SAN LUIS & DELTA-MENDOTA WATER AUTHORITY

Public Comment
SJR Selenium Control BPA
Deadline: 9/22/10 by 12 noon

RECEIVED
SEP 22 2010
SWRCB EXECUTIVE

September 22, 2010

Jeanine Jones
Clerk to the Board
State Water Resources Control Board
1001 I Street
Sacramento, CA 95814
Sent via email to: commentletters@waterboards.ca.gov

RE: Proposed Approval of Amendments to the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins to Address Selenium Control in the San Joaquin River Basin

Dear Board Members:

I am the drainage coordinator for the Grassland Basin Drainers (GBD). The GBD is a group of agricultural water and drainage districts organized under the umbrella of the San Luis & Delta-Mendota Water Authority (Water Authority) to implement the Grassland Bypass Project. The Water Authority and the United States Bureau of Reclamation (Reclamation) are the signatories to the Agreement for the Continued Use of the San Luis Drain and are joint holders of the waste discharge permit issued by the Central Valley Regional Water Quality Control Board (Regional Board) for the Grassland Bypass Project.. We appreciate your taking up the matter of approval of the Central Valley Regional Board's action on May 27, 2010 amending the above water quality control plan. We request that the State Board approve the amendments to the Basin Plan adopted under Central Valley Water Board Resolution R5-2010-0046.

The extension of the compliance date for meeting selenium objectives in Mud Slough and a short section of the San Joaquin River is an essential element to the GBD's efforts to implement an environmentally responsible solution to the selenium issues in our area. In order to fully execute our plan we require additional time to perfect the final elements of our in-valley drainage solution. Our progress has been delayed due to unexpected delays in funding. Although the Basin Plan Amendment grants our area additional time to finalize our project, our discharges will continue to be controlled by Waste Discharge Requirement and strict provisions of the Use Agreement.

The Use Agreement requires the region to meet specific load limits that for the first five years are set at the San Joaquin River Selenium Total Maximum Daily Load (TMDL) levels and drop well below the TMDL levels in years six through ten. The agreement utilizes multiple economic incentives to ensure that the region eliminates agriculturally induced selenium discharges to Mud Slough and the San Joaquin River as soon as practicable within the ten year maximum term. Over the term of the agreement, selenium load limit decrease, incentive fees for exceeding these limits increase, and mitigation requirement expand. The

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project also includes a robust monitoring program including both water quality and biological monitoring. The intricate provisions of the Use Agreement were negotiated over many years with input from Federal, State, and Local government agencies as well as environmental stakeholders. The entire project is governed by an Oversight Committee consisting of representatives from the USEPA, USFWS, CDFG, CVRWQCB, and USBR.

The substantial reduction of both selenium and salt discharges from the area to the San Joaquin River are proof that this regulatory structure is effective. The area farmers have reduced salt discharges by 77% and selenium discharges by 89% since 1995. These efforts have required substantial investments in regional infrastructure and major investments by individual growers to implement practices to reduce discharges. The Grassland Basin Drainers' proven record of implementing innovative projects to meet very challenging discharge limits shows the commitment of these farmers to implement an environmentally responsible solution to the selenium challenge while maintaining the viability of some of the most productive farm land in the state and nation.

A primary benefit of the Grassland Bypass Project and the continued use of the San Luis Drain is to eliminate agricultural drainage from over 96 miles of wetland channels. The water quality improvements from this project were substantial and immediate. This Basin Plan amendment allows the continuation of these wetland benefits while the area implements the final phases of the environmentally responsible plan to eliminate agricultural drainage from 97,000 acres of prime farmland.

Despite our proven track record, some continue to have concerns about the viability of our project. The structure of the Use Agreement and the continuous oversight of the project by multiple agencies will ensure that the area meets it commitments and avoids potential environmental problems. In an effort to address lingering concerns, we have reviewed the comments addressed to the Central Valley Water Board and submit the attached comments from Entrix specifically related to the issue of impacts to migrating salmon in the San Joaquin River. These comments add to the responses provided by the Central Valley Water Board by describing specific factual information and scientific considerations supporting the conclusion that continuation of the Project will have a minimal effect on salmon being restored to the River.

The GBP is a successful drainage control program. For all the reasons stated above, we respectfully request that the State Water Resources Control Board approve the amendments to the Basin Plan adopted under Central Valley Water Board Resolution R5-2010-0046.

Very truly yours,

Joseph C. McGahan
Drainage Coordinator
Grassland Basin Drainers

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September 20, 2010

Joseph C. McGahan
Drainage Coordinator
Grassland Basin Drainers
P. O. Box 1122
Hanford, CA 93232

Submitted via email to commentletters@waterboards.ca.gov

RE: Proposed Approval of Amendments to the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins to Address Selenium Control in the San Joaquin River Basin

Dear Joe:

At your request, I am writing in response to comments by in a letter to David Hayes of the Bureau of Reclamation (Reclamation) from C-WIN dated December 9, 2010 (Attachment A). As you are aware, I was the lead author of the aquatic biology section of the EIR/EIS. I am an aquatic ecologist with over 24 years of experience evaluating the impacts of man's activities on salmonids along the western United States and particularly in California. My resume is included in Attachment B.

The C_WIN letter was received after the adoption of the CEQA document for that project. In this letter, C-WIN presents an email from Dr. Dennis Lemly on his review of information sent to him by C-WIN. Dr. Lemly reviewed Beckon and Mauer (2008), the U.S. Fish and Wildlife Service (USFWS) comments on the draft EIR/EIS, and Reclamation's response to those comments. Based on his review, he questions the conclusion made in the EIR/EIS that "the project is unlikely to have a significant impact on fish reintroduced as part of the San Joaquin River Restoration Program (SJRRP), because both projects would be expected to improve conditions for salmonids in the SJR and, therefore, they would not have a cumulatively significant impact."

