankton. The mysid shrimp, Neomysis awatschensis, was the most important of these plankton. It occurred in stomachs more frequently than any other organism and it formed most of the total food volume [(Table 2)]. The stomach of one adult shad contained more than 4,000 N. awatschensis. Copepods and cladocerans were the only other food of importance. Some stomachs contained an estimated 3,000 of these plankters. The amphipods, Corophium stimpsoni and/or Corophium spinicorne, occurred in a significant percentage of the stomachs; however, no stomach contained more than 10 individuals and I conclude that Corophium were not really important to adult shad.

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TABLE 2

Stomach Contents of Adult American Shad

Food Item	Percent Frequency of Occurrence					Pe of V
	Fall	Winter	Spring	Summer	Average	
Copepods and Cladocerans	37.5	--	38.3	11.1	31.5	1
Mysid shrimp (*Neomysis awatschensis*)	62.5	100.0	61.7	96.3	70.1	8
Amphipod (*Corophium* spp.)	--	33.3	17.3	25.9	17.3	
Asiatic clam (*Corbicula fluminea*)	--	--	7.4	--	4.7	
Unidentified fish larvae	--	--	1.2	--	0.8	
Seed	--	--	1.2	--	0.8	
Stomachs examined	25	4	180	60	269	
Stomachs containing food	16	3	81	27	127	

TABLE 2

Stomach Contents of Adult American Shad

The occurrence of zooplankton in stomachs of adult shad was directly related to concentrations of zooplankton in the environment (Figure 2). Zooplankton were collected from the environment with a Clarke-Bumpus net towed for 10 minutes on the days the stomachs were collected. During April and May, stomachs of shad from the upper San Joaquin River at Mossdale, the Mokelumne River and Old River were generally empty. Zooplankton populations in these areas were low. Food was generally present in the stomachs of shad from the Sacramento River and Sycamore, Hog and Indian sloughs. Zooplankton concentrations were high in these areas. There was no relationship between the occurrence of food in stomachs and gonad maturation.

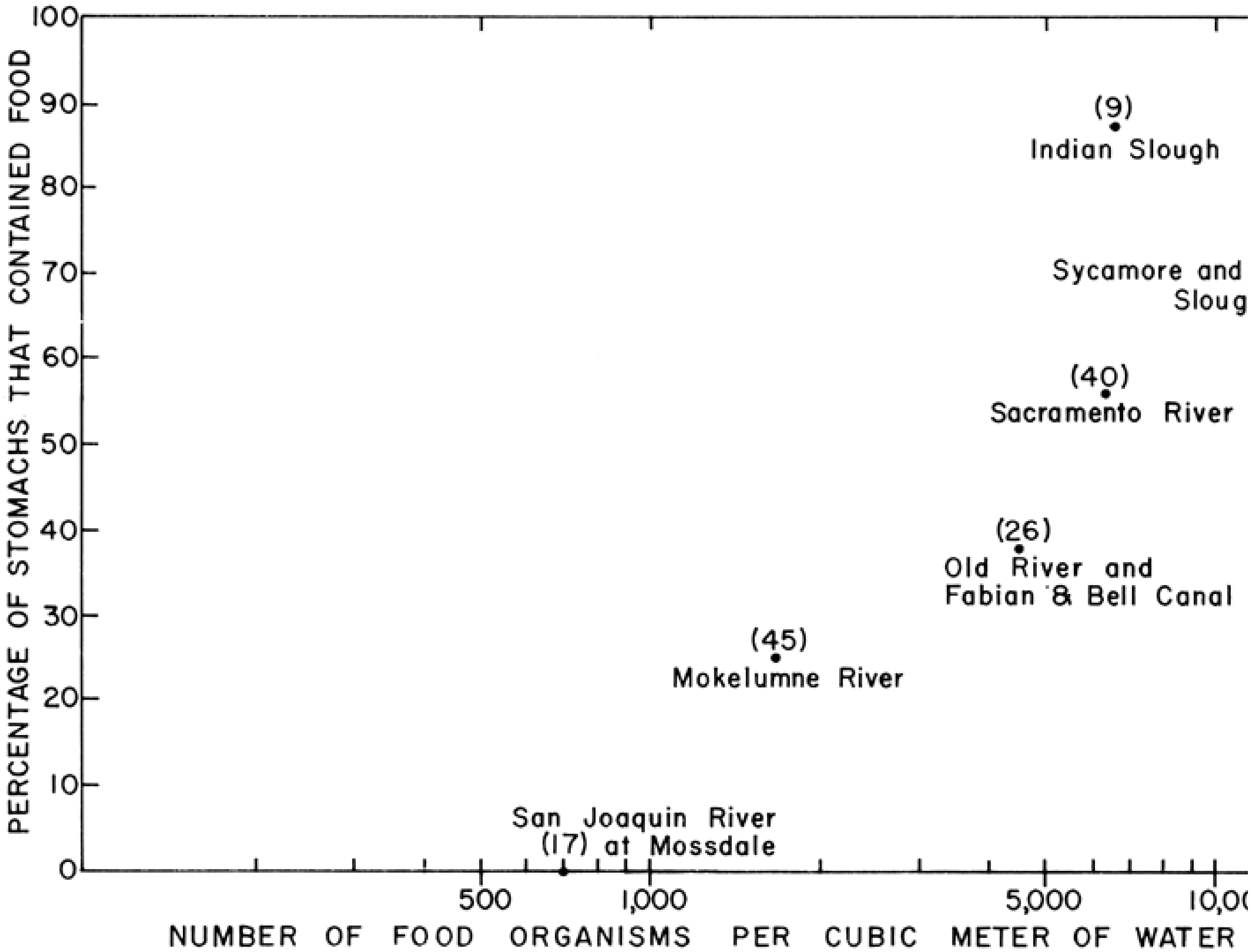

FIGURE 2. Concentrations of food in the environment compared with percentag stomachs of adult American shad that contained food during April and May 1964. parisons are only for areas where more than five stomachs were examined. Numbe stomachs examined are in parentheses.

FIGURE 2. Concentrations of food in the environment compared with percentages of stomachs of adult American shad that contained food during April and May 1964. Comparisons are only for areas where more than five stomachs were examined. Numbers of stomachs examined are in parentheses

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Contrary to my findings, other biologists (Smith, 1896; Brice, 1898; Leim, 1924; Hildebrand and Schroeder, 1928; Hatton, 1940) have reported that adult shad do not actively feed while in fresh water. Mansueti and Kolb (1953) have reported that shad in the northern waters of the East Coast begin to feed soon after spawning. Atkinson (1951) has attributed the absence of food in stomachs of shad from fresh water to the size of freshwater plankton, since many freshwater plankton are probably too small to be filtered and retained by the gill rakers.

YOUNG SHAD

Catch Analysis

Shad of the 1963 and 1964 year-classes were collected with midwater and otter trawls. The mean number of shad younger than 1 year caught with the midwater trawl was 57.3 and with the otter trawl, the mean number was 3.1. The otter trawl is more efficient (see Sasaki, p. 46), so the difference in the magnitude of these catches indicates that young shad occurred primarily near the surface. In a study of the vertical distribution of fishes at the U. S. Bureau of Reclamation pumping plant in the south Delta, the U. S. Department of the Interior (1957) also found that young shad occurred primarily at the surface.

Because young shad were most concentrated at the surface, the otter trawl catch varied greatly depending on the depth of the sampling station. In deep areas the otter trawl seldom caught shad. When it was towed over shoals, the otter trawl caught as many as 233 young shad, but there it was actually straining water near the surface. Since the otter trawl fished at variable distances below the surface and the catches were generally small, only the catches of shad in the midwater trawl were analyzed in determining the abundance, distribution, and movements of young shad.

In order to follow the migration of one year-class of young shad through the Delta, data collected during July 1963 were included in my analysis of the distribution and movements of the 1963 year-class. Some exploratory trawls preceding the inception of the regular sampling program were made during that month.

Shad of the 1963 year-class were abundant in the midwater trawl catches through November 1963 (Figure 3). During July the greatest concentrations of young shad occurred in the South Fork of the Mokelumne River, and young shad were also numerous in the Sacramento River at Isleton, and in the North Fork of the Mokelumne River (Figure 4). They were fairly well concentrated in the San Joaquin River at Santa Clara Shoal, the first station below the mouth of the Mokelumne River, but concentrations at West Island, a more seaward station in the San Joaquin River, were quite low. A seaward movement of this year-class was evident in September and October. During these months large concentrations of young shad appeared in the Sacramento River and in the San Joaquin River below the mouth of the Mokelumne River. Young shad were also numerous in both forks of the Mokelumne River and sloughs tributary to the South Fork of the Mokelumne River. By November, significant numbers of young shad were caught only in the Sacramento River and in the San Joaquin River below the Mokelumne River.

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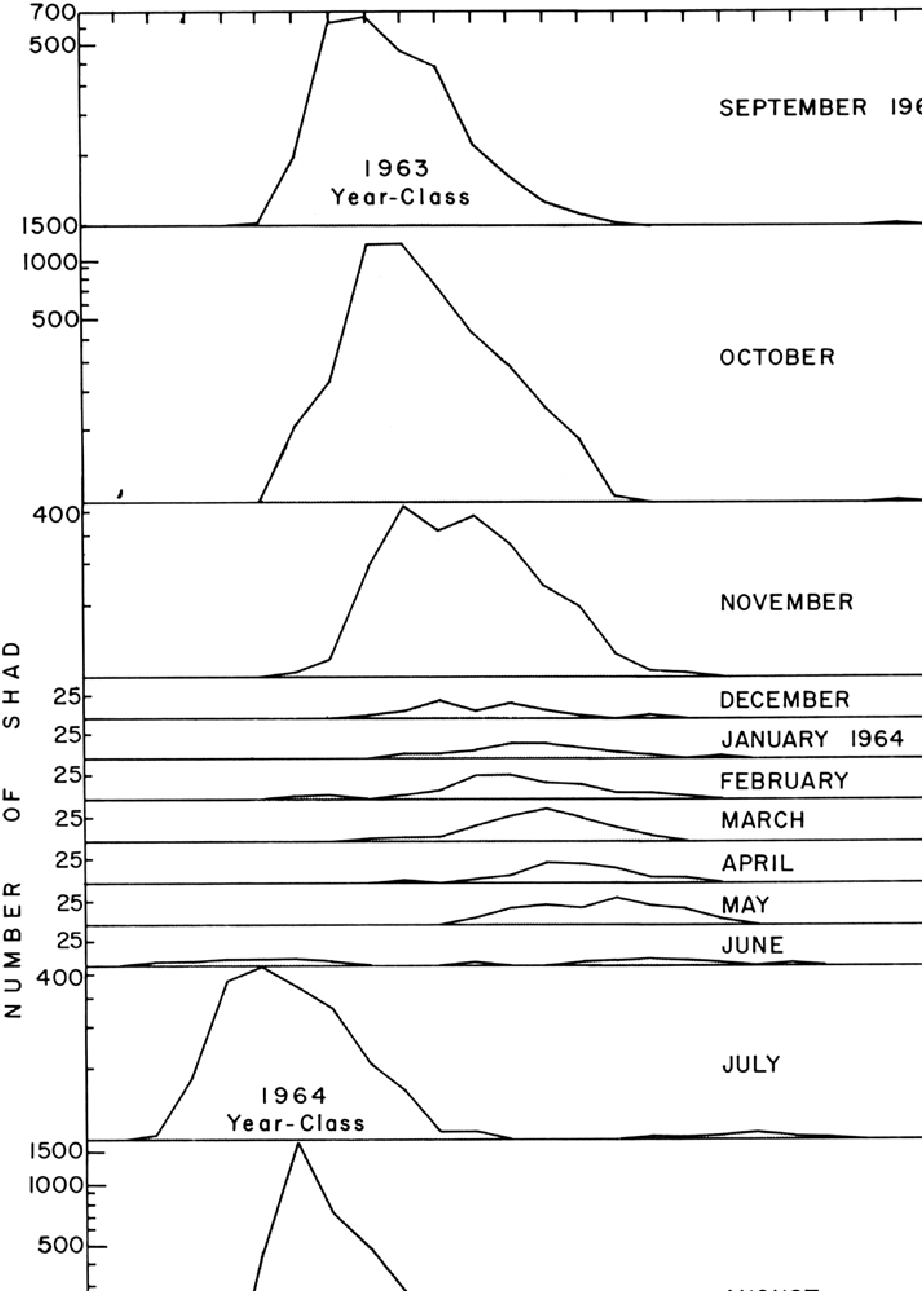
700
500
SEPTEMBER 196
1963
Year-Class
1500
1000
500
OCTOBER
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NOVEMBER
NUMBER OF SHAD
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DECEMBER
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25
FEBRUARY
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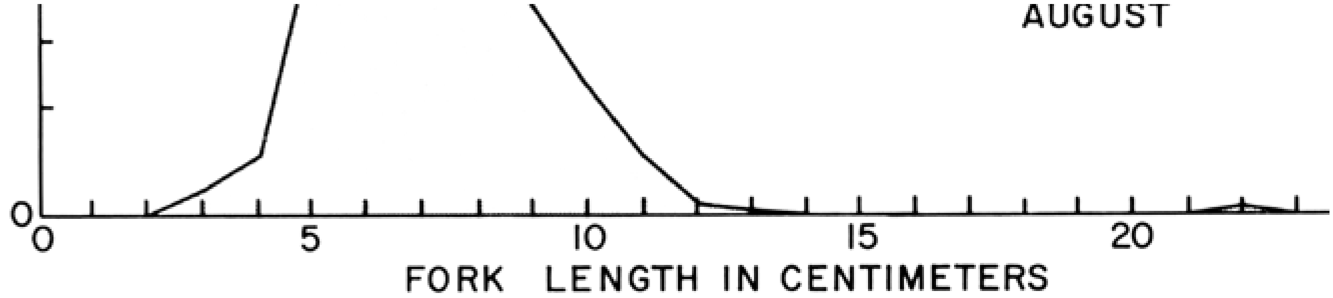

FIGURE 3. Length frequency distribution of American shad caught in the midwater

FIGURE 3. Length frequency distribution of American shad caught in the midwater trawl

Ganssle (1966) presents further evidence that the center of the population was moving seaward. He made his largest catches of shad of the 1963 year-class in the estuary below the Delta during November

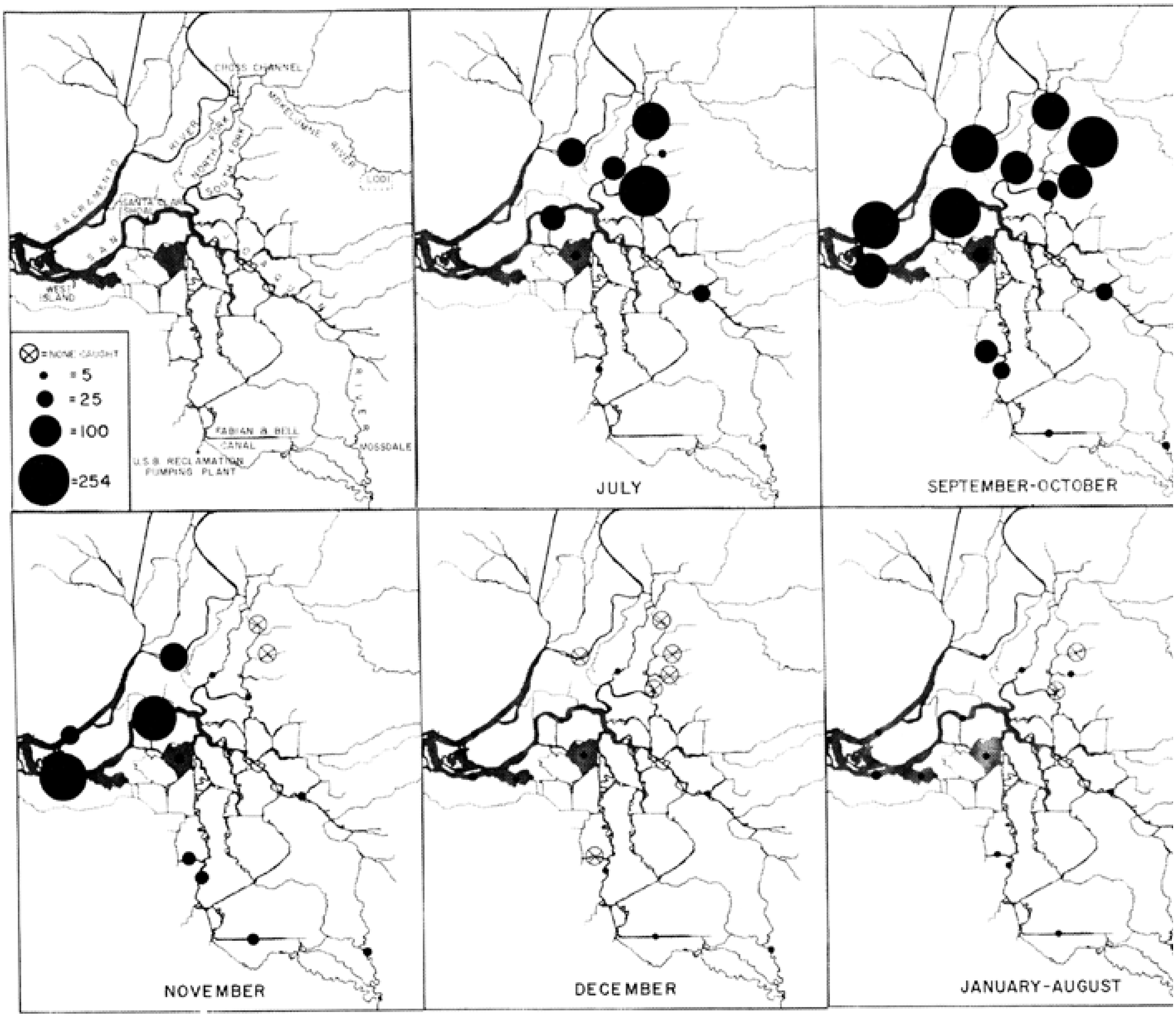

FIGURE 4. Concentrations of American shad of the 1963 year-class in the Sacrament Joaquin Delta between July 1963 and August 1964. The area of each circle represen mean number of shad caught in a 10-minute tow with the midwater trawl.

FIGURE 4. Concentrations of American shad of the 1963 year-class in the Sacramento-San Joaquin Delta between July 1963 and August 1964. The area of each circle represents the mean number of shad caught in a 10-minute tow with the midwater trawl

1963. The movement out of the Delta was virtually complete by December; during this month the catches were low in all areas.

Shad of the 1964 year-class first entered the midwater trawl catches during June 1964; however, large numbers were not caught until July (Figure 3). During July, the largest concentrations of shad of this year-class occurred in the South Fork of the Mokelumne River and tributary sloughs (Figure 5). Young shad were also numerous in the San Joaquin River below the mouth of the Mokelumne River. Concentrations in the Sacramento River and in the North Fork of the Mokelumne River were relatively small. In August, the catch of young shad increased in the Sacramento River, the North Fork of the Mokelumne River, and the San Joaquin River below the Mokelumne River; however, the largest concentrations still occurred in the South Fork of the Mokelumne River where the catches of young shad also increased.

Young shad were abundant only in areas receiving the seaward flow of the Sacramento and Mokelumne rivers. During the period when they were abundant, all of the flow in the North Fork of the Mokelumne River came from the Sacramento River via the cross channel at Walnut Grove (Figure 4). No water from the Mokelumne River above the Delta was flowing down the North Fork (Calif. Dept. Water Res., Delta Studies Section, pers. commun.); therefore, all of the young shad

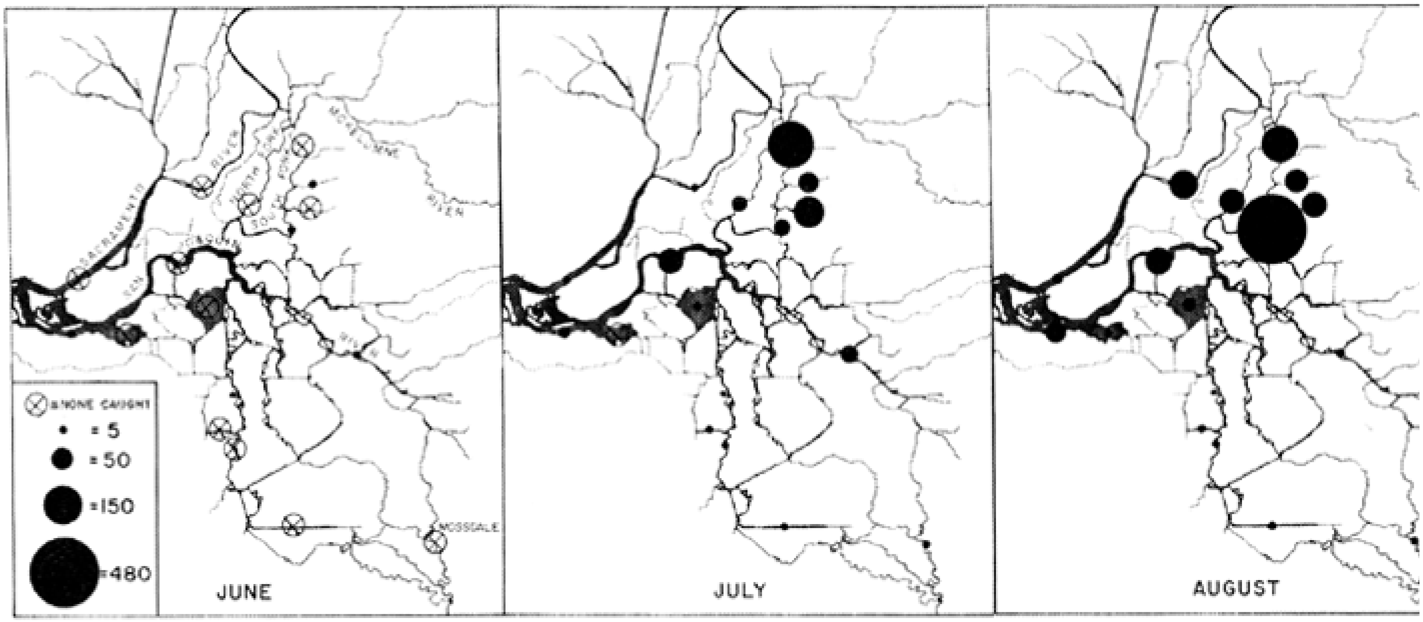

FIGURE 5. Concentrations of American shad of the 1964 year-class in the Sacrament Joaquin Delta between June 1964 and August 1964. The area of each circle repr the mean number of shad caught in a 10-minute tow with the midwater trawl.

FIGURE 5. Concentrations of American shad of the 1964 year-class in the Sacramento-San Joaquin Delta between June 1964 and August 1964. The area of each circle represents the mean number of shad caught in a 10-minute tow with the midwater trawl

caught in the North Fork were probably downstream migrants from the Sacramento.

The flow from the Mokelumne River above the Delta was small, and much of the flow in the South Fork of the Mokelumne River also came from the Sacramento River, so some of the young shad in the South Fork of the Mokelumne River were probably from the Sacramento River.

Because catches of young shad in the South Fork of the Mokelumne River during the summer were considerably larger than catches in either the Sacramento River or North Fork of the Mokelumne River during the summer (Figures 4 and 5), I believe that most of the shad caught in the South Fork were spawned in the Mokelumne River. If they had been spawned in the Sacramento River, the catches there and in the North Fork of the Mokelumne River (where the water was entirely from the Sacramento River) should have been as high or higher than the catches in the South Fork of the Mokelumne River.

It is reasonable to expect shad spawned in the Mokelumne River to arrive in the Delta earlier than shad from the Sacramento River. Any spawning in the Mokelumne River must occur close to the Delta. A dam at Lodi prevents adult shad from migrating up the Mokelumne River more than 20 or 25 miles above my sampling stations on the South Fork. The most important of the known spawning areas in the Sacramento River system is much farther above the Delta.

Food Habits

A detailed study of feeding habits of young shad was not attempted. The few stomachs that were examined contained cladocerans and copepods. Atlantic Coast studies on young shad food habits (Maxfield, 1953; McHugh, 1955; Walburg, 1956; Massmann, 1963) have shown that small crustaceans and insects are the common foods. Maxfield (1953) and Walburg (1956) thought that young shad utilized those food items which were most readily available.

SUMMARY AND DISCUSSION

Adult Shad

Between September 1, 1963 and August 31, 1964, indices of concentrations of adult American shad in various areas of the Sacramento-San Joaquin Delta were obtained with set gill nets. These indices indicated that adult shad were abundant in the Delta only in the spring during their spawning migration. By supplementing information about the numbers of adult shad caught in the gill nets with data on their gonad maturation, I interpreted similar catches in different areas to have different meanings. The numbers of shad ascending the Sacramento and Mokelumne rivers were judged to be much larger than numbers of shad ascending the San Joaquin River or entering the Delta south of the San Joaquin River.

Biologists on the Atlantic Coast (Leach, 1925; Bigelow and Schroeder, 1953; Talbot, 1954; Massmann and Pacheco, 1957) have suggested that migrations of adult shad are influenced by water temperature, but the range of temperatures at which the heaviest migrations have been reported is wide (7.7° to 18.9°C). In the spring of 1963, the California Department of Fish and Game found that the migration of adult shad into the Yuba River (a tributary of the Sacramento River system) started when minimum daily water temperatures were 10.0°C (unpublished). During my study, most of the adult shad were in the Delta while water temperatures were between 11.1° and 21.1°C.

Radtke (see p. 25) has suggested that adult striped bass on their spawning migration reacted negatively to high concentrations of dissolved solids in water originating in the San Joaquin River. Since a number of shad nearing spawning condition was caught in Fabian and Bell Canal, an area with water originating in the San Joaquin River, it appears that shad do not react negatively to this water.

A large percentage of the shad that spawn in the upper rivers apparently die after spawning. A high mortality of spent shad occurs in many other river systems. On the East Coast, almost all shad in streams south of Chesapeake Bay die after their initial spawning run (Talbot and Sykes, 1958).

Adult shad fed primarily on the mysid, Neomysis awatschensis, and cladocerans and copepods. The frequency of occurrence of these plankton in stomachs of shad was directly related to the degree of concentration of these plankton in the environment.

Young Shad

Indices of concentration of young shad were obtained with a midwater trawl. These indices indicated that young shad were abundant only in the Sacramento River, Mokelumne River and tributary sloughs, and in areas of the San Joaquin River receiving the seaward flow of the Sacramento and Mokelumne rivers. In 1963 and again in 1964, large numbers of young shad first entered the catch in July.

Data presented by Ganssle (1966) and my own data are evidence that young shad migrated downstream out of the Delta in September, October, and November.

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Sykes and Lehman (1957) described the fall downstream migration of juvenile shad from the Delaware River. They found that the migration was dependent on the lowering of the water temperature, or an increase in water flow, or both of these factors.

Results of an unpublished study by the California Department of Fish and Game on the Yuba River suggest that the timing of the seaward migration of young shad may not be determined by temperature and/or flow. This study indicated that young shad commence their seaward migration as soon as they are hatched. Therefore, the period of the migration of young shad through the Delta may depend largely on time and area of spawning.

Some movements of young shad within the Delta may be related to local food abundance. During the fall, large concentrations of young shad were present in the dead-end sloughs tributary to the Mokelumne River (Figure 4). Turner (1966) has indicated that cladocerans and copepods were scarce in the Mokelumne River whereas they were numerous in the dead-end sloughs.

Erkkila, *et al.* (1950) sampled shad in the Delta from June through December in 1948. They reported an extensive downstream migration of young shad in late June and July, but they caught few shad after August 1. In 1963, I caught large numbers of young shad through November. The difference between my results and theirs is almost surely attributable to a difference in the efficiency of our nets. The shad caught in their nets in 1948 were smaller than those caught in the midwater trawl during 1963 [(Table 3)]. So I believe that the tow nets used by Erkkila, *et al.*, were less efficient than the midwater trawl for sampling the larger young shad that were abundant in the fall, and the midwater trawl was less efficient in capturing the smaller shad that were abundant in the summer. I conclude that the migration of young shad through the Delta starts in late June and extends through November.

TABLE 3

Mean Lengths and Mean Numbers of Shad Caught in Tow Nets Used by Erkkila, et al. in 1948 and in the Midwater Trawl in 1963

Sampling Gear	Month		
	July	September	November
Tow net used by Erkkila, *et al.* 5 foot diameter, ¼ inch stretch mesh	3 towing cycles July 2–August 3, 1948: 2.2, 2.5, 3.3 cm; 69.5 shad per tow	2 towing cycles September 6–29, 1948: 5.9, 7.0 cm; 7.0 shad per tow	1 towing cycle Nov 9–12, 1948: 7.4 cn shad per tow
Midwater trawl—10 foot by 10 foot, cod end—¾ inch stretch mesh	July 1963: 4.6 cm; 54.0 shad per tow	September 1963: 8.5 cm; 75.4 shad per tow	November 1963: 10. 40.6 shad per tow

TABLE 3

Mean Lengths and Mean Numbers of Shad Caught in Tow Nets Used by Erkkila, et al. in 1948 and in the Midwater Trawl in 1963

In 1963 and 1964, few young shad were caught either in the upper San Joaquin River at Mossdale or in the south Delta. In 1948 and 1949, Erkkila, *et al.*, also found that shad were much more abundant in the Mokelumne and Sacramento rivers than in the San Joaquin River. No good evidence is available to explain the scarcity of shad in the San

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Joaquin River drainage, but there is one obvious possibility. The shad run may be limited by irrigation diversions. A large percentage of the young shad migrate down the Sacramento and Mokelumne rivers to the Delta during the summer and early fall. In the 55-mile section of the San Joaquin River between the mouth of the Merced River and Mossdale, unscreened irrigation diversions remove much of the flow during this period. In recent years, the entire stream has been diverted during the summer by a sand dam a few miles above Mossdale. A large portion of the shad run is probably removed along with the flow.

LITERATURE CITED

Atkinson, Clinton E. 1951. Feeding habit of adults shad, Alosa sapidissima, in fresh water, Ecology, *32* (3) : 556–557. Bigelow, Henry B., and William C. Schroeder. 1953. Fishes of the Gulf of Maine. U. S. Fish and Wildl. Serv., Fish Bull., *53* (74) : 1–577. Brice, John C. 1898. A manual of fish culture. *In* U. S. Comm. Fish and Fisheries, Rept., 1897, App. : 1–340. Erkkila, Leo F., James W. Moffett, Oliver B. Cope, Bernard F. Smith and Reed S. Nielson. 1950. Sacramento-San Joaquin Delta fishery resources : Effects of Tracy pumping plant and Delta cross channel. U. S. Fish and Wildl. Serv., Spec. Sci., Rept. : Fish., (56) : 1–109. Ganssle, David. 1966. Fishes and decapods of San Pablo and Suisun Bays, p. 64–94. *In* D. W. Kelley, (ed.), Ecological studies of the Sacramento-San Joaquin Estuary. Calif. Fish and Game, Fish Bull., (133) : 1–133. Hatton, S. Ross. 1940. Progress report on Central Valley fisheries investigation, 1939. Calif. Fish and Game, *26* (4) : 335–373. Hildebrand, S. F., and W. C. Schroeder. 1928. Fishes of Chesapeake Bay. U. S. Bur. Fish., Bull., *43* : 1–366. Leach, Glen C. 1925. Artificial propagation of shad. *In* U. S. Comm. Fish., Rept., 1924, App. 8 : 459–486. Leim, A. H. 1924. The life history of the shad, Alosa sapidissima (Wilson), with special reference to the factors limiting its abundance. Contrib. Canad. Biol., N. S. *2* (11) : 163–284. Mansueti, Romeo, and Haven Kolb. 1953. A historical review of the shad fisheries of North America. Chesapeake Biol. Lab. Publ., (97) : 1–293. Massmann, William H. 1963. Summer food of juvenile American shad in Virginia waters. Chesapeake Sci., *4* (4) : 167–171. Massmann, William H., and Anthony L. Pacheco. 1957. Shad catches and water temperatures in Virginia. J. Wildl. Manage., *21* (3) : 351–352. Maxfield, Galen H. 1953. The food habits of hatchery-produced, pond-cultured shad reared to a length of two inches.

Chesapeake Biol. Lab., Publ., (98) : 1–38. McHugh, J. L. 1955. The world's best fishing hole. Internat. Oceanog. Found., Bull., *1* (2) : 34–39. Smith, H. M. 1896. A review of the history and results of the attempts to acclimatize fish and other water animals in the Pacific states. U. S. Fish Comm., Bull., *15* : 379–472. Sykes, James E., and Burton A. Lehman. 1957. Past and present Delaware River shad fishery and considerations for its future. U. S. Fish and Wildl. Serv., Res. Rept., (46) : 1–25. Talbot, Gerald B. 1955. Factors associated with fluctuations in abundance of Hudson River shad. U. S. Fish and Wildl. Serv., Fish. Bull., *56* (101) : 373–413. Talbot, Gerald B., and James E. Sykes. 1958. Atlantic coast migrations of American shad. U. S. Fish and Wildl. Serv., Fish. Bull., *58* (142) : 473–490. Turner, Jerry L. 1966. The seasonal distribution of crustacean plankters in the Sacramento-San Joaquin Delta, p. 95–104. *In* D. W. Kelley, (ed.), Ecological studies of the Sacramento-San Joaquin Estuary. Calif. Fish and Game, Fish Bull., (133) : 1–133. U. S. Department of the Interior. 1957. Fish protection at the Tracy pumping plant, Central Valley Project, California. Bureau of Reclamation, Reg. 2, Sacramento, Calif., and Fish and Wildlife Service, Reg. 1, Portland 1, Ore., 96 p. Walburg, Charles H. 1956. Observations on the food and growth of juvenile American shad. Alosa sapidissima. Trans. Amer. Fish Soc., *86* : 302–306.

DISTRIBUTION AND FOOD HABITS OF KING SALMON, ONCORHYNCHUS TSHAWYTSCHA, AND STEELHEAD RAINBOW TROUT, SALMO GAIRDNERII, IN THE SACRAMENTO-SAN JOAQUIN DELTA

SHOKEN SASAKI

Young king salmon from the Sacramento River system moved downstream toward the sea through all channels of the north Delta. Most of the young king salmon caught in the south Delta probably also originated from the Sacramento River.

The downstream migration of young king salmon through the Delta peaked in May and June in 1964. There is some, but not conclusive, evidence that this migration is later now than it was in past years.

The adult king salmon and steelhead did not feed while in the Delta, but the young of both fed primarily on adult insects during their downstream journey.

KING SALMON

Adults

Adult king salmon pass through the Delta en route to their spawning grounds in the upper rivers and tributaries. They are abundant in the Delta only when this movement is in progress.

Our nets were neither designed nor set to take adult king salmon and only 50 were taken during the entire year of sampling. All were caught in the gill nets. The highest catches were in the Sacramento River during the fall when the large fall run of king salmon is migrating up the Sacramento River to spawn.

Migration of king salmon in the Sacramento-San Joaquin River system has been found at one time to occur in two distinct runs, fall and spring (Rutter, 1903; Needham, *et. al.,* 1940; Hallock, *et al.,* 1957). There was some evidence that a small winter run occurred, overlapping that of the spring (Needham, *et al.,* 1940; Hallock, *et al.,* 1957) but in recent years the winter run has expanded and its importance has increased (Dept. Fish and Game, Marine Resources Branch, pers. commun.). Hallock, *et al.* (1957) found peak numbers of king salmon at Fremont Weir on the Sacramento River above the Delta in September 1953. Van Woert (1955) reported highest numbers of adult king salmon at Fremont during the months of September and October 1954.

Forty-six of the 47 adult king salmon stomachs examined were empty. The stomach of one collected in lower San Joaquin River during July of 1964 contained eight Neomysis awatschensis.

Young

After spawning in the tributaries above the Delta, the adult king salmon die. The young hatch and eventually migrate downstream. These are the fish that were caught as they passed through the Delta on their way to the sea.

No young king salmon were taken in the gill nets. The smallest mesh used in the gill nets (2½" stretch mesh) was too large to catch them.

Only 67 young king salmon were caught with the otter trawl, but 1,205 were collected with the midwater trawl. Since the midwater trawl fishes about the upper 10 feet of water, this indicates that young king salmon migrate downstream near the surface. Hallock and Van Woert (1959) found in their sampling of fingerling king salmon in the Sacramento River near Red Bluff that the greatest numbers occurred only 2 to 4 feet under the surface. Hatton (1940), sampling at Hood in the Sacramento River, found the young to occur in the upper 8 feet of water.

The largest concentrations of young king salmon occurred at Mokelumne River, Sacramento River, and lower San Joaquin River stations (Figure 1). King salmon were found throughout the year at these stations but most were taken during May and June (Figures 1 and 2). It is suspected that the majority of the king salmon taken at the Mokelumne River stations, the lower San Joaquin River stations and even the stations in Old River and Indian Slough were from the Sacramento River system. At that time of the year (May–June) the cross channel at Walnut Grove was open and most of the water in the North Fork, and about half of the water in the South Fork of the Mokelumne River, came from the Sacramento River (Dept. of Water Resources, Delta Studies Section, pers. commun.). At this time, water in Old River was also Sacramento River water flowing south (upstream) to the U. S. Bureau of Reclamation pumping plant.

Concentrations of young salmon were very low in the southern and eastern parts of the Delta (Figure 1). Almost all of the few king salmon that were caught in these areas were taken in April, May, and June.

The peak downstream movement of king salmon through the Delta occurred in May and June (Figure 2). This peak appears to occur later than it did in the past [(Table 1)]. Rutter (1903), Hatton (1940), and Erkkila, *et al.* (1950) reported that the peak migration occurred in March. The U. S. Bureau of Reclamation fish collection facility, which screens water entering the Delta-Mendota Canal from Old River, reported peak catches of fingerling king salmon in April during 1957, 1959, and 1960, and in May during 1961, 1962, and 1964. Data from the Carquinez Strait (Messersmith, 1966) and that of our study show peak catches in May and June of 1962 and 1964, respectively.

These apparent changes may only reflect the sampling gear used. King salmon young that migrate downstream in May and June are larger, and this size fish may have avoided the nets used in the earlier studies. Evidence from Tracy fish collection facility is contrary to this. The peaks of king salmon collection there have been progressively later in recent years.

The increased average length of king salmon (Table 1) and the fact that they appear to migrate downstream later than they did several years ago do not suggest any change in the timing of the adult spawning, but rather a delay in the young moving downstream.

Hatchery king salmon releases may also affect the size of the salmon and time of runs although we do not know if the number of young

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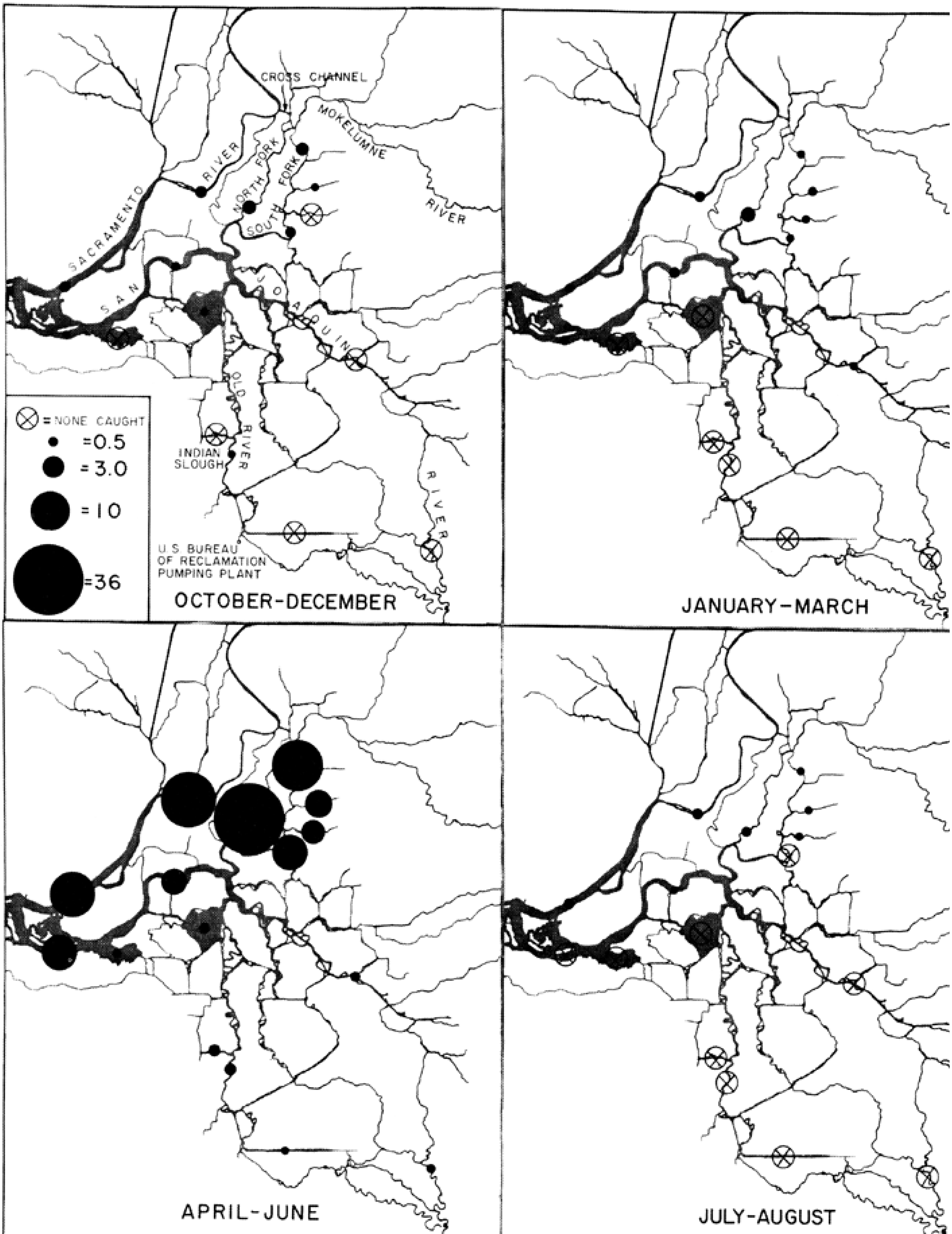

FIGURE 1. Average midwater trawl catches of king salmon downstream migrants in Sacramento-San Joaquin Delta during 1963–1964.

FIGURE 1. Average midwater trawl catches of king salmon downstream migrants in the Sacramento-San Joaquin Delta during 1963–1964

salmon released from hatcheries could cause changes in the natural migration picture.

The concentration of the San Joaquin River king salmon downstream migrants was very low in comparison to that of the Sacramento River migrants in 1964 (Figure 3).

Erkkila, *et al.* (1950) collected young king salmon migrating down both the Sacramento and the San Joaquin Rivers in 1949 (Figure 3). The migration down the San Joaquin River was one to two months later than that in the Sacramento. Our catches are not comparable to

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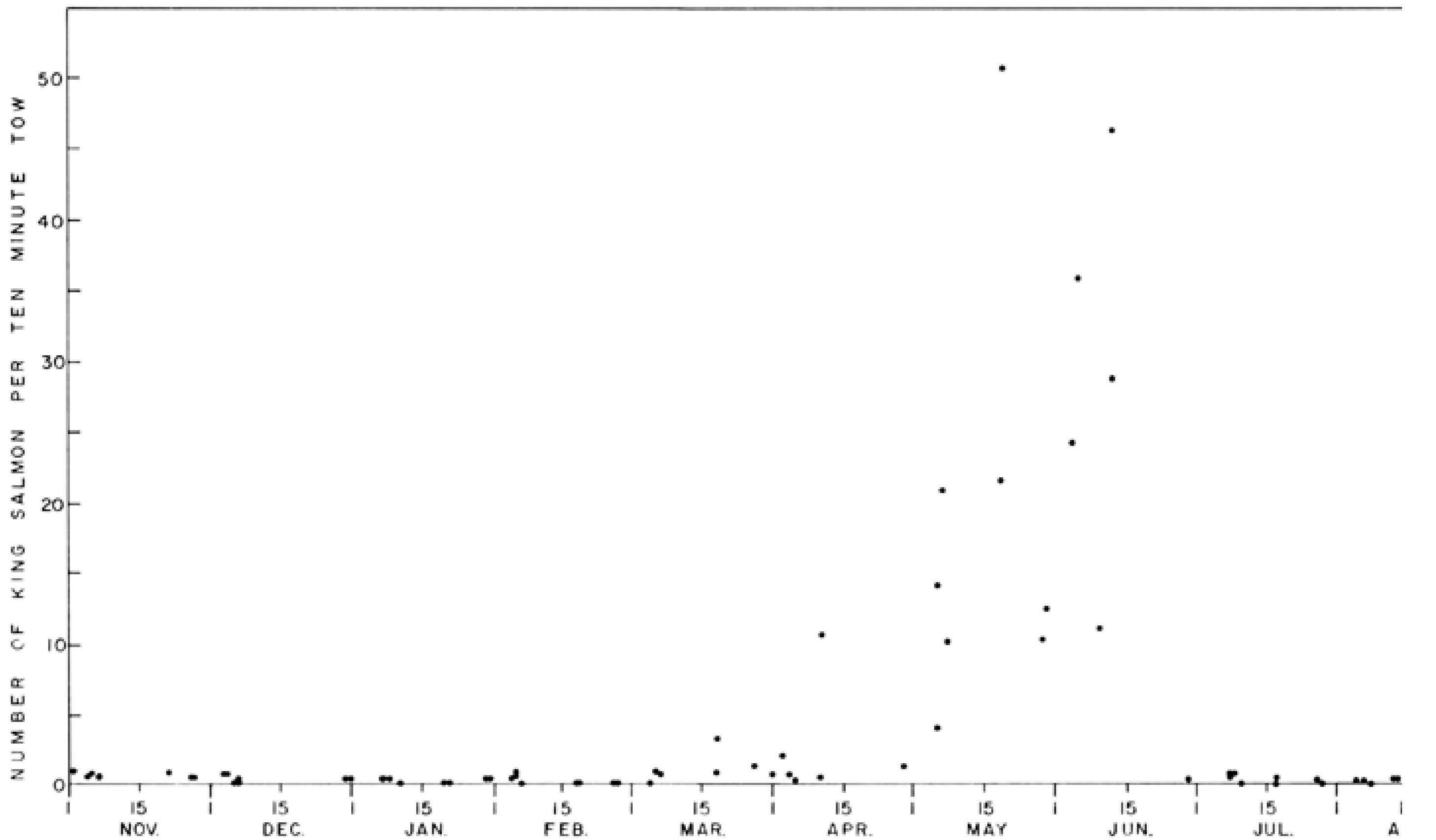

FIGURE 2. Average midwater trawl catches of king salmon downstream migrants i Sacramento River, Mokelumne River, and lower San Joaquin River from November 1, to August 31, 1964.

FIGURE 2. Average midwater trawl catches of king salmon downstream migrants in the Sacramento River, Mokelumne River, and lower San Joaquin River from November 1, 1963 to August 31, 1964

Erkkila's, but the proportion of fish taken in the two rivers each year is comparable. The catch of young king salmon in the San Joaquin River during 1949 was much higher compared to that of the Sacramento River catch than it was in 1964. This reflects the well documented decline [(Table 2)] of the San Joaquin River runs of adult king salmon.

TABLE 1

Comparison of Peak Migration of Young King Salmon Migrants for Differen Years Through the Sacramento-San Joaquin Delta

Year	Reference	Sampling Gear	Mesh Size	Station Location	Peak Migration Period	Ave. I Du Pe
1899	Rutter (1903)	Circular bag, 4 feet in diameter	½″ stretch	Walnut Grove	March	4.4 cı
1939	Hatton (1940)	Fyke net, 5 feet in diameter	½″ stretch	Hood	March	3.9 cı
1949	Erkkila, et al. (1950)	Tow net, 5 feet in diameter at mouth	½″ stretch	Five stations on Sacramento River from Walnut Grove to Pittsburg	March	3.8 cı
1957	U.S. Bureau of Reclamation fish collecting facility (unpub. records)	Louver screen at pumping plant	------	Old River at U.S. Bureau of Reclation pumping plant	April	---
1959	"	"	------	"	April	---
1960	"	"	------	"	April	---
1961	"	"	------	"	May	---
1962	"	"	------	"	May	---
1962	Messersmith (1966)	25′ x 25′ midwater trawl	½″ stretch	Carquinez Strait	May-June	8.5
1964	U.S. Bureau of Reclamation fish collecting facility (unpub. records)	Louver screen at pumping plant	------	Old River at U.S. Bureau of Reclamation pumping plant	May	---
1964	Delta Study	15′ x 15′ midwater trawl	¾″ stretch	Two stations on Sacramento River	May-June	8.3 c

TABLE 1

Comparison of Peak Migration of Young King Salmon Migrants for Different Years Through the Sacramento-San Joaquin Delta

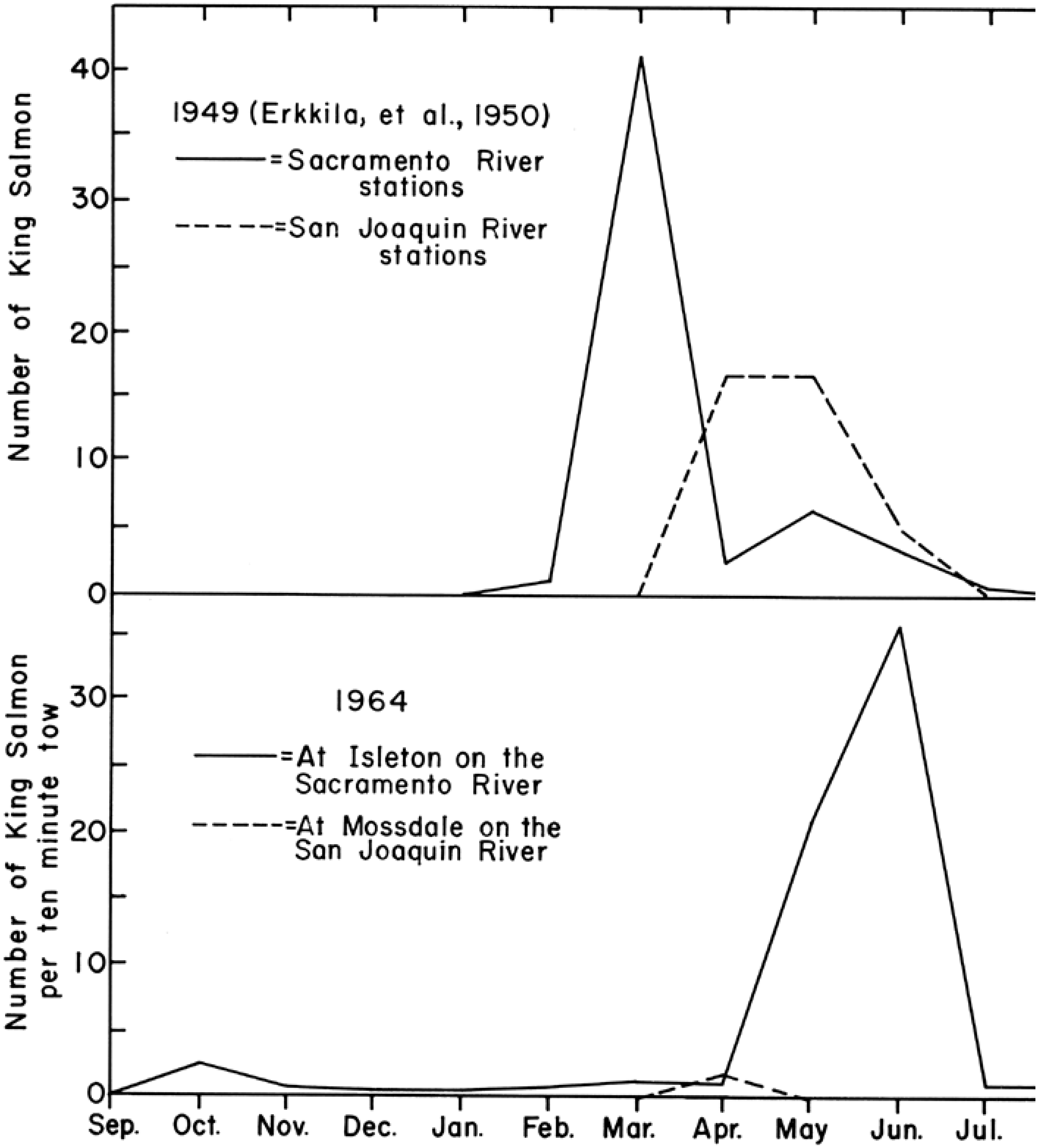

FIGURE 3. King salmon downstream migrants in the Sacramento and San Joaquin for 1949 and 1964.

FIGURE 3. King salmon downstream migrants in the Sacramento and San Joaquin rivers for 1949 and 1964

TABLE 2

Fall Run Adult King Salmon Population Estimates for San Joaquin River Tributaries above Mossdale in Thousands of Fish [1]

Year	Stanislaus	Tuolumne	Merced	Total
1953	35	45	*	80
1954	22	40	4	66
1955	7	20	*	27
1956	5	6	*	11
1957	4	8	*	12
1958	6	32	*	38
1959	4	46	*	50
1960	8	45	*	53
1961	2	0.5	*	2.5
1962	*	*	*	0.5
1963	*	*	*	*
1964	4	2	*	6

* Less than 500.
[1] Compiled by Marine Resources Branch, Calif. Dept. of Fish and Game.

TABLE 2

Fall Run Adult King Salmon Population Estimates for San Joaquin River Tributaries above Mossdale in Thousands of Fish

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Out of 469 young king salmon stomachs examined, 322 contained food. Insects were the primary food of young king salmon. They were found in 74 percent of the stomachs containing food [(Table 3)]. No aquatic organism was in more than 19 percent of the stomachs. Aquatic organisms were of some local importance, however, especially tendipedid larvae and pupae in the Sacramento River at Isleton, Neomysis awatschensis in the lower Sacramento River, lower San Joaquin River and flooded islands, and Corophium spp. in the lower San Joaquin River and flooded islands. Rutter (1903) and Scofield (1913) also found insects to be the most important food item of young king salmon.

TABLE 3

Stomach Contents of Young King Salmon

Food Item	Percent Frequency of Occurrence					
	Sacramento River at Isleton	Sacramento River at Sherman Isl.	Lower San Joaquin River	Flooded Islands	Other Areas	Ave and
Microplankton	5.0	--	10.9	22.2	0.7	5
Mysid shrimp (*Neomysis awatschensis*)	5.0	31.4	31.2	61.1	0.7	14
Amphipods (*Corophium*)	16.7	8.6	34.4	61.1	11.0	18
Terrestrial Arachnids	1.7	2.9	4.7	--	--	3
Tendipedids	46.7	2.9	6.2	11.1	9.7	16
Other insects	70.0	60.0	67.2	33.3	89.0	73
Fishes	--	8.6	1.6	--	2.1	1
Seeds	--	--	--	--	0.7	0
Stomachs examined	75	68	88	22	216	46
Stomachs containing food	60	35	64	18	145	32

TABLE 3

Stomach Contents of Young King Salmon

STEELHEAD RAINBOW TROUT

As with the king salmon, the steelhead young and adults are only present in the Delta when they are migrating to or from the sea. Only 30 adult steelhead were caught, all with the gill net, and 15 young steelhead, mostly with the midwater trawl, during the entire year of sampling in the Delta.

Past work indicates that peak runs of adult steelhead in the Sacramento River occur in the fall as they migrate upstream to spawn (Van Woert, 1955; Hallock, *et al.*, 1957). Yearling steelhead migrate through the Delta in the largest numbers during spring. The Marine Resources Branch trawl operations in Carquinez Strait in 1961 and 1962 show peak numbers in April and May, indicating a downstream migration at that time (Messermith, 1966).

Adult steelhead probably do not feed in the Delta. Eighteen stomachs out of 19 examined were empty. The stomach of one steelhead caught in Big Break (a flooded island) contained two Corophium spp. Only 5 of 14 stomachs of yearling steelhead examined contained food. of these five stomachs, four contained adult insects, two contained tendipedid larvae and pupae, and one contained a Corophium spp.

LITERATURE CITED

Erkkila, Leo F., James W. Moffett, Oliver B. Cope, Bernard R. Smith and Reed S. Nielson. 1950. Sacramento-San Joaquin Delta fishery resources: Effects of Tracy pumping plant and Delta cross channel. U. S. Fish and Wildl. Serv. Spec. Sci. Rept., Fish., (56) : 1–109. Hallock, Richard J., D. H. Fry, Jr. and Don A. LaFaunce. 1957. The use of wire fyke traps to estimate the runs of adult salmon and steelhead in the Sacramento River. Calif. Fish and Game, *43* (4) : 271–298. Hallock, Richard J., and William F. Van Woert. 1959. A survey of anadromous fish losses in irrigation diversions from the Sacramento and San Joaquin Rivers. Calif. Fish and Game, *45* (4) : 227–266. Hatton, Ross S. 1940. Progress report on Central Valley fisheries investigations. Calif. Fish and Game, *26* (4) : 334–372. Messersmith, James. 1966. Fishes collected in Carquinez Strait in 1961–1962, p. 57–63. *In* D. W. Kelley (ed.), Ecological studies of the Sacramento-San Joaquin Estuary. Calif. Dept. Fish and Game, Fish Bull., (133) : 1–133. Needham, Paul R., Osgood R. Smith and Harry A. Hanson. 1940. Salmon salvage problems in relation to Shasta Dam, California and notes on the biology of the Sacramento River salmon. Trans. Amer. Fish. Soc., *70*: 55–69. Rutter, Claudsley. 1903. Natural history of the quinnat salmon: A report of investigations in the Sacramento River, 1896–1901. U. S. Fish. Comm., Bull., *22*: 65–141. Scofield, N. B. 1913. A general report on the chinook salmon investigation carried on during the spring and summer of 1911. Calif. Dept. Fish and Game, Fish Bull., (1) :

34–41. Van Woert, William F. 1955. Time pattern of migration of salmon and steelhead into the upper Sacramento River during the 1954–55 season. Calif. Dept. Fish and Game, Inland Fish. Rept., (55–17) : 1–3.

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DISTRIBUTION OF SMELT, JUVENILE STURGEON, AND STARRY FLOUNDER IN THE SACRAMENTO-SAN JOAQUIN DELTA WITH OBSERVATIONS ON FOOD OF STURGEON

LARRY D. RADTKE

SMELT

Two species of smelt occur in the Sacramento-San Joaquin Delta. They are the pond smelt, Hypomesus transpacificus, and the Sacramento smelt, Spirinchus thaleichthys. The former is found along the Pacific Coast from San Francisco to Alaska and Japan. The latter occurs primarily in the San Francisco Bay area and the lower Sacramento-San Joaquin Delta. Fish of both species move into the Delta in the winter and spring to spawn.

Pond Smelt

A total of 1,960 pond smelt was caught in the midwater trawl and 461 in the otter trawl during our year of sampling. A single size group, probably the 1963 year-class, dominated the catch from September through May (Figure 1). From June through August, this group diminished and young-of-the-year (1964 year-class) began to enter the catch.

In the fall of 1963, we caught few pond smelt except in the Sacramento River at Sherman Island (Figure 2). During the winter, catches at Sherman Island were lower than they had been in the fall but catches at most other stations were higher. In the spring, pond smelt were caught at all stations. Pond smelt had apparently become widely distributed in the Delta during the winter and remained so during the spring. This movement may be associated with spawning. A total of 11 ripe females were caught in February, 6 in March, 24 in April, and 8 in May. One spent female was caught in March, 6 in April, and 3 in May. In Japan, Shiraishi (1952) found that a lacustrine population of pond smelt ascended tributaries from January to March to spawn. Sato (1950) states that in the spring, pond smelt along the coast of Alaska, Siberia, and Japan ascend estuaries as far as fresh water to spawn.

In the summer catches were low except for the station in the Sacramento River at Sherman Island. About 70 percent of the pond smelt caught during June, July, and August were young of the year (Figure 1).

Sacramento Smelt

A total of 45 Sacramento smelt was caught in the midwater trawl and 51 in the otter trawl. Like pond smelt, the fish caught from December to May were predominantly of a single size group, probably the 1963 year-class (Figure 3). During the summer, the number of older fish diminished and young-of-the-year (1964 year-class) entered the catch.

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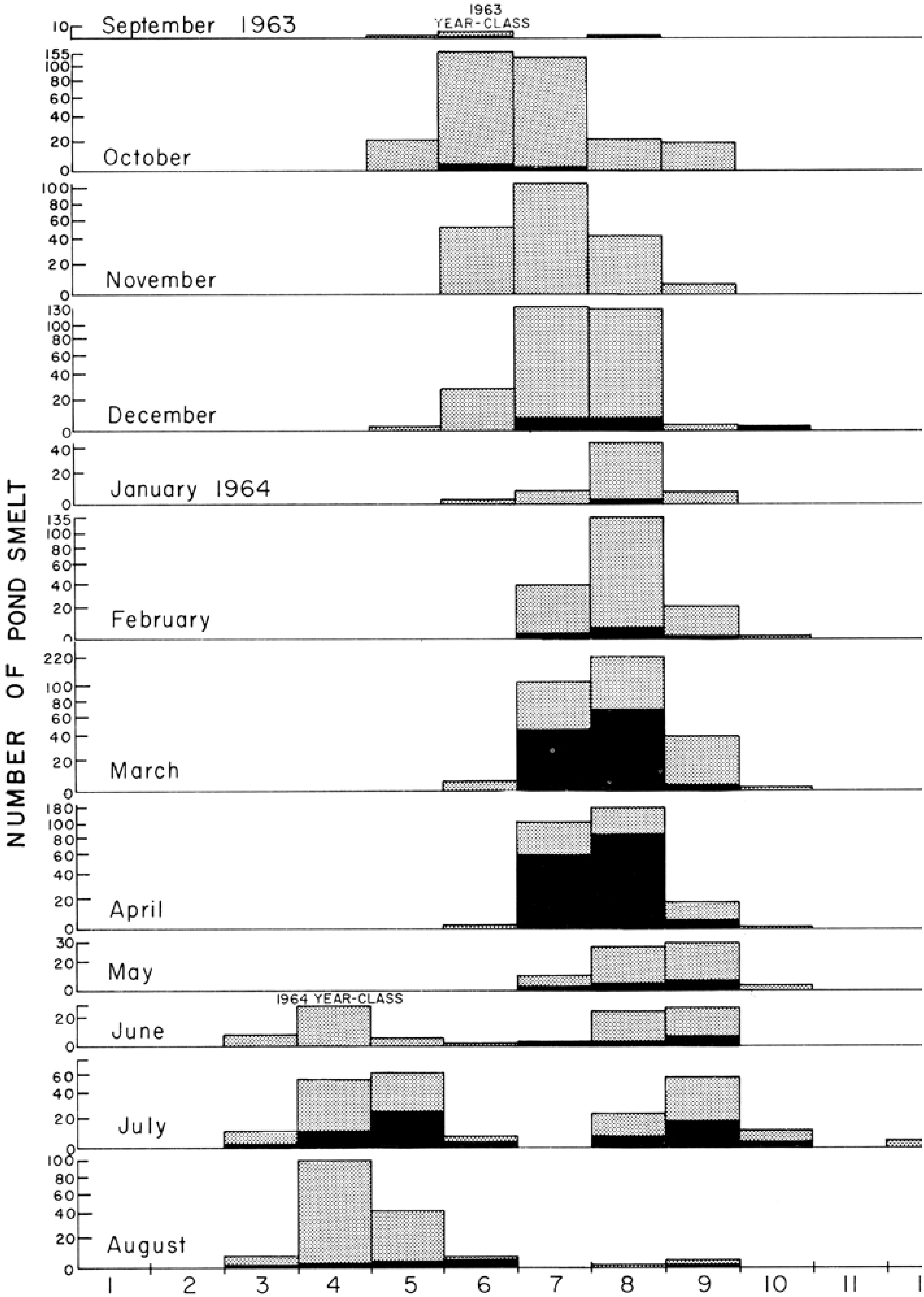

NUMBER OF POND SMELT
September 1963
1963 YEAR-CLASS
October
November
December
January 1964
February
March
April
May
June
1964 YEAR-CLASS
July
August
1
2
3
4
5
6
7
8
9
10
11
1

FORK LENGTH IN CENTIMETERS

FIGURE 1. Length-frequency distribution of pond smelt caught in the Delta with mid trawl (black) and otter trawl (shaded) from September 1963 through August 1964.

FIGURE 1. Length-frequency distribution of pond smelt caught in the Delta with midwater trawl (black) and otter trawl (shaded) from September 1963 through August 1964

No Sacramento smelt were caught in the Delta in the fall (Figure 4). Highest catches during the rest of the year were in the western Delta.

The spawning season appears to extend from midwinter to early spring. Two ripe females were taken in December, four in January, eight in February, four in March, and one in April. One spent female

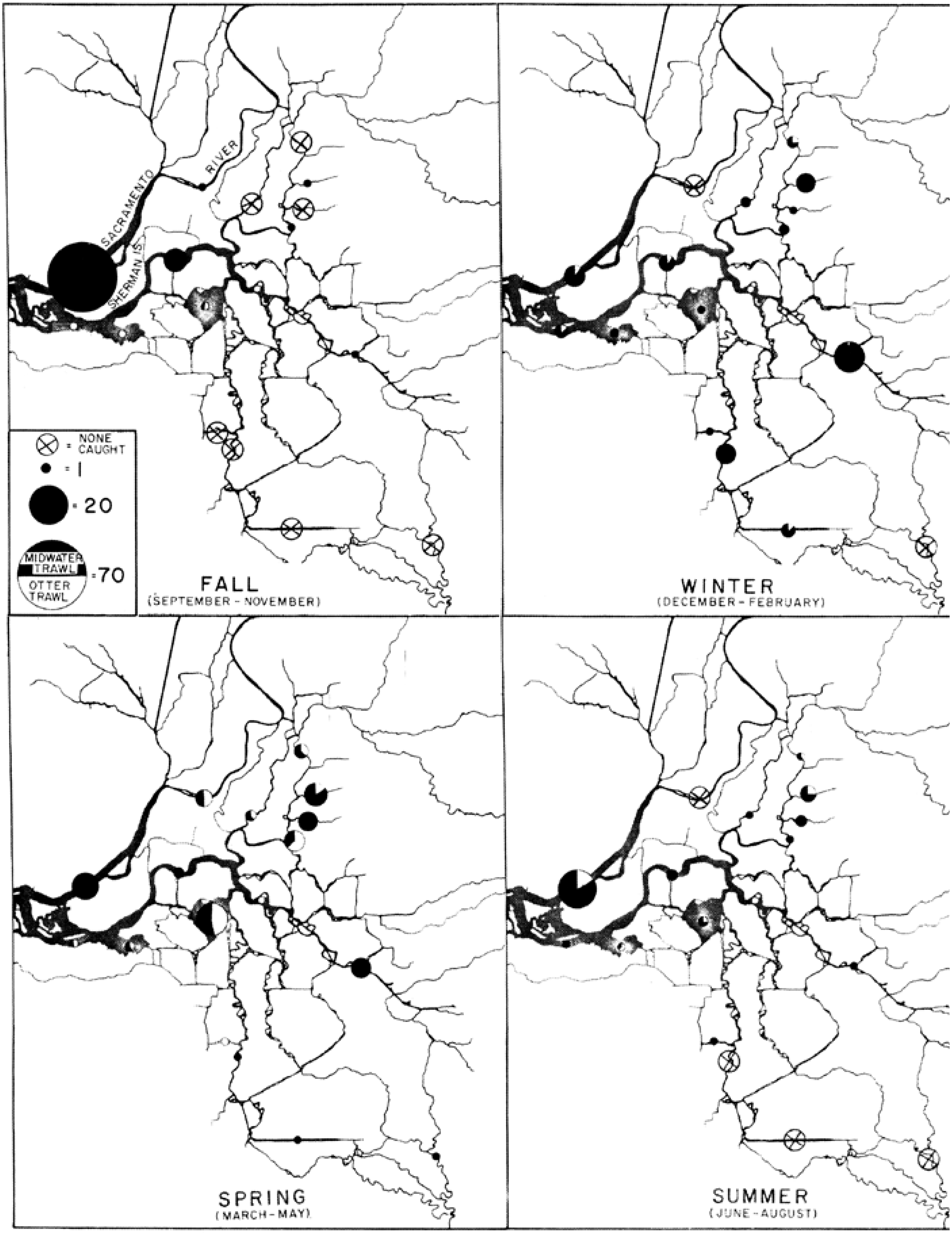

FIGURE 2. Distribution of pond smelt in the Delta. The area of each circle represent sum of mean midwater and otter trawl catches.

FIGURE 2. Distribution of pond smelt in the Delta. The area of each circle represents the sum of mean midwater and otter trawl catches

was found in March. Ganssle (1966) found ripening Sacramento smelt below the Delta in San Pablo and western Suisun bays in March and April 1963.

About 87 percent of the fish caught in the Delta during June, July, and August 1964 were young-of-the-year (Figure 3).

Discussion

Our catches suggest that both species of smelt migrated upstream from the bay into the Delta during the winter. Ganssle (op. cit.) found concentrations of both pond and Sacramento smelt just below the Delta in Suisun Bay in the fall of 1963. The comparatively large catch

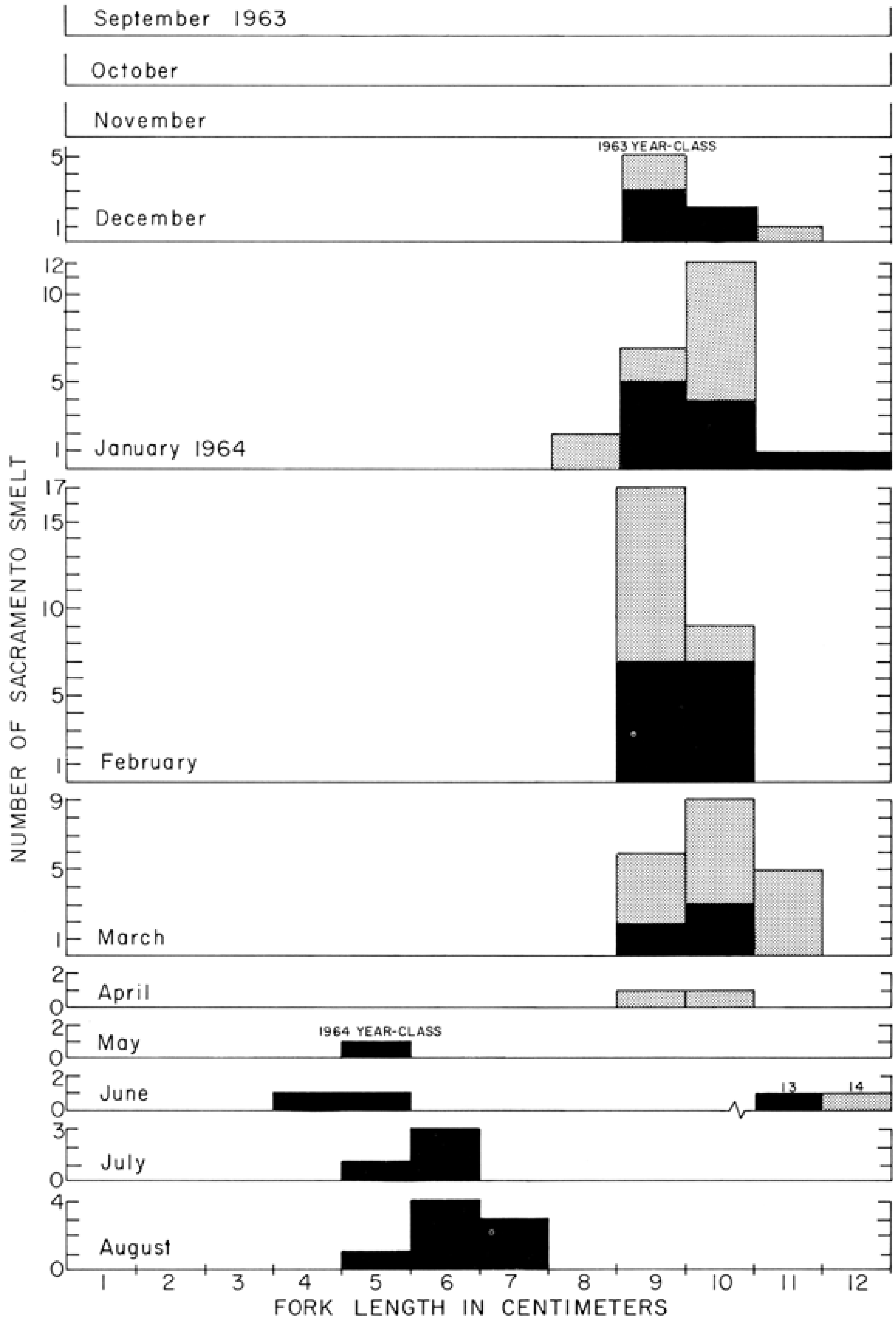

FIGURE 3. Length-frequency distribution of Sacramento smelt caught in the Delta with mid-

water trawl (black) and otter trawl (shaded) from December 1963 through August 1964. None were caught from September through November.

FIGURE 3. Length-frequency distribution of Sacramento smelt caught in the Delta with midwater trawl (black) and otter trawl (shaded) from December 1963 through August 1964. None were caught from September through November

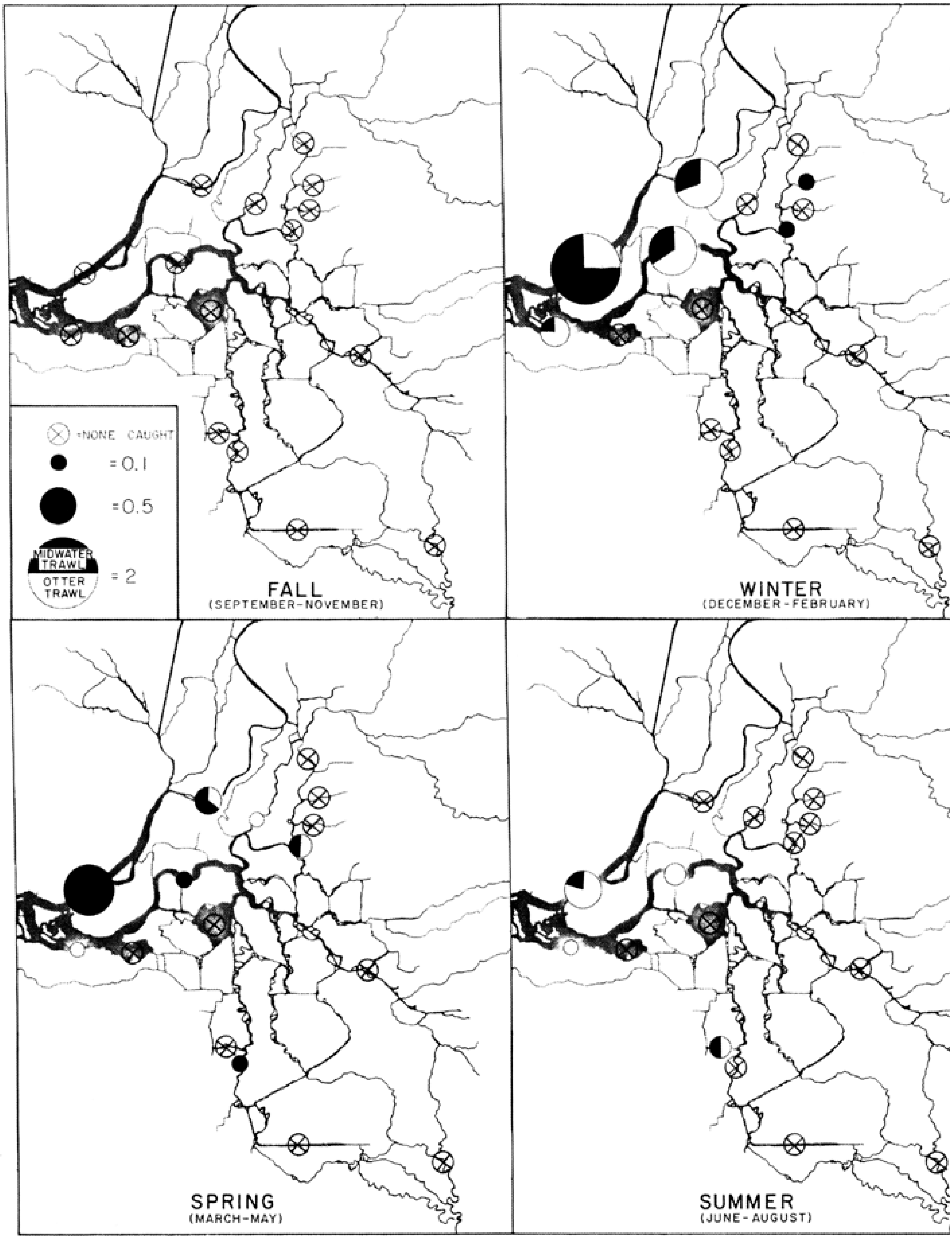

FIGURE 4. Distribution of Sacramento smelt in the Delta. The area of each circle repr the sum of mean midwater and otter trawl catches.

FIGURE 4. Distribution of Sacramento smelt in the Delta. The area of each circle represents the sum of mean midwater and otter trawl catches

of pond smelt in the Sacramento River at Sherman Island in the fall probably represents part of the same concentration Ganssle found in Suisun Bay.

The fact that catches of both species of smelt were predominantly of single size groups during the spawning migration suggests that heavy adult mortality occurs sometime during the year. Few large smelt were caught in the Delta in the summer of 1964, and Ganssle (op. cit.) found few large smelt below the Delta in Suisun Bay then, although he caught many small fish. Erkkila, et al. (1950) report high numbers of young pond smelt in the Sacramento River near Sherman Island in July and August 1948. They found few adults in the Delta at that time. If most

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smelt lived to spawn more than once, larger size groups, or at least a wider size range, should have been found during the spawning migration and adult fish should have been caught in the Delta or bay after the spawning season.

Hart and McHugh (1944) state that there is evidence that the eulachon, Thaleichthys pacificus, and the surf smelt, Hypomesus pretiosus, die after spawning. Pond and Sacramento smelt are closely related to these species and may undergo similar mortality.

STURGEON

Two species of sturgeon are found in the Sacramento-San Joaquin Delta. They are the white sturgeon, Acipenser transmontanus, and the green sturgeon, A. medirostris. Both species are generally regarded as being anadromous, but little is known about the time or location of spawning in the Sacramento-San Joaquin River systems.

This paper deals with distribution of juvenile sturgeon only, because we did not catch adults. Juvenile sturgeon were present throughout the year in the Delta. Both species were most common in the western Delta. The major food items of both were the mysid shrimp, Neomysis awatschensis, and the amphipod, Corophium.

White Sturgeon

A total of 75 white sturgeon was caught in gill nets and 35 in the otter trawl. Three size groups were distinguishable in the catch (Figure 5). The largest individual was a 102 cm male taken in the San Joaquin near Mossdale in April. According to the growth rates measured by Pycha (1956), fish of the three distinguishable size groups were 1, 2, and 4 years old, and the largest individual was about 11 years old. No ripe sturgeon were caught. All but the largest fish were probably juveniles.

Juvenile white sturgeon were caught in most areas of the Delta, but the catches did not indicate a systematic movement (Figure 6). Over 60 percent of the total were caught in the Sacramento River.

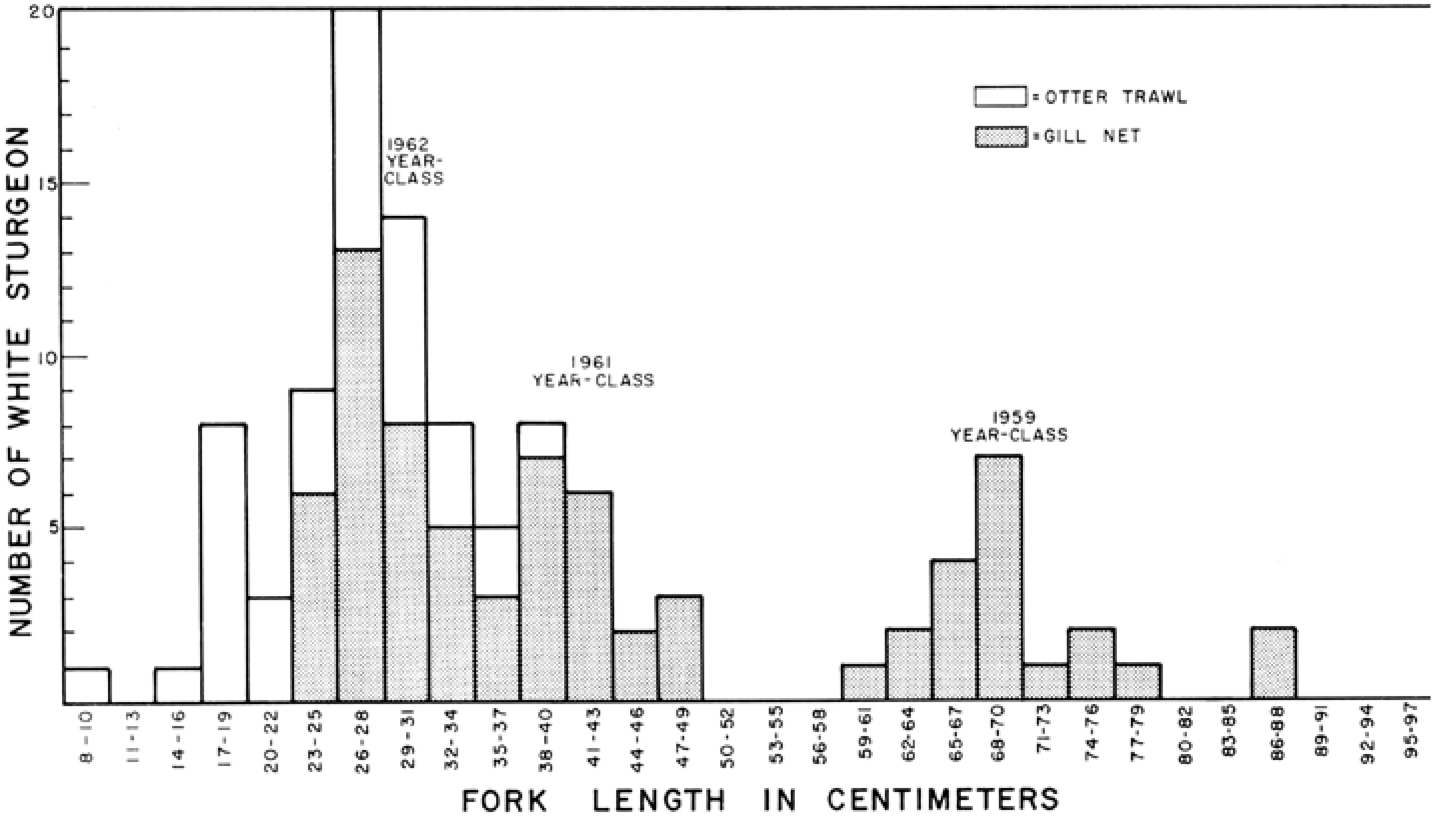

FIGURE 5. Length-frequency distribution of white sturgeon caught in the Delta wit nets and otter trawl from September 1963 through August 1964.

FIGURE 5. Length-frequency distribution of white sturgeon caught in the Delta with gill nets and otter trawl from September 1963 through August 1964

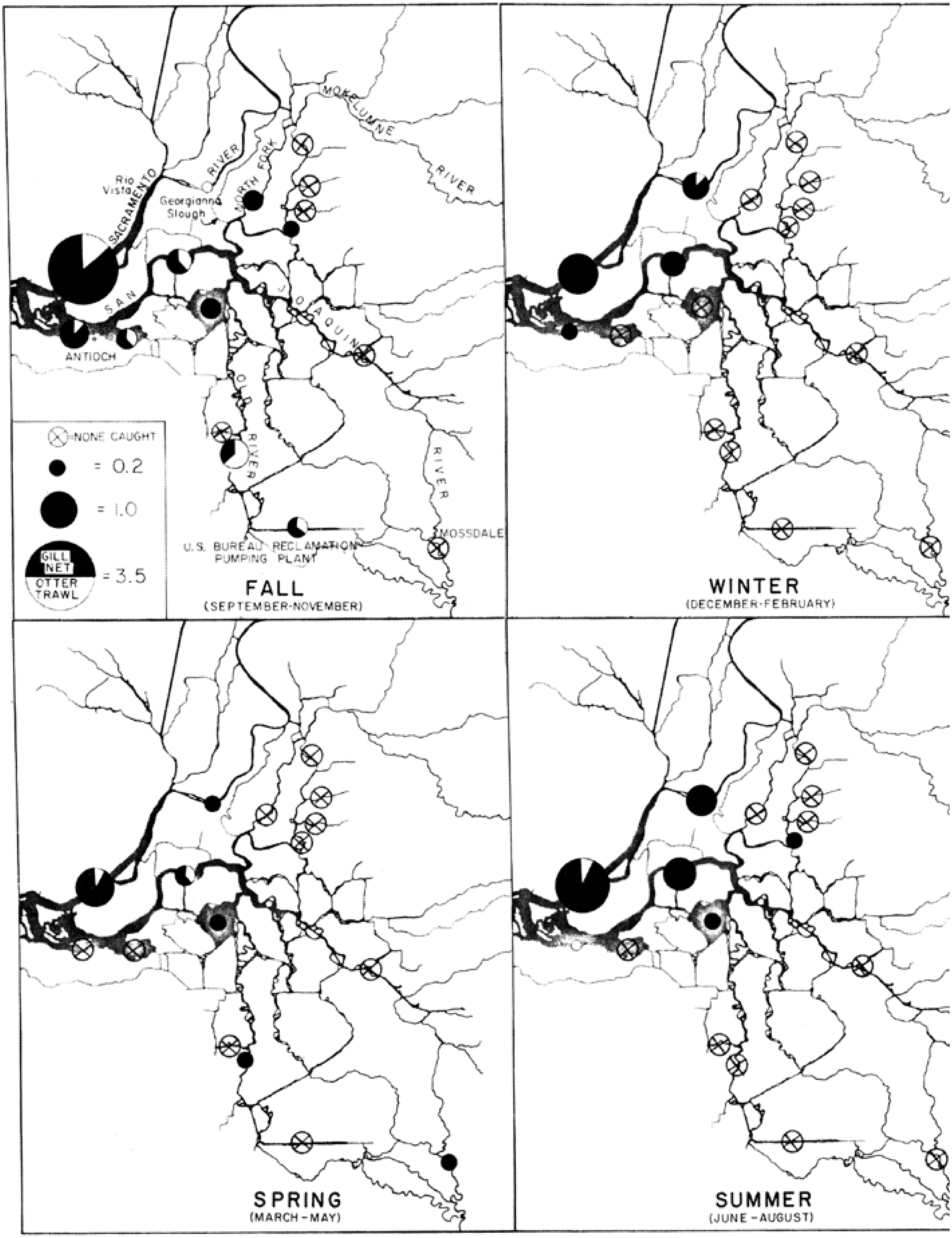

FIGURE 6. Distribution of juvenile white sturgeon in the Delta. The area of each represents the sum of mean gill net and otter trawl catches.

FIGURE 6. Distribution of juvenile white sturgeon in the Delta. The area of each circle represents the sum of mean gill net and otter trawl catches

In May 1965, William Heubach (pers. commun.) caught two very small white sturgeon in a plankton net towed on the bottom at a depth of about 35 feet. One was 22 mm *TL*, caught in the North Fork of the Mokelumne River near its junction with Georgiana Slough, and the other was 62 mm *TL*, caught in the Sacramento River near Rio Vista. Turner (see page 141) reports the occurrence of sturgeon roe in the stomach of a white catfish caught in the lower San Joaquin River in April 1964.

Food Habits

Food habits of white sturgeon were determined by examining stomach contents of 105 fish caught with gill nets and the otter trawl. Corophium and Neomysis awatschensis were probably the most important foods of smaller white sturgeon [(Table 1)]. Other foods of smaller sturgeon were polychaete worms, tendipedids, and small American shad, Alosa sapidissima.

Larger white sturgeon (40–102 cm) utilized N. awatschensis heavily throughout the year. Corophium were found in their stomachs in winter, spring, and summer. The only other foods found were the shrimp, Paleomon macrodactylus, and the Asiatic clam, Corbicula fluminea; both were found only in the fall.

Green Sturgeon

We caught 138 green sturgeon in gill nets and 28 in the otter trawl. Two size groups were distinguishable in the catch (Figure 7). Little is known about the growth characteristics of green sturgeon, but all those taken were probably juveniles.

Few juvenile green sturgeon were caught until summer when fairly large catches were taken with gill nets in the San Joaquin River at Santa Clara Shoal (10.5 per gill net unit on June 25, 35.5 on July 22, and 20.5 on August 26; Figure 8). Nearly all of these were caught in a shoal area where the water was about 3 to 8 feet deep.

Food Habits

Food habits were determined by examining 74 green sturgeon caught with the gill nets and the otter trawl. Corophium appeared to be the most important food of smaller green sturgeon. It was the only item found in the eight smaller green sturgeon (19–39 cm) examined in the fall [(Table 2)]. None were examined in the winter. All those examined in the spring and summer had eaten Corophium, which made up over half the volume of their diet during these seasons. N. awatschensis was also utilized heavily during spring and summer. One fish examined in the spring had eaten shrimp that we could not identify.

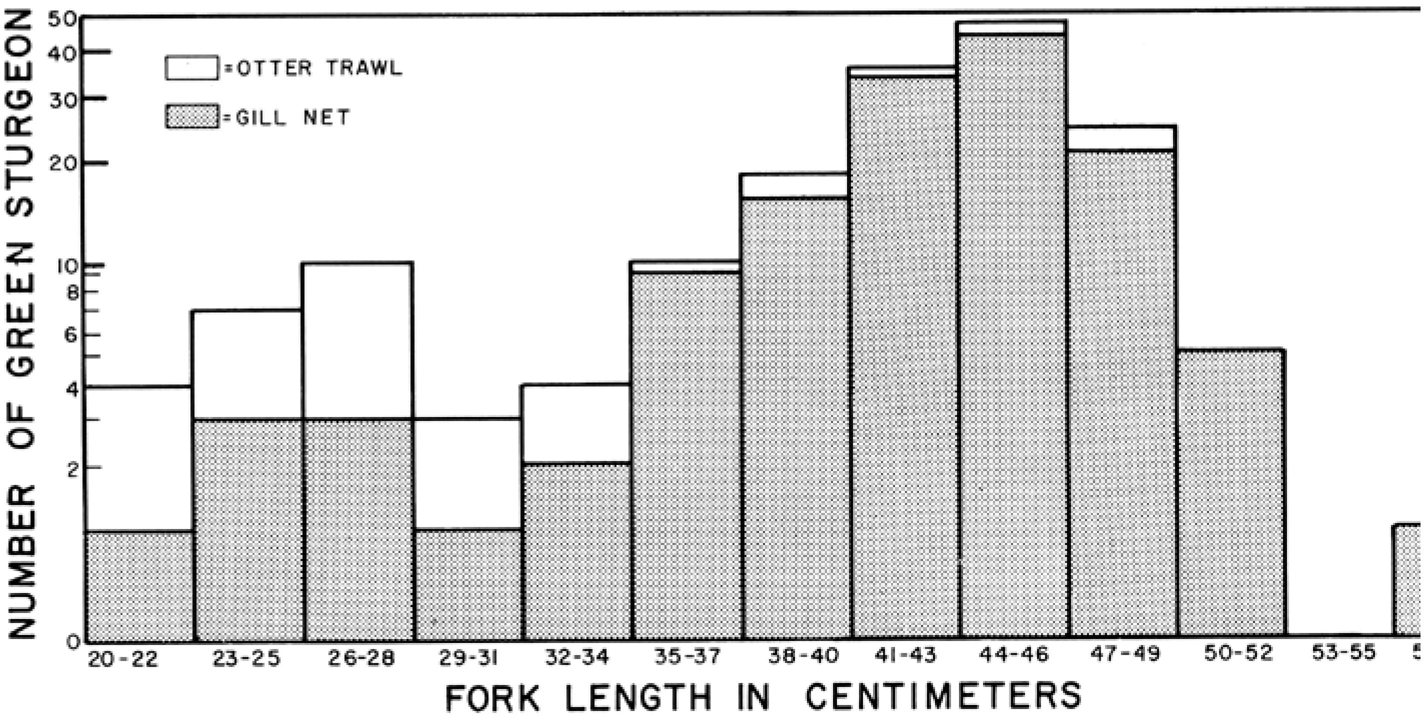

FIGURE 7. Length-frequency distribution of green sturgeon caught in the Delta wit nets and otter trawl from September 1963 through August 1964.

FIGURE 7. Length-frequency distribution of green sturgeon caught in the Delta with gill nets and otter trawl from September 1963 through August 1964

TABLE 1

Stomach Contents of White Sturgeon

Food Item	19–39 cm White Sturgeon										
	Fall		Winter		Spring		Summer		All year		
	Pct. Freq. Occ.	Pct. Tot. Vol.	Pct. Freq. Occ.	Pct. Tot. Vol.	Pct. Freq. Occ.	Pct. Tot. Vol.	Pct. Freq. Occ.	Pct. Tot. Vol.	Pct. Freq. Occ.	Pct. Tot. Vol.	I F (
Polychaetes	--	--	20.0	7.8	--	--	--	--	1.8	0.5	
Mysid shrimp (*Neomysis awatschensis*)	17.2	41.2	60.0	35.1	61.5	33.6	100.0	92.9	44.6	45.9	8
Amphipods (*Corophium*)	96.6	58.8	100.0	57.1	76.9	51.0	44.4	7.1	83.9	50.9	
Oriental shrimp (*Paleomon macrodactylus*)	--	--	--	--	--	--	--	--	--	--	2
Tendipedids	--	--	--	--	7.7	0.1	--	--	1.8	Tr.	
Asiatic clam (*Corbicula fluminea*)	--	--	--	--	--	--	--	--	--	--	2
American shad (*Alosa sapidissima*)	--	--	--	--	7.7	15.3	--	--	1.8	2.7	
Stomachs examined	35		7		18		11		71		
Stomachs containing food	29		5		13		9		56		

TABLE 1

Stomach Contents of White Sturgeon

TABLE 2

Stomach Contents of Green Sturgeon

	19–39 cm Green Sturgeon									
	Fall		Winter		Spring		Summer		All year	
Food Item	Pct. Freq. Occ.	Pct. Tot. Vol.	Pct. Freq. Occ.	Pct. Tot. Vol.	Pct. Freq. Occ.	Pct. Tot. Vol.	Pct. Freq. Occ.	Pct. Tot. Vol.	Pct. Freq. Occ.	Pct. Tot. Vol.
Mysid shrimp (*Neomysis awatschensis*)	--	--	--	--	40.0	38.3	75.0	43.0	50.0	33.2
Amphipods (*Corophium*)	100.0	100.0	--	--	100.0	54.7	100.0	57.0	100.0	63.9
Unidentified shrimp	--	--	--	--	10.0	7.0	--	--	3.8	2.8
Stomachs examined	8		0		10		12		30	
Stomachs containing food	4		0		10		12		26	

TABLE 2

Stomach Contents of Green Sturgeon

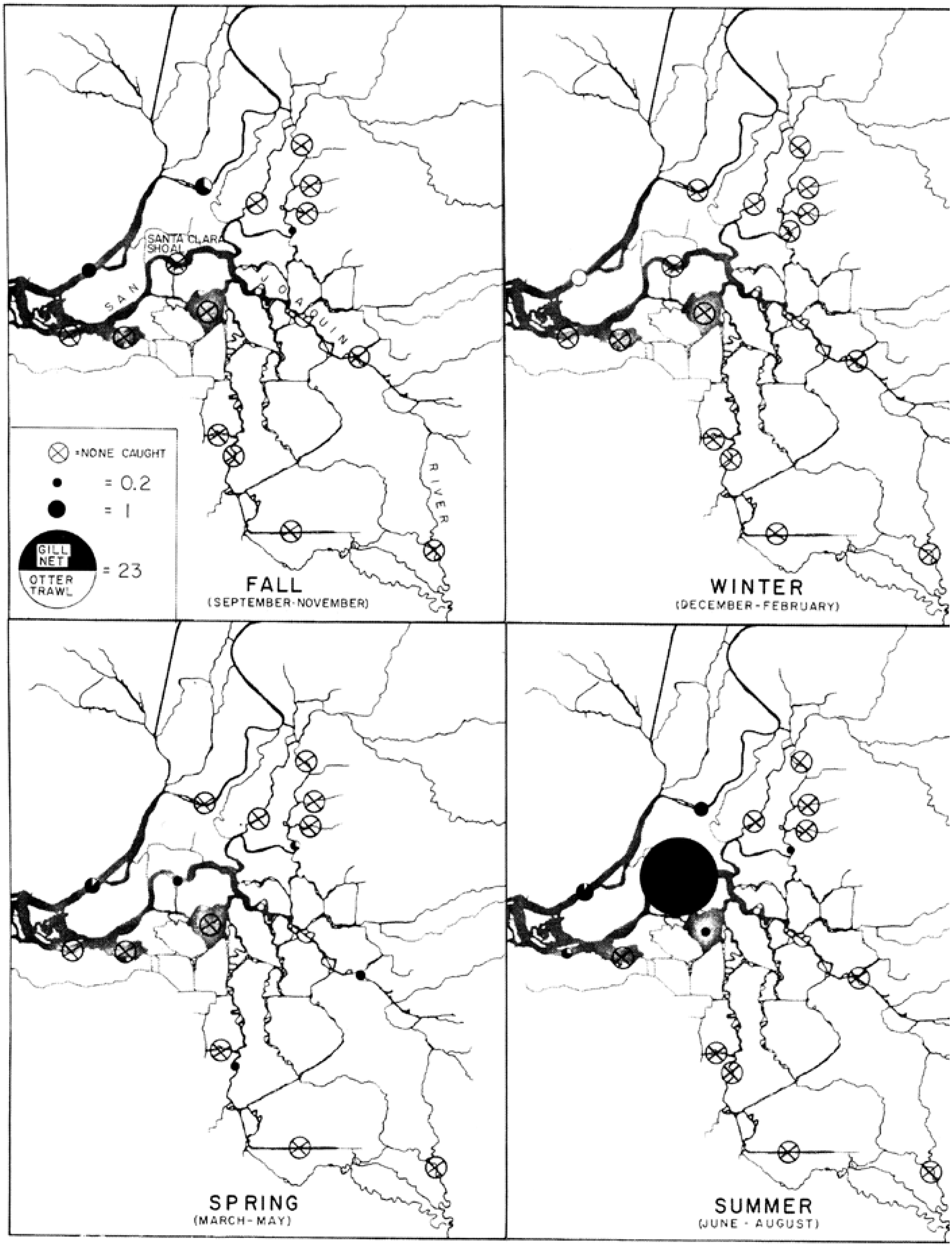

FIGURE 8. Distribution of juvenile green sturgeon in the Delta. The area of each represents the sum of mean gill net and otter trawl catches.

FIGURE 8. Distribution of juvenile green sturgeon in the Delta. The area of each circle represents the sum of mean gill net and otter trawl catches

Only one green sturgeon of the larger size group (40–57 cm) was examined in the fall; it had eaten only Corophium. None were examined in the winter. N. awatschensis was utilized by all fish examined in the spring, and it made up nearly the entire bulk of their diet. In the summer more fish had eaten Corophium than had eaten N. awatschensis, but the latter made up a much greater volume of the diet than the former.

Discussion

Juvenile white sturgeon were present in the Delta all year. They were particularly common in the lower Sacramento River. Ganssle (1966) found that white sturgeon in Suisun Bay, just below the Delta,

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were generally smaller than those in San Pablo Bay. Pycha (op. cit.) states that white sturgeon less than 40 inches long seem to be present throughout the Delta the year round.

Bajkov (1951) analyzed tag returns and catch records from the commercial and sport fisheries in the Columbia River from Bonneville Dam to the mouth. He concluded that small and medium-size fish migrate upstream during fall and early winter and downstream during late winter and spring. He suggests that the upstream movement is a feeding migration related to the availability of salmon and lamprey carcasses in the upstream areas, and the downstream movement is associated with an abundance of smelt in the lower river during late winter and spring.

The relatively high catch of green sturgeon in the San Joaquin River at Santa Clara Shoal in the summer suggests an abrupt movement into this area. These fish probably moved upriver from the bay, perhaps to feed.

In general, bottom feeders such as sturgeon utilize food items most readily available to them. The general lack of organisms larger than Neomysis awatschensis in the diet in the Delta is probably due to a lack of suitable larger organisms in the environment (Hazel and Kelley, 1966). However, the Asiatic clam, which is abundant over most of the Delta, was nearly absent from our samples. In other areas, where large food organisms are available, sturgeon utilize them. For example, Ganssle (op. cit.) found larger invertebrates such as clams, Macoma sp., and the isopod, Synidotea laticauda, to be the important foods of sturgeon in San Pablo Bay, and anglers have found the bay shrimp, Crago franciscorum, an effective bait for sturgeon in San Pablo and Suisun bays.

The only previous study of sturgeon food habits in the Delta above the City of Antioch is that by Schreiber (1962). He collected 30 young-of-the-year white sturgeon averaging 20.3 cm *FL*, at the fish screens of the Bureau of Reclamation pumping plant on Old River (see Figure 6) during August, September, and October of 1956 and 1958. of 21 stomachs containing food, Corophium spinicorne were in 90 percent, Neomysis mercedis (now N. awatschensis) in 10 percent, tendipedid larvae in 19 percent, and tendipedid adults in 5 percent.

STARRY FLOUNDER

The starry flounder, Platichthys stellatus, occupies the bays, inlets, and sounds of the Pacific Coast from the Santa Ynez River, California, to the Alaskan Peninsula. It is common in San Pablo and Suisun bays below the Sacramento-San Joaquin Delta. The role of this species in the Delta appears to be a minor one. It is euryhaline and probably ranges into the Delta from the bay area. Some spawning may occur in the Delta, and there is evidence that striped bass feed upon some of the young there (see Stevens, p. 73).

A total of 273 starry flounder was caught in the otter trawl and 2 in the gill net. Assuming that the growth rate of the fish in the Delta was similar to that of fish in Monterey Bay (Orcutt, 1950), the fish caught in the Delta from October through April were probably 1 or 2 years old. None were sexually mature.

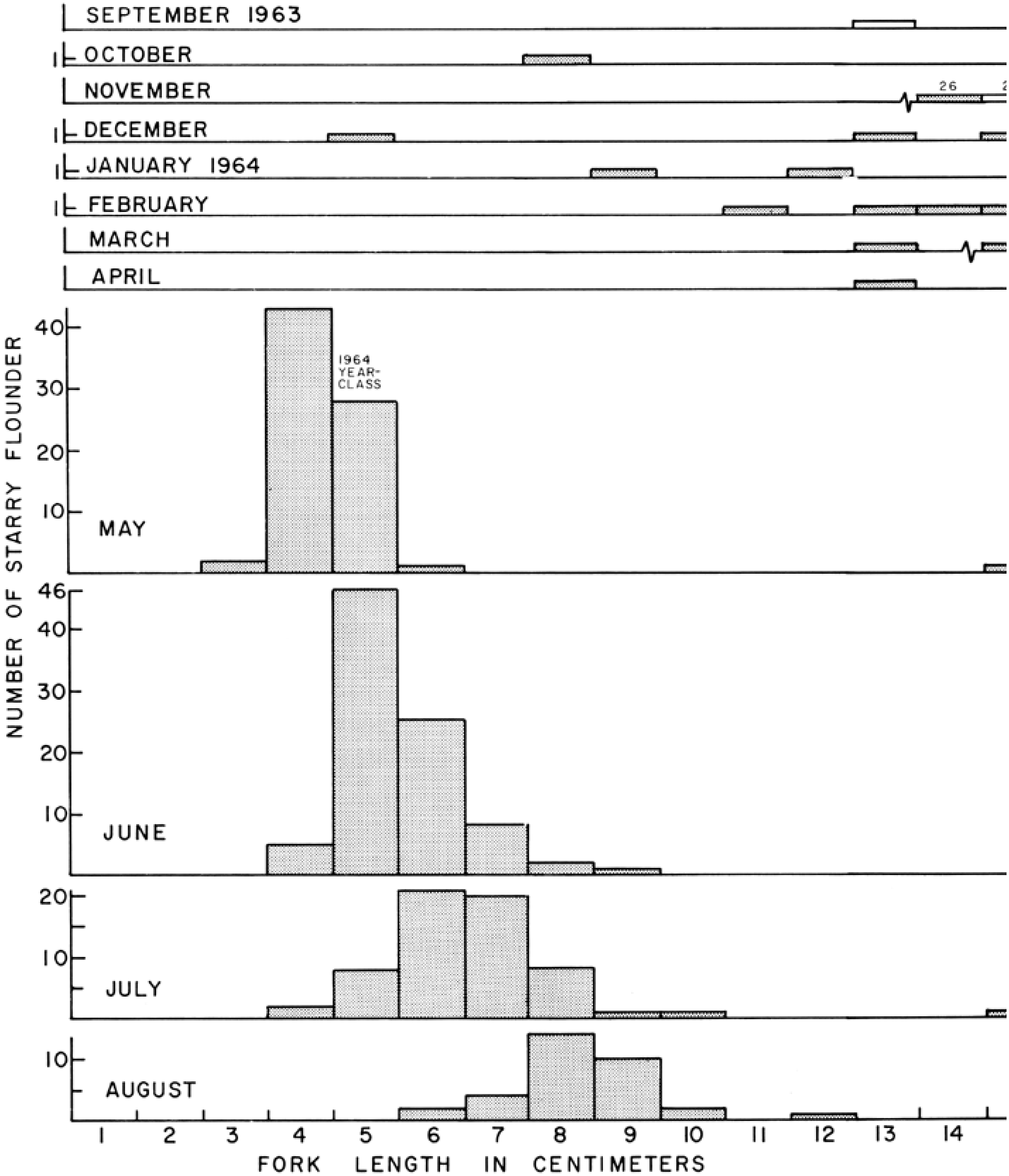

FIGURE 9. Length-frequency distribution of starry flounder caught in the Delta with trawl (shaded) and gill net (white) from September 1963 through August 1964.

FIGURE 9. Length-frequency distribution of starry flounder caught in the Delta with otter trawl (shaded) and gill net (white) from September 1963 through August 1964

From May through August a group of smaller fish, ranging from 3 to 10 cm *TL*, dominated the catch (Figure 9). Since starry flounder spawn in the winter, these were probably young-of-the-year (1964 year-class). Starry flounder occurred in most parts of the Delta, but most were taken in the San Joaquin River, the Sacramento River, the South Fork of the Mokelumne River at Terminous, and in the flooded islands, Franks Tract and Big Break in spring and summer (Figure 10). Timothy C. Farley (pers. commun.) collected some very small juveniles (8–15 mm *TL*) in plankton nets while towing for striped bass eggs and larvae in the lower San Joaquin River in April and May 1963 and 1964.

The starry flounder has long been regarded as being euryhaline. It is common below the Sacramento-San Joaquin Delta in Suisun and San Pablo bays (Ganssle, op. cit.) where salinities range from nearly

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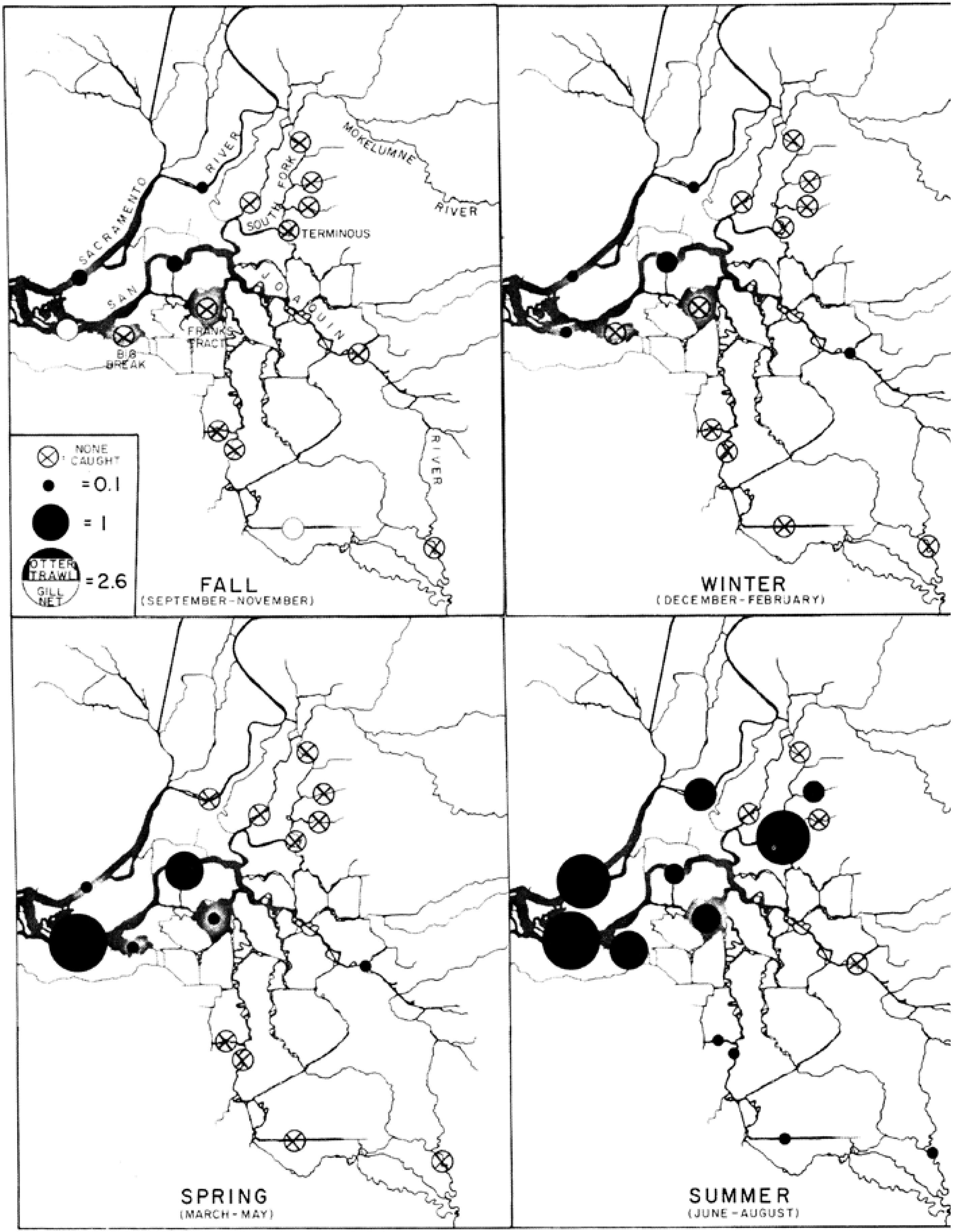

FIGURE 10. Distribution of starry flounder in the Delta. The area of each circle repre the sum of mean otter trawl and gill net catches.

FIGURE 10. Distribution of starry flounder in the Delta. The area of each circle represents the sum of mean otter trawl and gill net catches

sea water to fresh water. Carl (1937) found a small population in a brackish water lagoon in British Columbia. Gunter (1942) reports the occurrence of starry flounder 75 miles up the Columbia River.

Most of the starry flounder we caught in the Delta were young-of-the-year, but whether the adults spawn there or not is unknown.

LITERATURE CITED

Bajkov, A. D. 1951. Migration of white sturgeon (Acipenser transmontanus) in the Columbia River. Oregon Fish Comm., Res. Briefs, 3(2): 8–21. Carl, G. C. 1937. Flora and fauna of brackish water. Ecology 18: 446–453. Erkkila, Leo F., James W. Moffett, Oliver B. Cope, Bernard R. Smith and Reed S. Nielson. 1950. Sacramento-San Joaquin Delta fishery resources: Effects of Tracy

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pumping plant and Delta cross channel. U.S. Fish and Wildl. Serv., Spec. Sci. Rept., Fish., (56) : 1–109. Ganssle, David. 1966. Fishes and decapods of San Pablo and Suisun Bays, p. 64–94. *In* D. W. Kelley (ed.), Ecological studies of the Sacramento-San Joaquin Estuary. Calif. Dept. Fish and Game, Fish Bull., (133) : 1–133. Gunter, Gordon. 1942. A list of fishes of the mainland of North and middle America recorded from both fresh water and sea water. Amer. Midl. Nat., *28* : 305–326. Hart, John Lawson, and J. Laurence McHugh. 1944. The smelts (Osmeridae) of British Columbia. Fish. Res. Bd. Canada, Bull., (64) : 1–27. Hazel, Charles R., and D. W. Kelley. 1966. Zoobenthos of the Sacramento-San Joaquin Delta, p. 113–133. *In* D. W. Kelley (ed.), Ecological studies of the Sacramento-San Joaquin Estuary. Calif. Fish and Game, Fish Bull., (133) : 1–133. Orcutt, Harold George. 1950. The life history of the starry flounder, Platichthys stellatus (Pallas). Calif. Dept. Fish and Game, Fish Bull., (78) : 1–64. Pycha, Richard A. 1956. Progress report on white sturgeon studies. Calif. Fish and Game *42*(1) : 23–35. Sato, Ryuhei. 1950. Biological observations on the pond smelt, Hypomesus olidus (Pallas), in Lake Kogawara, Aomori prefecture, Japan. I. Habits and age composition of the spawning fishes. Tohoku J. Agr. Res. *1*(1) : 87–95. Schreiber, Max R. 1962. Observations on the food habits of juvenile white sturgeon. Calif. Fish and Game *48*(1) : 79–80. Shiraishi, Yoshikazu. 1952. Study on spawning migration of pond smelt, Hypomesus olidus, by marking in Lake Suwa. Tokyo Freshwater Fish. Res. Lab. Bull. *1*(1) : 26–40.

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DISTRIBUTION AND FOOD HABITS OF ICTALURID FISHES IN THE SACRAMENTO-SAN JOAQUIN DELTA

JERRY L. TURNER

The number of catfish anglers in California ranks second only to those who catch trout (Ryan, 1959). The Sacramento-San Joaquin Delta is particularly important because it provides over half the catfish caught by anglers in the State. The white catfish is the most numerous species of catfish in the Delta.

This report is a description of the distribution and food habits of the four species of the Ictaluridae or catfish family that were caught during 12 months of sampling in the Sacramento-San Joaquin Delta. The catfish taken were brown bullhead, Ictalurus nebulosus, black bullhead, Ictalurus melas, channel catfish, Ictalurus punctatus, and white catfish, Ictalurus catus. None are native fish.

Each species of catfish occupies a different environment in the Delta. Both the brown and black bullheads were taken in greatest numbers in quiet waters of the dead-end sloughs. Channel catfish were concentrated in swifter water in the river channels upstream from the central Delta. Adult white catfish were most abundant in dead-end sloughs, flooded islands, and the San Joaquin River below Stockton while their young were taken in channels in the southern and eastern Delta.

All the catfish were omnivorous, feeding on whatever was available on the bottom. Corophium, Neomysis and tendipedids were the most frequent food items for all sizes of catfish. The importance of larger food items such as fishes and crayfish increased as the size of the catfish increased.

The growth rate of white catfish in the Delta is slow, a condition which could be due to a limited or unavailable food supply, particularly for the larger catfish.

TOTAL CATCH

Catfish were taken with the otter and midwater trawls and with set gill nets. Most of the brown bullheads, black bullheads, channel catfish and white catfish were taken with the otter trawl [(Table 1)]. A number of older white catfish was also caught with the gill net and midwater trawl.

TABLE 1

Total Numbers of Various Ictalurids Taken With Gill Nets, Otter and Midwater Trawls

Species	Gill net	Otter trawl	Midwater trawl	Tot num
Brown bullhead	7	76	6	
Black bullhead	7	86	7	
Channel catfish	24	540	7	
Young-of-the-year white catfish	--	14,472	86	14
Juvenile and adult white catfish	2,366	7,776	576	10

TABLE 1

Total Numbers of Various Ictalurids Taken With Gill Nets, Otter and Midwater Trawls

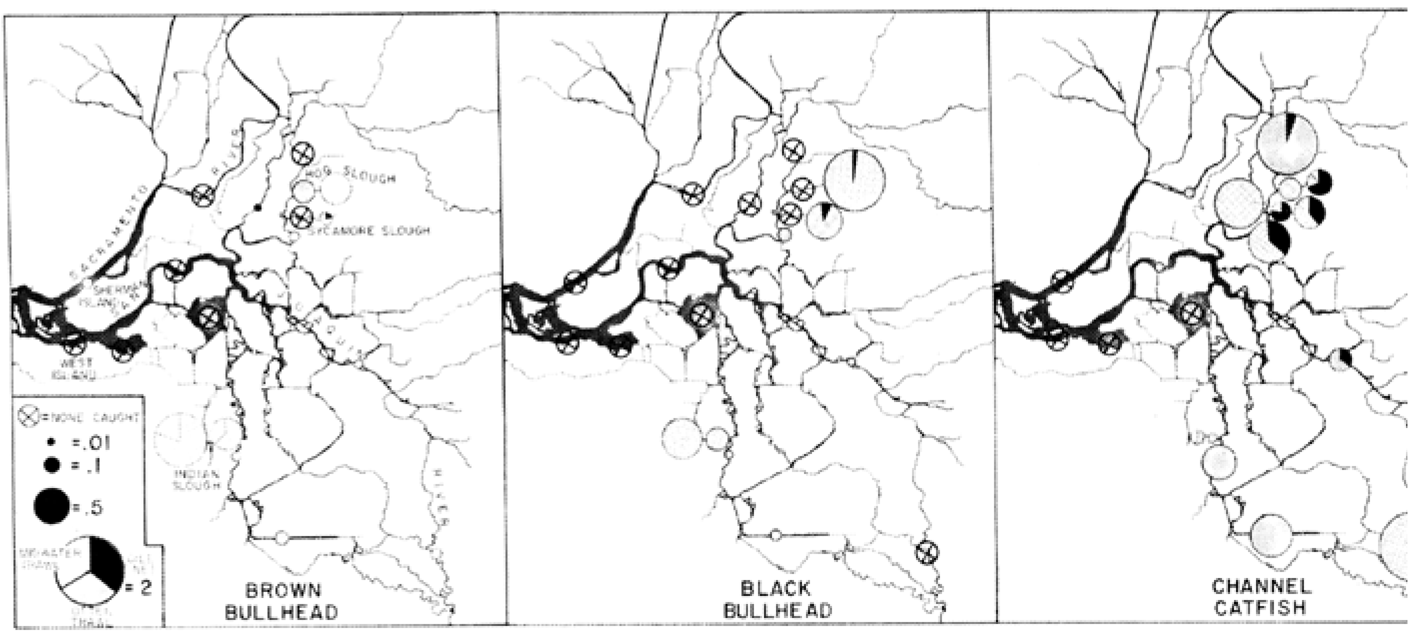

FIGURE 1. Distribution of brown bullheads, black bullheads, and channel catfish. The of each circle is proportional to the sum of the mean catch of fish taken with the trawl, midwater trawl, and gill net.

FIGURE 1. Distribution of brown bullheads, black bullheads, and channel catfish. The area of each circle is proportional to the sum of the mean catch of fish taken with the otter trawl, midwater trawl, and gill net

The white catfish made up over 97 percent of our total catch with all types of gear.

BROWN AND BLACK BULLHEADS

Out of 189 brown and black bullheads caught in the Delta, 161 were taken from the dead-end sloughs—Hog, Sycamore, and Indian (Figure 1). Three-fourths of these were caught at the stations farthest from the mouth of the sloughs. Brown bullheads were not taken in the western Delta except for one fish caught at Sherman Island on the Sacramento River. No black bullheads were caught in the western Delta.

The brown bullheads ranged in fork length from 8 to 31 cm with an average length of 21.1 cm. The black bullheads ranged in fork length from 12 to 29 cm with an average length of 21.2 cm.

Our analysis of the stomachs of 56 brown bullheads and 60 black bullheads disclosed that they consumed a variety of benthic organisms. The most frequently found food was the amphipod, Corophium. They were found in 80 percent of the brown bullhead and 92 percent of the black bullhead stomachs examined [(Table 2)]. It also made up 16.7 percent of the volume of food found in the brown bullhead and 19.3 percent of the volume of food in the black bullhead. The mysid shrimp, Neomysis awatschensis, and a variety of other foods including unidentified dragonfly nymphs; unidentified fishes, tendipedid larvae and pupae; crayfish, Pacifastacus leniusculus; amphipod, Gammarus; isopod, Exosphaeroma oregonensis; were less frequently found in the brown and black bullhead stomachs. However, dragonfly nymphs made up 40 percent of the volume of brown bullhead stomach contents, and fishes made up 40 percent of the volume of black bullhead stomach contents.

CHANNEL CATFISH

Most of the 571 channel catfish taken were caught in areas of fast water in rivers and channels upstream from the central Delta (Figures 1 and 2). No channel catfish were taken in the western Delta (Sherman Island on the Sacramento River and West Island on the San Joaquin River).

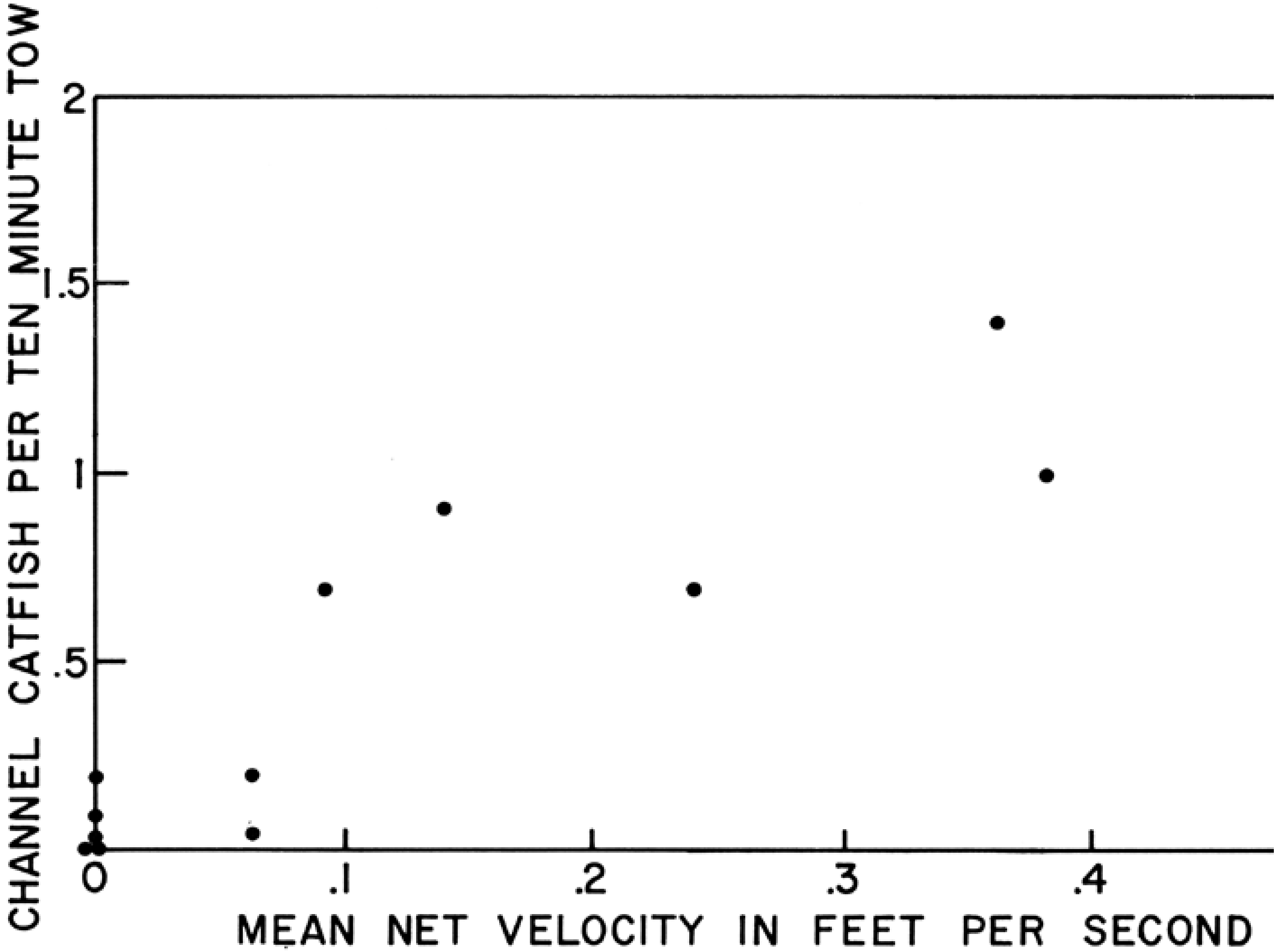

FIGURE 2. Comparison of the mean annual catch of channel catfish taken by otter with the mean annual net velocity of flow at our sampling stations. Radtke (see p describes net velocity of flow.

FIGURE 2. Comparison of the mean annual catch of channel catfish taken by otter trawl with the mean annual net velocity of flow at our sampling stations. Radtke (see p. 24) describes net velocity of flow

TABLE 2

Stomach Contents of Brown and Black Bullheads

Food item	Brown Bullhead		Black Bullhead	
	Percent frequency occurrence	Percent volume	Percent frequency occurrence	Perc volu
Annelids				
Unidentified Annelids	--	--	2.1	.
Crustaceans				
Mysid shrimp (*Neomysis awatschensis*)	31.8	2.0	52.1	3.
Isopod (*Exosphaeroma oregonensis*)	4.5	9.1	2.1	16.
Amphipod (*Corophium*)	79.5	16.7	91.7	19.
Amphipod (*Gammarus*)	2.3	1.2	--	--
Crayfish (*Pacifastacus leniusculus*)	6.8	16.8	2.1	3.
Insects				
Unidentified dragonfly nymphs	9.1	40.3	2.1	1.
Tendipedids	9.1	.2	27.1	1.
Other insects	4.5	2.2	2.1	.
Molluscs				
Asiatic clam (*Corbicula fluminea*)	4.5	--	2.1	--
Unidentified snails	4.5	8.8	2.1	10.
Fishes				
Unidentified fishes	2.3	.7	8.3	39.
Fish eggs	2.3	1.8	--	--
Miscellaneous				
Seeds	--	--	4.2	3.
Peat (Percent of total stomachs examined)	5.4	--	3.3	--
Stomachs examined	56		60	
Stomachs containing food	44		48	

TABLE 2

Stomach Contents of Brown and Black Bullheads

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The channel catfish ranged in size from 4 to 53 cm *FL*. Most were less than 15 cm in length with an average length of 12.1 cm.

Corophium was the most important food of channel catfish under 20 cm long. We found them in 94 percent of the 203 stomachs examined [(Table 3)]. They made up 85 percent of the total volume of the stomach contents. Tendipedidae larvae and Neomysis awatschensis were of much lesser importance.

TABLE 3

Stomach Contents of Channel Catfish

Food item	Catfish less than 20 cm.		Catfish 20 cm. and lo	
	Percent frequency occurrence	Percent volume	Percent frequency occurrence	Perc volu
Crustaceans				
Mysid shrimp (*Neomysis awatschensis*)	13.8	3.2	13.3	0.
Isopod (*Exosphaeroma oregonensis*)	1.1	2.5	--	--
Amphipod (*Corophium*)	93.9	85.1	80.0	1.
Crayfish (*Pacifastacus leniusculus*)	--	--	20.0	55.
Insects				
Tendipedids	26.5	4.6	6.7	--
Other insects	4.4	4.2	6.7	0.
Molluscs				
Asiatic clam (*Corbicula fluminea*)	0.6	--	20.0	8.
Fishes				
Unidentified fishes	--	--	13.3	24.
Fish eggs	0.6	--	--	--
Mammals				
Unidentified mammal	--	--	6.7	10.
Miscellaneous				
Seeds	0.6	0.4	--	--
Garbage	--	--	6.7	--
Stomachs examined	203		23	
Stomachs containing food	181		15	

TABLE 3

Stomach Contents of Channel Catfish

The stomachs of 23 channel catfish over 20 cm contained a variety of benthic organisms. Small amounts of Corophium were in 12 of the 15 stomachs that contained food. Larger organisms such as crayfish, Pacifastacus leniusculus; forage fishes; and adult clams, Corbicula fluminea occurred in seven stomachs and formed 88 percent of the diet bulk. One catfish had consumed a small unidentified mammal.

YOUNG-OF-THE-YEAR WHITE CATFISH

More than 25,000 white catfish were caught during the year of sampling. The 1963 and 1964 year-classes were identified by a length-frequency analysis of the catch (Figure 3). The 1963 year-class grew from a range of 4 to 12 cm in September 1963 to a range of 10 to 16 cm in August 1964. The 1964 year-class grew from 2 to 5 cm long in July to 4 to 8 cm long in August.

Distribution

The major concentrations of the 1963 year class of white catfish in the fall of 1963 were in the San Joaquin River below Stockton and in Old River at Victoria Island (Figure 4). Very low numbers were

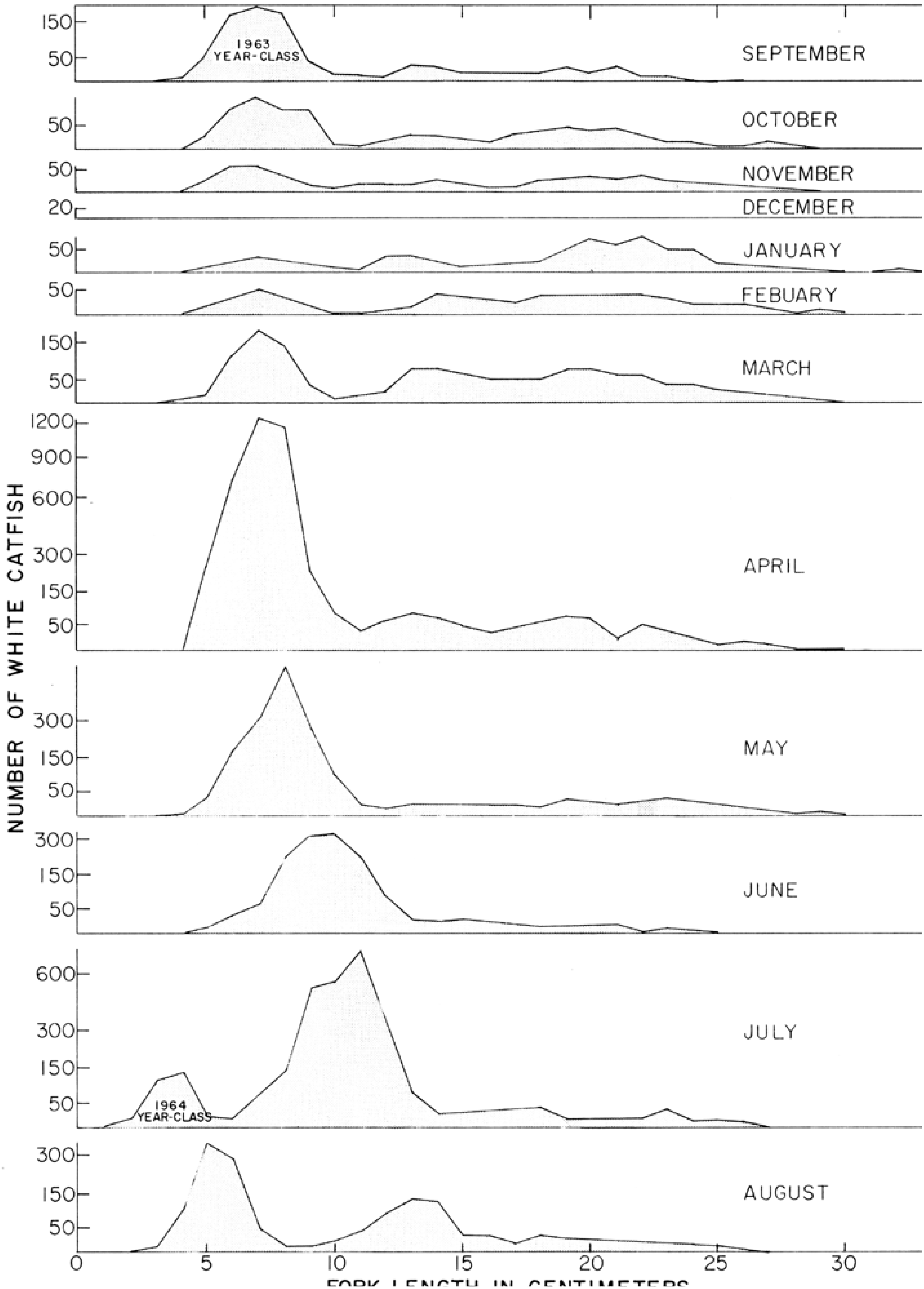
150
50
1963
YEAR-CLASS
SEPTEMBER
50
OCTOBER
50
NOVEMBER
20
DECEMBER
50
JANUARY
50
FEBUARY
150
50
MARCH
1200
900
600
300
150
50
APRIL
NUMBER OF WHITE CATFISH
300
150
50
MAY
300
150
50
JUNE
600
300
150
50
1964
YEAR-CLASS
JULY
300
150
50
AUGUST
0
5
10
15
20
25
30

FIGURE 3. Length frequency of catch of white catfish taken by otter trawl.

FIGURE 3. Length frequency of catch of white catfish taken by otter trawl

caught in the western Delta and very few were taken in the northern Delta. Our catches in the winter were low at every station. The catches from March through August were very similar to the fall period. No young-of-the-year white catfish were caught in the Sacramento River at Isleton.

The 1964 year-class of young white catfish were caught in our nets only in July and August 1964. Their distribution pattern was very similar to that of the 1963 young-of-the-year in September–November

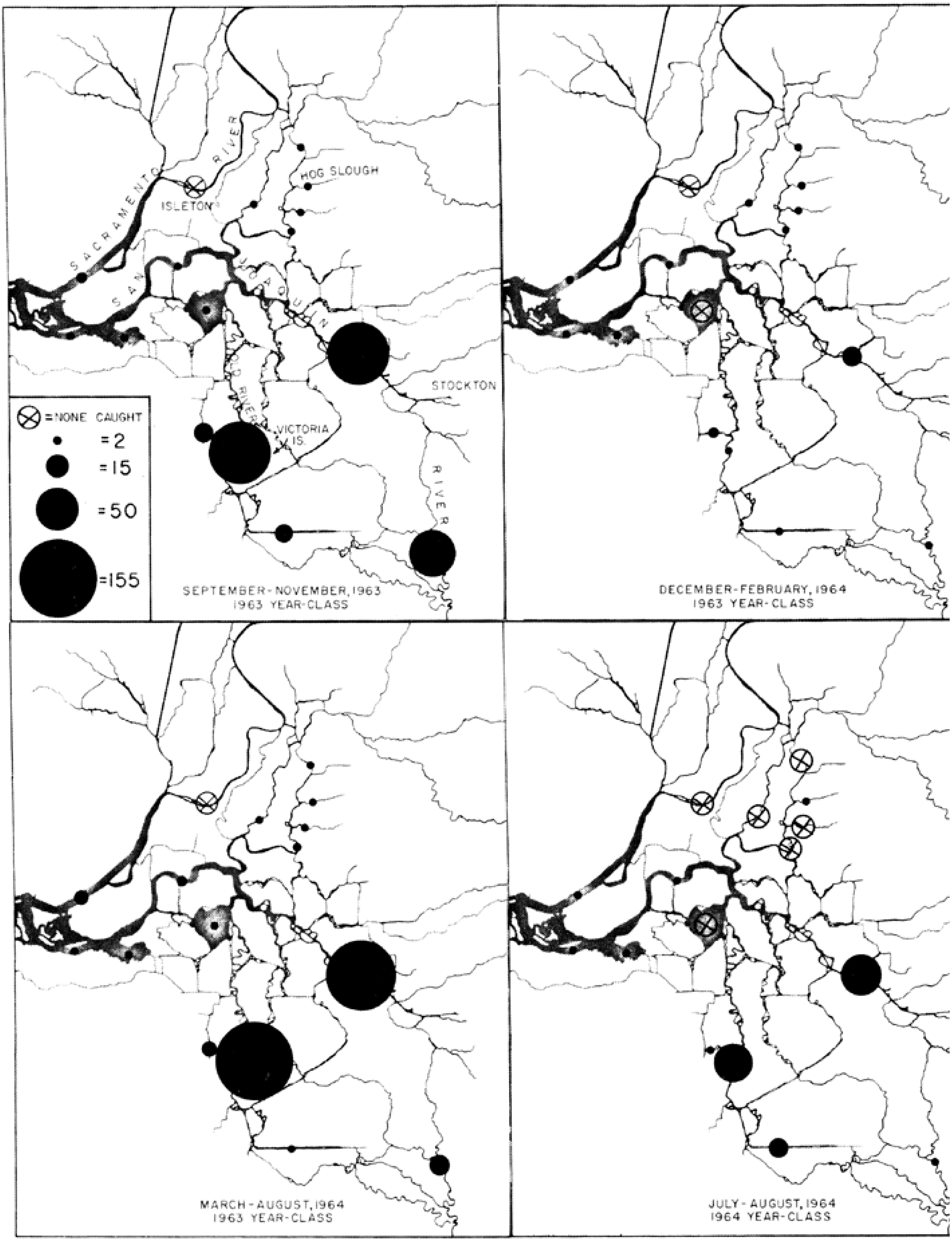

FIGURE 4. Distribution of the 1963 and 1964 year-classes of young white catfish. The of each circle is proportional to the mean seasonal catch at each sampling station.

FIGURE 4. Distribution of the 1963 and 1964 year-classes of young white catfish. The area of each circle is proportional to the mean seasonal catch at each sampling station

1963 (Figure 4). Many were taken in the south Delta, few in the western Delta, and except for one fish taken in Hog Slough, none were taken in the northern Delta. The greatest concentrations were again taken in the San Joaquin River below Stockton and in Old River at Victoria Island.

Food Habits

Our analysis of the stomachs of 967 young-of-the-year catfish disclosed that they fed almost entirely on Corophium, Neomysis awatschensis, and tendipedids [(Table 4)]. Corophium was the most important food. It was found in 94 percent of the stomachs, and it made up 80

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percent of the volume of food. N. awatschensis occurred in at least 10 percent of the stomachs throughout all seasons and was especially common in the diet during the summer. Tendipedids also were eaten most frequently in the summer. Four young catfish in their second summer had eaten small fish.

TABLE 4

Stomach Contents of Young White Catfish

Food item	Percent frequency of occurrence					P v
	Fall	Winter	Spring	Summer	Average	se
Mysid shrimp (*Neomysis awatschensis*)	13.4	10.7	17.6	31.5	21.3	
Amphipod (*Corophium*)	92.0	96.0	95.9	92.9	93.9	
Tendipedids	13.9	1.3	8.6	22.1	14.3	
Fishes	--	--	--	1.3	0.5	
Stomachs examined	227	110	283	347	967	
Stomachs containing food	187	75	244	308	814	

TABLE 4

Stomach Contents of Young White Catfish

The diet of young white catfish was not the same throughout the Delta (Figure 5). Corophium was consumed in large numbers at every station throughout the year. N. awatschensis was an important food in the fall and summer at Isleton and Sherman Island on the Sacramento River and at Santa Clara Shoal and West Island on the lower San Joaquin River. Tendipedid larvae and pupae were common in the diet of the young catfish in Old River at Victoria Island and at Fabian Canal, especially during the summer and fall. They formed a significant part of the diet in the San Joaquin River at Mossdale in the fall, spring, and summer. Our knowledge of the winter diet in the San Joaquin River at Mossdale is limited. We analyzed only six stomachs that contained food; Corophium was the only food that had been consumed.

JUVENILE AND ADULT WHITE CATFISH

Large numbers of juvenile and adult white catfish were taken by both the gill net and otter trawl. The monthly catch with the two gears varied considerably. The monthly otter trawl catch was high in the fall and low in the summer (Figure 6). The gill net catch was less variable with increased catches from February through June.

White catfish caught in the Delta were quite small. Over 85 percent of our gill net catch was 25 cm or less *FL* (Figure 7). The largest fish caught was 57 cm.

Distribution

White catfish were taken at almost every sampling station with both otter and midwater trawls and gill nets (Figure 8). Catches were highest in the quiet water areas of Hog and Sycamore Slough, Franks Tract, and in the San Joaquin River below Stockton. Few catfish were taken in the fast flowing areas of the Sacramento and Mokelumne rivers. Only three white catfish were taken in over a year's sampling with all three gears in the Sacramento River at Isleton.

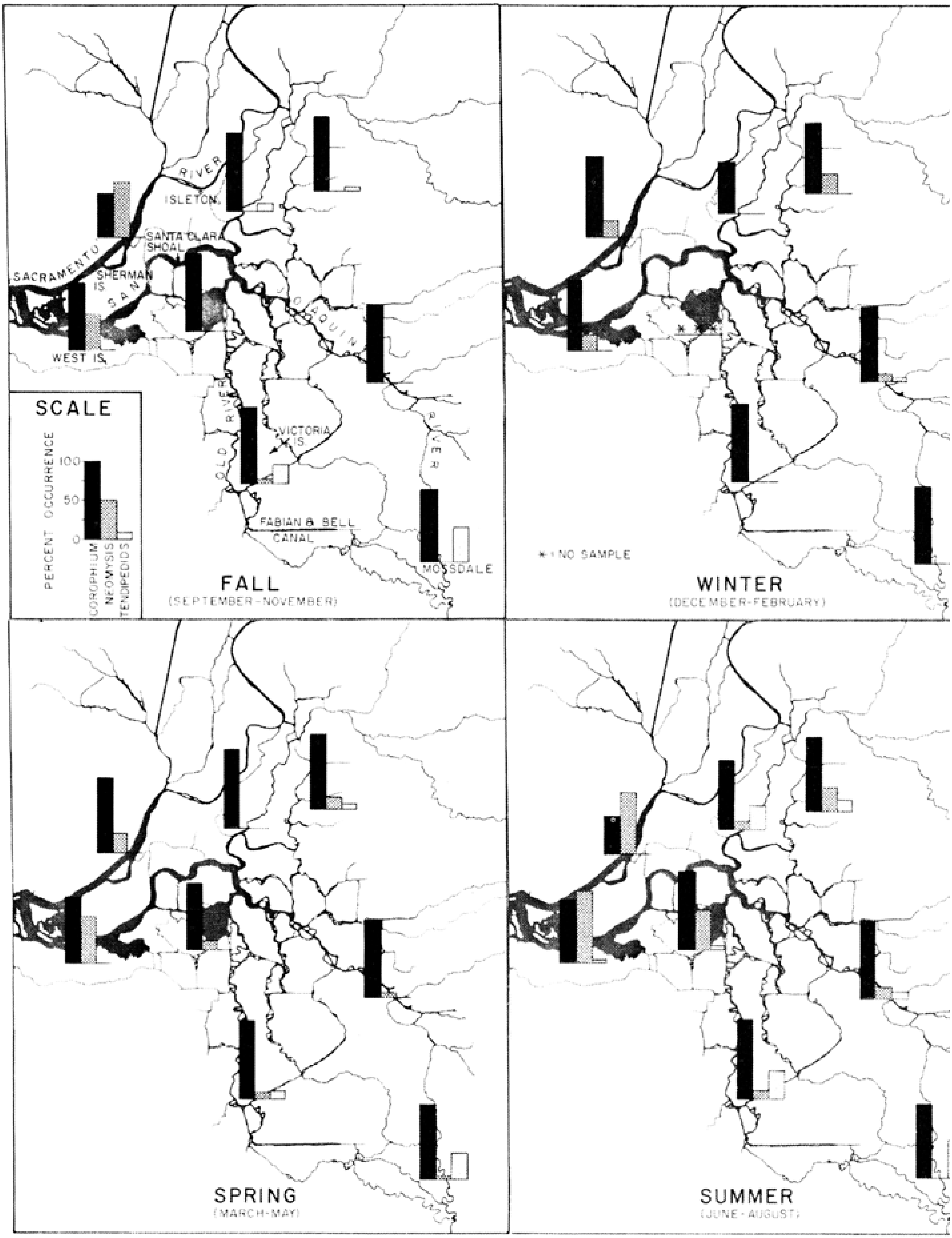

FIGURE 5. Comparison of the percent frequency of occurrence of major food items i stomachs of young white catfish at various sampling stations in the Delta.

FIGURE 5. Comparison of the percent frequency of occurrence of major food items in the stomachs of young white catfish at various sampling stations in the Delta

Time of Spawning

The first spent female that we caught was taken on June 10, 1964 at Sycamore Slough when the water temperature was 18.9° C. Most spent females were taken during July and August [(Table 5)]. Very few white catfish were classified as sexually ripe (free-flowing eggs when the abdomen is squeezed). McCammon (1957) found that white catfish spawn in the Delta in June and July when water temperatures reach 21.1° C.

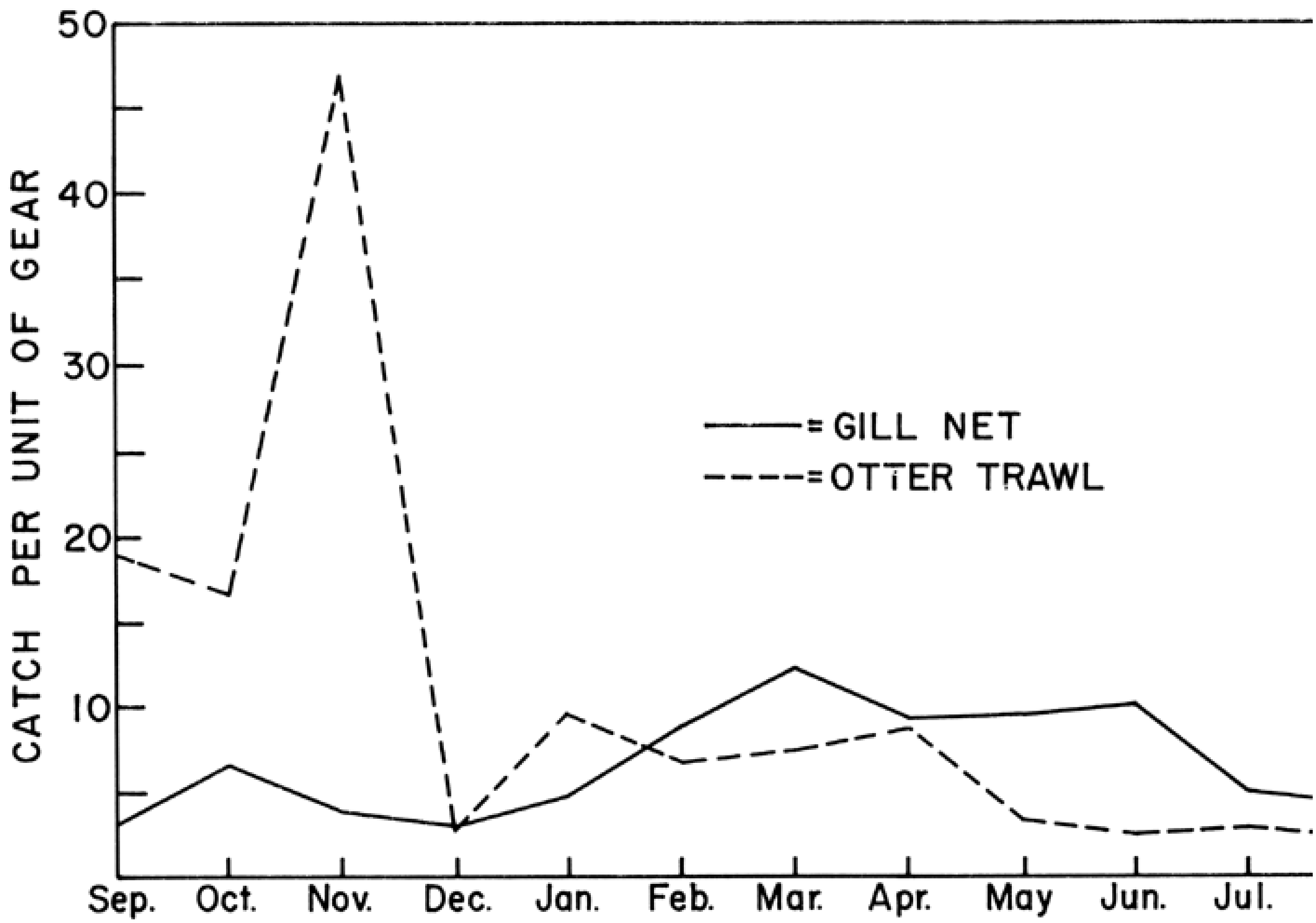

FIGURE 6. Mean monthly catch of juvenile and adult white catfish taken with otter t and gill net.

FIGURE 6. Mean monthly catch of juvenile and adult white catfish taken with otter trawl and gill net

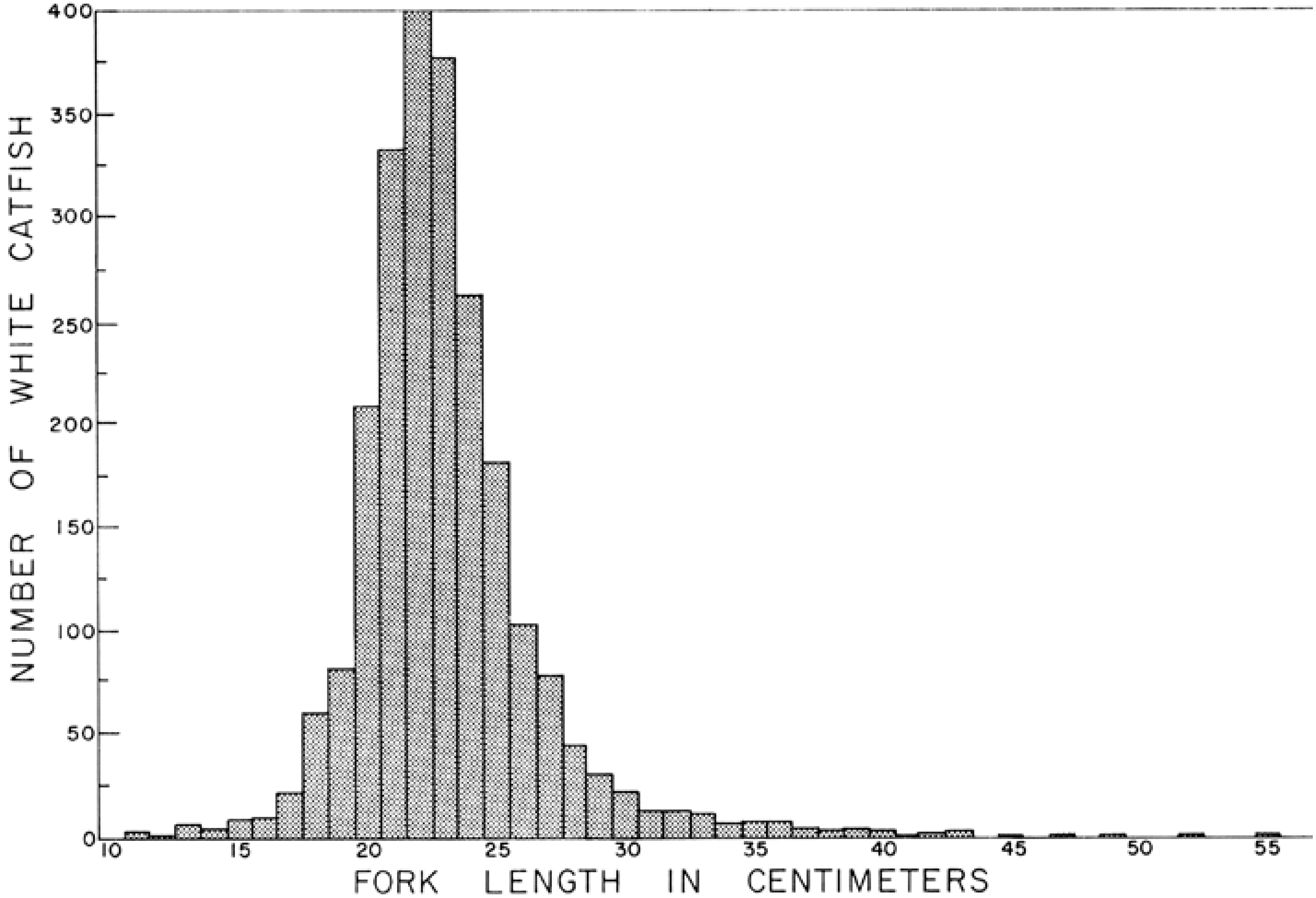

FIGURE 7. Length frequency of all white catfish taken with gill nets.

FIGURE 7. Length frequency of all white catfish taken with gill nets

Food Habits

Our analysis of the stomachs of 3,467 juvenile and adult white catfish shows their food habits to be much more diversified than those of the young white catfish, but the same two invertebrates most common in the diet of the young (Corophium and Neomysis awatschensis)

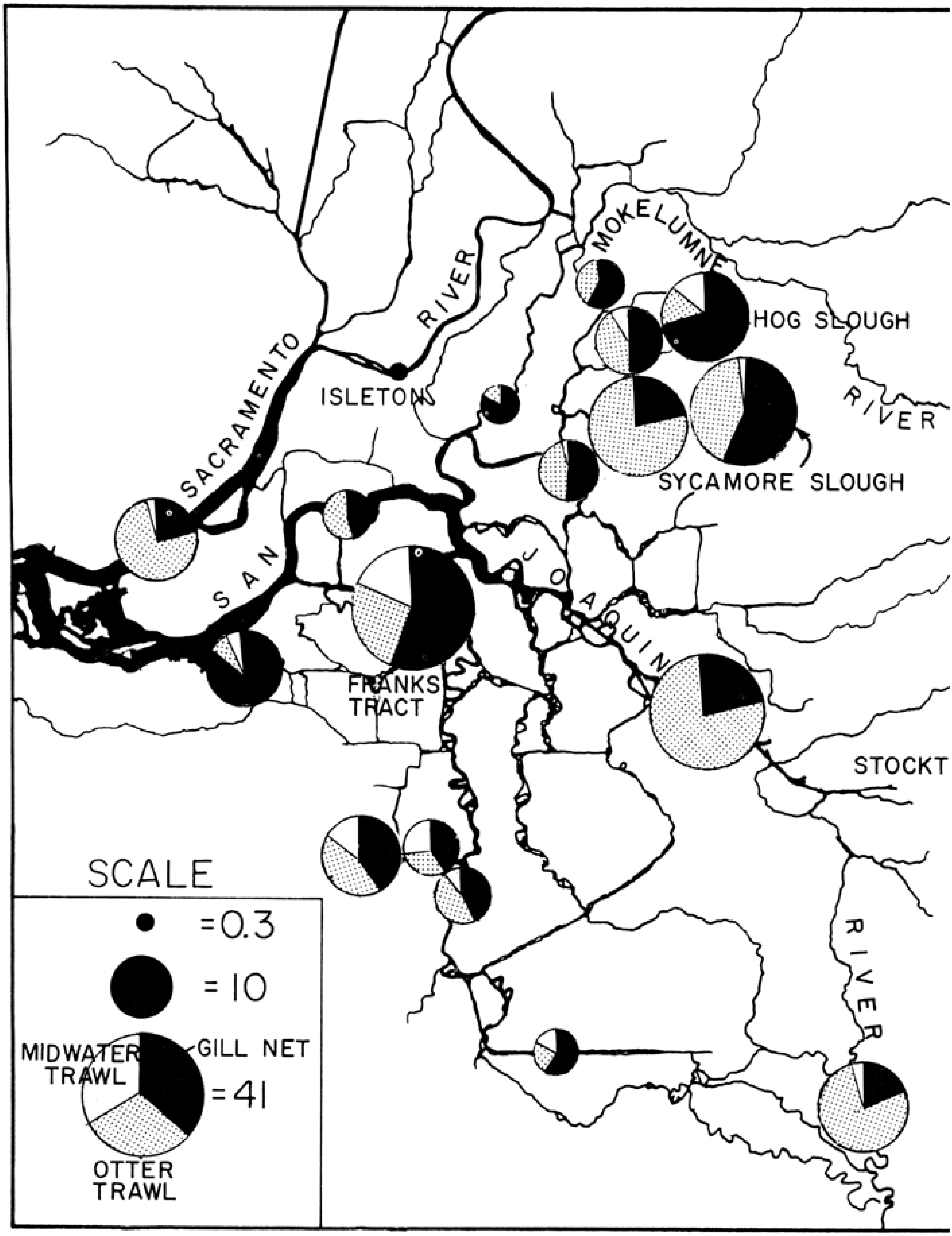

FIGURE 8. Distribution of juvenile and adult white catfish. The area of each circl proportional to the sum of the mean catch of fish taken by otter trawl, midwater tı

and gill net.

FIGURE 8. Distribution of juvenile and adult white catfish. The area of each circle is proportional to the sum of the mean catch of fish taken by otter trawl, midwater trawl, and gill net

were the most common food of the older fish [(Table 6)]. Corophium were found in more than 80 percent of all stomachs during all seasons and comprised 17.3 percent of the volume of food taken. N. awatschensis were found in 21 to 44 percent of the stomachs depending on the season. They were the only food items that appeared in more than 10 percent of the stomachs examined.

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TABLE 5

Sexual Maturity of Female White Catfish [1]

Month	Stage of Maturity				Sam[ple] Siz[e]
	Immature	Developing	Ripe	Spent	
September	85	15	--	--	39
October	42	58	--	--	59
November	4	96	--	--	27
December	--	100	--	--	51
January	--	100	--	--	55
February	--	100	--	--	86
March	--	100	--	--	124
April	--	100	--	--	98
May	--	100	--	--	51
June	1	84	5	10	62
July	2	28	--	70	40
August	18	--	4	78	50

[1] Figures describe percent of the total Delta sample in each stage of gonad development.

TABLE 5

Sexual Maturity of Female White Catfish

TABLE 6

Stomach Contents of Juvenile and Adult White Catfish

Food Item	Percent Frequency of Occurrence					P V
	Fall	Winter	Spring	Summer	Average	S
Bryozoans						
Pectinatella	4.2	0.2	--	0.3	1.1	
Annelids						
Earthworm (*Lumbricus terrestris*)	--	0.3	--	--	0.1	
Polychaetes	--	--	--	0.5	0.1	
Unidentified leech	--	1.0	0.1	0.5	0.4	
Unidentified Annelids	--	0.3	--	--	0.1	
Crustaceans						
Copepoda	--	--	--	0.3	--	
Mysid shrimp (*Neomysis awatschensis*)	21.3	43.8	30.8	33.2	32.3	
Isopod (*Exosphaeroma oregonensis*)	0.9	1.0	1.2	1.3	1.1	
Amphipod (*Corophium*)	82.3	85.4	94.5	84.0	87.6	
Amphipod (*Gammarus*)	--	--	0.1	--	--	
Crayfish (*Pacifastacus leniusculus*)	2.7	1.5	0.7	2.1	1.6	
Crab (*Rhithropanopeus*)	0.5	--	--	--	0.1	
Unidentified shrimp	--	0.2	--	0.3	0.1	
Insects						
Tendipedids	5.6	8.0	6.3	7.3	6.7	
Other Insects	2.0	1.6	1.0	2.1	1.6	
Molluscs						
Asiatic clam (*Corbicula fluminea*)	3.4	3.8	4.4	8.4	4.7	
Unidentified slugs	0.4	--	--	--	0.1	
Unidentified snails	0.5	0.2	0.1	--	0.2	
Vertebrates						
Sardine bait	0.5	2.6	1.0	--	1.1	
Fishes	2.3	3.8	2.0	5.8	3.1	
Fish eggs	--	--	0.4	0.3	0.2	
Unidentified lizard	--	0.2	--	--	--	
Bird remains	--	0.3	0.1	0.3	0.2	
Mammal remains	0.2	0.5	0.5	--	0.3	
Miscellaneous						
Seeds and berries	1.6	0.2	--	1.6	0.7	
Bone	--	--	0.2	--	0.1	
Paper	0.2	--	--	--	--	
Peat (Percent of total stomachs examined)	13.5	10.7	11.6	8.5	11.4	
Stomachs examined	936	826	1,060	645	3,467	
Stomachs containing food	554	610	815	382	2,361	

TABLE 6

Stomach Contents of Juvenile and Adult White Catfish

Fishes did not occur in more than 5.8 percent of the stomachs during any season and appeared in only 3.1 percent of all the stomachs we examined. However, 41 percent of the total volume of the stomach contents were fish. Most of the fishes were consumed by white catfish larger than 20 cm. They included Dorosoma petenense, Alosa sapidissima, Roccus saxatilis, Hypomesus olidus, Lampetra ayresi, Clupea pallasi, and Lepomis macrochirus.

Crayfish occurred in relatively few stomachs but formed a large portion of the diet bulk. often, only chelipeds or walking legs were found in the stomachs.

During the fall, white catfish in dead-end sloughs ate the bryozoan, Pectinatella sp. Sometimes only the statoblasts were present in stomachs. Pectinatella was not eaten in other environments.

Other items consumed include the clam, Corbicula fluminea; sardine bait; the crab, Rithropanopeus sp.; aquatic snails; terrestrial slugs; insects; seeds and berries; and annelids including leeches and the earthworm, Lumbricus terrestris. Some of the larger catfish had eaten small mammals and birds. One stomach contained a pair of coot, Fulica americana, feet. Another catfish consumed an unidentified lizard. Approximately 3 cc of sturgeon (Acipenser sp.) roe was in the stomach of a catfish taken during April in the lower San Joaquin River. Quantities of peat and other vegetable matter were often in stomachs. It is not known if this material was ingested intentionally, or if it was eaten accidentally while the catfish were foraging on benthic items.

As with young white catfish, the diet of older white catfish varies throughout the Delta. Corophium, the most important food, was eaten frequently at every sampling station (Figure 9). Neomysis awatschensis was common in their diet in the western Delta throughout the year particularly at Sherman Island on the Sacramento River and at West Island on the San Joaquin River. It was never a common item in the diet of catfish taken at Mossdale on the San Joaquin River. Fishes were never a common item in the diet of older white catfish. They did appear most frequently in the stomachs of white catfish in dead-end sloughs and in the San Joaquin River below Stockton. They occurred least frequently in the diet of catfish in the Mokelumne River.

DISCUSSION

The four species of Ictalurids occupy somewhat different environments in the Delta. The channel catfish were found in swift water situations where few bullheads or white catfish were caught. The bullheads, both brown and black, were most common in dead-end sloughs. Their distribution in the Delta was very similar to the distribution of Centrarchids (see Turner, p. 145). White catfish were also common in dead-end sloughs as well as flooded islands and the San Joaquin River below Stockton. No bullheads or channel catfish were caught in flooded islands and very low numbers were taken in the San Joaquin River below Stockton.

Both channel catfish and bullheads appear to avoid the western Delta. Ganssle (1966) reported that he caught no channel catfish and only two bullheads in over 18 months of sampling in the estuary below the Delta. McCammon and LaFaunce (1961), following an extensive

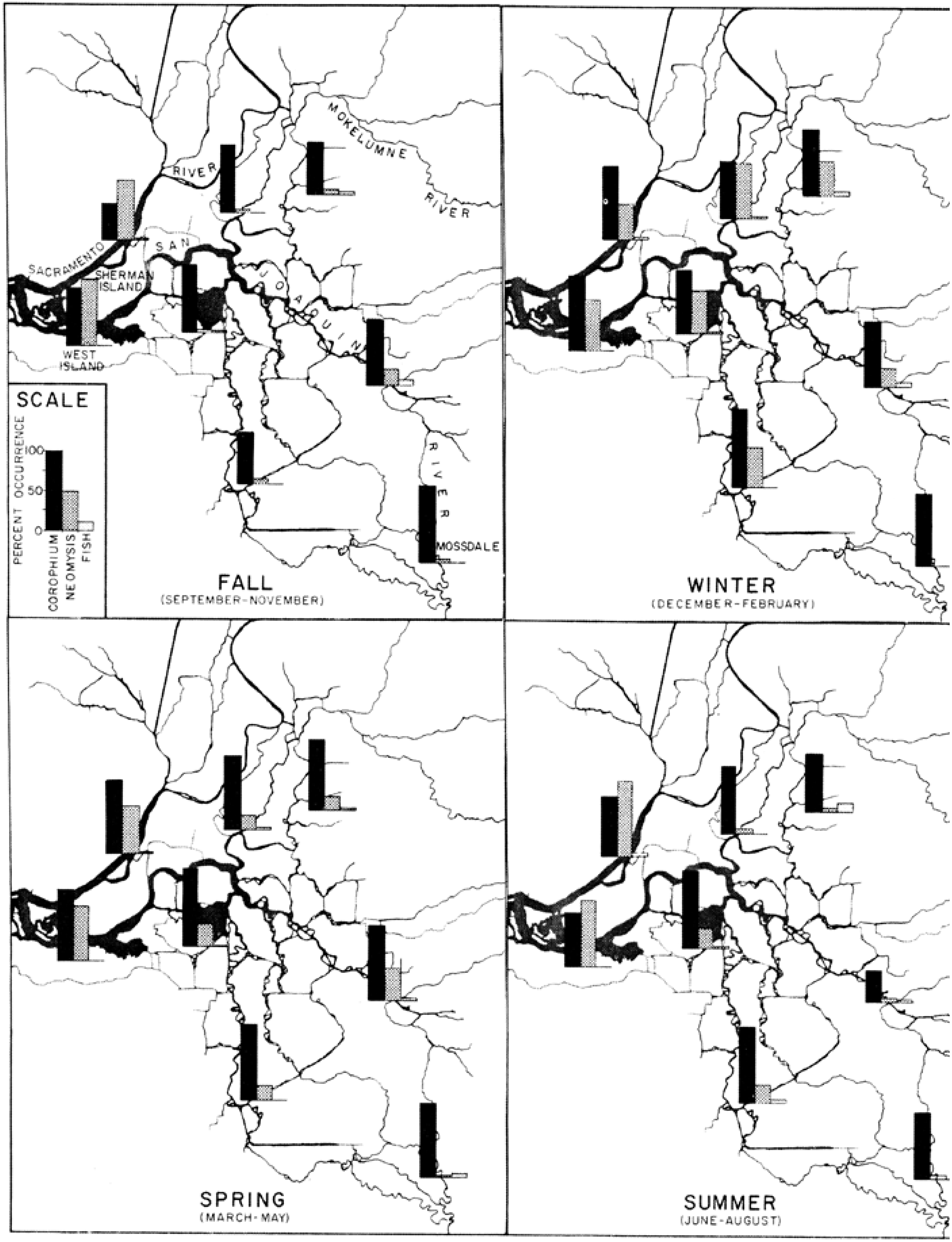

FIGURE 9. Comparison of the percent frequency of occurrence of major food items i stomachs of juvenile and adult white catfish at various sampling stations in the I

FIGURE 9. Comparison of the percent frequency of occurrence of major food items in the stomachs of juvenile and adult white catfish at various sampling stations in the Delta

tagging study in the Sacramento River, felt that channel catfish avoided the western Delta due to brackish water intrusion.

Most of the channel catfish taken were small and were caught near the edge of the Delta. These fish may have moved down from the rivers above the Delta. McCammon and LaFaunce (1961) reported that a sizable fishery for channel catfish exists in the Sacramento River some 50 miles above the Delta.

White catfish exhibit a much greater tolerance for brackish water than the other catfish. Ganssle (1966) reported limited catches of white catfish in the estuary downstream from our sampling area. In

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the eastern United States the white catfish are common in the coastal streams.

McCammon (1957) found that the growth rate of white catfish in the Delta was steady but very slow. This might be due to a limited or unavailable food supply, particularly of a suitable size for the larger catfish. Comparison of the total lengths of various age-groups of white catfish from the Santee-Cooper Reservoir in South Carolina (Stevens, 1959) with the fork lengths of various age groups in the Sacramento-San Joaquin Delta (McCammon, 1957) indicates that the growth rate for the first two years of life in both areas is similar but the older fish grow much faster in Santee-Cooper Reservoir. A 4-year old fish was 10.7 inches long in Santee-Cooper Reservoir compared to 8.5 inches in the Delta; a 9-year old fish was 18.5 inches long compared to 14 inches. Stevens also found that fish were consumed by 64.4 percent of *all* the white catfish taken in the Santee-Cooper Reservoir. We found fish in the stomachs of only 5.8 percent of the *older* white catfish taken in the Delta during the season when they fed most heavily on fish.

We found very little change in frequency of occurrence of certain food items in the diet with increased size of the white catfish; the same two invertebrates most frequent in the stomachs of young-of-the-year white catfish were also most frequent in the diet of the older fish. Ivlev (1961) reported that predatory fish prefer to devour victims of the largest possible size so that they obtain optimum growth for the energy expended. Prey of smaller sizes also serve as food but as the prey gets smaller and are thus further from the optimum size, they are pursued with less intensity. Nikolsky (1963) found that young pike feed on planktonic crustaceans but very soon the amount of energy expended on the capture of the crustaceans starts to exceed their caloric value, and the pike begins to feed on fish. If the pike is retained on planktonic crustaceans, it gradually ceases to grow.

Why the larger white catfish in the Delta do not feed more on fish is unknown. Perhaps forage fish are unavailable. The Delta is very turbid, with Secchi disk readings, varying from 5.1 to 35.4 inches during our study. Although catfish are not generally considered "sight feeders", the poor visibility in the Delta could affect their ability to capture fish, thereby restricting their diet to the more easily captured invertebrates. This could result in poorer growth.

LITERATURE CITED

Ganssle, David. 1966. Fishes and decapods of San Pablo and Suisun Bays, p. 64–94, *In* D. W. Kelley, (ed.), Ecological studies of the Sacramento-San Joaquin Estuary. Calif. Fish and Game, Fish Bull., (133) : 1–133. Ivlev, V. S. 1961. Experimental ecology of the feeding of fishes. Yale Univ. Press, New Haven, 302 p. McCammon, George W. 1957. Anglers "purr" as Delta catfish study pays off. Outdoor Calif., 18(3) : 12–14. McCammon, George W., and Don A. LaFaunce. 1961. Mortality rates and movement in the channel catfish population of the Sacramento Valley. Calif. Fish and Game, 47(1) : 5–26. Nikolsky, G. V. 1963. The ecology of fishes. Academic Press, Inc., New York, 352 p. Ryan, James H. 1959. California inland angling estimates for 1954, 1956, and 1957. Calif. Fish and Game, 45(2) : 93–109. Stevens, Robert E. 1959. The white and channel catfishes of the Santee-Cooper Reservoir and tail race sanctuary. Southeastern Assoc. Game and Fish Comm., Proc. 13th Ann. Conf. p. 203–219.

DISTRIBUTION AND FOOD HABITS OF CENTRARCHID FISHES IN THE SACRAMENTO-SAN JOAQUIN DELTA

JERRY L. TURNER

Members of the centrarchid or sunfish family taken in the Sacramento-San Joaquin Delta were black crappie, Pomoxis nigromaculatus, white crappie, Pomoxis annularis, bluegill, Lepomis macrochirus, warmouth, Chaenobryttus gulosus, largemouth bass, Micropterus salmoides, green sunfish, Lepomis cyanellus, and Sacramento perch, Archoplites interruptus. The only native representative is the Sacramento perch; all the others were introduced years ago.

The major concentrations of centrarchids were found in the quiet sloughs off the main channels. Black crappie, bluegill, and warmouth were the most abundant species caught. Only a few green sunfish and largemouth bass were taken. The Sacramento perch and white crappie were extremely rare. Most of these centrarchids were unusually small, a condition that could be a result of the turbid water in the Delta. Their food habits are similar to that reported by workers in other areas except that a mysid shrimp and amphipods are the major invertebrates eaten rather than aquatic insects.

DISTRIBUTION AND CATCH

Centrarchids were sampled with the otter and midwater trawls and gill nets but most were taken with the trawls [(Table 1)]. Very few centrarchids were collected with gill nets.

TABLE 1

Total Number of Black Crappie, Bluegill and Warmouth Taken With Gill Ne Otter Trawl and Midwater Trawl

Species	Gill Net	Otter Trawl	Midwater Trawl	Tota Numb
Black Crappie	428	4,860	3,096	8,384
Bluegill	87	2,700	288	3,075
Warmouth Bass	17	216	7	240

TABLE 1

Total Number of Black Crappie, Bluegill and Warmouth Taken With Gill Net, Otter Trawl and Midwater Trawl

The seasonal catch with all three sampling gears fluctuated considerably (Figure 1). Otter trawl catches were highest from September through January and midwater trawl catches were highest from February through June. The gill net catches were consistently low throughout the year.

The centrarchids collected in the Delta were unusually small (Figure 2). Only a third of the black crappie and very few warmouth and bluegill were over 20 cm (8 inches) *FL*.