In his email, Dr. Lemly says that the Beckon and Mauer (2008) report "clearly shows that there are/will be substantial negative effects (perhaps above 50% mortality) based on existing and anticipated waterborne selenium concentrations." Beckon and Mauer (2008) (Attachment C) provide information about the concentrations of selenium that are likely to cause adverse effects to salmonids based on dietary exposures to selenium enriched foods for 90 days. In their paper they conclude that a tissue selenium concentration of 1.84 μg/g in salmon is likely to cause 10 percent higher mortality than salmon would experience if the selenium concentrations were near optimal (their Figure 8). This tissue concentration corresponds to a waterborne concentration of 3.3 μg/l (their Figure 10). They cite information from Saiki et al. (1991) indicating that in 1987, young salmon migrating through the San Joaquin River accumulated selenium at levels likely to kill more than 25 percent of those exposed. In the next sentence, they acknowledge that selenium concentrations in the San Joaquin River have been reduced since 1987, but conclude that the relationship in the 1987 data indicates "there remains substantial ongoing risk to migrating juvenile Chinook salmon in the San Joaquin River". This conclusion is reached with no discussion of the current or projected future selenium concentrations or consideration of the duration over which juvenile salmon are likely to be exposed to these unspecified concentrations.

The EIR/EIS conclusion of no significant impact was explained in detail in the response to comment USFWS-10 in the FEIR/EIS, Appendix I, starting on page I-59 (excerpted in Attachment D). This conclusion focused on the 3 mile reach of the San Joaquin River between Mud Slough and the Merced River. This area experiences the highest concentrations of selenium that salmon or steelhead would be exposed to as a result of the project. Salmon and steelhead would not be able to access Mud Slough or the San Luis Drain, because of fish barriers that would be installed at the mouth of Mud and Salt Slough as part of the SJRRP. This 3 mile reach is located 100 miles or more downstream of the primary spawning and rearing areas anticipated in the SJRRP (Stillwater Sciences 2003) and represents less than 1 percent of the total amount of habitat below Friant Dam.

The conclusions in the EIR/EIS was based upon information contained in Beckon and Mauer (2008) and considered their 3.3 µg/l standard for 10% mortality of salmonids, the 4 µg/l for warmwater fish, and the 5 µg/l the water quality objectives set by the State Board for selenium in the project area. In addition, this evaluation considered the projected concentrations of selenium in the area of the San Joaquin River salmon and steelhead would be expected to occupy after initiation of the GBP and the SJRRP. Selenium concentrations were calculated for 2012 through 2017 based on current selenium discharges from the Grassland Bypass, projected future decreases in these discharges, and projected future flows resulting from the GBP and the SJRRP. This was evaluated using recent data from the project area for a Normal-Wet water year (2005 a wet condition) and a Critical-High water year (2008 critically dry condition), using the water year type descriptions from the SJRRP. Finally it evaluated this information based on the migration timing of spring-run Chinook salmon and Central Valley steelhead and the amount of time they would likely be present in the area most affected by the project, the San Joaquin River between Mud Slough and the mouth of the Merced River.

As described in Appendix I and in the SJRRP program documents, once established adults of both spring-run Chinook salmon and Central Valley steelhead would be expected to migrate upstream quickly through the San Joaquin River to reach holding habitat and spawning gravels in Reach 1 of the San Joaquin River, located 100 miles above the GBP project area (Stillwater Sciences 2003). Adult Chinook salmon and steelhead do not feed in freshwater, so would have no exposure to elevated selenium concentrations through their diet, which is the primary route of selenium exposure (Beckon and Mauer 2008). Therefore adults of these species would have minimal risk from their exposure during their upstream migration.

The SJRRP requires that salmon be introduced to the San Joaquin River no later than fall 2012, so the first juveniles would be expected to emigrate in the spring of 2013. Juvenile spring-run Chinook salmon and steelhead may rear for several months to more than a year in freshwater before emigrating to the ocean (Moyle 2002). Migration rates for juvenile Chinook salmon range from 1 to 20 miles a day (Williams 2006), with rates depending on fish size, time of year, water temperature and suitability of foraging habitat. Migration rates increase with increasing values of the first three parameters. Emigration is expected to occur between January and May. Ward et al. (2004) reports that some juvenile Chinook salmon stop in areas of favorable habitat during the downstream migration and rear for periods exceeding 2 months. It is unclear what proportion of the population exhibits this behavior, and this is based on observation of populations in the Butte Creek watershed, where environmental conditions are substantially different than in the San Joaquin River. These prolonged periods of rearing are typically associated with floodplain habitats. There is floodplain habitat on the San Joaquin River between Mud Slough and the Merced River. It is unknown at what flows these floodplains would be inundated, or how long they would be inundated. Assuming that these floodplains are inundated in wet and above normal years, they would be inundated in about 1 year in every 3 based on the historic record of water year types maintained by DWR. During the remaining years, all fish would be expected to migrate at rates of 1 to 20 miles per day, meaning they would spend only a few days in 3 mile reach of the San Joaquin River that is most affected by the project. Under a worst case scenario, a highly unlikely event, some proportion of the population may rear in this area for more than 2 months.

Projected selenium concentrations in this portion of the SJR were provided in Appendix I of the FEIR/EIS and is included in Attachment D. Waterborne selenium concentrations were projected for 2012 through 2017 for wet and dry conditions. This shows that based on project related changes in flow and selenium concentrations from the project area and flow changes projected to occur as a result of the SJRRP, the average 1-3 month concentration rarely exceeded the 3.3 µg/l standard suggested by Beckon and Mauer (2008), and was generally substantially lower. The only time it did exceed 3.3 µg/l was in early January, in which the average incorporated the selenium concentrations from the fall months when selenium concentrations were higher, but juvenile salmon would not be present. Even in wetter year when an unknown proportion of salmon and steelhead may be present for longer periods, the 3.3 µg/l threshold is not exceed for the 90 days necessary to cause the 10 percent mortality identified in Beckon and Mauer (2008) and therefore, there would be little effect on salmon and steelhead. While the proportion of the total populations that might use this area is unknown, this area represents only 1 percent of the total length of the river and similarly small proportion of the habitat. Upstream areas are likely to provide much more suitable habitat for rearing (Stillwater Sciences 2003, SJRRP TAC 2009) and this 3 mile reach is likely to warm quickly in the spring in response to rising air temperatures. Therefore the proportion of the population using this area for extended periods would be expected to be very small.

In 2 years out of every 3, salmon and steelhead would only be in this area of the river for a few days, and therefore their exposure to selenium concentrations would be much lower. Instantaneous concentrations rarely exceeded 3.3 µg/l and this usually occurs in late April or May when fish would be larger and temperatures would be warming, indicating fish would be moving quickly downstream (Williams 2006), again indicating the duration of exposure to even briefly elevated selenium concentrations would be minimal, and there would be no significant effect on these fish.

Appendix I acknowledges uncertainties in the analysis based upon limited information on selenium toxicity for salmon, appropriate lag times, life history patterns that might be exhibited by fish reintroduced into this area by the SJRRP, and the frequency and duration of floodplain inundation in the affected area. However, even when the worst case with regard to these uncertainties is considered, the project would still result in less than 10 percent mortality to a small fraction of the population, and thus would be less than significant.

This project was reviewed by NMFS and they found that the project was not likely to neither adversely affect the spring-run Chinook salmon or Central Valley steelhead nor adversely modify their critical habitat. Reclamation considered the information above, and the C-WIN letter in adopting the Record of Decision for the GBP.

Lastly, the Final Use Agreement for the project includes an oversight committee comprised of the chief regional administrators for Reclamation, the USFWS, Environmental Protection Agency, California Department of Fish and Game and the Central Valley Regional Water Quality Control Board. This committee would oversee the continued monitoring of water, fish tissue, and food items for juvenile salmon reintroduced to the San Joaquin River and evaluate the time juvenile salmon reintroduced to the

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river are likely to spend in different reaches of the river. If tissue concentrations in food items for salmon reach 3 μg/g dry weight, the Oversight Committee process would be triggered, and the Committee, with input from Reclamation and other interested parties will evaluate risks to salmonids and determine whether there are feasible measures to reduce potential impacts.

Literature Cited:

Beckon, W. and T. Mauer 2008. Potential Effects Of Selenium Contamination On Federally-Listed Species Resulting From Delivery Of Federal Water To The San Luis Unit. Preapred by the U.S. Fish and Wildlife Service for the U.S. Bureau of Reclamation under Agreement # 05AA210003

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Ward, P., T. McReynolds, and C. Garman 2004. Butte and Big Chico Creeks Spring-run Chinook salmon, Oncorhynchus tshawytscha, Life History Investigation 2002-2003. Inland Fisheries Administrative Report No. 2004-6

Williams, J. 2006. Central Valley Salmon. A perspective on Chinook and steelhead in the Central Valley of California. San Francisco Estuary and Watershed Science 4(3) Article 2.

Sincerely,

L. M. Wise Jr.

Lawrence M. Wise
Senior Consultant/Aquatic Ecology

Attachment A: C-WIN letter with Lemly email
Attachment B: Resume
Attachment C: Beckon and Mauer 2008
Attachment D: Response to USFWS Comment 10, from FEIR, Appendix I, Page I-59

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Attachment A
C-WIN Letter

california water impact network

December 9, 2009

David Hayes
Deputy Secretary of the Interior
1849 C St., NW
Washington, D.C. 20240

Re: New Information on Toxicity of Grasslands Bypass Project to Salmonids

Dear Mr. Hayes:

The California Water Impact requested and received an independent review by Dennis Lemly, Ph.D. of the selenium impacts to salmonids from the proposed Grasslands Bypass Project 2010-2019, attached. As you are aware, a Record of Decision is imminent on this project because the Use Agreement between Reclamation and the Grasslands Drainers for the San Luis Drain expires this month.

Dr. Lemly has confirmed that there will be 50% mortality of juvenile Chinook salmon and Central Valley Steelhead in the San Joaquin River as a result of continuation of the Grasslands Bypass Project. This bodes poorly for both Central Valley Steelhead, a threatened species, and San Joaquin River Chinook, a species proposed for restoration through the San Joaquin River Settlement Act.

C-WIN urges you to reconsider our request to only renew the San Luis Drain Use Agreement for two years. The additional time will allow Interior to utilize USGS' Decision Analysis Process to take a hard look at land retirement in the entire San Luis Unit (including the San Luis Drainage ROD) as the ultimate solution to the drainage problem. Land retirement is the only economically and financially feasible alternative, as stated in numerous documents by USGS, Reclamation, the U.S. Fish and Wildlife Service and others.

I am requesting a meeting with you and/or your staff prior to signing the Record of Decision for the Grasslands Bypass Project. Please contact Tom Stokely of my staff at 530-926-9727 to arrange the details of the meeting.