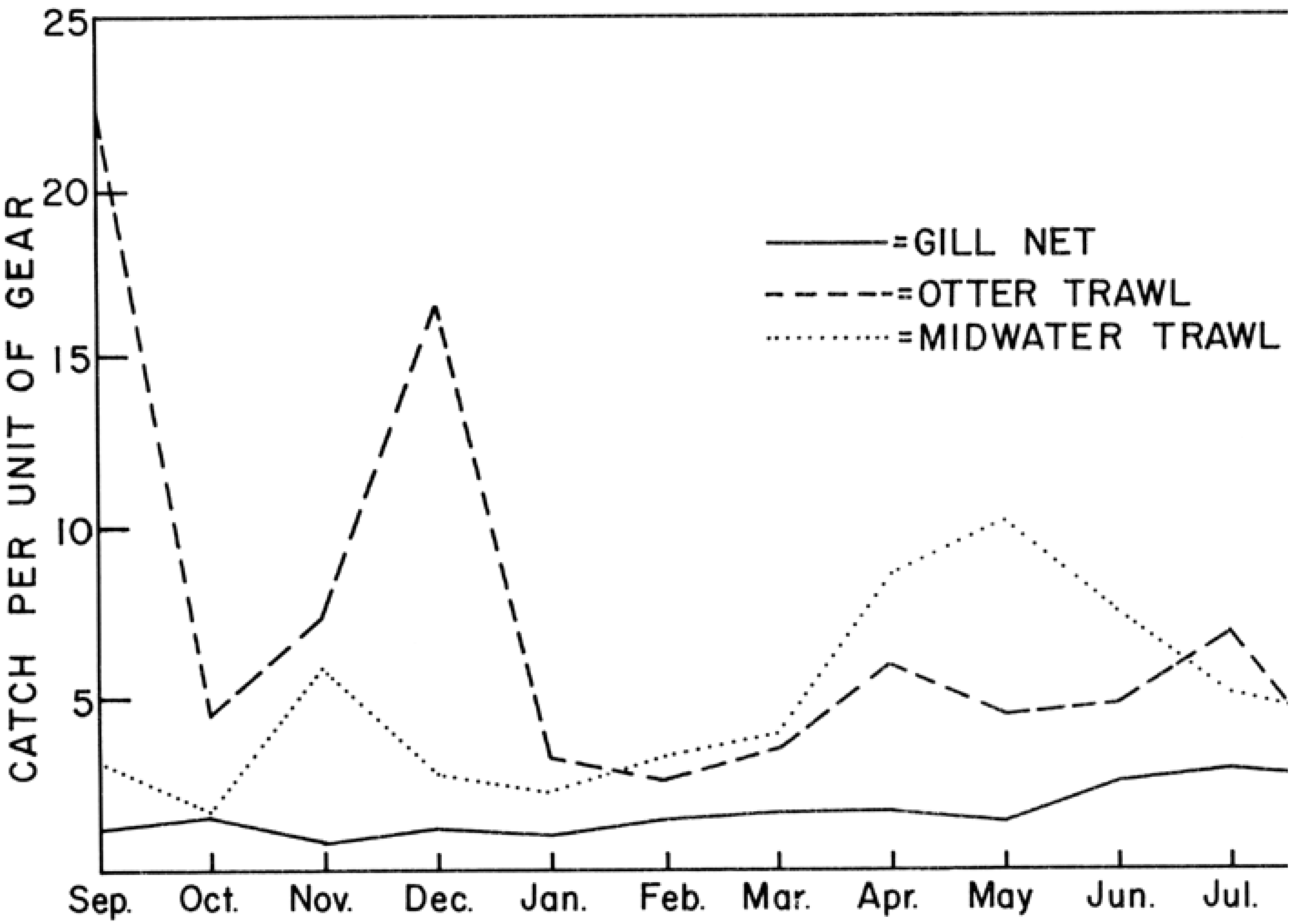

FIGURE 1. Average monthly catch of centrarchids taken with otter trawl, midwater t and gill net.

FIGURE 1. Average monthly catch of centrarchids taken with otter trawl, midwater trawl, and gill net

A total of 10,670 out of 11,699 black crappie, bluegill and warmouth bass caught in the Delta were taken in the dead-end Hog, Sycamore and Indian sloughs (Figure 3). Two-thirds of these were caught at the upper-most sampling station in these sloughs. Very few were taken from any other area in the Delta.

Largemouth bass were commonly caught by anglers in limited areas in the Delta but we caught only 34 in our sampling. One was taken with the otter trawl and one with the midwater trawl in 12 months of sampling. Thirty-two largemouth bass were taken with gill nets. Twenty-four of these were caught in Hog, Sycamore, and Indian slough (all dead-end sloughs).

Only 15 green sunfish were caught in the Delta of which 12 were taken in Hog, Sycamore, and Indian sloughs.

One white crappie and one Sacramento perch were taken during our sampling. The white crappie was caught in April at Mossdale on the San Joaquin River and the Sacramento perch was caught in May in Sycamore Slough. The Sacramento perch, the only native centrarchid, was considered very numerous in the sloughs and slow moving channels of the Delta in the early days. Rutter (1907) reported that they were becoming rare.

FOOD HABITS

Food Habits of Black Crappie

The food habits of black crappie were described by examining the stomachs of 1,476 fish. So that diet could be related to fish size, each fish was classed as belonging to one of three size groups: "small" (5 to 10 cm), "medium" (11 to 20 cm) and "large" (> 21 cm).

The mysid shrimp, Neomysis awatschensis, and amphipods, Corophium, were the most common food items of all sizes of black crappie.

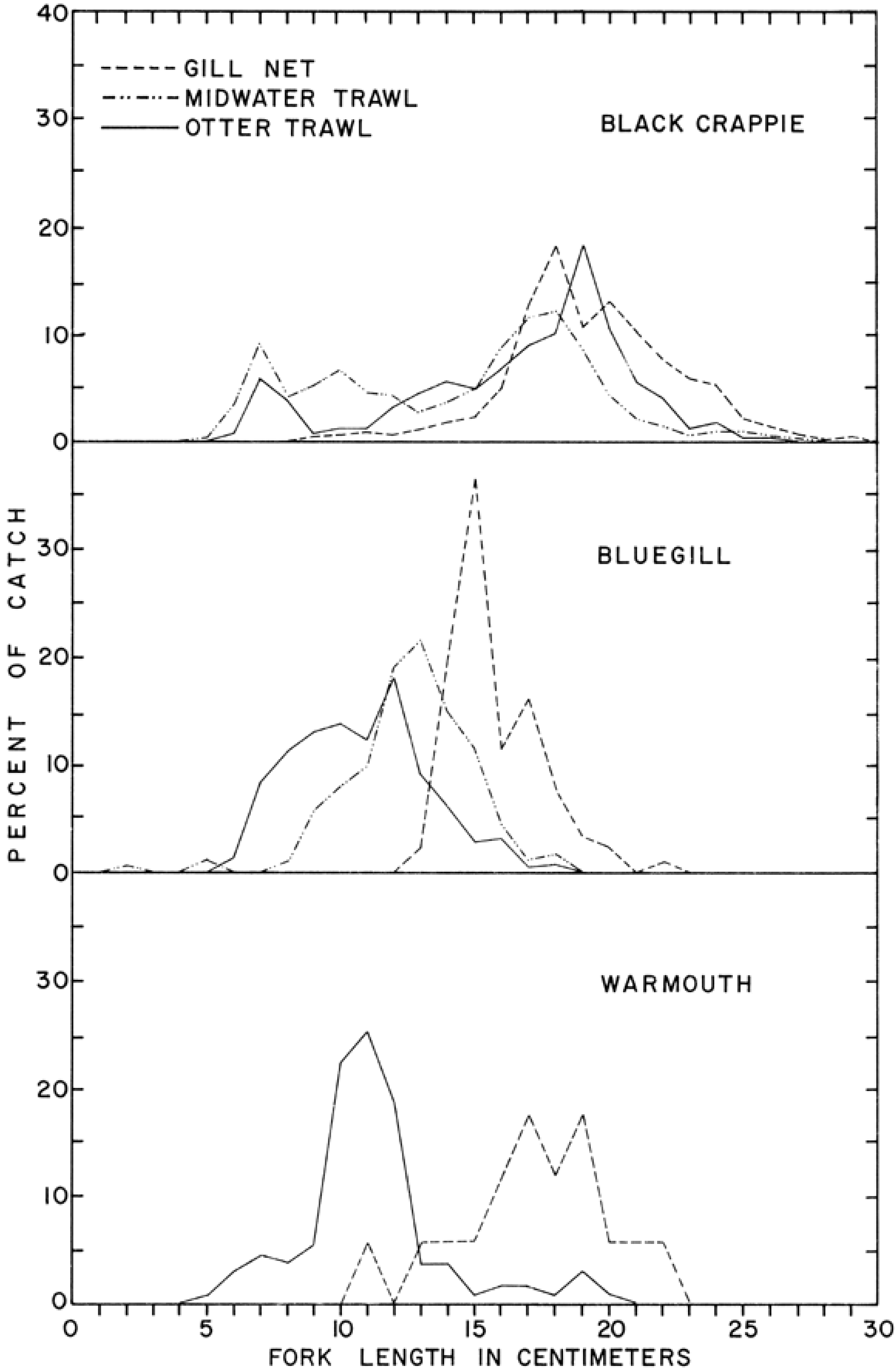

FIGURE 2. Length frequency of black crappie, bluegill, and warmouth taken with mid-

water trawl, otter trawl, and gill nets.

FIGURE 2. Length frequency of black crappie, bluegill, and warmouth taken with midwater trawl, otter trawl, and gill nets

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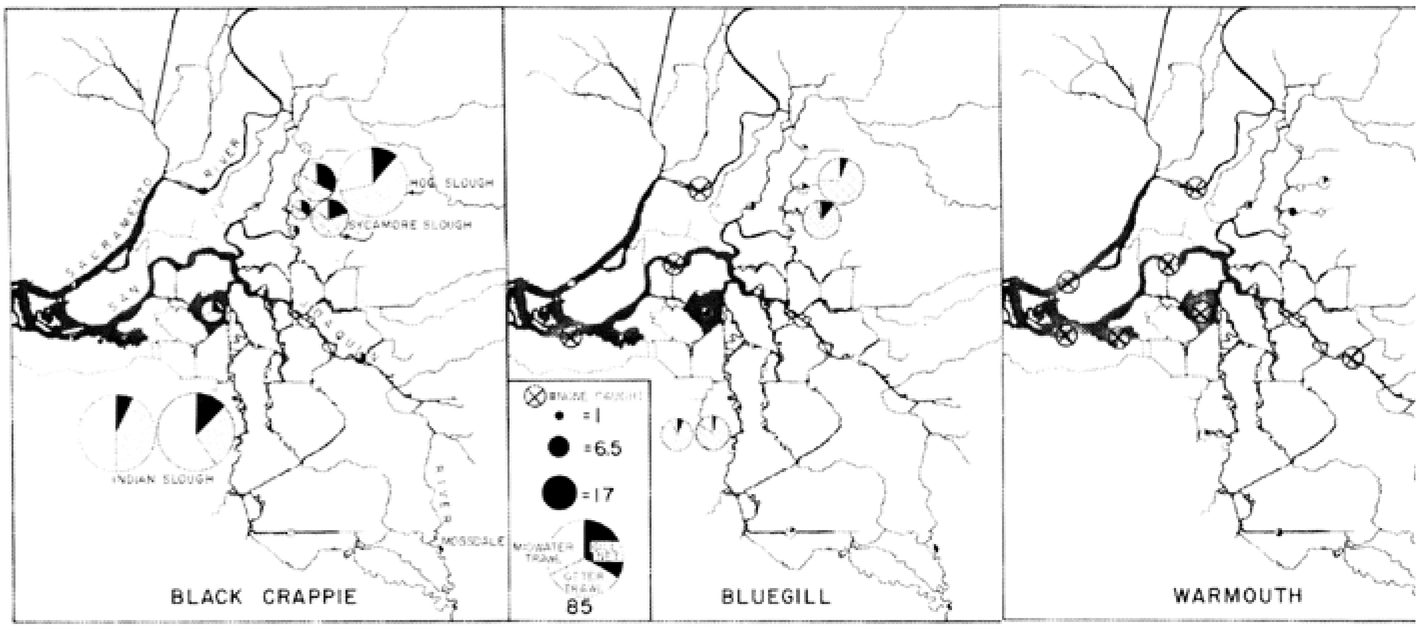

FIGURE 3. Distribution of black crappie, bluegill, and warmouth in the Sacrament Joaquin Delta. The area of each circle is proportional to the sum of the mean catch the otter trawl, midwater trawl, and gill net.

FIGURE 3. Distribution of black crappie, bluegill, and warmouth in the Sacramento-San Joaquin Delta. The area of each circle is proportional to the sum of the mean catches of the otter trawl, midwater trawl, and gill net

N. awatschensis was present in the stomachs of most crappie of all sizes. They made up 44, 24, and 7 percent of the volume of food of the "small", "medium", and "large" crappie (Tables [2], [3], [4]). Corophium occurred in at least 50 percent of the stomachs of all sizes of black crappie and formed 16, 10, and 4 percent of the volume of food.

TABLE 2

Stomach Contents of 5 to 10 cm Black Crappie

Food item	Percent frequency of occurrence					Pe of vc
	Fall	Winter	Spring	Summer	Average	
Crustaceans						
Copepod and Cladocera	--	--	39.1	16.7	28.0	2
Mysid shrimp (*Neomysis awatschensis*)	100.0	100.0	78.3	38.9	72.0	4
Amphipod (*Corophium*)	100.0	40.0	60.9	27.8	50.7	1
Insects						
Tendipedids	--	10.0	17.4	44.4	22.7	
Unidentified insects	--	--	--	5.6	1.3	
Fishes						
Unidentified fishes	--	--	2.2	--	1.3	
Stomachs examined	1	10	47	18	76	
Stomachs containing food	1	10	46	18	75	

TABLE 2

Stomach Contents of 5 to 10 cm Black Crappie

Cladocerans and copepods occurred in 28 percent of the stomachs of small crappie and comprised 28 percent of their volume of food. Tendipedid larvae and pupae were also of some importance to the small crappie.

The isopod, Exosphaeroma oregonensis; the crayfish, Pacifastacus leniusculus; the amphipod, Gammarus; and adult insects were consumed but were of minor value to the crappie.

Forage fish became important as crappie increased in size. They occurred in 1, 17, and 33 percent of the stomachs, and formed 1, 60, and 88 percent of the volume of food for the small, medium, and large black crappie. Threadfin shad, Dorosoma petenense, and young-of-the-year

TABLE 3

Stomach Contents of 11 to 20 cm Black Crappie

Food item	Percent frequency of occurrence					Pe of vo
	Fall	Winter	Spring	Summer	Average	
Bryozoans						
Pectinatella sp.	2.6	--	--	--	0.2	
Annelids						
Unidentified leech	--	0.7	--	0.5	0.3	
Crustaceans						
Copepoda and Cladocera	1.3	0.7	14.0	2.8	5.8	
Mysid shrimp (*Neomysis awatschensis*)	51.9	91.0	87.1	72.1	78.0	[illegible]
Isopod (*Exosphaeroma oregonensis*)	--	2.1	2.2	2.5	2.1	
Amphipod (*Corophium*)	44.2	47.9	75.9	69.6	65.9	
Amphipod (*Gammarus*)	--	--	0.4	0.8	0.4	
Crayfish (*Pacifastacus leniusculus*)	1.3	--	0.7	--	0.3	
Insects						
Tendipedids	1.3	6.9	16.9	--	6.5	
Other insects	--	1.4	3.2	3.8	2.9	
Fishes						
Threadfin shad (*Dorosoma petenense*)	7.8	2.1	--	7.0	4.1	[illegible]
American shad (*Alosa sapidissima*)	--	--	--	1.5	0.7	
Unidentified Clupeids	--	0.7	--	0.5	0.3	
King salmon (*Oncorhynchus tshawytscha*)	--	--	0.4	--	0.1	
Pond smelt (*Hypomesus transpacificus*)	--	--	--	0.5	0.2	
White catfish (*Ictalurus catus*)	--	--	--	1.3	0.6	
Striped bass (*Roccus saxatilis*)	--	0.7	0.4	10.6	4.9	[illegible]
Unidentified fishes	19.5	2.8	1.1	5.8	6.1	[illegible]
Stomachs examined	100	147	283	425	955	
Stomachs containing food	77	118	278	398	871	

TABLE 3

Stomach Contents of 11 to 20 cm Black Crappie

TABLE 4

Stomach Contents of Black Crappie Longer Than 20 cm

Food item	Percent frequency of occurrence					Pe of vo
	Fall	Winter	Spring	Summer	Average	
Annelids						
Unidentified leech	--	1.1	0.8	--	0.5	
Crustaceans						
Copepoda and Cladocera	--	1.1	0.8	--	0.5	
Mysid shrimp (*Neomysis awatschensis*)	26.0	80.0	72.8	61.4	64.8	
Isopod (*Exosphaeroma oregonensis*)	2.0	--	0.8	2.1	1.2	
Amphipod (*Corophium*)	50.0	46.2	69.6	73.6	63.3	
Amphipod (*Gammarus*)	--	--	0.8	--	0.2	
Crayfish (*Pacifastacus leniusculus*)	2.0	--	0.8	0.7	0.7	
Insects						
Tendipedids	4.0	5.5	9.6	15.7	10.1	
Other insects	4.0	1.1	2.4	1.4	2.0	
Fishes						
Threadfin shad (*Dorosoma petenense*)	12.0	22.0	7.2	5.7	10.6	5
American shad (*Alosa sapidissima*)	--	--	0.8	0.7	0.5	
Unidentified Clupeids	8.0	--	--	1.4	1.5	
King salmon (*Oncorhynchus tshawytscha*)	--	--	2.4	--	0.7	
Pond smelt (*Hypomesus transpacificus*)	2.0	--	--	--	0.2	
Goldfish (*Carassius auratus*)	--	1.1	--	--	0.2	
Striped bass (*Roccus saxatilis*)	14.0	--	--	27.1	11.1	2
Bluegill (*Lepomis macrochirus*)	2.0	--	--	--	0.2	
Unidentified fishes	14.0	3.3	7.2	8.6	7.6	
Stomachs examined	65	93	132	155	445	
Stomachs containing food	50	91	124	140	405	

TABLE 4

Stomach Contents of Black Crappie Longer Than 20 cm

striped bass, Roccus saxatilis, were the major fish eaten. Small numbers of king salmon, Oncorhynchus tshawytscha; pond smelt, Hypomesus transpacificus; American shad, Alosa sapidissima; goldfish, Carassius auratus; bluegill, Lepomis macrochirus; and white catfish, Ictalurus catus were also consumed.

Small crappie feed principally on small invertebrates and change to a fish diet as they grow larger (Figure 4). Sasaki (see p. 48) and Turner (see p. 160) have shown that young striped bass and threadfin shad, the most important prey species, are at peak abundance during the summer and fall. Predation on forage fishes was also most intense during these seasons. Many large crappie that fed on forage fishes had not eaten invertebrates. Selection for forage fishes rather than a decrease in numbers of invertebrates in the environment is probably the reason for the decline in consumption of invertebrates during the fall.

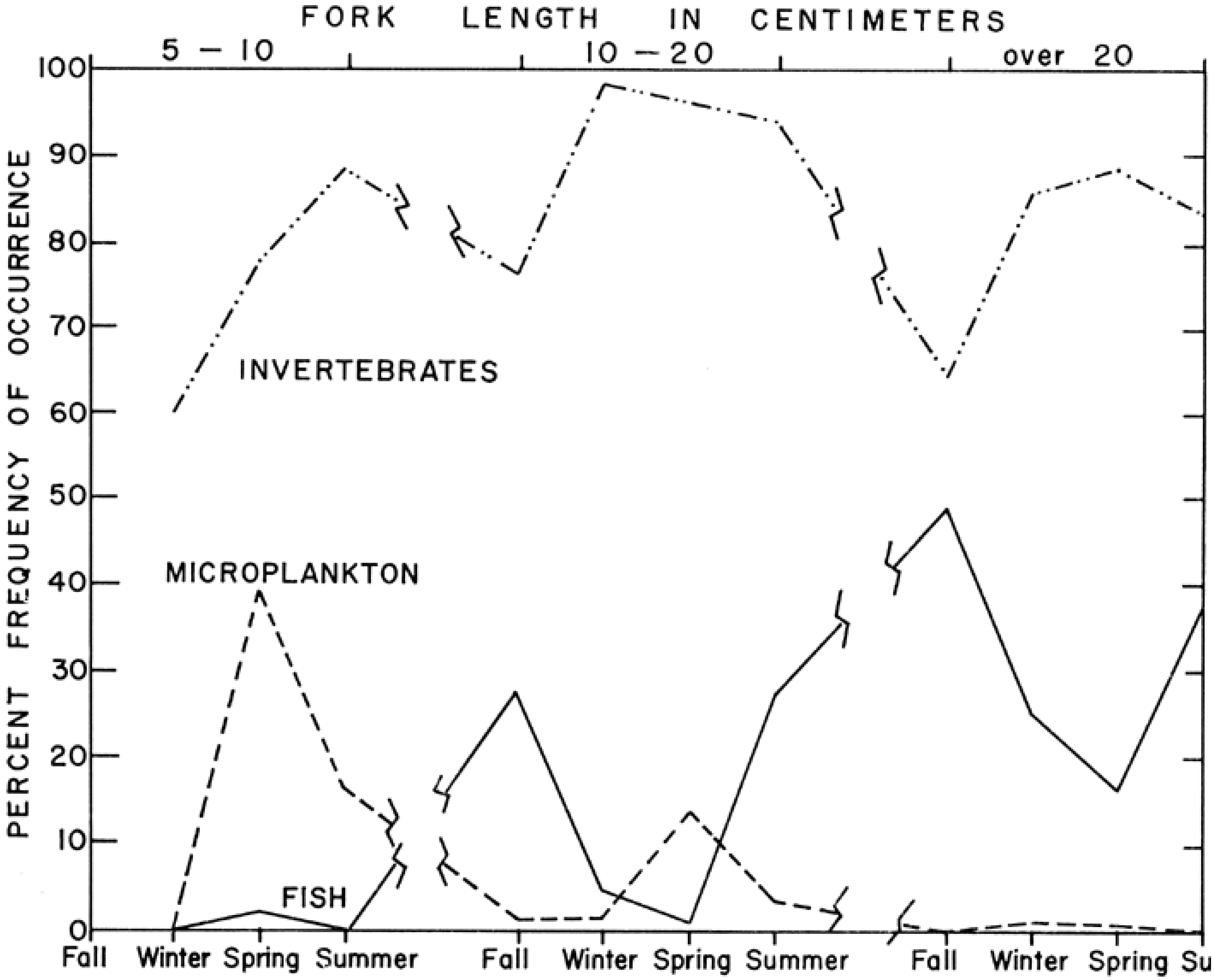

FIGURE 4. Percent frequency of occurrence of food items in the diet of black c
from fall, 1963 through summer, 1964.

FIGURE 4. Percent frequency of occurrence of food items in the diet of black crappie from fall, 1963 through summer, 1964

Food Habits of Warmouth

Our analysis of the stomach contents of 105 warmouth indicates that Corophium and Neomysis awatschensis were the most common food [(Table 5)]. Crayfish, bluegill, white catfish and unidentifiable fish formed a large part of the diet volume, but only occurred in a relatively small percent of the stomachs. The isopod, Exosphaeroma oregonensis, and the clam, Corbicula fluminea, were also found. Only the larger (over 14 cm) warmouth had eaten crayfish.

TABLE 5

Stomach Contents of Warmouth

Food item	Percent frequency of occurrence					P of v
	Fall	Winter	Spring	Summer	Average	
Crustaceans						
Mysid shrimp (*Neomysis awatschensis*)	--	72.7	59.5	29.7	46.1	
Isopod (*Exosphaeroma oregonensis*)	--	9.1	2.7	8.1	5.6	
Amphipod (*Corophium*)	--	18.2	89.2	67.6	67.4	
Crayfish (*Pacifastacus leniusculus*)	100.0	18.2	8.1	18.9	18.0	
Molluscs						
Asiatic clam (*Corbicula fluminea*)	--	--	--	2.7	1.1	
Fishes						
White catfish (*Ictalurus catus*)	--	--	--	10.8	4.5	
Bluegill (*Lepomis macrochirus*)	25.0	--	--	--	1.1	
Unidentified fishes	--	9.1	--	--	1.1	
Miscellaneous						
Peat (percent of total stomachs)	--	--	--	10.6	4.8	
Stomachs examined	5	12	41	47	105	
Stomachs containing food	4	11	37	37	89	

TABLE 5

Stomach Contents of Warmouth

Food Habits of Bluegill

The stomach contents of 436 bluegill were examined. the amphipod, Corophium, was the major food item. It was found in 87 percent of the stomachs and it comprised 31 percent of the volume of food [(Table 6)]. Tendipedid larvae and pupae were found in 45 percent of the stomachs but they provided only 7 percent of the volume of the stomach

TABLE 6

Stomach Contents of Bluegill

Food item	Percent frequency of occurrence					P o v
	Fall	Winter	Spring	Summer	Average	
Annelids						
Earthworm (*Lumbricus terrestris*)	--	1.1	--	--	0.3	
Polychaeta	5.6	1.1	0.7	0.8	1.0	
Unidentified Annelids	--	--	--	0.8	0.3	
Crustaceans						
Copepoda	--	--	0.7	--	0.3	
Mysid shrimp (*Neomysis awatschensis*)	--	8.6	--	1.6	2.6	
Isopod (*Exosphaeroma oregonensis*)	--	5.4	7.4	9.7	7.3	
Amphipod (*Corophium*)	88.9	82.8	93.9	80.6	86.7	
Amphipod (*Gammarus*)	--	--	0.7	--	0.3	
Crayfish (*Pacifastacus leniusculus*)	--	--	0.7	--	0.3	
Insects						
Tendipedids	61.1	24.7	52.7	47.6	44.6	
Other insects	27.8	--	4.7	8.9	6.0	
Miscellaneous						
Terrestrial Arachnids	--	--	0.7	--	0.3	
Asiatic clam (*Corbicula fluminea*)	--	--	0.7	4.0	1.6	
Unidentified aquatic snail	--	1.1	--	--	0.3	
Unidentified fishes	--	1.1	--	0.8	0.5	
Seeds	5.6	--	--	0.8	0.5	
Stomachs examined	25	109	159	143	436	
Stomachs containing food	18	93	148	124	383	

TABLE 6

Stomach Contents of Bluegill

contents. The isopod, Exosphaeroma oregonensis, formed 40 percent of the diet bulk but occurred in only 7 percent of the stomachs examined.

Food Habits of Largemouth Bass

The food habits of largemouth bass were based on the examination of 55 stomachs. Five small bass (6–8 cm long) were collected in Sycamore Slough during April. Their stomachs contained from one to seven unidentified damsel fly nymphs. Two of these bass also had consumed an insect we could not recognize.

Largemouth bass, 16 to 49 cm long, preyed primarily on fish and crayfish [(Table 7)]. One bass ate a king salmon, Oncorhynchus tshawytscha, 6 cm *FL*; all other recognizable fishes in the bass stomachs were either centrarchids or threadfin shad, Dorosoma petenense. Crayfish, Pacifastacus leniusculus, were present in 9 of 27 stomachs. An American bullfrog, Rana catesbeiana, 22 cm *TL* was eaten by a bass 44 cm long collected in Hog Slough. Small quantities of Neomysis, Corophium, tendipedid larvae and pupae, and unidentified insect larvae were also consumed.

TABLE 7

Stomach Contents of 16 to 49 cm Largemouth Bass

Food Item	Percent Frequency of Occurrence	Percent of Total Vol
Crustaceans		
Mysid shrimp (*Neomysis awatschensis*)	3.7	—
Amphipod (*Corophium*)	3.7	—
Crayfish (*Pacifastacus leniusculus*)	33.3	15.5
Insects		
Tendipedids	3.7	—
Other insects	3.7	—
Amphibian		
Bullfrog (*Rana catesbeiana*)	3.7	51.4
Fishes		
Threadfin shad (*Dorosoma petenense*)	14.8	3.3
King salmon (*Oncorhynchus tshawytscha*)	3.7	0.4
Bluegill (*Lepomis macrochirus*)	18.5	19.4
Black crappie (*Pomoxis nigromaculatus*)	7.4	4.6
Unidentified fishes	18.5	5.3
Stomachs examined	50	—
Stomachs containing food	27	—

TABLE 7

Stomach Contents of 16 to 49 cm Largemouth Bass

DISCUSSION

The native habitat of most members of the centrarchid family is the quiet waters of lakes and backwaters of large rivers. We found the largest concentrations of centrarchids in the Delta in the quiet waters of dead-end sloughs off the main channels. Very few were taken in any other type of habitat.

The higher catches in the upper end of the sloughs may be due to more available food there. Turner (1966) found higher concentrations of zooplankton toward the upper end of Sycamore Slough.

Few fish were caught that were 20 cm (8 inches) or more in length. This is unusual as in most places centrarchids grow much larger. Murphy (1951) reported that the mean length of black crappie caught

by anglers over a 4-year period in Clear Lake, California, was 11.5 inches. Beland and Sasaki (1962) found the mean length of black crappie caught by anglers in San Vicente Reservoir, California, was 11.3 inches. Hall, Jenkins, and Finnell (1954) reported that crappie should reach 10 inches in their fourth year of life to provide adequate fishing for the angler. We did not age the crappie but very few were 10 inches in length in the Delta (1.3 percent of gill net catch).

Murphy (1951) reported that the mean length of bluegill caught by the angler in Clear Lake was 8.1 inches. Few bluegill were 20 cm (8 inches) or longer with the largest being only 22 cm.

One factor that may affect the growth of centrarchids in the Delta is turbidity. Secchi disk readings in the Delta ranged from 13 to 90 cm (5.1 to 35.4 inches) and averaging 43 cm (17 inches). Hall, Jenkins, and Finnell (1954) found from a study of numerous reservoirs in Oklahoma that the majority of poor-growing crappie populations (both black and white crappie) were found in turbid waters. Information on actual measured turbidities was not available. Buck (1956) reported from further studies in Oklahoma reservoirs that te growth of both largemouth bass and bluegill was considerably less in bodies of water with high turbidities.

The results of our food habit studies of centrarchids in the Delta differ somewhat from that reported by workers in other areas. We found that an amphipod, Corophium, and mysid shrimp, Neomysis awatschensis, rather than aquatic insects, were the primary invertebrates in their diet. Larimore (1957) reported the dominant food of adult warmouth to be crayfish, fish, and aquatic insects. McCormick (1940), Ball (1948), and Seaburg and Moyle (1964) have indicated that invertebrates (particularly aquatic insects) form the greatest portion of the diet of bluegill. Reid (1950) found the chief food of young black crappie to be microplankton. Dendy (1946), Reid (1950), and Lux and Smith (1960) determined that the food of adult crappie consists largely of aquatic insects, crustaceans, and fishes. Dendy (1946), Schedermeyer and Lewis (1946), and McCammon, LaFaunce and Seeley (1964) indicated that small fishes and crayfish are common foods of largemouth bass.

LITERATURE CITED

Ball, R. C. 1948. Relationship between available fish food, feeding habits of fish and total fish production in a Michigan Lake. Mich. Univ. Agr. Exp. Sta., Tech. Bull., (206) : 1–59. Beland, Richard D., and Shoken Sasaki. 1962. San Vicente Reservoir, San Diego County, California, catch records 1959–60. Calif. Dept. Fish and Game, Inland Fish. Admin. Rept., (62–7) : 1–22. Buck, D. Homer. 1956. Effects of turbidity on fish and fishing. Okla. Fish. Res. Lab. Rept., (56) : 1–62. Dendy, Jack S. 1946. Food of several species of fish in Norris Reservoir, Tennessee. Reelfoot Lake Biol. Sta. Rept., *10* : 105–127. Hall, Gordon E., Robert M. Jenkins and Joe C. Finnell. 1954. The influence of environmental conditions upon the growth of white crappie and black crappie in Oklahoma waters. Okla. Fish. Res. Lab. Rept., (40) : 1–56. Larimore, R. Weldon. 1957. Ecological life history of the warmouth. Ill. Nat. Hist. Surv. Bull., *27*(1) : 1–83. Lux, Fred E., and Lloyd L. Smith, Jr. 1960. Some factors influencing seasonal changes in angler catch in the Minnesota Lake. Trans. Amer. Fish. Soc., *89*(1) : 67–79.

McCammon, George W., Don LaFaunce, and Charles M. Seeley. 1964. Observations on the food of fingerling largemouth bass in Clear Lake, Lake County, California. Calif. Fish and Game, *50*(3) : 158–169. McCormick, Elizabeth M. 1940. A study of the food of some Reelfoot Lake fishes. J. Tenn. Acad. Sci., *15* :64–75. Murphy, G. I. 1951. The fishery of Clear Lake, Lake County, California. Calif. Fish and Game, *37*(4) : 439–484. Reid, George K., Jr. 1950. Food of the black crappie, Pomoxis nigromaculatus (Le Sueur) in Orange Lake, Florida. Trans. Amer. Fish Soc., *79* : 145–154. Rutter, Cloudsley. 1907. The fishes of the Sacramento-San Joaquin basin, with a study of their distribution and variation. U. S. Bur. Fish. Bull., *27* : 103–152. Schedermeyer, Frank, and William M. Lewis. 1958. Utilization of gizzard shad by largemouth bass. Prog. Fish. Cult., *18*(3) : 137–138. Seaburg, Keith G., and John B. Moyle. 1964. Feeding habits, digestive rates, and growth of some Minnesota warmwater fishes. Trans. Amer. Fish. Soc., *93*(3) : 269–285. Turner, Jerry L. 1966. The seasonal distribution of crustacean plankters in the Sacramento-San Joaquin Delta, p. 95–104. *In* D. W. Kelley, (ed.), Ecological studies of the Sacramento-San Joaquin Estuary. Calif. Fish and Game, Fish Bull., (133) : 1–133.

DISTRIBUTION OF CYPRINID FISHES IN THE SACRAMENTO-SAN JOAQUIN DELTA

JERRY L. TURNER

Members of the cyprinid family in the Sacramento-San Joaquin Delta include the native Sacramento blackfish, Orthodon microlepidotus, Sacramento hitch, Lavinia exilicauda, splittail, Pogonichthys macrolepidotus, Sacramento squawfish, Ptychocheilus grandis, and the introduced carp, Cyprinus carpio, goldfish, Carassius auratus, and golden shiner, Notemigonus crysoleucas.

Carp were the most abundant of the cyprinids. Some evidence was found suggesting a migration of carp into the flooded islands of the Delta in early summer from the San Joaquin River above Stockton. No evidence was found of carp spawning in the Delta.

Highest densities of carp, Sacramento blackfish, Sacramento hitch and goldfish were in the San Joaquin River at Mossdale. The high concentrations of dissolved solids in this area may favor these members of the cyprinid family. Conversely, these same conditions may exclude the Sacramento squawfish which were never taken in that area of the San Joaquin River.

RESULTS

Cyprinids were taken with otter and midwater trawls and set gill nets. Greatest catches of the larger cyprinids, except for carp, were taken with gill nets [(Table 1)]. Most of the goldfish were taken with the otter trawl and most of the golden shiners with the midwater trawl. Only carp catches were large enough for an analysis of catch by different seasons. A total of 10,452 carp was taken with all three sampling gears.

TABLE 1

Total Number of Various Cyprinids Taken with Gill Net, Otter Trawl, and Midwater Trawl

Species	Gill Net	Otter Trawl	Midwater Trawl	Total Nu
Carp	3,396	5,616	1,440	10,452
Sacramento blackfish	236	22	136	394
Sacramento hitch	160	33	58	251
Splittail	244	184	108	536
Sacramento squawfish	124	11	7	142
Goldfish	14	320	86	420
Golden shiner	—	76	136	212

TABLE 1

Total Number of Various Cyprinids Taken with Gill Net, Otter Trawl, and Midwater Trawl

CARP

Distribution

Catches of carp were low when we began sampling in the fall of 1963; two exceptions were slightly higher catches made in Franks Tract and Big Break, both flooded islands (Figure 1). All catches

— 155 —

were low during the winter. In March and April the catches continued to be low at most stations but increased greatly at Mossdale on the San Joaquin River above Stockton. In May the catches at most stations still remained much the same but the catch at Mossdale was five times greater than at the next highest station.

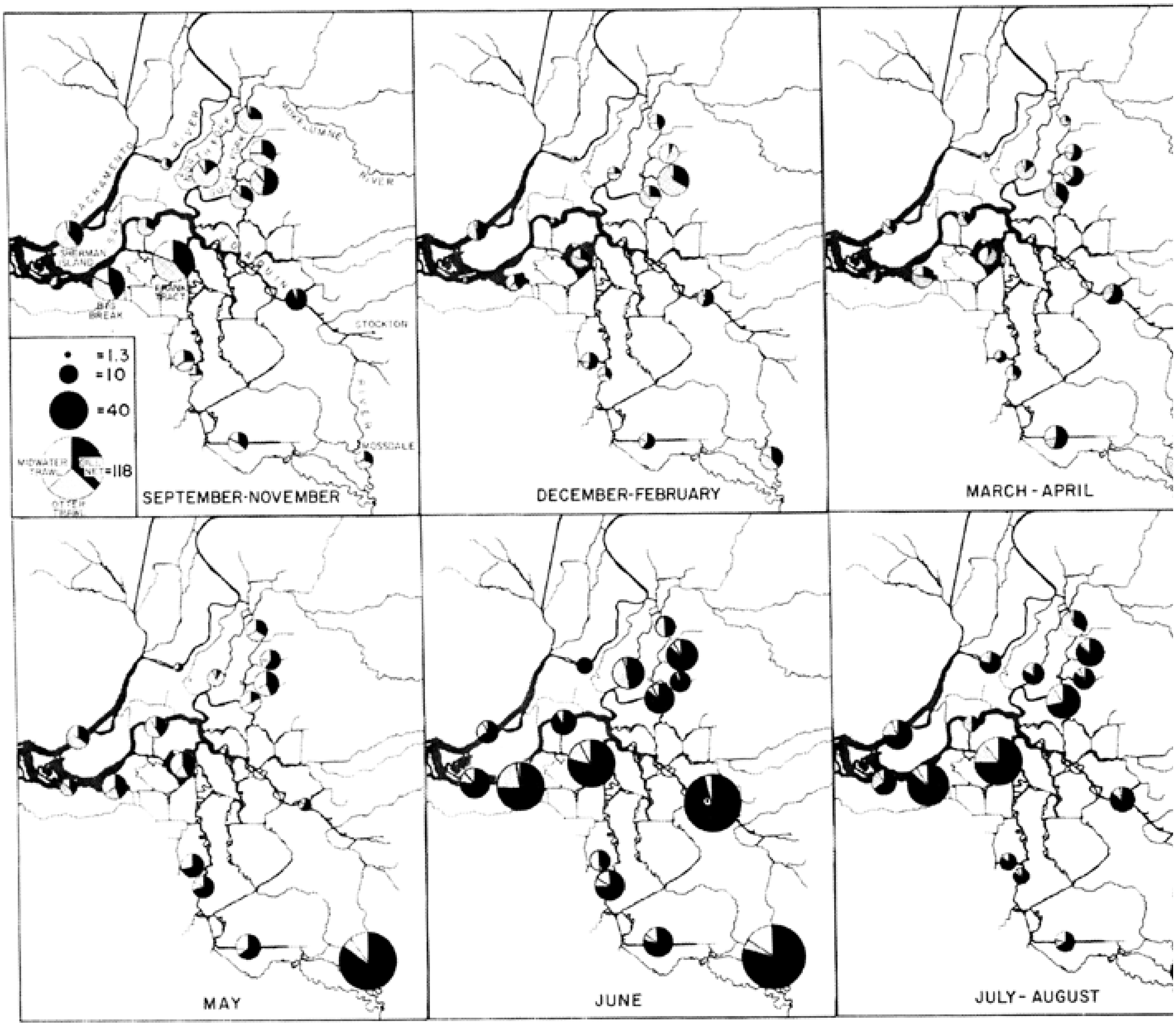

FIGURE 1. Distribution of carp in the Sacramento-San Joaquin Delta from September to August 1964. The area of each circle is proportional to the sum of the mean catcl the otter trawl, midwater trawl, and gill net.

FIGURE 1. Distribution of carp in the Sacramento-San Joaquin Delta from September 1963 to August 1964. The area of each circle is proportional to the sum of the mean catches of the other trawl, midwater trawl, and gill net

In June catches increased still further at Mossdale. They also greatly increased in the San Joaquin River below Stockton and in the two flooded islands but increased only modestly at all the other stations. During July and August the catches at these four stations declined.

Sexual Maturity

Our analysis of the gonad condition of female carp reveals no clear-cut spawning season. The first spent carp was examined on May 18; however, only about one-third of the fish examined in June, July, and August were spent [(Table 2)].

Length Frequency of Catch

A comparison of the monthly length frequency of catch of carp by both gill net and otter trawl shows almost no change in the size range of fish over the entire 12 months of sampling (Figure 2). There was almost no recruitment of smaller fish into the catch of either net during the year and no change in the average length of fish caught from month to month.

TABLE 2

Sexual Maturity of Female Carp. Figure Describes Percent of Total Sample in Each Stage of Gonad Development

Month	Stage of Maturity				Sample
	Immature	Maturing	Ripe	Spent	
April	0	100	—	—	49
May	4	89	—	7	45
June	2	52	17	29	161
July	12	50	7	31	232
August	18	28	19	35	246
September	1	99	—	—	76

TABLE 2

Sexual Maturity of Female Carp. Figure Describes Percent of Total Sample in Each Stage of Gonad Development

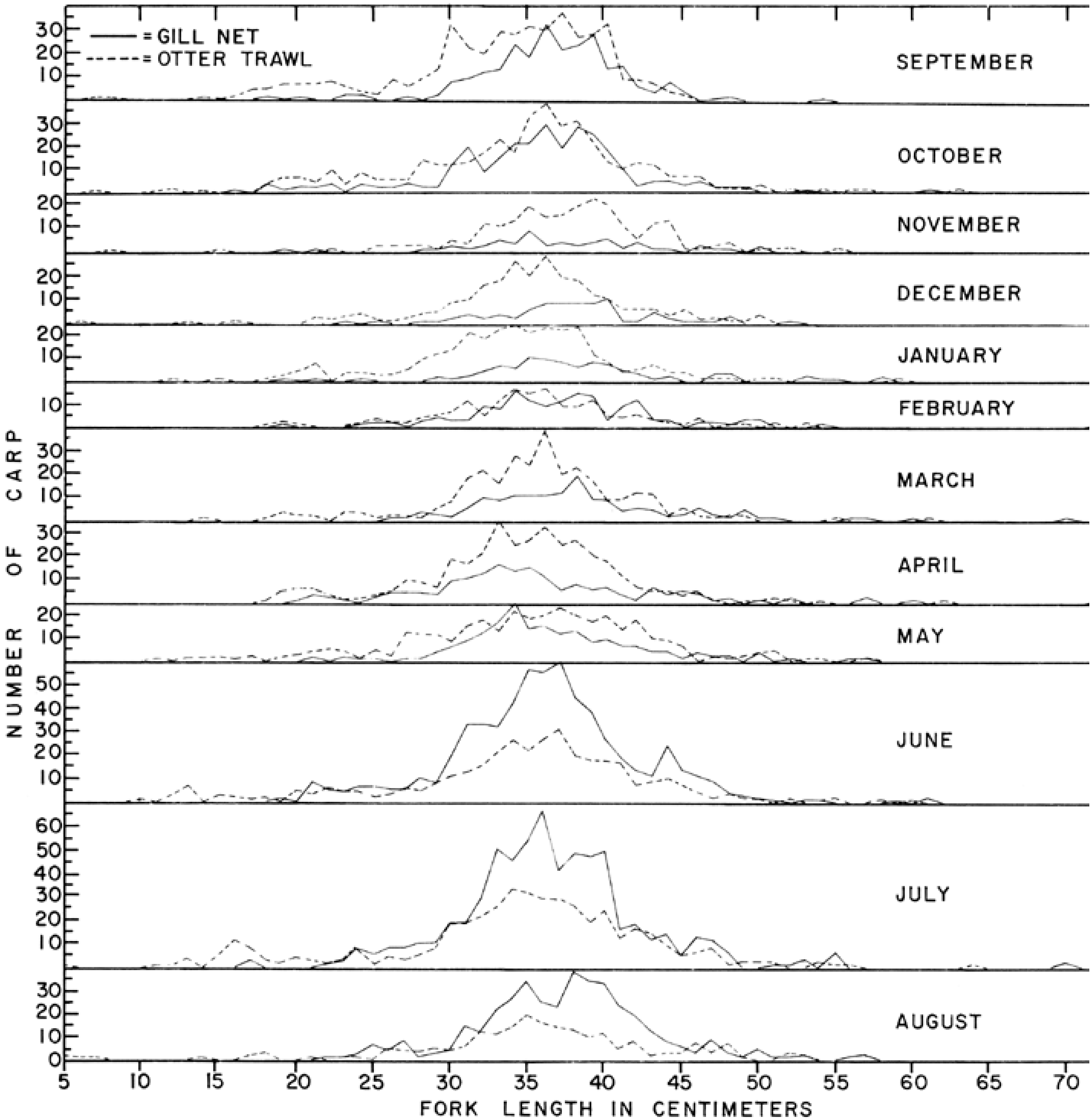

FIGURE 2. Length frequency of carp taken by otter trawl and gill net in the Sacram San Joaquin Delta.

FIGURE 2. Length frequency of carp taken by otter trawl and gill net in the Sacramento-San Joaquin Delta

Young-of-the-Year

Although adult carp were taken in greatest numbers in the San Joaquin River and flooded islands, there were no young-of-the-year carp taken in these areas with either midwater or otter trawls. Only 38 young-of-the-year carp were caught from September-December 1963

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and from June-August 1964. All these were taken at stations in the North or South Fork of the Mokelumne River or at Sherman Island on the Sacramento River; none in the San Joaquin River system. Carp were classified as young

-of-the-year if they were less than 15 cm before January 1. Other studies (Carlander, 1950) have reported that most young-of-the-year carp were less than 15 cm by January 1 after they were spawned.

SACRAMENTO BLACKFISH

Three hundred and ninety-four Sacramento blackfish were caught, of which 286 or 73 percent were taken in the San Joaquin River at Mossdale (Figure 3). A few were taken in the dead-end sloughs. Very few were caught in the western Delta. Blackfish in our catches ranged from 25 to 46 cm FL with an average length of 36.7 cm. One ripe fish was examined at Mossdale in July.

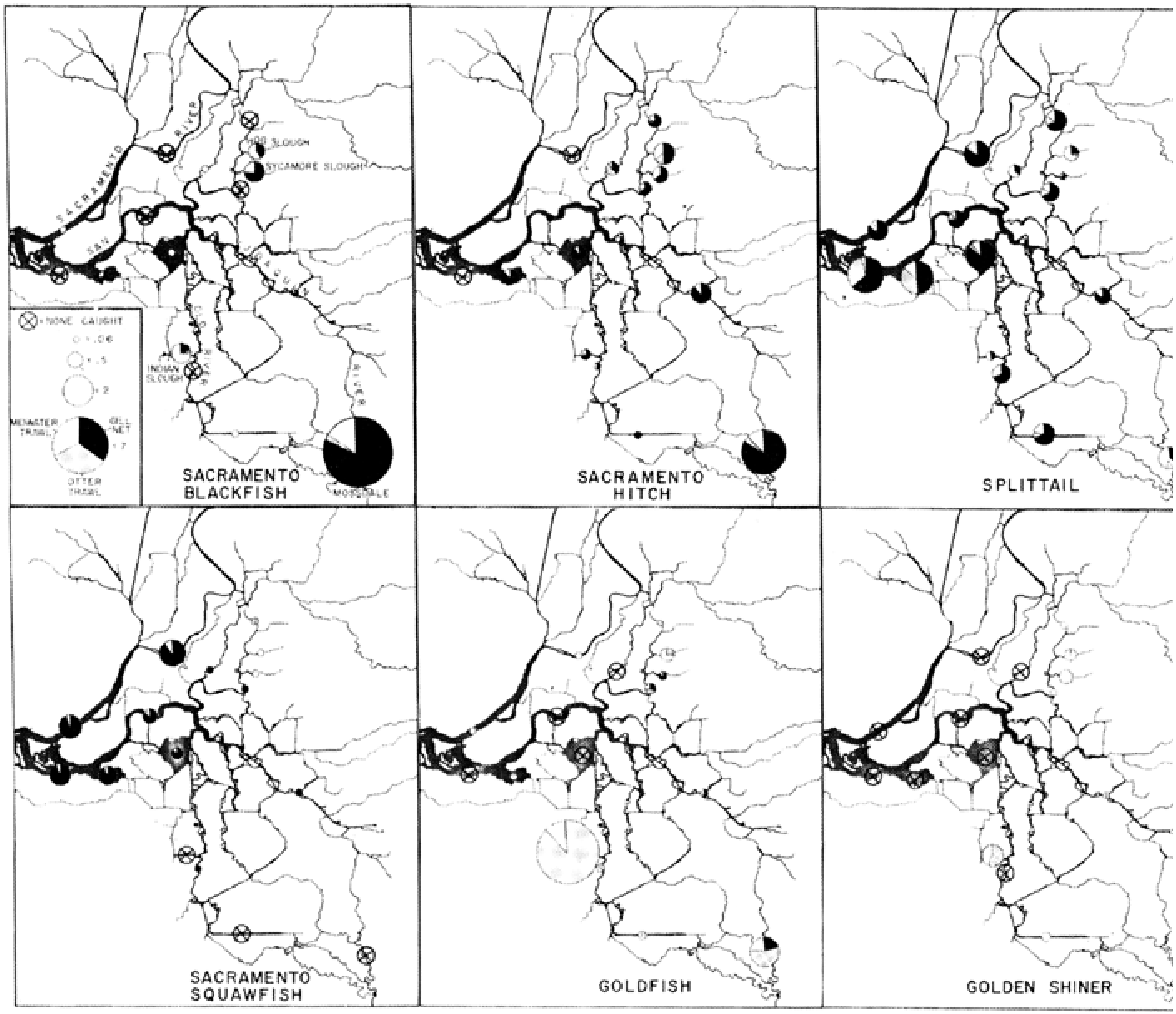

FIGURE 3. Distribution of various cyprinids in the Sacramento-San Joaquin Delta September 1963 to August 1964. The area of each circle is proportional to the sum mean catches of the otter trawl, midwater trawl, and gill net.

FIGURE 3. Distribution of various cyprinids in the Sacramento-San Joaquin Delta from September 1963 to August 1964. The area of each circle is proportional to the sum of the mean catches of the otter trawl, midwater trawl, and gill net

SACRAMENTO HITCH

Like the Sacramento blackfish, the greatest numbers of Sacramento hitch were caught at Mossdale on the San Joaquin River (Figure 3). A total of 251 hitch was caught in the Delta of which 116 were taken at Mossdale. Only a few were taken in the western Delta. They ranged in length from 13 to 32 cm FL with an average length of 25.8 cm. A total of 8 out of 10 females examined in June and July were spent.

SPLITTAIL

Splittails were taken at every station in the Delta and were the most evenly distributed of the cyprinids (Figure 3). They ranged in length from 4 to 37 cm FL and average 20.3 cm. All of the females examined in July (nine fish) were spent.

SACRAMENTO SQUAWFISH

Unlike the Sacramento hitch and Sacramento blackfish, almost all of the Sacramento squawfish were caught at stations in the Sacramento River drainage (Figure 3). None were taken in dead-end sloughs and only one caught in the south Delta at Victoria Island on Old River. The length of squawfish varied from 22 to 60 cm FL and averaged 44.1 cm. A total of 12 of 22 females examined from June through August were spent.

GOLDFISH

The greatest numbers of goldfish were taken in Indian Slough and at Mossdale on the San Joaquin River (Figure 3). Very few goldfish were caught at any other station. They ranged in length from 6 to 27 cm FL with an average of 14.6 cm.

GOLDEN SHINER

A total of 212 golden shiners were taken in the Delta. Most of these were caught in the dead-end Hog, Sycamore and Indian sloughs (Figure 3). They varied in length from 7 to 17 cm FL and averaged 10.7 cm.

DISCUSSION

Most of the increased catches of carp from April through August were made with the gill net. Very little change was evident in the average catch of otter trawl and midwater trawls. Gill nets are passive fishing gear and the fish must catch themselves. Our gill net catches of carp were lowest during the winter months which was expected due to the cold water and reduced activity of the fish. From March through May, however, our catches increased greatly at Mossdale on the San Joaquin River but rose only slightly at other stations. In June our catches were high at Mossdale and below Stockton and in the two flooded islands.

The pattern of increase in carp catches, the relatively high percent of spent carp, and lack of any large catches of ripe carp, and the lack of young-of-the-year carp suggest that: (i) carp did not spawn in the Delta, and (ii) there was a movement of carp down the San Joaquin River into the Delta probably after spawning.

The few young-of-the-year carp that were caught were taken in the northern Delta in the Sacramento or Mokelumne River systems in the late summer and fall. Thomas (1967) mentioned the appearance of large numbers of small carp in the diet of striped bass in the upper Sacramento River above our study area. This occurred in the late summer and fall corresponding to drainage of the rice fields along the Feather River. These small carp might have been carried into the northern Delta from the Sacramento River.

Conditions for carp spawning may be poor in the Delta. Wales (1941) and Sigler (1958) reported that carp choose shallow waters of 6 inches to 3 feet deep to spawn. Carp eggs are slightly adhesive and usually stick to debris or plants or sink to the bottom. Any exposure to air will kill the eggs. There is little shallow water less than 3 feet in depth in the Delta, and tidal fluctuations would alternately flood and expose any eggs that were deposited in extremely shallow water. The water level of reservoirs has been dropped to kill carp eggs and reduce their populations in South Dakota (Shields, 1957).

The length frequency of catch with both gill net and otter trawl indicates the population is dominated by a certain size of fish (over 70 percent of the catch by all gears was 30–39 cm in length). This is not uncommon with carp populations, as a uniform size group or perhaps a single year-class has been known to dominate a carp population over a period of time (Mraz and Cooper, 1957).

Carp, Sacramento blackfish, and Sacramento hitch were all extremely abundant at Mossdale, more than at any other station in the Delta. During low flow months, flows in this reach of the San Joaquin River are made up almost entirely of irrigation return waters having high concentrations of dissolved solids (see Radtke, p. 25). These conditions appear to favor the carp, blackfish, and hitch. These same conditions may exclude the Sacramento squawfish which was never taken at Mossdale on the San Joaquin River or in the adjacent sampling stations with high total dissolved solids.

LITERATURE CITED

Carlander, Kenneth D. 1950. Handbook of freshwater fishery biology. Wm. C. Brown Co., Dubuque, Iowa, 281 p. Mraz, Donald, and Edwin L. Cooper. 1957. Natural reproduction and survival of carp in small ponds. J. Wildl. Manage., 21 (1): 66–69. Shields, James T. 1958. Experimental control of carp reproduction through water drawdowns in Fort Randall, South Dakota. Trans. Amer. Fish. Soc., 87: 23–33. Sigler, William F. 1958. The ecology and use of carp in Utah. St. Univ. Agr. Exp. Sta. Bull., (405): 1–63. Thomas, John L. 1967. The diet of juvenile and adult striped bass, Roccus saxatilis, in the Sacramento-San Joaquin River system. Calif. Fish and Game, 53(1): 49–62. Wales, J. H. 1942. Carp control work in Lake Almanor, 1941. Calif. Fish and Game, 28(1): 28–33.

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DISTRIBUTION OF THREADFIN SHAD, DOROSOMA PETENENSE; TULE PERCH, HYSTEROCARPUS TRASKII; SCULPIN SPP. AND CRAYFISH SPP. IN THE SACRAMENTO-SAN JOAQUIN DELTA

JERRY L. TURNER

THREADFIN SHAD

The threadfin shad, Dorosoma petenense, was introduced into southern California from Tennessee by the California Department of Fish and Game in November 1953 (Parsons and Kimsey, 1954). They were later introduced into several reservoirs in the Central Valley of California and have since found their way into the Sacramento-San Joaquin Delta. This paper is a description of their distribution in the Delta from September 1963 to August 1964 and their food habits from September 1963 to May 1964.

Threadfin shad were most abundant in September and were least abundant in January. We found evidence that low water temperatures during the winter caused a heavy mortality of threadfins. Animal matter, particularly crustacean plankton, was the most frequent item in the diet of the threadfin shad, but it and plant material were equally important on a volume basis. Threadfin shad concentrated in areas of high crustacean plankton abundance. It is doubtful that severe competition for food exists between young-of-the-year striped bass and threadfin shad because relatively few young bass inhabit the areas where threadfin shad are most abundant.

Distribution

More than 64,000 threadfin shad were captured during our sampling. Most of these fish were caught with the midwater trawl [(Table 1)]. Very few were captured with the otter trawl except at some of our shallow water stations. Only two threadfin shad were taken with the gill nets. Most were small enough to pass through the meshes.

TABLE 1

Total Number of Threadfin Shad, Tule Perch, and Sculpins Collected in the Gill Net, Otter Trawl, and Midwater Trawl

Species	Gill Net	Otter Trawl	Midwater Trawl	Total Nu[illegible]
Threadfin shad	2	2,268	62,136	64,4[illegible]
Tule perch	52	820	23	8[illegible]
Sculpins	—	97	—	[illegible]

TABLE 1

Total Number of Threadfin Shad, Tule Perch, and Sculpins Collected in the Gill Net, Otter Trawl, and Midwater Trawl

Threadfin shad were caught at every sampling station in the Delta (Figure 1). The greatest numbers were caught in late summer and fall

in Hog and Sycamore Slough (both dead-end sloughs) and in the San Joaquin River at Fourteen Mile Slough. A total of 1,625, 4,385, and 4,279 threadfish shad was taken in three successive 10-minute tows at Fourteen Mile Slough in September 1963. Few threadfin shad were caught at our stations in the western Delta.

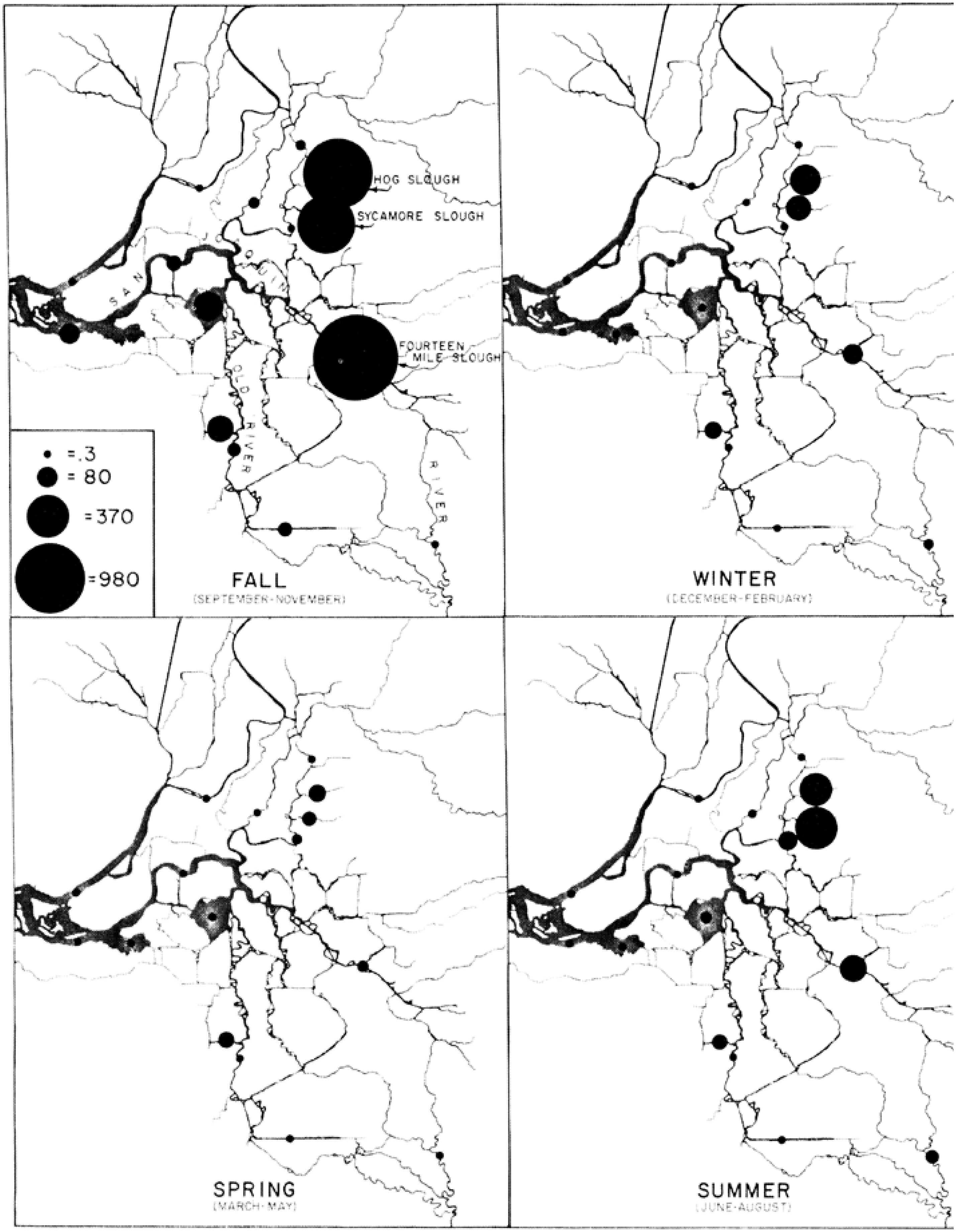

FIGURE 1. Distribution of threadfin shad in the Sacramento-San Joaquin Delta from
tember 1963 to August 1964. The area of each circle is proportional to the mean nu

FIGURE 1. Distribution of threadfin shad in the Sacramento-San Joaquin Delta from September 1963 to August 1964. The area of each circle is proportional to the mean number caught in the midwater trawl at each station

Most of the threadfin shad caught in the fall and winter ranged in length from 5 to 12 cm FL (Figure 2). These were of the 1963 year-class. Their numbers declined rapidly during late fall and winter

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and increased only slightly the following June. A second and smaller size group (the 1964 year-class) appeared in our catches in July 1964 and completely dominated our August sample.

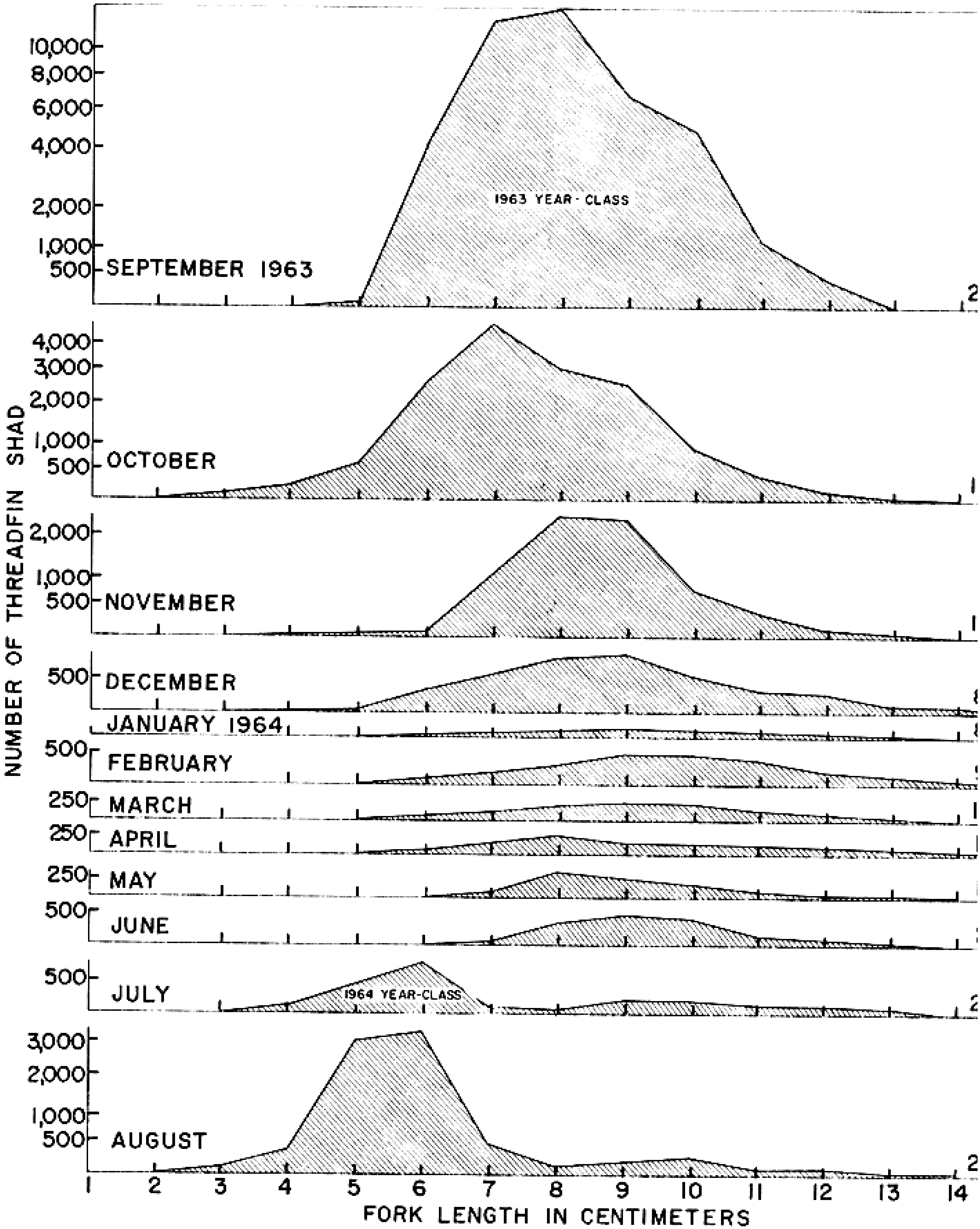

FIGURE 2. Length frequency of catch of all threadfin shad taken by midwater trawl September 1963 to August 1964. Average monthly temperature in degrees centigra noted in the right-hand margin.

FIGURE 2. Length frequency of catch of all threadfin shad taken by midwater trawl from September 1963 to August 1964. Average monthly

temperature in degrees centigrade is noted in the right-hand margin

Food Habits

Food habits of threadfin shad were determined by analyzing 518 stomachs collected from September 1963 to May 1964. These stomachs came from fish that were preserved in 10 percent formalin soon after they were collected. In the laboratory, the contents of each stomach and esophagus were washed into individual petri dishes and stained with rose bengal dye to facilitate identification and enumeration of

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food organisms. Cladocerans and copepods were found in most stomachs [(Table 2)]. Desmids, diatoms, and filamentous algae were found in many. A large portion of the contents of many stomachs was so ground up that it could not be recognized. We estimated that 53 percent of the total volume of the stomach contents was plant material. A number of stomachs contained sand. Kimsey, Hagy, and McCammon (1957) and Haskell (1959) also found quantities of sand in threadfin stomachs.

TABLE 2

Stomach Contents of Threadfin Shad in the Sacramento-San Joaquin Delta, 1963–1964

Food Item	Percent Frequency of Occur (Average of all Stations
Animal Matter	
Rotifers	26.5
Annelids	6.1
Cladocerans and Copepods	82.4
Amphipod (*Corophium*)	1.6
Amphipod (*Gammarus*)	0.2
Insect larvae	6.4
Asiatic clam (*Corbicula fluminea*)	4.2
Unidentified animal matter	80.9
Plant Matter	
Algae	46.1
Unidentified plant matter	66.1
Inorganic Matter	
Sand	54.8

TABLE 2

Stomach Contents of Threadfin Shad in the Sacramento-San Joaquin Delta, 1963–1964

Young Asiatic clams, Corbicula fluminea, averaging 1 mm greatest shell diameter, were common in the stomachs in the spring. One threadfin shad collected in Old River had eaten 26 clams. Young clams are regularly collected in plankton nets in the spring in the Delta (Hazel and Kelley, 1966).

The numbers of crustacean plankton ingested by individual threadfin shad at each station in the fall were directly related to the concentration of crustacean plankton in the environment (Figure 3). The concentration of crustacean plankton at each station was measured during a plankton survey conducted during the same months the shad were collected (Turner, 1966). Ivlev (1961) observed that the ration of a predator experiencing favorable feeding conditions cannot increase above a certain size. Because the curve in Figure 3 is not asymptotic, it indicates that optimum feeding conditions for threadfin shad may not have existed in the Delta at the time of our comparison.

The concentrations of threadfin shad in the Delta were directly related to the concentrations of crustacean plankton in the Delta (Figure 4). The areas of high plankton concentrations had low net velocities and high concentrations of dissolved solids (Turner, 1966).

DISCUSSION

Few threadfin shad were taken in the western Delta. Ganssle (1966) reported a decreasing catch of threadfin shad with increasing distance into the salinity gradient downstream from our study area. Kimsey (1958) found that threadfin shad live and show excellent growth in the Salton Sea but he did not believe that they spawned there. He

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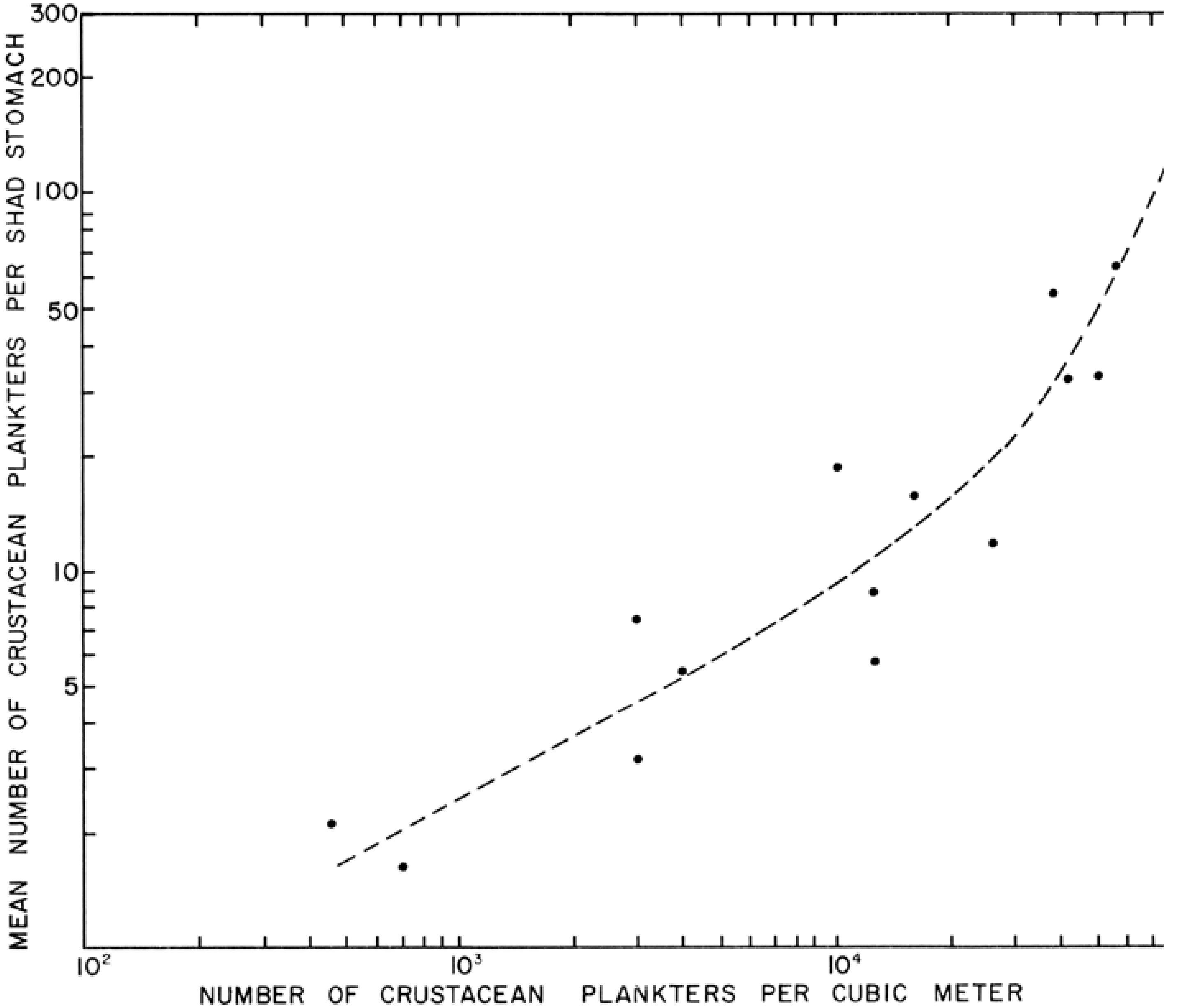


FIGURE 3. Mean number of crustacean plankters per threadfin shad stomach compared the concentration of crustacean plankters in the environment, September to November Comparisons were made only if five or more stomachs were examined.

FIGURE 3. Mean number of crustacean plankters per threadfin shad stomach compared with the concentration of crustacean plankters in the environment, September to November 1963. Comparisons were made only if five or more stomachs were examined

thought they were swept into the sea from adjacent waterways. Shad milt expressed into Salton Sea water, which approaches salt content of sea water, congealed into strings and was incapable of fertilization. Hendricks (1961) found that threadfin shad were most abundant in the Salton Sea near freshwater outlets.

A heavy mortality of threadfin shad must have occurred in the Delta during the winter months. Our catches of the 1963 year-class declined rapidly after September and increased only slightly the following summer. Dryer and Benson (1957) reported that heavy winter mortalities of threadfin shad are common in TVA waters. Parsons and Kimsey (1954) found that the mortality of threadfin shad was high when water temperatures were experimentally decreased from 10°C and 15.6°C to below 7.7°C, and they observed that very few fish survived when water temperatures were below 4.4°C. Water temperatures in the Delta averaged 8.0°C in December. The minimum temperature was 6.7°C.

Before the threadfin shad was introduced into the Central Valley of California, Kimsey (1958) expressed concern over the possibility that threadfin shad and small striped bass would compete for food in the Delta. I do not believe that competition between the two species is severe. Copepods and cladocerans are important foods of threadfin shad throughout their life but are important to striped bass only in their first 3 months of life (Heubach, et al., 1963). Relatively few young bass of this age inhabit the areas in the Delta where threadfin

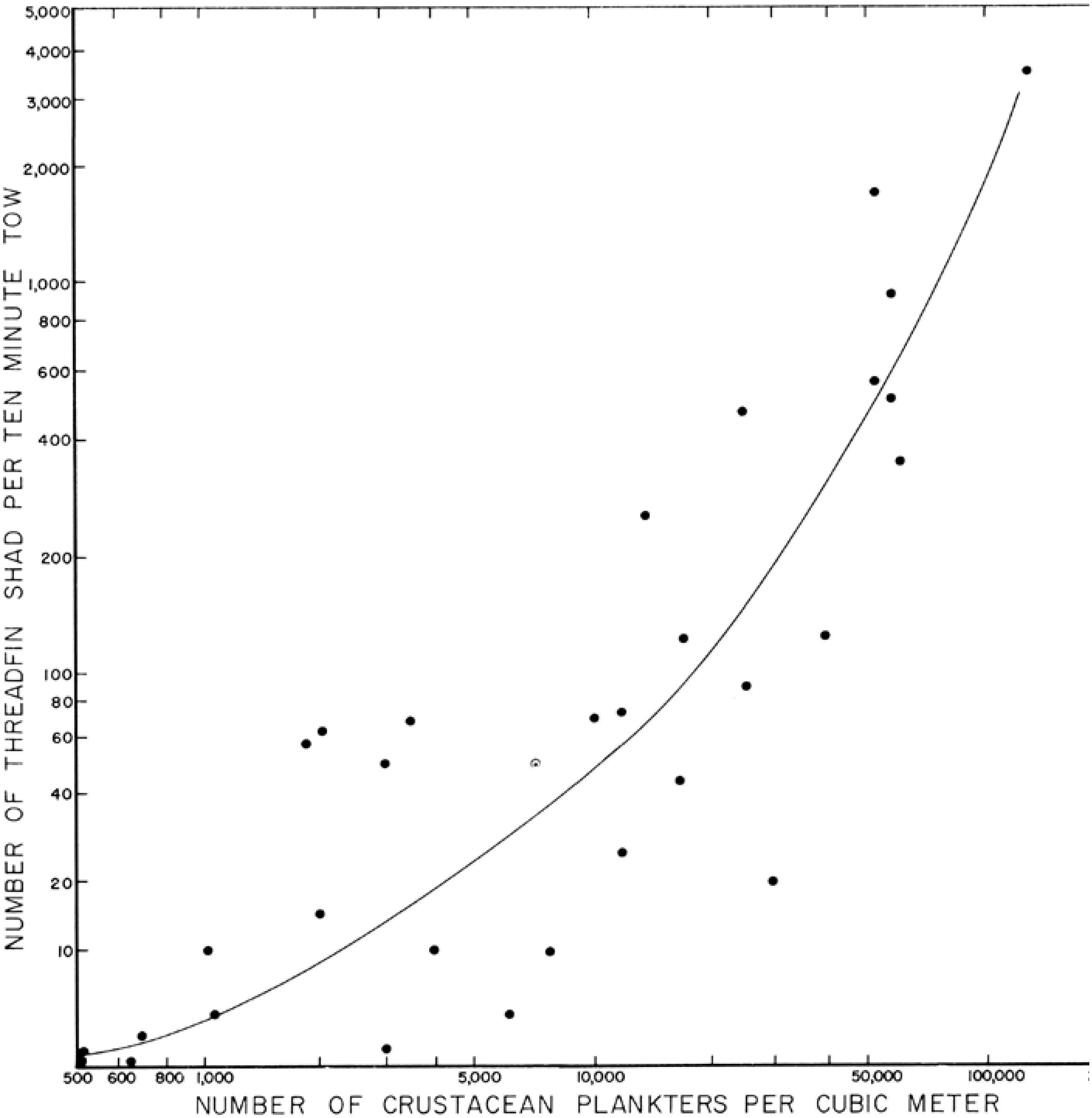


FIGURE 4. Number of threadfin shad taken per 10-minute tow by the midwater compared to number of crustacean plankters per cubic meter of water in the enviror September to November 1963.

FIGURE 4. Number of threadfin shad taken per 10-minute tow by the midwater trawl compared to number of crustacean plankters per cubic meter of water in the environment, September to November 1963

shad have become abundant. Chadwick (1964) demonstrated from extensive tow net surveys that in the summer most of the population of young bass (1 inch long) are within a few miles of the confluence of the Sacramento and San Joaquin rivers. Sasaki (see p. 49) found that young bass (2 inches and longer) were concentrated in the fall in the western Delta and were not abundant in other areas of the Delta. Stevens (see p. 72) reported that these young bass were not feeding on copepods or cladocerans but were feeding on larger organisms such as the mysid shrimp, Neomysis awatschensis, and the amphipod, Corophium. These larger organisms did not occur in the diet of the threadfin shad.

The small size of the threadfin shad makes it a very desirable food source for piscivorous fishes, but its importance as a forage fish in the Delta may be limited because it is abundant only in restricted areas of quiet water.

TULE PERCH

Eight hundred and seventy-five tule perch, Hysterocarpus, traskii, were collected with the otter and midwater trawls and with set gill nets (Table 1). Analysis of the tule perch distribution is based on the mean numbers caught in the otter trawl at each station over the entire sampling period.

The tule perch in our catches ranged from 4 to 20 cm FL; the mean was 10.9 cm.

Tule perch were relatively scarce in the Delta. The greatest concentrations were in stations upstream from the central Delta. Highest catches were made in the North and South Fork of the Mokelumne River. No tule perch were taken in the San Joaquin River below Stockton, the Sacramento River below Isleton, and in Old River below Fabian Canal (Figure 5). Limited numbers were taken in Franks Tract and Big Break.

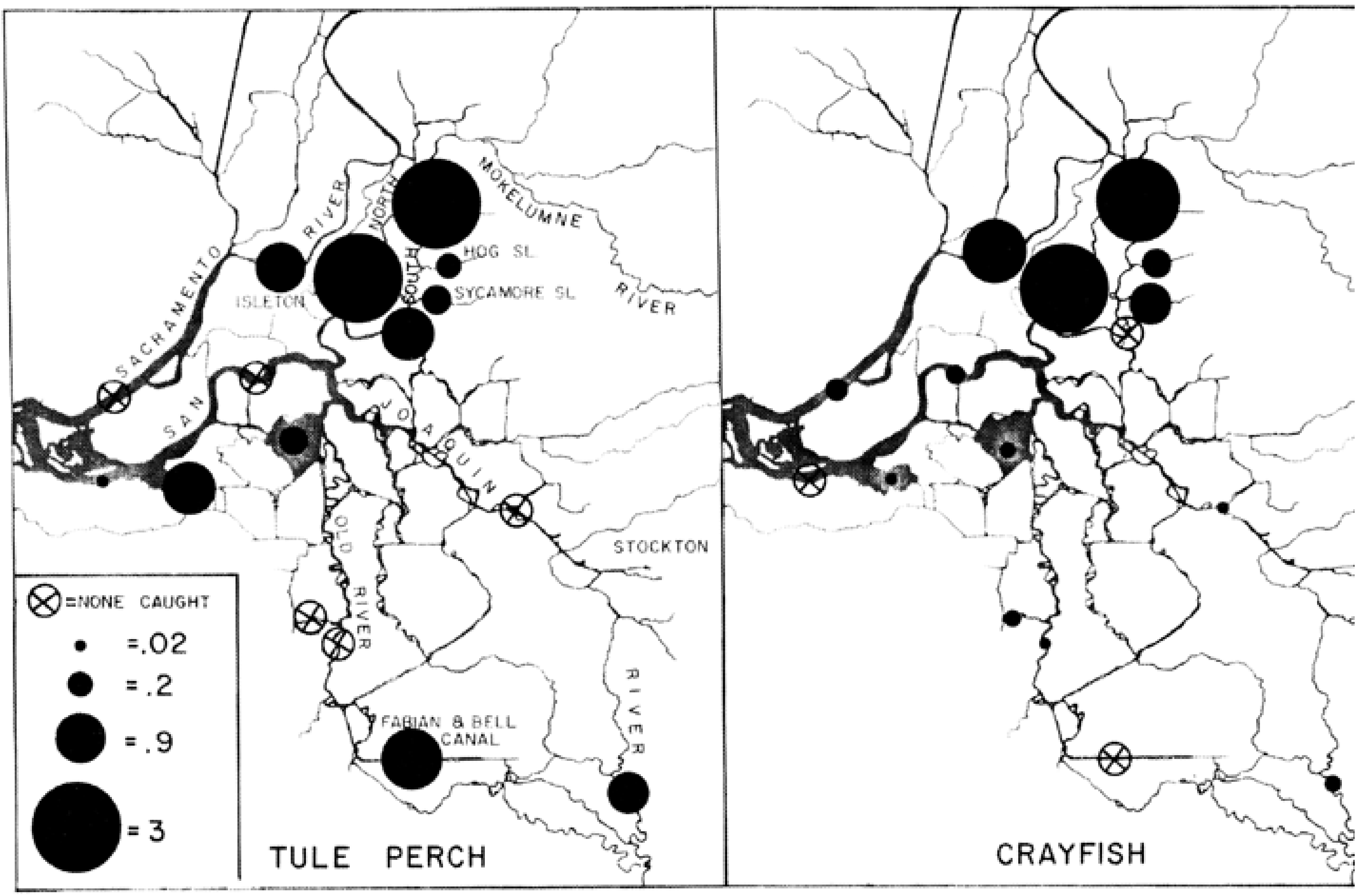


FIGURE 5. Distribution of (A) tule perch and (B) crayfish, both *Pacifastacus leniu* (common) and *Procambarus clarkii* (uncommon), in the Delta from September 19 August 1964. The area of each circle is proportional to the mean number caught i otter trawl at each station.

FIGURE 5. Distribution of (A) tule perch and (B) crayfish, both *Pacifastacus leniusculus* (common) and *Procambarus clarkii* (uncommon), in the Delta from September 1963 to August 1964. The area of each circle is proportional to the mean number caught in the otter trawl at each station

The tule perch was the only viviparous fish that we collected. A total of 14 females containing unborn young were collected in April and May in Sycamore and Hog Slough (dead-end sloughs), Franks Tract and Big Break (flooded island), and in the Mokelumne River. In June and July a total of 16 out of 21 females examined were spent.

The stomachs of 206 tule perch were examined to determine their food habits. They are primarily benthic feeders [(Table 3)]. Corophium occurred in the stomachs more frequently than any other organism. These amphipods made up over 91 percent of the diet bulk. Tendipedid larvae were also an important food source, especially for young-of-the-year tule perch. Tendipedids were consumed by 9 of 10 young-of-the-year collected during the summer in the Mokelumne River. Seventy-seven small Asiatic clams, Corbicula fluminea, were the only food in the stomachs of five tule perch captured during the spring in the Sacramento River at Isleton.

TABLE 3

Stomach Contents of Tule Perch in the Sacramento-San Joaquin Delta, 1963–1964

Food Item	Percent Frequency of Occurrence					Pe of V
	Fall	Winter	Spring	Summer	Average	
Mysid shrimp (*Neomysis awatschensis*)	—	9.1	—	—	2.4	
Isopod (*Exosphaeroma oregonensis*)	—	3.0	—	—	0.8	
Amphipod (*Corophium*)	100.0	90.0	87.2	77.5	86.3	[illegible]
Tendipedids	16.7	9.1	12.8	40.0	21.0	
Asiatic clam (*Corbicula fluminea*)	—	—	12.8	—	4.0	
Stomachs examined	22	58	58	68	206	
Stomachs containing food	12	33	39	40	124	

TABLE 3

Stomach Contents of Tule Perch in the Sacramento-San Joaquin Delta, 1963–1964

SCULPINS

Very low numbers of Pacific staghorn sculpin, Leptocottus armatus, and prickly sculpin, Cottus asper, were taken with the otter trawl (Table 1). The staghorn sculpin is a saltwater form that ranges into brackish and fresh water. The prickly sculpin is found in the fresh water of coastal streams. Regrettably, the two forms were not separated and their distribution cannot be described other than that one or the other was caught at every sampling station in the Delta. Large numbers of sculpin larvae, believed to the Cottus asper, were taken in plankton nets towed during the spring. Chadwick (1958) reported that large numbers of larvae of Cottus asper were taken in the Delta about the first of April.

CRAYFISH

Two species of crayfish, Pacifastacus leniusculus and Procambarus clarkii, were caught with otter trawls. Pacifastacus were much more numerous than Procambarus in our catches. The greatest concentrations of crayfish occurred in the northern Delta, particularly at Isleton on the Sacramento River and in the North and South Fork of the Mokelumne River (Figure 5). Very few crayfish were taken in other areas.

LITERATURE CITED

Chadwick, Harold K. 1958. A study of planktonic fish eggs and larvae of the Sacramento-San Joaquin Delta with special reference to the striped bass, Roccus saxatilis. Calif. Dept. Fish and Game, Inland Fish. Admin. Rept., (58–5): 1–22. Chadwick, Harold K. 1964. Annual abundance of young striped bass. Roccus saxatilis, in the Sacramento-San Joaquin Delta, California. Calif. Fish and Game 50(2): 69–99. Dryer, William, and Norman G. Benson. 1957. Observations on the influence of the New Johnsonville steam plant on fish and plankton populations. Southeastern Assoc. Game and Fish Comm., Proc. 10th Ann. Conf., p. 85–91. Ganssle, David. 1966. Fishes and decapods of San Pablo and Suisun Bay, p. 64–94. *In* D. W. Kelley, (ed), Ecological studies of the Sacramento-San Joaquin Estuary. Calif. Fish and Game, Fish Bull., (133): 1–133.

Haskell, William L. 1959. Diet of the Mississippi threadfin shad, Dorosoma petenense, in Arizona. Copeia, (4): 298–302. Hazel, Charles R., and D. W. Kelley. 1966. Zoobenthos of the Sacramento-San Joaquin Delta, p. 113–133. *In* D. W. Kelley, (ed.), Ecological studies of the Sacramento-San Joaquin Estuary. Calif. Fish and Game, Fish Bull., (133): 1–133. Hendricks, L. Joseph. 1961. The threadfin shad, Dorosoma petenense, p. 93–94. *In* Boyd W. Walker, (ed.), The ecology of the Salton Sea, California, in relation to the sportfishery. Calif. Fish and Game, Fish Bull., (113): 1–204. Heubach, William, Robert J. Toth and Alan M. McCready. 1963. Food of young-of-the-year striped bass (Roccus saxatilis) in the Sacramento-San Joaquin River system. Calif. Fish and Game 49(4): 224–239. Ivlev, V. S. 1961. Experimental ecology of the feeding of fishes. Yale Univ. Press, New Haven, 302 p. Kimsey, J. Bruce. 1958. Possible effects of introducing threadfin shad (Dorosoma petenense) into the Sacramento-San Joaquin Delta. Calif. Dept. Fish and Game, Inland Fish. Admin. Rept., (58–16): 1–21. Kimsey, J. Bruce, Robert H. Hagy and George W. McCammon. 1957. Progress report on the Mississippi threadfin shad, Dorosoma petenensis atchafaylae, in the Colorado River for 1956. Calif. Dept. Fish and Game, Inland Fish. Admin. Rept., (57–23): 1–48. Parsons, John W., and J. Bruce Kimsey. 1954. A report on the Mississippi threadfin shad. Prog. Fish Cult. 16(4): 179–181. Turner, Jerry L. 1966. Seasonal distribution of crustacean plankters in the Sacramento-San Joaquin Delta, p. 95–104. *In* D. W. Kelley, (ed.), Ecological studies of the Sacramento-San Joaquin Estuary. Calif. Fish and Game, Fish Bull., (133): 1–133.

1 Mean net velocity (in feet per second) = Net flow (in cubic feet per second)/cross sectional area of channel (in sq. ft.) Turner (1966) discusses this measurement and how it applies to flows in the Delta.

Exhibit “Q”

TESTIMONY OF ALEX HILDEBRAND
HEARING ON PROPOSED CEASE AND DESIST ORDER TO DWR AND USBR

My name is Alex Hildebrand. I was a Director of the South Delta Water Agency (SDWA) for 30 years and am currently the engineer for that Agency. A copy of the Agency's boundaries is provided as Attachment "A." I have testified many times before this Board as well as other regulatory and legislative bodies and was qualified as an expert witness with regard to the water quality and flow issues affecting the South Delta.

A copy of my current statement of qualifications is attached hereto as Attachment "B." Briefly, I have a B.S. in physics with minors in chemistry and engineering, and worked for Chevron until I retired in engineering and technical capacities including Assistant Chief Engineer of the Richmond Refinery and Director of the La Habra Research Laboratory. Since that time I have farmed approximately 150 acres on the San Joaquin River about 12 miles by river downstream of Vernalis in the South Delta. For the past 30 years, I have been intimately involved in the discussions, negotiations, regulatory proceedings and litigation to protect its diverters from the adverse effects of SWP and CVP and to insure the area has an adequate supply of good quality water.

My testimony for this proceeding is divided into four parts following a discussion of background. The first part deals with how the DWR and USBR can meet current salinity standards while using temporary rock barriers. It has been argued that the 0.7 EC requirement in internal channels cannot be reasonably met even after implementation of the SDIP and that it is therefore unreasonable to require it now. That assertion is incorrect. The second deals with the numerous interrelated benefits which result from compliance with permit conditions. The third part explains how I and others are personally affected. And the last part addresses the reconsideration of the Water Quality Response Plan.

I. <u>Background</u>

1) <u>Regulatory Background</u>

As set forth in the 1991 and 1995 Water Quality Control Plans, the two San Joaquin River standards (at Brandt Bridge and Vernalis) were to be implemented promptly. The two Old River standards (Old River near Middle River and Old River at Tracy Road Bridge) were to be implemented no later than December 31, 1997 (see Attachment "C"). The 1995 Plan therefore recognized that the San Joaquin River standards would be addressed with good quality flows on the River, while the Old River standards required other actions such as barriers which could not be immediately implemented.

In D-1641, the Board acknowledged that, "Construction of permanent barriers alone is not expected to result in attainment of the water quality objectives." The Board went on to note that the "objectives can be met consistently only by providing more dilution or by treatment." (See Attachment "D" D-1641 at page 88.)

Hence, in 2000, this Board recognized that permanent barrier installation and operation ***and*** other actions, including additional dilution flows, were necessary to meet the standards.

Since 1995 at the earliest, and 2000 at the latest, DWR and USBR have known that in order to meet the 0.7/1.0EC standards, they had to undertake actions ***in addition to the proposed barrier program.*** To my knowledge, DWR and USBR have undertaken no actions other than the barrier program.

As I understand the issues before the Board in this proceeding, the questions are first, whether a Cease and Desist Order should issue, and second, if so, what terms should be in such an order.

The answer to the first question is certainly "yes." Since DWR and USBR do not believe their current operations, including temporary barriers, will result in compliance with their permit terms, especially at the three interior South Delta stations, they should be ordered to comply. There appears to be no logical or practical reason for not requiring compliance with existing Water Quality Objectives and permit terms. This is especially true given that the Board determined over five years ago in D-1641 that compliance would indeed require additional dilution flows (or treatment). The fact that DWR and USBR knew the permanent operable barriers would not be built in the short term and did not undertake the necessary and anticipated other actions to secure and provide additional flows or treatment does not change the need for the objectives or the benefits therefrom.

I note that HR 2828 requires the USBR to develop a plan by the end of this year under which it will meet its water quality obligations on the San Joaquin River (see Attachment "E"). Since the Congress believes the Bureau should meet the objectives, one would think the SWRCB would too.

2) <u>Historical Background</u>

The changes in San Joaquin River flows and water quality pre-CVP and post CVP are set forth in the June 1980 Report entitled "*Effects of the CVP Upon the Southern Delta Water Supply Sacramento - San Joaquin River Delta, California.*" This Report and numerous other studies and investigations (including D-1641) have identified the operation of the CVP as the principle cause of the salinity problem in the lower San Joaquin River and Delta. However, the SWP's effects on flows in Delta channels and its joint efforts with the CVP in supplying export water to the San Joaquin Valley are significant contributory causes.

As a consequence of this problem, the SWRCB slowly adopted and even more slowly implemented water quality objectives to protect agricultural beneficial uses. Currently, only dilution water is used to meet the Vernalis standard. The delay in implementing the other three standards has allowed DWR and USBR to avoid taking other actions. [Although temporary barriers do trap some good quality export water which improves water quality in portions of Middle River and Tracy Old River compliance stations, the net flow is back (downstream) over the barriers and the water quality does not approach the 0.7 EC standard.

The dilution water needed to comply with the current Vernalis salinity objectives is required because the westside wetlands and farm lands receive Delta Mendota Canal (DMC) water which contains a large salt load. That salt load is then concentrated by crop and wetland evaporation. Most of the salt then drains to the river where it must be diluted.

II. Compliance with the 0.7/1.0EC internal South Delta salinity standard with Temporary barriers

The subject Water Quality Objectives can be met and the in-channel water supply in internal South Delta channels can be maintained at 0.7 EC from April through August with very little water cost to the CVP and SWP. This is the case both before and after permanent barriers are installed and other concurrent measures are provided. While using temporary barriers the following salinity control measures and others should be utilized.

1) Dilution Needs.

A) As water passes Vernalis, it slowly degrades due to evaporation, consumptive uses and urban discharges. This degradation is reflected in field data which DWR has collected and which is set forth in Attachment "F." The increase in salinity during low flows can be .1 EC or more from Vernalis to Brandt Bridge. The amount of dilution water needed to offset this rise in salinity at Brandt Bridge or elsewhere depends on the quality of the dilution water and the amount of the flow from Vernalis to Brandt Bridge. Dilution provided upstream of Vernalis can be used to lower salinity below 0.7 EC at Vernalis so that it will not rise above 0.7 EC at downstream locations. Dilution with Middle River water can be used to restore salinity to 0.7 EC at the point of dilution. To offset a 0.1 EC rise in salinity would take about 250 cfs of 0.4 EC dilution water when the Vernalis base flow is 1000 cfs. The 0.4 EC is representative of DMC water quality. If the dilution flow was provided from one of the tributaries, less of that better quality water would be required.

2) Dilution Opportunities.

A) New Melones is currently the only reservoir used by the USBR to meet the Vernalis standard. Whatever additional measures are undertaken to meet the downstream South Delta standards, the New Melones releases that would be required in the absence of these measures to meet the Vernalis standard will continue to be required at least in the short term. Additional releases could also be made from this source to contribute to meeting the other South Delta standards. This year as of June, the Bureau has allocated 180,000 acre-feet of New Melones storage for water quality purposes, but has used none of this amount (see Attachment "G;" personal communication with USBR staff). Obviously, in the short term, water is available from New Melones.

B) Additional water from the tributaries to the San Joaquin River could be purchased for release during the April through August time frame. In the recent past, hundreds of thousands of acre-feet have been purchased from the tributaries for a variety of reasons. As stated above, it would take less of this high quality water to provide the needed dilution than is the case when DMC water is used.

C) Upstream exchanges could also be coordinated to provide dilution flows. Given the various connections of the SWP and CVP distribution systems, exchanges between water users could be made to provide additional flows on the San Joaquin River. For example, this year excess and flood flows from Friant were diverted at the Mendota Pool for delivery to Westlands Water District and others. Some of that water could have been allowed to flow downstream in exchange for other DMC, California Aqueduct, or San Luis Reservoir supplies.

D) Water can also be recirculated through the DMC using one of its wasteways to deliver the flows to the San Joaquin River. The Bureau conducted such a recirculation pilot project in 2004 using DMC water released from the Newman Wasteway. The releases during that project had a significant impact on San Joaquin River quality. (See Attachment "H"). The 250 CFS recirculation release from the Newman Wasteway decreased the EC in the River from 1,200 to 900 (or 1.2 to 0.9 using the same parameters as the 0.7 standard) at the Patterson Measurement Station and from 700 to 600 (or 0.7 to 0.6) at the Vernalis Station. [The differing changes are due to the differing amounts of flow in the River at the two locations.] I also note that D-1641 specifically required the Bureau to investigate the use of such recirculation to assist in meeting water quality standards. I believe the Bureau has failed to meet the deadlines required by D-1641.

E) Transfers for EWA or other purposes can be coordinated such that the transfer water could be released during the April - August time frame. The transfer water would provide dilution but would not be lost as San Joaquin River and South Delta diversion needs do not change with flow fluctuations.

F) As the Board knows, CVP permits in addition to New Melones are burdened with the requirement of meeting the salinity objectives. Hence, releases from Friant, Shasta, Folsom, or San Luis could be used to supplement San Joaquin River flows. For example, the high flows this year from Friant re-charged (to some degree) the groundwater in the area at and above Gravelly Ford on the San Joaquin. The Bureau missed a perfect opportunity to test how much water would be lost from additional summer releases once that groundwater had been re-charged.

G) Temporary barrier operations result in net downstream flow back over the Middle River and Grant Line Canal barriers. Improved San Joaquin River water quality will also improve the Middle River and Grant Line quality. If this does not result in compliance at the Middle River and Old River Stations, other actions can be undertaken. The Middle River rock barrier can be improved to capture and retain more high tide water, and low lift pumps can be added at the barrier to increase the flow of high quality water up through Middle River and into Old River. This will maintain high quality water in Middle River, and the flow continuing into Old River will blend with the water flowing into the head of Old River. This will further reduce the salinity of the Old River water which is also reduced by the measures discussed above.

3) Recovery of Dilution Flows.

A) Any additional dilution flows added to the San Joaquin River are available for export as they pass through the South Delta. If the water cannot be currently pumped as additional exports, DWR and USBR could coordinate exchanges so that the water is pumped for such things as EWA purposes using the additional 500 CSF export authorization of the SWP or exchanged to replace or substitute for a transfer being accomplished under JPOD operations. Even if none of these authorizations were available, DWR and USBR could petition the Board for short term authorization to allow them to pump these additional dilution flows. One would assume the Board would look favorably upon such a request given that its underlying purpose is to meet existing Water Quality Objectives. Approval of such petition would be similar to D-1641's “no net loss” principle regarding fishery releases. In sum, all additional dilution flows would enter the South Delta and be available for export at the SWP and/or the CVP pumps. The losses should only be minimal. For example, the recirculation pilot program estimated the losses at less than 10%. I recall that carriage water losses for the DWR Dry Year Purchase Program were less than 5% in 2004.

It is important to note that the water deliveries of the CVP to its westside service area of the San Joaquin Valley, as assisted by the SWP, are the cause of the River’s salinity problems. As I understand it, other parties are asserting that the CVP and SWP should not be required to meet the standards if it adversely affects their deliveries or costs. It would be illogical and unfair to allow the continued delivery of the water which causes the salt problem, and yet not require that some of that delivered water be used to mitigate the salt problem.

III. Benefits Resulting From Compliance With The Salinity Objectives

I will now give an overview of the benefits from meeting the Water Quality Objectives which also addresses the question of whether a Cease and Desist Order should issue.

A) As the Board knows, the 0.7/1.0 EC standards were developed to protect agricultural beneficial uses. The voluminous studies, investigations, and testimony previously used by the Board in setting these standards was referenced in SDWA's presentation at the Periodic Review process workshops. Generally, EC's above 0.7 have an incremental adverse effect on crop production, which translates into a monetary damage to farmers.

B) To get a broad estimate of the damage that occurs as the EC of the water rises, I refer the Board to the previously submitted report of Dr. G. T. Orlob attached hereto as Attachment "I," and entitled "Impacts of San Joaquin River Quality On Crop Yields In The South Delta." Therein, Mr. Orlob calculated the crop damage in dollars between actual crop yields and the yields which would result if a standard of 500 TDS had been met. Using 1976 figures and dollars, the crop loss for the South Delta area was (15.70 - 8.64) $7.06 million. In 2005 dollars, it is approximately $24 million (using a CPI calculation at http://woodrow.mpls.frb.fed.us/research/data/us/calc/). This gives the Board a good idea of the scope of the crop damage if the EC downstream of Vernalis were allowed to exceed the current standard during the April through August time frame. The specific impacts on diverters is exemplified by the testimony of the other SDWA and CDWA witnesses.

C) We also know that virtually all of the San Joaquin River water ends up at the State and Federal pumps (see Testimony of Thomas Zuckerman, Exhibit No. CDWA-10). This is due to the fact that even with temporary barriers, the net flow is downstream over the Grant Line and Middle River barriers, and, that the water which continues down the mainstem of the River also mostly ends up at the pumps. Hence, the quality of export water is partially dependent on the quality of the San Joaquin River. Improving the River water quality in order to meet the standards will benefit export interests, especially municipal water users. Although I do not have the calculations, I understand that the Bureau has done investigations which determined the benefit to municipal water treatment plants resulting from improvements and source water quality.

D) The Board is also well aware of the dissolved oxygen (DO) problem in both the mainstem of the River, specifically in the Stockton Deep Water Ship Channel, and also generally throughout the South Delta. Two Basin Plan Objectives for DO apply to these waters. Additional good quality water added to the system for purpose of meeting the salinity standards will also help improve DO levels both because of the quality of the flows, and the additional flow/circulation they will provide.

E) The additional flows would also provide benefits to the various fisheries. We know that out-migrating salmon smolts are traveling through the system even after the spring pulse flow has ended. These fish would be helped by the higher flows. Other species, such as steelhead and smelt may also be benefitted by the higher flows. Use of the additional flows for dilution would provide an opportunity for the fishery agencies to examine the effects.

IV. Effects On Farming Operations

As I referenced above, I am a farmer on the San Joaquin River. I divert under both appropriative rights (see Attachment "J") and under my riparian rights (my chain of title documents are being introduced by a CDWA witness as Exhibit No. CDWA-6). I have personally experienced the adverse impacts of the SWP and CVP, and other upstream projects. I have had reduced crop yields due to high salinity of the River water. I have been unable to divert from the River due to decreased upstream flows and the destruction of the high tide which previously extend to the portion of the River I abut. Requiring the DWR and USBR to meet the previously established Water Quality Objectives which are contained in their permits would not only protect me, but also numerous other beneficial users of water. Farmers further downstream have experienced more loss due to salinity because salinity rises above the Vernalis standard as water flows downstream as previously discussed.

Finally, for clarification, the draft Cease and Desist Order states the temporary barriers are installed to mitigate the adverse effects of the HOR fish barrier. This is misleading. Although the federal funding for the temporary barriers was previously linked in CVPIA to the funding for the HOR fish barrier as mitigation of that barrier, that does not accurately describe why the other three tidal barriers are installed. It is my understanding that DWR now shoulders all of the costs of the temporary barrier program, though there may be some arrangement whereby USBR will pay its share in some other way. The temporary tidal barriers are installed to partially mitigate the adverse effects on water levels, quality, and quantity resulting from the operations of the CVP and SWP. At this date, the SWRCB should not be trying to avoid describing the true state of affairs in the South Delta. There is no disagreement that the projects lower water levels, decrease flows, reverse channel flows, cause stagnant zones and worsen water quality. The temporary tidal barriers are one of the preliminary steps in correcting these problems.

V. Water Quality Response Plan

Finally, I will address this Board's reconsideration of the Chief of the Division of Water Rights approval of the current Water Quality Response Plan for Joint Point of Diversion. In approving the current Response Plan, the Division Chief waived compliance with the currently existing Water Quality Objectives for Agricultural Beneficial Uses at the Brandt Bridge, Old River near Middle River and Old River at Tracy Road (sic) Bridge. This would appear to be not only beyond the Division Chief's authority and contrary to D-1641, but also directly contrary to the purpose of the Water Quality Response Plan.

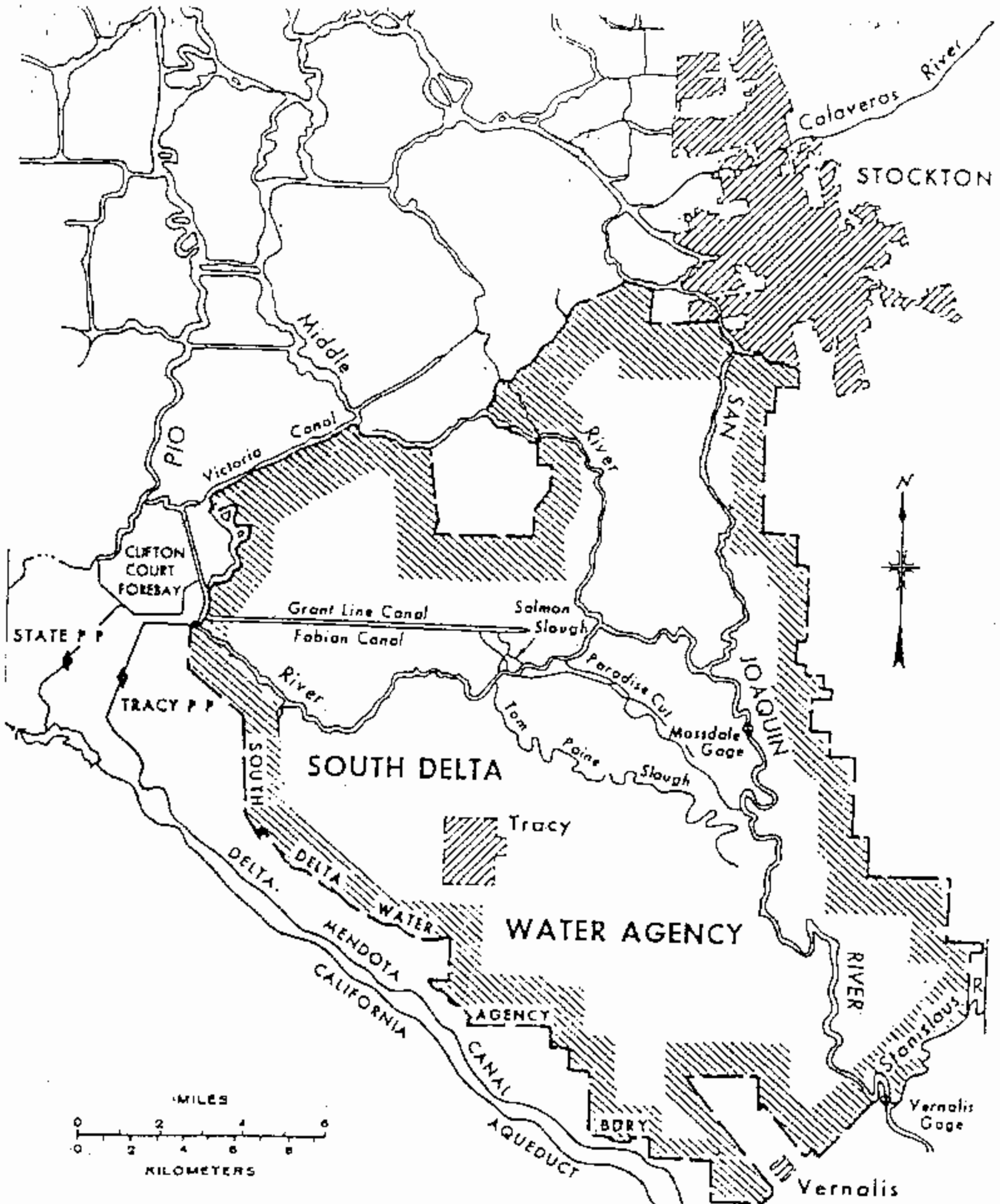
D-1641 requires as a condition to JPOD that the DWR and USBR "develop a response plan to ensure that the water quality in the southern and central Delta will not be significantly degraded through operations of the Joint Point of diversion to the injury of water users in the southern and central Delta" (see for example page 150-151 of D-1641). Approval of the plan was to come from the Division Chief.

The purpose of the plan is to ensure that the incremental affects on water quality resulting from JPOD do not injure other users. Inexplicably, the Division Chief decided that while she was protecting the Delta users from the incremental effects of JPOD on water quality, she would relax the existing Water Quality Objectives. In other words, she allowed a greater impact to water quality than she was protecting through the plan.

This bizarre decision by the Division Chief cannot stand and should be forthwith revoked. No further evidence is necessary to undo such an act which is not only beyond her authority but directly contrary to the explicit and implicit purposes of the Water Quality Response Plan. This Board will consider changes to the 1995 Water Quality Control Plan through the Periodic Review process and perhaps through the process resulting from DWR and USBR's Petition to delay implementation of their permit terms. The Response Plan process did not give any party notice that such a significant change was pending and so it would be unfair and wrong to allow it. Similarly, we belief a change in the standards would require new environmental evaluation.

SDWA requests that the Water Quality Response Plan not include the Division Chief's wrongful waiver of existing standards.

SDWA\Cease and Desist\Hildebrand Testimony Cease and Desist



NOTE: Minor sloughs and oxbows are not shown on this Figure.

SOUTH DELTA WATER AGENCY

Attachment "A"

STATEMENT OF QUALIFICATIONS OF
ALEX HILDEBRAND

Agriculturally Related Qualifications

° Past Director and Secretary of South Delta Water Agency for 30 years

° President of Delta Water Users Association

° President of McMullin Reclamation District No. 2075

° President of San Joaquin River Water Users Company (non-profit water distributor within District #2075)

° Director of California Central Valley Flood Control Association

° President of San Joaquin River Flood Control Association

° Director (and member of Water Committee) of San Joaquin County Farm Bureau

° Member of California Farm Bureau Water Advisory Committee

° Owner (since 1944) and resident operator (since 1963) of 150-acre farm (in District #2075). Have made observations for several years of the depth of water percolation in two of my fields by use of Tensiometers, and have observed over many years the dramatic effect of variation in applied water salinity on the production and quality of produce from our family produce plot.

° Participated in development of South Delta Barrier Program

° Active participant in San Joaquin River Management Plan

° Expert witness in numerous hearings before the State Water Resources Control Board

° Member CalFed Bay/Delta Advisory Council

Professional Qualifications

° Honors Degree in Physics from U.C. Berkeley

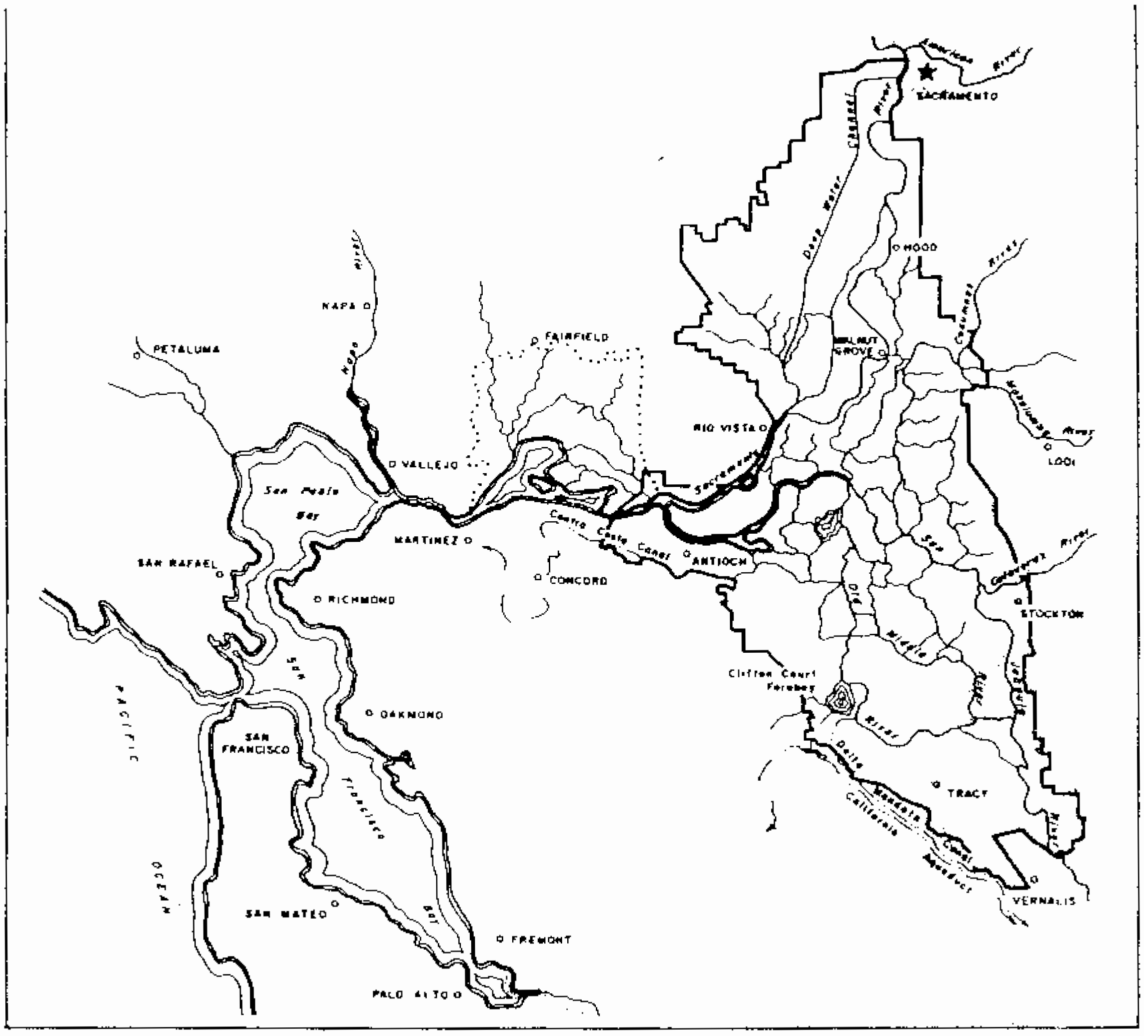
° Registered Professional Engineer

° Former Assistant Chief Engineer of Chevron's Richmond Refinery

° Retired Director of Chevron's Oil Field Research Laboratory. The research in that laboratory covered a broad spectrum of science and engineering, including substantial research on the flow of

Attachment "B"

fluids through permeable earth materials (both in laboratory and field tests) together with the movement of dissolved materials. This work required an understanding of the mechanisms of fluid flow, the physical chemistry involved, and the consequences of non-uniform permeability. Also responsible for analyzing and determining the applicability of these research results to commercial operations.



DRAFT

WATER QUALITY CONTROL PLAN

for the

San Francisco Bay/ Sacramento-San Joaquin Delta Estuary

MAY 1995

STATE WATER RESOURCES CONTROL BOARD

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

Attachment "C"

4. **Southern Delta agricultural salinity objectives.** Elevated salinity in the southern Delta is caused by low flows, salts imported in irrigation water by the State and federal water projects, and discharges of land-derived salts, primarily from agricultural drainage. Implementation of the objectives will be accomplished through the release of adequate flows to the San Joaquin River and control of saline agricultural drainage to the San Joaquin River and its tributaries. Implementation of the agricultural salinity objectives for the two Old River sites shall be phased in so that compliance with the objectives is achieved by December 31, 1997.

REVISED
Water Right Decision 1641

In the Matter of:

Implementation of Water Quality Objectives for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary;

A Petition to Change Points of Diversion of the Central Valley Project and the State Water Project in the Southern Delta; and

A Petition to Change Places of Use and Purposes of Use of the Central Valley Project

Adopted December 29, 1999

Revised March 15, 2000
in accordance with Order WR 2000-02

STATE WATER RESOURCES CONTROL BOARD
CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

Attachment "D"

DWR, SDWA, Stockton, and the USDI presented evidence regarding the barriers. The main benefit of the barriers is improved water levels in the southern Delta. (SWRCB 87, p. S1.) The barriers also benefit water quality by improving circulation in the southern Delta. (R.T. p. 7525.) The barriers generally improve water quality in the southern Delta because salts otherwise trapped in the channels are transported out of the area due to the enhanced circulation. (DWR 37, pp. 12-13.) The barriers reduce the amount of salt imported by way of the Delta-Mendota Canal, which should result in some long-term improvement in the quality of the San Joaquin River. (R.T. p. 3905.) The improved quality of water delivered through the Delta-Mendota Canal should result in improvements to the salinity of drainage water that returns to the river. (R.T. p. 3731.)

The construction of permanent barriers alone is not expected to result in attainment of the water quality objectives. (R.T. pp. 3672, 3710, 3787-3788; DWR 37, p. 15; SWRCB 1e, pp. [IX 30]-[IX-41].) The objectives can be met consistently only by providing more dilution or by treatment. (R.T. p. 3737.) The modeling studies indicate that even when the barriers do not result in attainment of the standards, water quality generally improves as a result of the permanent barriers. The exception is at Brandt Bridge where water quality may worsen slightly at times due to barrier operation. (R.T. p. 3677; DWR 37, p. 18; SWRCB 1e, Figures [IX-19]-[IX-26].) Barriers may result in slightly worse water quality in the mainstem of the San Joaquin River in the Delta, but the more saline water is quickly diluted. (DWR 37.) Modeling shows that construction and operation of the temporary barriers should achieve water quality of 1.0 mmhos/cm at the interior stations under most hydrologic conditions.

The DWR and the USBR are partially responsible for salinity problems in the southern Delta because of hydrologic changes that are caused by export pumping. Therefore, this order amends the export permits of the DWR and of the USBR to require the projects to take actions that will achieve the benefits of the permanent barriers in the southern Delta to help meet the 1995 Bay-Delta Plan's interior Delta salinity objectives by April 1, 2005. Until then, the DWR and the USBR will be required to meet a salinity requirement of 1.0 mmhos/cm. If, after actions are taken to achieve the benefits of barriers, it is determined that it is not feasible to fully implement the objectives, the SWRCB will consider revising the interior Delta salinity objectives when it reviews the 1995 Bay-Delta Plan. The USBR and the DWR will be responsible to take any actions required by CEQA, NEPA, and the federal and State ESA prior to constructing the barriers.

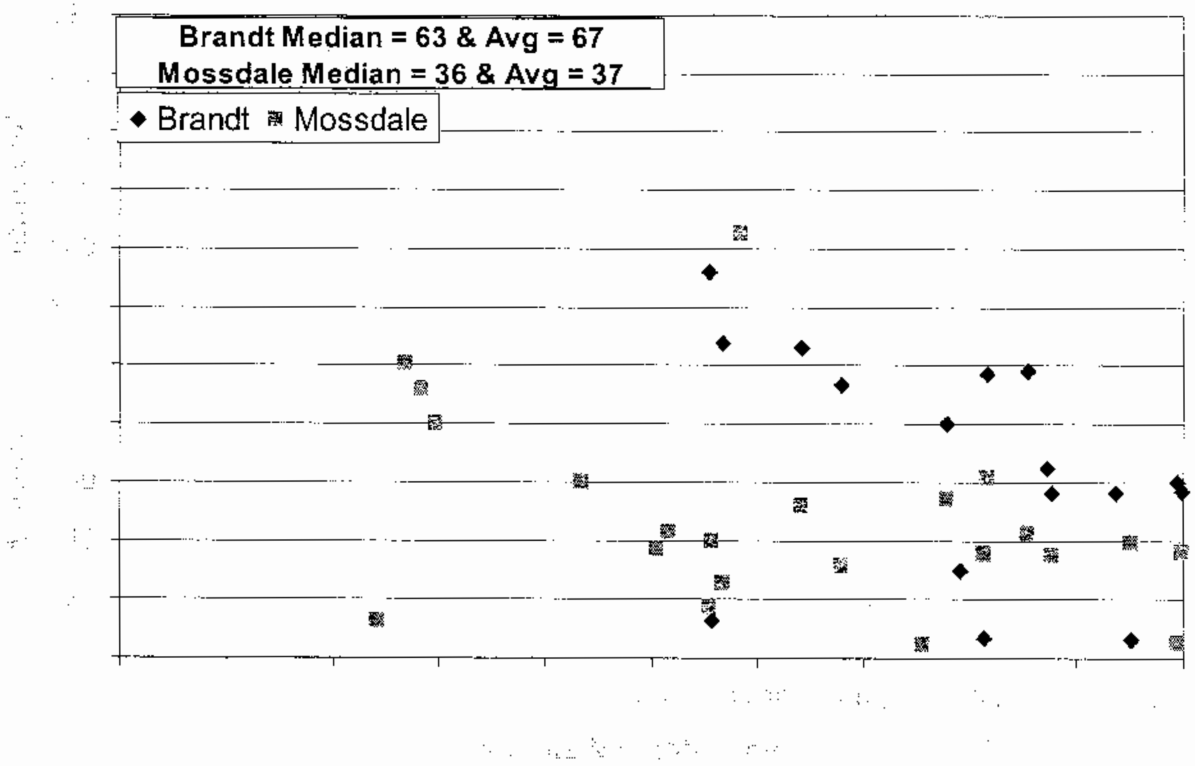
Public Law 108-361

Sec. 103 (d) (2)

(D) PROGRAM TO MEET STANDARDS.-- (i) IN GENERAL.--Prior to increasing export limits from the Delta for the purposes of conveying water to south-of-Delta Central Valley Project contractors or increasing deliveries through an intertie, the Secretary shall, not later than 1 year after the date of enactment of this Act, in consultation with the Governor, develop and initiate implementation of a program to meet all existing water quality standards and objectives for which the Central Valley Project has responsibility. (ii) MEASURES.--In developing and implementing the program, the Secretary shall include, to the max- imum extent feasible, the measures described in clauses (iii) through (vii). (iii) RECIRCULATION PROGRAM.--The Secretary shall incorporate into the program a recirculation pro- gram to provide flow, reduce salinity concentrations in the San Joaquin River, and reduce the reliance on the New Melones Reservoir for meeting water quality and fishery flow objectives through the use of excess capacity in export pumping and conveyance facilities.

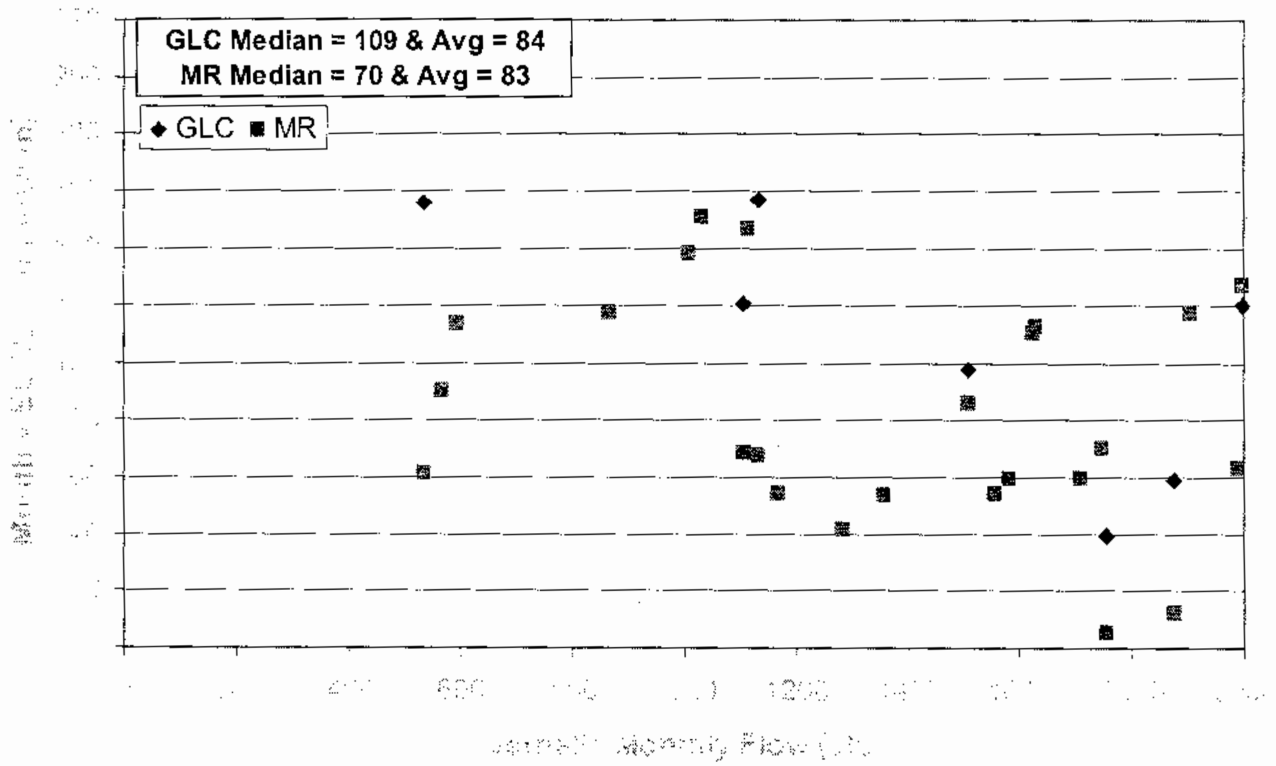
Attachment "E"

Monthly EC Diff (Brandt/Mossdale – Vernalis) When Vernalis Flow < 2000 cfs During 1987-1997 (June-August)

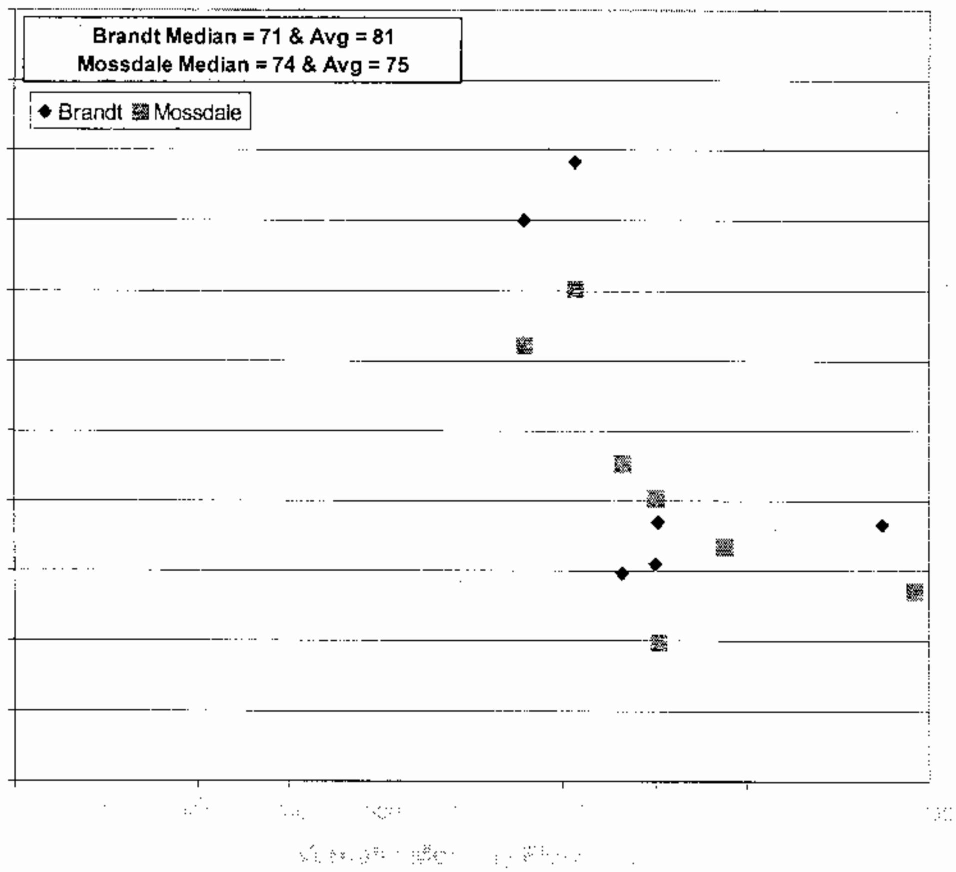


Attachment "F"

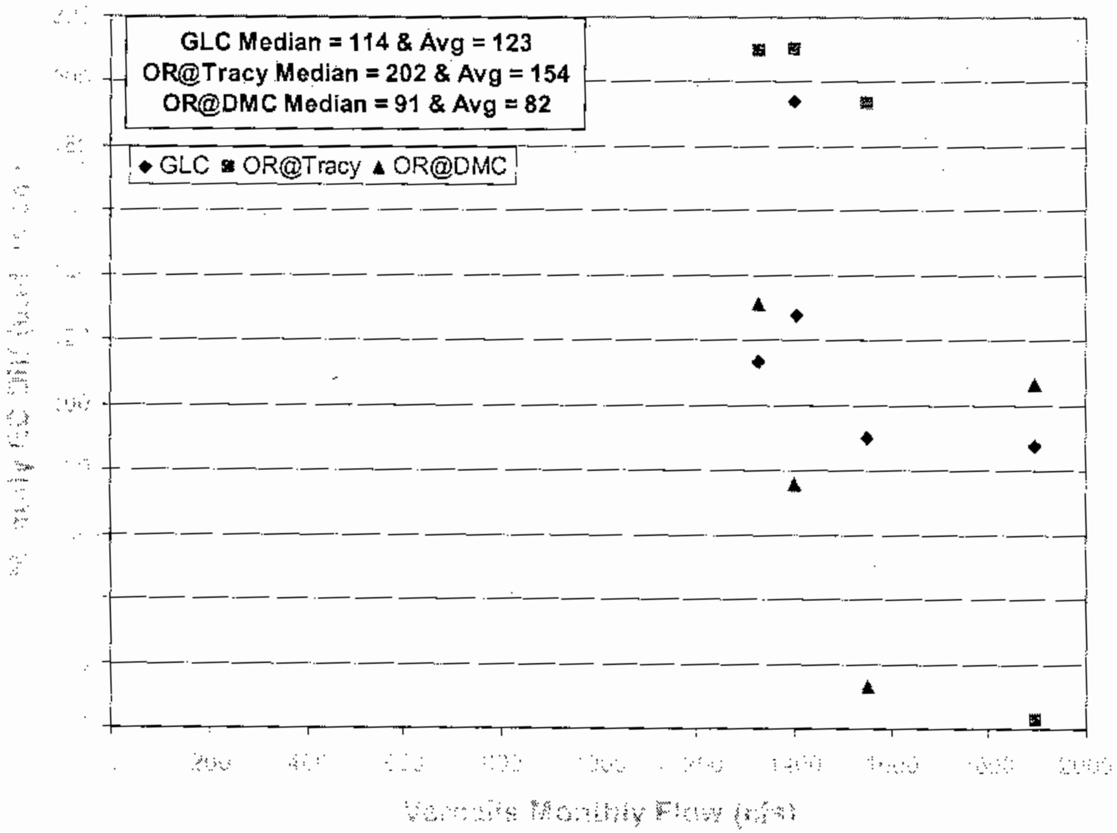
Monthly EC Diff (GLC/MR – Vernalis) When Vernalis Flow < 2000 cfs During 1987-1997 (June-August)



Monthly EC Diff (Brandt/Mossdale – Vernalis) When Vernalis Flow < 2000 cfs During 1999-2002 (June-August)



Monthly EC Diff (GLC/OR@Tracy/OR@DMC – Vernalis) When Vernalis Flow < 2000 cfs During 1999-2002 (June-August)



Subj: **Re: New Melones**
Date: 9/22/2005 8:24:50 A.M. Pacific Standard Time
From: EKITECK@mp.usbr.gov
To: Jherrlaw@aol.com

Hello John,

The final allocation for Vernalis water quality (in June) according to the IOP was 180,000 ac-ft. Thus far there have been no releases this year for salinity.

Elizabeth

>>> <Jherrlaw@aol.com> 9/21/2005 3:49:02 PM >>>
Dear Elizabeth:

Can you give me the current figures for amounts of water allocated
for
water quality (salinity) and the amounts actually used this year
from/in Mew
Melones? Thanks, JOHN

John Herrick, Esq.
4255 Pacific Avenue, Suite 2
Stockton, CA 95207
(209) 956-0150
(209) 956-0154 Fax

Attachment "G"

RECLAMATION
Managing Water in the West

Recirculation Pilot Study Final Report

Stanislaus County, California
Mid-Pacific Region

Recirculation Pilot Study Attachment "H"

Final Report

Stanislaus County, California
Mid-Pacific Region

prepared by

Division of Planning

Delta and Integrated Resource Planning Branch

Sharon McHale, AICP, Project Manager
Erika Kegel, P.E., Civil Engineer

Decision Analysis Branch

Gene Lee, Water Quality Specialist

Central Valley Operations Office

Water Operations Division

Paul Fujitani, Chief
Peggy Manza, P.E., Hydraulic Engineer

South-Central California Area Office

M. Chris Eacock, Natural Resource Specialist

As with TSS, it is unknown from the study if the turbidity level exiting the Wasteway would have decreased to the level of the upstream site given a longer period of time for the sediment to flush out. Methods should be considered that reduce sediment mobilization in the Wasteway, and therefore turbidity impacts to the River, if recirculation is going to be evaluated further.

Dissolved Oxygen

The CVRWQCB basin plan lists 5.0 mg/L as the most stringent objective for dissolved oxygen (DO). DO concentration of the DMC water entering the Wasteway hovered around 8 mg/L. Water exiting the Wasteway during the initial flush dropped below 5 mg/L, and then rose to a concentration around 7 mg/L. Levels in the lower River did not drop below the 5 mg/L water quality goal, but the addition of the recirculated water from the Wasteway decreased the average DO concentration in the River from 8.3 mg/L at the upstream site to 7.7 mg/L at the downstream site.

Water Quality Monitoring Summary

Analysis of the data shows that implementation of the recirculation pilot study impacted the River water quality for the following parameters: aluminum, metolachlor, TKN, total phosphorus, ammonia as nitrogen, TOC, TSS, DO, and turbidity. In assessing the data for the above parameters, a declining trend in concentration over the course of the pilot study was noted with the exception of aluminum, TSS, and turbidity. The initial elevated levels shown for these chemical constituents were the result of the first flush effect caused by the mobilization of accumulated agricultural drainage, channel bottom sediments, and vegetation in the Newman Wasteway.

For the three parameters that were elevated due to the discharge of CVP water, none exceeded the most stringent water quality standards. TSS and turbidity effects attributable to recirculation were expected and could be reduced through design and structural improvements and/or operation of the Wasteway. The elevated aluminum levels may be the result of analytical matrix problems and will be investigated further.

Flow and Salinity Data

In addition to the data collected by the study team in the vicinity of the Newman Wasteway, flow and salinity data from existing gauges along the River were also downloaded from the CDEC website. This data was analyzed to quantify the impact of the study on the River at the Wasteway, as well as determine if the impacts were measurable at downstream monitoring stations.

Analysis of flow data

The flow data plotted in Figure 11 shows an abrupt increase in flow in the River at Newman (NEW) about 12 hours into the study, and about 24 hours at the Patterson (SJP) gauge. Both stations show an abrupt spike in flow which peaked at a little over 600 cfs at both stations (located about 14 miles apart). The 250 cfs flow introduced from the Wasteway was diminished in amplitude to about 200 cfs when the pulse reached the Newman gauging station then increased to the full 250 cfs about 48 hours into the study. The pulse was only 150 cfs when it reached the Patterson gauging station about 12 hours later, then increased to 200 cfs about 72 hours into the study. Since the Fremont Ford and Mud Slough gauges showed stable flows for the first week of the pilot study, the increased flow in the River can be attributed to the discharge from the Newman Wasteway.

Mud Slough (MSG) and San Joaquin River at Fremont Ford (FFB) are the main sources of water upstream of the Wasteway. Fremont Ford diminished from 150 cfs to about 100 cfs after the first week (160 hours) of the pilot study. Newman flows were reduced from 600 cfs to 500 cfs at about the same time – the Patterson gauge showed flow diminishing by the same amount, although starting at about day 4 (100 hours) after onset of the pilot study. The greater flow decrease at Patterson as compared to flow at Fremont Ford can be attributed to the decreased tributary inflow from the Merced River (see Figure 12). The Merced River diminished from 100 cfs to about 50 cfs after the first week (144 hours) of the pilot study.

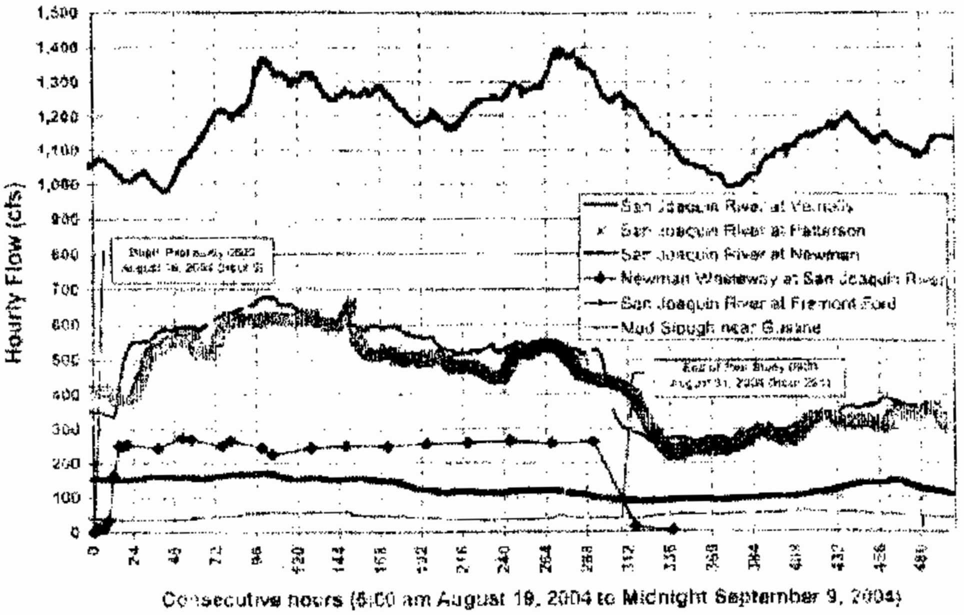


Figure 11. Analysis of San Joaquin River and main tributary flow data.

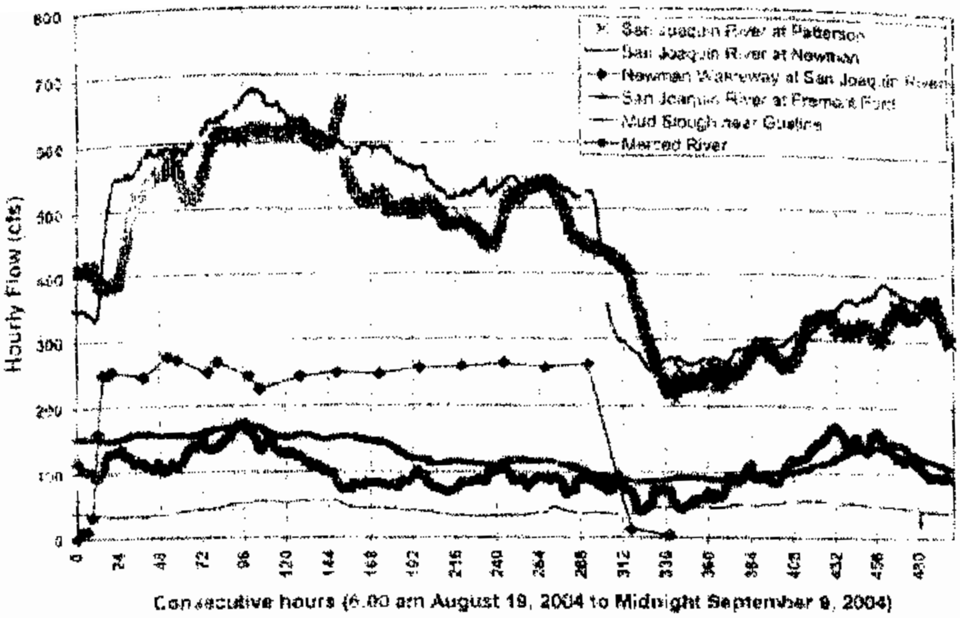


Figure 12. San Joaquin River tributary flow data.

Because there are no major tributaries between the Newman and Patterson gauges, the flow records should be very similar. However, the Patterson gauge data does not document as high of an initial increase from recirculation flow as that recorded at the Newman gauge. That muted response coincided with an increase in diversion by West Stanislaus Irrigation District commencing 20 hours into the pilot study. In contrast, diversion by the Patterson Irrigation District remained quite static at about 125 cfs throughout the pilot study (see Figure 13). Other variations in the Patterson gauge data can be attributed to ungauged surface drain inflows, seepage losses, and late season riparian diversions along the reach between the Newman and Patterson gauges. Because the recirculation pilot study was not designed to monitor all inflows to and diversions from the River, quantification of these flows was not possible.

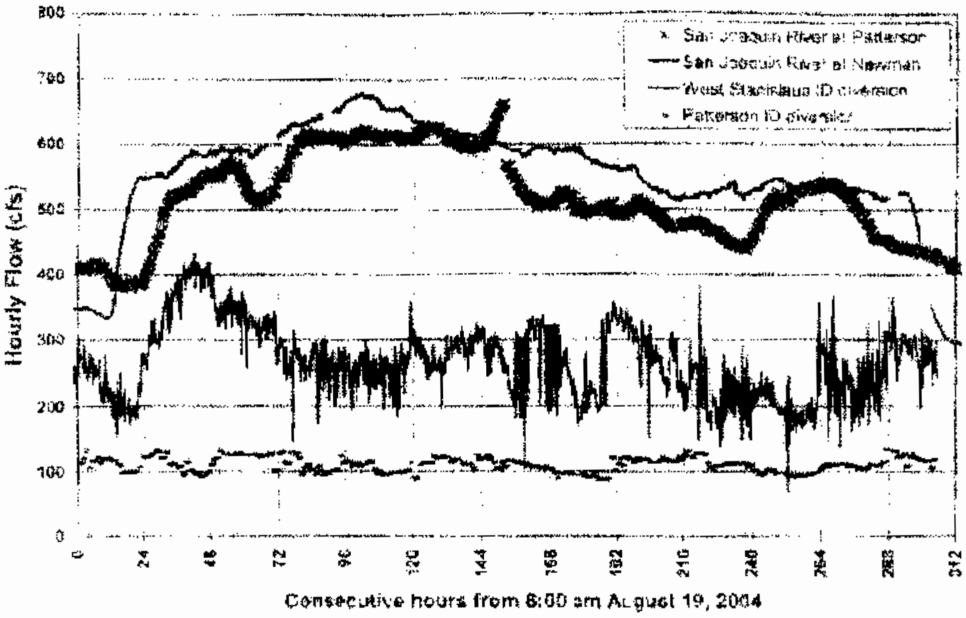


Figure 13. Effect of riparian diversion at Patterson ID and West Stanislaus ID on flow at San Joaquin River at Patterson.

Analysis of electrical conductivity data

D-1641 established a San Joaquin River agricultural salinity objective of 1000 μS/cm between April and August and 700 μS/cm between September and March to be met at Vernalis. Evaluation of the impact of recirculation on salinity, as measured by electrical conductivity (EC), was an objective of the pilot study.

In Figure 14 the displacement of salt in the Wasteway begins about 17:30, eleven and a half hours after the initial release of water into the Wasteway, and continues until about 7:00 the next morning after which time the Wasteway EC takes the characteristic signal of the diverted DMC water.

Interpretation of the EC data is more complex than the flow data on the San Joaquin River. Upon initial observation, the data does not exhibit the inverse relationship between flow and salt concentration expected at the San Joaquin River stations. In the case of the Patterson monitoring site, about 36 hours into the study the EC dropped from approximately 1200 μS/cm to less than 900 μS/cm until the seventh day of the pilot study after which the EC steadily climbed (see Figure 15). The EC increase can be attributed to upstream salinity changes. As shown in Figure 15, the EC concentration upstream of the Wasteway at Fremont Ford was stable near 1150 μS/cm for the first three days of the pilot study, then increased to 1600 μS/cm between day 6 and end of the study (after 290 hours). This 50% EC increase correlated with an approximate 50% reduction in flow during the same period, thus the salt load remained about the same.

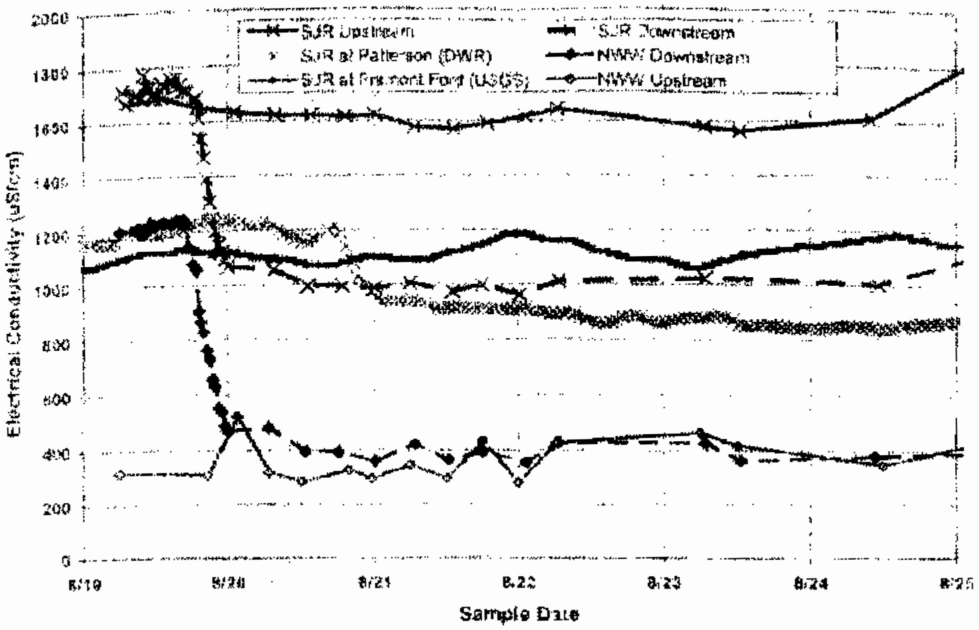


Figure 14. Effect of Recirculation on EC after 6 days (144 hours) at various main stem river sites as well as upstream and downstream sites along the Newman Wasteway

The Vernalis EC data showed a lagged response to the recirculated flow. The reduction in EC from about 700 μS/cm to 600 μS/cm occurred approximately 48 hours after the flow pulse was first evident at the Patterson gauging station. Similar to the trend at Patterson, after the initial drop around hour 72 the EC at Vernalis slowly increased during the 291 hour study period and was about 650 μS/cm at the end of the pilot study.

Initially it was thought that the drop in EC at Vernalis was not as great as might be expected given the reduction at Patterson. After analyzing the EC response with respect to the relative flow contribution from recirculation, the observed drop in Vernalis EC was found to be consistent. The flow at Patterson was only 400 cfs prior to arrival of the 200 cfs recirculation pulse, which provided a 50% increase in flow. The recirculated flow only increased the flow at Vernalis by 20%, from 1000 to 1200 cfs. From such a small increase in the flow at Vernalis one would expect the observed modest reduction in EC.

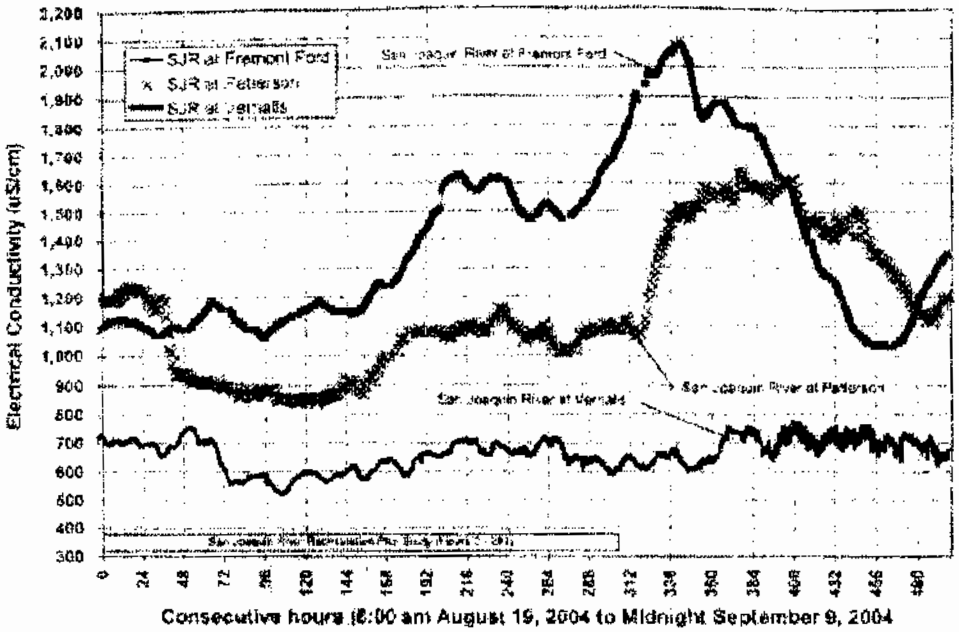


Figure 15. Effect of recirculation on EC after 21 days at various main stem San Joaquin River sites.

Figure 10 shows steady flows in Mud Slough and in the River passing Fremont Ford during the pilot study. These sites represent upstream or baseline conditions in the River and Grasslands Basin. Figure 14 shows an abrupt rise in salinity at Fremont Ford during the study that may have been caused by flushing out the refuges in preparation for the new season. The rise in salinity was diminished by the pilot study flow (reduced 500 uS/cm @ hour 240). This data shows a clear benefit of recirculation.

Findings and Conclusions

Water Quality Assessment

The pilot study showed clearly that recirculated flow through the Newman Wasteway was effective in increasing flow and reducing the EC concentration at Vernalis. The pilot study also demonstrated agency coordination at its best; data collection was well coordinated and a complete water quality characterization of the first flush flow from the Wasteway was obtained. The analysis does suggest, however, that real-time water quality monitoring and management will be essential if recirculation is to realize savings in New Melones water quality releases. A short-term increase in riparian diversion by the West Stanislaus Irrigation District resulted in a much lower response at Vernalis than was expected during the first two days of the pilot study. It was later determined that West Stanislaus Irrigation District had increased diversions for two days and then cutback again to the conditions that existed when the pilot study was initiated. A decision to increase recirculation flows in response to the less than expected Vernalis EC would have resulted in excess dilution and water wastage as West Stanislaus Irrigation District reduced its river diversion. Therefore, real-time flow and EC monitoring data from mainstem River stations, including the major Westside tributaries and the diversions, will be essential for full implementation of any future recirculation program.

Water Supply Assessment

There were no water supply impacts to CVP contractors as a result of the pilot study. It was difficult to accurately measure the losses due to insufficient data and controls during the recirculation operation. There are several irrigation districts which have tailwater flow into the San Joaquin River which are in the process of being calibrated, and monitoring data was not available during the pilot study. In addition, data on the quantities of water diverted from the San Joaquin River by the water districts is limited beyond the data available for West Stanislaus Irrigation District and Patterson Irrigation District. Without a higher level of detail, it is difficult to determine exactly how much of the water released through the Newman Wasteway was lost to the system between the release point and Vernalis. Therefore, monitoring of recirculation water will be an essential component of any future study when, and if, another test of recirculation is performed or a full-scale recirculation program is implemented.

IMPACT OF SAN JOAQUIN RIVER QUALITY ON CROP YIELDS IN THE SOUTH DELTA

G. T. Orlob

INTRODUCTION

The agricultural productivity of lands within the South Delta Water Agency is dependent upon both the quantity of water that enters the Delta at Vernalis and its quality. It is also determined in part by the nature of soils, i.e. their permeabilities and leaching requirements to avoid excessive accumulation of salinity during the growing season. In general, fine textured soils such as those that comprise the major part of South Delta lands have lower permeabilities, and thus require higher quality of applied water to assure optimal crop growth without loss of yield.

To demonstrate the nature and dependence of agricultural productivity in the South Delta on San Joaquin River quality, it is necessary to consider the following factors:

1. Soil characteristics, i.e. permeabilities and field leaching fractions, and variability of these over the lands of the South Delta,

2. Crop yields in relation to water quality, soil characteristics, and crop type,

3. Quality of water available in South Delta channels during the growing season, and

4. Cropping pattern and crop value for the South Delta.

Attachment "I"

Combining these factors in a quantitative framework results in estimates of the sensitivity of the South Delta area to water quality at Vernalis.

SOIL CHARACTERISTICS

Soils of the South Delta, identified in the most recent soil survey of the area, have been organized into five groups according to field permeabilities. These are depicted on the general soil map for the South Delta area (SDWA Exhibit 106), and for a smaller representative area in the vicinity of Old River between the San Joaquin River and Salmon Slough (SDWA Exhibit 107). Characteristics of these soil groups, which are considered indicative of *between-field* variability in the South Delta, are given in Table 1.

Table 1. Soil Groups in the South Delta

Group	Map Color Code	Percent of area	Permeability description in/hr
A	brown	40	slow < 0.2
B	blue	34	mod. slow 0.2 - 0.6
C	yellow	17	moderate 0.6 - 2
D	green	6	mod. rapid 2 - 6
E	red	3	rapid > 6

Leaching characteristics of South Delta soils were derived from the 1976 South Delta Salinity Status Study (SDWA Exhibit 104), using observed EC_es and applied water EC_ws for 51 sites at 10 different locations. Leaching fractions (LF) were calculated for both spring and fall EC_e profiles at all sites (102 determinations) according to the relation

$$LF = \frac{EC_w}{2(EC_e)_d} \quad (1)$$

where

EC_w = electrical conductivity of applied water, mmhos/cm (dS/m)

$(EC_e)_d$ = electrical conductivity of soil solution extract at drainage horizon (assumed to be the maximum in the EC_e profiles) mmhos/cm (dS/m)

Mean leaching fractions ($\overline{LF}$) and standard deviations from the mean (σ) were determined for each location (up to 15 observations in some cases). It was found that σ ranged widely, from about 25 to 65 percent of $\overline{LF}$. An average of about one-third, i.e. $\sigma = \overline{LF}/3$, was adopted as representative of *in-field* variation in leaching during the growing season.

Soil permeabilities and leaching fractions were related to one another by identifying specific locations (Salinity Study, SDWA Exhibit 104) with permeability groups (Soil Permeability Map, SDWA Exhibit 106). Calculated LFs were plotted against permeabilities as shown in Figure 1. While some scatter is apparent, owing largely to in-field variation, there appears to be a fairly consistent relationship between permeability and leaching fraction.

In subsequent calculations, values of $\overline{LF}$ and standard deviations of the distributions shown in Figure 1 are identified with the various soils as they are actually classified for the South Delta (SDWA Exhibit 106). These values for the moderate to slow permeability soils are:

Group	$\overline{LF}$	σ
A	0.053	0.0177
B	0.093	0.0310
C	0.188	0.0627

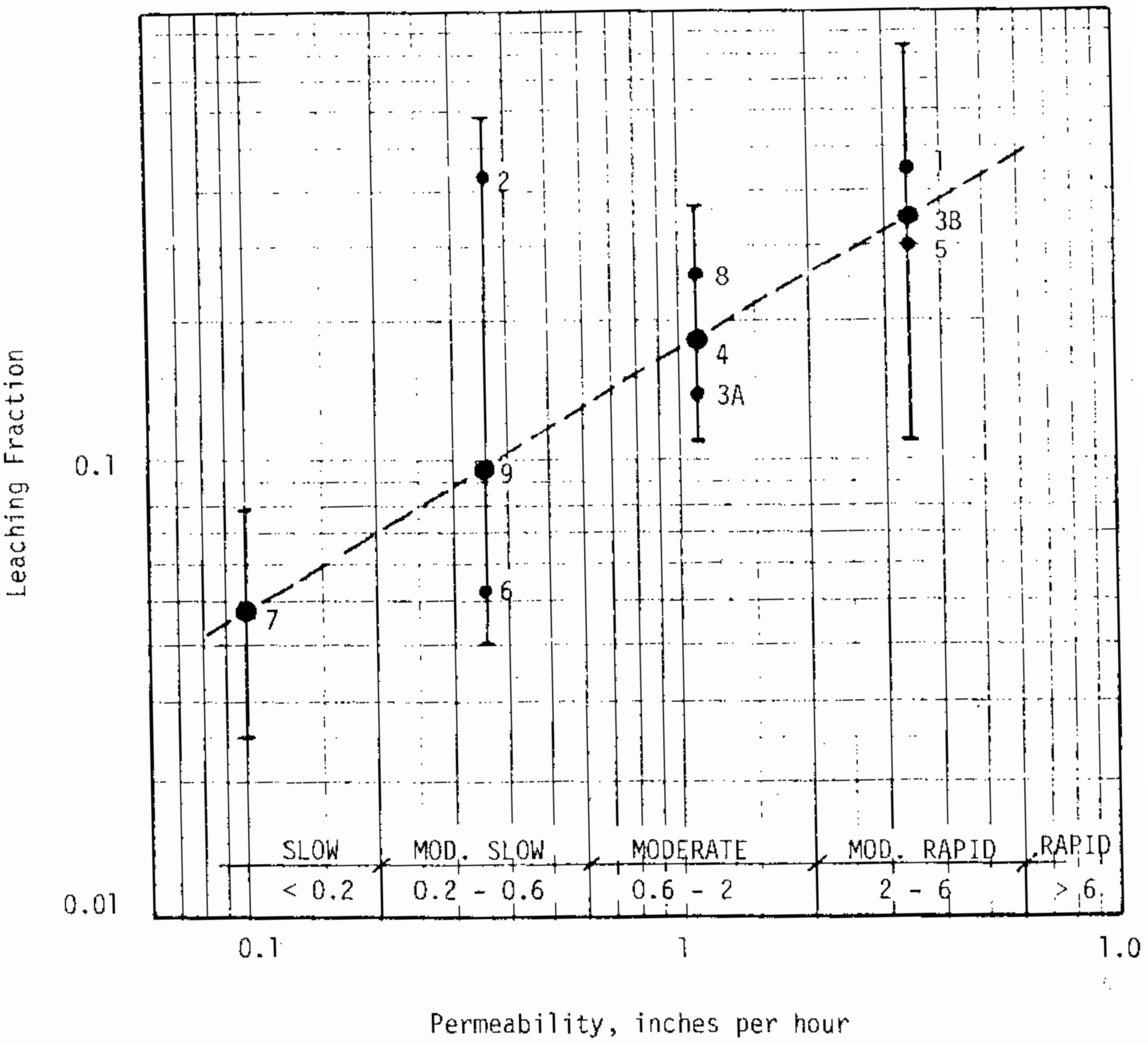


Figure 1. RELATIONSHIP BETWEEN LEACHING FRACTION AND FIELD PERMEABILITY, SOUTH DELTA SOILS

CROP YIELD VS WATER QUALITY

The relationship between yield decrement, leaching fraction, and applied water quality is given by

$$\Delta Y = S(EC_w \{ \frac{1 + LF}{5LF} \} - B) \qquad (2)$$

where

ΔY = yield decrement, percent

S = unit decrement, percent/mmho/cm

B = threshold EC_e, mmhos/cm

and other terms are as previously defined. Values of S and B for various crops are found in FAO Irrigation and Drainage Paper 29 as revised (SDWA Exhibit 105) and were supplemented by the Water Quality Advisory Panel for the South Delta Salinity Status Study (SDWA Exhibit 103).

The yield decrement for a field with variable LF is determined by combining equation (2) with the probability density function for LF and integrating from 0 to LF_c, a fraction above which no decrement in yield occurs.

$$\Delta Y = \int_0^{LF_c} S \left[EC_w \{\frac{1 + LF}{5\ LF}\} - B \right] \frac{\exp}{\sigma\sqrt{2\Pi}} \left(- \frac{1}{2} \frac{(LF-\overline{LF})^2}{\sigma^2} \right) dLF \qquad (3)$$

where all terms are as previously defined.

A yield decrement--quality relationship for a particular soil, e.g. Group A, is obtained by carrying out the integration of equation (3) over the range of EC_w that is of interest. In the case of the South Delta, this was 0.7 to 1.3 mmhos/cm, corresponding to a range of TDS of roughly 450 to 825 mg/L. The properties of the soil are given by $\overline{LF}$ and σ and the susceptibility of the crop by S and B. Representative yield decrement--quality relationships used in this study are summarized for the six most sensitive crops and the three soil groups in Table 2.

Table 2. Yield Decrement at Function of Water Quality, Soil Type, and Crop

	Yield Decrement, Δy, percent					
EC_w,dS/m	Beans	Corn	Alfalfa	Tomatoes	Fruit & Nuts	Grapes
			Soil Group A, $\overline{LF}$ = 0.053, σ = 0.0177			
0.4	19	4	-	-	10	3
0.7	42	18	9	8	34	16
1.0	68	34	19	21	61	29
			Soil Group B, $\overline{LF}$ = 0.093, σ = 0.0310			
0.4	6	-	-	-	2	-
0.7	18	4	2	2	10	4
1.0	33	12	6	4	24	12
			Soil Group C, $\overline{LF}$ = 0.188, σ = 0.0627			
0.4	-	-	-	-	-	-
0.7	3	1	-	-	2	-
1.0	9	2	1	1	4	2

REVENUE LOSS DUE TO QUALITY DEGRADATION

The dollar value of potential crop losses for a given water quality and soil is estimated from the known acreage of specific crops, the market value per acre, and the decrement calculated by equation (3), and is given by

$$C_T = \frac{1}{100} \sum_{i=1}^{n} \sum_{j=1}^{m} A_{ij}\, c_{ij}\, \Delta Y_{ij} \qquad (4)$$

where

C_T = total potential loss, $

A = area, acres

c = value of crop, $/acre

ΔY = yield decrement, percent

i = crop, 1 to n

j = soil group, 1 to m

A representative cropping pattern for the South Delta Water Agency, i.e. values of A_{ij}, is derived from a survey of the San Joaquin County Agricultural Department for the period 1971-1975. Typical unit values of crops, i.e. values of C_{ij}, were derived from the 1980 San Joaquin Agricultural Report. These data are summarized in Table 3.

Table 3. Cropping Pattern for the South Delta Water Agency

Crop	Percent of total area	Area acres	Crop Value \$/acre[1]
Beans	8	9,840	656
Corn	9	11,070	563
Alfalfa	26	31,980	732
Tomatoes	14	17,220	2110
Fruit and Nuts	5	6,150	2154[2]
Grapes	0.8	1,000	1358
Grains	16	19,680	426
Asparagus	7	8,610	1434
Sugar beets	10	12,300	1235
Other	4.2	5,150	-
Total	100	123,000	

Source: San Joaquin County Agricultural Department survey data within the SDWA for the 1971-75 period

[1]1980 values

[2]average of peaches and walnuts

CASE STUDY EXAMPLE

To illustrate the application of the procedure for estimation of potential crop losses due to water quality degradation, two scenarios are considered.

1. Actual conditions of water quality prevailing in the South Delta during 1976, and

2. 1976 conditions modified by the assumption of New Melones Project operation to maintain 500 mg/L TDS at Vernalis.

The procedure entails the following steps:

a. Simulation of hydrodynamics and water quality for the South Delta for the agricultural season, using the mathematical models of the estuarial system (SDWA Exhibit 82),

b. Estimation of the average quality of water supplied to each of 10 subareas of the South Delta, as identified in Figure 2,

c. Calculation of the yield decrement ΔY expected for each soil type (3), crop (6), and subarea(10) by application of Equation 3.

d. Summation of incremental costs due to loss of yield, by application of Equation 4,

e. Comparison of cost differences attributed to water quality control by New Melones.

Results of water quality simulations are presented in Figures 3 and 4. Conditions shown are for mid-July, considered to be representative of the quality of water available at the peak of the irrigation season. From the results of the two simulations, the average quality of water available to the 10 subareas may be estimated as that of the most accessible channel serving the area. These are summarized in Table 4.

Yield decrements were estimated from the relationships summarized in Table 2. These were then weighted by subarea and soil group in relation to the entire SDWA area, and summed to obtain the aggregate decrement for each crop type. These were then applied to the total value of the crop to obtain the decrement in revenue. Table 5 summarizes the calculations.

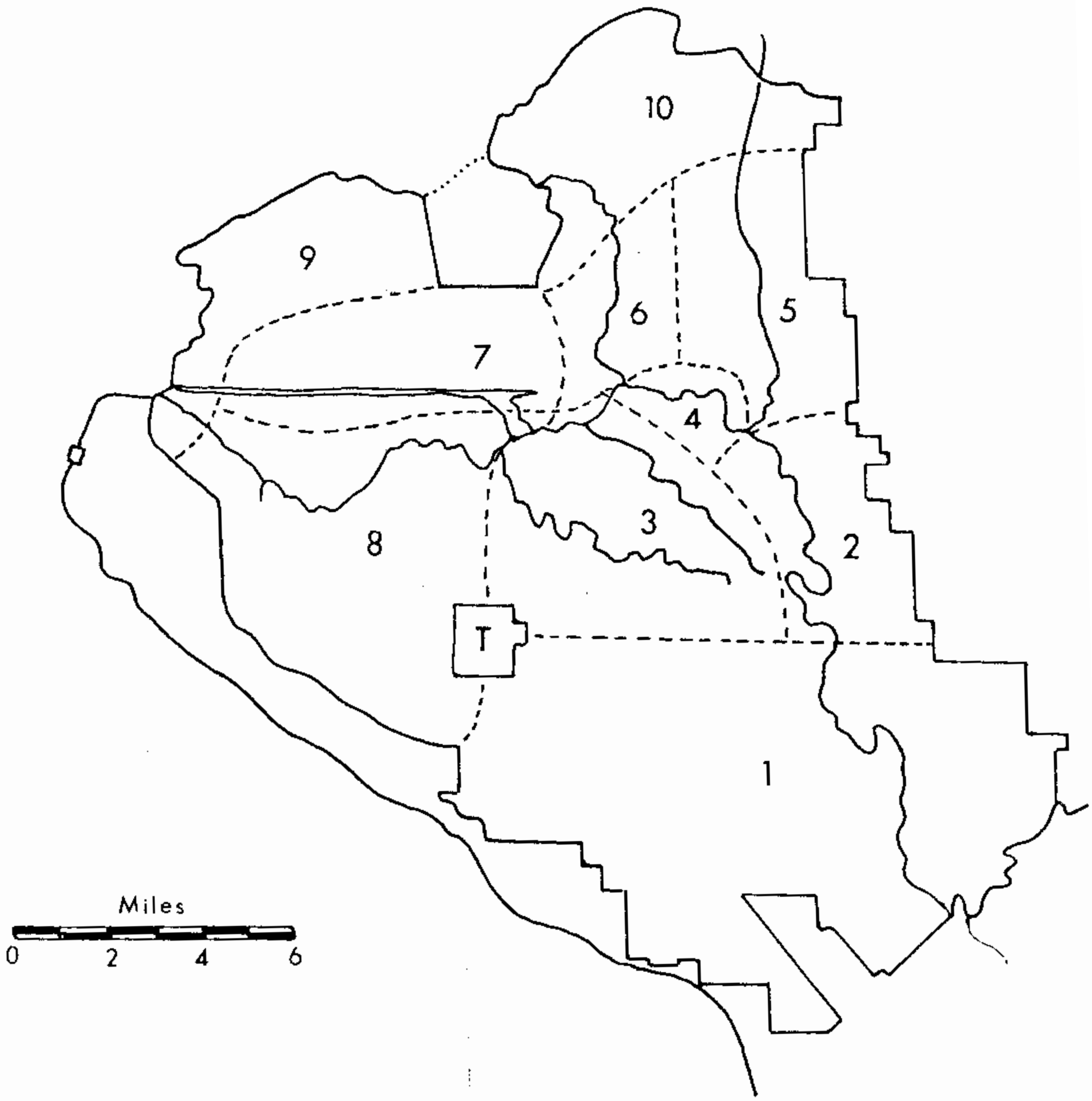


Figure 2. AGRICULTURAL SUBAREAS, SOUTH DELTA WATER AGENCY

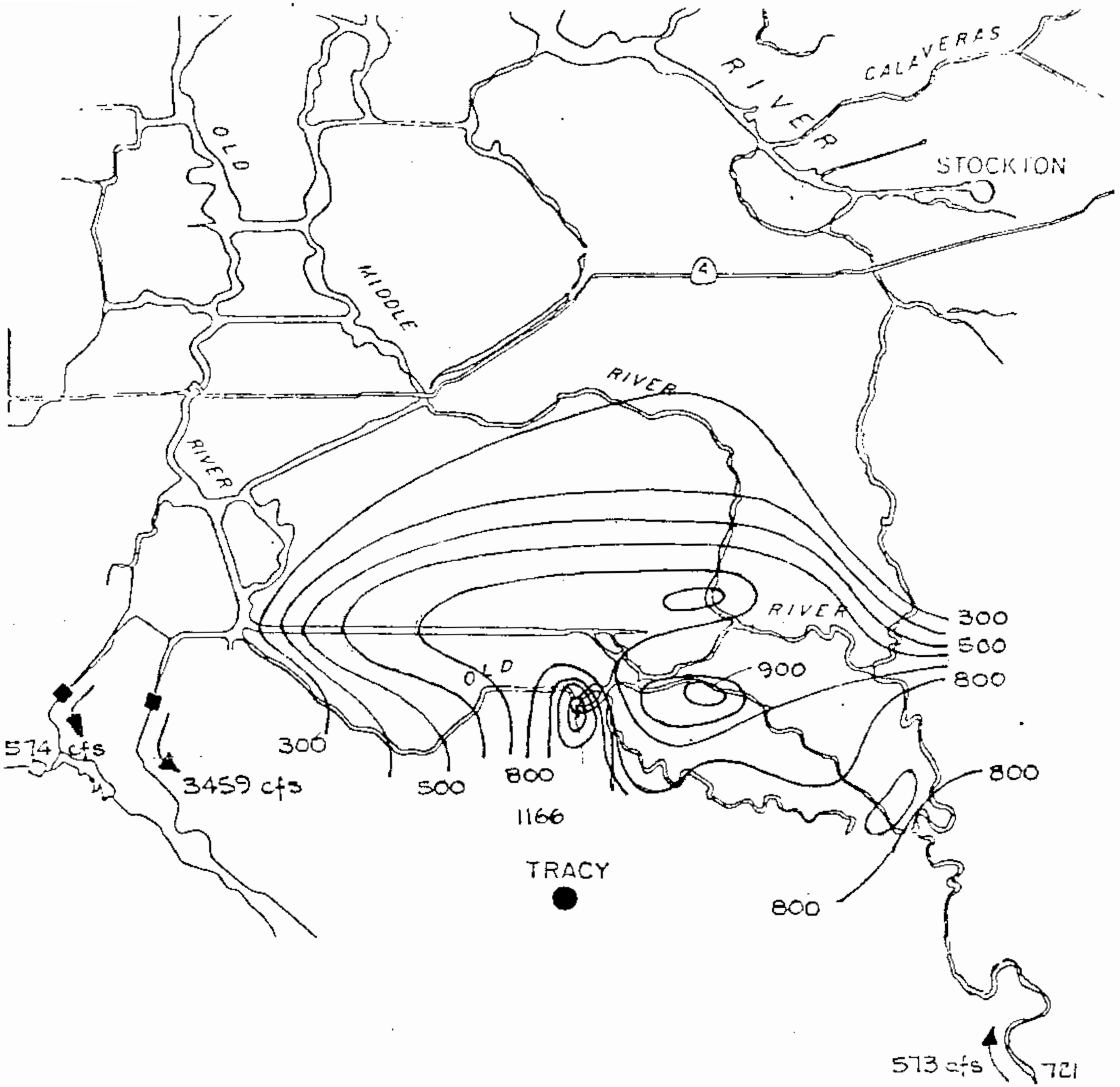


Figure 3. SIMULATED WATER QUALITY IN SOUTH DELTA CHANNELS, MID-JULY 1976, ACTUAL HYDROLOGY
(Contours are of equal TDS, mg/L)

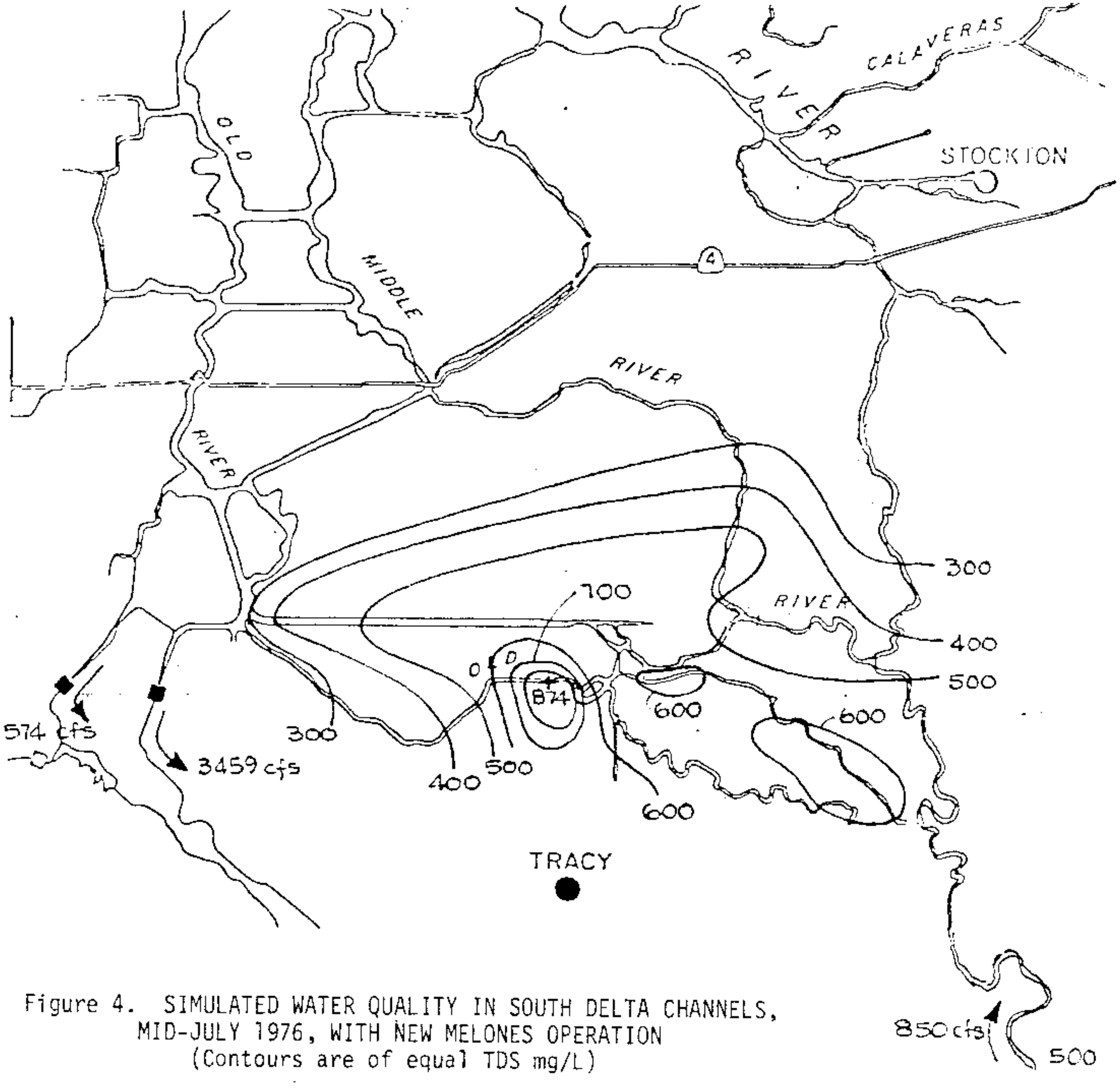


Figure 4. SIMULATED WATER QUALITY IN SOUTH DELTA CHANNELS, MID-JULY 1976, WITH NEW MELONES OPERATION
(Contours are of equal TDS mg/L)

Table 4. Comparison of Crop Loss for 1976 Conditions in South Delta With and Without New Melones Water Quality, Mid-July (Day 195)

Subarea	1976		1976 w/N.M.	
	TDS	EC*	TDS	EC*
1	753	1.19	496	0.77
2	812	1.28	492	0.76
3	777	1.22	559	0.87
4	675	1.06	487	0.77
5	244	0.36	264	0.40
6	684	1.07	486	0.75
7	710	1.12	521	0.81
8	673	1.06	575	0.90
9	227	0.34	226	0.34
10	297	0.45	282	0.43

* EC = (TDS - 18)/620, mmhos/cm

DISCUSSION

Results of this case study illustrate the potential impacts of water quality degradation on the agricultural productivity of lands within the South Delta Water Agency. These impacts are likely to be most severe in areas served by channels in which circulation is not sufficient for unidirectional transport of salt loads entering the Delta at Vernalis. Such was the case in 1976, the case investigated. It is noted that while the area is estimated to have suffered a substantial loss of productivity in this period--as much as 18 percent of the value of salt sensitive crops--this loss could be diminished by improving quality and flow at the upstream boundary at Vernalis. The apparent loss with New Melones operation, i.e. with a maximum TDS of 500 mg/L maintained by releases from the reservoir, would have been reduced by about one half, to roughly 10 percent of the total value of salt sensitive crops.