808 Romero Canyon Road, Santa Barbara, CA 93108, email: caroleekrieger@cox.net, Phone: 805.969.0824, Fax: 805.565.3394

california water impact network

Respectfully submitted,

Carolee Krieger

Carolee Krieger, President
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Attachments: Request to Dennis Lemly from Tom Stokely
Response from Dennis Lemly
Dennis Lemly's Qualifications

cc: David Nawi
Don Glaser, BOR Regional Director
Rod McGinnis, NMFS
Ren Lohoefener, USFWS
Dan Nelson, San Luis Delta-Mendota Water Authority
Alexis Strauss, USEPA
Charles Hoppin, Chairman SWRCB
Karl Longley, Chairman CVRWQCB
John McCamman, Department of Fish and Game
Lester Snow, Department of Water Resources
Mark Madison, City of Stockton
Rudy Schnagl, CVRWQCB
Interested parties

Tom Stokely

From: "Tom Stokely" <tstokely@att.net>
To: <dlemly@fs.fed.us>
Sent: Monday, December 07, 2009 10:23 AM
Attach: Beckon_Maurer_2008_Effects_Selenium_Listed_Species.pdf; gbp_feis_i_02_commentsandresponses_USFWS.pdf
Subject: Request for Review of Grasslands Bypass Project Selenium Effects on Salmonids

Dennis Lemly,
Research Biologist
USDA-Forest Service
Dept of Biology, Wake Forest University
Box 7325
Winston-Salem, NC 27109
dlemly@fs.fed.us

Sent Via e-mail to:

Re: Grasslands Bypass Project and Selenium Toxicity to Salmonids

Dear Mr. Lemly:

I am requesting that you review the attached information and any other information you may have regarding the Grasslands Bypass Project and toxicity to Salmonids and other organisms.

The Grasslands Bypass Project (see http://www.usbr.gov/newsroom/newsrelease/detail.cfm?RecordID=30201) collects and concentrates agricultural drainage water from the approximately 90,000 acres in the northerly area of the San Luis Unit of the Central Valley Project. The drainage water contains high levels of salt, selenium, boron and other substances, including mercury. In order to avoid contamination of wildlife refuges and other wetlands (duck clubs) with selenium and other toxins, the contaminated water goes into a reopened portion of the San Luis Drain which drains directly into Mud Slough, a tributary of the San Joaquin River. Selenium concentrations are 54 ppb on a 30 day running average. The Proposed Project would continue use of the San Luis Drain and discharge contaminated drainage water into Mud Slough through 2019. The project proponents admit that neither the technology nor funding exists to treat the drainage water without discharge into the San Luis Drain, Mud Slough and the San Joaquin River, but are hoping for a miracle to occur in the next 10 years.

The Final EIS/EIR (Bureau of Reclamation/San Luis Delta Mendota Water Authority) for the project responded to comments from the US Fish and Wildlife Service and others that the project would adversely affect restoration of Chinook salmon and Central Valley Steelhead (a federally threatened species) through selenium exposure (see response to USFWS comment 10, attached). It appears that the response is incorrect based on information by Beckon and Maurer, attached. Selenium toxicity appears to be greater than assumed by the lead agencies, as well as the residence/exposure time of Salmonids in the contaminated reaches of the San Joaquin River.

I would appreciate your independent opinion on the adequacy of the response to the US

Fish and Wildlife Service's comments and the response. The Bureau of Reclamation is about to make a Record of Decision on this project at any moment, so any information you provide could provide important independent analysis of the proposed action.

If you have any questions or require additional information, please don't hesitate to contact me at 530-926-9727 or my cell phone at 530-524-0315.

Sincerely,

Tom Stokely
Water Policy Coordinator
California Water Impact Network
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Tom Stokely

From: "Dennis Lemly" <dlemly@fs.fed.us>
To: "Tom Stokely" <tstokely@att.net>
Sent: Wednesday, December 09, 2009 6:18 AM
Attach: Lemly-TechnicalQualifications.doc
Subject: Re: Request for Review of Grasslands Bypass Project Selenium Effects on Salmonids

Hello Tom,

I have reviewed the information you sent, specifically, the US Fish and Wildlife Service technical analysis of selenium risks to Chinook salmon and steelhead associated with the Grasslands Bypass Project (GBP) by Beckon and Maurer, the US Fish and Wildlife Service comments to USBR on the Final EIS, and USBR's response to those comments.

After close inspection of these reports, comments, and responses, I can only conclude that the Proposed Action and the Alternative Action pose unacceptable risks to the health and well-being of extant and to-be-established populations of migratory fish.

The report by Beckon and Maurer clearly shows that there are/will be substantial negative effects (perhaps above 50% mortality) based on existing and anticipated waterborne selenium concentrations. This is a technically sound report. Although USBR casts doubt on one key study (Hamilton et al. 1980) due to mortality in controls, the results were identical for both field-source and experimental diets (which did not have those problems).

It is interesting that USBR essentially admits there are substantial risks in its response to USFWS comments (Appendix I, Public Comments and Responses, page I-65) "However, as discussed above, there is considerable uncertainty in this analysis due to lack of data on Se bioaccumulation and toxicity in salmonids as well as limited data on likely exposure periods. Due to this uncertainty, it was assumed in the Draft EIS/EIR that there could be potential negative impacts to Chinook salmon and steelhead under the Proposed Action and Alternative Action, independent of the SJRRP"

Curiously, despite this admission of uncertainty and potential for negative impacts, USBR goes on to conclude that "GBP is unlikely to have a significant impact on the fish reintroduced as part of the SJRRP. Because both projects would be expected to improve conditions for salmonids in the SJR and, therefore, they would not have a cumulatively significant impact".

Clearly, this latter statement is based on hopes and not facts.

USBR wants it both ways...........identify a problem but then say there is no problem.

Acknowledging that substantial uncertainty (and thus ecological risk) exists cannot logically be followed by concluding that there will be no problem.

This is a blatant contradiction and their is no credible scientific basis for USBR to claim there will be no cumulatively significant impact.

The correct conclusion is that available data and a reasonable interpretation of it clearly shows that significant risks of substantial selenium toxicity exist which will not be eliminated or substantially lessened by GBP or SJRRP.

I hope these brief comments adequately express my grave concerns about what USBR is proposing.

Please let me know if I can be of further assistance.

I have attached a statement of my technical qualifications for your information.

Sincerely,
A. Dennis Lemly, Ph.D.