Table 5. Estimated Loss of Crop Revenue Due to Water Quality Degradation, Case Study: 1976 and 1976 With New Melones Operation

Crop	Area[1]	Unit Value[2]	Mkt. Value	Loss of Crop Revenue, 10^6 \$ — Actual 1976 $\Delta Y/100$	Actual 1976 ΔC	1976 w/N.Melones $\Delta Y/100$	1976 w/N.Melones ΔC
	acres	\$/acre	10^6 \$		\$		\$
Beans	9,840	656	6.46	0.406	2.62	0.331	2.14
Corn	11,070	563	6.23	0.201	1.25	0.105	0.65
Alfalfa	31,980	732	23.41	0.102	2.81	0.051	1.19
Tomatoes	17,220	2110	36.33	0.111	4.03	0.052	1.89
Fruit & Nuts	6,150	2154	13.25	0.359	4.76	0.199	2.64
Grapes	1,000	1358	1.36	0.169	0.23	0.093	0.13
TOTALS	72,260[3]		87.04		15.70		8.64

[1] 1971-75 average

[2] 1980 San Joaquin County Agriculture Department

[3] Does not include 50,740 acres of salt tolerant crops

It should be noted, however, that the presumption that the target quality could be assured by New Melones releases is conditioned by the availability of water in storage for quality control. In some years, the entire volume allocated for this purpose may be released before the critical period of crop growth, as early as mid-April in the case of 1987. With the expectation of increased yield of salinity from the San Joaquin Basin, it will be increasingly difficult to achieve quality control at Vernalis, and in the South Delta, under the present mode of operation and with the current limitations imposed on storage for water quality control.

Another important factor which is illuminated by this example is the increased sensitivity of crops to damage when they are grown in soils of only moderate permeability, less than necessary to achieve optimum leaching during irrigation. A high proportion of South Delta soils are of this type; more than a third are classified as having "slow" permeabilities, less than 0.2 inches per hour. These soils have inherently poor leaching characteristics, with leaching fractions averaging 10 percent or less. Moreover, the wide variability in permeabilities in South Delta soils, over the entire area and even within the same field, exacerbates the leaching problem. Significant fractions of an irrigated area may be comparatively less permeable than the average, requiring higher quality water to avoid potential crop damage due to salinization in sensitive zones.

In summary, soils of the South Delta are found to be more sensitive than normal because of their lower average permeabilities and natural heterogeneity. Crops normally grown in the area are impacted adversely when water quality is not sufficient to preclude buildup of salinity in the soil profile during the irrigation season. Obvious solutions to this problem lie in enhanced water quality in South Delta channels and reductions in the salt load carried into the estuary by the San Joaquin River.

State Water Resources Control Board
DIVISION OF WATER RIGHTS
P.O. Box 2000 SACRAMENTO, CA 95812-2000
901 P STREET, SACRAMENTO, CA
(916) 657-1364 FAX: (916) 657-1485

A 0 1 9 1 9 4

REPORT OF LICENSEE FOR

1994, 1995, 1996

OWNER OF RECORD: BARBARA F. HILDEBRAND, ALEXANDER HILDEBRAND

APPLICATION: A019194

LICENSE: 007144

ALEXANDER HILDEBRAND
23443 SOUTH HAYS ROAD
MANTECA, CA 95336

TELEPHONE NUMBER:
(209) 823-4166

IF OWNER'S NAME/ADDRESS/PHONE NO. IS WRONG OR MISSING, PLEASE CORRECT.

SOURCE:		COUNTY:
SAN JOAQUIN RIVER		SAN JOAQUIN
PURPOSE:	**DIVERSION/STORAGE SEASON:**	**ACRES/HP:**
IRRIGATION	MAY 01 TO NOV 01 ✓	40 AC
STOCKWATERING	MAY 01 TO NOV 01 ✓	0 AC

AMOUNT: 0.5 CFS 0 AC-FT

THIS REPORT IS REQUIRED BY THE TERMS AND CONDITIONS OF YOUR LICENSE

IMPORTANT: EVERY license is subject to the conditions therein. I have currently reviewed my license: YES [✓] NO [ ]. I am complying with the conditions of my license: YES [✓] NO [ ]. Identify any noncompliance by license term number under "Remarks" on reverse side. This report is important in providing the record of use needed in maintaining your water right. It should be filled out carefully and returned promptly to the above-listed address.

THE PROJECT HAS BEEN ABANDONED, AND I REQUEST REVOCATION OF THE LICENSE: YES [ ].

COMPLETE FOR DIRECT DIVERSION PROJECTS

1. Have you used the full licensed amount of water each year? YES [✓] NO [ ]
2. State the quantity of water used each month in gallons or acre-feet (if not known, check months water was used).

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
1994			✓		✓	✓	✓		✓				
1995			Flood		✓	✓	✓	✓	✓	✓			
1996				✓	✓	✓	✓	✓					

COMPLETE FOR STORAGE PROJECTS

	1994	1995	1996
3. Did your reservoir spill this year?			
4. If not, how many feet below spillway vertically was the water level at maximum storage?			
5. Have you emptied the reservoir?			
6. How many feet below spillway vertically was it drawn down at end of season?			

(Continued on reverse side)

1996

State Water Resources Control Board
Bay-Delta Hearings Application No. 5626
PARTICIPANT:
EXHIBIT: SDWA 061
INTRODUCED: 6/24/99
ACCEPTED IN EVIDENCE (YES) NO
DATE 6/24/99

Attachment "J"

State Water Resources Control Board
DIVISION OF WATER RIGHTS
P.O. Box 2000 SACRAMENTO, CA 95812-2000
501 P STREET, SACRAMENTO, CA
(916) 657-1364 FAX: (916) 657-1485

A 0 1 7 9 5 0

REPORT OF LICENSEE FOR

1994, 1995, 1996

OWNER OF RECORD: BARBARA F HILDEBRAND, ALEXANDER HILDEBRAND

APPLICATION: A017950

ALEXANDER HILDEBRAND
23443 SOUTH HAYS ROAD
MANTECA, CA 95336

LICENSE: 007143

TELEPHONE NUMBER:
(209) 823-4166

IF OWNER'S NAME/ADDRESS/PHONE NO. IS WRONG OR MISSING, PLEASE CORRECT.

SOURCE: SAN JOAQUIN RIVER

COUNTY: SAN JOAQUIN

PURPOSE:	DIVERSION/STORAGE SEASON:	ACRES/HP:
STOCKWATERING	APR 01 TO NOV 01 /	0 AC
IRRIGATION	APR 01 TO NOV 01 /	24 AC

AMOUNT: 0.3 CFS 0 AC-FT

THIS REPORT IS REQUIRED BY THE TERMS AND CONDITIONS OF YOUR LICENSE

IMPORTANT! EVERY license is subject to the conditions therein. I have currently reviewed my license: YES [ ] NO [ ]. I am complying with the conditions of my license: YES [ ] NO [ ]. Identify any noncompliance by license term number under "Remarks" on reverse side. This report is important in providing the record of use needed in maintaining your water right. It should be filled out carefully and returned promptly to the above-listed address.

THE PROJECT HAS BEEN ABANDONED, AND I REQUEST REVOCATION OF THE LICENSE: YES [ ]

COMPLETE FOR DIRECT DIVERSION PROJECTS

1. Have you used the full licensed amount of water each year? YES [✓] NO [ ]
2. State the quantity of water used each month in gallons or acre-feet (If not known, check months water was used)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
1994			✓		✓	✓	✓	✓	✓	✓			
1995			[illegible]			✓	✓	✓	✓	✓			
1996						✓	✓	✓	✓				

COMPLETE FOR STORAGE PROJECTS

	1994	1995	1996
3. Did your reservoir spill this year?			
4. If yes, how many feet below spillway vertically was the water level at maximum storage?			
5. Have you emptied the reservoir?			
6. How many feet below spillway vertically was it drawn down at end of season?			

(Continued on reverse side)

1996

TERRY L. PRICHARD

Certified Consulting Professional Agronomist and Soil Scientist and Crop Advisor

6601 South Stanley Road, Stockton, California 95215
(209) 886-5301

October 13, 2005

Mr. John Herrick
4255 Pacific Avenue, Suite 2
Stockton, CA 95207

Re: "SWRCB's Hearing on a Cease and Desist Order Against DWR and USBR."

Dear John:

As the SWRCB hears testimony and takes evidence on whether and under what conditions a Cease and Desist Order should issue, you have asked me to comment on the necessity and underlying reasons why the 0.7/1.0 EC standards were adopted."

In setting the water quality objectives for the Southern Delta an array of crops was selected. The crops represented were annual and perennial. The annual crop (beans) water use timings are early spring to mid summer where as the perennial (alfalfa) uses water for the entire growing season. Secondly, the seasonal water use is considerably different with beans at about one-half that of alfalfa. Therefore, the required leaching volume is higher in the alfalfa using the same irrigation water quality. There are also factors which can limit the amount of irrigation water application. The first is related to the stand survival. Alfalfa is sensitive to over watering conditions which can significantly reduce stands from water logging and Phytopthera root rot, ultimately reducing yield. Secondly, the number of required cultural operations such as drying down the soil to support equipment for harvest, along with the time required to to cure and bale can limit irrigation opportunities. Additionally, variation in soil permeability in the Southern Delta and the depth to groundwater can limit the achievable leaching fraction.

The South Delta contains soils with significant variation with respect to texture and structure which leads to differences in permeability. The variability in permeability exists on an area wide and field basis. This variability is pointed out in the "Water Quality Considerations for the South Delta Water Agency 1981" report showing 84 distinctly different soil series (SCS 1992). These soils vary widely in permeability and water retention levels. Adding to the difficulty to achieve the required leaching fraction is the existence of high water tables especially during the winter, which cause upward movement of salts and lack of effective leaching.

For the bulk of the summer (April 1st to August 31st) the objectives were set at 0.7 mmhos/cm EC following with the last 2 months of the irrigation season (September 1st through October) at 1.0 mmhos/cm EC. This objective resulted in the bulk of the alfalfa seasonal irrigation to be 0.7 and a small portion at 1.0 allowing for adequate leaching under most conditions.

Hence, although beans and alfalfa were selected as representative of crops needing protection from high salinity concentrations, the combination of varying soil types and limitations on application and leaching also require that a certain level of quality be maintained for many other crops. For example, although the many acres of grapes and walnuts may be able to withstand a higher salinity concentration under other conditions, the nature of the South Delta soils, water tables and management practices determines that those and other crops also need to have the current objective maintained or crop yields will decline.

Sincerely,

Terry L. Prichard, Certified Professional Soil Scientist, Agronomist, and Crop Advisor

TESTIMONY OF JERRY ROBINSON
HEARING ON PROPOSED CEASE AND DESIST ORDER TO DWR AND USBR

My name is Jerry Robinson. I am a Director of the South Delta Water Agency and am currently its President. I was raised in the Delta and have farmed there for the past 40 years.

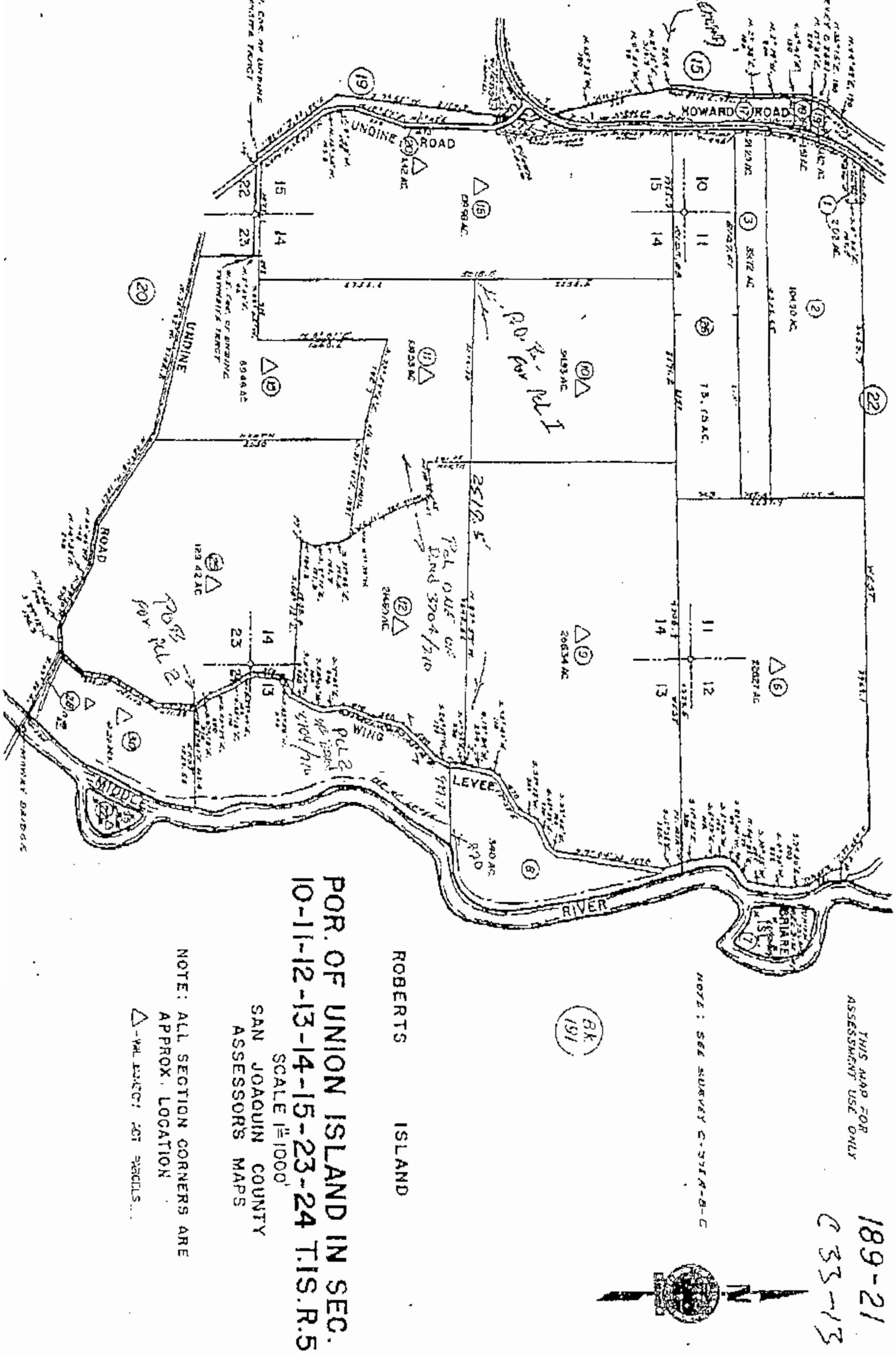
One of the farming operations in which I am involved is Lafayette Ranch, located on the eastern side of Union Island, and bordering Middle River (see Attachment “A”). This ranch diverts under License #003677 (Attachment “B” is a recent Report of Licensee for that license), although we also assert a riparian right. Lafayette Ranch currently grows tomatoes, cabbage, safflower, and in the past has grown alfalfa, wheat, and corn.

As a farmer downstream of Vernalis, we do not receive the full protection of the salinity standard at that location as water quality degrades as it travels downstream. I understand this Board first developed the 0.7/1.0 EC objective for Old River near Middle River in 1991, but that since that time, the 0.7 portion of the standard has not been enforced or applied until April of 2005.

As a long-time Director of the South Delta Water Agency, I am generally familiar with the ongoing problems of water quality, circulation, height, and quantity in the South Delta. It is my belief that after having gone this long without the necessary protection of the standards, the SWRCB should require the DWR and USBR to meet the 0.7/1.0 EC standards at the three interior South Delta stations, and not excuse or delay compliance.

Improved water quality resulting from enforcement of the standards will benefit not only me and my neighbors but provide multiple benefits to all users of Delta water.

SDWA-4



Attachment "A"

State Water Resources Control Board
DIVISION OF WATER RIGHTS
P.O. Box 2000 SACRAMENTO, CA 95812-2000
901 P STREET, SACRAMENTO, CA
(916) 657-1364 FAX: (916) 657-1485

A 0 1 1 6 9 4

REPORT OF LICENSEE FOR 1994, 1995, 1996

OWNER OF RECORD: I S ROBINSON, I NEWTON ROBINSON

APPLICATION: A011694

LICENSE: 003677

I NEWTON ROBINSON
7000 S INLAND DR
STOCKTON, CA 95206

TELEPHONE NUMBER:
(209) 466-7915

IF OWNER'S NAME/ADDRESS/PHONE NO. IS WRONG OR MISSING, PLEASE CORRECT.

SOURCE: MIDDLE RIVER

COUNTY: SAN JOAQUIN

PURPOSE:	DIVERSION/STORAGE SEASON:	ACRES/HP:
STOCKWATERING	JAN 01 TO DEC 31 /	0 AC
IRRIGATION	JAN 01 TO DEC 31 /	427.6 AC

AMOUNT: 4.5 CFS 0 AC-FT

THIS REPORT IS REQUIRED BY THE TERMS AND CONDITIONS OF YOUR LICENSE

IMPORTANT! EVERY license is subject to the conditions therein. I have currently reviewed my license: YES [X] NO [ ]. I am complying with the conditions of my license: YES [X] NO [ ]. Identify any noncompliance by license term number under "Remarks" on reverse side. This report is important in providing the record of use needed in maintaining your water right. It should be filled out carefully and returned promptly to the above-listed address.

THE PROJECT HAS BEEN ABANDONED, AND I REQUEST REVOCATION OF THE LICENSE: YES [ ].

COMPLETE FOR DIRECT DIVERSION PROJECTS

1. Have you used the full licensed amount of water each year? YES [ ] NO [X]. Sufficient rainfall.
2. State the quantity of water used each month in gallons or acre-feet (if not known, check months water was used).

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual
1994			X	X	X	X	X	X	X	X	X		
1995			X	X	X	X	X	X	X	X	X		
1996			X	X	X	X	X	X	X	X	X		

COMPLETE FOR STORAGE PROJECTS

	1994	1995	1996
3. Did your reservoir spill this year?			
4. If not, how many feet below spillway vertically was the water level at maximum storage?			
5. Have you emptied the reservoir?			
6. How many feet below spillway vertically was it drawn down at end of season?			

(Continues on reverse side)

1996

Attachment "B"

USE (COMPLETE FOR ALL PROJECTS) (see page 1 for year of use)

7. Acreage irrigated	427.5	427.5	427.5
8. Stockwatering - number of stock			
9. Domestic - number of persons			
garden area, etc.			
10. Recreational - nature of use			
11. Industrial - nature of use			
12. Municipal - approximate population			
13. Power generation - K.W.			
14. Other ______			

15. If no water was used in one or more years, briefly state the reason under "Remarks".

16. If the location of the point of diversion or place of use or type of use(s) has been changed and the permission of this Board has not yet been obtained, please describe nature of changes under "Remarks".

PLEASE ANSWER ONLY THOSE QUESTIONS BELOW WHICH ARE APPLICABLE TO YOUR PROJECT.

CONSERVATION OF WATER

17. Describe any water conservation efforts you may have started: ______

18. If credit toward beneficial use of water under this license for water not used due to a conservation effort is claimed under Section 1011 of the Water Code, please show the amounts of water conserved:
19___ ______(af/mg) 19___ ______(af/mg) 19___ ______(af/mg)

WATER QUALITY AND WASTEWATER RECLAMATION

19. Are you now or have you been using reclaimed water from a wastewater treatment facility, desalination facility or water polluted by waste to a degree which unreasonably affects such water for other beneficial uses? YES [ ] NO [X]

20. If credit toward use under this license through substitution of reclaimed water, desalinated water or polluted water in lieu of appropriated water is claimed under Section 1010 of the Water Code, please show amounts of reduced diversion and amounts of reclaimed water used: 19___ ______(af/mg) 19___ ______(af/mg) 19___ ______(af/mg)

CONJUNCTIVE USE OF SURFACE WATER AND GROUNDWATER

21. Are you now using groundwater in lieu of surface water? YES [ ] NO [X]

22. If credit toward use under this license through substitution of groundwater in lieu of appropriated water is claimed under Section 1011.5 of the Water Code, please show the amounts of groundwater used:
19___ ______(af/mg) 19___ ______(af/mg) 19___ ______(af/mg)

REMARKS: (Identify the item you are explaining. Additional pages may be attached.)

I declare under penalty of perjury that the information in this report is true to the best of my knowledge and belief:

Date:______ Sign Here: [signature] R. N. Robinson Jr.
LICENSEE (OR AGENT OR DESIGNEE)

TESTIMONY OF WILLIAM "CHIP" SALMON

My name is William Salmon. I reside at 7749 West Undine Road, Stockton, California. For the past five years I have been the manager of ABF Services, Inc. ("ABF") and I also own and lease other property in the South Delta which I farm separately.

As manager of ABF, I farm a piece of property at the east end of Grant Line Canal as indicated on Attachment "A." It is my understanding this property is riparian to both Grant Line Canal and Middle River. The crops on this property have included walnuts, grapes, beans, alfalfa, tomatoes and other row crops.

In the last few years, I have noticed an increasing and substantial damage to the crops resulting from salinity. This problem has been verified by representatives of the Ag Extension Service and by a laboratory analysis done by my fertilizer representative at John Taylor Fertilizer. Attachment "B" is a copy of the tissue analysis of the walnuts. It indicates acute chloride toxicity.

Attachments "C" and "D" are certain water quality sampling data from DWR for Middle River and Grant Line Canal, the two places from which I diverted water for this property. The Middle River data for 2002 shows EC levels in the 700 and 800 range for most of the year, especially in summer. The Grant Line Canal data (measured at Doughty Cut) shows EC in August was generally above 800 and sometimes 900. For the summer months in general, the level was most always above 700, though of course there were fluctuations. The EC objective at Vernalis for agriculture during the summer months is 700.

I have also attached some pictures as Attachment "E" which show some of the salt damage to the crops. Copies are difficult to view, but they do show the burned margins of the leaves and arrested growth associated with the salt damage.

The data for the damages in 2002 are as follows. The 105 acres of walnuts had a decrease in yield form 254,580 tons in 1999 to 105,380 in 2002 for the Payne variety and 85,420 tons in 1999 to 33,440 tons for the Westside variety. There was obvious leaf burn and stunted growth on the walnuts from the salts. Although the orchard would have to have been removed eventually due to a virus, it still should have had many more years of production left. However, I had to remove the orchard in 2002 because of the decrease in yield at a cost of $450 - $550 per acre which included tree removal, root removal and associated labor.

SDWA-3

The grapes are 47 acres of the Chardonnay variety. The sugar levels necessary to allow harvest for the contract I have were never reached, the grapes actually began to turn into raisins and the vines to defoliate. Although I did harvest some of them for juice, basically the entire crop was lost.

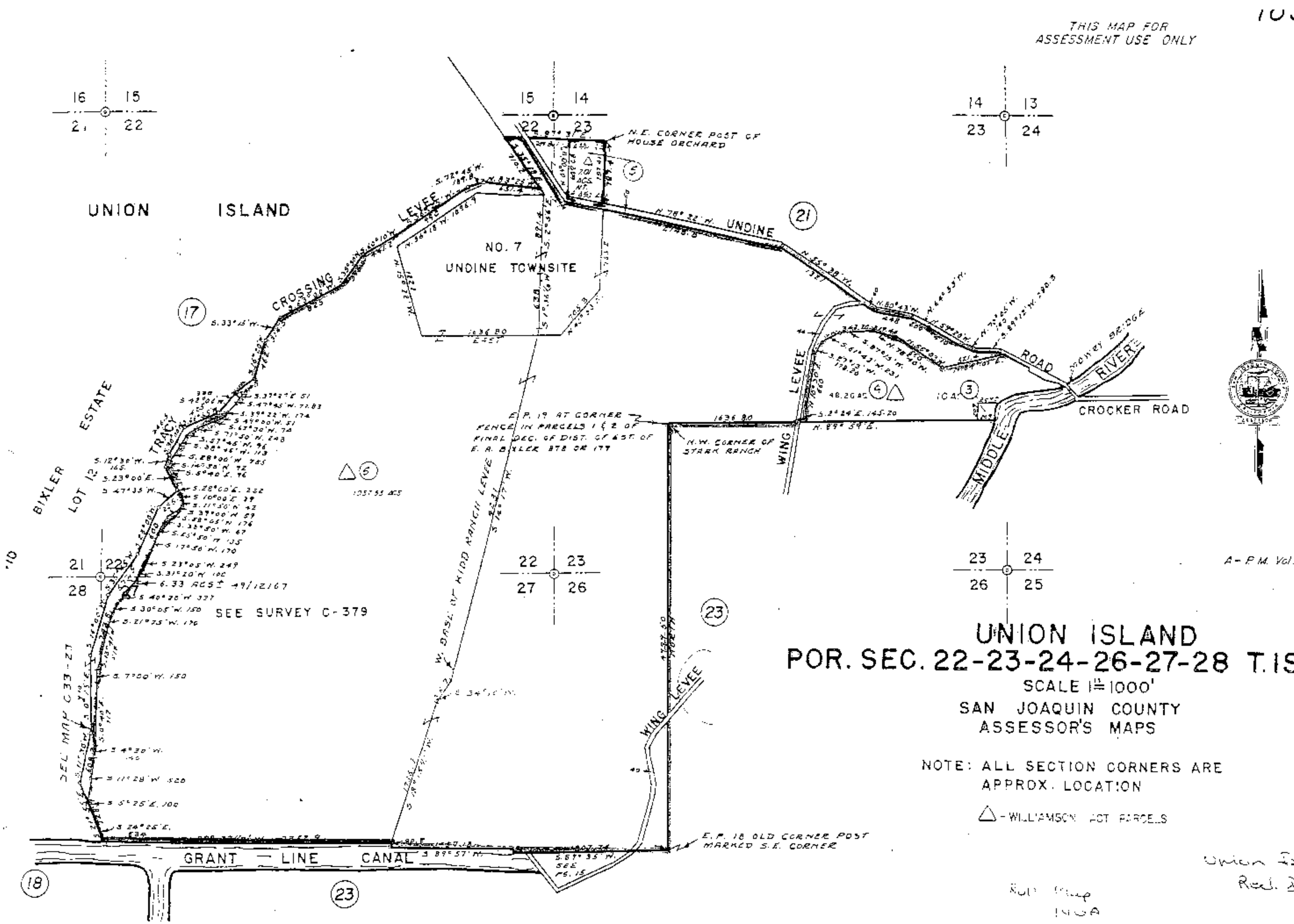
Beans were planted on 68 acres. The stunted growth of the plants was very obvious and the crop yield was one-half of other fields using the same seed and cultural practices. This acreage yielded 10 sacks per acre while the others were 20.

Although I have not calculated the current year's problems, the Chardonnay grapes are again stressed and will have a decreased yield and the young walnut tress I have planted which include the varieties of Tulare and Chandler are suffering from chloride stress.

To address this problem over the years I have applied soil amendments such as gypsum and have flooded the fields in winter to attempt to flush out the salts. However, the soil ph in combination with the salty water binds the chlorides and prevents leaching. The walnuts and grapes acreage are installed with tile drainage, but even that aid to drainage was inadequate.

If the water quality in the interior South Delta channels, including the Middle River near Old River compliance location was maintained at the 700 EC standard (April through August), the salt problems I am experiencing would certainly decrease and result in a direct economic benefit to ABF and associated parties. It is my personal belief that the State Water Resources Control Board should require DWR and USBR to comply with their respective permit conditions and meet the South Delta Water Quality Objectives.

Attachment "A"



LABORATORY ANALYSIS REPORT EVALUATION

JOHN TAYLOR FERTILIZERS

Fieldman: Albert Giannecchini **Customer: ABF**

Sample ID: 19

Sample Date: August 31, 2001

Soil: **Tissue: X** **Water:**

Crop: Walnut

As suspected by visual examination these young trees are suffering from acute chloride toxicity. The toxicity threshold for chloride in walnuts is 0.3%. At existing levels of 2.75% the source of chloride accumulation must be determined and aggressive corrective measures must be implemented or risk significant mortality. Steps should include periodic monitoring of irrigation water particularly if salt-water intrusion is suspected. Backhoe pits should be excavated this fall to observe the soil profile and collect soil samples at various depths to identify where in the profile Cl has accumulated. Some form of subsurface drainage systems may need to be installed to prevent this event from reoccurring in the future.

Attachment "B"

REPORT NUMBER

01-248-016

A & L WESTERN AGRICULTURAL LABORATORIES

1311 WOODLAND AVE #1 • MODESTO, CALIFORNIA 95351 • (209) 529-4080 • FAX (209) 529-4736

Client No: 1420

SEND TO:
JOHN TAYLOR FERTILIZERS
PO BOX 15289
SACRAMENTO, CA 95851-

GROWER: ABF

SAMPLES SUBMITTED BY:

PLANT ANALYSIS

DATE OF REPORT 09/07/2001 PAGE 1

	REPORT OF ANALYSIS IN PERCENT								REPORT OF ANALYSIS PARTS PER MILLION							
SAMPLE NUMBER	N NITROGEN	S SULFUR	P PHOSPHORUS	K POTASSIUM	Mg MAGNESIUM	Ca CALCIUM	Na SODIUM	Cl CHLORIDE	Fe IRON	Al ALUMINUM	Mn MANGANESE	B BORON	Cu COPPER	Zn ZINC	NO_3-N NITRATE-NITROGEN	
19								2.75								

Sample #	Date	Lab #	Crop	Stage/Part
19	08/31	47275	WALNUTS	

DEFINITION OF INTERPRETATION RATINGS

When interpretation of plant analysis results are given, they will be listed as follows

D or Deficient: Plants should be showing visible symptoms of a nutritional deficiency. Plant growth would definitely be curtailed by an insufficient amount of this element

L or Low: Plants may be normal in appearance but probably will be responsive to fertilization with this element

S or Sufficient: Plants contain adequate amounts of this element for maximum yield and are normal in appearance

H or High: Optimum yields can be expected and plants are normal in appearance. However, concentrations of this element are higher than normally anticipated

E or Excessive: Plants probably show symptoms of a nutritional disorder or stunted growth. Yields may be reduced significantly by an excessive amount of this element

A & L WESTERN AGRICULTURAL LABORATORIES

BY MIKE BUTTRESS, CPAg

Chloride Toxicity

The 2.0% Cl found in the most recent leaf sample clearly indicates a chloride toxicity. No chloride containing fertilizers have been applied so the source is either naturally in the soil or is carried in the irrigation water. The portable EC meter I used to test puddles formed below emitters revealed a water EC of approximately 1.0. This is higher than desired and it is possible that we are experiencing salt intrusion from the river. Complicating the problem is the deficit irrigations being practiced. As we dry down the soil the amount of salt remains static but the CONCENTRATION in the soil water increases, thus the accumulation in plant tissues. In arid climates where crops are grown using saline water, such as in Israel, they minimize salt damage by maintaining adequate soil moisture and avoiding dry down. This is a dilemma for ABF as they need to deliberately stress the vines for quality but by doing so they may be exaggerating salt injury. We may wish to excavate a few backhoe pits this fall-winter to explore the soil profile looking for layers that may be restricting leaching of salts as well as collect soil samples throughout the profile to determine where salts are accumulating.

TO: **Albert Giannecchini**

FROM: **Carl Bruice**

DATE: **September 6, 2001**

SUBJECT: **ABF Grape Issues**

TO: MR BILL SALMON

SUBJECT: SOUTH DELTA WATER QUALITY

Enclosed is a copy of the *South Delta Water Quality: 2001 Temporary Barriers Project* report. I also included some preliminary water quality data for Undine Road for 2002-03. Currently, the 2002 report is a work in progress. I will send you a copy as soon as it's completed. If you have any questions or would like any additional information, please call or email me.

Sincerely,

Shaun Philippart

Shaun Philippart
Resource Assessment Branch
Department of Water Resources
(916) 227-2615
sphilipp@water.ca.gov

Attachment "C"

MIDDLE RIVER @ UNDINE ROAD (B9D75011230)
South Delta Temporary Barriers Project - 2002 Weekly Water Quality Sampling Data

	FIELD READINGS					BRYTE LAB RESULTS						
DATE & TIME (mm/dd/yy PST)	TEMP. (°C)	D.O. (mg/L)	E.C. (uS/cm)	TURB. (NTU)	GAGE HEIGHT (ft)	NH_3-N (mg/L)	NO_2+NO_3-N (mg/L)	ORG.-N (mg/L)	PO_4 (mg/L)	TURB. (NTU)	CHL.-A (ug/L)	PHEO.-A (ug/L)
3/26/02 7:23	13.2	7.5	946	10.8	5.02							
4/2/02 6:54	17.7	7.8	993		4.86	0.06	1.3	1.0	0.09	26.0	57.80	15.30
4/9/02 5:31	17.1	8.1	866	20.6	4.62							
4/16/02 6:21	16.0	9.2	653		4.53	0.03	1.3	1.2	0.09	13	36.7	10.9
4/23/02 5:35	16.5	8.0	393	10.3	4.60							
4/30/02 5:30	13.1	8.4	374		4.41	0.13	0.96	0.5	0.22	26.0	7.43	3.60
5/7/02 5:33	15.7	8.8	391	12.2	5.20							
5/14/02 5:50	15.8	7.9	419		5.30	0.05	0.97	0.3	0.08	11.0	7.75	3.37
5/21/02 5:31	16.8	7.6	548	8.9	5.43							
5/28/02 5:53	19.4	8.7	561		6.00	0.02	1.2	0.3	0.07	22.0	41.40	11.60
6/4/02 5:40	21.1	8.5	692	24.3	5.35							
6/11/02 5:40	19.6	10.4	764		5.44	0.04	0.90	0.7	0.06	43.0	57.10	28
6/18/02 5:55	21.0	7.2	801	24.8	5.00							
6/25/02 5:34	22.4	8.2	764		5.94	0.11	0.75	1.0	0.03	35.0	83.8	42.3
7/2/02 7:41	25.7	6.3	732	20.0	4.35							
7/9/02 6:30	23.9	7.7	750		6.30	0.06	1.20	0.6	0.09	28.0	90.8	32.2
7/16/02 8:10	23.5	6.6	767	22.2	4.40							
7/23/02 6:45	23.5	6.2	792		6.74	0.18	1.28	0.9	0.12	32.0	43.2	29.1
7/30/02 7:50	23.7	7.3	751	18.7	4.70							
8/6/02 6:40	21.9	7.6	770		6.06	0.1	1.4	1.1	0.14	32.0	39.7	22.1
8/13/02 5:45	25.0	7.6	853	34.8	4.75							
8/20/02 7:35	20.7	6.8	833		6.00	0.18	1.1	0.6	0.12	28.0	67.2	21.4
8/27/02 5:46	22.2	8.4	796	15.5	4.38							
9/3/02 6:03	23.8	6.8	793		5.78	0.2	1.5	0.6	0.1	38.0	69.1	42.8
9/10/02 5:55	20.6	10.0	799	15.9	4.64							
9/17/02 5:57	21.0	7.2	831		5.81	0.17	1.8	0.5	0.11	25.0	66.3	25.9
9/24/02 6:30	22.2	5.6	846	11.8	4.85							
10/1/02 6:05	19.1	6.6	767		5.64	0.14	2.1	0.9	0.12	17.0	13.2	9.22
10/8/02 5:50	19.4	8.6	747	19.0	4.80							
10/15/02 6:16	18.0	8.8	757		5.37	0.15	1.7	1.1	0.11	14.0	27.1	11.8
10/22/02 5:40	16.6	8.3	493	10.8	5.02							
10/29/02 7:34	14.5	7.8	718		5.04	0.14	1.17	0.4	0.11	10.0	8.81	3.91
11/5/02 7:10	12.2	8.2	701	6.3	5.10							
11/12/02 6:45	14.2	8.1	666		5.10	0.16	1.16	0.7	0.17	21.0	5.16	3.17
11/19/02 7:15	11.5	6.1	884	4.4	8.43							
11/26/02 6:40	11.4	7.7	922		3.30	0.25	1.60	1.1	0.14	8.0	7.04	2.31
12/3/02 6:25	10.1	9.3	924	33.7	4.35							

[shaded] = Middle River barrier in place from 4/15/02 - 11/21/02.

	TEMP. (°C)	D.O. (mg/L)	E.C. (uS/cm)	TURB. (NTU)	GAGE HEIGHT (ft)	NH_3-N (mg/L)	NO_2+NO_3-N (mg/L)	ORG.-N (mg/L)	PO_4 (mg/L)	TURB. (NTU)	CHL.-A (ug/L)	PHEO.-A (ug/L)
MAXIMUM	25.70	10.40	884.00	34.80	8.43	0.20	2.10	1.20	0.22	43.00	90.80	42.80
MINIMUM	11.50	5.60	374.00	4.35	4.35	0.02	0.75	0.30	0.03	10.00	5.16	3.17
MEAN	19.39	7.80	700.19	16.24	5.33	0.12	1.28	0.71	0.11	24.69	41.55	18.82
Range	14.20	4.80	510.00	30.45	4.08	0.18	1.35	0.90	0.19	33.00	85.64	39.63
Standard Deviation	3.91	1.09	145.63	7.92	0.84	0.06	0.35	0.29	0.04	9.94	28.55	13.56
Sample Variance	15.26	1.19	21,206.74	62.78	0.70	0.00	0.13	0.08	0.00	98.90	815.13	183.97
Standard Error	3.94	1.07	138.65	7.65	0.88	0.06	0.34	0.29	0.05	10.17	22.24	6.15
Median	20.10	7.85	754.00	15.70	5.15	0.14	1.20	0.65	0.11	25.50	40.55	16.50
Mode	19.40	7.60	764.00	#N/A	6.00	0.18	1.20	0.60	0.12	28.00	#N/A	11.60
Kurtosis	-0.85	0.13	0.31	0.47	4.86	-1.29	0.61	-1.12	1.97	-0.87	-1.19	-0.98
Skewness	-0.37	0.17	-1.19	0.65	1.74	-0.38	0.86	0.23	0.84	0.11	0.21	0.45
Count	32	32	32	16	32	16	16	16	16	16	16	16
Confidence Level (95%)	1.35	0.38	50.46	3.88	0.29	0.03	0.17	0.14	0.02	4.87	13.99	6.65

* All descriptive statistics were calculated from data recorded while the Middle River barrier was in place.

Electrical Conductivity in MilliS for Doughty Cut Above Grant Line Canal
Period of Record 7/25/02 to Present
Provided by DWR by Mike Abiolui; Taken from CDEC

7/25/02 8:30	790
7/25/02 8:45	790
7/25/02 9:00	794
7/25/02 9:15	795
7/25/02 9:30	796
7/25/02 9:45	796
7/25/02 10:00	797
7/25/02 10:15	797
7/25/02 10:30	798
7/25/02 10:45	797
7/25/02 11:00	799
7/25/02 11:15	797
7/25/02 11:30	798
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7/25/02 12:30	798
7/25/02 12:45	798
7/25/02 13:00	797
7/25/02 13:15	796
7/25/02 13:30	796
7/25/02 13:45	784
7/25/02 14:00	779
7/25/02 14:15	775
7/25/02 14:30	775
7/25/02 14:45	772
7/25/02 15:00	753
7/25/02 15:15	753
7/25/02 15:30	756
7/25/02 15:45	755
7/25/02 16:00	750
7/25/02 16:15	753
7/25/02 16:30	751
7/25/02 16:45	751
7/25/02 17:00	747
7/25/02 17:15	750
7/25/02 17:30	757
7/25/02 17:45	756
7/25/02 18:00	754
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7/25/02 18:30	755
7/25/02 18:45	757
7/25/02 19:00	740
7/25/02 19:15	744
7/25/02 19:30	752
7/25/02 19:45	742
7/25/02 20:00	748
7/25/02 20:15	750
7/25/02 20:30	741
7/25/02 20:45	745
7/25/02 21:00	745
7/25/02 21:15	762
7/25/02 21:30	768
7/25/02 21:45	788
7/25/02 22:00	785
7/25/02 22:15	790
7/25/02 22:30	788
7/25/02 22:45	788
7/25/02 23:00	788
7/25/02 23:15	785
7/25/02 23:30	782
7/25/02 23:45	777
7/26/02 0:00	772
7/26/02 0:15	768
7/26/02 0:30	766
7/26/02 0:45	763
7/26/02 1:00	759
7/26/02 1:15	756
7/26/02 1:30	758
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8/2/02 13:45	725
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8/3/02 9:30	769
8/3/02 9:45	771

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8/3/02 10:45	771	8/3/02 23:00	780	8/4/02 11:15	787
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8/3/02 11:15	769	8/3/02 23:30	777	8/4/02 11:45	787
8/3/02 11:30	772	8/3/02 23:45	775	8/4/02 12:00	788
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8/3/02 12:15	776	8/4/02 0:30	772	8/4/02 12:45	790
8/3/02 12:30	776	8/4/02 0:45	772	8/4/02 13:00	789
8/3/02 12:45	776	8/4/02 1:00	771	8/4/02 13:15	787
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8/3/02 13:15	777	8/4/02 1:30	770	8/4/02 13:45	787
8/3/02 13:30	777	8/4/02 1:45	769	8/4/02 14:00	788
8/3/02 13:45	777	8/4/02 2:00	768	8/4/02 14:15	790
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8/3/02 14:45	778	8/4/02 3:00	757	8/4/02 15:15	795
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8/3/02 16:00	783	8/4/02 4:15	757	8/4/02 16:30	807
8/3/02 16:15	775	8/4/02 4:30	749	8/4/02 16:45	806
8/3/02 16:30	780	8/4/02 4:45	738	8/4/02 17:00	808
8/3/02 16:45	782	8/4/02 5:00	739	8/4/02 17:15	808
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8/3/02 18:00	793	8/4/02 6:15	746	8/4/02 18:30	817
8/3/02 18:15	792	8/4/02 6:30	745	8/4/02 18:45	820
8/3/02 18:30	791	8/4/02 6:45	769	8/4/02 19:00	818
8/3/02 18:45	786	8/4/02 7:00	774	8/4/02 19:15	818
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8/3/02 20:00	782	8/4/02 8:15	778	8/4/02 20:30	812
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8/3/02 20:45	782	8/4/02 9:00	782	8/4/02 21:15	813
8/3/02 21:00	783	8/4/02 9:15	784	8/4/02 21:30	812
8/3/02 21:15	781	8/4/02 9:30	783	8/4/02 21:45	814
8/3/02 21:30	781	8/4/02 9:45	784	8/4/02 22:00	813
8/3/02 21:45	779	8/4/02 10:00	784	8/4/02 22:15	811
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8/4/02 23:15	810	8/5/02 11:30	776	8/5/02 23:45	806
8/4/02 23:30	809	8/5/02 11:45	774	8/6/02 0:00	805
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8/5/02 0:00	806	8/5/02 12:15	774	8/6/02 0:30	806
8/5/02 0:15	808	8/5/02 12:30	773	8/6/02 0:45	804
8/5/02 0:30	806	8/5/02 12:45	776	8/6/02 1:00	805
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8/5/02 1:00	809	8/5/02 13:15	776	8/6/02 1:30	804
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8/5/02 1:30	809	8/5/02 13:45	774	8/6/02 2:00	808
8/5/02 1:45	810	8/5/02 14:00	777	8/6/02 2:15	807
8/5/02 2:00	806	8/5/02 14:15	775	8/6/02 2:30	813
8/5/02 2:15	797	8/5/02 14:30	780	8/6/02 2:45	811
8/5/02 2:30	791	8/5/02 14:45	774	8/6/02 3:00	805
8/5/02 2:45	793	8/5/02 15:00	778	8/6/02 3:15	805
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8/5/02 3:15	804	8/5/02 15:30	786	8/6/02 3:45	807
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8/5/02 4:00	806	8/5/02 16:15	788	8/6/02 4:30	808
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8/5/02 5:15	806	8/5/02 17:30	785	8/6/02 5:45	807
8/5/02 5:30	807	8/5/02 17:45	794	8/6/02 6:00	806
8/5/02 5:45	806	8/5/02 18:00	801	8/6/02 6:15	803
8/5/02 6:00	806	8/5/02 18:15	804	8/6/02 6:30	802
8/5/02 6:15	805	8/5/02 18:30	810	8/6/02 6:45	798
8/5/02 6:30	803	8/5/02 18:45	808	8/6/02 7:00	793
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8/5/02 7:15	798	8/5/02 19:30	824	8/6/02 7:45	776
8/5/02 7:30	798	8/5/02 19:45	819	8/6/02 8:00	776
8/5/02 7:45	797	8/5/02 20:00	816	8/6/02 8:15	771
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8/5/02 8:15	784	8/5/02 20:30	817	8/6/02 8:45	769
8/5/02 8:30	786	8/5/02 20:45	816	8/6/02 9:00	759
8/5/02 8:45	783	8/5/02 21:00	814	8/6/02 9:15	755
8/5/02 9:00	782	8/5/02 21:15	808	8/6/02 9:30	751
8/5/02 9:15	782	8/5/02 21:30	806	8/6/02 9:45	749
8/5/02 9:30	779	8/5/02 21:45	801	8/6/02 10:00	755
8/5/02 9:45	781	8/5/02 22:00	799	8/6/02 10:15	753
8/5/02 10:00	778	8/5/02 22:15	798	8/6/02 10:30	744
8/5/02 10:15	774	8/5/02 22:30	805	8/6/02 10:45	744
8/5/02 10:30	778	8/5/02 22:45	794	8/6/02 11:00	746
8/5/02 10:45	780	8/5/02 23:00	805	8/6/02 11:15	748

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8/6/02 12:00	785	8/7/02 0:15	782	8/7/02 12:30	763
8/6/02 12:15	755	8/7/02 0:30	782	8/7/02 12:45	766
8/6/02 12:30	760	8/7/02 0:45	782	8/7/02 13:00	765
8/6/02 12:45	760	8/7/02 1:00	780	8/7/02 13:15	763
8/6/02 13:00	760	8/7/02 1:15	777	8/7/02 13:30	768
8/6/02 13:15	760	8/7/02 1:30	779	8/7/02 13:45	762
8/6/02 13:30	760	8/7/02 1:45	779	8/7/02 14:00	766
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8/6/02 14:15	762	8/7/02 2:30	775	8/7/02 14:45	761
8/6/02 14:30	762	8/7/02 2:45	775	8/7/02 15:00	765
8/6/02 14:45	764	8/7/02 3:00	775	8/7/02 15:15	767
8/6/02 15:00	762	8/7/02 3:15	774	8/7/02 15:30	766
8/6/02 15:15	761	8/7/02 3:30	775	8/7/02 15:45	766
8/6/02 15:30	766	8/7/02 3:45	775	8/7/02 16:00	767
8/6/02 15:45	762	8/7/02 4:00	776	8/7/02 16:15	769
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8/6/02 17:45	765	8/7/02 6:00	777	8/7/02 18:15	770
8/6/02 18:00	766	8/7/02 6:15	775	8/7/02 18:30	769
8/6/02 18:15	766	8/7/02 6:30	775	8/7/02 18:45	770
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8/6/02 21:00	806	8/7/02 9:15	775	8/7/02 21:30	810
8/6/02 21:15	793	8/7/02 9:30	774	8/7/02 21:45	812
8/6/02 21:30	788	8/7/02 9:45	774	8/7/02 22:00	817
8/6/02 21:45	786	8/7/02 10:00	775	8/7/02 22:15	815
8/6/02 22:00	784	8/7/02 10:15	775	8/7/02 22:30	819
8/6/02 22:15	785	8/7/02 10:30	769	8/7/02 22:45	817
8/6/02 22:30	784	8/7/02 10:45	769	8/7/02 23:00	816
8/6/02 22:45	783	8/7/02 11:00	766	8/7/02 23:15	808
8/6/02 23:00	782	8/7/02 11:15	766	8/7/02 23:30	811
8/6/02 23:15	783	8/7/02 11:30	768	8/7/02 23:45	804
8/6/02 23:30	784	8/7/02 11:45	762	8/8/02 0:00	804

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8/8/02 0:30	807	8/8/02 12:45	787	8/9/02 1:00	818
8/8/02 0:45	809	8/8/02 13:00	786	8/9/02 1:15	823
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8/8/02 2:15	802	8/8/02 14:30	782	8/9/02 2:45	813
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8/8/02 2:45	787	8/8/02 15:00	785	8/9/02 3:15	806
8/8/02 3:00	786	8/8/02 15:15	786	8/9/02 3:30	810
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8/8/02 4:15	788	8/8/02 16:30	783	8/9/02 4:45	813
8/8/02 4:30	793	8/8/02 16:45	785	8/9/02 5:00	813
8/8/02 4:45	795	8/8/02 17:00	786	8/9/02 5:15	810
8/8/02 5:00	794	8/8/02 17:15	791	8/9/02 5:30	811
8/8/02 5:15	795	8/8/02 17:30	788	8/9/02 5:45	810
8/8/02 5:30	789	8/8/02 17:45	789	8/9/02 6:00	808
8/8/02 5:45	787	8/8/02 18:00	790	8/9/02 6:15	808
8/8/02 6:00	788	8/8/02 18:15	790	8/9/02 6:30	808
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8/8/02 6:30	788	8/8/02 18:45	791	8/9/02 7:00	809
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8/8/02 7:00	791	8/8/02 19:15	795	8/9/02 7:30	812
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8/8/02 8:15	794	8/8/02 20:30	812	8/9/02 8:45	810
8/8/02 8:30	793	8/8/02 20:45	817	8/9/02 9:00	810
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8/8/02 9:00	794	8/8/02 21:15	828	8/9/02 9:30	813
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8/8/02 9:30	795	8/8/02 21:45	828	8/9/02 10:00	815
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8/8/02 10:00	795	8/8/02 22:15	822	8/9/02 10:30	815
8/8/02 10:15	793	8/8/02 22:30	819	8/9/02 10:45	817
8/8/02 10:30	791	8/8/02 22:45	820	8/9/02 11:00	816
8/8/02 10:45	791	8/8/02 23:00	825	8/9/02 11:15	816
8/8/02 11:00	788	8/8/02 23:15	826	8/9/02 11:30	816
8/8/02 11:15	790	8/8/02 23:30	821	8/9/02 11:45	816
8/8/02 11:30	785	8/8/02 23:45	823	8/9/02 12:00	815
8/8/02 11:45	786	8/9/02 0:00	823	8/9/02 12:15	814
8/8/02 12:00	788	8/9/02 0:15	826	8/9/02 12:30	814
8/8/02 12:15	784	8/9/02 0:30	823	8/9/02 12:45	813

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8/9/02 13:30	814	8/10/02 1:45	825	8/10/02 14:00	832
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8/9/02 14:00	814	8/10/02 2:15	823	8/10/02 14:30	838
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8/9/02 15:00	820	8/10/02 3:15	824	8/10/02 15:30	853
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8/9/02 15:30	824	8/10/02 3:45	821	8/10/02 16:00	852
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8/9/02 16:30	838	8/10/02 4:45	817	8/10/02 17:00	854
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8/9/02 17:45	824	8/10/02 6:00	819	8/10/02 18:15	843
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8/9/02 18:15	825	8/10/02 6:30	816	8/10/02 18:45	838
8/9/02 18:30	821	8/10/02 6:45	817	8/10/02 19:00	840
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8/9/02 22:30	814	8/10/02 10:45	826	8/10/02 23:00	834
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8/9/02 23:30	820	8/10/02 11:45	829	8/11/02 0:00	836
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8/12/02 13:00	896
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8/12/02 14:30	898
8/12/02 14:45	901

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8/12/02 15:15	901	8/13/02 3:30	856	8/13/02 15:45	873
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8/12/02 16:00	903	8/13/02 4:15	837	8/13/02 16:30	874
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8/12/02 17:30	903	8/13/02 5:45	820	8/13/02 18:00	865
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8/12/02 18:00	887	8/13/02 6:15	815	8/13/02 18:30	863
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8/12/02 18:30	888	8/13/02 6:45	812	8/13/02 19:00	864
8/12/02 18:45	887	8/13/02 7:00	819	8/13/02 19:15	863
8/12/02 19:00	887	8/13/02 7:15	834	8/13/02 19:30	861
8/12/02 19:15	889	8/13/02 7:30	845	8/13/02 19:45	860
8/12/02 19:30	884	8/13/02 7:45	849	8/13/02 20:00	860
8/12/02 19:45	882	8/13/02 8:00	852	8/13/02 20:15	857
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8/12/02 20:15	878	8/13/02 8:30	852	8/13/02 20:45	852
8/12/02 20:30	877	8/13/02 8:45	851	8/13/02 21:00	852
8/12/02 20:45	874	8/13/02 9:00	852	8/13/02 21:15	849
8/12/02 21:00	873	8/13/02 9:15	852	8/13/02 21:30	851
8/12/02 21:15	872	8/13/02 9:30	854	8/13/02 21:45	851
8/12/02 21:30	871	8/13/02 9:45	853	8/13/02 22:00	852
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8/12/02 22:00	869	8/13/02 10:15	867	8/13/02 22:30	846
8/12/02 22:15	870	8/13/02 10:30	867	8/13/02 22:45	847
8/12/02 22:30	870	8/13/02 10:45	872	8/13/02 23:00	847
8/12/02 22:45	871	8/13/02 11:00	874	8/13/02 23:15	848
8/12/02 23:00	880	8/13/02 11:15	876	8/13/02 23:30	845
8/12/02 23:15	884	8/13/02 11:30	874	8/13/02 23:45	847
8/12/02 23:30	884	8/13/02 11:45	875	8/14/02 0:00	845
8/12/02 23:45	880	8/13/02 12:00	870	8/14/02 0:15	847
8/13/02 0:00	880	8/13/02 12:15	869	8/14/02 0:30	848
8/13/02 0:15	879	8/13/02 12:30	873	8/14/02 0:45	845
8/13/02 0:30	882	8/13/02 12:45	874	8/14/02 1:00	842
8/13/02 0:45	884	8/13/02 13:00	873	8/14/02 1:15	842
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8/13/02 1:15	882	8/13/02 13:30	873	8/14/02 1:45	849
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8/13/02 1:45	884	8/13/02 14:00	876	8/14/02 2:15	851
8/13/02 2:00	882	8/13/02 14:15	877	8/14/02 2:30	850
8/13/02 2:15	881	8/13/02 14:30	872	8/14/02 2:45	849
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8/13/02 2:45	878	8/13/02 15:00	873	8/14/02 3:15	850
8/13/02 3:00	875	8/13/02 15:15	875	8/14/02 3:30	849

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8/14/02 4:15	835	8/14/02 16:30	853	8/15/02 4:45	821
8/14/02 4:30	833	8/14/02 16:45	854	8/15/02 5:00	820
8/14/02 4:45	829	8/14/02 17:00	851	8/15/02 5:15	819
8/14/02 5:00	825	8/14/02 17:15	852	8/15/02 5:30	818
8/14/02 5:15	824	8/14/02 17:30	849	8/15/02 5:45	819
8/14/02 5:30	820	8/14/02 17:45	849	8/15/02 6:00	817
8/14/02 5:45	818	8/14/02 18:00	849	8/15/02 6:15	816
8/14/02 6:00	814	8/14/02 18:15	851	8/15/02 6:30	828
8/14/02 6:15	813	8/14/02 18:30	847	8/15/02 6:45	846
8/14/02 6:30	810	8/14/02 18:45	848	8/15/02 7:00	843
8/14/02 6:45	810	8/14/02 19:00	848	8/15/02 7:15	851
8/14/02 7:00	810	8/14/02 19:15	847	8/15/02 7:30	853
8/14/02 7:15	820	8/14/02 19:30	849	8/15/02 7:45	856
8/14/02 7:30	832	8/14/02 19:45	850	8/15/02 8:00	854
8/14/02 7:45	835	8/14/02 20:00	849	8/15/02 8:15	855
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8/14/02 8:30	848	8/14/02 20:45	842	8/15/02 9:00	856
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8/14/02 9:15	851	8/14/02 21:30	838	8/15/02 9:45	833
8/14/02 9:30	851	8/14/02 21:45	836	8/15/02 10:00	830
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8/14/02 10:00	843	8/14/02 22:15	834	8/15/02 10:30	829
8/14/02 10:15	845	8/14/02 22:30	834	8/15/02 10:45	825
8/14/02 10:30	847	8/14/02 22:45	839	8/15/02 11:00	826
8/14/02 10:45	846	8/14/02 23:00	840	8/15/02 11:15	823
8/14/02 11:00	846	8/14/02 23:15	837	8/15/02 11:30	813
8/14/02 11:15	846	8/14/02 23:30	836	8/15/02 11:45	815
8/14/02 11:30	852	8/14/02 23:45	838	8/15/02 12:00	816
8/14/02 11:45	852	8/15/02 0:00	838	8/15/02 12:15	815
8/14/02 12:00	857	8/15/02 0:15	838	8/15/02 12:30	814
8/14/02 12:15	856	8/15/02 0:30	836	8/15/02 12:45	812
8/14/02 12:30	856	8/15/02 0:45	837	8/15/02 13:00	812
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8/14/02 13:00	853	8/15/02 1:15	835	8/15/02 13:30	812
8/14/02 13:15	855	8/15/02 1:30	834	8/15/02 13:45	812
8/14/02 13:30	857	8/15/02 1:45	836	8/15/02 14:00	815
8/14/02 13:45	856	8/15/02 2:00	836	8/15/02 14:15	815
8/14/02 14:00	858	8/15/02 2:15	835	8/15/02 14:30	814
8/14/02 14:15	855	8/15/02 2:30	835	8/15/02 14:45	815
8/14/02 14:30	857	8/15/02 2:45	836	8/15/02 15:00	817
8/14/02 14:45	856	8/15/02 3:00	839	8/15/02 15:15	816
8/14/02 15:00	856	8/15/02 3:15	841	8/15/02 15:30	816
8/14/02 15:15	856	8/15/02 3:30	843	8/15/02 15:45	819
8/14/02 15:30	854	8/15/02 3:45	841	8/15/02 16:00	821
8/14/02 15:45	853	8/15/02 4:00	835	8/15/02 16:15	825

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8/15/02 16:45	837	8/16/02 5:00	759	8/16/02 17:15	823
8/15/02 17:00	840	8/16/02 5:15	760	8/16/02 17:30	821
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8/15/02 17:30	839	8/16/02 5:45	760	8/16/02 18:00	809
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8/15/02 18:45	841	8/16/02 7:00	736	8/16/02 19:15	793
8/15/02 19:00	842	8/16/02 7:15	736	8/16/02 19:30	793
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8/15/02 20:00	840	8/16/02 8:15	764	8/16/02 20:30	783
8/15/02 20:15	841	8/16/02 8:30	767.5	8/16/02 20:45	783
8/15/02 20:30	830	8/16/02 8:45	767.5	8/16/02 21:00	782
8/15/02 20:45	823	8/16/02 9:00	767.5	8/16/02 21:15	781
8/15/02 21:00	817	8/16/02 9:15	767.5	8/16/02 21:30	782
8/15/02 21:15	814	8/16/02 9:30	767.5	8/16/02 21:45	781
8/15/02 21:30	812	8/16/02 9:45	767.5	8/16/02 22:00	781
8/15/02 21:45	812	8/16/02 10:00	767.5	8/16/02 22:15	779
8/15/02 22:00	808	8/16/02 10:15	767.5	8/16/02 22:30	781
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8/30/02 5:00	643	8/30/02 17:15	713	8/31/02 5:30	683
8/30/02 5:15	644	8/30/02 17:30	712	8/31/02 5:45	682
8/30/02 5:30	645	8/30/02 17:45	710	8/31/02 6:00	680
8/30/02 5:45	645	8/30/02 18:00	709	8/31/02 6:15	677
8/30/02 6:00	646	8/30/02 18:15	710	8/31/02 6:30	676
8/30/02 6:15	646	8/30/02 18:30	710	8/31/02 6:45	674
8/30/02 6:30	646	8/30/02 18:45	707	8/31/02 7:00	674
8/30/02 6:45	644	8/30/02 19:00	704	8/31/02 7:15	684
8/30/02 7:00	638	8/30/02 19:15	702	8/31/02 7:30	696
8/30/02 7:15	633	8/30/02 19:30	701	8/31/02 7:45	701
8/30/02 7:30	653	8/30/02 19:45	699	8/31/02 8:00	706
8/30/02 7:45	672	8/30/02 20:00	699	8/31/02 8:15	710
8/30/02 8:00	675	8/30/02 20:15	700	8/31/02 8:30	712
8/30/02 8:15	680	8/30/02 20:30	701	8/31/02 8:45	714

8/31/02 9:00	714	8/31/02 21:15	760	9/1/02 9:30	725
8/31/02 9:15	714	8/31/02 21:30	759	9/1/02 9:45	724
8/31/02 9:30	715	8/31/02 21:45	757	9/1/02 10:00	724
8/31/02 9:45	715	8/31/02 22:00	756	9/1/02 10:15	723
8/31/02 10:00	716	8/31/02 22:15	754	9/1/02 10:30	723
8/31/02 10:15	716	8/31/02 22:30	753	9/1/02 10:45	722
8/31/02 10:30	716	8/31/02 22:45	752	9/1/02 11:00	722
8/31/02 10:45	717	8/31/02 23:00	751	9/1/02 11:15	722
8/31/02 11:00	718	8/31/02 23:15	751	9/1/02 11:30	721
8/31/02 11:15	718	8/31/02 23:30	749	9/1/02 11:45	722
8/31/02 11:30	717	8/31/02 23:45	747	9/1/02 12:00	721
8/31/02 11:45	718	9/1/02 0:00	747	9/1/02 12:15	720
8/31/02 12:00	720	9/1/02 0:15	746	9/1/02 12:30	723
8/31/02 12:15	722	9/1/02 0:30	750	9/1/02 12:45	721
8/31/02 12:30	720	9/1/02 0:45	748	9/1/02 13:00	720
8/31/02 12:45	722	9/1/02 1:00	746	9/1/02 13:15	720
8/31/02 13:00	724	9/1/02 1:15	742	9/1/02 13:30	720
8/31/02 13:15	724	9/1/02 1:30	739	9/1/02 13:45	721
8/31/02 13:30	725	9/1/02 1:45	738	9/1/02 14:00	722
8/31/02 13:45	723	9/1/02 2:00	752	9/1/02 14:15	722
8/31/02 14:00	728	9/1/02 2:15	754	9/1/02 14:30	723
8/31/02 14:15	732	9/1/02 2:30	741	9/1/02 14:45	723
8/31/02 14:30	733	9/1/02 2:45	739	9/1/02 15:00	723
8/31/02 14:45	734	9/1/02 3:00	738	9/1/02 15:15	725
8/31/02 15:00	735	9/1/02 3:15	738	9/1/02 15:30	725
8/31/02 15:15	736	9/1/02 3:30	738	9/1/02 15:45	728
8/31/02 15:30	736	9/1/02 3:45	740	9/1/02 16:00	730
8/31/02 15:45	740	9/1/02 4:00	742	9/1/02 16:15	733
8/31/02 16:00	741	9/1/02 4:15	741	9/1/02 16:30	733
8/31/02 16:15	742	9/1/02 4:30	734	9/1/02 16:45	737
8/31/02 16:30	742	9/1/02 4:45	731	9/1/02 17:00	736
8/31/02 16:45	742	9/1/02 5:00	721	9/1/02 17:15	738
8/31/02 17:00	746	9/1/02 5:15	734	9/1/02 17:30	738
8/31/02 17:15	757	9/1/02 5:30	735	9/1/02 17:45	741
8/31/02 17:30	757	9/1/02 5:45	729	9/1/02 18:00	744
8/31/02 17:45	758	9/1/02 6:00	718	9/1/02 18:15	749
8/31/02 18:00	759	9/1/02 6:15	712	9/1/02 18:30	753
8/31/02 18:15	760	9/1/02 6:30	714	9/1/02 18:45	755
8/31/02 18:30	758	9/1/02 6:45	715	9/1/02 19:00	757
8/31/02 18:45	758	9/1/02 7:00	721	9/1/02 19:15	759
8/31/02 19:00	757	9/1/02 7:15	724	9/1/02 19:30	758
8/31/02 19:15	759	9/1/02 7:30	723	9/1/02 19:45	760
8/31/02 19:30	758	9/1/02 7:45	723	9/1/02 20:00	761
8/31/02 19:45	757	9/1/02 8:00	723	9/1/02 20:15	761
8/31/02 20:00	757	9/1/02 8:15	724	9/1/02 20:30	760
8/31/02 20:15	758	9/1/02 8:30	723	9/1/02 20:45	761
8/31/02 20:30	761	9/1/02 8:45	723	9/1/02 21:00	763
8/31/02 20:45	760	9/1/02 9:00	723	9/1/02 21:15	762
8/31/02 21:00	760	9/1/02 9:15	723	9/1/02 21:30	761

Attachment "E"

The Economic Impact on San Joaquin County of Yield Decrement from Reduction in San Joaquin River Quality

Prepared for South Delta Water Agency et al.

By

Prairie Economics LLC

SDWA-6

I. Introduction

This study provides a partial estimate of the economic impact of degraded water quality in the San Joaquin River. Building upon a previous study[1] by G.T. Orlob, this study analyzes the estimated crop decrement of six crop types in the South Delta resulting from increases in salinity of the San Joaquin River. The six crop types include: beans, corn, alfalfa, tomatoes, fruit and nuts and grapes. The estimated value of the lost crops is subsequently analyzed using an input-output model to estimate the overall economic impact from the loss of yields due to water degradation.

The study is an attempt to quantify the economic impact of higher salinity water flows in the San Joaquin River, the estimates presented herein must be interpreted with care. Some caveats regarding the results of this study:

- Additional crop types may also be affected by increased salinity but are not included in this analysis.
- Assumptions are necessarily made regarding soil conditions and distribution in the study area and the crops planted under each type of soil conditions that will differ from actual planting behavior and may somewhat distort the final estimates.
- It is unknown what the exact salinity of irrigation water will be at different points downstream of Vernalis. This study assumes for tractability, that a single salinity level prevails at all points downstream over the region of examined.

[1] Impact of San Joaquin River Quality on Crop Values in the South Delta

- Although we know that water qualities in the Central Delta will be better than those in the South Delta, salt impacts occur in that area at lower levels. For purposes of this analysis, I concluded that treating the whole study area the same was appropriate as indicating what results from incremental increases in salinity.

While all of these factors affect, to varying degrees, the precision of the estimates in this study, they do not change the qualitative or sign of the impacts nor do they have a great influence on the magnitude of the changes arising from increased salinity in the San Joaquin River.

II. Yield Decrement Due to Increased Salinity

This study does not involve primary research into the effects of salinity changes on crop yields nor does it investigate the ability of various soil types to leach properly. Instead it builds upon the research into the relationship between soil types, leaching and yield decrements conducted in the report by Dr. Orlob and referenced in section I.

Dr. Orlob's study investigates the relationship between the permeability of the soils in the South Delta and the leaching characteristics of these soils. Dr. Orlob details the percent of soil groups in the South Delta by permeability. The overwhelming share of soil groups fall in the slow to moderate permeability classification (91%).

Leaching characteristics were derived from the 1976 South Delta Salinity Status Study (as referenced in the Orlob study) using observed EC_es and applied water EC_ws for 51 sites at 10 different locations. Leaching fractions (LF) were calculated for both spring and fall EC_e

profiles at all sites (102 determinations) using the following relation:

$$LF = \frac{EC_w}{2(EC_e)_d}$$

$$LF = Leaching\ Fraction$$
$$EC_W = electrical\ conductivity\ of\ applied\ water, mmhos/cm\ (dS/m)$$
$$(EC_e)_d = electrical\ conductivity\ of\ soil\ solution\ extract\ at\ drainage\ horizon$$
$$(assumed\ to\ be\ the\ maximum\ in\ the\ EC_e\ profiles)\ mmhos/cm\ (dS/m)$$

Mean leaching fractions $(\overline{LF})$ and standard deviations (σ) were determined for each location. It was found that there was a large range for the standard deviation ranging from 25 to 65 percent of mean leaching fraction. Dr. Orlob adopted an average standard deviation equal to $(\overline{LF}/3)$ as representative of in-field variation in leaching during the growing season.

Soil permeabilities and leaching fractions were related to one another by identifying specific locations from the Salinity Study (as referenced in the Orlob study) with permeability groups from a Soil Permeability Map (as referenced in the Orlob study). A consistent direct relationship between permeability and leaching fractions emerged with some variability that Dr. Orlob attributed to in-field variation.

From subsequent calculations he classifies soils in the South Delta into three groups; A, B, and C with mean leaching fractions equal to 0.053, 0.093 and 0.188 and standard deviations of 0.0177, 0.0310, and 0.0627 respectively. These parameters of the probability density function for LF are used in subsequent calculation of yield decrement by soil type and water quality that are subsequently calculated by Dr. Orlob.

The relationship between yield decrement, leaching fraction and applied water quality are given by the following equation (equation 2 in Orlob's study):

$$\Delta Y = S(EC_w\{\frac{1+LF}{5LF}\} - B)$$

$Where:$
$\Delta Y = \text{ yield decrement, percent}$
$S = \text{unit decrement, percent / mmho / cm}$
$B = \text{threshold } EC_e\text{, mmhos / cm.}$

Values of S and B for various crops are taken from FAO Irrigation and Drainage Paper 29 (as referenced in the Orlob study) and supplemented by the Water Quality Advisory Panel for the South Delta Salinity Status Study (as referenced in the Orlob study).

Since the LF can vary over a given field, the yield decrement is determined by combining the above relationship with the probability density function for LF (assumed to be normal by Dr. Orlob) and integrating over a range from 0 to LF_c, a fraction above which there is no decrement in yield. The new equation for yield decrement thus becomes (equation 3 in Orlob's study):

$$\Delta Y = \int_0^{LF_c} S \left[EC_w \left\{ \frac{1+LF}{5LF} \right\} - B \right] \frac{1}{\sigma\sqrt{2\pi}} \left(\frac{1}{2} \frac{(LF - \overline{LF})}{\sigma^2} \right) dLF \,.$$

The yield decrement-water quality relationship for a given soil group is obtained by integrating over the range of EC_w that is of interest. For the South Delta he uses a range of 0.7 to 1.3 mmhos/cm. The characteristics of the soil are summarized by mean leaching fraction $(\overline{LF})$ and standard deviation (σ) and the susceptibility of the crop is parameterized by S and B. Orlob provides representative yield decrement-water quality relationships for the six crops and three soil types in Table 2 of his report. The yield decrements are summarized provided for three values of EC_w: 0.4, 0.7 and 1.0 dS/m. Since historically 0.7 has been maintained at Vernalis we use this salinity level as the baseline for this study.

Using Orlob's yield decrement table we examine crop decrement for increases of salinity levels equal to 0.8, 0.9 and 1.0 dS/m. This is accomplished by interpolating the crop decrement from salinity levels between the baseline 0.7 dS/m and 1.0 dS/m for increments of 0.1 dS/m. Results are displayed in Table A.

Table A; Yield Decrement (Percent), By Soil Group and Salinity Levels

Soil Group A
LF = 0.053, sigma = 0.0177

ECw	**Beans**	**Corn**	**Alfalfa**	**Tomatoes**	**Fruit & Nuts**	**Grapes**
0.7	0.00	0.00	0.00	0.00	0.00	0.00
0.8	8.67	5.33	3.33	4.33	9.00	4.33
0.9	17.33	10.67	6.67	8.67	18.00	8.67
1.0	26.00	16.00	10.00	13.00	27.00	13.00

Soil Group B
LF = 0.093, sigma = 0.0310

ECw	**Beans**	**Corn**	**Alfalfa**	**Tomatoes**	**Fruit & Nuts**	**Grapes**
0.7	0.00	0.00	0.00	0.00	0.00	0.00
0.8	5.00	2.67	1.33	0.67	4.67	2.67
0.9	10.00	5.33	2.67	1.33	9.33	5.33
1.0	15.00	8.00	4.00	2.00	14.00	8.00

Soil Group C

LF = 0.188, sigma = 0.0627		Beans	Corn	Alfalfa	Tomatoes	Fruit & Nuts	Grapes
ECw							
	0.7	0.00	0.00	0.00	0.00	0.00	0.00
	0.8	2.00	0.33	0.33	0.33	0.67	0.67
	0.9	4.00	0.67	0.67	0.67	1.33	1.33
	1.0	6.00	1.00	1.00	1.00	2.00	2.00

Table A is read as follows. If the salinity level remains at 0.7, the current baseline, no additional yield decrement would occur. As salinity is increased, yield decrements increase for all crops. The decline is more pronounced for soil group A, less pronounced for soil group C.

In order to know precisely what the yield decrement would be for each crop requires knowledge of the soil type(s) in which each crop is planted. Since this data was not available a simplifying assumption that each crops acreage is planted uniformly and in the same proportion as the three types of soil in the South Delta.

Commodities and farmed acreages were extracted from the 2004 San Joaquin County Agricultural Commissioner's Office Pesticide Permitting Program Database and commodity valuation was obtained from the San Joaquin County 2004 Annual Crop Report, which is being offered as evidence in this proceeding. Using these data and distributing each crop over the three soil types as described above, yields the following distribution of the total value of the six crop yields by soil type.

Table B; South Delta Crop Value by Soil Grouping (Dollars)

	Beans	Corn	Alfalfa	Tomatoes	Fruit & Nuts	Grapes
Soil Group A	$3,916,938	$14,764,135	$17,271,999	$29,897,231	$17,155,066	$2,601,210
Soil Group B	$3,329,397	$12,549,515	$14,681,199	$25,412,646	$14,581,806	$2,211,029
Soil Group C	$2,546,010	$9,596,688	$11,226,799	$19,433,200	$11,150,793	$1,690,787

Multiplying the yield decrements derived from the Orlob Study (Table A) with the value of crops planted in each soil group (Table B) for each of the salinity levels yields the estimated value of lost yields for each crop, soil type and salinity level. These estimates are detailed in Table C and aggregated over soil type in Table D.

Table C; Dollar Value of Estimated Loss in Crop Yields by Soil Group and Salinity

Soil Group A

ECw	Beans	Corn	Alfalfa	Tomatoes	Fruit & Nuts	Grapes
0.7	$0	$0	$0	$0	$0	$0
0.8	$339,468	$787,421	$575,733	$1,295,547	$1,543,956	$112,719
0.9	$678,936	$1,574,841	$1,151,467	$2,591,093	$3,087,912	$225,438
1.0	$1,018,404	$2,362,262	$1,727,200	$3,886,640	$4,631,868	$338,157

Soil Group B	Beans	Corn	Alfalfa	Tomatoes	Fruit & Nuts	Grapes
ECw						
0.7	$0	$0	$0	$0	$0	$0
0.8	$166,470	$334,654	$195,749	$169,418	$680,484	$58,961
0.9	$332,940	$669,307	$391,499	$338,835	$1,360,969	$117,922
1.0	$499,410	$1,003,961	$587,248	$508,253	$2,041,453	$176,882

Soil Group C	Beans	Corn	Alfalfa	Tomatoes	Fruit & Nuts	Grapes
ECw						
0.7	$0	$0	$0	$0	$0	$0
0.8	$50,920	$31,989	$37,423	$64,777	$74,339	$11,272
0.9	$101,840	$63,978	$74,845	$129,555	$148,677	$22,544
1.0	$152,761	$95,967	$112,268	$194,332	$223,016	$33,816

Table D; Dollar Value of Estimated Crop Loss by Salinity Level

	Beans	Corn	Alfalfa	Tomatoes	Fruit & Nuts	Grapes
Ecw						
0.8	**$556,858**	**$1,154,063**	**$808,905**	**$1,529,742**	**$2,298,779**	**$182,952**

0.9	**$1,011,876**	**$2,244,149**	**$1,542,965**	**$2,929,929**	**$4,448,880**	**$343,360**
1.0	**$1,670,574**	**$3,462,190**	**$2,426,716**	**$4,589,225**	**$6,896,337**	**$548,855**

The impact on crop revenue stemming from increases in salinity of the water in the San Joaquin River is significant. These numbers are sobering; however it does not reflect the total economic impact of this reduction in crop yield on San Joaquin County.

III. The Economic Impact of a Reduction in Crop Yield

When economic activity is reduced (or increased) in one sector of the economy the repercussion of this decrease is not contained to the sector of origin. Because of interdependencies inherent in a region's economy, the change in activity in the original sector is propagated throughout the rest of the region's economy, contracting output (spending) in other sectors. In order to capture these effects, models that reflect this interdependency should be used to assess the total impact of the change in agricultural output caused by increased salinity in the San Joaquin River.

Input-Output models are commonly used to conduct economic impact analysis as they model the interdependencies between sectors of the economy. Input-Output models statistically quantify the relationship between businesses and between consumers and businesses. Once the structure of the economy of a region has been developed, economic activity in one sector of the economy can be traced as it is propagated throughout the rest of the economy. Thus, when activity changes in one sector the subsequent changes on the rest of the economy can be estimated.

The total economic impact of a change in economic activity in one (or more) sector(s) is comprised of three different effects. The direct effect, which is the change in originating sector(s) that starts the process, and in this case it is the reduction of output in the agricultural sectors caused by increased salinity. The secondary impact of this spending arises from inter-industry purchases triggered by the direct expenditures and is know as the indirect effect. The tertiary impact stems from the spending of employees in the affected primary and secondary industries. These consumer expenditures comprise the induced effect.

A commonly used metaphor for the different types of impacts is a stone tossed into a pond. The stone symbolizes the event or activity whose impact is being measured and the pond represents the economy of the region being analyzed. The initial splash, as the stone hits the pond, is analogous to the direct effect, while the waves and ripples that emanate out from that splash represent the indirect and induced effects on the economy.

In terms of the above metaphor the stone in this case is the reduction crop yields and the pond through which this is propagated is the economy of San Joaquin County (The Stockton-Lodi MSA).

IV. Economic Impact Results

In order to measure the economic impact we use one of three commonly employed input-output models. The results are generated using a version of the IMPLAN model which is widely used and was originally developed by the U.S. Department of

Agriculture. The results are presented in tables 1 through 9 below. The economic impact is estimated for each of the three salinity levels; 0.8, 0.9, and 1.0.   Fore each salinity level three tables of results are presented depicting the economic impact of estimated crop decrements on economic output by industrial sector measured in 2005 dollars, on employment by industrial sector, and on tax revenues accruing to Federal, State/Local governments by revenue type and measured in 2005 dollars.

The economic impacts on San Joaquin County, like the yield decrements themselves, increase with the projected levels of salinity.   The individual crop losses at each level of salinity may not seem as significant when examined individually. However, when the losses are pooled together and allowed to ripple throughout the region the numbers quickly become more noteworthy.

Examining the results of the impact study for the crop decrement caused by allowing salinity levels to rise to 1.0 dS/m can be found in tables 7, 8 and 9 demonstrates that significant damage is inflicted on the San Joaquin economy by this reduction in water quality. Loss of output in the economy reaches nearly 32 million dollars and 386 jobs are lost in the county. As a result of all this lost economic activity the tax revenues accruing to state and local governments decline by 1.4 million dollars.

In summary, the true economic impact of reduced salinity levels in the San Joaquin River cannot just be gauged by looking at the value of crop decrement resulting from higher salinity in irrigation water. While the estimates of the dollar loss of individual crop yields in the South Delta are not small, especially to the farmers who lose this revenue, the full impact of these losses is much higher than these crop by crop figures alone. When the total value of lost crops is aggregated and a full economic impact study conducted, the potential damage inflicted by a reduction in river quality become readily apparent.

Water Quality EC_W = 0.8 MMHOS/CM
Employment Impact

Table 1

Industry	Direct	Indirect	Induced	**Total**
Ag, Forestry, Fish & Hunting	(75.1)	(21.5)	(0.2)	(96.7)
Mining	0.0	(0.0)	(0.0)	(0.0)
Utilities	0.0	(0.2)	(0.1)	(0.2)
Construction	0.0	(0.4)	(0.1)	(0.5)
Manufacturing	0.0	(1.7)	(0.5)	(2.2)
Wholesale Trade	0.0	(1.7)	(0.5)	(2.2)
Transportation & Warehousing	0.0	(1.5)	(0.6)	(2.1)
Retail Trade	0.0	(0.3)	(3.7)	(4.1)
Information	0.0	(0.1)	(0.3)	(0.4)
Finance & Insurance	0.0	(1.1)	(1.2)	(2.3)
Real Estate & Rental	0.0	(2.7)	(0.8)	(3.5)
Professional Scientific & Tech Services	0.0	(0.9)	(0.7)	(1.6)
Management of Companies	0.0	(0.1)	(0.2)	(0.3)
Administrative & Waste Services	0.0	(0.8)	(0.9)	(1.7)
Educational Services	0.0	(0.0)	(0.5)	(0.5)
Health & Social Services	0.0	(0.0)	(3.8)	(3.8)
Arts- Entertainment & Recreation	0.0	(0.1)	(0.6)	(0.7)
Accommodation & Food Services	0.0	(0.2)	(2.6)	(2.7)
Other Services	0.0	(0.9)	(1.9)	(2.7)
Government & Non NAICs	0.0	(0.2)	(0.2)	(0.4)
Total	(75.1)	(34.3)	(19.4)	(128.7)

Water Quality EC_W = 0.8 MMHOS/CM

Table 2

Output Impact

Industry	Direct	Indirect	Induced	**Total**
Ag, Forestry, Fish & Hunting	(6,837,314)	(807,905)	(19,886)	(7,665,105)
Mining	0	(6,476)	(1,758)	(8,235)
Utilities	0	(56,477)	(28,268)	(84,746)
Construction	0	(36,404)	(12,889)	(49,293)
Manufacturing	0	(258,091)	(97,680)	(355,771)
Wholesale Trade	0	(217,092)	(69,320)	(286,412)
Transportation & Warehousing	0	(149,173)	(51,809)	(200,983)
Retail trade	0	(18,242)	(216,251)	(234,493)
Information	0	(27,239)	(54,907)	(82,146)
Finance & Insurance	0	(166,688)	(175,565)	(342,253)
Real Estate & Rental	0	(375,451)	(103,826)	(479,277)
Professional- Scientific & Tech Services	0	(62,496)	(57,014)	(119,510)
Management of Companies	0	(10,256)	(15,451)	(25,707)
Administrative & Waste Services	0	(43,145)	(42,640)	(85,786)
Educational Services	0	(1,478)	(22,836)	(24,315)
Health & Social Services	0	(14)	(307,287)	(307,301)
Arts- Entertainment & Recreation	0	(3,992)	(19,892)	(23,884)
Accommodation & Food Services	0	(9,537)	(115,884)	(125,421)
Other Services	0	(93,778)	(123,701)	(217,479)
Government & Non NAICs	0	(34,066)	(245,475)	(279,540)
Total	(6,837,314)	(2,378,000)	(1,782,341)	(10,997,655)

Table 3

Water Quality EC_W = 0.8 MMHOS/CM

Tax Impact

	Employee Compensation	Proprietary Income	Household Expenditures	Enterprises (Corporations)	Indirect Business Tax	Total
Corporate Profits Tax				(136,314)		(136,314)
Indirect Bus Tax: Custom Duty					(7,429)	(7,429)
Indirect Bus Tax: Excise Taxes					(23,911)	(23,911)
Indirect Bus Tax: Fed Non-Taxes					(8,439)	(8,439)
Personal Tax: Estate and Gift Tax						0
Personal Tax: Income Tax			(372,727)			(372,727)
Personal Tax: Non-Taxes (Fines- Fees)			(3,147)			(3,147)
Social Ins Tax- Employee Contribution	(126,575)	(28,780)				(155,355)
Social Ins Tax- Employer Contribution	(131,075)					(131,075)
Federal Government Non-Defense Total	(257,650)	(28,780)	(375,874)	(136,314)	(39,780)	(838,399)
Corporate Profits Tax				(33,315)		(33,315)
Dividends				(396)		(396)
Indirect Bus Tax: Motor Vehicle License					(2,005)	(2,005)
Indirect Bus Tax: Other Taxes					(16,321)	(16,321)
Indirect Bus Tax: Property Tax					(102,048)	(102,048)
Indirect Bus Tax: S/L Non-Taxes					(18,147)	(18,147)
Indirect Bus Tax: Sales Tax					(150,744)	(150,744)
Indirect Bus Tax: Severance Tax					(77)	(77)
Personal Tax: Estate and Gift Tax						0
Personal Tax: Income Tax			(107,987)			(107,987)
Personal Tax: Motor Vehicle License			(3,378)			(3,378)
Personal Tax: Non-Taxes (Fines- Fees)			(28,401)			(28,401)
Personal Tax: Other Tax (Fish/Hunt)			(509)			(509)
Personal Tax: Property Taxes			(1,421)			(1,421)
Social Ins Tax- Employee Contribution	(1,558)					(1,558)
Social Ins Tax- Employer Contribution	(5,608)					(5,608)
State/Local Govt. Non-Education Total	(7,166)	0	(141,696)	(33,710)	(289,342)	(471,915)
Total	(264,816)	(28,780)	(517,570)	(170,025)	(329,122)	(1,310,313)

Water Quality EC_W = 0.9 MMHOS/CM

Employment Impact

Table 4

Industry	Direct	Indirect	Induced	**Total**
Ag, Forestry, Fish & Hunting	(144.0)	(41.2)	(0.4)	(185.6)
Mining	0.0	(0.1)	(0.0)	(0.1)
Utilities	0.0	(0.3)	(0.1)	(0.4)
Construction	0.0	(0.7)	(0.2)	(0.9)
Manufacturing	0.0	(3.3)	(0.9)	(4.2)
Wholesale Trade	0.0	(3.2)	(1.0)	(4.2)
Transportation & Warehousing	0.0	(2.8)	(1.2)	(4.0)
Retail Trade	0.0	(0.6)	(7.2)	(7.8)
Information	0.0	(0.3)	(0.5)	(0.8)
Finance & Insurance	0.0	(2.1)	(2.3)	(4.4)
Real Estate & Rental	0.0	(5.1)	(1.6)	(6.7)
Professional Scientific & Tech Services	0.0	(1.7)	(1.4)	(3.1)
Management of Companies	0.0	(0.2)	(0.3)	(0.5)
Administrative & Waste Services	0.0	(1.5)	(1.8)	(3.3)
Educational Services	0.0	(0.1)	(0.9)	(1.0)
Health & Social Services	0.0	(0.0)	(7.3)	(7.3)
Arts- Entertainment & Recreation	0.0	(0.2)	(1.2)	(1.4)
Accommodation & Food Services	0.0	(0.3)	(4.9)	(5.2)
Other Services	0.0	(1.6)	(3.6)	(5.2)
Government & Non NAICs	0.0	(0.4)	(0.3)	(0.7)
Total	(144.0)	(65.7)	(37.2)	(246.9)

Table 5

Water Quality EC_W = 0.9 MMHOS/CM

Output Impact

Industry	Direct	Indirect	Induced	**Total**
Ag, Forestry, Fish & Hunting	(13,107,820)	(1,549,612)	(38,164)	(14,695,596)
Mining	0	(12,405)	(3,374)	(15,780)
Utilities	0	(108,219)	(54,251)	(162,471)
Construction	0	(69,760)	(24,736)	(94,496)
Manufacturing	0	(494,596)	(187,463)	(682,058)
Wholesale Trade	0	(415,670)	(133,036)	(548,706)
Transportation & Warehousing	0	(285,611)	(99,430)	(385,041)
Retail trade	0	(34,955)	(415,018)	(449,972)
Information	0	(52,198)	(105,374)	(157,572)
Finance & Insurance	0	(319,823)	(336,935)	(656,758)
Real Estate & Rental	0	(719,179)	(199,258)	(918,437)
Professional- Scientific & Tech Services	0	(119,837)	(109,419)	(229,256)
Management of Companies	0	(19,646)	(29,652)	(49,298)
Administrative & Waste Services	0	(82,659)	(81,833)	(164,493)
Educational Services	0	(2,832)	(43,826)	(46,658)
Health & Social Services	0	(28)	(589,729)	(589,757)
Arts- Entertainment & Recreation	0	(7,657)	(38,176)	(45,833)
Accommodation & Food Services	0	(18,279)	(222,400)	(240,678)
Other Services	0	(179,731)	(237,401)	(417,132)
Government & Non NAICs	0	(65,271)	(471,102)	(536,374)
Total	(13,107,820)	(4,557,968)	(3,420,578)	(21,086,366)

Table 6

Water Quality EC_W = 0.9 MMHOS/CM
Tax Impact

	Employee Compensation	Proprietary Income	Household Expenditures	Enterprises (Corporations)	Indirect Business Tax	Total
Corporate Profits Tax				(261,141)		(261,141)
Indirect Bus Tax: Custom Duty					(14,255)	(14,255)
Indirect Bus Tax: Excise Taxes					(45,878)	(45,878)
Indirect Bus Tax: Fed Non-Taxes					(16,192)	(16,192)
Personal Tax: Estate and Gift Tax						0
Personal Tax: Income Tax			(715,318)			(715,318)
Personal Tax: Non-Taxes (Fines- Fees)			(6,041)			(6,041)
Social Ins Tax- Employee Contribution	(242,929)	(55,223)				(298,152)
Social Ins Tax- Employer Contribution	(251,566)					(251,566)
Federal Government Non-Defense Total	(494,495)	(55,223)	(721,358)	(261,141)	(76,324)	(1,608,542)
Corporate Profits Tax				(63,822)		(63,822)
Dividends				(758)		(758)
Indirect Bus Tax: Motor Vehicle License					(3,847)	(3,847)
Indirect Bus Tax: Other Taxes					(31,315)	(31,315)
Indirect Bus Tax: Property Tax					(195,798)	(195,798)
Indirect Bus Tax: S/L Non-Taxes					(34,818)	(34,818)
Indirect Bus Tax: Sales Tax					(289,230)	(289,230)
Indirect Bus Tax: Severance Tax					(148)	(148)
Personal Tax: Estate and Gift Tax						0
Personal Tax: Income Tax			(207,244)			(207,244)
Personal Tax: Motor Vehicle License			(6,483)			(6,483)
Personal Tax: Non-Taxes (Fines- Fees)			(54,505)			(54,505)
Personal Tax: Other Tax (Fish/Hunt)			(977)			(977)
Personal Tax: Property Taxes			(2,727)			(2,727)
Social Ins Tax- Employee Contribution	(2,990)					(2,990)
Social Ins Tax- Employer Contribution	(10,764)					(10,764)
State/Local Govt. Non-Education Total	(13,754)	0	(271,935)	(64,580)	(555,155)	(905,424)
Total	(508,249)	(55,223)	(993,293)	(325,721)	(631,479)	(2,513,965)

Water Quality EC_W = 1.0 MMHOS/CM

Employment Impact

Table 7

Industry	Direct	Indirect	Induced	**Total**
Ag, Forestry, Fish & Hunting	(225.2)	(64.4)	(0.6)	(290.2)
Mining	0.0	(0.1)	(0.0)	(0.1)
Utilities	0.0	(0.5)	(0.2)	(0.7)
Construction	0.0	(1.1)	(0.4)	(1.4)
Manufacturing	0.0	(5.2)	(1.4)	(6.6)
Wholesale Trade	0.0	(5.0)	(1.6)	(6.6)
Transportation & Warehousing	0.0	(4.4)	(1.8)	(6.2)
Retail Trade	0.0	(1.0)	(11.2)	(12.2)
Information	0.0	(0.4)	(0.8)	(1.2)
Finance & Insurance	0.0	(3.3)	(3.6)	(6.9)
Real Estate & Rental	0.0	(8.0)	(2.5)	(10.6)
Professional Scientific & Tech Services	0.0	(2.7)	(2.2)	(4.9)
Management of Companies	0.0	(0.3)	(0.5)	(0.8)
Administrative & Waste Services	0.0	(2.4)	(2.8)	(5.2)
Educational Services	0.0	(0.1)	(1.4)	(1.5)
Health & Social Services	0.0	(0.0)	(11.4)	(11.4)
Arts- Entertainment & Recreation	0.0	(0.3)	(1.8)	(2.1)
Accommodation & Food Services	0.0	(0.5)	(7.7)	(8.2)
Other Services	0.0	(2.6)	(5.6)	(8.2)
Government & Non NAICs	0.0	(0.6)	(0.5)	(1.1)
Total	(225.2)	(102.8)	(58.1)	(386.1)

Water Quality EC_W = 1.0 MMHOS/CM

Table 8

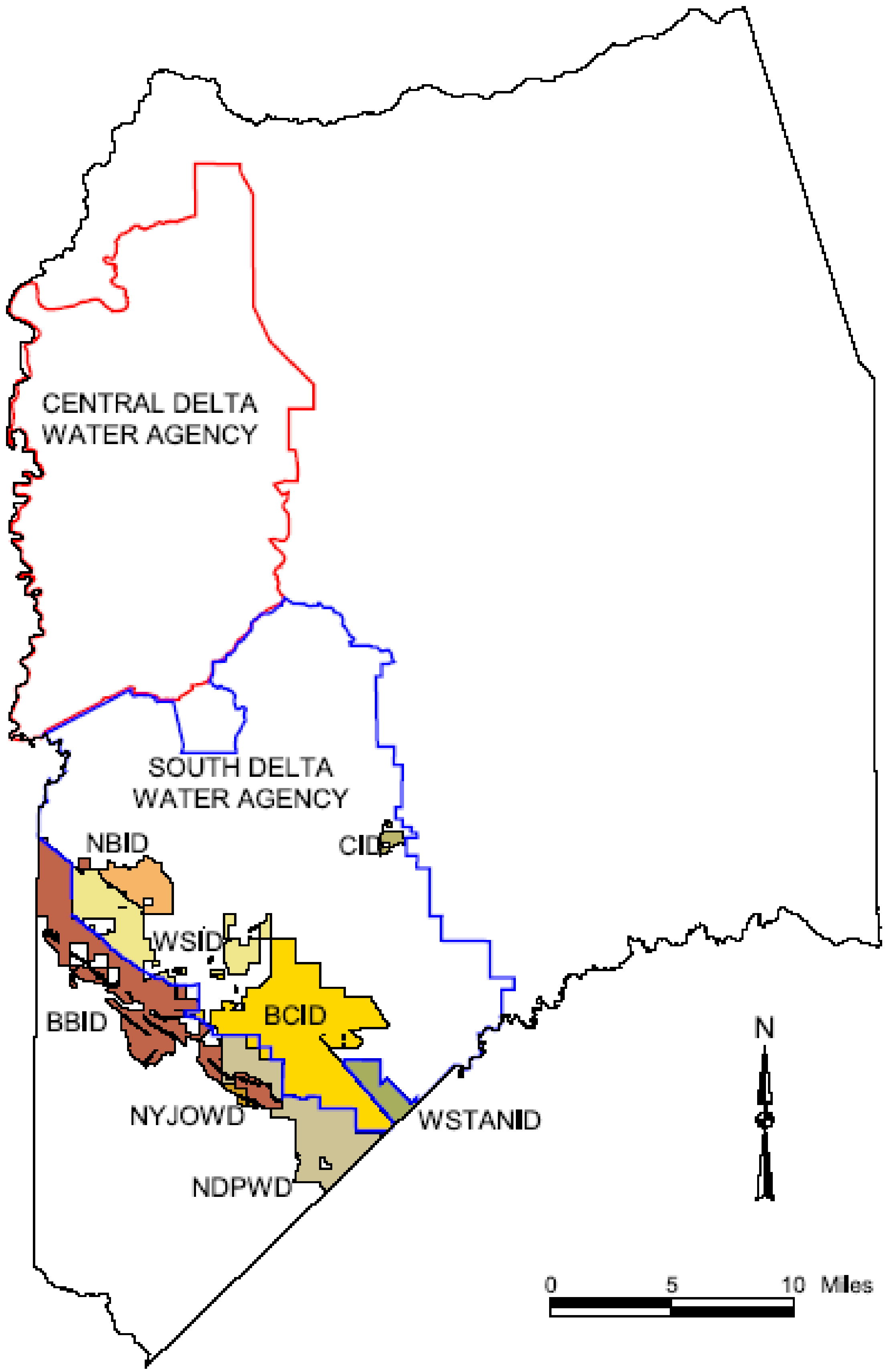
Output Impact

Industry	Direct	Indirect	Induced	**Total**
Ag, Forestry, Fish & Hunting	(20,511,940)	(2,423,715)	(59,658)	(22,995,312)
Mining	0	(19,429)	(5,275)	(24,704)
Utilities	0	(169,431)	(84,805)	(254,237)
Construction	0	(109,213)	(38,667)	(147,880)
Manufacturing	0	(774,272)	(293,040)	(1,067,313)
Wholesale Trade	0	(651,275)	(207,961)	(859,236)
Transportation & Warehousing	0	(447,520)	(155,428)	(602,948)
Retail trade	0	(54,727)	(648,752)	(703,479)
Information	0	(81,717)	(164,720)	(246,437)
Finance & Insurance	0	(500,064)	(526,695)	(1,026,759)
Real Estate & Rental	0	(1,126,353)	(311,479)	(1,437,832)
Professional- Scientific & Tech Services	0	(187,487)	(171,043)	(358,530)
Management of Companies	0	(30,768)	(46,352)	(77,120)
Administrative & Waste Services	0	(129,436)	(127,921)	(257,357)
Educational Services	0	(4,435)	(68,509)	(72,944)
Health & Social Services	0	(43)	(921,860)	(921,904)
Arts- Entertainment & Recreation	0	(11,975)	(59,677)	(71,652)
Accommodation & Food Services	0	(28,611)	(347,653)	(376,264)
Other Services	0	(281,333)	(371,103)	(652,436)
Government & Non NAICs	0	(102,197)	(736,424)	(838,621)
Total	(20,511,940)	(7,134,001)	(5,347,023)	(32,992,963)

Table 9

Water Quality EC_W = 1.0 MMHOS/CM
Tax Impact

	Employee Compensation	Proprietary Income	Household Expenditures	Enterprises (Corporations)	Indirect Business Tax	Total
Corporate Profits Tax				(408,943)		(408,943)
Indirect Bus Tax: Custom Duty					(22,288)	(22,288)
Indirect Bus Tax: Excise Taxes					(71,733)	(71,733)
Indirect Bus Tax: Fed Non-Taxes					(25,318)	(25,318)
Personal Tax: Estate and Gift Tax						0
Personal Tax: Income Tax			(1,118,180)			(1,118,180)
Personal Tax: Non-Taxes (Fines- Fees)			(9,442)			(9,442)
Social Ins Tax- Employee Contribution	(379,725)	(86,341)				(466,066)
Social Ins Tax- Employer Contribution	(393,226)					(393,226)
Federal Government Non-Defense Total	(772,951)	(86,341)	(1,127,622)	(408,943)	(119,339)	(2,515,196)
Corporate Profits Tax				(99,944)		(99,944)
Dividends				(1,187)		(1,187)
Indirect Bus Tax: Motor Vehicle License					(6,015)	(6,015)
Indirect Bus Tax: Other Taxes					(48,963)	(48,963)
Indirect Bus Tax: Property Tax					(306,144)	(306,144)
Indirect Bus Tax: S/L Non-Taxes					(54,440)	(54,440)
Indirect Bus Tax: Sales Tax					(452,233)	(452,233)
Indirect Bus Tax: Severance Tax					(231)	(231)
Personal Tax: Estate and Gift Tax						0
Personal Tax: Income Tax			(323,962)			(323,962)
Personal Tax: Motor Vehicle License			(10,134)			(10,134)
Personal Tax: Non-Taxes (Fines- Fees)			(85,202)			(85,202)
Personal Tax: Other Tax (Fish/Hunt)			(1,527)			(1,527)
Personal Tax: Property Taxes			(4,262)			(4,262)
Social Ins Tax- Employee Contribution	(4,674)					(4,674)
Social Ins Tax- Employer Contribution	(16,825)					(16,825)
State/Local Govt. Non-Education Total	(21,499)	0	(425,088)	(101,131)	(868,026)	(1,415,744)
Total	(794,449)	(86,341)	(1,552,710)	(510,074)	(987,365)	(3,930,940)


CENTRAL DELTA
WATER AGENCY
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WATER AGENCY
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NYJOWD
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STATEMENT OF QUALIFICATIONS
Sean M. Snaith, Ph.D.

B.S. Economics, with Honors, Allegheny College, 1989
M.A. Pennsylvania State University, 1994

Ph.D. Pennsylvania State University, 1996

Current position:

Director, Business Forecasting Center

Associate Professor of Business Economics

Eberhardt School of Business

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ATTACHMENT "A"

Exhibit “R”

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Attorney for SOUTH DELTA
WATER AGENCY and

BEFORE THE

STATE WATER RESOURCES CONTROL BOARD

Potential Changes to the Bay-Delta Water Quality Control Plan; Draft Substitute Environmental Documents in Support thereof	DECLARATION OF JERRY ROBINSON

I, Jerry Robinson, declare as follows:

1. I am 70 years old and have resided on Roberts Island, San Joaquin County all of my life.

2. I have farmed land on Roberts Island, Union Island and other local areas for approximately 50+ years on behalf of myself and/or family related farming entities or partnerships.

3. I am a Board member and President of the South Delta Water Agency, and have served on numerous other Reclamation District and agricultural related boards throughout my farming career.

3. I am familiar with the local soil, surface water, ground water and crops in the South Delta, and have been involved in various processes, investigations and analyses dealing with these issues for many years.

4. Tile drain systems, in the South Delta are for the specific purpose of intercepting (as far as possible) the ground water and to keep it out of the root zone of the crops because that ground water is generally too salty for the crops grown in this area. These drains also receive

excess applied surface water that passed through the root zone, but that excess surface water and the amount of salt it contains is extremely small when compared to the ground water and the salt therein.

4. Various crops are grown in the South Delta, including permanent trees like walnuts and almonds, vines such as grapes and blueberries, alfalfa, corn, tomatoes and many other row crops. I am generally familiar with each of these crops.

5. Many local crops have roots which extend down to and into the shallow ground water of our area. Most of the ground water under Roberts Island, Union Island, Fabian Tract and portions of Naglee-Burke Tract, Pescadero Tract and Stewart Tract is from 3 - 8 feet in depth. As such, the roots of walnuts, almonds, grapes and alfalfa certainly extend down to this ground water. To some extent those crops will use some of this ground water to the extent possible, though our farming practices attempt to minimize root contact with that ground water. Notwithstanding our efforts, the salty ground water is regularly re-introduced back into many crop root zones, which of course makes leaching more difficult.

6.. In our area we also have open drain ditches which too serve as methods of lowering the ground water. As the open ditch drain fills with water (seeping from the neighboring soils) it is pumped out, back into the river. However, because the soils in the area are not uniform in composition, the water does not flow evenly or consistently. This means that as we pump out the deep open drain ditches the water surface in those drains is actually lower than the neighboring ground water. I witnessed this near the time of this declaration where I excavated a hole in one of my alfalfa field on Bowman Road, Roberts Island. The ground water was at approximately 3 feet, while the neighboring open drain ditch had a water level one or two feet deeper.

8. Because the federal Central Valley Project causes hundreds of thousands of tons of salt to enter the San Joaquin River upstream of the Delta, local farmers have been forced to take actions necessary to lessen the effects of that salt through good management practices. I do not believe the current salinity standards in our area are protective of agriculture given my experience.

I declare under penalty of perjury under the laws of the State of California that the foregoing is true and correct.

Dated: 3/29/13

Jerry Robinson

Exhibit “S”

October 10, 2011
Public Draft
(Revised)

Economic Sustainability Plan for the Sacramento-San Joaquin Delta

Delta Protection Commission

Adopted by the Delta Protection Commission on October 25, 2011

Public comments are welcome. Please submit your comments to: espcomments@pacific.edu

Draft Executive Summary

Economic Sustainability Plan for the Sacramento-San Joaquin River Delta

The Sacramento-San Joaquin River Delta is a unique place of economic, environmental, historic and cultural significance. The land and water resources of the Delta support significant agricultural and recreation economies, and the Delta also has an important role as an infrastructure hub for water, energy, and transportation. The region's rich history boasts of bustling, river-based commerce before the automobile age, and its cultural uniqueness includes the only rural town in America built by early Chinese immigrants. As the largest estuary on the west coast of the Americas, the Delta also is a place of striking natural beauty and ecological significance that is struggling with serious environmental degradation problems. Although surrounded by growing cities, the Delta remains a highly-productive agricultural area with rural charms, landscapes, and waterscapes not found elsewhere in California.

In recent years, there has been great concern over increasing environmental degradation in the Delta and over court decisions that reduced the quantity of water delivered to southern California through the state and federal water project intakes in the south Delta to protect endangered fish. Combined with additional concerns about the stability of the Delta's levee system, these concerns led the California legislature to pass the Delta Reform Act of 2009. The Act created the Delta Stewardship Council and charged it with developing a Delta Plan to achieve the coequal goals of "providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem."

Recognizing the potential impact of the Delta Plan on the people and economy of the Delta, the Delta Reform Act stated that the coequal goals of water supply reliability and restoring the Delta ecosystem "shall be achieved in a manner that protects and enhances the unique cultural, recreational, natural resource, and agricultural values of the Delta as an evolving place." Among the measures to address this goal, the Delta Protection Commission was tasked with developing this Economic Sustainability Plan to inform the Delta Stewardship Council's development of the Delta Plan.

The concept of economic sustainability and the objective to "protect and enhance the unique cultural, recreational, natural resources, and agricultural values of the California Delta as an evolving place," can be interpreted in different ways. In economic terms, most stakeholders agreed that a minimum requirement is to maintain the economic value of the entire Delta economy in the future, and many believed in a stronger interpretation of enhancement of every key economic sector. The Fifth Staff Draft of the Delta Stewardship Council's Delta Plan uses performance measures that follow this stronger interpretation of economic sustainability where growth in one sector is not a substitute for deterioration in another area. In contrast, non-Delta water interests take a narrower view, and claim that "evolving place" means that the Delta is in a state of inevitable decline and only a handful of "unique" values need to be protected. Regardless of the interpretation, it is clear that the Stewardship Council must consider the Delta economy when preparing the Delta Plan. In addition, most stakeholders agree that this objective requires the protection of the cultural and historical heritage and the long-term economic viability of the Delta's historical Legacy Communities.

The Economic Sustainability Plan (ESP) measures the key elements of the Delta economy, develops strategies to enhance the economy, and analyzes the impacts of several important proposals for the Delta Plan on the region's economic sustainability. The analysis in this Economic Sustainability Plan shows that it is possible to protect and enhance the Delta economy and be consistent with the coequal goals. The ESP finds that a large investment in strengthening the Delta's levee and emergency response systems is a cost-effective approach to improving water supply reliability, economic sustainability in the Delta, and reliable energy, transportation, and water infrastructure that serves statewide interests. The ESP also finds that most proposals for ecosystem restoration can be consistent with economic sustainability.

The Economy and Infrastructure of the Delta: Baseline, Trends, and Strategies for Improvement

The boundaries of the Legal Delta are shown in Figure A. The Delta Protection Act of 1992 defined the Delta boundaries including the Primary and Secondary Zone and created the Delta Protection Commission, charging it with developing a Land Use and Resource Management Plan for the Primary Zone. The majority of the Delta's 738,000 acres of land is in the rural and agricultural Primary Zone. The population of the Primary Zone is approximately 12,000 and has remained steady in the nearly 20 years since the passage of the Delta Protection Act.

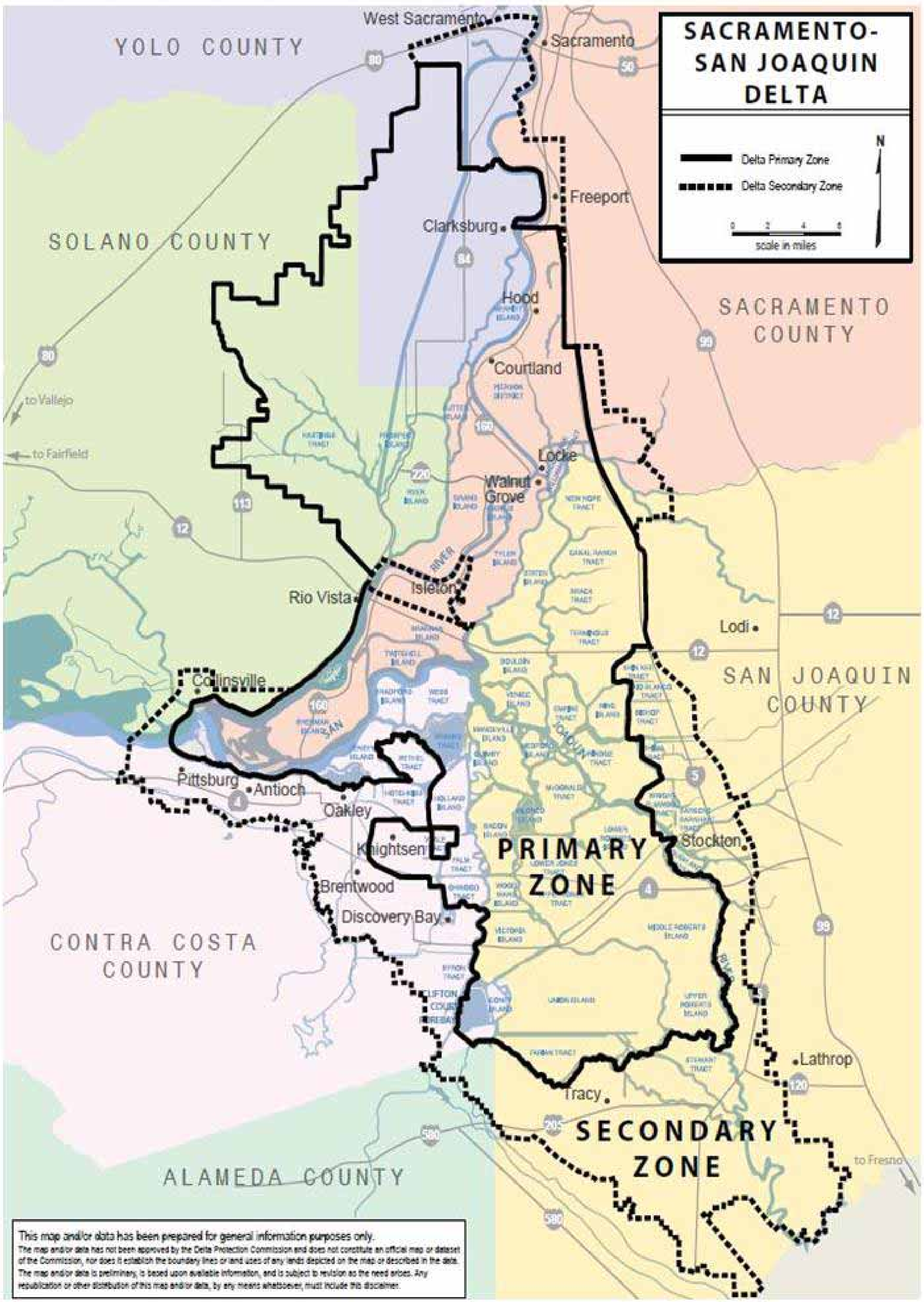
The Legal Delta, including both the Primary Zone and Secondary Zone, contains significant portions of five counties, Contra Costa, Sacramento, San Joaquin, Solano and Yolo, and a small rural corner of Alameda County. The Delta includes parts of several large cities including Antioch, Pittsburg, Stockton, Sacramento, Tracy, and West Sacramento. The legal Delta has a population of 571,000, according to the 2010 Census, which has increased by about 200,000 people—more than 50 percent—in the 20 years since the 1990 Census. All of the population growth, and virtually all of the Delta's urbanized land, is located within the Delta's Secondary Zone.

The Primary Zone economy is export-oriented and creates jobs and income far in excess of the population and workforce that resides in the Primary Zone. The Secondary Zone and the counties surrounding the Delta supply the Primary Zone economy with a workforce, services, manufacturing, and transportation that add value to the agricultural, energy, and other resource-based output of the Delta.

The ESP calculated measures of industry concentration for the Legal Delta with measures of both employment and output, and identified three clear areas of relative concentration: 1) Agriculture; 2) Transportation, Warehousing, and Utilities; and 3) Construction, Housing, and Real Estate. All of these areas are potentially impacted by the Delta Plan. Since there is great interest in recreation and tourism as an economic driver in the Delta, it is significant to note that the tourism-oriented Arts, Entertainment, and Recreation sector tied with Information and Management for the lowest concentration of the 21 industries analyzed in the Legal Delta. However, water-based recreation in the Delta is a significant economic driver, and as discussed in Chapter 8, most of its economic impact is in the retail and hospitality sector.

The Delta Reform Act of 2009 and the Delta Protection Act of 1992 are primarily concerned with the natural resources of the Delta and the economic activity sustained by those resources, such as agriculture and outdoor recreation. In addition, the resources of the Delta support significant water, energy, and transportation infrastructure that serves the Delta, regional, and state economies, and an important commercial and recreational salmon fishery throughout the state. Indeed, an important economic cluster in the Delta is Transportation, Warehousing, and Utilities, and their development is directly dependent on maintaining and enhancing the Delta as a regional transportation and energy hub. The ESP conducted a closer analysis of three important areas for the Delta's economic sustainability: agriculture; recreation and tourism; and infrastructure. The remainder of this section looks more closely at the baseline, trends, and strategies for enhancing these areas of the Delta economy.

Figure A Map of Primary and Secondary Zones of the Sacramento-San Joaquin Delta



Delta Agriculture

Agriculture is the dominant land use in the Delta. Farmland makes up about two-thirds of the area of the Delta, and nearly 80 percent of all Delta farmland is classified as Prime Farmland, the highest quality designation given by the California Farmland Mapping and Monitoring Program. In contrast, less than 20 percent of all farmland in California is Prime Farmland.

Corn and alfalfa occupy the greatest acreage in the Delta, whereas processing tomatoes and wine grapes generate the most crop revenue. These crops have important links to three value-added manufacturing sectors in the region: wineries, canneries, and dairy products. Asparagus and pears are historically high-value crops in the Delta and continue to be significant contributors, although acreage of both has decreased. The majority of pumpkins and blueberries grown in California come from the Delta and reflect the variety of products. Total agricultural revenues in the Delta were estimated at $795 million in 2009, including $702 million in crop revenue and $93 million from animals and animal products.

Nearly 80 percent of Delta farmland is used for lower-value field and grain crops, pasture, and grazing lands. These lands are important to supporting animal agriculture in the Delta and the larger region, most notably the California dairy industry where scarcity and costs of forage crops has become a challenge. Animal agriculture is less prevalent in the Delta than in other areas of the San Joaquin Valley, but milk is still the fifth most valuable agricultural commodity produced in the Delta, and animal production generates about 12 percent of Delta farm revenue. In contrast, milk is the most valuable agricultural product in San Joaquin County and other nearby areas in the San Joaquin Valley, and the Delta is an important source of local feed.

High-value vineyards, truck, and deciduous crops generate close to 70 percent of crop revenue in the Delta on about 20 percent of the Delta's farmland, and account for 80 percent of the economic impact of Delta agriculture when value-added manufacturing such as canneries and wineries are included. Like other areas in the Central Valley, Delta agriculture is expected to continue a gradual trend towards higher-value crops over time, increasing the contribution of Delta agriculture to the regional economy.

The economic impact analysis estimates that Delta crop and animal production has an economic impact of roughly 9,700 jobs, $683 million in value added, and $1.4 billion in output in the five Delta counties. Across all of California, the economic impact of Delta agriculture is approximately 13,000 jobs, $819 million in value added, and $1.6 billion in output.[1]

When related value-added manufacturing such as wineries, canneries, and dairy products are included with the impact of Delta agriculture, the total economic impact of Delta agriculture is roughly 13,200 jobs, $1.059 billion in value-added, and $2.647 billion in economic output in the five Delta counties. Including value-added manufacturing, the statewide impact of Delta agriculture is about 25,000 jobs, $2.135 billion in value-added, and $5.372 billion in economic output. Additional details and analysis of Delta agriculture can be found in Chapter 7 of the Economic Sustainability Plan.

[1] The economic impact analysis of agriculture, recreation, and tourism utilizes the IMPLAN model to calculate what are commonly known as the "ripple" effects on other industries such as the purchase of inputs in the local economy and local consumer spending supported by the income. Jobs are reported as annual monthly averages and will vary by season. Value added measures total regional income generated by the activity and is comparable to gross domestic product. Output sums the total revenue of enterprise which is higher than the value added or income created by the enterprise.

Delta Recreation and Tourism

Recreation is an integral part of the Delta economy, generating roughly 12 million visitor days of use annually and approximately $250 million dollars visitor spending in the Delta each year. Of the roughly 12 million visitor days spent in the Delta each year, approximately 8 million days are for resource-related activities (e.g., boating and fishing), 2 million days are for right-of-way-related and tourism activities (e.g., bicycling and driving for pleasure), and 2 million days are for urban parks-related activities (e.g., picnicking and organized sports).

Boating and fishing have the biggest economic impact, and are estimated to generate nearly 80 percent of the recreation and tourism spending in the Delta, including significant expenditures on lodging, meals, supplies, marina services, and fuel. In addition to visitor spending, non-trip spending such as boat purchases and marina rentals are estimated at roughly $60 million annually for total recreation-related spending of $312 million annually in the Delta. Delta recreation and tourism supports over 3,000 jobs in the five Delta counties. These jobs provide about $100 million in labor income and a total of $175 million in value added to the regional economy. Across all of California, Delta recreation and tourism supports over 5,200 jobs, and contributes about $348 million in value added.

Despite significant population growth in the market area, the available data suggests that boating and fishing activity in the Delta has grown little in the past 20 years. Boat registrations, employment at marinas and boating-related industries, and the number of marinas are virtually unchanged over the past two decades. This trend could reflect concerns about water and fishing quality in the Delta, and could also be influenced by the poor economy, high fuel prices, and broader trends in boating and fishing participation across the nation.

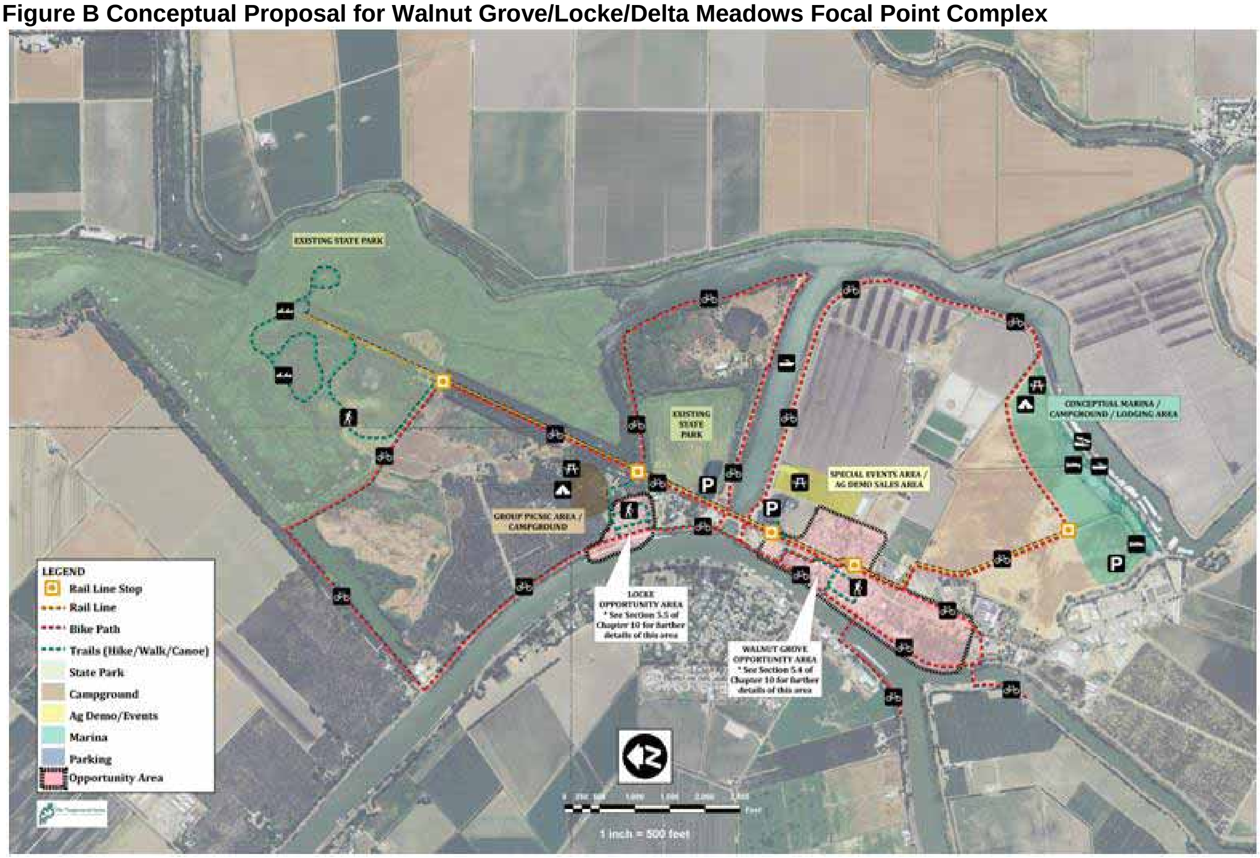
While boating and water recreation will remain the largest piece of the Delta recreation industry, land-based activities such as agritourism, wine tasting, wildlife watching, historic and cultural tourism, bicycling, and driving for pleasure are likely to drive future growth in Delta recreation. The majority of visitors to the Delta are from Northern California, an area with great population growth potential but also with nearby locations with successful land-based recreation and tourism economies that compete with the Delta for visitors. The residents of a dozen counties around the Delta represent the principal market for future growth in Delta visitation. This market area has a population of approximately 11.9 million people, and projections indicate this figure could grow by about 50 percent or 5.7 million people by 2050.

Because of slow expected growth in boating recreation and the relatively small base of land-based tourism in the Delta, we project Delta recreation and tourism will grow more slowly than the regional population. If resource quality and recreational facilities are maintained so that the Delta retains its current level of competitiveness as a recreation destination, visitation could increase by 3.4 million visitor days and in-Delta spending could increase by nearly $80 million, roughly 35 percent, over 40 years.

A plan for the enhancement of recreation in the Delta centers on five location-based strategies: specific waterways, points of interest, focal point complexes, natural habitat areas, and urban edge areas that surround the Delta. Recreation development in the Delta should be coordinated, consistent, branded, and marketed. A National Heritage Area could be an effective means to brand and coordinate strategies to enhance resource-based recreation, agritourism, and historical and cultural tourism.

Figure B is a conceptual illustration of what a viable focal point complex could look like in the historic area of Walnut Grove and Locke. The figure shows coordinated development of a public park at Delta Meadows with a private sector catalyst development in a modern marina and recreation facility that is tied together with a network of non-motorized trails that include revitalized, historic commercial districts of the Legacy Communities. Successful execution of this type of plan would require improved flood control and a facilitator to encourage and coordinate the public and private investments. Additional details on recreation and tourism enhancement strategies are in Chapter 8 of the Economic Sustainability Plan.

Figure B Conceptual Proposal for Walnut Grove/Locke/Delta Meadows Focal Point Complex



Delta Infrastructure Services

The Delta is a critical infrastructure hub for the regional and state economy. While the Delta's importance to the state water system is well-known, its importance to energy, transportation, and in-Delta municipal and industrial water supplies is less appreciated. As discussed in Chapter 5 and mapped in Appendix D, all of these infrastructure services are vulnerable to floods, earthquakes, and sea-level rise, and require the continued maintenance and enhancement of the Delta's levee system.

The Delta is an important energy resource for California. The Delta contains the largest natural gas production field in California, as well as its largest natural gas storage facility below McDonald Island in the central Delta. In addition to heating and cooking, natural gas fuels the majority of California's electricity supply, and natural gas power plants in the five Delta counties, many within the legal Delta, produce 20 percent of California's natural gas-powered electricity. Major electricity transmission lines in the Delta interconnect California with the Pacific Northwest and carry roughly 10 percent of the state's summer electricity load. Gasoline and aviation fuel pipelines crossing the Delta supply large portions of Northern California and Nevada. Besides these energy resources, wind and solar resources are being studied for further development. Taken together, the Delta's contribution to the state's energy network is comparable to its contribution to the state water system.

The Delta also contains increasingly important parts of the inter-regional transportation network that supports the regional and in-Delta economy. As east-west transportation corridors to the north and south of the Delta become increasingly congested and constrained, the demand for through-Delta transportation is growing rapidly. The ports of Stockton and Sacramento are focal points of regional economic development and rely on through-Delta shipping channels. The ports' marine highway corridor project will increase and diversify the water freight that moves through the Delta and relieve air pollution and traffic in the region. Traffic data shows large increases on highways in the Secondary Zone, as well as through the middle of the Primary Zone on State Route 12, and smaller but significant increases on State Route 4 in the Primary Zone. Through-Delta railways are also an important link in the transportation system.

The Secondary Zone of the Delta and the surrounding counties also draw a significant portion of their municipal and industrial water supplies from the Delta. Changes to Delta water quality—whether an increase in salts or organic carbon—have important effects on urban water supplies in and around the Delta. Significant deterioration of in-Delta water quality could increase water treatment costs by tens of millions of dollars each year and require hundreds of millions of dollars in capital investment in advanced treatment facilities for utilities serving Delta urban areas.

Two Key Issues for Economic Sustainability in the Delta

Delta Levees and Economic Sustainability

Since the early 20th century, the current-day Delta levee system has provided flood control that allows productive agricultural and urban uses of land, channels water for urban and agricultural uses, protects critical infrastructure, and creates a desirable setting for boating and water-based recreation in an environment unique in California. The levee system is the foundation on which the entire Delta economy is built. Therefore, a sustainable Delta economy requires a sustainable levee system.

It has been the goal of the State and the federal government, working through the Department of Water Resources (DWR), the U.S. Army Corps of Engineers (USACE), and the local reclamation districts, to meet the Delta-specific PL 84-99 standard since 1982 when DWR and USACE produced a joint report on the Delta levees, which recommended the basis for this standard. If effectively used, funds currently in the pipeline should bring the Delta levees close to achieving this goal. When these funds have been expended, more than $698 million will have been invested in improvements to the Delta levees since 1973. These improvements have created significantly improved Delta levees through modern engineering and construction, making obsolete the historical data that is still sometimes used for planning or predicting rates of levee failure.

Three approaches can help all jurisdictions and planners further reduce the risks resulting from the failure of the Delta levees. These approaches are: (1) build even more robust levees, (2) improve both regular maintenance and monitoring and flood fighting and emergency response following earthquakes, and (3) improve preparedness for dealing with failures after they occur. With regard to the first approach, the big question is not whether they should be improved to the

Delta-specific PL 84-99 standard. Instead, the key question is whether in order to support and enhance various in-Delta, regional, State and federal interests they should be improved to a higher standard in order to address hazards posed by not only floods, but also earthquakes and sea-level rise. Our conclusion is that these improvements would be advantageous not only for flood control and protection against earthquakes and sea-level rise, but because they also would allow for planting vegetation on the water side of the levees—an essential component of Delta ecosystem repair. These further-improved levees would have wider crowns to provide for two-way traffic and could easily be further widened at selected locations to allow the construction of new tourist and recreational facilities out of the statutory floodplain.

Improvement of most Delta "lowland" levees, the levees that protect lands below sea-level, and selected other levees to this higher standard would cost $1 to $2 billion in base construction costs over the cost of reaching the PL 84-99 standard. Including vegetation and habitat enhancement, total program costs might be in the order of $4 billion, similar to the cost projected by the PPIC (2007) in their "Fortress Delta" alternative. While the billions of dollars required to build levees to this higher standard is a large investment, it is a cost-effective joint solution that simultaneously reduces risk to all Delta infrastructure. While a $12 billion investment in isolated conveyance may allow for somewhat larger water exports, it doesn't protect other critical infrastructure, and billions in additional investments would still be required to protect highways, energy, and other water and transportation infrastructure. Just as a species by species approach is an inefficient and ineffective way to protect ecosystems, a system by system approach is an inefficient and ineffective way to protect the state's infrastructure. Chapter 5 contains a detailed assessment of the Delta levee system.

Sustainable Legacy Communities: Where the Challenges and Strategies Come Together

Economic opportunities and constraints facing the Delta's Legacy Communities mirror those in the broader Primary Zone. The current economies of the Legacy Communities are agriculturally based, providing support services and limited workforce housing for the Primary Zone's largest industry as well as some housing for retirees and service and professional workers who commute into nearby urban areas such as Sacramento. Despite the current base in agriculture and rural bedroom and retirement communities, much of the revitalization strategies for Legacy Communities are based on growing their appeal as destinations for recreation and tourism. This includes promoting the emerging agritourism sector—including wine and local foods—as an economic development theme.

However, a strict and multi-layered regulatory framework places limits on economic development opportunities within the Delta's Legacy Communities. The aging and occasionally sub-standard building stock needs improvement, potentially utilizing redevelopment of existing buildings and/or a limited amount of new development in order to accommodate visitor- and local-serving enterprises. New investment is especially important because the existing base of hospitality- and tourism-related enterprises is very limited and insufficient to attract and capture significant tourist activity. The most developed recreation and tourism enterprises in the Delta are campgrounds and marinas that serve water-based recreation; these are mostly located outside the Legacy Communities and often outside the Primary Zone.

An already burdensome regulatory environment has been made significantly worse by the recent remapping of FEMA flood zones. All of the Legacy Communities along the Sacramento River have either been or are in the final process of being remapped into the 100-year floodplain. The requirements of this designation can make major property investments financially infeasible, and many stakeholders are concerned that the flood zone designation could cause the Legacy Communities to slowly wither away. It is clear that the economic sustainability of the Legacy Communities is dependent on levee and flood-control investments as well as other strategies to address the constraints of flood zone designation.

Despite these challenges, the Legacy Communities have significant historical, cultural, and economic values and the potential to become attractive destinations for visitors and more prosperous, higher quality of life for residents. Chapter 10 includes more detailed visions and strategies for Legacy Communities, including case studies of Walnut Grove, Locke, and Clarksburg.

Impact of Water Supply and Ecosystem Restoration Proposals on the Delta Economy

Current proposals for new water supply and ecosystem restoration projects have serious implications for economic sustainability in the Delta. The isolated conveyance and many habitat restoration proposals are being developed in the Bay Delta Conservation Plan (BDCP), and the Economic Sustainability Plan relies on the November 2010 draft of the BDCP to describe these proposals. In addition, other proposals regarding Delta levees, land use regulation, and economic development have been made by the Delta Stewardship Council, Department of Water Resources, the Public Policy Institute of California, and the Delta Vision Strategic Plan.

Figure C summarizes the estimated impacts of the proposed actions. In Figure C, red shading indicates a negative effect of $20 million or more annually, orange is negative effect of less than $20 million annually, yellow represents little or no effect, and green are economic benefits. Three proposals—isolated conveyance, 65,000 acres of tidal marsh, and six-island open water area—have negative effects in all three critical areas of the economy, with a negative impact exceeding $20 million in at least one area. These proposals are clearly incompatible with economic sustainability at their current levels.

Proposals that would reduce the capacity or affected acreage of these proposals by 70-80 percent (i.e. 3,000 cfs conveyance, under 25,000 acres of tidal marsh, one small flooded island) were not evaluated, but may be consistent with economic sustainability. The other conservation measures have a mix of negative, neutral, and positive effects and could be consistent with economic sustainability with cooperative planning and appropriate mitigation of local impacts. The effects of all these proposals are analyzed in detail in Part 2 (Chapters 6 through 9).

Figure C Summary of Impacts of Policy Scenarios

Proposals/Impacts	**Agriculture**	**Recreation & Tourism**	**Infrastructure Services**
1. Isolated Conveyance Facility (*15,000 cfs tunnel in dual conveyance system*)	1) Water quality losses $20m-$80m annually, increased risk 2) Footprint displaces $10m to $15m in annual crops	Potential fishing benefits, but negative effects from North Delta intakes and water quality are larger	1) Water quality negative impacts on M&I supplies 2) Risk of lost support for levee investment
2. Habitat Proposals:			
a) Yolo Bypass Fishery Enhancements	Losses $1m to $5m annually, dependent on flood duration	Potential recreation benefits	Flood control benefits
b) San Joaquin River Floodplain Restoration	1) BDCP proposal - 10,000 acres, up to $20m annual crop loss 2) Paradise cut alternative: 2,000 acres – collaborative plan	Potential recreation benefits	Flood control benefits
c) 65,000 acres of tidal marsh restoration	$18m to $77m annual crop losses, low losses in Suisun Marsh/ highest losses in South Delta	South Delta tidal marsh likely negative recreational impacts	1) South Delta & Cache Slough tidal marsh could increase organic carbon in municipal water supplies 2) Suisun Marsh and west Delta restoration could have positive impacts on Delta water quality
d) "Natural Communities" Protection: 32,000 acres of easements and 8,000 acres rangeland conversion	Agricultural losses range from $5m to $25m annually	Wildlife viewing could generate new recreation visits, although spending is low for this activity.	Minimal impact
3) Six Island Open Water Scenario	$12m in annual crop losses	Recreation impact very large as located in most popular boating area. Eliminates wind-protected channels and 40% of Delta marinas in immediate area exposed to negative impact	Empire Tract has new Stockton water intake. Organic carbon impact to Stockton water supply, and silting of shipping channel.
4) DSC Covered Actions Regulation	Potentially large impacts on all sectors. Deter investments with increased cost and uncertainty.		
5) Delta Vision Economic Development Strategies	National Heritage Area designation could be useful (DPC feasibility study in progress). Delta Investment Fund is useful, but prospects for funding are very uncertain. Other ideas have limited potential and feasibility.		

Recommendations for Economic Sustainability in the Delta

The recommendations are organized around eight topics. Considering the recommendations together, the overall strategy is consistent with economic sustainability in the Delta and the coequal goals of increased water supply reliability and ecological restoration. Chapter 12 includes more detailed descriptions and discussion of the proposed recommendations.

Levees and Public Safety Recommendations

- Improve and maintain all non-project levees to at least the Delta-specific PL 84-99 standard.
- Improve most "lowland" levees and selected other levees to a higher Delta-specific standard that more fully addresses the risks due to earthquakes, extreme floods, and sea-level rise, allows for improved flood fighting and emergency response, provides improved protection for legacy communities, and allows for growth of vegetation on the water side of levees to improve habitat.
- The Delta Levee Subventions and Special Projects Program should continue to be supported.
- Transfer to a regional agency with fee assessment authority on levee beneficiaries of responsibility for allocating funds for the longer-term improvement of Delta levees and the coordination of Delta emergency preparedness, response, and recovery.
- In addition to providing funding for longer-term levee improvements, provide on-going funding for regular levee maintenance and expanded emergency preparedness, response, and recovery.
- Reduce or eliminate regulatory impediments to action by the creation of a one-stop permitting system for selected activities within the Delta including dredging, levee construction, and ecosystem restoration.

General Recommendations for Economic Sustainability

- Designate a regional agency to implement and facilitate economic development efforts. The main tasks of this entity are: marketing and branding, permitting and regulatory assistance, planning and coordination, and strategically managing the Delta Investment Fund as described in Section 1 of Chapter 11.
- Economic impacts of habitat creation and development of facilities for export water supply should be fully mitigated.
- Land use planning and regulation must be clear and consistent across agencies.

Recommendations for the Economic Sustainability of Agriculture

- Maintain and enhance the value of Delta agriculture.
- Limit the loss of productive farmland to urbanization, habitat, and flooding to the greatest practical extent.

- Protect Delta water quality and water supplies for agriculture.

- Support growth in agritourism.

- Support local value-added processing of Delta crops.

Recommendations for Economic Sustainability of Recreation and Tourism

- Protect and enhance private enterprise-based recreation with support from state and local public agencies.

- Focus recreation development in five location-based concepts:
    - Enhance Delta waterways
    - Develop dispersed points of interest and activity areas
    - Create focal point destination complexes with natural areas, parks, Legacy Communities, marinas, historic features, and trails
    - Expand public access to natural habitat areas
    - Create recreation-oriented buffers at Delta urban edges

- Implement Economic Sustainability Plan through specific strategies such as consistency planning and regulation refinement, coordination among state and local agencies, obtaining strategic levee protection for Legacy Communities and key recreation areas, designating a marketing and economic development facilitator, and providing key funding for catalyst projects and agencies.

Recommendations for Infrastructure

- Planning of levee investments must fully consider the economic value of infrastructure services along with all other benefits.

- All owners and operators of infrastructure that depend on Delta levees must contribute to levee system investment and maintenance.

- Protect and improve Delta water quality and supply for agricultural, municipal and industrial uses.

- Ensure that future development of infrastructure in the Delta is aligned with economic sustainability strategies.

- Support expansion and development of the ports.

Recommendations for Habitat and Ecosystem Improvements

- Emphasize strategies with little or no conflict with the Delta economy such as increased fresh water flows, growth of vegetation on enlarged levees, restoration of mid-channel berms, and reactivation of upstream floodplains.

- Expanded and enhanced flood bypasses can be consistent with economic sustainability if agencies work with local stakeholders to minimize and mitigate economic impacts.

- Tidal marsh habitat plans should be significantly reduced.
- Increased open-water habitat in the Delta is not recommended.
- Include recreation facility development in habitat enhancement plans when possible.
- Habitat restoration should start on State-owned land and only occur on private lands with willing sellers consistent with local land use plans.

Recommendations for Water Supply Reliability

- Continuing the through-Delta conveyance is important to economic sustainability in the Delta and can be consistent with water supply reliability within and outside the Delta.
- A dual conveyance plan with a large, 15,000 cfs isolated conveyance facility has large conflicts with Delta economic sustainability and has high risk for Delta stakeholders.
- Options to large isolated conveyance must be fully and consistently evaluated.

Recommendations for Research and Monitoring

- New recreation data is needed and should be updated regularly.
- Maintain an Economic Sustainability Scoreboard to track progress.
- The Delta Science Program should sponsor more engineering and economic studies in addition to ecological research.
- Increase alignment among the various research and planning initiatives.

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Acronyms & Abbreviations

AAR	Association of American Railroads
ACE	Altamont Commuter Express
ACS	The American Community Survey
The Act	Delta Reform Act of 2009
AIC	Agricultural Issues Center
AWAF	Abandoned Watercraft Abatement Fund
BART	Bay Area Rapid Transit
BDCP	Bay Delta Conservation Plan
BEA	Bureau of Economic Analysis
BLS	Bureau of Labor Statistics
BMP	Best Management Practices
BNSF	Burlington Northern Santa Fe Railway
Cal EMA	California Emergency Management
Caltrans	California Department of Transportation
CBDA	California Bay-Delta Authority
CCWD	Contra Costa Water District
CDBG	Community Development Block Grant
CDEC	California Data Exchange Center
CDWR	California Department of Water Resources
CEQA	California Environmental Quality Act
Cfs	Cubic Feet per Second
CM	Conservation Measure
CPI	Consumer Price Index
CTTC	California Trade and Tourism Commission
CVFPP	Central Valley Flood Protection Plan
CVP	Central Valley Project
CWC	California Water Code
The Delta	The Sacramento–San Joaquin Delta
DAPC	The Delta Area Planning Council
DBW	Department of Boating and Waterways
DDRMT	Delta Dredging and Reuse Management Team
Delta Conservancy	The Sacramento–San Joaquin Delta Conservancy
DFG	Department of Fish and Game
DHCCP	Delta Habitat Conservation and Conveyance Plan
DMMO	Dredge Material Management Office
DMV	Department of Motor Vehicles
DPC	Delta Protection Commission
DRMS	Delta Risk Management Strategy
DSC	Delta Stewardship Council
DTVT	Daily total vehicle trips
DWR	Department of Water Resources
EDI	Economic Development Initiative
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
ESA	Federal Endangered Species Act
ESP	Economic Sustainability Plan
EPA	Environmental Protection Agency
FDPA	Flood Desaster Protection Act of 1973

FEMA	Federal Emergency Management Agency
FIS	Flood Insurance Study
FMPP	California Farmland Mapping and Monitoring Program
FY	Fiscal Year
GED	General Educational Development
GIS	Geographic Information System
GRP	Gross Regional Product
HMP	Hazard Mitigation Plan
HTE	Hultgren-Tillis Engineers
IEP	Inter-Agency Ecological Program
IRP	Independent Review Panel
IRR	Internal Rate of Return
JPA	Joint-Powers Authority
LED	Local Employment Dynamics
LEHD	Longitudinal Employer-Household Dynamics
LiDAR	Light Detection and Ranging
LMA	Locke Management Association
LTMS	Long-Term Management Strategy
MGD	Million Gallons Per Day
MLLW	Mean Lower Low Water
MOU	Memorandum of Understanding
MW	Megawatt
MWD	Metropolitan Water District of Southern California
NAICS	North American Industry Classification System
NAIP	National Agriculture Imagery Program
NASS	National Agricultural Statistics Service
NBA	North Bay Aqueduct
NETS	National Establishment Time Series
NFIP	National Flood Insurance Program
NGO	Non-Governmental Organization
NRC	National Research Council
NCCPA	California Natural Communities Conservation Planning Act
NP	Non-Project
NPDES	National Pollutant Discharge Elimination System
NP-NU	Non-Project Non-Urban
NULE	Non-Urban Levee Evaluations
PG&E	Pacific Gas and Electric Company
PL	Public Law
POD	Pelagic Organism Decline
PPIC	Public Policy Institute of California
PWC	Personal Watercraft
RESIN	Resilient and Sustainable Infrastructure Networks
ROA	Restoration Opportunity Area
ROW	Right of Way
SA	Study Area
SAFCA	Sacramento Area Flood Control Agency
SB	Senate Bill
SFHA	Special Flood Hazard Area
SHRA	Sacramento Housing and Redevelopment Agency
SJAFCA	San Joaquin Area Flood Control Agency
SPK	The Sacramento District of U.S. Army Corps of Engineers.

SRA	State Recreation Area
SWP	State Water Project
SWRCB	State Water Resources Control Board
TNC	The Nature Conservancy
TRPA	Tahoe Regional Planning Agency
UC	University of California
ULDC	Urban Levee Design Criteria
ULE	Urban Levee Evaluations
UOP	University of the Pacific
UPL	Urban Project Levee
UPRR	Union Pacific Railroad
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WSAFCA	West Sacramento Area Flood Control Agency

Glossary of Key Terms

Appellation

A designated region of winegrowing (e.g., the Clarksburg appellation in Yolo County, which has 10 wineries and 11,000 acres of vineyards).

Bay Delta Conservation Plan

The Bay Delta Conservation Plan is being prepared through a collaboration of state, federal, and local water agencies, state and federal fish agencies, environmental organizations, and other interested parties with the goal of protecting and restoring the ecological health of California's Sacramento–San Joaquin River Delta and providing a more reliable water supply.

Bay-Delta Accord

CALFED Bay Delta Accord is an agreement developed by State and federal agencies with stakeholders. It initiated a long-term planning process to improve the Delta and increase the reliability of its water supply.

CALFED

CALFED coordinates with 25 state and federal agencies to improve California's water supply and the health of the San Francisco Bay/Sacramento–San Joaquin River Delta.

California Bay-Delta Authority

Created in 2003, this body oversees the implementation of the CALFED program. It is comprised of state and federal agency representatives, public members, a member of the Bay-Delta Public Advisory Board, ex-officio legislative members, and members at large. The California Bay-Delta Act of 2003 established the Authority as CALFED's governance structure.

California Emergency Management Agency

Responsible for the coordination of overall state agency response to major disasters in support of local government.

California Natural Resources Agency

Previously called the California Resources Agency. Pertinent to the Delta, departments within the agency include Department of Boating and Waterways, Department of Conservation, Department of Fish and Game, Department of Forestry and Fire Protection, Department of Parks and Recreation, and Department of Water Resources.

California Water Resources Development Bond Act

Also known as the Burns-Porter Act, this bill was narrowly passed by California voters in 1960. It approved funding for the State Water Project.

California Trade and Tourism Commission

Among its many activities and services, CTTC maintains data and survey numbers on tourism and the economic impact of tourism within the State of California.

Central Valley Flood Protection Plan

Established by Senate Bill 5 in 2008. It is to be an integrated flood-management plan for the Sacramento–San Joaquin River Flood Management System, and its development is overseen by the California Department of Water Resources (DWR). The plan is required by law to be complete by Jan. 1, 2012.

Central Valley Project

A network of 20 dams plus reservoirs, aqueducts, canals, and pumping stations to provide flood control, water storage, and water delivery throughout California's central valley, stretching from the Klamath River in the north state to the Kern River near Bakersfield. Begun in 1933, the CVP is an ongoing project.

Delta Primary Zone

The lower elevation and largely water-covered and agricultural lands in the "core" of the Legal Delta, approximately 500,000 acres of waterways, levees, and farmed lands extending over portions of five counties: Solano, Yolo, Sacramento, San Joaquin, and Contra Costa

Delta Secondary Zone

The higher elevation and already-developed area outside the Primary Zone and within the Legal Delta

The Legal Delta

The entire region of the Delta including both the Primary Zone and the Secondary Zone

Delta Area Planning Council

Established in the early 1970s and funded by Delta. It adopted a plan for the region which supported agricultural and recreational land uses.

Delta Community Area Plan (1983)

Designates most of the Delta as permanent agricultural land in 80-, 40-, and 20-acre parcels

Delta Legacy Communities

A handful of selected Delta towns that have high cultural, historic, or ambiance value that give the Delta a distinctive sense of place. Examples are Clarksburg, Courtland, Isleton, Locke, Ryde, and Walnut Grove. A goal of the Economic Sustainability Plan is to promote economic development/sustainability in these Legacy Communities in a way that will capitalize on and preserve each community's unique characteristics.

Delta Protection Act of 1992

This act established the Delta Protection Commission, defined the Primary Zone and the Secondary Zone of the Delta. The Delta Protection Act requires the DPC to prepare, adopt, review, and maintain a comprehensive long-term resource management plan for land uses within the Primary Zone.

Delta Protection Commission

Established by the California Legislature in 1992, membership includes State agencies, local counties and cities, and Delta water agencies. The DPC was charged with preparing a land-use and resource-management plan for the Primary Zone of the Delta, addressing agriculture, recreation, and wildlife habitat on land areas. Action of local governments in the Primary Zone can be appealed to the DPC. The commission has no authority over State or federal agencies or their programs or projects.

Delta Protection Commission Land Use and Resource Management Plan

The Delta Protection Act requires the DPC to prepare, adopt, review, and maintain a comprehensive long-term resource management plan for land uses within the Primary Zone. The original plan was drafted, reviewed, and adopted by the DPC on February 23, 1995. The policies of the plan were adopted as regulations in December 2000. The DPC established a planning advisory committee, which began meeting in September 2008 and revised the plan; DPC adopted the revisions in 2010.

Delta Reform Act of 2009

This act established the Delta Stewardship Council (DSC) and directs completion of its Delta Plan by January 1, 2012.

Delta Stewardship Council

The primary responsibility of the Delta Stewardship Council is to develop, adopt, and implement by January 1, 2012, a legally enforceable, comprehensive, long-term management plan for the Sacramento–San Joaquin Delta and the Suisun Marsh—the Delta Plan—that will achieve the coequal goals of "providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem" and does this "in a manner that protects and enhances the unique cultural, recreational, natural resource, and agricultural values of the Delta as an evolving place."

Delta Vision Blue-Ribbon Task Force

A Blue-Ribbon Task Force of seven appointed citizens that supervised preparation of a Delta Vision for adoption and submittal to the Delta Vision Committee (2006-2008)

Delta Vision Strategic Plan:

The result of the Blue-Ribbon Task Force, the plan was presented to the governor in 2008. It contained seven over-arching goals, the first of which was to "Legally acknowledge the coequal goals of restoring the Delta ecosystem and creating a more reliable water supply for California." Other goals target ecosystem restoration, water conservation, water conveyance and storage, risk reduction and levee investment, and a new governance structure to achieve the goals.

Department of Water Resources

Located within the Resources Agency, oversees the state's water management, flood protection, the State Water Project, and water planning.

Direct effects

In economic impact assessment, direct effects are the changes in sales (output), wages (personal income), and jobs (employment) related exclusively to each sector. This includes all sales and costs incurred by both visitors and residents.

Employment

In economic impact assessment employment demonstrates the number of full- and part-time jobs generated on an annual basis.

Hazard Mitigation Plan (FEMA)

This levee standard provides for a 16-foot crown width, a 1-foot freeboard above the 100-year water surface elevation, minimum 1.5-to-1 waterside slopes, and minimum 2-to-1 landslides slopes.

Indirect effects

In economic impact assessment, indirect effects represent the iterative impacts of inter-industry transactions as supplying industries respond to the increased demands from the direct recipient of these revenues. An example of indirect effects would include a hotel increasing its purchase of linen to meet the demand of people staying overnight in the Delta.

Induced effects

In economic impact assessment induced effects reflect household consumption expenditures of direct and indirect sector employees. Examples of induced benefits include employee's expenditures on items such as retail purchases, housing, medical services, banking, and insurance.

Isolated Conveyance Facility

A canal or pipeline that transports water between two different locations while keeping it separate from Delta water.

Johnston-Baker-Andal-Boatwright Delta Protection Act of 1992

The act created the Delta Protection Commission and divided the Legal Delta into two zones—the Primary Zone and the Secondary Zone.

Labor Income

Labor income is also referred to as personal income or employee compensation. It includes wages, salaries, benefits, and all other employer contributions. This measures the financial value of associated employment.

Levee

Structures built adjacent to rivers in the Sacramento–San Joaquin Delta for flood control and water conveyance. There are nearly 1,000 miles of levees in the Legal Delta.

Locke Management Association

Created as a form of governance for the town of Locke. Membership of the board is equally balanced between building owners, government representatives, and representatives of local Chinese cultural groups.

Non-project levees

Levees built and maintained by local reclamation districts.

Output

Output is sometimes referred to as revenue or sales. Output accounts for the total changes in the value of production in an industry for a given time period. This includes revenue from all sources of income to determine current activity levels.

PL 84-99

A standard for levee construction. In 1987, the U.S. Army Corps of Engineers set the federal Delta-specific standards for levees in Public Law 84-99 sets the federal Delta-specific standards for levees in 1987. It provides for a crown width of 16 feet, freeboard of 1.5 feet over the 100-year water surface elevation, a minimum waterside slope of 2-to-1, and landside slopes that vary as a function of the depth of peat and the height of the levee such that the static factor of safety on slope stability is not less than 1.25

Project levees

Project levees were constructed by the U.S. Army Corps of Engineers as part of Federal-State flood control projects and were turned over to the State for operations and maintenance. The State has in turn generally passed on the responsibility for routine maintenance to local reclamation districts, although the Paterno Decision confirmed the State's continued basic liability with respect to these levees.

Sacramento–San Joaquin Delta Conservancy

Legislation enacted in 2009 created the conservancy to act as a primary State agency to implement ecosystem restoration in the Legal Delta and to support environmental protection and the economic well-being of Delta residents.

State Water Project

Approved by voters in 1960, the State Water Project provides water for 25 million Californians (two-thirds of the state's population) and 750,000 acres of irrigated farmland. Approved by voters in 1960, the State Water Project is a water storage and delivery system of 34 storage facilities, reservoirs, and lakes; 20 pumping plants, 4 pumping-generation plants; 5 hydroelectric power plants, and 700 miles of open canals and pipelines. It is maintained and operated by the California Department of Water Resources.

Total effects

In economic impact assessment, total effects are the sum of the direct, indirect, and induced effects

Urban Levee Design Criteria

The ULDC is generally consistent with the SPK practice and has the same geometric requirements. However, the ULDC goes much further in defining required practice in a number of other areas including seismic loadings, encroachments, penetrations and vegetation.

Value Added

Value added, represents the distinct value added to a product during the production process.

Chapter 1: Introduction

The Sacramento-San Joaquin River Delta is a unique place of economic, environmental, historic, and cultural significance. The land and water resources of the Delta support significant agricultural and recreation economies, and the Delta also has an important role as an infrastructure hub for water, energy, and transportation. The region's rich history boasts of bustling, river-based commerce before the automobile age, and its cultural uniqueness includes the only rural town in America build by early Chinese immigrants. As the largest estuary on the west coast of the Americas, the Delta also is a place of striking natural beauty and ecological significance that is struggling with serious environmental degradation problems. Although surrounded by growing cities, the Delta remains a highly-productive agricultural area with rural charms, landscapes, and waterscapes not found elsewhere in California.

In recent years, there has been great concern over increasing environmental degradation in the Delta and over court decisions that reduced the quantity of water delivered to southern California through the state and federal water project intakes in the south Delta to protect endangered fish. Combined with additional concerns about the stability of the Delta's levee system, these concerns led the California legislature to pass the Delta Reform Act of 2009. The Act created the Delta Stewardship Council and charged it with developing a Delta Plan to achieve the coequal goals of "providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem."

Recognizing the potential impact of the Delta Plan on the people and economy of the Delta, the Delta Reform Act stated that the coequal goals of water supply reliability and restoring the Delta ecosystem "shall be achieved in a manner that protects and enhances the unique cultural, recreational, natural resource, and agricultural values of the Delta as an evolving place." Among the measures to address this goal, the Delta Protection Commission was tasked with developing this Economic Sustainability Plan to inform the Delta Stewardship Council's development of the Delta Plan.

The Legislature established the following guidelines for the Economic Sustainability Plan in the Delta Reform Act of 2009.

The economic sustainability plan shall include information and recommendations that inform the Delta Stewardship Council's policies regarding the socioeconomic sustainability of the Delta region. (b) The economic sustainability plan shall include, but not be limited to, all of the following:

(1) *Public safety recommendations, such as flood protection recommendations.*
(2) *The economic goals, policies, and objectives in local general plans and other local economic efforts, including recommendations on continued socioeconomic sustainability of agriculture and its infrastructure and legacy communities in the Delta.*
(3) *Comments and recommendations to the Department of Water Resources concerning its periodic update of the flood management plan for the Delta.*
(4) *Identification of ways to encourage recreational investment along the key river corridors, as appropriate.*

Since a key purpose of this Economic Sustainability Plan is to inform the Delta Plan under development by the Delta Stewardship Council, this report analyzes the impact of key policies being considered for the plan on the economic sustainability of the Delta. Many of the most significant proposals for the Delta are being developed in the Bay Delta Conservation Plan (BDCP). The policy proposals can be grouped into four categories: 1) water conveyance, 2) habitat creation, 3) levees, and 4) land use regulation. The report also considers many aspects of economic sustainability in the Delta that are unrelated to these water policy proposals including economic development recommendations in the 2008 Delta Vision Strategic Plan.

Thus, in addition to the goals stated in legislation, the following goals have also been established as critical to developing information and recommendations to support economic sustainability in the Delta.

- Provide a thorough analysis of the baseline and trends for key sectors of the Delta economy.
- Identify the linkages between the Delta economy and the regional and state economy.
- Provide the most complete available assessment of the condition of Delta levees.
- Develop a vision for economic sustainability of Delta Legacy Communities.
- Create a detailed model of the effects of water policy proposals on Delta agriculture.
- Assess the effect of water policy proposals on the recreation and tourism economy, other economic sectors, and key Delta infrastructure.
- Integrate the findings into a general set of economic sustainability recommendations and strategies for the Delta.
- Integrate the findings into a specific set of recommendations on the issues under consideration by the Delta Stewardship Council for inclusion in the Delta Plan.

Many of these goals involve new research and analysis to support Delta decision making. The last two goals integrate these findings into specific recommendations for policy and economic development and make up the Economic Sustainability Plan.

In order to be adopted into the Stewardship Council's Delta Plan, the recommendations in the Economic Sustainability Plan must be consistent with the coequal goals of improving water supply reliability and protecting, restoring, and enhancing the Delta ecosystem. The legislature also stated that the "coequal goals shall be achieved in a manner that protects and enhances the unique cultural, recreational, natural resource, and agricultural values of the Delta as an evolving place." Thus, the Economic Sustainability Plan can provide important guidance on evaluating the degree to which proposed actions to address the coequal goals support or conflict with the objective of protecting and enhancing the Delta.

The concept of economic sustainability and the objective to "protect and enhance the unique cultural, recreational, natural resources, and agricultural values of the California Delta as an evolving place" can be interpreted in different ways. In economic terms, there is near consensus that a minimum requirement is to maintain the economic value of the entire Delta economy in the future. The Fifth Staff Draft of the Delta Stewardship Council's Delta Plan uses a stronger definition of economic sustainability where growth in one sector is not a substitute for deterioration in another area. Specifically, the Fifth Staff Draft Delta Plan defines performance measures for economic sustainability as maintaining or increasing gross revenues in each of three key sectors: agriculture, recreation, and ecotourism/agritourism. In addition, there is broad agreement that this objective requires the protection of the cultural and historical heritage and the long-term economic viability of the Delta's historical Legacy Communities.

Limitations of the Plan

While the list of goals is lengthy, there are a few related issues that are outside the scope of this assessment. As an economic sustainability plan, the focus of the report is the long-run prospects of ongoing economic activities, not short-term impacts from investments or events. In addition, the assessment is limited to the economic impacts in the Delta region and the impact of activities that originate or primarily take place within the Delta. Thus, it is important to emphasize the following two limitations.

1. *The report does not assess short-run economic impacts of proposed capital spending.*

   Many of the policy proposals evaluated in the report—including levee upgrades, isolated water conveyance facilities, and habitat restoration projects—involve millions or billions of dollars in capital investment. The construction activity for these investments would create a substantial short-run burst of economic activity in the Delta region, creating local jobs and income. Although these short-run impacts are not part of our economic sustainability assessment, other reports may address these issues in the future.[1] We caution readers that the regional economic impacts of a capital investment are not necessarily proportional to the size of the expenditure, as different projects have very different cost compositions, varying levels of local expenditures, and therefore highly variable regional impacts. For example, levee improvements could be designed and constructed with expertise and equipment inside the Delta, whereas a larger share of spending for design and equipment needed for complex, isolated conveyance tunnels would necessarily occur outside the Delta. In addition, the construction process itself would disrupt traffic and existing economic activity in the Delta in complex ways that have not been sufficiently described.

2. *The report is not a comprehensive cost-benefit analysis of Delta water conveyance options*.

   New water conveyance facilities are the most significant and controversial proposal for the Delta. As the work plan for this project was developed, the main proposal in the BDCP was a 15,000-cfs tunnel conveyance, but the process was being opened up to consider a much broader variety of options to improve the reliability of conveyance. The 15,000-cfs tunnel remains the leading proposal and is the only alternative to through-Delta conveyance examined in this report due to the infeasibility of analyzing so many alternatives and the lack of detailed descriptions for the alternatives. Some qualitative inferences can be made about different size conveyance based on the 15,000 cfs analysis, but more detailed analysis is not feasible at this time. In addition, all of the water conveyance proposals have costs and benefits that extend far outside the Delta. This report assesses the effect of the tunnel conveyance on the Delta economy, which is an important input to a comprehensive cost-benefit analysis with a statewide focus. In a few places, out-of-Delta impacts are considered when they have implications for the

[1] At the September 27, 2011 BDCP meeting, "Employment Impacts for Proposed Bay Delta Water Conveyance Tunnel Options" was presented. The analysis is reasonable, and the presentation includes the appropriate qualifications and caveats, just as this report is stating the limitations up front. The presentation did not include impacts for alternative options such as large levee upgrades, investments in alternative water supplies such as efficiency improvements, water recycling, and desalination. In addition, the presentation does not consider the negative employment impacts of the substantial increase in water rates this project would create.
http://baydeltaconservationplan.com/Libraries/News/Employment_Impacts_for_Proposed_Bay_Delta_Conveyance_Tunnel_Options.sflb.ashx

operation of in-Delta assets such as water conveyance that could have important implications for the Delta economy.

3. *The report is not a comprehensive cost-benefit analysis of ecosystem improvement and restoration proposals.*
   The intrinsic value of a healthy Bay-Delta estuarine ecosystem is high and a restored ecosystem would also enhance some market economic values outside the Delta, such as commercial and sport salmon fishing. These are values that would be incorporated into a comprehensive cost-benefit analysis of ecosystem measures, but are outside the scope of our analysis on the Delta economy.

With respect to these last two limitations, comprehensively evaluating the statewide costs and benefits of proposed water supply infrastructure and ecosystem restoration proposals is not the role of the Delta Protection Commission or the Economic Sustainability Plan (ESP). It is the role of the agencies that will make the decisions about what goes into the Delta Stewardship Council's Delta Plan. This includes the Delta Stewardship Council itself as well as the state and federal agencies involved in developing the Bay Delta Conservation Plan (BDCP). At this point, neither of the draft Delta Plan or the working groups of the BDCP contains any plans for comprehensive benefit-cost analysis to inform decision making.[2] There are many guides to conducting such an analysis, including, but not limited to, the Department of Water Resources' Economic Analysis Guidebook (2008).[3] The analysis in the Economic Sustainability Plan could be used as a component or first step towards this broader analysis.

Geographic Focus of the Study

The boundaries of the Legal Delta are shown in Figure 1. The Delta Protection Act of 1992 defined the Delta boundaries including the Primary and Secondary Zone and created the Delta Protection Commission, charging it with developing a Land Use and Resource Management Plan for the Primary Zone. The majority of the Delta's 738,000 acres of land is in the rural and agricultural Primary Zone. The population of the Primary Zone is approximately 12,000 and has remained steady in the nearly 20 years since the passage of the Delta Protection Act.

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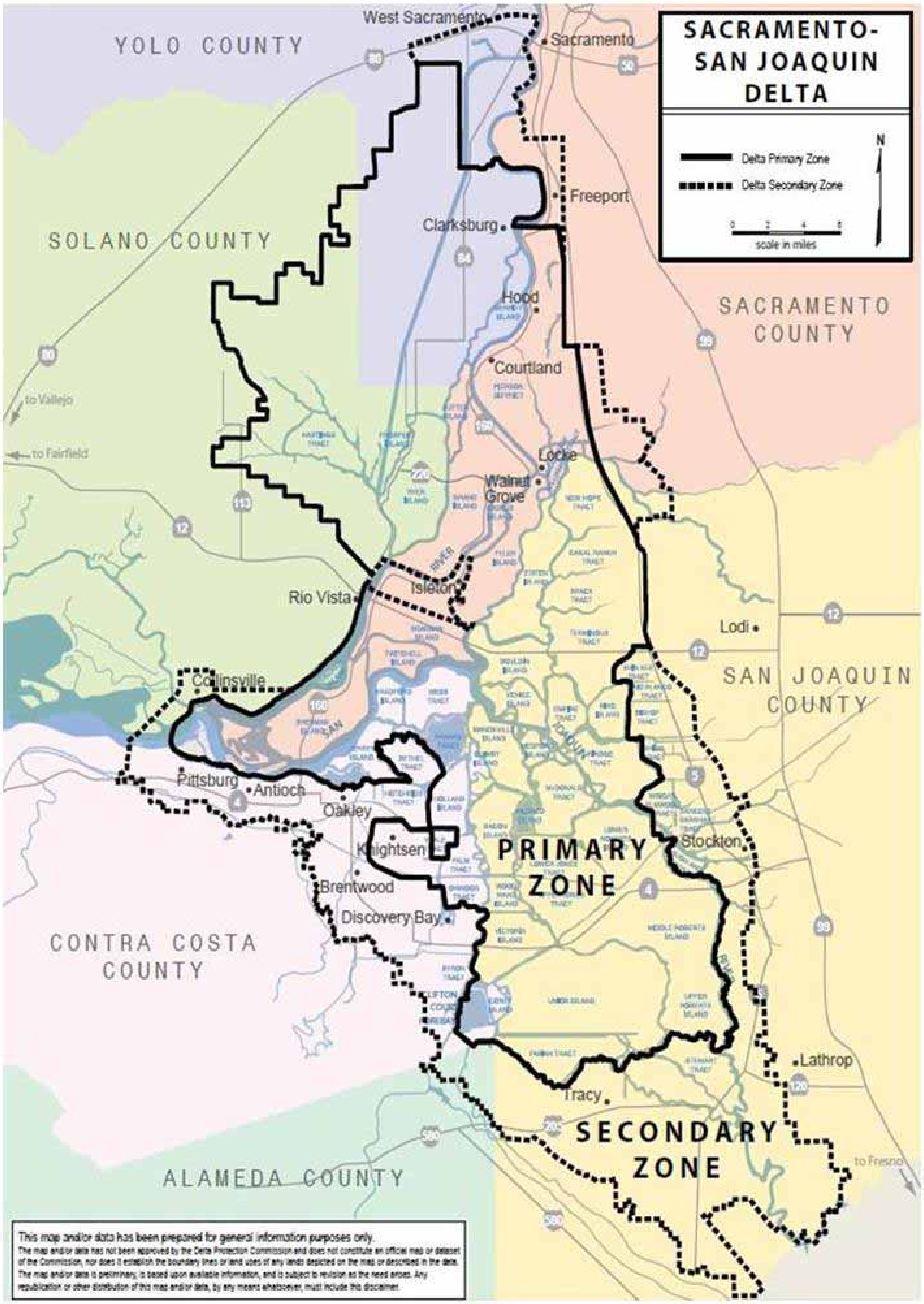
[2] In response to a question at the September 27, 2011 BDCP meeting, Deputy Resources Secretary Meral said a more comprehensive economic analysis was beginning, although it was unclear whether it would be a full cost-benefit analysis and what alternatives would be analyzed. At this time, there is no related BDCP workgroup or official announcement of this project, its scope and timeframe.
[3] California Department of Water Resources (CDWR). 2008. *Economic Analysis Guidebook*. http://www.water.ca.gov/economics/downloads/Guidebook_June_08/EconGuidebook.pdf.

Figure 1 Map of the Primary and Secondary Zones of the Sacramento San Joaquin Delta



Source: Delta Protection Commission. Accessed 2011-06-30

The Legal Delta including both the Primary Zone and Secondary Zone, contains significant portions of five counties, Contra Costa, Sacramento, San Joaquin, Solano, and Yolo, and a small rural corner of Alameda County. The Delta includes parts of several large cities including Antioch, Pittsburg, Stockton, Sacramento, Tracy, and West Sacramento. The Legal Delta has a population of 571,000, according to the 2010 Census, which has increased by about 200,000 people—more than 50 percent—in the 20 years since the 1990 Census. All of the population growth, and virtually all of the Delta's urbanized land, is located within the Delta's Secondary Zone.

The Delta's economy, like its population, is primarily urban and service oriented. However, the Delta Reform Act of 2009 and the Delta Protection Act of 1992 are primarily concerned with the natural resources of the Delta and the economic activity sustained by those resources such as agriculture and outdoor recreation. In addition, the resources of the Delta support significant water, energy, and transportation infrastructure that serve the Delta, regional and state economies, and an important commercial and recreational salmon fishery throughout the state.

Chapter 2 of this report gives an overview of the entire Delta economy and socio-economic trends. Detailed study is reserved for the resource-related industries and sectors that could be significantly affected by the Delta Reform Act: agriculture, recreation and tourism, and the infrastructure services that depend on the levees, land, and water resources of the Delta. These resources are concentrated in the Primary Zone. Despite the urban nature of the Secondary Zone, it has important economic linkages with the Primary Zone and its resources.

The Legal Delta, both primary and secondary, includes portions of several counties and cities and does not conform to the usual boundaries that define economic data and models. This creates several challenges for this project, and an effort was made to approximate the Legal Delta boundaries with Census block groups, tracts, zip codes, and geocoded establishment data when available. However, the boundaries of what constitutes the Primary Zone or a given community can change based on the data source being utilized. The report authors have tried to be clear throughout the report regarding the definitions, but readers should be aware that variations in data reported reflect the differences in data sources available for a rural area that spans five counties.

Organization of the Report

There are three parts of the report that follow this Introduction. Part One presents critical background and overview information. Part One includes a broad overview of economic and demographic data for the Delta; an assessment of the current state of Delta levees, emergency response, and financial resources available to improve the levees; a very brief review of Delta ecosystem issues, and a review of key laws and land-use plans and how they interact in the Delta. Part Two analyzes specific industry sectors in the Delta, the baseline and trends of these industries, and the expected effects of various policy proposals. Part Three discusses integrative, cross-cutting issues including a chapter that explores the future of Legacy Communities. The final chapter in Part Three concludes the report by presenting a set of recommended strategies and policies to support economic sustainability in the Delta.

Part One: Background and Context for the Economic Sustainability Plan

Chapter 2: Overview of the People and Economy of the Delta

1 Overview and Key Findings

This chapter provides an overview of the key demographic and economic conditions and trends in the Sacramento-San Joaquin Delta, including detailed information for both the Primary and Secondary Zones. The chapter is intended to provide baseline information to support the creation of an Economic Sustainability Plan for the Delta.

The analysis focuses primarily on data-driven results and information based largely on government data sources, which are documented throughout. To the extent possible, the findings rely on the most up-to-date and geographically-refined data available, including block-level data from the 2010 Decennial Census. It is important to note that the analysis relies on a variety of disparate data sources with differing geographic reporting areas (see Appendix B). The detailed data and calculations documenting the findings presented in this chapter are also provided (see Appendix B).

This section highlights key socioeconomic indicators for the Primary, Secondary, and Legal Delta. Overall, the data review suggests that the Delta is a relatively diverse, growing, and economically integrated region that in many respects is out-performing the state as a whole. However, within this larger context, the Delta's Primary Zone functions as a distinct sub-region with a demographic and economic profile that differs in many ways from both the region and state. Although most of these differences stem from the more rural and sparsely populated nature of the Primary Zone, some are indicative of a less diversified and underperforming economy. The key indicators underlying these conclusions are summarized below.

- **Population Growth**: While the Legal Delta has experienced relatively robust population growth over the last 20 years, increasing by about 54 percent since 1990 compared to 25 percent statewide, the Primary Zone population has remained essentially unchanged. The impressive growth rate of the Legal Delta is largely attributable to its position on the fringe of large metropolitan areas in Northern California. However, the Primary Zone does not appear to be participating in this regional or statewide growth, in part because it lacks the public infrastructure and services necessary to support robust growth and in part because there are restrictive land use regulations on new development. In particular, the Central and Southern Delta (south of Walnut Grove and including the SR12 corridor east of Rio Vista) has contracted since 2000, with total population falling by approximately 500 people, a decrease of roughly 6.5 percent.

- **Age, Race, and Ethnicity**: While the Legal Delta is made up of a relatively young and racially and ethnically diverse population, the Primary Delta is older and predominantly White and non-Hispanic. In the Legal Delta, approximately 43 percent of residents describe themselves as non-White and approximately 81 percent are younger than 55 years of age, similar to the 39 percent and 79 percent statewide, respectively. In contrast, only about 25 percent of Primary Zone residents describe themselves as non-White and about 62 percent are younger than 55 years of age. The Primary Zone's below-average household size (with about 70 percent of households containing fewer than three people compared to about 54 percent statewide) is consistent with the older age profile, suggesting a relatively high share of households without children. Demographic trends in the larger Legal Delta reflect birth and migration patterns emanating from Northern California's growing urban centers, but these patterns appear to be having less of an impact on the Primary Zone. Since 2000, the age distribution of the population in the Legal Delta has not changed dramatically, likely because of an influx of younger people in the Secondary Zone. In contrast, the age distribution in the Primary Zone has shifted older, with people age 55 and up accounting for a significantly greater share of the population, up from about 24 percent in 2000 to 38 percent today.

- **Employment**: While the Legal Delta possesses a relatively diversified and stable economy, with no one sector accounting for more than 13 percent of employment, the Primary Zone is a highly resource-driven economy with a heavy reliance on agriculture and, to a lesser degree, recreation. The Legal Delta's four top employment sectors—retail, education, health care, and accommodations and food services—account for about 44 percent of all jobs, with a relatively equal distribution among each. In contrast, agriculture alone makes up about 44 percent of total employment in the Primary Zone.
- **Industry Clusters:** Location quotients were calculated for employment and gross regional product to identify key industry clusters in the Delta. The analysis identified three key industries for the Delta economy in both the Primary and Secondary Zones:
  - Agriculture
  - Transportation, Warehousing, and Utilities
  - Construction, Housing, and Real Estate
- **Export Sectors**: Exports represent a key measure of a region's economic base because they bring new money into a region instead of re-circulating existing income.[4] While the proportion of economic output represented by exports in the Legal Delta is relatively high compared to the state as a whole (33 percent versus 24 percent in California), the Sacramento River Corridor is distinctly export-oriented, with exports making up approximately 64 percent of output.

2 The People of the Delta

The demographic attributes and unique capacities of Delta residents will have important implications for the region's economic development prospects. This section explores the demographic conditions and trends in the Delta, focusing on such factors as population growth, age, education, household characteristics, labor force participation, and commute patterns. The analysis distinguishes between the Delta's Primary and Secondary Zones. A more detailed discussion of these trends for selected Delta Legacy Communities is provided separately.

2.1 Demographic Conditions and Trends

2.1.1 Population

There has been significant population growth within the Legal Delta since 1990, almost entirely attributable to the expanding urban areas contained within the Secondary Zone. Specifically, the Secondary Zone contains an estimated 560,000 residents according to the 2010 Decennial Census, up from about 360,000 in 1990, a 56 percent increase (the state as a whole increased by 25 percent during this period). In contrast, the Census reports roughly 12,000 residents living in the Primary Zone in 2010, about the same number as 20 years ago.[5] Currently, the population within the Primary Delta represents about 2 percent of the Legal Delta's total and this proportion appears to be shrinking.

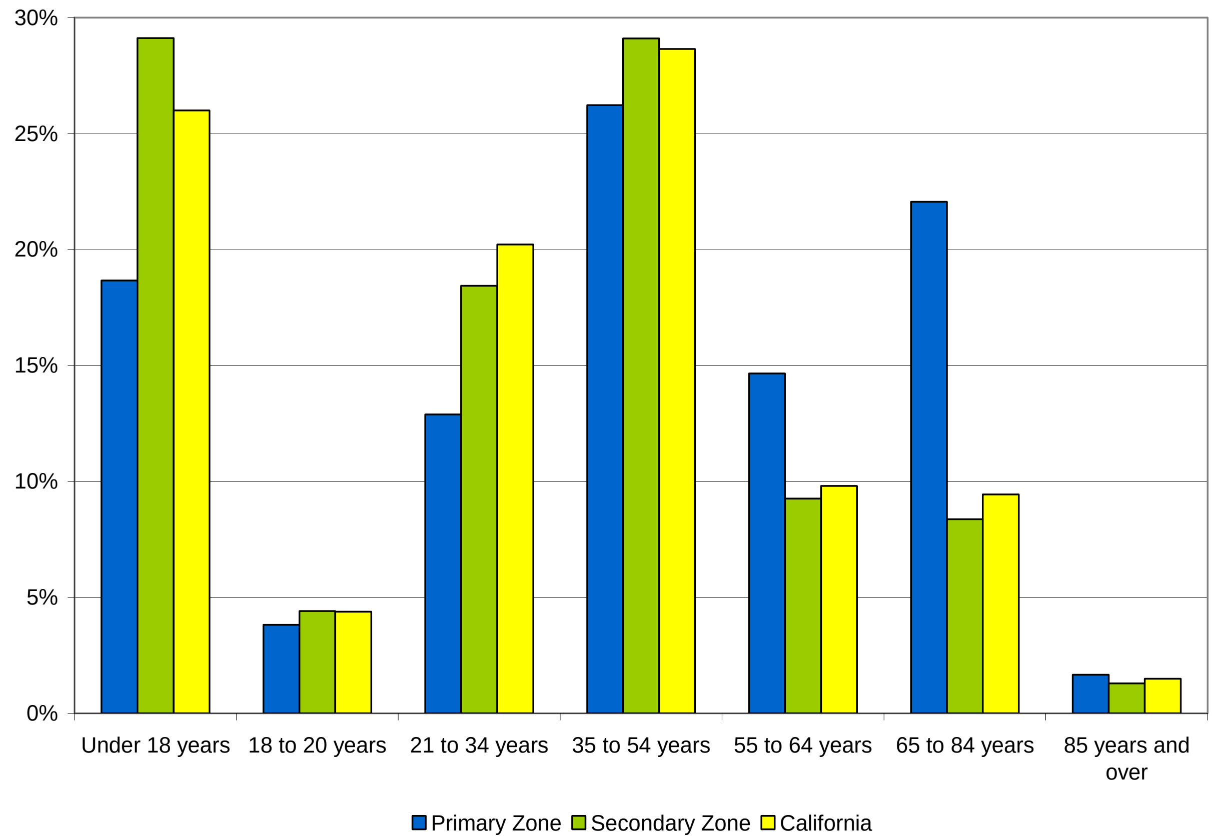
[4] In the context of this study, the term "exports" refers to goods and services provided to areas outside of the Delta, rather than to international markets exclusively.
[5] Note that changing Census boundaries limit the precision of block-level trend analysis.

The Primary Zone encompasses about 67 percent of the Legal Delta's total land area. It is a highly rural and sparsely populated area surrounded by relatively fast-growing urban areas in or adjacent to the Secondary Zone.[6] A variety of inter-related factors are preventing growth in the Secondary Zone from spreading to the Primary Zone, most notably regulatory prohibitions, lack of public infrastructure, and economic feasibility. The relatively fast growth in the Secondary Zone is largely attributable to its role in accommodating spill-over growth from large, land-constrained urban centers in the San Francisco, Sacramento, and Stockton metropolitan areas.

2.1.2 Age and Household Composition

Overall, the age and household composition of the resident population in the Legal Delta is similar to California as a whole, albeit with slightly younger and larger families. Almost half of the population (47 percent) is in the 21 to 54 year age group, the prime income generating cohort, mirroring the state (49 percent). The Legal Delta has a slightly higher proportion of youth than California as a whole, with about 29 percent below 18 years (compared to 26 percent statewide). In addition, about 72 percent of all households in the Legal Delta contain families (i.e., relatives) and 49 percent contain three or more people, compared to 68 percent and 46 percent, respectively, for the state as a whole.

Figure 2 Age Distribution in the Delta



Source: 2005-9 American Community Survey, Census Bureau

[6] Based on an estimated 491,592 acres in the Primary Zone and 243,798 acres in the Secondary Zone (Framework Study).

The age and household composition of residents in the Primary Zone is indicative of a region populated by older individuals without children living in relatively small households. The Primary Zone population in the 21 to 34 years age group comprises only 13 percent of the total population (compared to 20 percent in California) while population in the 65 to 84 years age group makes up 22 percent of total population (compared to 9 percent in California). Meanwhile, about 70 percent of the households contain two or fewer people, compared to 54 percent statewide. Combined, these data suggest a resident population with lower household consumption (small households without children) and income generation (retirees) than both the Legal Delta and state.

2.1.3 Race and Ethnicity

The population of the Primary Zone is generally Caucasian, with residents identifying themselves as White making up approximately 75 percent of the population. About 7 percent of the Primary Zone population reports being of Asian descent. The relatively urbanized Secondary Zone is somewhat more diverse, with greater shares of the population identifying themselves as Asian (13 percent) and African American (11 percent). By comparison, the California population is about 61 percent White, 12 percent Asian, and 6 percent African American.

Figure 3 Race in the Primary Zone

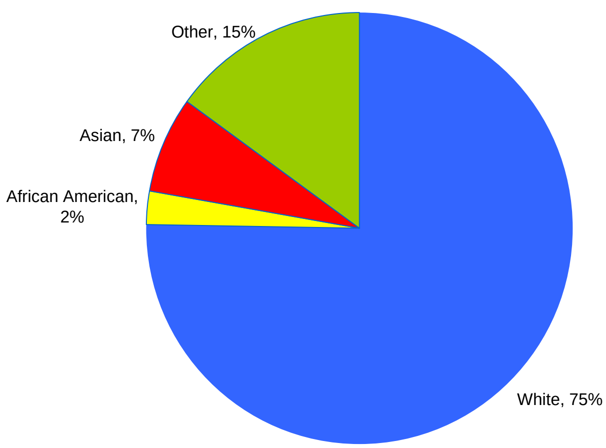
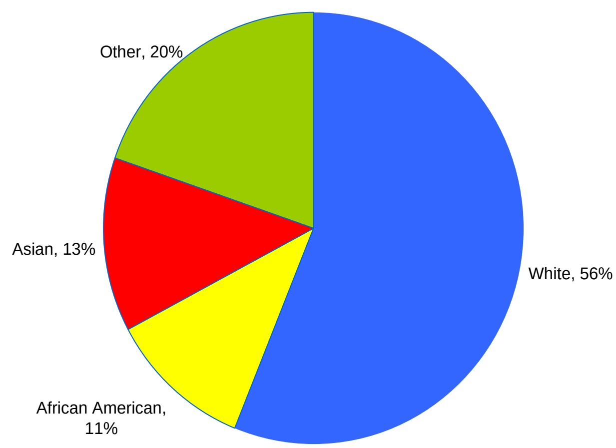


Figure 4 Race in the Secondary Zone



Source: 2005-9 American Community Survey, Census Bureau

Across all race categories, approximately 26 percent of the Primary Zone population and 30 percent of the Secondary Zone populations report being of Hispanic origin, smaller shares of the total population than in California overall, where Hispanics make up roughly 36 percent of the population.

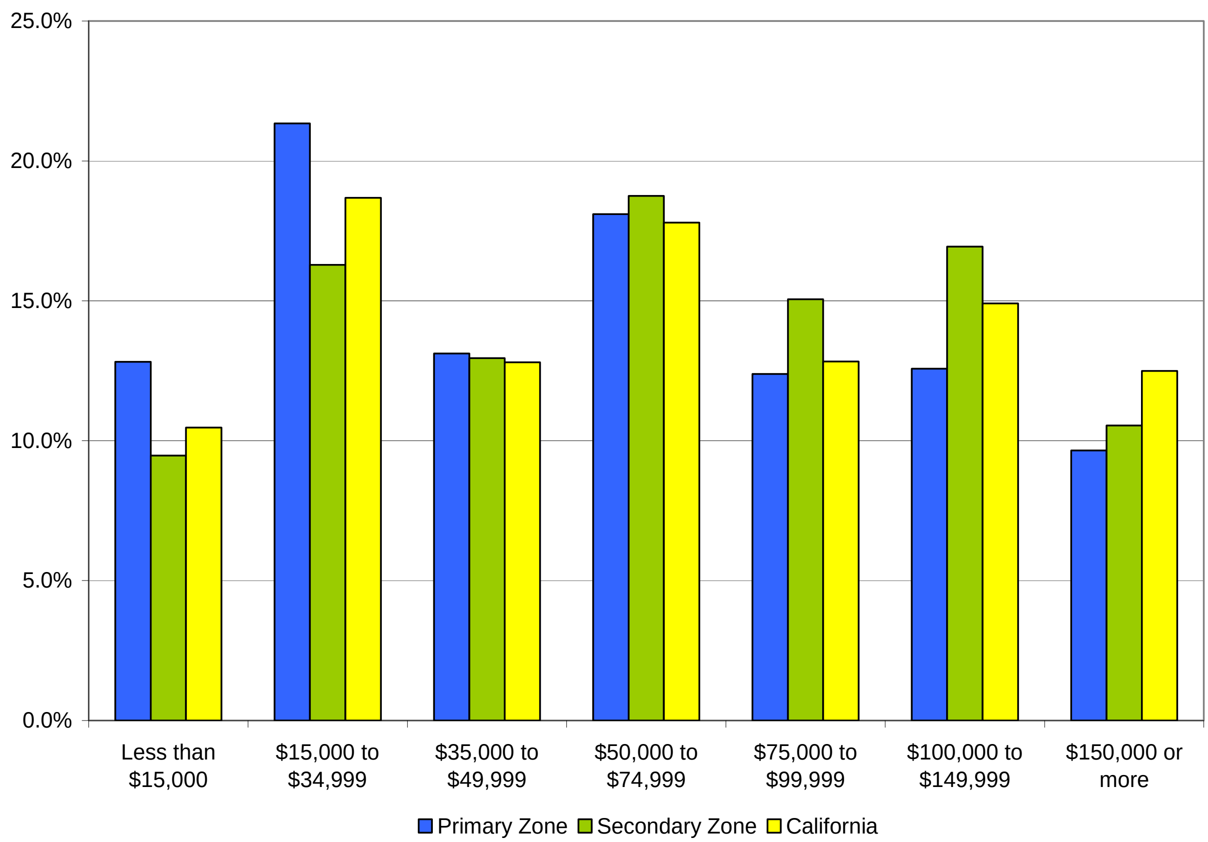
2.1.4 Educational Attainment

In general the residents of the Legal Delta are well educated compared with Californians as a whole, with several caveats. For example, the Legal Delta has fewer high school drop-outs than the state overall, at 17 percent compared to 20 percent. However, about 32 percent of Legal Delta residents have successfully obtained some form of post-secondary (higher) education degree, compared to 37 percent statewide. Interestingly, the Primary Zone has slightly higher education levels than the Secondary Zone with 36 percent completing post-secondary training and 9 percent holding a graduate or professional degree (compared to 31 percent and 6 percent, respectively, in the Secondary Zone).

2.1.5 Income

The household income distribution in the Primary Zone is generally similar to California overall. While a slightly greater proportion of Primary Zone households have a total household income of less than $35,000 (34 percent versus 29 percent in California), a similar proportion of Primary Zone households have income between $35,000 and $100,000, compared to California overall. A greater share of California's households earn more than $100,000, explaining the higher average household income in California. Household incomes in the Secondary Zone are more concentrated in the $50,000 to $150,000 range, as compared with the Primary Zone and California overall.

Figure 5 Income Distribution in the Delta



Source: 2005-9 American Community Survey, Census Bureau

2.2 Housing Trends

2.2.1 New Development

Despite the lack of population growth, there has been some residential development in the Primary Zone. Between 1990 and 2010, the number of housing units increased by about 10 percent, from approximately 4,500 to nearly 5,000. The discrepancy between population and housing growth generally reflects declining household size, increased vacancies, and second-home construction (e.g., vacation homes). By comparison, the Secondary Zone gained more than 66,000 net new housing units during this same period, an increase of nearly 50 percent, a slightly slower growth rate than population. This trend is consistent with the above-average household size in this region.

2.2.2 Ownership

Approximately 71 percent of the occupied housing units in the Primary Zone are inhabited by owners. While this is significantly greater than in California overall, where only about 58 percent of homes are owner-occupied, this is generally consistent with home ownership rates observed in more rural areas, where rental housing is scarce. In the Secondary Zone, which is more urban, owner-occupied housing units make up about 66 percent of occupied housing units.

2.2.3 Foreclosures

Given the Secondary Zone's position on the edge of several large metropolitan areas, it was particularly vulnerable to the sub-prime-led foreclosure crisis that disproportionately hit a number of California communities on the urban fringe. Data concerning foreclosures occurring between May 2010 and April 2011, obtained from RealtyTrac, substantiate this trend. These data show that the Secondary Zone has a foreclosure rate of 9.8 percent, compared to only 4.2 percent in the Primary Zone. Also, the foreclosure rate in the Secondary Zone is notably higher than the five-county region (8.5 percent) and the state (5.8 percent).

2.3 Labor Force Participation and Commute Patterns

Only about 54 percent of the Primary Zone population is in the labor force (employed or seeking work), and approximately 24 percent of the zone's residents are above retirement age. The unemployment rate in the Primary Zone (7 percent) is slightly lower than in California (8 percent), according to data from 2005 through 2009. In the Secondary Zone, a greater share of the population is in the workforce (64 percent), which is fairly consistent with California overall. However, unemployment in the Secondary Zone is higher (10 percent) than in the Primary Zone and California, according to data from 2005 through 2009.

It is also interesting to note that the Legal Delta has a low ratio of jobs to workers compared to the Primary Zone. Despite this fact, workers and residents in both the Legal Delta and the Primary Zone have relatively complex commute patterns, which suggest that residents generally work elsewhere. In the Primary Zone, roughly 88 percent of employed residents work outside of the Primary Zone. For example, the employed residents of the Primary Zone commute to Sacramento (6 percent), Stockton (6 percent), Rio Vista (3 percent), and San Francisco (3 percent). The employed residents of the Secondary Zone work in Stockton (14 percent), Sacramento (7 percent), San Francisco (4 percent), Antioch (4 percent), and other locations.

The employed residents of the Primary Zone work primarily in agriculture (12 percent), education (11 percent), construction (10 percent), and health care (8 percent). Of the employed Primary Zone residents, approximately 63 percent are employed by for-profit enterprises, 20 percent are employed by government entities, 10 percent are self-employed, and 7 percent are employed by not-for-profit organizations. The employed residents of the Secondary Zone are less concentrated in agriculture (1.3 percent), construction (9.1 percent), and educational services (7.6 percent) and more concentrated in health care (12.7 percent) and retail trade (12.4 percent).

Together the labor force participation and commute patterns suggest that Primary Zone workers commonly out-commute to jobs in education, construction, and health care, while the in-commuters occupy lower-skilled jobs in agriculture and manufacturing. Despite a healthy ratio of jobs to residents, the Primary Zone serves as a “bedroom community” for professionals commuting to Stockton, Sacramento, and other nearby urban areas.

3 Baseline Economic Conditions and Trends in the Delta

An effective Economic Sustainability Plan for the Delta must be based on a solid understanding of the economic conditions and key drivers. Consequently, to further assess economic development, this analysis evaluates employment, output, and trade flows in the Delta to ascertain economic fundamentals and growth prospects. The analysis draws on a variety of data sources and relies on common economic development tools and metrics, including location quotients and export-orientation analysis.

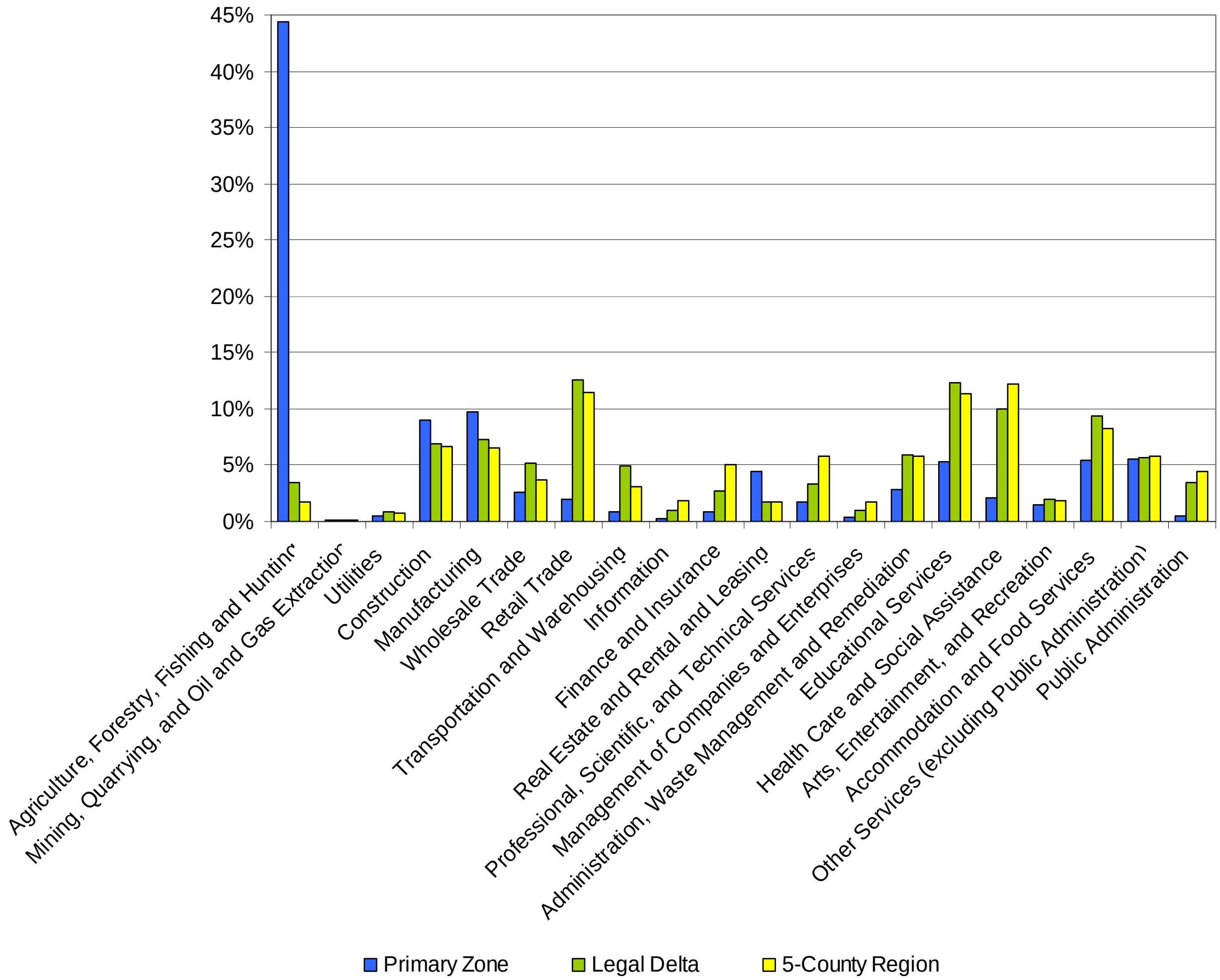
3.1 Employment by Sector

According to data from the Bureau of Economic Analysis, there are 1.826 million jobs in the five-county Delta region (Contra Costa, Sacramento, San Joaquin, Solano, and Yolo counties). Overall, nearly 23 percent of employment in the region is categorized as proprietor employment (i.e., self-employed), including nearly 38 percent of farm employment.

The Bureau of Economic Analysis’s comprehensive employment data are unavailable for the Primary Zone of the Delta. However, the U.S. Census Bureau, through its Local Employment Dynamics-Longitudinal Employer-Household Dynamics (LED-LEHD) program, provides data within unique geographies such as the Delta zones but excludes most self-employed workers. Adjusting the LED-LEHD estimate upward to account for the additional share of employment reported by the Bureau of Economic Analysis in the five-county region, this analysis estimates that there are roughly 200,000 jobs in the Legal Delta. In addition, the LED-LEHD program reports approximately 4,360 jobs in the Primary Zone, which suggests total employment of nearly 6,500 jobs (approximately 3 percent of the Legal Delta) after the adjustment for undercounting.

Overall, the Legal Delta appears to have a relatively balanced level of employment across a number of sectors, in sharp contrast to the Primary Zone. Specifically, four sectors, retail (13 percent), education (12 percent), health care and social services (10 percent), and accommodation and food service (9 percent), averaged about 44 percent of total jobs between 2007 and 2009.

Figure 6 Distribution of Employment by Industry in the Delta Region (2007-9)



Source: Center for Economic Studies (LED-LEHD), Census Bureau

Employment in the Primary Zone of the Delta is highly concentrated in the agricultural sector, which accounts for over 44 percent of all jobs. Over the seven-year period from 2002 to 2009, agriculture accounted for almost 58 percent of total employment in the region. Other important industries include manufacturing and construction, which account for 10 and 9 percent of Primary Zone jobs, respectively. Together, these three industries comprised more than 60 percent of Primary Zone jobs. Recreation-related industries, which generally include the retail; arts, entertainment, and recreation; and accommodation and food services sectors, account for roughly 9 percent of jobs in the Primary Zone.

3.2 Location Quotient Analysis

Location quotient analysis is a method commonly used to identify strengths in a local economy. The technique identifies concentrations in a local economy relative to a larger reference economy. In this analysis, the location quotient compares distributions of employment by industry to determine if there are industries that comprise a greater proportion of employment in the local economy relative to the state economy. Specifically, this analysis compares the employment composition of the Primary Zone and Legal Delta to employment composition in California.

In the Primary Zone, the location quotient analysis points to relatively high employment concentrations in the following sectors:

- Agriculture, forestry, fishing, and hunting[7]
- Real estate and rental and leasing[8]
- Construction[9]
- Mining, quarrying, and oil and gas extraction[10]
- Manufacturing[11]

In the Legal Delta, the location quotient analysis points to relatively high employment concentrations in the following sectors:

- Transportation and warehousing[12]
- Agriculture, forestry, fishing, and hunting
- Construction
- Educational services[13]
- Utilities[14]

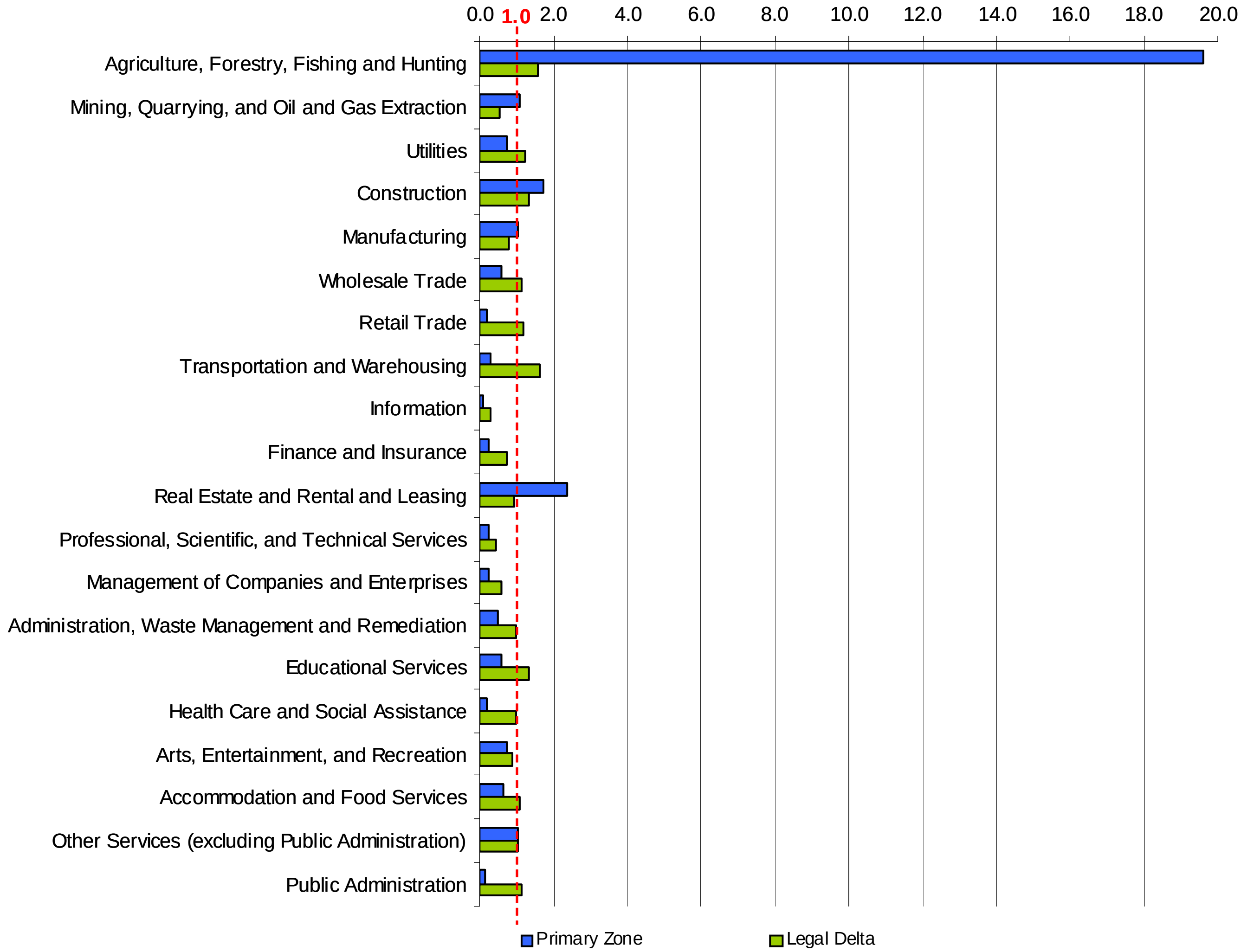
Figure 7 presents location quotients for employment in the Delta versus the State of California. A location quotient of 1.0 indicates that employment in the local area is the same share of total employment as in the state as a whole. If the location quotient is more than 1.0, local employment in the sector is concentrated compared with the state. As shown, the location quotient for agricultural employment in the Primary Zone is nearly 20, indicating extraordinarily high employment in this sector relative to total employment, as compared with the state.

Employment in the real estate sector is also relatively concentrated in the Primary Zone. Real Estate is closely tied to recreation, with several visitor-serving businesses in the Delta categorized as real estate entities. Real estate businesses in the Primary Zone range from marinas to self-storage facilities to independent real estate brokers. While this industry

[7] The agriculture, forestry, fishing and hunting sector comprises establishments primarily engaged in growing crops, raising animals, harvesting timber, and harvesting fish and other animals from a farm, ranch, or their natural habitats. (BLS)
[8] The real estate and rental and leasing sector comprises establishments primarily engaged in renting, leasing, or otherwise allowing the use of tangible or intangible assets, and establishments providing related services. (BLS)
[9] The construction sector comprises establishments primarily engaged in the construction of buildings or engineering projects (e.g., highways and utility systems). (BLS)
[10] The mining sector comprises establishments that extract naturally occurring mineral solids, such as coal and ores; liquid minerals, such as crude petroleum; and gases, such as natural gas. (BLS)
[11] The Manufacturing sector comprises establishments engaged in the mechanical, physical, or chemical transformation of materials, substances, or components into new products. (BLS)
[12] The transportation and warehousing sector includes industries providing transportation of passengers and cargo, warehousing and storage for goods, scenic and sightseeing transportation, and support activities related to modes of transportation. (BLS)
[13] The educational services sector comprises establishments that provide instruction and training in a wide variety of subjects. This instruction and training is provided by specialized establishments, such as schools, colleges, universities, and training centers. (BLS)
[14] The utilities sector comprises establishments engaged in the provision of the following utility services: electric power, natural gas, steam supply, water supply, and sewage removal. (BLS)

comprises only about 4 percent of jobs in the Primary Zone, that is more than two times the industry's share of employment in the state.

Figure 7 Location Quotient for Employment in the Delta Versus California



Source: Center for Economic Studies (LED-LEHD), Census Bureau

Construction businesses also cluster in the Primary Zone. Firms in this industry are primarily engaged in residential construction. Construction firms in the Primary Zone are frequently found at the urban-rural fringe, where large parcels of land are available proximate to dense populations. Employment in this sector makes up about 9 percent of employment in the Primary Zone, versus about 5 percent of employment in California.
While mining, quarrying, and oil and gas extraction supports a relatively low level of employment in the Delta, this sector's share of total employment is greater in Primary Zone than statewide. With a location quotient of 1.1, employment in the mining, quarrying, and oil and gas extraction sector is notable, likely due to the natural gas production, pipelines, and storage in the area.

Manufacturing, with its close ties to agriculture and recreation, is also an important employer in the Primary Zone. The manufacturing sector includes businesses with operations that range from agricultural implement fabrication to wine production to boat construction.

An additional location quotient analysis of the gross regional product (GRP) in the Legal Delta compared to the state reveals the importance of the utilities sector in the Delta.[15] While employment in this industry is somewhat concentrated in this sector in the Legal Delta, it is particularly notable that utilities account for nearly 5 percent of the gross regional product of the Legal Delta, versus only about 2 percent of the California economy. Of the 21 sectors analyzed for GRP location quotients, the top five industry clusters in the Legal Delta are: Utilities, Transportation and Warehousing, Imputed Rental Value for Owner-Occupied Housing, Construction, and Agriculture. Given the focus on the recreation economy in Delta planning efforts, it is notable that the Arts, Entertainment and Recreation sector's location quotient of 0.31 is in a three-way tie for the last place with the Information and Management sectors.

Considering all the various measures of industry concentration, there are three critical clusters for the Delta economy in both the Primary and Secondary Zones:

- Agriculture
- Transportation, Warehousing, and Utilities
- Construction, Housing, and Real Estate

All three of these critical areas could be significantly affected by Delta planning efforts. Given the importance of agriculture in the Primary Zone, the Economic Sustainability Plan includes a focused analysis of this sector in Chapter 7. The Delta recreation economy is addressed by Chapter 8, because of its relationship to the Delta environment. Utilities and other infrastructure-related activities are discussed in Chapter 9.

3.3 Export Orientation

IMPLAN, a regional economic model that describes economic relationships between industries, is a valuable tool for evaluation of trade and exports in the Delta. This analysis relies on data from IMPLAN to consider the degree to which specific Delta industries are export-oriented, thereby bringing new money into the regional economy. A key measure of a region's economic base is the amount or percentage of economic activity, services, or sales that are exported outside of the local area. Exports from the Delta bring new dollars into an economy rather than re-circulating existing dollars.

IMPLAN data are available by U.S. Postal Service ZIP codes, which are not perfectly consistent with Delta boundaries, particularly in the Primary Zone. The Economic Sustainability Plan considers two geographies comprised of ZIP codes, including the ZIP codes that best represent the economy of the Legal Delta and ZIP codes in the Sacramento River Corridor (see Appendix B). Based on IMPLAN data for these geographies, exports represent about 33 percent of total output in the Legal Delta and 64 percent in the Sacramento River Corridor, compared to 24 percent in the state as a whole. These data suggest that economic output in the Delta is heavily biased towards producing goods and services for consumption elsewhere. Not surprisingly, agriculture is a highly export-oriented sector with exports accounting for 83 percent of total output in this sector in the Sacramento River Corridor. Utilities and manufacturing are also significant export-driven industries in the Delta.

[15] Location quotient analysis of gross regional product relies on data from IMPLAN (see Appendix B).

Chapter 3: The Delta Ecosystem and Economic Sustainability

The history of the Sacramento-San Joaquin Delta and its ecosystem, its current status and value, and the various proposals to repair or restore the ecosystem are covered in numerous reports and technical papers. A good overview, which includes 12 pages of technical references, is provided by the Delta Ecosystem White Paper, dated October 18, 2010, prepared for the Delta Stewardship Council.[16] The executive summary states that:

> *"The Delta and Suisun Marsh ecosystem, as a large component of the San Francisco Estuary, was once one of the most biologically productive and diverse ecosystems on the west coast, supporting a wide array of native plant and wildlife species and providing important habitat for many migratory species. The Delta ecosystem is now in peril. As a result of human activity to reclaim farmland, protect areas from flood, and provide water for agriculture and communities; discharge of wastes from agriculture, industry, and urban areas; and the introduction of harmful invasive species, the Delta has been modified in ways that adversely influence ecosystem function and compromise its ability to support a healthy ecosystem. These changes not only affect the species that live there, but also the ecosystem services that benefit humans, such as improved water quality, agricultural productivity, healthy commercial and sport fisheries, flood protection, and recreation."*

The purpose of this chapter is to list key considerations as background to a more focused assessment of the evolving Delta economy centered on agriculture, recreation and tourism, and infrastructure. While a healthy ecosystem has intrinsic economic values, as stated in Chapter 1, our focus is on the more tangible economic impacts on the economy of the Delta. Ecosystem restoration will have a variety of impacts on the Delta economy, both positive and negative.

1 Brief Background

In the early 19th century the Delta was composed of intertidal wetlands, riparian forest and scrub, nontidal wetlands and grasslands, floodplains, and seasonal wetlands, all contained within an intricate network of branching waterways, as shown in Figure 11. Following the Gold Rush, encouraged by state and federal legislation, most of the Delta was drained and leveed for agricultural purposes. This transformation was largely completed by the early 20th century, resulting in the geometry of the Delta that we know today. Other changes include the introduction of an enormous quantity of mining debris in the second half of the 19th century prior to the ban on hydraulic mining on federal lands and the subsequent widening and deepening of the lower Sacramento River by the federal government in order to facilitate the flushing of mining debris through the Delta; the dredging of the Sacramento and Stockton deep-water ship channels; the diversion of waters upstream from the Delta by various local, state, and federal irrigation projects; the regulation of river flows by the construction of dams for both flood control and irrigation purposes; and the extraction of water from the South Delta by the federal Central Valley Project and the State Water Project.

The consequence of all this alteration of the natural environment has been substantial modification of the ecosystem, judged by most observers to be in a decline that has steepened in recent years. As one measure, salmon runs continued in the millions for some years even after the first large dams were built but have greatly declined in recent years. Of particular note is the "pelagic organism decline" (POD) of the first decade of the current century. This has been the subject of exhaustive study and a comprehensive report prepared by the Inter-Agency

[16] http://www.deltacouncil.ca.gov/delta-plan

Ecological Program (IEP).[17] While there are many differing opinions about the principal reasons for this decline, a common observation is that the Delta has gradually been transformed from an estuarine environment to more that of a weedy lake that favors invasive species over native species.

2 Stressors

Good discussions of the “stressors” or “drivers” of the Delta ecosystem can be found in the IEP report on the POD and in the review performed by the Independent Science Board at the request of the DSC.[18] Because of the continuing debate over the relative importance of individual stressors or combination of stressors, we do not attempt a formal ranking of stressors but we do attempt to sort and list them, below, in a rational manner in order to inform subsequent discussion. Interactions between the listed stressors can be as important, or more important, than any of them in isolation. This is part of the reason that it is so difficult to complete a satisfactory effects analysis for any one or a combination of conservation measures.

A. Climate and flow

  a. Climate variability, including both the magnitude of winter and spring freshwater pulses and oceanic conditions

  b. Flow regime, the loss of natural flows through the Delta: reduced flows out of the San Joaquin and cross-flows that result from Sacramento River water being drawn to the export pumps in the South Delta

B. Landscape and vegetation: in particular the loss of connectivity, complexity, and variability

C. The measures that result from A and B: salinity, temperature, turbidity, natural nutrients

D. Introduced substances: unnatural nutrients, contaminants, disease

E. Harvest: entrainment, predation, fishing

One of the reasons that there is continuing debate about the relative importance of these stressors is that, as explained in the landmark paper on altered flow regimes by Bunn and Arthington,[19] the necessary detailed observations were not made during the decline of most rivers and estuaries to allow the development of robust detailed correlations of causes and effects on a scientific basis. Bunn and Arthington express the hope that that will be done as these ecological systems are restored, and that that will guide adaptive management of restoration efforts; in the meantime there is a need to go forward in accordance with broader principles and best management practices.

[17] http://science.calwater.ca.gov/pod/pod_index.html
[18] http://deltacouncil.ca.gov/docs/2011-01-26/final-memo-phil-isenberg-delta-isb-addressing-multiple-stressors-and-multiple-goals-
[19] Stuart E. Bunn and Angela H. Arthington, Basic Principles and Ecological Consequences of Altered Flow Regimes for Aquatic Biodiversity”, Environmental Management, Vol. 30, No. 4 (2002), pp. 492–507

3 Possible conservation and ecosystem restoration measures

Possible conservation and ecosystem restoration measures are being studied by the Bay Delta Conservation Plan (BDCP),[20] the Department of Fish and Game in connection with their Ecosystem Restoration Plan,[21] and the Delta Conservancy as part of its Strategic Plan development. Flow and water quality standards, which might have a very significant impact on the Delta ecosystem, are also under consideration by the State Water Resources Control Board.

While there is continuing debate over the importance of restoring more natural flows through the Delta, it seems clear that ecosystem restoration should start with a solution to the existing conveyance problems that makes a significant improvement in natural flows through the Delta. But many additional conservation measures might need to be taken to fully achieve the coequal goals. The broad principles that should be followed are relatively clear and should include restoring connectivity, complexity, and variability to the Delta ecosystem on a landscape scale (i.e., throughout the Delta) rather than on a piecemeal basis. It must also be recognized that the Delta ecosystem is not a closed system and that the ocean-bay-Delta-rivers system must be addressed as a whole.

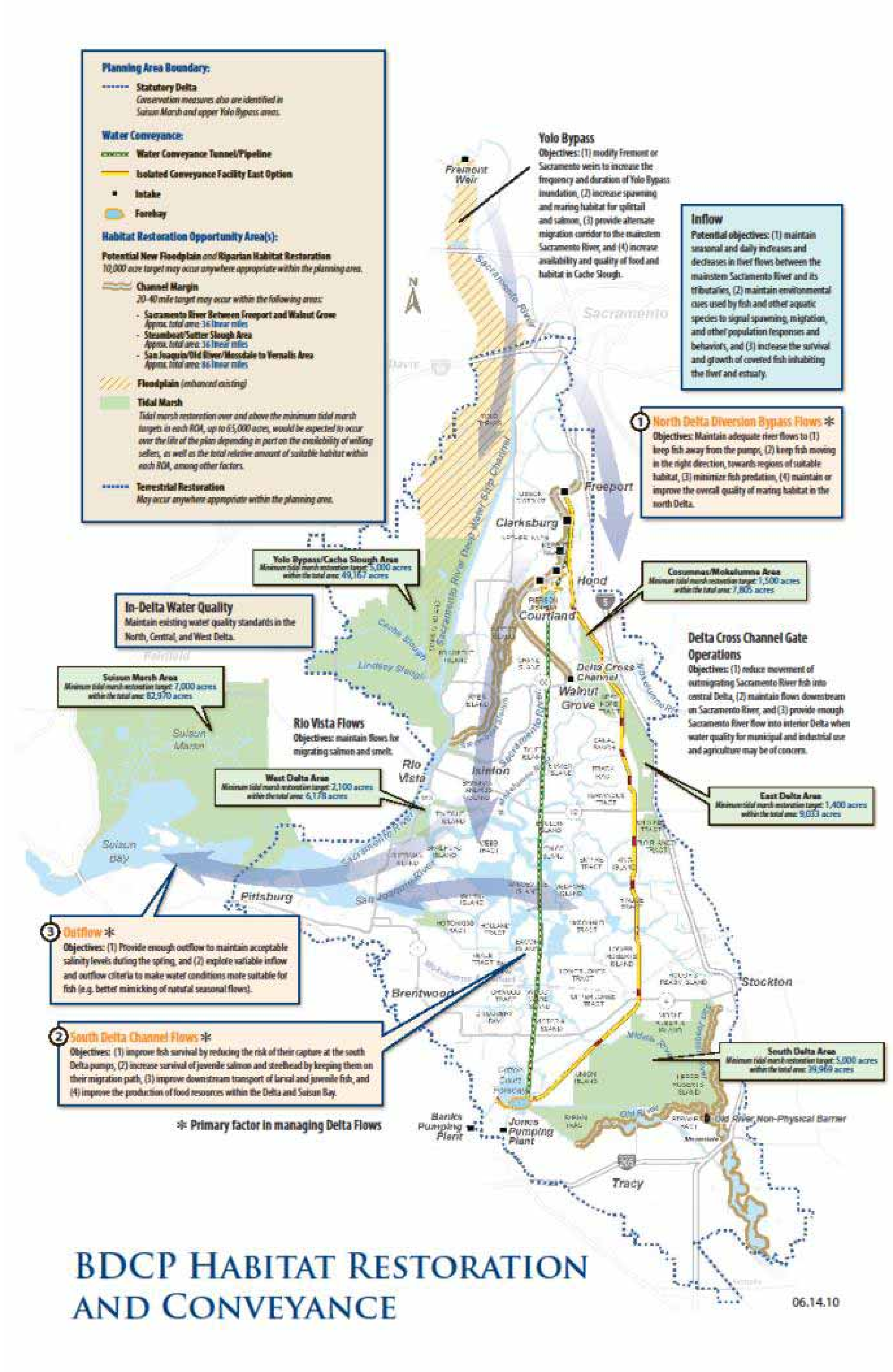
Most of the options under consideration by the BDCP attempt to improve flows in the Delta by moving part or all of the intakes from the south Delta to the north Delta rather than reducing the amount of water exported to the state and federal water projects. Moving the intakes would improve natural flows by minimizing the “reverse flows” that presently occur in the Old and Middle Rivers when the south Delta pumps are operated at high levels. However, the gain that might result by lower fish losses at the South Bay pumps is offset to at least some extent by possible adverse impacts on salmonids in the Sacramento River. In order to deal with that issue, it is expected the operational rules for any north Delta intakes will require significant bypass flows that will limit the amount of water than can be conveyed through tunnels to the South Delta. Thus, significant through-Delta flows will still be required, resulting in a dual conveyance system of moving freshwater around the Delta in an isolated facility in tandem with the current system of through-Delta conveyance.

The net effect is that it does not appear that the conveyance measures that are part of the BDCP will by themselves have a significant effect on achieving ecological recovery of the Bay-Delta estuary. Thus, the BDCP relies on a number of additional conservation measures to promote ecological recovery. Nineteen such measures were included in the November 2010 working draft of BDCP[22] and are illustrated in the aquatic habitat restoration map[23] that is shown as Figure 8.

The most prominent and costly elements of the BDCP restoration proposals are the isolated conveyance facility and the extensive areas that are targeted for tidal marsh restoration, including areas in the interior Delta that were not necessarily tidal marshes in the historic Delta. The BDCP has estimated that just the construction cost of this plan will be $15 billion or more.

[20] http://baydeltaconservationplan.com/Home.aspx
[21] http://www.dfg.ca.gov/erp/
[22] BDCP, Working Draft, Chapter 3, November 18, 2010, http://baydeltaconservationplan.com/BDCPPlanningProcess/DocumentsAndDrafts.aspx
[23] http://baydeltaconservationplan.com/BDCPPlanningProcess/BrochuresAndFactSheets.aspx

Figure 8 BDCP Habitat Restoration[24]



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[24] For a better resolution image see http://forecast.pacific.edu/desp-figs.html

4 Potential Impacts of Ecosystem Restoration on the Delta Economy

Improvements to the Delta ecosystem could have positive and negative effects on the Delta economy and quality of life. Potential positive effects include the following.

- Improving fisheries could help commercial and recreational fishing economies, although most of the economic benefit of improved salmon runs would be outside the Delta.
- Some habitat measures could increase flood protection.
- Increased freshwater flows would benefit water quality for a variety of in-Delta uses.
- Reducing contaminants would benefit water quality for a variety of in-Delta uses.
- Improved riparian habitat would improve the aesthetics of the Delta and make it a more desirable place for recreation.
- Other habitat measures could increase opportunities for wildlife viewing and related tourist activities.

However, some ecological improvements, including those listed below, would have negative effects on the Delta economy and quality of life.

- Habitat restoration could eliminate large amounts of farmland, reducing agricultural production, the Delta's largest industry.
- Some ecological restoration strategies could increase salinity, harming in-Delta uses of water.
- Some ecological restoration strategies could increase organic carbon levels in Delta water, causing problems for municipal and industrial users.
- Increased mosquito/vector problems from marsh restoration increases the risk of disease and creates a nuisance that makes the Delta less desirable for living, recreation, and tourism.
- Some marsh restoration could increase seepage and risk for levees on nearby islands.
- Some restoration measures are very expensive and will require large commitments of public financial resources from strained public budgets.

Some conservation measures would have mostly positive effects, whereas others could have large negative effects. In many instances, potential negative effects could be reduced through careful planning.

5 Ranking Ecosystem Restoration Proposals for Economic Sustainability in the Delta

The following conservation or ecosystem restoration measures appear to have the merit of complementing any increases in the natural flows through the Delta without adversely affecting existing agricultural and recreational uses in the Delta. Indeed, successful implementation of these measures would be expected to benefit recreation and potential eco-tourism.

- Restore sunken islands including Franks Tract and Western Sherman Island as tidal marsh and/or tule marsh.

- Restore the mid-channel berms which are in danger of being lost at many locations.
- Encourage the growth of native vegetation on the water side of all Delta levees, which will not only provide significant ecological benefits but also recreational and tourism benefits. At selected locations, this vegetation may be extended into the existing waterways on berms or up widened levees to create riparian habitat.
- Restore some measures of complexity to the Delta waterways: in addition to creating more natural channel margins as discussed above, make use of both set-back levees and berms to create more natural slough geometries and increase the variability of flows and residence times by modifying channel geometries by dredging and fill placement as appropriate.
- Restore historic floodplains upstream of the Delta in order to provide both flood management and ecosystem benefits.

Other conservation measures will impose some economic costs on the Delta, however, these costs can sometimes be avoided or mitigated through management and flexibility. In addition, there could be some off-setting benefits to recreation or flood control. The following list is an example of conservation measures with in-Delta economic costs that could be managed or mitigated.

- Encourage more farms to adopt habitat-friendly agricultural practices such as those already employed by The Nature Conservancy on Staten Island as well as many other farmers throughout the Delta.
- Construct new and improve existing flood bypasses.

Other proposed measures in the BDCP have potentially large negative effects on many aspects of the Delta economy with little or no offsetting benefits.[25] Not only do they take prime agricultural land out of production for uncertain ecosystem benefits, but they threaten to add significantly to water treatment costs, as discussed in Chapter 9 on Infrastructure, raise major concerns about the control of disease-carrying vectors, and have more negative than positive impacts on recreation and tourism. The most costly of these measures are:

- Isolated water conveyance facilities to move freshwater around the Delta via a tunnel or canal
- Creation of new tidal marsh areas, particularly in the interior Delta

The sizing of isolated conveyance and extent of tidal marsh restoration continue to be under evaluation. Reducing the capacity of isolated conveyance and the acreage targets for tidal marsh restoration would reduce negative effects on the Delta economy, although not necessarily in direct proportion to the changes in capacity or acres. The economic impacts of these measures are discussed in greater detail in subsequent chapters, particularly chapters in Part Two.

[25] Spending to operate and maintain the facilities will create some positive on-going economic activity in the Delta. However, much of that new spending is for energy, primarily increased electricity demand, which is a very arguable local economic benefit.

Chapter 4: Review of Key Policies and Planning Processes

Shortly after statehood in 1850, California started studying its water resources. From the early 1900s, plans were developed and implemented to move water from the water-rich north to the water-poor south through the Delta and to provide irrigation water for the San Joaquin Valley. Since the late 1970s regional governance of the Delta, hub of the California water system, has been implemented at the local, regional, and State levels. The current governance proposal retains local control over most actions, retains the Delta Protection Commission with limited authority over some local land-use decisions, and introduces the new Delta Stewardship Council as coordinator of all State-level programs including water quality, water supply, habitat enhancement, public access and recreation, and land use. While multiple local, State and federal regulatory programs affect the Delta economy and Delta land uses, this chapter focuses on the current and required local and State programs that most directly impact the Delta.

Water Conveyance

As early as 1919, a statewide water development project envisioned moving Sacramento River water through the San Joaquin Valley and over the Tehachapis to Southern California. A plan to implement such a project was approved in a 1933 $170 million bond act but the State turned over the lead to the federal government and the initial stages of the project including the construction of Shasta Dam, a pumping plant in the South Delta and the Delta Mendota Canal were completed in the 1950s as the federal Central Valley Project (CVP). A series of bills to expand the project was passed in the late 1950s and were funded by the 1960 California Water Resources Development Bond Act. This led in the 1960s to the State Water Project (SWP) which included the construction of Oroville Dam, a second pumping plant in the South Delta, the California Aqueduct , the pumping plant to lift water over the Tehachapis and terminal reservoirs in Southern California. The construction at this time also included the San Luis reservoir and canal which are components of the CVP and supply the Westlands Water District. In the early 1980s, legislation was proposed to construct a peripheral canal to convey water around the Delta to export pumps near Tracy to serve both the CVP and the SWP. The project was divisive and ultimately rejected by voters in June 1982.

Several years of drought, followed by downturns in Delta fisheries, led Governor Pete Wilson and Secretary of the Interior Bruce Babbitt to bring State and federal agencies to a joint CALFED process to address California and Delta water issues in 1994. The CALFED project resulted in a Record of Decision in 2000, which included multiple actions needed to address water and ecosystem management in the Delta and its watershed. The legislature established a State oversight body, the California Bay-Delta Authority. That body was later disbanded, and the CALFED program was folded into the California Natural Resources Agency. In 2006, the governor and legislature appointed a cabinet committee and a Delta Vision Blue-Ribbon Task Force to advise the cabinet committee. In 2007, the Task Force presented its Delta Vision and in 2008 prepared a strategic plan. In late 2009, the legislature enacted and the governor signed a package of laws to implement the recommendations creating the new Delta Stewardship Council, a Delta Conservancy, and modified the legislation authorizing the Delta Protection Commission (DPC), among other actions. Concurrently, work commenced around 2006 on an effort to obtain incidental take permits that would protect operations of the CVP and the SWP from repeated lawsuits based on the Endangered Species Act. This effort, known as the Bay Delta Conservation Plan (BDCP), is described in more detail below as is the Delta Vision process.

Governance

In the early 1970s, as agricultural lands in the Delta counties came under pressure for development from residential and other users, the five Delta counties came together to develop a regional strategy for future development of the Delta. The Delta Area Planning Council (DAPC), created through a Memorandum of Understanding and funded by the counties, adopted a plan for the region which supported agricultural and recreational land uses. Funding for the Delta Area Planning Council dwindled in the late 1980s and interest in State-level planning and coordination increased in the late 1980s.

In 1992, after the State conducted studies and hearings about the need to plan for the future of the Delta and the protection of its critical natural resources, the legislature approved the Johnston-Baker-Andal-Boatwright Delta Protection Act of 1992, authored by two assemblymembers and two senators, and signed into law by Governor Pete Wilson. The act created the DPC with membership from State agencies, local counties and cities, and Delta water agencies. Within the Legal Delta, defined in 1959 (Water Code Section 12220), the act divided the area into two zones: the Secondary Zone, which is the higher elevation and already-developed outer area of the Legal Delta, and the Primary Zone, the lower elevation and largely water-covered and agricultural lands in the "core" of the Legal Delta. The DPC was charged with preparing a land-use and resource-management plan for the Primary Zone of the Delta, addressing agriculture, recreation, and wildlife habitat on land areas. Control over the waters of the Delta remained with State and federal agencies. Action of local governments in the Primary Zone can be appealed to the DPC. Land uses in the Secondary Zone remain solely under the authority of local governments. The DPC has no authority over State or federal agencies or their programs or projects.[26]

1 County General Plans and the Delta

General plans, first authorized in California in 1927, must now include seven elements: land use, open space, conservation, housing, circulation, noise, and safety. Each general plan is a comprehensive long-term plan for the physical development of the county or city serving as a "blueprint" for development. More guidance is outlined in specific plans and in each county or city's zoning code; zoning codes are required to be in conformance with general plans. In 1993, each of the counties with lands within the Primary Zone supported agriculture, wildlife habitat, and recreation on Primary Zone lands. The unincorporated communities in the Primary Zone each have their own community plans/special area plans. These communities are Clarksburg in Yolo County, and Courtland, Locke, and Walnut Grove in Sacramento County. The City of Isleton is the only incorporated city in the Primary Zone and has its own general plan. Local government general plans do not apply to State or federal projects.

After the DPC adopted its original Land Use and Resource Management Plan for the Primary Zone of the Delta, each county and city was required to ensure that its general plan was consistent with the DPC's plan. All of the county and city general plans covering the Primary Zone were determined to be consistent with the DPC's plan although each county addresses these land uses and their protection in ways reflecting their community values and local history.

[26] Please see Chapter 1 for a map of the Primary and Secondary Zones of the Sacramento-San Joaquin Delta.

1.1 Contra Costa County

Contra Costa County has adopted an urban limit line; the Primary Zone within Contra Costa County is outside the urban limit line due to flood hazards, soil subsistence, lack of infrastructure, and lack of services. The areas to the north and east are designated Delta Recreation and Resources areas and portions of the Primary Zone are designated General Agriculture. The urban limit line will be reviewed in 2016.

1.1.1 General Plan (2005)

Contra Costa County has a program, the Contra Costa County Land Preservation Plan Ordinance, to maintain a specific ratio between developed land and open space land: 65 percent of the county will be preserved for agriculture, open space, wetlands, parks, and other nonurban uses, and 35 percent may be used for urban development. This ratio was originally adopted by the voters in November 1990 and renewed by voters in November 2006. The Primary Zone is within the area to remain in open space and low-intensity uses.

The Contra Costa General Plan uses several zoning codes to identify and protect the unique Delta land uses and characteristics of the Primary Zone lands in Contra Costa County. The general plan designates most Delta islands and nearby tracts as a special Delta Recreation and Resources Zone. The designation recognizes the location in the 100-year flood plan, the limited services, and the value as agricultural land, as wildlife habitat, and for low-intensity recreation. In these areas, the county allows agricultural uses, and with a use permit, recreation uses such as marinas, hunting clubs, campgrounds, and other forms of outdoor recreation. Minimum parcel size is 20 acres. Publicly-owned park land and all golf courses are designated Parks and Recreation. Transportation and utility corridors are designated Public Facilities. Water area uses include docks, boating, and fishing. Publicly-owned land, wetlands, tidelands, and areas of significant ecological resources are designated Open Space. The areas west of Veale and Hotchkiss Tracts are designated Agricultural Land. The existing parcels are mostly between 10 and 50 acres. Jersey Island is designated Public/Semi-Public and has been used for disposal of treated wastewater.

Agricultural Core: The agricultural core is comprised of prime soils which are considered the very best soils for farming a variety of crops. The agricultural core is east, south, and west of the city of Brentwood. Intensive row crops are being grown on much of this land, and a portion of the agricultural core is within the 100-year flood plain. The purpose of the agricultural core designation is to preserve and protect the most productive farmlands of the county, and the designation requires a higher minimum parcel size; “ranchette” development is discouraged. Ranchettes are rural residential lots as small as one to two acres, often five or ten acres. Uses are the same as in the Agricultural Land designation; however wineries and olive oil mills are appropriate in the agricultural core with a use permit. Residential density is one unit per 40 acres.

Policy 3-54 requires all management and development actions in the Primary Zone to be consistent with the goals, policies, and provisions of the Land Use and Resource Management Plan for the Primary Zone of the Delta.

1.1.2 East County Area Plan

An area plan for a portion of the Primary Zone in East Contra Costa County was adopted in 1985 and includes: Holland, Palm, Orwood Tracts, and Coney Island. Allowed uses include public and private outdoor recreation, equestrian facilities, wind energy systems, single family residences on larger lots, quarries, oil and gas wells, pipelines and transmission lines, vet/kennels, and public uses.

1.1.3 City of Oakley

The City of Oakley was incorporated in 1999. In 2004 the DPC reviewed the city's general plan for consistency with the DPC's Plan. The only area of the City of Oakley in the Delta Primary Zone is a 200-foot-wide band of water-covered lands along the shoreline. The water-covered area includes Antioch/Oakley Regional Shoreline (fishing and picnic facilities at the base of the Antioch Bridge) and the new Big Break Regional Shoreline. Both facilities are owned and managed by the East Bay Regional Park District. The city's general plan was found consistent with the DPC's plan.

1.1.4 Knightsen

Within the Primary Zone in Contra Costa County is one unincorporated community, Knightsen. Located at the intersection of Knightsen Avenue and Delta Road, east of Brentwood and south of Oakley, Knightsen was founded in 1888 at a station on the Atchison, Topeka and Santa Fe Railway line. The community, represented by an appointed Knightsen Town Municipal Council, is home to an elementary school, a post office, and a couple of commercial enterprises. The surrounding community is agricultural. Due to its history and characteristics, Knightsen has been discussed as a potential Legacy Community. (See Chapter 10 for more information.)

1.2 Sacramento County

The county has an urban limit line; the Delta is outside the urban limit line. Within the Primary Zone, there are several unincorporated communities with residential and commercial development as well as scattered areas of residential development along waterways. County decision makers are advised by the Delta Municipal Advisory Council made up of Delta residents.

1.2.1 General Plan (1993, currently being updated)

The Sacramento County General Plan was adopted in December 1993. The general plan defines areas of future growth in the county; these areas are out of the Delta. However, seven of the eleven Legacy Communities identified in the 2009 Sacramento-San Joaquin River Delta Reform Act (PRC Section 32301(f) are located within unincorporated Sacramento County. Land uses and future development in Freeport, Courtland, Locke, and Walnut Grove are subject to General Plan policies and typical zoning standards and to the land use and design standards in the Special Planning Area and Neighborhood Preservation Area Ordinances. The December 9, 1992 Land Use Diagram shows that the urban services boundary does not pass west of I–5. The land use diagram shows most of the Delta area designated as Agricultural Cropland. Areas of low-density residential use (1 to 12 dwelling units per acre) are located in the existing communities of Hood, Courtland, Locke, and Walnut Grove. Small areas are identified for Intensive Industrial and Extensive Industrial use south of Walnut Grove, along Twin Cities and River roads, and near Hood. The diagram shows recreational uses at the north tip of Sherman Island, Brannan Island State Park, the eastern portion of Andrus Island, the shoreline west of Isleton, and the area between the Delta Cross Channel and Locke. Several areas are identified as Natural Reserves including Lost Slough, Sherman Island Wildlife Area, the west tip of Grand Island, Stone Lakes, Delta Meadows, and the levees along Snodgrass, Sevenmile, and Steamboat sloughs.

The December 9, 1992 agricultural element of the general plan promotes protection of agricultural land, requires mitigation to provide in-kind protection when agricultural land is developed, promotes 300- to 500-foot-wide buffers between agricultural and non-agricultural uses; and sets minimum parcel sizes of 40 acres for soil classes I and II and 80 acres for soil classes III and IV.

The county does not accept applications to amend the land use diagram from recreational or agricultural cropland to any residential category, commercial and office, or industrial use unless the site is in the established Delta communities of Hood, Courtland, Locke, or Walnut Grove, or is a small expansion which supports the agricultural and recreational economies of the Delta.

The open space element of the general plan outlines strategies to protect critical open space resources of the county including acquisition of key areas and implementation programs to secure permanent open space, thus fixing the urban service boundary, and establishing open space linkages (natural land corridors).

The conservation element protects key resources including water and soil. Development is to be diverted from prime soil or soils of statewide importance; conversion of more than 50 acres of prime or statewide importance soils is deemed to have a significant environmental impact under the California Environmental Quality Act (CEQA); no golf courses are allowed on prime lands outside the urban service area boundary.

Issues currently under consideration in the updated general plan include revitalization of commercial corridors, inclusion of a new economic development element, analysis of future growth within the urban policy area and the urban services boundary, and smart growth principles.

1.2.2 The Delta Community Area Plan[27]

The Delta Community Area Plan (1983) designates most of the Delta as permanent agricultural land in 80-, 40-, and 20-acre parcels. Agricultural residential parcels are one and two acres. The communities of Hood, Courtland, and Walnut Grove are identified as locations for future residential development and commercial growth; residential development in the agricultural areas is discouraged.

Some water-covered areas are designated Delta Waterways and some as natural areas (Dolan Island, waterways near the tip of Sherman Island, a portion of Sevenmile and Snodgrass sloughs, and the south fork of the Mokelumne River), scenic areas (Steamboat, Sutter, and Georgiana sloughs), and restricted areas (Steamboat, Snodgrass, and Sevenmile sloughs). The area around Stone Lakes, much of Snodgrass Slough, the Delta Meadows area, the southwest tip of Grand Island, and Brannan Island State Park are designated Recreation Reserve. The islands at the tip of Sherman Island are designated Recreation with a Flood overlay.

Special plans have been prepared for the communities of Courtland, Hood, Locke, Walnut Grove, and Ryde and for the Lower Andrus Island Special Planning Area. These communities are the residential, commercial, processing, and retail centers in the Delta and have water and sewage treatment facilities and fire protection. These plans are codified in special zoning codes for Walnut Grove (1989) and Locke (2005).

[27] Please refer to Chapter 10 for maps of the Hood, Courtland, and Walnut Grove communities.

Sacramento County is currently evaluating new Winery, Farm Stand, and Farm Stay Ordinances to set standards for agricultural industries and to promote agricultural tourism and to provide new economic development opportunities. The winery ordinance would allow small wineries (less than 15,000 cases produced annually) by right in the General Agricultural (AG) zones and some Agricultural-Residential zones; large wineries (51,001+ cases annually) located General Agriculture zones will be subject to the approval of a conditional use permit.

The farm stand ordinance will allow the sale of food products that are locally grown in General Agriculture zones, and some Agricultural-Residential zones.

The farm stay ordinance will facilitate the operation of farm stays, expand the understanding of the role of agriculture in the County, and provide farmers with an opportunity to diversify income potential. No more than five guest rooms would be allowed per farm stay operation.

1.3 San Joaquin County

San Joaquin County promotes future growth within the existing cities and existing unincorporated communities. There are no unincorporated communities in San Joaquin County's portion of the Primary Zone; there are some permanent residents living at the large recreational development at Tower Park Marina in Terminous where Highway 12 meets Potato Slough.

1.3.1 General Plan (1992, currently being updated)

The county's general plan recognizes that the county will grow substantially in the future, but states that rural areas will accommodate minimal growth because open space and agricultural preservation are paramount in these areas. The County General Plan Map designates most of the Delta as General Agriculture. The waterways and channel islands are designated Resource Conservation. The general plan recognizes the Delta as an area of international importance and a major recreational, wildlife, agricultural, and economic resource.

There are two regional parks and one area designated Commercial Recreation at Terminous (Tower Park Marina). Commercial Recreation is defined as major development of at least 100 acres with potential of more than 500 people on a site. The general plan allows smaller areas of commercial recreation in agricultural areas because of specific location needs, such as direct access to natural resources. Typical uses include marinas, recreational vehicle parks, and golf courses. Commercial Recreation areas outside communities must have a public wastewater treatment system serving the entire planned area. The general plan states that recreational values of the Delta are to be protected, and that along the waterways, opportunities should be provided for bank fishing, boating, water skiing, hiking, bicycling, horseback riding, picnicking, and nature study. Waterway development and development on Delta islands is allowed to protect the natural beauty, the fisheries, wildlife, riparian vegetation, and the navigability of the water. The plan limits development on the Delta islands to water-dependent uses, recreation, and agricultural uses.

The open space policies of the general plan state that the Resource Conservation designation shall be used to protect significant resource areas, and that areas with serious development constraints, such as the Delta, should be predominantly maintained as open space. Policies also designate several Delta roads as scenic routes.

Agricultural lands make up the majority of the Primary Zone in San Joaquin County. The General Agriculture designation addresses areas where soils are capable of producing a wide variety of crops, where parcel sizes are large enough to support commercial agricultural activities, and where there is an existing commitment to commercial agriculture. In areas designated General Agriculture, development density is a maximum of one primary dwelling unit per 20 acres; additional dwelling units for farm employee housing and farm labor camps may be permitted. Minimum parcel sizes are 20 to 40 acres where irrigation water is available, 80 to 160 acres where water is not available for irrigation.

Uses allowed in the General Agriculture designation include crop production, feed and grain storage and sales, aerial crop spraying, and animal raising and sales. Additional activities such as resource recovery, dairy and canning operations, stockyards, and animal feed lots and sale yards require permits. The general plan prohibits further fragmentation of land designated for agricultural use. Parcels for home sites may be created, provided that the general plan density is not exceeded; a parcel may be created for a use granted by permit in the AG zone. Non-agricultural land uses at the edge of agricultural areas are required to incorporate adequate buffers (e.g., fences and setbacks) to prevent conflicts with adjoining agricultural operations.

1.4 Solano County

Development in Solano County is directed by county and city policies into the existing cities: Vacaville, Fairfield, Rio Vista, Vallejo, Suisun City, Dixon, and Benicia. Much of the land in the Primary Zone is above sea level and distant from the sloughs and rivers that provide riparian water for agriculture. There is also very little recreational development in the Primary Zone in Solano County. Portions of Prospect Island are designated Open Space: Marsh. An orderly growth initiative, Proposition A, passed in 1984, prohibits the Board of Supervisors from changing the general plan designation on agricultural lands, except in very limited circumstances. In 2008 voters adopted Measure T, which extends the Orderly Growth Initiative through 2028. There are no unincorporated communities in the Primary Zone in Solano County.

1.4.1 General Plan (2008)

Delta lands are designated Intensive Agriculture, if irrigated, and Extensive Agriculture, if not irrigated. Irrigated land is 80-acre minimum parcel or 40-acre minimum parcel for highly productive areas (orchard or vineyard). Unirrigated land is 160-acre minimum parcel size. The parcel sizes are based on the concept of “farmable unit,” defined as the size of parcels a farmer would consider leasing or purchasing for different agricultural purposes.

The general plan calls for protection of wetlands and riparian vegetation through formation and retention of parcels of sufficient size to preserve wetlands and protection of these lands from effects of development.

The general plan emphasizes the preservation of agricultural resources, opportunities for value-added agricultural activities, and agritourism, all to enhance agricultural economic viability.

1.4.2 City of Rio Vista[28]

General Plan 2001, adopted July 2002, includes policies that state “the City shall continue to support prohibitions/restriction on development within the Delta Protection Commission’s Primary and Secondary Zones.” (Policy 3.7.A (page 3-20) and that “The City shall seek to remove lands from the existing Sphere of Influence that are currently within the boundaries of the Delta and any lands that are placed in an open space land trust.“ (Policy 3.7.B, page 3-20). Within the current boundary of the Primary Zone, the General Plan depicts existing land uses

[28] Please refer to Chapter 10 for maps of the City of Rio Vista with respect to the Primary Zone.

included: airport, sewage treatment plant, heavy commercial/light industrial uses, and landfill. A triangular area northeast of Airport Road, the boundary of the Primary Zone, and bounded by the Sacramento River, is designated SA, Study Area. Most of the land uses were in place in 1993, and only minor modifications have been approved since then. General Plan 2001 supports study of a future replacement for the current bridge across the Sacramento River and supports use of Airport Road as a future means to move additional traffic above the capacity of State Highway 12. The General Plan does not support a bypass of the City of Rio Vista to the north or the south.

1.5 Yolo County

About half of Yolo County land within the Primary Zone is in the Yolo Bypass, a flood basin which is part of the federal flood control project between Collinsville and Red Bluff. The Yolo Bypass is west of the Port of Sacramento Deep Water Ship Channel and bounded by a levee located along the Yolo County-Solano County boundary. The eastern portion of Yolo County includes the unincorporated community of Clarksburg, Merritt Island, and agricultural lands in Reclamation districts 999 and 307.

1.5.1 2030 Countywide General Plan (2009)

The general plan designates Delta lands as A-1, Agricultural General Zone, and A-P, Agricultural Preserve for lands in Williamson Act contracts. AG policies in the county's general plan are protective of agricultural uses. New residential, suburban, commercial, and industrial uses are prohibited, unless directly related to and incidental to agriculture. Residential uses in agricultural areas are limited to farm owners or employees, and are directed toward lands unsuited for agricultural use. The general plan includes an Agriculture and Economic Development Element in support of agriculture, the primary economic driver of Yolo County. The element identifies wine grapes as the largest single crop in the fruit and nut category and describes the 64,640-acre Clarksburg appellation, which has 10 wineries and 11,000 acres of vineyards. The Agriculture and Economic Development Element also describes the key factors supporting agriculture: soil, important farmlands, water, crops, and agricultural infrastructure. The element supports compatibility with the Delta Plan (AG-6.1-4) and seeks to support and enhance the existing rural economy. The section on economic development emphasizes tourism and describes how services for tourists will also benefit local residents, and supports expansion of tourism "in a manner consistent with Yolo County's agricultural and open space emphasis."

1.5.2 Clarksburg General Plan[29]

There is one unincorporated community in the Primary Zone in Yolo County. A special plan has been prepared for the community of Clarksburg. The plan outlines areas for new residential growth, although the community has no community water or sewage disposal systems. No significant intensification of commercial and residential land use is proposed. The plan includes an urban limit line.

1.5.3 Clarksburg Agricultural District

In 2008, a new 40,000-acre agricultural district was adopted for Clarksburg, which supported wine grape growing, agricultural tourism, river- and Delta-related tourism, a historic mill site with boutique wineries, and creation of one wine appellation to include Clarksburg and Merritt Island Appellations. While this area is only 9 percent of the county's active farmland, it produces

[29] Please refer to Chapter 10 for maps the Clarksburg community.

almost 22 percent of the total value of the county's top five crops. The county is considering an array of possible tools that could be applied within the district including new regulatory standards, marketing assistance, lowering fees, allowing additional on-site housing, and designating economic focus points. The overlay district supports agricultural business development and expansion, including processing, commercial sales, and agricultural tourism. The county is evaluating agricultural commercial and agricultural industrial sites of about 100 acres in the Clarksburg area.

2 Delta Protection Commission Land Use and Resource Management Plan

In the 1980s, the State Lands Commission prepared a study of the Delta and its challenges. Subsequently the state senate created a Delta subcommittee to survey stakeholders and issue a report. Sen. Patrick Johnston worked with several other legislators during a two-year legislation-drafting process that culminated in passage of the Delta Protection Act of 1992. The act established the Delta Protection Commission (DPC), a State entity to plan for and guide the conservation and enhancement of the natural resources of the Delta, while sustaining agriculture and meeting increased recreational demand. The act defines a Primary Zone, which comprises the principal jurisdiction of the DPC, the largely agricultural, water, and open space areas in the center of the Legal Delta. The Secondary Zone is the area outside the Primary Zone and within the "Legal Delta (Water Code Section 12220)"; the Secondary Zone is not within the planning area of the DPC.

The Delta Protection Act requires the DPC to prepare, adopt, review, and maintain a comprehensive long-term resource management plan for land uses within the Primary Zone. The plan describes the needs and goals for the Delta and presents a statement of the policies, standards, and elements of the plan. Within 180 days of the adoption of the plan (or any amendments) by the commission, all local governments are required to submit proposed amendments to their general plans to the DPC. The amendments are required to ensure that local government general plans are consistent with the DPC's plan. The plan applies to land uses, not to water supply or water quality, and generally addresses local government issues and actions, not those of State or federal agencies. After adoption of the plan, local government actions could be appealed to the DPC for review of consistency with the land use plan. The DPC has no authority over State or federal agency projects or programs.

The Primary Zone includes approximately 500,000 acres of waterways, levees, and farmed lands extending over portions of five counties: Solano, Yolo, Sacramento, San Joaquin, and Contra Costa. The peat soil in the central Delta and the mineral soils in the higher elevations support a strong agricultural economy. The Delta lands currently have access to the 1,000 miles of rivers and sloughs throughout the region for irrigation water. These waterways provide habitats for many aquatic species and the uplands provide year-round and seasonal habitats and are popular for recreation. The goals of the plan are to "protect, maintain, and where possible, enhance and restore the overall quality of the Delta environment, including but not limited to agriculture, wildlife habitats, and recreational activities; assure orderly, balanced conservation and development of Delta land resources and improve flood protection by structural and nonstructural means to ensure an increased level of public health and safety."

The plan was drafted, reviewed, and adopted by the DPC on February 23, 1995. The policies of the Plan were adopted as regulations in December 2000. To ensure that the plan remained current, the DPC established a planning advisory committee that began meeting in September 2008. The committee, which represented a broad spectrum of Delta interests, met over several months and prepared draft revisions to the plan in December 2008. The revisions were presented at public workshops throughout the Delta and to the DPC in March 2009. After holding multiple public hearings, the DPC adopted revisions to the plan on February 26, 2010.

The plan consists of three sections: Part I, the Introduction; Part II, Elements; and Part III, Program Implementation. Each element includes an introductory discussion, which provides the framework from which the goals and policies are derived. Policies are the directions for action the local governments must embrace and support through local general plans. The elements address land use, agriculture, natural resources, recreation, and access (including marine patrol, boater education, and safety programs), water, levees, and utilities and infrastructure. Legislation passed in 2009 modified the membership of the DPC and added new tasks including preparation of a Delta Economic Sustainability Plan for submittal to the Delta Stewardship Council.

3 State of California Planning for the Delta

Since 1991 the governor's office has directed State agencies to work together and with federal agencies to identify problems and possible solutions to Delta issues such as ensuring water supplies for export to the Central Valley, Southern California, and the Bay Area. Also since 1991, Cabinet secretaries were convened as the Governor's Water Council, Club Fed was created to provide coordination on Delta water issues, and CALFED was created by the Bay-Delta Accord, all resulting in the Record of Decision, adopted in 2000, outlining a plan of action for the Delta and its watershed. A new agency, the California Bay Delta Authority, was created by the California state legislature to implement the Record of Decision, reorganize, and then move to existing State agencies, but for multiple reasons, including lack of financial support from the federal government, this process was not brought to fruition. Governor Arnold Schwarzenegger then authorized a new planning process in 2006 under the Delta Vision Blue Ribbon Task Force.

3.1 Delta Vision

In 2006, Governor Schwarzenegger established a two-year planning process for the Delta through Executive Order S-17-06. A Blue Ribbon Task force of seven appointed citizens supervised preparation of a Delta Vision for adoption and submittal to the Delta Vision Committee. The Delta Vision Committee—five cabinet secretaries for resources, environmental protection, business, transportation and housing, public utilities commission and food and agriculture—submitted a report based on the Delta Vision to the governor at the end of 2008. Also participating in the process were a 43-member Stakeholder Coordination Group, work groups, and state agency staffs. Phil Isenberg, Chair of the Blue Ribbon Task Force, was subsequently appointed Chair of the Delta Stewardship Council.

The Delta Vision, completed in October 2008, includes 12 visions recommendations based on seven goals. Within each goal, the Delta Vision includes strategies and recommended actions to implement those strategies. Many of the actions were incorporated into the suite of legislation passed by the California legislature in 2009. The Delta Vision goals include:

- Goal 1: Legally acknowledge the coequal goals of restoring the Delta ecosystem and creating a more reliable water supply for California
- Goal 2: Recognize and enhance the unique cultural, recreational, and agricultural values of the California Delta as an evolving place, an action critical to achieving the coequal goals
- Goal 3: Restore the Delta ecosystem as the heart of a healthy estuary
- Goal 4: Promote statewide water conservation, efficiency, and sustainable use

- Goal 5: Build facilities to improve the existing water conveyance system and expand statewide storage, and operate both to achieve the coequal goals
- Goal 6: Reduce risks to people, property, and state interests in the Delta by effective emergency preparedness, appropriate land uses, and strategic levee investments
- Goal 7 Establish a new governance structure with the authority, responsibility, accountability, science support, and secure funding to achieve these goals

Within Goal 2, the Delta Vision more specifically recommended the following actions.

- Application for federal designation of the Delta as a National Heritage Area and expansion of the State Recreation Area network in the Delta
- Establishment of market incentives and infrastructure to protect, refocus, and enhance the economic and public values of the Delta agriculture
- Develop a regional economic plan to support increased investment in agriculture, recreation, tourism, and other resilient land uses
- Establishment of a Delta Investment Fund to provide funds for regional economic development and adaption
- Adoption of land use policies that enhance the Delta's unique values and that are compatible with public safety, levee, and infrastructure strategies in Goal 6

These specific strategies in Goal 2 are considered in more detail in subsequent chapters.

3.2 Sacramento-San Joaquin Delta Conservancy

The 2009 suite of legislation created the Sacramento-San Joaquin Delta Conservancy to act as a primary State agency to implement ecosystem restoration in the Legal Delta and to support environmental protection and the economic well-being of Delta residents. The Delta Conservancy can also fund projects in the Suisun Marsh, west of the Legal Delta. The 12 tasks assigned to the Delta Conservancy are listed below.

1. Protect and enhance habitat and habitat restoration.
2. Protect and preserve Delta agriculture and working landscapes.
3. Provide increased opportunities for tourism and recreation.
4. Promote Delta Legacy Communities and economic vitality in the Delta in coordination with the Delta Protection Commission.
5. Increase the resilience of the Delta to the effects of natural disasters such as floods and earthquakes, in coordination with the Delta Protection Commission.
6. Protect and improve water quality.
7. Assist the Delta regional economy through the operation of the Delta Conservancy's program.
8. Identify priority projects and initiatives for which funding is needed.
9. Protect, conserve, and restore the region's physical, agricultural, cultural, historical, and living resources.
10. Assist local entities in the implementation of their habitat conservation plans and natural community conservation plans.
11. Facilitate protection and safe-harbor agreements under the federal Endangered Species Act of 1973 and the California Endangered Species Act for adjacent land owners and local public agencies.
12. Promote environmental education.

The Conservancy is governed by a board consisting of 11 voting members and two non-voting members (State Senate member and State Assembly member), and 10 liaison advisors representing local, State, and federal environmental and economic interests in the Delta.

Members are appointed by each of the five Delta county boards of supervisors, by the governor, and by the California Senate and Assembly. The liaison advisors are appointed by their respective agencies or organizations. The Delta Conservancy adopted an interim strategic plan in January 2011 and will adopt a final strategic plan by January 2013.

3.3 Delta Reform Act of 2009

The Delta Reform Act of 2009 (SB X7 1, Steinberg) includes multiple actions and programs. The act establishes the seven-member Delta Stewardship Council and directs completion of its Delta plan by January 1, 2012.

In addition, the Delta Stewardship Council is directed to appoint an independent science board, engage the federal government, , and start Delta ecosystem restoration projects. The act also requires improved reporting of water diversions and uses, imposes penalties for those violating water rights laws, improves monitoring and reporting to the State Water Board, authorizes the State Water Board to initiate statutory adjudications, requires appointment of a Delta Watermaster, and expands water rights fee authority.

The act sets a statewide target of 20 percent reduction in urban per capita water use by 2020 and requires most agricultural water supplies to prepare and adopt water management plans by 2012. The act creates a new Sacramento-San Joaquin Delta Conservancy for the Delta and the Suisun Marsh. In addition, the act reconstituted the DPC and required preparation of a regional economic sustainability plan.

The act moves the state toward a groundwater basin monitoring program by 2012. The Act requires the State Water Board to develop new flow criteria for the Delta ecosystem to protect public trust resources, and to develop a schedule to complete instream flow studies for the Delta watershed by 2012 and for rivers and streams outside the Sacramento River watershed by 2018.

3.4 Delta Stewardship Council Delta Plan

The primary responsibility of the Delta Stewardship Council is to develop, adopt, and implement by January 1, 2012, a legally enforceable, comprehensive, long-term management plan for the Sacramento-San Joaquin Delta and the Suisun Marsh—the Delta Plan—that will achieve the coequal goals of “providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem” and does this “in a manner that protects and enhances the unique cultural, recreational, natural resource, and agricultural values of the Delta as an evolving place.”

The Delta Stewardship Council is to achieve the following objectives.

a) Manage the Delta’s water and environmental resources and the water resources of the state over the long term.
b) Protect and enhance the unique cultural, recreational, and agricultural values of the Delta as an evolving place.
c) Restore the Delta ecosystem, including fisheries and wildlife, as the heart of a healthy estuary and wetland ecosystem.
d) Promote statewide water conservation, water-use efficiency, and sustainable water use.
e) Improve water quality to protect human health and the environment consistent with achieving water-quality objectives in the Delta.
f) Improve the water conveyance system and expand statewide water storage.

g) Reduce risks to people, property, and State interests in the Delta by effective emergency preparedness, appropriate land uses, and investments in flood protection.
h) Establish a new governance structure with the authority, responsibility, accountability, scientific support, and adequate and secure funding to achieve these objectives.

The 2012 Delta Plan is to be a long-term management plan and will be updated every five years. Some elements of the Delta Plan will have regulatory effects. Any plan, project, or program that meets certain criteria will be subject to regulations included in the Delta Plan, and the project proponents must certify consistency with the Delta Plan.

The Delta Plan will include a series of non-regulatory recommendations to be considered by other agencies, the legislature, or the governor.

The Delta Plan will present a view of the diversity of the water supply system and its components, including demands for water and how water is currently used, together with the need for an improved Delta ecosystem. The planning time frame is year 2100, using monitoring and adjusting of decisions, “adaptive management,” informed by the best available science. Additional components of the Delta Plan include emergency response plans for each of the Delta counties and for the State and federal water projects, the DPC’s Economic Sustainability Plan for the Delta, and the Department of Parks and Recreation’s Delta Recreation Plan (released May 2011). A proposed financing plan will also be included in the Delta Plan; legislative action will be required to implement a financing plan.

The Delta Plan will also include regulatory policies and recommendations for actions that will contribute to enhanced water supply reliability, reduce reliance on water exports from the Delta in meeting California’s future water supply needs, help restore the Delta ecosystem, reduce flood risk, and improve the collection of water use data and other information that will guide the next Delta Plan update. For the current draft of the Delta Plan, see http://deltacouncil.ca.gov/

4 Bay Delta Conservation Plan

The Bay Delta Conservation Plan (BDCP) is being prepared through a collaboration of state, federal, and local water agencies, state and federal fish agencies, environmental organizations, and other interested parties with the goal of protecting and restoring the ecological health of the Delta and providing a more reliable water supply. The BDCP is being developed in compliance with the Federal Endangered Species Act (ESA) and the California Natural Communities Conservation Planning Act (NCCPA) and will, if completed, provide the basis for the issuance of endangered species permits for the operation of the state and federal water projects for the next 50 years.

This multi-stakeholder Habitat Conservation Plan/Natural Communities Conservation Plan process has been underway since 2006. The BDCP and a companion program known as the Delta Habitat Conservation and Conveyance Plan (DHCCP), which involves design of improved conveyance facilities and preparation of environmental documents to cover construction of the preferred alternative, is financed entirely by the State and Federal Water Contractors, the agencies that receive water deliveries from the SWP and the CVP. However, the BDCP and DHCCP processes are managed by the California Resources Agency and the Department of Water Resources. Delta stakeholders have been excluded from much of the BDCP process, and continue to be excluded from the BDCP management committee despite efforts by the Brown administration in 2011 to be more inclusive through the creation of working groups.

The goal was to have a completed BDCP and a record of decision by the end of 2010 but that deadline was not met. Instead, a working draft was issued in November 2010 to show progress and illustrate the current state of the plan.

The over 1,100-page November 2010 draft addresses impacts to 11 species of fish, 6 species of mammals, 12 species of birds, 2 species of reptiles, 3 species of amphibians, 8 species of invertebrates, and 21 species of plants.. For the aquatic species, the draft addresses multiple stressors including: habitat loss and modification, food limitations, altered flows, passage impediments and barriers, water quality, entrainment, predators, illegal harvest, stranding, and dredging. A principal conclusion in the draft is that addressing the identified stressors will require creation of thousands of acres of aquatic habitat and construction of multiple new intakes in the North Delta and movement of export water around the Delta to the conveyance canals.[30]

The November 2010 Draft was reviewed by a panel appointed by the National Research Council at the request of Senator Feinstein and the Secretary for the Interior. The panel released its findings in May 2011.[31] This review criticized the BDCP for rushing to a preferred alternative – an isolated conveyance around the Delta – before evaluating different approaches to determine how well they achieve preferred outcomes; for failing to incorporate the best available scientific information about the Delta ecosystem; for ignoring the freshwater flow needs of the Delta ecosystem and San Francisco Bay and omitting any consideration of water conservation as part of the planfor lacking a clear overarching strategy or clear goals and objectives.

However, by the time the NRC review was released, the management of the BDCP and DHCCP processes had been taken over by the new Brown administration and the processes had been reorganized to some extent. The new administration promised more transparency in decision making and is working to address the criticisms made by the NRC panel. Their current goal is to issue a public draft of the EIR/EIS by June 2012 and to obtain a record of decision by February 2013. Five alternatives for improved conveyance, which actually expand to ten when alternatives within alternatives are considered,[32] are currently being examined in the EIR/EIS process. However, only the “preferred alternative” of the November 2010 draft, which consists of five new 3,000 cfs intakes on the Sacramento River in the North Delta and twin tunnels under the Delta, is being subjected to a complete effects analysis.[33]

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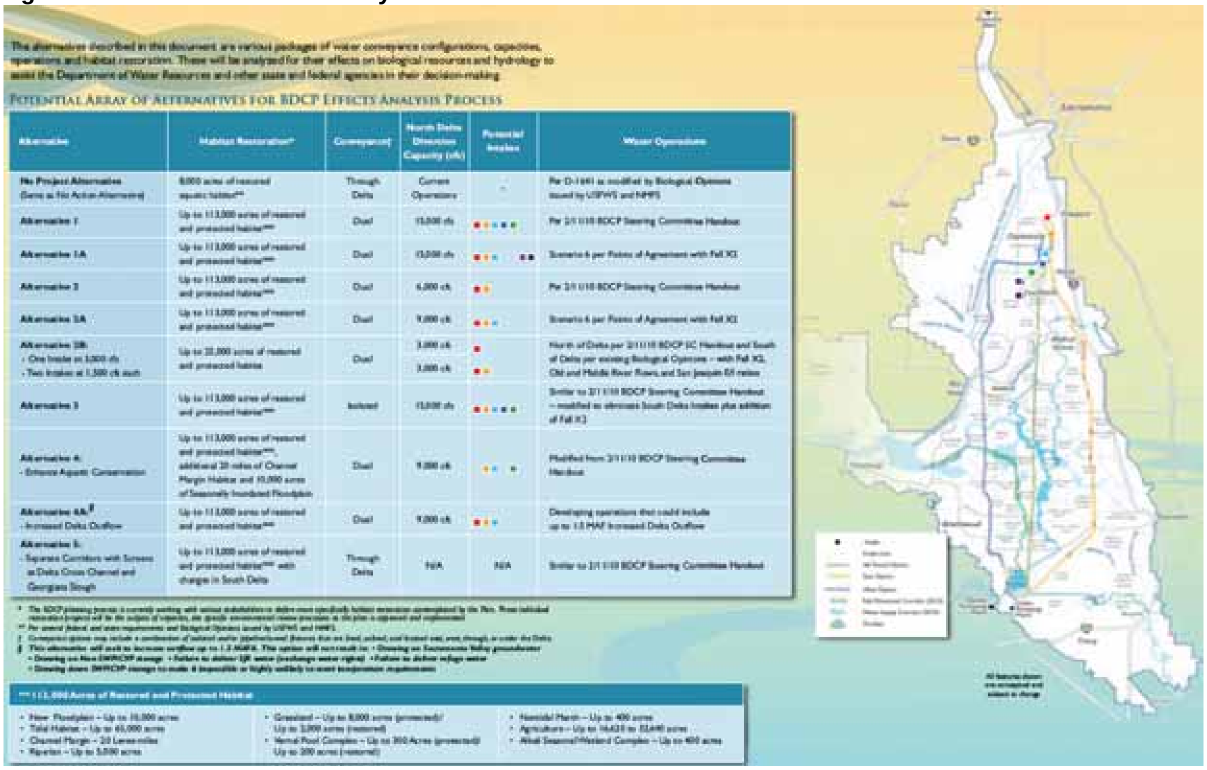
[30] The November 2010 draft is available on the BDCP web site: http://baydeltaconservationplan.com/BDCPPlanningProcess/DocumentsAndDrafts.aspx

[31] http://www.nap.edu/catalog.php?record_id=13148

[32] http://baydeltaconservationplan.com/News/News.aspx: Conveyance Presentation_September 2011_ FINAL.pdf: 08-11-BDCP-EIR-EISFactSheet_v5.pdf

[33] Page A-60 in *Appendix A: Conceptual Foundation and Analytical Framework for Effects Analysis, Administrative Draft Bay Delta Conservation Plan*. September 2011. Accessed at: http://www.deltacouncil.ca.gov/sites/default/files/documents/files/App_A_Conceptual_Foundation_Analytical%20Framework_092911_v_DSP.pdf

Figure 9 BDCP Alternative Conveyance Measures[34]



The selection of the alternatives that are under study and the possibility of completing satisfactory studies on this new schedule has been questioned by an influential group environmental NGOs[35] amongst others and the BDCP remains an evolving work in progress at this time.

5 Conclusions

Water is extremely valuable to all Californians. Adequate water supplies are critically important to agriculture and industry, and for urban health and resource protection. Northern California is a significant source of the state's water projects' exports , and this water moves through the Sacramento-San Joaquin Delta. USGS notes that of the 22 million acre feet of annual discharge generated in the Sacramento River Basin, 11.6 million acre feet are used in basin and six million acre feet are exported to the water projects. Many programs and plans have been developed over the last 100 years to transport this water to agricultural and urban users in other parts of the state. All these programs and plans included elements to protect the riparian water rights of upstream rights holders and Delta water rights holders. These water rights are key to the longevity and vitality of Delta agriculture and the Delta region as a whole.

In recent decades, much effort has been made to promote the health of the Delta by a variety of agencies, commissions, and other governmental bodies. Today, local and State agencies have long-standing policies and programs to protect and enhance the natural resources, recreational

[34] For a better resolution image see http://forecast.pacific.edu/desp-figs.html. Source: BDCP Alternatives Factsheet, August 2011 Update. Accessed at: http://bdcpweb.com/Libraries/2011_Working_Groups/08-11-BDCP-EIR-EISFACTSHEET_V5.sflb.ashx

[35] Letter of August 23 from American Rivers et al. to Jerry Meral and David Nawi; letter of September 30 from American Rivers et al. to John Laird and David Hayes, see http://aquafornia.com/archives/55439

values, and wildlife habitats in the Delta Primary Zone—the agricultural, riparian, and water-based area in the core of the Delta. Other State and federal programs are in place to protect Delta resources and support local government plans that have been in place since the early 1980s. Stewardship of Delta water resources continues to evolve as issues such as sustainability, water supply and quality, habitat, and access become more complex.

Local planning efforts continue to evolve to address the needs of each jurisdiction as economic, political and environmental forces affect local land uses and societal changes. The State programs currently under development should evaluate the needs and impacts on each county as well as the Delta as a region in order to direct appropriate resources to address the economic needs and impacts identified in the Delta.

Chapter 5: Flood, Earthquake and Sea-Level Rise Risk Management

1 Overview and Key Findings

The present-day Delta is defined geographically and hydraulically by levees, creating a landscape that differs from that of the historic, natural Delta. In place since the early 20th century, the current-day levee system provides flood control, channels water for urban and agricultural uses, and creates an environment unique in California. According to the Delta Reform Act of 2009, it is the policy of the State to "protect, maintain, and, where possible, enhance and restore the overall quality of the Delta environment, including, but not limited to, agriculture, wildlife habitat, and recreational activities" and also to "improve flood protection by structural and non-structural means to ensure and increased level of public health and safety."[36] These goals require a robust levee system.

For the purposes of this plan, an up-to-date map of Delta levees was created. This map serves as the basis for an updated tabulation of levee lengths, which shows that in the Legal Delta, there are just under 1,000 miles of permanently maintained levees, of which 380 miles are project levees constructed or improved by the U.S. Army Corps of Engineers (USACE), and an additional 63 miles are urban non-project levees, as defined by recent state legislation. Within the overall total, there are 613 miles of lowland levees, defined as those levees that protect lands in the Delta that are below sea level. The lowland levees are the levees that are most critical to the preservation of the Delta and to achieving the coequal goals of water supply reliability and ecosystem restoration. Of these lowland levees, 143 miles are project levees located largely along the Sacramento River. The remaining 470 miles of non-project lowland levees need to be maintained and enhanced primarily by the State and the local reclamation districts.

Of the 470 miles of non-project, lowland levees, less than 100 miles fall below FEMA's Hazard Mitigation Plan (HMP) "standard" and another 100 miles or so are already at or about the Corps of Engineers Delta-specific PL 84-99 standard. While the first priority should be to bring all Delta levees up to at least the HMP standard, it has been the goal of the state and federal governments, working through the Department of Water Resources (DWR), the U.S. Army Corps of Engineers (USACE), and the local reclamation districts, to meet the higher Delta-specific PL 84-99 standard since 1982 when DWR and USACE produced a joint report on the Delta levees which recommended the basis for this standard. Funds currently available from the Federal government, voter-approved state bond measures, and local cost shares should bring all Delta levees close to achieving this goal. When funds currently in the immediate pipeline have been expended, more than $698 million will have been invested in improvements to the Delta levees since 1973. These improvements have created significantly improved Delta levees through modern engineering and construction, making obsolete the historic data that is still sometimes used for planning or predicting rates of levee failure.

Three approaches can help all jurisdictions and planners further reduce the risks resulting from the failure of the Delta levees. These approaches are: (1) build even more robust levees, (2) improve regular maintenance and inspections, flood-fighting at times of high water surfaces and emergency response following earthquakes, and (3) improve preparedness for dealing with failures after they occur. With regard to the first approach, the big question with respect to the lowland Delta levees is not whether they should be improved to the Delta-specific PL 84-99 standard—that is already happening—but whether they should be improved to a higher

[36] Delta Reform Act, 2009, W.C. 29702 (b), (d)

standard in order to address hazards posed by floods, earthquakes, and sea-level rise. These improvements would also allow for planting vegetation on the water side of the levees—an essential component Delta ecosystem repair. These further-improved levees would have wider crowns to provide for two-way traffic and could easily be further widened at selected locations to allow the construction of new tourist and recreational facilities out of the statutory floodplain. Improvement of most lowland levees and selected additional levees to this higher standard is estimated to have base engineering and construction costs of $1-2 billion. Enhancements for ecosystem restoration and other purposes and program management could increase the cost to as much as $4 billion. In addition, it is suggested that $50 million per year should be provided for continuing maintenance and inspections and emergency preparedness, response and recovery and that a single Delta region-centric agency should assume the responsibility for allocating this funding. Three broad sources of funding and economic justifications for the investments are discussed later in this chapter

These estimated costs are not dissimilar to that of the "Fortress Delta" strategy described in the 2007 "Envisioning Futures" report by the PPIC as one of the alternatives for increasing water supply. Provision of water supply reliability through improvement of the levee system now appears to be significantly cheaper than the proposed isolated conveyance. Regardless, a further-improved levee system will make a significant contribution to the achievement of the coequal goals of water supply reliability and ecosystem restoration that were stated in the Delta Reform Act rather than impeding it.

2 Background

The history of the Delta levees is relatively well-known (Thompson, 1957;[37] The Delta Atlas, 1995;[38] Mount and Twiss, 2005;[39] DRMS, 2009'[40] Delta Stewardship Council Flood Risk White Paper, 2010;[41] Zuckerman, 2011[42]) and is not repeated in its entirety here. Some of the levees in the Delta are flood-control project levees, built by the federal government and turned over to the State for maintenance, but most of the Delta levees were built or re-constructed and are maintained by local reclamation districts. There are only a few levees that are not maintained by local reclamation districts and are thus privately owned and maintained. The State has also passed responsibility for maintenance of most of the flood-control project levees to the local reclamation districts although it directly maintains some of the levees on the Sacramento River. Regardless of the State now relying on local reclamation districts for the execution of much of the work on Delta levees, much of this work is supported with state funds in recognition of the State's long-term interests and obligations. These obligations flow in part from the State's acceptance of the grant of federal lands in accordance with the Swamp and Overflowed Lands Acts. For example, in Kimball v. Reclamation Fund Commissioners,[43] the Supreme Court of California held that he, Kimball "must be held to have known, when he took the title, that the

[37] Thompson, J., *Settlement Geography of the Sacramento-San Joaquin Delta*, *California,* Ph.D. dissertation, Stanford University, 1957.
[38] http://baydeltaoffice.water.ca.gov/DeltaAtlas/index.cfm
[39] Mount, J.F. and R. Twiss, *Subsidence, sea level rise, seismicity in the Sacramento-San Joaquin Delta*, San Francisco Estuary and Watershed Science, v. 3, article 5, 2005.
[40] California Department of Water Resources, Delta Risk Management Strategy Final Phase 1 Report, 2009, http://www.water.ca.gov/floodmgmt/dsmo/sab/drmsp/phase1_information.cfm
[41] Delta Stewardship Council, Flood Risk White Paper, 2010, http://deltacouncil.ca.gov/delta-plan.
[42] Zuckerman, T., Comments on the Third Staff Draft of the Delta Plan, Delta Stewardship Council, 2011, http://deltacouncil.ca.gov/public-comments/read/195
[43] 45 Cal. 344, 1873

State, by accepting the grant, had assumed an obligation to reclaim the land, and that it had already inaugurated a system for that purpose. He was bound in law to take notice of the public statues above mentioned, and must be deemed to have accepted the title in subordination to the paramount right and duty of the State to cause the land to be reclaimed. He cannot now, therefore, be permitted to set up his own wishes, nor his private interests, in opposition to the performance, by the State, of the obligation which it assumed to the Federal Government."

A good summary of the history and current status of the Delta levees is also provided in a technical memorandum prepared for the Department of Water Resources (DWR) by outside consultants,[44] and referenced subsequently as the DWR Technical Memorandum (2011). The Technical Memorandum finds that the existing Delta levees comprise a system and that it is misleading to evaluate the value of individual levees or islands without considering the benefits that the overall system of levees provides, and that the Delta levees now protect much more than agriculture. In this respect the draft Technical Memorandum is simply repeating points made in the CALFED Levee System Integrity Program Plan,[45] which said:

> *The benefits of an improved Delta Levee system include greater protection to the Delta agricultural resources, municipalities, infrastructure, wildlife habitat, and water quality as well as navigation and conveyance benefits. The wide range of beneficiaries of the Delta Levee System Integrity program include Delta local agencies; landowners; farmers; boaters; wildlife; and operators of railroads, state highway, utilities, and water distribution facilities. Delta Water users and exporters also benefit from increased protection to water quality. Federal interests benefit from improvements to conveyance, navigation, commerce, and the environment, and from reduced flood damage.*

In the language of the draft Technical Memorandum:

> *While some reports propose leaving islands flooded or state that it is too expensive to continue a state grants program for levee maintenance, the fact remains that a large portion of the state economy is dependent on export water, which in turn is dependent upon the Delta levees for preservation of water quality and for conveyance. If a decision were made today to address this single issue, it would require more than a decade before an alternative conveyance could be in place. During all of that time the purity and availability of export flow would remain dependent on the Delta levee system. Delta levees provide protection for a wide variety of benefits. If levees fail and several islands were flooded, adverse consequences would be expected far beyond direct loss due to flooding on islands and tracts. Most island surfaces are so far below sea level that the resulting deep water would contrast markedly with the 1850 "natural" Delta. The water body created by a levee failure may be good habitat for some species and poor habitat for others. Tidal exchange from Suisun and San Francisco Bays would be increased and Delta salinity would be likely to rise at least during dry seasons and dry years. Water supply conveyance to remaining Delta islands, to Contra Costa County, and to the State Water Project and the Central Valley Project may be disrupted by salinity intrusion some*

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[44] California Department of Water Resources, Staff DRAFT, "Background/Reference Memoranda, Delta Region Integrated Flood Management Key Considerations and Statewide Implications," July 15, 2011. This document was released for limited public review on July 15, 2011. Both the technical memorandum and the related "Framework for Department of Water Resources Investments in Delta Integrated Flood Management" are in draft form and are subject to change, but the basic findings of the technical memorandum are unlikely to change and several of its findings are mentioned herein.
[45] http://calwater.ca.gov/content/Documents/library/305-1.pdf

of the time. Infrastructure systems, including Delta highways and pipelines, might be blocked. Delta towns and their economic activity might be jeopardized. Adjacent islands would become much more vulnerable due to seepage or increased wave action.

The principal Delta levees that are currently being maintained are shown in Figure 10 and are listed in Table 1. Previous listing of Delta levees have been provided in the Table 6 of the Delta Atlas and in Table 3 of The CALFED Levee System Integrity Program Plan, but these listings and any accompanying maps are not available in electronic form and the accuracy of some of the mileages involved is questioned by reclamation district engineers. Therefore, in order to provide a table that was consistent with a current map, an updated listing was prepared as part of this study. DWR does not maintain a centralized GIS system, but with the help of DWR staff three different GIS data sets, all based on the 2007 LiDAR surveys conducted for DWR, were obtained from two different offices of URS Corporation. The most complete of these was labeled “Division of Flood Management” and this was used as starting point in developing an updated map. However, because many embankments which do not represent levees that are currently being maintained, are height-limited levees, or are dry levees that are not critical to flood protection, were mapped as levees, these were deleted. Canal embankments were not mapped as levees in this data set but the embankments on either side of the Delta Cross Channel and the northern side of the Contra Costa Canal on Hotchkiss Tract have been counted as flood-control levees in our compilation. In a GIS system all lines are modeled as segments whose lengths can be calculated automatically so that the total lengths around each island or tract can readily be obtained and these are the lengths that are shown in Table 1. Thus the map in Figure 10 and the lengths listed in Table 1 are consistent with each other. To the extent possible, the lengths have been cross-checked with ground survey data provided by reclamation district engineers.[46]

By way of comparison with Figure 10, a reconstruction of the historic Delta based on Atwater (1982)[47] is shown in Figure 11. Figure 11 shows that the historic Delta contained no large expanses of open water, but instead was comprised of a dendritic system of channels and sloughs that traversed generally marshy terrain. Natural levees, created along the edges of major waterways, were overtopped only in high water events and supported riparian and even upland vegetation. When the modern Delta was created by diking and dredging in the late 19th century and very early 20th centuries, some of the man-made levees were constructed over the natural levees, but many were not. Those waterways that were created by dredging do not have bordering levees that were founded on natural levees. In many other cases the modern levees were not sited directly over the natural levees. Sketches developed by KSN Inc. illustrating the history of development of both the dredger cuts and other modern levees are shown as Figures 12 and 13.

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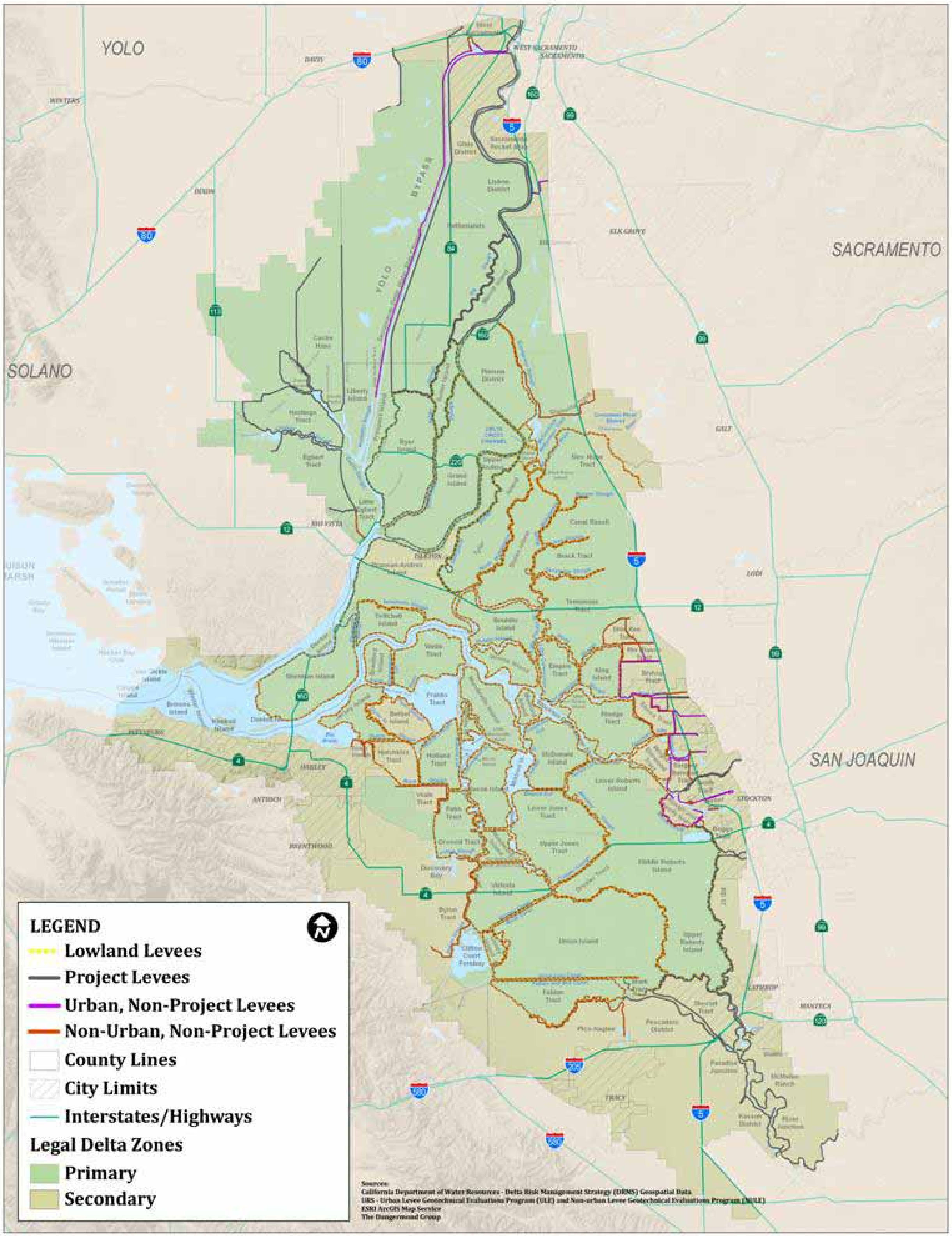
[46] Copies of Figure 10 and some of the subsequent figures in this chapter are not particularly legible when reproduced at normal report size but high resolution copies may be obtained by following the instructions on the DPC web site. These figures have been designed for use as wall posters with dimensions of about 3 by 4 feet.

[47] Atwater, B., Geologic Maps of the Sacramento-San Joaquin Delta, California, USGS Miscellaneous Field Studies Map MF-1401, 1982.

Figure 10 Delta Levees[48]



[48] For high resolution image see http://forecast.pacific.edu/desp-figs.html

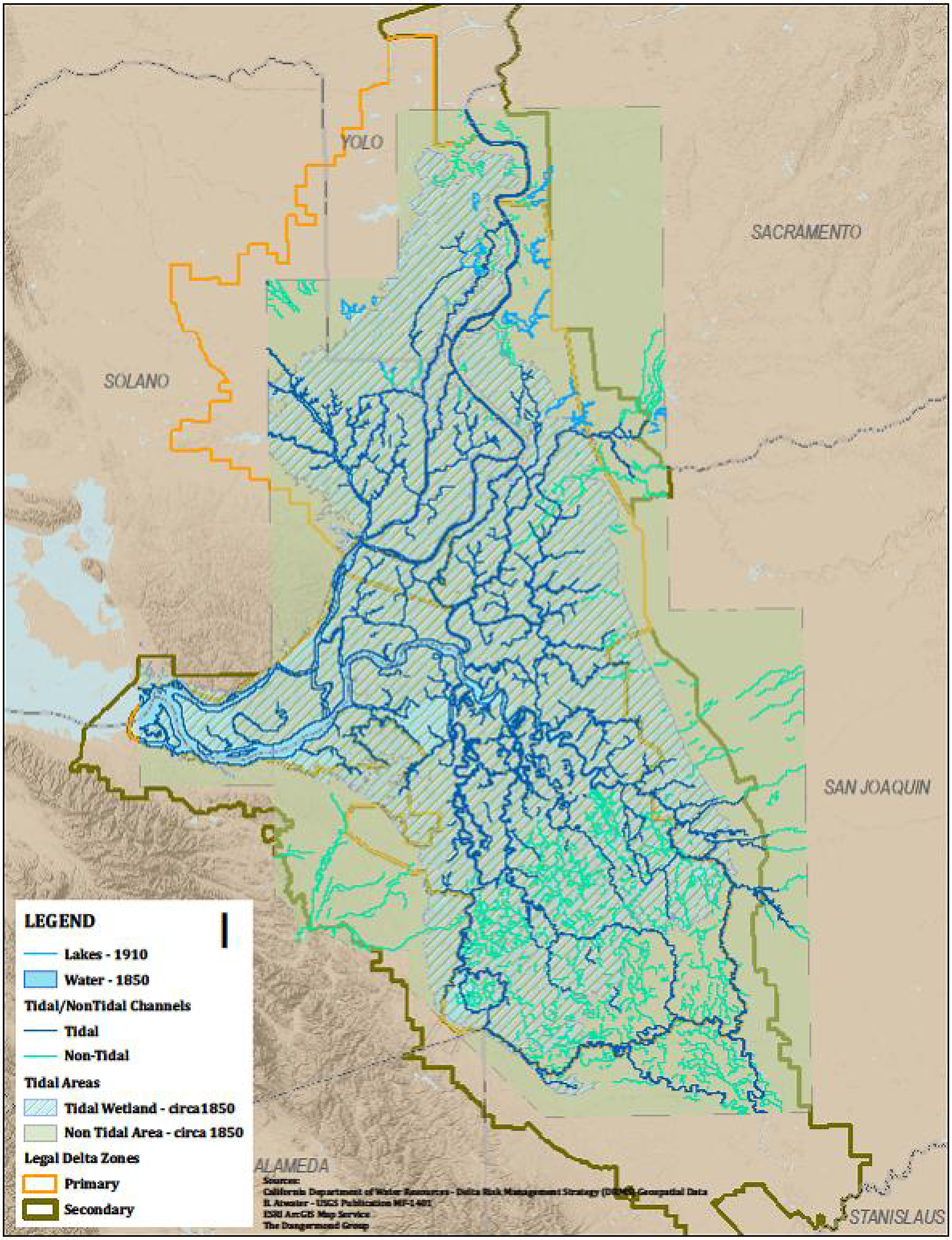
Table 1 Delta Levees (Part 1 of 2)

(A)	(B)	(C)	(D)	(E)	(F)	(G)	(I)
List Number	District Number	Reclamation District	Miles of Levee				
			Project	Urban NP	NP-NU	Total	Lowland
1	556	Andrus Island	11.2	0.0	0.0	11.2	Yes
2	2126	Atlas Tract	0.0	2.3	0	2.3	No
3	2028	Bacon Island	0.0	0.0	14.3	14.3	Yes
4		Bear Creek	3.3	0.0	0.0	3.3	No
5		Bethel Island	0.0	0.0	11.5	11.5	Yes
6	2042	Bishop Tract	0.0	6.5	1.6	8.1	No
7	404	Boggs Tract	4.0	0.6	0.6	5.2	No
8	756	Bouldin Island	0.0	0.0	18.0	18.0	Yes
9	2033	Brack Tract	0.0	0.0	10.0	10.0	Yes
10	2059	Bradford Island	0.0	0.0	7.4	7.4	Yes
11	317/407	Brannan-Andrus	17.5	0.0	10.1	27.6	Yes
12	800	Byron Tract	0.0	0.0	9.5	9.5	No
13	2098	Cache Haas	10.9	0.0	0.0	10.9	No
14	2086	Canal Ranch	0.0	0.0	7.5	7.5	Yes
15	2117	Coney Island	0.0	0.0	5.5	5.5	Yes
16	2111	Dead Horse Is.	0.0	0.0	2.6	2.6	Yes
17	2137	Dutch Slough	0.0	0.0	4.1	4.1	No
19	536	Egbert Tract	10.6	0.0	1.8	12.4	No
20	813	Ehrheart	1.8	0.0	3	4.8	No
21	2029	Empire Tract	0.0	0.0	10.5	10.5	Yes
22	773	Fabian Tract	0.0	0.0	18.8	18.8	Yes
23	2113	Fay Island	0.0	0.0	1.6	1.6	Yes
24	1002	Glanville Tract	0.0	0.0	7.1	7.1	No
25	765	Glide	1.7	0.0	0.0	1.7	No
26	3	Grand Island	28.7	0.0	0.0	28.7	Yes
27	2060	Hastings Tract	15.6	0.0	0.0	15.6	No
28	999	Netherlands	32.2	0	0	32.2	No
29	2025	Holland Tract	0.0	0.0	11.0	11.0	Yes
30	799	Hotchkiss Tract	0.0	0.0	8.8	8.8	Yes
31	830	Jersey Island	0.0	0.0	15.5	15.5	Yes
32	2038/2039	Jones Tract	0.0	0.0	18.4	18.4	Yes
33	2085	Kasson	6.3	0.0	0.0	6.3	No
34	2044	King Island	0.0	0.0	9.1	9.1	Yes
35	369	Libby McNeil	1.0	0.0	2.8	3.8	Yes
36	1608	Lincoln Village	0.0	3.3	0.6	3.9	No
37	307	Lisbon	6.6	0.0	0.0	6.6	No
38		Maintenance Area 9	12.6	1.5	0.0	14.1	No
39	2027	Mandeville Island	0.0	0.0	14.3	14.3	Yes
40	2030	McDonald Island	0.0	0.0	13.7	13.7	Yes
41	2075	McMullin	7.4	0.0	0.0	7.4	No
42	2041	Medford Island	0.0	0.0	5.9	5.9	Yes
43	150	Merritt Island	17.7	0	0	17.7	No
44	2107	Mossdale 2	4.3	0.0	0.0	4.3	No
45	17	Mossdale Tract	15.8	0.0	0.0	15.8	No
46	348	New Hope Tract	0.0	0.0	15.1	15.1	Yes
47	2064	Palm-Orwood Tract	0.0	0.0	14.4	14.4	Yes
48	2095	Paradise	4.9	0.0	0.0	4.9	No

Table 2 Delta Levees (Part 2 of 2)

(A)	(B)	(C)	(D)	(E)	(F)	(G)	(I)
List Number	District Number	Reclamation District	Miles of Levee				
			Project	Urban NP	NP-NU	Total	Lowland
49	2058	Pesadero Tract	6.6	0.0	0	6.6	No
50	2104	Peters	6.8	0.0	0.0	6.8	No
51	551	Pierson District	6.8	0.0	7.3	14.1	Yes
52	1007	Pico-Naglee Tract	0.0	0.0	9.5	9.5	No
53	2090	Quimby Island	0.0	0.0	7.0	7.0	Yes
54	755	Randall	1.8	0.0	0.0	1.8	No
55	744	Rec District	3.9	0.0	0.0	3.9	No
56	673	Rec District	0.2	0.0	0.0	0.2	No
57	2037	Rindge Tract	0.0	0.0	15.8	15.8	Yes
58	2114	Rio Blanco Tract	0.0	1.8	4.1	5.9	No
59	2064	River Junction	9.7	0.0	0.0	9.7	No
60	524/544/684	Roberts Island	16.4	0.0	34.1	50.5	Yes
61		Rough/Ready Island	0.0	5.5	0.0	5.5	No
62	501	Ryer Island	20.2	0.0	0.0	20.2	Yes
63	2074	Sargent Barnhart	2.1	2.9	2.5	7.5	No
64	341	Sherman Island	9.6	0.0	9.9	19.5	Yes
65	2115	Shima Tract	0.0	7.0	7.3	14.3	No
66		Shin Kee Tract	0.0	0.0	7.0	7	No
67	1614	Smith Tract	5.9	3.3	1.0	10.2	No
68	2089	Stark	2.8	0.0	0.8	3.6	Yes
69	38	Staten Island	0.0	0.0	25.4	25.4	Yes
70	2062	Stewart Tract	12.2	0.0	0.0	12.2	No
71	349	Sutter Island	12.4	0.0	0.0	12.4	Yes
72	548	Terminous Tract	0.0	0.0	16.1	16.1	Yes
73	1601	Twitchell Island	2.5	0.0	9.3	11.8	Yes
74	563	Tyler Island	12.1	0.0	10.3	22.4	Yes
75	1	Union Island	1.1	0.0	28.8	29.9	Yes
76	2065	Veale Tract	0.0	0.0	5.0	5	No
77	2023	Venice Island	0.0	0.0	12.4	12.4	Yes
78	2040	Victoria Island	0.0	0.0	15.1	15.1	Yes
79	554	Walnut Grove East	0.9	0.0	2.5	3.4	Yes
80	2094	Walthall	3.2	0.0	0.0	3.2	No
81	2026	Webb Tract	0.0	0.0	12.9	12.9	Yes
82	828	Weber	0.0	1.7	0.6	2.3	No
83	900	West Sacramento	15.0	26.6	1.6	43.2	No
84	2096	Wetherbee	0.2	0.0	0.0	0.2	No
85	2072	Woodward Island	0.0	0.0	8.9	8.9	Yes
86	2119	Wright-Elmwood Tract	0.0	0.0	7.1	7.1	Yes
87	2068	Yolano	8.8	0.0	0.0	8.8	No
88		Yolo Bypass Unit 4	4.2	0.0	0.0	4.2	No
	Lowland Total		143.2	0.0	470.5	613.7	
	Grand Total		379.5	63.0	537.4	979.9	

Figure 11 The Historic Delta[49]



[49] For high resolution image see http://forecast.pacific.edu/desp-figs.html

It is well known that many of the Delta islands have subsided since they were first diked so that most of the land surfaces within these islands are now below sea level. However, the rates of subsidence have decreased markedly in recent years. That issue is discussed in more detail in Appendix E. Reasonably current land surface elevations interpreted from DWR's 2007 LiDAR surveys are shown in Figure 14.[50] The mostly deeply subsided land is about 30 feet below sea level, but only a fraction of the Legal Delta is more than 15 feet below sea level, as shown by the dark blue coloring in Figure 14. The subsidence has been restricted to the areas of the western and central Delta that are underlain by peat. There are also extensive areas to the north and the south within the Legal Delta that have not been affected by subsidence.

Figure 12 Construction of Delta Levees

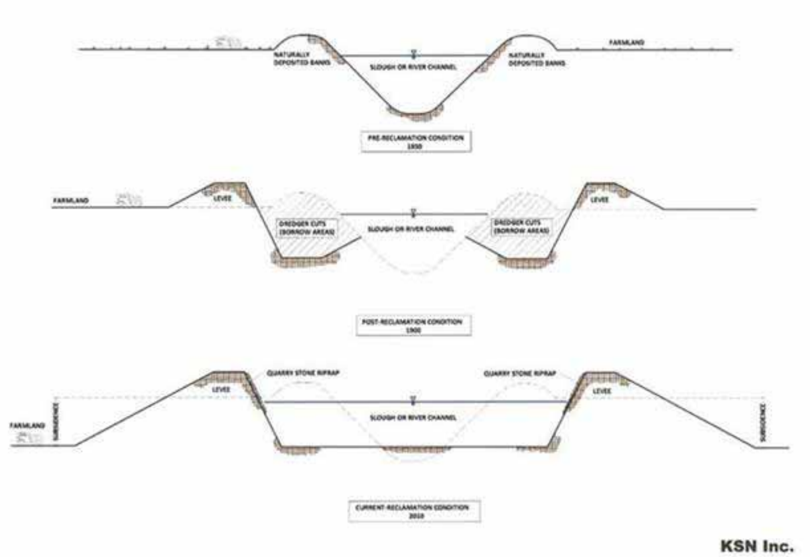
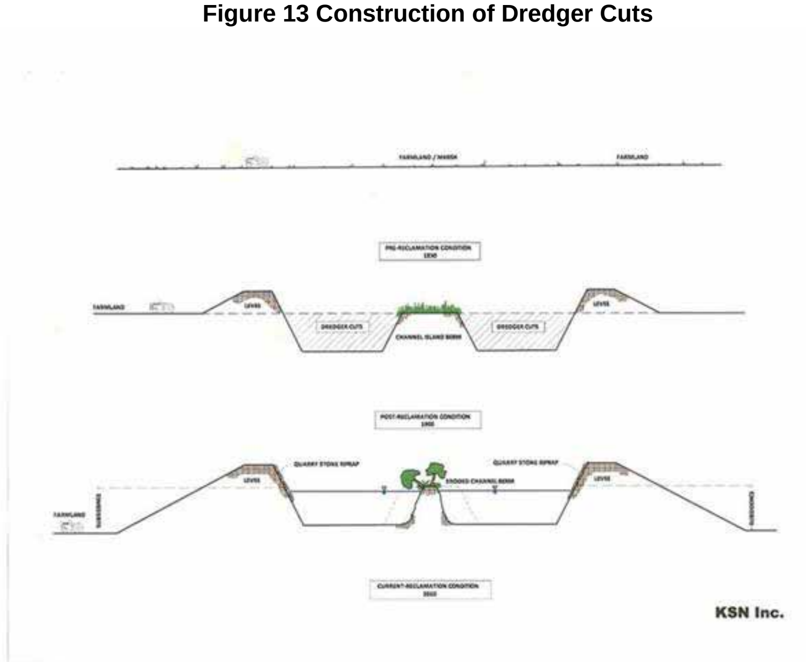
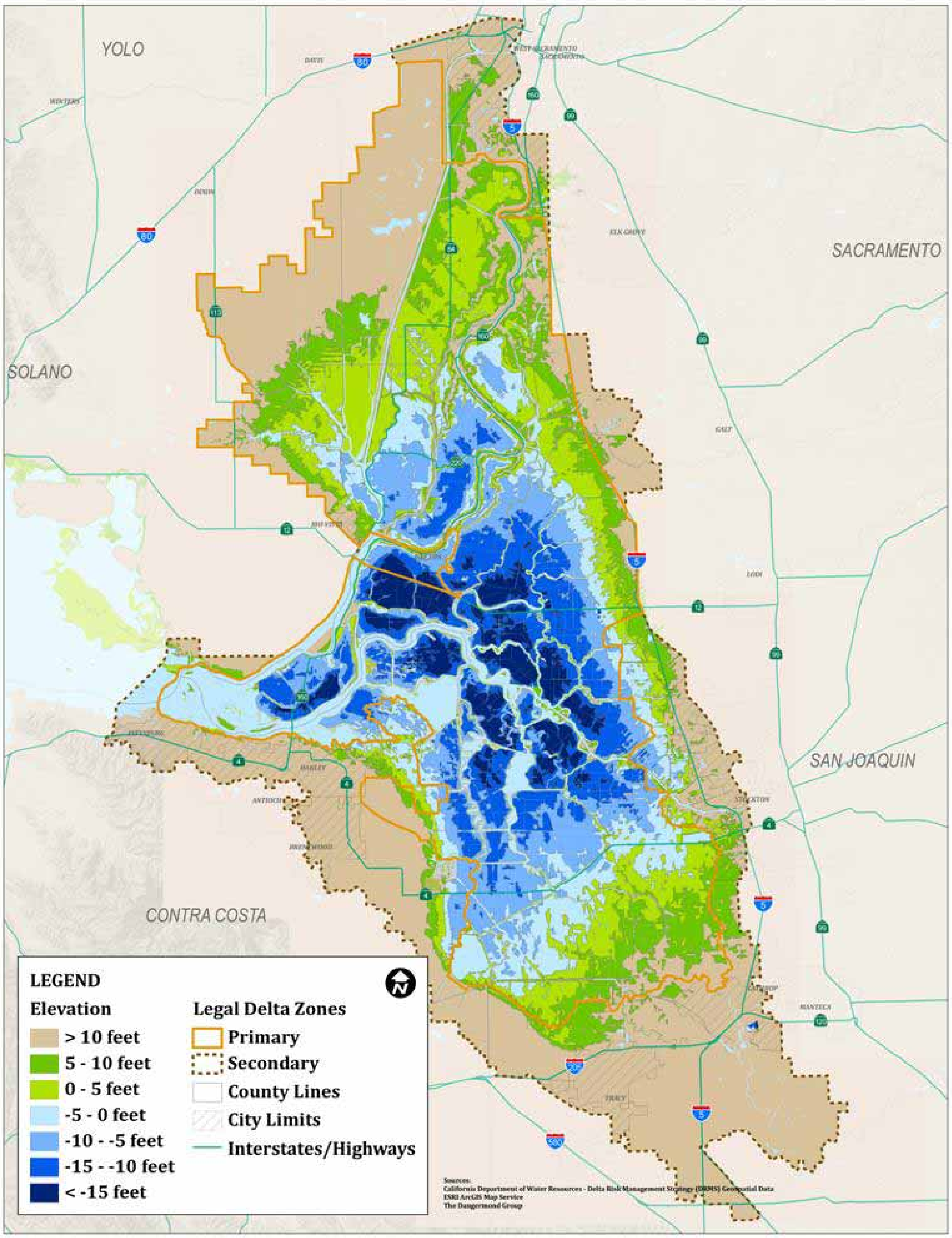


Figure 13 Construction of Dredger Cuts



[50] Based on DRMS GIS data set developed by URS Corporation and provided by DWR.

Figure 14 Current Elevations of Delta Land Surface[51]



[51] For high resolution image see http://forecast.pacific.edu/desp-figs.html

There is a popular impression that there are 1,100 miles of Delta levees all in poor condition. This has led to concern that there is a high probability of widespread failures in the event of flooding, earthquakes, or sea-level rise. While most Delta levees need further improvement, many miles of the Delta levees are actually in quite good condition.[52]

Only the levees within the Legal Delta that are currently being maintained and are candidates for further improvement are shown in Figure 10. Levees such as those around Liberty Island and Prospect Island, which lie within the Yolo Bypass, and the levees around the McCormack-Williamson Tract, which have always been height limited and are slated for removal, are not shown. With the removal of levees that are not being maintained and dry-land levees, the total length of the Delta levees is 980 miles, that is, just under 1,000 miles. The division of these levees into project, non-project urban, and other non-project levees and their significance is explained in the following sections. While the levees can be broken into different classifications, it is important to recognize that they all work together as a system. The draft DWR Technical Memorandum (2011) states: "The Delta's system of levees … and interconnected channels operate as a single, multi-function, flood management system. The failure of one levee can increase the risk of other levee failures, increasing the need for levee maintenance on adjoining islands in an effort to prevent additional levee failures. In addition, the large benefits to regions outside the Delta make it difficult to consider one island or tract separately from all others."

3 Status of Delta Levees

3.1 Categories of Levees

3.1.1 Project Levees

Project levees were constructed or improved by the U.S. Army Corps of Engineers (USACE) as part of federal-state flood-control projects and were turned over to the State for operations and maintenance. The State has in turn generally passed on the responsibility for routine maintenance to local reclamation districts, although the Paterno Decision[53] confirmed the State's continued basic liability with respect to these levees. The State Plan of Flood Control Descriptive Document, dated November 2010, delineates project levees and provides the names of the local maintenance agencies. Project levees within the Delta, as delineated in the GIS data set obtained through DWR, are identified in Figure 10. These levees were built to standards that generally exceed the PL 84-99 criteria described below.

3.1.2 Urban Levees

SB 5,[54] enacted in 2007, calls for a minimum of 200-year flood protection for urban and urbanizing areas in the Sacramento-San Joaquin Valley. SB 5 also limits the conditions for further development if this level of flood protection has not been achieved, conditions have not been imposed on the development to provide this level of flood protection, or adequate progress towards achieving this level of protection cannot be shown. DWR is developing criteria for these

[52] Selected photographs taken during a period of relatively high water in March 2011 are shown in Appendix C.
[53] *Paterno v. State of California* (2003) 113 Cal.App.4th 998.
[54] SB 5 (Machado) was the centerpiece of a far-reaching flood-control package of legislation. It requires the Department of Water Resources to prepare a Central Valley Flood Protection Plan and allows local jurisdictions to prepare their own plans only if they include specified elements that are consistent with the state plan.

urban levees that will generally be more stringent than the current criteria for project levees. These criteria are discussed below.

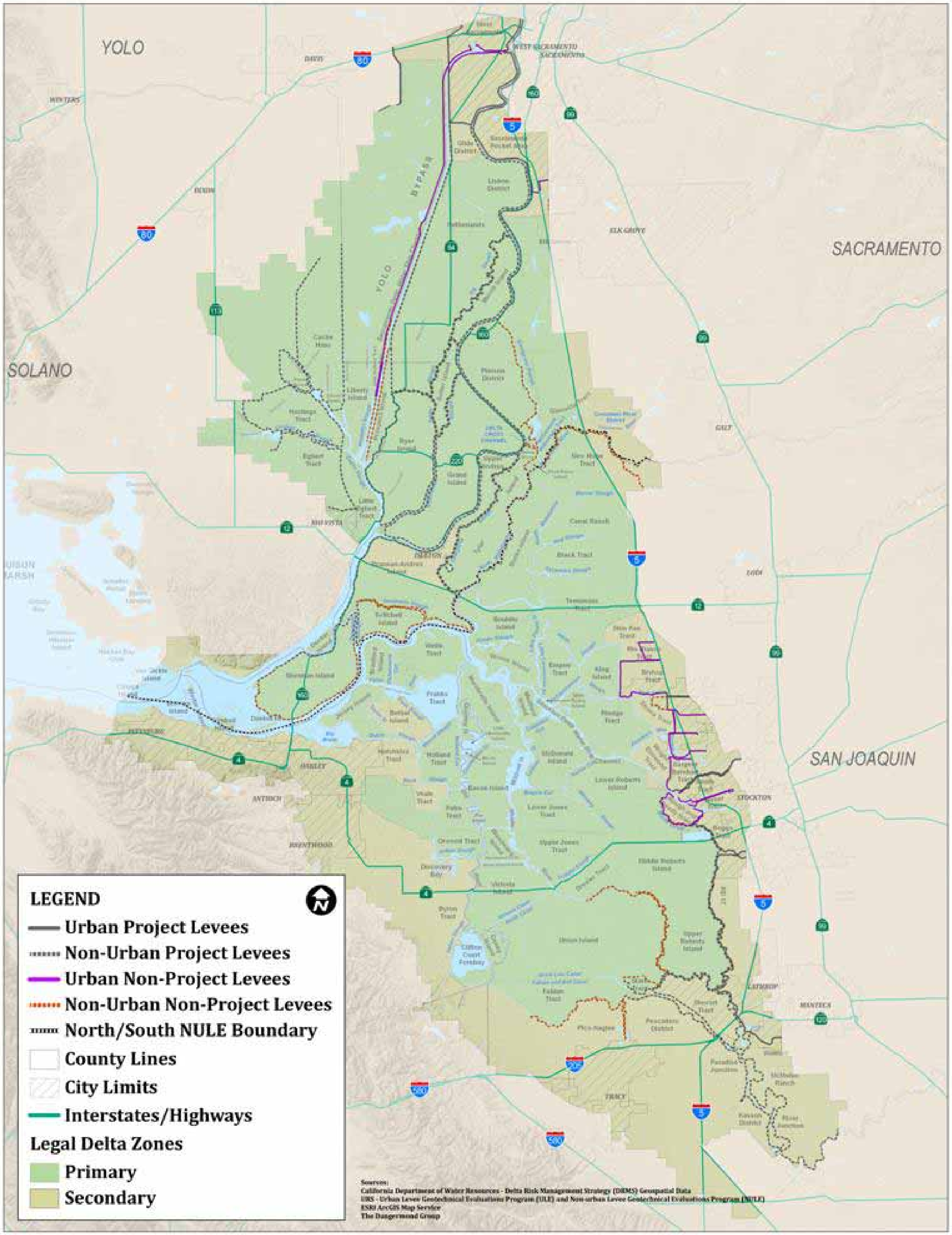
Recognizing the need for higher levels of flood protection, the major urban areas in the Sacramento-San Joaquin Valley have each formed a Joint Powers Authority (JPA) to implement levee improvements, in part using funds from the DWR Early Implementation Program. Three of these JPAs overlap the Legal Delta—West Sacramento Area Flood Control Agency (WSAFCA), Sacramento Area Flood Control Agency (SAFCA), and San Joaquin Area Flood Control Agency (SJAFCA).

Prompted by the Paterno Decision and SB 5, DWR is undertaking a major investigation of both riverine and Delta levees that is divided into two components, the Urban Levee Evaluations (ULE), and the Non-Urban Levee Evaluations (NULE) (Inamine et al., 2010).[55] These evaluations include detailed site investigations and some analyses and are intended to inform the Central Valley Flood Protection Plan (CVFPP) as to the likely level of effort that will be required for final design and the construction of improvements. Those levees within the legal Delta that are included in ULE and NULE, as identified in a GIS data set specifically obtained through DWR for this purpose, are shown in Figure 15,[56] superimposed on the mapping of project and non-project levees. Some of these DWR-designated urban levees are project levees and some are not. Because there are special requirements for urban levees, as well as special sources of funding for improvements, the urban levees that are not also project levees are identified in Figure 10 and Table 1. There are a total of 122 miles of urban levees in the Delta of which 63 miles are non-project levees.

[55] Inamine, M. et al., California's Levee Evaluation Program, US Society of Dams, 30th Conference, Sacramento, April 2010.

[56] Based on GIS data set provided by DWR and URS Corporation.

Figure 15 Urban and Non-Urban Levee Evaluation Programs[57]



[57] For high resolution image see http://forecast.pacific.edu/desp-figs.html

3.1.3 Other Special Levees

While the Delta levees were originally constructed to protect agricultural lands and the small communities that developed primarily along the shipping routes up the Sacramento River, they now are critically important to preserving water quality, to through-Delta conveyance of water, and to the vast array of infrastructure that criss-cross the Delta. The islands that are critical to these functions are discussed and illustrated in Appendix D. It may be seen in Appendix D that most, if not all, islands are also critical to something else besides agriculture and the Legacy Communities. It should also be noted that the mapping of infrastructure in Appendix D is taken from DRMS and is not necessarily complete. For security and other reasons, some data such as the location of liquid fuel pipelines and fiber-optic cables are closely held and are not included on publically available maps. Urban infrastructure in the Secondary Zone is also not shown.

3.1.4 Summary and Discussion

As may be seen in Table 1, just under 1,000 miles of levees are currently being maintained within the Legal Delta. But of these, 443 miles are either project or urban levees. If these levees are subtracted from the total of 980 miles, there are only 537 miles that need to be maintained and perhaps improved primarily by the State and the reclamation districts. The DWR draft Technical Memorandum (2011) makes a distinction between non-project levees that have special status in the California Water Code and are eligible for State assistance and other levees that might be owned by public agencies or private entities that are not eligible for State assistance. The technical memorandum indicates that those levees eligible for State assistance are shown on page 38 of the Delta Atlas.[58]

If urban areas and levees that are primarily flood-control levees in the north and south Delta are excluded from the total count, there are only 613 miles of "lowland" levees which protect lands below sea level. These are levees that are largely founded on peat and thus surround lands that have subsided. They are identified in Figure 10 by yellow dotted lines that are superimposed on either the black or red lines. Of these lowland levees, 143 miles are project levees, primarily located along the Sacramento River. That leaves approximately 470 miles of lowland levees that need to be maintained and enhanced primarily by the State and the local reclamation districts. Even this number errs on the high side because we have counted levee miles by island or tract and some islands or tracts that we have included in the "lowland" count, like Roberts Island for instance, have substantial areas above sea level. Thus, not all lowland levees are equally important but their definition is a significant step in prioritizing the relative importance of the various Delta levees. The 470-mile length might also be reduced by combining some of the existing islands and tracts into larger polders. Of this sub-set of the lowland levees, over 100 miles already exceed the PL 84-99 standard that is discussed below, leaving perhaps 350 miles in need of improvement to the PL 84-99 standard.[59] While the project and urban levees may have issues with encroachments, penetrations, and vegetation and otherwise be in need of improvement, there are other mechanisms for dealing with these issues, and the project and urban levees are fundamentally flood-control levees rather than levees that are key to protecting water quality, the conveyance of water through the Delta, and protecting and enhancing the Delta as a place.

[58] http://baydeltaoffice.water.ca.gov/DeltaAtlas/index.cfm

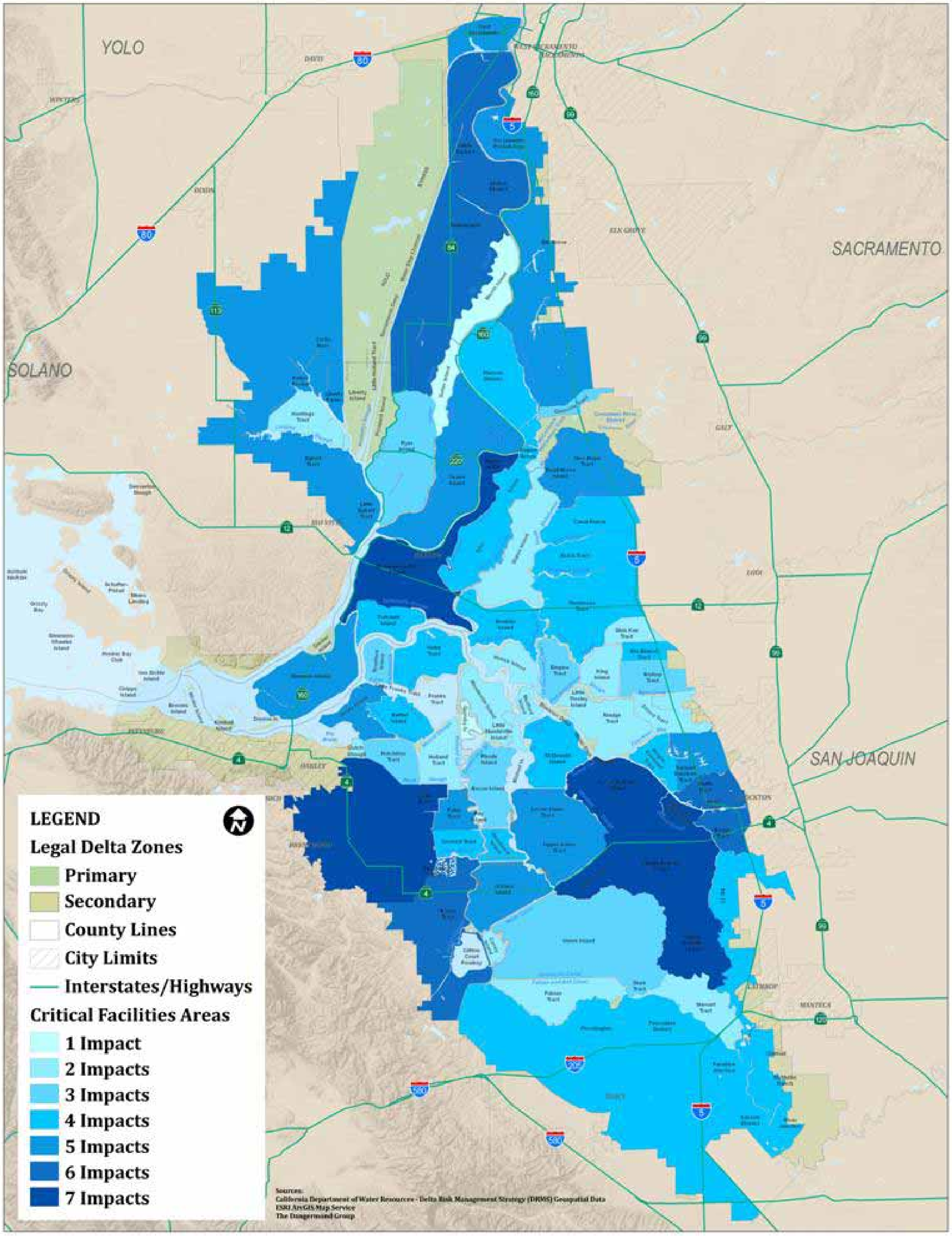
[59] Based on discussions with reclamation district engineers. These estimates will be refined and formalized in the 5-year plans that are now required as a prerequisite for state funding but the preparation of these 5-year plans has been delayed by delays in releasing the funding to develop them.

The definition of certain levees in Table 1 as "lowland" levees is not exact and at present has no legal significance. Most of the levees that have been called out as lowland levees are in the Primary Zone, although Bethel Island and Hotchkiss Tract have been included because they are two of the eight western island and tracts that are judged to be critical for preventing salinity intrusion; Wright-Elwood Tract also has been included because of its importance in protecting already urbanized areas to the east. The definition of these lowland levees is very useful for planning purposes because it is the islands that have significant land areas below sea level that are most exposed to the increasing risk posed by possible sea-level rise and that also serve to prevent salinity intrusion. Unlike islands and tracts where the land surface is above sea level, these islands cannot be drained naturally and have to be pumped out after first repairing the levee. Further, failure and flooding of even one of these islands potentially increases both the wave action and the seepage forces on the adjacent islands so that if the island is not repaired and drained promptly, progressive failure of additional islands may occur. Clear evidence of the effect of a single flooded island on adjacent islands was provided by the fact that levee integrity on Woodward and Victoria Islands was compromised by the failure and flooding of Upper Jones Tract in 2004.[60] Thus, the maintenance and improvement of the lowland levees are critical to the achievement of the coequal goals set forth in the Delta Reform Act of 2009. The concept of defining lowland levees is similar in purpose to the designation in the 2008 PPIC report[61] of 34 islands as core or significant islands.

All of the islands shown in Appendix D, which have levees protecting infrastructure or critical facilities of one form or another, are superimposed in Figure 16. Figure 16 is not necessarily complete and does not attempt to weight the relative value of the various kinds of infrastructure, but it illustrates the widespread distribution of significant infrastructure in the Delta and shows that most, if not all, islands or tracts house significant infrastructure or border important shipping or conveyance pathways.

[60] Neudeck,Christopher, KSN, Inc., personal communication.
[61] Lund, J., et al., *Comparing Futures for the Sacramento-San Joaquin Delta*, Public Policy Institute of California, San Francisco, CA, August 2008.

Figure 16 All Islands Containing Critical Facilities[62]



[62] For high resolution image see http://forecast.pacific.edu/desp-figs.html

3.2 Levee Standards

A detailed discussion of the various standards that might apply to Delta levees was given by Betchart (2008).[63] Betchart's list can be simplified into the five standards listed below. Because the Delta is a unique place with unique soil conditions, some levee standards that are applicable elsewhere are not applicable in the Delta. These unique considerations are discussed in Appendix E.

Hazard Mitigation Plan (HMP)

The Hazard Mitigation Plan (HMP) "standard" is not an engineering standard but is a simple geometric levee description that was devised by FEMA in order to establish minimum requirements for federal disaster relief. It provides for a 16-foot crown width, a 1-foot freeboard above the 100-year water surface elevation, minimum 1.5-to-1 waterside slopes, and minimum 2-to-1 landslides slopes. Most existing Delta levees generally meet this standard, but because Delta levees built of or over peat are subject to on-going settlement, there is continuing argument over how literally this standard should be interpreted. The current regulatory position is stated in a MOU signed in February 2010 between Cal EMA and FEMA, as discussed by Betchart (2011).[64] However, notwithstanding its importance to disaster-relief funding, no engineer familiar with the Delta considers the HMP geometry to be adequate for even basic flood protection, and the reclamation districts are generally working towards full compliance with the higher PL 84-99 standard. While there are some miles of levees that, pending further improvement, waver around the HMP geometry, there are at present only about 50 miles that fall below HMP,[65] and even those levees fall short only by about a foot of elevation. As noted in the DWR Technical Memorandum, while achieving the HMP geometry is not really a goal from an engineering perspective, consistently meeting it is not only a first step towards the real short-term goal, which is PL 84-99, but is also important from the point of view of the State in maximizing federal assistance following any disaster.

While levee standards are generally thought of in engineering terms and vegetation on levees is discouraged, the treatment of levee vegetation is critical in the Delta (and elsewhere in California) where preservation or restoration of riparian habitat is an important goal. Vegetation management guidelines for local, non-project Delta levees that were adopted in 1994 require that the crown and the landside slope and a ten-foot strip along the landside toe must be cleared of visually obstructive vegetation, although mature trees may be retained. All vegetation except for grasses must be removed from the top five feet of the waterside slope. The guidelines suggest that naturally growing vegetation below the cleared area should be pruned or removed only to the extent necessary to insure levee safety and ease of inspection.

Public Law (PL) 84-99

Among other actions, Public Law 84-99 allows the Corps of Engineers to rehabilitate flood protection systems during a disaster. In order to qualify, the flood system must have already been enrolled into the Corps' Rehabilitation and Inspection Program. In 1987, the Sacramento District of USACE established a Delta-specific standard for levees, based on the Bulletin 192-82 joint DWR-USACE study that is described below, but with the requirement for 1.5 feet of freeboard reduced to being over the 100-year water surface elevation rather than the 300-year water surface elevation. Within the legal Delta this standard plus various maintenance and

[63] Betchart, W., Delta Levees – Types, Uses and Policy Options, Prepared for Delta Vision, August 2008.
[64] Betchart, W., Memo to Delta Levees and Habitat Advisory Committee with attached MOU, 2011.
[65] Based on discussions with reclamation district engineers. See previous footnote regarding the development of 5-year plans.

inspection requirements must be met in order to qualify for rehabilitation under PL 84-99. The Corps was careful to note that "the recommended guidelines are Delta-Specific and they are not intended to establish design standards for the 537 miles of non-federal levees in the Sacramento-San Joaquin Legal Delta, but to provide uniform procedures to be used by the Corps of Engineers in determining eligibility under PL 84-99, as amended." In the preceding Bulletin 192-82 study it had been stated that "while the Corps' design has accounted for small earthquakes, the lack of actual experience of the impacts of earthquakes on Delta soils leaves some doubt that levees, even after rehabilitation, could withstand an earthquake of Richter magnitude 5 or greater if the epicenter occurred in the Delta, or of magnitude 8 on the San Andreas or Hayward faults." Thus, earthquakes were considered but not fully accounted for.

While sometimes referred to as the PL 84-99 Ag standard, this standard actually applies to both agricultural and urban levees within the Legal Delta. The standard adds a stability requirement to what is otherwise principally a geometric standard. It provides for a crown width of 16 feet, freeboard of 1.5 feet over the 100-year water surface elevation, a minimum waterside slope of 2-to-1, and landside slopes that vary as a function of the depth of peat and the height of the levee such that the static factor of safety on slope stability is not less than 1.25. Very approximately, the landslide slope can be 2-to-1 for levee heights no greater than 5 feet, can be 3-to-1 for levee heights no greater than 10 feet, can be 4-to-1 for levee heights no greater than 20 feet, and has to be 5-to-1 for levee heights of 25 feet or greater. Alternately, the minimum factor of safety can be achieved by construction of a landside toe berm. While this standard only calls for a minimum crown width of 16 feet, some reclamation districts are already planning for or are constructing improved levees with a 22-foot crown width, adequate for a two-lane, sealed road. This allows for two-way traffic in emergency situations and is to be encouraged. While this standard does not fully address earthquake loadings, the flatter slopes and/or landslide berms that are required for levees built over peat means that they are fundamentally less likely to suffer major distress as a result of earthquake loadings. This Delta-specific standard leads to the result that levees in the western and central Delta which overlie peat are likely to be less susceptible to damage in earthquakes than levees in the north and south Delta, which both overlie more sandy soils and tend to be composed of sandy soils and thus are more susceptible to liquefaction. While the Delta-specific PL 84-99 standard includes no specific guidelines on vegetation, it is assumed that the Corps national standards on levee vegetation, which basically ban all significant vegetation on both land and watersides, apply unless a specific variance from those standards is obtained. This question is currently the subject of a significant debate between the State of California and USACE, with the State arguing for the positive engineering and environmental benefits of vegetation on the waterside slopes of levees. The State's position is indicated by the proposed provisions for urban levees which are noted below.

Sacramento District (SPK)

While not directly applicable to Delta levees, the Geotechnical Levee Practice of the Sacramento District of USACE (designated SPK) has some relevance because it informs both the Urban and Non-Urban Levee Evaluation programs and the DWR Urban Levee Design Criteria that are presently being developed. This SPK Practice calls for a minimum crown width of 20 feet for main-line levees and minimum water and landside slopes of 3-to-1. Existing levees, with landside slopes as steep as 2-to-1, may be retained in rehabilitation projects if their historic performance has been satisfactory. This move to 3-to-1 slopes is driven by maintenance issues as much as slope stability and seepage issues. The practice also suggests minimum requirements for geotechnical investigations and analyses. Although it describes recommended standard practice, it also makes it clear (and this aspect is often overlooked) that the responsible engineers should use appropriate judgment as a function of site-specific conditions and experience.

Urban Levee Design Criteria (ULDC)
DWR was directed by SB 5 to develop appropriate standards for urban levees, and version four of the Interim Levee Design Criteria for Urban and Urbanizing Areas in the Sacramento-San Joaquin Valley was published in December 2010. These criteria are now being finalized as the Urban Levee Design Criteria which will eventually become a State regulation. The ULDC is generally consistent with the SPK Practice and has the same geometric requirements. However, the ULDC goes much further in defining required practice in a number of other areas including seismic loadings, encroachments, penetrations and vegetation. With regard to vegetation, the draft ULDC language generally prohibits vegetation in accordance with the USACE national policy but allows woody vegetation on portions of the waterside slope and riverbank or berm for a newly constructed levee if a specially-designed waterside planting berm is added or the levee section is otherwise widened. In the case of the repair or improvement of existing levees, the draft ULDC language allows trees and other vegetation to be preserved over the long term if they provide important or critical habitat or erosion protection, soil reinforcement or sediment recruitment. In order to mitigate possible adverse effects of roots, where feasible the overall width of the levee should be widened landward by at least 15 feet or an effective root or seepage barrier shall be installed within the upper 10–15 feet below the levee crown. For other levees with pre-existing vegetation, the UDLC requires inspection and thinning in accordance with the Central Valley Flood System Improvement Framework. It is suggested that these provisions are generally applicable to Delta levees.

Proposed Higher Delta Levees Standard
With the exception of the ULDC, which addresses design and/or quick repair of levees for 200-year return period earthquakes, none of the above standards explicitly address seismically-resistant design, or design for greater than 100-year water surface elevations and possible sea-level rise. The 1983 Delta Levees Investigation (see Section 3.3.1 below) did suggest that Delta levees should be designed for 300-year water surface elevations but that suggestion has not been included in subsequent standards or revisions. Although updated estimates of water surface elevations from the Central Valley Flood Protection Plan are still pending, it is commonly believed that water surface elevations in much of the Delta are strongly influenced by tides and that 300- or even 500-year water surface elevations are only a foot or two higher than 100-year elevations. Pyke (2011)[66] has suggested that an appropriate standard for the design of Delta levees might be to design for 500-year flood and earthquake loadings. Likely, adoption of the ULDC requirement for three feet of freeboard over the 100-year water surface elevation coupled with superior flood-fighting would effectively provide 500-year flood protection. Building to this standard and increasing the crown width to a minimum of 22 feet would increase the cost only marginally over the cost of complying with the Delta-specific PL 84-99 standard and this “PL 84-99 plus” standard may be sufficient for many Delta levees long-term. If the levee in question does not contain or is not underlain by loose sands that are susceptible to liquefaction, these PL 84-99 plus levees should be considered to be seismically robust. However, in order to more fully address earthquake loadings, possible sea-level rise and to provide the option for adding vegetation on the water side of levees, a higher Delta levees standard is required. This standard should particularly be required of most of the lowland levees which face the biggest hazard due to possible sea-level rise and are also the most critical to salinity intrusion, but it might be selectively applied to other Delta levees.

[66] Pyke, R., Comments of the First Staff Draft of the Delta Plan, Delta Stewardship Council, February 2011, http://deltacouncil.ca.gov/public-comments/read/143?page=1

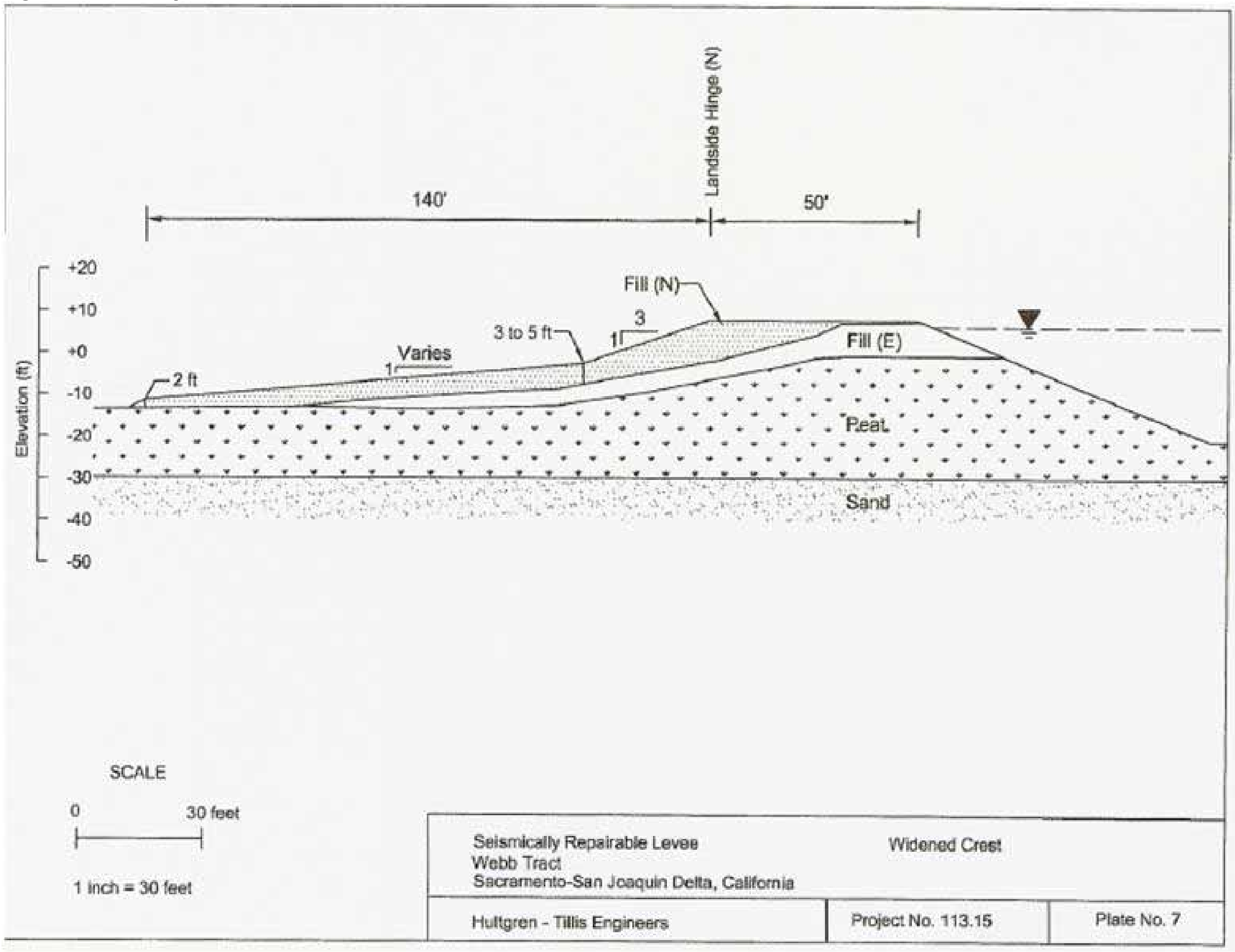
As an example of a levee with increased seismic resistance that also meets other objectives, the cross-section of a proposed seismically-resistant levee taken from a report by Hultgren-Tillis Engineers (HTE) for Reclamation District 2026 (Webb Tract)[67] is shown in Figure 17. Even when assuming that some liquefaction might occur both in the embankment and the foundation, this study indicates that deformations would be limited by the addition of a landslide buttress, as shown in the figure. A key feature of the design shown in Figure 17 is the wide crest. Wider crests not only provide a more robust levee, but also allow for more efficient emergency response. Levees with wider crests are also the most economical way to provide for possible sea-level rise. While it is the policy of the State to plan for 55 inches of sea-level rise by the year 2100, the probability of that magnitude of sea-level rise is actually very small. While it is not cost-effective or rational to construct levees to those elevations today, the provision of a wider crest today has two benefits: providing a more robust levee immediately, allowing more room for flood-fighting or emergency response following earthquakes, and allowing a choice of methods for raising the crest elevation in the event of actual sea-level rise. In addition, the provision of a wider crest also allows for retaining or planting vegetation on the waterside of the levee in accordance with the ULDC guidelines. Such planting should be an essential component of any comprehensive plan to repair the Delta ecosystem. Local widening of these levees would also allow for the construction of new recreational and tourist facilities out of the flood plain.

HTE estimated that this design would cost approximately $2 million per mile in 2009. HTE also looked at more elaborate designs which included either or both of a slurry trench wall or an internal drain. Those designs added up to $5 million per mile to the incremental cost but we believe that the additional features are not generally required and that an average cost of $2-3 million per mile is a reasonable estimate at this time. If it is assumed that anywhere from 300-600 miles of levees need to be upgraded to this standard, the basic engineering and construction cost would be in the order of $1-2 billion although the overall program cost might well be higher.

By comparison the 2007 PPIC report “Envisioning Futures”[68] listed in Table 8.2 an alternative labeled Fortress Delta (Dutch standards) which had a total cost greater than $4 billion and in Appendix E it is explained that was based on an estimated cost of $10 million per mile, applied to 300 to 500 miles of levees. The $10 million per mile figure was obtained by taking a $5 million per mile figure based on “recent informal estimates by water managers … including significant structural work” and doubling it because “Dutch levels of levee protection … would probably involve changes in many islands and channels, straining current construction and levee material capacity”. If it is assumed that “structural work” means including a slurry trench wall or internal drain then the $5 million per mile estimate is not inconsistent with the HTE estimates and these measures are in fact likely to be required to obtain “Dutch levels of levee protection” since currently Dutch levees are variously designed for 2,500 to 10,000 year levels of protection. However, the societal and economic considerations in the Netherlands are even more demanding than those in the Delta and we believe that a lesser upgrade to something like a 500 or 1000-year level of protection is appropriate for the Delta

[67] Hultgren-Tillis Engineers, Geotechnical Evaluation, Seismically Repairable Levee, Webb Tract, Report to Reclamation District 2026, December 2009.
[68] Lund, J., et al., *Envisioning Futures for the Sacramento-San Joaquin Delta*, Public Policy Institute of California, San Francisco, CA, 2007.

Figure 17 Example Delta Levee Cross Section



3.3 Previous Studies of Delta Levees

3.3.1 Delta Levees Investigation, DWR Bulletin 192-82

In 1976 the legislature directed DWR to prepare a plan for the preservation of the Delta levees. After a joint study with USACE, a definitive plan for the improvement of all Delta levees was completed six years later and published as Bulletin 192-82,[69] which recommended a levee standard similar to the current Delta-specific PL 84-99 standard but with a requirement for 1.5 feet of freeboard over the 300-year water surface elevation. The forward to the report, signed by Ronald Robie, then Director of DWR, states in part:

> *Now is the time for a decision. The most significant element in a decision on what action to take is how much can we afford and who will pay? These questions can only be answered by the Legislature, the local landowners, and the Congress.*
>
> *There is a danger that taking a short-term view of Delta flooding problems will merely pass the tough issues on to the next generation. Short-run economic decisions may serve to subsidize private interest as the expense of the general public. The great challenge for the*

[69] Delta Levees Investigation, Department of Water Resources, Bulletin 192-82, December 1982.

Delta is to find an equitable way of financing a very uncertain long-term future. The political process is the traditional arena for handling these kinds of issues and is the right forum for the next step in Delta deliberations.

These policy issues must be addressed today. In the event the Legislature determines that a major responsibility for levee restoration should fall upon the State, a bond issue or other form of capital financing must be developed and approved by the people.

At that time, it was estimated that improving all levees to the proposed Bulletin 192-82 standard would cost $930 million if implemented immediately. However, although funding of the subventions program continued at a relatively low level, financing was never put in place to implement this more significant levee-improvement plan.

3.3.2 CALFED Levee System Integrity Program

A similar study, called the CALFED Levee System Integrity Program, was subsequently conducted as part of the CALFED program.[70] The executive summary of the Levee System Integrity Program Plan, dated July 2000, contains the following statements:

The benefits of an improved Delta Levee system include greater protection to the Delta agricultural resources, municipalities, infrastructure, wildlife habitat, and water quality as well as navigation and conveyance benefits. The wide range of beneficiaries of the Delta Levee System Integrity program include Delta local agencies; landowners; farmers; boaters; wildlife; and operators of railroads, state highway, utilities, and water distribution facilities. Delta Water users and exporters also benefit from increased protection to water quality. Federal interests benefit from improvements to conveyance, navigation, commerce, and the environment, and from reduced flood damage.

Recognizing these potential benefits, state and local agencies formed a partnership to reconstruct Delta levees. This effort has resulted in a steady improvement in the Delta levee system. The success of the Delta in the 1997 and 1998 flood events illustrates the value of the approximately $100 million of improvements made with SB 34 funds and over $10 million in emergency PL 84-99 work performed for the U.S. Army Corps of Engineers. These funds, in addition to local funds, have resulted in over $160 million in improvements to Delta levees since the SB program's inception in 1988.

However, the summary continues with:

Many Delta levees do not provide a level of flood protection commensurate with the high value of beneficial uses they protect. As mandated by the California State legislature and adopted by CALFED, the physical characteristics of the Delta should be preserved essentially in their present form. This is necessary to protect the beneficial uses of the Delta. The key to preserving the Delta's physical characteristics and to achieving CALFED's objectives is the levee system. Over the next 30 years CALFED will invest billions of dollars in the Delta. The levees must protect this investment.

*The existing levee program (*the subventions program*) was intended to improve Delta levees up to the California/Federal Emergency Management Agency (FEMA) Hazard Mitigation Plan (HMP) Standard. As of January 1998, 36 of 62 (58%) Delta islands and*

[70] Op. cit.

tracts were in compliance with the HMP standard. This has resulted in a significant improvement in the ability to protect the beneficial uses of the Delta. However, as CALFED invests in the Delta, more is at risk. Therefore CALFED has chosen to improve the Delta levees to a higher level.

The CALFED Levee program will institute a program that is cost-shared among the beneficial users to reconstruct Delta levees to the Corps' PL 84-99 Delta Specific Standard. This action will increase levee reliability and reduce emergency repair costs. In addition, levee districts meeting this standard are eligible for federal emergency assistance under PL 84-99.

The plan to improve the levees to the PL 84-99 standard was not new. It had been recommended in Bulletin 192-82. The CALFED study estimated that the cost of improving all the Delta levees to the PL 84-99 standard ranged from $367 million to $1.051 billion, not inconsistent with the $930 million estimated in 1982. But again, no funding materialized until in 2006, in the wake of the Paterno Decision, Propositions 84 and 1E provided for up to $615 million to be spent on Delta levees.[71] The slow pace of disbursement of these funds is discussed subsequently but, in effect, this was the funding that had been recommended first by Bulletin 182-92 and then by CALFED.

The CALFED plan also discussed the fact that funding for levee work is insufficient, inconsistent, and often delayed; that dredging is required to increase channel capacity and to provide material for levee reconstruction, habitat restoration and creation, and subsidence control, but that dredging had been curtailed due to regulatory constraints, causing dredging equipment and trained manpower to leave the Delta; that emergency response capabilities need to be continuously refined and funding increased; that levee reconstruction and maintenance sometimes conflicts with management of terrestrial and aquatic habitat resources; that obtaining permits for levee work can sometimes be difficult and time consuming; and that while subsidence may adversely affect levee integrity, this can be corrected.

With respect to seismic loadings, the plan said:

Some CALFED stakeholders are concerned that earthquakes may pose a catastrophic threat to Delta levees, that seismic forces could cause multiple levee failures in a short time, and that such a catastrophe could overwhelm the current emergency response system.

CALFED agrees that earthquakes pose a potential threat. In addition, Delta levees are at risk from floods, seepage, subsidence, and other threats. To address this concern, CALFED has begun a risk assessment to quantify these risks and to develop a risk management strategy.

The plan listed 10 possible risk management options which included improving emergency response capabilities and reducing the fragility of the levees and indicated that the final Risk Management Plan might include a combination of the 10 options. CALFED never completed the Risk Management Plan, and the effort evolved into the Department of Water Resources' Delta Risk Management Strategy.

[71] Some sources indicate that $775 million was intended to be spent on Delta levees but the draft DWR Technical memorandum indicates that only $615 million was made available by these propositions.

3.3.3 Delta Risk Management Strategy

AB 1200 (authored by John Laird, the current California Secretary for Natural Resources) required that DWR evaluate the potential impacts on water supplies derived from the Delta based on 50-,100-, and 200-year projections for each of the following possible impacts: subsidence, earthquakes, floods, climate change and sea-level rise, or a combination of these impacts. This legislation had the effect of changing the CALFED recommended study into what became the Delta Risk Management Strategy (DRMS) and the Risk Management Plan envisioned by CALFED has never been completed.

DRMS was conducted for the Department of Water Resources (DWR) by a team of consultants led by URS Corporation and Jack R. Benjamin & Associates.[72] The study was designed to have two phases. The first phase was an assessment of the then-current (2005) risks to the Delta and the second phase was to have been a projection of future risks assuming various scenarios. The Phase One draft generated a great volume of critical comments, and the effort required to respond to them cut into the available funding for Phase 2. The Phase 1 Risk Analysis Report was released in 2009, but the report on the modified Phase 2 study has only just been released.