Technical Qualifications Satement
Dr. A. Dennis Lemly

I have spent over 30 years investigating the effects of selenium pollution in aquatic ecosystems. I have extensive experience conducting field and laboratory research on selenium toxicology, primarily involving aquatic cycling, bioaccumulation, and effects on fish. These studies include intensive investigations of the two most substantial cases of selenium pollution that have taken place in the USA; (1) Belews Lake, North Carolina, where 19 species of fish were eliminated, and (2) Kesterson Marsh, California, where thousands of aquatic birds were poisoned. My career began in the late 1970's with studies of the landmark pollution event at Belews Lake, which established the fundamental principles of selenium bioaccumulation and reproductive toxicity in fish. In the 1980's, I was a research project manager for the U.S. Fish and Wildlife Service, directing studies that determined impacts of selenium from agricultural irrigation on aquatic life at Kesterson and in 14 other western states. In the 1990's, the emphasis of my research shifted to the development of methods and guidelines for hazard assessment and water quality criteria for selenium, which led to the publication of a reference book (see item 42 below). This handbook contains the first comprehensive assessment tools for evaluating selenium pollution on an ecosystem scale. I have consulted on selenium contamination issues ranging from landfill leachate in Hong Kong to mountaintop removal coal mining in West Virginia. I provide the methods and technical guidance necessary to identify, evaluate, and correct aquatic selenium problems before they become significant toxic threats to fish and wildlife populations. I have devised and applied techniques for protecting aquatic life in habitats from the Arctic to the tropics, and from high mountain streams to coastal lagoons. I have Masters and Doctorate degrees in biology from Wake Forest University.

PUBLICATIONS ON SELENIUM:

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Attachment B
Resume

ENTRIX

Down to Earth. Down to Business.

Lawrence M. Wise, Jr.

SENIOR CONSULTANT

DISCIPLINE/SPECIALTY

- Aquatic Ecology
- Habitat Assessment
- Hydroelectric Relicensing
- Water Supply
- ESA Consultation
- NEPA/CEQA
- Instream Flow Assessment

EDUCATION

- M.A., Marine Biology, San Francisco State University, 1997
- B.S., Marine Biology and Limnology, San Francisco State University, 1986

CONTINUING EDUCATION AND CERTIFICATIONS

- Indicators of Hydrologic Alteration. The Nature Conservancy. June 27-28, 2005.
- Geomorphology in Stream Restoration. U. C. Berkeley extension program, April 24-28, 1995.
- IF 310 - Using the Physical Habitat Simulation System (PHABSIM). USFWS and Colorado State University, January 30 - February 3, 1989.

SAFETY/CERTIFICATIONS

- CPR and Blood Bourne Pathogen, April 2008
- Basic First Aid, March 2007
- HAZWOPPER Supervisor Training, Nov 1996
- HAZWOPPER 40 hr. Nov. 1989

PROFESSIONAL AFFILIATIONS

- American Fisheries Society

SUMMARY OF QUALIFICATIONS

Mr. Wise is a Senior Fisheries Biologist with over 24 years of experience in the ecology of freshwater, estuarine, and marine systems. He has extensive experience in planning and implementing environmental impact, population and habitat assessment studies in aquatic environments. Much of this work has involved assessing the impacts of projects affecting water need and availability for aquatic resources as part of environmental documents under the National Environmental Policy Act (NEPA), the California Environmental Quality Act (CEQA), biological assessments for ESA consultation, and Exhibit Es for hydroelectric relicensing. Mr. Wise has also worked on a wide range of other projects including invasive species control, water treatment plant discharges, aggregate mining operations, Natural Resource Damage Assessments (NRDA) associated with oil and chemical spills, and NPDES permitting. Mr. Wise has worked extensively on rivers and streams throughout the west coast and on fisheries issues in the San Francisco Bay-Delta. Clients have included private companies, water districts, and state and federal agencies.

Mr. Wise's career has focused on the impacts of man's activities on aquatic ecosystems, from alpine streams to the nearshore marine environment and all aquatic habitats in between. Throughout his career, Mr. Wise has worked assessing the ecological needs of resident and anadromous salmonids and the potential effects of different types of activities on these species. He has evaluated the effects of hydroelectric projects, municipal and agricultural diversions, mining activities, wastewater outfalls, chemical and oil spills on salmonid species. Other species of special status and other communities have frequently been of interest as well. These include the endangered California freshwater shrimp (*Syncaris pacificus*), which resides only in Marin and Sonoma counties and the native non-game fish of the San Joaquin River, where Mr. Wise worked with resource agencies and Southern California Edison Co. to develop one of the first management plans designed to protect and promote this community. He also has conducted several studies of marine and estuarine infaunal communities and their response to wastewater outfalls and habitat restoration measures.

RELEVANT EXPERIENCE

Grassland Bypass Project EIR/EIS

Mr. Wise served as lead investigator for evaluating the effects of extending the duration of the Grassland Bypass Project Use Agreement on fish and aquatic resources. The key issue was extending the time in which the project proponents would continue to release selenium into Mud Slough and the San Joaquin River. This evaluation was accomplished through a review of pertinent literature to establish relevant exposure thresholds, modeling of selenium concentrations and duration of exposure in various areas that would be impacted by the project, and coupling this with life history information for selected species to determine exposure effects. Species of primary concern included steelhead and splittail, which can occur in the project area under current conditions. The potential effect of the project on spring-run Chinook salmon that are proposed to be reintroduced to the San Joaquin River under the San Joaquin River Restoration Plan were also considered.

San Joaquin River Restoration Plan – Reach 4B Project EIR/EIS.