Although led by very competent principal investigators, the DRMS effort was always hampered by being schedule-driven rather than quality driven. The DRMS Phase One report was extensively reviewed, including a review by an independent review panel (IRP) assembled by the Cal-Fed Science Program. The reviews were generally critical of the study. After revisions had been made, the IRP review[73] concluded that "the revised DRMS Phase 1 report is now appropriate for use in DRMS Phase 2 and serves as a useful tool to inform policymakers and others concerning possible resource allocations and strategies for addressing risks in the Delta." But the IRP expressed concerns:

> "*This conclusion, however, is subject to some important caveats. First, the IRP cautions users of this revised DRMS Phase 1 report that future estimates of consequences must be viewed as projections that can provide relative indicators of directions of effects, not predictions to be interpreted literally. Second, anyone using the results of the DRMS scenarios must be aware that ecosystem effects are not fully captured in the analysis....*"

Although the DRMS developed a good framework for assessing risks to the Delta levees, the effort had data gaps that were never filled, as acknowledged in the note on page 1-1 of the report. Gaps such of these in data and knowledge tend to drive the estimates of fragilities down, and the risks up. However, despite the warning from the IRP, the numerical results from the DRMS Phase 1 report are widely quoted and used in other studies, painting a more pessimistic picture of the Delta levee system than is warranted. Just one example of the questionable results is presented by the last map in the DRMS Executive Summary depicting a high probability of flooding for Sargent-Barnhart Tract, which houses Stockton's most expensive neighborhood, known as Brookside. This tract has had modern levees that meet 200-year urban standards and is shown as having a mean annual probability of failure of greater than 7 percent, while the adjacent Wright-Elmwood Tract, which is undeveloped and has relatively poorer levees, is shown as having a mean annual probability of failure of only 1-3 percent. In addition, recent improvements have been made to many urban levees in addition to recent and on-going

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[72] http://www.water.ca.gov/floodmgmt/dsmo/sab/drmsp/

[73] The independent review panel (IRP) comments on the DRMS Phase I draft report are published on the State's archived CALFED website: http://calwater.ca.gov/science/drms/drms_irp.html.

improvements to non-urban levees under the Delta levees subventions and special projects programs and these improvements are not reflected in the DRMS Phase 1 assessment.

The DRMS Phase 2 study focuses on risk reduction as opposed to risk analysis and evaluates the costs and benefits of four alternative scenarios for levee improvement and conveyance. Although Phase 2 was not released until June 2011, the forward to the report notes that it was completed in 2009, which explains why it utilizes costs for isolated conveyance that are less than half more current cost estimates. Like Phase 1, Phase 2 did not include acquisition of updated data. The report states:

> *Similar to the Delta Risk Management Strategy (DRMS) Phase 1 Risk Analysis Report (URS/JBA 2007h), the DRMS Phase 2 Risk Reduction Report was carried out for the most part using existing information (data and analyses). The Phase 2 schedule did not afford the opportunity to conduct field studies, laboratory tests, or research investigations.*

Section 20 of the report lists a number of assumptions and limitations, and concludes:

> *The complexity of the issues in the Delta and the limited time available to undertake the Phase 2 effort means that additional scenarios that could not be developed in this phase will require consideration. Further, the performance of sensitivity analyses of the scenarios themselves would be valuable to assess the importance of the major components of the scenarios on the overall risk reduction benefits. Other ongoing agency initiatives will likely require consideration of additional scenarios.*

While these limitations and the awkward construction of scenarios discussed below make the final conclusions of the Phase 2 report unreliable, the DRMS phase 2 report is still a wealth of detailed information regarding individual components of the scenarios. In fact, the key findings relative to the two types of levee upgrades that were considered (and are listed below) are not inconsistent with the present study.

- *Most of the Delta levees already meet the HMP standard.*
- *Some of the levees in the central Delta (project levees) already meet the PL 84-99 standards.*
- *The cost of upgrading 764 miles of selected non-project levees (levees that do not meet PL 84-99 standards) in the central Delta to PL 84-99 standards is about $1.2 billion.*
- *The cost of upgrading 187 miles of selected levees around urban centers to UPL standards is $750 million.*
- *Upgrading levees to meet the target standards will reduce the probability of failure due to flooding. However, these upgrades do not guarantee that the upgraded levees, particularly those upgraded to PL 84-99 standards, will not fail during a 100-year flood. The 1.5 feet of freeboard is insufficient for regions subject to high winds during floods.*
- *Upgrading levees to meet the PL 84-99 and UPL standards does not reduce the seismic risk of levee failure.*

Elsewhere the report says that “upgrading the levees to the Pl 84-99 and UPL standards would <u>do little</u> to reduce the risk of failure under seismic loading.” However, curiously, the report says nothing about what it would take to further upgrade the critical levees so that they are more robust under seismic loadings.

Rather Scenario 1, which is entitled “Improved Levees,” assumes that the levees are not robust under seismic loadings and estimates the cost of hardening the state highways that cross the Delta, by putting them on piles like the elevated section of the Yolo Causeway, and the BNSF railway and the Mokelumne Aqueducts, either by building seismically-resistant embankments with a 50-foot crown width on either side of the existing railway and aqueducts, or by placing the railway and aqueducts on a single embankment with a 180-foot crown width. The cost of these hardening measures was estimated to be $6.1 billion for the highways and $3.3-3.9 billion for the infrastructure corridor. Adding these figures to the cost of the planned levee improvements resulted in a stated total capital cost for Scenario 1 of $10.4 billion, as reported in Table 1 of the executive summary. Thus, the “Improved Levees” scenario is not a broad improvement of Delta levees as described in this report, but has 60 percent of the total cost allocated to putting a few state highways on piers, a strategy that the report notes does not generate benefits equal to the costs and creates numerous problems for the network of local Delta roads. It should be titled an “elevated highways” scenario since that is its most prominent feature, as highways do not have to be elevated for the type of improved levees strategy described in the ESP.

Likewise Scenario 2, which is titled “Through Delta Conveyance (Armored Pathway),” ignores the possibility of a general upgrade to levees that are more robust under seismic loading and instead assumes the construction of 115 miles of new seismically-resistant setback levees, at a cost of $38 million per mile. The total capital cost of the scenario is $15.6 billion, because this strategy is also paired with $5 billion in costs to put roads on piers.

Scenarios 3 and 4 examine isolated and dual conveyance, and greatly misrepresent the costs of these strategies as being comparable to or cheaper than through Delta conveyance strategies. First, they utilize out-of-date costs for isolated conveyance that are under $5 billion compared to current estimates of $12 billion or more. Second, these scenarios also reduce cost by not including the $3.3 billion armored infrastructure corridor included in Scenarios 1 and 2. As a result, the costs and composition of the four illustrative scenarios are constructed in such a way that the final conclusions are of little value.

This study concludes that most lowland Delta levees and selected other levees can be made robust under seismic loadings for a base engineering and construction cost of $1-2 billion. Even if the total program cost were $4 billion as suggested by PPIC (2007), a true “improved levees” scenario would have much lower costs than the version in DRMS and would perform much better in reducing the costs of in-Delta flood losses as well as out-of-Delta losses from water supply reliability and therefore have higher benefits. Although it is impossible to draw conclusions without a complete analysis, a true “improved levees” scenario would likely have a much higher benefit-cost ratio than the other scenarios considered in DRMS phase 2.

3.3.4 Delta Islands and Levees Feasibility Study

Meanwhile, the successor to the Bulletin 192-82 and CALFED studies is the USACE Delta Islands and Levees Feasibility Study, which is an on-going effort in collaboration with DWR.[74] The official description of the study is:

> *This feasibility study is USACE’s mechanism to participate in a cost-shared solution to a variety of water resources needs for which we have the authority. Results of state planning efforts will be used to help define problems, opportunities, and specific planning objectives. The feasibility study will address ecosystem restoration and flood risk*

[74] http://www.spk.usace.army.mil/projects/civil/Delta/News.html

management, and may also investigate related issues such as water quality and water supply. USACE and DWR signed a Feasibility Cost Sharing Agreement (FCSA) in May 2006.

The initial public findings and outreach are not expected until later this year. Thus, three joint State-Federal efforts over the last 30 years have had significant positive impact in that they have generated the concept of improving Delta levees to the PL 84-99 standard and have supported the continuation of the funding that is provided under the subventions program and the additional funding that was authorized under Propositions 84 and 1E and the CALFED Levee Stability program. However, they have not yet led to a strategy which will make the Delta sustainable longer-term facing the hazards due to floods, earthquakes, and possible sea-level rise.

4 Risk Reduction Strategies

There are three basic approaches to addressing the risks posed to the Delta levees by floods and earthquakes. One is to simply make the up-front investment to improve the existing levees so that they are more robust; a second is to make the preparations in advance for improved flood-fighting and/or emergency repairs following an earthquake so that breaches do not occur; the third is to make preparations in advance for repair of breaches and the draining of any flooded islands if breaches do occur so that the consequences are minimized. These three approaches are discussed in more detail in the following sections, and is followed by a discussion of economic justification for investing in risk reduction strategies.

4.1 Improve the robustness of the existing levees

This is the standard approach to reducing risk: invest up-front in making everything more robust. As discussed earlier, a series of reports over three decades have concluded that Delta levees should be improved to the Delta-specific PL 84-99 standard. However, the Department of Water Resources has released a draft "Framework for DWR Investments in Delta Integrated Flood Management,"[75] a document that was only released for public comment on July 15, 2011, but had already been forwarded to the Delta Stewardship Council, that states or implies that the HMP "standard" provides an adequate basic level of protection against floods and earthquakes for Delta levees. The exact language of the draft Framework is:

As funding is available, DWR intends to cooperate with local public agencies to develop local plans to improve levees within the Delta levee network to at least the HMP standard. Some levees may warrant additional investment to provide a level of protection beyond the HMP standard, but these projects likely would need to be justified based on one of the other categories of benefit described in this section.

Apparently on the basis of this language, the 5th staff draft of the Delta Plan, in Table 7-1, indicates that levees built only to the HMP "standard" are acceptable for protection of agricultural lands. However, the HMP "standard" is not an engineering standard. It is a minimum configuration agreed to by the state and federal governments for the purpose of defining a serious levee in order to protect the federal government from facing possible exposure to the cost of repairing levees that are height limited or not seriously being maintained. Since 1982, the minimum standard for engineered levees in the Delta has been the Delta-specific standard

[75] California Department of Water Resources, DRAFT V3 DHF and SMB, "A Framework for Department of Water Resources Investments in Delta Integrated Flood Management," February 14, 2011.

that was recommended in Bulletin 192-82 and subsequently adopted by the Corps of Engineers as the PL 84-99 standard for Delta levees. This Delta-specific PL 84-99 standard was also adopted in the CALFED Levee System Integrity Program Plan as the minimum standard for Delta levees. That plan specifically said:

> *The CALFED Levee program will institute a program that is cost-shared among the beneficial users to reconstruct Delta levees to the Corps' PL 84-99 Delta Specific Standard. This action will increase levee reliability and reduce emergency repair costs. In addition, levee districts meeting this standard are eligible for federal emergency assistance under PL 84-99*.

The draft Framework and the draft Delta Plan would roll back 30 years of joint state-federal co-operation without sufficient justification. The draft Framework is inconsistent with DWR's own draft Technical Memorandum (2011) that is cited in the Framework document, not to mention CALFED and Bulletin 192-82. Given that it is possible, even likely, that FEMA will raise the minimum levee standard required for reimbursement after a disaster from the HMP standard to the PL 84-99 or some higher standard, the proposed policy change means the state would be forgoing the opportunity for significant federal financial assistance to sustain and enhance the Delta. As discussed in more detail below in section 4.4, the call in the draft Framework for economic justification for improvements to levees from HMP to PL 84-99 standards can be economically justified for most, and possibly all, Delta levees. Thus, implementing the DWR Framework could delay necessary investments and increase administrative costs that reduce available resources and increase risk.

In stark contrast to the DWR proposal for a lower Delta levee standard, this Plan argues that many Delta levees should be improved beyond PL 84-99 levels to a higher Delta levee standard described in section 3.2. The argument for making this additional investment is pretty straight-forward: even the Delta-specific PL 84-99 standard does not provide adequate protection from more extreme floods and earthquakes and does not provide a basis for adaption should sea level rise at an enhanced rate. Assuming a cost of $2–3 million per mile for 300 to 600 miles of levees, the $1–2 billion minimum investment that would be required to improve most lowland levees and selected other levees to this higher standard is small compared to the value of the land that they protect, the recreational benefits that they provide, the value of the infrastructure that crosses the Delta, and the increased reliability of water conveyance through the Delta. Furthermore, the cost is substantially lower than improving water supply reliability with isolated conveyance.

4.2 Improve both inspections and emergency preparedness and response to prevent failures

As discussed above and in Appendix E, few if any levee failures actually occur without warning. There is normally a few days to a few weeks warning of flood events. Earthquakes occur without warning, but the consequences of even a moderate-to-large earthquake that affects the Delta are more likely to be some slumping rather than immediate breaches. Even sunny-day failures may be preceded by signs of trouble. Since levee failures typically come after days or weeks of initial warnings, it is clearly cost-effective to invest in emergency preparedness and modern investigative techniques to head off failures before they occur.

Below are some of the measures that might improve this kind of emergency preparedness.

- Create stockpiles of the newer types of temporary means for raising levees such as

“Aquatubes” or “Aquafences.” These allow for temporary increases in the levee height when a particularly severe flood threatens or after an earthquake. These devices can quickly raise the crest of a levee over much greater lengths than can be accomplished with conventional sandbags.

- Create stockpiles of appropriate materials to deal with enhanced seepage and develop the means to transport them quickly to any point in the Delta.
- Set in place plans and procedures for emergency repairs to levees following an earthquake. This might include borrowing from landside toe-berms as suggested above.
- Use newer technology, such as that developed at the University of Texas at Austin by Professor Kenneth Stokoe for monitoring highway and airfield pavements, to conduct periodic inspections of the levees. This technique senses small changes in the levee, such as those caused by rodent burrowing, and thus flags locations that require more detailed inspection.
- Install simple fiber-optic cables at the toes of levees as suggest by Professor Jason de Jong of UC Davis in order to sense deformations. Again, this technique flags locations that require more detailed inspection and, in the event of an earthquake or terrorist activity, would immediately identify trouble spots for emergency managers and national security personnel.

Improved federal, state, county, and community coordination is equally important in preventing failures. Notwithstanding improvements in coordination that are currently being worked on, the suggestion made elsewhere that responsibility for emergency-response planning be turned over to a Delta-region authority with an appropriate funding base appears to have great merit.

4.3 Improve both immediate response and longer-term recovery after failures

In general, emergency response following a breach involves two elements. The first of these is very immediate and involves controlling the spread of flood waters, evacuating threatened people and livestock, and minimizing damage. In the riverine environment this might involve blocking freeway underpasses or otherwise reinforcing secondary levees and making relief cuts through levees to drain floodwaters back into the river system at a lower point on the river. To be effective, these actions require detailed emergency planning and preparation. However, while this kind of planning and preparation should be made for the Delta islands, there is likely little that can be done in this regard on most of the more deeply-subsided islands following a breach. It is difficult or impossible to reduce or stop the flow of water until the island is flooded and water levels equalize. Once that has happened, the breach can be repaired and the island pumped out. However, as illustrated by the repair of the 2004 Upper Jones Tract failure, unnecessary delays and expense can occur unless the repair of the breach is planned and executed properly. In that case larger rocks were used to initially plug the breach but there were insufficient fines to limit continuing seepage to an acceptable rate. That resulted in construction of a waterside berm with provision for the planting vegetation on a bench in part as mitigation for encroachment into the channel, as may be seen in Figure C7 in Appendix C. Thus forward planning and stockpiling of suitable materials for repair of levee breaches is very desirable. In the absence of a one-stop permitting mechanism, it also seems very desirable that this forward planning includes establishment of a fast-track procedure for acquiring any necessary permits or authorizations. Speedy repair of breaches and pumping out of flooded islands not only minimizes damage and losses on the island in question but also the losses that occur as a result of enhanced seepage into adjacent islands.

4.4 Current planning efforts

4.4.1 High-Level Coordination

In response to SB 27, the California Emergency Management Agency, Cal EMA, organized a Delta Multi-Hazard Coordination Task Force. Since funding was never provided by the legislature, this task force operated on limited funding to develop a draft report that recommends that $11.5 million be allocated for various planning studies and that a permanent emergency response fund of $50-150 million be established. Some of the recommended planning efforts appear to overlap with DWR-USACE activities that are already under way, but the final Task Force report has not yet been released.

4.4.2 DWR Emergency Planning

The current DWR studies were initiated by the Metropolitan Water District of Southern California (MWD) which, commencing in February 2006, undertook a study of two options for minimizing the interruption of exports resulting from a hypothetical 50 levee breaches/20 flooded islands scenario. The pre-event scenario involved advance construction of levee and river-flow barriers to block saltwater from entering the south Delta in a major emergency. It was estimated to cost $330-485 million. The post-event strategy allowed saltwater to enter the entire Delta, followed by the creation of an emergency freshwater pathway to the export pumps. The cost estimate for this strategy was about $50 million for pre-positioning of materials, with an ultimate cost of perhaps $200 million. MWD then elected in April 2007 to pursue the second alternative in association with the State Water Contractors and DWR using funds from propositions 84 and 1E to the maximum extent possible.

By January 2008 DWR was reporting on progress on the adopted strategy. At that time, contracts had been signed for the delivery of 240,000 tons of rock to three stockpiles in Rio Vista, Hood, and the Port of Stockton by June 2008. A planned second phase would have increased the quantity of rock at each location and added additional “breach closure materials.”

That work has now apparently been subsumed into the development of a broader program which is intended to guide DWR’s activities during an emergency.[76] This program includes three components:

1. Development of a plan for flood emergency preparedness response and recovery in the Delta. This plan consists of three elements:

    A. In association with USACE, development of a GIS-based flood contingency maps and associated data.

    B. Development of strategies for minimizing the delay in restoring fresh water to the export pumps. This includes advanced modeling of salinity intrusion and risk assessments. Although no results have been officially reported, it is understood that these studies suggest that the Delta flushes out more rapidly than had previously been expected, and that exports could be resumed in a maximum of six months, but more likely in a shorter period, even if multiple islands have been flooded. These studies are expected to produce tools that can be used to guide short-term water conveyance and upstream reservoir operations and prioritization of possible placement of emergency

[76] Delta Flood Emergency Preparedness, Response and Recovery Program, An Overview, DWR Brochure, June 2011, and presentation to Delta Stewardship Council, September 23, 2011.

rock barriers and levee repairs.

C. Definition of the roles and responsibilities of DWR emergency response personnel and coordination with other agencies.

2. Coordination and integration of DWR's plan with the plans of other Delta flood response agencies.

3. Development and implementation of flood emergency response facilities in the Delta. Implementation of this item requires additional legislation to allow redirection of bond funding for this purpose.

4.4.3 County-Level Planning

Work is continuing on various county emergency response plans but these are more oriented to immediate response and public safety than to repair of levee breaches and de-watering of flooded islands. Nonetheless, there are many elements of these plans, such as the flood maps and guide developed by San Joaquin County[77] that could be usefully extended to cover the entire Delta. However, rather than having individual county plans, it would seem to be desirable to have a single integrated Delta-wide emergency response plan that identifies only as sub-sets the actions that need to be taken by the individual counties.

4.5 Discussion of Alternate Risk Reduction Strategies

In summary, while some progress is being made on all three approaches to risk reduction, much of the DWR effort appears to be directed to the third approach, responding to failures after they have happened, instead of preventing them. The current round of DWR studies should be certainly be completed, but going forward much more emphasis should be given to the issues raised by Baldwin (2011),[78] most notably that a regional emergency response agency is required, and that the regional emergency response agency should place much more emphasis on preparation for flood-fighting and emergency response following earthquakes, as discussed herein in Section 4.2.

4.6 Economics of Risk Reduction Strategies

Figure 16 indicates that there are few, if any, islands in the Delta that are in purely agricultural use. However, even the discussions of agricultural value focus only on property value or net profits to farmers, ignoring all the other income and economic activity created by farm employees, suppliers, and related enterprises. For many islands, the energy and transportation infrastructure, homes and businesses far exceed the agricultural value. Even if a flooded island were purely agricultural, permanent flooding would have adverse impacts on the levees of adjacent islands through wave action and enhanced seepage. In addition to the agricultural and infrastructure losses and stress on adjacent levees, though Delta conveyance of water is impacted in the short term, and if islands were to be left in a flooded condition, both in-Delta and out-of-Delta uses of water would be impacted by other water quality issues such as increases in

[77] http://sjmap.org/oesmg/gfcm/Flood_Map_Guide_Final_6-1-10.pdf
[78] Baldwin, R., San Joaquin County Comments on the First Staff Draft of the Delta Plan, 2011, http://deltacouncil.ca.gov/public-comments/read/143?page=1

organic carbon. As noted by both Healey and Mount (2007)[79] and Suddeth (2011),[80] the ecological benefits of additional flooded islands are uncertain, whereas many agricultural islands (particularly those with low-value crops that are said to be not worth saving) provide critical habitat to migrating birds along the Pacific flyway. According to the draft DWR Technical Memorandum, the Delta levees presently provide a home for as many as 500 species, including several rare and endangered species, in its current configuration. Thus, although the current Delta is not as productive and valuable an ecosystem as the historic Delta, it still has considerable ecological value. As discussed elsewhere in this report, creating large open water areas would impact recreation and tourism because most Delta boaters are attracted to the Delta for its meandering, wind-protected channels. Finally, flooded islands also have much higher evaporation rates than agricultural lands so that there is a net loss of water from the system.[81] The following is a summary list of the economic assets and values protected by Delta levees:

- Net farm profits (capitalized into farmland values)
- Residential and commercial structures
- Flood protection of nearby islands/levees (reduced flood-control costs)
- Critical infrastructure such as fuel pipelines, natural gas wells and storage, electricity transmission lines, highways and roads, railroads, deep-water shipping channels, communications infrastructure (TV/radio/phone towers)
- Other income generated by agriculture production (ripple effects)
- Water quality for municipal and industrial users in and outside the Delta
- Wildlife habitat
- Water conveyance
- Water supply (reduced freshwater consumption)
- Recreational values (primarily boating channels and hunting areas)
- Lost opportunity for future beneficial uses

A good start on a more comprehensive assessment of the economics of levee upgrades, repairing breaches and draining flooded islands was made by Suddeth et al. (2008) and refined in Suddeth et al. (2010). In this very influential study, Suddeth et al. calculated the net expected costs for 34 subsided Delta islands and three scenarios: no upgrades from the 2005 conditions estimated by DRMS; upgrades to the Delta-specific PL 84-99 standard; and upgrades to that standard plus an additional 1 foot of freeboard. In addition to an estimate of agricultural land value for each island, the analysis included the value of structures on the islands. The analysis considered the estimated costs of repairing breaches and draining flooded islands and the costs of not repairing islands, which included the cost of rebuilding or re-locating roads and the cost of fortifying nearby islands, in order to make decisions on whether or not to recover flooded islands. In terms of the bullet list above, Suddeth et al. account for most of the first four value categories, but their model does not address the more difficult to measure impacts in the rest of the list.

In their initial analysis, Suddeth et al. find that it is not “economically optimal” to upgrade levees to the PL 84-99 standard, and only cost-effective to repair 18 to 23 of the 34 islands if they fail.

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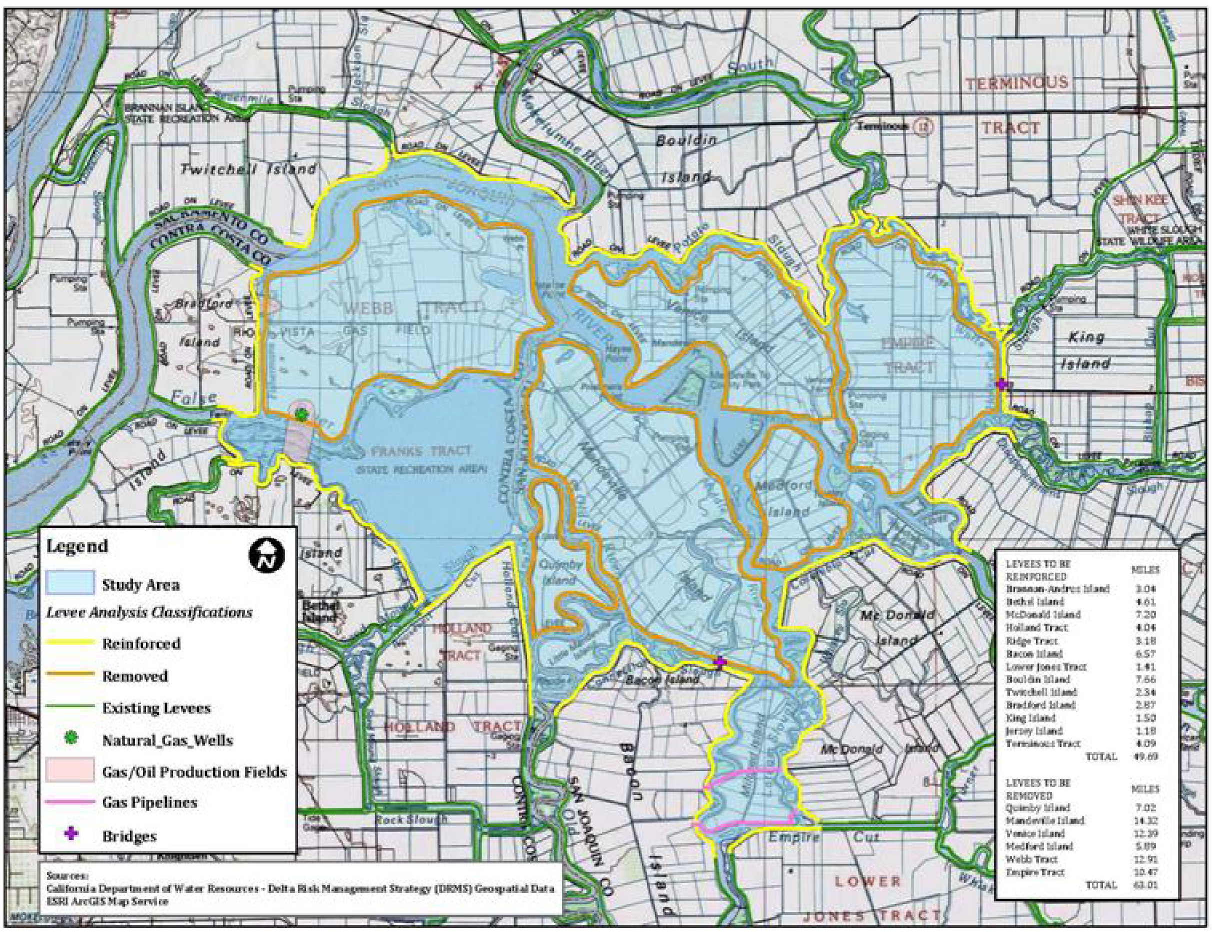
[79] Healey, M., and J. Mount, Delta Levees and Ecosystem Function, Memorandum to John Kirlin, Executive Director of Delta Vision, November 2007.
[80] Suddeth. R., Policy Implications of Permanently Flooded Islands in the Sacramento-San Joaquin Delta, UC Davis Center for Watershed Sciences, 2011, http://watershed.ucdavis.edu/pdf/.
[81] Sacramento Valley Water Use Survey 1977, DWR Bulletin 168, October 1978.

However, this result is very dependent on the assumed costs, values, and failure probabilities, and sensitivity analysis in the article show significant changes when assumptions are adjusted to more realistic values. For example, the initial analysis assumes most agricultural land is worth $2,500 per acre based on a simulation of net profits, when current appraisals for Delta farmland are $6,000 per acre and nearby cropland without Delta flood risk is valued at $10-12,000 per acre. In addition, estimated probabilities of levee failure were taken from DRMS which a previous section explains are thought to err significantly on the conservative side. While the cost estimates that were used for levee upgrades to PL 84-99 were reasonable, it was assumed that each upgrade only reduced the probability of failure by 10 percent. In contrast, DRMS phase 2 report estimated a 24 percent decline in failure probabilities from PL 84-99 upgrade, and improvements might well be even greater, especially if the levee system is upgraded to uniform compliance with the PL 84-99 standard. In addition, the estimated cost of reinforcing the surrounding islands (and thus limiting the propagation of failures) is low, and other costs associated with leaving islands flooded (including the adverse effects on recreation and water quality) were neglected.

Figure 18 The Suddeth et al. (2010) Inland Sea[82]



Fortunately, the most recent version (2010) of the paper includes some much needed sensitivity analysis to the study assumptions. In the most interesting scenario, the authors tripled their

[82] For high resolution image see http://forecast.pacific.edu/desp-figs.html

assumed property values and “Do Not Repair” costs in what they call an “extreme case.” In our view, this scenario is not extreme at all, but uses far more accurate values for two key variables. The results show nine islands that are not repaired, including six contiguous islands in the Central Delta and three small islands scattered in other areas. The results are displayed in Figure 9 of Suddeth et al. and the six central Delta islands are displayed in Figure 18 above.

These six islands in the Central Delta are the most likely candidates for conversion to open water, because they are relatively free of people, property and infrastructure and support mostly low-value crops. Thus, we have included this open water scenario as a policy scenario in subsequent chapters to more fully assess the potential effects to areas not considered by Suddeth et al. such as recreation and several categories of infrastructure. More details are found in subsequent chapters but we preview the results here to complete the present discussion.

The total length of the levees around the six islands is 63 miles, and the total length of the surrounding levees that would have to be improved to a higher standard to deal with higher wave heights and seepage is approximately 50 miles. If Webb Tract, which is one of the eight western islands called out for their importance to protecting against salinity intrusion, and Empire Tract, which houses the new City of Stockton water intake, were to be omitted from the list, the length of the levees removed would drop to 43 miles. The length of levees that would need to be improved, however, would only drop to approximately 45 miles. In our judgment, the cost of reinforcing the surrounding levees to cope with higher wave height and seepage forces would likely be much greater than the $1-2 million per mile cost of improving the levees on the existing islands, thus on the basis of the cost of improving and maintaining levees alone, the creation of this inland sea cannot be economically justified. But there are also additional factors that must be considered. First, Suddeth et al. did not account for major new water supply facilities for the City of Stockton that are being completed on Empire Tract. Accounting for this facility, Empire Tract would surely be excluded from the “do not repair” list, and the water quality problems from permanent flooding of nearby Medford, Venice, and Mandeville Islands would increase due to the nearby intake. Second, this open-water area is in the heart of the Delta’s most popular area for boating recreation and is surrounded by about half of the Delta’s marinas. The recreation experts on our study team, and numerous interviews with Delta recreationists unanimously agreed that this large open-water area would have a large negative effect on the Delta boating economy, for the boating attraction is the Delta’s unique meandering channels protected from wind and waves. Third, although these islands are free of major highways and railroads, almost all of them border the Stockton Deep-water Shipping Channel, and their permanent flooding would create several problems for the Port including the need for increased dredging that is already constrained by a tight time window for environmental reasons. As discussed in the infrastructure chapter, expanding the Port of Stockton is at the center of the region’s economic development, transportation, and air pollution reduction plans.

Taking into account these additional costs, Quimby Island is the only one of these six that might reasonably be considered for a “do not repair” list and eventual conversion to open water. Using this framework, the other three small islands that might be considered for “do not repair” status are Coney, Fay, and Dead Horse. The levee lengths on these islands range from 1.6 miles on Fay to 7 miles on Quimby for a grand total of 16.7 levee miles on the four candidate islands that may be expendable among the hundreds of miles of Delta levees. Even if upgrading and repairing these islands were not technically cost-effective, there would still be some benefits from the investment so that the net savings from letting the 16.7 miles of levees go would be relatively small. In our view, these very small potential savings are not worth the cost, delays, risk, and complexity created by requiring island-by-island, project-by-project justification of every upgrade from the HMP to the PL 84-99 standard as proposed in the DWR Draft Framework.

Given that federal assistance for costly repairs to islands is linked to achieving the Delta-specific PL 84-99 standard, the decision of whether to repair islands in the case of a breach is parallel and virtually the equivalent of whether the levees should be upgraded to the Delta-specific PL 84-99 standard. Thus, the above discussion summarizes the economic argument for our recommendation to upgrade all Delta levees to the Delta-specific PL 84-99 standard.

A second question is whether upgrading Delta lowland levees to a new higher Delta standard is economically justified. The primary economic justification for this additional upgrade is that it is a cost-effective and more financially feasible alternative to other proposals that address the coequal goals of water supply reliability and ecosystem restoration. A robust, seismically-resistant levee system would make a large improvement to water supply reliability. According to this study, $1–2 billion would be sufficient to achieve this higher standard with costs potentially increasing to $4 billion to allow for program management costs and ecosystem enhancements. This is much less expensive than the $12 billion cost estimate of isolated or dual conveyance, although dual conveyance would result in somewhat higher water exports. Water exporters have expressed concerns about whether the $12 billion isolated conveyance is cost-effective and have yet to develop a viable finance plan. Not only are upgraded levees less costly, but they provide a much broader set of benefits. While water exporters would have to pay all the costs of isolated conveyance, they could share the much lower costs of levee upgrades with others.

Water supply is not the only major infrastructure in the Delta that requires protection from seismic risk. Although they were not the focus of the 2009 Delta Reform Act, transportation, energy, and in-Delta water supplies are also critical infrastructure vulnerable to a seismic event. Upgraded levees are a cost-effective joint solution to the problem, rather than a more costly system by system approach. The infeasibility and extreme cost of the system-by-system approach is evidenced by the earlier discussion of the DRMS Phase 2 trial scenarios. Individually protecting Delta highways by building on piers cost $6 billion, individually protecting energy and aqueducts in a south Delta infrastructure corridor cost $4 billion, and individually protecting water exports costs $12 billion. The total cost of individualized solution approach is in excess of $20 billion, and some systems, not to mention in-Delta lives and property, have received no additional protection with the system-by-system approach.

This proposal to make the Delta levees more resistant to earthquake loadings is a logical extension of other seismic retrofit work that has been conducted in the Bay-Delta region since the 1989 Loma Prieta earthquake. These upgrades have already been performed for highways and bridges, dams, water supply systems, and the BART system. The Delta levees are the last major infrastructure element in the Bay-Delta region that needs to be upgraded to modern seismic standards. In order to put the proposed spending of a further $1-4 billion on Delta levees in perspective, it is noted that the Water System Improvement Program of the San Francisco Public Utilities Commission, which is basically a seismic upgrade of the Hetch-Hetchy aqueduct system, is costing $4.6 billion.[83]

Improvement of lowland levees to this standard means that they might also meet the Urban Levee Design Standard but that does not mean that it would be appropriate to construct higher-density housing behind them. It would not. The argument advanced by some that improvement

[83] http://sfwater.org/index.aspx?page=115

of the Delta levees to a higher standard would lead to urbanization assumes a set of other regulatory controls would disappear and that a market would suddenly appear for an urbanized Delta. The Delta Protection Commission, Stewardship Council, and five county general plans are all highly protective of a rural, agricultural Delta and have regulatory authority that would limit significant urbanization. It is true that the additional flood protection would support some reinvestment and revitalization of Legacy Communities, and might facilitate the construction of some limited new recreation and tourism facilities to support enhanced recreation. However, this is a benefit to improved levees, not a cost. Existing law requires that the Delta be protected and enhanced, albeit as an evolving place, and our professional assessment is that most lowland levees need to be improved to this higher standard in order to accomplish this and that it is economically realistic to do so.

Although the details and reasoning is a little different, the recommendation of improved levees in this study is similar to the "Fortress Delta" alternative in the 2007 PPIC report, "Envisioning Futures for the Sacramento-San Joaquin Delta.[84] Although the PPIC evaluation showed that the "Fortress Delta" was the best of the "freshwater Delta" solutions, it was rejected from further consideration in the screening analysis due to "extreme costs." The alternatives that passed the initial PPIC screening for further consideration either involved a peripheral canal estimated to cost $2–3 billion and ecosystem alternatives that do not satisfy the coequal goal of water supply reliability. Given that isolated conveyance is now estimated to cost $12-15 billion, and water supply reliability state law, our proposal for enhancing Delta levees is little more than suggesting that the 2007 PPIC rejection of the "Fortress Delta" alternative should be reconsidered in light of new information and developments.

5 Levee Improvement Strategies and Funding

Commencing in 1973, funding has been provided by the State of California to assist the Delta reclamation districts under two programs.

The Delta Levees Maintenance Subventions Program provides financial assistance to local levee-maintaining agencies for the maintenance and repair of levees in the Delta. It is authorized in the California Water Code, Sections 12980 through 12995. It has been in effect since passage of the Way Bill in 1973, which has since been modified periodically by legislation. One of these modifications provides for the inclusion of project levees in the program as long as more than 50 percent of the island is in the Primary Zone of the Delta, CWC 12980(f). Project levees in the Secondary Zone are not eligible for subventions funding. The intent of the legislation, as stated in the Water Code, is to preserve the Delta as it exists at the present time. A summary of expenditures under the subventions program is included as Table 3.[85] Through FY 2009-2010 the State has provided $147 million against a local share of $118 million for a total of $265 million. Details of the current procedures for prioritizing subvention funding and the required local cost shares are provided in the draft DWR Technical Memorandum (2011).

[84] http://www.ppic.org/main/publication.asp?i=671
[85] Provided by DWR and also included in the DWR Technical Memorandum.

Table 3 Delta Levee Subventions Maintenance Program State & Local Cost Share 1973-2010

	STATE						
Fiscal Years	Maintenance Reimburs.	Priority 1	Priority2	Priority 3	Total Reimburs.	Local Share	**Sub-Total**
	(1)	(2)	(3)	(3)			
	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	**$1,000**
1973-74	200				200	272	472
1974-75	175				175	483	658
1975-76	-				-	-	-
1976-77	190				190	395	585
1977-78	175				175	486	661
1978-79	175				175	323	498
1979-80	-				-	-	-
1980-81	-				-	-	-
1981-82	1,421				1,421	2,091	3512
1982-83	1,334				1,334	1,929	3263
1983-84	1,384				1,384	3,803	5187
1984-85	1,817				1,817	2,279	4096
1985-86	1,335				1,335	1,628	2963
1986-87	1,736				1,736	2,097	3833
1987-88	1,882				1,882	1,501	3383
1988-89	1,295	3,705			5,000	4,371	9371
1989-90	1,913	3,407			5,320	8,668	13988
1990-91	1,610	3,689			5,299	8,404	13703
1991-92	2,266	159			2,425	10,449	12874
1992-93	1,823				1,823	4,244	6067
1993-94	1,774	2,916	376	15	5,081	2,070	7151
1994-95	2,371	2,770			5,141	2,233	7374
1995-96	1,449	2,097			3,546	1,602	5148
1996-97	1,758	1,790			3,548	2,158	5706
1997-98	4,432	2,647			7,079	2,974	10053
1998-99	3,412	1,738			5,150	2,341	7491
1999-00	3,085	3,194	58		6,337	2,715	9052
2000-01	4,954	3,053	55		8,062	3,371	11433
2001-02	3,777	1,784			5,561	2,515	8076
2002-03	3,554	1,446			5,000	4,666	9666
2003-04	4,029	1,996			6,025	6,102	12127
2004-05	4,698	1,227			5,925	6,476	12401
2005-06	5,364	358			5,722	4,220	9942
2006-07	4,485	1,505			5,990	6,647	12637
2007-08	5,645	8,503	2,148		16,296	6,210	22506
2008-09	6,810	4,515	545		11,870	4,799	16669
2009-10	7,254	2,131	41		9,426	3880	13306
	89,582	**54,630**	**3,223**	**15**	**147,450**	**118,402**	**265,852**

(1) Excess maintenance over the maintenance cap and DFG costs are included in the maintenance.
(2) Priority 1 includes HMP and Bulletin 192-82 work.
(3) Priority 2 is priority 1 excess cost over $100,000 per mile cap. Priority 3 is land use changes

The Delta Levees Special Flood Control Projects provides financial assistance to local levee-maintaining agencies for rehabilitation of levees in the Delta. The program was established by the California Legislature under SB 34, SB 1065, and AB 360. The special projects program is authorized in the California Water Code, Sections 12300 through 12314. This program initially focused on flood-control projects and related habitat projects for eight western Delta Islands—Bethel, Bradford, Holland, Hotchkiss, Jersey, Sherman, Twitchell, and Webb Islands—and for the Towns of Thornton and Walnut Grove; in 1996 it was extended to the rest of the Delta. Details regarding the current prioritization of special projects funding and the required local cost shares are also provided in the draft DWR Technical Memorandum. Also, special project bond funding has been authorized for the protection of the Mokelumne Aqueduct, for those levees whose failure would jeopardize water conveyance through the Delta, and projects that reduce subsidence and assist in restoring the ecosystem of the Delta.

A summary of expenditures under the special projects program is included as Table 4.[86] The figure for FY 2009-10 includes $35 million specially designated by the legislature for improvements to the five islands that protect the Mokelumne Aqueduct, $32 million for HMP projects, and about $26 million for Delta-specific PL 84-99 projects. The expenditures for FY 2007-8, 2008-9, and 2009-10 are larger than in previous years because of bond funding approved by the voters in Propositions 84[87] and 1E.[88] Through FY 2009-10, a total of $237 million will have been expended through the special projects program.

Table 4 Delta Levee Program Special Projects State Expenditure 1989-2010

Fiscal Year	Planning & Engineering	Levee Construction	Habitat Enhancement	Total Expenditures
1989-1990	$15,000	$0	$0	$15,000
1990-1991	$5,210,000	$810,000	$0	$6,020,000
1991-1992	$709,400	$4,085,000	$0	$4,794,400
1992-1993	$668,500	$4,148,000	$0	$4,816,500
1993-1994	$140,000	$6,318,054	$0	$6,458,054
1994-1995	$300,505	$1,896,518	$0	$2,197,023
1995-1996	$30,000	$1,419,370	$0	$1,449,370
1996-1997	$513,618	$4,117,720	$0	$4,631,338
1997-1998	$609	$3,201,434	$0	$3,202,043
1998-1999	$0	$2,233,787	$4,035,000	$6,268,787
1999-2000	$80,555	$1,994,673	$4,009,134	$6,084,362
2000-2001	$199,613	$4,183,526	$3,837,381	$8,220,520
2001-2002	$0	$1,333,548	$1,138,797	$2,472,345
2002-2003	$800,985	$6,645,234	$6,961,843	$14,408,062
2003-2004	$95,979	$704,381	$1,118,243	$1,918,603
2004-2005	$188,044	$2,408,507	$972,500	$3,569,051
2005-2006	$553,989	$8,510,163	$446,193	$9,510,345
2006-2007	$922,127	$8,209,557	$59,500	$9,191,184
2007-2008	$1,606,681	$18,449,127	$144,000	$20,199,808
2008-2009	$4,115,986	$18,608,588	$0	$22,724,574
2009-2010	$2,346,311	$91,274,764	$6,117,538	$99,738,613
Totals:	**$18,497,902**	**$190,551,951**	**$28,840,129**	**$237,889,982**

Note: Funds for projects in FY 2008-2009 and FY 2009-2010 have been encumbered but in most cases have yet to be released due to recent, state-wide budgetary uncertainty.

An additional $195 million is currently available from USACE through the CALFED Levee Stability Program. The USACE funding was authorized by the CALFED Bay Delta Authorization

[86] Provided by DWR and also included the DWR Technical Memorandum.

[87] The Safe Drinking Water, Water Quality and Supply, Flood Control, River and Coastal Protection Bond Act of 2006 (Proposition 84) authorizes $5.388 billion in general obligation bonds to fund safe drinking water, water quality and supply, flood control, waterway and natural resource protection, water pollution and contamination control, state and local park improvements, public access to natural resources, and water conservation efforts.

[88] The Disaster Preparedness and Flood Protection Bond Act of 2006 (Proposition 1E) authorizes $4.09 billion in general obligation bonds to rebuild and repair California's most vulnerable flood-control structures to protect homes and prevent loss of life from flood-related disasters, including levee failures, flash floods, and mudslides and to protect California's drinking water supply system by rebuilding Delta levees that are vulnerable to earthquakes and storms. Proposition 84 enhances these efforts with an additional $800 million for flood-control projects.

Act of 2004 which provided for USACE participation in the then CALFED program. These funds are specifically for raising levees to the Delta-specific PL 84-99 standard which was the goal of that program.

The total investment in Delta levees since the inception of these programs will be $698 million plus the local shares for the special projects and the CALFED Levee Stability Program once the funding in the pipeline is expended. The fact that over $351 million of this has already been spent is reflected in the generally improved condition of the levees. Also, because levees tend to fail at their weakest point, such as where they were constructed over old sloughs, many levees have already failed and then been repaired and improved at their weakest point, with the result that the present levee system is more robust than it was before the breaches. Also, concurrent with the cessation of dredging, there has been increased placement of rock riprap on the water side of the levees. Taken together, these three observations mean that historic data on the rate of levee breaches is no longer relevant, and out-of-date data compiled on the previously weaker system should not be repeated in current reports and discussions.

Table 4-1 of the DWR Technical Memorandum provides a breakdown of the funds appropriated for expenditure in the Delta from Propositions 84 and 1E. These funds total $615 million. Table 4-2 of the DWR Technical memorandum provides a breakdown of both the funds committed and the funds expended to February 2010. A total of $293 million had been committed to the subventions and special projects programs and $70 million had actually been expended at that point. The total funds committed amounted to $492 million and the total funds expended amount to $166 million, so that significant funds have been committed or expended for other purposes which include contracts, program delivery, emergency, the urban and non-urban levee evaluation programs, the Sacramento bank restoration program, and bond servicing costs. Approximately $123 million remain uncommitted.

Improvement of Delta levees from at or about the HMP standard to the Delta-specific PL 84-99 standard costs in the order of $1-2 million per mile,[89] the biggest variable being whether suitable borrow material is available on-island or whether it has to be trucked or barged from adjacent islands. With the funds that are in the immediate pipeline plus the remaining bond funds, all the lowland Delta levees and most other Delta levees should be improved so that they are at or about the Delta-specific PL 84-99 standard. Indeed, if expenditure of the bond funds had not been delayed by State spending freezes and other issues, this standard could have been generally met already. Even after all Delta levees have been brought up to the PL 84-99 standard, some continuing funding will still be necessary to take care of unexpected settlements and other maintenance, but this funding might be at a reduced level. For budget purposes it is suggested that a sum in the order of $20 million per year should be allocated for this purpose, but, as discussed subsequently, the year-to-year spending might vary and should be balanced against funding for emergency preparedness and the setting aside of funds for future emergency response and recovery.

As noted above, both the subventions program and the special projects program make provision for the enhancement of fish and wildlife habitat in conjunction with levee improvements. Several alternatives for accomplishing this are illustrated in Figure 6 of the CALFED Levee System Integrity Program Plan including the construction of new waterside berms and the widening or rolling back of the existing levees. These improvements cost much less than the kind of setback levees discussed in the DRMS Phase 2 report, which involves construction of entirely new levees on virgin ground, and might typically cost in the order of an additional $1-2 million per

[89] Based on discussions with reclamation district engineers and DRMS Phase 2 report.

mile. The existing funding provides for a certain amount of this kind of enhancement but if the Delta Conservancy Strategic Plan and the Delta Plan call for more extensive enhancements of this kind, additional funding will be needed.

The cost of improvement of most lowland levees and selected additional levees to a higher Delta-specific standard that will provide 200-year plus protection for floods, earthquakes and sea-level rise and that will incorporate ecologically friendly vegetation on the water side is more difficult to estimate precisely. After improvement to the Delta-specific PL 84-99 standard, levees that do not contain saturated, loose sands may come close to meeting this standard although they would still benefit from wider crowns. Additional width also makes planting on the water side, which is desirable for a number of reasons and may be required by the Delta Plan, much more feasible. Determination of which levees do require additional improvement will require more detailed studies, but prioritization of further improvements is relatively straightforward and does not necessarily require risk analyses or cost-benefit studies. Regardless of whether or not they contain sands susceptible to liquefaction, most lowland levees should be improved to this higher standard because they face the most immediate threat from possible sea-level rise and help prevent salinity intrusion. Certain other levees which are judged to be critical to protecting infrastructure might also be improved to this higher standard if they are shown to contain sands that are susceptible to liquefaction. Figure 16 provides an initial indication of which islands and tracts might be considered to have relatively high priority for further improvements. These further improvements might cost in the order of an additional $2-3 million per mile. If it is assumed that this improvement is required over 300–600 miles of non-project, non-urban levees, the total cost might be as low as $1 billion. However, for general planning and budgeting purposes, it might be desirable to use a higher number like $2 billion. The biggest variable in these estimates is whether or not suitable fill is available on the same island or has to be trucked or barged in. That in turn is both a function of the availability of the materials and the cooperation of the landowners, for on-island borrowing may take some land out of agricultural production. The above estimates assume a combination of on- and off-island borrow sources. If only on-island borrow is used, these cost might be reduced by as much as 50 percent. Alternately, if the regulatory impediments to dredging in the Delta are resolved, good-quality fill material could be obtained for a cost comparable to that of on-island borrow. While there are other potential uses for the dredge spoils that will result from either deepening of the deep-water ship channels or from maintenance dredging, their use for levee improvements would provide a means to keep down the cost of those improvements. These figures also assume that design and construction are executed by the local reclamation districts. If managed directly by DWR or USACE, these costs should be multiplied by a factor of as much as 2 or 3. Costs for non-urban and non-project levee improvements are much lower than costs for improvements to urban levees, which have to factor in encroachments and penetrations and where there is often no land available for widening the levees. This has resulted in the widespread use of deep-cutoff walls that are installed through the existing levees. In addition, there are significant bureaucratic issues which add to the cost, especially when there are many landowners involved. This results in the "soft costs" being as much as 50 percent of the actual construction costs on these projects. Although the possible need to take a strip of agricultural land on the Delta islands and the need to move existing drainage channels, siphons, and pumps are still issues, the cost implications are much smaller for Delta levees and only a relatively small number of landowners have to be accommodated.

The estimated cost of $1-2 billion for improving Delta levees beyond the PL 84-99 standard that is given above not only assumes that the work would be executed by the reclamation districts but also that engineering and permitting costs are no greater than they are at present. This figure also provides only for basic levee construction on existing alignments, not for planting and other environmentally-friendly enhancements. While planting vegetation on the water side of widened levees would add little to this cost, the creation of waterside berms or rolling the levee back as previously discussed in connection with improvements to the PL 84-99 standard might add 50 to 100 percent to the cost. Construction of setback levees on a new alignment would involve land acquisition issues and add significantly to the cost, especially where the setback levee is constructed over peat that has not previously been consolidated.

There are special considerations for levees that protect Legacy Communities in the Delta. Detailed estimation of the likely cost of improving those levees awaits policy decisions that have not yet been made. However, if the levees on the relevant islands are upgraded to the proposed new Delta standard, the Legacy Communities, and also industrial/commercial facilities that serve Delta agriculture such as wineries, crush-pads, and cold storage facilities, would automatically be afforded superior flood protection and special "ring levees" should not be required. In many cases superior flood protection is in fact already provided to these communities and facilities by the existing project levees. For instance, the project levee that borders the Sacramento River in Walnut Creek East already has a wide crown, exceeding 50 feet at some locations, in order to accommodate a two-lane highway with parking on either side. While some additional improvements might be required elsewhere to protect legacy communities, the issue is more one of non-compliance with vegetation and encroachment and calculated seepage gradient requirements that are included in various USACE and FEMA guidelines and policies, rather than real flood risk. This issue could be addressed much more cost-effectively by granting variations from national policies rather than requiring unnecessary construction which might destroy the communities that are trying to be protected.

There are three potential sources of funding from within the Delta for maintenance, improvements, and emergency response: (1) the traditional funding from the landowners, who also make in-kind contributions to inspection and maintenance; (2) the owners of the infrastructure that passes through the Delta; and (3) the agencies that convey water through the Delta. The Delta Stewardship Council has proposed the creation of a new agency, the Delta Flood Risk Management Assessment District, with fee assessment authority. Local government officials in the Delta have expressed concerns about this proposal, and have expressed a preference for a joint powers authority (JPA) of the five counties or the Delta Protection Commission take on this role. Regardless of the entity, and leaving politics aside and just looking at this as an engineering management and risk reduction issue, it would be beneficial for a Delta region-centric entity to allocate the funding of Delta levee improvements once the present bond funding is exhausted, or even sooner. This entity should also be the entity that is responsible for coordinating emergency preparedness and response because of the trade-off that has been previously discussed of investments in levee improvements and in emergency preparedness and response. Only if funding of both levee improvements and emergency preparedness response and recovery is controlled by a single entity whose prime concern is the protection and enhancement of the Delta in addition to consistency with the coequal goals, will it be possible to make a rational and efficient allocation of the available funds.

In addition to the funding of the improvement of selected levees to the higher Delta-specific standard, continuing funding will be required for maintenance of the existing levees and for emergency preparedness response and recovery. It has been suggested above that $20 million per year might be an appropriate sum for continuing maintenance of all Delta levees, but this figure might vary from year to year as more or less money is put into emergency preparedness response and recovery. A total sum in the order of $50 million per year might be appropriate to cover both maintenance and inspection and emergency preparedness. Some fraction of this sum should be set aside each year to provide for emergency response and recovery to supplement any fund that the State has established for that purpose in the meantime. To put this sum into perspective, although the total cost should not be borne by either highway users or water conveyance alone, if it were borne by highway users, there would need to be a toll of $2 on each use of the state highways in the Delta and if it were borne by the state and federal water contractors, there would need to be an additional charge of $10 per acre-foot, assuming average exports of 5 maf. It would also be entirely reasonable that the state and federal governments contribute funding to this entity. If it is the policy of the State to protect and enhance the Delta because that is judged to be of benefit to the region and the state, then it becomes the State's responsibility to provide funding that could, for instance, be directed primarily to widening levees so that they can accommodate vegetation on the water side and allow construction of improved recreational and tourism facilities that benefit the entire region and beyond. Outside its operation of the Central Valley Project, the federal government has interests and obligations that include the continuing downstream effects of hydraulic mining on federal lands, navigable waterways, and national economic security.

Implementation of the necessary improvements to Delta levees would be greatly helped by reducing or eliminating regulatory impediments to action by the creation of a one-stop permitting system for selected activities within the Delta including dredging, levee construction, and ecosystem restoration.

6 Periodic Update of the Flood Management Plan for the Delta

One of the four specific directives regarding the Economic Sustainability Plan that was given in the 2009 legislation is to include "comments and recommendations to the Department of Water Resources concerning its periodic update of the flood management plan for the Delta." These recommendations are:

1. Update the expected maximum water surface elevations in the Delta taking into account both the findings and the recommendations of the Central Valley Flood Protection Plan and climate change considerations. This should be done as soon as possible without waiting for the 2017 update of the Central Valley Flood Protection Plan.

2. Make provision in the Central Valley Flood Protection Plan and otherwise for re-activation of historic flood plains upstream from the Delta and by additional flood bypasses, such as the proposed Lower San Joaquin River Flood Bypass, in order to reduce peak water surface elevations in the Delta.

3. Reaffirm that it is the policy of the State to improve and maintain all non-project levees to at least the Delta-specific PL 84-99 standard.

4. Establish an additional policy to improve most "lowland" levees and selected other levees to a higher Delta-specific standard that more fully addresses the risks due to earthquakes, extreme floods, and sea-level rise, allows for improved flood fighting and emergency response, provides improved protection for legacy communities, and allows for growth of vegetation on the water side of levees to improve habitat. Define this standard in more detail as necessary.

5. Cooperate with other state and federal agencies to facilitate the renewed use of appropriate dredging in the Delta.

6. Establish as state policy that in the future any flooded islands will be recovered and that existing flooded islands should be restored as tidal habitat in order to reduce the loadings on adjacent islands in addition to providing ecosystem benefits.

Part Two: Analysis of Key Economic Sectors in the Delta

Chapter 6: Framework for Analysis

This chapter describes a framework of policy scenarios that will be considered in chapters 7– 9 which contain detailed analyses of key components of the Delta economy: agriculture; recreation and tourism; and infrastructure including energy, transportation and water systems. The first two areas were called out in Delta Protection Commission's Framework Study as the key drivers of the Delta economy. Additional research for chapter 2 of this report identified Transportation, Warehousing, and Utilities as an additional economic driver for the Legal Delta, and this sector is closely tied to energy, transportation and water infrastructure. In addition, infrastructure by definition underlies all parts of the Delta economy. The research and outreach for this report has revealed the importance of the Delta as a regional and state infrastructure hub and Delta policies currently under development have significant implications for a broad range of infrastructure. This chapter discusses the framework that will be utilized for the detailed analysis of the key sectors, and defines the scenarios for policy choices that will be made in the Delta in four important areas: water conveyance, habitat enhancement, levee and flood control investment, and land-use regulation.

Each of the following three chapters follows a common framework. First is a data-driven description of the current baseline and trends for the sector, which may include reference to other significant reports on the sector. Second is discussion of the likely outcomes for the economic sector under the baseline policy scenario, followed by recommendations that might improve economic sustainability under the baseline scenario. Third, each chapter includes an evaluation of the positive and negative impacts of alternative policy choices on economic sustainability in each area. Some topics, such as taking land out of agricultural production, are suited for a detailed quantitative analysis. Other topics, such as how the creation of tidal marsh could affect Delta tourism and recreation, will necessarily rely on more qualitative analysis and expert opinion. Finally, each chapter will include discussion of additional issues or proposals as appropriate, including relevant strategies outlined in the Delta Vision strategic plan. In some chapters, there will be discussion of additional issues or proposals. For example, the recreation chapter will discuss a recent recreation plan developed by California State Parks.

1 Baseline Scenario

The baseline analytical scenario is the vision that includes few major policy changes. However, it is not a "status quo" scenario as some significant human and environmental changes are likely in the Delta between now and 2050. Population growth will continue in the Delta counties, some agricultural land will be developed in the secondary zone within city boundaries, sea level is expected to increase by a foot, tertiary treatment will become operational at most municipal wastewater plants discharging into the Delta and improve water quality, and significant investment in levees will occur.

As discussed in Chapter 2, the population of the region surrounding the Delta is growing. The 2010 Census found the population in the five Delta counties was 3,767,312 and grew at a 1.4 percent annual rate over the decade, slightly faster than the 1 percent annual growth rate for the state of California. Based on the 2010 Census results, the forecasting firm Global Insight projects the five-county population will reach 5.57 million in 2040, a growth rate that projects to 6.1 million in 2050. Higher projections from the California Department of Finance, most recently updated in 2007, put the 2050 population at 6.9 million. Despite this growth, the population of the Primary Zone of the Delta has remained steady, and is projected to remain constant in the baseline scenario. In contrast, the Secondary Zone will continue to experience significant growth within the boundaries of its incorporated cities.

For the four policy choices, the baseline scenario is as follows. The baseline scenarios are not recommended policy choices, but simply represent the most logical starting place for the analysis. Baseline conditions could be recommended for some policy choices, but not others.

- *Baseline Water Conveyance*: Through-Delta Conveyance. Under this scenario, water would continue to be conveyed to the south Delta pumps through Delta channels. The level of water diversions would be constrained to less than 5 million acre feet per year in compliance with the current biological opinions.
- *Baseline Habitat Conservation Measures*: None. None of the habitat conservation measures outlined in the BDCP drafts would be implemented in the baseline scenario. The positive and negative impacts of each of the major conservation measures will be assessed individually in the other scenarios.
- *Baseline Flood Control*: All levees upgraded to PL 84-99. As discussed in Chapter 5, the upgrade of most Delta levees to PL 84-99 standards is a reasonable expectation with currently identified resources and on-going maintenance. Most levee breaks would be repaired to original conditions and islands restored. Unincorporated towns in the Primary Zone would remain in the 100-year flood plain, significantly constraining development. Urban areas in the Secondary Zone such as West Sacramento would successfully achieve 200-year flood protection status in accordance with current plans.
- *Baseline Land Use Policy*: Current Policy. Delta Protection Commission guidelines remain in place over the Primary Zone, and land-use planning and regulation would remain under the jurisdiction of local governments. The Delta Stewardship Council does not take an active regulatory role in regards to Delta land use.

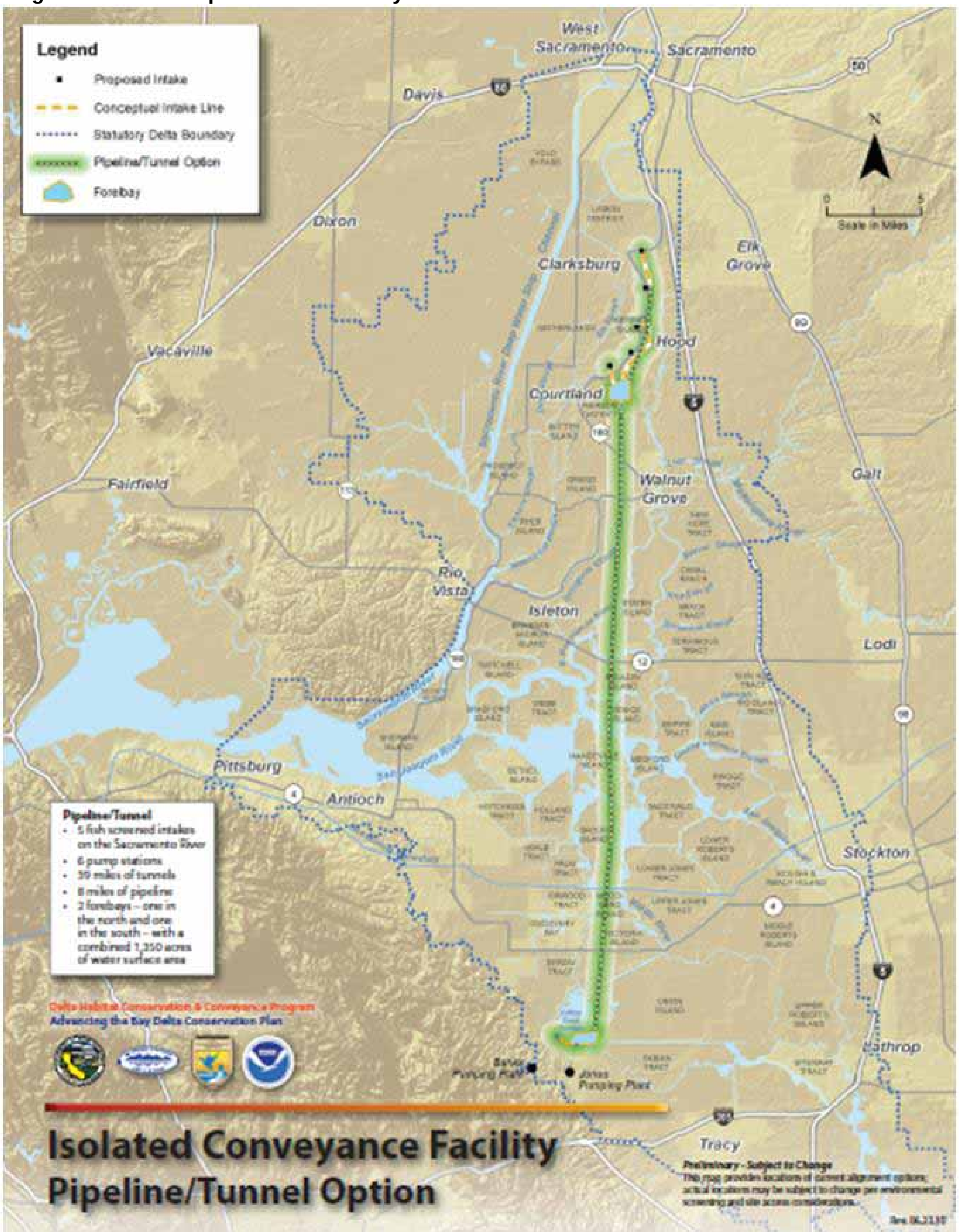
2 Isolated Conveyance Scenario

The leading proposal for new water conveyance facilities in the Delta is a 15,000 cfs (cubic feet per second) tunnel extending from the Sacramento River near Hood to the CVP and SWP pumps near Tracy. The facility would include a pair of 34-mile long, 33 ft. diameter tunnels running between a new intermediate forebay near Courtland to a new forebay adjacent to the existing Clifton Court Forebay near Tracy. Five new water intakes would be built along the Sacramento River between Clarksburg and Courtland, and another 13 miles of pipeline would be required to convey water from the five intakes to the intermediate forebay. Each of the five intakes and the intermediate forebay would have pumping plants with a combined 210 MW electrical load.

According to the operational criteria described in the latest BDCP documents, the new conveyance would increase average water exports from the Delta in 2025 from 4.7 maf with through-Delta conveyance under the existing biological opinions to 5.4 to 5.9 maf. The footprint of a tunnel is significantly less than a surface canal, it will still consume roughly 8,000 acres, mostly agricultural land in Sacramento and San Joaquin counties. The new intake facilities will significantly alter the shoreline of the Sacramento River between Clarksburg and Courtland.

The goals for in-Delta agricultural, municipal, and industrial water quality are among the most important provisions for the Delta economy. Both the November 2010 draft BDCP and a May 2011 revised operation documents state that existing D-1641 water quality standards will be met in the north and west Delta with the measuring point moved slightly upstream in the Sacramento River. Notably, none of the BDCP operations descriptions make any commitments to water quality in the central or southern Delta, the areas at most risk from increasing salinity impacts from isolated conveyance. The uncertainty surrounding Delta water quality impacts and the importance of the issue to the Delta economy makes it one of the most difficult issues to assess in the economic sustainability plan.

Figure 19 BDCP Map of Tunnel Conveyance[90]



[90] For a better resolution image see http://forecast.pacific.edu/desp-figs.html

While alternative sizing and other options for water conveyance are under development and consideration, none of these options has been described in sufficient detail at this time to be included in this analysis. Thus, the tunnel conveyance described in the most recent BDCP is the only alternative to through-Delta conveyance that will be considered in this report. As alternatives—such as a smaller 3,000 cfs isolated conveyance facility—are developed in more detail, additional analysis would be warranted.

Box 1 Financing Isolated Conveyance: Potential Risks for Delta Communities and Taxpayers

While the impacts on the state and federal water projects is generally beyond the scope of this plan, the financial feasibility of water contractors' plans to pay for the proposed isolated conveyance is of critical importance to economic sustainability in the Delta. There are significant questions as to whether isolated conveyance is financially feasible, especially if operated under the proposed operating criteria that would not significantly increase water exports. Despite years of work on the BDCP, there is still no finance plan while the cost estimates continue to rise.

Inadequate financing could create serious problems such as 1) pressure to increase water exports from the Delta beyond agreed upon environmental and in-Delta water quality protections, 2) pressure to divert funds from Delta mitigation, habitat improvement, and flood control programs, 3) subsidies that divert general tax revenues from other public needs, 4) increased pressure for transfers of water from San Joaquin Valley agriculture to urban customers that could adversely affect the San Joaquin Valley agricultural economy over and above losses to Delta agriculture, and 5) the risk of a costly stranded asset that unnecessarily burdens water ratepayers for decades.

3 Habitat Conservation Scenarios

In addition to isolated water conveyance, the BDCP proposes 18 additional conservation measures. Similar conservation measures are under consideration by the Delta Stewardship Council for the Delta Plan, and some of these measures are also included in the Ecosystem Restoration Program proposed by the Department of Fish and Game. In this report, we use the draft BDCP descriptions of the conservation measures, because they are more detailed and thereby better suited to the analysis.

The individual conservation measures could have negative or positive impacts on different aspects of the Delta economy. Our analysis will not examine all 18 measures, but focus on four major proposals that would change the current use of 1,000 acres or more of Delta land. For simplicity, the measures will be considered individually rather than as a package at this initial stage. The four major conservation measures include:

- *Yolo Bypass Fisheries Enhancements*: Requires thousands of acres in new flowage easements. More frequent flooding and improved fish passage in the Yolo bypass will benefit fish and flood control, but will reduce agricultural production.
- *San Joaquin River Floodplain Restoration*: Creation of new seasonally-inundated floodplain habitat along the San Joaquin River between Vernalis and Stockton using setback levees. Approximately 10,000 acres of land would be in the new floodplain.
- *Tidal Habitat Restoration*: Up to 65,000 acres in agricultural land converted to tidal habitat in designated zones throughout the Delta. This scenario requires breaching levees and restoring subsided islands to shallow water habitat. If fully implemented, this strategy would affect the most agricultural land and have the highest capital costs. Preliminary cost estimates are $1.5 billion or more than $23,000 per acre of tidal marsh created.
- *Natural Communities Protection*: There are several elements to this conservation measure including the acquisition of 8,000 acres of rangeland for conversion to natural

grasslands, acquiring agricultural easements or purchases on 32,000 acres that would be restricted to "wildlife friendly" agriculture, and the conversion of 700 acres of rangeland to vernal pools and alkali wetlands.

For all of these measures, it is important to note that there are alternatives to the BDCP proposals being developed, and that the BDCP proposals are continuing to be refined in work groups. For example, there is an alternative to the San Joaquin River floodplain proposal in BDCP for an enhanced flood bypass at Paradise Cut. The alternative proposal has been negotiated between environmental groups and local landowners and reclamation districts. Another example is Yolo County's efforts to work with the BDCP's Yolo Fisheries Enhancement Working Group to reduce the agricultural impacts and develop mitigation measures.

4 Levee Scenarios

Investment in levees and other flood control measures could be more or less than described in the baseline scenario. Some have proposed creating large expanses of open water habitat in the Delta through the intentional flooding of Delta islands or an explicit policy of not repairing islands when and if they flood in the future. On the other hand, an increased level of levee investment within the Primary Zone could bring some areas to 100-year or 200-year levels of flood protection and allow increased opportunities for economic development.

Six Island Open Water Scenario
There have been proposals to transform large expanses of the Delta to open water. Proponents argue that open water could provide environmental benefits to native fishes, and that it isn't cost-effective to repair or upgrade levees around most Delta islands. The most expansive proposals would transform 20 or more Delta islands to open water, and are illustrated in the "eco-friendly" Delta map in a recent report from the Public Policy Institute of California. As discussed in detail in an appendix, the Suddeth, Mount and Lund (2010) analysis understates the benefits and overstates the costs of maintaining Delta islands. In addition, this strategy faces substantial legal and political hurdles that make the more expansive open water scenarios exceedingly unlikely. A very expansive open water scenario is clearly incompatible with economic sustainability in the Delta, and there is little point in evaluating it in detail.

However, a smaller open-water scenario is likely to be considered as a possible component of the Stewardship Council's Delta plan and is more economically, legally, and politically viable. A smaller scenario is illustrated in a recent letter from Jeff Mount to the Delta Stewardship Council, and in Figure 9 of the Suddeth, Mount and Lund (2010) paper. [91] The result comes from running the Suddeth, Mount, and Lund analysis with assumed property values that more closely match market values and a more accurate infrastructure costs, but still does not capture all of the economic benefits provided by the levees. Thus, this scenario can be considered a reasonable upper-bound on the extent of open water that could be economically justified in the Delta. Most notably, the figures illustrate six contiguous islands in the Central Delta as open water. These islands are the most attractive candidates for open-water habitat because they are very sparsely populated, mostly grow low-value agricultural crops, and are not crossed by completed major physical infrastructure such as highways, railroads, or natural gas pipelines.

While the lack of physical infrastructure and population substantially reduces the cost of permanent flooding compared to nearby islands like Bouldin and McDonald, eliminating these islands would still entail significant economic costs. These costs would include but are not

[91] http://watershed.ucdavis.edu/pdf/Suddeth-Mount-et-al-2010-SFEWS.pdf

limited to the elimination of about 10,000 acres of farmland and some recreational facilities, increased dredging costs for the Stockton Deepwater Ship Channel, and significant reinforcement of nearly 50 miles of adjacent levees that would be subject to increased pressure from waves and under seepage.

Increase to Higher Standard Levees in Targeted Areas
In this scenario, areas surrounding strategically targeted areas would have levees upgraded beyond the PL 84-99 standard. As explained in Chapter 5, these could be upgrades to increase seismic resistance, or they could be targeted upgrades to support at least 100-year flood protection in and around Legacy Communities to allow development and investment consistent with the rural character of the Delta. This scenario would also further the statewide goal of increased water supply reliability, would allow the growth of natural vegetation on the water side of the levees as part of an overall ecosystem restoration plan, provide a basis for addressing possible sea-level rise, and would provide increased protection for the critical infrastructure that passes through the Delta.

5 Regulatory Scenarios

In the following chapters, we take an initial pass at envisioning how adjustments to the land-use regulatory framework could affect economic sustainability in the Delta. The draft Delta Plan under development by the Delta Stewardship Council envisions expanded land-use regulations in the Legal Delta to support the coequal goals of water supply reliability and ecosystem restoration. In contrast, some of the Delta counties are interested in reducing the restrictions in the current Delta Protection Commission guidelines in concert with increased flood control investments.

Increasing the regulatory power of the Delta Stewardship Council could affect economic sustainability in the Delta. As the Stewardship Council's fifth draft plan is written, most proposed investment in the Legal Delta outside the spheres of influence of incorporated cities could be regulated by the Delta Stewardship Council. In particular, any location that is a potential location for a conservation measure or water conveyance facility in the future is explicitly called out in the Delta Plan for increased regulation. Compared to the current regulatory framework, the proposal would increase the level of regulation in the Primary Zone and expand the regulatory reach of State agencies in the Delta into much of the Secondary Zone. The policy would restrict and increase the cost and risk of property improvements for many Delta residents, businesses, and local governments beyond that experienced in other areas of the state making the Delta a comparatively less attractive area for new investment. The new regulatory policies are described in Chapter 4 of the Delta Plan which is currently in its fifth draft with a sixth draft expected in a few weeks. These new regulations could have profound implications for the Delta economy, although implementation details and how they will work in practice are still uncertain.

While the trend is towards increasing regulation at the state level, some local governments around the Delta are interested in reducing regulation to promote economic development. The signs of stagnation within existing communities are thought by some to be caused by excessive regulation that discourages new investment. One mechanism proposed for reducing regulation is to shift some of the Delta Legacy Communities from the Primary to the Secondary Zone, an unlikely change since it would require an act of the State legislature which seems more inclined to expand the area within the Primary Zone rather than reduce it.

In addition to the Delta Protection Commission Plan and County General Plans, it is important to note that all of these areas have been remapped into the FEMA 100-year flood zone, or are in the process of being added to the 100-year flood zone. Thus, reduced regulation would have little impact unless it were combined with increased flood-control investments and technical evaluations to achieve designation for 100-year flood protection or potentially 200-year urban flood protection in the designated area. In some areas outside the Delta, development generates resources finance flood-control investments, but in the Delta Legacy Communities the scale of development required to finance levee upgrades would be inconsistent with the rural character of the Delta, County General Plans, not to mention the plans of state agencies such as the Delta Protection Commission and Delta Stewardship Council. Thus, some of the analytical chapters consider the increased flood control and reduced land-use regulation scenarios as a package rather than individually.

6 Delta Vision Strategies

As discussed in Chapter 4, the October 2008 Delta Vision Strategic Plan provided a list of strategies and actions to support their second goal, "Recognize and enhance the unique cultural, recreational and agricultural values of the California Delta as an evolving place, an action critical to achieving the coequal goals." The specific actions were:

- Apply for designation of the Delta as a federally recognized National Heritage Area.
- Expand the State Park and Recreation Area network in the Delta.
- Establish special Delta designations within existing federal and state agricultural support programs, primarily regional labeling and marketing programs.
- Conduct research and development for agricultural sustainability in the Delta, focusing on developing agricultural practices consistent with habitat and ecosystem restoration.
- Establish new markets for innovative agricultural practices such as carbon sequestration credits and conservation easements.
- Charge the Delta Protection Commission with creating a regional economic development plan that addresses agriculture, recreation, tourism, and innovative land use.
- Establish enterprise zones that use tax incentives to spur investment at the major "gateways" to the Delta.
- Establish a Delta Investment Fund for regional economic development and adaptation. Initiate the fund with state funding, and structure it to accept revenues from federal, state, local, and private sources.
- Adopt land-use policies that enhance the Delta's unique values and that are compatible with the public safety, levee, and infrastructure strategies.

For some of the strategies, action is in progress or complete such as the feasibility study for Natural Heritage areas,[92] a recent report from the UC Agricultural Issues Center that assessed the viability of some alternative and innovative agricultural approaches in the Delta,[93] and the preparation of this Economic Sustainability Plan.

The state budget and larger fiscal trends have presented significant challenges for some of the other strategies. While State Parks has developed a plan for the Delta, fiscal pressures have put all the state parks and recreation areas in the Delta on the closure list, the opposite of expanding the network. Enterprise zones were initially targeted for elimination in the 2011-12 state budget. Although enterprise zones survived this year's budget cuts, actions continue to reduced and reform enterprise zones, and the prospect for approving significant new enterprise

[92] http://www.delta.ca.gov/heritage.htm
[93] http://aic.ucdavis.edu/publications/AIC_Delta_study_final.pdf

zones is low. Regardless, much of the Delta is already in Enterprise Zones, including virtually all of the Delta in San Joaquin County.

Other strategies are discussed when appropriate in the analytical chapters, and promising strategies will be reinforced in the final recommendations including specific priorities and strategies for the Delta Investment Fund.

Chapter 7: Agriculture

1 Overview and Key findings

- Close to 80 percent of all farmland in the Delta is classified as Prime Farmland, the California Farmland Mapping and Monitoring Program's highest designated tier.
- Total cropped acreage in 2010 was 423,727 acres, not including approximately 38,000 acres of grazing land.
- The top five Delta crops in terms of acreage are: 1) Corn, 2) Alfalfa, 3) Processing Tomatoes, 4) Wheat, and 5) Wine Grapes.
- Total crop value in 2009 was approximately $702 million. Truck and vineyard crops account for 59 percent of crop revenues on 18 percent of acreage.
- The top five Delta crops in terms of value are: 1) Processing Tomatoes, 2) Wine Grapes, 3) Corn, 4) Alfalfa, and 5) Asparagus.
- The highest per-acre values in the Delta come from truck crops mainly situated in the southern Delta and deciduous crops principally located in the northern Delta.
- The approximately $702 million in Delta crop production and $93 million in Delta animal and animal product revenue has an economic impact of 9,681 jobs, $683 million in value added and $1.416 billion in output in the five Delta counties. Across all of California, the economic impact of Delta agriculture is 12,934 jobs, $819 million in value added, and $1.643 billion in output.
- When related value-added manufacturing such as wineries, canneries, and dairy products are included with the impact of Delta agriculture, the total economic impact of Delta agriculture is 13,179 jobs, $1.059 billion in value-added, and nearly $2.647 billion in economic output in the five Delta counties. Including value-added manufacturing, the statewide impact of Delta agriculture is 25,125 jobs, $2.135 billion in value-added, and $5.372 billion in economic output.
- The 10-year land allocation forecast in the baseline scenario predicts a future increase in vineyards, deciduous, and truck crops, and decreases in grain and pasture crops. Field crops will continue to account for 50 percent or more Delta agriculture acreage for the foreseeable future. This shift of 5 percent of land to higher value crops could lead to an approximately $111 million gain in crop revenues.
- The potential impact of policy changes on Delta salinity is highly uncertain at this time and depends on decisions on water quality standards and the effect of isolated conveyance. A preliminary estimate of losses from increased salinity is between $20 million and $80 million per year. The loss of farmland to construct the conveyance facility is estimated to generate an additional $10 to $15 million in crop losses per year.

- The agricultural impacts of most of the BDCP conservation measures are difficult to quantify due to the lack of precision in site specification and other details. Broad ranges of potential annual crop losses have been calculated from the land requirements and descriptions of easement costs in the draft BDCP.
    - Tidal habitat restoration losses range from $18 to $77 million annually with lower losses when restoration is targeted to Suisun Marsh.
    - Natural Communities Protection losses are estimated to range from $5 to $25 million annually.
    - San Joaquin River Floodplain crop losses are estimated at $5 to $20 million annually, and could be reduced significantly by implementing an alternative proposal to expand an existing bypass at Paradise Cut.
    - Yolo Bypass Fishery Enhancements could generate crop losses between $7 and $10 million annually.

2 Current Status and Trends

2.1 Mapping Delta Agriculture

Delta agriculture is part of a complex and constantly-changing landscape, and it presents many challenges to precise measurement. Over the past few years, studies and data-collection by a range of state and federal agencies have yielded results which provide a detailed overview of the Delta's diverse agricultural backdrop. The use of empirical techniques such as satellite imaging, digitization of farm records, field surveys, and public review have accumulated a wealth of information pertinent to policymaking. None of the data sources described below is complete in itself, but collectively leveraged they create the best available picture of Delta agriculture and its broad role in the Delta economy.

2.1.1 Land Use Data

Field Borders

California law requires full reporting of agricultural pesticide use. Each Delta county collects information from farmers on all crop fields in which pesticide applications are conducted. Through the use of geographic information system (GIS) software, four of the Delta counties digitally map that data to form a mosaic of agricultural fields within their borders. This data is extremely useful, as it provides recent data on fields intended for actual use and harvest, and includes specific information on the crops each land manager intends to grow in the coming year. This data enables analysis of Delta agriculture at an extremely granular level, that of the individual crop field. Approximately 90 percent of Delta acreage in this study is represented at this level. One challenge presented by this data is that though the vast majority of crop fields have some form of pesticide application, the small percentage that do not is not included and must be estimated by other means.

National Agricultural Statistics Service

For the two counties which do not digitally map their field borders, satellite remote sensing data captured and made available by the National Agricultural Statistics Service (NASS) provides good information. The data collected by this agency is applied in a wide range of agricultural applications, and the accuracy of the methods used to determine crop type is quantified in detail. Though less accurate than direct field borders reporting, this data shows agriculture not permitted for pesticide use, and provides a means to survey Delta land not covered by field borders.

Farmland Mapping and Monitoring Program

For estimates of total farmland acreage, GIS data collected by the California Farmland Mapping and Monitoring Program (FMMP) was employed. This state program uses a combination of satellite imagery, public review, and field surveys to produce a complete map of the state's agricultural lands. FMMP maps were leveraged by making use of their categorization of grazing land. Though grazing land is not actively farmed, it is sometimes incorrectly captured in the NASS data as active pastureland; close examination of areas marked by FMMP as grazing land eliminated such errors.

National Agriculture Imagery Program

Public aerial photography provided by the National Agriculture Imagery Program is used to resolve major inconsistencies between the previously described data sources. While it is impossible to eliminate the more minute discrepancies, for large acreage areas in which conflicts are noted, NAIP photos allow a direct look at the area in question in order to ascertain into what land use category a parcel should be attributed.

UC Berkeley Resilient and Sustainable Infrastructure Networks (RESIN)

The RESIN project at Berkeley mapped areas of the Delta region expected to undergo urbanization in the future. These were used to determine the extent of urbanization expected to occur on agricultural lands, and those effects are included in the long-term forecasts of agricultural land allocation presented in Section 5.

2.1.2 Revenues, Profits, and Costs Data

County Crop Reports

In order to determine aggregate revenues from Delta crop production, crop yield and price figures published in each county's 2009 crop report were used. These were the most recent figures available at the time the data was compiled. Though the values used in reporting are collected through a variety of sources and represent average yields for the entire county, they offer the most practical means of determining total revenues from Delta agriculture. Where possible, outside sources were consulted to obtain more accurate values for Delta-specific agriculture.

University of California Cost and Return Studies

The University of California Cooperative Extension prepares extremely detailed studies on the costs and returns associated with establishing and maintaining various crops in different regions of the state. Where available, this analysis drew from the UC Cooperative Extension studies conducted in Delta regions to calculate various costs and profits expected from different agricultural operations in the Delta region.

2.2 Crop Categories

In order to facilitate presentation and analysis of Delta agriculture, it is necessary to categorize crops into a limited number of discrete categories. In addition to enabling the use of econometric techniques for forecasting future land use, these categories allow for the broader overview of Delta agriculture presented in the tables and maps throughout this report. Examples of major Delta crops from each category are outlined in Table 5 below, and the full crop category table is included in Appendix G.[94]

[94] In response to a suggestion by the California Department of Food and Agriculture at both a DPC meeting and a comment letter on an earlier draft, alfalfa was moved from the pasture to field crop category in this draft. In addition to the significant change of reclassifying alfalfa, some additional

Table 5 Crop Category Examples

Deciduous	*Almond, Cherry, Pear, Walnut*
Field	*Alfalfa, Corn, Rice*
Grain	*Barley, Oats, Wheat*
Pasture	*Pastureland, Clover*
Truck	*Tomato, Asparagus, Potato, Blueberry*
Vineyard	*Grapes*

2.3 Delta Agricultural Acreage

Total Farmland Acreage

All agricultural production in the Delta is dependent on high-quality farmland able to support it. Adequate soil quality, moisture, and temperatures are just a few of the characteristics necessary to support sustainable high yields. FMMP mapping uses a tiered system of farmland categories which provide a comprehensive view of agriculture suitability around the Delta. Since FMMP surveys are updated every two years, they also allow observation of the continuing effects of urban growth and expansion on agricultural farmland. The table and figure below offer a snapshot of Delta farmland in 2008, the most recent year from which FMMP maps are available. The total size of available farmland in the Delta is 500,383 acres, with almost 80 percent of the total acreage designated in the FMMP's top tier of Prime Farmland.

Table 6 Total Farmland Acreage, 2008

County		**Class**	
San Joaquin	267,741	Prime Farmland	396,554
Sacramento	71,722	Farmland of Statewide Importance	33,360
Yolo	54,644		
Solano	53,509	Unique Farmland	29,525
Contra Costa	49,685	Farmland of Local Importance	40,944
Alameda	3,082		
Total	**500,383**	**Total**	**500,383**

Harvested Acreage and Crop Allocation

This analysis places the total number of Delta acres in agricultural production in 2010 at 461,380 acres. Acreage includes all irrigated crops and pastureland, and grazing land. Table 7 depicts the total acreage of each crop category by county, as well as totals for the entire Delta. Table 8 depicts the largest crops by total acreage.

adjustments were also made to low acreage crops so that the groups were more consistent across value, salt tolerance, and crop type.

Table 7 Delta Agricultural Acreage, 2010

Crop Category	*San Joaquin*	*Sacramento*	*Yolo*[1]	*Solano*[1]	*Contra Costa*[2]	*Alameda*[2]	**TOTAL**
Deciduous	7,127	6,902	816	486	1,426	82	**16,839**
Field	127,912	33,178	13,082	16,097	22,591	789	**213,649**
Grain	21,222	7,589	9,141	14,295	14,196	2,262	**68,705**
Pasture	3,724	3,957	7,465	19,738	6,243	223	**41,350**
Truck	43,158	3,661	3,789	1,755	248	4	**52,615**
Vineyard	10,477	8,295	9,194	1,528	1,074	1	**30,569**
Grazing Land[3]	433	2,846	11,499	18,600	2,284	1,991	**37,653**
TOTAL	**214,053**	**66,428**	**54,986**	**72,499**	**48,062**	**5,352**	**461,380**

[1] Pasture acreage adjusted using NASS estimates.

[2] NASS data used due to lack of recorded field borders.

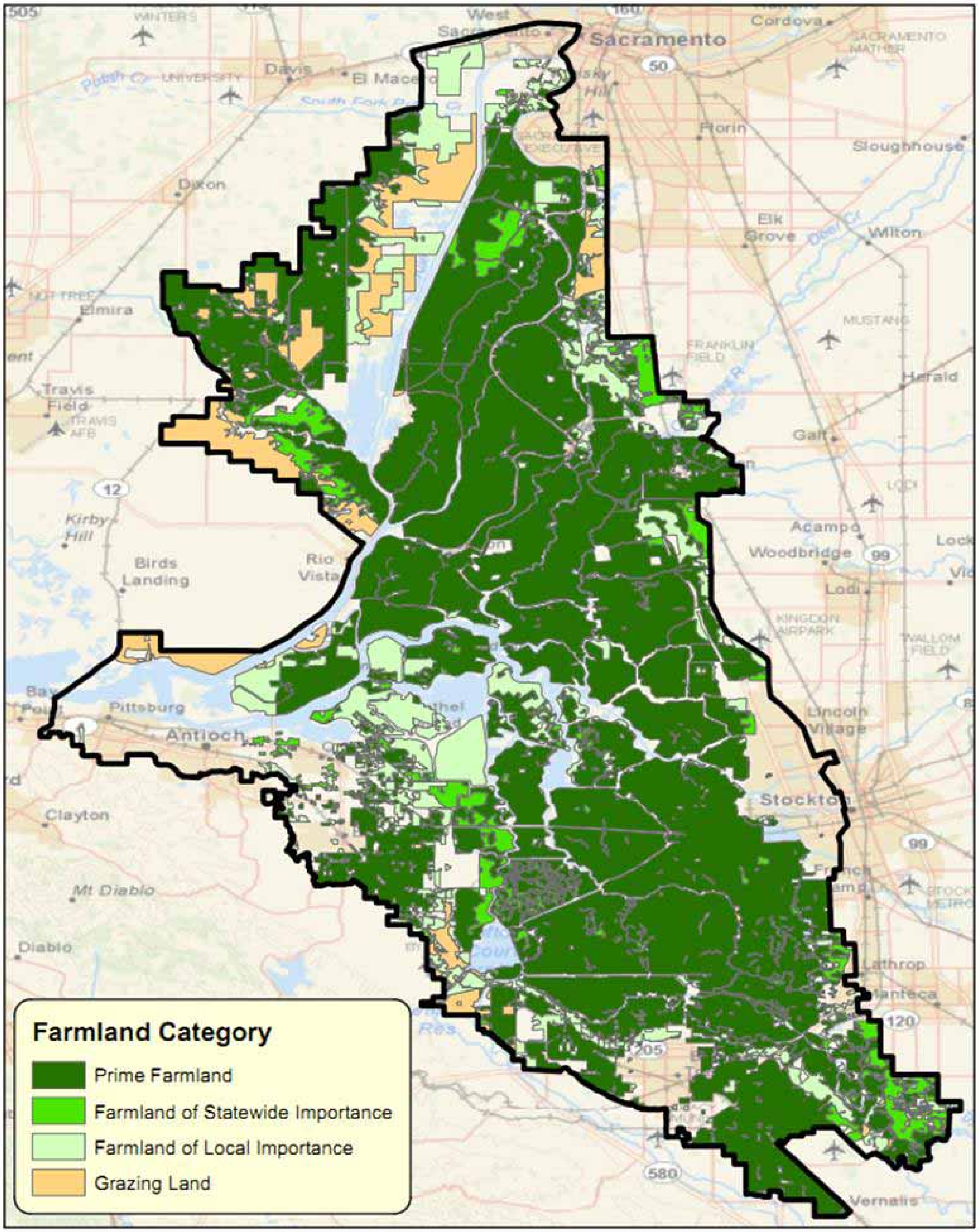
[3] Grazing land acreage estimated from FMMP data.

Table 8 Top 20 Delta Crops by Acreage, 2009

	Crop	Acreage	Value
1.	Corn	105,362	$92,975,715
2.	Alfalfa	91,978	$66,027,076
3.	Processing Tomatoes	38,123	$117,242,615
4.	Wheat	34,151	$17,549,215
5.	Wine Grapes	30,148	$104,990,142
6.	Oats	15,847	$4,195,540
7.	Safflower	8,874	$3,312,014
8.	Asparagus	7,217	$50,050,037
9.	Pear	5,912	$36,746,649
10.	Bean, Dried	5,493	$3,990,318
11.	Rice	4,874	$6,822,488
12.	Ryegrass	4,398	$1,061,436
13.	Cucumber	3,737	$7,866,553
14.	Turf	3,633	$31,643,344
15.	Potato	3,353	$28,605,465
16.	Almond	3,121	$8,776,101
17.	Sudangrass	3,025	$1,398,634
18.	Walnut	2,512	$9,453,874
19.	Pumpkin	2,103	$7,926,038
20.	Watermelon	1,717	$7,953,590

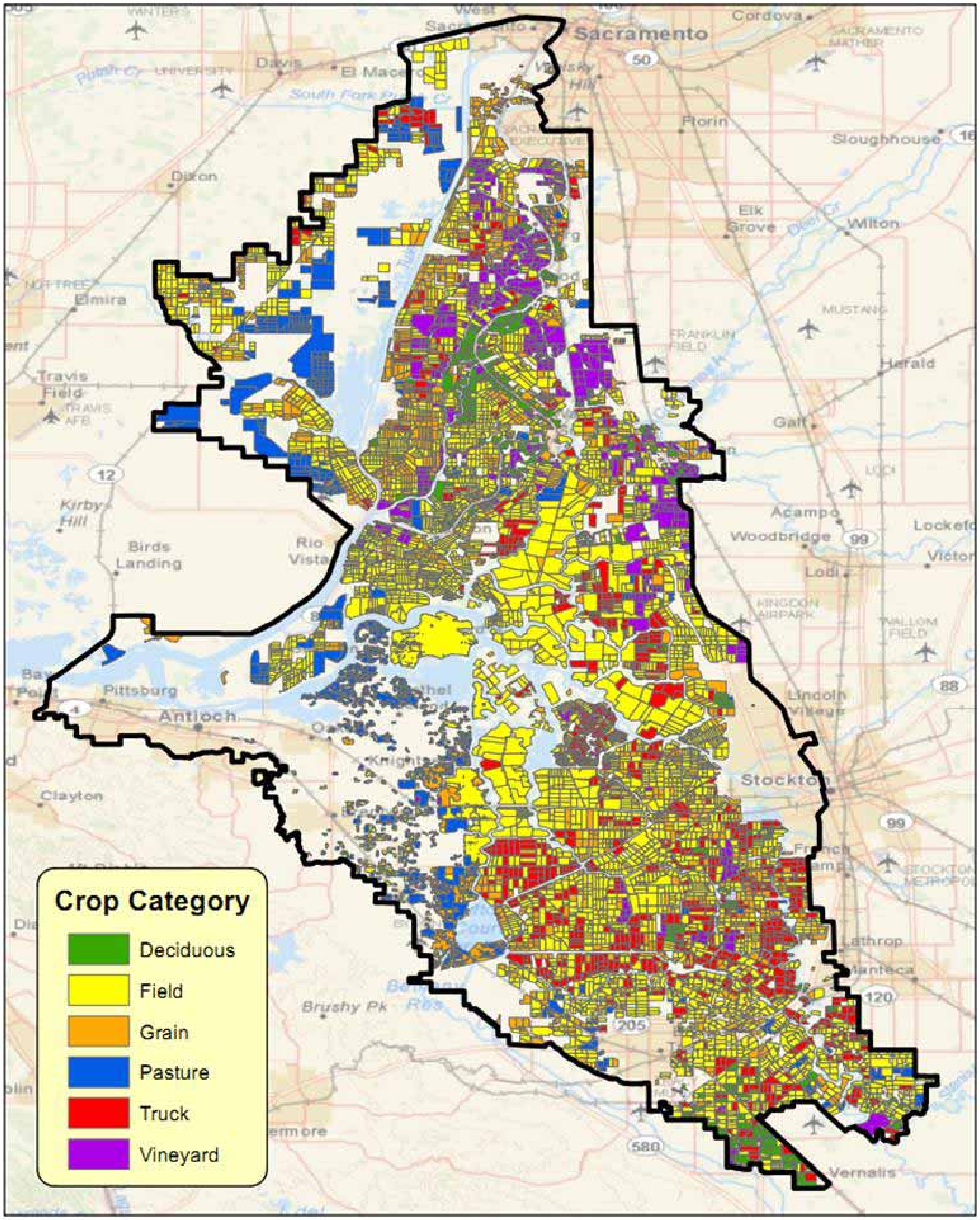
Note: 2009 acreages used in order to provide accompanying value estimates, which were not available for 2010.

Figure 20 FMMP Delta Farmland Coverage[95]



[95] For high resolution image see http://forecast.pacific.edu/desp-figs.html

Figure 21 Agricultural Land Cover, 2010[96]



[96] Note: Grazing Land indicated on previous figure. For high resolution image see http://forecast.pacific.edu/desp-figs.html

2.4 Delta Agricultural Revenues

Total Delta agriculture revenues can be calculated using the acreage analysis described above and multiplying the 2009 acreage of each individual crop by the yield and unit price reported in that year's county crop reports. This produces a total of $702 million in revenues from Delta agriculture in 2009. Tables 9 and 10 depict total revenue by crop category in each county and the top revenue-generating Delta crops.

Table 9 Delta Agricultural Revenues, 2009 (in $1000s)

Crop Category	*San Joaquin*	*Sacramento*	*Yolo*	*Solano* [1]	*Contra Costa* [2]	*Alameda* [3]	TOTAL
Deciduous	25,118	41,738	3,345	1,347	8,667	355	**80,570**
Field	107,001	22,071	9,341	12,418	21,398	398	**172,627**
Grain	15,535	3,276	2,587	7,512	288	1,059	**30,257**
Pasture	741	438	411	1,717	1,013	270	**4,590**
Truck	248,982	20,847	15,987	8,949	13,871	17	**308,653**
Vineyard	32,099	28,474	32,718	5,042	6,657	3	**104,993**
Grazing Land [4]	9	57	230	372	46	40	**754**
TOTAL	**429,485**	**116,901**	**64,619**	**37,357**	**51,940**	**2,142**	**702,444**

[1] Crop value calculations use 2010 field borders acreage.

[2] Values for non-grazing land include all reported county crop report acreage due to lack of reported field borders.

[3] Values computed using 2010 NASS acreage estimates and average crop category values.

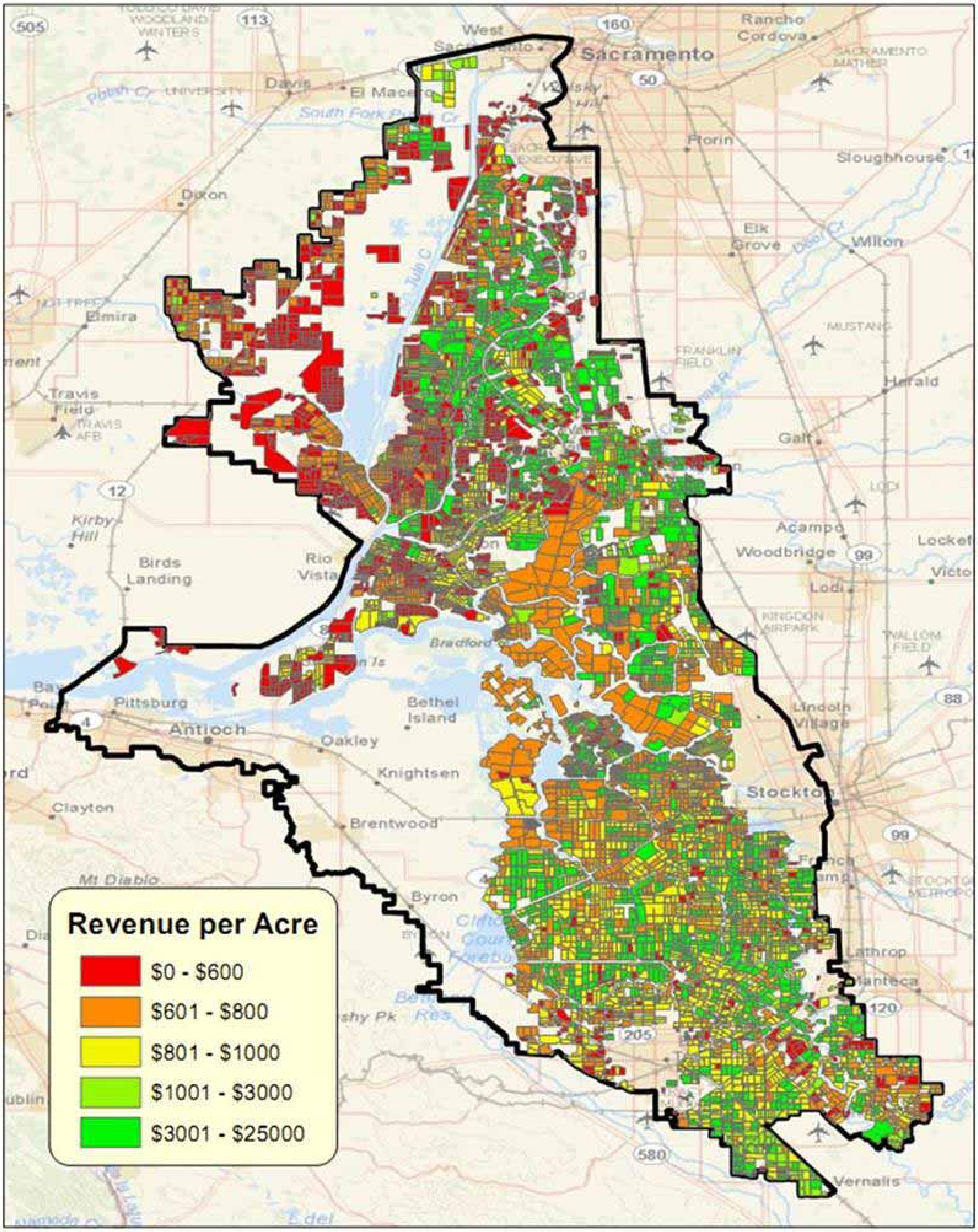
[4] Grazing land acreage estimated from 2008 FMMP data and valued at $20 an acre.

Table 10 Top 20 Delta Crops by Value, 2009

	Crop	Value	Acreage
1.	Processing Tomatoes	$117,242,615	38,123
2.	Wine Grapes	$104,990,142	30,148
3.	Corn	$92,975,715	105,362
4.	Alfalfa	$66,027,076	91,978
5.	Asparagus	$50,050,037	7,217
6.	Pear	$36,746,649	5,912
7.	Turf	$31,643,344	3,633
8.	Potato	$28,605,465	3,353
9.	Blueberry	$25,255,917	1,097
10.	Wheat	$17,549,215	34,151
11.	Cherry	$11,490,843	1,855
12.	Almond	$8,776,101	3,121
13.	Walnut	$9,453,874	2,902
14.	Watermelon	$7,953,590	1,717
15.	Pumpkin	$7,926,038	2,104
16.	Cucumber	$7,866,553	3,529
17.	Rice	$6,822,488	4,874
18.	Pepper	$6,247,592	1,289
19.	Apple	$4,455,826	846
20.	Oat	$4,195,540	15,847

Note: Kern County crop report value used for turf value, as no Delta counties report turf separately from other nursery crops.

Figure 22 Average Revenues per Acre[97]



[97] Using Field Borders Data, Contra Costa County is not included in the figure because data was not available in this format. For high resolution image see http://forecast.pacific.edu/desp-figs.html

3 Economic Impact of Delta Agriculture

The previous sections focused on the value and composition of crop production in Delta agriculture. To calculate the economic impact of agriculture in the Delta, two additional areas needed to be considered: 1) the value of animal agriculture in the Delta, and 2) the output of local food and beverage manufacturing firms that are located in the region because of Delta crop output. The section concludes with a brief discussion of impact analysis and policy analysis and how to interpret the results, and a discussion and comparison with related estimates by the Department of Water Resources.

3.1 Animal Production in the Delta

Animal and animal product output in the Delta is more difficult to estimate than crop production. It is clear that the Delta is not as oriented towards crop production as many other areas in the Central Valley, although a significant amount of its crop production is alfalfa and field crops that are consumed by animal enterprises outside the Delta. Other reports by the Department of Water Resources and the Delta Stewardship Council White Papers have estimated animal-related output in the Delta at about $90 million per year, significantly less than crop production. Estimates produced for this study are very similar. Enterprise data from Dun and Bradstreet and NETS were used to identify dairy, cattle, and other animal production enterprises located within the legal Delta, and this figure was compared to the total number in the counties. The percentage of animal enterprises in each county located in the Delta was applied to the total animal production in the crop reports for each of the five Delta counties, resulting in an estimate of $93 million in animal output, shown in Table 11.

Table 11 Animal Output in the Delta

Animal Output	Value
Cattle	$24,097,110
Sheep, Poultry, other Livestock	$3,160,977
Milk	$64,322,406
Wool	$94,628
Apiculture	$1,712,879
Total Animal and Animal Products	**$93,388,000**

3.2 Value Added Processing: Food and Beverage Manufacturing

The value of farm production is typically measured as the revenue earned by farm operations for selling crops. “Farm gate” values are reported in County Crop Reports and are the measures of agricultural revenues used in this chapter and most other discussions of agricultural values. Some farm products are not transformed significantly, and therefore have little additional value added to them between the farm and when they are shipped out of the region, or received by retailers or food service providers for sale to local consumers. Tree nuts such as almonds and walnuts, cotton, and many fresh fruits and vegetables are examples of high-value agricultural crops that have little additional value added to them before they are exported from the state or region. In contrast, wine grapes, processing tomatoes and milk are examples of farm products that have significant processing and value added by local food and beverage manufacturers.

Food and beverage manufacturing is an important economic sector in California and the five Delta Counties. Some of that manufacturing only exists in the region because of local farm output, whereas many food and beverage manufacturing enterprises such as bakeries are located in a region to serve the local market or for other reasons. Wineries, most fruit and vegetable canneries such as tomato paste, and most dairy product manufacturing such as cheese, butter, and fluid milk in California is closely linked to local farm production.[98] Wine grapes also have a large associated tourist economy. Thus, valuing wine grapes to the California economy at the “farm gate” significantly understates their true value to the economy.

Comparing data for food and beverage manufacturing from the 2007 Economic Census to 2007 farm production in California for the associated farm products illustrates the point.[99] The value of wine grape production at the farm gate in 2007 was $1.855 billion according to the California Department of Food and Agriculture, but the value of shipments from California wineries was $10.764 billion, 5.8 times the agricultural value of the wine grapes harvested on 480,000 acres in California in 2007 (or $22,400 of output per acre). The Delta is about 5 percent of California’s wine grape production. Milk was the highest value California farm product in 2007 at $7.33 billion in agricultural production. Virtually all of that milk was used by various segments of California’s dairy product manufacturing industry (NAICS 3115, includes fluid milk, cheese, ice cream, etc.) which recorded a value of shipments of $12.467 billion in 2007, 1.7 times the value of raw milk in agricultural reports. Roughly 2 million acres of irrigated crops in California supported the dairy industry, about 10 percent of which is in the Delta, although a significant amount of feed is also imported from other states. Disaggregated data on processing tomatoes is unavailable as it is combined in NAICS code with all fruit and vegetable canning, but data from major tomato processor Morning Star suggests that the value of shipments in the tomato paste production is roughly 2 times the value of processing tomatoes purchased from local farms.[100] Thus, the $849 million in processing tomatoes produced in 2007 would be conservatively supporting about $1.7 billion in canned tomato products production,[101] from about 300,000 acres of production of which a little more than 10 percent is in the Delta.

The point is that all of the four most significant crops in the Delta—alfalfa, corn, processing tomatoes, and wine grapes—are supporting a significant value-added chain in the region and state. In contrast, crops such as nuts, cotton, and even produce such as lettuce, melons, and broccoli may have higher farm gate values and agricultural revenue per acre, but less economic value is added to the crop in the region or state between the farm and consumers. Almonds have slightly higher agricultural receipts than wine grapes in California, but wine grapes generate more than five times the income of almonds. Processing tomatoes and cotton have similar agricultural receipts, but processing tomatoes generate more than double the income for the state. Thus, when measuring and comparing the contribution of various regions to the state’s economy, an approach that focuses solely on agricultural receipts is easy to calculate but is too narrow and will significantly undervalue the Delta’s contribution relative to areas further south in the Valley that receive water exported from the Delta.

[98] It should be noted that relatively “low value” alfalfa and corn silage production in California is an important part of the dairy product value chain as well.
[99] 2007 is the most recent year for which the value of shipments data is available at the 5-digit NAICS level that identifies wineries as a separate manufacturing category, NAICS 31213.
[100] See exhibit 2 and exhibit 8 in this presentation, http://www.morningstarco.com/statdocs/2010%20Exhibits%20Brochure.pdf
[101] Morning Star is known for low cost tomato paste production; other higher valued canned tomato products are likely adding more value than bulk tomato paste production, which absorbs roughly 75 percent of California’s processing tomato production, according to Morning Star.

To be conservative in the modeling, only food and beverage manufacturing where a clear link to regional production could be identified and reasonably estimated are used in the economic impact analysis, and all analysis is presented with and without the related manufacturing component. Although Delta crops are definitely consumed in large quantities by dairies outside the Delta, these dairies also use grain and alfalfa transported significant distances and could increase the use of these imported feeds if necessary, although at higher cost. Thus, dairy production outside the Legal Delta is not attributed to Delta agriculture in proportion to the Delta's contribution to dairy cattle feed. Some additional value-added processing to cattle production and fruits and vegetables other than tomatoes and cattle are excluded due to measurement difficulties. The complexity of the industry and limited data makes it difficult to precisely estimate the entire value-chain and linkages, but this analysis is important to capture the overall scale and contribution of agricultural production to the region.

As discussed above, our estimate of value-added manufacturing focuses on three industries: wineries, tomato canning, and dairy product manufacturing. Delta wine grapes are roughly 5 percent of California production by both weight and value. The prices are similar to state averages, much higher than other areas of the Central Valley but much lower than premier growing areas such as Napa and Sonoma. Winery capacity in the Delta and the five Delta counties is small relative to local production, but Napa and Modesto winery capacity is very high relative to local production. The data and interviews with local producers support that most Delta wine grape production is contracted to large Napa County wineries or Modesto-based Gallo. Using state and regional shares of wine grape production from the Delta, and county winery output estimates from IMPLAN, we estimate that $181 million of winery output in the five Delta counties is dependent on Delta wine grapes, and $541 million of winery output in adjacent counties (Napa and Stanislaus) is sourced from the Delta. The $117 million in processing tomato output is estimated to support $234 million in cannery output based on the Morning Star input data.

Delta farms produce less than 1 percent of California's milk, but produce roughly 10 percent of the state's alfalfa and forage crops, critical and increasingly scarce and costly inputs to the dairy industry. Although there are few dairies in the Delta, maps of dairy cow concentration in the San Joaquin Valley indicate large nearby clusters between Highway 99 and I-5 between Manteca and Merced, and in southeast San Joaquin County near Escalon.[102] Clearly the Delta is more critical to the state's industry than the milk production data shows, but quantifying its importance is difficult since Dairy producers can import feed and adjust the mix of feeds in cow rations in response to scarce local feed sources. One could argue Delta agriculture supports anywhere from 1 percent ($137 million) to 10 percent ($1.37 billion) of California's dairy product industry. As a rough estimate in this range, we link 5 percent ($687 million) of California dairy product manufacturing to Delta agriculture, a similar contribution as winery production, and attribute half of this total ($344 million) to dairy products produced in the five Delta counties, which is a little less than half of all dairy product manufacturing in the Delta counties.[103]

3.3 Economic Impact Estimates

The IMPLAN 3 model calibrated to 2008 regional and statewide economic data was used to estimate the overall economic impact of Delta agriculture. See Appendix F for a description of the IMPLAN model and formal definitions of terms such as direct, indirect, and induced effects. Following a methodology initially proposed by UC-Davis agricultural economists, the default

[102] EPA Dairy Cow Concentration Map. http://www.epa.gov/region9/ag/dairy/images/CED0601309_2.gif
[103] There is one very large cheese manufacturer of note in the legal Delta, Leprino Foods in Tracy.

IMPLAN production functions were adjusted to account for the unusually high use of contract labor in California agriculture.[104]

Table 12 Agriculture Related Output Used for the IMPLAN model

Industry	Output Value (millions $)
1 Oilseed farming	3.3
2 Grain farming	135.9
3 Vegetable and melon farming	250.1
4 Fruit farming	191.7
5 Tree nut farming	20.1
10 All other crop farming	101.5
11 Cattle ranching and farming	27.2
12 Dairy cattle and milk production	64.3
14 Animal production, except cattle and poultry and eggs	1.8
Food/Beverage Manufacturing in expanded analysis	
54 Fruit and vegetable canning, pickling, and drying	234 in Delta counties & statewide
55-58 Dairy Products Manufacturing	344 in Delta counties 687 statewide
72 Wineries	180.5 in Delta counties 722 statewide

For the five-county economic impact model, Delta agricultural production and Delta-dependent food processing and winery production was distributed across IMPLAN production sectors according to Table 12. In the initial model, only the impacts of the $795 million in direct agricultural production were modeled. As shown in Table 13, the approximately $702 million in Delta crop production and $93 million in Delta animal and animal product revenue has an economic impact of 9,681 jobs, $683 million in value added and $1.416 billion in output in the five Delta counties. Table 14 shows that across all of California, the economic impact of Delta agriculture is 12,934 jobs, $819 million in value added, and $1.642 billion in output. This equates to an employment multiplier of 12.2 jobs per million dollars in output in the five Delta Counties and 16.2 jobs per million dollars in output when evaluated statewide. These multipliers are very consistent, if not low, compared to other studies. In a recent essay published by UC-Davis, Howitt et al. (2011) states that agricultural employment multipliers typically range from 16 to 27 jobs per million dollars.[105]

To get a more complete picture of the full economic impact of Delta agriculture, the impact of linked food and beverage manufacturing for wineries, tomato canning and dairy products were included as described in the previous section. These upward linkages must be estimated separately, because the indirect effects of the IMPLAN model only includes backwards linkages from purchased inputs. To avoid double counting impacts from the initial stage, the indirect effects attributed to the purchase of crops as inputs were netted out of the results. For example,

[104] The production functions were adjusted to ensure that virtually all (97 percent) of the output of the agricultural service sector was utilized by the regional agriculture industry, a common sense adjustment and a methodology that recently yielded good predictions of the employment effects of the 2009 drought in the San Joaquin Valley.
[105] Howitt, R.E., D. MacEwan and J Medellin-Azuara, “Drought, Jobs, and Controversy: Revisiting 2009,” *ARE Update*, 14 (6) (2011): 1-4.

for wineries, the indirect effects associated with purchasing wine grapes were estimated and removed from the total to avoid double counting the impact of growing wine grapes. The total five-county economic impacts are displayed in Table 15. Delta agriculture supported 13,179 jobs, $1.059 billion in value-added, and $2.647 billion in output in the five Delta counties. For the California economic impact model, the additional $541 million of Delta dependent winery production and $344 million in dairy product production from adjacent counties and was added to the totals. The economic impact rises from this extra production, and also because the indirect and induced effects grow when considered on a statewide rather than five-county basis. Table 16 shows that across the State of California, Delta agriculture supports nearly 25,125 jobs, over $2.135 billion in value added, and over $5.372 billion in output.[106] Even when using this more expansive view of impacts, the employment multipliers are 16 to 32 jobs per million dollars of agricultural production, similar to the range described as typical by Howitt et al.

Caution is advised before using the more expansive multipliers to estimate the potential long-range socio-economic impacts of the policy changes described in this chapter. These are current economic impact estimates for Delta agriculture, and do not take into account potential substitution or adjustment strategies that may be employed. For example, wineries or canneries could purchase inputs from different sources if Delta tomatoes or wine grapes became unavailable, so the multipliers from the broader scenario including food processing would be too large for analyzing long-range policy impacts, particularly at the statewide level.

Table 13 Economic Impact of Delta Agriculture on 5 Delta Counties (not including processing)

Impact Type	Employment	Labor Income	Value Added	Output
Direct Effect	4,132	$146,710,832	$361,683,700	$815,797,504
Indirect Effect	4,051	$155,957,376	$192,082,400	$380,246,048
Induced Effect	1,499	$69,450,720	$129,108,300	$219,740,912
Total Effect	**9,681**	**$372,118,912**	**$682,874,400**	**$1,415,784,448**

Table 14 Economic Impact of Delta Agriculture on California (not including processing)

Impact Type	Employment	Labor Income	Value Added	Output
Direct Effect	5,104	$158,528,784	$361,683,600	$815,797,504
Indirect Effect	5,502	$207,782,128	$241,993,300	$447,518,752
Induced Effect	2,328	$119,379,712	$215,517,800	$379,519,392
Total Effect	**12,934**	**$485,690,624**	**$819,194,800**	**$1,642,835,712**

[106] The Department of Water Resources has called these estimates inflated and inflammatory in comments, including to the Delta Stewardship Council. The accusation is strange since DWR's own estimate of Delta agricultural production of $817.6 million is higher than in this study. Interestingly, DWR has not estimated any employment impacts of Delta agriculture, but used employment multipliers of 50-60 jobs per million dollars of agricultural output in the San Joaquin Valley in their highly publicized 2009 drought reports. If DWR were to apply similar multipliers to their estimate of Delta agricultural output, they would estimate that Delta agriculture creates 41,000 to 49,000 jobs, far higher than the estimates in this report.

Table 15 Economic Impact of Delta Agriculture on 5 Delta Counties

Impact Type	Employment	Labor Income	Value Added	Output
Direct Effect	4,741	228,911,960.00	471,262,100.00	1,481,674,024.00
Indirect Effect	6,051	254,344,539.00	382,429,640.00	815,208,284.00
Induced Effect	2,387	110,719,252.00	205,761,890.00	350,242,252.00
Total Effect	**13,179**	**593,975,736.00**	**1,059,453,520.00**	**2,647,124,544.00**

Table 16 Economic Impact of Delta Agriculture on California

Impact Type	Employment	Labor Income	Value Added	Output
Direct Effect	6,561	346,581,914.00	635,165,930.00	2,321,849,056.00
Indirect Effect	12,568	597,716,444.00	944,157,270.00	2,071,220,424.00
Induced Effect	5,997	307,918,480.00	555,771,680.00	978,945,200.00
Total Effect	**25,125**	**1,252,216,824.00**	**2,135,095,400.00**	**5,372,014,752.00**

4 Other Agriculture Issues

There has been significant interest in alternative forms of agriculture in the Delta, as well as new approaches to increase agricultural revenue. Many of the ideas have been proposed in Delta Vision and other Delta related plans and reports. Ideas include increased agritourism, regional branding and marketing of Delta crops, growing crops for biofuels, subsidence-reversal agriculture, and growing crops for carbon sequestration purposes and the marketing of carbon credits. Some of the ideas are promoted for the dual benefits of ecosystem restoration and reducing flood risks, whereas others are primarily seen as a way to enhance local agricultural income.

Most of these options were evaluated in a recent report by the UC Davis Agricultural Issues Center (AIC) developed for the California Department of Food and Agriculture and presented to the Delta Stewardship Council. In virtually all cases, the AIC report determined that the ideas have very limited potential to develop a significant market in the Delta. For example, most Delta crops are commodities such as corn and processing tomatoes for which branding is not effective.

Agritourism, defined as recreational, educational, and other visits to working farms, is a small but fast growing source of income for farms in the region. As discussed in the Appendix of the recreation and tourism chapter,[107] agritourism was estimated by USDA to generate $4 million in income for farms in the five Delta counties in 2007. Assuming agritourism in the Delta is proportional to overall agriculture in the county, a roughly 25 percent share, agritourism generated roughly $1 million in revenue in 2007. An inventory of agritourism enterprises in California maintained by UC cooperative extension (http://www.calagtour.org/) identifies 91 agritourism operations in the five Delta counties, and 12 (13 percent) of these are located in the Delta. Over half of the Delta agritourism enterprises were in Contra Costa County where there is a cluster of U-pick orchards and other farms open to tourists around Brentwood. Only one of the 20 agritourism locations in San Joaquin County was in the Delta, but it was a very large

[107] Appendix H

attraction at Dell'Osso Family Farm adjacent to Interstate 5 near Lathrop that is estimated to draw over 100,000 visitors each fall to its corn maze and other attractions. Currently, it appears that agritourism is only significant in the suburban edges of the Delta secondary zone, and it is probably best suited to these areas. Agritourism is discussed in more detail as a potential growth strategy for tourism and Legacy Communities in subsequent chapter.

A January 2011 report prepared for the Nature Conservancy examines the potential of carbon capture wetland farms and low carbon agriculture in the Delta.[108] Although carbon capture wetland farms could generate environmental benefits and potentially reverse subsidence on Delta islands, the report casts doubt on whether carbon capture farming is economically viable, although the authors encourage large-scale demonstration projects to further research the potential. Specifically, the authors state:

> "Our analysis illustrates that Carbon Capture Wetland Farms are unlikely to provide a clear incentive to both landowners and investors without either fairly high carbon prices or some type of grant or payment scheme to subsidize some of the costs of conversion and annual management." (p. 106)

The report also details other problems including increased methylmercury, organic carbon, and mosquitos that could have negative impacts on various aspects of the Delta economy. The report discusses other low carbon changes to agriculture including conversion to rice growing and reduced tillage practices that may be more economically feasible. The authors encourage large-scale demonstration projects to more fully research the potential of carbon capture wetland farms.

5 Modeling Crop Choice in the Delta

A multinomial logit model is used to estimate farmers crop choice at the field level in the Delta. Since its development in the early 1970s, the multinomial logit model has been extensively used to statistically model choices between multiple options, and has been applied to myriad settings including occupational choice, health care choices, and crop choices among others.[109] Professor Daniel McFadden of UC Berkeley was a significant contributor to the development of the multinomial logit and related models for which he was awarded the Nobel Prize in Economic Sciences in 2000. In addition to crop choice, the approach has been used to study a variety of problems in agriculture over the past three decades including studies of irrigation technology choices (Caswell and Zilberman, 1985), and crop management practices (Wu, Adams, Kling, and Tanaka, 2004; Wu and Babcock 1998).[110]

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[108] A. Merrill, S. Siegel, B. Morris, A. Ferguson, G. Young, C. Ingram, P. Bachand, Holly Shepley, Maia Singer, Noah Hume, "Greenhouse Gas Reduction and Environmental Benefits in the Sacramento-San Joaquin Delta: Advancing Carbon Capture Wetland Farms and Exploring Potential for Low Carbon Agriculture," prepared for The Nature Conservancy, Sacramento, California, 2010. Available at: http://www.stillwatersci.com/

[109] Maddala, G.S., *Limited Dependent and Qualitative Variables in Econometrics.* Cambridge University Press, 1993.

[110] Caswell, M.F. and D. Zilberman, "The choice of irrigation technologies in California," *American Journal of Agricultural Economics* (1985), 67: 224-34.
Wu, J. and B. A. Babcock, "The choice of tillage, rotation, and soil testing practices: Economic and environmental implications," *American Journal of Agricultural Economics* (1998), 80: 494-511.
Wu, J., R.M. Adams, C.L. Kling, and K. Tanaka, "From micro-level decisions to landscape changes: An assessment of agricultural conservation policies," *American Journal of Agricultural Economics* (2004), 86: 26-41.

The multinomial logit model is used to predict agricultural land allocation, conditional on its current land use and other exogenous variables, including soil quality, a multi-year average of irrigation water salinity, temperature, slope, elevation, field size, and dummy variables for year and conservation zone to capture fixed effects. The model generates estimates of the probability of observing a given crop type in each specified field over a long-term time horizon. It was trained on a dataset of over 6,000 individual crop fields for which annual crop data was tabulated for each year from 2002 through 2010, excluding 2005 for which reliable data was not available. All of the explanatory variables were statistically significant and of the expected signs. More details on the model input data and output results are provided in Appendix G. The impact on Delta crop allocations under various scenarios is described in tables on the following pages.

There is significant urbanization pressure in the Secondary Zone of the Delta, so the model was run with and without the inclusion of land that is expected to be developed by 2050. We determined this area using the urbanization probability maps generated by the UC Berkeley RESIN project with some minor adjustments to the high and very high probability categories to conform to the sphere of influence of cities in the Secondary Zone and discussions with city officials and local developers with knowledge of land development plans. Table 17 depicts the agricultural crop acreage expected to convert to urbanized land, while Figure 23 displays the affected fields. All of these fields are excluded in the forecast with urbanization effects.

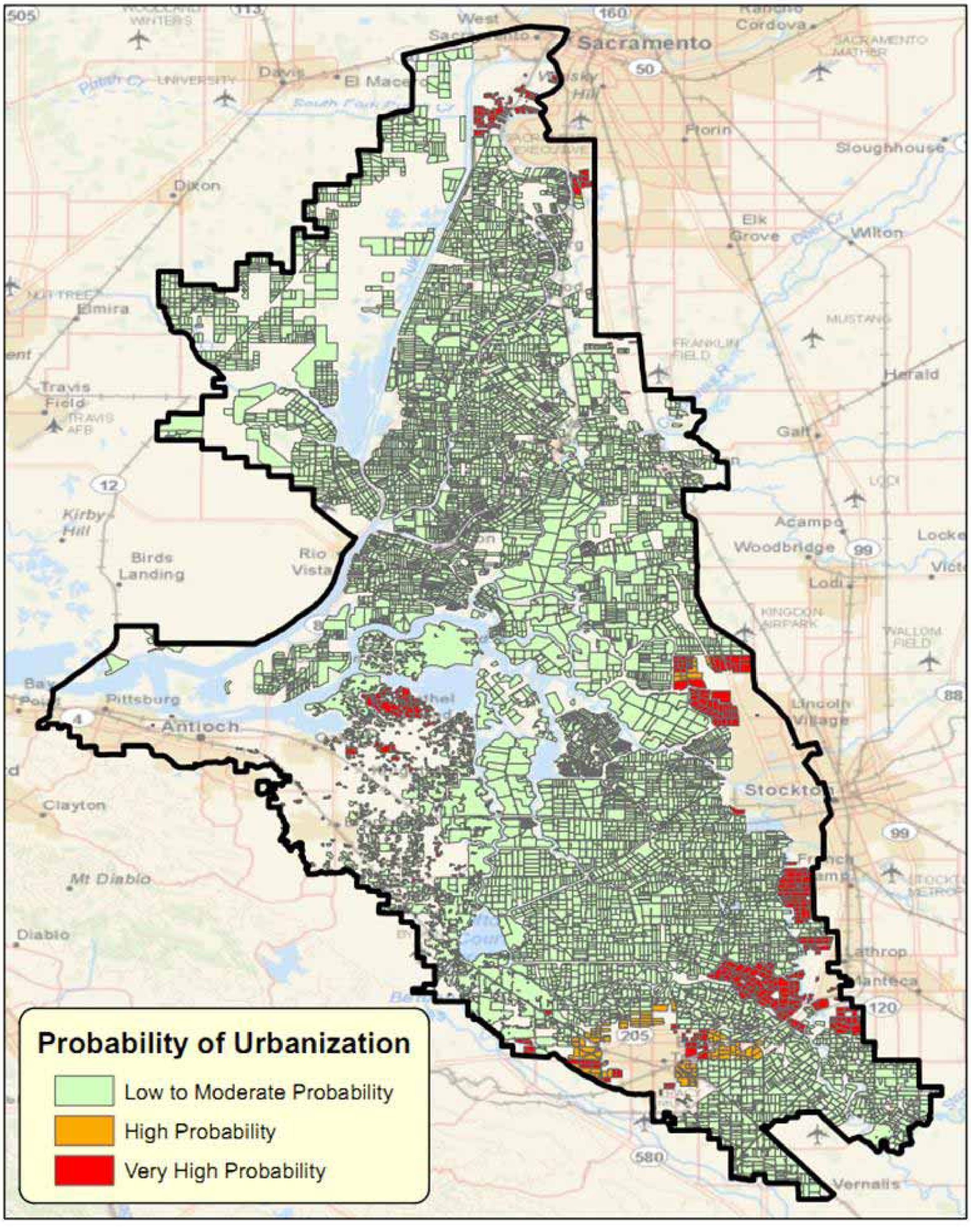
Overall, urbanization will reduce agricultural production in the Delta due to the loss of land. However, it should be noted that the Delta's location in the heart of the growing Northern California megaregion surrounded by growing cities creates opportunity for the majority of farmland that remains in production. Wu, Fisher, and Pasqual (2011) find that the revenue opportunities created by urbanization could outweigh the negative impacts on farm infrastructure and production costs due to growing market opportunities for higher-value crops such as vineyards, fresh vegetables, and nursery products.[111] In a later section of this report, we also discuss the presence and growth of agritourism around the urban fringe.

Table 17 Crop Acreage with High or Very High Probability of Urbanization

Crop Category	High Probability	Very High Probability	Total
Deciduous	72	588	660
Field	3,598	8,210	11,808
Grain	597	6,095	6,692
Pasture	531	703	1,234
Truck	604	5,111	5,715
Vineyard	1	515	516
All Crops	**5,403**	**21,222**	**26,625**

[111] Wu, J., M. Fisher, and U. Pasqual, "Urbanization and the Viability of Local Agricultural Economies," *Land Economics* (2011), 87: 109-125.

Figure 23 Crop Fields with High or Very High Probability of Urbanization[112]



[112] For high resolution image see http://forecast.pacific.edu/desp-figs.html

Table 18 Long-run Land Allocation Forecast

Scenario	Deciduous	Field	Grain	Pasture	Truck	Vineyard
Current Land Allocation	3.97%	50.42%	16.21%	9.76%	12.42%	7.21%
Baseline Forecast	5.12%	51.11%	11.46%	6.80%	17.74%	7.76%
Forecast with Urbanization Effects	5.26%	51.13%	11.02%	7.08%	17.24%	8.26%
Forecast with Urbanization Effects vs. Current Allocation						
Land Allocation Change	1.29%	0.71%	-5.19%	-2.68%	4.83%	1.04%
Relative Crop Allocation Change	32.34%	1.41%	-32.01%	-27.45%	38.87%	14.46%
Forecast with Urbanization Effects vs. Baseline Forecast						
Land Allocation Change	0.14%	0.02%	-0.44%	0.28%	-0.50%	0.50%
Relative Crop Allocation Change	2.66%	0.05%	-3.81%	4.10%	-2.81%	6.41%

The results of the long-run land allocation forecast are contained in Table 18 above. Significant growth is predicted in truck, deciduous, and vineyard crops, with the largest decline among grain and pasture crops. Forecasted revenue changes are illustrated in Table 19 below. It indicates a trend towards increased planting of high-value crops, which would lead to an estimated $111 million increase in total agriculture revenue assuming current crop acreage and average crop class revenue using 2009 prices. Taking into account the 26,625 acres expected to undergo urbanization, annual revenues are expected to increase by $68 million, a decline of $43 million per year compared to the baseline.

Table 19 Long-run Agricultural Revenue Forecast

Crop Category	Average Revenue per Acre	Forecasted Acreage Change			Forecasted Revenue Change		
		Baseline	*Urbanization*	*Urbanization vs. Baseline*	*Baseline*	*Urbanization*	*Urbanization vs. Baseline*
Deciduous	$4,612	4,869	4,046	-823	$22,455,695	$18,660,853	-$3,794,841
Field	$780	2,921	-10,595	-13,516	$2,278,075	-$8,264,247	-$10,542,321
Grain	$426	-20,138	-24,926	-4,788	-$8,578,785	-$10,618,569	-$2,039,784
Pasture	$116	-12,532	-13,236	-704	-$1,453,712	-$1,535,376	-$81,664
Truck	$3,903	22,566	15,862	-6,704	$88,076,852	$61,909,659	-$26,167,192
Vineyard	$3,566	2,314	2,222	-91	$8,251,441	$7,925,330	-$326,111
				Total Revenue Change	**$111,029,565**	**$68,077,651**	**-$42,951,914**

Many future crop allocations are possible, and these results depict the most likely allocation calculated by the model. It predicts a modest (approximately 5 percent) shift towards higher-value crops over several decades, with field crops holding steady at over 50 percent of Delta cropland over time. Some comments have pointed to a decline in higher-value truck crops in the Delta to cast doubt on the model results. However, that recent decline is due to the rapid loss of tens of thousands of acres in the Delta's signature asparagus crop which has declined to a mere 7,000 acres from reported levels near 70,000 acres in the 1960s. The California Asparagus Board reports acreage was relatively stable during the 1990s, then dropped from 37,000 acres statewide in 2000 to a mere 12,000 acres in 2010, with a little over half of the acreage in the Delta. Asparagus is a labor-intensive crop, and increased competition from the growth of lower-cost producers in Peru and Mexico has impacted California producers.

However, other truck crops including tomatoes, peppers, cucumbers, pumpkins and blueberries have shown modest growth in recent years, and it is hard to see asparagus production in the Delta dropping all the way to zero given its iconic status at local festivals, growing consumption, and the demand for the fresh market. Even in the unlikely prospect that asparagus were to completely disappear from the Delta, the lower bound of zero production would soon stop the downward trend.

Thus, the 16,000 acre increase in truck crops predicted by the model is plausible, certainly over the 2050 planning horizon of this study. In contrast, other comments and recent trends suggest the prediction for 2,000 acres of additional vineyards is too small given current trends. In comments received from Delta farmers, most expected the most rapid growth in vineyards, as much as another 20,000 acres over the next one to two decades. Current trends and the 64,000 acres of available land in the growing Clarksburg American Viticultural Area suggest this is possible, if not probable. Overall, the 5 percent shift from lower-value crops such as grains to higher-value crops is a reasonable, if not conservative, forecast through 2050. Markets will change and projections are, of course, uncertain and could be more or less than predicted. Nevertheless, the trend towards higher-value crops is consistent with broad trends throughout the Central Valley, although the shift to higher-value crops in other areas has been dominated by growth in tree nuts. However, the shift towards permanent crops in the rest of the Valley and growing urbanization around the Delta creates a market opportunity for increased specialization in truck and vineyard crops in the Delta. In spite of this, truck crops and vineyards, with the notable exception of asparagus, are sensitive to salinity.

6 Impact of Policy Scenarios

6.1 Background on Salinity and Delta Agriculture

The impact of salinity and potential salinity changes on Delta agriculture is a contentious topic.[113] There are two current proposals that could affect salinity in the Delta:

1. A proposal to increase the salinity levels allowed in the south Delta from 700 ec to 1000 ec during the growing season, and from 1000 ec to 1400 ec at other times, a 40-42 percent increase. This is known as the D-1641 standard, and the proposed change is currently being considered by the State Water Resources Control Board (SWRCB). The Department of Water Resources and State and Federal Water Contractors support the change, whereas the Central and South Delta Water Agencies oppose the change.

2. A proposal to shift from through-Delta conveyance to "dual conveyance" utilizing an isolated conveyance facility as proposed in the draft BDCP. The operation of dual conveyance is the subject of continued modeling, but the intention would be to use the isolated conveyance as much as possible while still maintaining south Delta water quality standards. Under the current through-Delta conveyance, salinity levels in the south Delta vary substantially from year to year, and are often much lower than the current 700 ec standard while running at or above the standard in dry years. Thus, under dual conveyance that diverts more water around the Delta in wet years, it is expected that south Delta salinity will run close to the D-1641 standard most of the time, making "every year a drought" in the words of a Delta farmer. The effect could be an increase in the average level of salinity of 25-50 percent even

[113] In the report, for consistency among databases, salinity is measured by electroconductivity (ec) in units of micro Siemens per centimeter.

if the 700 ec standard is always met, and a potential doubling in average salinity levels if dual conveyance were combined with an increase of the D-1641 standard to 1000 ec.[114]

In addition to the current proposals, concerns have been expressed by Delta agriculture interests that isolated conveyance could lead to future increases in salinity that would exceed the levels discussed above. They point to emergency declarations by the Governor during periods of drought that temporarily suspend water quality standards and current efforts to weaken environmental and water quality protections through legislation and the courts. The pressures on water quality standards could increase if a $12 billion isolated conveyance facility is built as water exporters attempt to maximize the value of the isolated facility they are financing, and the commitment to maintaining Delta levees could decrease.

The 2007 PPIC "Envisioning Futures" report estimated the potential impacts of a peripheral canal on Delta agriculture by modeling a tenfold and twentyfold increase in Delta salinity, far greater than the salinity increases contemplated in this chapter. In contrast, the same PPIC report estimates a similar isolated facility operated in a dual conveyance system would rarely if ever exceed 1000 ec as discussed above.

Perhaps the most contentious issue isn't the level of salinity changes, but whether salinity will have significant impacts on Delta agriculture at proposed levels. In focus groups, Delta farmers have told us that they monitor salinity levels closely in their current operations, and that some already incur significant costs in chemicals and drainage systems to deal with current levels of salinity. In contrast, the Department of Water Resources and water contractors argue that there would be no loss to Delta agriculture, even if the SWRCB adopted a 1000 ec standard in the south Delta. For example, Department of Water Resources' comments to an earlier draft of this report state,

> *"The salinity objective established by the State Water Resources Control Board is determined by the most salt-sensitive crop grown in the Delta—beans. The EC value has been determined to provide full yields for these most salt-sensitive crops when best-management is practiced by farmers. If the SWP with the isolated facility is operated to meet this objective, then water quality conditions in the Delta would be adequate to allow full crops yields for all crops grown in the Delta and no loss of revenue would occur at all."*[115]

The position that there is no impact on Delta agriculture from proposed increases to Delta salinity levels is based on a report by Hoffman (2010).[116] Hoffman uses well-established yield functions for crops typically grown in the south Delta to estimate potential loss to Delta farmers from changes to salinity. The yield functions depend on the leaching fraction of the soil. Yield loss can occur at low levels of salinity when leaching fractions are low, and crops can tolerate higher salinity in irrigation water when leaching fractions are high. The Hoffman (2010) report states (p. 51),

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[114] Modeling by William Fleenor reported in the 2007 PPIC report indicates that ec would rarely if ever exceed 1000 ec with a dual conveyance system.
[115] See page 42 of comments at http://www.delta.ca.gov/res/docs/ESP%20Comments%20-%20DWR.pdf.
[116] "Salt Tolerance of Crops in the Southern Sacramento-San Joaquin Delta," Final Report, January 5, 2010, by Glenn Hoffman. Prepared for the California EPA and the State Water Resource Control Board. http://www.swrcb.ca.gov/waterrights/water_issues/programs/bay_delta/bay_delta_plan/water_quality_control_planning/docs/final_study_report.pdf

> "The leaching fraction in the South Delta is difficult to estimate because measurements of soil salinity or salt concentration of drainage water are not measured routinely."

In his calculations, Hoffman generally assumes leaching fractions of 0.15 or above. This is supported by deriving leaching fractions from water samples collected from tile drains in an area in the southwest corner of the south Delta, and a 1976 study of soil salinity in nine locations of the south Delta by Meyer et al.[117] Hoffman's assumed leaching fractions are strongly contested by Delta water agencies.[118] Delta water agencies point out that Hoffman is using tile drains from an area in the southwest corner of the Delta characterized by clay soils and low water tables not typically found in the Delta, and that the sample points used by Meyer are also not broadly representative of the area. They contend that high water tables and soil permeability conditions in most of the south Delta produce low leaching fractions and high sensitivity to irrigation water salinity, and provided a report by Dr. G.T. Orlob that calculated yield loss for soils with a leaching fraction of .05 and estimates this soil type characterizes roughly 40 percent of south Delta cropland.[119] The Orlob report estimates the following percent yield decrements for crops in this soil type where applied water salinity is 1000 ec: beans, -68 percent; corn, -34 percent; alfalfa, -19 percent; tomatoes, -21 percent;, fruit and nuts, -61 percent; and grapes, -29 percent. Similar to Hoffman, Orlob estimates virtually no impact on yields if leaching fractions are 0.18.

A simple comparison of south Delta soil maps and the sampling locations utilized by Hoffman confirms that they are not a representative sample of the region. Thus, Hoffman's conclusion regarding the 1000 ec standard is based on an untested hypothesis about soil conditions in the south Delta. The hypothesis could be tested by conducting the appropriate soil tests on a truly representative sample of cropland in the south Delta, but that data is not available. The empirical analysis in this report can be seen as an alternative approach to testing the hypothesis with existing crop production data. If salinity below 1000 ec has no impact on crop yields in the Delta, then an empirical study should show no relationship between salinity and crop choice controlling for the environmental conditions of the field and other factors.

Incorporating measurements of salinity throughout the Delta as an exogenous variable in the multinomial logit model allows for capturing the marginal impacts on crop choice of changes in salinity. These observations can then be used to predict how the agricultural composition of the southern Delta would change if it were subjected to various scenarios of increasing salinity. The average revenues of the different crop classes are then used to estimate total impacts on the Delta's annual agricultural revenue. The model inputs and results are described in more depth in Appendix G.

To our knowledge, the only other economic study to model the impact of salinity on Delta agriculture is the 2007 PPIC report.[120] In contrast to the econometric approach of this report, they build a Delta Agricultural Production Model using the positive mathematical programming

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[117] Meyer, J. L., Carlton, A., Kegel, F., Ayers, R. S., "South Delta Salinity Status Report," University of California, Davis, CA, 1976, 16 p.

[118] Personal communication with John Herrick, July 5, 2011. See also a presentation to the State Water Board:
http://www.swrcb.ca.gov/waterrights/water_issues/programs/bay_delta/bay_delta_plan/water_quality_control_planning/docs/060611wrkshp/sdwa.pdf, and comments on the Hoffman report to the State Board, http://www.swrcb.ca.gov/waterrights/water_issues/programs/bay_delta/bay_delta_plan/water_quality_control_planning/cmmnts052311/john_herrick.pdf.

[119] G.T. Orlob, *Impact of San Joaquin River Quality on Crop Yields in the South Delta,* 1987.

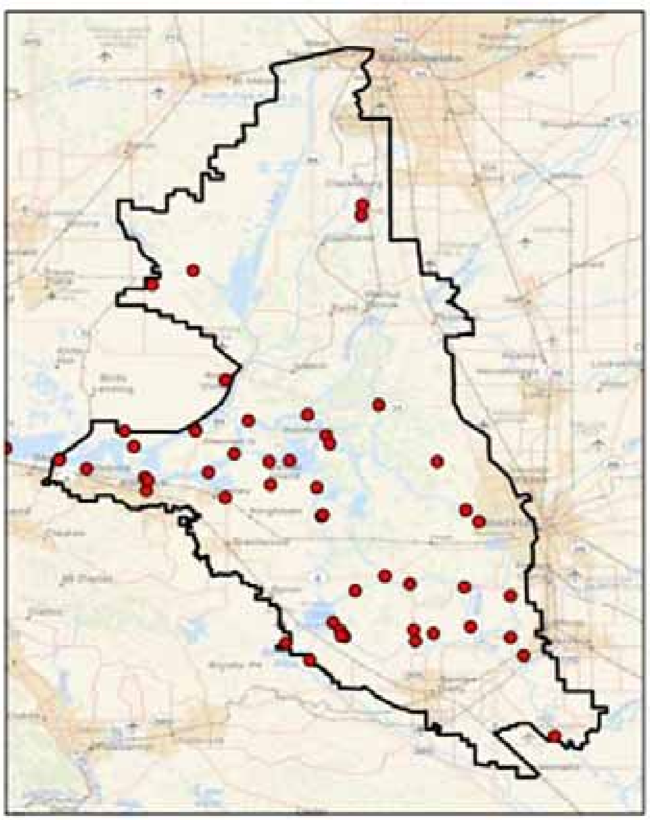
[120] Details of the model are in Appendix D, http://www.ppic.org/content/pubs/report/R_207JLR.pdf.

approach.[121] The Hoffman yield functions are built into the model, and the report states regarding current salinity levels, “most of the stations have an EC less than 1 mS/cm, which in practice means no effect on agricultural production.” Thus, the study is assuming leaching fractions above 0.15 as in the Hoffman report. Nevertheless, the study predicts potentially large impacts of salinity from a peripheral canal and other strategies to increase salinity, ranging from 25-60 percent declines in Delta agricultural revenue, and 8-40 percent declines in irrigated acreage as water quality in some areas could decline to levels unsuitable for any crop. If the same model were applied to dual conveyance that would keep salinity at or below the 1000 ec threshold, it would predict virtually no loss in agricultural output in parallel to the argument of the Department of Water Resources, because the Hoffman threshold functions for crop yield are built in.

6.1.1 Salinity Data

For the purposes of baseline salinity modeling, salinity data has been collected for over 50 sites in the Delta region. An analysis of salinity impacts required the creation of a variable representing average salinity on an annual basis. Based on information gained in a working group and further consultation with Delta farmers, a decision was made to use a value for the average salinity observed between May and August, when sensitive crops are most vulnerable to salinity changes in the Delta. Salinity is represented using measures of electroconductivity (ec), in units of micro Siemens per centimeter.

Figure 24 Salinity Observation Stations[122]



[121] Howitt, R.E. 1995. Positive Mathematical Programming. *American Journal of Agricultural Economics* 77: 329-342.
[122] For high resolution image see http://forecast.pacific.edu/desp-figs.html

The modeling also required the ability to map salinity values to each individual crop field. In order to predict these values, salinity measurements were averaged across all observation sites in a three-mile radius of each crop field. The measurement value of the nearest station was used for fields without multiple monitoring stations within that radius. This generated standardized estimations of salinity for fields throughout the Delta using a replicable technique. A map of the salinity observation stations used as inputs is depicted in Figure 24, and the sources of the station data are described below.

Interagency Ecological Program (IEP)
The IEP samples discrete water-quality data at 19 sites throughout the Delta. The sites are chosen in an attempt to represent the major inflows and outflows of the Delta, with new data sampled monthly. All reported observations undergo a detailed quality assurance process prior to being made publicly available. Sampling sites are mapped in GIS using longitudinal and latitudinal coordinates provided by the IEP.

California Data Exchange Center (CDEC)
Additional salinity data is collected from 45 Delta water monitoring stations reported through the CDEC. The sites are maintained by a variety of organizations, including the California Department of Water Resources, the U.S. Bureau of Reclamation, and the U.S. Geological Survey. The sites are sampled daily, and the monthly average is taken based on reported daily values.

Tables in Appendix G provide more detail about how average salinity varies across space and years in the Delta. It is important to emphasize that the data is presented here as a season long average, and thus masks important spikes that often occur during years when the average is considerably lower. The ten-year sample for which detailed information is provided includes six dry years with very high salinity from 2001–2002, 2004, and 2007–2009. Salinity was significantly lower in other years. During 2008, average salinity levels in most of the Delta were 60 percent to 80 percent higher than in 2006. In the north Delta, average salinity is less than 200 ec in most years and there is relatively less variation between years. In contrast, the south Delta averaged 646 ec in 2008 and 408 ec in 2006, with some areas averaging 800 ec or more in 2008 and 2009. Thus, the south Delta experiences significantly higher levels of salinity and more variation than the north Delta. This reflects many factors, including the significant differences in water quality between the Sacramento and San Joaquin Rivers.

6.1.2 Salinity Modeling

As discussed earlier and shown in the model results in Appendix G, the multinomial logit model found salinity to have a statistically significant impact on crop choice in the Delta. Since virtually all of the fields in the sample have irrigation water supplies below the 1000 ec, the finding does not support the assumption that there are no agricultural impacts below 1000 ec as argued by the Department of Water Resources and others.

For preliminary calculations of impacts, scenarios were established for percentage increases in salinity for the southern Delta regions, comprising fields within BDCP conservation zones 6 through 9. In reality, salinity would not increase uniformly across the region, and future simulations of the model with more spatially precise estimates of salinity changes could generate more accurate and detailed results. However, the current predictions in Table 20 below are a good initial estimate of the magnitude of agricultural revenue impacts that could be generated by crop shifting from salinity changes.

Table 20 Forecasted Crop Revenue Impacts from Increasing Delta Salinity

		Forecast Acreage					Total Revenue				
Crop Category	**Crop Category Avg. Revenue per Acre**	**Baseline**	**25% Salinity Increase**	**50% Salinity Increase**	**100% Salinity Increase**	**200% Salinity Increase**	**Baseline**	**25% Salinity Increase**	**50% Salinity Increase**	**100% Salinity Increase**	**200% Salinity Increase**
	[a]	**[b]**	**[c]**	**[d]**	**[e]**	**[f]**	**[g]**	**[h]**	**[i]**	**[j]**	**[k]**
Deciduous	$4,612	6,954	5,971	5,051	3,486	1,499	$32,071,848	$27,538,252	$23,295,212	$16,077,432	$6,913,388
Field	$780	80,752	83,621	85,246	85,011	74,848	$62,986,560	$65,224,380	$66,491,880	$66,308,580	$58,381,440
Grain	$426	15,925	19,197	22,734	30,335	45,892	$6,784,050	$8,177,922	$9,684,684	$12,922,710	$19,549,992
Pasture	$116	2,963	3,757	4,667	6,810	12,056	$343,708	$435,812	$541,372	$789,960	$1,398,496
Truck	$3,903	29,804	24,460	19,843	12,741	5,029	$116,325,012	$95,467,380	$77,447,229	$49,728,123	$19,628,187
Vineyard	$3,566	3,519	2,911	2,376	1,534	594	$12,548,754	$10,380,626	$8,472,816	$5,470,244	$2,118,204
				Total Revenue			**$231,059,932**	**$207,224,372**	**$185,933,193**	**$151,297,049**	**$107,989,707**
				Scenario Revenue Losses				**-$23,835,560**	**-$45,126,739**	**-$79,762,883**	**-$123,070,225**

Notes:

Modeled regions include 2010 field borders acreage located within specified BDCP conservation zones.

[a] is the average crop class revenue per acre based on 2009 yield and price data from county crop reports.

[a] is the forecasted acreage of each crop class under the specified baseline salinity conditions.

[c]- [f] are the forecasted acreage of each crop class assuming a 25-200% increase in salinity levels

[g] = [a] * [b]

[h] = [a] * [c]

[i] = [a] * [d]

[j] = [a] * [e]

[k] = [a] * [f]

The model predicts a large shift from high-value truck and vineyard crops to lower-value grain and pasture crops should salinity levels rise in the south Delta. This shift would have significant revenue impacts on Delta agriculture. The forecasted shifts in crop distribution are intuitive, as they reflect the salt sensitivity of the dominant Delta crops in each crop category. Processing tomatoes, the dominant truck crop in the Delta, are salt-sensitive, as are wine grapes. Both are expected to decline, while salt-tolerant grain and low-value pasture crops are expected to increase in acreage. Deciduous crops are largely salt-sensitive and are also expected to face decreasing acreage in the south Delta under forecasted salinity increases.

As shown in Table 20, a 25 to 50 percent increase in south Delta salinity could cause a $24 million to $45 million reduction in crop revenue, and the roughly 40 percent proposed increase in south Delta salinity standards falls in this range. The model projects an $80 million revenue loss from a doubling of south Delta salinity, and the potential for larger losses if salinity were to increase further is illustrated by a $123 million loss.

It is important to note that the estimated revenue losses in Table 20 are solely due to crop shifts, and the model does not estimate any potential impacts from yield declines as salinity increases. Further, it does not move any land out of agricultural production as salinity increases, it merely assigns it to lower value categories, and does not account for accumulation of salinity over time. Thus, the losses could be even higher if accounting for these effects, especially for the higher levels of salinity increase. On the other hand, the losses in Table 20 probably include a few upland areas in the Delta that would be little impacted by increased salinity in Delta channels, and these could be areas with higher concentrations of high-value deciduous crops. As discussed earlier, as more spatially disaggregated data on potential salinity changes become available, the estimated effects could be adjusted to take advantage of that data.

6.1.3 Agricultural Revenue Impacts of Isolated Conveyance

As discussed above, the potential revenue impacts of introducing an isolated conveyance facility operated as dual conveyance in combination with continued through-Delta conveyance is closely linked to south Delta salinity standards. If south Delta salinity standards remain at their current levels, the water quality impacts of dual conveyance could be as low as $20 million per year. If an isolated conveyance is introduced and salinity standards are relaxed, the model predicts up to $80 million in lost agricultural revenue per year. There still is significant uncertainty regarding the exact impacts of isolated conveyance, but $20 million to $80 million in annual revenue impacts is a reasonable range based on this modeling. The $20 million to $80 million annual decline is significantly different than the estimates of no loss based on the threshold yield functions and untested assumptions regarding soil leaching fractions.

In addition to water quality impacts, the footprint of an isolated conveyance facility will also take a significant amount of land out of agricultural production, especially in the north Delta. The November 2010 draft BDCP estimates that roughly 8,000 acres will still be required for a tunnel conveyance system, even though the land requirements are much lower than a surface canal. Most of the affected acres are in relatively high-value agricultural lands in the north Delta that currently average about $2,000 per acre per year in revenue. Using detailed acreages allocated across crop classes in the draft BDCP, the land consumption of the isolated conveyance project would result in an additional $10 to $15 million annual loss to Delta agricultural revenues. A surface canal would impact roughly four times the amount of agricultural land.

6.2 Agricultural Revenue Impacts from Habitat Conservation Scenarios

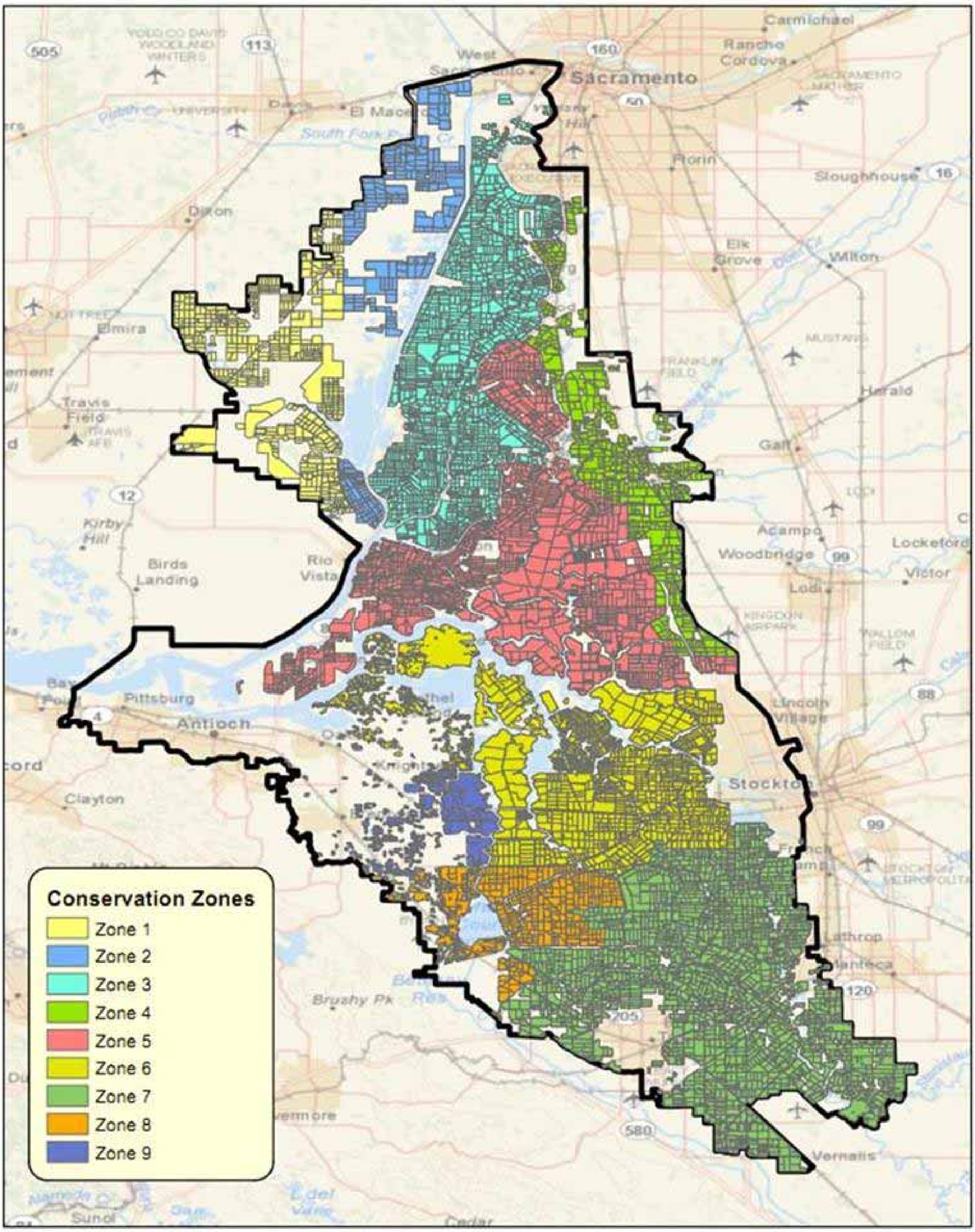
As outlined in Chapter 6, this report seeks to address impacts of four major conservation measures proposed by the BDCP. An extremely precise examination of agriculture impacts is not currently possible due to the lack of specificity provided in the BDCP as to where lands would potentially be conserved or restored. The best spatial approximation of targeted areas is provided by the BDCP's delineation of Conservation Zones and Restoration Opportunity Areas (ROAs) for which conservation investments are proposed. Replicating the spatial extent of these zones and analyzing the agricultural landscape of each gives an estimate of the impacts on agriculture that each conservation measure would entail.

Table 21 below illustrates the total agricultural acreage and average revenue generated by crops fields in each of the BDCP's conservation zones. In addition, a list of the conservation measures with significant impacts in each conservation zone is provided. A map of Delta crop fields and their associated conservation zone is included in Figure 25.

Table 21 Agricultural Composition of BDCP Conservation Zones

Conservation Zone	Agricultural Acreage (2010)	Revenue per Acre (2009)	Relevant Conservation Measures
1	31,030	$463	CM3, CM4
2	14,064	$802	CM2, CM3, CM4
3	59,011	$1,474	CM6
4	26,441	$2,075	CM3, CM4, CM6
5	75,239	$1,838	CM3, CM4, CM6
6	71,219	$1,885	
7	89,716	$1,823	CM3, CM4, CM6
8	27,595	NA	
9	15,809	NA	

Figure 25 BDCP Conservation Zones[123]



[123] For high resolution image see http://forecast.pacific.edu/desp-figs.html

6.2.1 Yolo Bypass Fisheries Enhancement

Major impacts on agriculture from Yolo Bypass Fisheries Enhancement will come from the potential acquisition of lands through fee-title or conservation and flood easements. The largest source of revenue in the affected conservation zone comes from rice fields located along the northern region of the Yolo Bypass, and the use of rangeland could also be impacted. Table 22 estimates current Yolo Bypass crop production excluding grazing land, which might add another $500,000 to the total of $27.1 million. Total agricultural revenue in the Legal Delta area is currently estimated at about $11 million. However, the majority of high-value rice fields is located in the area of the Yolo Bypass north of the Legal Delta, and is estimated to generate almost $16 million in annual revenue and could experience the most significant direct impacts. Given that it is impossible to enhance the Yolo Bypass fishery flows in the legal Delta without simultaneously affecting the area outside the legal Delta, we consider impacts beyond the legal Delta for this conservation measure.

The November 2010 draft BDCP estimates that new flowage easements would be required for 21,500 acres on the eastern bypass or as much as 48,000 acres assuming western tributary flows also flooded the central and western portions of the bypass. Current documents from the BDCP working group are focused on the Fremont Weir Gated Channel operations with an impact on 17,000 acres, and most important, would inundate 7,000 to 10,000 acres in most years after March 1, which gets into the time period where flooding interferes with agricultural planting.[124]

Yolo County is working with UC-Davis on an analysis of the agricultural impacts of more frequent flooding of the Yolo Bypass for fish habitat. The study has more detailed crop, yield and price data than is currently available.[125]

The November 2010 draft BDCP estimates new flowage easements would average 25 percent of property value on 21,500 acres in the bypass, using the current agricultural revenue that implies a roughly $7 million annual decline in crop revenue. If, as in the September 2011 discussion document, roughly 10,000 acres were flooded to preclude production in about 60 percent of years, average lost agricultural revenue could be as high as $10 million. Thus, our rough estimate of potential lost agricultural revenue from Yolo Bypass Fishery enhancements is $7 million to $10 million.

Yolo County is working with the BDCP Yolo Bypass Fishery Enhancement Working Group to develop a proposed project that minimizes or avoids impacts to existing land uses, and provides full mitigation for tax revenue and economic impacts. Like other preliminary cost estimates for habitat measures, the estimated impacts could change as plans change over time.

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[124] Potential Operation Pattern for Fremont Weir Gated Channel, or "Notch," September 23, 2011 Draft for Discussion Purposes. Available at www.baydeltaconservationplan.com.

[125] Some preliminary modeling results are in Garnache, C. and R.E. Howitt. 2011 "Analyzing the Tradeoffs Between Agriculture and Native Species: The Case of the Yolo Bypass Floodplain." Selected Paper prepared for presentation at the AERE 2011 Summer Conference, Seatlle, June 9-10, 2011.

Table 22 Yolo Bypass Crop Acreage and Revenue, 2009[126]

	Inside Legal Delta		*Outside Legal Delta*	
Crop Category	**Acres**	**Value**	**Acres**	**Value**
Deciduous	73	$314,000	0	$0
Field	5,026	$3,961,837	7,760	$11,087,862
Grain	1,179	$394,461	370	$145,050
Pasture	4,415	$241,030	0	$0
Truck	1,875	$6,321,309	1,500	$4,634,129
Vineyard	0	$0	0	$0
Total	**12,568**	**$11,232,637**	**9,630**	**$15,867,041**
YOLO BYPASS TOTAL			**22,198**	**$27,099,678**

6.2.2 Natural Communities Protection

The Natural Communities Protection strategy has several elements. The most significant for agricultural production in the Delta would be the conversion of 8,000 acres of grazing land to native grasslands, and the creation of nearly 33,000 acres of agricultural habitat through fee-title purchases or easement acquisition. Since grazing lands crop value is roughly $20 per acre, the loss of 8,000 acres would amount to only $160,000 per year. However, that measure probably understates the total impact on cattle production in the region, as this would represent a roughly 30 percent loss in the current grazing land that supports cattle production estimated at $24 million per year. The increase in irrigated pasture that could be created through the 32,000 acres of “agricultural habitat” protection could offset this loss and thereby minimize any impact on the cattle industry.

The most significant part of this conservation strategy is the acquisition of nearly 33,000 acres in “wildlife friendly” agricultural easements. The draft BDCP does not give specific information about implementation, but offers some general guidelines that can be used to anticipate impacts. Pages 2-130-132 of the November 2010 draft BDCP identify alfalfa, irrigated pasture, and rice as crops that provide high habitat values, and orchards and vineyards as crops that provide little habitat value. Other cultivated annual crops such as corn, tomatoes, grains, and other truck crops are described as providing seasonal habitat value with high variation among crop types. The high habitat value crops generate average revenue of $100 to $1,400 per acre, whereas the low habitat value crop types generate average revenues of $3,500 to $4,500 per acre. The draft BDCP estimates the costs of land and easement acquisition of cultivated habitat at $8,000 per acre ($260 million for 32,600 acres) which suggests that at least some permanent crops will be targeted for acquisition given current land prices.

Roughly 13,000 acres of the “agricultural habitat” is targeted for Conservation Zones 1 and 2 which include most of the Cache Slough area in Solano County and the Yolo Bypass. These areas average less than $1,000 per acre in crop value and are already mostly planted in the preferred crop types for habitat. Thus, the creation of “agricultural habitat” in this area would presumably lock in current cropping patterns, and have little impact on agricultural revenue compared to current levels.

[126] Yolo bypass crop production varies widely from year to year and as explained earlier, our field level data does not fields that did not have pesticide use filings (e.g. organic). Detailed studies in progress by UC-Davis will likely have more detailed and complete data.

Approximately 10,000 acres of agricultural habitat is targeted for Conservation Zone 4, in the northeast Delta, and Conservation Zone 7, the south Delta. These areas have average revenues of approximately $2,000 per acre, among the highest value croplands in the Delta. Vineyards are a significant part of CZ4, and there is much potential growth for this region. Presumably, the objective of this conservation measure would be to stop or reduce vineyards in this region in favor of pasture, alfalfa, or corn as grown by the Nature Conservancy on Staten Island. In the south Delta, there are some vineyards as well as significant numbers of truck crops that might be viewed as less wildlife friendly. The anticipated easement costs suggests a displacement of $300 to $400 per year in net profit, which might translate to roughly $1000 per year in net production.

Overall, the natural communities and agricultural habitat protection is among the most difficult to value the agricultural revenue impacts. Considering the discussion above, an agricultural revenue loss of $5 million to $25 million per year is a reasonable estimate at full implementation. The use of more limited term easements or a conservation reserve program model instead of fee-simple and permanent easement purchases might be considered. This would reduce the impact on the agricultural economy by allowing Delta agriculture more flexibility to respond to future market changes.

6.2.3 San Joaquin River Floodplain Restoration

The November 2010 draft BDCP calls for the restoration of 10,000 acres of seasonally-inundated floodplain habitat over a 40-year period, with 1,000 acres restored in the first 15 years. No specific regions are outlined, though the BDCP notes that “the most promising opportunities for large-scale restoration are in the south Delta along the San Joaquin River, Old River, and Middle River channels…” These areas fall almost entirely within conservation zone 7, which is largely occupied by high-value alfalfa and tomato crops and has an average per-acre revenue of $1,823. In addition, the identified areas are almost entirely in agricultural production, and a large proportion of the restored floodplain would almost certainly affect land currently in production. Based on current production, the San Joaquin River Floodplain Restoration could reduce annual agricultural revenue by $15 million to $20 million per year.

An alternative proposal focused on enhancing the flood bypass at Paradise Cut has been developed cooperatively between environmental groups and local Delta landowners. This proposal would generate significant flood control and ecosystem benefits while limiting agricultural impacts to 2,000 acres, thereby reducing agricultural impacts by up to 80 percent. The alternative proposal is recommended in the fourth draft of the Delta Stewardship Council’s Delta Plan. The details of these plans are very uncertain at this time, and BDCP planning does not seem to be as well developed as it is for Yolo Bypass Fishery Enhancements at this point. Given the uncertainty, the estimate of potential lost agricultural revenue ranges between $3 million and $20 million per year depending on what plans are implemented.

6.2.4 Tidal Habitat Restoration

Of the major conservation measures addressed in this report, tidal habitat restoration has the most clearly defined geographic areas and restoration targets. Tidal habitat also has by far the largest potential economic impact on agriculture due to the high acreage targets and the fact that it eliminates all agricultural uses rather than limits agricultural activity with measures such as conservation easements. The agricultural fields contained in each Restoration Opportunity Area (ROA) are shown in Figure 26, with their acreage and value in each region depicted in Table 23 below. The BDCP outlines various restoration targets to be achieved over the next 40 years, with a final target of 65,000 restored acres in the Delta and Suisun Marsh. In addition, there are minimum values for acreage in each of the four ROAs which must be restored, as shown in Table 23. A minimum of 7,000 acres is targeted for Suisun Marsh, which lowers the maximum target for tidal habitat in the Delta to 58,000 acres.

Table 23 Agricultural Composition of BDCP Restoration Opportunity Area

Restoration Opportunity Area (ROA)	Total Acreage	Agricultural Acreage (2010)*	Minimum Restoration Target (Acres)	Revenue per Acre (2009)
Cache Slough Complex	49,167	19,854	5,000	$491
Cosumnes/Mokelumne River	7,805	7,840	1,500	$2,175
South Delta	39,969	34,914	5,000	$2,151
West Delta	6,178	2,587	2,100	$1,279
TOTAL	**103,119**	**65,195**	**13,600**	**$2,014**

*Values may be slightly inflated due to large fields centered within the ROA which extend past its borders.

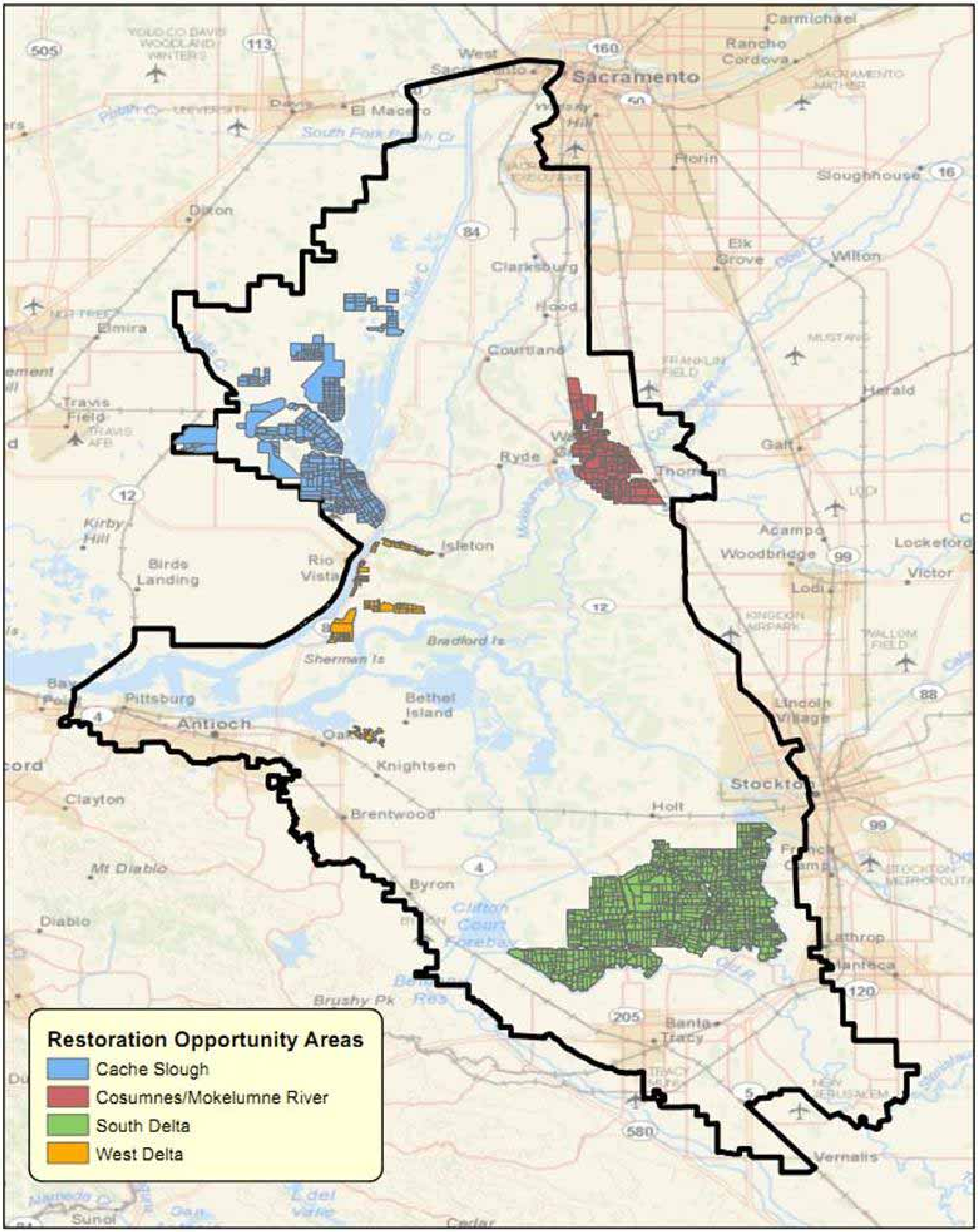
As can be seen in Table 23, in some regions even the minimum restoration targets will require the acquisition of land currently used in crop production. In addition, both the Cosumnes/Mokelumne River ROA and the South Delta ROA are centered in some of the highest revenue agricultural areas of the Delta. Even if over 50,000 acres were restored in Suisun Marsh so that only the minimum restoration targets were reached in the four Delta ROAs, total agricultural revenue loss would be about $18 million per year with nearly $11 million of the total loss occurring in the south Delta. If only the minimum were restored in Suisun Marsh and the remaining 58,000 acres were proportionally distributed across the Delta, the estimated revenue loss would reach $77 million per year with about a $46 million loss in the South Delta.

Tidal marsh restoration in Cache Slough has been discussed for decades because restoration in the area would have little impact on the current through-Delta conveyance of fresh water, and it has desirable environmental and elevation characteristics. Table 23 indicates that its lower revenue per acre might make it a target area for economic reasons, although representatives from Solano County have said that the low revenues per acre can be partially attributed to the regulatory and planning “cloud” that has been over the area for years and discouraged investment in higher-value crops. A March 2008 report by Kurt Richter of the University California Agricultural Issues Center[127] provides a detailed tract by tract analysis of the potential impacts of tidal habitat restoration proposals in Cache Slough and Suisun Marsh that go beyond the direct loss of agricultural production.

The report finds that the least costly way to attain the ecological restoration goals for Cache Slough area would be to convert Hastings Island, Egbert Tract and Little Egbert Tract to tidal habitat. These three areas “would provide over 17,000 acres of habitat and remove $9.6 million from the agricultural economy in Solano County (2006 dollars).” The report also notes that restoration of these three areas “will require that the levees around Ryer Island, North Ryer Island and Hass Slough be moved or redesigned since the new system will increase the threat of underseepage,” and notes other concerns related to waterfowl habitat and water quality.

[127] Richter, K.R., “The Potential Impact of the Delta and Suisun Marsh Habitat Restoration Plans on Agricultural Production in Solano County,” University of California Agricultural Issues Center, March 14, 2008.

Figure 26 BDCP Restoration Opportunity Areas[128]



[128] For high resolution image see http://forecast.pacific.edu/desp-figs.html

The wide range of potential agriculture losses ranging from $18 million to $77 million annually illustrate the risk and uncertainty this conservation strategy poses for Delta agriculture. Compared to the other conservation measures, the tidal marsh restoration strategy entails the largest necessary direct impacts on Delta agricultural production, and also has some of the highest direct implementation costs for BDCP. The BDCP currently states that the majority of these targeted lands will be determined “based on land availability, biological value, and practicability considerations.” The absence of agricultural impacts from the described methodology is a notable omission considering the potential implications for the Delta economy. Targeting criteria that avoids high-value agriculture lands and reduced target acreages, particularly in the south Delta, should be considered.

6.2.5 Summary and Additional Concerns Regarding Habitat and Agriculture

Considered together, the four habitat conservation measures here could reduce agricultural output in the Delta between $33 million and $137 million per year. The wide range shows the importance of considering agricultural impacts when designing conservation measures. The $33 million revenue loss scenario shows that it is possible for significant habitat restoration to be compatible with economic sustainability of Delta agriculture if it is carefully planned to minimize impacts. However, the potential for $137 million in direct losses to agricultural output shows that habitat restoration could also have severe negative impacts on the Delta economy.

There are additional risks to Delta agriculture from habitat restoration measures in addition to the direct losses to agricultural production described in this section. The following list of additional concerns is taken from a letter from Deputy Natural Resources Secretary Jerry Meral inviting participants to a September 13, 2011 meeting on the potential impacts of the BDCP habitat projects on agriculture.

- Increased risk of levee failure due to changes in levee configurations with tidal habitat restoration actions
- Water quality and salinity issues for agricultural irrigation as a potential result of water facilities operations and tidal habitat restoration
- Water elevation changes at agricultural intakes as a result of water facilities operations
- Effects on agricultural land from adjacent restored tidal habitat, such as seepage
- Neighbor effects of increased endangered wildlife species on BDCP preserves next to agricultural lands
- Increased presence of listed fish species at agricultural diversions and potential regulatory effects where aquatic habitat restoration increases listed fish densities
- Weed control on habitat lands
- Mosquito and vector control issues

In addition to these impacts, participants in the meeting raised concerns about the potential for decreased property values even if land is not being restored, and increased crop loss from feeding and predation of wildlife such as birds attracted to nearby restored habitats.

6.3 Loss of Agricultural Value from Open Water Scenario

The central Delta open water scenario discussed in Chapter 6 would result in a loss of agricultural production on the flooded islands. The impacts can be quantified simply by looking at the agricultural farmland currently in production on each island. If the six islands were flooded, almost 13,000 acres would be lost, with a corresponding loss of around $11 million dollars in direct revenues per year. The islands are largely composed of low-value field crops, with average revenue per acre significantly below that of the Delta as a whole. A summary of the affected islands is depicted below in Table 24. As discussed in Chapters 4 and 6, it is highly unlikely that Empire Tract would be flooded due to new water supply infrastructure for the City of Stockton.

Table 24 Six Island Agricultural Composition

Island	Agricultural Acreage (2010)	Total Revenue (2009)	Revenue per Acre (2009)
Mandeville	2,345	$2,198,583	$1,117
Medford	365	$279,797	$715
Quimby	629	$487,720	$776
Venice	2,587	$2,008,844	$765
Webb	4,469	$3,467,869	$776
Empire	2,521	$2,539,318	$1,031
TOTAL	**12,916**	**$10,982,131**	**$981**

6.4 Impact of Land Use Regulatory Changes on Delta Agriculture

The “covered actions” provisions of 5th Draft of the Delta Plan have raised concerns about increased regulatory costs or constraints on Delta agriculture. For example, on page 54, the Delta Plan attempts to clarify what are “covered actions” regulated by the Delta Plan by saying, “Routine agricultural practices are unlikely to be considered a covered action unless they have a significant impact on the achievement of the coequal goals or flood risk.” The statement has created concerns that increased regulation could affect investment to supporting farm structures such as packing sheds or regulating the planting of permanent or crops that are deemed to be less wildlife friendly. There are also concerns about potential impacts on property values.

Chapter 8: Recreation and Tourism

1 Overview and Key Findings

- Recreation is an integral part of the Delta, complementing its multiple resources and contributing to the economic vitality of the region. Residents of nearby areas visit virtually every day, generating a total of roughly 12 million visitor days of use annually and a direct economic impact of more than a quarter of a billion dollars in spending.
- The Sacramento-San Joaquin Delta is an area where a diversity of recreation experiences is evident, from boating in open water or through winding tree-covered channels, to hunting or wildlife viewing, studying local California history, or tasting award-winning local wines.
- Several physical and operational constraints have an impact on current facilities and recreation access, including sediment accumulation, water gates, screens, and barriers, invasive species, waterway obstructions, water quality, lack of boat-in destinations and access points, user group conflicts, private land trespass, and complex regulations.
- While a percentage of visitors to the Delta come from elsewhere, the majority of visitors are from Northern California. These visitors represent the focal market for Delta recreation growth opportunities in the future, and their places of origin define the Market Area for this study. The total Market Area had a population estimate of approximately 11.9 million in 2010, with projections of 17.6 million by 2050.
- Recreation visitation for 2010 is estimated to be approximately 8 million *resource-related* (e.g., boating and fishing) visitor days of use per year, 2 million *urban parks-related* (e.g., golf, picnic, and turf sports), and 2 million *right-of-way-related* (e.g., bicycling and driving for pleasure) recreation visitors/year. The total number of activity days is conservatively estimated at approximately 12 million/year.[129]
- An up-to-date visitor survey with new primary data, particularly on non-boating and non-fishing recreation, is needed to better document existing recreation visitation and spending.
- Employment within the Primary Zone in recreation-related economic sectors—including marinas, water craft rental, boat dealers, and boat building and repair—has been relatively flat over the past 20 years.
- The principle changes and trends that could affect the present recreation use and demand over the next 50–90 years are: physical changes to the Delta due to water conveyance management changes and rising sea levels, increasing population and development growth, increasing agritourism, non-consumptive resources-based recreation, habitat-related recreation, and the likely desire for closer-to-home recreation.
- The current direct spending in the Delta region from *resource-related* and *right-of-way/tourism-related* trips and related non-trip spending is estimated at roughly $312 million inside the Delta (in 2011 dollars). Additional economic impacts associated with urban recreation are not quantified, but are likely significant.
- Delta recreation and tourism supports over 3,000 jobs in the five Delta counties. These jobs provide about $100 million in labor income and a total of $175 million in value added to the regional economy.
- Delta recreation and tourism supports over 5,200 jobs across all of California, and contributes about $348 million in value added.

[129] Estimates are based on limited data combined with professional judgment.

- State Parks' *Recreation Proposal for the Sacramento-San Joaquin Delta and Suisun Marsh* offers a strong framework for needs and opportunities for the provision of recreation and tourism in the Delta by state agencies.
- When attracting visitors and expanding recreation access to waterways and landside recreation improvements, potential negative impacts on agriculture from increased tourism and recreation can be minimized by focusing recreation uses and activities through expansion of existing recreation sites, development in Legacy Communities, creating buffer areas adjacent to agriculture, and increasing public safety enforcement.
- Growth of recreation in the Delta can be fostered through five location-based strategies, which would emphasize increased public access and related private development:
  - Delta waterways, specialized by boating type;
  - Dispersed, small points of interest and activity areas such as marinas, farmer's markets, wineries, restaurants;
  - Focal point complexes such as Legacy Communities or Bethel Island/Jersey Island/Big Break;
  - Natural habitat areas; and
  - The edges of existing and emerging urban areas that surround the Delta such as Stockton, Tracy, Rio Vista, and Lathrop.
- If resource quality and recreational facilities are maintained such that the Delta retains its current level of competitiveness as a recreation destination, baseline forecasts for visitation show increases of 3.4 million visitor days, or about 35 percent, over 40 years. If this Plan is implemented, recreation visitation in the Delta (including resource-related recreation, right-of-way recreation, and tourism) would increase over baseline.
- Assuming that current visitor spending patterns remain unchanged and Delta business growth accommodates recreation-related spending increases, baseline visitation growth is estimated to increase spending in the Delta roughly $78 million (2011$) to about $329 million (2011$) by 2050. Plan implementation could increase the economic impact of recreation over the baseline.
- Possible policy scenarios are qualitatively evaluated as to their primary elements and their potential positive and negative impacts on recreation.
  - Scenarios evaluated may affect recreation visitation by either decreasing visitation or increasing visitation over the baseline scenario, with the expected largest potential for negative impacts from increased regulatory changes or the six-island flooding and the largest potential for positive impacts from the habitat conservation scenario.
  - Visitation changes would also affect recreation-related spending in the Delta, as compared with the baseline forecast. It is anticipated that the magnitude of these potential changes is smaller in magnitude than the potential economic impacts to the agricultural economy.
  - The largest anticipated potential negative impacts would result from regulation changes, six-island flooding, salinity increases in the central and south Delta, large tidal marsh creation in the south Delta, and intake and pumping stations near Clarksburg and Courtland.
  - Positive impacts could result overall through project enhancements to fishing, wildlife viewing and nature study, and Delta-as-a-Place.
- A significant operational constraint for future growth in recreation demand is that there currently exists no Delta brand, overall marketing strategy, or significant-scale focal point area. An existing organization should be designated as a Delta recreation and tourism marketing and economic development facilitator.

- Recommended Implementation Strategies include consistency planning and regulation refinement, public/private coordination and partnerships, multi-agency coordination, strategic levee protection, Delta-wide marketing, and financing.

2 Introduction

The Delta is a significant natural place in California—a mixture of meandering rivers, sloughs, back bays, shipping channels, small communities, historic sites, and agricultural islands with farm markets and wineries. It is a vast area, covering over half a million acres, with about 60 larger tracts and islands and over 650 linear miles of waterways and channels.

The Delta links California's Central Valley with the San Francisco Bay. It is surrounded by cities (some of which have historic roots) and urbanizing areas at the edge of the Delta, and its two primary rivers, the Sacramento and the San Joaquin.

Approximately 12 million people live within close proximity of the Delta, yet most do not see it as a vital water source for the state, as a rich biological resource, or as an important agricultural production area, although it is all of these. For most, the Delta is best known for the recreation opportunities found there.

The Delta gives visitors a place to slow down and relax, to taste earth's bounty, and to leave the urban areas behind. It is called California's boating paradise, and is one of the state's most important fishing and waterfowl hunting resources, a place with natural habitats for bird watching and nature study, and a scenic place to meander and explore by boat or car.

Recreation is an integral part of the Delta, complementing its multiple resources and contributing to the economic vitality and livability of the region. Residents of nearby areas visit virtually every day, generating a total of roughly 12 million visitor days of use annually and a direct economic impact of more than a quarter of a billion dollars in spending.

3 Current Status and Trends

3.1 Understanding 'Delta as a Place' Today

The Delta is difficult to characterize as both a region and, likewise, a recreation destination. Unlike well-known water recreation destinations such as Lake Tahoe or Shasta Lake, the Delta is not a single entity and cannot easily be conceived in its entirety. It has highly varied physical attributes and covers a vast and varied landscape that can be viewed and accessed from activity points that are so disparate, it is possible to repeatedly visit the Delta and still have little understanding of exactly what the Delta is or how large it is.

Extending more than 50 miles from north to south, the Delta is sometimes centered on a wide river, though more often it is a network of narrow channels, sloughs, and islands. It presents itself from two distinct vantage points, each of which represents a completely different character. One view is from the water, where the landscape typically lies, unseen, behind tall levees and riparian vegetation, with only distant mountains visible. From the perspective of thicket-edged sloughs, narrow rock-faced channels, or spreading, open waterways, there is little landside context. The other view of the Delta, the landside perspective, largely precludes the water environment, which can be glimpsed primarily from levee-top roads and bridges. The predominant visual character landside is the agricultural landscape, which is as varied as the waterscape hidden on the other side of the levees.

This setting creates a place of paradox; it is a region that can be unapproachable and unapparent to visitors. For those who do not already know and visit the Delta, it can be a place that exists in name alone. Many people drive through the Delta without a clear sense of being in it and less notion of where it begins and where it ends.

Defining the Delta for visitors and recreation users is a necessary and yet difficult task. Because of the scope of the disparate environment, recreation destinations appear as a network of smaller recreation locations, each one suited to a different type of activity. To windsurfers, the open and windy waters of the larger channels flowing along the western side of Sherman Island might define the Delta. Sailors coming up from San Francisco Bay would define the Delta as offering protected deeper channels and coves. Water skiers and wake boarders might define the Delta by its protected narrower and straighter channels to the south, near Discovery Bay. Fishermen will be attracted to other aspects of the Delta, with differing characteristics, as varied as the fish they are seeking. So, too, kayakers, canoeists, pleasure cruisers, house-boaters, birders, hunters, and others, each seeking an aspect of the Delta specific to their interests and pursuits, will define the Delta in their own specific terms.

Recreationists from the landside may see a completely different Delta. Shoreline fishermen share the environment seen by those on the water and from the few recreation sites on land such as campgrounds and picnic areas. Hunters working fields and the edges of sloughs might never see open waterways as they seek game. For the vast majority of visitors to the Delta who never reach the water's edge, the landscape will be essentially one of agricultural fields, levee roads with river views, wineries and produce outlets, and sometimes, a Legacy Community's historical or cultural landmarks.

3.2 Existing Physical Conditions

3.2.1 Resource and Facility Analysis

3.2.1.1 Existing Facilities

In the Delta, people seeking recreation experiences primarily go to private enterprises, including marinas, restaurants, retail establishments, wineries, and farm stands. Public recreation facilities exist, but they are limited and many are natural resources-based, restricted-use areas such as the Department of Fish and Game's Wildlife Areas and Stone Lakes National Wildlife Refuge. Private nonprofit organizations such as The Nature Conservancy, Yolo Basin Foundation, and Solano Land Trust also provide recreation opportunities, which generally are related to habitat areas.

3.2.1.2 Private Facilities

Marinas are a common Delta access point for water recreation. Of the 95 marinas surveyed in 2001 as part of *The 2002 Sacramento-San Joaquin Delta Boating Needs Assessment,*[130] 92 were private and three were public facilities. Of the 92 private facilities, 87 were open to the public and five were private membership-based yacht clubs. These 92 private marinas provided a number of facilities to the Delta boater, including boat slips, launch ramps, parking, restrooms, restaurants, picnic facilities, camping sites, pumpouts, used oil collection centers, recycling centers, and fuel stations. Current data regarding business establishments in the Delta indicate that the number of marinas has not changed significantly since the early 2000s. Figure 27 provides a map of recreation zones and Figure 28 shows recreation facilities. Table 25

[130] DBW 2002

summarizes all facilities, as of 2002, by recreation zone with additional information about these zones.

Table 25 Summary of Facilities and Resources by Recreation Zone

	Recreation Zones						
	Northern Delta Gateway (North)	Bypass (Northwest)	Delta Hub (Central)	Delta Breezeway (West)	San Joaquin Delta Corridor (East)	Southern Delta Reaches (South)	Total
Linear Miles of Contiguous Waterways	61	58	132	152	122	110	635
Number of Marinas	8	1	12	56	13	5	95
Boat Slips	988	76	1,271	5,990	2,786	563	11,674
Transient Tie-Ups	20	18	69	115	69	18	309
Launch Ramps	3	1	9	27	11	4	55
Marina Parking Spaces	522	38	918	4,826	1,989	432	8,725
Day-Use Picnic Sites	40	0	52	183	26	23	324
Camp/RV Sites	54	0	247	1,501	327	53	2,182
Fuel Stations[131]	3	0	7	28	12	6	56
Source: DBW 2002, Table 2-1, Page 2-5							

The Delta's other major private recreation facilities are the numerous private hunting clubs, which typically are associated with agricultural lands. Very little information exists on the number of these facilities or the number of hunters who utilize them. In a 1997 survey, the Delta Protection Commission identified 23 private hunting facilities, most in Yolo County. Conversations with hunters indicate that many additional formal and informal hunting clubs are located throughout the Delta.

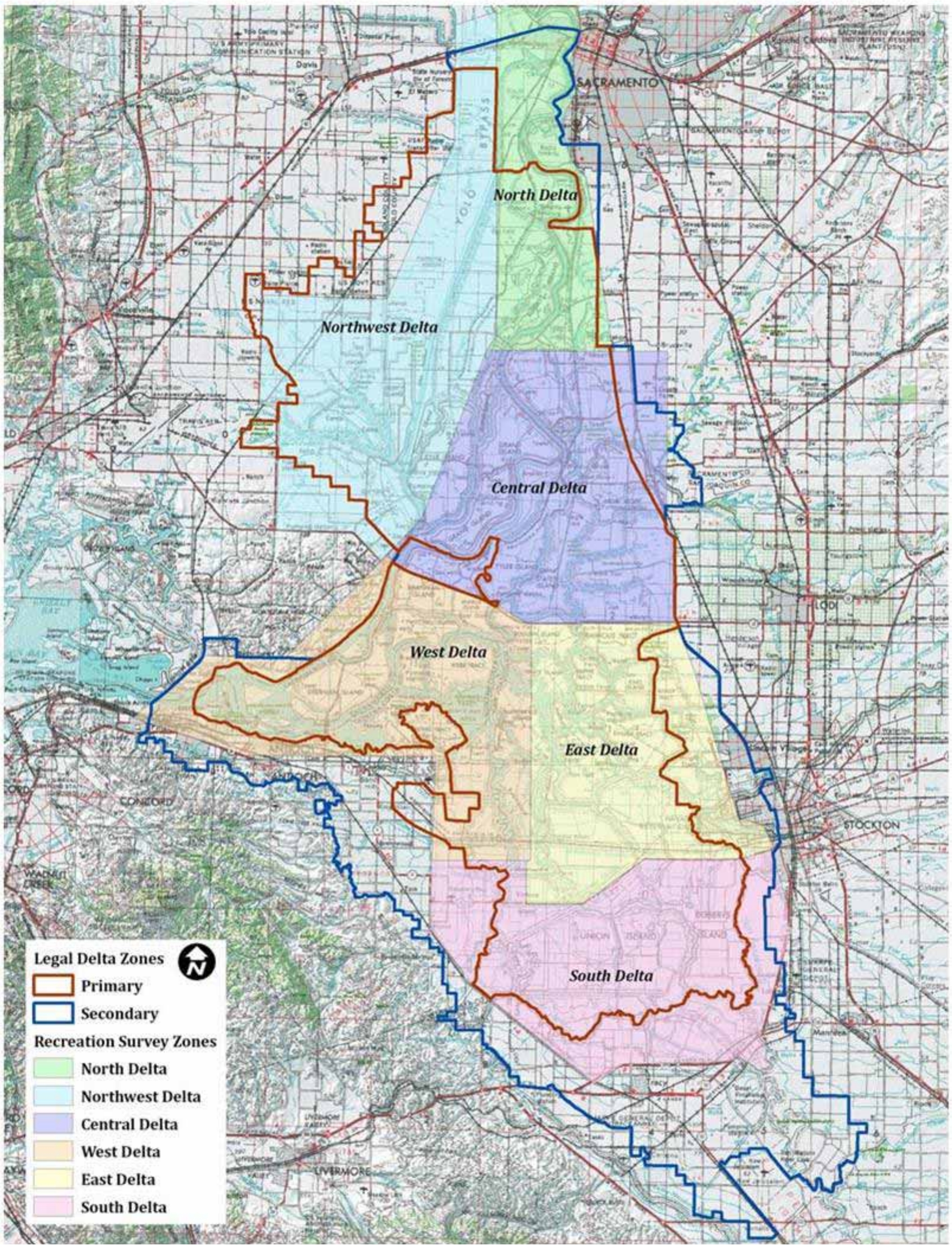
Private nonprofit organizations such as The Nature Conservancy and the Solano Land Trust also provide for some public recreation on facilities that they manage. The Cosumnes River Preserve includes lands owned by both public and not-for-profit organizations such as Bureau of Land Management, Department of Fish and Game (DFG), Department of Water Resources (DWR), The Nature Conservancy (TNC), Ducks Unlimited, Sacramento County, and the State Lands Commission. The preserve has a visitor center with picnic areas, interpretive displays,

[131] A phone and internet survey was completed as part of this project to update the total number of marinas, camping facilities, fuel stations, and other facility numbers. Section 3.2.1.4 and Appendix I include details about those facility numbers. However, the numbers in Table 25 are left as is, as those were taken directly from the DBW 2002 survey, still provide a general magnitude of totals, are broken down by recreation zones, and all numbers have not been updated.

restrooms, and three designated hiking trails and allows bird watching, photography, hiking, and paddling.

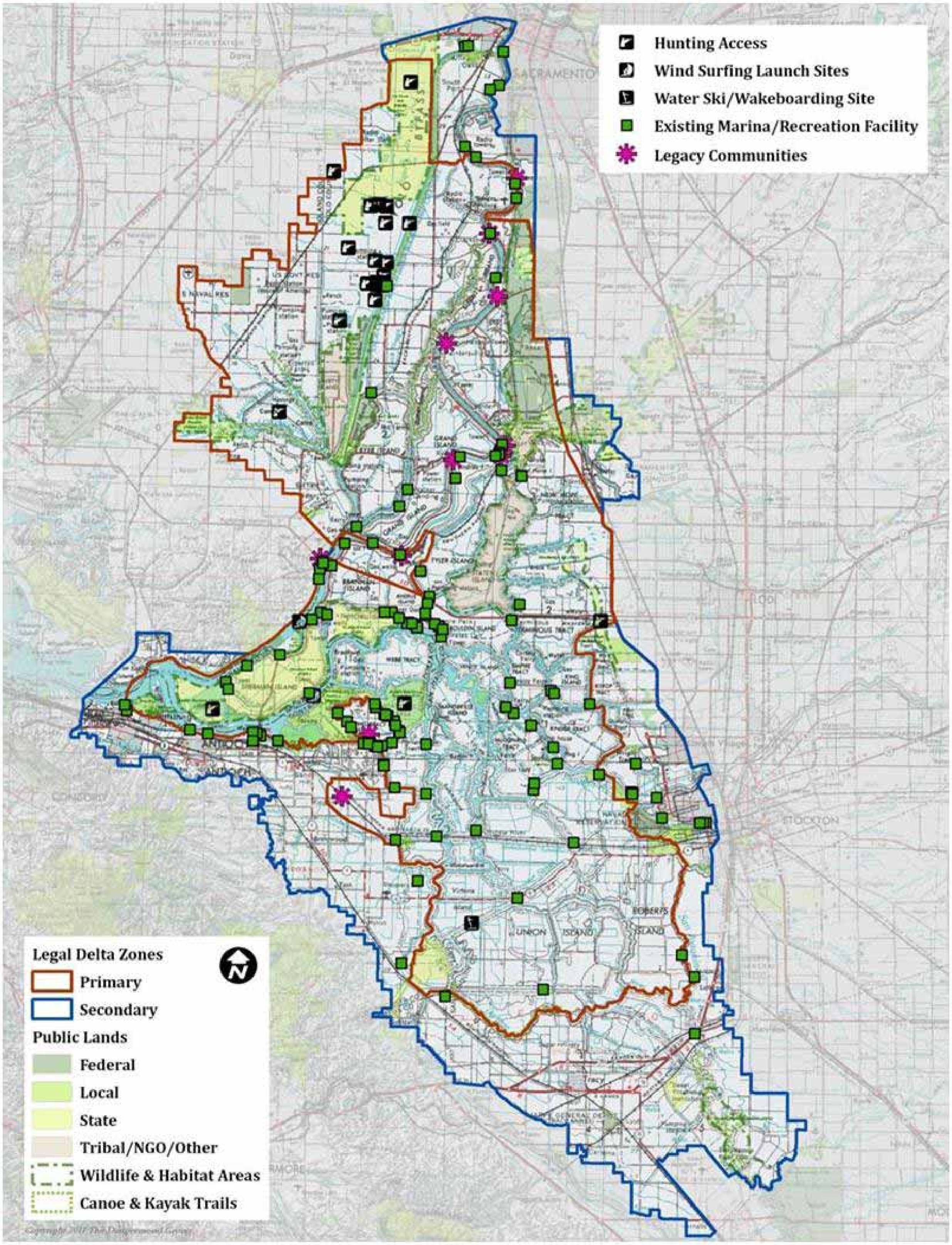
Additional private facilities include those catering to Delta-as-a-Place recreationists and tourists, including restaurants, agricultural stands, and wineries. A recent study found 25 attractions/historic places, 17 farmers markets, and nine wineries/tasting rooms (Figure 29).

Figure 27 Delta Recreation Zones[132]



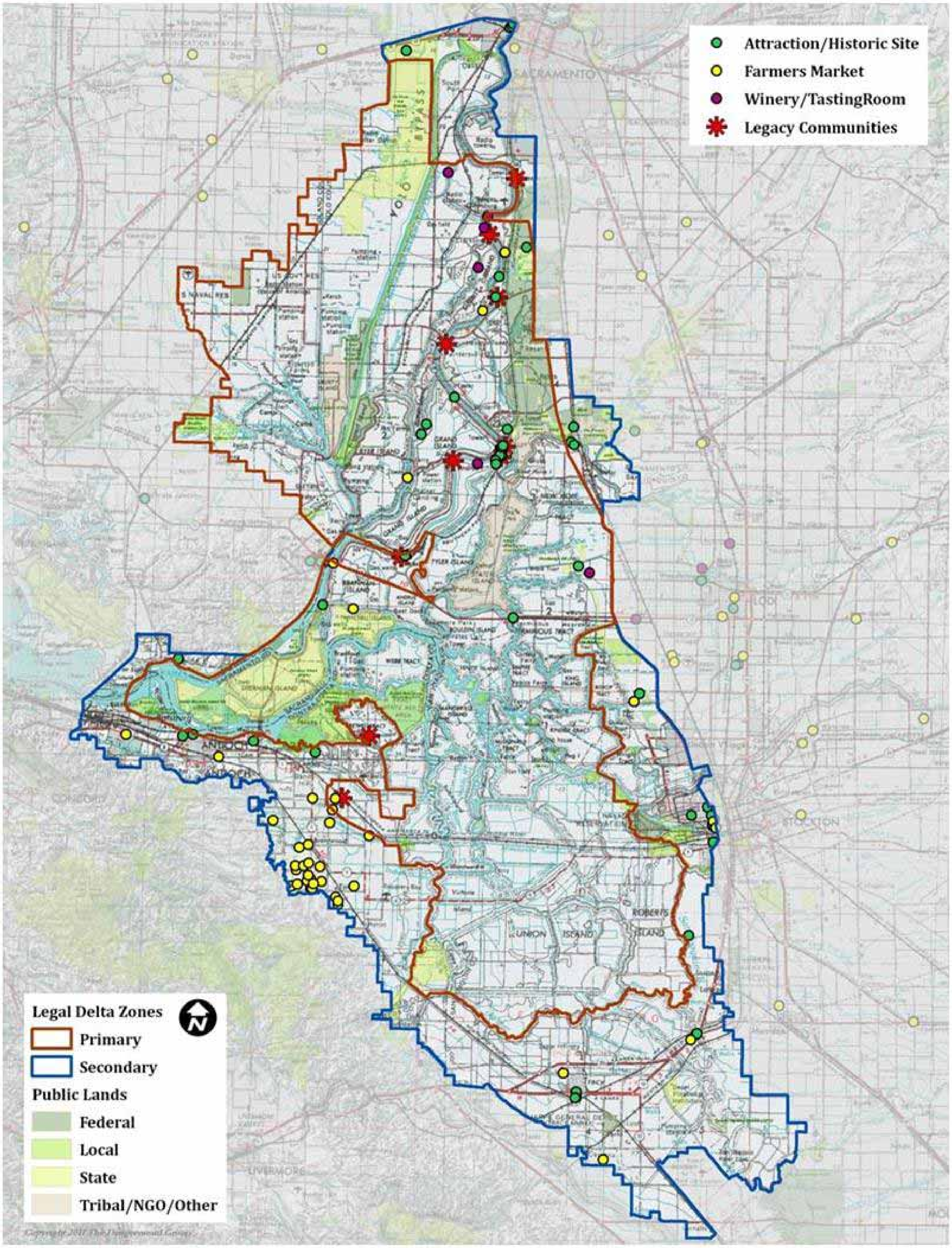
[132] For high resolution image see http://forecast.pacific.edu/desp-figs.html

Figure 28 Delta Recreation Facilities[133]



133 For high resolution image see http://forecast.pacific.edu/desp-figs.html

Figure 29 Delta Tourism Facilities[134]



[134] For high resolution image see http://forecast.pacific.edu/desp-figs.html

3.2.1.3 Public Facilities

There are a number of publicly-owned lands in the Delta, covering almost 40,000 acres. A percentage of these lands is open to public recreation access, including hiking, day use, fishing, hunting, and wildlife viewing. Stone Lakes National Wildlife Refuge is the largest public facility, with 6,200 service-managed acres within its 18,000-acre boundary, but provides limited public access in the form of waterfowl hunting, guided hikes, special events, bird watching, and canoe/kayak tours. Stone Lakes is in the process of opening a new trails and visitor facility, the Blue Heron Trails Visitor Contact Station, which will feature a universally accessible trail, interpretation, an unstructured play area, restroom, and outdoor amphitheater. It is scheduled to open in November 2011.

Brannon Island State Recreation Area provides some of the best public facilities in the Delta, including three group picnic sites, 300 general picnic sites, 78 miles of non-motorized trails, grassy areas, a campground with 102 developed sites, six group camping sites, a boat launch ramp, sewage/bilge pumpouts, non-motorized boat access, a swimming area, and berths and tie-ups for transient boats.[135,136] The Department of Fish and Game owns and manages a number of Wildlife Areas, including Acker Island, Lower Sherman Island, Sherman Island, Woodbridge Ecological Reserve, and Yolo Bypass Wildlife Area. These facilities provide for a variety of activities, from bird watching tours to hunting, fishing, wildlife viewing, and education.

A number of public access trails exist or are in development, including the American Discovery Trail, Mokelumne Coast-to-Crest Trail, and the Great Delta Trail. These trails currently support or will provide public access for a variety of recreation activities, including hiking and biking. Additionally, State Highway 160 is a designated State Scenic Highway. A number of water trails have also been proposed.

There are also a number of local and regional parks within the Delta, including those provided by the cities of Tracy, Stockton, and Lathrop, the counties of Sacramento, San Joaquin, and Yolo, and regional providers such as East Bay Regional Parks District. These parks and facilities include Antioch Marina, Antioch Public Boat Ramp, Big Break Regional Shoreline, Garcia Bend Park Launch Ramp, Louis Park Boat Launching Facility, Morelli Park Boat Launching Facility, Sandy Beach Park and Boat Launch Facility, Hogback Island Access, and Sherman Island Public Access Facility. Figure 28 above shows some of these public facilities.

3.2.1.4 Recreation Enterprises in the Delta

A variety of data on business enterprises in the Delta describe economic activity attributable to recreation and tourism. As seen in Table 26 below, nearly 100 business enterprises within the Primary Zone are recreation-related. In the Secondary Zone, there are nearly 1,500 recreation-related enterprises, though many businesses likely provide for broad urban and non-local recreation opportunities in addition to serving Delta recreation.

[135] State Parks 2010, p. 20-21.
[136] This site is on the State Parks closure list and may be closed to public access as of July 1, 2012.

Table 26 Data for Recreation-Related Enterprises within the Legal Delta in 2008[137]

	Primary Zone	Secondary Zone
Industry	**Number of Establishments**	**Number of Establishments**
Boat Building	1	19
Recreational Vehicle Dealers	0	4
Boat Dealers	8	30
Scenic and Sightseeing	0	2
Performing Arts, Spectator Sports, and Related Industries	4	208
Museums, Historical Sites, and Similar Institutions	1	16
Amusement, Gambling, and Recreation Industries (including marinas)	34	255
Accommodation	22	148
Food Services and Drinking Places	26	778
Total	96	1,460
Source: NETS; UOP		

Many enterprises within the Delta, especially the marinas, offer more than one service. The chart above lists enterprises based on their primary business classification and the numbers may undercount certain services. For instance, several marinas also have restaurants, campgrounds, and a convenience store, provide boat repair services, and have fuel docks. In order to provide a picture of the facilities and services that are offered by enterprises within the Delta, further research was done of individual establishments, as detailed in Appendix I. Through this process, the following facilities or services were identified.[138]

Table 27 Businesses Offering Recreation-Related Facilities and Services within the Delta

	Number of Facilities or Services
Marinas	112
Camping/RV Facilities	64
Restaurants[139]	81
Fuel Docks	45
Boat Builders	16
Boat Dealers	35
Boat Repair Facilities	49
Source: NETS, UOP	

Within the recreation-related businesses, the detail for "Accommodations" was further expanded and is presented in Table 27. There are very few choices for recreation travelers for overnight accommodation within the Primary Zone. The only establishment that provides rooms within the Primary Zone is the Ryde Hotel. There are a number of additional hotels, motels, and bed and breakfasts within the Secondary Zone; however, they seem to primarily cater to travelers

[137] Boat repair services were also examined. In total there are 37 establishments offering boat repair services - five in the primary zone and 32 in the secondary zone. These establishments are included in Table 27 under Marinas, Boat Dealers and Boat Builders.
[138] Note that numbers between Tables 26 and 27 cannot be directly compared as Table 26 lists each individual business only once, while Table 27 may count the same business multiple times if it provides multiple services.
[139] Restaurants listed here include those associated with marinas, in the Primary Zone, or located in Legacy Communities.

through the area, rather than Delta recreationists. Also, as listed above in Table 25, there are approximately 2,100 campsites within the Delta.

Table 28 Accommodations within the Delta (excluding campsites)

	Hotels, Motels, and B&Bs	
	Number of Establishments	**Number of Rooms**
Primary Zone	1	32
Isleton and Rio Vista	4	56
Secondary Zone	70	4,451
Delta Total	75	4,539
Note: There are also 84 small cabins available for rent in campgrounds, and 31 additional rooms available for special events, primarily weddings at Grand Island Mansion.		
Source: NETS, UOP		

3.2.1.5 Physical Constraints

There are several physical constraints related to Delta recreation which are detailed in *The Aquatic Recreation Component of the Delta Recreation Strategy Plan.*[140] The following constraints have an impact on current facilities and recreation access and are described in more detail below.

- Sediment accumulation in channels and waterways/shallow water
- Water gates, screens, and barriers
- Invasive aquatic vegetation that congests waterways, negatively affects water quality, destroys wildlife habitat, and clogs water supply pumps
- Waterway obstructions such as snags, submerged debris, abandoned vessels, and floating objects
- Water quality
- Lack of boating destinations, particularly beach frontages
- Highly sensitive habitat areas which restrict public access
- User group conflicts
- Private lands and agriculture-recreation conflicts
- Lack of fishing access from the shore and boat launches
- Water management, regulation, and other issues

Sediment Accumulation in Channels, Waterways, and Marinas

Sediment deposits and siltation affect both Delta waterways and marinas. For instance, silt can accumulate from three to eight feet in a given year at marina facilities along the Sacramento River. Sedimentation has led to the closure of marinas and boating facilities in severely-clogged channels.

The stringent regulations and lengthy, complex permit requirements for dredging silt out of channels and marinas burdens marina owners and boating facility operators. Marina operators have stated that dredging-related regulations should be streamlined or better coordinated among regulatory agencies to provide marina owners more flexibility in the removal of silt materials. In addition, channel dredging for levee maintenance is currently being slowed by the same regulation/permitting constraints.

[140] DPC 2006, pp. 56-69

The U.S. Army Corps of Engineers is spearheading a multiple-agency process called the Delta Dredged Sediment Long-Term Management Strategy (LTMS)[141] that aims to, among other goals, clarify the permitting process relative to Delta dredging and reuse projects. They are working to create an effective multi-agency task force called the Delta Dredging and Reuse Management Team (DDRMT), similar to the inter-agency Dredge Material Management Office (DMMO) which exists in San Francisco Bay. They are also working on drafting a Joint Permit Application.[142]

Water Gates, Screens, and Barriers
The Delta Cross Channel and gates, located in Walnut Grove, is an important link for recreational boaters. Although originally built just for water management, it allows, when open, for direct access to some of the most popular boating areas in the Delta. In recent years, it has been open most days per year, but operation periods are variable and boaters typically do not know in advance whether it will be open or not. It addition, its dimensions do not allow for use by larger boats or sailboats.

Other gates, screens, and barriers that exist throughout the Delta include Montezuma Slough Salinity Gates, South Delta Temporary Barriers (operated by DWR), and a wide variety of bridges and drawbridges. The proposed Two-Gates project has been developed by the U.S. Bureau of Reclamation and the Department of Water Resources. This project would install gates on Old River and Connection Slough in order to manipulate the flow of turbid water to keep Delta smelt away from export facilities.[143] This proposed project, currently on hold, would install temporary barriers along the two waterways, which are heavily used by boaters. As currently proposed, the gates would be closed at all times during certain times of the year, prohibiting boat passage.

Invasive Aquatic Vegetation
Two non-native plants that have invaded the Delta are water hyacinth and *Egeria densa*. Water hyacinths float on the surface as well as root along shorelines, while *Egeria densa* is a subsurface water weed. By the 1980s severe infestations of water hyacinth had clogged navigation channels and marinas, creating problems for marina owners, safety hazards for boaters, and issues for the native ecosystem. *Egeria densa* forms dense, submerged mats of vegetation, which can accentuate the process of siltation (discussed above), be dangerous for swimmers, and create operational problems for both boaters and water infrastructure. DBW has primary responsbility for removing water hyacinth and *Egeria densa*, though the program is underfunded compared to the magnitude of the problem. More recently, South American Spongeplant (*Limnobium laevigatum*), a floating plant similar to water hyacinth, has been found in California waterways and is being watched by local and state agencies for potential infestations.[144] DBW does not currently have authorization to remove or treat Spongeplant.

Waterway Obstructions
Prior studies have repeatedly cited water obstructions as a significant problem for boaters. The Franks Tract area has been identified as an especially dangerous area for boating because it

[141] For more information, see http://www.deltaltms.com/index.htm
[142] http://www.deltaltms.com/DredDispReusePer.htm
[143] http://www.usbr.gov/mp/2gates/docs/2-Gates_Factsheet_latest.pdf and http://www.water.ca.gov/deltainit/docs/TwoGatesProject.pdf
[144] Akers, Patrick. Aquatic Weed Integrated Vegetation Management Plan – Contra Costa Delta. Updated 10/9/2010. Found at http://www.delta.ca.gov/res/docs/Spongeplant%207%2028%2011.pdf

was once a levee-protected island and now, although flooded, is shallow and obstructed by submerged levees and vegetation debris.

Snags, debris, floating logs, and abandoned vessels in the river and sloughs are very dangerous to boaters throughout the Delta. Until about 20 years ago, U.S. Army Corps of Engineers was responsible for keeping the waterways clear but no longer provides that service. The responsibility has fallen to local county sheriffs' departments, which lack the manpower, proper equipment, and funding to adequately provide obstruction-removal services and to remove the seasonal "crop" of flotsam that follows winter high-water flows. Some local assistance funding for the removal of abandoned recreational vessels and other navigational hazards is provided through the Department of Boating and Waterways' Abandoned Watercraft Abatement Fund (AWAF) grant program, though needs exceed funding availability.

Water Quality

Surveys of boaters utilizing the Delta have frequently revealed water quality as the top or one of the top-mentioned concerns or issues. In a survey conducted as part of the *Sacramento-San Joaquin Delta Boating Needs Assessement,*[145] 74 percent of large-boat owners and 79 percent of small-boat owners identified water quality as an attribute of concern in the Delta. Concerns associated with water quality included risks or perceived risks related to body contact, possible sewage contamination, aquatic weeds, and water clarity. Boater perceptions of water quality may also differ from water quality best suited for native fish species (i.e., turbidity). In a 2009 study, 70 percent of boaters were concerned about water quality for drinking while 63 percent of boaters were concerned about water quality for swimming.[146]

Boating Destinations

Surveys of boaters also have found a high desire for more boat-in destinations within the Delta.[147] These requests tend to take three different forms.

1. Major boat-in, mooring, and camping attractions such as the Delta Meadows.
2. Numerous smaller day-use areas with restrooms, picnic, and beach facilities.
3. Additional convenience docks adjacent to Legacy Communities such as that established adjacent to Walnut Grove.

These facilities can create problems for adjacent agricultural interests. If development of such new areas is contemplated, they should be placed adjacent to public lands or in areas that avoid the risk of trespass, vandalism, and other conflicts.

Highly Sensitive Habitat Areas

There are several existing proposals (e.g., Delta Plan, Ecosystem Restoration Program) to expand and enhance habitat areas in certain waterways and islands. Conflicts can occur between recreational boating and habitat interests, depending on the boating activity, speed, motor, seasons, and frequency. Additionally, conflicts may result if the public is precluded from recreational access in these proposed restored-habitat areas.

3.3 Existing Operations Conditions

There are several operations-condition issues and constraints that were also described in *The Aquatic Recreation Component of the Delta Recreation Strategy Plan.*[148] A summary of the

[145] DBW 2002, p. 4-23
[146] DBW 2009, p. 134
[147] DBW 2002, p. 3-12 – 3-14
[148] DPC 2006, pp. 56-69

potential operational constraints discussed include user group conflicts, water management related constraints, and regulation and law enforcement issues. Most of these issues are compounded by the lack of an overall responsible agency throughout the Delta, due to the overlapping jurisdictions of several counties and cities.

User Group Conflicts
The diversity of boating activities in the Delta, from high-speed wakeboarding and personal watercraft (PWC) usage to fishing and non-motorized craft (e.g., canoe, kayak) results in conflicts between some user groups. Such conflicts are normally just a lack of common courtesy, rather than citable offenses. However, when one responsible entity manages water recreation use, basic rules and regulations can be established to avoid conflicts. A single responsible entity or common set of regulations does not generally exist in the Delta, with the exception of “No Wake Zones” adjacent to marinas. In addition, marine patrol is fractured between ten different agencies over five counties. Safety laws are the primary concern, along with enforcement of pollution laws, speed violations, negligent operators, equipment violations, lack of life jackets, alcohol consumption, and poaching.

Private Lands/Agriculture-Recreation Conflicts
Another serious and common problem is trespass on private property. Frequently, trespass violations stem from recreationists’ misunderstanding of what property is public and what is private. Clear signage, however, does not deter some who desire to use a specific area.

Water Management
The lack of jurisdictional coordination, with no single agency ultimately responsible for management, has left an absence of adequate, coordinated waterway maintenance and security in order to enforce regulations and control user group conflicts. Additionally, there is a lack of information sources about the Delta to assist recreation users who are unfamiliar with the Delta.

Regulation
The regulatory structure in the Delta is complex, with local, state, and federal regulatory agencies imposing many overlapping layers of law on private businesses. Many of these policies and plans are summarized in Chapter 4. In many cases, regulations that are created to protect the Delta environment also inhibit the functioning of recreation-related businesses, or the development of new businesses. One example is the number of agencies that have input into the permitting process required to dredge a marina. Those can include up to three federal agencies, seven state agencies, and three local agencies; the process can take upwards of two years.[149]

Other issues
Other primary issues and operational risks that affect recreation and its economic potential include aging marinas and other infrastructure, lack of dredging, threatened public parks closures, continued lack of adequate levels of public funding for law enforcement and operations and maintenance of public facilities, development encroachment, flood and earthquake risk, rising sea level, water conveyance management changes, and increasing traffic.

[149] DPC 2006, p. 59

3.4 Visitation and Demand

3.4.1 Defining Market Area

In order to describe the economic impact of recreation on the Delta economy, the market area for Delta recreationists needs to be defined. Planners need to understand what percentage of users come from which areas, such as Delta counties, surrounding counties, Southern California, the western region of the United States, and beyond national borders.

In *The Sacramento-San Joaquin Delta Boating Needs Assessment,* the concepts of the Delta Primary and Secondary Market Areas were introduced.[150] A survey of statewide registered boat owners found that 77 percent of respondents who reported they had recently boated in the Delta resided within approximately 75 miles of the Delta.[151] This area was designated as the Primary Market Area for the Delta and included the counties of Alameda, Calaveras, Contra Costa, Marin, Napa, Sacramento, San Francisco, San Joaquin, San Mateo, Santa Clara, Santa Cruz, Solano, and Stanislaus. The study further defined a Secondary Market Area which represented the point of origin of another 8 percent of all Delta boating trips. The Secondary Market Area includes the counties of Amador, Colusa, El Dorado, Lake, Mariposa, Mendocino, Merced, Monterey, Placer, San Benito, Sonoma, Sutter, Tuolumne, and Yolo. Combined, the Primary and Secondary Market Areas represent approximately 85 percent of all Delta boating visitors (Figure 30).

Although this concept was developed for boating recreation, it is applicable to Delta recreation as a whole. While some visitors to the Delta do come from Southern California, out-of-state, and international locations, the majority of visitors are from Northern California. These visitors represent the focal market for Delta recreation growth opportunities in the future. Population statistics and trends for the Market Area are presented in Table 29. Activity participation numbers and demand models will focus on this area. In summary, the total Market Area had a population estimate of approximately 12 million in 2010, with projections of 17.6 million by 2050.

Table 29 Population Projections for the Primary and Secondary Market Areas

	2010	**2020**	**2030**	**2040**	**2050**
Market Area Population (millions)	11.9	13.4	14.9	16.3	17.6
Growth Rate		12.7%	10.8%	9.3%	7.9%
Source: Global Insight Forecast, 2010 Census Results					

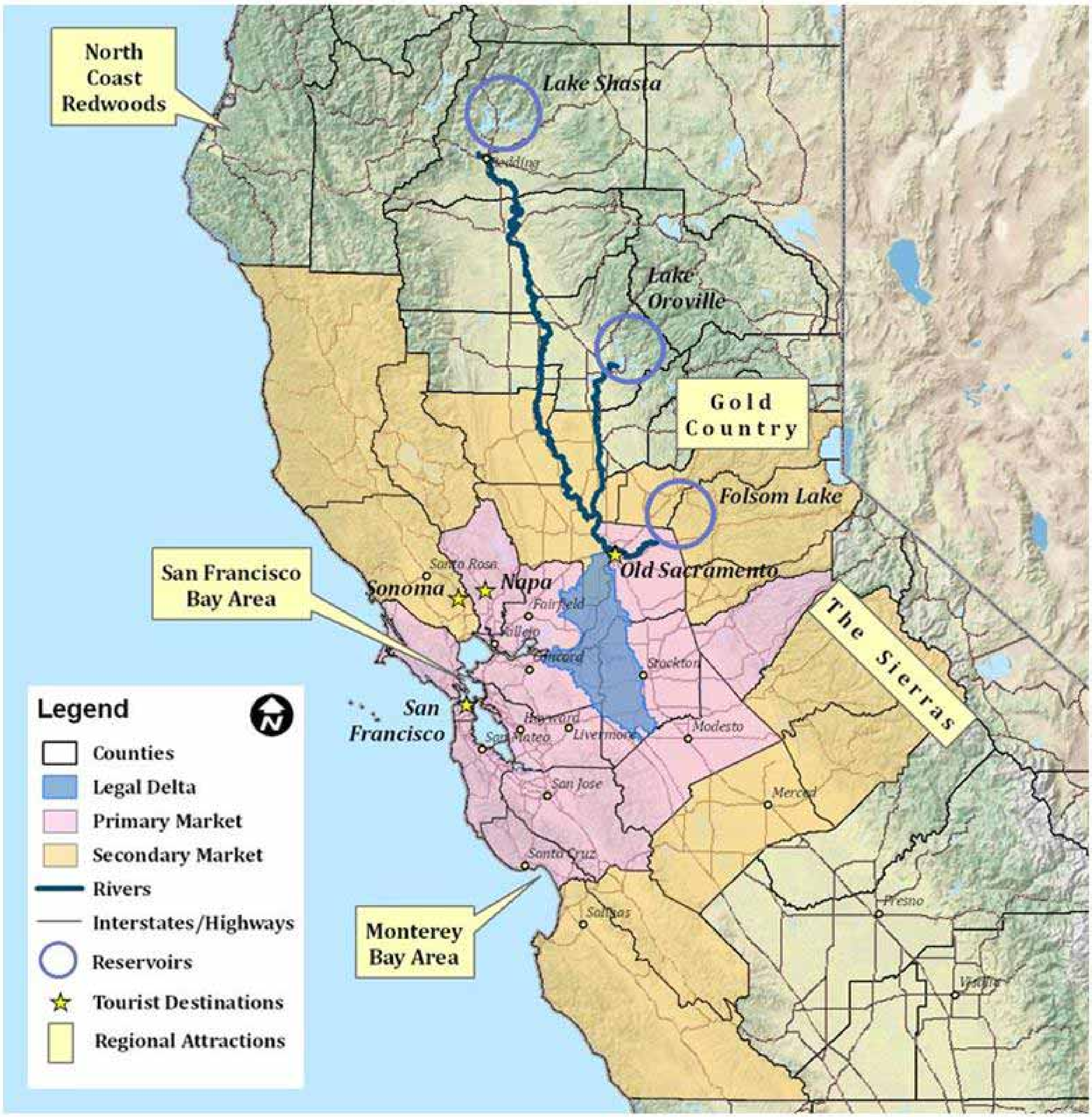
Within the Market Area for Delta recreation, other recreation areas actively compete for participants and their dollars. Residents of the Market Area have several different natural resource-oriented destinations within Northern California that they could visit. Boaters can visit several reservoirs throughout Northern California, including Shasta Lake, Lake Oroville, and Folsom Lake, or can recreate on the San Francisco Bay. Anglers can fish in the numerous reservoirs, but also in the streams and rivers feeding those lakes and reservoirs, such as the Feather River, American River, and Sacramento River. People visiting historic or cultural areas can also visit Old Sacramento, Gold Country, or San Francisco. Wine tourists can visit Napa,

[150] DBW 2002, p. 6-4 - 6-6

[151] A more recent statewide survey of boaters supports this overall Market Area conclusion, noting that boaters from the Central Valley, Sacramento Basin, and San Francisco Bay Area boated more days per year on the Delta than boaters from other regions of the state (DBW et. al 2011, p. 86-87).

Sonoma, or the Sierra foothills. Other recreation and tourist destinations in Northern California include the Monterey Bay area, San Francisco Bay area, the Sierras, and north coast redwoods.

Figure 30 Delta Market Area and Competing Regions[152]



3.4.2 Statewide Recreation Survey/Study Summaries

In order to present an update on the current status and overall trends of recreation and tourism in the Delta, a multitude of sources is reviewed, ranging from U.S. Fish and Wildlife Service to Delta Protection Commission publications. Unfortunately, no one study or survey presents a

152 For high resolution image see http://forecast.pacific.edu/desp-figs.html

complete picture of current recreation and tourism visitation and economic impact in the Delta. Summary information from relevant studies is presented below.

3.4.2.1 State Parks Surveys Recreation Demand Overview

State Parks completes a *Survey on Public Opinions and Attitudes on Outdoor Recreation in California* approximately every five years to comply with federal grant regulations and to "provide a comprehensive view of the outdoor recreation patterns and preferences of Californians."[153] This survey instrument represents the best, most recently available data on recreation preferences of Californians. Statewide demand and participation rates for a sample of specific recreation activities that occur in the Delta are listed in Table 30.

Table 30 Summary of 2008 Survey of Public Opinions on Outdoor Recreation in California Demand and Participation Rates for Selected Activities Statewide in California

Activity Type	Participation Rate	Average Annual Participation in Days
Walking for fitness or pleasure	74%	73
Bicycling on paved surfaces	36 %	38
Wildlife viewing, bird watching, viewing natural scenery	46%	27
Outdoor Photography	33%	26
Driving for pleasure, sightseeing, driving through natural scenery	60%	22
Bicycling on unpaved surfaces and trails	16%	20
Hunting	4%	17
Day hiking on trails	47%	16
Sail boating	6%	14
Fishing – freshwater	21%	13
Swimming in freshwater lakes, rivers and/or streams	31%	10
RV/trailer camping with hookups	11%	9
Motor boating, personal watercraft	15%	9
Visiting historic or cultural sites	55%	8
Picnicking in picnic areas	67%	7
Attending outdoor cultural events	56%	7
Camping in developed sites with facilities	39%	7
Visiting outdoor nature museums, zoos, gardens, or arboretums	58%	6
Paddle sports	15%	5
Source: State Parks		

The most popular activities by participation rates are walking for fitness and pleasure, picnicking, and driving for pleasure, followed by visiting outdoor nature museums, attending outdoor cultural events, and visiting historic or cultural sites. The activities which enjoy the highest participation rates (i.e., people who participate tend to participate more often) are walking for fitness or pleasure, bicycling on paved surfaces, wildlife viewing, outdoor photography, driving for pleasure, and bicycling on unpaved surfaces and trails. State Parks also breaks down participation rates by region, but these regions do not overlap well with the defined Market Area. Thus, only statewide data is reported.

[153] State Parks 2009

3.4.2.2 U.S. Fish and Wildlife Service

The U.S. Fish and Wildlife Service (USFWS) *2006 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation–California* presents findings from a survey completed every five years to measure the importance of wildlife-based recreation. The survey indicates that in 2006, approximately 7 percent of the total population in California participated in either hunting or fishing activities, while 21 percent of the population participated in wildlife watching. The results of the survey are summarized in Table 31. Both participation rates and average annual days of participation per year are lower than in the State Parks survey, which may be due to differing methodologies. USFWS also collects information on average trip expenditures.

Table 31 Summary of 2006 National Survey of Fishing, Hunting, and Wildlife-Associated Activities in California by Residents and Nonresidents

Activity Type	Participation Rate	Average Annual Days of Participation	Average Trip Expenditures Per Day Per Participant (2006$)
Fishing (Anglers)	6%	11	$62
Hunting (Hunters)	1%	12	$68
Wildlife Watching (Away From Home Participants)	21%	16	$44

3.4.2.3 Department of Boating and Waterways

The Department of Boating and Waterways (DBW) *2007-2009 California Boater Survey* reports on a statewide assessment of boating habits and environmental awareness of boaters. The survey reported that in 2007, 17.8 percent of boat owners surveyed boated in the Sacramento-San Joaquin Delta as least once a year, using their boats on average 20.9 days in that location.[154] Comparatively, in 2009, 26.8 percent of those surveyed boated in the Delta, using their boats on average 25.4 days per year.[155] The report does not discuss any reasons for the discrepancies in numbers, or any conclusions as to whether the increase in 2009 rates represents an increase in Delta recreation, or is a reflection of sampling differences.[156] However, the participation rates reported in these surveys are of comparable magnitude to the 23 percent participation of boaters statewide that reported recreating in the Delta in a 1997 survey (see Section 3.4.3.2). The average number of days of participation, however, is much higher than those reported on statewide or national surveys (see above) for fishing or boating.

3.4.2.4 State Registration and License Numbers

Another way to assess potential recreation demand is through an analysis of State registration and license numbers. These numbers represent actual numbers, rather than estimates of participation rates, and can help predict potential demand.

Registered Vessels

In California, owners of any sail-powered vessels over eight feet in length and any motor-driven vessel (regardless of length) that is not documented by the U.S. Coast Guard must register their boat with the Department of Motor Vehicles (DMV). Vessels propelled solely by oars or paddles

[154] DBW 2011, p. 24
[155] Ibid, p. 86
[156] The study does, however, point out that surveys were not completed by a random sample of boaters, but rather boaters who were approached on the docks, or at boat shows. The report states, “Thus, all findings are best viewed as particular to the given sample (i.e. those boaters who participated) rather than representative of the entire population of interest (i.e. all California boaters).” DBW 2011, p. 14

(e.g., kayak, canoes) do not have to be registered.[157] In 2010, statewide, DMV reported 810,008 vessel registrations. As registrations are also reported by county, the Primary and Secondary Market Areas can be highlighted. In 2010, there were 214,163 vessels registered within the Primary Market Area and an additional 103,408 within the Secondary Market Area.[158]

Resident Sport Fishing

In 2009, 1,179,312 resident sport fishing licenses statewide were issued by the Department of Fish and Game (DFG).[159] It is difficult to identify licenses by county, as DFG reports figures based on the county in which the license was sold, not by the origin county of the purchaser. However, DFG required all anglers who fished within the tidal influences of the Bay-Delta and downstream of dams within the watershed to purchase a Bay-Delta Sport Fishing Enhancement Stamp from 2004 to 2009. In 2009, 284,641 anglers purchased that stamp. Although a portion of anglers who purchased that stamp may have only fished upstream of the Delta, those numbers seem to provide a general magnitude snapshot of anglers in the Delta (i.e., approximately 275,000 anglers recreated in the Delta in 2009). Using this number, combined with estimates from both USFWS and State Parks that anglers fish, on average, 12 days per year, results in approximately 3.3 million fishing activity days in the Delta in 2010. Note, however, that this number does not differentiate between shore anglers or those who fish from a boat.

Hunting

In 2009, the State issued 1,056,556 game bird hunting licenses and 1,683,445 general hunting licenses, which is approximately 6 percent of the adult California population. The hunting percentage tracks well with demand numbers from State Parks.

3.4.3 Delta-Specific Recreation Survey/Study Summaries

There are several Delta-specific surveys that have been completed over the past 20 years regarding recreation, including Sacramento-San Joaquin Delta Outdoor Recreation Survey,[160] North Delta Recreation Use Survey,[161] Sacramento-San Joaquin Delta Boating Needs Assessment,[162] and Sacramento San-Joaquin Delta Recreation Survey.[163] The more recent are summarized below.

Unfortunately, there have been no recent comprehensive visitor surveys within the Delta focused on Delta recreationist's activities and spending patterns. Also, most surveys that have been done have only focused on boaters and anglers, the highest percentage of recreationists in the Delta, but not the only ones. This lack of primary data hampers planning and marketing efforts.

[157] A DBW study estimated a total of over 1.7 million non-motorized boats (a category which includes inflatables, kayaks, canoes, rowing boats, sailboards/kiteboards, small sailboats, and others) in California in 2006 (DBW 2009, p. 2-1 – 2-2).
[158] http://www.dbw.ca.gov/PDF/VesselReg/Vessel10.pdf
[159] http://www.dfg.ca.gov/licensing/
[160] DWR 1980
[161] DWR 1997
[162] DBW 2002
[163] State Parks 1997

3.4.3.1 Sacramento-San Joaquin Delta Boating Needs Assessment

As part of *The 2002 Sacramento-San Joaquin Delta Boating Needs Assessment,*[164] California boat owners were surveyed regarding their preferences and facility needs for boating in the Delta. The survey group was broken down into owners of large boats (equal to or greater than 26 feet in length) and small boats (less than 26 feet in length). In this statewide survey, 52 percent of all owners of large boats had boated in the Delta, with 68 percent of those having been in the previous two years. Conversely, only 40 percent of all small-boat owners had been boating in the Delta, with 61 percent of those having done so in the two previous years.[165]

Combined with the survey information, the 2002 study also completed a demand forecast analysis of annual boating-related visitor days, estimated at 6.4 to 6.6 million in 2000 with a projected growth to 8 million by 2020.[166] This survey information provides the best estimate of boating-related recreation activity days in the Delta. However, it does not estimate the amount of expenditures for the boaters in the Delta. And, while boating and companion activities (fishing from a boat, swimming from the boat, etc.) represents one of the highest percentage of existing recreation uses in the Delta, it is not a full picture of all recreation.

3.4.3.2 Sacramento-San Joaquin Delta Recreation Survey

In 1997, State Parks published the *Sacramento-San Joaquin Delta Recreation Survey,* which separately surveyed boat owners and licensed anglers regarding their use of the Delta resources and how much money they spent recreating in the Delta.

The survey found that 23.5 percent of registered boat owners in California recreated in the Delta, spending an average of $11.75 outside the Delta and $17.20 inside the Delta (1996 dollars), a total of $28.95 per day per person. The survey also found 23 percent of licensed anglers in the state fish in the Delta, spending an average of $15.91 outside the Delta and $13.57 inside the Delta (1996 dollars), a total of $29.48 per day per person. The top five other recreation activities that boaters indicated they participated in included (in order of preference) sightseeing, viewing wildlife, fishing from shore, picnicking, and walking for pleasure. The top five non-fishing activities which anglers engaged in while in the Delta were sightseeing, boating, viewing wildlife, swimming, and walking for pleasure.

3.4.4 Delta Recreation and Tourism Visitation Estimates

There are few counts of visitor attendance in the Delta. Those that exist are limited and only represent a fraction of what is estimated to be the actual visitor count. Visitation numbers that were reported equal less than one million visitors and are presented in Table 32.

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[164] DBW 2002

[165] For large boat owners, 52% of 68% translates to about 35% overall boater participation. For small boat owners, 40% x 61% = 24.4% of overall boaters. While the small boat participation number is similar to that described in State Parks survey (Section 3.4.3.2) and the recent DBW survey (Section 3.4.2.3), the large boater participation rates are higher.

[166] DBW 2002, Table 6-11

Table 32 Summary of Actual Visitation to the Delta

Site	Numbers
Brannon Island SRA (day use, 2009)	88,459
Brannon Island SRA (camping, 2009)	36,069
Delta Meadows State Park (day use, 2009)	18,933
Delta Meadows State Park (camping, 2009)	2,155
Franks Tract SRA	24,305
Stone Lakes National Wildlife Refuge (USFWS) (approx.)	7,000
Cosumnes River Preserve (approx.)	70,000
Lower Sherman Island (DFG) (approx.)	5,000
White Slough Wildlife Area (DFG) (approx.)	12,000
Yolo Basin Wildlife Area (USFWS) (approx., includes student tours)	30,000
Sherman Island (Sacramento County)	25,000
Hogback Island Fishing Access (Sacramento County)	10,800
Clarksburg Boat Launch (Yolo County)	1,713
Belden's Landing (Solano County)	15,642
Sandy Beach Park (Solano County)	100,611
Dos Reis Park (San Joaquin County)	25,815
Mossdale Crossing Regional Park (San Joaquin County)	23,630
Oak Grove Regional Park (San Joaquin County)	84,058
Westgate Landing (San Joaquin County)	10,283
Isleton Crawdad Festival (approx.)	200,000
Rio Vista Bass Derby and Festival (approx.)	12,000
Totals	**796,480**
Sources: State Parks 2010, personal communications	

3.4.5 Visitation Estimates by Recreation Activity Types

As actual visitor counts and current visitor survey data are lacking, visitation must be estimated. One way to estimate visitation is by looking at overall participation estimates based on survey data such as that collected by State Parks. These participation estimates can then be related to the Market Area population to derive estimates. However, participation rates vary over time as recreation activities become more or less popular.

Section 3.4.2.1 presented information regarding participation in selected activities that occur in the Delta from the most recent State Parks *Survey on Public Opinions and Attitudes on Outdoor Recreation in California.* As this survey has been taken approximately every five years, it is also a useful tool in looking at activity participation rate changes over time. In general, the activity types in which Californians participate and the level of participation have varied over time in specific activities, including freshwater fishing, backpacking, wildlife viewing, sports, swimming in a pool, etc. Over various surveys, State Parks has changed certain categories, listing 42 activity categories in 1992, to 55 in 2002, and 39 in 2008. It is difficult to track trends in individual activity categories due to changes in survey methodologies and questions. However, the percentage breakdown between three broad clusters of recreation activities has tended to remain relatively constant.

Resource-related recreation includes that which occurs in resource-related areas, including state and national parks, forest service lands, nature areas, reservoirs, rivers, the ocean, mountains, etc. Types of resource-related recreation include wildlife viewing, hunting, fishing, boating, beach activities, camping, skiing, snowboarding, and swimming in lakes, rivers, and the ocean. Since 1992, approximately 25–30 percent of all recreation has been resource related in California.

Urban Parks-related recreation includes those activities that generally take place in developed parks, such as using play equipment, swimming in a pool, using open turf areas, golf, tennis, and team sports. Since 1992, urban parks-related recreation has represented approximately 16–23 percent of all recreation activity days.

Right of Way/Tourism-related recreation represents the largest levels of participation over time and includes hiking, jogging, walking, bicycling on paved surfaces, driving for pleasure, off-highway vehicle use, and other road- and trail-based recreation. Since 1992, this type of recreation has represented approximately 48–58 percent of all activity days in California, with walking for fitness and pleasure generally the highest ranked activity, by both percentage of participants and number of days of participation.

In the Delta, there is some level of use in each of the three recreation categories: Resource-related, urban parks-related, and right-of-way/tourism-related. As one of the more unique resource attraction areas in the state, it is only logical that primary uses would be resource-related activities. These include all variety of boating, camping, nature study/bird watching, hunting, and fishing. As described above, an estimate of 6.4 million boating visitor days per year (including fishing from a boat) was completed in 2000.[167] As part of the study, projections were made that this use would grow by 1 percent a year, but with the recent recession's impact, on motor boating in particular, as well as the overall lack of investment in facilities and upgrades over the past 20 years, the 2000 count likely reflects today's usage level. None of the remaining activities has had Delta-only surveys or counts, but from review of known visitation to specific sites, data regarding permits and licenses, it is estimated that these remaining uses account for roughly 1.5 million visitor days of use annually. When combined with boating, this gives a total of approximately 8 million resource-related visitor days of use per year.

The cities bordering the Delta have taken advantage of the Delta's waterways and scenic resources by locating both resource-related facilities and standard city parks on the edges of the Delta. For instance, Sacramento's Garcia Bend Park, on the Sacramento River, combines boat launching, bank fishing, and levee-top trails with organized sports, children's play, and informal park day uses. Stockton has located its largest city park and a major recreation-related redevelopment area adjacent to Delta waterways. There are approximately 300 acres of urban park and recreation areas bordering Delta resources located in the various communities which surround the Delta. On average throughout California, urban parks receive approximately 10,000 visits per acre per year.[168] Estimated conservatively, 2 million visitor days of urban parks-related use occurs within the Primary and Secondary Zones.

Driving for pleasure in the Delta is very popular and is a prime example of the right of way/tourism-related recreation use. This recreation category also includes bicycling, hiking, and walking. The winding roadways, interesting bridges, scenic views of waterways and agricultural areas, Legacy Communities, and historic structures all contribute to its visual appeal. The ability to buy fresh fruits and vegetables straight from the grower, visit a winery and sample their product, stop and pick up a freshly made deli sandwich or an ice cream at a 50-year-old grocery store all deepen the Delta experience. To many, the resources are part of the charm—the

[167] DBW 2002
[168] Dangermond 1993, Table 15.2, p. 219

historical town of Locke, the wildlife preserves, or even the beautiful oak tree canopies shading the roadway.

There have not been any use-participation estimates or surveys for this recreation activity in the Delta. However, the total participation in driving for pleasure in the Market Area can be estimated at 160 million annual participation days[169] (note that driving for pleasure is frequently combined with other recreation activities). As discussed above, the Market Area has a number of competing destinations including Monterey/Santa Cruz, Bay Area, Coast, Redwoods, Wine Country, Gold Country, and the Sierra Nevada. Assuming the Delta is able to capture 1–2 percent of that overall market, driving for pleasure and associated activities (e.g., visiting historic sites and farm stands, etc.) in the Delta generates significant visitation. Using these estimates, right-of-way-related recreation is approximately 2 million visitor days per year.

Combining the above estimates (8 million resource-related and 2 million right-of-way-related) would result in a total of 10 million annual visits in the Delta, plus 2 million in urban parks around the edge. In the 1990s, State Parks estimated an annual use of 12 million days in the Delta. Since that time, population in the Market Area has increased; however, there have been limited investments in new facilities or upgrades to existing facilities. The constraints outlined in Sections 3.2 and 3.3 above have not been resolved, and in some cases have been only exacerbated over time (e.g., lack of dredging, water quality). Additionally, the recession of 2007-2009 has negatively affected recreation and tourism, as well as boat registrations. Absent new research, this 12 million visits per year estimate seems to be a reasonable, conservative working number until additional primary data collection is performed.

3.4.6 Market Demand-Based Delta Visitation Estimates

Visitor estimations can be tested based on calculations of demand generated from population numbers using participation rates and frequencies. In summary, first, participation rates for various Delta activities were determined. Using these participation rates and estimates for activity days of participation (described above) and adjusting for multiple activities in a day, demand numbers (expressed as visitor days) for the Market Area can be estimated. Following that, a determination of what percentage of market demand the Delta will capture versus other recreation opportunity areas available to the Market Area is made. These estimates result in a range of 8.2–15.2 million recreation visitor activity days per year in 2010. In Appendix H, the model for demand-based participation is presented.

These recreation activities can also be broken down into the categories described above: Resource-related, urban parks-related, and right-of-way/tourism-related. The urban parks-related category was not included in these estimates, which was previously estimated to be another 2 million activity days per year. Resource-related activities result in a range of 4.5–10.7 million activity days per year, while right-of-way/tourism-related activities result in a range of 1.7–2.5 million activity days per year. These ranges are similar in magnitude to those discussed above and are summarized in Table 33.

[169] 12 million population x 60 percent participation x 22 average days (taken from Table 25)

Table 33 Summary of Visitation Estimates to the Delta

Type	Estimate of Visitor Days (2010) (millions)		
Activity Type Estimates		**Estimate**	
Resource Related		8.0	
Right-of-Way Related		2.0	
Urban Parks Related		2.0	
Total		12.0	
Demand Based Estimates	**Low Estimate**	**Medium Estimate**	**High Estimate**
Resource Related	4.5	7.6	10.7
Right-of-Way Related	1.7	2.1	2.5
Urban Parks Related*	N/A	2.0	N/A
Totals	8.2	11.7	15.2

Sources: U.S. Census, State Parks 2009, The Dangermond Group, EPS
* Demand for urban parks is not estimated by the visitor market analysis.

These estimates are based on limited available data and profession judgment of the planning team. New primary data from an up-to-date visitor survey is needed to better document existing recreation visitation and spending, including non-boating and non-fishing recreationists, and should be undertaken as a first step in future Delta recreation planning and marketing efforts.

3.5 Economic Impact/Benefits

3.5.1 Current Economic Impact Model

The economic impact of Delta recreation is first assessed based on estimated medium visitation levels and trip-related spending, with non-trip spending added subsequently. As described in Section 3.4, it is estimated that the Delta currently receives approximately 7.6 million resource-related visitor days and 2.1 million right-of-way/tourism days (market demand-based estimates). This analysis estimates that average per-day expenditures for the resource-related and right-of-way/tourism recreation activities range from about $27 to $76 (2011$) depending on the activity type, of which about $13 to $34 is spent in the Delta. Based on these per-day spending levels and the estimated Delta visitation, direct spending in the Delta economy attributable to resource-related and right-of-way/tourism recreation is estimated at approximately $251 million (2011$).

This visitation-based economic impact estimate focuses on resource-related recreation, including boating, fishing, hunting, and other activities (e.g., wildlife viewing), and right-of-way/tourism activities, including hiking, biking, driving for pleasure, and cultural activities. The analysis does not account for activities at the urban fringe, including urban park recreation (e.g., team sports). Resource-related and right-of-way/tourism activities are believed to account for the majority of economic impacts of recreation occurring in the Delta.

Table 34 Estimated Resource-Related and Right-of-Way/Tourism Visitation to the Delta by Activity

Activity	**Visitor Days**	Percent of Total
Boating, Fishing, and Camping	6.4 Million	66%
Hunting	500,000	5%
Other Resource-Related and ROW Activities	900,000	9%
Driving for Pleasure and Tourism	1.9 Million	20%
Total Delta	9.7 Million	100%

Sources: Sacramento-San Joaquin Delta Boating Needs Assessment (2000); The Dangermond Group
Note: Activity categories reflect similarities in economic spending patterns.

The economic impact of recreation within the Delta is calculated by multiplying activity-specific visitor days by per-day expenditure estimates. A visitor day is defined to be a day at a recreation site by a single person doing any and all activities. While visitors may participate in multiple activities, the analysis defines a primary activity to avoid double-counting visitors. The analysis relies on the distribution of visitation by primary activity shown in Table 34.

The analysis relies on average expenditures reported by boaters (including anglers), hunters, and recreationists participating in wildlife-associated activities to estimate spending in the Delta. Specifically, the analysis uses spending data from the Sacramento-San Joaquin Delta Recreation Survey[170] and the National Survey of Fishing, Hunting, and Wildlife-Associated Recreation.[171] The analysis considers expenditures outside and inside the Delta, based on boating and fishing expenditure patterns reported by the Sacramento-San Joaquin Delta Recreation Survey. Daily spending estimates from the Sacramento-San Joaquin Delta Recreation Survey are updated to reflect real spending increases observed by the National Survey of Fishing, Hunting, and Wildlife-Associated Recreation between 1996 and 2006. The analysis assumes that resource-related and some right-of way activities (e.g., biking and hiking) spending is generally consistent with expenditure patterns reported for wildlife viewing trips in the National Survey of Fishing, Hunting, and Wildlife-Associated Recreation. Driving-for-pleasure spending is also based on National Survey of Fishing, Hunting, and Wildlife-Associated Recreation, though these data are adjusted to reflect lower levels of spending on lodging and recreational activities for driving-for-pleasure visits. All spending estimates are inflated to 2011 dollars using the Bureau of Labor Statistics Consumer Price Index (CPI).

Table 35 Estimated Per-Day Per Visitor Expenditure by Activity (2011$)

	Expenditure Outside Delta	Expenditure Inside Delta	Total Expenditure
Boating, Fishing, and Camping			
Accommodation	$2.76	$5.25	$8.00
Food	$5.25	$8.34	$13.58
Supplies	$8.76	$11.34	$20.10
Other	$3.99	$5.46	$9.45
Total	$20.75	$30.38	$51.13
Hunting			
Accommodation	$12.30	$9.06	$21.36
Food	$3.88	$3.92	$7.80
Supplies	$20.21	$14.24	$34.45
Other	$5.70	$6.93	$12.63
Total	$42.08	$34.15	$76.24
Other Resource-Related and ROW Activities			
Accommodation	$6.31	$4.65	$10.97
Food	$6.38	$6.45	$12.83
Supplies	$6.04	$4.25	$10.29
Other	$1.45	$1.77	$3.22
Total	$20.19	$17.12	$37.31
Driving for Pleasure and Tourism			
Accommodation	$1.58	$1.16	$2.74
Food	$6.38	$6.45	$12.83
Supplies	$6.04	$4.25	$10.29
Other	$0.73	$0.88	$1.61
Total	$14.72	$12.75	$27.47
Sources: Sacramento-San Joaquin Delta Recreation Survey (1997); National Survey of Fishing, Hunting, and Wildlife-Associated Recreation (1996 and 2006). *Note that "Accommodation" includes spending at campsites.*			

[170] State Parks 1997
[171] USFWS 1996 and USFWS 2006

The analysis estimates direct trip-related economic impacts from resource-related and right-of-way/tourism recreation by multiplying medium estimates for activity-specific visitor days by the per-day expenditure estimates. Current direct impacts are estimated at $251 million inside the Delta (2011 dollars), as shown in Table 35.

Table 36 Estimated Direct Delta Recreation Trip Spending Impacts by Activity (2011$)

	Expenditure Inside Delta
Boating, Fishing, and Camping	
Accommodation	$33,572,000
Food	$53,354,000
Supplies	$72,571,000
Other	$34,929,000
Total	$194,426,000
Hunting	
Accommodation	$4,822,000
Food	$2,087,000
Supplies	$7,579,000
Other	$3,690,000
Total	$18,177,000
Other Resource-Related and ROW Activities	
Accommodation	$3,110,000
Food	$4,312,000
Supplies	$2,843,000
Other	$1,183,000
Total	$11,449,000
Driving for Pleasure and Tourism	
Accommodation	$2,456,000
Food	$13,621,000
Supplies	$8,980,000
Other	$1,868,000
Total	$26,925,000
Resource-Related and ROW/Tourism Total	
Accommodation	$43,960,000
Food	$73,374,000
Supplies	$91,973,000
Other	$41,670,000
Total	$250,978,000

While visitor spending occurs in a wide variety of categories, the bulk of visitor spending is likely to occur at recreation facilities, overnight accommodations, restaurants and bars, food and beverage stores, gas stations, and convenience stores. Comparing the estimated expenditure levels with total Delta revenue estimates for these industries shows that Delta recreation and tourism generates a large share of sales for these industries. For example, our estimates show that Delta recreation accounts for 90 percent of recreation sector spending, 58 percent of accommodation spending, 16 percent of sporting goods retail spending (including book and hobby stores), 12 percent of gas station sales, and 7 percent of restaurant and bar spending in the legal Delta.[172]

In addition, non-trip recreation spending can be attributed to the recreational opportunities in the Delta. In particular, the recreation impact analysis considers boat dealer, boat repair, and boat

[172] Industry and retail data from IMPLAN and ESRI, respectively.

storage business revenues in the Delta. The analysis quantifies retail boat sales and repair service revenues using establishment-level micro data from Hoover's and NETS. These data provide an estimate of total annual boat sales and repair service revenues at Delta business establishments. The analysis reveals that boat sales and services generate roughly $44 million per year for Delta businesses. In addition, the analysis estimates revenues associated with boat storage at $17 million per year in the Delta. This figure reflects year-round storage of 7,200 boats at an average monthly cost of $200 per boat.[173] In total, the analysis estimates current non-trip recreation spending in the Delta at about $61 million annually.

Combining trip-related and non-trip recreation spending in the Delta, the analysis estimates current annual direct spending on Delta recreation is approximately $312 million. Table 37 maps the $312 million in spending into more specific expenditure categories that are used for the economic impact analysis with IMPLAN.

Table 37 Estimated Direct Delta Recreation Trip Spending by IMPLAN sectors

Trip-Related Recreation Spending		
Hotels and motels	$	26,699,278
Other accommodations (i.e., campgrounds)	$	17,799,518
Food services and drinking places	$	63,364,613
Retail - Food and beverage stores	$	28,153,123
Retail - Gasoline	$	65,485,709
Retail - Sporting goods, hobby, book, and music	$	7,969,036
Other amusement and recreation industries (i.e., marinas)	$	34,806,041
Retail - General merchandise	$	6,862,926
Non-Trip Recreation Spending		
Retail - Motor vehicle and parts (i.e., boat dealers)	$	44,000,000
Other amusement and recreation industries (i.e., marinas)	$	17,000,000
Total	**$**	**312,140,244**

Table 38 summarizes the economic impact of recreation on the five-county Delta region as modeled with IMPLAN. Delta recreation and tourism supports about 3,063 jobs in the region including nearly 1,100 in restaurants and bars, 268 in hotels and motels, and 388 jobs at marinas. These jobs provide about $100 million in labor income, and a total of $175 million in value added to the regional economy. Based on a descriptive analysis of job location in the Delta in earlier chapters, it appears that the majority of these jobs are located in the Secondary Zone.

[173] Storage of 7,200 boats reflects 60 percent occupancy of the Delta's roughly 12,000 boat slips. Some boats may be transferred to dry storage during winter months. Occupancy data and storage rates were collected through an informal survey of Delta marina/boat storage facilities.

Table 38 Economic Impact of Delta Recreation and Tourism on Five Delta Counties

Impact Type	Employment	Labor Income	Value Added	Output
Trip-Related Recreation and Tourism Impacts				
Direct Effect	1,953.5	$52,553,680	$ 86,648,100	$166,731,376
Indirect Effect	395.2	$20,301,232	$ 34,425,490	$ 64,612,876
Induced Effect	367.2	$16,665,778	$ 30,962,200	$ 52,752,976
Total Effect	2,715.9	$89,520,688	$152,035,800	$284,097,216
Non-Trip Recreation and Tourism Impacts				
Direct Effect	217.2	$8,579,242	$12,625,960	$25,404,000
Indirect Effect	70.2	$3,468,025	$6,087,784	$11,016,298
Induced Effect	60.6	$2,752,687	$5,112,832	$8,711,717
Total Effect	348	$14,799,954	$23,826,570	$45,132,016
Total Recreation and Tourism Impacts				
Direct Effect	2,170.7	$61,132,922	$99,274,060	$192,135,376
Indirect Effect	465.4	$23,769,257	$40,513,274	$75,629,174
Induced Effect	427.8	$19,418,465	$36,075,032	$61,464,693
Total Effect	3,063.9	$104,320,642	$175,862,370	$329,229,232

Table 39 shows the statewide impacts of Delta recreation and tourism. For these impacts, we estimate an additional $205 million in recreation-related spending outside the Delta for supplies and travel. Statewide, Delta recreation and tourism supported over 5,200 jobs and $348 million in value added.

Table 39 Economic Impact of Delta Recreation and Tourism on California

Impact Type	Employment	Labor Income	Value Added	Output
Trip-Related Recreation and Tourism Impacts				
Direct Effect	3,360.8	$102,039,290	$167,234,460	$315,199,104
Indirect Effect	929.8	$53,570,841	$91,479,454	$172,312,474
Induced Effect	993.0	$49,566,491	$89,599,932	$157,679,829
Total Effect	5,283.6	$205,176,626	$348,313,870	$645,191,408

3.5.2 The Economic Impact of Recreational Boating and Fishing in the Delta

As a follow-up to the 1997 State Parks survey, Goldman et al. produced a report, The Economic Impact of Recreational Boating and Fishing in the Delta.[174] Using data from the 1997 survey on numbers of anglers and registered boat owners and their reported expenditures, Goldman et al. estimated the expenditures of registered boaters at $247 million in the Delta, generating $445 million in total output, $183 million in income, $279 million in value added, and 8,058 jobs in the overall Delta region. For licensed anglers, expenditures totaled $186 million in the Delta, generating $336 million in total output, $138 million in income, $209 million in value added, and 6,152 jobs in the overall Delta region. The authors note that the impacts from boating and

[174] Goldman et al., 1998

fishing can not be aggregated, as many boaters fished, and many anglers boated. The authors also note that these numbers do not include the many other recreationists who participate in Delta-based activities such as driving for pleasure, non-registered boaters (i.e., kayaks and canoes), non-licensed anglers, hunters who do not boat, etc., and so is not a complete picture of the economic impacts of Delta recreation.

While the estimates of total recreation spending in the Delta are similar between the ESP and the Goldman study, at about $250 million (Goldman's boating estimate), there are two primary reasons why the Goldman study estimates significantly higher total regional employment and output attributable to recreation in the Delta. These factors are (1) the change over time in output per worker and (2) the method of accounting for direct output. Goldman's economic data is from 1994 when each nominal dollar of spending supported more employment than it does today. Specifically, the Goldman study indicates that total output of roughly $55,000 from Delta boating activities supports one job in the regional economy, while in today's economy the ESP finds that it takes approximately $105,000 in boating-related output to support one job. Furthermore, the Goldman study appears to count the full value of boater spending as production output value, whereas the ESP measures output in retail industries using the retail margin (i.e., the addition to the price of a product when the product is sold through a retailer). In the ESP, the $251 million estimate of in-Delta spending translates to approximately $167 million in direct output, whereas the Goldman study seems to treat the full value of sales revenue (e.g., $247 million of in-Delta boater spending) as direct output. Accounting for this difference, the Goldman study and the ESP reveal a very similar economic output multiplier within the regional economy.

3.6 Trends

The current status in Delta recreation shows a place of diverse recreation experiences, with approximately 12 million annual visitors, having an economic impact on the region of over $300 million. Yet, this recreation mecca is also suffering from economic conditions, physical and operational constraints, pressures on water supply, regulations that restrict development, and other internal and external issues. These trends must be taken into account when projecting the Delta's recreation potential over the next 50 years, as must the Delta's recreation history.

One way of estimating recreation use over the next 50 years is to look back in time. Fifty years ago (1960s), people engaged in virtually all the recreation activities they now enjoy. User survey data exists going back a little over 50 years. There are approximately 35 different outdoor recreation activities identified by State Parks with data collected nearly every five years over the 50-year period. Most of the activities track their growth with population, but some are decreasing in percentage of the total, while others have increased.

As discussed previously, the one factor that is relatively constant is the percentage breakdown between the three broad clusters of recreation activities: resource-related, urban parks-related, and right-of-way/tourism-related, i.e., 20 percent (16-23 percent) of activities take place in urban developed parks and golf courses; 50 percent (48-58 percent) are right-of-way related, including jogging, walking, bicycling, and driving for pleasure; and the remaining 30 percent (25-30 percent) occur in resource-related areas including state and national parks, forest service lands, nature areas, reservoirs, and rivers. These percentages have remained relatively constant over time, regardless of demographic changes. Another rather constant factor to consider is that approximately 70-80 percent of the total recreation use is simple, close to home, and with very little expenditure required for special equipment.

Therefore, it is anticipated that the outdoor recreation uses we find today will still exist, that the predominance of the activities will be simple, close to home, and require little expenditures, and that around 20 percent of the use will be developed urban park-related, 50 percent right-of-way-related, and 30 percent resource-related.

The Delta may likely become even more important for these types of uses because the populations that encircle it are expanding. Elsewhere, close-by outdoor recreation opportunities are rapidly disappearing. But the combination of land use protections, flood vulnerability, and rich agriculture land provide the likelihood that the Delta will still remain relatively unchanged in coming years.

In the Delta, the present uses are highly related to the availability and condition of private facilities. Most of the boating and fishing activities rely upon private marinas, even though the activities occur on public waterways. Most of the hunting in the Delta also occurs at private hunting clubs. Most Delta-as-a-Place destinations are related to wineries, farm stands, and commercial establishments in the Legacy Communities.

Developed local and state resource-related recreation areas in the Delta are quite limited, when compared to other areas in the state. Most public lands are nature and wildlife reserves, supporting nature study and bird-watching and, in some cases, hunting, but their public access facilities are either secondary to their mission or still primarily in the planning stages. They appear to have capacity to accommodate increased use over time. Some urban parks have been developed along the edges of the Delta, primarily in Stockton.

Another way to look at trends is through latent (i.e., unmet) demand revealed by survey data. State Parks survey data reports on latent demand by activity category.[175] The following activities were found by State Parks to be the top five activities that adults would like to participate in more often:

1. Walking for fitness or pleasure
2. Camping in developed sites
3. Bicycling on paved surfaces
4. Day hiking on trails
5. Picnicking in picnic areas

All of these activities take place in the Delta and represent an opportunity for growing visitation, if facilities were available and attractive.

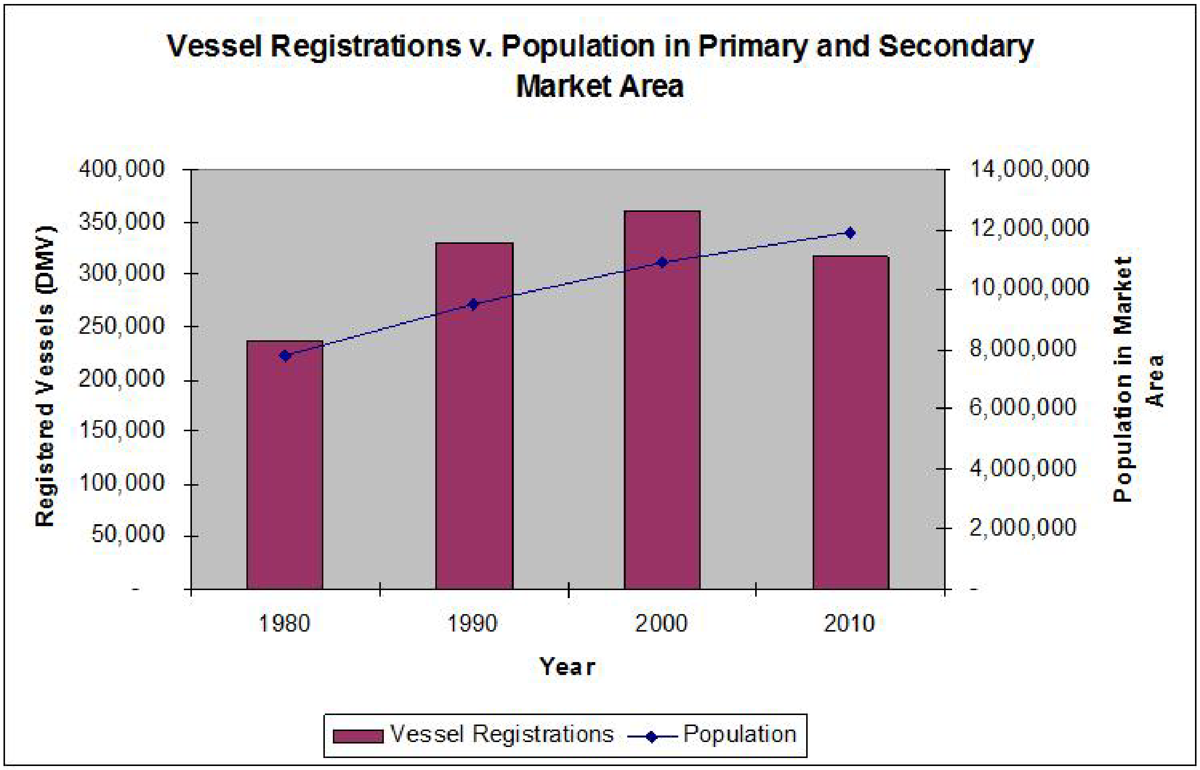
USFWS reported on trends since 1996 in fishing, hunting, and wildlife viewing. Overall in California, fishing has declined 36 percent since 1996, while hunting has declined 45 percent (though it has been flat since 2001).[176] Conversely, away-from-home wildlife watching is up 23 percent since 1996. These data seem to represent a trend away from consumptive recreation (i.e., hunting and fishing) and towards non-consumptive wildlife recreation (i.e., bird watching and nature photography). State Parks figures also support these trends. Recreational programming and facilities in the Delta should respond to this trend.

Section 3.4.2.3 above highlighted current (2010) boat registration numbers. Vessel registrations are down substantially since 2000 in both the state and the Primary and Secondary Market

[175] State Parks 2009, p. 36
[176] USFWS 2006

Area. In 2000, vessel registrations were at 902,447 statewide, and 359,541 in the Market Area, compared to 2010 numbers of 810,008 statewide and 317,571 in the Market Area. These numbers represent a decrease of 11 percent statewide and 13 percent in the Market Area. The 2010 number, however, is likely affected by the ongoing “great recession” and increasing costs of fuel and it cannot yet be determined if it represents a new trend. Figure 31 below shows boat registrations versus population over the past 40 years in the Market Area.

Figure 31 Vessel Registration v. Population in Primary and Secondary Market Area, 1980-2010



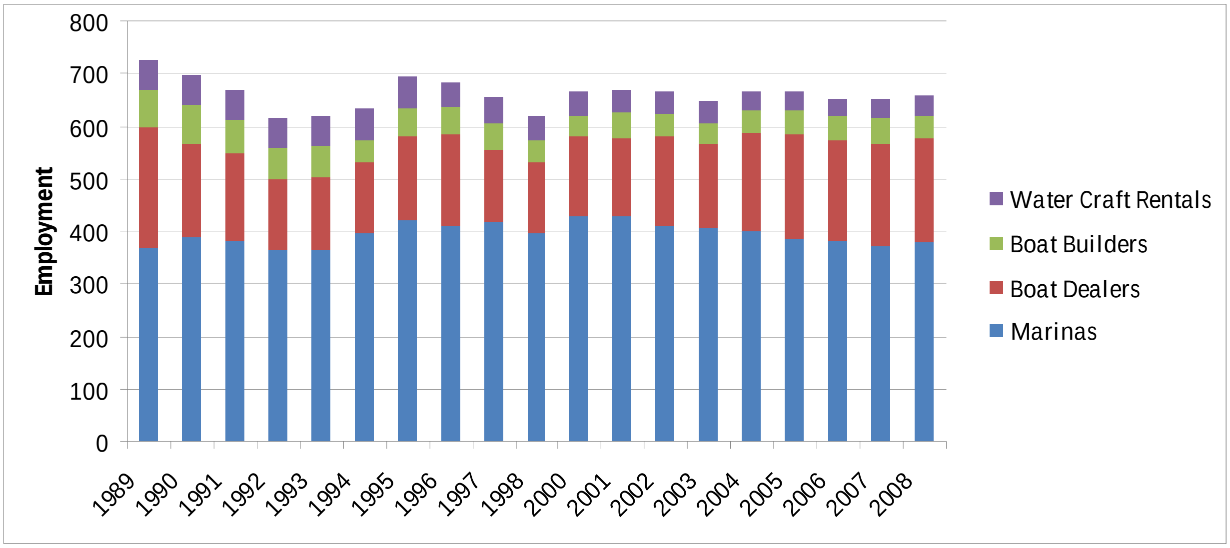
While boat registrations were increasing at a faster pace than population growth through the 1980s, they have increased at a slower pace than population growth since then, and as mentioned above, have decreased overall since 2000. As boating is the dominant recreational activity in the Delta, these trends indicate that motorized and sail boating may not keep pace with population growth over the next 50 years.

Trends in non-motorized boating, however, seem to counter those of motorized boating, with DBW estimating that California households owning non-motorized boats increased from 7.11 percent of households in 2002 to 8.46 percent in 2010, with kayaks accounting for almost one-half of estimated participation.[177] Overall, the report concludes that “the number of non-motorized boating participants is expected to continue to increase”.[178] This report also notes that per-trip expenditures for non-motorized boaters are less than per-trip expenditures for motorized boaters,[179] a conclusion which has implications for continuing economic sustainability.

[177] DBW 2009, p. 9-1 – 9-6
[178] Ibid, p. 9-11
[179] Ibid, p. 4-5

Available business enterprise-based data reveal stagnation in the Delta's recreation economy. Over the past 20 years, employment in marina enterprises has been relatively flat. In 1990, the database counts 95 marina-related establishments, 90 in 2000, and 93 in 2008. Likewise, employment by water-based recreation-related establishments has remained relatively constant over the past 20 years, as demonstrated by Figure 32.

Figure 32 Employment in Legal Delta for Water-Based Recreation Sectors, 1989-2008



Source: NETS

There are several other external or societal trends that could affect the present recreation use and demand over the next 50 years.

- Physical changes to the Delta related to habitat restoration and water deliveries, which will likely result in increased habitat acres and water surfaces with a potential decline in agriculture acreage
- Increasing population and development growth surrounding the Delta, forming a larger urban ring around significant portions, with probable exceptions for valuable, healthy near-urban ecosystems and productive agricultural lands
- Increasing population seeking out various forms of outdoor resource-related recreation, increasing the significance of the Delta as a contrast to local urbanized areas
- An increasing interest in maintaining close-to-urban agriculture to supply fresh fruits and vegetables
- Increasing concerns over "nature deficit disorder" among young people and greater interest in youth access to meaningful natural experiences
- Health concerns, such as obesity, and the need for more exercise activities
- Continued decline and stagnation of existing facilities without new capital investments

3.7 State Parks Recreation Proposal for the Sacramento-San Joaquin Delta and Suisun Marsh[180]

Under SBx7-1, State Parks was directed to prepare a proposal "to expand within the Delta the network of state recreation areas, combining existing and newly designated areas."[181] The resulting *Recreation Proposal for the Sacramento-San Joaquin Delta and Suisun Marsh*

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[180] State Parks 2011
[181] Water Code Section 85301(c)(1)

discusses existing demand, existing resources, trends, and recommendations and outcomes. By its legislative mandate, the report focuses on public sector resources and state agencies. In this report, State Parks introduces the concept of a Gateway-Basecamp-Adventure strategy. A Gateway is defined as a "community on the edge…providing information to visitors about recreation opportunities available in an area and equipping them with supplies for the adventure."[182] A Basecamp is a "park, resort, or town…providing services, as well as facilities."[183] One would depart for an "Adventure" or activity from a gateway or basecamp. Gateways, basecamps, and adventure areas State Parks recommends are linked by scenic highways and biking, hiking, and boating trails. Around this strategy, State Parks discusses the importance of partnerships, and recommends building a Delta brand, providing direction, diversifying activities, and minimizing costs by seizing multi-use opportunities.

Using the Gateway-Basecamp-Adventure strategy, State Parks recommends improvements to existing State Parks within and along the edge of the Delta, and describes four potential future State Parks in the Delta-Suisun Marsh Region: Barker Slough, Elkhorn Basin, Wright-Elmwood Tract, and South Delta.[184] State Parks also provides recommendations for other state agencies, including DFG, DBW, Caltrans, DWR, the State Lands Commission, Delta Protection Commission, Delta Conservancy, and Coastal Conservancy. Other recommendations include completing the recreation trails system in the Delta and for DPC to continue to pursue a National Heritage Area designation.[185]

Important to this Economic Sustainability Plan, State Parks also recommends ways to increase recreation contribution to the Delta economy.

- Promote recreation to increase spending
- Increase the variety of recreation available
- Encourage visitors to stay longer and experience additional activities
- Offer a mix of both affordable and higher cost recreation activities
- Increase spending for supplies and equipment in Gateways
- Enhance and promote scenic highways and trails

State Parks *Recreation Proposal for the Sacramento San Joaquin Delta and Suisun Marsh* offers a strong framework for needs and opportunities for the provision of recreation and tourism in the Delta by state agencies. However, the report concludes, "Recreation and tourism can also help sustain the region's economy and enhance its quality of life. This report's recommendations may remain just a glittering vision, however, without new funds for recreation."[186]

3.8 Key Findings

- The Sacramento-San Joaquin Delta is an area where a diversity of recreation experiences is evident, from boating in open water or through winding tree-covered channels, to hunting or wildlife viewing, studying local California history, or tasting award-winning local wines. Several physical and operational constraints have an impact on current facilities and recreation access, including sediment accumulation, water gates, screens, and barriers,

[182] State Parks 2011, p. 6
[183] Ibid
[184] Ibid, p. 22-24
[185] Ibid, p. 26-29
[186] Ibid, p. 34

invasive species, waterway obstructions, water quality, lack of boat-in destinations and access points, user group conflicts, private land trespass, and complex regulations.

- While a percentage of visitors to the Delta come from elsewhere, the majority of visitors are from Northern California. These visitors represent the focal market for Delta recreation growth opportunities in the future, and their places of origin define the market area for this study. The total Market Area had a population estimate of approximately 11.9 million in 2010, with projections of 17.6 million by 2050.
- Recreation visitation for 2010 is estimated to be approximately 8 million *resource-related* (e.g., boating and fishing) visitor days of use per year, 2 million *urban parks-related* (e.g., golf, picnic, and turf sports), and 2 million *right-of-way-related* (e.g., bicycling and driving for pleasure) recreation visitors/year. The total number of activity days is conservatively estimated at approximately 12 million/year.[187]
- An up-to-date visitor survey with new primary data, particularly on non-boating and non-fishing recreation, is needed to better document existing recreation visitation and spending. Employment in recreation-related economic sectors, including marinas, water craft rental, boat dealers, and boat building and repair, within the Primary Zone has been relatively flat over the past 20 years.
- The principal changes and trends that could affect the present recreation use and demand over the next 50-90 years are: physical changes to the Delta due to water conveyance management changes and rising sea levels, increasing population and development growth, increasing agritourism, non-consumptive resources-based recreation, and habitat-related recreation, and the likely desire for closer to home recreation.
- The current direct spending in the Delta region from *resource-related* and *right-of-way/tourism-related* trips and related non-trip spending is estimated at roughly $312 million inside the Delta (in 2011 dollars). Additional economic impacts associated with urban recreation are not quantified, but are likely significant.
- Delta recreation and tourism supports over 3,000 jobs in the five Delta counties. These jobs provide about $100 million in labor income, and a total of $175 million in value added to the regional economy.
- Delta recreation and tourism supports over 5,200 jobs across all of California, and contributes about $348 million in value added.
- State Parks *Recreation Proposal for the Sacramento-San Joaquin Delta and Suisun Marsh* offers a strong framework for needs and opportunities for the provision of recreation and tourism in the Delta by state agencies.

4 Outcomes and Strategies

The prior section discussed the current status of recreation in the Delta, including existing facilities and estimates for existing visitation and economic impacts. There was also a short discussion on current trends. In this section, a plan is developed for a strategy for economic sustainability for Delta recreation and tourism.

The proposed recreation portion of the Delta Economic Sustainability Plan brings together information regarding baseline conditions described in Chapter 6 with three topic areas—constraints/issues, influences on the Delta as an evolving place, and potential responses—as a means of determining how the Delta might evolve over time. Principles, goals and physical strategies are then applied in order to develop the proposed recreation plan.

[187] Estimates are based on limited available data combined with professional judgment.

4.1 Opportunities and Constraints

There are many current and future potential constraints and issues which will shape recreation potential in the Delta. Several existing physical and operational items were described in Sections 3.2 and 3.3 of this chapter. Those that would have the most significant impacts on future planning scenarios are expanded below.

4.1.1 Limited Access and Visibility

The Delta is a recreation landscape of two faces: one seen from the water and the other experienced largely from a car or in one of the Legacy Communities. For all its hundreds of miles of waterways, the waters of the Delta can be publicly accessed in a relatively few places. Dotted with private marinas and few public parks, boats can only reach Delta waters from these boat slips and ramps, as well as from private docks and remote put-in spots outside the Delta. Transient tie-ups or places to temporarily tie up a boat are also limited. Similarly, there are relatively few landside recreation facilities that offer public fishing, camping, or picnicking, and overnight hospitality options are relatively few. With few communities, parks, trails, and public destinations, the vast land area for the most part is accessible only through the windshield.

4.1.2 No Distinct Delta Identity

For the same reason the Delta lacks a distinct identity as place, it lacks both an operational and marketing identity. Unlike a known brand like “Monterey,” “Delta” lacks brand recognition. In addition, it lacks a strong identifying focal point area, like Fisherman’s Wharf and the Monterey Bay Aquarium. For all its beauty, allure, and recreational diversity, the Delta functions as a largely underutilized destination, unknown to many in the larger Sacramento and Bay areas and the state, and not easily discoverable to those who do not already know and use the area.

4.1.3 Two Contrasting Physical Environments

The Delta comprises two contrasting physical environments that bump against one another, sometimes harmoniously and sometimes in conflict. Many agricultural islands, hidden from the waterways by levees, lie significantly below river level. This physical, visual, and land use juxtaposition makes the edge between the two environments problematic and limits access to waterways.

Boating use occurs on public waterways that abut, for the most part, privately-owned agricultural or residential property. It is the inclination of boaters to occasionally beach their boats and access the shoreline, which can result in trespass and potential damage to private property. Boat wakes can damage levees. Levees, subject to erosion, are often lined with armor, which discourages landing by boaters and precludes shoreline recreation use other than incidental bank fishing by landside fishermen. The resulting environment allows for boat passage but virtually no shoreline recreation use in these areas, a significant deterrent to expanded boating use. Aesthetic values of unvegetated riprap levees are low, further diminishing their appeal.

4.1.4 Private Marina Limitations

Most boat access to Delta waterways is provided through private marinas and boat launch ramps; State and local public launch facilities are provided to a limited degree. There are relatively few opportunities for overnight stays for boaters without self-contained facilities. Over the years, the private marina market has adjusted to provide for the demand for boat storage slip space, which is the primary revenue source for marina operators. Launch ramps and parking space for trailered boats is available in limited supply at marinas as boat launch revenues generally are not a significant revenue source and land for parking is limited landside of the levees.

Marinas face siltation of their boat basins, and costs and regulatory hurdles to maintenance are significant. Many marinas and resorts are aging and suffer from deferred maintenance, diminishing their appeal to new users.

A further limiting factor to increased use by visitors trailering boats to the Delta is its “hidden” quality. Boat put-in locations are often not easily seen and must be sought out by the first-time visitor. Many facilities are located in out-of-the-way locations. Further, given the narrow spaces many marinas occupy, with parking and roadways built atop narrow levees, launching and parking maneuvers can be challenging, even for experienced operators. Boating use has tended to be relatively local in nature and therefore primarily a day-use activity, which limits economic activity generated by recreation.

4.1.5 Other Facility Limitations

In addition to private marinas that only offer slip rentals, launching, and related services, some private resorts offer camping and day-use facilities. Resorts of this kind are limited, revenue potential is also limited, and these resorts operate on at a tight margin. There are some state and local parks that also offer similar facilities, however, such landside recreation amenities are relatively rare in the Delta.

Traditionally, in the Delta, recreation improvements have been largely provided by the private sector, and public investment in land and facilities has been small. Declining public recreation budgets have contributed to declining maintenance and facility quality and no schedule for expanded development. State and local agencies have developed multiple plans for expanding Delta recreation that have remained unfunded for many years. The most recent plan by State Parks, *Recreation Proposal for the Sacramento-San Joaquin Delta and Suisun Marsh*, states that no funding is available for implementation and the largest State Park in the Delta, Brannon Island State Recreation Area, is currently on the proposed closure list.

4.1.6 Waterway Concerns

An additional constraint to expanded boating use in the Delta is its geography. By its nature, a labyrinth of waterways that lacks obvious navigational landmarks, the boater unfamiliar with it can easily become lost. Although increasing use of GPS devices reduces this risk, many inexperienced boaters continue to be reluctant to tackle Delta navigation.

Similarly, Delta waterways can be unpredictable in depth and contain unseen underwater hazards that can discourage the uninitiated boater. Snags, sandbars, and submerged levees are common hazards that can catch the casual boater.

Water quality is also an issue to some boaters and shoreline users in the Delta. With limited clarity and concern over water quality, some are deterred from engaging in water contact in the Delta. Velocity of currents makes swimming more hazardous in some locations. Many boat owners avoid saline water, and salt water intrusion could render increasing areas of the Delta off limits to these boaters. Invasive aquatic plants, including water hyacinth and *Egeria densa*, further reduce access and appeal to boaters and fishermen by impeding navigation and damaging boat motors.

4.1.7 Regulatory Environment

While most local jurisdictions, including counties and cities, have policies that encourage recreation in the Delta, they also have regulations which preclude or severely limit new development or services, or redevelopment of existing facilities. So, while protecting the atmosphere of the Delta-as-a-Place, these same policies also inhibit economic growth and sustainability. Additionally, several state and federal agencies have regulatory authority over changes to Delta facilities. The effects are felt from businesses in Legacy Communities to isolated wineries to marinas and other pubic and private recreation facilities. For instance, permits for a new marina or even a marina upgrade may require input from the local county, the State Department of Boating and Waterways, Delta Protection Commission, State Lands Commission, Reclamation Board, State Department of Fish and Game, Regional Water Quality Control Board, U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, and National Marine Fisheries Service. These many layers of regulations are, at best, costly, time consuming, and confusing, and, at worst, completely prohibitive to new recreation developments or enhancements.

4.2 Opportunities and Influences

This Plan is charged with working within the context of the Delta as an evolving place. The existing baseline conditions, as well as its constraints and issues, will affect that evolution. The following key opportunities and influences will also help shape that future.

4.2.1 Increasing Demand

By 2050, population in the counties surrounding the Delta is projected to grow by 50–60 percent. As population and gasoline prices increase, there will be a growing focus on recreation opportunities close to population centers. The Delta is not only close to major population centers, but accessible via the interstate and state highway network that surrounds and bisects it. Increasingly, past experience would indicate, the Delta, will become a primary source of open space and recreation activity for the greater Northern California region.

If so, existing boating access and landside recreation opportunities today will be inadequate to attract and accommodate this growing demand. New opportunities to experience the existing and restored natural habitats of the Delta will likely attract new visitors. Similarly, increased agritourism should create demand for expanded overnight visits to Legacy Communities and the growing wine region. Recreation, wildlife viewing, and agritourism will likely grow together, fueling the interest in the Delta and reinforcing its emerging identity as “place”. A synergy between these uses will create new opportunities for visitation and economic activity in the Delta.

4.2.2 Physical Capacity of Delta Waterways

Current levels of boating and fishing fall far short of the physical capacity of the Delta waterways for recreation. Within the great size and diversity of Delta waterways, there is significant capacity for additional boating use and diversity in the future. Population growth will expand the demand for all forms of recreation in the Delta. These uses can be accommodated through expanded points of access via land- and water-based facilities. These facilities in some cases would require conversion of land from other uses.

4.2.3 Public Lands

Nearly all public lands that have been acquired in recent years within the Delta have been set aside as wildlife habitat but provide little or no public recreation use or access. There may be significant opportunities to include appropriate public use that would be compatible with habitat-management objectives. Renewed funding for implementation of agency recreation plans, such as State Parks' *Recreation Proposal for the Sacramento-San Joaquin Delta and Suisun Marsh*, could provide a significant expansion of access and facilities that could boost recreation use.

4.2.4 Quality of Life

The Delta appeals to both residents and visitors not only because various Delta features combine to create a unique aesthetic, but also because the tangible attributes and the intangible Delta aesthetic add value to their lives. Planners can anticipate that residents and recreationists will express strong viewpoints on suggested plans or changes that would have an impact on the Delta's quality-of-life features, and that residents and visitors will want these quality-of-life values incorporated in planning efforts.

4.2.5 Delta-as-a-Place

The Delta must be a better-defined destination for visitors. Increased programming, special events, festivals, and marketing have the potential to significantly increase visitation and recreation use Delta-wide. Linking the vitality and tourist appeal within Legacy Communities would boost overall Delta recreation and attract a new segment of visitors. Joint marketing of events in these communities tied to farm trail, wine trail, and boat trail tourism would be a further means of increasing visitation, visitor spending, and economic activity. These steps, adjunct to traditional Delta recreation enhancements, would boost the identity of the Delta as a destination with multiple attractions and enhance Delta branding and recognition.

The Delta-as-a-Place identity would also be enhanced by efforts to identify and establish Gateways and edges to the Delta that reinforce its unique landscape character, particularly along the primary east-west highway corridors.

4.2.6 Market Area Development

Projected population growth within communities on the edge of the Delta may likely create additional demand for recreation offerings. Urban water-front recreation improvements such as those built by the City of Stockton over the last few years will provide capacity for new visitors to participate in leisure activities. This trend could continue if communities such as Rio Vista, Tracy, and Lathrop orient planned development towards the Delta, interconnecting recreation corridors on the periphery of the Delta, and contributing to buffer zones between urbanized areas and the Delta to provide additional recreation opportunities.

Development of Delta-edge and cross-Delta trails, connection of open space areas, and capturing land and water views within the Delta can further add to the growing fabric of Delta recreation and access and the capacity to accommodate additional visitors.

4.2.7 Agriculture Trends

Evolutions occurring in agriculture include increases in wine grapes and wineries, a growing interest in developing a coordinated "farm trails" effort with the goal of increasing agritourism and direct sale of agriculture products, and the desire to "brand" Delta agriculture products. These three efforts could influence Delta recreation economics.

4.2.8 Recreation Activity Trends

Recreation use patterns continue to evolve. Basic recreation activities are generally constant, but trends occur within the activity. For instance, in boating, there are two trends where large craft are increasing faster than small craft, and participation in non-motorized boating is increasing at a faster rate than motorized. Other trends involve the provision of high-end camping, recreation-oriented urban redevelopment and development centers, and increased interest in small rural communities.

4.2.9 Coequal Goals and Risk Management

The efforts and ultimate implementation to meet the coequal goals of protecting, restoring, and enhancing the Delta ecosystem and creating a reliable water supply will influence future recreation developments and activities in the Delta. Studies of and responses to numerous potential concerns including land subsidence, earthquakes, rising seas, and changing precipitation patterns could also influence the future of recreation and tourism in the Delta.

4.2.10 Future Prominence

As growth in the region and the state continues over the coming decades, the Delta has the potential to emerge as a recreation resource of increasing value and appeal and its prominence as a destination will expand accordingly. Increasing water-oriented recreation demand and the associated demand for landside recreation activities can combine with the growing appeal of agritourism and locally-grown food and wine to reinforce the identity of the Delta as a unique and desirable recreation destination for the northern California region.

4.3 Potential Responses

The potential response to the constraints, issues, and influences should shape the Delta's Recreation Economic Sustainability Plan. In the past, various federal, state, and local agencies, as well as nonprofit and for-profit entities have each contributed pieces of the total recreation picture in a somewhat uncoordinated fashion.

California State Parks, in the *Recreation Proposal for the Sacramento-San Joaquin Delta and Suisun Marsh*[188] lays out a coordinated response for the various state agencies involved in the Delta. It also speaks to the need for both itself and other state agencies to partner with local agencies, nonprofits, and private businesses.

One of the most successful and easily understood examples of creating a recreation destination in California is the Monterey Old Fisherman's Wharf which, in a small area, attracts in excess of six million visitors annually. It is a merger of public and private efforts wherein agencies created a synergistic setting for private enterprise. The city built the wharf, marina infrastructure, parking lots, and access roads, the State Department of Boating and Waterways provided marina development loans, and State Parks contributed an adjacent visitor center and historic building restorations.[189] The private sector created and operates the restaurants and shops along with providing fishing, whale watching, and other recreation activities. The Fisherman's Wharf Association helps to coordinate and market the wharf. State Parks continues to operate Monterey State Historic Park, a collection of historic houses and buildings, with interpretation, educational programs, and special events support from the nonprofit Monterey State Historic Park Association.[190,191]

[188] State Parks 2011
[189] http://montereywharf.com/index.php?page=history
[190] http://www.parks.ca.gov/default.asp?page_id=575
[191] http://www.montereystatehistoricparkassociation.org/index.html

Private enterprise is both the existing and future driver of economic sustainability in the Delta, but its future success level can be shaped by the public facility contributions and regulatory environment. This Plan recommends developing a synergistic response between state and local agencies, nonprofits, and the private sector.

The implementation of the ESP will be very complex. Overcoming the multiple steps, regulations, and planning processes by either agencies or individuals can be difficult for normal projects. But, the multiplicity of agencies and interlocking safeguards and regulations in the Delta multiplies the difficulties. It is recommended that a facilitator organization be named to assist implementation efforts, to coordinate funding, and to stimulate funding for vital actions. A more in-depth discussion is presented in Chapter 11 of this report.

4.4 Recreation Enhancement Principles and Goals

It is recommended that the following principles and goals be used to guide development of planning scenarios for future Delta recreation. These principles and goals were developed to minimize current constraints and to take advantage of current and future opportunities. This Plan was developed with the following guidelines at the forefront.

- Avoid developing recreation facilities within high flood risk areas or areas inaccessible during emergency flood events.
- Avoid conflicts with vital habitat resources.
- Respect and protect agriculture areas. Avoid locating recreation sites in areas that would create conflicts with agriculture and instead site, when possible, in more compatible areas such as around the edges of the Delta, in combination with Legacy Communities, and by expanding existing areas.
- Respect and protect hunting activities by avoiding spatial and/or timing conflicts with other activities.
- Create positive park, open space, and trail edges that buffer the Delta from encroaching urban and suburban areas.
- Encourage both commercial and public recreation facilities—including marinas, food service, overnight accommodations, and standard community park developments—within or on the edge of Legacy Communities and existing recreation areas.
- Develop appropriate visitor-serving access facilities at wildlife areas providing nature study, bird-watching, and environmental education. Include interpretive signage to educate the public about the natural resources values of the Delta and their need for protection.
- Recognize private enterprise's primary role in providing recreation facilities and encourage and facilitate appropriate expansion to keep up with increasing populations and changing demand.
- Support programs to assist existing private recreation providers, such as identifying or providing loan funds, coordinating marina dredging and permitting, and helping them respond to sea-level changes.
- Recognize the multiplicity of public agencies and nonprofit entities which provide recreation in the Delta and encourage coordination in planning for, and provision of, recreation opportunities.
- Utilize State Parks Basecamp, Gateway, and Adventure concepts, as described in the *Recreation Proposal for the Sacramento-San Joaquin Delta and Suisun Marsh,* which encourages the concentration of new facilities within and near existing recreation areas while developing and enhancing the attractiveness of points of interest in appropriate locations throughout the Delta.[192]

[192] State Parks 2011

- Promote the creation of recreation destinations as focal points of the Delta. Such multi-interest complexes should each highlight Delta values by incorporating one or more Legacy Communities, marina resorts, public and private recreation basecamp areas, natural wildlife areas, and trails. The complexes should be based upon existing community values and highlight existing Delta and community resources.
- Encourage the creation of settings for private enterprise development through the development of ancillary public facilities such as trails, event venues, community docks, etc.
- Advocate for overnight extended stay within or adjacent to the Delta through program offerings, multiple points of interest, and available accommodations.
- Increase the public's awareness of the Delta as a desirable recreation destination through better regional coordination, advertising and signage, marketing, and promotional-scale events.
- Identify and develop appropriate opportunities for small boat-in day-use areas, as well as larger destinations akin to Delta Meadows for boaters. Such areas should provide basic facilities for boaters, such as docks, tie-ups, restrooms, as well as opportunities to participate in many different forms of recreation.
- Develop appropriate locations throughout the Delta for a network of hard-surface non-motorized, multi-use trails, as well as boat trails for both motorized and non-motorized craft, including completing planning and implementation of the Great Delta Trail,[193] and trails recommendations from State Parks.[194]
- Ensure appropriate and coordinated response to operational issues including exotic aquatic vegetation control, boater safety enforcement, waterway maintenance, abandoned and derelict boat removal, boating hazard control, etc.
- Provide additional on-shore access facilities for shore fishing and motorized and non-motorized boat launching.

4.5 Recreation Enhancement Strategy

4.5.1 Basic Approach

4.5.1.1 Planning Interrelationships

The Delta Stewardship Council Delta Plan provides recommendations for the Delta as an Evolving Place. Relative to this Economic Sustainability Plan, the Delta Plan recommends that "ways to encourage recreational investment along the key river corridors be identified."[195] State Parks, in its recreation proposal for the Delta,[196] looks at the Delta and Suisun Marsh as a whole, including State Recreation Areas, wildlife areas, and other state facilities. The scope of this Economic Sustainability Plan for recreation encompasses the entire Legal Delta, with a focus on the Primary Zone, but will also include Legacy Communities, marinas, agritourism, and other private enterprise activities.

It is anticipated that the final Delta Plan, State Parks' recreation proposal, and the DPC's Land Use and Resources Management Plan may need to be refined for consistency with this Plan. Ultimately, any refinements to a final recommended action plan need to be supported by both the recreation and resident community of the Delta.

[193] DPC 2010
[194] State Parks 2011
[195] DSC August 2011 p. 197 (Fifth Staff Draft)
[196] State Parks 2011

4.5.1.2 Components

State Parks' recreation proposal coordinates with and provides recommendations for each of the state agencies involved in various portions of the recreation sector in the Delta. It does not, however, provide recommendations for local agencies and private enterprises. Private enterprise presently constitutes nearly all of the economic activity related to recreation in the Delta. Therefore, this Plan examines all three sectors and the potential synergies between state agencies, local agencies, and the private sector.

4.5.1.3 Catalysts

A key strategy for achieving synergies between the public and private sectors is to plan for relationships wherein public agency facilities interrelate, complement, and create catalyst settings for private enterprise activities, while at the same time providing public services. These services can include both recreation facilities as well as vital infrastructure to support both public and private areas. Catalyst settings should be created whereby joint public-private efforts could support an expanding and diversifying menu of recreation and cultural attractions and events, as well as overnight accommodations, restaurants, retail, and other services.

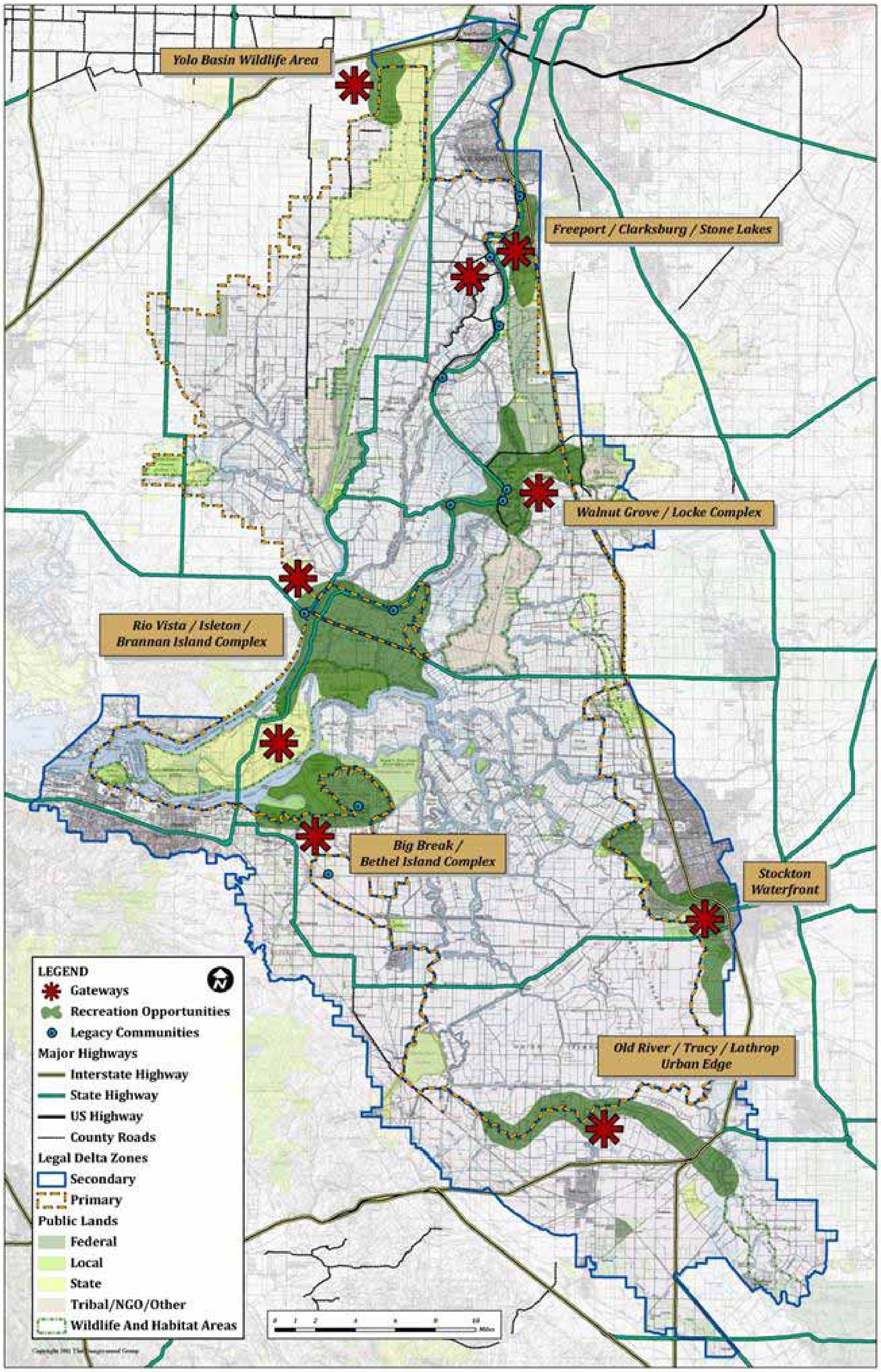
4.5.1.4 Location

Concept locations for where catalyst settings, facilities, and activities could be accomplished are proposed below. The locations are primarily focused around the edges of the Delta and in and around Legacy Communities. These recommended locations are based upon the principles and goals previously discussed, and consist of the following five concepts (See Figure 33).

1. Delta waterways
2. Dispersed, small points of interest and activity areas
3. Focal point destinations
4. Public access to existing and planned natural habitat areas
5. Delta-urban edges (the edges of existing and emerging urban areas that surround the Delta) such as Stockton, Tracy, Rio Vista, and Lathrop

Each concept and how it relates to influences and proposed locations is described in greater detail below.

Figure 33 Recreation Enhancement Strategy Plan[197]



[197] For high resolution image see http://forecast.pacific.edu/desp-figs.html

4.5.2 Delta Waterways

The primary location for recreation in the Delta is, of course, the waterways. These waterways are diverse—narrow, wide, tree-lined or channelized, windy or quiet. Boaters have, over time, selected areas for their specialty activities such as windsurfing, waterskiing, cruising, paddling, etc. For instance, the waters flowing along the northwestern side of Sherman Island are a mecca to windsurfers and kiteboarders. Specialty needs are associated with most of these diverse activities.

The Delta Protection Commission's 2006 *Aquatic Recreation Component of the Delta Recreation Strategy Plan* is still very applicable. It recognized the existing use areas, access points, and marinas, and provided recommendations regarding their enhancement, refurbishment, and expansion. In addition, the report recommended three priority new enhancements.

It recommends that non-motorized boating trails be established in six different locations on waterways where habitat values are primary and where such use would not conflict with power-boating activities. A second recommendation is that major boat-to destinations, similar to Delta Meadows, be established in other parts of the Delta. Further study is required to determine where these might be appropriate, but four possible areas were provided. The third recommendation was that smaller boat-in day-use areas with adequate facilities and transient tie-ups be established in appropriate locations throughout the Delta. Suggested elements and features for these areas, as well as location criteria, are provided within the report, but no specific locations are identified.

In addition, the report indicated the need for continued navigability of waterways, as well as provision of new and expanded facilities in the future. These included more boat launching ramps, marina slips, boating support facilities, public access to waterways for anglers, and convenience docks related to Legacy Communities and points of interest.

The 2006 *Aquatic Recreation Component of the Delta Recreation Strategy Plan* predates the present, more comprehensive legislatively mandated Delta planning efforts. The above elements to the plan are still relevant and applicable, but some of the new influences on the Delta's evolution will require additional responses as related to Delta waterways recreation.

- The efforts of creating a sustainable, healthy ecosystem will likely create additional waterways that should be reserved for the increasing interest in non-motorized boating.
- Plans to create salmonid-friendly edges to the lower Sacramento River could influence the location of, and facilities for, windsurfing and board sailing activities in this strategic location.
- Reliable water supply facility studies should be coordinated with recreation potentials in order to avoid impacts and to potentially provide additional recreation opportunities.
- Potential risk management strategies including setback levees should be studied for possible joint use for waterway-related recreation. Such strategies may require relocations of existing access facilities and it is recommended that such relocations, if necessary, take the opportunity to provide complete, up-to-date facilities.

4.5.3 Dispersed Points of Interest and Activity Areas

The Delta's diverse points of interest and activity areas are dispersed throughout its vast landscape. These features grant the Delta a distinctive character, especially in contrast with the surrounding urban and even rural agriculture landscapes. Overall, this aspect has come to be referred to as Delta-as-a-Place. These diverse points of interest—the small Legacy Communities, the loose network of marinas scattered throughout the area, the farm stands, wineries, and surrounding agricultural landscapes, winding waterways, and intriguing riparian landscapes—underscore the need to protect, enhance, and expand the elements that give the Delta its charm and sense of place. The sheer number and diversity of things to see and do is a valuable feature.

The expansion, over time, of additional areas will be accomplished primarily through private enterprise responding to opportunities such as farm markets, wineries, art galleries, restaurants, etc. On the public side, the Department of Water Resources[198] identified, in a past study, approximately 40 small day-use, launching, and fishing access locations that were economically viable, but which were never developed. State Parks has identified 13 park and facilities expansions and development.[199] Federal, state, and nonprofit wildlife entities have planned facilities for increasing and managing public access and use.

Policies should be developed to encourage private development of additional appropriate facilities in non-conflicting locations and funding needs to be identified to accomplish appropriate public agency-planned improvements.

4.5.4 Focal Point Destinations

An important way to expand recreational capacity, increase visitor spending and lengths of stay, and draw new visitors to the Delta is to create destination complexes, similar to State Parks' Gateway-Basecamp-Adventure concepts.[200] By concentrating multiple recreation opportunities in an interconnected location, these complexes would provide focal points to visitors, particularly new visitors, and also present opportunities for businesses to develop economically viable operations. These complexes should include, and build upon, the primary values of the Delta.

Three locations have been identified that already have complexes of the values of natural areas, parks, Legacy Communities, marinas, historic features, and trail potentials. They are: (1) Walnut Grove/Locke/Cosumnes River Preserve, (2) Brannan Island/Rio Vista/Isleton, and (3) Bethel Island/Jersey Island/Big Break. In addition, an emerging complex along the edges of Stockton also has the potential to be developed into a focal point destination.

The first focal point destination is proposed to include the Legacy Communities of Locke, Walnut Grove, Ryde, Cortland, and Hood, as well as Delta Meadows, the Cosumnes River Preserve, and Staten Island. Figure 34 below presents a conceptual drawing of proposed features. Additional public facilities should include developed day-use and camping facilities at Delta Meadows, events venues, further improvements/restorations at Locke, and wildlife viewing/nature study opportunities. A network of water and land trails would knit together the complex and give it a sense of cohesion. A segment of the historic railway connection between Old Sacramento and the Delta could be used to foster the growth of critical mass at this complex, making it more attractive for investment. Chapter 10 discusses some strategies for the Legacy Communities, but additional features and activities could be evaluated to assist in creating viable settings for private enterprise operations.

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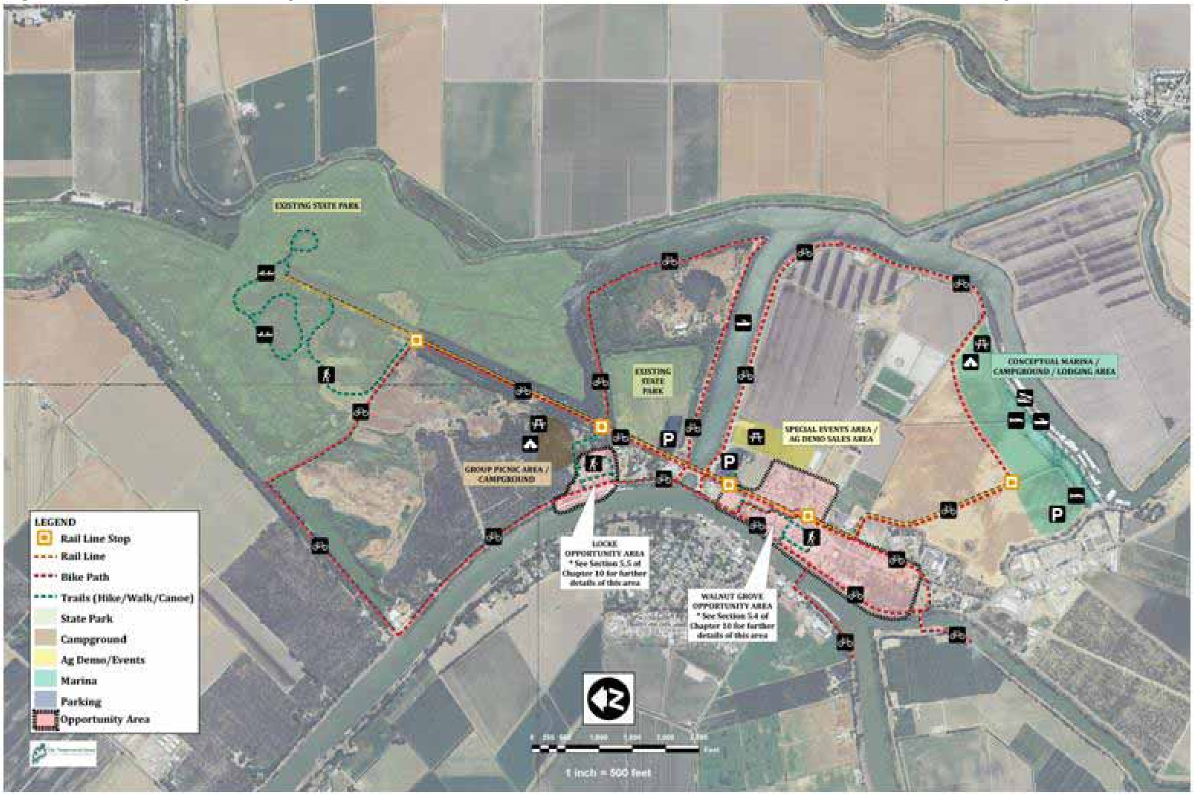
[198] DWR 1981
[199] State Parks 2011
[200] Ibid, p. 6

Figure 34 Conceptual Proposal for Walnut Grove/Locke/Delta Meadows Focal Point Complex[201]



The Brannan Island/Rio Vista focal point destination complex is proposed to include Isleton, the emerging Delta Discovery Center and Farmer's Market, and the marina complex around the junction of the San Joaquin and Old Mokelumne Rivers. Possible habitat areas on Twitchell and Sherman Islands, the windsurfing oriented Sacramento County Regional Park on Sherman Island, and Brannan Island State Recreation Area could be knit together with the communities and marinas with a network of trails. Development of additional features to create settings for private enterprise should also be evaluated for this proposed destination complex.

The Bethel Island focal point would include its marina and existing businesses, Big Break Regional Park, and a natural-lands conversion of Jersey Island. As with the other proposed complexes, these areas could potentially be tied together and enhanced with both landside and water trails.

The proposed focal point along Stockton's edge has a different character and does not include a Legacy Community or a major natural landscape feature. The planning and emerging development for the area, however, create a Delta-related focal point area because the recent designation of the westerly portion of Wright-Elmwood Tract as open space and a possible State Recreation Area, in partnership with local agencies, provides the opportunity for additional park, trail, and habitat restoration improvements.

4.5.5 Natural Habitat Areas

The fourth location-based recreation enhancement strategy is the association of appropriate visitor access to natural habitat areas with and on the edges of the Delta. Three existing natural

[201] For high resolution image see http://forecast.pacific.edu/desp-figs.html

habitat areas have the potential of providing expanded environmental education and nature-appreciation opportunities: the Jepson Prairie/Calhoun Cut area at the head of Cache Creek, the Yolo Basin Wildlife Area east of Davis, and the Stone Lakes State Park and National Wildlife Refuge. These three natural habitat areas, in combination with the previously identified focal point areas, are important assets of the greater Delta. They all have the need for improved visitor access and interpretive facilities.[202]

4.5.6 Delta-Urban Edges

The final location-based recreation enhancement strategy is the establishment of Delta-serving and urban recreation areas, as well as natural habitat zones, around the edges of the Delta. These should be located between the Delta and adjacent urban areas—from Stockton around to Antioch and Bethel Island, including the north edge of Tracy and Lathrop, and in selected locations such as Rio Vista. It is recommended that criteria be developed to assist in locating this interface zone (open space corridor) generally in conjunction with existing urban limit lines, in an area that would optimize its value for habitat enhancement with active park nodes and interconnecting trails.

4.6 Baseline Visitation Potential

A market demand-based model of visitation for current conditions was developed as a baseline. This model is based on population, participation rates, activity days, and market capture rates. The same model can be used to predict visitation in the future, making adjustments to participation rates and market demand capture rates based on assumptions discussed above, as well as on general recreation trends that may influence recreation participation rates in the future, also discussed above. General assumptions for this baseline scenario forecast follow.

- Market Area population will increase by approximately 50 percent between 2010 and 2050.
- It is estimated that approximately 20 percent of the future recreation use will trend towards developed urban park-related, 30 percent right-of-way-related, and 50 percent resource-related.
- There is a trend away from consumptive recreation (e.g., hunting and fishing) and towards non-consumptive wildlife recreation (e.g., bird watching and nature photography).
- Increasing participation in agritourism is likely.
- Gas prices will continue to increase, with a responding trend towards recreating closer to home.
- Boating trends will shift towards non-motorized boats (i.e., more canoe/kayaks) in protected waterways.
- The proposed Great Delta Trail will be completed.

Based on these trends, quantitative visitor-day projections have been developed for the baseline scenario and are presented in Table 40. Note that this scenario does not represent status quo (i.e., disinvestment and stagnating visitation), but represents a conservatively optimistic perspective which includes the assumptions that follow.

- Visitation is based on overall trends described above.
- There will be increased investment to address deferred maintenance of existing facilities.
- There is enough capacity within existing waterways to capture growth.

[202] As described in Section 3.2.1.3, Stone Lakes National Wildlife Refuge is in the process of building expanded visitor-serving facilities.

- In most instances, growth in recreation activities will keep pace with population increases, with additional growth in wildlife-related, non-consumptive activities, and slowing growth in motor boating, fishing, and hunting.
- If disinvestment in facilities and stagnation continue, visitation may not keep pace with population growth, as has been seen over the past 20 years.

Table 40 Summary of Predicted Visitor Days under Baseline Scenario (in millions)

Activity Type	2010	2020	2030	2040	2050
Resource Related	7.6	8.3	8.9	9.5	10.0
Right-of-Way/Tourism Related	2.1	2.4	2.6	2.9	3.1

If the proposed plan is implemented, additional visitation is predicted to occur beyond baseline. General assumptions from the principles outlined above for this plan implementation scenario forecast follow.

- All activities increase slightly in the Delta due to implementation by an operating facilitating organization in marketing and promotional special events and festivals.
- An additional increase in Legacy Community and tourism, related to focal point development focused around the communities.
- Additional increases would be realized due to habitat conservation and increased levee protection.

4.7 Economic Potential

4.7.1 Recreation Spending

Based on a quantitative framework, estimates have been made of potential future recreation levels and associated spending in the Delta. As discussed above, recreation participation trends and Delta competitiveness over the next 40 years were considered. Again, the baseline forecast assumes that resource quality and recreational facilities are maintained such that the Delta retains its current level of competitiveness as a recreation destination.

Under the baseline scenario, recreation visitation in the Delta (including resource-related recreation, ROW recreation, and tourism) increases by roughly 3.4 million visitor days, or about 35 percent, over 40 years. Assuming that current visitor spending patterns remain unchanged and Delta business growth accommodates recreation-related spending increases, baseline visitation growth is estimated to increase spending in the Delta by roughly $78 million (2011$) to about $329 million (2011$) by 2050. Under the plan implementation scenario, recreation visitation and associated economic impacts in the Delta (including resource-related recreation, ROW recreation, and tourism) would increase over baseline.

4.8 Key Findings

- When attracting visitors and expanding recreation access to waterways and landside recreation improvements, potential negative impacts on agriculture from increased tourism and recreation can be minimized by focusing recreation uses and activities through expansion of existing recreation sites, development in Legacy Communities, creating buffer areas adjacent to agriculture, and increasing public safety enforcement.
- The future growth of recreation in the Delta consists of five location-based strategies which would emphasize:
  - Delta waterways, specialized by boating type;

- Dispersed, small points of interest and activity areas such as marinas, farmer's markets, wineries, restaurants;
- Focal point complexes such as Legacy Communities or Bethel Island/Jersey Island/Big Break;
- Natural habitat areas; and
- The edges of existing and emerging urban areas that surround the Delta such as Stockton, Tracy, Rio Vista, and Lathrop.

- If resource quality and recreational facilities are maintained such that the Delta retains its current level of competitiveness as a recreation destination, baseline forecasts for visitation show increases of 3.4 million visitor days, or about 35 percent, over 40 years. If this Plan is implemented, recreation visitation in the Delta could increase beyond baseline.
- Assuming that current visitor spending patterns remain unchanged and Delta business growth accommodates recreation-related spending increases, baseline visitation growth is estimated to increase spending in the Delta roughly $78 million (2011$) to about $329 million (2011$) by 2050. Plan implementation could increase the economic impact of recreation over the baseline.

5 Impact of Policy Scenarios

Four possible policy scenarios are qualitatively evaluated as to their primary elements and their potential positive and negative influences on recreation for purposes of discovering major areas of potential concern.

5.1 Policy Scenarios Influences on Recreation Potential

5.1.1 Assumptions Under All Scenarios

In Chapter 6, different policy scenarios were presented on which to base analysis for future economic impacts. Although not explicitly discussed, it is assumed that the purpose of any of the scenarios other than the baseline is to achieve the stated purpose of the Delta Reform Act and that the policies would achieve the coequal goals of water conveyance and habitat protection. Thus, under all scenarios, it is assumed explicitly as follows.

- Water quality in the Delta will improve overall (though salinity intrusion may still be a factor).
- Fisheries will be improved.
- Any project will be mitigated appropriately (suggestions to follow in later sections) for potential significant impacts to recreation, the Legacy Communities, and the economic sustainability of the Delta.
- Water exports from the Delta will continue.

5.1.2 Isolated Conveyance Scenario

In Chapter 6, the Isolated Conveyance Scenario was described and included the following features.

- Five new water intakes would be built along the Sacramento River between Clarksburg and Courtland.
- A new forebay would be constructed near Courtland where water from the five intakes would be collected and then pumped into an isolated conveyance pipeline under the Delta, extending to a new afterbay near the Clifton Court Forebay.
- Land would be removed from agriculture uses for the intake-pumping stations and the forebay and afterbay.

- Approximately 8,000 acres of agricultural land would be utilized in Sacramento and San Joaquin counties.

This scenario would affect existing and future recreation uses in a number of ways, some potentially positive and others negative, including the following.

- Since the water intakes would be upstream from the confluence of the Sacramento and San Joaquin rivers, it is expected that salinity in the water at the confluence of the two rivers and further south will increase. Water quality would decrease in the resulting relative stagnant waterways. This change in water salinity and quality will likely affect fishing, boating, and hunting in the lower Delta.
- The pumping intake stations will introduce an "industrial" quality along approximately five to ten miles of the Sacramento River, creating significant visual impacts to this rural, scenic stretch of river. In addition, the sound and night lighting related to these facilities will change the setting of the existing Legacy Communities. Together these features will reduce the Delta-as-a-Place character and the value of the Delta as a tourism destination.
- Moving the intake of fresh water to the north will likely have a beneficial effect on fisheries by allowing a more natural outflow of the remaining water out to sea. This move could improve fishing in parts of the Delta.
- It is unknown how the loss of agricultural lands would affect hunting opportunities, based upon long-term land use of the lands needed for construction.

5.1.3 Habitat Conservation Scenario

The habitat conservation scenario was described in Chapter 6 with changes resulting from the following project elements.

- More frequent flooding and improved fish passage along 22,000 to 48,000 acres in the Yolo Bypass with the intention to improve fisheries
- Creating approximately 10,000 acres of new floodplain along the San Joaquin River using setback levees
- Restoring tidal marsh habitat on up to 65,000 acres in agricultural land throughout the Delta
- Natural Communities Protection, including converting 8,000 acres of rangeland to natural grasslands, restricting 32,000 acres of agriculture to "wildlife friendly" practices, and converting 700 acres of rangeland to vernal pools and alkali wetlands
- Restoring approximately 20 miles of channel margin along North Delta waterways through setback levees and shallow water habitat

The number of potential influences on future recreation from this scenario may include any of the following.

- Creating the larger acreage (50,000± acres) of tidal marsh at the south end of the Delta could have devastating effects on salinity in the South Delta, as well as create strong currents in the channels leading to this area. Both would have significant impacts on boating and fishing. In addition, likely changes to agriculture lands could reduce hunting opportunities.
- Specifics regarding channel margin improvements are not described. Most of these impacts can be avoided or mitigated through appropriate design. Potential conflicts could arise from reducing or eliminating windsurfer access, creating use restrictions on other forms of boating, eliminating State and county park facilities with access to the river, and restricting shore fishing.
- The conversion of agricultural lands to habitat could decrease hunting opportunities if farmland conversions are of lands also used for hunting.

- Details regarding the San Joaquin River floodway are not described. If adequate in width, it could accommodate natural vegetation, trails, and recreation opportunities similar to the American River Parkway. If limited in carrying capacity, it could be restrictive regarding these recreation elements as is the Yolo bypass between Davis and West Sacramento.
- Wildlife viewing/photography and paddle sports and other nature-associated recreation will likely be positively influenced, if restored habitat areas also include public access facilities.
- Yolo Bypass fisheries amendments may negatively impact existing hunting clubs in the area.
- Increased fishing will likely occur due to better fisheries.
- Boating overall could increase with increased habitat and water quality.
- Camping would increase to support increasing nature-related recreation, if new sites and successful synergies can be established.

5.1.4 Flood Control Scenario

The flood control scenario was described in Chapter 6, with two general possibilities:

1. Flooding six central Delta islands: Webb, Venice, Empire, Mandeville, Medford, and Quimby, and leaving them in open water
2. Increasing levee upgrades, including levee upgrades around the Legacy Communities

The number of potential influences on future recreation from the flooded-island scenario may include the considerations listed below.

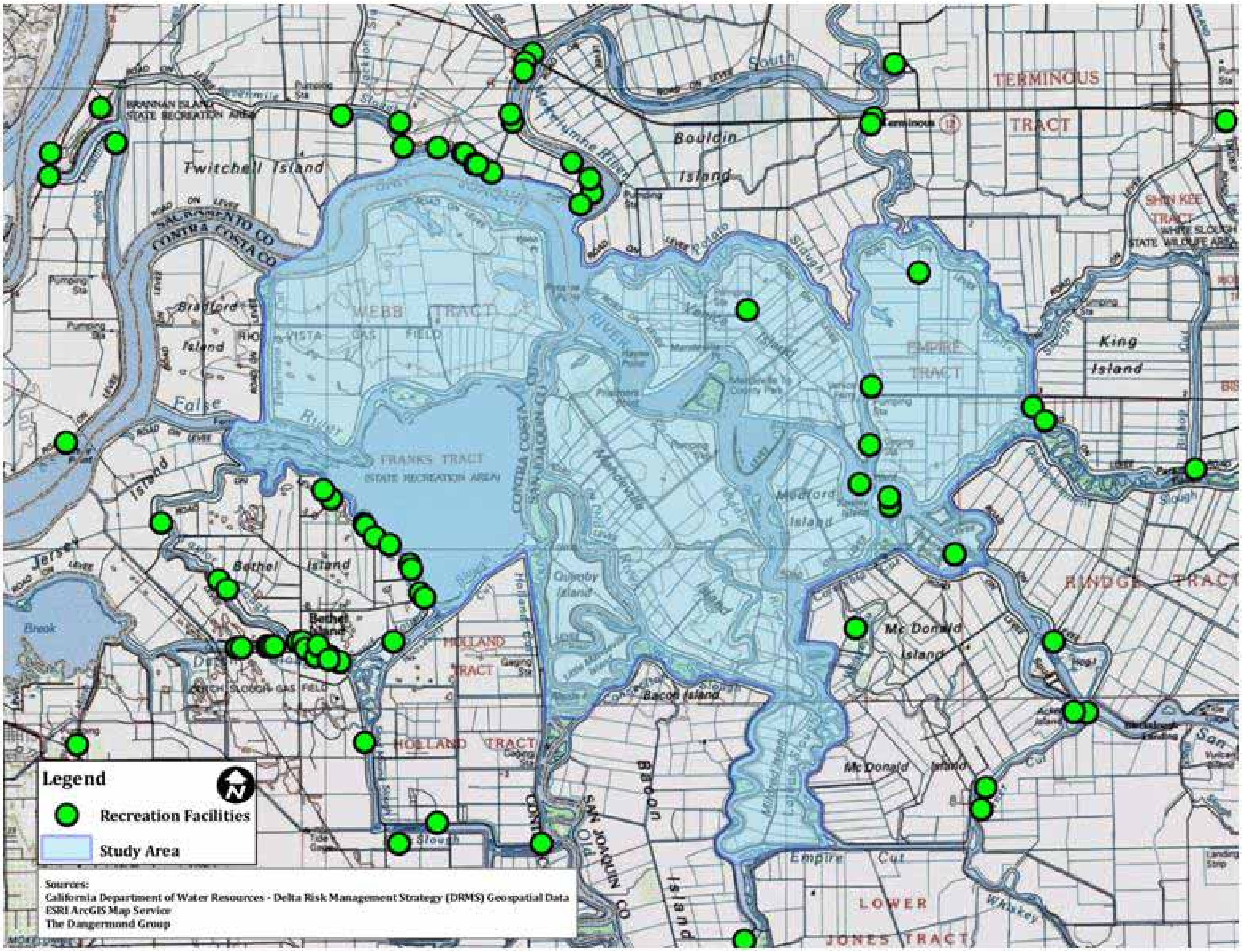
- The winding, protected, freshwater channels and waterways are the primary appeal of the Delta to boaters. Substituting a large open body of water at this proposed location will severely affect the existing boating use, and have very little offsetting use. The existing uses in this area are fishing, water skiing, personal watercraft use, speed boating, house-boating, cruising, and, to a limited degree, windsurfing.
- While a large open body of water would have severe negative effects on all these users, the open water area could arguably be more conducive to sailing. There are a number of factors, however, that will minimize sailing as a potential substitute use.
  - The flooded islands, if similar to existing flooded islands, will have water hazards, snags, and partially-submerged debris, making them dangerous to less knowledgeable boaters.
  - Most Delta boaters are from the Bay area, where sailing is far superior and closer with many adequate local marinas which, at present, are not fully occupied.
  - Those boaters in the Sacramento metropolitan area who enjoy sailing are primarily berthed at Folsom Lake, which has more favorable winds and higher water quality than found in the six-island area.
  - Sail boat densities on the water are lower than motor boat densities.
- Approximately 40 percent of all the marinas in the Delta are clustered around or near this potential area and another 5 percent are along the San Joaquin River from Pittsburg to Antioch. These marinas are also, on average, larger than those in other parts of the Delta. The resulting negative impact to the largest single recreation activity in the Delta could be very severe. See Figure 35 which overlays existing marinas and recreation facilities over the six-island flood scenario.
- This open water will have unknown changes to fisheries, which will affect anglers.
- The elimination of hunt clubs on those islands will reduce hunting.

The increased levee upgrade scenario may have a number of potential influences on future recreation, including the following impacts.

- Better protection of marinas, allowing investment in facilities

- Increased protection of Legacy Communities, resulting in more right-of-way/tourism activity
- Unknown changes to fisheries

Figure 35 Existing Recreation Facilities in the Vicinity of Six-Island Flood Scenario[203]



5.1.5 Regulatory Changes Scenario

Proposed regulatory changes are not known at this time. The following potentials could have a negative effect on recreation.

Increased Regulation

- Regulations against water, sewer, and building developments would make it difficult for both existing and new enterprises to locate within the Delta or to respond to changing market demands. These restrictions could adversely affect park expansions, marinas and related resorts, Legacy Communities, wineries, and direct sale of agriculture products, most likely creating further stagnation in recreation and tourism visitation.
- Blanket prohibitions against further development within the Secondary Zone could have an unfavorable influence on the park and recreation values around the edges of the Delta.

[203] For high resolution image see http://forecast.pacific.edu/desp-figs.html

- Continuing and/or increasing restrictions and regulations on dredging and vegetation controls in and around marinas could have severe negative influences on such recreation providers.

Decreased Regulation

- The reduction or removal of land use, historic preservation and agriculture protection regulations could affect the scenic values of the Delta and subsequent tourism use.

5.1.6 Policy Scenarios Influences Summary

Table 41 presents a summary of predicted potential influences to recreation and tourism by the policy scenarios described above, with range estimates of potential impacts to visitation in 2050, as compared to the baseline scenario presented in Section 4. These predictions reflect a combination of data and professional judgment of the researchers, and are intended to provide a general sense of the expected scale of the impact relative to current levels. Note that these impacts are presented in relationship to population growth, so a “Flat” trend would keep pace with population growth, while “Increase” would grow faster than population. “Decrease” would grow slower than population and may or may not represent an actual decrease in raw numbers of visitor days.

Table 41 Predicted Trends in Major Recreation Categories under Policy Scenarios Conditions

	Policy Scenarios				
Activity Type	**Isolated Conveyance**	**Habitat Conservation**	**Flood Control – Six Islands**	**Flood Control – Increased Levees**	**Regulatory Changes**
Resource Related					
Boating	Decrease	Increase	Decrease	Flat	Decrease
Fishing	Flat	Increase	Decrease	Flat	Decrease
Hunting	Decrease	Flat/Decrease	Decrease	Flat	Flat
Wildlife Viewing/Outdoor Photography	Flat	Increase	Flat	Flat	Flat
Camping	Decrease	Increase	Decrease	Flat	Flat
Right-of-Way/Tourism Related	Decrease	Flat	Flat	Increase	Decrease
Urban Parks Related	Flat	Flat	Flat	Flat	Decrease
Overall	Decrease	Increase	Decrease	Flat	Decrease

- The isolated conveyance scenario could lower recreation spending in the Delta.
- The habitat conservation scenario could increase recreation spending in the Delta.
- The six-island open water scenario could lower recreation spending in the Delta.
- The increased levee scenario could increase recreation spending in the Delta.
- The increased land use restrictions scenario could lower recreation spending in the Delta.

The probable future condition of the Delta will not, however, occur as a result of a single policy scenario, but of necessity, will be a combination solution. Among these various scenarios, there is an opportunity to avoid the largest potential negative impacts and to emphasize positive solutions.

5.2 Impact Analysis

This report has analyzed existing recreation uses and projected a baseline forward to 2050. It also has analyzed the negative and positive influences to the baseline from various elements of proposed scenarios. Analysis has also been made of actions that could be taken to increase recreation visitation over the baseline, or to mitigate for some unavoidable impacts. The Recreation Enhancement Plan outlined in this report describes such actions. The following summarizes the largest potentially negative future impacts and the possible positive influences to economic sustainability for recreation in the Delta.

5.2.1 Negative Impacts

Of all the potential negative impacts, our analysis indicates that the following five items are the most significant. They are listed in order of magnitude. These major items are most likely significant enough that major changes to the project would be required, rather than simple mitigation measures.

1. *Regulation Changes.* If increased and burdensome land use regulations prohibited most or all permits for remodeling or constructing commercial and recreation facilities, they would have the largest negative impact on recreation use in the Delta. At best, it would bring growth in recreation to a standstill in all but hunting and wildlife viewing/outdoor photography. It is quite likely that an actual decline in recreation levels would occur as facilities continue to age and become out of date.
2. *Six-Island Flooding.* As previously described, the purposeful flooding of the six islands, basically north and east of the existing open water area of Frank's Tract, could result in a major reduction of boating in the Delta. Over 50 percent of the Delta's marinas are located within or in close proximity to this area, and would suffer both direct and indirect negative impacts. Boating, fishing, hunting, camping, and tourism-related activities are all anticipated to be negatively affected.
3. *Salinity Increases in the Central and South Delta.* This possibility is based upon the concern that an isolated conveyance which removes all export water at the north end of the Delta will create increased water stagnation and salinity in the central and south Delta. If that occurs, it would affect boating, fishing, and camping.
4. *Large Tidal Marsh in South Delta.* A large-scale tidal marsh area in the south Delta would likely increase salinity and strong currents in the waterways leading to the south Delta. It would affect boating and fishing, and may impact hunting due to the loss of agriculture properties jointly used for hunting.
5. *Intake and Pumping Stations—Clarksburg to Courtland.* These pumping stations, if placed along the river at this location, could seriously impact the Delta-as-a-Place recreation and tourism. This is one of the primary entry and destination areas in the Delta; the industrial scale, noise, and night lighting could transform its character.

In addition, there are other lesser impacts as previously described. These can most likely be mitigated through careful planning.

5.2.2 Positive Influences

There could be positive influences to recreation within future scenario predictions. Specifically, three elements of certain scenarios would likely have the most positive influence on recreation use.

1. *Fishing Enhancements.* The various fishery enhancements proposed in the habitat conversion and isolated conveyance scenarios are expected to help restore fisheries, and thereby elevate fishing use.
2. *Wildlife Viewing/Nature Study.* The proposed expansion of natural preserves and wildlife-friendly agriculture would increase the opportunities for wildlife viewing and nature study.
3. *Delta-As-A-Place Enhancement.* The increase in wildlife viewing opportunities will likely have a synergistic effect on the Delta-as-a-Place visitation.

6 Implementation Strategies

There are a number of key strategies that should be utilized in order to assist in the implementation of the recreation portion of the ESP. Some of these strategies and actions are described below. Many could be funded through the Delta Investment Fund or Delta Conservancy Fund.

6.1 Consistency and Regulation Refinement

Consistency refinements between the Delta Plan, the ESP, State Parks recreation proposal, and local city and county plans may be necessary after the adoption of the Delta Plan. In addition, specific plans may be required for recreational areas along with regulation refinements to facilitate implementation of their development. Priority for specific plan development should be given to two focal point areas, Walnut Grove/Locke and Rio Vista/Isleton/Brannon Island, because of their Delta-wide catalyst and branding potentials.

6.2 Public/Private Coordination and Partnerships

Nearly all recreation opportunities in the Delta are provided by private enterprise and are dependent on basic public investments in roadways, levees, and other infrastructure improvements. Public investment in synergistic recreation improvements can expand services to the public while creating settings for additional or expanded private facilities. Such coordinated action will be important in facilitating actions within Legacy Communities and edge communities, as well as with dispersed recreation points throughout the Delta.

6.3 Multi-Agency Coordination

Developing and expanding the major recreation complexes recommended in the ESP require cooperation and coordination between two or more agencies, which can forge unique relationships with those communities bordering the Delta. For example, coordination of Delta protection limits and urban limit lines can facilitate the creation of Delta buffering park/open space/trail areas. State and local park agencies can form joint powers authority to aid in implementation of development in other areas. A JPA may allow appropriate coordination and a more expedited implementation schedule.

6.4 Strategic Levee Protection

Obtaining adequate flood protection is of the utmost importance in order to foster additional meaningful economic activity in the Delta. New and improved levees are necessary to encourage new investment and reinvestment in the Legacy Communities and recommended recreation areas. Strategic levee enhancements and/or the construction of ring levees in order to protect key assets should be carried out using any existing or new funding sources.

6.5 Delta-wide Marketing

Among the opportunities and constraints discussed previously is the lack of a Delta brand or overall marketing strategy. The average potential visitor has to overcome a number of barriers in order to recreate in the Delta: it is hard to see “the Delta,” there’s no main entrance or focal point for information and activities, and facilities are sparse, spread out, and hard to access. The California Trade and Tourism Commission (CTTC) places the Delta in the Central Valley (as one of 12 travel regions CTTC promotes throughout the state) rather than promoting the Delta as its own unique travel region.[204]

As early as 30 years ago, 41 economically feasible recreation improvements, studied by the Department of Water Resources, were not developed because of the lack of an entity that could be responsible for their care. As a part of this report, major recreation improvements have been identified that could stimulate visitation and economic benefits. A responsive, Delta-focused public recreation, planning, development, and management facilitator organization is vital to accomplishment of such a program. To be effective, this organization needs an assured funding source that can be relied upon for both development and operation. The organization also needs to have the authority to assist in marketing the Delta, to facilitate actions by private enterprise, and to assist with, or manage, the operation of state and local recreation facilities. This organization is discussed further in Chapter 11.

6.6 Financing Strategies

There are several steps outlined above that need to occur before development of any new major recreation areas described in this Plan can occur. Each step, including ensuring consistency among plans, developing specific area plans and streamlining regulations to accomplish them, levee enhancements, as well as organization, administration, development and operation, all will require funding and will take time. Concurrent with this planning, however, there are several recommended strategies that could be initiated as soon as funding could be made available, and which would all affect positive economic changes within the Delta. Several suggestions follow which could affect many different areas and services.

Agritourism/Legacy Communities
A "Delta farm trails" should be established to market the farmer's market, direct sale, wineries, and related Legacy Community businesses. A grant could be provided to an existing Delta-wide nonprofit to develop brochures, marketing, and a signage program, and to help willing farms with necessary improvements. These farm trails could be joined and co-marketed with existing wildlife viewing programs and opportunities.

Department of Boating and Waterways
Additional funding could be provided to the Department of Boating and Waterways existing programs to remove abandoned vessels, combat invasive species (including water hyacinth, *Egeria densa,* and South American Spongeplant (*Limnobium laevigatum*) (with accompanying authorization to treat), and develop more waterway access for fishing and boating, including non-motorized boating access and community convenience docks. Funding also could be provided to DBW to create designated boating and canoe/kayak water trails, including planning, and developing access points, as well as additional grant and low-interest loan funds to allow private enterprise upgrades and development.

Department of Parks and Recreation
Immediate funding could be provided for State Parks to complete planning and development of Delta Meadows State Park, with connections to Locke and other heritage and natural resources in the area. Additionally, planned[205] upgrades to Brannon Island could be completed, with funding to allow the park to remain open. Additional funding could be provided for further

[204] The twelve regions are North Coast, Shasta Cascade, Gold Country, San Francisco Bay Area, Central Valley, High Sierra, Central Coast, Los Angeles, Orange County, San Diego, Inland Empire, and Deserts. http://www.visitcalifornia.com/Explore/
[205] State Parks 2011, p. 22-23

implementation of recommendations in the *Recreation Proposal for the Sacramento-San Joaquin Delta and Suisun Marsh.*[206]

Delta Protection Commission
Funding could be provided to DPC to match federal funds for initial implementation of the NHA, if it is recommended and approved. Funding could also be provided for planning and implementation of beginning segments of the Great Delta Trail, especially those segments on existing public lands.

Delta Conservancy
Funding to the Delta Conservancy Fund would allow the Conservancy to offer grant funding to local agencies, nonprofit organizations, and private entrepreneurs which provide recreation and tourism services in the Delta. These funds could be used to improve visitor centers and services at natural habitat areas, make Gateway entry improvements, and expand visitor service offerings.

Local Governments
Funding could be provided to local governments to enable them to participate fully in ongoing planning processes. In addition, designated funds could allow counties and cities to dedicate staff to entitlement processing or creating one-stop permitting centers for the Delta. It could also allow local governments to participate in a Delta-wide economic development process or a JPA.

6.7 Key Findings

- Possible policy scenarios are qualitatively evaluated as to their primary elements and their potential positive and negative impacts on recreation.
    - Scenarios evaluated may affect recreation visitation by either decreasing visitation or increasing visitation over the baseline scenario, with the expected largest potential for negative impacts from increased regulatory changes or the six-island flooding and the largest potential for positive impacts from the habitat conservation scenario.
    - Visitation changes would also affect recreation-related spending in the Delta, as compared with the baseline forecast. It is anticipated that the magnitude of these potential changes is smaller in magnitude than the potential economic impacts to the agricultural economy.
    - The largest anticipated potential negative impacts would results from regulation changes, six-island flooding, salinity increases in the central and south Delta, creation of a large tidal marsh in the south Delta, and intake and pumping stations near Clarksburg and Courtland.
    - Positive impacts could result overall through project enhancements to fishing, wildlife viewing, and nature study, and Delta-as-a-Place.
- A significant operational constraint for future growth in recreation demand is that there currently exists no Delta brand, overall marketing strategy, or significant-scale focal point area. An existing organization should be designated as a Delta recreation and tourism marketing and economic development facilitator.

Recommended Implementation Strategies include consistent planning and regulation refinement, public/private coordination and partnerships, multi-agency coordination, strategic levee protection, Delta-wide marketing, and financing.

[206] Ibid, p. 22-24

Chapter 9: Infrastructure

1 Overview and Key Findings

The Delta is located in the geographic center of the Northern California megaregion and serves as an infrastructure hub for the megaregion as well as the local, regional and state economies. While the Delta's importance to the state water system is well-known, its importance to energy, transportation, and in-Delta municipal and industrial water supplies is less appreciated. This chapter focuses on infrastructure that directly serves communities within the Legal Delta and the adjacent region, but it also includes analysis of infrastructure that serves the megaregion and other regions.

An idea of the variety and extent of infrastructure in the Delta is provided by Figure 36.[207] This chapter reviews and analyzes the range of infrastructure within the framework detailed in Chapter Six across three critical categories: (1) transportation; (2) energy; and (3) water resources.

The key findings are:

- Levee investments must fully consider the value of infrastructure. Ignoring or incompletely assessing the value and cost of infrastructure could lead to dangerous underinvestment in levees and create risks for energy, transportation, and water supply infrastructure of critical local, regional, and state-wide significance.
- All owners and operators of infrastructure that depend on Delta levees do not currently contribute to levee system investment and maintenance. Some infrastructure owners contribute but others do not.
- Extraction of water from the Delta is critical to the economy. Declining water quality as result of increased salts or organic carbon would significantly increase costs for households, business, and industry in and around the Delta.
- Infrastructure demands within and around the Delta will require significant future investment. It will be necessary to ensure development of the infrastructure in the Delta is aligned with economic sustainability strategies.
- Development of the Delta's transportation infrastructure in general, but especially its ports and marine facilities, will support greater interregional integration, competitiveness, and economic development.
- Delta water quality is potentially threatened by isolated conveyance, some of the conservation measures, and the six-island open-water scenario. However, other proposals such as the Lower San Joaquin River Bypass support multiple goals. The bypass would reduce peak water surface elevations in the San Joaquin River adjacent to Lathrop and Stockton and provide ecosystem benefits from activating floodplains that increase organic carbon for a short duration and during high flows, which would minimize impacts on water quality.

[207] Based on DRMS GIS data set developed by URS Corporation and provided by DWR.

Figure 36 Select Delta Infrastructure[208]

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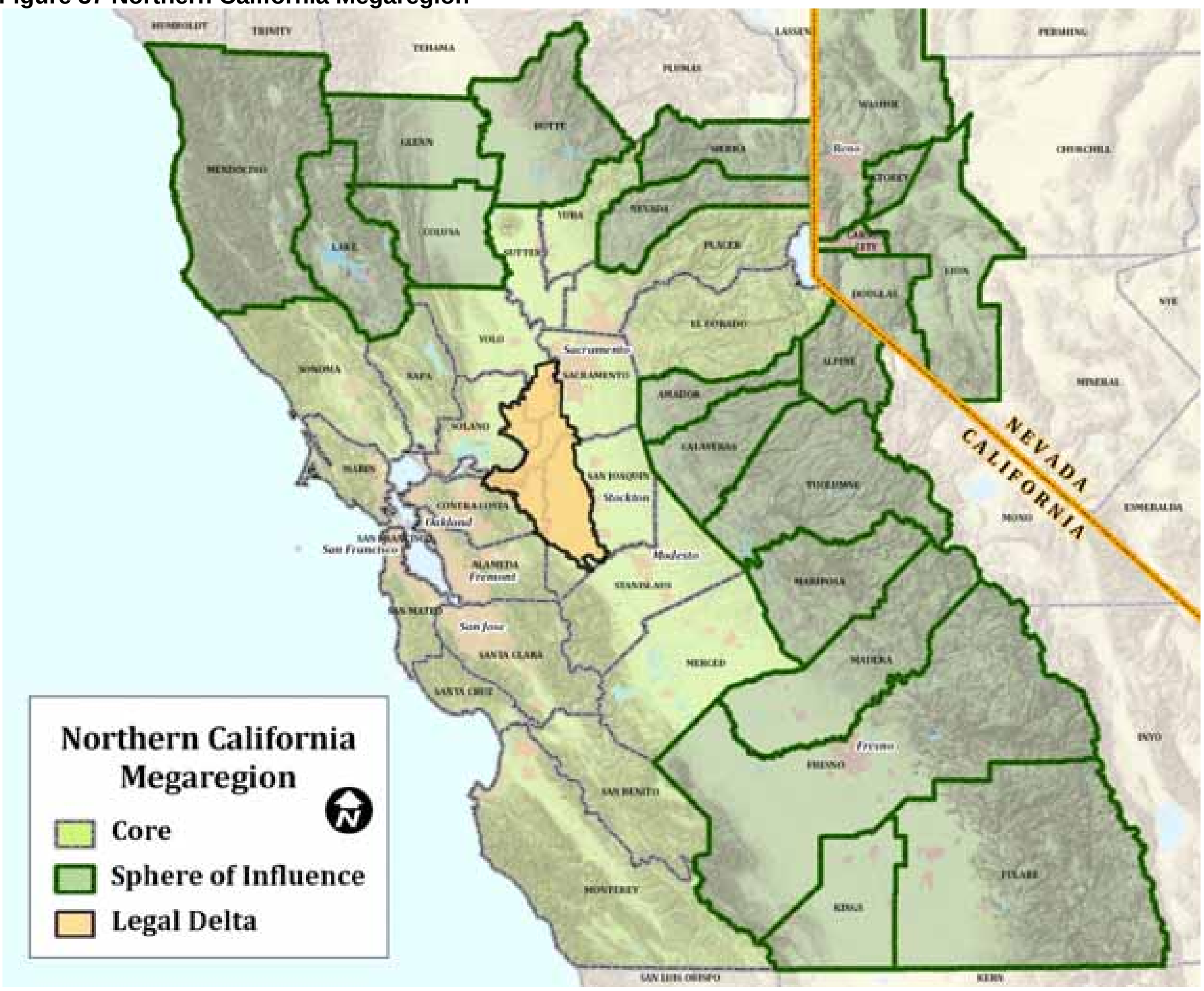
208 For high resolution image see http://forecast.pacific.edu/desp-figs.html

2 An Infrastructure Hub for the Northern California Megaregion

The Delta is in the center of the Northern California megaregion; the region is depicted in Figure 37.[209] This is one of 11 emerging megaregions in the U.S. identified as drivers of national growth in the 21st century.[210] In 2010, the Northern California megaregion's population totaled 14.6 million people. While 80 percent of that population was located within the megaregion's 21-county "core," that core accounted for less than 39 percent of the megaregion's total area.[211] In 2010, the megaregion's gross regional product exceeded $780 billion.[212]

Figure 37 Northern California Megaregion[213]



[209] The 41-county Northern California megaregion referred to herein is defined by the analysis of G. Metcalf and E. Terplan, "The Northern California Megaregion," SPUR Urbanist, November 1, 2007.

[210] For further details and references on U.S. megaregions see the America 2050 website: www.America2050.org

[211] Population and land area based on U.S. Census Bureau*, Census 2010 Summary File 1*. 2010 Census. Accessed August 12, 2011 at factfinder2.census.gov

[212] Based on Bureau of Economic Analysis*, BEA regional economic accounts*. Accessed August 12, 2011 at www.bea.gov/regional/

[213] For high resolution image see http://forecast.pacific.edu/desp-figs.html. The geography of the Northern California megaregion is based on G. Metcalf and E. Terplan, "The Northern California Megaregion," SPUR Urbanist, November 2, 1007. Accessed at www.spur.org/publications/library/article/mappingthenortherncaliforniamegaregion11012007

The Northern California megaregion has followed a common development path, characterized by initial nodes being followed by suburbanization and infilling between nodes. This pattern has generated considerable urban development around the Delta and within the Secondary Zone of the Delta itself. However, as detailed in Chapter 4 and 10, a range of planning and land use restrictions have limited urban encroachment in the Primary Zone. Therefore, the Delta's comparatively rural nature and its centrality to the megaregion have combined to reinforce the Delta's historic role as a regional infrastructure hub.

Megaregions like the Northern California megaregion are envisioned to become more cohesive in coming decades as technology and globalization enhances integration of core metropolitan areas and their broader sphere of influence. However, if these agglomeration advantages are to be realized it is critical that the megaregion's infrastructure facilitates integration of the range of economic function contained within its "megazone."[214] The Delta's infrastructure services are thereby poised to play an important role in development of the Northern California megaregion's advantages in the global economy in the coming decades.[215]

3 Transportation

Since the discovery of gold in 1848, the Delta has served as a key transportation hub linking the coastal cities of the San Francisco Bay area with the inland cities of the Central Valley and beyond. Contemporary Delta transportation has evolved to provide a critical array of intra- and interregional infrastructure linking the area's population and its diverse concentration of agriculture, manufacturing, distribution, warehousing, and retailers.[216] Through its transportation corridors the Delta also facilitates public safety, a healthy business climate, and recreational opportunities. As such, the Delta's transportation infrastructure provides important capacity for long-term sustainable growth in the Delta and beyond by facilitating the efficient movement of people and goods. However, access provided by the Delta's transportation infrastructure requires systemic maintenance and investment if it is to enhance and sustain its relevance in a global environment of increasingly efficient, multi-modal, and integrated transportation.

3.1 Road Transportation

There are three state highways in the Delta's Primary Zone (SR 4, SR 12, and SR 160). These highways are principal road transit routes through that region. In addition, the Delta's Secondary Zone hosts three Interstate freeways (I-5, I-80, and I-205) and is bordered by two others (I-580 and I-680). The 2007 Status and Trends of Delta-Suisun Services report identified evidence of Delta traffic growth disproportionate to population growth.[217] That trend continues to be evident in recent years. Table 42 reports an index of daily total vehicle trips (DTVT) on these transportation corridors between 1992 and 2009 as well as actual 2009 DTVTs. Accordingly, excluding some sections of SR 160, traffic volumes on highways and freeways increased between 23 percent and 65 percent during this period. In comparison, population in the five-

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[214] P. Todorovich (ed.), *America 2050: An Infrastructure Vision for 21st Century America*. New York: America 2050, 2008. http://www.america2050.org/pdf/2050_Report_Infrastructure_2008.pdf

[215] S. Sassen, "Megaregions: Benefits beyond Sharing Trains and Parking Lots?" *The Economic Geography of Megaregions,* The Policy Research Institute for the Region, Woodrow Wilson School of Public and International Affairs, Princeton University, February 9, 2007. http://wws.princeton.edu/research/prior-publications/conference-books/megaregions.pdf

[216] DPC, *Final Draft Delta Protection Commission Economic Sustainability Plan Framework Study Volume II,* Delta Protection Commission. December 6, 2010.

[217] DWR, *Status and Trends of Delta-Suisun Services,* Public Review Draft, Department of Water Resources, March 2007.

county region increased by 20 percent, ranging between 12 percent (Solano County) and 26 percent (Yolo County and San Joaquin County) during the same period.[218]

Table 42 Daily Total Vehicle Trips (DTVT) on Key Transportation Routes 1992-2009

Route	Intersection	1992	1995	2000	2005	2006	2007	2008	2009	2009 DTVTs
CA-12	CA-84 (Rio Vista)	100	93	111	147	150	150	134	129	***39,000***
CA-12	I-5 (Lodi)	100	99	97	151	153	153	134	134	***31,000***
CA-160	CA-220 (Walnut Grove)	100	64	73	80	81	81	70	70	***4,700***
CA-160	Wilbur Ave (Antioch)	100	94	113	125	140	136	124	123	***25,000***
CA-160	Isleton Bridge (Isleton)	100	71	73	80	81	81	73	73	***6,150***
CA-4	Byron Highw ay (Byron)	100	108	125	131	123	125	112	117	***38,600***
CA-4	Roberts Road (Stockton)	100	115	N/A	N/A	165	153	139	135	***19,400***
CA-4	Port Chicago Freew ay (Concord)	100	105	140	184	177	179	171	165	***277,000***
I-205	Old Route 50 (Tracy)	100	115	139	169	170	170	180	160	***195,000***
I-5	I Street (Sacramento)	100	116	133	161	166	167	155	159	***364,000***
I-5	CA-12 (Lodi)	100	103	113	166	169	169	156	156	***130,000***
I-5	French Camp Overcross (French Camp)	100	105	108	174	176	176	159	159	***196,000***
I-80	I-5 (Sacramento)	100	82	114	124	127	134	128	126	***231,000***
I-80	CA 113 (Davis)	100	107	123	137	135	130	126	135	***246,000***

Source: Caltrans traffic volume data. Traffic Data Branch. Accessed June 30, 2011: http://www.dot.ca.gov/hq/traffops/saferesr/trafdata/index.htm

Box 2 California State Route 12 Corridor: Challenges and Opportunities

Many of the challenges and opportunities of road transportation in the Delta occur along the California State Route 12 corridor, which bisects the Delta from the east at Interstate-5 near Lodi to the west at Rio Vista. The corridor provides important interregional linkages between the Bay Area and the San Joaquin Valley. It is also an important emergency access route into the Delta for first responders. In addition, the corridor is a principal access route for Delta recreators. As such, the corridor has an important role in both inter- and intra-regional growth. However, growing inward Bay Area commuting, expanding freight and goods transportation across the Delta, future development of Rio Vista, and enhanced use of Travis Air Force Base as a passenger/freight airport all pose significant challenges and opportunities for the corridor in general and the Delta in particular. These potential increases in demand on the corridor create opportunities to enhance access for existing in-Delta users, expand multi-modal access within and across the Delta, as well as increase the corridor's general safety and facilitate marketing of the Delta as a place. Nonetheless, the increased demand may also generate congestion, enhance negative environmental effects, degrade safety along the corridor, and inhibit access to other parts of the Delta. The presence of several drawbridges along the route adds further complexity to the associated challenges as increased recreational usage and shipping to the Port of West Sacramento may compound congestion along this important road transportation corridor. However, as discussed later in this chapter, development of the M-580 Marine Highway Corridor may relieve some congestion by decreasing the number of drayage trucks.