Mr. Wise is overseeing the analysis of this project on biological resources in Reach 4B in the vicinity of Los Banos, CA. The SJRRP seeks to reintroduce spring-run Chinook salmon to the San Joaquin River below Friant Dam, with the goal of reestablishing a self sustaining population. Fall-run Chinook salmon may also be reintroduced, and steelhead are likely to re-colonize this area as habitat conditions improve. Reach 4B is anticipated to serve as a passage corridor for these fish, but will also support populations of native fish. A number of terrestrial species could also be impacted including blunt nosed leopard lizard, San Joaquin kit fox, Swainson's hawk, burrowing owl, as well as several plant species and vernal pool habitats. The Reach 4B project would establish migration pathways and create floodplain habitat in this area of the river, using the natural channel, which has been dewatered for over 40 years, and the Eastside and Mariposa bypass channels.

Supplemental EIR for the Environmental Water Account - U.S. Bureau of Reclamation (Subcontractor to CDM)
The Environmental Water Account is a environmental mitigation to protect fish during sensitive periods in the Delta. This program can restrict water deliveries through the Delta at environmentally sensitive times and replace this water during less sensitive periods. The program acquires water through purchase or a variety of other means. This water is moved to the south-of-Delta area during periods with lower environmental sensitivity. This water can then be used to offset delivery needs during periods that cause greater harm. Mr. Wise prepared the fisheries and aquatic ecosystem analysis for the supplement to the 2004 EIR to extend this EIR through 2011. He worked collaboratively with the EWA Team, including representatives from the Bureau of Reclamation, Department of Water Resources, California Department of Fish and Game, U.S. Fish and Wildlife Service, and National Marine Fisheries Service to develop evaluation methods and criteria for assessing the effects of this project on Delta species and habitat, with a specific focus on delta smelt, anadromous salmonids and pelagic organism decline. The assessment also includes evaluation of a number of other listed or recreationally or commercially important species. This document has been reviewed with minimal comment by the EWA Team and the public. It is expected to be finalized in late 2008.

Delta Mendota Canal Recirculation Project - Account – U.S. Bureau of Reclamation and Department of Water Resources (Subcontractor to URS)
The Delta Mendota Canal Recirculation Project was a proposal to use excess pumping capacity at the Jones (Cental Valley Project) and Banks (State Water Project) pumping plants in the South Delta to deliver water into the San Joaquin River upstream of Vernalis. The intent of this project was to reduce reliance on New Melones Reservoir in meeting water quality objectives on the San Joaquin River at Vernalis and make the water saved available for other beneficial uses. ENTRIX conducted a highly successful, collaborative effort with resource agency scientists to develop assessment techniques and evaluation criteria acceptable to all parties for evaluating the effects of this project on aquatic resources in the Sacramento-San Joaquin Delta, the San Joaquin River, and the Stanislaus River. The principal species of concern included all races of anadromous salmon, delta smelt, green sturgeon, white sturgeon, longfin smelt, striped bass, American shad and threadfin shad. This collaboration was front-loaded into the project to avoid or minimize disagreements later in the evaluation process that have delayed or derailed projects historically. The project team completed the Initial Alternatives Implementation Report and Plan Formulation Report, which use successively more narrowly focused evaluation approaches to assess a broad range of alternatives and winnow this range down into those, which will be evaluated in an EIR/EIS for the project. The project was placed on hold when the project did not appear to be feasible based on a number of concerns.

Bay Delta Conservation Plan
Mr. Wise is assisting SAIC and the BDCP Steering Committee in the development of conservation elements for inclusion in the BDCP HCP/NCCP. Mr. Wise has provided assistance in identifying and researching and presenting information on "other stressors" in the delta, including hatchery practices, dissolved oxygen concentrations, and toxic contaminants. Mr. Wise prepared material to assist in the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) Model evaluation of a variety of conservation measures relating to water operations, habitat restortation, and a variety of other stressors including pesticides, invasive species, food webs, and non-project diversions. Mr. Wise is the lead investigator of the effects of the BDCP on delta and longfin smelt.

Attachment C
Beckon and Mauer 2008

U. S. Department of the Interior
Fish and Wildlife Service

Potential Effects Of Selenium Contamination On Federally-Listed Species Resulting From Delivery Of Federal Water To The San Luis Unit

U.S. Fish and Wildlife Service
Sacramento Fish and Wildlife Office
Environmental Contaminants Division

Artwork by Miriam Morrill

For the U. S. Bureau of Reclamation
Under Agreement # 05AA210003

March 2008

Potential Effects Of Selenium Contamination On Federally-Listed Species Resulting From Delivery Of Federal Water To The San Luis Unit

Prepared By:

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For the U. S. Bureau of Reclamation
Under Agreement # 05AA210003

Introduction

Federal water delivered to the San Luis Unit (the Project) is used principally for irrigated agriculture. Due to a nearly-impervious soil layer, irrigated agriculture in this area is unsustainable without subsurface drainage to keep the water table below the root zone of crops and to ameliorate the accumulation of salts in the soil. Therefore, an analysis of the effects of the delivery of federal water must include the effects of subsurface drainwater that may seep, be conveyed, or be carried by floodwaters downstream into sloughs and rivers and thence into the San Francisco Bay/Delta estuary.

Within the direct footprint of the project, consideration must be given to the effects of conveying and storing drainwater, as well as applying drainwater to irrigate salt-tolerant plants in reuse areas, and evaporating drainwater in evaporation ponds or solar evaporators. These are likely to be components of any long-term continuation of irrigated agriculture in the San Luis Unit. In this area, the subsurface drainage of irrigated lands mobilizes selenium that has been historically sequestered in the soil. Selenium concentrations in agricultural drainwater from this area reach levels that, when bioaccumulated through food chains, cause adverse effects on aquatic and aquatic-dependent wildlife. Where such drainwater is applied to uplands, as in reuse areas, strictly terrestrial wildlife may be impacted as well.

Downstream from the San Luis Unit, any drainwater from the Project area is diluted by relatively low-selenium water from rivers that drain the Sierra Nevada Mountains. However, as the San Joaquin River reaches the San Francisco Bay/Delta estuary, flow velocities decrease and salinity increases. In these slow-moving, saline waters, with abundant introduced filter-feeding invertebrates, ecosystems have developed that evidently are much more effective than riverine ecosystems at bioconcentrating water-borne selenium. Therefore, potential downstream effects must be considered.

Although selenium is the principle contaminant of concern in drainwater from this area, mercury in the soil may be similarly mobilized and bioconcentrated to toxic concentrations in food chains. However, less is known about mercury contamination in the San Luis Unit, and measures to minimize and mitigate selenium contamination could ameliorate the risk of mercury toxicity as well. The discussion below focuses on selenium and on the species that are most sensitive and most likely to be exposed to selenium as a result of the delivery of federal water to the San Luis Unit.

San Joaquin kit fox (*Vulpes macrotis mutica*)

Status: The San Joaquin kit fox has been federally listed as endangered throughout its range since 1967 (32 FR 4001). It is endemic to the western San Joaquin Valley in the vicinity of the San Luis Unit (Figure 1).

Life history summary: Studies of kit fox and their small mammal prey in the vicinity of Kesterson Reservoir indicate that kit foxes are likely to forage in drainwater reuse areas and around evaporation ponds where selenium concentrations in their prey are likely to be well above levels known to cause adverse effects in members of the canid family of carnivores to which kit fox belong.

Risk of selenium exposure: No toxicity tests have been performed on kit fox. The most closely related surrogate species for which toxicity data are available is the domestic dog (*Canis familiaris*), which is in the same family (Canidae) as the San Joaquin kit fox. Dogs exposed to 7.2 µg/g (dry weight) dietary (organic) selenium suffered adverse effects, including reduced appetite, subnormal growth, and poorly developed ovaries and testes (Rhian and Moxon 1943). The 7.2 µg/g concentration is a Lowest Observed Adverse Effect Concentration (LOAEC); the actual toxicity threshold for domestic dogs must be an unknown amount below this value. Further, any extrapolation of dog toxicity data to kit foxes must include an uncertainty factor to account for the risk that kit foxes may be more sensitive than dogs. Therefore, given available data, an appropriate selenium dietary toxicity threshold for San Joaquin kit fox diet must be well below 7.2 µg/g.

Areas of the San Luis Unit supplied directly with relatively good quality federal water are probably best represented by the small mammals collected by Clark (1989) on the Volta Wildlife Management Area in 1984. Clark did not report whole-body selenium analyses of these mammals, but his reported analyses of liver selenium indicate that selenium concentrations in the small mammal prey of San Joaquin kit foxes at Volta were as much as two orders of magnitude less than concentrations at the drainwater evaporation ponds of Kesterson Reservoir. For example, the California voles captured at Volta Pond 5 in May 1984 (n=5) had a mean liver selenium concentration of 0.228 µg/g; the same species collected at Kesterson pond 2 at the same time (n=5) had a mean (geometric) liver selenium concentration of 119 µg/g (Clark 1989). Since background selenium concentrations in mammal livers are about 1-10 µg/g

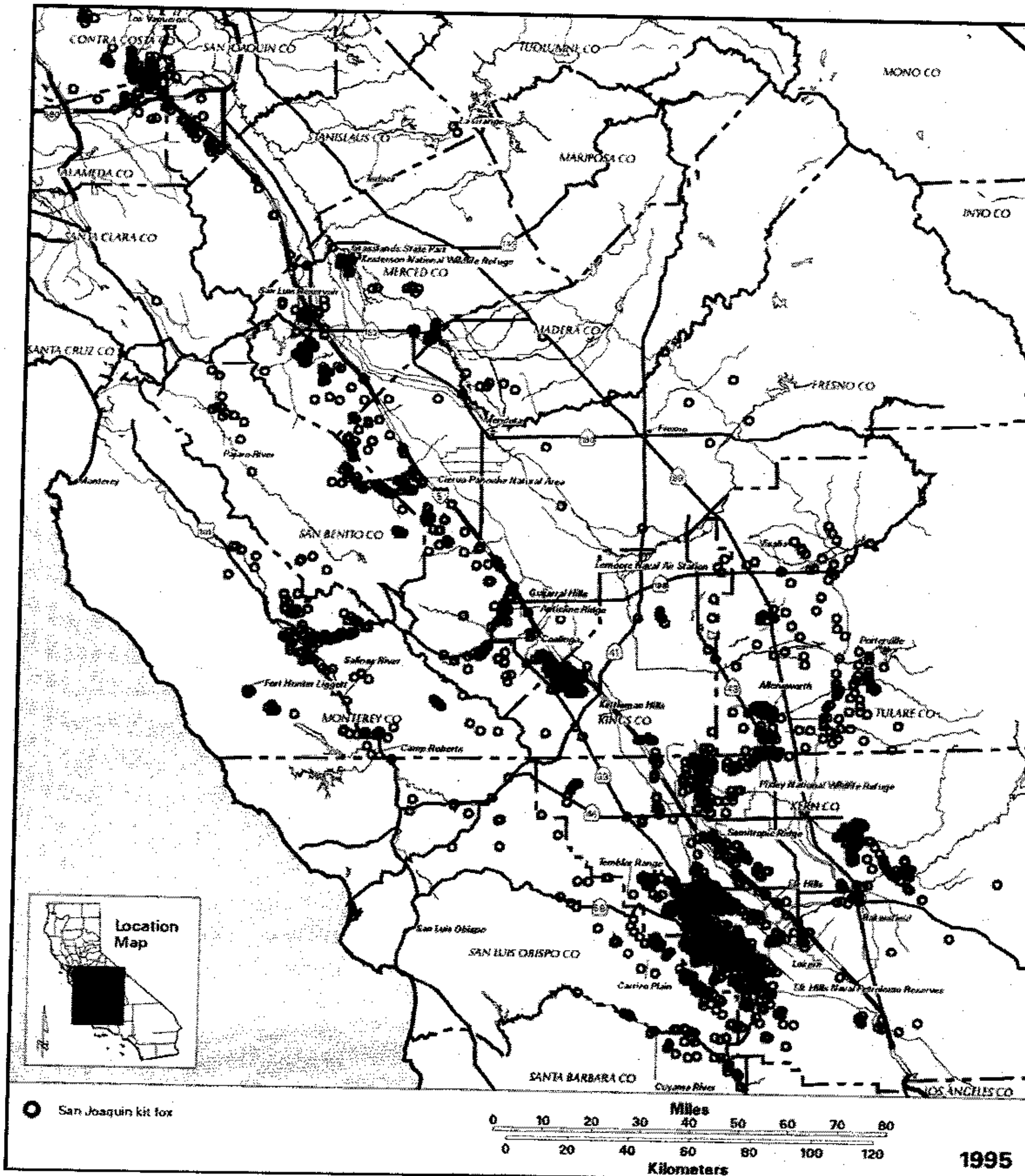

Figure 1. San Joaquin kit fox distributional records (Williams *et al.* 1998).

(NIWQP 1998), it seems likely that in portions of the Project area that are supplied with good quality water, selenium concentrations in prey pose no threat to the San Joaquin kit fox.

The San Luis Unit includes some localities that have (or are expected to have, as a consequence of application of federal water) elevated concentrations of selenium in soil and surface water or near-surface groundwater. Such localities include open ditches that convey subsurface drainwater, retired or fallowed seleniferous farm land, and drainwater reuse projects. Open drainwater conveyances are probably best represented by evaporation ponds of Kesterson Reservoir in the early 1980s.

The history of Kesterson Reservoir in the 1980s provides the best available information on potential exposure of the San Joaquin kit fox to contaminants due to the proposed action. Paveglio and Clifton (1988) sighted San Joaquin kit fox 39 times in 108 night surveys in the Kesterson Reservoir area between September 1986 and August 1988. They trapped and radio-tagged two kit fox within one mile of Kesterson Reservoir. They found that kit fox frequently used the San Luis Drain road, which formed the eastern boundary of Kesterson Reservoir. The California vole was the most important component of the diet of kit foxes in the Kesterson area (Paveglio and Clifton 1988). Clark (1987, 1989) collected small mammals, including California voles at Kesterson Reservoir in 1984. He found selenium concentrations of 13 and 33 µg/g (mean 23.0 µg/g) in California voles collected at Pond 2 of Kesterson Reservoir. The average selenium concentration in all California voles collected at all ponds of the reservoir (n=5) was 10.4 µg/g. The average selenium concentrations in prey items of kit fox collected at Kesterson Reservoir while the ponds were operational was as follows:

Species	Number Collected	Mean Selenium Concentration (µg/g whole body dry wt.)
House mouse	5	18.5
Western harvest mouse	5	12.5
Ornate shrew	4	47.9
California vole	5	10.4

Seleniferous uplands that usually lack ponded water are best represented by data from Kesterson after it was closed and low-lying areas were filled (CH2MHILL 1999). This data is as follows:

Species	Number Collected	Mean Selenium Concentration (µg/g whole body dry wt.)
House mouse	31	7.9
Western harvest mouse	17	7.7
Ornate shrew	1	7.5
Deer mouse	30	6.7
California vole	7	4.4

Because the mean concentrations of all San Joaquin kit fox prey items analyzed are about the level of the domestic dog LOAEC (7.2 µg/g, from above), it is likely that in any locations where San Joaquin kit fox range over upland portions of the Project area that may be contaminated with selenium (e.g. reuse areas), these foxes are potentially at risk from dietary intake of selenium. The average selenium concentration of each of the kit fox prey items sampled at Kesterson

Reservoir evaporation ponds was well above the dog LOAEC. Therefore, it is possible that selenium contamination in the small-mammal diet of kit foxes in the vicinity of Project evaporation ponds or solar evaporators may put San Joaquin kit foxes at risk.

If reuse areas and evaporation basins are fenced to exclude kit fox, or if other measures are taken to exclude kit fox from the project areas, recovery of remnant populations of kit fox may be impacted by loss of existing or potential habitat.

Kangaroo rats (*Dipodomys sp.*)
including:
Giant kangaroo rat (*Dipodomys ingens*)
Fresno kangaroo rat (*Dipodomys nitratoides exilis*)
Tipton kangaroo rat (*Dipodomys nitratoides nitratoides*)

Status: Three kangaroo rats in the vicinity of the San Luis Unit have been federally listed as endangered throughout their respective ranges: the Fresno kangaroo rat since 1985 (50 FR 4222-4226), the giant kangaroo rat since 1987 (52 FR 283-288), and the Tipton kangaroo rat since 1988 (53 FR 25608-25611). All three species are endemic to the San Joaquin Valley and found only in the vicinity of the San Luis Unit. The ranges of the giant and Tipton kangaroo rats extend farther south to the west side of the Tulare Basin (**Figure 2**).

Life history summary: All three species of kangaroo rat are primarily seed eaters, but also eat insects as well as green plants. All three species are found in annual grassland and saltbush scrub in alkaline soils (Williams *et al.* 1998).

Risk of selenium exposure: We are not aware of any selenium toxicity studies with kangaroo rats. Sublethal liver changes have been found in laboratory rats (*Rattus norvegicus*) following lifetime exposure to natural selenium in the diet at a concentration of 1.4 µg/g (dry weight) and reduced longevity was found at 3 µg/g in the lifetime diet (Eisler 1985). Olson (1986) also reported reproductive selenosis in rats that consumed wheat with a concentration of 3 µg/