(Source: The information above is a compilation of issues drawn from the Moving Forward State Route 12 Corridor Study. For further information see: www.movingsr12forward.com)

The decline in vehicle traffic along SR 160 is notable. SR 160 has Scenic Roadway designation and as such it is an important driving-for-pleasure resource within the Delta. When examined, the largest decline in vehicle traffic occurred between 1992 and 1995, with some recovery followed by a period of flat to slightly declining traffic volumes along SR 160 in the northern Delta between 1995 and 2009, and with some growth in the southern portion of the route.[219]

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[218] Population calculations based on Census Bureau midyear population estimates. Accessed from: http://www.census.gov/popest/counties/counties.html

[219] See Chapter 8, Recreation and Tourism for a discussion of trends in driving for pleasure in the Delta.

The trends in truck traffic are more diverse as indicated in Table 43. Truck traffic has decreased markedly in some areas, such as the 45 percent decline in truck traffic on I-80 near Davis. However, truck traffic has increased in other areas, particularly along the I-5 corridor: traffic increased by 112 percent near Lodi, 66 percent near Sacramento, and 59 percent near French Camp.

Table 43 Daily Total Truck Trips (DTTT) on Key Transportation Routes 1992-2009

Route	Intersection	1992	1995	2000	2005	2006	2007	2008	2009	2009 DTVTs
CA-12	CA-84 (Rio Vista)	100	90	87	136	137	137	120	120	3,871
CA-12	I-5 (Lodi)	100	78	76	90	92	92	83	83	4,519
CA-4	Byron Highw ay (Byron)	100	80	124	130	123	124	111	116	5,775
CA-4	Roberts Road (Stockton)	100	103	137	76	164	152	138	134	2,471
CA-4	Port Chicago Freew ay (Concord)	100	97	109	139	134	135	129	124	14,779
I-205	Old Route 50 (Tracy)	100	114	138	103	104	104	110	94	12,240
I-5	I Street (Sacramento)	100	120	136	166	171	173	162	166	17,856
I-5	CA-12 (Lodi)	100	142	144	231	233	233	212	212	23,459
I-5	French Camp Overcross (French Camp)	100	124	138	151	153	174	159	159	49,480
I-80	I-5 (Sac)	100	111	156	131	134	140	135	132	16,428
I-80	CA 113 (Davis)	100	59	69	55	53	54	52	55	8,107

Source: Caltrans traffic volume data. Traffic Data Branch. Accessed June 30, 2011: http://www.dot.ca.gov/hq/traffops/saferesr/trafdata/index.htm

The Delta's central location in the Northern California megaregion and the significant highway and freeway infrastructure through and around it make it an important road transportation hub. Proximity to the large urban populations in the Bay Area, with comparatively less expensive property, further facilitates road freight, logistics, and other supply-chain facilities in parts of the Delta's Secondary Zone as well as adjoining areas. This road freight transportation nexus is additionally supported by I-5 & CA-99 which provide north-south access from Mexico to Canada as well as I-80 which provides road freight transportation linkages to the eastern U.S. Given the trends in road-based freight transportation and continued population growth in the megaregion characterized by increased integration, the baseline trend for the Delta's road transportation infrastructure is further growth in demand. [220]

Table 44 Legal Delta Road Infrastructure in 100-year floodplain[221]

	Quantity	Asset Value (millions)
Highway Bridges (count)	182	353.4
Highway Roads (miles)	182	316.9
Non-Highway Bridges (count)	41	21.5
Minor Roads (miles)	1,453	1,534.5
Major Roads (miles)	157	274.1

Utilizing the Department of Water Resources (DWR) Delta Risk Management Strategy (DRMS) Phase 1 study of infrastructure in the Delta,[222] we are able to identify both road infrastructure in the Delta's current 100 year floodplain and that study's estimate of this road infrastructure's

[220] It is important to note that this analysis has not examined the likelihood of further provision of road infrastructure in the Delta.
[221] These figures were derived from Table 7-2a in DWR, *Technical Memorandum: Delta Risk Management Strategy (DRMS) Phase 1 Topical Area: Impact to Infrastructure,* June 15, 2007. See Appendix J for further details.
[222] Table 7-2a from DWR, *Technical Memorandum: Delta Risk Management Strategy (DRMS) Phase 1 Topical Area: Impact to Infrastructure,* June 15, 2007.

asset value.[223] As seen in Table 44, the Delta has nearly 1,800 miles of road and over 220 bridges in its 100-year floodplain.[224] In total, the asset value of this road infrastructure is estimated to be in excess of $2.5 billion. Besides the infrastructure identified in Table 44, it is worth noting that there are also five operational ferries in the Delta's 100-year floodplain; two of the five ferries are operated by Caltrans and the other three ferries are privately operated.[225] This road infrastructure is dependent upon the Delta's flood protection system to prevent damage during flooding events. While the baseline assumes PL 84-99 standards for all levees in the Delta, at this standard there is still significant risk of damage from flooding and earthquake events.[226]

3.2 Rail Infrastructure

The Delta's short-line railroad was historically an important transportation resource for the region's agricultural industry.[227] Currently, two of the largest railroads in North America, Burlington Northern Santa Fe (BNSF) railway and the Union Pacific railroad (UPRR),[228] posses an extensive rail network that passes through and encircles the Delta as it links the Bay Area with the Central Valley and beyond. These lines are further complemented by short-line and rail rapid transit systems within and adjoining the Delta to form an extensive regional rail transport infrastructure with multimodal linkages.

The Delta's rail freight infrastructure is a critical component of the regional transportation system. Rail access to the Port of West Sacramento and the Port of Stockton facilitates the ports' role as regional bulk and general cargo provision. Freight rail is particularly competitive with long-distance freight, which facilitates outward and inward shipment of goods from across California, the nation, and internationally. Railroads are also four times more fuel efficient than trucks on average, which reduces emissions.[229] Therefore, the rail freight system affords reduced congestion on the road infrastructure by relieving the need for long-haul trucking and by providing a greater carrying capacity. These efficiencies in rail freight offer an important means to facilitate economic expansion in the megaregion without excessively burdening the local environment.

In addition to freight transportation, there is an established passenger rail network that passes through the Delta and provides important interregional connections. The Amtrak San Joaquin route provides rail services from Bakersfield to Sacramento and Oakland. The San Joaquin thereby provides passenger rail services through a large portion of the Central Valley and the

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[223] This 100-year floodplain is an imaginary boundary that defines the area around the Delta, an overview of this boundary is provided in Figure 13-1 in DWR, *Technical Memorandum: Delta Risk Management Strategy (DRMS) Phase 1 Topical Area: Impact to Infrastructure,* June 15, 2007. Throughout estimates are derived by the authors as they were not identified in the DWR report as such.

[224] Figure D2 in Appendix D is a map which shows islands in the Delta 100-year floodplain that protect highways.

[225] Caltrans, *SR-12 Comprehensive Corridor Evaluation and Corridor Management Plan from SR-29 to I-5, 2011.*

[226] The DRMS study has conducted a road closure cost estimate with daily costs ranging between $100,000 and $24,060,000 per day. Table 24 in DWR, *Technical Memorandum: Delta Risk Management Strategy (DRMS) Phase 1 Topical Area: Economic Consequences,* Department of Water Resources, May 2008.

[227] DPC, Utilities and Infrastructure, Background Report, 1994.

[228] Together BNSF and UPRR accounted for 47 percent of all freight railroad revenue in the United States in 2009. Note: Author's calculation based on AAR (2011) and AAR (2010).

[229] AAR (2011) "An Overview of America's Freight Railroads," *American Association of Railroads, Background Paper*. April 2011.

Bay Area. It also provides access to other Amtrak routes including the Capitol Corridor, which travels just outside the Legal Delta but also provides an important interregional rail link between the Central Valley and the Bay Area.

Table 45 presents an index of Amtrak ridership, measured in terms of passengers boarding and detraining, at select stations along the San Joaquin route. While the individual stations' ridership varied considerably, they all have seen a steady growth ranging between 23 percent and 67 percent increases from 2004 to 2010. Across the entirety of the San Joaquin route there were 960,165 passenger trips in 2010.[230]

Table 45 Index of Amtrak Passengers Boarding & Detraining (PBDs) by Station, 2004-2010 and 2010 Value

Station	2004	2005	2006	2007	2008	2009	2010	2010 PBTs
Sacramento	100	108	107	113	133	129	128	***1,090,122***
Lodi	100	91	104	95	126	122	123	***7,443***
Stockton	100	97	109	109	128	126	135	***234,678***
Modesto	100	98	104	109	129	127	134	***95,532***
Antioch	100	102	110	118	141	140	167	***34,417***

Source: National Association of Railroad Passengers, Amtrak factsheets. Accessed June 30, 2011: http://www.narprail.org/cms/images/uploads/fels/index.htm

Box 3 Intermodal Transportation of Freight

Intermodal freight is an important component of transportation in and around the Delta. Szyliowicz (2000) describes intermodal transport: "*Intermodal freight transport involves the transportation of freight in an intermodal container or vehicle, using multiple modes of transportation (rail, ship, and truck), without any handling of the freight itself when changing modes. The method reduces cargo handling, and so improves security, reduces damages and losses, and allows freight to be transported faster*." Central to intermodal transport is maximization of each mode's comparative advantage to simultaneously optimize existing resources while enhancing component productivity as well as the overall productivity of the entire transportation system. Intermodal freight transport has been the fastest growing segment of rail freight traffic over the past quarter century (AAR 2011: 2). As a result of its decreasing traffic congestion and transportation costs, intermodal freight in and around the Delta supports the inter- and intra-regional competitiveness of the Northern California megaregion. According to the AAR (2011) nearly 60 percent of intermodal rail consist of imports or exports, which also makes intermodal transport an important component of international trade. While there are no intermodal terminals in the Delta itself, there are six intermodal terminals operated by BNSF and UPRR in the five-county region. These facilities have and/or are developing ties with nearby logistics clusters, in-Delta and nearby -ports, and warehousing facilities. Furthermore, through rail linkages across the Central Valley and beyond, intermodal rail more generally facilitates California's foreign trade.

Sources: Szyliowicz, J.S. (2000) Intermodalism: The Challenge and the Promise. *NCIT Final Report*.
AAR (2011) "An Overview of America's Freight Railroads," *American Association of Railroads, Background Paper*. April 2011.

The Altamont Commuter Express (ACE Rail) is another important passenger rail network that passes through the Delta. ACE Rail is a commuter train operating between Stockton and San Jose. It thereby facilitates workers in the Silicon Valley accessing more affordable housing from the Central Valley. Table 46 presents an annual index of ridership across the entirety of the ACE Rail route between 2004 and 2010. While there were 676,444 passenger trips on ACE Rail in 2010, the economic recession appears to have significantly depressed ridership along the route beginning in 2009.

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[230] NAPRAIL, *Amtrak Fact Sheet: San Joaquins Service.* Accessed June 30, 2011: http://www.narprail.org/cms/images/uploads/fels/trains/39.pdf

Table 46 Index of ACE Rail Ridership 2004-2010 and Actual Passengers in 2010[231]

	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2010 Passengers**
Total Annual Ridership	100	96	105	117	134	106	105	***676,444***

Source: ACE Rail ridership information was provided by the San Joaquin Regional Rail Commission

These three passenger rail corridors each rank among the busiest in the United States.[232] Especially in the context of the projected growth that will occur in the megaregion over the next few decades, it is likely that this regional rail infrastructure, including those parts in the Delta, will experience significant growth in demand. [233]

Table 47 Legal Delta Rail Infrastructure in 100-year floodplain[234]

	Quantity	Asset Value (millions)
Rail Facilities (count)	9	23.2
Rail Bridges (count)	10	10.0
Railroads (miles)	74	111.7

Utilizing the DWR DRMS Phase 1 study of infrastructure in the Delta,[235] we are able to identify both rail infrastructure in the Delta's current 100-year floodplain and that study's estimate of this rail infrastructure's asset value. As seen in Table 47, the Delta has 74 miles of railroad and 10 bridges in its 100-year floodplain.[236] In total, the asset value of this rail infrastructure is estimated to be in excess of $145 million. It is important to note that the rail infrastructure reported in Table 47 includes some historic short-line railroads which are not currently operated. The rail infrastructure identified in the table is dependent upon the Delta's flood protection system to prevent damage during flooding events. While the baseline assumes PL 84-99 standards for all levees in the Delta at this standard there is still significant risk of damage from flooding and earthquake events.[237]

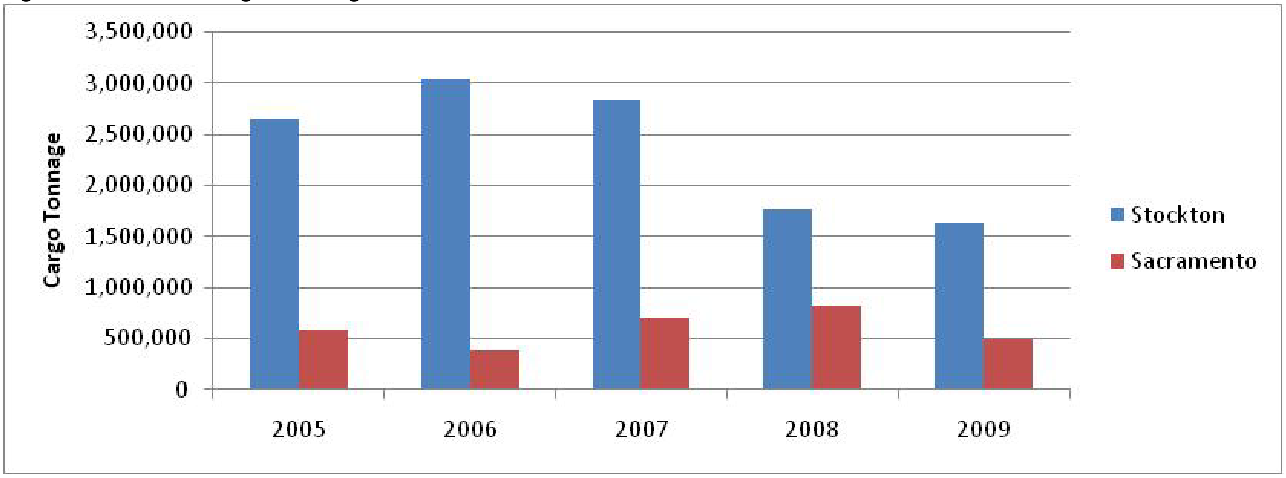
3.3 Ports and Maritime Infrastructure

The Delta hosts several ports, the most significant being the Port of Stockton and the Port of West Sacramento.[238] The Stockton Deep Water Ship Channel was constructed in 1927 and the

[231] ACE Rail ridership information was provided by the San Joaquin Regional Rail Commission and compiled by the ESP project team.
[232] Amtrak, "National Fact Sheet: FY2010," 2011. Accessed at: http://www.amtrak.com/
[233] It is important to note that this analysis has not examined the likelihood of further provision of rail infrastructure in the Delta or other areas.
[234] These figures were derived from Table 7-2a in DWR, *Technical Memorandum: Delta Risk Management Strategy (DRMS) Phase 1 Topical Area: Impact to Infrastructure,* June 15, 2007. See Appendix J for further details.
[235] Table 7-2a from DWR, *Technical Memorandum: Delta Risk Management Strategy (DRMS) Phase 1 Topical Area: Impact to Infrastructure,* June 15, 2007.
[236] Figure D3 in Appendix D is a map which shows islands in the Delta 100-year floodplain that protect the BNSF railway.
[237] The DRMS study has conducted a rail closure cost estimate with daily costs ranging between $202,625 and $804,000 per day. Tables 25 and 26 in DWR, *Technical Memorandum: Delta Risk Management Strategy (DRMS) Phase 1 Topical Area: Economic Consequences,* Department of Water Resources, May 2008.
[238] According to *World Port Source* the Delta hosts five ports with some cargo capacity. These are: Port of Pittsburg, Port of Stockton, Port of West Sacramento, Rio Vista Harbor, and San Joaquin Harbor. Accessed at: www.worldportsource.com

Sacramento Deep Water Ship Channel in 1963.[239] The Port of West Sacramento is located 79 nautical miles from the Golden Gate Bridge and consists of 150 acres of operating terminals that currently handle a variety of bulk, break-bulk (general cargo), and project cargos. The Port of Stockton is located 75 nautical miles from the Golden Gate Bridge; it operates a diversified transportation center that encompasses 2,000 acres of operating area.[240]

Figure 38 Annual Cargo Tonnage Ports of West Sacramento and Stockton 2005-2009



Source: U.S. Army Corps of Engineers Waterborne Commerce Statistics Center. Accessed June 30, 2011: http://www.ndc.iwr.usace.army.mil//wcsc/webpub09/webpubpart-4.htm

Facilitated by their rail linkages to the BNSF and UPRR networks, both the Port of Stockton and the Port of West Sacramento have become increasingly important shipping centers for bulk and

Box 4 Delta Shipping and the M-580 Marine Highway Corridor

In 2010, it was announced that the ports of Oakland, Stockton, and West Sacramento would be part of the national Marine Highway Program through a short sea shipping network called the M-580 Marine Highway Corridor. This marine highway will reduce truck transportation of containers on the Bay Area's congested road infrastructure through regularly schedule barge service. When the marine highway is fully operational, these two Delta ports will further deepen the regions' freight transportation infrastructure and significantly deepen multi-modal linkages. Similar to the advantages of rail transportation in comparison to truck transportation, but over smaller distances, the short sea shipping system will alleviate traffic congestion on the region's road infrastructure, and reduce costs as well as enhance air quality because of greater fuel efficiency. The Port of Oakland moves more than 99 percent of the containerized goods moving through Northern California. In 2010, there were 2.3 million containers moved through the Port of Oakland and by 2020 its volume is expected to increase by another 65 percent. Given this expansion and constraints around the port, development of the M-580 will offer significant opportunities for additional linkages beyond transportation and warehousing. In this regard, the Port of Stockton's West Complex development should realize important synergies as it seeks to build out industrial, commercial and maritime use of the former military facility that since 2000 has formed part of the port.

Sources: Port of Oakland website. Accessed at : http://www.portofoakland.com/maritime/facts_cargo.asp
Marad (2010) "Marine Highway Corridor Descriptions," Department of Transportation Maritime Administration. Accessed at: http://www.marad.dot.gov/documents/Marine_Highway_Corridors13_Sep_10.pdf
Port of Stockton, "Port of Stockton West Complex Development Plan," Final EIR, 2004.

[239] DWR, *Status and Trends of Delta-Suisun Services,* Public Review Draft, Department of Water Resources, March 2007.
[240] Port of Stockton website. Accessed at: http://www.portofstockton.com/

general cargos as the Port of Oakland has seen its container operations grow in dominance and other ports in the Bay Area reach capacity constraints. Figure 38 illustrates the growing cargo tonnage at both ports before the economic recession decreased tonnage.

As inland ports, both Stockton and West Sacramento are dependent on dredged deep water shipping channels. The levees and islands adjoining these channels provide important flows that prevent the channels from excessively silting-up. Nonetheless, both deep water shipping channels need to be dredged on a regular basis to maintain draft on the river of sufficient depth for vessels to navigate. In the case of the Stockton deep water shipping channel, there have been some challenges maintaining the channel depth at its specified depth of 35 feet at mean lower, low water (MLLW).[241] The Port of West Sacramento's deep water shipping channel is specified to a depth of 30 feet MLLW. Currently, both channels are seeking to further deepen their respective depths as demand for channel depths grows amongst the world's cargo ships.[242]

As with the other key components of transportation infrastructure in the Delta, the baseline trend for the Delta's ports and maritime infrastructure is for sustained expansion. This growth will be concentrated in the Ports of Stockton and West Sacramento, but given their existing rail linkages, and regional trends, opportunities exist for the port facilities in the West Delta as well. This expansion also appears likely to be tied to local, statewide and national expansion of foreign trade.

Table 48 Legal Delta Port and Maritime Infrastructure in 100-year floodplain[243]

	Quantity	Asset Value (millions)
Maritime Docks & Channel Markers (count)	40	102.9

Again, utilizing the DWR DRMS Phase 1 study of infrastructure in the Delta,[244] we are able to identify both the quantity of infrastructure in the Delta and that study's estimate of this infrastructure's asset value. As seen in Table 48, the Delta has some 40 maritime docks and channel markers.[245] In total, the asset value of this infrastructure is estimated to be in excess of $102 million.

3.4 Air Transportation Infrastructure

There are 11 general aviation airports located within the Legal Delta. These facilities are listed in Table 49. Besides those facilities, there are also small landing strips for property owners' use and small agricultural air strips used by commercial crop-dusting services.[246] Sacramento International Airport, Stockton Metropolitan Airport, and Travis Air Force Base are all located near the Legal Delta.

[241] Interview with the Port of Stockton, August 18, 2011.
[242] The Port of Stockton provided an illustrative estimate that an extra foot of draft in the deep water shipping channel would provide another $180,000 in revenue per vessel. Source: Email to author on August 22, 2011.
[243] These figures were derived from Table 7-2a in DWR, *Technical Memorandum: Delta Risk Management Strategy (DRMS) Phase 1 Topical Area: Impact to Infrastructure,* June 15, 2007. See Appendix J for further details.
[244] Table 7-2a from DWR, *Technical Memorandum: Delta Risk Management Strategy (DRMS) Phase 1 Topical Area: Impact to Infrastructure,* June 15, 2007.
[245] Figure D5 in Appendix D is a map which shows islands in the Delta 100-year floodplain that border the deep water shipping channels.
[246] DPC, *Utilities and Infrastructure,* Background Report, 1994.

Table 49 Aviation Facilities in the Legal Delta

Name	County	City	Category
Byron Airport	Contra Costa	Byron	General Aviation
Las Serpientas Airport	Contra Costa	Brentwood	General Aviation
Funny Farm Airport	Contra Costa	Brentwood	General Aviation
Spezia Airport	Sacramento	Isleton	General Aviation
Tracy Municipal Airport	San Joaquin	Tracy	General Aviation
Kingdon Airport	San Joaquin	Lodi	General Aviation
Lost Isle Seaplane Base	San Joaquin	Stockton	General Aviation
New Jerusalem Airport	San Joaquin	Tracy	General Aviation
33 Strip Airport	San Joaquin	Tracy	General Aviation
Rio Vista Municipal Airport	Solano	Rio Vista	General Aviation
Borges-Clarksburg Airport	Yolo	Clarksburg	General Aviation

Source: http://www.airport-data.com - Accessed June 30, 2011.

While there are no major airports in the Delta itself, the growing megaregion's population will likely create increased demand for the aviation facilities around the Delta and could expand demand for aviation facilities in the Delta. However, given the linkages that Delta aviation facilities have with agricultural services and to a lesser degree with recreation, it is likely they will parallel those sectors' baselines of higher-value agricultural crops and growing recreational activities although somewhat less than the broader regional population growth.[247]

Table 50 Legal Delta Aviation Infrastructure in 100-year floodplain[248]

	Quantity	Asset Value (millions)
Airports (count)	2	86.2

Utilizing the DWR DRMS Phase 1 study of infrastructure in the Delta,[249] we are again able to identify both the quantity of aviation infrastructure in the Delta and that study's estimate of this infrastructure's asset value. As seen in Table 50, the Delta has two airports located within its 100-year floodplain.[250] In total, the asset value of this aviation infrastructure is estimated to be in excess of $86 million.

3.5 Impact of Policy Scenarios on Transportation Infrastructure

While the baseline scenarios for each of the transportation systems have been discussed in their respective subsections, it is worth emphasizing that the risks to infrastructure as a result of potential flooding events is not likely to be limited to the loss of infrastructure itself. In many cases there are alternative routes and/or modes available for much of the Delta's transportation infrastructure. Nonetheless, the capacity of those alternatives is constrained and those constraints may or may not change in the future.

[247] See Chapters 7 and 8 for information on the baseline trends in agriculture and tourism respectively.
[248] These figures were derived from Table 7-2a in DWR, *Technical Memorandum: Delta Risk Management Strategy (DRMS) Phase 1 Topical Area: Impact to Infrastructure,* June 15, 2007. See Appendix J for further details.
[249] Table 7-2a from DWR, *Technical Memorandum: Delta Risk Management Strategy (DRMS) Phase 1 Topical Area: Impact to Infrastructure,* June 15, 2007.
[250] Figure D5 in Appendix D is a map which shows islands in the Delta 100-year floodplain that border the deep water shipping channels.

Under the baseline assumption of a PL84-99 standard of levee protection,[251] some non-negligible risks remain for parts of the Delta's transportation infrastructure. It is important to recognize the systemic relationships between the Delta's transportation infrastructure and that of the larger megaregion and beyond. Dynamic changes in components outside of the Delta could drastically alter the importance of through-Delta transportation. The robustness of the existing Delta infrastructure could thereby take on very different levels of significance. Based upon discussions with key stakeholders of the various components in the transportation infrastructure system and a review of previous analyses, some of the likely impacts on the Delta's transportation from the policy scenarios presented in Chapter 6 include:

• **Habitat Conservation:** While details of the location of tidal habitat matter; one specific area of concern would be the potential for additional silting of the deep water shipping channel. If the tidal habitat were located next to or near either of the deep water shipping channels, additional silting could occur which would incur significant costs and potentially inhibit commerce with the ports.

• **Open Water Scenario:** In terms of transportation infrastructure, there are minimal assets in the six islands. The existing infrastructure identified through the DWR DRMS study is presented in Table 51.[252] The infrastructure on the islands is primarily local in nature and would not have significant impacts of the larger regional transportation system.

Table 51 Transportation Infrastructure in the Six Island Open Water Scenario

	Quantity	Asset Value (millions)
Non-Highway Bridges (count)	1	0.5
Minor Roads (miles)	31	33.0

However, presence of the open water would expose the Stockton deep water shipping channel to rougher seas and increase silting, which as discussed above would be problematic and costly to the shipping system.

• **Higher Standard Levees Scenario:** Additional levee protection under this scenario would place the transportation infrastructure well above the 100-year standard. This protection would reduce the risk of local damage to the transportation infrastructure systems and reduce the likelihood of interruptions to the broader regional transportation system with which the Delta's infrastructure is increasingly important.

• **Regulatory Scenario:** The increased regulation scenario would potentially impact maintenance of the transportation infrastructure by adding another layer of approval, with potential delays and costs. In addition, the potential for denial would add risk and uncertainty to transportation infrastructure investments in the Delta. These would increase the costs of infrastructure investments and thereby likely lead to less transportation infrastructure investment in the Delta. Conversely, the streamlining of regulations would reduce delays and associated costs of infrastructure maintenance and facilitate capital investments by making a favorable environment for considered infrastructure projects.

[251] See Chapter 5 (Flood Control and Public Safety) and Chapter 6 (Framework for Economic Analysis) for further information regarding this standard as the baseline level of protection.
[252] Table 7-2a from DWR, *Technical Memorandum: Delta Risk Management Strategy (DRMS) Phase 1 Topical Area: Impact to Infrastructure,* June 15, 2007.

• **Delta Vision Scenarios:** The Delta Vision proposals for National Heritage recognition and land use policies would offer potentially useful means to ensure that transportation infrastructure is consistent with maintaining and evolving the Delta as a place. The enterprise zone designation proposal would support the transportation system and associated enterprise development along the value chain.[253] Expansion of the State Park and Recreation Area network could support and be supported by development of the Delta's transportation infrastructure. Lastly, the Delta Investment Fund would also be a useful measure to increase transportation infrastructure that supports the broader consistent sustainable economic growth of the Delta.

4 Energy

The largely rural and unpopulated nature of the Delta's Primary Zone makes it a valuable location for energy infrastructure; significant regional natural gas pipelines, underground natural gas storage, and electricity transmission lines are present in the region. This infrastructure provides critical linkages to nearby electrical generation facilities that are significant features of the State's power generation capacity.

4.1 Natural Gas

The Delta hosts major natural gas pipelines, production, and storage facilities. There is approximately 242 miles of natural gas pipeline with an estimated asset value in excess of $325 million that serve regional users and the local gas fields in the Delta's 100-year floodplain.[254] There are two major natural fields in the Delta: the Rio Vista Gas Field and the French Camp Gas Field. The Rio Vista Field, the larger of the two, is California's largest natural gas field. Combined, these two fields produced 43 percent of California's non-associated, independent-from-oil production, natural gas and 13 percent of the State's total natural gas production in 2009.[255] In the Delta's 100-year floodplain alone, there are an estimated 287 natural gas wells and 111 square miles of natural gas fields.[256] Pacific Gas and Electric's (PG&E) underground storage facility at McDonald Island is the largest natural gas storage facility in the state with approximately 82 Bcf of gas storage capacity, which provides up to one-third of PG&E's peak natural gas supply.[257] This natural gas infrastructure also has important linkages with the proximate electricity generation facilities. A large portion of the Delta's natural gas infrastructure is located within the Delta's 100-year floodplain and as such may be damaged and disrupted during flooding events even with the baseline PL 84-99 standard of protection.[258]

[253] Currently, there is an enterprise zone in San Joaquin County that covers large parts of the Delta. In addition, conditional designation has been granted to enterprise zones in Pittsburg, West Sacramento, and Sacramento. (Source: California Association of Enterprise Zones, www.caez.org)

[254] These figures were derived from Table 7-2a in DWR, *Technical Memorandum: Delta Risk Management Strategy (DRMS) Phase 1 Topical Area: Impact to Infrastructure,* June 15, 2007. See Appendix J for further details.

[255] DOGGR, *Report of the state oil & gas supervisor: 2009*. Department of Oil, Gas, and Geothermal Resources, California Department of Conservation, 2010.

[256] These figures were derived from Table 7-2a in DWR, *Technical Memorandum: Delta Risk Management Strategy (DRMS) Phase 1 Topical Area: Impact to Infrastructure,* June 15, 2007. See Appendix J for further details.

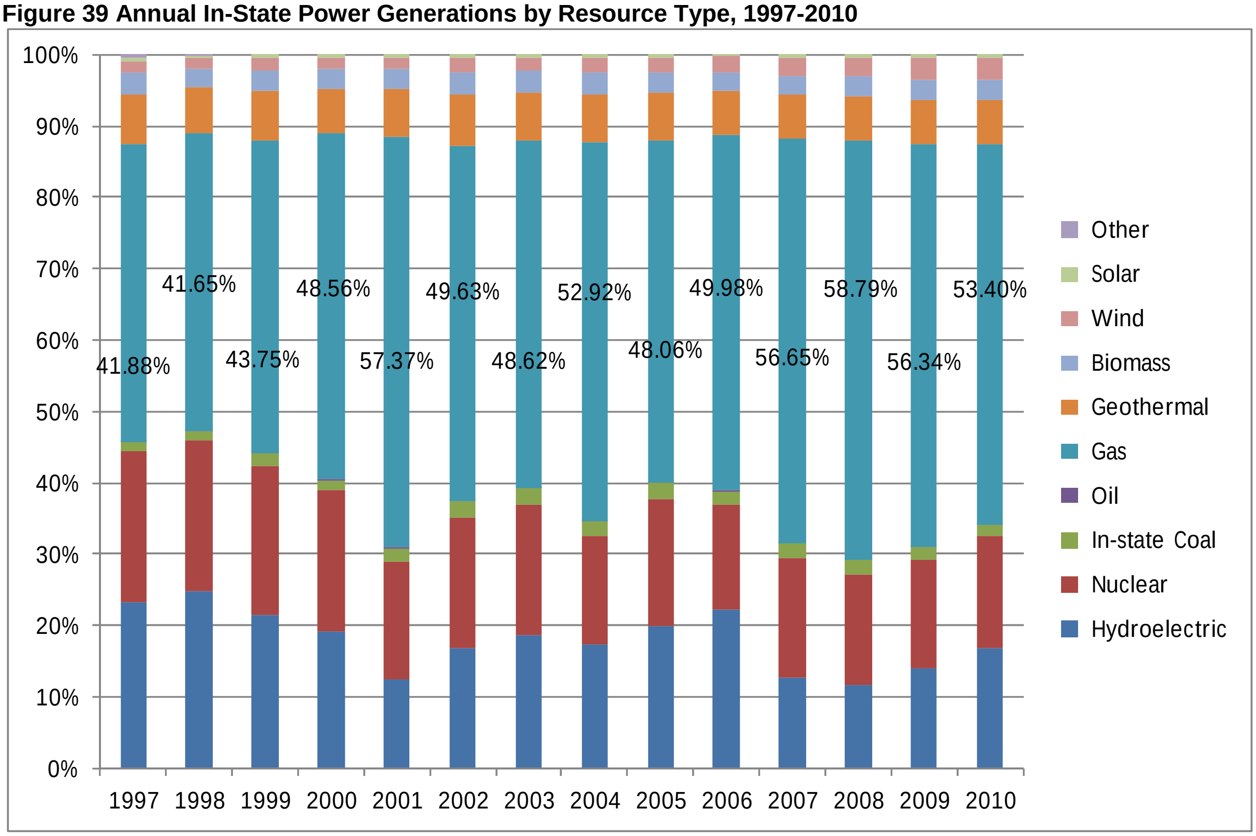
[257] California Public Utilities Commission, "California Natural Gas Infrastructure," January 2010.

[258] The DRMS study has estimated the monthly winter cost of a loss of the McDonald Island storage facility to be $114.4 million and the potential daily natural gas well production loss to equal $870,800. Table 24 and page 54 in DWR, *Technical Memorandum: Delta Risk Management Strategy (DRMS) Phase 1 Topical Area: Economic Consequences,* Department of Water Resources, May 2008. Figure D7 in Appendix D is a map which shows islands in the Delta 100-year floodplain with natural gas storage, fields, and pipelines.

4.2 Electricity Generation Systems

The Legal Delta and nearby power facilities are significant sources of energy for California's electrical grid. Natural gas has become an increasingly significant resource in California's electricity generation, rising in its contribution from 42 percent of the State's total electricity generation in 1997 to 53 percent in 2010.[259] This rise in natural gas use in electricity generation is highly relevant given the Delta's natural gas infrastructure. The Legal Delta hosts 23 power plants with generation from natural gas, petroleum coke, wind, biomass, and landfill gas.[260] The most significant was natural gas-based generation; in 2010, plants within the Legal Delta generated nearly 10 percent of the State's total natural gas-based electricity, and plants within the five-county Delta region generated nearly 20 percent of the State's total natural gas-based electricity.[261]

Figure 39 Annual In-State Power Generations by Resource Type, 1997-2010



Source: California Energy Almanac, July 8, 2011 update. Accessed at: http://energyalmanac.ca.gov/

The Delta's electricity generation capacity is largely located outside of the 100-year floodplain, but the single power plant located within the floodplain has an estimated asset value of $130 million. [262]

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[259] California Energy Commission, *The California Energy Almanac*. Accessed June 30, 2011.
[260] For a list of the plants, their Mw capacity, primary fuel, and owner, see Appendix J.
[261] Power generation facilities in the Legal Delta generated nearly a third of the State's coal and coal-derived generation, but this only totaled 1,072 Gwh in 2010 and is a product of petroleum coke inputs supplied to these facilities from nearby oil refineries.
[262] Derived from Table 7-2a from DWR, *Technical Memorandum: Delta Risk Management Strategy (DRMS) Phase 1 Topical Area: Impact to Infrastructure,* June 15, 2007.

4.3 Electricity Distribution Systems

According to the 2007 Department of Water Resources *Status and Trends of Delta-Suisun Services Report,* PG&E, the Sacramento Municipal Utility District, and Western Area Power Administration oversee most of the transmission lines and provide local electricity services within the Delta.[263] There are three major electric transmission lines that cross the Delta and interconnect California with loads and generation facilities across the Pacific Northwest. These transmission lines usually operate with combined loads near 4,000MW, but will run loads up to 4,800MW. In total the three lines carry roughly 10 percent of California's summer electricity load. Besides those three major transmission lines, there is a network of lower kilovolt lines in the Delta with combined loads of approximately 1,900MW. [264]

Table 52 Legal Delta Energy Transmission Infrastructure in 100-year floodplain[265]

	Quantity	Asset Value (millions)
Substations (Count)	32	$32.0
Transmission Lines (miles)	326	$448.4

Utilizing the DWR DRMS Phase 1 study of infrastructure in the Delta,[266] we are able to identify both energy transmission infrastructure in the Delta's current 100-year floodplain and that study's estimate of its asset value. As seen in Table 52, the Delta has 326 miles of transmission lines and 32 substations in its 100-year floodplain. In total, the asset value of this rail infrastructure is estimated to be in excess of $480 million.[267] While the baseline PL 84-99 standard for all levees in the Delta is assumed, flooding and earthquake events at this level of protection are not trivial and could place significant strain on the inter-state distribution system as well as entail significant local outages in and around the Delta.[268]

4.4 Other Energy Infrastructure

There are several pipelines of major regional significance that carry gasoline and aviation fuel across the Delta from Bay Area refineries to depots for distribution throughout Northern California and Nevada. This pipeline infrastructure extends from the Delta to Sacramento and Stockton onwards to Fresno and Bakersfield as well as to Chico and Reno. These pipelines supply roughly half of all transportation fuel used in the megaregion as well as being the principal source of fuel to several military bases across Northern California and Nevada.[269]

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263 DWR, *Status and Trends of Delta-Suisun Services,* Public Review Draft, Department of Water Resources, March 2007.

264 DWR, *Technical Memorandum: Delta Risk Management Strategy (DRMS) Phase 1 Topical Area: Economic Consequences*, 2008.

265 These figures were derived from Table 7-2a in DWR, *Technical Memorandum: Delta Risk Management Strategy (DRMS) Phase 1 Topical Area: Impact to Infrastructure,* June 15, 2007. See Appendix J for further details.

266 Table 7-2a from DWR, *Technical Memorandum: Delta Risk Management Strategy (DRMS) Phase 1 Topical Area: Impact to Infrastructure,* June 15, 2007.

267 Figure D8 in Appendix D is a map which shows islands in the Delta 100-year floodplain that protect electric power transmission lines and substation.

268 The DRMS study has conducted a power distribution cost estimate focused on two of the three major transmission lines with a two-month outage estimated costs equal to $42 million. Tables 19 in DWR, *Technical Memorandum: Delta Risk Management Strategy (DRMS) Phase 1 Topical Area: Economic Consequences,* Department of Water Resources, May 2008.

269 DWR 2007 *Status and Trends of Delta-Suisun Services*. Public Review Draft. Department of Water Resources. March 2007.

Table 53 Legal Delta Fuel Infrastructure in 100-year floodplain[270]

	Quantity	Asset Value (millions)
Petroleum Pipelines (miles)	70	$77.3
Oil Depot (count)	10	$30

Utilizing the DWR DRMS Phase 1 study of infrastructure in the Delta, we identified approximately 70 miles of fuel pipeline and 10 oil depots in the Delta's current 100-year floodplain worth an estimated $107 million. While the baseline PL 84-99 standard for all levees in the Delta is assumed, the potential loss of this critical infrastructure would require massive mobilization of tanker trucks to minimize as far as possible associated fuel disruptions.[271]

Lastly, it is significant that the geologic structure of the Delta's associated sedimentary basin also appears to offer promising opportunities for potential CO_2 sequestration (capture and storage of carbon dioxide). This important potential development to reduce atmospheric man-made CO_2 emissions has identified the Delta's Sacramento Basin as one of the five most promising basins for CO_2 sequestration from an analysis of over 100 basins in California.[272]

4.5 Impact of Policy Scenarios on Energy Infrastructure

The baseline scenario for the various components of energy infrastructure in the Delta is assumed to be highly correlated with that of the Northern California megaregion. In general, the Delta's energy infrastructure should expand at a rate near to that of the megaregion. However, risks from flooding and earthquake events under the PL84-99 levee standard are assumed to have a greater downside probability, thereby decreasing the relative and absolute extent of the Delta's energy infrastructure. In addition, changes in power generation and transmission as well as fuel technologies or associated resources may increase or decrease the attractiveness of the Delta as an energy infrastructure node. With these caveats, some of the likely impacts on the Delta's energy infrastructure from the policy scenarios presented in Chapter 6 include:

- **Isolated Conveyance Scenario**: This is likely to have relatively minor direct impacts on the Delta's energy infrastructure. However, there are probable indirect impacts on at least some of the energy infrastructure as a result of increased energy requirements for pumping capacity in the isolated facility.

- **Habitat Conservation:** While this is also likely to be relatively minor, some conservation measures such as tidal habitat may restrict access to natural gas fields.

- **Open Water Scenario:** Based on our analysis of existing infrastructure identified through the DWR DRMS study, the only component of energy infrastructure in the six islands is a natural gas field on Webb Island. That infrastructure consists of an 83-acre natural gas field, one

[270] These figures were derived from Table 7-2a in DWR (2007) *Technical Memorandum: Delta Risk Management Strategy (DRMS) Phase 1 Topical Area: Impact to Infrastructure,* June 15, 2007. See Appendix J for further details.
[271] The DRMS study has estimated costs on California consumers alone (excluding Northern California and military bases) from a loss of two of the systems to equal at least $25 million per day. Page 58 in DWR (2008) *Technical Memorandum: Delta Risk Management Strategy (DRMS) Phase 1 Topical Area: Economic Consequences*. Department of Water Resources, May 2008.
[272] Downey and Clinkenbeard, 2005. *An Overview of Geologic Carbon Sequestration Potential in California*. California Geological Survey.

natural gas well, and a quarter mile of natural gas pipeline with an estimated asset value of $250,000.[273]

• **Higher-Standard Levees Scenario:** Assuming other factors are held constant, a higher level of levee protection would reduce the risks of energy infrastructure losses and likely lead to a greater probability for expansion of the Delta's energy infrastructure with associated investment above the baseline.

• **Delta Vision Scenarios:** As with Transportation infrastructure, the Delta Vision proposals for National Heritage recognition and land use policies would offer a potentially useful means to ensure that energy infrastructure is consistent with maintaining and evolving the Delta as a place.

5 Water Resources

5.1 Water Supply Infrastructure for Delta Communities and the Delta Region

Communities in and surrounding the Legal Delta rely on a variety of water supplies including groundwater, direct diversions from natural flows in the Delta, and diversion of surface water supplies that originate upstream from the Delta. For simplicity, this section focuses on municipal water supplies for Delta communities that divert water directly from the Delta. The largest municipal sources in this category are the Contra Costa Water District, which has several

Box 5 Salinity Impacts on Industrial Users of Delta Water

Beside agriculture, there are numerous industrial users of water from the Delta. These industries are primarily located in or near the western Delta and include power plants, steel mills, and oil refineries. Some of these industrial users maintain their own Delta intakes while others are provided industrial water by the local water districts. A large amount of water is used by these industries as boiler feedwater and for their cooling towers. Because of strict water quality requirements for optimal performance, degradation such as that from increased salinity reduces operating efficiencies or increases the cost of pre-treatment and creates adverse economic impacts. By way of illustrating these impacts on cooling tower systems, we examine an example of two refineries that are supplied industrial water by Contra Costa Water District. Increased salinity reduces thermal conductivity, decreasing cooling tower performance, and requires more water to cycle through to maintain performance. It was estimated that a 20 percent increase in salinity above average would require an additional 17 percent increase in industrial water purchases for the cooling towers' operation. Those increased water purchases would add approximately $985,000 in costs per year for the two refineries combined. The higher salinity would also accelerate corrosion of the cooling systems with associated increased costs for replacement, downtime, and reduced operating efficiency. There are numerous industrial customers in the Delta area whose operations would likely be significantly affected by increased salinity in the Delta. Therefore, the annual costs associated with increased salinity would be much greater than the illustrative estimate.

Note: This discussion draws on comments and estimates made regarding the August 9, 2011 Draft version of the ESP. Those comments were made by the Contra Costa Water District and are available at the Delta Protection Commission website: http://www.delta.ca.gov/ESP_Comments.htm.

intakes in the western and south Delta, and the new City of Stockton water supply project that is currently under construction. The City of Antioch also has an important water supply intake at the western edge of the Delta, and purchases water from the Contra Costa Water District when

[273] Table 7-2a from DWR (2007) *Technical Memorandum: Delta Risk Management Strategy (DRMS) Phase 1 Topical Area: Impact to Infrastructure,* June 15, 2007.

the water quality at their intake deteriorates to poor levels.[274] The Solano County Water Agency has a major water intake in the northwest Delta that serves significant areas in a Delta county and nearby Napa, but does not directly serve customers in the Legal Delta. The City of Tracy receives a portion of its supply from the federal Central Valley Project that serves areas to the south, but has added other supplemental supplies in recent years to reduce its dependence on this source.

Box 6 Salinity Impacts on Residential Users of Delta Water[275]

There are a range of factors, including rising sea level and conveyance options that may increase the salinity of Delta water. Whatever the cause, saltier source water requires more water and energy to produce quality drinking water and also generates greenhouse gas. Owing to their intakes' proximity to the San Francisco Bay, the western Delta communities typically bear the initial impacts of increased Delta salinity. The City of Antioch, for instance, has been diverting fresh water from its intake since the 1860s, but when salinity levels are too high to utilize this water, Antioch purchases water from CCWD for an additional $750,000 per month or approximately $3 million per season on average. Therefore, as rising salinity levels reduce the operating horizon for their intake, the cost of providing water to their customers rises. CCWD has estimated the impacts associated with a 20 percent increase in fall salinity at their Rock Slough intake to equate to an additional operating cost of $94,000 per month due to increased releases from Vaqueros Reservoir and subsequent increased pumping to refill the reservoir. The additional energy requirements associated with increased use of Los Vaqueros Reservoir to dilute the saltier water would generate an additional estimated 190 metric tons of CO_2 emissions. Furthermore, CCWD is currently investigating a brackish water desalinization plant to be developed collaboratively with four other utilities. The estimated capital costs for this plant are between $150 million and $180 million, with annual operation and maintenance costs between $10 million and $13 million.

As for agriculture, water quality is a critical consideration for these users, although its impacts can be controlled to a greater extent than for agriculture by using modern water treatment procedures, which may be very expensive. Water quality impacts on agriculture are discussed in Chapter 7. There are numerous potential sources of significant changes to Delta water quality; several are discussed in the context of the scenarios below. However, the following two other factors may also significantly influence baseline Delta water quality.

1) It is the policy of the State to plan for 55 inches of sea-level rise by 2100, although there is a wide range of estimates available and little consensus among the scientific community. Regardless of the exact amount of sea level rise, rises in sea level approaching this number would have a significant effect on tidal action and salinity in the Delta. These effects could be partially mitigated by adaptive management and engineering, and by careful restoration of habitat designed to absorb tidal energy in the far western Delta and the Suisun Marsh. Maintenance and improvement of the levees on the eight western islands will become even more critical as sea level continues to rise.[276]

2) Changes in the water quality of the San Joaquin River are another significant factor affecting overall water quality of the Delta. Further degradation of the water quality in the San Joaquin

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[274] The City of Antioch is partially reimbursed for these purchases according to the terms of a 1968 settlement agreement between the City of Antioch and the DWR.
[275] The impacts discussed in this box are derived from comments and consultations with both the City of Antioch and the Contra Costa Water District.
[276] Figure D1 in Appendix D is a map which shows the western islands and tracts in the Delta that have been identified as being critical to buffer against saltwater intrusion.

River is a long-standing problem with no easy solution. Actions directed towards updating specified flow criteria to improve water quality through salinity objectives may be realized through changes to the Bay-Delta Plan by the State Water Resources Control Board (SWRCD).[277]

In addition to the intake facilities themselves there are several associated pipelines conveying water from and through the Delta. Utilizing the DWR DRMS Phase 1 study of infrastructure in the Delta, we identified approximately 50 miles of aqueduct in the Delta's current 100-year floodplain worth an estimated $1.3 billion.[278] It is important to recognize that municipal water users have exhibited significant gains in efficiency and the continuation of these trends will likely reduce the relative demands on in-Delta water supplies despite future growth in the megaregion.

5.2 Wastewater Management Systems for Delta Communities

Many Delta communities discharge treated wastewater into the rivers and sloughs of the Delta. Such discharges are regulated by the State and Regional Water Boards through National Pollutant Discharge Elimination System (NPDES) permits to provide protection of all designated beneficial uses in the Delta. In recent years, the Central Valley Regional Water Quality Board has ordered virtually all Delta wastewater dischargers to significantly upgrade their plants to advanced treatment. Some wastewater utilities are in the process of constructing new facilities, whereas others, including the Sacramento Regional County Sanitation District facility, the largest wastewater treatment facility discharging to the Delta, are in the planning stages after recent regulatory decisions by the Central Valley Regional Water Board. Although the costs vary between utilities, the costs for upgrades to advanced treatment are significant compared to secondary treatment.[279] These treatment improvements may make some improvements to Delta water quality. This effort represents a significant investment from communities in and surrounding the Delta, and is an action item already in progress that supports the coequal goals.[280]

5.3 Impact of Policy Scenarios on Water Resources Infrastructure

- **Isolated Conveyance Scenario**:

The isolated conveyance scenario proposes construction of new intakes for exporting water from the Sacramento River to areas south of the Delta. Assuming that there is no separate action taken on San Joaquin River water quality, this would tend to reduce water quality in the entire Delta, which at present is sustained by the flow of relatively fresh Sacramento River water through the Delta. While it is reported that the current preferred conveyance alternative would include some through-Delta flow, the operating rules have not yet been fixed and there is no

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[277] Currently the SWRCB is targeting the summer of 2012 for adoption of these amendments to the flow and salinity objectives. For details see: http://www.waterboards.ca.gov/water_issues/programs/delta.shtml

[278] These figures were derived from Table 7-2a in DWR (2007) *Technical Memorandum: DRMS Phase 1 Topical Area: Impact to Infrastructure,* June 15, 2007.

[279] An example of the benefits derived from these investments in wastewater treatment facilities have been seen at the Port of Stockton where once the City of Stockton began operation of its nitrification facility a mile up river in 2006, aeration at the port was finally able to achieve their operating targets. (Source: DWR, *Final Report: Stockton Deep Water Ship Channel Demonstration Dissolved Oxygen Aeration Facility Project,* Department of Water Resources, 2010.)

[280] Utilizing the DWR DRMS Phase 1 study, 15 wastewater treatment facilities were identified in the Delta's current 100-year floodplain worth an estimated $2.2 billion. (Source: Table 7-2a in DWR, *Technical Memorandum: DRMS Phase 1 Topical Area: Impact to Infrastructure,* June 15, 2007. See Appendix J for further details.

consensus on the BDCP effects analyses. Therefore, it is likely that isolated conveyance will increase salinity in the Delta even though the extent of these impacts is uncertain. As discussed above, increased salinity will tend to raise industrial and residential water costs, particularly in the western Delta. This will be problematic for the communities dependent on Delta water, especially if these additional costs are not mitigated.

• **Habitat Conservation:** The proposed conversion to tidal wetlands of lands around the periphery of the Delta, principally in the Cache Slough area and in the South Delta, would be beneficial for a range of fish species because of the steady introduction of organic carbon into the rivers and sloughs of the Delta. However, this same increase in organic carbon can have a significant impact on municipal water supplies because it can only be treated with advanced water treatment technology. A general idea of the estimated costs associated with this advanced water treatment is presented in Table 54.[281] While it is unlikely that all of the water providers in the Delta would need to implement advanced water treatment, it is illustrative of the potential impacts from the creation of environments for threatened and endangered species to thrive if they are located close to critical water supplies.

Table 54 Estimated advanced treatment costs

	MGD Capacity	Capital Costs (millions)	Annual O&M Costs (millions)
CCWD	125	$94	$7.2
NBA	121	$40-$90	$9-$29
Antioch*	38.0	$12-$28	$2.2-9.1
Stockton	30.0	$15	$3.5
*Estimated from other utilities			

A strategy for creating additional tidal marshes that could have fewer impacts to Delta water quality would be to restore the sunken islands in the far western Delta (and also perhaps Frank's Tract) as tidal marshes and to convert what are presently managed wetlands in the Suisun Marsh to tidal wetlands. This could have less impact on the introduction of organic carbon into municipal water supplies and could help mitigate salinity intrusion into the Delta.

A second kind of conservation measure, restoration of historic floodplains to temporarily store floodwater, could also increase organic carbon loading. This generally requires the removal of levees or the construction of new set-back levees. Re-activation of historic floodplains contributes to flood control by reducing the peak water-surface elevation as a flood crests and stretching out the flood hydrograph. It also directly restores one important element of the natural ecosystem, the burst of organic carbon introduced to the aquatic environment during flood crest. However, because this is only a temporary burst, rather than a sustained introduction of organic carbon, and it only occurs during periods of high flows, the consequences for municipal water treatment are not as severe. An excellent example of this approach to floodplain restoration is provided by the proposed Lower San Joaquin Bypass project which would widen Paradise Cut and reduce peak-water surface elevations in the San Joaquin River as it passes Lathrop and Stockton.[282]

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[281] Treatment costs in Table 54 are estimates provided in consultation with the Contra Costa Water District (CCWD), the City of Stockton, and the Solano County Water Agency (North Bay Aqueduct (NBA), The range of costs for Antioch are scaled estimates based on the range of capital and O&M costs provided by the other agencies. It is important to note that the actual cost will depend on the type of technology required.

[282] Lower San Joaquin River Flood Bypass Proposal, South Delta Levee Protection and Channel Maintenance Authority, submitted to California Department of Water Resources, March, 2011.

• **Open Water Scenario:** The open water scenario would entail the removal of the City of Stockton's Delta Water Supply intake on Empire Tract. This $217 million project is currently under construction by the City of Stockton to replace surface water resources and protect groundwater supplies. Initially the intake will allow 30 million gallons per day (MGD) to be treated, with further expansion planned for capacity to treat up to 160 MGD.[283]

• **Higher-Standard Levees Scenario:** A failure of levees and the failure to restore flooded islands is yet another potential source of water quality degradation. As noted elsewhere, the ecological benefits of leaving islands flooded, or even deliberately breaching islands where the land surface is presently below sea level, are uncertain. What is clear, however, is that increasing open water in the Delta could have an adverse effect on adjacent islands as a result of increasing wave action and seepage forces, and could contribute to the conversion of the Delta from an estuarine ecosystem to that of a weedy lake. Water quality could be degraded as a result of increased salinity intrusion and as a result of more organic carbon and introduced organisms. These adverse effects would be mitigated by improving levees to a higher standard.

[283] Delta Water Supply Project website. Accessed at: http://www.deltawatersupplyproject.com/

Part Three: Integration and Recommendations

Chapter 10: Legacy Communities

The Legacy Communities of the Sacramento-San Joaquin Delta are integral to the cultural fabric of the Delta. These towns provide key services and support functions for surrounding residents and businesses, serve as important visitor waypoints, offer unique cultural activities, and lend great character to the Delta as a place. These communities have existed to support agriculture and recreation activities in the Delta, and until recently have been economically sustainable in their own right. However, demographic, economic, and land use trends have changed these communities considerably—some to the extent that visible signs of underutilization and decline are prevalent—and continued evolution of economics and public policy in the Delta will greatly affect their ability to thrive in the future.

The State of California has recognized the importance of cultural heritage in the Legacy Communities and has mandated that the Economic Sustainability Plan include recommendations concerning these communities.[284] This report indicates that there is great potential for revitalization of the Delta's Legacy Communities, and this chapter seeks to support this endeavor by documenting the historical framework and socio-economic conditions of these areas, analyzing ways in which these communities relate to larger contexts and may adapt in the future, creating the principles for future economic prosperity, and recommending strategies by which a sustainable vision can be implemented.

1 Overview and Key Findings

The Delta Reform Act of 2009 (SB X7 1) identifies the Delta's Legacy Communities as Bethel Island, Clarksburg, Courtland, Freeport, Hood, Isleton, Knightsen, Rio Vista, Ryde, Locke, and Walnut Grove. This chapter focuses primarily on the unincorporated Legacy Communities of the Sacramento River Corridor, including Clarksburg, Courtland, Hood, Isleton, Locke, Ryde, and Walnut Grove, providing a general overview of each.[285] In addition, Clarksburg, Walnut Grove, and Locke have been selected for more detailed study and focused economic sustainability planning.[286] This chapter discusses a potential "vision" of a sustainable future for each of these focal communities, the goal being to preserve their rich cultural histories while simultaneously providing for economic prosperity. The chapter also provides a high-level implementation strategy for the Legacy Communities. It is anticipated that facets of the strategy presented here may be applicable to other Legacy Communities in the Delta.

A primary aspect of sustainability planning for the Delta's Legacy Communities is the notion of enhancing legacy themes and creating better awareness of each of these distinctive communities. It is contemplated that promoting the uniqueness of these communities, in combination with strategic investments, will attract new residents, businesses, and visitors, thereby stimulating overall economic health and sustainability. To fully realize the economic potential of the Legacy Communities will require a comprehensive plan. Accordingly, the Economic Sustainability Plan provides a multi-faceted vision for Clarksburg, Walnut Grove, and Locke that touches on historic preservation, economic development, urban design, recreation,

[284] Delta Reform Act of 2009 (SB X7 1)

[285] While the Delta Reform Act of 2009 (SB X7 1) identifies additional "Legacy Communities," the ESP focuses on the communities of the Sacramento River Corridor. Findings and recommendations from the ESP may serve as a useful template for analysis of other Legacy Communities.

[286] Clarksburg, Walnut Grove, and Locke reflect a broad range of community typologies (character and land use mix) found in the Primary Zone.

marketing, and other factors. In addition, the Economic Sustainability Plan considers the need for a coordinated effort to reinvest in the Legacy Communities.

The vision for each community and the overarching implementation strategy rely on extensive research of historical context, analysis of socioeconomic conditions, and public input. This chapter includes historical narratives, presents local demographic and economic data, and incorporates findings from community outreach. The chapter also reflects findings from field work, including assessments of community character and site-specific development opportunities. The following presents key opportunities and constraints for the Legacy Communities; the high-level vision for Clarksburg, Walnut Grove, and Locke; and an overview of the implementation strategy.

1.1 Opportunities and Strengths

Agriculture is the primary driver of economic activity in the Delta. As documented in detail throughout the Economic Sustainability Plan, the agriculture industry is the primary economic engine of the Delta. Along with the agriculture industry, the Legacy Communities have matured and evolved over time. The health of agriculture production around the Legacy Communities remains critical to the sustainability of the Legacy Communities.

Outdoor and cultural recreation is essential to long-term sustainability. Already a well-known and heavily visited recreation area, visitors are an important source of revenue for Delta businesses. It is crucial to maintain and enhance recreational offerings in the Delta and to add to or strengthen the region's visitor-serving amenities, ensuring that the Delta remains a top visitor destination for outdoor and cultural recreation in Northern California.

Improved lodging, entertainment, and retail options capture additional tourism dollars. Despite the significant number of recreation visitors to the Delta, there are relatively few hotel rooms, stores, and attractions to capture visitor spending. Overnight accommodations and entertainment options, in combination with supporting retail, could increase visitation, length of stay, and spending in the Delta, but will require substantial reduction of risk to attract investors given the other inherent risks of projects in this sector.

Transportation-related improvements are needed to enhance the visual landscape, attract visitors, and improve public safety. Roadway landscaping, signage, bike lanes, sidewalks, parking, transportation services, and other transportation-related improvements are needed in the Delta. Investments in transportation will improve quality of life for residents and increase tourism potential.

Restored historic buildings and contextual infill development improve community aesthetics and support economic growth. The Legacy Communities offer a unique sense of place and history that must be preserved. Historic preservation should be pursued in concert with new projects. Reinvestment and new investment in real estate is critical to economic sustainability. Development projects that are consistent with the existing community fabric will be an important factor in retention and recruitment of businesses. This will require increased regulatory flexibility to facilitate the use and adaptive reuse of vacant buildings. Meaningful progress in Locke should be among the highest priorities within the Primary Zone in this regard, as this unique community has the potential to catalyze tourism activity and related subsequent investments.

Agricultural tourism has growth potential. Agritourism and rural recreation is currently found throughout the Delta and is growing. Farms and other agricultural businesses (including wineries) are increasingly leisure destinations, with businesses seeking direct sales and brand awareness and visitors seeking fresh food and a physical connection to their food source. However, substantial growth from current baseline conditions will require coordinated efforts to brand and market the region and its sub-districts, with the objective of breaking the Delta down to districts with distinct branding identities.

Festivals and community celebrations raise awareness and generate economic activity. There are numerous festivals and community events each year that boost tourism and business activity in Delta. Additional visitor programming, coordinated scheduling, marketing, and branding could increase the economic benefits of existing and future events in the Delta.

1.2 Constraints and Challenges

There is an over-arching need to reduce investment risk in order to spur economic activity in the Legacy Communities. Several factors work together to suppress business activity and economic growth, including incongruent and lengthy regulatory requirements between local, county, state, and federal entities, and significant flood risks.

A strict and multi-layered regulatory framework limits economic development. With numerous government agencies overseeing land use in the Legacy Communities, permitting new projects is frequently a costly and lengthy process. Furthermore, some projects are disallowed entirely. The Delta Plan's proposed "covered action" provision needs to be carefully reviewed to avoid further complicating and hindering economic development in the Primary Zone.

Risks associated with insufficient flood protection limit new investment. Adequate flood protection is essential to economic development in the Delta. Costly new and improved levees are necessary to encourage reinvestment and new investment in the Legacy Communities. Without levee investment, property owners are burdened by flood insurance requirements, as well as significant design, permitting, and financing hurdles for building improvements and new construction.

Housing options for Delta workers are limited. Only about one in ten employees working in the Primary Zone also lives there.[287] Without sufficient workforce housing, Delta employers must recruit non-local employees who must commute into the Delta to work, thereby compromising the environmental sustainability of the Legacy Communities. The need for workforce housing is an important policy concern for the Legacy Communities.

1.3 The Vision for Clarksburg, Walnut Grove, and Locke

Clarksburg – A Vibrant Agricultural Community. Clarksburg's primary competitive advantage is its agricultural abundance, with rural bucolic charm in close proximity to Sacramento. This area produces exceptional agricultural goods, most notably wine grapes, and attracts visitors who tour farm country and local wineries. The Economic Sustainability Plan proposes that the vision for Clarksburg build on momentum in the areas of agricultural tourism and value-added agricultural processing. Clarksburg should retain its historic character, grow as a food and wine destination, and attract new agriculture-related craft production businesses. In addition, some key local neighborhood services and amenities would work to make this community more

[287] Commute patterns are discussed in detail in Chapter 2.

attractive to visitors and local residents. Some increase in population growth, sensitively directed toward appropriate infill sites, would likely be necessary to achieve minimum market-based thresholds for retail or service sector business creation.

Walnut Grove – The Heart of the Delta's Sacramento River Corridor. Walnut Grove is centrally located, with a cluster of businesses providing residents, workers, and visitors a variety of goods and services not found elsewhere in the Primary Zone. The Economic Sustainability Plan proposes that the vision for Walnut Grove build on its status as a hub of local businesses and services. Walnut Grove should preserve its community character; grow and diversify business activity; and continue to strengthen its physical connection to the Sacramento River.

Locke – A Historic Delta Community. Locke is known for its cultural heritage, historical significance, unique building stock, and points of interest. With great sensitivity to cultural, historical, and environmental values, the Economic Sustainability Plan proposes that Locke leverage its notable assets to increase tourism and spending in the community. Locke should preserve its historic character, offer improved hospitality and visitor services, and revitalize its "main street" business environment.

1.4 Implementation

Designate an agency to manage and implement economic sustainability efforts in the Delta. A designated entity responsible for economic development and community reinvestment should plan, coordinate, and participate in the implementation of the Economic Sustainability Plan. Future planning efforts would build on recommendations and findings from this Plan, refining the goals for the Legacy Communities and prioritizing potential strategic actions. The agency would ensure that strategic actions, such as marketing efforts and economic development, are implemented in a systematic, efficient, and consistent fashion throughout the Legacy Communities. Additionally, the agency might contribute to implementation directly, either carrying out implementation actions independently or by coordinating partnerships between public and private sector actors. This topic is discussed in greater detail in Chapter 11 of this report.

Conduct additional study of potential community investment options. The Economic Sustainability Plan considers a number of strategic actions for the communities of Clarksburg, Walnut Grove, and Locke. In addition, opportunity sites are evaluated for higher and better land use potential. The proposed strategic actions and the review of opportunity sites presented in this chapter are intentionally high-level. As community-specific economic sustainability goals are refined over time, associated strategic actions will need to be updated and further detailed. Potential investments must be studied in detail to assess cost effectiveness and priority relative to a complete set of potential investments throughout all of the Legacy Communities.

Use the Delta Investment Fund to support economic development initiatives in Legacy Communities. Inadequate infrastructure is a major barrier to investment in the Legacy Communities. Funding for infrastructure (capital and maintenance) will be essential to promoting private sector investment in the future.

2 Existing Conditions and Trends

This section provides an overview of the Legacy Communities, including historical context, socioeconomic conditions, regulatory environment, and recent development projects.

2.1 Overview of the Legacy Communities

Although settlement and use patterns throughout the Delta occurred in tentative stages as early as the 1830s, it was not until the Congressional acts of 1850 and 1858 giving title of lands to the State and subsequently allowing the sale to individuals, that the Legacy Communities began to form. Concentrated agricultural use of the Sacramento Valley began with John Sutter's land grants of 1841. The emergence of New Helvetia as an important trading post subsequently led to the establishment of a shipping wharf.[288] The confluence of three historical events—the California Gold Rush, the Second Industrial Revolution, which brought steam paddlewheel shipping and steam trains, and the end of the Mexican-American War—led to tremendous increases in population in San Francisco and the Bay area. As this population raced to extract the gold, the Delta became a valuable transportation, hunting, and fishing resource. Although the gold resources waned and miners rushed off to other finds, the agricultural and trading tradition of the area was already firmly established. As landowners looked for increased farming opportunities, the Delta became the focus of concentrated reclamation efforts.

The next 60 years saw the construction of levees and the draining of wetlands, which shaped much of the Delta that exists today. By 1920, reclamation of the Delta was complete and agriculture replaced gold as the regional economic driver. With dredging also complete, the Sacramento River became a predominant commerce route and recreation destination. Over the next several decades, the short-term mining practices and destruction of Delta ecosystems that took place during the gold rush subsided and were replaced by long-term management of the land and resources, including the building of permanent communities. Today, the Legacy Communities remain closely tied to the local agricultural economy and the Sacramento River.

The Legacy Communities of specific focus in the Economic Sustainability Plan are located in the Sacramento River Corridor and include Clarksburg, Courtland, Hood, Isleton, Locke, Ryde, and Walnut Grove. All Legacy Communities discussed in SB X7 1 are shown in Figure 40, and are briefly described below.

- **Bethel Island**, which is located just outside of the cities of Antioch and Oakley, is well-known as a recreation destination in the Delta. Relatively proximate to the San Francisco Bay area, Bethel Island offers residents and visitors retail and restaurants, a golf course, several marinas, and access to some the Delta's best waterways.

- **Clarksburg,** located in Yolo County on the west side of the Sacramento River, is well known for grape production and home to large-scale wine producer Bogle. The Old Sugar Mill, a redeveloped factory repurposed as wine tasting and production facility and event center, is a popular visitor attraction.

- **Courtland**, located in Sacramento County on the east side of the Sacramento River, is recognized for the significant pear production in the area. Each year, the Courtland Pear Fair celebrates the harvest.

- **Freeport** is the northernmost Legacy Community, located in Sacramento County, near the border of the City of Sacramento. Established as a port during after the California gold rush, Freeport has a distinct heritage in the history of goods movement in the Sacramento region.

[288] http://www.sacdelta.com/hist.html and http://www.ppic.org/content/pubs/report/R_207JLChapter2R.pdf

- **Isleton**, an incorporated city located in southwestern Sacramento County near Rio Vista, contains a 19th century-era main street with numerous community- and visitor-serving businesses. The city is well known for its Crawdad Festival (Cajun Festival).

- **Knightsen** is a small residential/farming community located near Oakley in Contra Costa County. Knightsen has become known for several horse ranching operations in its vicinity.

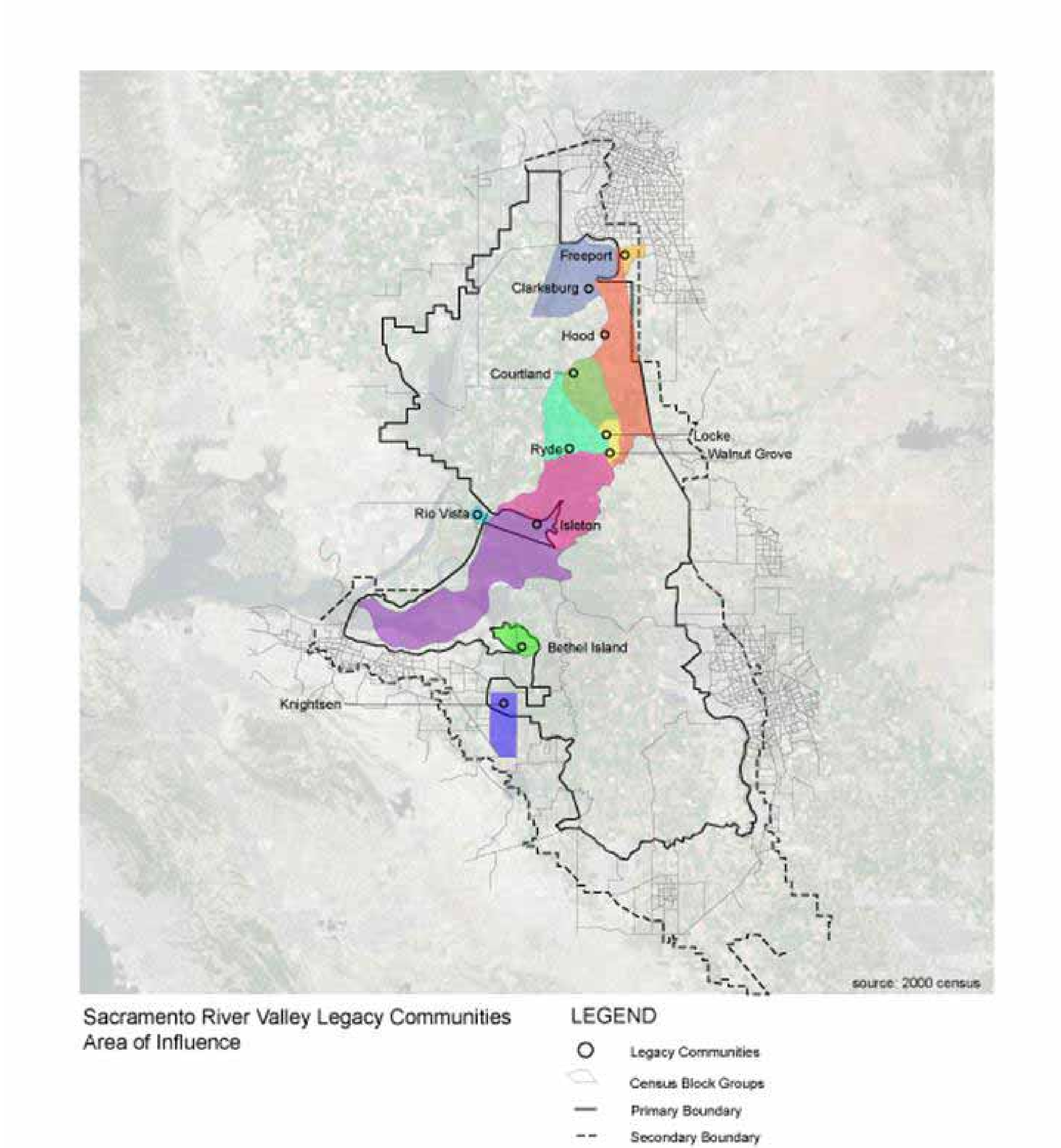
- **Locke**, located in Sacramento County on the east side of the Sacramento River, is nationally-significant example of a historic Chinese-American rural village. The town is a distinguished visitor destination in the Delta, with numerous points of interest, including the Locke Boarding House, Locke Chinese School, Locke Memorial Park, among others.

- **Rio Vista** is an incorporated city in Solano County. The most populated of all Legacy Communities, Rio Vista is home to many business and personal services which serve rural residents as well as visitors the Delta, and features an assortment of grocery stores, banks, restaurants, and other amenities.

- **Ryde**, located in Sacramento County on the west side of the Sacramento River, is well known for the historic Ryde Hotel and Event Center. Built in 1927, the recently refurbished Ryde Hotel is a Delta landmark and highly-regarded wedding and event venue.

- **Walnut Grove**, located in Sacramento County on the east and west sides of the Sacramento River, is a bustling small town with businesses, residences, a library, and a school. Walnut Grove is centrally located within the Sacramento River Corridor and offers many modern goods and services for businesses, residents, and visitors.

Figure 40Sacramento-San Joaquin Delta Legacy Communities[289]



289 For high resolution image see http://forecast.pacific.edu/desp-figs.html

2.2 Socioeconomics

Building on Chapter 2 (Overview of the People and Economy of the Delta), this section examines key demographic and economic conditions and trends in the Legacy Communities. The analysis focuses primarily on data-driven results and information from government data sources, including data from the U.S. Census Bureau. The Economic Sustainability Plan relies on Census block group-level data to evaluate the characteristics of population and jobs in the Legacy Communities.[290] Figure 40 shows the geographic boundaries of the block group data considered by this chapter. Appendix K provides detailed data tables supporting the findings discussed here.

2.2.1 Population Trends and Characteristics

According to Census 2010, there are approximately 6,600 residents in the Sacramento River Corridor Legacy Community block groups, an increase of almost 10 percent over year 2000 population. Most of the Legacy Community block groups experienced growth, with the greatest population growth (in percentage terms) observed in the block group that includes Hood, Freeport, and areas along Interstate 5. However, the block groups that include Isleton and Clarksburg grew at a much slower rate, with very little to slightly negative population growth since 2000.

The age distribution of residents in the Legacy Communities is generally similar to the Primary Zone overall, with few children and a high proportion of older residents, as compared to the population of the Legal Delta. In the Legacy Communities, the population under the age of 18 is only 18 percent of the population (compared to 29 percent in the Legal Delta) and the population age 55 and older is 36 percent of the population (compared to 20 percent in the Legal Delta). Census Bureau age data reveal more young residents in eastern Walnut Grove and Locke, with 25 percent of the population under the age of 18. In contrast, the Census Bureau indicates that population around Hood is notably older, with roughly 62 percent of residents over the age of 55.

The residents of the Legacy Communities are primarily White, although other racial groups and ethnicities are also well-represented. Eastern Walnut Grove and Locke are quite diverse, with Asians making up 38 percent of the population and Hispanics making up 40 percent of the population. Courtland also has a notable Hispanic population, with about 66 percent of the population reporting that ethnicity.

Across the Legacy Communities, the Census Bureau reports wide disparities in household income, with average household incomes ranging from less than $30,000 to over $90,000 per year. The highest average income is found around Ryde (including western Walnut Grove), where the Census Bureau reports an average household income of $92,200 (well above the average of $79,200 in the Legal Delta). However, directly across the Sacramento River in eastern Walnut Grove and Locke, the Census Bureau finds that average household income is significantly lower, at about $28,500.

The educational attainment of residents around the Legacy Communities is also varied, with notable correlation to the household income patterns. Around Ryde, almost 34 percent of residents hold a bachelor’s degree, a significantly greater percentage than in the Primary Zone

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[290] Although these geographic boundaries may differ from some other political or locally-accepted definitions of the Legacy Communities, U.S. Census Bureau data from the American Community Survey was the best information available at the time the analysis was conducted.

and Delta overall. In contrast, over 26 percent of eastern Walnut Grove and Locke residents are without a high school diploma or GED. The figure is even higher around Courtland, where about 34 percent of residents do not have a high school diploma or GED. However, Courtland also has a relatively high percentage of college graduates.

2.2.2 Labor Force and Economy

Similar to the Primary Zone overall, Census Bureau data concerning the Legacy Communities indicate that these residential areas serve as bedroom communities for nearby cities such as Sacramento and Stockton (i.e., most residents of these communities do not work in there). In fact, only about 12 percent of working residents in the Legacy Communities hold jobs close to home, in the Sacramento River Corridor.[291] Consistent with this finding, only about 15 percent of workers living in the Legacy Communities are employed in the agriculture, fishing, and forestry sector. However, agriculture sector workers make up a greater share of resident employment in eastern Walnut Grove and Locke (32 percent) and Clarksburg (25 percent). By comparison, only about one percent of workers living in Isleton are employed in the agriculture sector.

After agriculture, working residents of the Legacy Communities are commonly employed in the construction and education sectors, 11 percent and 10 percent respectively. In Isleton, almost one in five working residents has a construction industry job. In Courtland, nearly one quarter of working residents have a job in the education sector. In addition, closer to Sacramento, in the block group that includes Hood, nearly one quarter of working residents have a health care industry job. Residents are also commonly employed in manufacturing and administrative/waste services. Of employed residents in the Legacy Communities, approximately 64 percent are employed by for-profit enterprises, slightly lower than the roughly 68 percent observed in the Legal Delta.[292]

Jobs based in the Legacy Communities are most concentrated in agriculture- and recreation-related sectors. Census Bureau data indicate that employment in these industries makes up well over half of the jobs in the Legacy Communities. There are also notable employment concentrations in the construction, education and health, and trade, transportation, and utilities sectors.

2.3 Planning and Regulatory Overview

The complex, multi-jurisdictional regulatory environment that exists in the Legacy Communities today creates uncertainty and risk for investors considering a variety of economic development initiatives, including opening or expanding small businesses. Local municipal agencies (cities and counties) exert regulatory control for many items requiring land use approval (including building permits, subdivision maps, etc.). In addition, state and federal agencies also possess regulatory power over land use decisions, particularly in the Primary Zone. Despite efforts to coordinate land use planning and regulation in the Legacy Communities (see Chapter 4: Review of Key Policies and Planning Process), the current regulatory framework creates a significant burden for economic development projects. In fact, it is the opinion of many Legacy Community stakeholders that regulatory discord between the local and state entities is a key factor influencing disinvestment in the Legacy Communities. Additional discussion of regulatory constraints can be found in section 3.2.2.

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[291] LED-LEHD inflow/outflow data
[292] US Census Bureau, American Community Survey 2005-09.

2.4 Notable Real Estate Development Projects

Over the past several years, many real estate development projects have been proposed throughout the Delta, both in the outlying Secondary Zone as well within the heart of the Primary Zone and even within the Legacy Communities. These projects can shed light upon key issues that should be considered as part of an economic strategy for the Legacy Communities and are briefly discussed below.

2.4.1 Old Sugar Mill

The Old Sugar Mill project in Clarksburg is an important example of the challenges associated with real estate development in the Legacy Communities. While the project as it exists today (a winery and event venue) is a success story, project proponents originally conceived a mixed-use plan with a housing component that did not receive regulatory approval.

Originally constructed in the late 1930s to process sugar beets, the sugar mill became an aging and dilapidated structure after the processing facility was shut down in 1993. Redevelopment plans called for a mixed-use village that would incorporate 162 residential dwelling units and significant commercial and industrial space, including micro-wineries and an events venue. The residential component would have nearly doubled the population of Clarksburg. The housing component of the project generated local concern over potential impacts to the Clarksburg's small-town character, which were evaluated and addressed throughout the project's environmental review process.

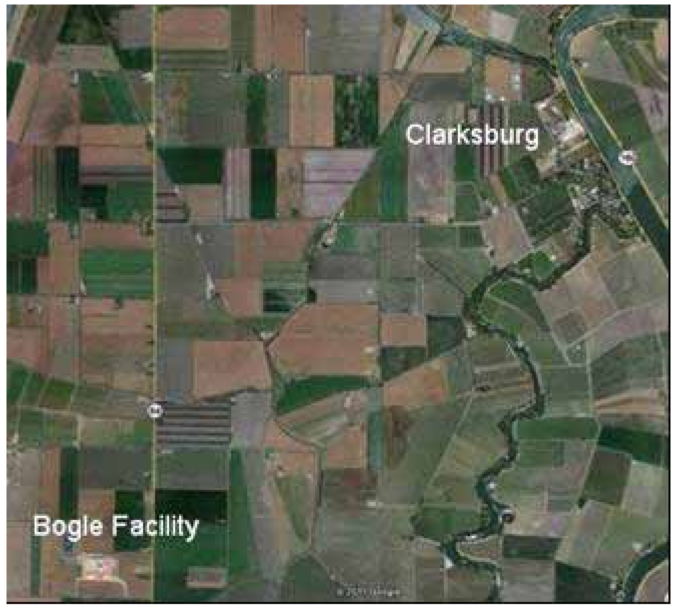
The project gained municipal approval from Yolo County in 2006. However, approval was also subject to the Delta Protection Commission's Land Use Management Plan. The Delta Protection Commission denied project approval in January 2007, citing flood control, residential/agricultural buffers, and residential density issues. According to local stakeholders, the ruling sent a strong signal to the development community and potential project investors concerning entitlement risk in the Primary Zone of the Delta.

Although the residential portion of the site was never constructed, project developers have moved forward with the rehabilitation and adaptive reuse of the sugar mill structure for commercial uses. The site is successfully operated today as a micro-winery and event facility. With programming such as the Delta Wine and Art Faire, the Old Sugar Mill has become a well-known visitor attraction and the primary venue for Clarksburg Appellation wine tasting.

2.4.2 Bogle Vineyards Delta Winery

Bogle Vineyards, a Clarksburg-based grape grower and wine maker, is expanding operations in Clarksburg. This development of a new winemaking facility is an important example of how public sector actors can facilitate development in the Legacy Communities. The new Bogle Vineyards Delta Winery facility in Clarksburg is located at the intersection of Jefferson Boulevard and Hamilton Road, outside of the developed town area, as shown in the map below.

Approved by Yolo County in 2010, construction is underway and the first phase is expected to be completed in 2011. Once fully completed, this winemaking facility will handle all aspects of wine production, from receiving and crushing grapes to packaging wine for shipment.



Yolo County streamlined the approval process for Bogle. Specifically, the latest Yolo County general plan designated 100 acres of Clarksburg for agricultural-industrial use. This designation simplified the project approval by negating the requirement for a General Plan amendment and associated environmental review under the California Environmental Quality Act (CEQA). In addition, the County is also considering reducing its development fees, subsidizing marketing efforts, relaxing regulatory standards, and using other methods to attract similar types of investment.[293]

The completion of the Bogle Vineyards Delta Winery will represent an important step in Clarksburg's continued evolution as a wine and food destination. For many years, processing facilities of this type were not easily developed in Clarksburg because of planning and zoning constraints. The facility contributes to the economic sustainability of the Delta by allowing Bogle to process grapes locally, retaining the added value of the final product within the Delta.

2.4.3 Isleton Residential Project

The recent failure of a significant residential project in Isleton demonstrates the potential scale and physical attributes of a sizable development project within the Legacy Communities, while it also reveals the market risk associated with residential development and small business in this area. In 2006, Del Valle Homes of Modesto broke ground on a 650-unit residential project in Isleton. The first phase of development covered forty acres, with plans for 250 single-family homes, which would have doubled the size of the town. The homes were proposed to be approximately 3,300 square feet over three stories, with garages on the ground floor, and situated on narrow lots. As construction on the project began, commercial property owners in Isleton started renovating their retail spaces and new businesses opened.

[293] Initial Study for Bogle Vineyards Delta Winery, Yolo County Planning and Public Works Department, November 2009.

However, by 2007, the economy had turned and Isleton was hit hard. As a result, only 18 of the 250 homes were built and none of these homes was offered for sale. The development project has completely halted, the model homes currently sit empty, and there are no known plans to resume the project. In addition to losses incurred by the developer, the failure of this project has negatively impacted the communities, as many of the newly opened stores have closed.[294] Although there are many reasons for this project's woes, its failure demonstrates the notion that new home developments in the Legacy Communities should fit the scale, character, and market of the local area.

3 Economic Development Potential

As the Delta evolves as a place, there are likely to be numerous opportunities for the Legacy Communities to progress toward improved economic sustainability. However, these communities also face a variety of challenges and constraints that must be addressed. This section explores the potential prospects for economic prosperity in the Legacy Communities, with detailed consideration of the current limitations to growth and revitalization.

The Legacy Communities are largely a product of their environment, having developed over time along with the agriculture- and recreation-based economy in the Delta. Agriculture will likely remain the dominant economic sector in the Delta (see Chapter 7: Agriculture) and the Legacy Communities will continue to serve as economic hubs for agricultural workers and a variety of agriculture-related businesses. Looking forward, there will likely be opportunities for the Legacy Communities to continue to diversify their agriculture-related goods production and services and can look to the recreation sector as a significance contributor to the economic development potential of the Legacy Communities in the future. Delta recreation will strengthen and diversify in the future, as urban populations in Northern California increase. Under a baseline scenario, the Economic Sustainability Plan recreation analysis indicates potential for a 35 percent increase in recreation visitation to the Delta by 2050. Building on this growth potential, the recreation analysis presents potential recreation development strategies to diversify recreational offerings in the Delta (see Chapter 8: Recreation).

The Legacy Communities must also diversify business activities to satisfy the demands of visitors to the Delta. The Delta offers an array of scenic, historic, recreational, and agricultural attractions that if developed and marketed appropriately, could serve as an economic development driver in the Legacy Communities. For example, in areas where compelling recreation opportunities are proximate to Legacy Communities (e.g., Delta Meadows near eastern Walnut Grove and Locke), there are likely to be opportunities to develop visitor-targeted services and market a compelling tourism package. All of the Legacy Communities hold substantial potential in this regard. Recognizing the tremendous potential for recreation to catalyze growth in the Legacy Communities, this section focuses on strategic economic opportunities related to Delta recreation as well as overarching improvement concepts for the Legacy Communities.

3.1 Economic Development Opportunities

This section considers potential economic development opportunities in the Legacy Communities, including lodging and visitor amenities, historic preservation, design and planning improvements, and event programming (e.g., festivals and heritage celebrations). While this section offers some specific recommendations that align with and build upon some of the recreation recommendations in Chapter 8, economic sustainability in the Legacy Communities

[294] City of Isleton and local real estate brokers

requires that planning efforts adapt and evolve over time. Factors affecting strategic planning include changing agricultural crop and production activities, the emergence of enhanced recreational opportunities, improved flood protection, demographic changes, and shifting market preferences.

Assuming that economic development opportunities in the Legacy Communities are generally limited to the current community footprints and logical extensions thereof, there are a multitude of opportunities and options for improving community gateways, connecting community anchors, rehabilitating and repurposing historic structures, and undertaking selective infill development projects to expand and diversify the local economy. These initiatives will involve the public and private sectors, with the public sector focused on securing infrastructure funding and ensuring workable land use policies, and the private sector deploying a combination of public and private sector financial resources with the intent of receiving returns commensurate with prevailing levels of risk.

3.1.1 Lodging and Visitor Amenities

There are very few lodging opportunities within all of the Legacy Communities. Although the Ryde Hotel is a historic landmark and local institution, it has reportedly struggled in recent years, despite strong revenue generation from weddings and other events. The only other formal lodging facilities within the Legacy Communities are in Isleton, and according to local sources, these motels are struggling as well. Altogether, the Legacy Communities offer fewer than 100 hotel rooms, none of which are modern or managed by major hospitality companies. While attracting more viable options for overnight lodging would help to bring additional people to the Delta, it would also present the opportunity to capture a much greater share of visitor spending.

The lack of new hotel rooms in the Legacy Communities reflects the risks associated with the development and operation of new lodging assets. While a major hotel or resort with modern amenities (e.g., personal services, retail offerings, etc.) would elevate the stature of the Delta, investment risks associated with uncertain market demand and project entitlement deter major hospitality groups from pursuing such projects. Further discouraging hospitality investments, the Delta has not been organized, branded, or marketed competitively within the region. Given current economic and policy conditions in the Delta, it is unlikely that major hotel or resort proposal will emerge within the next decade.

The seclusion of the Delta has become one of its main selling points, with restrictive permitting practices and challenging economic conditions creating a somewhat “sleepy” setting, contributing to the Delta’s mystique. As a result, opportunities exist to leverage the authentic historic character of the Legacy Communities, which attract a consumer segment that values unique cultural assets over national brands. Bed and breakfast lodging and campsite business opportunities are therefore realistic alternatives to more risky and expensive hotel or resort projects, though longer-term opportunities for such investments still exist, depending on local sentiments about growth and land use, as well as required entitlement and flood protection improvements.

The introduction of additional restaurants and other visitor-serving uses, integrated within key activity nodes, would be a natural fit as the Legacy Communities grow and diversify, though local stakeholders have emphasized the need to protect existing businesses by avoiding head-on competition to the extent possible. While a number of small museums and interpretative centers are in operation, economic development efforts could promote additional visitor-oriented centers (e.g., Delta Discovery Center), possibly highlighting local food and agriculture, ecology and the environment, water infrastructure, or other local interest topics, making use of advanced-technology exhibits that capture the interest of families and a broad range of visitors.

Presenting (siting and designing) visitor amenities in a coordinated way throughout the Delta would go hand in hand with a concerted effort to increase the number of lodging rooms or other overnight accommodations. Increasing the number of overnight stays would greatly improve average visitor expenditures throughout the Delta, enhancing economic performance and long-run sustainability for the Legacy Communities.

3.1.2 Historic Preservation

There are many opportunities throughout the Delta to retain its rich history and to leverage distinctive architectural assets to attract visitors and generate economic benefits. Significant historic structures should be preserved and restored so that these exceptional resources are not lost forever. In particular, there is a tremendous opportunity for businesses in Locke to capitalize on the town's unique history and cultural value. By systematically restoring existing historic structures and enhancing opportunities for visitors to learn about and experience the area's heritage, while also raising its profile through marketing and branding efforts, Locke can be elevated as a tourist destination. In addition, the establishment of a National Heritage Area (NHA) that encompasses the Legacy Communities would generate specific benefits for historic preservation (see Chapter 8: Recreation).

3.1.3 Event Programming

Community events such as festivals and heritage celebrations are good opportunities to instill civic pride in Legacy Community residents and to raise the profile of the area to visitors from outside of the area. Although community events do currently occur in the Legacy Communities, they mostly draw from a shallow market and rarely spur multi-day tourist visits. Enhancing, growing, and strategically marketing events in the Legacy Communities presents an opportunity to capture increased tourism and spending, generating more economic activity to support businesses in the Legacy Communities.

While the Delta Chambers and individual event promoters currently publicize events throughout the Delta region, events and other programs in the Legacy Communities should be coordinated with an overarching marketing and branding strategy. Coordinating Delta branding and marketing will be crucial to expanding the current market penetration of Delta events, ideally attracting more visitors from San Francisco, Oakland, San Jose, and other major northern California cities to the Delta for longer stays, including overnight visits. A good example of regional tourism promotion is found in Monterey County, where the Convention and Visitors Bureau does an excellent job promoting regional tourism to specific market segments though various media channels, including the internet, radio, and television.

3.2 Economic Development Constraints

The potential for private sector economic development activities to be undertaken in the Legacy Communities is directly tied to risk-reward tradeoffs, as compared with alternative investment options. The quantification of risk and ability to generate enough revenue to satisfy a minimum threshold rate of return (or discount rate[295]) associated with that risk is the primary determinant in an investor's decision to move forward with a project. Factors specific to Legacy Communities that affect the magnitude and certainty of investor return are discussed below in the context of catalyzing small-scale infill development that can bring additional housing, services, and amenities to existing communities and facilitating the recreational concepts contemplated by the Economic Sustainability Plan (see Chapter 8: Recreation), through the development of lodging, restaurants, and other visitor-related amenities. This section considers a variety of potential project risk factors in the Legacy Communities, including location, entitlement, market, financing, development, infrastructure, flood control, transportation, utilities, and communications characteristics.

3.2.1 Land and Location Characteristics.

Current land use management in and around the Legacy Communities ensures that greenfield land development potential will be very limited. Though there may be some unique exceptions, the regulatory limitations on land use force new development to infill development opportunities, primarily within the Legacy Communities. Infill development in this context brings a slew of specific development challenges, including:

- Irregularly-shaped parcels that complicate building design and construction
- Aged or insufficient infrastructure that requires upgrades
- Sub-surface issues (e.g., contamination) that may be poorly documented and costly
- Floodplain building requirements (e.g., elevated foundations) that complicate design[296]
- Challenges associated with renovating historic structures that increase project costs
- Financing for small-scale mixed use projects in untested markets that is very limited

Given these challenges and the generally high degree of complexity and uncertainty associated with infill development in the Legacy Communities, it will take a dedicated development team, and likely public sector partners, to successfully complete meaningful infill development projects that benefit the local economy.

3.2.2 Entitlement Characteristics

The risk characteristics of project entitlement in the Legacy Communities indicate that this is among the most risky investment climates for a real estate developer in the U.S. This characterization is primarily a function of the arduous entitlement process in the Primary Zone, in combination with instances of community opposition to growth within the Legacy Communities. The entitlement process for a project in a Legacy Community is extremely complex and time consuming. In some cases, approvals extended by a County may be overruled by the Delta Protection Commission, and involvement with multiple regulating agencies (e.g., U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, state government, county government, etc.) is expected for larger projects. The risk of being "bounced" between multiple agencies during the entitlement process was showcased in the recent rejection of the residential portion of the Sugar Mill project in Clarksburg.

The diagram below (Figure 41) represents a typical project entitlement process in the Primary Zone portion of Sacramento County and identifies potential areas that could add additional time and risk to an already lengthy process. As a project proponent develops conceptual plans,

[295] The discount rate is the targeted internal rate of return on an initial investment that accounts for all inherent project risks.
[296] National Flood Insurance Program (FEMA)

proactive input from both the Local Community Councils and the Delta Conservancy are recommended to align the project direction with Community Plans and the Conservancy's legislative concerns. In addition, there may be additional input from community associations as in the case of Locke, or historic preservation requirements.

Following the initial input, the project will undergo the county approval process. This multi-layered procedure includes input from multiple local, county, and state agencies and includes pre-submittal review, initial review, applicant response, environmental documentation (CEQA), public hearings, appeal procedures, and determination. Approval is also subject to the requirements of the DPC's Land Use and Resource Management Plan.

As part of the Delta Plan, the Delta Stewardship Council (DSC) is proposing a new layer of project review and approval in the Delta. The Draft Delta Plan refers to "covered actions", projects which would receive additional scrutiny to determine their consistency with the State's coequal goals for the Delta. Determination of covered actions and DSC review are currently being developed and the ultimate requirements of the Delta Plan will have great impact on the length and financial risk associated with project proposals. For example, it is contemplated that the completion of CEQA documentation, a lengthy and costly process, may be necessary prior to DSC review and a subsequent 30-day appeal window, creating a major risk for potential investors. In addition, it may be that determination of a covered action requires a county board of supervisors calendar item, a condition that will greatly increase the burden of the process, as compared with determination at staff level. There is also the question of whether this determination will require a public hearing. While the number of non-local agencies involved with permitting is consistent with other natural areas in California, it is far greater than in typical infill locations. Together, these entitlement processes create risks associated with increased permitting time, expense, and success probability.

Box 7 Improving the Entitlement Process: A Brief Case Study of Lake Tahoe

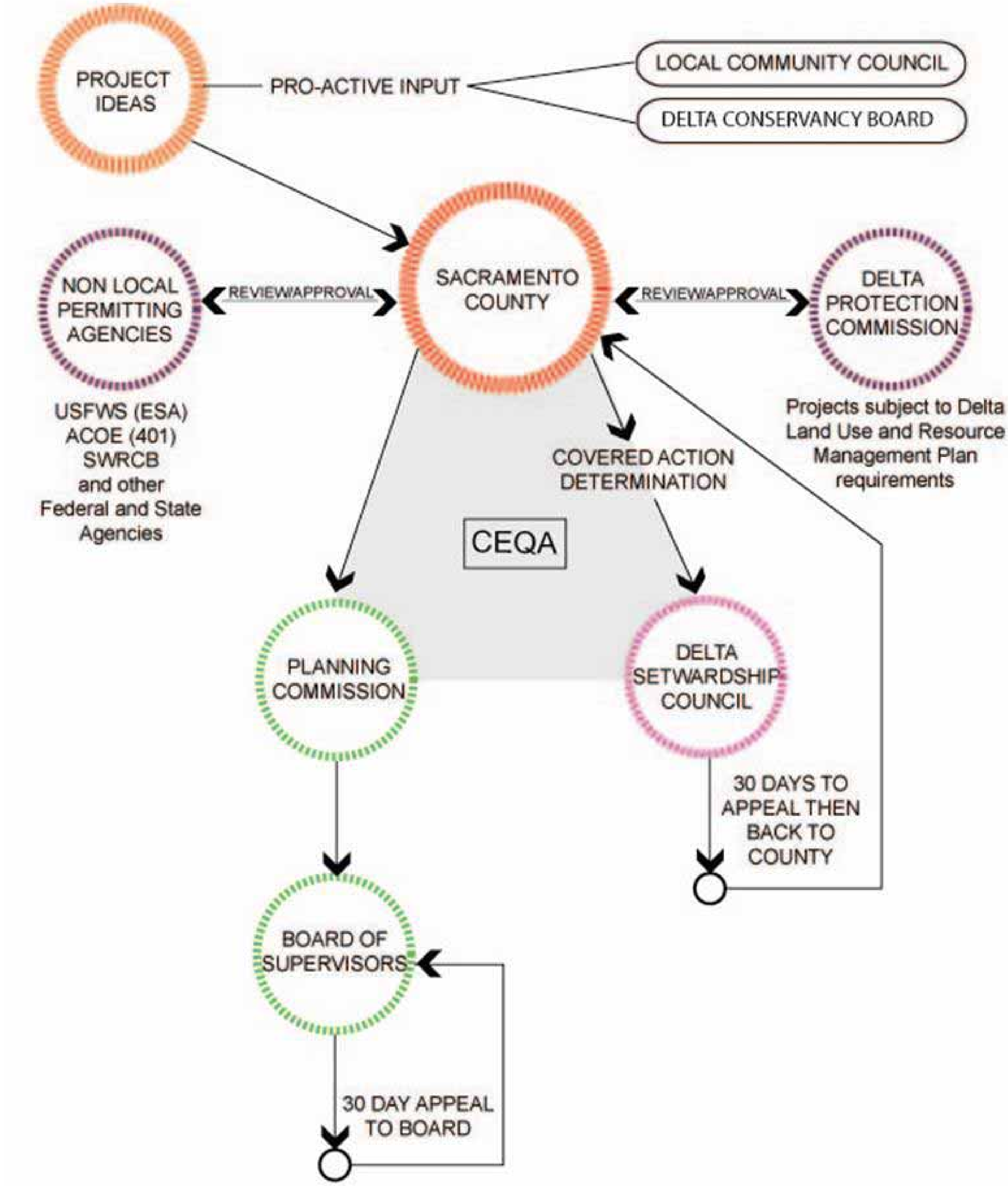
The entitlement dynamic in the Primary Zone of the Delta is a very powerful deterrent to investment. As has been demonstrated in the Lake Tahoe area, the approval uncertainty involving both county governments and the Tahoe Regional Planning Agency (TRPA) has effectively curtailed development of visitor accommodations and other investments along the North Shore of Lake Tahoe over decades, resulting in a motel room stock with an average age of 50 years, despite immediate proximity to a world-renowned natural resource attraction (according to Smith Travel Research and Economic & Planning Systems, Inc.). This uncertainty stems largely from two key factors that are comparable within the Delta. First, the TRPA and the counties' development regulations are developed from distinct mandates, and although they are intended to be coordinated, language in the codes that is subject to interpretation or is not clearly directive is interpreted by each agency under their own filter sets. Second, as each agency updates its regulatory policies, coordination within the two agencies continually lags as a result of update timelines, staffing, processing, and other factors.

In the case of Tahoe, steps are presently being taken to reform the development approval process to allow projects that use best management practices (BMPs) that minimize environmental impacts (e.g., storm water runoff), advanced infrastructure systems, and planning concepts that cluster development in a village format, protecting viewsheds and public access to the Lake.

As part of a pilot project program, projects that adhere to these key elements have an opportunity to receive coordinated development approvals and avoid the "whipsaw" effect resulting from inconsistent standards among disparate agencies. While this process is still being refined in Tahoe and is subject to an ongoing debate between various interests, it does indicate a potential direction for the DPC, counties, and other regulators in the Delta. Clear delineation and consistent interpretation and enforcement of entitlements will immensely improve prospects for attracting investment, even if these regulations remain appropriately stringent.

It is also notable that most of the local Community Plans were prepared in the 1980s and their CEQA documentation is in need of updating. As a result, coordination between the Community Plans, Conservancy concerns, DPC and DSC requirements, and other agencies is likely to be problematic for project proponents. While many project approvals require this type of inter-agency coordination, coordination with the DPC and potentially DSC is significantly beyond what would be required in areas outside the Delta, and thus presents additional potential stumbling blocks and risk.

Figure 41 Framework for Project Approval in Unincorporated Sacramento County/Primary Zone



Updated planning and associated CEQA documentation will help to improve coordination and reduce development risk in the Legacy Communities. A Programmatic Environmental Impact Report (EIR) for the Community Plans should be considered. A Programmatic EIR may be prepared on a series of actions that can be characterized as one large project (i.e., related by geography, actions, rules, regulations, plans, or other general criteria) or as individual activities under the same statutory or regulatory authority and having generally similar environmental effects which can be mitigated in similar ways.[297] Use of the Program EIR enables the Lead Agency to characterize the overall program as the project being approved at that time. When individual activities within the program are proposed, the lead agency is required to examine the individual activities to determine whether their effects were fully analyzed in the Program EIR. If so, these may be categorically exempt from further environmental review. If not, additional review may be necessary.

The ability to consolidate the concerns of multiple agencies and organizations within a comprehensive environmental document is a valuable tool used by numerous regulatory agencies to provide clarity and certainty in evaluating development proposals. A simplified, streamlined entitlement process is needed to encourage investment and economic development. However, changes to the entitlement process, as with other aspects of promoting growth and diversification in the Legacy Communities, should be vetted and refined through an extended community outreach processes, to ensure that local support for candidate projects is in place.

3.2.3 Project Planning and Market Concerns

Given the unique nature and small scale of potential infill development in the Legacy Communities, many of the typical market demand metrics used by developers and investors, such as regional economic projections and standard real estate market analysis techniques are of limited value. In the Legacy Communities, development opportunities are fine-grained and require dedicated “champions” to see through well-conceived and appropriate concepts. In many cases, success or failure relies on the quality of the project proponent to a greater degree than economic fundamentals (though the current economic environment is prohibitive).

Development that occurs in the Legacy Communities will likely occur “organically,” evolving in small increments over the mid- to long-term, with very few opportunities for large master-planned concepts.[298] With limited population densities around the Legacy Communities, many typical urban consumer services are not economically feasible (e.g., standard-format shopping centers with supermarkets and related in-line shops generally require at least 3,000 dwelling units). As such, the mainstream real estate development industry is likely to bypass the Delta, based on the inherent market risks, including constrained growth potential and seasonality concerns. Meaningful investment and economic diversification through infill development will most likely be brought about by local economic developers that are interested in improving the community in addition to turning a profit.

Development in this context often requires a public-private partnership, where strategic public investments are made in coordination with private-sector catalyst projects, with a shared vision of future community form and function. While there are numerous examples of successful public-private real estate projects, a very small slice of the development community possesses

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[297] CEQA Guidelines § 15168(a)(b)

[298] The 20-year evolution of 4th Street in Berkeley by developer Denny Abrams is a good example of “organic development” in which a local developer with a long-term vision and dedicated to a parcel-by-parcel approach often subsidizes specific users to achieve ideal land use/tenanting mix.

the skills, dedication, and interest in engaging in this type of development. Further, public agencies presently lack the financial resources to expand redevelopment efforts or fund infrastructure and public services.[299] However, establishment of an investment fund for economic development could successfully attract developers to partnership projection. For this approach to work, public agencies would need to clarify the over-arching vision of the Delta, including the Legacy Communities. Currently, the lack of public sector coordination in the Delta undermines the public perception of the region, limits market potential, and hinders investor interest in the region.

3.2.4 Development Financing

Construction and financing issues are closely related to the entitlement risks discussed earlier in this section. In particular, the requirements for new development in a floodplain are particularly burdensome. These costs include flood insurance and the cost (and likely infeasibility) of raising foundations above base flood elevations in established, urbanized areas.

Alternatively, levee improvements that reduce flood risks are also staggeringly high (see Chapter 5 for detailed discussion of Delta levees). With costs which might be as much as $5 million per mile,[300] to upgrade levees and protect Legacy Communities from the 100-year flood event, it is clear that local real estate development ventures and existing businesses and residents cannot carry the cost of such improvements solely through local reclamation districts.

This issue demands further consideration and is described further in section 3.2.6 below. Development financing requires that flood risks be addressed. Without undesirable project modifications or further investment in levees or relief from excessive regulatory requirements, financial institutions cannot support development in the Legacy Communities.

3.2.5 Investment and Development

For a land development project entailing substantial complexity and risk, a required return on investment (also known as a “discount rate”)[301] will typically be in the range of 15 to 25 percent or more. The table below provides an example of a typical discount rate summary sheet that an investor might consider in attempting to quantify the potential return on investment.

[299] In this regard, the concept of facilitating additional workforce housing must be tempered with the reality that adequate social and public safety services may be difficult to maintain in an unincorporated area.
[300] Personal communication with Bob Pyke, consulting engineer.
[301] Expressed as an internal rate of return (IRR).

Table 55 Discount Rate Requirements

Risk Type	Risk Premium Range	Pertinent Issues in Legacy Communities	Estimated Risk Premium [1]
Land and Location Characteristics	2-10%	Removed from urbanized areas, lack of infrastructure, environmental issues, etc.	8%
Entitlement Risks	0-10%	Extremely complex entitlement process	8%
Project Planning Risks	2-10%	Inflexible zoning; reduced ability to respond to market fluctuations	8%
Development/ Construction Risks	2-6%	Flood risks, environmental issues, etc.	5%
Financing Risks	1-6%	Case specific; conservatively assumes low-level financing risks	6%
Market Risks	1-10%	Lack of market area growth, poor performance of previous projects	8%
Cash Flow Projection Risks	(2)-5%	Case-specific; conservatively assumes low-level cash projection risks	2%
Base Discount Rate		T-Bond with 10 year maturity, (September, 2011)	2%
Total Estimated Risk Premium	**6-57%**		**47%**

[1] These values are provided as high-level illustrative estimates.
Source: Economic & Planning Systems, Inc.

Risks and uncertainties associated with infill development in the Legacy Communities are clearly at the high end of the spectrum, putting the required rate of return for development well outside the typical range of 15 to 25 percent. With a concerted effort to mitigate identified problems, however, Legacy Community projects could become more reasonable investments, attractive to patient and insightful developers interested in community development, particularly if strongly backed with public funding and coordination on infrastructure, flood control, and other key issues.

3.2.6 Flood Control

Establishing adequate flood protection is a crucial issue which severely constrains development in the Delta. New development must be protected from 100-year flood risk or meet strict building requirements that limit potential damages from a flood event.

3.2.6.1 The National Flood Insurance Program

The National Flood Insurance Program (NFIP) is administered primarily under the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973 (FDPA). The FDPA made the purchase of flood insurance mandatory for the protection of property located in a Special Flood Hazard Area (SFHA) in participating communities. The Act of 1973 expanded the NFIP by increasing limits of coverage and the aggregate insurance authorized by establishing requirements for communities that wish to participate in the program. In 1979, the Federal Emergency Management Agency (FEMA) was established as an independent agency, absorbing the Federal Insurance Administration and the NFIP.

Today, nearly 20,000 communities across the United States participate in the NFIP. By adopting and enforcing floodplain management ordinances that reduce the potential for severe flood damage, communities qualify local homeowners, renters, and business owners for federally-backed flood insurance. For a community to enter the program, FEMA must conducts a Flood Insurance Study (FIS) which analyzes river flows, storm tides, hydrologic/hydraulic factors, and rainfall and topographic surveys. FEMA then uses these data to create the flood hazard maps that outline a community's different flood risk areas. Once FEMA provides a community with the flood hazard information upon which floodplain management regulations are based, the community is required to adopt a floodplain management ordinance that meets or exceeds the minimum NFIP requirements. The purpose of the floodplain management regulations is to ensure that participating communities take into account flood hazards, to the extent that they are known, in all official actions relating to land management and use.[302]

FEMA has determined that several areas within Sacramento County, including Walnut Grove, Freeport, Hood, Courtland, Locke, and Delta Islands will be affected by revised flood insurance maps. FEMA recently remapped Yolo County, de-accrediting levees that protect Clarksburg. Currently, in Sacramento County, unless a developer with a pending or proposed project agrees to construct above the base flood elevation, as required by the County's Floodplain Management Ordinance, staff cannot approve the issuance of a Floodplain Management Permit for projects in decertification areas. Commercial and industrial projects may be considered below the flood hazard elevation on a case-by-case basis, if designed in a manner deemed to be flood-proofed. All new homes and substantial improvements or repairs must be elevated above the flood hazard.[303]

There are special considerations for levees that protect Legacy Communities in the Delta (see Appendix D). Detailed estimation of the likely cost of improving those levees awaits policy decisions that have not yet been made. However, if the levees on the relevant islands are upgraded to the proposed new Delta standard recommended by the ESP (see Chapter 5), the Legacy Communities, and also industrial/commercial facilities that serve Delta agriculture such as wineries and cold storage facilities, would automatically be afforded superior flood protection and special "ring levees" should not be required. In many cases superior flood protection is already provided to these communities and facilities by the existing project levees. For instance, the project levee that borders the Sacramento River in eastern Walnut Grove already has a wide crown, exceeding 50 feet at some locations, in order to accommodate a two-lane highway with parking on either side. While some additional improvements might be required elsewhere to protect Legacy Communities, the issue is more attributable to non-compliance with vegetation, encroachment, and calculated seepage gradient requirements than real flood risk. FEMA compliance issues could likely be addressed much more cost effectively through variances from federal standards than construction, which has the potential to destroy the communities these plans are created to protect.

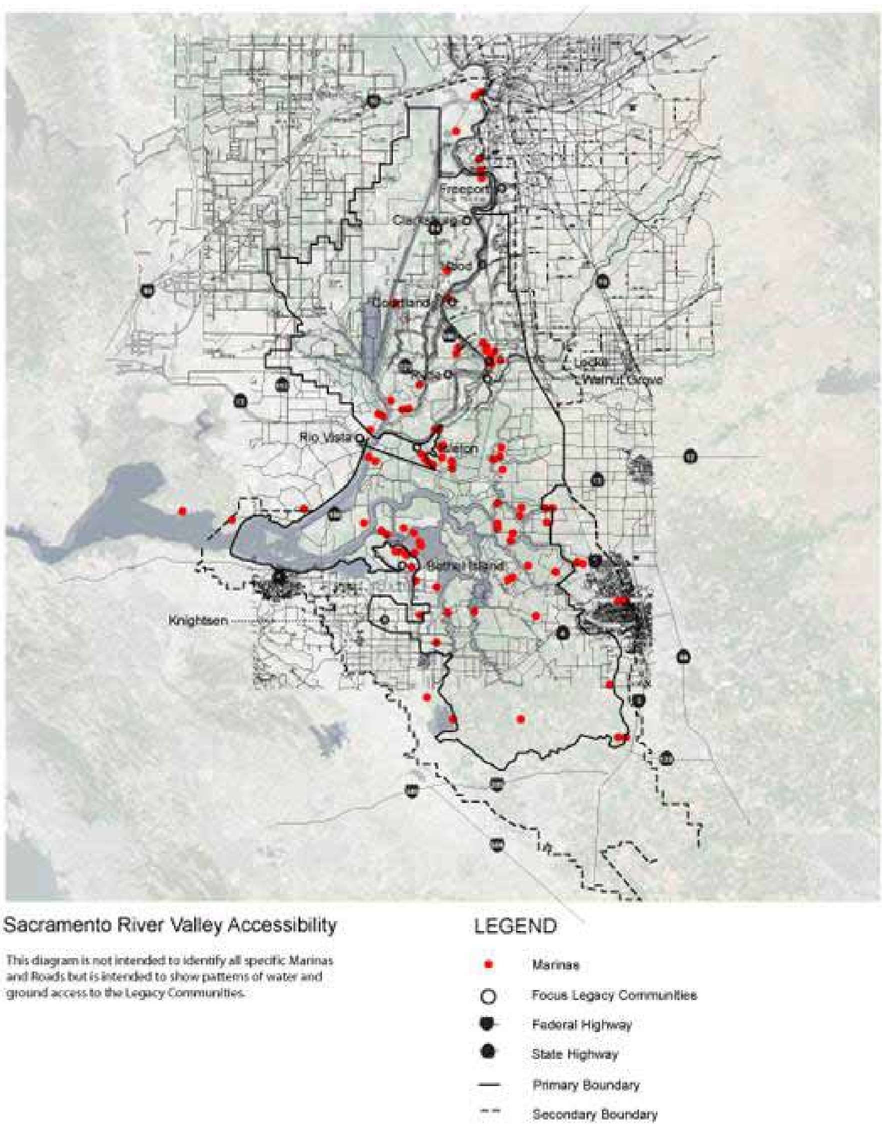
3.2.7 Transportation and Access

By land, access to the Legacy Communities is constrained. Local levy roads are narrow and dangerous. Generally, these roads cannot be widened without substantial costs. Access to the

[302] FEMA (http://www.fema.gov/about/programs/nfip/index.shtm)
[303] "Substantial improvement" (as defined by FEMA) refers to any reconstruction or improvement of a structure, the cost of which equals or exceeds 50 percent of the market value of the structure. However, substantial improvement does not include either (1) any project for improvement of a structure to comply with existing state or local health, sanitary, or safety code specifications which are solely necessary to assure safe living conditions or (2) any alteration of a "Historic Structure."

Legacy Communities is more limited by water, as boat launch locations and short-term slips for visitor docking appear to be undersupplied. While transportation and access to the Legacy Communities does not seem to be a primary constraint for economic development today, it is important to recognize that limitations in this area do affect investment decisions and that future growth could require significant investments in transportation and access. In some instances, transportation and access improvements could spur investment, though additional study is required to identify such strategic transportation and access projects.[304]

Figure 42 Sacramento River Valley Accessibility[305]



[304] Infrastructure in the Delta is addressed in detail in Chapter 9.
[305] For high resolution image see http://forecast.pacific.edu/desp-figs.html

Box 8 Case Study Framework Examples: Sutter Creek and Winters

Other communities in the region have newly created (or in some cases longstanding) programs and policies that lend themselves to establishing a "brand" or strategic direction that contributes to economic sustainability, community vitality, and civic engagement on the part of residents and visitors alike. As a result, these communities are thriving, small-scale, functional towns that serve as local and regional hubs of activity.

Sutter Creek and Winters, discussed below, might serve as models for economic and cultural enhancement in the Legacy Communities. These distinctly different communities, in dissimilar physical settings, point to directions in which the Legacy Communities could possibly evolve and remain viable into the future.

Sutter Creek in Amador County, California (population 2,500) has established a co-brand with other nearby towns in the Gold Country as well as with California's "Golden Chain Highway 49." Sutter Creek has been able to capitalize on its historical roots, developing as a retail and service hub for residents and visitors. Some key elements of the town's success include the following:

- Well-preserved architecture
- New development that complements existing buildings in the historic core
- Clean public and private realms
- Amenities include post office, retail, and restaurants
- Walkable streets
- Active business association
- City-sponsored website and Facebook page
- Comprehensive marketing efforts promoting festivals, events, attractions, and destinations
- Brand focus on tourism, wine, and antiques
- Regularly occurring, year-round community programming

Main Street, Sutter Creek, CA

Winters, in western Yolo County, California (population 6,600) is cultivating a brand centered on wine, slow food, and agriculture. Regionally-acclaimed eating and entertainment establishments such as the Buckhorn Steakhouse restaurant and Palms Playhouse are popular with locals and visitors alike, and attract clientele from throughout the region. Some key elements of the town's success include the following:

- Quality historic preservation
- Redevelopment efforts including streetscape, park, pedestrian bridge
- Walkable streets
- City-sponsored website, Facebook page, and Twitter account
- Brand focus on food, agricultural heritage, and wineries
- Economic Advisory Committee
- Numerous local events (e.g., Tempfest, Plein Air Festival)

Main Street, Winters, CA

3.2.8 Water and Sewer

Many of the Legacy Communities suffer from inadequate water and sewer infrastructure facilities. For example, Clarksburg has no regional sewer or water infrastructure. Instead, each developed parcel in Clarksburg is served by its own well and septic system. This condition prevents sustainable development of the community in the long term, primarily in terms of potential effects on public health and water quality.

There are no plans to provide municipal services to the community. If any meaningful development is to be implemented in the future, the issue of sewer and water services must be solved, which is a significant barrier to growth. Water and sewer limitations were significant issues in the planning of the Old Sugar Mill and Bogle Delta Winery projects, although these issues were ultimately resolved through the engineering and design of expanded wells, self-contained wastewater treatment facilities, packing plants, and other methods.

The western portion of Walnut Grove is served by California American Water and the eastern portion is served by Sacramento County Water Agency, as is the community of Hood. The entirety of Walnut Grove, Courtland, and Locke are served by the Sacramento County Sewer District for wastewater services. With water and sewer service in place, these Legacy Communities are somewhat better positioned for new development.[306]

3.2.9 Telecommunications

Currently, the cellular telephone coverage is inconsistent throughout the Delta, although service providers are reportedly working to enhance their service. In addition, internet access in most Delta communities is very limited, which prevents certain businesses and "telecommuters" from operating and working in some areas of the Delta. Where limitations exist, improved digital connectivity would be significant step in enhancing the economic competitiveness of the Legacy Communities.[307]

4 Overarching Implementation Strategies

There are a number of overarching economic development strategies that apply to all Legacy Communities which should be carried out in order to enhance the prospects for economic sustainability in the Delta.

Investment Fund. The "Delta Investment Fund" has been established to help achieve economic development goals in the Primary Zone, although funding sources have not been secured at this time. Moving forward, financial resources should be directed to key initiatives that will enhance economic activity. Priority uses of this funding might include infrastructure improvements, gap funding for catalytic development projects, economic development assistance, and marketing/branding efforts.

Strategic Levee Protection. Obtaining adequate flood protection is of the utmost importance to fostering economic sustainability in the Delta. Although costly, new and improved levees will encourage investment and reinvestment in some Legacy Community areas where flood protection is currently inadequate. Strategic levee enhancements to protect key assets should be carried out using any existing or new funding sources.

[306] Ibid.
[307] Ibid.

Streamlined Entitlement Process. As discussed throughout this chapter, the complex, multi-jurisdictional entitlement process severely limits the ability for new projects to be brought to market. A more transparent, understandable, and predictable entitlement process would greatly reduce the risk in new economic endeavors in the Primary Zone. Technical assistance and the creation of an "entitlement handbook" for prospective investors (to assist in evaluating potential projects) would facilitate project evaluation, planning, and development.

Historic Preservation. The Legacy Communities offer a unique sense of place and history that should be preserved for future generations. However, as structures age and communities decline, reinvestment and new investment in real estate assets is critical to economic sustainability. Development projects that are consistent with the existing community fabric should be encouraged, particularly as a strategy to retain and recruit businesses in the Legacy Communities.

Coordinated Economic Development. Although many economic development initiatives are already underway in the Delta, these efforts (along with new initiatives) should be coordinated in a systematic way that will maximize the benefit to the area as a whole. A singular "facilitator organization" should be designated responsibility for planning, coordinating, and managing economic development efforts. One key component of this effort should be a coordinated, highly-visible branding campaign that is used to raise the profile of the Delta and its constituent communities for the purposes of tourism and agricultural enhancement. In addition, helping to secure tax incentives and other local and regional economic development tools should be part of this organization's charge.

5 Focused Evaluation of Clarksburg, Walnut Grove, and Locke

In this section, the Economic Sustainability Plan considers three Legacy Communities in detail, providing an overview of each community, a potential "vision" for the future, and specific economic development goals that are consistent with the vision. The assessment focuses on Clarksburg, Walnut Grove, and Locke, three distinct communities that generally reflect the broad range of community typologies found in the Primary Zone of the Delta.

5.1 Clarksburg Overview

This overview considers the history and socioeconomics within the Legacy Community of Clarksburg.

5.1.1 History

Like other towns on the Sacramento River in the Delta, Clarksburg grew to serve the early farmers who arrived shortly after gold was discovered in 1849. Historical accounts of Clarksburg indicate that it was settled in stages beginning as early as 1850. Farmers and hunters built homes on pilings or boats to survive the continual flooding of the area. Immigrants flocked to California from the United States, Europe, and later from Asia. To get to the gold fields from San Francisco, early "49ers" traveled by boat up the Sacramento River, observing the vast rich areas of the Delta along the way. In Clarksburg, the first settlers included Josiah Green on the upper end of Merritt Island and a Portuguese settlement on the lower end of Lisbon Tract. Green purchased property from an agent in San Francisco and arrived to find the land flooded. Green subsequently built levees around his property, reportedly the first reclamation project in the Delta.[308]

[308] Background Report on Land Use and Development, Delta Protection Commission, 1994.

In 1916, the Holland Land Company refinanced the holdings of the failed Netherlands Farm Company, located their headquarters just outside Clarksburg, and built levees, canals, roads, bridges, power lines, and more than 90 buildings.[309] The property was subdivided and sold for farming. Sugar beets were the primary crop on the Holland Tract, and Clarksburg quickly became a commercial and social center in the area. The Sugar Mill refinery was constructed in 1934-35 and was the primary economic center of the community until it stopped operations in 1993 and finally closed in 1990.

During its sugar beet farming period, Clarksburg grew into a complete community, with schools, churches, a library, a fire district, retail businesses, as well as a wide array of civic organizations. The building stock in Clarksburg still reflects the community's history and growth patterns, with older homes and structures located adjacent to the levee and more recent development adjacent to the agricultural lands. At the heart of the community are the Delta Elementary Charter School, Clarksburg Middle School, and Delta High School. At each end of the community are industrial lands, with the Old Sugar Mill to the north and Ramos Oil to the South. The commercial district is concentrated on Clarksburg Road, between South River Road and Willow Avenue.

5.1.2 Socioeconomics

Today, the area that comprises the Clarksburg Census Block Groups contains approximately 1,275 people. Though it is a multi-generational community, Clarksburg's population is characterized by an older age profile, with over 30 percent of residents age 55 and up (as compared to approximately 20 percent in the Legal Delta). The residents of Clarksburg are generally White, with residents identifying themselves as "White alone" making up approximately 91 percent of the population (significantly higher than the 57 percent in the Legal Delta). Household income in Clarksburg is similar to that of the Legal Delta at about $81,000 per year.

Although 18 percent of Clarksburg residents work in Clarksburg, over four out of five working residents commute to work elsewhere. The labor force residing in Clarksburg commutes to various locations throughout Northern California, most notably, the City of Sacramento. Clarksburg jobs are filled by employees living throughout the region, particularly from Sacramento, Elk Grove, West Sacramento, and Rio Vista. However, 17 percent of Clarksburg jobs are held by residents of the community, which is relatively high proportion compared to the other Legacy Communities.

Following the collapse of the sugar beet processing in the region, Clarksburg's farmers were forced to adapt by growing new crops. Owing to its climate and fertile ground, wine grape production has become very successful in the area. Clarksburg is now a major producer of wine grapes for export and local wine production. With the opening of many local family and corporate wineries and the recent renovation of the Old Sugar Mill as an event center and wine co-op providing a venue for nearby wineries to directly market their products to tourists from throughout the region, Clarksburg is enjoying an agricultural renaissance.

Culturally, Clarksburg has been—and continues to be—home to families that share common community values, particularly related to good stewardship of the land. Volunteer organizations (e.g., fire department), local schools, and churches continue to be central to the community fabric. While many of residents must commute to jobs in Sacramento and other cities, and

[309] County of Yolo, Clarksburg General Plan Historical Perspective.

commercial businesses in town have dwindled over time, the residential community and its local farming traditions continue to thrive in Clarksburg.

5.2 Vision for Clarksburg: A Vibrant Agricultural Community

Clarksburg's primary competitive advantage as a community is its agricultural abundance. This region is known to produce exceptional agricultural products, most notably wine grapes and other wine products, and the culture of the town is very supportive of this agricultural heritage. Continued community sustainability in Clarksburg will depend upon several key factors:

- Because the community is predominantly built out within the Urban Limit Line, and the fact that there is no water or sewer infrastructure, maintaining and upgrading the existing building stock will be essential to maintaining its character and desirability. While many of the residential lots are zoned for multi-family, the density of these properties is low and most sites are already occupied by single family houses. The recent designation of Clarksburg as a deep floodplain creates significant obstacles to residential remodeling and construction. In addition, regulatory hurdles adopted and proposed by the State will further increase costs or prohibit residential development altogether.

- The recent successful appeal of the multi-use (i.e., commercial, industrial, and residential) specific plan proposed for the Sugar Mill site highlights the regulatory uncertainty confronting proposals that include increasing residential density within the Urban Limit Line of an existing primary zone community . The Sugar Mill occupies approximately 35 percent of the land within the Urban Limit Line. This site is the most appropriate for infill development, provided regulatory uncertainties are successfully addressed in the planning process. The community, the county and the State must resolve the vision and policies for this site if it is to be successfully integrated into the community and the Delta region as an agritourism destination.

- A community of this size does not support a local commercial/retail sector as is evidenced by the commercial vacancies and one small local market. In addition, Clarksburg is less than 6 miles from the retail/commercial services at Pocket Road and Meadowview Road in Sacramento. Clarksburg has already begun to establish a local agritourism center in the Sugar Mill representing local, family-owned wineries. To enhance its regional draw, additional overnight accommodations, food and wine venues, and support services should be encouraged. However, unless the regulatory hurdles proposed by the State are successfully addressed, the risks associated with restoration and enhancement of structures will inhibit sustainability.

- Although it has a small private marina, Clarksburg does not have extensive waterfront development along the river. Public investment in enhancing this link has the potential to greatly increase access to the community for the significant numbers of water-based users.

- The 2030 General Plan currently designates the various school sites as Public/ Quasi-Public. If a future consolidation within the school district closes the middle and/or high schools, the community will need to assess the most appropriate use for the site, given the limitations of community infrastructure and services.

- The complete absence of water and sewer infrastructure within the community means that either a project will have to have enough density to create its own treatment facility (as the Old Sugar Mill Specific Plan proposed), or small enough to be served by an on-site septic system. The provision of community-wide infrastructure within the Urban Limit Line would not only facilitate agritourism development, but would also protect the long-term health of residents.

An economically sustainable vision for Clarksburg should build upon the momentum already gained in this key sector, while continuing to selectively add to the suite of local- and visitor-serving amenities in the community. Key tenets of the vision for Clarksburg include the following:

Preserved Historic Character: Clarksburg's established, attractive, and high-quality building stock should be maintained and/or enhanced. Planning should identify adaptive reuse opportunities and assess their potential benefits to the community.

Establishment as a Regional Food and Wine Destination: Over the last 25 years, the Clarksburg region has emerged as a premier Chardonnay-producing area, and the Clarksburg appellation is coming into its own as a high-quality wine grape-growing region. Clarksburg has the potential to become a regional destination by enhancing the current offerings and adding high-quality visitor attractions related to wine, vineyards, slow food, and the "loco-vore" movement.

Enhanced Resident and Visitor Amenities: Opportunities to add a variety of resident- and visitor-serving amenities should be carefully evaluated. Such uses could potentially include retail stores, restaurants, wine tasting rooms, and small-scale lodging (e.g., bed and breakfast establishments).

Increased Value-Added Agriculture Processing: In order to provide jobs and increase personal income created and retained within the community, select value-added processing facilities should be encouraged.

Figure 43 below shows a visionary plan for Clarksburg. Key information and aspects of this vision include the following:

- Clarksburg is primarily a single-family residential community with a strong relationship to agriculture and community institutions. This is supported by its physical layout and focus on organizations such as the charter school, library, churches, and civic groups. There are few vacant lots and there is limited opportunity for additional single-family residential development.

- The primary opportunity in Clarksburg continues to be the Old Sugar Mill property. Accounting for approximately 35 percent of the land area, redevelopment on this property has already created an agritourism destination within a 20-minute drive of Sacramento. This property provides additional opportunities to enhance agritourism with the potential for additional wineries, food services, entertainment, retail, and educational venues.

- Although the application for a multi-use specific plan on the site was blocked, an opportunity for visitor lodgings exists, dependent upon the will of the community and the availability of private investment. This type of use could potentially create a catalyst for additional commercial activity.

- The neighborhood commercial area at the entry to the community on Clarksburg Road is underutilized. There is the opportunity to reposition this area to serve both the residents and visitors to the area.

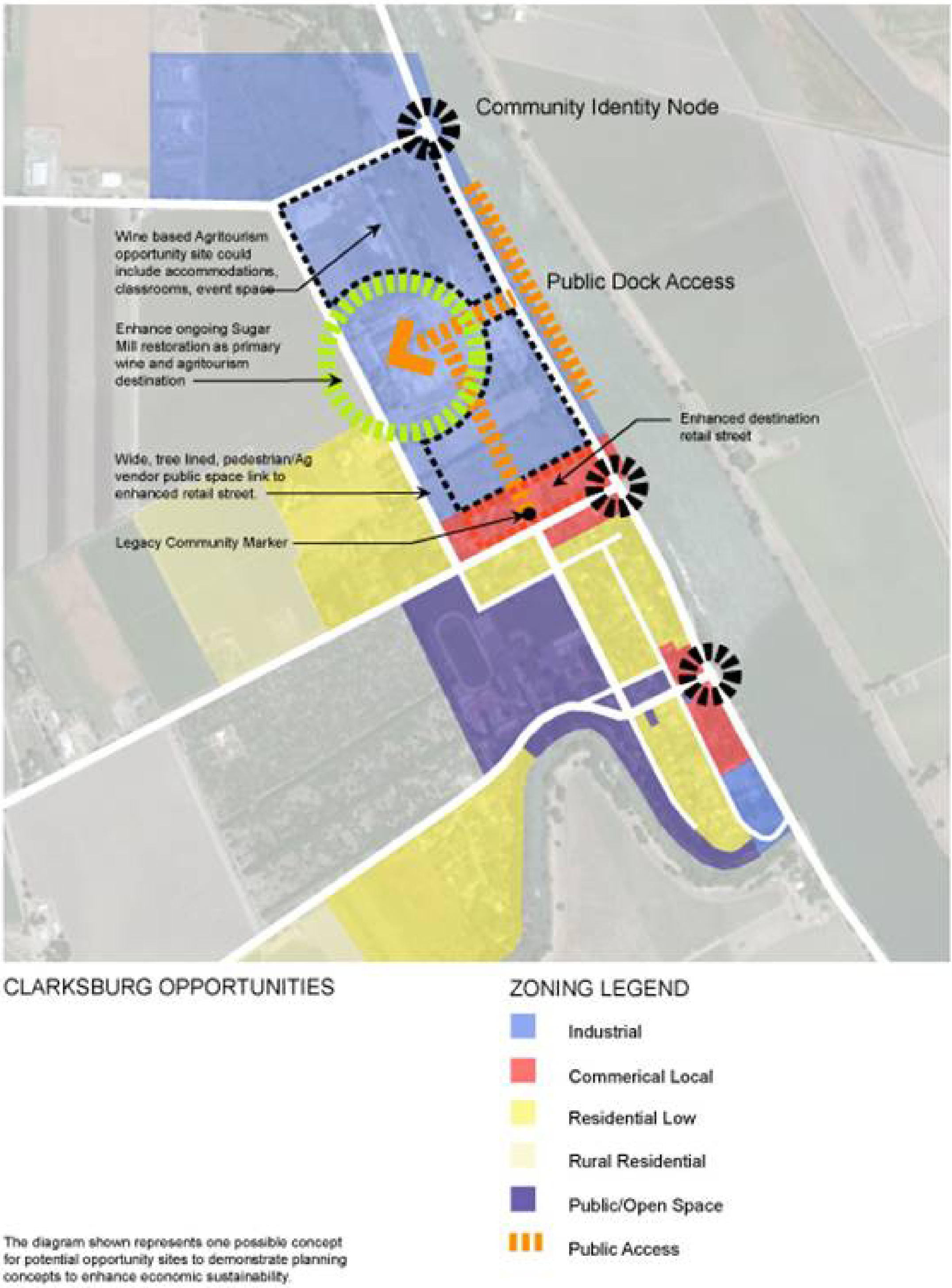
- While the commercial area serves as a buffer between the residential neighborhood and the Old Sugar Mill, an active, wide, linear pedestrian and food vendor connection between the site and the residents along the School Street right-of-way has the potential to provide local agriculture providers a place to sell their products and an active place-making link between the visitor focused uses and the residents.

- Boat access to the community and Sugar Mill could be greatly improved with a public boat dock with pedestrian links across South River Road.

- As with all of the Legacy Communities, its history and relationship to the river and agriculture are rich with character. The display and teaching of this history through interpretative Legacy Community markers is an opportunity for both residents and visitors.

- Clarksburg's three primary entry points from South River Road are Willow Point Road, Clarksburg Road, and Netherlands Road. There are opportunities to create "community identity nodes" at these intersections to create identification and way finding for out-of-town visitors to the area.

Figure 43 Clarksburg Vision and Opportunity Sites[310]



[310] For high resolution image see http://forecast.pacific.edu/desp-figs.html

5.2.1 Economic Development Goals for Clarksburg

Based on the planning concept and rationale presented above, the Economic Sustainability Plan recommends the following high-level goals for economic development in Clarksburg.

- Growth in the wine and viticulture industry, including local crushing, fermentation, bottling, and storage facilities
- New agriculture-related businesses, building on the success of the Old Sugar Mill
- Increased tourism, particularly agritourism activities (e.g., farm stays)
- New businesses offering locally-produced agricultural products
- Basic support services for tourists and visitors (e.g., boat-docking facility)
- Localized branding that is consistent with an overarching Delta brand
- Retention of existing local businesses

5.3 Walnut Grove and Locke Overview

This overview considers the history and socioeconomics within the Legacy Communities of Walnut Grove and Locke.

5.3.1 Walnut Grove History

Walnut Grove is one of the oldest towns in the Delta, founded in 1850-51 by John W. Sharp, who established a general store, brickyard, blacksmith shop, lumber mill, and one of the earliest post offices in the west. Sharp also opened the first hotel, school, and ferry operation (across the river). The town, which developed on both sides of the river, quickly prospered as an agricultural center and riverboat stop.[311] By 1865, Walnut Grove had become a major shipping port for agricultural products and fish. Walnut Grove played an important economic role in the region, providing goods, services, and workforce housing.

After Sharp's death in 1880, the town continued to flourish. The two sides of Walnut Grove evolved separately, with the east side of town emerging as the commercial and business center. In these early years, Chinese businessmen created a vibrant service and entertainment center serving Chinese agricultural workers. Just before the turn of the century, Japanese businessmen settled in Walnut Grove, opening numerous businesses to serve the community. By 1905, Japanese immigrants were farming nearly 80 percent of the land around Walnut Grove."[312] Following a fire in 1915, a Japanese commercial district emerged, comprised of nearly 70 businesses.

Since the 1882 Chinese Exclusion Act barred Chinese from becoming citizens and the 1913 Alien Land Act barred anyone who was not a citizen of the United States from purchasing land, local landowners leased land in the north end of the east side of Walnut Grove to the Chinese, and later to the Japanese, to construct housing and commercial structures. The east side of town included boarding houses for agricultural laborers, shops, restaurants, gaming halls, tong buildings, a Chinese school, and residences. By the 1930s, this area also included a Japanese

[311] Compiled from Mary L. Manieri, "Walnut Grove Chinese-American Historic District," "Walnut Grove Japanese-American Historic District," and "Walnut Grove Commercial/Residential Historic District," (Sacramento County, California) National Register of Historic Places Registration Form, Washington, D.C.: U.S. Department of the Interior, National Park Service, 1990; and Tushio Sakai and Carol Branan, "Walnut Grove Gakuen Hall," (Sacramento County, California) National Register Registration Form, Washington, D.C.: U.S. Department of the Interior, National Park Service, 1980.
[312] Ibid.

Buddhist temple, a Japanese Methodist church, and a Japanese school. A segregated, public "Oriental School" operated in east Walnut Grove from 1921 until 1946.

In the early 1920s, Bob Clampett bought what is now Clampett Tract, on Grand Island (western Walnut Grove), from Robert Kercheval. Clampett drained the tract and subdivided the area into residential lots. In the 1930s, churches and businesses were added in Clampett Tract.

Despite the efforts of some local leaders to encourage more European Americans to settle in Walnut Grove, it remained predominantly Asian until the 1940s. As a segregated community, only Whites were allowed to live on the western side of the river. The Chinese population was aging and dwindling at that time, primarily because of the strict immigration laws, and the Japanese were removed to relocation camps at the beginning of World War II. With the loss of the Asian community, Walnut Grove's role as an Asian-oriented service and social center diminished, although it continued to serve as an important agricultural support center.

The Sacramento Housing and Redevelopment Agency (SHRA) began working in the Delta in the mid- to late-1970s. By the early 1980s, SHRA had established a Redevelopment Project Area in Walnut Grove. SHRA assisted the Homeowners and Merchants Association with property acquisitions (addressing land versus structure ownership issues) and began an aggressive revitalization program. In particular, SHRA constructed curbs, gutters, sidewalks, open space, a fire station, parking lots, sewer and water improvements, and a community boat dock. In addition, SHRA undertook a commercial revitalization program, which included commercial loans, grants, façade rebates, and technical assistance to the Walnut Grove Area Chamber of Commerce. The redevelopment project area expired in 2004 and SHRA has since suspended its involvement in the area.

5.3.2 Locke History

The history of Locke is closely tied to that of Walnut Grove. In 1915, when a fire destroyed the Chinese settlement in Walnut Grove, a group of Chinese residents leased land from Locke family to build new homes and shops. Locke eventually grew into a bustling town. Between 1916 and 1920, restaurants, dry goods stores, hardware stores, grocery stores, brothels, and a merchant's association were established. Later, a drug store, soda fountain, post office, tobacco shop, shoe repair shop, bakery, theater, boarding houses, and opium rooms located in the town. At its peak, 600 residents and as many as 1,500 short-term and seasonal workers and visitors occupied Locke. However, Locke entered into decline as the Chinese population decreased due to strict immigration laws. In the latter half of the 20^{th} century, Locke deteriorated to the point that the community was in danger of condemnation.[313]

Locke is the last remaining rural Chinatown in the United States and the entire community was placed on the National Register of Historic Places in 1970. In 2000, SHRA began a four-year process to address property ownership issues in Locke. In addition, SHRA assisted with building stabilization and facilitated construction of a new sewer system (assisted by a grant from the U.S. Department of Agriculture). In total, more than $3 million in federal Community Development Block Grant (CDBG) and Economic Development Initiative (EDI) funds were spent on these activities.[314]

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[313] www.locketown.com
[314] Sacramento Housing and Redevelopment Agency article:
http://www.shra.org/SuccessStories/CommunityRevitalization.aspx#The_Transformation_of_Phoenix_Park

In 2004, the SHRA turned over ownership of the subdivided land in Locke over to the building owners. As a condition of receiving the land from the SHRA, buyers accepted property conditions and limitations concerning the use of the buildings, historic architecture, sale requirements (i.e., right of first refusal for descendants of the original settlers), and town management structure. In 2005, the California Department of State Parks purchased the Locke Boardinghouse, built in 1915, and have restored it in partnership with SHRA. Opened in 2008, the Locke Boarding House serves as a visitor center and interpretive center for visitors and residents.

5.3.3 Socioeconomics of Walnut Grove and Locke

While Walnut Grove and Locke are very distinct communities, the available socioeconomic data is limited and these communities must be analyzed together. Data from the U.S. Census Bureau's American Community Survey is available at the block group level, with eastern Walnut Grove and Locke located in the same block group (as shown in Figure 40). Western Walnut Grove and Ryde are also analyzed together due to the limitations of the available data.

Eastern Walnut Grove and Locke contain a very high concentration of Asian residents, with approximately 38 percent identifying themselves as "Asian alone," which is significantly higher than the reported 13 percent in the Legal Delta. On the other side of the Sacramento River in western Walnut Grove/Ryde, the racial composition is quite different. Only about 3 percent of residents in western Walnut Grove/Ryde identify themselves as "Asian alone," while 56 percent identify themselves as "White alone."

Household income differences between eastern Walnut Gove/Lock and western Walnut Grove/Ryde are notable as well. At roughly $29,000 per year, the average household income in eastern Walnut Grove/Locke is much lower than in the Legal Delta and the lowest of all Legacy Communities. More than 45 percent of households in eastern Walnut Grove/Locke report an income less than $15,000, compared to just 10 percent in the Legal Delta. By comparison, the residents of western Walnut Grove/Ryde are considerably more affluent. The average household income in western Walnut Grove/Ryde is $92,000, compared to roughly $80,000 in the Legal Delta. It is also noteworthy that more than 27 percent of western Walnut Grove/Ryde households earn more than $150,000 per year, compared to just over 11 percent in the Legal Delta.

The residents of eastern Walnut Grove/Locke frequently work outside of the area in which they live. Only 9 percent of these residents actually work within their local area. Many of these residents commute to the city of Sacramento, Stockton, West Sacramento, and San Jose. Commute patterns are similar in western Walnut Grove/Ryde, where about 15 percent of residents work in the local area. Residents frequently commute to Sacramento, Stockton, and Rio Vista. Jobs in eastern Walnut Grove/Locke are filled by workers from throughout the region, most notably from Sacramento, Elk Grove, Galt, Stockton, and Lodi. Only approximately 4 percent of eastern Walnut Grove/Locke workers live there too. Commute patterns in western Walnut Grove/Ryde are similar, although a higher proportion of workers (about 13 percent) also live there.

5.4 Vision for Walnut Grove: Heart of the Sacramento River Corridor

Walnut Grove is unique in that it is one of the few Delta communities that occupies both sides of the river, with the primary residential area on the West and the commercial area and historic Asian communities located on the East. The building stock in the residential community represents a range of typologies, from small pre-WW II homes to modern estate properties. In the commercial district, many historic structures and newer structures line the top of the levee. At the base of the levee, a mixed area of historic structures, post-war homes, community services, an elementary school and a community center are lined along both sides of the former rail line. The community continues to be a service center for the agricultural businesses, as well as a destination for both water- and auto-based tourists.

There are multiple opportunity sites within Walnut Grove that could provide multi-family housing or tourist accommodations in close proximity to services. However, proposed regulatory policies could either prevent this infill development or create significant entitlement risk. The General Plan indicates the need for additional housing, and Walnut Grove has both the opportunity sites and infrastructure in place to provide for future housing needs.

- Walnut Grove has a valuable public dock with direct access to the core retail area. These retail uses currently cater to residents, daytime workers, and tourists. Because some businesses are at the top of the Sacramento River levee, they present opportunities to create a valuable pedestrian-oriented commercial node.

- Because Walnut Grove has commercial zones on both sides of the river, the Sacramento River bridge is an important linkage within the community. There is an opportunity to enhance the commercial area on the western side, particularly with a better pedestrian and bicycle crossing at the bridge.

- Consistent with the recommendations of the Recreation Chapter (see Chapter 8), the former rail line presents the opportunity to link the Delta Meadows River Park, the historic Locke community, and the historic Japanese and Chinese areas of Walnut Grove. Public improvements along the rail corridor have the potential to stimulate investment in Walnut Grove.

Walnut Grove is centrally located with the Sacramento River Corridor and contains many key services and amenities that are not available outside of nearby cities. Walnut Grove has the potential to build upon this role as a local commerce center.

Key tenets of a vision for Walnut Grove include the following:

Preserved Historic Character: Walnut Grove's established, attractive, and high-quality building stock should be maintained and/or enhanced. Planning should identify adaptive reuse opportunities and assess their potential benefits to the community.

Increased Resident, Visitor, and Business Services: Opportunities to add a variety commercial uses should be carefully evaluated. Additional retail stores, business service providers, and restaurant operations could be feasible, if undertaken as part of a broader strategy.

Improved Connection to the Sacramento River: The recent construction of water-side docking facilities in Walnut Grove have enhanced the ability for users to access the river and have created momentum which should be leveraged by efforts to enhance connections between the river and town.

Figure 44 below shows a planning concept for Walnut Grove and Locke (combined here for perspective). Figure 45 presents the Walnut Grove concept in detail. Key information for this vision includes the following.

- The east side of Walnut Grove includes a single-family residential area that has some infill opportunities. However, there are several properties along the levee that have higher-density zoning and could be opportunity sites for additional workforce housing or visitor accommodations.

- At the levee edge, there are several commercial sites. There is the potential for this area to become a mixed-use area with housing, services, and amenities at elevations that provide views and access to the river.

- East Walnut Grove is a complex community of historic districts and sites, single-family residences, industrial and institutional uses, and local commercial uses. There are several vacant or underutilized sites that represent opportunities for infill development including housing, commercial, industrial, and visitor accommodations.

- There is also the potential to create a strong pedestrian focus to River Road on both in both the East and West commercial areas as the levee is relatively wide. As the community evolves, linking these two commercial areas with enhanced connections across the bridge could provide a strong sense of place for Walnut Grove and create a significant visitor destination.

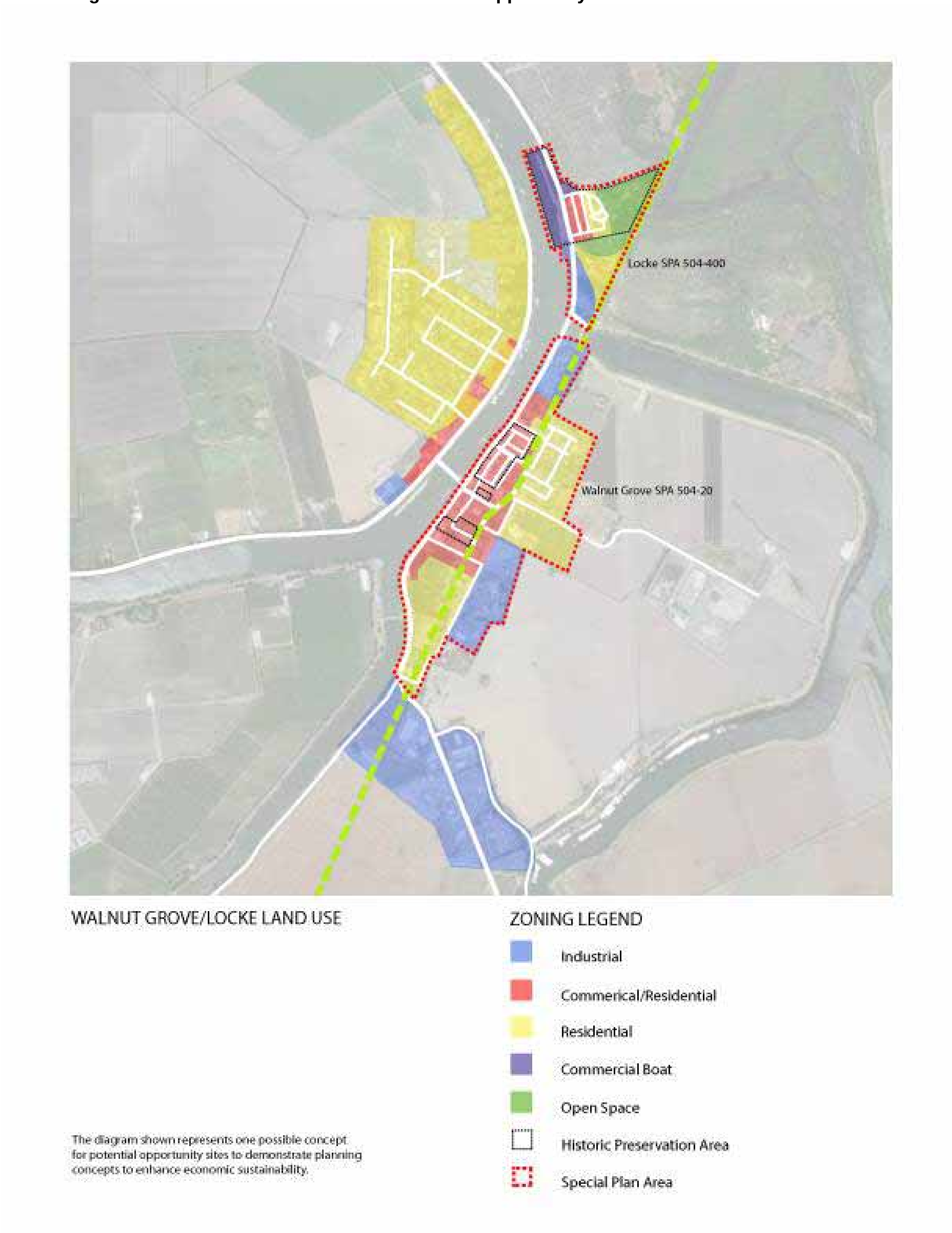
- There is at least one example of successful historic restoration and adaptive re-use in the historic movie theater as a metalwork sculpture studio and showroom. Encouraging this type of restoration in the area could serve to both preserve the history of the community and energize it with new activity.

- Two large opportunity sites, one residential and one industrial at the Southwest end of East Walnut Grove provide great opportunities to continue support of the agriculture industry and develop significant housing or visitor accommodations.

- The abandoned railroad right of way and Grove Street provide the opportunity to create a link between the Delta Meadows River Park trail to the North and potential recreation and interpretive venues to the South. This opportunity links potential development sites, historic areas, residential neighborhoods, and potential future recreation areas. Creating the link and activating it with commercial uses and visitor accommodations could work toward positioning Walnut Grove as a primary Delta destination.

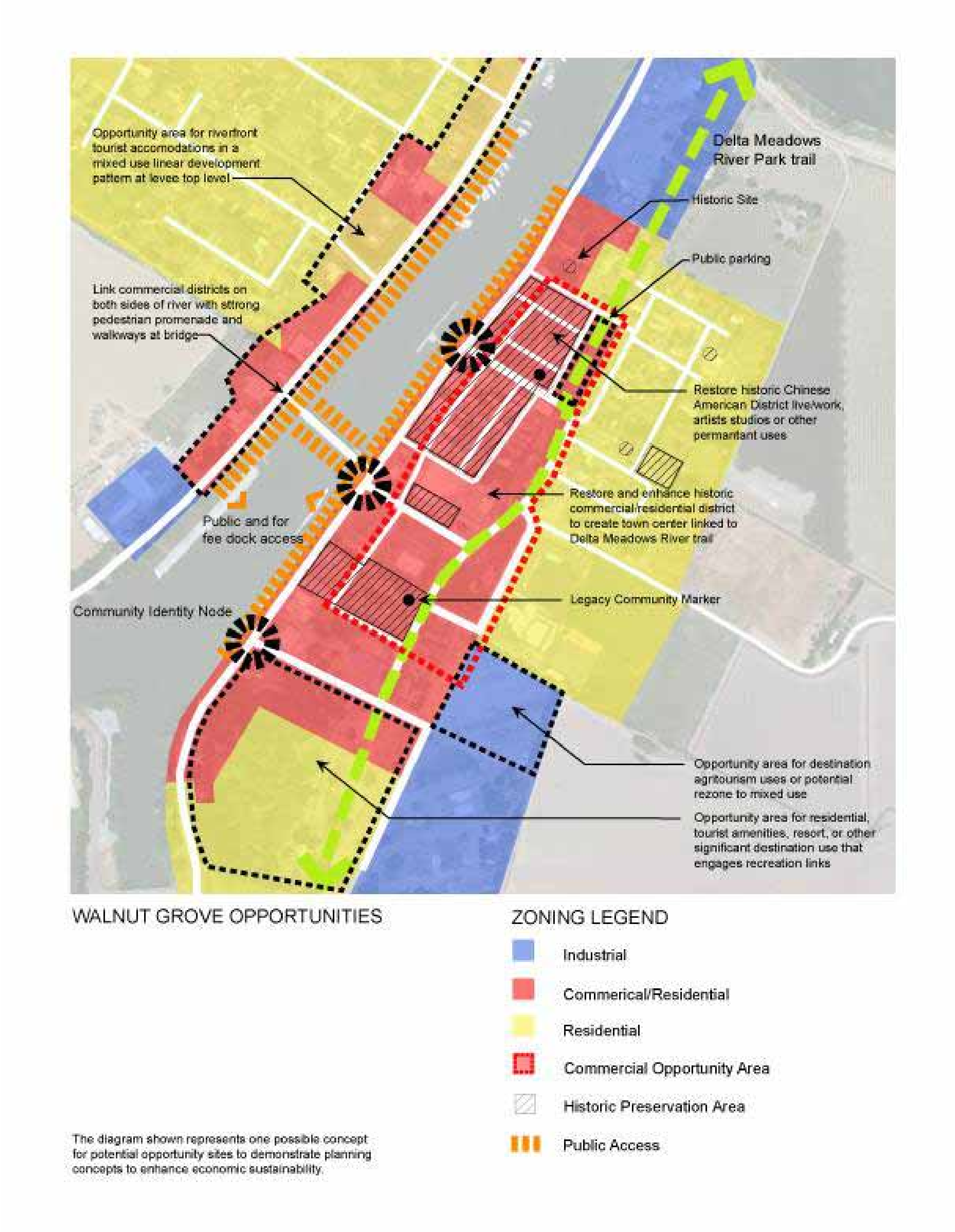
- As with Clarksburg, Walnut Grove has multiple opportunities for Legacy Community markers and community identity nodes to increase interest and education, as well as to orient visitors.

Figure 44 Walnut Grove and Locke Vision and Opportunity Sites[315]



[315] For high resolution image see http://forecast.pacific.edu/desp-figs.html

Figure 45 Walnut Grove Vision and Opportunity Sites[316]



[316] For high resolution image see http://forecast.pacific.edu/desp-figs.html

5.5 Vision for Locke: A Historic Delta Community

Locke is known for its cultural heritage, historical significance, unique building stock, and visitor attractions. These assets should be bolstered in a culturally, ecologically, and economically sustainable manner. Nearly all of the historic structures in Locke are in need of extensive restoration. According to Sacramento County planning officials there are multiple agency policy requirements, federal, state, and county, that would need to be addressed, and potentially waived, to permit this activity.

Locke is a Legacy Community that has struggled to survive both economically and physically. A majority of Locke's buildings are in great need of restoration and yet Locke holds tremendous historic and cultural significance as one of the only towns built by the Chinese immigrants for their community. In addition, the western adaptation of the Chinese Shop House typology makes Locke's architecture a national landmark. Restoration and adaptive reuse of these structures could provide Locke with the catalyst necessary for sustainability.

Key tenets of a vision for Locke include the following:

Preserved Historic Character: Locke's unique, historic building stock should be maintained and/or enhanced.

Improved Hospitality and Visitor Services: Opportunities to add a variety of visitor-serving uses should be evaluated. Uses might include retail stores, restaurants, and wine tasting rooms. Improved ground-level retail spaces would provide locations for businesses seeking to capitalize on the recreation enhancements around Locke, including Delta Meadows (see Chapter 8: Recreation).

Revitalized Main Street Business Environment: The scale and walkability of "main street" in Locke is conducive to visitor-oriented retail. Efforts to maintain and enhance storefronts should be undertaken with the objective of creating an improved destination for tourism.

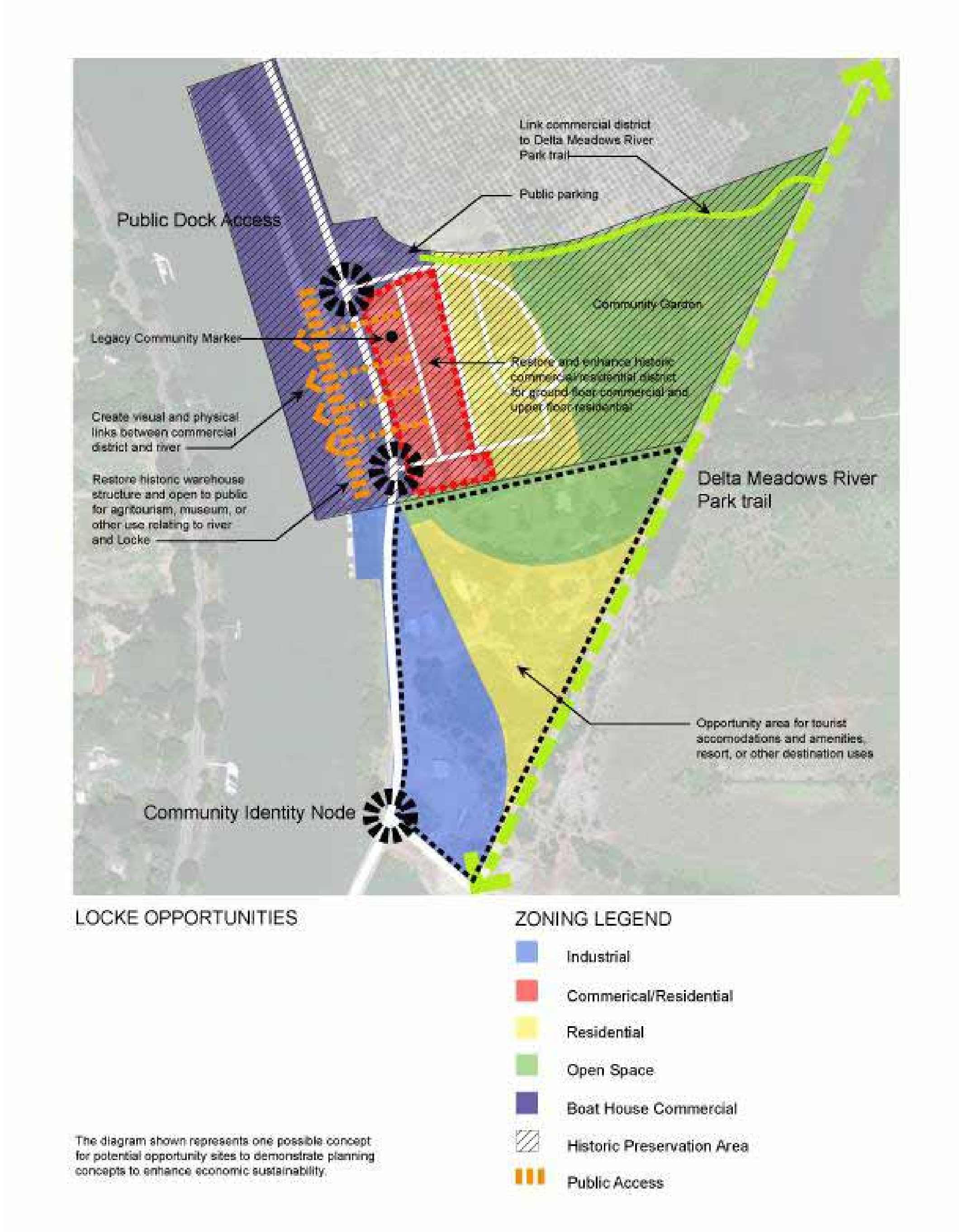
Figure 46 below shows a planning concept for Locke. Key information for this vision include the following.

- The historic wharf warehouse presents a unique opportunity to restore a significant historic structure as a catalyst to restoration of the entire community. Purchase of the structure and restoration for public uses such as agritourism vendors, historical interpretive exhibits, and even tourist accommodations could provide a destination for overnight visitors. It is currently under private ownership and would likely need a public-private partnership to ensure success.
- There is an opportunity site in the industrial zone along the river that is outside of the Historic Preservation Area and could be used as a recreation or agritourism venue. However, the risk associated with rezoning would need to be addressed before investment would occur.
- Locke has spent considerable energy in creating educational opportunities about its history, yet with so few visitor accommodations nearby, there are limited opportunities for overnight visits. The existing historic Shop Houses have the ability to accommodate live/work, artists' studios, bed and breakfast accommodations, and entertainment venues.
- At the southern end of Locke the open space, residential, and industrial properties provide an opportunity to create tourist accommodations, amenities, a resort, or other destination

uses. This site could leverage the expansive community garden, the surrounding agriculture, and the Delta Meadows River Park trail.

- The new public parking lot in Locke could provide or accommodate a trailhead link to the Delta Meadows River Park trail which is adjacent to the community garden.
- As with Clarksburg and Walnut Grove, Locke has opportunities for Legacy Community markers to augment the existing museums and parks, and community identity nodes.

Figure 46 Locke Vision and Opportunity Sites[317]



317 For high resolution image see http://forecast.pacific.edu/desp-figs.html

5.5.1 Goals for Economic Development in Walnut Grove and Locke

Based on the planning concept and rationale presented above, the Economic Sustainability Plan recommends the following high-level goals for economic development in Walnut Grove and Locke.

- Quality building rehabilitation and adaptive reuse project
- Historical interpretation exhibits and publicly-accessible cultural and historic sites
- New businesses providing services related to agriculture and recreation
- New businesses offering locally-produced agricultural products
- Localized branding that is consistent with an overarching Delta brand
- Basic support services for tourists and visitors (e.g., restrooms, taxi/shuttle services)
- Retention of existing local businesses

Chapter 11: Integrated Issues for Delta Economic Sustainability

A number of issues and strategies cut across multiple chapters and topics that are analyzed in the Economic Sustainability Plan. In this chapter, we explain some of these cross-cutting recommendations in greater detail, and call out a few issues for additional clarification and emphasis. The first integrated issue discussed in this chapter is a more detailed and integrated discussion of the economic development facilitator organization recommended in the recreation and tourism and legacy community chapters. Other issues include the levees and infrastructure system, the future roles of recreation and agriculture in the Delta economy, and how the Economic Sustainability Plan is consistent with the coequal goals of the Delta Reform Act.

1 Integrated Issue 1: Facilitator Organization for Delta Economic Sustainability

1.1 Facilitator Roles and Responsibilities

As discussed in both the recreation and Legacy Community chapters of the Economic Sustainability Plan (ESP), a major challenge to achieving long-term sustainability in the Delta is action-oriented government and public/private coordination. While the Delta holds great potential for new recreational facilities and enhanced Legacy Communities in the future, the public sector must promote and manage sustainable growth in an integrated and holistic fashion. This section explores the concept of designating a “facilitator organization” in the Delta—the Delta Protection Commission or a joint powers authority of local agencies—to strategically coordinate and implement recreation-related projects and economic development.

Economic sustainability in the Delta requires that agricultural and recreational opportunities and the Legacy Communities evolve over time. Currently, the obstacles associated with planning, financing, development, and operation of a significant recreation area or Legacy Community development opportunity is difficult and time consuming. With its multiple cities, counties, special districts (both within and outside the Delta), state and federal agencies, along with numerous nonprofit and for-profit interests, the implementation process is a formidable challenge in the Delta. Complicating matters further, the Delta Stewardship Council, created in legislation to achieve the state mandated coequal goals for the Delta, has proposed additional regulatory policies that apply to certain proposed plans, programs, and projects by local and state agencies (i.e., “covered actions”).

In order to solve some of the complexities related to recreation, the ESP proposes a broad recreation vision concept that is compatible with State Parks Recreation Proposal, which in turn was structured and coordinated with other state agencies. The ESP’s recreation economic development recommendations follow on that planning, in coordination with the Legacy Communities. The Legacy Communities must evolve to better serve and attract visitors to the Delta, by anchoring and enhancing the experience in the Delta. Strategic planning of the Legacy Communities needs to occur in lock step with recreation planning to maximize economic benefits from investments in the Delta.

As presented in Chapter 8, recreation and tourism is an integral part of the Delta, complementing its multiple resources and contributing to the economic vitality of the region. Residents of nearby areas visit virtually every day, generating a total of roughly 12 million visitor days of use annually and a direct economic impact of more than a quarter of a billion dollars in spending. Private enterprise is both the existing and future driver of economic sustainability in the Delta, but its future success level can be shaped by the public facility contributions and regulatory environment. The implementation of the ESP will be very complex. Overcoming the multiple steps, regulations, and planning processes by either agencies or individuals can be difficult for normal projects, but the multiplicity of agencies and interlocking safeguards and regulations in the Delta multiplies the difficulties. It is recommended that a facilitator organization be named to assist implementation efforts, to coordinate funding, and to stimulate funding for vital actions.

Box 9 National Heritage Area

The Delta Protection Commission, as mandated by SBX-7, is currently completing a feasibility study for a National Heritage Area (NHA) and determining what that designation might mean for the Delta (Senate Bill X7, 2009). Pursing the NHA designation has also been recommended by the Delta Plan and also in State Parks' recreation proposal for the Delta (State Parks 2011 p. 29-30). The management entity for an NHA may fill some of the needed roles of a facilitator organization.

A National Heritage Area is designated by Congress as "a place where natural, cultural, and historic resources combine to form a cohesive, nationally important landscape." (http://www.delta.ca.gov/res/docs/InfoSheet_NHA.pdf). National stature would be achieved through NHA designation, enabling the Delta to gain visibility as a destination for persons as close as the Bay Area and Sacramento region, as well as on a national and international level. NHA designation can also be used as a marketing tool, to help brand the unique aspects of the Delta, such as its waterways and levees, long history of agricultural production, numerous recreational opportunities and diverse rural communities and cultural groups. Federal seed money is granted with NHA designation, which can be utilized to leverage other funds from public and private sources. NHA designation also has the capabilities to offer the following additional benefits.

- Provide sustainable economic development.
- Promote heritage tourism and recreation in the Delta that is aligned with existing land uses.
- Offer environmental and cultural interpretation and educational opportunities.
- Facilitate partnerships to undertake projects such as historic preservation with the consent and involvement of willing landowners.
- Develop necessary visitor amenities in the Delta such as waste receptacles, public restrooms and directional signage.
- Improve local quality of life and retain local control.

Senator Dianne Feinstein introduced S.29: Sacramento-San Joaquin Delta National Heritage Area Establishment Act on January 25, 2011,1 while Rep. John Garamendi introduced H.R. 486 on January 26, 2011. Both bills would establish the Sacramento-San Joaquin Delta National Heritage Area and designate the Delta Protection Commission as the management entity. Pursuing the National Heritage Area designation as previously also been recommended by State Parks, the Delta Stewardship Council, and the Delta Blue Ribbon Task Force.

As has been discussed elsewhere in the ESP, the Legacy Communities represent key focal points of Delta culture, and provide logical locations for supporting functions related to agriculture-, recreation-, and population-serving services. As with any community, the physical layout and condition of these communities requires adaptation and improvement over time by private sector investors in order to remain viable. However, this endeavor is not simple in the Delta, and the paucity of recent investment reflects a local land use policy regimen that is problematic in terms of predictability and economic viability. In short, these communities are not living up to their economic potential as catalysts or receivers of economic diversification and growth. Without considerable simplification and coordination of the local investment climate, it is unlikely that the proposed recreational facilities and Legacy Community enhancements embodied within the ESP will be realized. It is vital that some organization take on the role of actively facilitating solutions and actions to the many impediments to sustained economic viability.

Currently, there are numerous organizations actively involved in implementing Delta-wide programs and services, including the Discover the Delta Foundation and the Delta Chamber of Commerce. These organizations do a lot with limited resources, but currently lack the capacity to implement ambitious recreation and economic development concepts. Coordinated efforts are needed between state and federal agencies, local governments, the private sector, and the local community. Going forward, substantial coordination needs to occur to meet economic sustainability goals in the following areas:

- **Recreation Enhancement.** Recreation facilities require ongoing reinvestment and new investment in order to meet the changing needs and desires of the recreationist or tourist. As previously described, the majority of recreation services are delivered in the Delta by private enterprises, predominantly marinas. Yet, more than 70 percent of the marinas in the Delta are over 40 years old and are in need of an estimated $127 million in upgrades, replacement, and repair.[318] Upgrading and enhancing these private facilities, as well as creating new catalyst public/private focal areas for recreation is essential to the continuing economic sustainability of the Delta region.

- **Strategic Levee Protection.** Obtaining adequate flood protection is of the utmost importance in order to foster additional meaningful economic activity in the recreation areas, Legacy Communities, and certain agricultural enterprises. Although levees are costly, improved flood protection is necessary to encourage new investment and reinvestment in the Legacy Communities, particularly in light of recent (and proposed) changes to FEMA maps.

- **Streamlined Entitlement Process.** The complex, multi-jurisdictional entitlement process in the Primary Zone severely limits the ability for new projects to be brought to market. A more transparent and predictable entitlement process would greatly reduce the risk to new economic endeavors in the Delta.

- **Historic Preservation.** The Legacy Communities offer a unique sense of place and history that should be preserved in the built environment for future generations to experience and enjoy. However, as structures age and decline, reinvestment and new investment in real estate is critical to economic sustainability. Therefore, development projects that are consistent with the existing community fabric should be encouraged and embraced. Retaining historical character is critical to the retention and recruitment of businesses in the Legacy Communities.

A well-funded facilitator organization is needed to provide planning consistency in the Delta, guide public and private projects through the regulatory process, contribute technical assistance, obtain supplemental funding (e.g., grants), and offer compelling marketing services. Specific tasks to be conducted by this organization might include the following:

- **Planning tasks** might include the development of approved master or specific plans, synchronized with public and private sector improvements throughout the Primary Zone. Efforts toward consistent planning are needed to achieve consensus concerning

[318] DBW 2002, p. 5-5 – 5-8

investment priorities. The planning process could also identify and recommend regulatory changes to facilitate realization of these plans.

- **Permit processing** requires clarity and transparency to encourage private sector investment. Permitting should be streamlined and supported by the facilitator organization through technical assistance to investors and developers. In addition, the facilitator would create and maintain a Delta "entitlement handbook" for prospective investors. Another role for this organization may be to recommend ways for agencies to streamline regulations in ways that would encourage appropriate development while continuing to protect the Delta resources.

- **Economic development tasks** could include coordination of economic development efforts with major prospective funding initiatives (e.g., regional tax sharing, broad-based levy assessments, etc.). Economic development efforts would facilitate specific catalyst projects by securing entitlements, assisting in land assembly, and providing "gap funding" (also addressed below). This could also include technical services such as training and professional development support for local businesses.

- **Financial responsibilities** could include prioritization of funding goals, pursuing available state and federal funding, working to create regional funding mechanisms for capital and maintenance, and finalizing annual capital improvement and service provision programs. This function could also include an informational clearing house services to ensure that prospective investors are aware of funding opportunities, tax incentives, and other programs.

- **Marketing responsibilities** are critical to future growth and diversification, and include promotion and coordination of festivals and special events, the formation and organization of wine tours, farm tours, and boat tours, use of web and social media technology linking potential visitors to activities, festivals, and facilities. Overall, serious consideration needs to be given to redefining the Delta through a major marketing and branding campaign, and these efforts need to be linked to specific economic development goals and objectives. By linking projects and events related to the major drivers of tourism (e.g., boaters, fishing organizations, wine purveyors, farm stands, tour operators, and overnight accommodations), visitors could more easily formulate weekend itineraries to take advantage of multiple Delta offerings. Coordinated branding and marketing of certain Delta agricultural products may also increase their recognition and value.

- **Operations and Management responsibilities** may help streamline development and implementation of signage, visitor centers, and/or kiosks at entry points or gateways to the Delta, marina dredging, as well as visitor amenities and sanitation. Implementation and operations of regional land and water trails could also be overseen by this organization. This organization may also assist in coordinating law enforcement and/or emergency response.

1.2 Facilitator Organization Recommendation

It is recommended that a formal and detailed organizational analysis be conducted to take the facilitator organization from concept to reality. There are many types of organizations which could potentially adopt a facilitator role, including nonprofit organizations, public agencies (state and local), public/private partnerships, and others. Existing organizations that currently are operating in the Delta may have existing alignment with this role (e.g., the Delta Protection Commission, Delta Conservancy, local cities and counties, the Discover the Delta Foundation, State Parks, and others). For example, the Discover the Delta Foundation has built an attractive farmer's market/information center at the junction of state routes 160 and 12, and has plans for a visitor's center. They may be able to partner with others to expand this concept to other gateway areas. A Joint Powers Authority could be developed by Delta counties, cities, and state agencies which own or operate recreation areas in the Delta to provide one-stop visitor information services.

The following are key criteria to consider in either choosing an existing entity or creating a new consortium.

- Support of local communities/governments and state agencies
- Ability to take action and effectuate change
- Flexibility to coordinate between multiple agencies and affected stakeholders
- Funding support for internal operations
- Compatibility with existing mission and orientation
- Ability to coordinate and prioritize funding for competing projects

The facilitator organization will require adequate ongoing funding to plan, develop, market, and, potentially, operate improved facilities and activities. Long-term funding might come from mitigation from future Delta capital projects and potentially through the Delta Investment Fund.

The matrix below presents a listing of existing organizations that could potentially adopt a facilitator role and the criteria that could be used to evaluate which organization could best move forward in this role.

Table 56 Delta Recreation Facilitator Opportunities and Constraints Matrix

	Potential Facilitator						
	Existing Local Control/ No Central Authority	Existing Nonprofit Organi-zation (i.e. Discover the Delta Foundation)	State Parks	Delta Con-servancy	National Heritage Area with DPC as manage-ment entity	Public/ Private Partnership	Delta Economic Development Joint Powers Authority (cities, counties)
Criteria							
Public/ Private	Both	Private	Public	Public	Public	Private	Public
Can take action and effectuate change	Limited	Limited	Limited	Limited	Yes	Yes	Yes
Funding Potential	As exists	Fundraising potential	Limited	Limited	Matching federal funds	Assessment District on local businesses	Funded by partner agencies - limited
Can coordinate between multiple agencies and stakeholders	No	Maybe	Maybe	Yes	Yes	Yes	Yes
Existing Mission	Yes	No	Partial	Partial	Partial	No	No
Allow for central marketing of Delta	No	Yes	No	Maybe	Yes	Yes	Yes
Produces stability/ encourages facility growth/ improvements	No	Yes	No	Maybe	Yes	Maybe	Maybe
Help alleviate use conflicts	No	Maybe	No	Maybe	Maybe	Maybe	Yes
Can promote/ produce additional festivals/ special events	Yes	Yes	With partners	With partners	With partners	Yes	Yes
Can identify and establish gateways	Yes	Yes	Maybe	Yes	Yes	Yes	Yes
Act as clearinghouse for information for private entrepreneurs	No	Yes	No	Yes	Yes	Yes	Yes
Ability to coordinate and prioritize funding	No	No	No	Yes	Yes	Yes	Yes
Support of local communities	Yes	Yes	Partial	Not Yet	DPC, yes, NHA not yet	Yes	Yes

The facilitator must be sufficiently funded to develop, market, and, potentially, operate improved facilities and activities described in this report.

Currently, the two best potential candidates to take on this Facilitator Organization role seem to include the DPC (or some sub-committee thereof), or a Joint Powers Authority (JPA) comprised of public and/or private entities with the Delta's economic well-being at heart. More discussion regarding each of these potential options follows below:

Option 1: Delta Protection Commission. The Delta Protection Commission is potentially suited to such a role. Its board is composed of both state and local agencies, it has respect from the community, and it has land use authority through the Land Use and Resource Management Plan. The DPC's role could be expanded to include economic development and marketing in the Delta. It would coordinate sustainability planning and development and could administer the Delta Investment Fund in the most effective way to prioritize catalyst projects. Through its potential designation as the management entity of a National Heritage Area (discussed in more detail below), it could undertake Delta-wide marketing and branding. The DPC could work in collaboration with the Delta Conservancy to provide grants and training to local agencies for local implementation of the Economic Sustainability Plan recommended strategies. It could also work with Joint Powers Authorities established between State Parks and local agencies to develop recreation areas or establish Gateways or Basecamps. Potential federal funds to the NHA could be matched through the Delta Investment Fund and the Delta Conservancy funds.

Option 2: County Joint Powers Authority (JPA). Local counties and their related redevelopment agencies have done an excellent job of protecting sensitive agricultural and resource areas and lobbying for improved public facilities (e.g., public moorage). As an alternative to DPC oversight, a Five County JPA could be formed. The strength of this option is related to the fact that individual counties have been excellent stewards of the Delta, have managed public safety and other services provision, and have conducted extensive redevelopment efforts (particularly in Sacramento County) in the past. Counties have been strong advocates for local land use control, and have the inherent trust of the communities in this regard.

2 Integrated Issue 2: Levees and Economic Sustainability

Since the early 20th century, the current-day Delta levee system provides flood control that allows productive agricultural and urban uses of land, channels water for urban and agricultural uses, protects critical infrastructure, and creates a desirable setting for boating and water-based recreation in an environment unique in California. The levee system is the foundation on which the entire Delta economy is built. Therefore, a sustainable Delta economy requires a sustainable levee system.

It has been the goal of the State and the federal government, working through the Department of Water Resources (DWR), the U.S. Army Corps of Engineers (USACE), and the local reclamation districts, to meet the PL 84-99 standard since 1982 when DWR and USACE produced a joint report on the Delta levees which recommended the basis for this standard. If effectively used, funds currently in the pipeline should bring the Delta levees close to achieving this goal. When these funds have been expended, more than $698 million will have been invested in improvements to the Delta levees since 1973. These improvements have created significantly improved Delta levees through modern engineering and construction, making obsolete the historic data that is still sometimes used for planning or predicting rates of levee failure.

Three approaches can help all jurisdictions and planners further reduce the risks resulting from the failure of the Delta levees. These approaches are: (1) build even more robust levees, (2) improve both regular maintenance and monitoring and flood-fighting and emergency response following earthquakes, and (3) improve preparedness for dealing with failures after they occur. With regard to the first approach, the big question is not whether they should be improved to the Delta-specific PL 84-99 standard. Instead, the key question is whether in order to support and enhance various in-Delta, regional, state, and federal interests they should be improved to a higher standard in order to address hazards posed by not only floods, but also earthquakes and sea-level rise. Our conclusion is that these improvements would be advantageous not only for flood control and protection against earthquakes and sea-level rise, but because they also would allow for planting vegetation on the water side of the levees—an essential component of Delta ecosystem repair. These further-improved levees would have wider crowns to provide for two-way traffic and could easily be further widened at selected locations to allow the construction of new tourist and recreational facilities out of the statutory floodplain.

Improvement of most Delta lowland levees and selected other levees to this higher standard would cost $1 to $2 billion in base construction costs over the cost of reaching the PL 84-99 standard. Including vegetation and habitat enhancement, total program costs might be in the order of $4 billion, similar to the cost projected by the PPIC (2007) in their “Fortress Delta” alternative. While the billions of dollars required to build levees to this higher standard is an enormous investment, it is a cost-effective joint solution that simultaneously reduces risk to all Delta infrastructure. While a $12 billion investment in isolated conveyance may allow for somewhat larger water exports, it doesn’t protect other critical infrastructure and billions in additional investments would still be required to protect highways, energy, and other water and transportation infrastructure. Just as a species by species approach is an inefficient and ineffective way to protect ecosystems, a system by system approach is an inefficient and ineffective way to protect the state’s infrastructure.

3 Integrated Issue 3: Relative Roles of Agriculture, Recreation, and Tourism

Agriculture is the main economic driver in the Delta, generating three to five times the regional economic impact of recreation and tourism. On average, a dollar of crop production in the Delta has more regional employment and income impact than a dollar of recreation and tourism spending in the Delta. This result is important for economic sustainability since many proposals to change the Delta would reduce agricultural production with hopes of increasing recreation and tourism. However, the growth of the recreation and agriculture economies is not necessarily in conflict. For example, flood control investments and improved water quality are critical to the future of both the recreation and agriculture economies. In addition, continuing growth in Delta wineries and agritourism will generate income for both sectors.

While recreation trips to the Delta are a significant contributor to the Delta economy and are expected to increase, increasing the economic impact of tourism spending requires increasing spending per trip to the Delta and the local economic impact of spending that does occur. The lower economic impact of recreation and tourism spending is because fuel and retail purchases dominate expenditures for the types of recreation and tourism that are currently available in the Delta. Although these are local expenditures, the goods are typically produced elsewhere have relatively low multiplier effects on the regional economy.

This requires diversification through new investment in high value-added, land-based tourist services that generate more local income and jobs than retail and fuel expenditures. A successful strategy would require significant new investment in hospitality enterprises within the Delta, and also stimulate investments needed to sustain and enhance the large existing economy associated with Delta boating. Increasing day trips for wildlife viewing and other ecologically-based activities is unlikely to generate significant increases to in-Delta economic activity, especially without new investment in services that encourage longer visits and overnight stays. This is a difficult challenge given the market and regulatory constraints of operating in the Delta. Chapters 8 and 10 provide some visions of more successful recreation and tourism focal points in the Delta that could occur if investment is encouraged and coordinated.

When it comes to agriculture, the prospects for Delta agriculture are good. If land and water resources are protected in the Delta, the plan projects about a 5 percent shift of land towards higher-value vineyards and truck crops, while the corn and alfalfa remaining steady at roughly half of Delta agricultural land with prices remaining strong in the future. If urban encroachment is limited to existing sphere of influence of cities as we recommend, Delta agriculture will lose roughly 26,000 acres and $44 million in annual output to urbanization at current prices. The Delta could likely absorb a similar loss of agricultural land to habitat through 2050, and still meet the goal of maintaining and enhancing the value of Delta agriculture that will remain a solid, sustainable foundation for the Delta economy.

4 Integrated Issue 4: The Coequal Goals and Economic Sustainability

The Delta Reform Act of 2009 states:

> Coequal goals means the two goals of providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem. The coequal goals shall be achieved in a manner that protects and enhances the unique cultural, recreational, natural resource, and agricultural values of the Delta as an evolving place. (Water Code section 85054)

The Delta Reform Act does not endorse any specific actions to achieve the coequal goals, and there are many options for both water supply reliability and protecting, restoring, and enhancing the Delta ecosystem. It does not precisely define terms such as water supply reliability. Reliability clearly means reducing the risk of catastrophic interruptions and uncertainty over supplies, but it is not clear whether it means an increasing supply of water deliveries. The BDCP alone is evaluating at least five water conveyance options, and it is not evaluating all options, including the investment in a seismically-resistant levee system as described in this plan. Similarly, the BDCP includes 18 non-conveyance habitat strategies and is also not exhaustive of all the options to improve the Delta ecosystem.

The presence of the second sentence acknowledges that the coequal goals could conflict with protecting and enhancing the Delta. While the coequal goals must be satisfied, it expresses a clear preference for strategies that sustain and enhance the Delta over strategies that do not. Thus, one objective of the Economic Sustainability Plan has been to evaluate some of the leading proposals for the Delta to identify the strategies that do and do not “protect and enhance” the Delta. Because of the large number of options to achieve the coequal goals, the Economic Sustainability Plan can still be consistent with the coequal goals even as it recommends against a very small number of the available choices. The “evolving place” phrase recognizes that the Delta will and must change, and that status quo strategies are not acceptable.

The Economic Sustainability Plan recommends a set of actions that would dramatically change the Delta from its current state. The Economic Sustainability Plan would significantly improve water supply reliability by creating a seismically resistant levee system with enhanced emergency response that effectively addresses the risk of catastrophic, long-term interruption of water deliveries, the most important goal of water supply reliability. The Economic Sustainability Plan recommends many actions to improve the Delta ecosystem, including actions that support the Delta economy and even some actions that have significant costs for the Delta economy. The Economic Sustainability Plan presents a positive view of the Delta's economic future with strategies that are informed and realistic about the challenges it faces. Because of its lower cost and compatibility with Delta economic interests, the Economic Sustainability Plan is also a more feasible and realistic path to achieving the coequal goals than Delta plans that are built around large, isolated water conveyance facilities.

Chapter 12: Recommended Strategies and Actions for Economic Sustainability

The research and analysis for the Economic Sustainability Plan resulted in a number of findings and identified many important issues. The key findings are summarized at the beginning of each chapter, and the previous chapter further develops some important integrated issues that cut across the various topics. This final chapter presents the specific recommendations that support economic sustainability in the Delta.

Although the focus of this plan is the Delta, it is also a part of ongoing statewide planning initiatives related to the broader State's interests in the Delta's water resources and ecosystem. The plan recommends many specific actions where the State's coequal goals of water supply reliability and ecosystem restoration are consistent with the requirement to restore and enhance the Delta, and also identifies some proposed strategies that have conflicts with economic sustainability. Overall, the recommended strategies are consistent with the coequal goals of the 2009 Delta Reform Act.

1 Levees and Public Safety Recommendations

Levees are the fundamental infrastructure that supports the Delta and its economy. Chapter 5 contains a detailed analysis of the levee system and related emergency response and public safety issues. Levee investments are essential to economic sustainability in the Delta and are the most cost-effective strategy to achieve water supply reliability.

- **Improve and maintain all non-project levees to at least the Delta-specific PL 84-99 standard.** This engineering standard has been developed and supported by numerous studies and should remain the basic standard for non-project levees. These improvements are attainable and have economic benefits that exceed their cost, particularly when considered in the context of the systemic value of multiple infrastructure systems protected by the levee system. Achieving this goal will increase water supply reliability, and will leverage the substantial benefit of federal support through USACE in the event of future levee failures. Project levees should also be improved as necessary and maintained to a similar standard.

- **Improve most "lowland" levees and selected other levees to a higher Delta-specific standard that more fully addresses the risks due to earthquakes, extreme floods, and sea-level rise, allows for improved flood fighting and emergency response, provides improved protection for legacy communities, and allows for growth of vegetation on the water side of levees to improve habitat.** Improvement of most Delta lowland levees and selected other levees to this higher standard would cost $1 to $2 billion in base construction costs over the cost of reaching the PL 84-99 standard. Including vegetation and habitat enhancement, total program costs might be in the order of $4 billion, similar to the cost projected by the PPIC (2007) in their "Fortress Delta" alternative. While this is a longer-term program, planning should be initiated immediately.

- **The Delta Levee Subventions and Special Projects Program should continue to be supported.** These successful programs have significantly improved the performance of Delta levees in recent decades.

- **Transfer to a regional agency with fee assessment authority on levee beneficiaries of responsibility for allocating funds for the longer-term improvement of Delta levees and the coordination of Delta emergency preparedness, response, and recovery merits further consideration.** The Delta Stewardship Council has proposed the creation of a new agency, the Delta Flood Risk Management Assessment District, with fee assessment authority on levee beneficiaries including some beneficiaries that are not currently assessed for levee maintenance and improvement. In accordance with California Constitution Article XIII D sections 3 and 4, specific benefit assessment authority and approval must be in place before funding can be assured. Whatever agency is given these powers by the legislature should also be the vehicle for distributing any additional funds that are provided by the state and federal governments for levee investments. Formation of a new regional agency, such as a JPA consisting of the five Delta counties, or another entity approved by the Delta Protection Commission should have no impact on any existing liabilities associated with levee failures. This regional agency should place much more emphasis on preventative maintenance and inspections, flood fighting, and emergency response following earthquakes before any breach occurs than is currently the case. This agency would necessarily work in close cooperation with county, state, and federal emergency management programs and in particular would closely coordinate with the Department of Water Resources and the Bureau of Reclamation following single or multiple levee breaches as these organizations would continue to control water conveyance and upstream reservoir operations.

- **In addition to providing funding for longer-term levee improvements, provide ongoing funding for regular levee maintenance and expanded emergency preparedness, response, and recovery**. This sum should cover nonproject and project levees as defined in Water Code sections 12980(e) and (f). The division of this funding between regular physical maintenance of the levee system and emergency preparedness, response, and recovery should be determined by the regional agency that assumes responsibility for both these activities. A portion of these funds should be set aside each year for dealing with emergencies when they occur. Such annual funding should be in addition to an initial emergency fund contribution.

- **Reduce or eliminate regulatory impediments to action by the creation of a one-stop permitting system for selected activities within the Delta including dredging, levee construction, and ecosystem restoration.** Regulatory impediments add significant cost to these activities and reduction or elimination of these impediments will allow more efficient improvements and thus improve economic sustainability.

2 General Recommendations for Economic Sustainability

This section details several general economic development recommendations that span individual sectors.

- **Designate a regional agency to implement and facilitate economic development efforts.** Several of the analysis chapters, particularly the recreation and tourism analysis and legacy community chapter, identified a cross-cutting need for a regional organization to strategically organize and facilitate economic development activities. The task to facilitate economic development strategies should be placed within the Delta Protection Commission or joint powers authority (JPA) led by local governments. The main tasks of this entity are: marketing and branding, permitting and regulatory assistance, planning and coordination with counties and cities, and strategically managing the Delta Investment Fund. Section 1 of

Chapter 11 provides more details on the needed duties of the organization and evaluates the pros and cons of several candidate entities to take on the role.

- **Economic impacts of habitat creation and development of facilities for export water supply should be fully mitigated.** Local governments already face challenges delivering adequate public services to the rural Delta, and habitat development and other strategies could increase demand on local services while reducing the local tax base. Compensation for property taxes, assessments, and payments to property owners are essential parts of mitigation, but do not mitigate socio-economic impacts including lost income and sales in related industries and their associated tax revenues. Measuring and effectively compensating communities for dispersed and indirect net economic impacts should be further explored.

- **Land use planning and regulation must be clear and consistent across agencies.** The "covered action" component of the Delta Plan introduces a new element to land use planning that reduces local control and could increase uncertainty and risk to prospective investors. Increasing complexity of the Delta regulatory environment puts the Delta economy at a competitive disadvantage for new investment and will limit the ability of the Delta economy to evolve and be sustainable in a changing environment. It is vitally important that permitting, planning and regulation be streamlined, consistent, and coordinated across agencies. Local governments should be funded to develop base flood elevations.

3 Recommendations for the Economic Sustainability of Agriculture

Agriculture is the largest and most vital industry in the Delta. This section identifies the performance goal for Delta agriculture and several strategies to achieve it.

- **Maintain and enhance the value of Delta agriculture.** This goal is aligned with the performance measure in the Delta Stewardship Council's Fifth Draft of the Delta Plan, and can be attained in a way that is consistent with the State's coequal goals. The potential of other industries to replace any loss in economic output from Delta agriculture is limited.

- **Limit the loss of productive farmland to urbanization, habitat, and flooding to the greatest practical extent.** Some loss of farm land to these factors is inevitable, but continuing shifts of Delta agriculture to higher-valued crops and more value-added activities will compensate if land loss is not too great. To facilitate this goal, future residential development must be limited to the extent of city limits, city spheres of influence, and unincorporated areas that are consistent with city and county general plans. In addition, habitat measures must target existing public lands, lower-value agricultural lands, and consider adjusting acreage goals as discussed in the habitat recommendations.

- **Protect Delta water quality and water supplies for agriculture.** Increasing salinity levels and interference with water supply and flow—whether through changes to standards, operations of water export facilities, or habitat development—will harm Delta agriculture production.

- **Support growth in agritourism.** Agritourism is currently a very small contributor to the Delta's agricultural value, but is fast growing. Most agritourism is currently in the Secondary Zone close to urban areas, but could also be further developed in and around Legacy Communities and focal point recreation areas. Local area plans should support agritourism where appropriate.

- **Support local value-added processing of Delta crops.** Yolo County's agricultural and industrial zone that facilitated local expansion of the successful Bogle Winery is an example of a successful strategy. In addition to local governments, regulations from state and federal agencies such as FEMA that inhibit investment in value-added processing should be examined and streamlined where possible. This could be a role for the regional economic development entity described in Section 2. Besides the growth in wineries, this strategy can be applied to other emerging sectors such as olive pressing.

4 Recommendations for Economic Sustainability of Recreation and Tourism

Although recreation and tourism make a smaller contribution to the Delta economy than agriculture, it is a vital sector with growth potential that enhances quality of life for both residents and visitors. However, current trends in Delta recreation reveal signs of stagnation, and significant actions are required in order to capture the potential growth. Chapter 8 contains a detailed recreation and tourism enhancement strategy that contains 18 guiding principles developed to minimize constraints and take advantage of current and future influences and opportunities, resulting in five place-based strategies.

- **Protect and enhance private enterprise-based recreation with support from state and local public agencies.** Most of the economic activity related to recreation is generated by private enterprise. Public agencies can provide catalyst settings, recreation facilities, streamline permitting, and infrastructure to improve access, enhance and create settings for private development, and services.

- **Focus recreation development in five location-based concepts:**

  1) Enhance Delta Waterways
  2) Develop Dispersed Points of Interest and Activity Areas
  3) Create Focal Point Destination Complexes with natural areas, parks, Legacy Communities, marinas, historic features, and trails
  4) Expand public access to Natural Habitat Areas
  5) Create recreation-oriented buffers at Delta urban edges

- **Implement Economic Sustainability Plan through specific strategies**. Recommended strategies include consistency planning and regulation refinement, coordination among state and local agencies, obtaining strategic levee protection for legacy communities and key recreation areas, designating a marketing and economic development facilitator, and providing key funding for catalyst projects and agencies.

5 Recommendations for Infrastructure

The Delta's natural resources and its central location in the Northern California megaregion support its role as an infrastructure hub of local, state, and national importance. Chapter 9 analyzes key components of the Delta's infrastructure services, and identifies several means to ensure these goals are achieved.

- **Planning of levee investments must fully consider the economic value of infrastructure services along with all other benefits.** Comparisons of levee costs to farmland values substantially understate the value and importance of the levee system. Increased levee investment is needed to sustain critical energy, transportation, and water supply infrastructure.

- **All owners and operators of infrastructure that depend on Delta levees must contribute to levee system investment and maintenance.** Some infrastructure systems make little or no financial contribution to sustaining Delta levees. All infrastructure services, including transportation, energy, and through-Delta conveyance of water must support levee investment.

- **Protect and improve Delta water quality and supply for agricultural, municipal and industrial uses.** Both salts and organic carbon significantly increase costs for farms, households, business and industry, in and outside the Delta.

- **Ensure that future development of infrastructure in the Delta is aligned with economic sustainability strategies**. Infrastructure demands within and around the Delta will require significant future investment. For example, investment in Delta roads and highways should be integrated with strategies to enhance agriculture, recreation, Legacy Communities, and emergency preparedness in the Delta, as well as minimize conflicts between uses. This could be a role for the Regional Economic Development Entity.

- **Support expansion and development of the ports.** The Marine Highway Corridor initiative offers significant environmental and infrastructure benefits for the greater Northern California Region, and is catalyzing economic development around Stockton, West Sacramento, and the state. More generally, development of these ports and marine facilities in the Pittsburg, Antioch, and Collinsville areas will support greater inter-regional integration, competitiveness, and economic development in the state.

6 Recommendations for Habitat and Ecosystem Improvements

Improving the Delta ecosystem is important to Delta communities, required by the coequal goals, and in some cases can benefit the Delta economy. However, there are some ecosystem proposals that can negatively impact the Delta economy and quality of life while having very uncertain benefits for the ecosystem. For example, the Economic Sustainability Plan finds that BDCP habitat proposals (not including conveyance) would reduce annual Delta agriculture revenues between $33 million and $137 million per year depending on how they are implemented. An evolving Delta economy could adapt to a $33 million decrease in agricultural revenue from habitat development, but a $137 million annual loss would create significant dislocation that could not be made up in other sectors. The wide variation shows the critical importance of considering Delta economic impacts when planning habitat projects.

- **Emphasize strategies with little or no conflict with the Delta economy.** Examples include increased fresh water flows, growth of vegetation on enlarged levees, restoration of mid-channel berms, and reactivation of upstream floodplains.

- **Expanded and enhanced flood bypasses can be consistent with economic sustainability if agencies work with local stakeholders to minimize and mitigate economic impacts.** Enhancing flood bypasses benefits fish and flood control, but can significantly impact agricultural production. The proposal to expand and enhance the Paradise Cut bypass in the South Delta is an example of an effective compromise between environmental groups and local landowners, and should be implemented.

- **Tidal marsh habitat plans should be significantly reduced.** Conversion of agricultural land to tidal marsh habitat creates significant economic, health, and water supply concerns with uncertain benefits for fish species. Tidal marsh would take high-value agricultural land out of production, negatively impact water quality for in-Delta and out-of-Delta users, increase seepage risks for nearby levees and lands, potentially increase water use, and create mosquito and vector control problems. Any tidal marsh habitat plans should be developed in cooperation with local stakeholders.

- **Increased open-water habitat in the Delta is not recommended.** Flooded islands in the Delta would create similar problems to tidal marsh, increase wave and seepage forces on adjacent islands and levees, and could have other significant negative effects on recreational boating and existing marinas and recreational facilities. The ecosystem benefits of open water are uncertain.

- **Include recreation facility development in habitat enhancement plans when possible.** Habitat restoration plans should be aware of the recreation and tourism enhancement strategy and look for co-development opportunities.

- **Habitat restoration should start on State-owned land and only occur on private lands with willing sellers consistent with local land use plans.** While willing sellers of habitat and easements are essential, it is important to note that compensating owners of land does not mitigate the socio-economic impacts of taking farm land out of production for habitat. In most cases, the loss in employee, supplier, and processor income in addition to other community spillover effects significantly exceeds the loss in farm income that is compensated through a voluntary sale.

7 Recommendations for Water Supply Reliability

Water supply reliability is required by the Delta Reform Act, but not defined. Reducing the risk of interruptions in water supply from earthquakes or floods is clearly one aspect of reliability, but there is debate about whether increasing reliability means increasing the quantity of water exported from the Delta or allows for decreasing it. The state policy to reduce reliance on the Delta suggests that lower exports from the Delta can be consistent with reliability as long as export supplies are more stable and secure. Regardless of the definition of reliability, sustaining and enhancing the Delta as a place requires consideration of the potential impacts of measures to improve water supply reliability on the Delta economy and quality of life. There are four primary areas of in-Delta impacts: 1) water quality; 2) land consumption by water supply infrastructure; 3) visual, noise, and other operational impacts of supply intakes; and 4) the risk of reduced water quality and/or the risk of reduced levee investments in the future.

- **Continuing the through-Delta conveyance is important to economic sustainability in the Delta and can be consistent with water supply reliability within and outside the Delta.** The substantial levee investments recommended in the ESP will substantially increase the reliability of through-Delta conveyance at a much lower cost than isolated conveyance.

- **A dual conveyance plan with a large, 15,000 cfs isolated conveyance facility has large conflicts with Delta economic sustainability and has high risk for Delta stakeholders**. Even if water quality standards were maintained, a large facility would have significant agricultural impacts, as well as negative quality of life and tourism impacts. The biggest long-term problem with isolated conveyance is the risk of lower water quality to maximize the value of the large facility to the exporters paying for the facility, and a reduced commitment to levee investment and maintenance by the State and water exporters that puts the Delta economy and other regional infrastructure at greater risk.

- **Options to large isolated conveyance must be fully and consistently evaluated**. In addition to through-Delta conveyance with the large levee upgrades, maintenance, and emergency measures recommended in this plan, these options include, but are not limited to a smaller-capacity isolated conveyance, the Delta Corridors plan, and proposals to move export intakes to the Western Delta in conjunction with additional south of Delta storage.

8 Recommendations for Research and Monitoring

The research for the Economic Sustainability Plan exposed some significant data and research gaps regarding the Delta economy and infrastructure systems. New data and research can help clear up points of disagreement and facilitate progress towards Delta solutions.

- **New recreation data is needed and should be updated regularly.** A key first step is to improve data on recreation and tourism use with an updated visitor survey and additional primary data collection that is repeated on five-year intervals. This data is crucial for future recreation planning and marketing, and could inform ecosystem restoration plans.

- **Maintain an Economic Sustainability Scoreboard to track progress.** Agricultural data is more available than recreation but should be consistently collected and compiled over time. Indicators for infrastructure, other economic sectors, and socio-economic status should also be developed and tracked to inform implementation of the plan.

- **The Delta Science Program should sponsor more engineering and economic studies in addition to ecological research.** Information gaps surrounding Delta levees, local economic impacts, and valuation of benefits, and costs of ecosystem restoration hinder Delta decision making and should be a higher priority for scientific research funding.

- **Increase alignment among the various research and planning initiatives.** Updates of the Delta Plan should consider periodic updates of the Economic Sustainability Plan.

Bibliography

Agricultural Issues Center. 2011. "AIC Delta Study Final." University of California, Davis. Accessed online: http://ebookbrowse.com/aic-delta-study-final-pdf-d114951800

Akers, Patrick. 2010. "Aquatic Weed Integrated Vegetation Management Plan – Contra Costa Delta." Updated 10/9/2010. Accessed online: http://www.delta.ca.gov/res/docs/Spongeplant%207%2028%2011.pdf

Atwater, B. 1982. "Geologic Maps of the Sacramento-San Joaquin Delta, California." USGS Miscellaneous Field Studies Map MF-1401. U.S. Geological Survey, U.S. Department of the Interior.

Baldwin, R. 2011. "San Joaquin County Comments on the First Staff Draft of the Delta Plan." Delta Stewardship Council. Accessed online: http://deltacouncil.ca.gov/public-comments/read/143?page=1.

Betchart, Will B. 2008. "Delta Levees – Types, Uses and Policy Options." Prepared for Delta Vision, August.

Betchart, Will B. 2011. Memo to Delta Levees and Habitat Advisory Committee, California Department of Water Resources, with attached MOU.

CALFED Bay-Delta Program. 1995. *Delta Atlas.* California Department of Water Resources. Accessed online: http://baydeltaoffice.water.ca.gov/DeltaAtlas/index.cfm.

CALFED Bay-Delta Program. 2000. *Levee System Integrity Program Plan.* Prepared for California Department of Water Resources, California Department of Fish and Game, and US Army Corps of Engineers.

CALFED Bay-Delta Program. 2007. "First Independent Review of the DRMS Phase 1 Report." Accessed online: http://calwater.ca.gov/science/drms/drms_irp.html

California Department of Boating and Waterways. 2002. *Sacramento-San Joaquin Delta Boating Needs Assessment (2000-2020)*. Prepared by The Dangermond Group, Sacramento, California.

California Department of Boating and Waterways. 2011 *California Coastal Commission, Santa Monica Bay Restoration Foundation, Keep the Delta Clean Program. 2011. 2007-2009* California Boater Survey Report, prepared by researchers at the Public Research Institute, San Francisco State University.

California Department of Boating and Waterways. 2009. Non-Motorized Boating in California, prepared by NewPoint Group.

California Department of Conservation: Department of Oil, Gas, and Geothermal Resources. 2010. "Report of the State Oil & Gas Supervisor."

California Department of Fish and Game. 2001. "Licensing." Accessed online: http://www.dfg.ca.gov/licensing/

California Department of Motor Vehicles. 2011. "Total Vessel Registrations by County." Accessed online: http://www.dbw.ca.gov/PDF/VesselReg/Vessel10.pdf

California Department of Parks and Recreation. 1997. *Sacramento-San Joaquin Delta Recreation Survey*.

California Department of Parks and Recreation. 2009. *Surveys on Public Opinions and Attitudes on Outdoor Recreation in California*.

California Department of Parks and Recreation. 2010. *California State Park System Statistical Report: 2008/2009 Fiscal Year*. Planning Division, California Department of Parks and Recreation.

California Department of Parks and Recreation. 2011. *Recreation Proposal for the Sacramento-San Joaquin Delta and Suisun Marsh (Draft for Public Review, 5/3/11).* Planning Division, California Department of Parks and Recreation.

California Department of Transportation. 2009. Caltrans Traffic Volume Data, 2002-2009. Traffic Data Branch. Accessed online: http://www.dot.ca.gov/hq/traffops/saferesr/trafdata/index.htm

California Department of Transportation. 2011. *SR-12 Comprehensive Corridor Evaluation and Corridor Management Plan from SR-29 to I-5*.

California Department of Water Resources. 1982. “Delta Levees Investigation.” Bulletin 192-81, December.

California Department of Water Resources. 1995. *Delta Atlas*. Page 38. Accessed online: http://baydeltaoffice.water.ca.gov/DeltaAtlas/06-FloodControl.pdf

California Department of Water Resources. 2007. “Status and Trends of Delta-Suisun Services.” Accessed online: http://deltavision.ca.gov/DeltaVisionStatusTrends.shtml

California Department of Water Resources. 2009. *Delta Risk Management Strategy Final Phase 1 Report.* Accessed online: http://www.water.ca.gov/floodmgmt/dsmo/sab/drmsp/phase1_information.cfm.

California Department of Water Resources. 2011. *Delta Risk Management Strategy Final Phase 2 Report*. Accessed online: http://www.water.ca.gov/floodmgmt/dsmo/sab/drmsp/phase2_information.cfm

California Department of Water Resources. 2011. Flood Management: *Delta Risk Management Strategy.*

California Department of Water Resources. 2011. DRAFT V3 DHF and SMB, “A Framework for Department of Water Resources Investments in Delta Integrated Flood Management.”

California Department of Water Resources. 2011. Staff DRAFT, “Background/Reference Memoranda, Delta Region Integrated Flood Management Key Considerations and Statewide Implications.”

California Energy Commission. 1997-2010. “California Energy Almanac.” Accessed online: http://energyalmanac.ca.gov/

California Public Utilities Commission. 2010. *California Natural Gas Infrastructure*.

California Regional Economic Analysis Project. 2011. Business Forecasting Center, Eberhardt School of Business, University of the Pacific and the Pacific Northwest Regional Economic Analysis Project. Accessed online: http://california.reaproject.org/

California Senate Local Government Committee. 2010. *What’s So Special About Special Districts (4th Ed.)*. Accessed online: http://www.csda.net/index.php?option=com_remository&Itemid=247&func=startdown&id=12

Center for Economic Studies (LED-LEHD). Longitudinal Employer-Household Dynamics. United States Census Bureau. Accessed online: http://lehd.did.census.gov/led/index.php

Contra Costa County Community Development Department. 2005. “Contra Costa County General Plan”. Accessed online: http://www.co.contra-costa.ca.us/depart/cd/current/advance/GeneralPlan/CCCGeneralPlan.pdf

County of Sacramento. 1993. “Sacramento County General Plan”. Accessed online: http://www.msa2.saccounty.net/planning/Pages/GeneralPlan.aspx

Dangermond, Pete. 1993. “Parks and Recreation: Vital to a Way of Life.” In T. Palmer, ed. 1993. *California's Threatened Environment: Restoring the Dream.* Planning and Conservation League Foundation. Covelo, California: Island Press. P. 219.

Delta Dredged Sediment Long-Term Management Strategy (LTMS). 2011. US Army Corps of Engineers. Accessed online: http://deltaltms.com/

Delta Protection Commission. 1994. “Utilities and Infrastructure: Background Report.”

Delta Protection Commission. 1997. “Inventory of Recreation Facilities.”

Delta Protection Commission. 2006. “The Aquatic Recreation Component of the Delta Recreation Strategy Plan.” Prepared by The Dangermond Group, Sacramento, California.

Delta Protection Commission. 2010. "The Great California Delta Trail Blueprint Report for Contra Costa and Solano Counties." Prepared by: Alta Planning + Design.

Delta Protection Commission. 2010. *Framework for a Delta Economic Sustainability Plan*. Prepared by Bay Area Economics.

Delta Protection Commission. 2011. National Heritage Areas. Accessed online: http://www.delta.ca.gov/heritage.htm

Delta Protection Commission. 2011. Sacramento-San Joaquin Delta map. Accessed online: http://www.delta.ca.gov/res/docs/map/delta.pdf

Delta Stewardship Council. 2010. Flood Risk White Paper. Accessed online: www.deltacouncil.ca.gov/white-papers

Delta Stewarship County. 2011. "Fifth Staff Daft Delta Plan".Accessed online: http://www.deltacouncil.ca.gov/sites/default/files/documents/files/Fifth_Staff_Draft_Delta_Plan_080211.pdf

Downey and Clinkenbeard. 2005. "An Overview of Geologic Carbon Sequestration Potential in California." California Geologic Survey, Sacramento, California.

Federal Emergency Management Agency. 2010. Region IX RiskMAP. *Guide to Flood Contingency Mapping*. Accessed online: http://sjmap.org/oesmg/gfcm/flood_map_guide_final_6-1-10.pdf

Geidel, Marcia A. and Susan J. Moore, in association with Edilberto Z. Cajucom. 1981. *Sacramento-San Joaquin Delta Recreation Concept Plan*. Prepared for California Department of Water Resources.

Goldman, George, Bruce McWilliams, Vijay Pradhan, and Cheryl Brown. 1998. *The Economic Impact of Recreational Boating and Fishing in the Delta.* Department of Agricultural and Resource Economics. University of California, Berkeley. November 1998. Page 12.

Healey, M., and J. Mount. 2007. "Delta Levees and Ecosystem Function." Memorandum to John Kirlin, Executive Director of Delta Vision. November 2007.

Hoover's. 2010. "Enterprise Database." Dun and Bradstreet. Accessed online: http://subscriber.hoovers.com

Howitt, Richard. 2007. "Delta Dilemmas: Reconciling Water-Supply Reliability and Environmental Goals." *Agricultural and Resource Economics Update*, Volume 10(4): 1-4.

Hultgren-Tillis Engineers. 2009. Geotechnical Evaluation, Seismically Repairable Levee, Webb Tract. Report to Reclamation District 2026, December.

Inamine, M. et al. 2010. "California's Levee Evaluation Program." Paper presented at US Society of Dams, 30th Conference, Sacramento, California.

Lower San Joaquin River Flood Bypass Proposal. South Delta Levee Protection and Channel Maintenance Authority. Submitted to California Department of Water Resources, March, 2011.

Merrill, A., S. Siegel, B. Morris, A. Ferguson, G. Young, C. Ingram, P. Bachand, H. Shepley, M. Singer, and N. Hume. 2010. *Greenhouse gas reduction and environmental benefits in the Sacramento-San Joaquin Delta: advancing carbon capture wetland farms and exploring potential for low carbon agriculture*. Prepared for The Nature Conservancy, Sacramento, California. Accessed online: http://www.stillwatersci.com/search.php?page=0&s=0&key=a&type=reports&order=year&d=d

Mount, J.F. and R. Twiss. 2005. "Subsidence, sea level rise, seismicity in the Sacramento–San Joaquin Delta." *San Francisco Estuary and Watershed Science*, Volume 3, article 5.

NARPRAIL. 2011. Amtrak Fact Sheet: *San Joaquin Service. Status and Trends of Delta-Suisun Services*. Public Review Draft.

National Establishment Time-Series (NETS) Database. 2011. Walls & Associates. Accessed online: http://www.youreconomy.org/

National Park Service. 2011. "Heritage Areas 101." U.S. Department of the Interior. Accessed online: http://www.delta.ca.gov/res/docs/InfoSheet_NHA.pdf
NDC (National Data Center). 2009. "US Army Corps of Engineers Waterborne Commerce Statistics Center." 2005-2009 data accessed online 6-30-2011: http://www.ndc.iwr.usace.army.mil//wcsc/webpub09/webpubpart-4.htm
North American Industry Classification System. 2011. U.S. Census Bureau. Accessed online: http://www.census.gov/eos/www/naics/
Paterno v. State of California. 2003. 113 Cal.App.4th 998.
Port of Stockton. 2011. *Maritime Highway Project Brochure*. Accessed online: http://www.portofstockton.com/Downloads/SSS%20Brochure.pdf
Pyke, R. 2011. "Comments of the First Staff Draft of the Delta Plan." Delta Stewardship Council. February, 2011. Accessed online: http://deltacouncil.ca.gov/public-comments/read/143?page=1.
RealtyTrac. 2011. Foreclosure Trends, State & Trends. Accessed online: http://www.realtytrac.com/trendcenter/ca/sacramento-county-trend.html
Rio Vista Community Development Department. 2002. "City of Rio Vista General Plan 2001". Accessed online: http://www.rio-vista-ca.com/general-plan
San Francisco Public Utilities Commission. 2011. Water System Improvement Program. Accessed online: http://sfwater.org/index.aspx?page=115.
San Joaquin County Community Development Department. 1992. "San Joaquin County General Plan 2010". Accessed online: http://issuu.com/mintier/docs/sjcgp1992_v1
Solano County Planning and Services Department. 2008. "Solano County General Plan". Accessed online: http://www.co.solano.ca.us/depts/rm/planning/general_plan.asp
South Delta Levee Protection and Channel Maintenance Authority. 2011. "Lower San Joaquin River Flood Bypass Proposal." Submitted to California Department of Water Resources.
Suddeth, R., J. Mount, and J. Lund. 2008. "Levee Decisions and Sustainability for the Sacramento-San Joaquin Delta." In *Comparing Futures for the Sacramento-San Joaquin Delta*, Public Policy Institute of California, San Francisco, California.
Suddeth. R. 2011. "Policy Implications of Permanently Flooded Islands in the Sacramento-San Joaquin Delta." University of California, Davis, Center for Watershed Sciences. Accessed online: http://watershed.ucdavis.edu/pdf/Suddeth_Policy_Implications_of_Flooded_Islands_080110.pdf
Thompson, J. 1957. "Settlement Geography of the Sacramento–San Joaquin Delta, California." PhD dissertation, Stanford University.
Timar, Thomas. 2006. "How California Funds K-12 Education." Institute for Research on Education Policy and Practice, Stanford University. Accessed online: http://irepp.stanford.edu/documents/GDF/STUDIES/02-Timar/2-Timar(3-07).pdf
US Army Corps of Engineers. 2011. *Delta Dredged Sediment Long-Term Management Strategy*. Accessed online: http://www.deltaltms.com/index.htm
US Army Corps of Engineers. 2011. Sacramento-San Joaquin Delta newsletter. Accessed online: http://www.spk.usace.army.mil/projects/civil/Delta/News.html
U.S. Bureau of Labor Statistics. Workforce Statistics. United States Department of Labor. Accessed online: http://www.bls.gov/iag/tgs/iag62.htm
U.S. Bureau of Reclamation. The 2-Gates Fish Protection Demonstration Project. Accessed online: http://www.usbr.gov/mp/2gates/docs/2-gates_factsheet_latest.pdf
U.S. Census Bureau. 2009. "2005-2009 American Community Survey (ACS)." U.S. Department of Commerce. Accessed online: http://factfinder.census.gov/
U.S. Census Bureau. 2009. "Longitudinal Employer-Household Dynamics. OnTheMap." Prepared with U.S. Department of the Interior, U.S. Department of Commerce. Accessed online: http://lehd.did.census.gov/led/index.php.

U.S. Department of the Interior. 1996. “National Survey of Fishing, Hunting, and Wildlife-Associated Recreation.” Prepared by Fish and Wildlife Service, U.S. Department of Commerce, and U.S. Census Bureau.
U.S. Department of the Interior. 2006. “National Survey of Fishing, Hunting, and Wildlife-Associated Recreation.” Prepared by Fish and Wildlife Service, U.S. Department of Commerce, and U.S. Census Bureau.
Yolo County Department of Planning and Public Works. 2009. “2030 Countywide General Plan. Accessed online: http://www.yolocounty.org/Index.aspx?page=1965
Yolo County Planning Commission. 2001. “Clarksburg General Plan”. Accessed online: www.yolocounty.org/Modules/ShowDocument.aspx?documentid=15783
Zengler, H. Airport-Data.com. http://www.airport-data.com/
Zuckerman, T. 2011. “Comments on the Third Staff Draft of the Delta Plan.” Delta Stewardship Council. Accessed online: http://deltacouncil.ca.gov/public-comments/read/195.

Legislation and Acts

“Sacramento-San Joaquin Delta National Heritage Area Establishment Act.” 2011. S-29. Feinstein, Dianne. Available online: http://www.govtrack.us/congress/bill.xpd?bill=s112-29
“Sacramento-San Joaquin Delta National Heritage Area Establishment Act.” 2011. H.R. 486. Garamendi, John. Available online: http://www.govtrack.us/congress/bill.xpd?bill=h112-486
“Central Valley Flood Protection Act of 2008.” Senate Bill 5 (Implementing): Machado, Florez, Wolk, Steinberg, Laird.
“The Safe Drinking Water, Water Quality and Supply, Flood Control and Coastal Protection Bond Act of 2006.” Proposition 84. Accessed online: www.lao.ca.gov/handouts/resources/2006/Prop_84_08_08_06.pdf
“The Disaster Preparedness and Flood Protection Bond Act of 2006.” Proposition 1-E / AB142: Nunez/Perata. AB 142: (Proposition 1E). Accessed online: http://www.leginfo.ca.gov/pub/05-06/bill/asm/ab_0101-0150/ab_140_bill_20060504_amended_sen.pdf
“Delta Protection Act Of 1992”. Johnson/Baker/Andal/Boatwright. SB 1866. Accessed online: http://ceres.ca.gov/planning/pzd/2000/pzd2000_web/pzd2000_misc21.html

Exhibit “T”

State of California The Resources Agency

Memorandum

Date : JUL 11 2001

To : Mike Ford
Office of State Water Project Planning

From : Karl P. Winkler, Chief
Central District
Department of Water Resources

Subject: Reclamation District 544 Seepage Monitoring Study

Central District is pleased to present the attached report, *Reclamation District 544 Seepage Monitoring Study, 2000-2001*. This report presents seepage monitoring results from Upper Roberts Island. Surface and groundwater level monitoring was initiated in April 2000 to evaluate the effects of the operation of the temporary fish barrier at the head of Old River on shallow groundwater levels on Upper Roberts Island. This work was completed at the request of the Temporary Barriers Project and Land Management Section of the Office of State Water Project Planning with the cooperation of Reclamation District (RD) 544 and several landowners.

Data was collected from seven groundwater monitoring stations and a river stage gage along the San Joaquin River at Upper Roberts Island. During the study period, river stage and groundwater levels did not rise above the Island's land surface and seepage was not observed.

If you have any questions regarding this report, please contact Mark Souverville at (916) 227-7601.

Attachment

SURNAME

DWR 155 (Rev. 2/86)

Mark Souverville 07/11/01	07/11/01	7-12-01	

Reclamation District 544 Seepage Monitoring Study
2000-2001

This report presents seepage monitoring results from Upper Roberts Island. Surface and groundwater level monitoring was initiated in April 2000 to evaluate the effects of the operation of the temporary fish barrier at the head of Old River on shallow groundwater levels on Upper Roberts Island. This work was completed at the request of the Temporary Barriers Project and Land Management Section of the Office of State Water Project Planning with the cooperation of Reclamation District (RD) 544 and several landowners.

Introduction

Upper Roberts Island is an agricultural area in the south Delta, bounded on the west by Middle River, on the south by Old River and on the east by the San Joaquin River. The north end of the head of Old River barrier rests on the Island's Old River levee at the point where it branches from the San Joaquin River. The head of Old River barrier is operated to benefit fisheries. Studies conducted by the U.S. Fish and Wildlife Service suggest that there may be a higher rate of survival for salmon smolt emigrating through the San Joaquin River rather than Old River (DWR 1998, 1999). The barrier is emplaced to prevent outmigrating salmonids in the San Joaquin River from entering Old River and subsequently the Central Valley and State Water Project pumps. It is constructed in the spring and fall of each year, except during high flows.

Streamflow and stage on the east and west sides of Upper Roberts Island is affected by the barrier. During periods of barrier operation, flow and stage in Old River are reduced while flow and stage along the San Joaquin River are increased.

Landowners on Upper Roberts Island have been concerned that the rise in San Joaquin River stage due to the fish barrier has caused a rise in the groundwater levels on the Island, creating a negative impact on crop production. The fish barrier at the head of Old River is bounded on both ends by private land, and temporary entry permits are required to install the barrier. The landowners on Upper Roberts Island have requested, as a condition of the temporary entry permits, that the Department of Water Resources (DWR) monitor groundwater levels on the Island to evaluate seepage

Monitoring Site Selection

Three seepage monitoring sites were chosen on Upper Roberts Island in coordination with Jerry Robinson, President of RD 544, Bill Darsie of Kjeldsen, Sinnock and Neudeck, and staff from DWR's Office of State Water Project Planning (OSWPP) and Central District (CD). A regional map (Figure 1) shows the location of the three monitoring sites, the San Joaquin River stage gages, and the head of Old River barrier. Well locations at each site were determined after evaluating boring samples and nearby surface features, such as canals. These locations are shown on topographic maps of the three sites (Figures 2-4). Each site has two shallow wells, one near the levee toe and the other approximately 150 feet inland from the toe, to monitor the groundwater gradients adjacent to the San Joaquin River. An additional deeper well was drilled at Site 1 to attempt to determine the vertical gradient.

Monitoring Network Installation

Seven wells were installed prior to the spring 2000 emplacement of the head of Old River barrier. The well depths range from 18 to 40 feet below the ground surface with each well having a 5-foot screened interval. The goal was to install the wells within a saturated, coarse-grained unit beneath each site. A truck-mounted Central Mine Equipment 750 drill rig was used to drill the borings. All borings were advanced with 8-inch diameter hollow stem augers. Soils were collected for description using a continuous sampling tube. Details of the drilling, descriptions of the soils, and field classifications of the soils are provided on the drill hole logs in Appendix A. The construction details of each monitoring well are included with each well log. Table 1 lists the depth, reference point elevation, and screened interval for each well.

Well	Boring Depth[1]	Well Depth[1]	Screened Interval[1]	Reference Point Elevation[2]
UR1A	30	28	23-28	16.15
UR1B	27	25	20-25	16.24
UR1C	40	40	35-40	16.01
UR2A	20	17	12-17	12.57
UR2B	21	19	14-19	12.21
UR3A	18	17	12-17	9.89
UR3B	20	20	15-20	9.92

1. Depth below ground surface in feet
2. Reference point at top of plastic casing

National Geodetic Vertical Datum 1929

Table 1. Well Depths and Reference Point Elevations

In addition to the groundwater monitoring well installations, a temporary tide gage was installed in April 2000. The gage was mounted on an existing pumping platform in the San Joaquin River about 1,500 feet downstream from the temporary barrier. A permanent station is planned to be constructed by fall 2001. The San Joaquin River stage is compared to groundwater levels on Upper Roberts Island to determine the effect of river stage on groundwater levels.

CD staff surveyed the monitoring network for elevation and horizontal position. The U.S. Army Corps of Engineers (USACE) and U.S. Geological Survey benchmark "Tidal 6," National Geodetic Vertical Datum 29, elevation 16.85 feet, is the datum for this survey. The "Tidal 6" benchmark is located on the north levee of Old River near the temporary barrier. The elevation survey determined reference point and ground surface elevations at each monitoring well and a reference point elevation on the San Joaquin River tide gage.

Topographic maps of the seepage monitoring sites and adjacent river section, Figures 2 through 7, were constructed using data from USACE, Sacramento District. Ayres Associates, under contract to USACE, collected hydrographic and photogrammetric survey data of the San Joaquin River Basin in 1998. Along with geologic information from boring logs, USACE's data was used to develop cross sections perpendicular to the San Joaquin River at the seepage monitoring sites.

Well	Northing (Meters)	Easting (Meters)	Ground Surface Elevation (Feet)
UR1A	4186190	647406	13.06
UR1B	4186337	647391	13.04
UR1C	4186340	647390	13.01
UR2A	4190671	647506	9.38
UR2B	4190657	647460	8.96
UR3A	4191875	647681	6.67
UR3B	4191887	647639	7.24

CD staff determined geographic coordinates of the wells using a Trimble Pro XR Global Positioning System.

Universal Transverse Mercator Zone 10 projection

Table 2. Well Locations

Hydrogeology

The soils encountered at the three sites occur as alternating layers containing varying amounts of clay, silt and/or sand mixtures. Saturated coarse-grained layers were encountered at each site for placement of well screens. For a detailed description, refer to the drill hole logs in Appendix A.

At Site 1, as shown in Figure 5, alternating clay and silt layers were observed from the surface up to 24 feet below ground surface (bgs) during drilling. Total depth of borings for UR1A, UR1B and UR1C were 30 feet, 27 feet and 40 feet respectively. Water bearing sand occurs from 24 feet to the total depth of boring (TD) in UR1A, from 21 to 25 feet in UR1B, and from 20 to 24 feet and 29 feet to TD in UR1C. A clay layer occurs between two water bearing sand layers at depths of 25 feet to TD in UR1B and 24 to 29 feet in UR1C.

At Site 2, as shown in Figure 6, clay was observed from the surface up to 8 feet bgs. Total depth of borings for UR2A and UR2B were 20 feet and 21 feet respectively. Water-bearing sand occurs from 13 to 17 feet in UR2A, and from 15 feet to TD in UR2B. A clay layer occurs between two permeable sand layers at depths of 11 to 13 feet in UR2A and 14 to 15 feet in UR2B. Silt occurs from 17 feet to TD in UR2A.

At Site 3, as shown in Figure 7, alternating clay and silt layers were observed from the surface up to 11 feet bgs. Total depth of borings for UR3A and UR3B were 18 feet and 20 feet respectively. Permeable sand occurring from the surface to a depth of 6 feet in UR3A overlies silty clay that is present to a depth of 11 feet. Water-bearing sand occurs from 11 to 17 feet in UR3A and 10 to 13 feet and 16 feet to TD in UR3B. Clay occurs from 13 to 16 feet in UR3B.

Data from the geologic borings indicate that water bearing sand layers beneath each site likely extend to the left bank of the San Joaquin River (Figures 5 through 7). Groundwater should move freely within these sands, but the soils overlying these sands are primarily silts and clays, except at well UR3A. These silts and clays will impede the vertical movement of groundwater.

Monitoring Activities

The period of record for stage and groundwater elevation data in this report is April 20, 2000 to April 20, 2001. Groundwater elevation levels in each well are measured and recorded hourly using an In-situ Troll datalogger/transducer. The data is collected monthly with a palmtop computer. Stage data is measured and recorded hourly by a Hydrolab Datasonde 3. The data is collected monthly with a laptop computer. The San Joaquin River at Brandt Bridge station, maintained by DWR, measures and records stage data at 15-minute intervals. The river stage gage at Vernalis is operated jointly by the U.S. Geological Survey and DWR. It measures and records hourly stage data and posts it to the California Data Exchange Center web page.

Monitoring Results

The collected data were evaluated by creating hydrographs for each site showing groundwater elevation, ground surface elevation and San Joaquin River stage (Figures 8 through 15). Vertical lines bracket the periods of construction and removal of the head of Old River fish barrier. A solid horizontal line represents the ground surface at the monitoring site.

The following observations can be made from the San Joaquin River hydrograph, Figure 8. Over the period of record, water levels in the monitoring wells and the stage gage on the San Joaquin River at Upper Roberts Island peaked in April 2000, during a period of reservoir releases for the Vernalis Adaptive Management Plan (VAMP). Stage data from Vernalis, located 13 miles southeast and upstream of the barrier, show that the same activities (occurrences) that influence stage at

Vernalis are the primary influences on San Joaquin River stage along Upper Roberts Island.

The following observations can be made from the Site 1 hydrographs, Figures 9 through 13. Changes in groundwater elevation at the site mimic changes in the adjacent river stage but are less pronounced and lag slightly behind. The groundwater elevation in well UR1A was the most responsive to changes in river stage. During the period of record, the highest recorded river stage at the temporary gage on the San Joaquin River was 7.59 feet, coincident with a groundwater elevation of 6.38 feet (depth of 6.68 bgs) in well UR1A. During the period of record, the San Joaquin River maintained stage above groundwater from April 20, 2000 to mid May, the beginning of October to the beginning of December and mid February to mid March. During these periods, groundwater elevations in well UR1A were closer to river stage than to groundwater elevations in wells UR1B and UR1C. From mid May to mid August, the San Joaquin River maintained stage below groundwater elevations and groundwater elevations in well UR1A were predominantly below well UR1B. The elevation of groundwater in well UR1B is consistently slightly higher than in well UR1C, but the water level trends in the two wells are nearly identical. The predominant groundwater elevation gradient has been away from the San Joaquin River.

The following observations can be made from the Site 2 hydrograph, Figure 14. Changes in groundwater elevation at the site mimic changes in the river stage, downstream approximately 1.4 river miles at Brandt Bridge, but are less pronounced. The groundwater elevation in well UR2A was more responsive to changes in river stage than the groundwater elevation in well UR2B. During the period of record, the highest recorded San Joaquin River stage at Brandt Bridge was 5.51 feet, coincident with a groundwater elevation of 4.84 feet (depth of 4.54 bgs) in well UR2A. During the period of record, the San Joaquin River stage at Brandt Bridge was not observed above groundwater elevations in either well for any extended period. When stage did rise above groundwater elevation, however, the groundwater elevation in well UR2A approached river stage at a greater rate than the groundwater elevation in well UR2B. From April 20, 2000 to mid June, the San Joaquin River at Brandt Bridge maintained stage below groundwater elevations. During this period there were two events, at the end of May and beginning of June, when significant dips in stage were observed. As they occurred, the groundwater elevation in well UR2A shifted toward the river stage more than the groundwater elevation in well UR2B. The elevation of groundwater in well UR2B is consistently slightly higher than in well UR2A, and the water level trends in the two wells are nearly identical. The predominant groundwater elevation gradient has been towards the San Joaquin River.

The following observations can be made from the Site 3 hydrograph, Figure 15. Changes in groundwater elevation at the site mimic changes in the river stage at Brandt Bridge, which is just downstream of Site 3, but are less pronounced and lag slightly behind. The groundwater elevation in well UR3A was more responsive than the groundwater elevation in well UR3B to changes in river stage. During the period of record, the highest recorded San Joaquin River stage at Brandt

Bridge was 5.51 feet, coincident with a groundwater elevation of 3.69 feet (depth of 2.98 bgs) in well UR3A. During the period of record, the San Joaquin River stage at Brandt Bridge was above Site 3 groundwater elevations from mid June 2000 to the beginning of February 2001. During this time, groundwater elevations in the wells declined nearly 2 feet from June to mid August while the river stage maintained an elevation range of approximately 2 to 3 feet above sea level. The decline in well UR3B was also greater than well UR3A during this time. The elevation of groundwater in well UR3A is consistently higher than in well UR3B, and the water level trends in the two wells are nearly identical. In May 2000, an irrigation ditch, constructed nearly 50 feet from well UR3A and only 10 feet from well UR3B, was in use. Simultaneously, groundwater elevation levels in both wells rose sharply and, for a brief period, were greater in well UR3B than in well UR3A. The predominant groundwater elevation gradient is away from the San Joaquin River.

Summary

San Joaquin River stage elevation data and groundwater elevation data indicate that permeable strata underlying the Island are laterally continuous and are likely to be in contact with the riverbed. In general, groundwater in permeable strata such as these will fluctuate in response to changes in river stage. This relationship is seen in the hydrographs for each site (Figures 9, 14 and 15) where water levels in the wells respond to changes in river stage. When the stage increases in the San Joaquin River, the groundwater levels will rise towards the land surface, but not as rapidly as the river stage rises. Over the monitoring period, river stage has not reached a level sufficient to raise groundwater levels to the point where seepage may occur.

In some cases, the water levels in the wells may not accurately represent the water levels in the soils. The vertical movement of groundwater at these monitoring sites is likely to be inhibited by fine-grained sediments occurring above the saturated sand zones in which the well screens are completed. Therefore, rising water levels recorded in the wells are likely to be above the level of the surrounding water table. After a period of time, the water table may reach the water level in the well. The time necessary for this to occur is dependent upon the characteristics and distribution of soils that the groundwater must rise through.

A shallow permeable sand zone occurring at well UR3A is unique to the project. The vertical movement of groundwater at this location would not be restricted by overlying silts and clays, unlike other monitoring sites. If the sand layer is laterally continuous and in contact with the riverbed, groundwater at this well could respond quickly to rising river stage. Seepage may occur here soon after the river stage rises above the ground surface.

The stage and duration required for seepage to occur is dependent upon antecedent soil moisture conditions, topography, geology and soils, location and gradient of groundwater table, and local drainage works (DWR Bulletin 125, page 15). The lowest surface water stage necessary for seepage to occur at a particular site is called the critical base level (page 17). Once a site's critical base level is reached, seepage may occur if the stage is maintained or rises. Critical base levels typically occur at or above the level of the adjacent ground surface. The monitoring system will not indicate when seepage occurs. It can indicate when critical base level is reached and the length of time it is maintained.

Conclusions

1. Over the monitoring period, groundwater levels and river stage did not rise to the land surface.

2. Over the monitoring period, seepage was not observed.

3. Geologic conditions most likely to allow seepage were found at Site 3.

Recommendations

Continue to monitor river stage and groundwater levels until seepage conditions are observed. The data will be used to determine the critical base level when seepage occurs.

References

Hills, Edward E. & Armstrong, George A. *Sacramento Valley Seepage Investigation.* California Department of Water Resources. Bulletin No. 125. 1967.

Salah-Mars, Said & Luscher, Ulrich. *Supplemental Geotechnical Report: Levee Stability and Seepage Report for the Delta Wetlands Project Revised EIR/EIS.* URS Greiner Woodward Clyde. May 2000.

California Department of Water Resources (DWR). 1999. *Temporary Barriers Project, 1998 Fishery, Water Quality, and Vegetation Monitoring Report, Sacramento, California.* 80 pp. plus appendices.

California Department of Water Resources (DWR). 1998. *Temporary Barriers Project, 1997 Fishery, Water Quality, and Vegetation Monitoring Report, Sacramento, California.* 124 pp.

California Department of Water Resources (DWR) and U.S. Bureau of Reclamation (USBR). 1999. *Biological Assessment, Effects of the Central Valley Project and State Water Project Operations From October 1998 Through March 2000 on Steelhead and Spring-run Salmon.* 211 pp.

Figures

Study Area and Site Locations

RD 544 Seepage Monitoring Study

Department of Water Resources
Central District
Geology and Groundwater Section

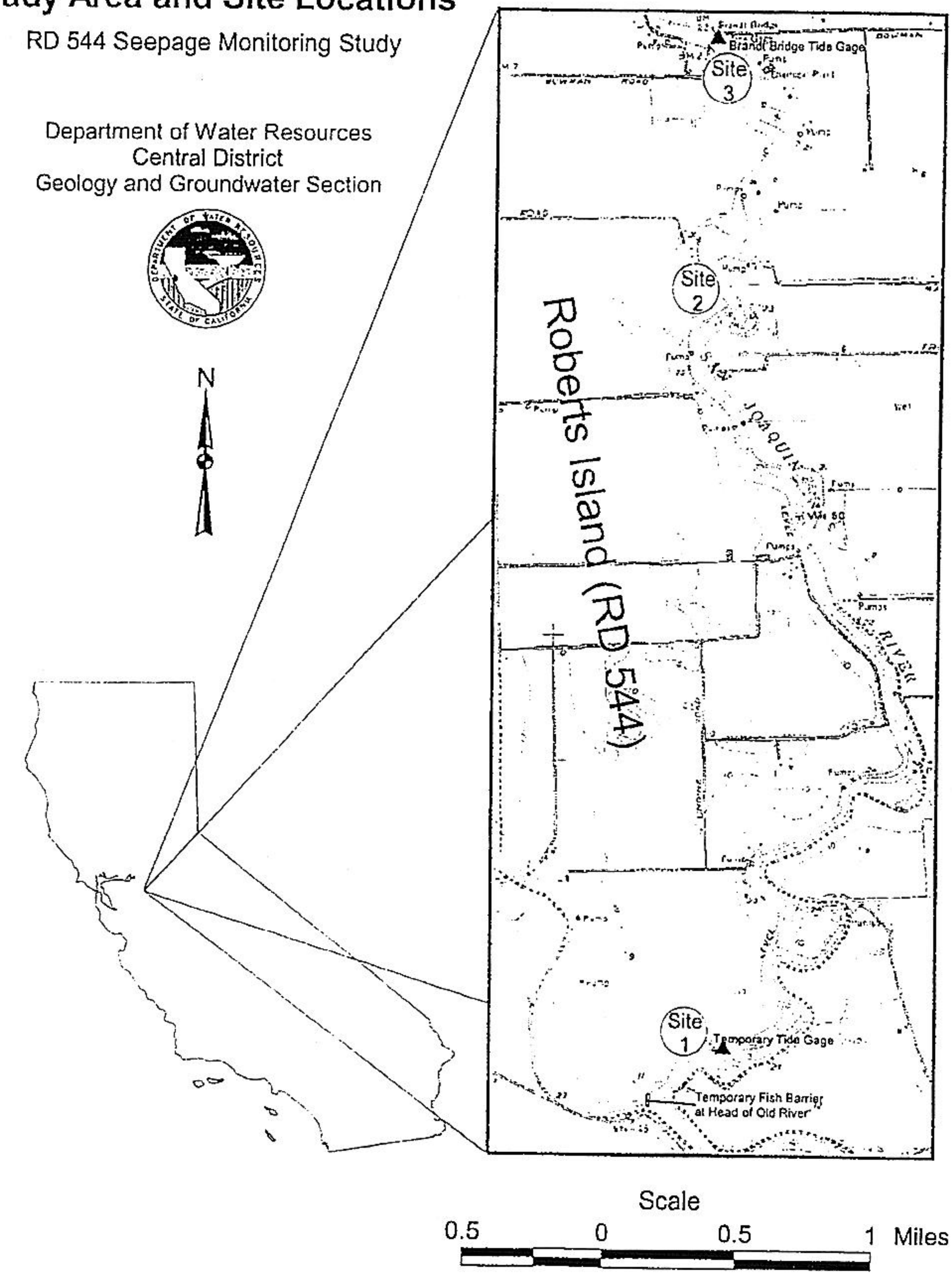
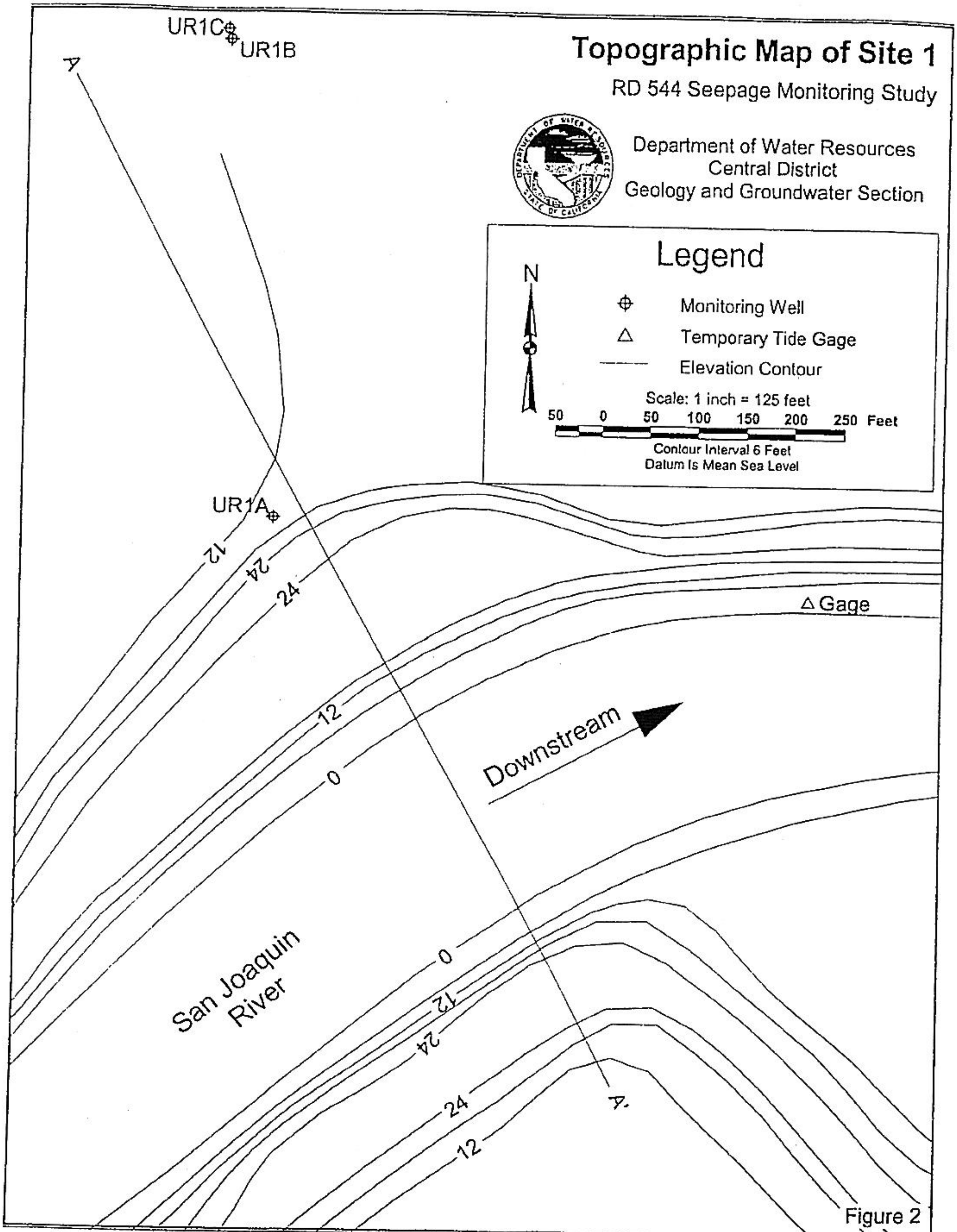
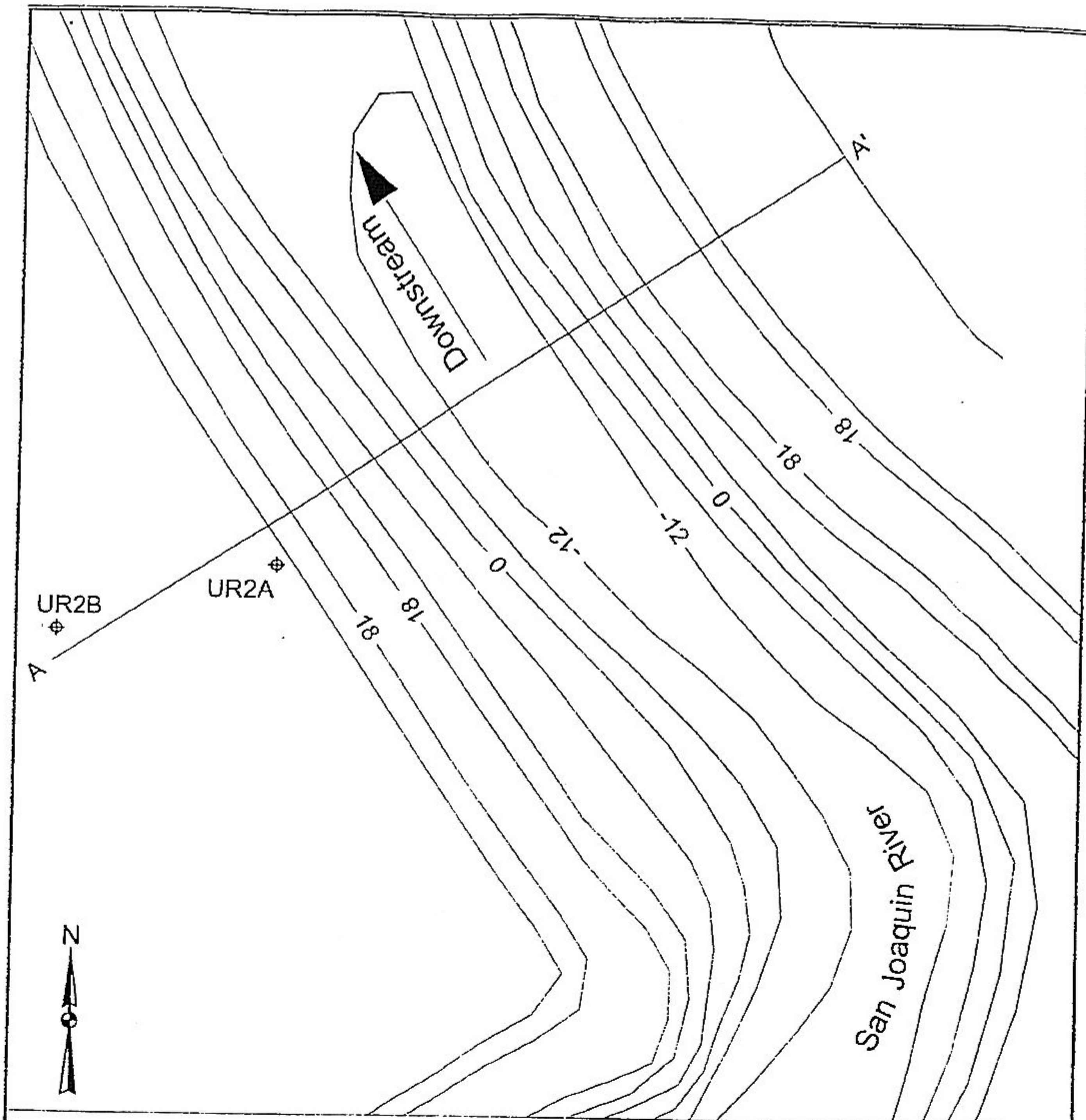


Figure 1


Topographic Map of Site 1
RD 544 Seepage Monitoring Study
Department of Water Resources
Central District
Geology and Groundwater Section
Legend
N
Monitoring Well
Temporary Tide Gage
Elevation Contour
Scale: 1 inch = 125 feet
50 0 50 100 150 200 250 Feet
Contour Interval 6 Feet
Datum Is Mean Sea Level
UR1C
UR1B
UR1A
A
A'
12
24
24
Gage
12
0
Downstream
0
12
24
24
12
San Joaquin River
Figure 2



Legend

Monitoring Well
Elevation Contour

Scale: 1 inch = 100 feet
100 0 100 200 Feet

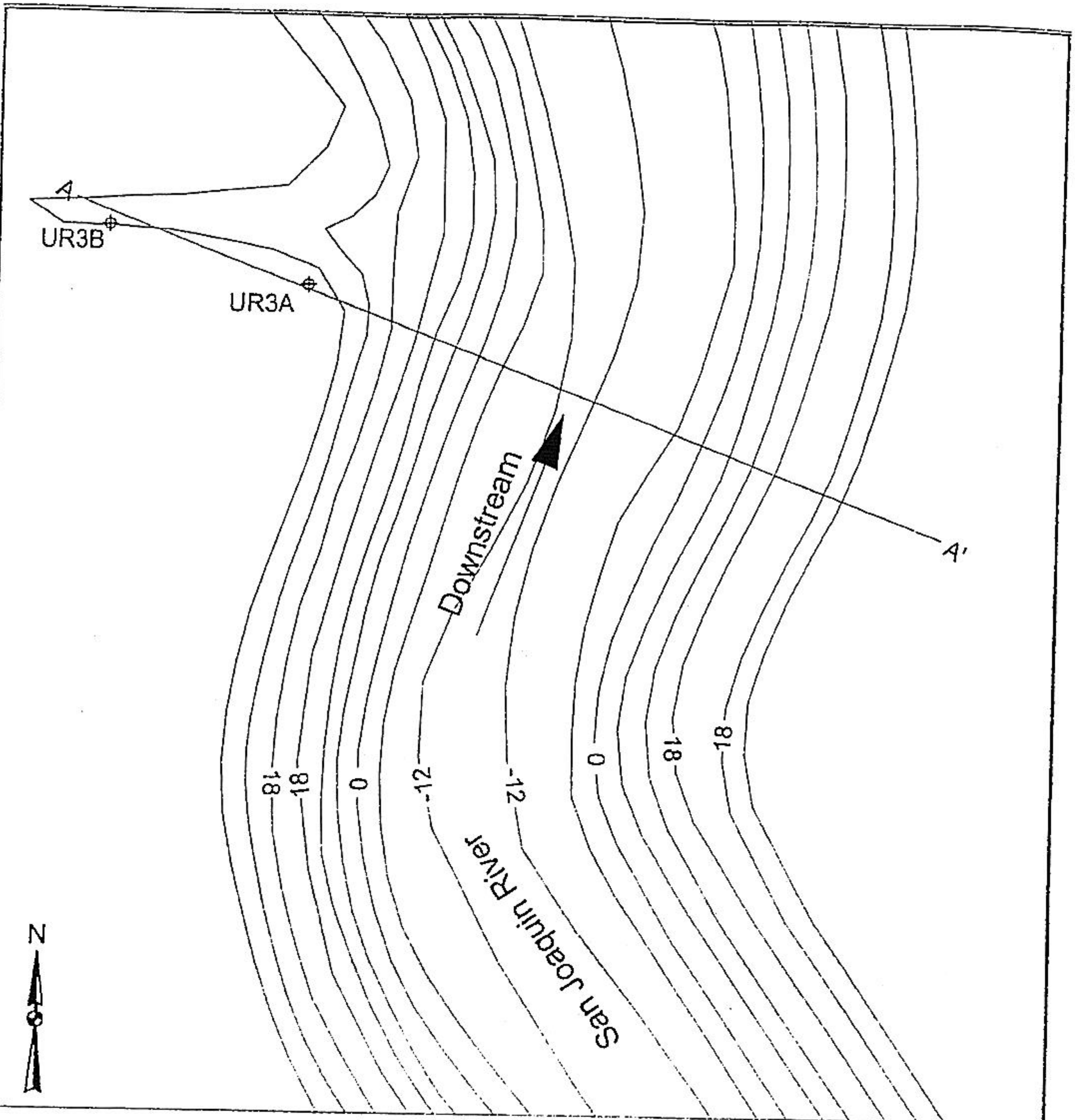
Contour Interval 6 Feet
Datum Is Mean Sea Level

Topographic Map of Site 2

RD 544 Seepage Monitoring Study

Department of Water Resources
Central District
Geology and Groundwater Section

Figure 3



Legend

Monitoring Well

Elevation Contour

Scale: 1 inch = 100 feet

100 0 100 200 Feet

Contour Interval 6 Feet

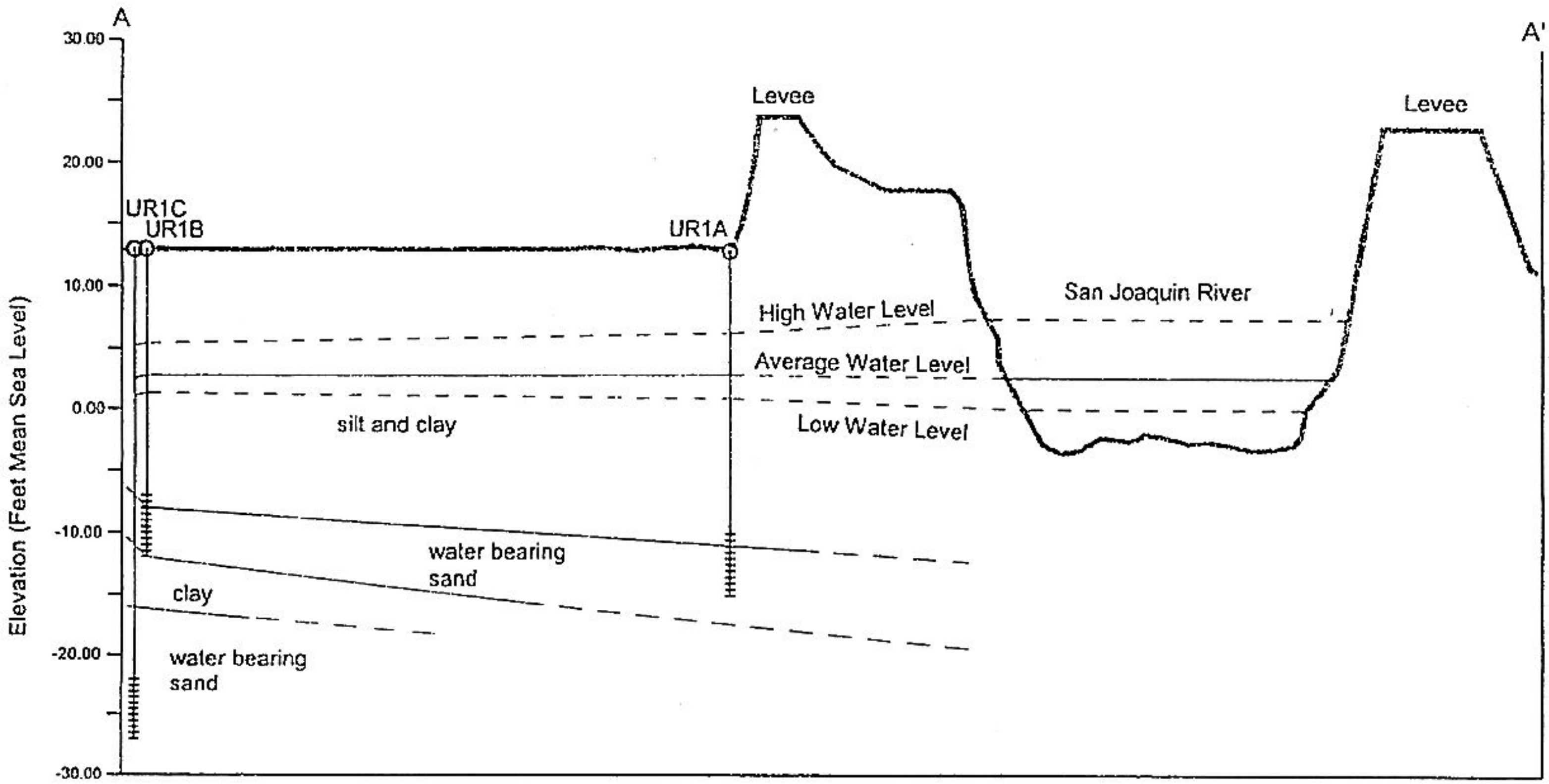
Datum Is Mean Sea Level

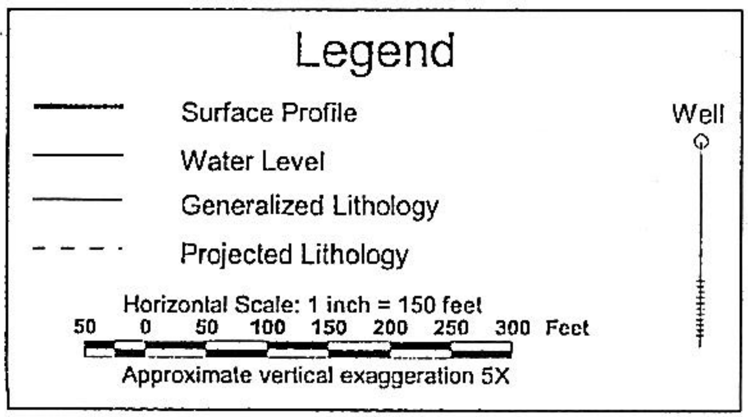
Topographic Map of Site 3

RD 544 Seepage Monitoring Study

Department of Water Resources
Central District
Geology and Groundwater Section

Figure 4



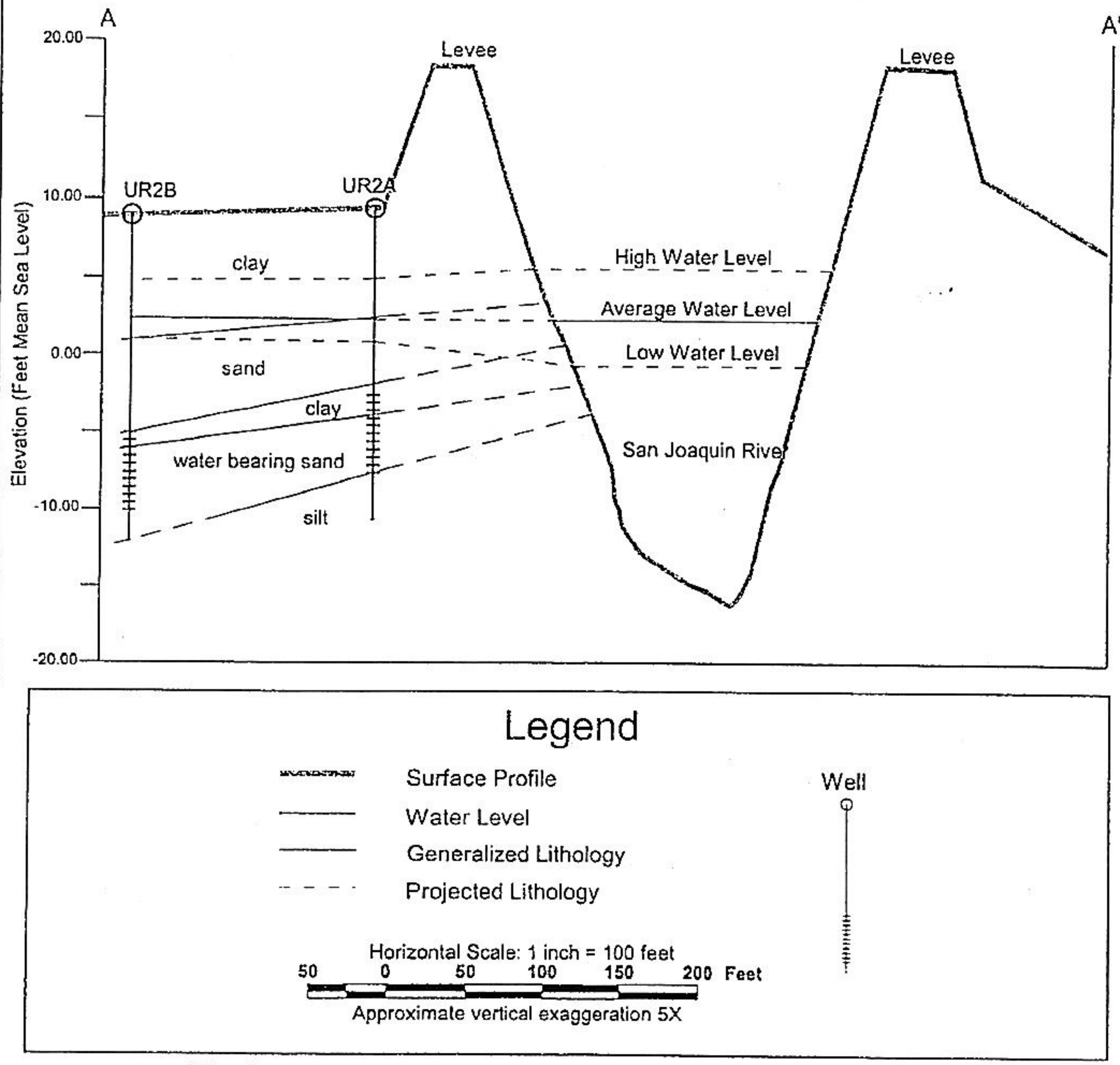


Hydrogeologic Cross Section A - A' of Site 1

RD 544 Seepage Monitoring Study

Department of Water Resources
Central District
Geology and Groundwater

Figure 5

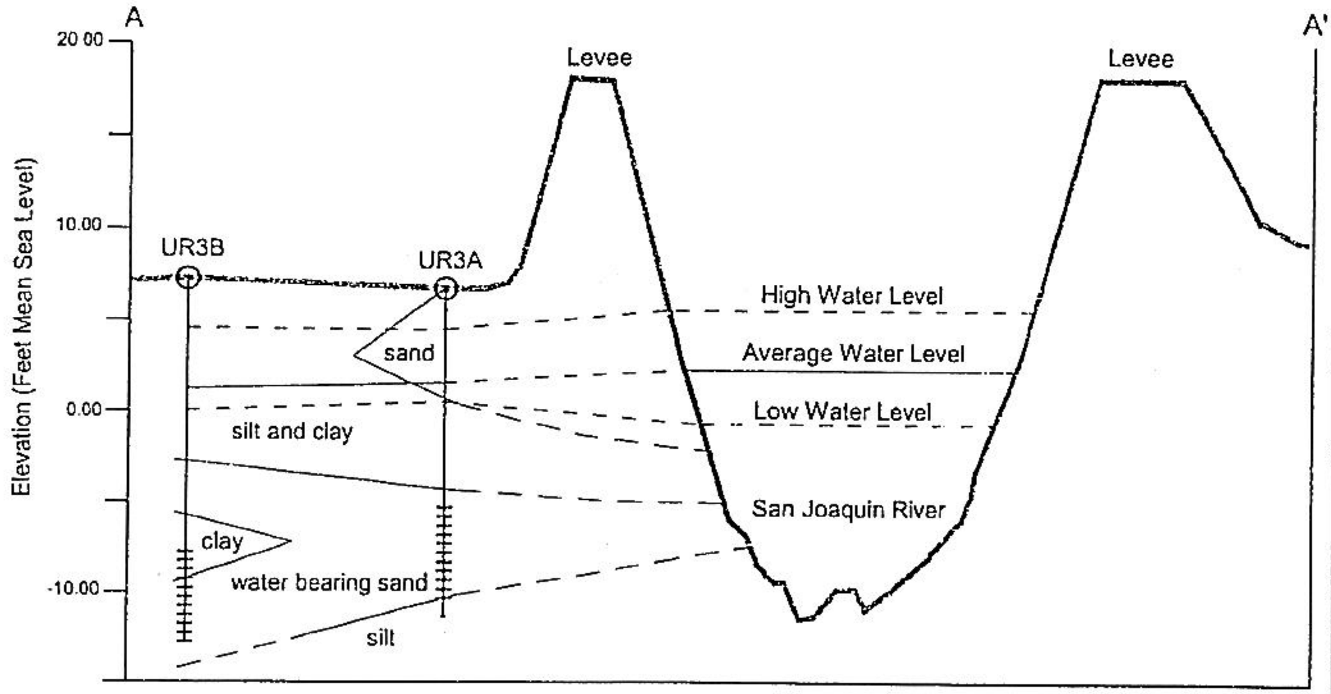


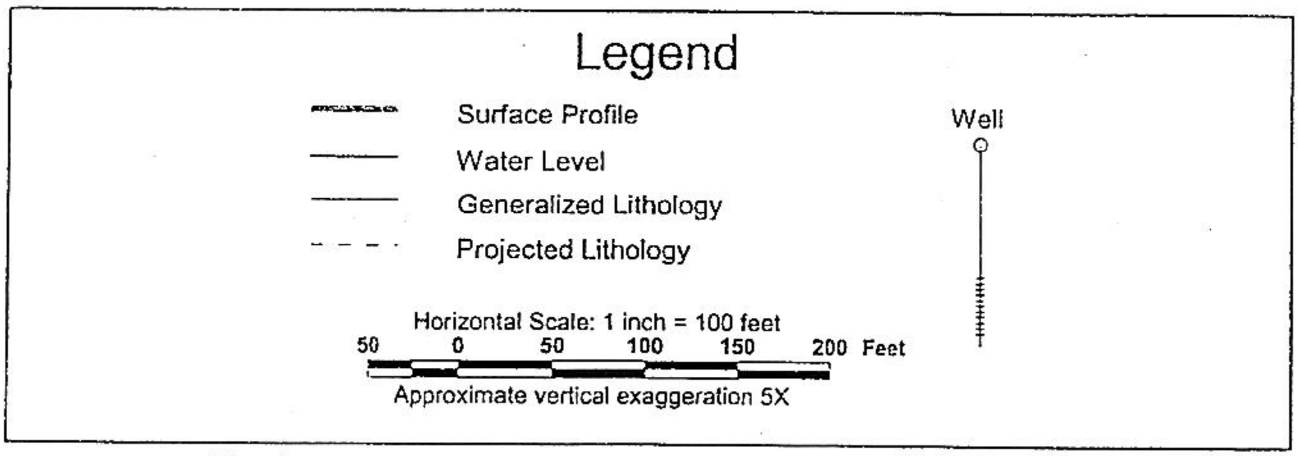
Hydrogeologic Cross Section A - A' of Site 2

RD 544 Seepage Monitoring Study

Department of Water Resources
Central District
Geology and Groundwater

Figure 6



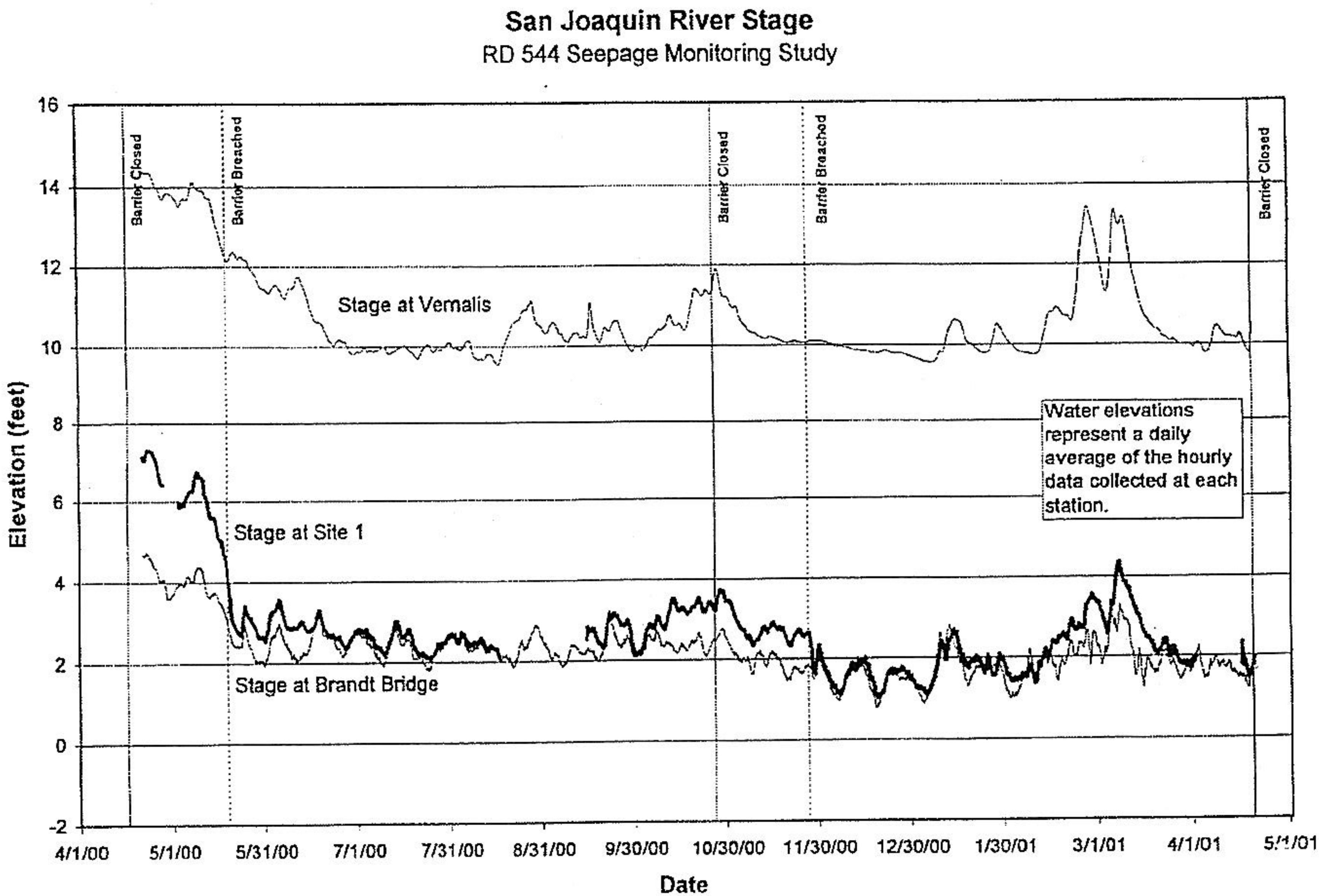


Hydrogeologic Cross Section A - A' of Site 3

RD 544 Seepage Monitoring Study

Department of Water Resources
Central District
Geology and Groundwater

Figure 7



Central District Geology and Groundwater

Figure 8

San Joaquin River Stage and Groundwater Levels at Site 1

RD 544 Seepage Monitoring Study

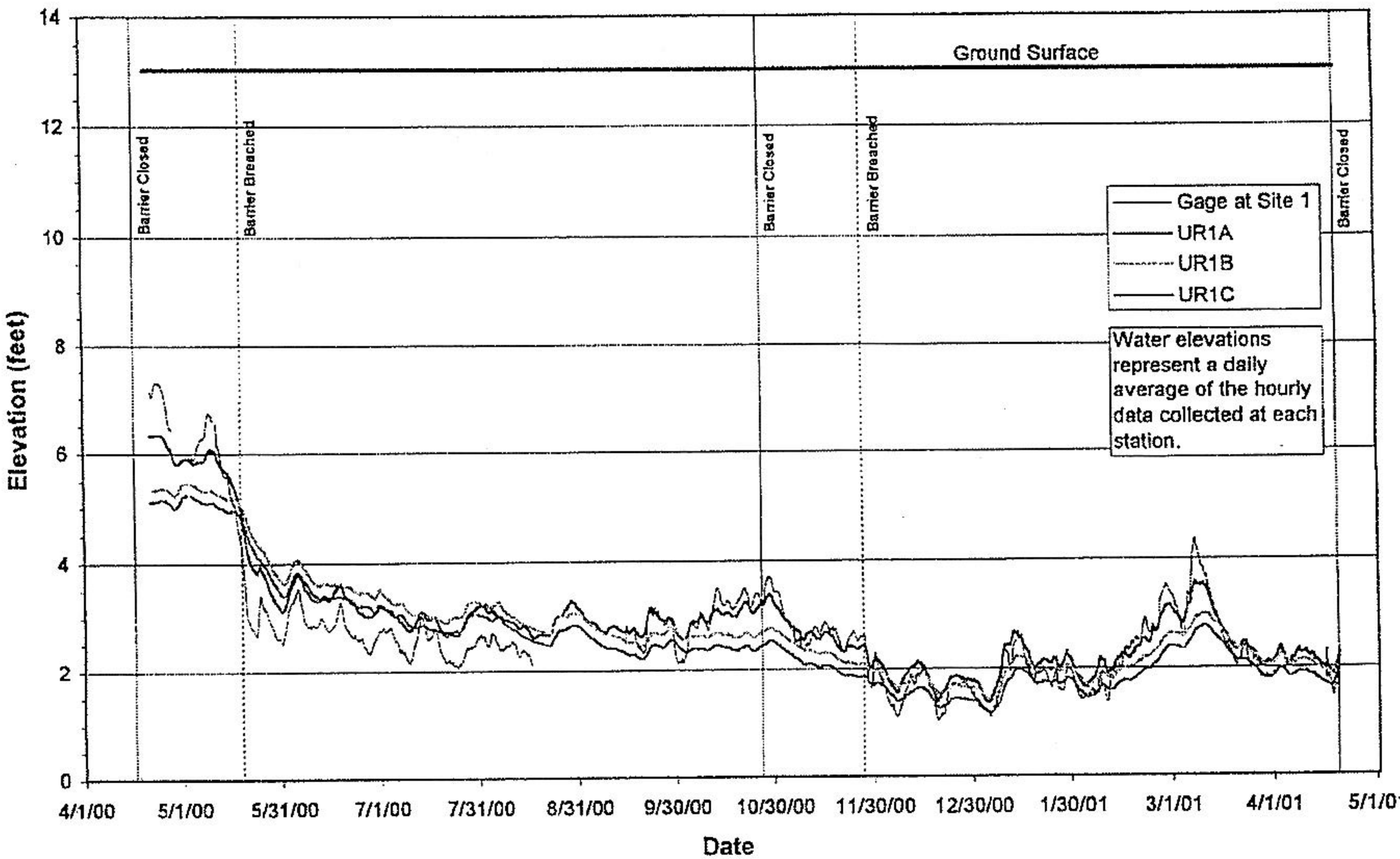
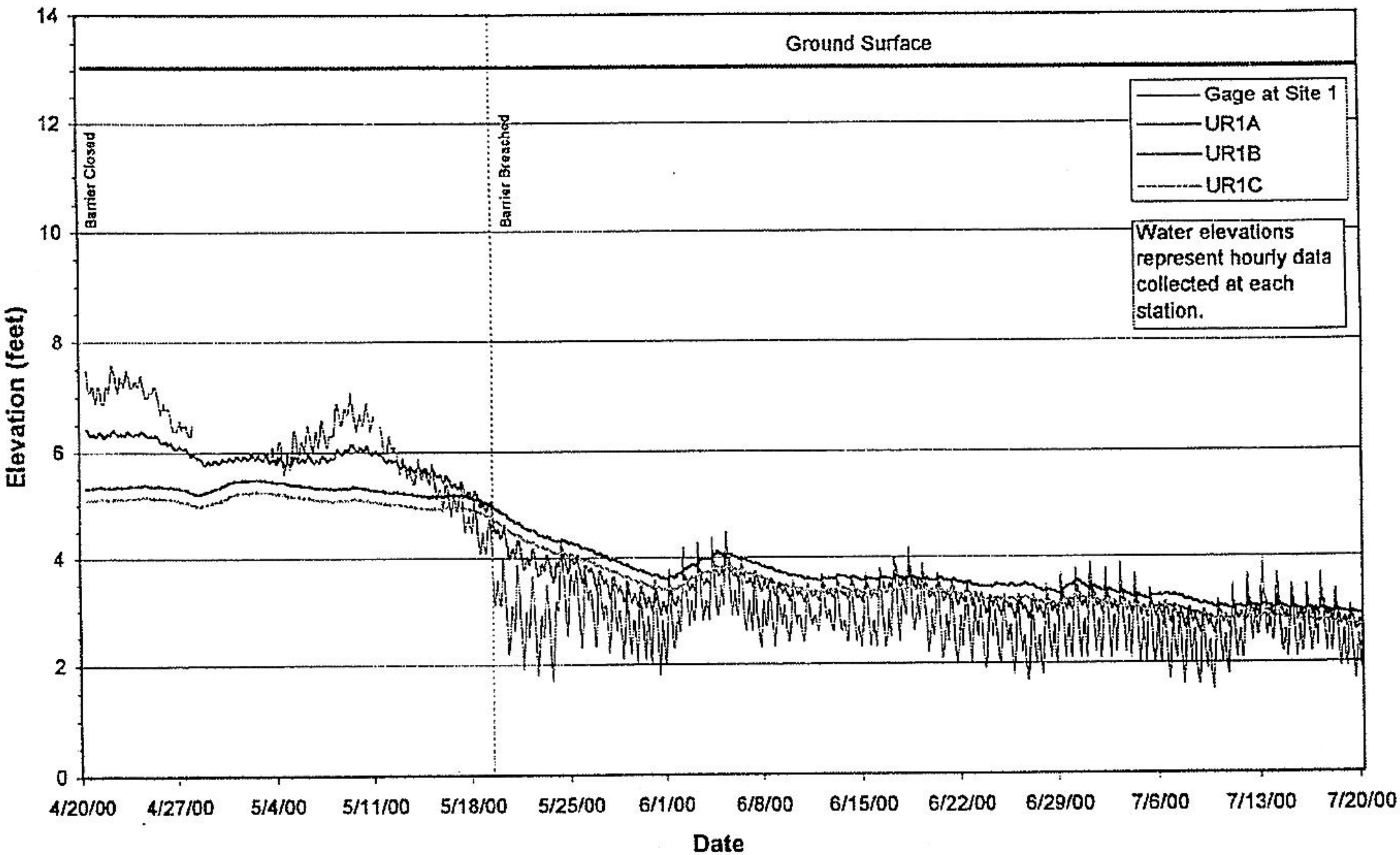


Figure 9

San Joaquin River Stage and Groundwater Levels at Site 1

RD 544 Seepage Monitoring Study

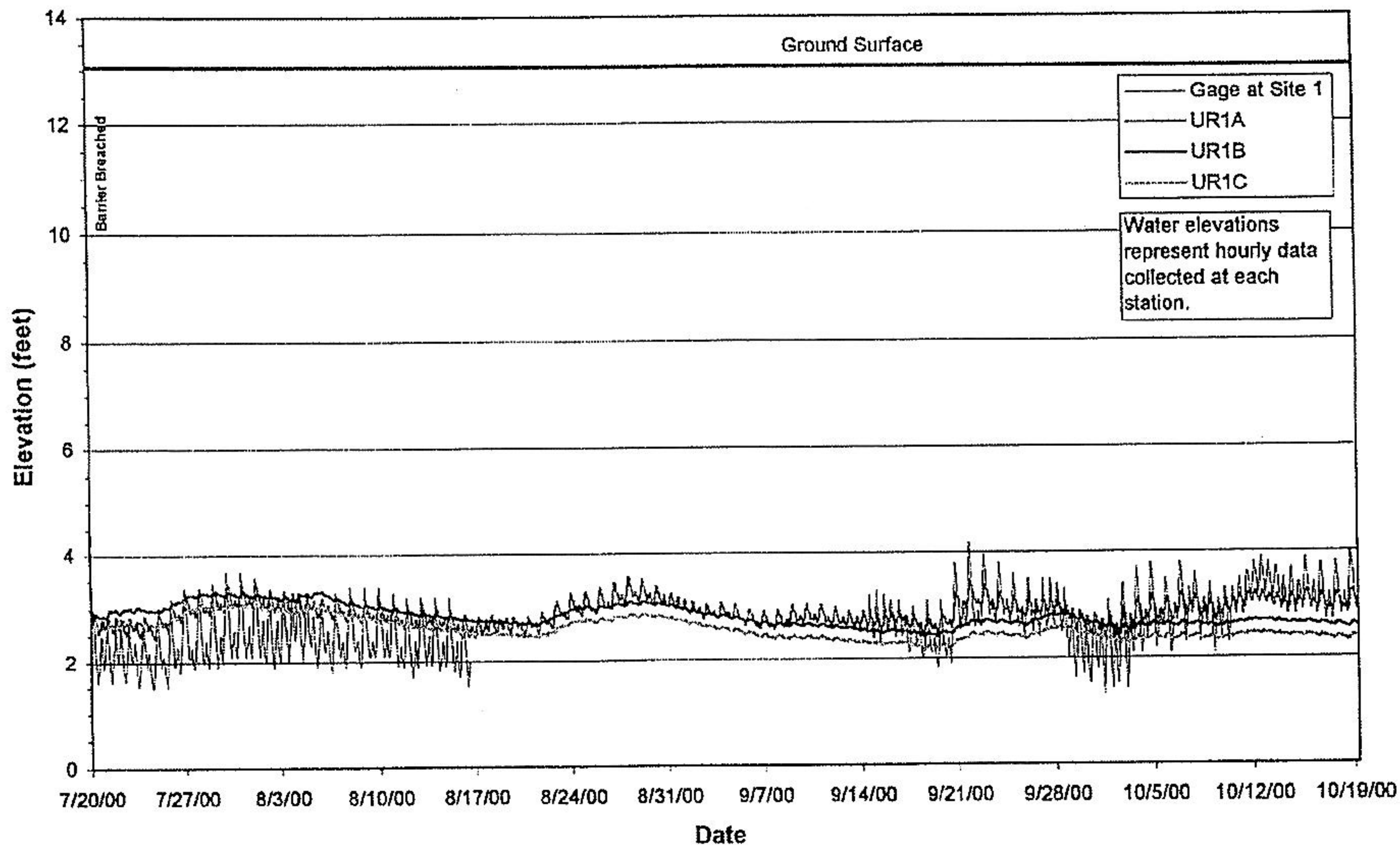


Central District Geology and Groundwater

Figure 10

San Joaquin River Stage and Groundwater Levels at Site 1

RD 544 Seepage Monitoring Study

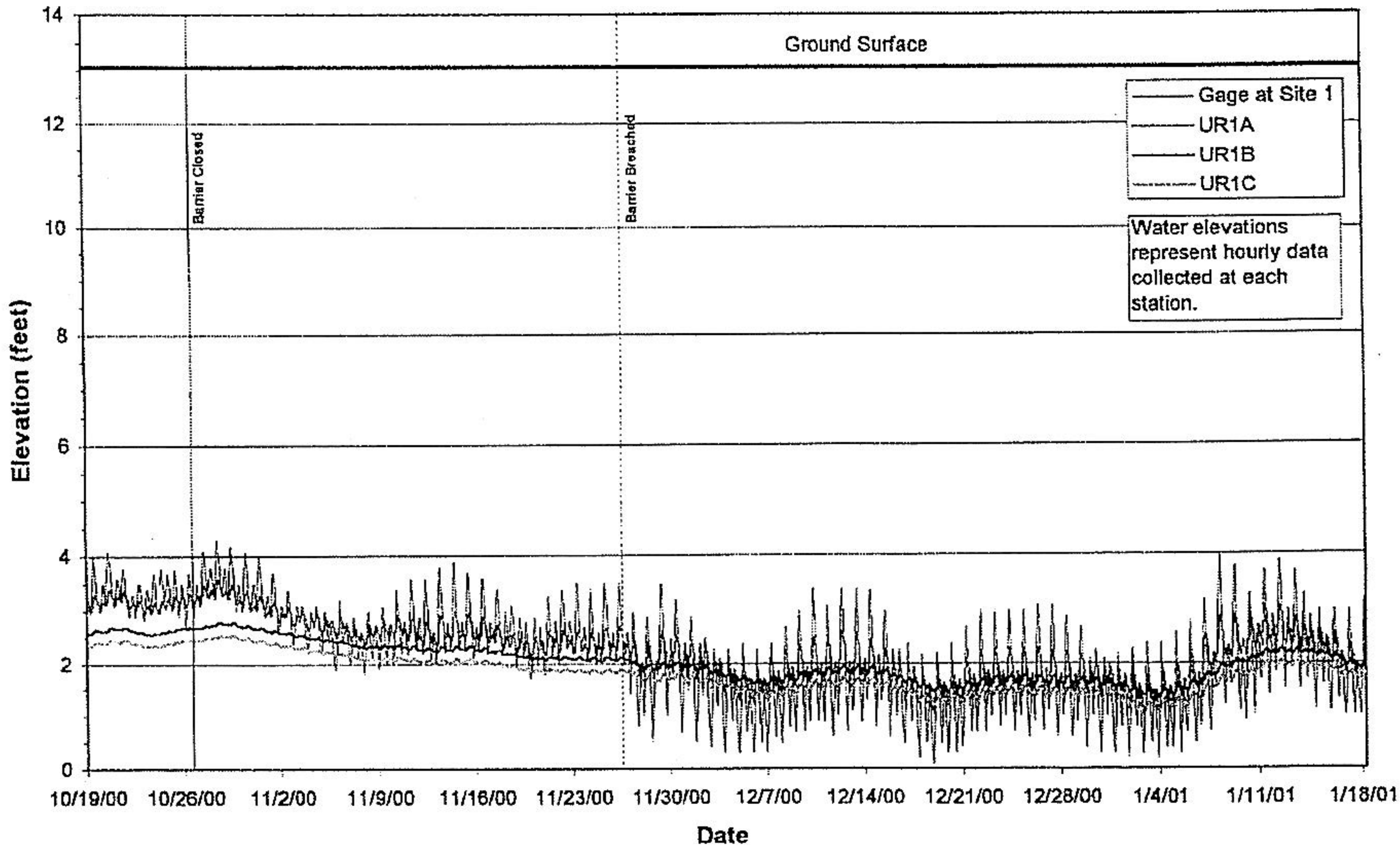


Central District Geology and Groundwater

Figure 11

San Joaquin River Stage and Groundwater Levels at Site 1

RD 544 Seepage Monitoring Study



San Joaquin River Stage and Groundwater Levels at Site 1

RD 544 Seepage Monitoring Study

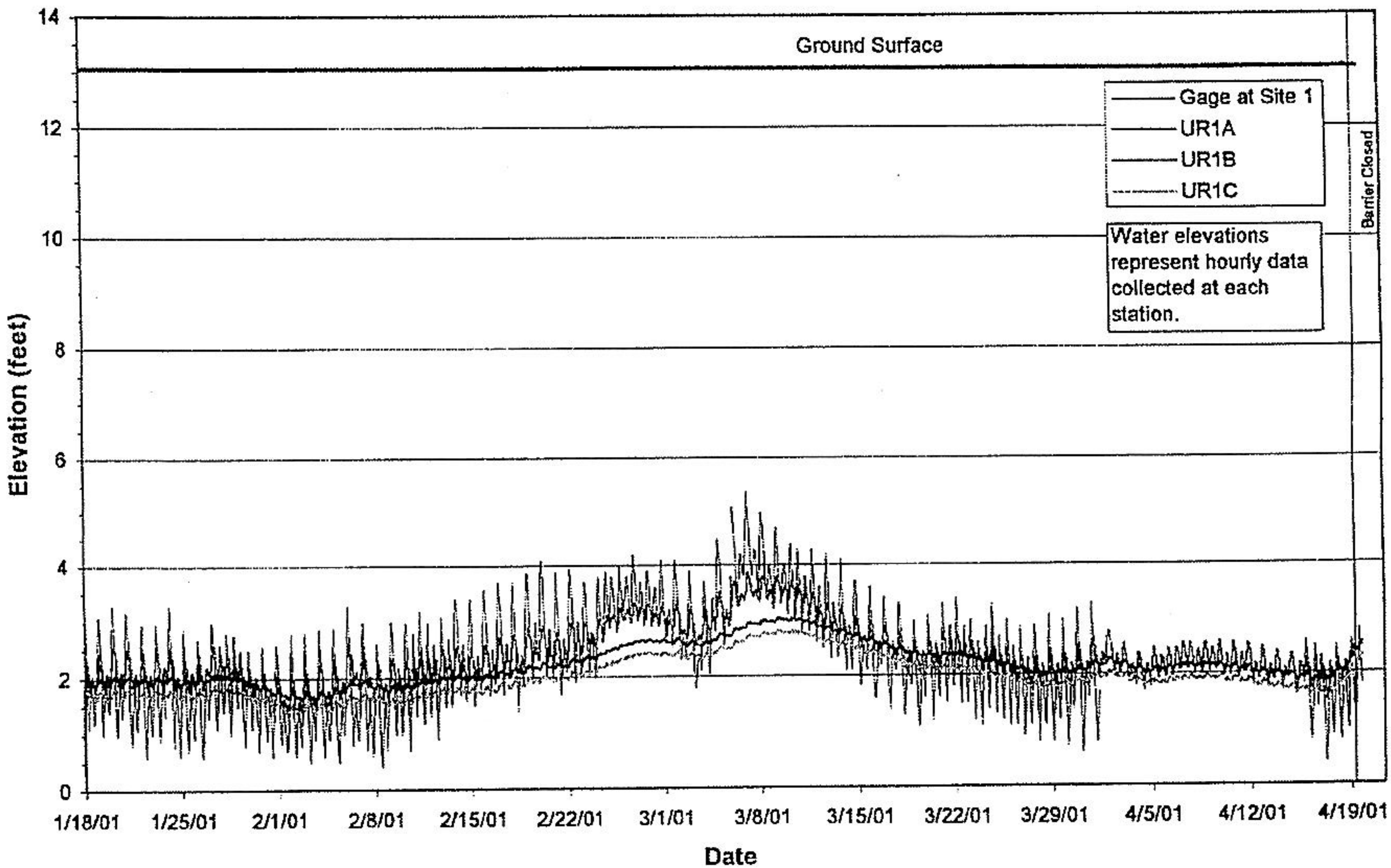


Figure 13

San Joaquin River Stage and Groundwater Levels at Site 2

RD 544 Seepage Monitoring Study

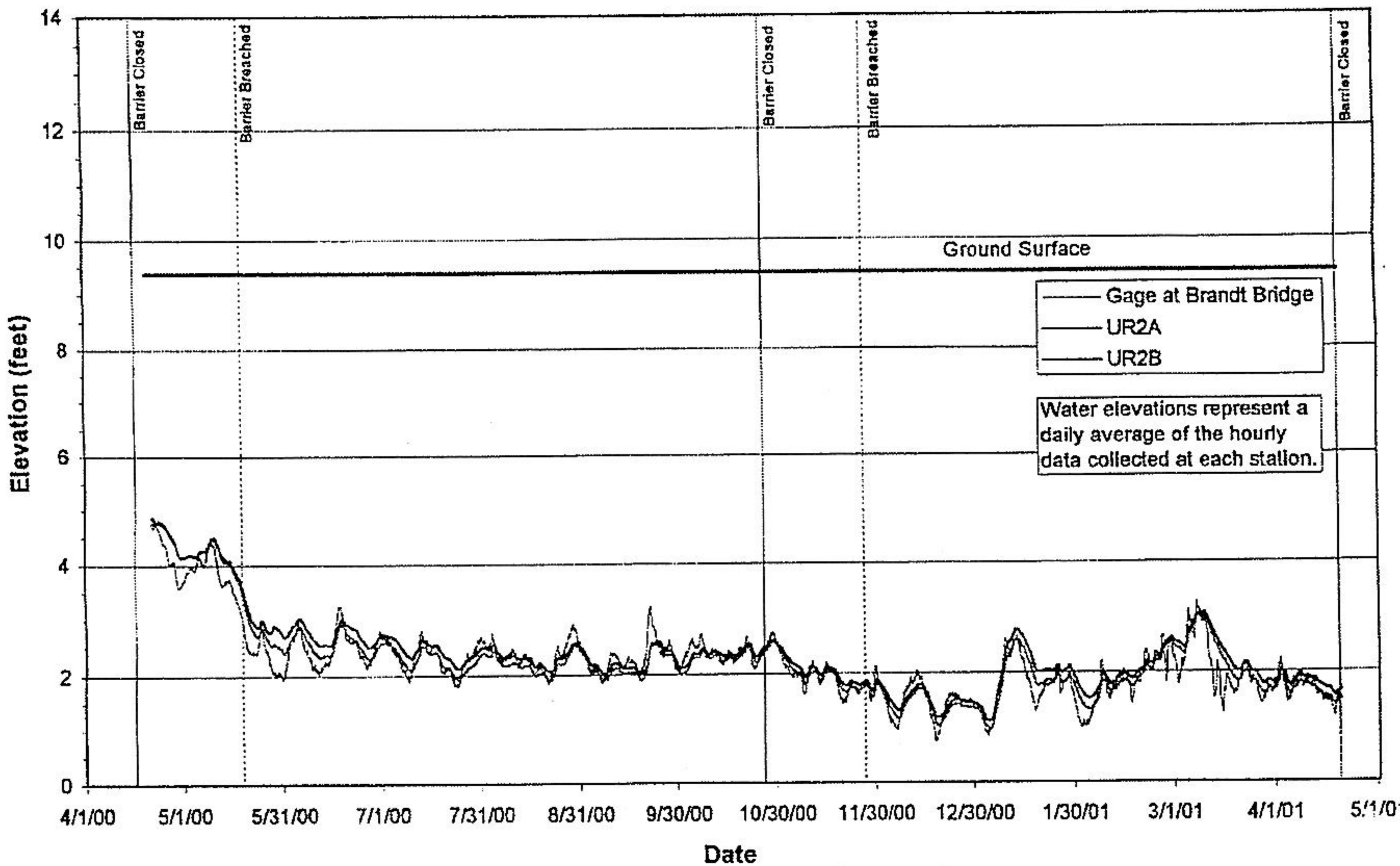
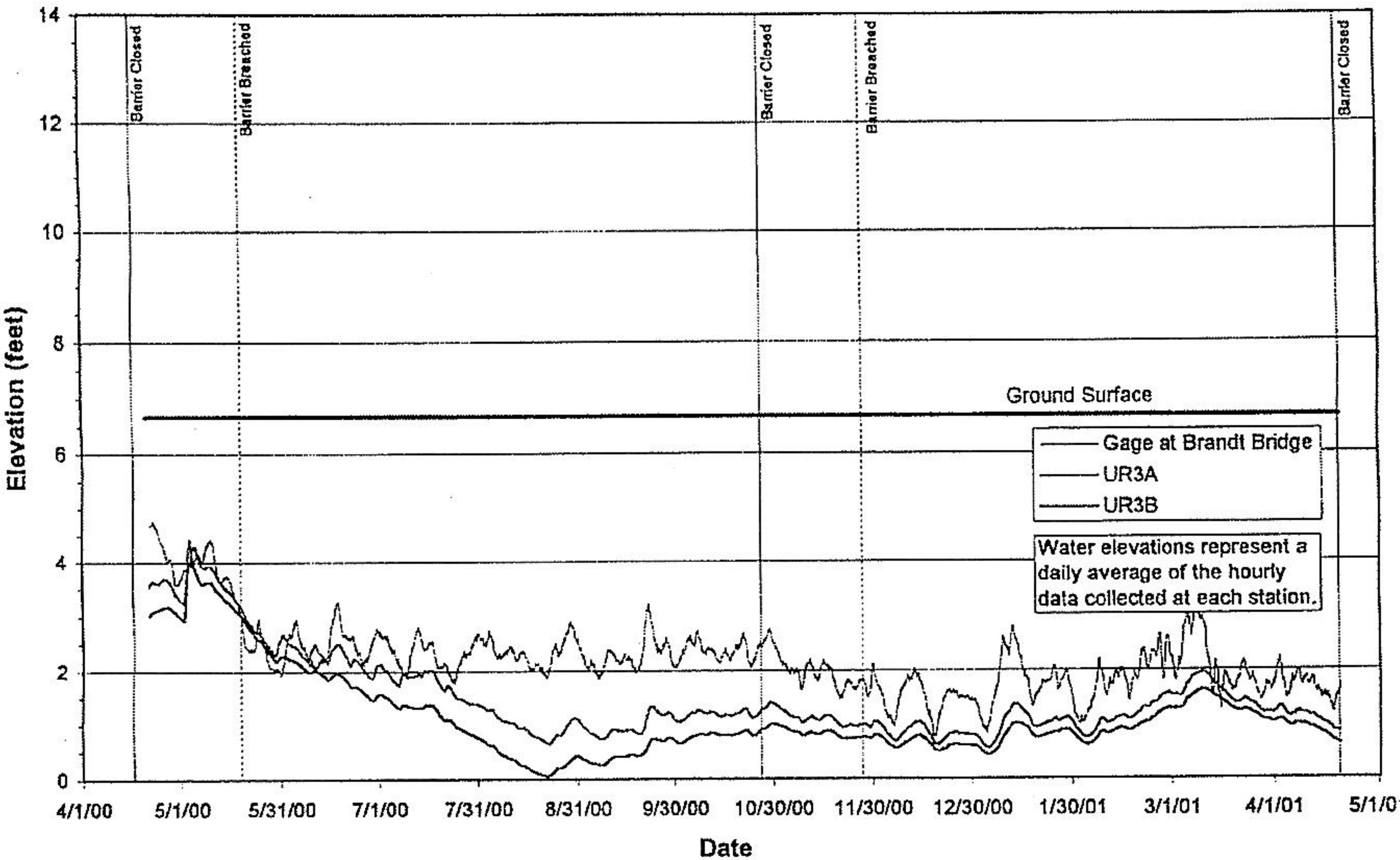


Figure 14

San Joaquin River Stage and Groundwater Levels at Site 3

RD 544 Seepage Monitoring Study



Central District Geology and Groundwater

Figure 15

Appendix

Drill Hole Logs and Well Completions

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES

DRILL HOLE LOG

SHEET 1 of 2
HOLE NO. UR-1-A
ELEV. 13.06 FEET
DEPTH 30.0 FEET
DATE DRILLED 04/06/00
ATTITUDE Vertical
LOGGED BY William Brewster
DEPTH TO WATER Not Determined

PROJECT Reclamation District 544 Seepage Monitoring Study
FEATURE Monitoring Wells
LOCATION
CONTR. Layne-Christensen DRILL RIG CME 750

DEPTH (ELEV.)	LOG	FIELD CLASSIFICATION AND DESCRIPTION	SAMPLE NO.	MODE	REMARKS
0.0 (13.06)		QUATERNARY ALLUVIUM DEPOSITS 0.0 to 30.0'		AD	CME Continuous Sampling
		0.0 - 5.0' No sample obtained. Cuttings indicate sandy soil.	NR	0.0/5.0	0.0 – 5.0' No sample obtained
2.0					
4.0					
6.0	CL	5.0 - 9.0' Silty Clay with Fine Sand, (CL): About 50% medium plasticity clay; about 50% non-plastic fines; reddish gray; moist; soft to medium stiff.	1	2.0/2.0	2-foot sample
8.0			2	3.0/3.0	3-foot sample. Clay in bottom of sampler.
	SW	9.0 - 9.5' Medium Sand, (SW): About 95% well sorted, clean, medium sand; about 5% fines; yellowish brown; moist.			
10.0					
12.0	CL	9.5 - 20.0' Clay with Silt, (CL): About 90% medium plasticity clay; about 10% non-plastic, micaceous fines; dark brown to gray; moist; soft to stiff.	3	5.0/5.0	5-foot sample
14.0					
16.0					Continued on next page.

DWR 485 (1) (Rev. 9-84)

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES

DRILL HOLE LOG

SHEET 2 OF 2

HOLE NO. UR-1-A

PROJECT & FEATURE Reclamation District 544 Seepage Monitoring Study, Monitoring Wells

DEPTH (ELEV.)	LOG	FIELD CLASSIFICATION AND DESCRIPTION	SAMPLE NO.	MODE	REMARKS
16.0		QUATERNARY ALLUVIUM DEPOSITS 0.0 to 30.0' (cont.) 9.5 - 20.0' Clay with Silt, (CL): About 90% medium plasticity clay; about 10% non-plastic, micaceous fines; dark brown to gray; moist; soft to stiff.		AD	CME Continuous Sampling
18.0	CL		5	5.0/5.0	5-foot sample
20.0		20.0 - 24.0' Silt with Sand, (ML): About 70% non-plastic fines; about 30% fine sand; olive-gray, wet.			
22.0	ML		6	5.0/5.0	5-foot sample
24.0		24.0 - 30.0' Silty Sand, (SM): About 85% fine to medium micaceous sand; about 15% non-plastic fines; grayish brown, saturated, medium dense.			
26.0			7		
28.0	SM			0.5/5.0	Lost the majority of sample down the hole due to loose, wet sand.
30.0 (-16.9)					Total Depth = 30.0 feet
32.0					
34.0					
36.0					

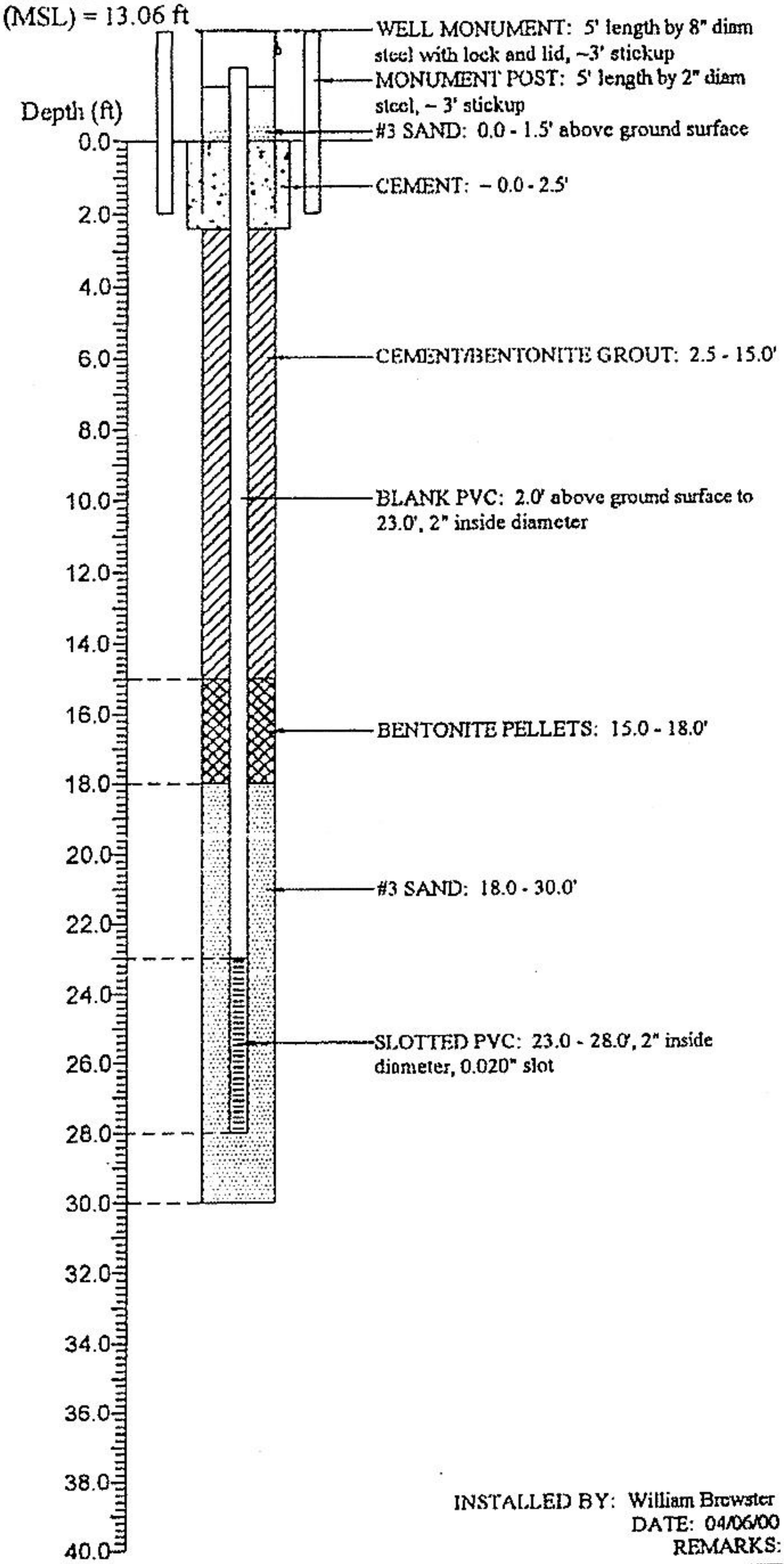
DWR 885 (2) (Rev. 9-84)

Reclamation District 544 Seepage Monitoring Study

Monitoring Well Completion of UR-1-A

Ground Surface Elevation (MSL) = 13.06 ft

Datum (UTM NAD 83):



INSTALLED BY: William Brewster

DATE: 04/06/00

REMARKS:

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES

DRILL HOLE LOG

SHEET 1 of 2

HOLE NO. UR-1-B

ELEV. 13.04 FEET

DEPTH 27.0 FEET

PROJECT Reclamation District 544 Seepage Monitoring Study

DATE DRILLED 04/07/00

FEATURE Monitoring Wells

ATTITUDE Vertical

LOCATION

LOGGED BY Mark Souverville

CONTR. Layne-Christensen DRILL RIG CME 750

DEPTH TO WATER Approximately 18 ft

DEPTH (ELEV.)	LOG	FIELD CLASSIFICATION AND DESCRIPTION	SAMPLE NO.	MODE	REMARKS
0.0 (13.06)		QUATERNARY ALLUVIUM DEPOSITS 0.0 to 27.0'		AD	CME Continuous Sampling
		0.0 - 7.0' Sandy Silt, (ML): About 80% non-plastic fines; about 20% fine to medium sand; olive-brown, damp, stiff.			
2.0			1		
4.0	ML			1.0/5.0	1-foot sample Lost majority of sample down hole.
6.0					
8.0		7.0 - 15.5' Sandy Clay, (CL): About 85% reddish gray, medium plasticity clay; about 15% olive-gray, fine sand; damp to moist; soft to medium stiff. Increase in moisture, decrease in clay at 9'. Occurrence of calechey and color change to gray-brown at 12'.	2	5.0/5.0	5-foot sample
10.0	CL				
12.0			3	5.0/5.0	5-foot sample
14.0					
16.0	ML	15.5 - 21.0' Sandy Silt, (ML): About 75% non-plastic fines; about 25% very fine to fine sand; light olive-brown, moist, soft. Wet from 18.0 –18.5'.	4	5.0/5.0	5-foot sample Continued on next page.

DWR 888 (1) (Rev. 9-84)

State of California
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DEPARTMENT OF WATER RESOURCES
DRILL HOLE LOG

SHEET 2 OF 2

HOLE NO. UR-1-B

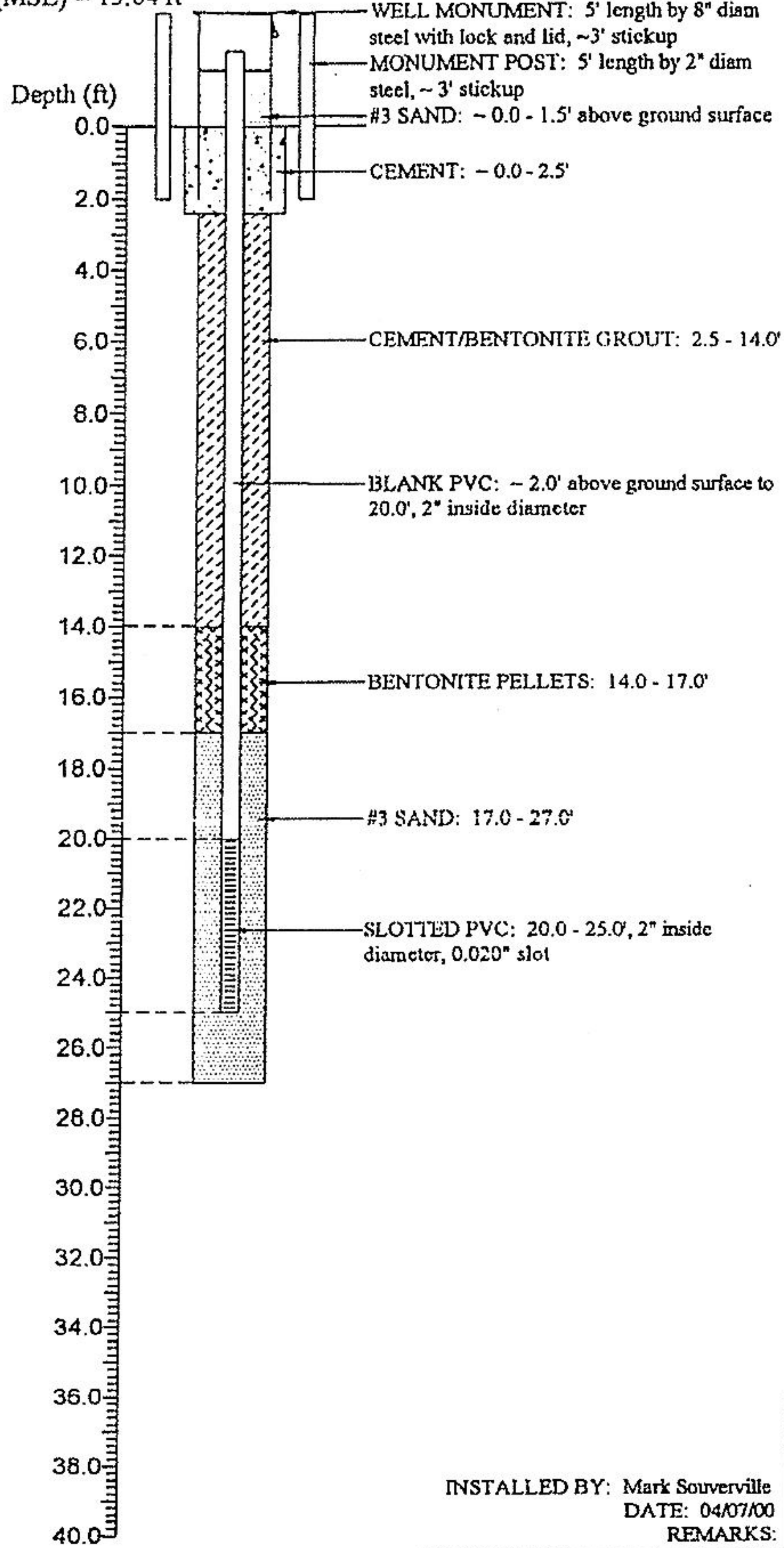
PROJECT & FEATURE Reclamation District 544 Seepage Monitoring Study, Monitoring Wells

DEPTH (ELEV.)	LOG	FIELD CLASSIFICATION AND DESCRIPTION	SAMPLE NO.	MODE	REMARKS
16.0		QUATERNARY ALLUVIUM DEPOSITS 0.0 to 27.0' (cont.)		AD	CME Continuous Sampling
18.0	ML	15.5 - 21.0' Sandy Silt, (ML): About 75% non-plastic fines; about 25% very fine to fine sand; light olive-brown, moist, wet from 18.0 – 18.5', soft.	4	5.0/5.0	5-foot sample
20.0					
22.0	SM	21.0 - 25.0' Silty Sand, (SM): About 85% fine to medium micaceous sand; about 15% non-plastic fines; grayish brown, saturated, medium dense.	5	5.0/5.0	5-foot sample
24.0					
26.0	CL	25.0 - 27.0' Sandy Clay, (CL): About 85% medium plasticity clay; about 15% fine to medium sand; light olive-brown, moist to wet, stiff.	6	2.0/2.0	2-foot sample
(-14.0)					Total Depth = 27.0 feet
28.0					
30.0					
32.0					
34.0					
36.0					

DWR 885 (2) (Rev. 9-84)

Monitoring Well Completion of UR-1-B

Ground Surface Elevation (MSL) = 13.04 ft
Datum (UTM NAD 83):



INSTALLED BY: Mark Souverville
DATE: 04/07/00
REMARKS:

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DEPARTMENT OF WATER RESOURCES

SHEET 1 of 3

HOLE NO. UR-1-C

DRILL HOLE LOG

ELEV. 13.01 FEET

DEPTH 40.0 FEET

PROJECT Reclamation District 544 Seepage Monitoring Study

DATE DRILLED 04/07/00

FEATURE Monitoring Wells

ATTITUDE Vertical

LOCATION

LOGGED BY Mark Souverville

CONTR. Layne-Christensen DRILL RIG CME 750

DEPTH TO WATER Approximately 18 ft

DEPTH (ELEV.)	LOG	FIELD CLASSIFICATION AND DESCRIPTION	SAMPLE NO.	MODE	REMARKS
0.0 (13.08)		QUATERNARY ALLUVIUM DEPOSITS 0.0 to 40.0'		AD	CME Continuous Sampling
2.0	ML	0.0 - 5.0' Sandy Silt, (ML): About 80% non-plastic fines; about 20% fine to medium sand; olive-brown, damp, stiff.	1		
4.0				1.5 / 5.0	1.5-foot sample Lost majority of sample down hole.
6.0		5.0 - 14.5' Sandy Clay, (CL): About 80% medium plasticity clay; about 20% fine to medium sand; olive-brown, damp to moist, medium stiff, very stiff 12 - 13'.			Sluff from above fell in sample tube, projected contact from ML to CL.
8.0			2	5.0 / 5.0	5-foot sample
10.0	CL				
12.0			3	5.0 / 5.0	5-foot sample
14.0					
16.0	ML	14.5 - 20.0' Sandy Silt, (ML): About 75% non-plastic fines; about 25% very fine to fine sand; light olive-brown, moist to wet, soft.	4	5.0 / 5.0	5-foot sample Continued on next page.

DWR 886 (1) (Rev. 9-84)

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES
DRILL HOLE LOG

SHEET 2 OF 3

HOLE NO. UR-1-C

PROJECT & FEATURE Reclamation District 544 Seepage Monitoring Study, Monitoring Wells

DEPTH (ELEV.)	LOG	FIELD CLASSIFICATION AND DESCRIPTION	SAMPLE NO.	MODE	REMARKS
16.0		QUATERNARY ALLUVIUM DEPOSITS 0.0 to 40.0'		AD	CME Continuous Sampling
		(cont.) 14.5 - 20.0' Sandy Silt, (ML): About 75% non-plastic fines; about 25% very fine to fine sand; light olive-brown, moist to wet, soft.			
18.0	ML		4	5.0 / 5.0	5-foot sample
20.0		20.0 - 24.0' Silty Sand, (SM): About 85% fine to medium micaceous sand; about 15% non-plastic fines; grayish brown, wet, medium dense.			
22.0	SM		5	5.0 / 5.0	5-foot sample
24.0		24.0 - 26.0' Sandy Clay, (CL): About 85% high plasticity clay; about 15% fine to coarse sand; light olive-brown with iron-oxide stains, wet to saturated, stiff.			
26.0	CL	26.0 - 29.0' Clay with Silt, (CL): About 90% high plasticity clay; about 10% non-plastic fines; yellow-brown (iron banding) to light olive-brown, moist to wet, stiff.	6	5.0 / 5.0	5-foot sample
28.0					
30.0		29.0 - 40.0' Silty Sand, (SM): About 85% fine to medium micaceous sand; about 15% non-plastic fines; light olive-brown to olive-brown, saturated, loose. Mica increases with depth.			
32.0	SM		7	5.0 / 5.0	5-foot sample
34.0					
36.0			8	5.0 / 5.0	5-foot sample Continued on next page.

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DRILL HOLE LOG

SHEET 3 OF 3

HOLE NO. UR-1-C

PROJECT & FEATURE Reclamation District 544 Seepage Monitoring Study, Monitoring Wells

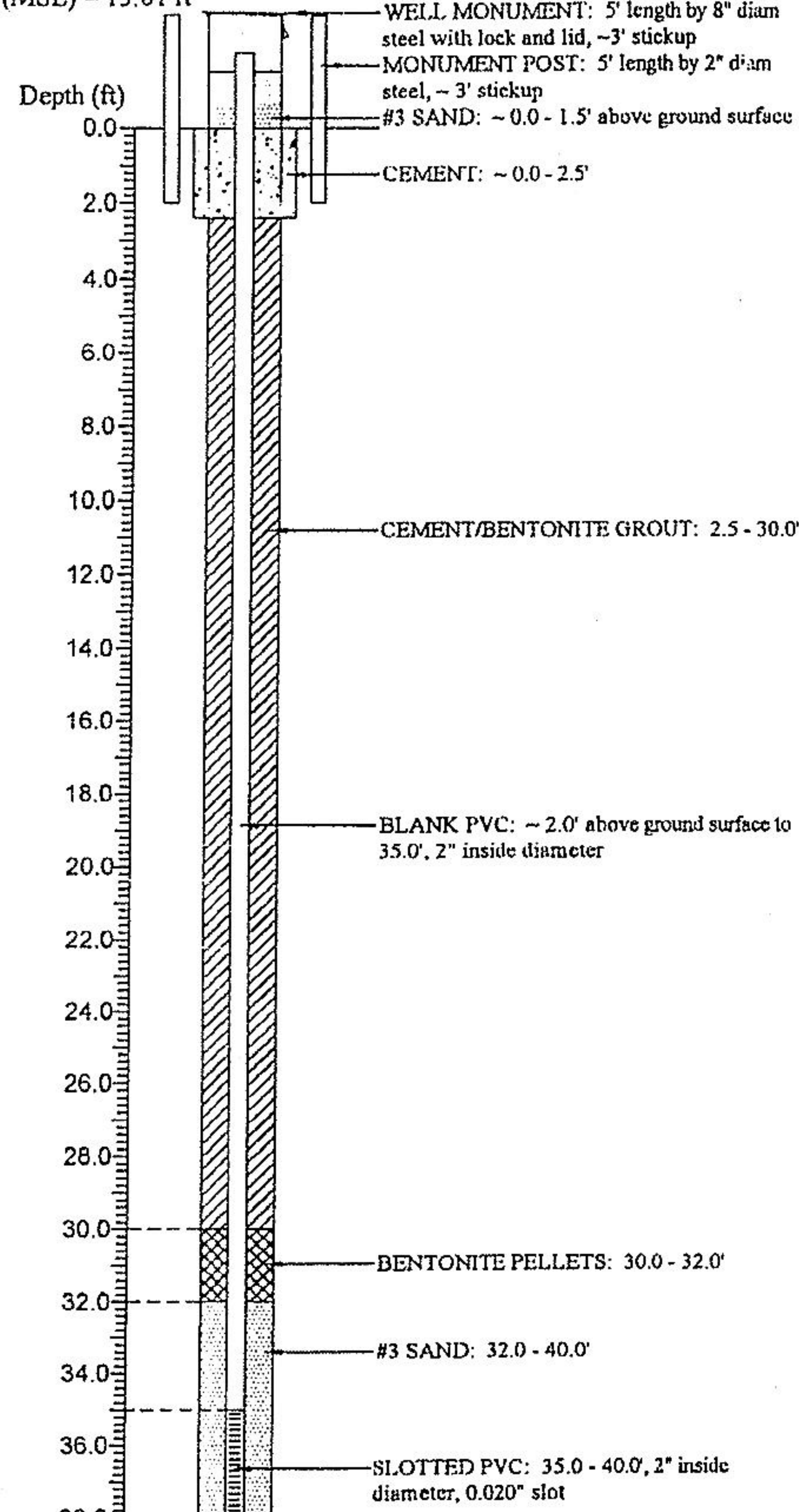
DEPTH (ELEV.)	LOG	FIELD CLASSIFICATION AND DESCRIPTION	SAMPLE NO.	MODE	REMARKS
36.0	(GP)s.c	QUATERNARY ALLUVIUM DEPOSITS 0.0 to 40.0'		AD	CME Continuous Sampling
		(cont.) 29.0 - 40.0' Silty Sand, (SM): About 85% fine to medium micaceous sand; about 15% non-plastic fines; light olive-brown to olive-brown, saturated, loose. Mica increases with depth.	8	5.0 / 5.0	5-foot sample
38.0					
40.0 (-27.0)					Total Depth = 40 feet
42.0					
44.0					

DWR 885 (2) (Rev. 9-84)

Reclamation District 544 Seepage Monitoring Study

Monitoring Well Completion of UR-1-C

Ground Surface Elevation (MSL) = 13.01 ft
Datum (UTM NAD 83):



INSTALLED BY: Mark Souverville
DATE: 04/07/00
REMARKS:

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The Resources Agency
DEPARTMENT OF WATER RESOURCES

SHEET 1 of 2

HOLE NO. UR-2-A

DRILL HOLE LOG

ELEV. 9.38 FEET

DEPTH 20.0 FEET

PROJECT Reclamation District 544 Seepage Monitoring Study

DATE DRILLED 04/06/00

FEATURE Monitoring Wells

ATTITUDE Vertical

LOCATION

LOGGED BY William Brewster

CONTR. Layne-Christensen DRILL RIG CME 750

DEPTH TO WATER Approximately 8 ft

DEPTH (ELEV.)	LOG	FIELD CLASSIFICATION AND DESCRIPTION	SAMPLE NO.	MODE	REMARKS
0.0 (13.06)		QUATERNARY ALLUVIUM DEPOSITS 20.0'		AD	CME Continuous Sampling
		0.0 - 5.0' No sample obtained Cuttings indicate sandy soil.	NR	0.0 / 5.0	0.0 - 5.0' No sample obtained, fell out of sampler.
2.0					
4.0					
6.0	CL	5.0 - 7.0' Clay, (CL): Brown; damp; stiff.	1	2.5 / 2.5	2.5-foot sample
8.0	SM	7.0 - 11.3' Sand with Silt and Clay, (SM): About 80% fine to medium sand; about 20% fines; light brown; moist.	2	2.5 / 2.5	2.5-foot sample
10.0					
12.0	CL	11.3 - 13.3' Clay with Silt, (CL): About 90% medium plasticity clay; about 10% non-plastic fines; brown to gray; wet; soft to stiff.	3	5.0 / 5.0	5-foot sample
14.0	SM	13.3 - 17.0' Silty Sand, (SM): About 85% medium to coarse sand; about 15% non-plastic fines; light brown; wet.			
16.0			4		Continued on next page.

DWR 886 (1) (Rev. 9-84)

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES
DRILL HOLE LOG

SHEET 2 OF 2
HOLE NO. UR-2-A

PROJECT & FEATURE Reclamation District 544 Seepage Monitoring Study, Monitoring Wells

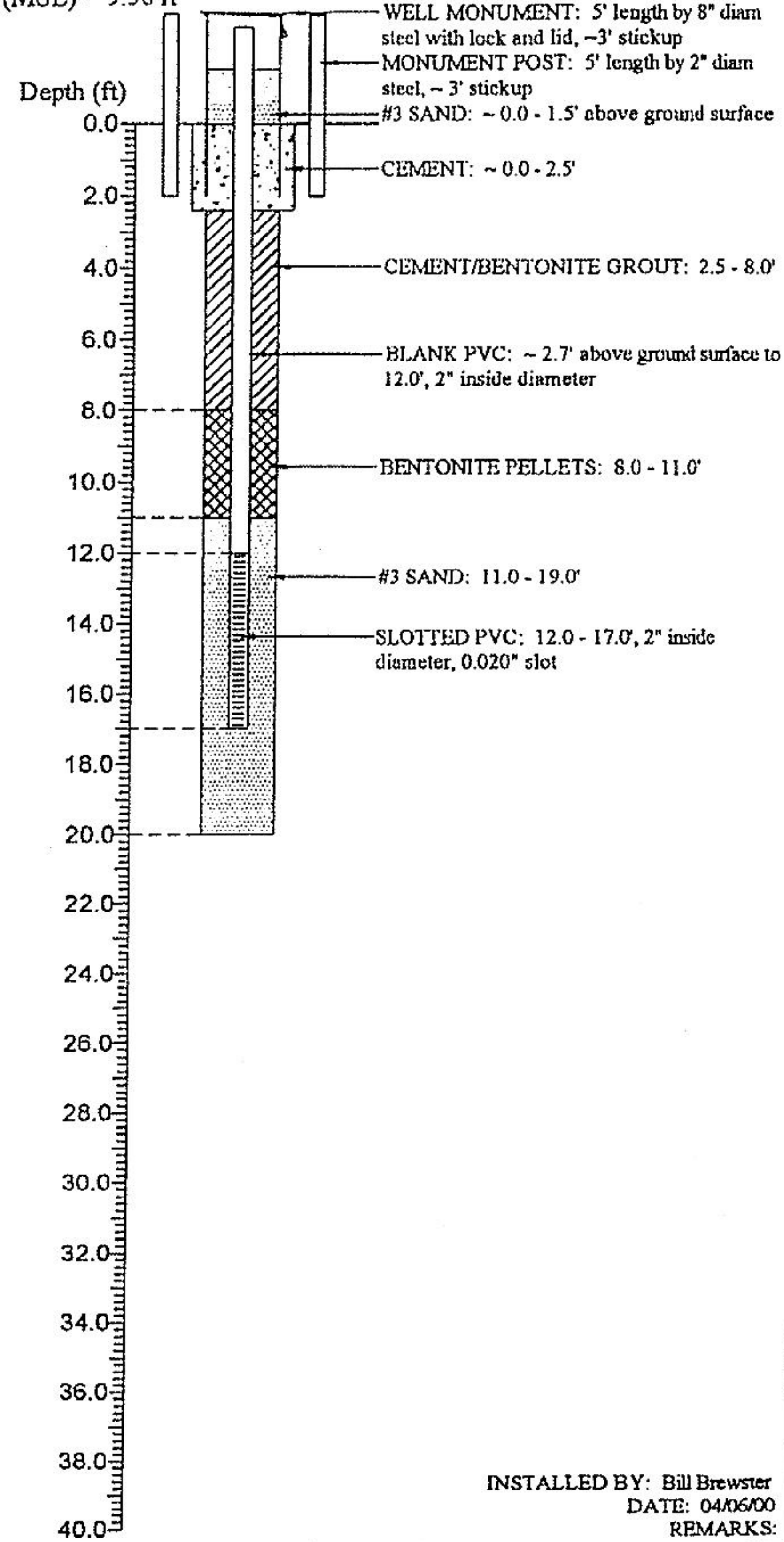
DEPTH (ELEV.)	LOG	FIELD CLASSIFICATION AND DESCRIPTION	SAMPLE NO.	MODE	REMARKS
16.0	SM	QUATERNARY ALLUVIUM DEPOSITS 0.0 to 20.0' (cont.) 13.3 - 17.0' Silty Sand, (SM): About 85% medium to coarse sand; about 15% non-plastic fines; light brown; wet.		AD	CME Continuous Sampling
18.0	ML	17.0 - 20.0' Silty Sand with Clay, (ML): About 60% fine sand; about 40% fines with slight plasticity; light brown, wet.	5	5.0 / 5.0	5-foot sample
20.0 (-10.6)					Total Depth = 20.0 feet
22.0					
24.0					
26.0					
28.0	SM				
30.0					
32.0					
34.0					
36.0					

DWR 885 (2) (Rev. 9-84)

Reclamation District 544 Seepage Monitoring Study

Monitoring Well Completion of UR-2-A

Ground Surface Elevation (MSL) = 9.38 ft
Datum (UTM NAD 83):



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DATE: 04/06/00
REMARKS:

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DRILL HOLE LOG

HOLE NO. UR-2-B

ELEV. 8.96 FEET

DEPTH 21.0 FEET

PROJECT Reclamation District 544 Seepage Monitoring Study

DATE DRILLED 04/06/00

FEATURE Monitoring Wells

ATTITUDE Vertical

LOCATION

LOGGED BY William Brewster

CONTR. Layne-Christensen DRILL RIG CME 750

DEPTH TO WATER Approximately 17 ft

DEPTH (ELEV.)	LOG	FIELD CLASSIFICATION AND DESCRIPTION	SAMPLE NO.	MODE	REMARKS
0.0 (8.96)		QUATERNARY ALLUVIUM DEPOSITS 0.0 to 21.0'		AD	CME Continuous Sampling 0.0 – 5.0' No sample obtained
2.0		0.0 - 5.5' Silty Clay (CL): About 70% low plasticity clay; about 30% non-plastic fines; mottled dark brown, dark grayish brown; moist; soft.	NR		
4.0	CL			0.0/5.0	
6.0		5.5 - 8.0' Sandy Clay, (CL): About 60% medium plasticity clay; about 40% medium sand; dark gray; moist; stiff.	1	2.5/2.5	2.5-foot sample
8.0		8.0 - 14.0' Silty Sand, (SM): About 80% medium sand; about 20% non-plastic fines; dark brown; moist.	2	2.5/2.5	2.5-foot sample
10.0	SM				
12.0			3	5.0/5.0	5-foot sample
14.0	CL	14.0 - 15.0' Sandy Silty Clay, (CL): About 50% clay; about 30% non-plastic fines; about 20% fine, micaceous sand; light brown; wet.			
16.0	SM	15.0 - 21.0' Sand with Silt, (SM): About 95% micaceous, fine to medium sand; about 5% non-plastic fines; light brown; moist; loose.	4		2.5-foot sample Continued on next page.

DWR 886 (1) (Rev. 9-84)

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES

DRILL HOLE LOG

SHEET 2 OF 2

HOLE NO. UR-2-B

PROJECT & FEATURE Reclamation District 544 Seepage Monitoring Study, Monitoring Wells

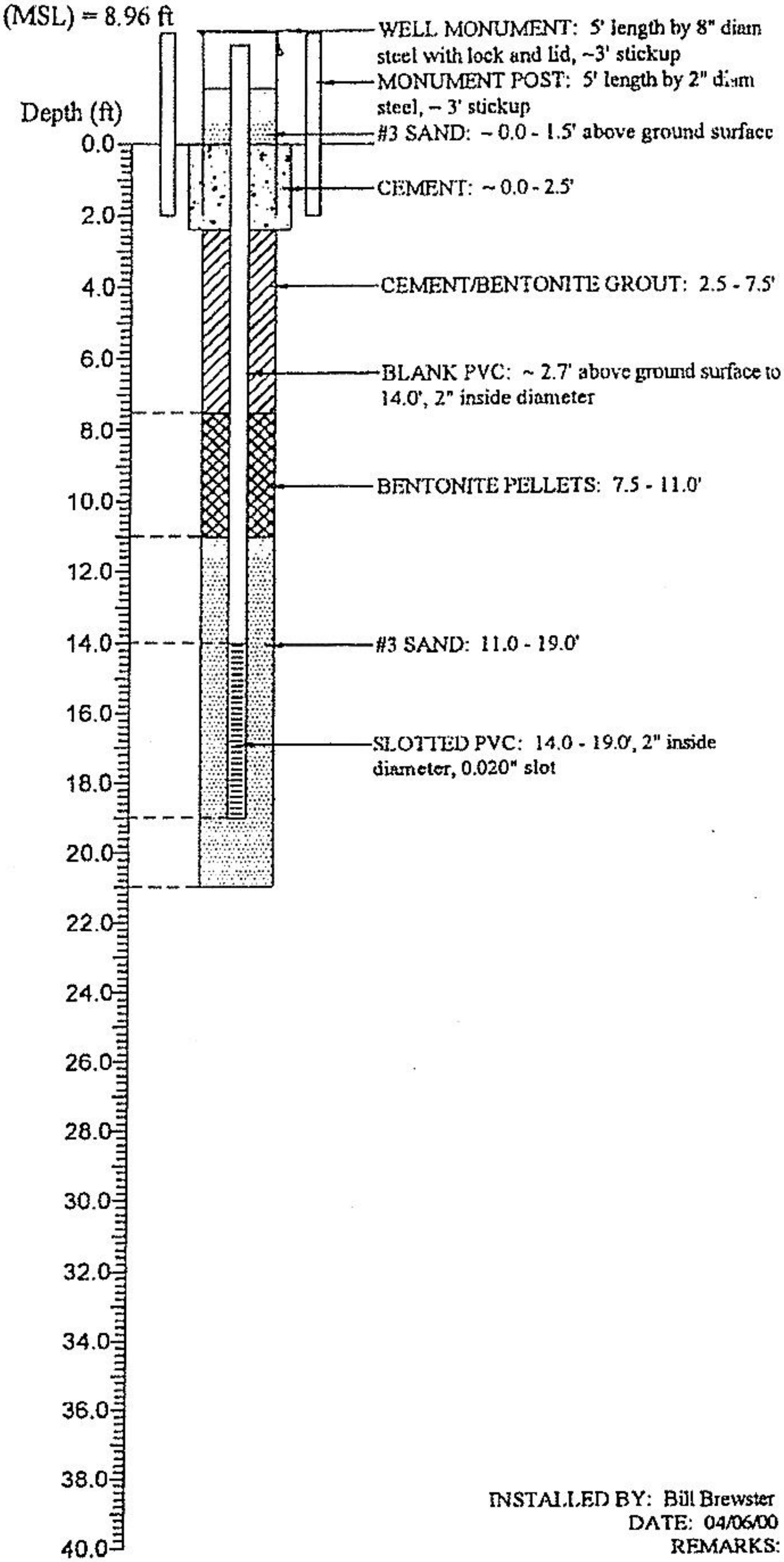
DEPTH (ELEV.)	LOG	FIELD CLASSIFICATION AND DESCRIPTION	SAMPLE NO.	MODE	REMARKS
16.0		QUATERNARY ALLUVIUM DEPOSITS 0.0 to 21.0'		AD	CME Continuous Sampling
18.0	SM	(cont.) 15.0 - 21.0' Sand with Silt, (SM): About 95% micaceous, fine to medium sand; about 5% non-plastic fines; light brown; moist, saturated at 17.5'; loose.	5	0.0/3.5	No sample retrieved, fell out of sampler due to high water content and loose soil.
20.0					
(-12.0)					Total Depth = 21.0 feet
22.0					
24.0					
26.0					
28.0					
30.0					
32.0					
34.0					
36.0					

DWR 885 (2) (Rev. 9-84)

Reclamation District 544 Seepage Monitoring Study

Monitoring Well Completion of UR-2-B

Ground Surface Elevation (MSL) = 8.96 ft
Datum (UTM NAD 83):



INSTALLED BY: Bill Brewster
DATE: 04/06/00
REMARKS:

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DEPARTMENT OF WATER RESOURCES

DRILL HOLE LOG

HOLE NO. UR-3-A

ELEV. 6.67 FEET

DEPTH 18.0 FEET

PROJECT Reclamation District 544 Seepage Monitoring Study

DATE DRILLED 04/05/00

FEATURE Monitoring Wells

ATTITUDE Vertical

LOCATION

LOGGED BY Mark Souverville

CONTR. Layne-Christensen

DRILL RIG CME 750

DEPTH TO WATER Approximately 11 ft

DEPTH (ELEV.)	LOG	FIELD CLASSIFICATION AND DESCRIPTION	SAMPLE NO.	MODE	REMARKS
0.0 (8.96)		QUATERNARY ALLUVIUM DEPOSITS 0.0 to 18.0'		AD	CME Continuous Sampling
2.0	SM	0.0 - 4.0' Silty Sand with trace Clay (SM): About 70% very fine to fine sand, some mica; about 30% non-plastic fines; dark grayish brown; moist; medium dense.	1		
4.0		4.0 - 6.0' Silty Sand, (SM): About 85% fine to medium sand, abundant mica; about 15% non-plastic fines; olive-brown; moist, wet from 5.0 - 5.5'; medium dense.		3.5 / 5.0	3.5-foot sample
6.0		6.0 - 11.0' Silty Clay, (CL): About 85% medium plasticity clay; about 15% non-plastic fines; very dark brown and dark gray; moist; soft.	2	5.0 / 5.0	5-foot sample
8.0	CL				
10.0					
12.0	SC	11.0 - 15.5' Sand with Clay, (SC): About 85% fine to medium sand; about 15% medium plasticity clay; iolive-brown; wet, loose.	3	5.0 / 5.0	5-foot sample
14.0					
16.0	SM	15.5 - 17.0' Silty Sand, (SM): About 85% fine to medium sand, abundant mica; about 15% non-plastic fines; light brown; saturated; loose.	4		5-foot sample Continued on next page.

DWR 886 (1) (Rev. 9-84)

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES

DRILL HOLE LOG

HOLE NO. UR-3-A

PROJECT & FEATURE Reclamation District 544 Seepage Monitoring Study, Monitoring Wells

DEPTH (ELEV.)	LOG	FIELD CLASSIFICATION AND DESCRIPTION	SAMPLE NO.	MODE	REMARKS
16.0	SM	QUATERNARY ALLUVIUM DEPOSITS 0.0 to 18.0' (cont.) 15.5 - 17.0' Silty Sand, (SM): About 85% fine to medium sand, abundant mica; about 15% non-plastic fines; light brown; saturated; loose.	4	AD 3.0/3.0	CME Continuous Sampling
	ML	17.0 – 18.0' Sandy Silt, (ML): About 80% non-plastic fines, about 20% fine to medium sand, abundant mica; mottled yellowish brown and olive-gray; damp; medium stiff.			
18.0 (-11.3)					Total Depth = 18.0 feet
20.0					
22.0					
24.0					
26.0					
28.0					
30.0					
32.0					
34.0					
36.0					

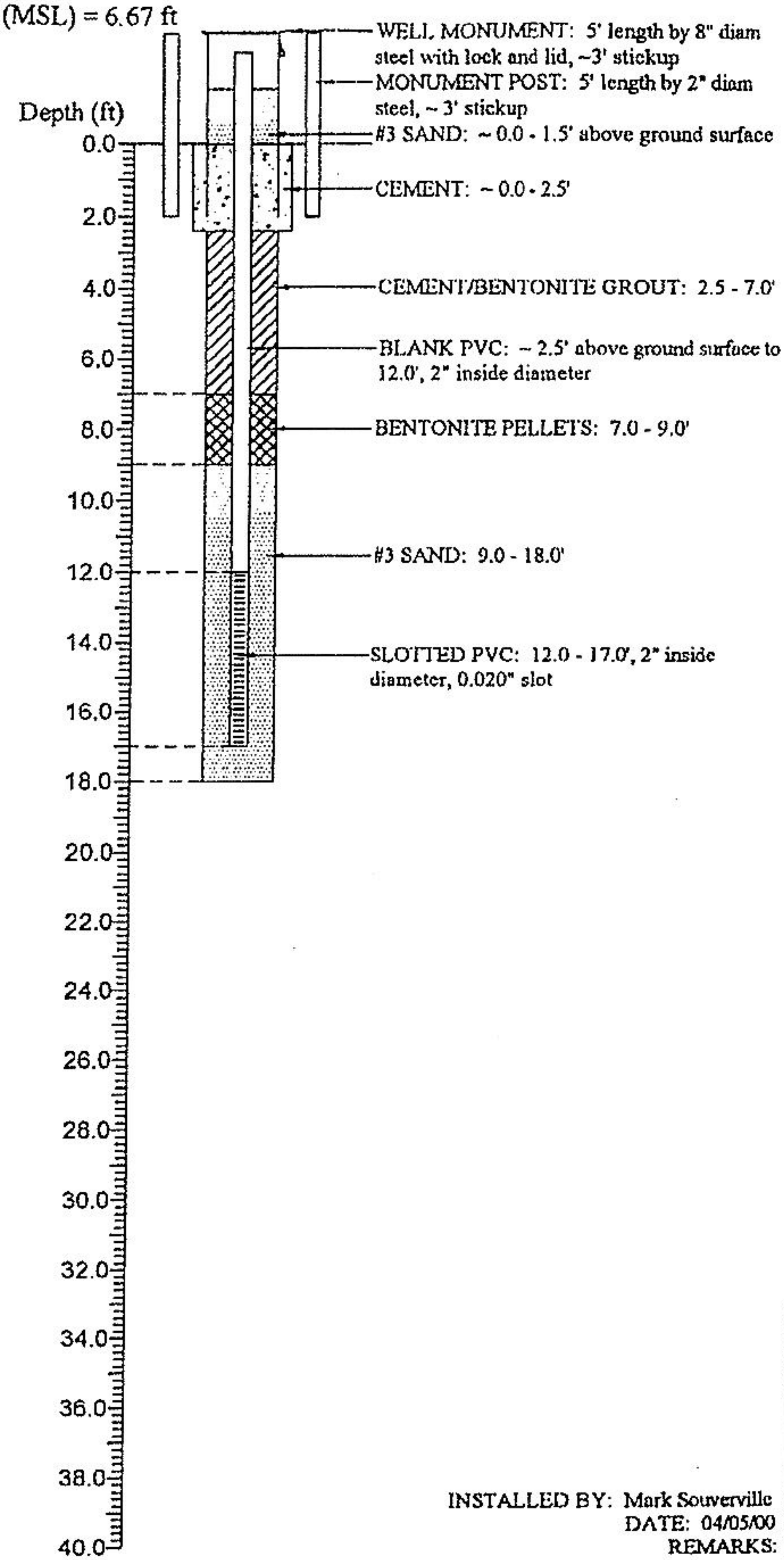
DWR 865 (2) (Rev. 9-84)

Reclamation District 544 Seepage Monitoring Study

Monitoring Well Completion of UR-3-A

Ground Surface Elevation (MSL) = 6.67 ft

Datum (UTM NAD 83):



INSTALLED BY: Mark Souverville
DATE: 04/05/00
REMARKS:

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES

DRILL HOLE LOG

SHEET 1 of 2
HOLE NO. UR-3-B
ELEV. 7.24 FEET
DEPTH 20.0 FEET

OJECT Reclamation District 544 Seepage Monitoring Study
DATE DRILLED 04/05/00
FEATURE Monitoring Wells
ATTITUDE Vertical
LOCATION
LOGGED BY Mark Souverville
CONTR. Layne-Christensen
DRILL RIG CME 750
DEPTH TO WATER Approximately 10 ft

DEPTH (ELEV.)	LOG	FIELD CLASSIFICATION AND DESCRIPTION	SAMPLE NO.	MODE	REMARKS
0.0 (8.96)		QUATERNARY ALLUVIUM DEPOSITS 0.0 to 20.0'		AD	CME Continuous Sampling
2.0		0.0 - 5.0' No sample obtained. Cuttings indicate sandy soil.	1	0.0 / 5.0	0.0 - 5.0' No sample obtained, fell out of sampler.
4.0					
6.0	CL	5.0 - 7.0' Sandy Clay, (CL): About 70% low plasticity clay; about 30% fine to medium sand; dark brown; moist; stiff; some organic material; some oxidation.			
8.0	ML	7.0 - 10.0' Sandy Silt with Clay, (ML): About 65% non-plastic fines; about 35% fine to medium sand; olive-brown; moist to wet; medium stiff; oxidation present.	2	5.0 / 5.0	5-foot sample
10.0					
12.0	SM	10.0 - 13.0' Silty Sand, (SM): About 85% fine sand; about 15% non-plastic fines; olive-gray; wet; medium dense.	3		
14.0	CL	13.0 - 16.5' Silty Clay, (CL): About 85% medium plasticity clay; about 15% non-plastic fines; light gray to olive-gray; moist; medium stiff.		5.0 / 5.0	5-foot sample
16.0			4		5-foot sample Continued on next page.

DWR 888 (1) (Rev. 8-84)

State of California
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DEPARTMENT OF WATER RESOURCES

DRILL HOLE LOG

SHEET 2 OF 2

HOLE NO. UR-3-B

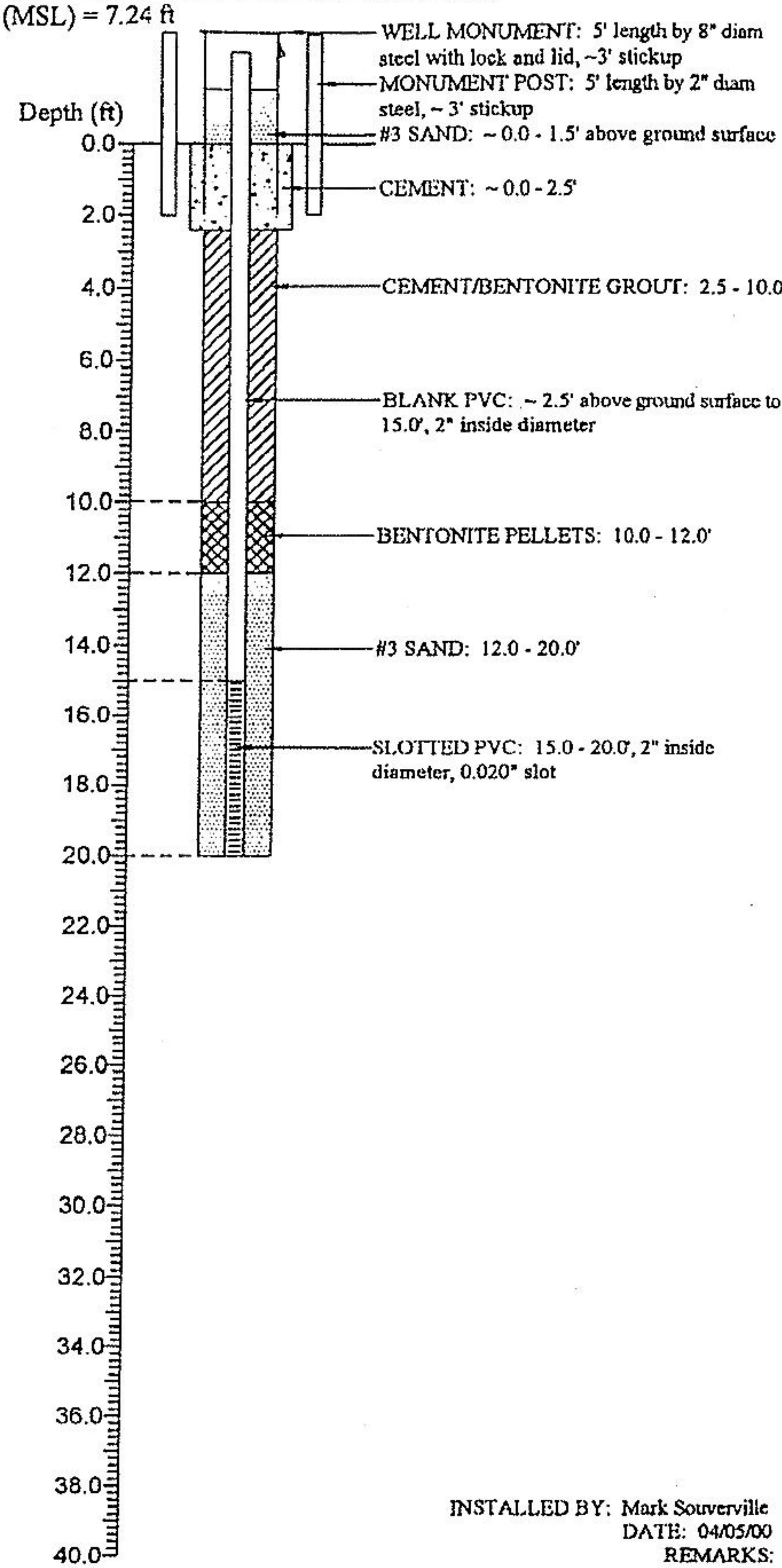
PROJECT & FEATURE Reclamation District 544 Seepage Monitoring Study, Monitoring Wells

DEPTH (ELEV.)	LOG	FIELD CLASSIFICATION AND DESCRIPTION	SAMPLE NO.	MODE	REMARKS
16.0	CL	(cont.) 13.0 - 16.5' Silty Clay, (CL): About 85% medium plasticity clay; about 15% non-plastic fines; light gray to olive-gray; moist; medium stiff.		AD	CME Continuous Sampling
18.0	SM	16.5 - 20.0' Silty Sand, (SM): About 80% fine to medium sand, abundant mica; about 20% non-plastic fines; gray brown; saturated; loose.	4	5.0 / 5.0	
20.0 (-12.8)					Total Depth = 20.0 feet
22.0					
24.0					
26.0					
28.0					
30.0					
32.0					
34.0					
36.0					

DWR 885 (2) (Rev. 9-84)

Reclamation District 544 Seepage Monitoring Study
Monitoring Well Completion of UR-3-B

Ground Surface Elevation (MSL) = 7.24 ft
Datum (UTM NAD 83):



INSTALLED BY: Mark Souverville
DATE: 04/05/00
REMARKS: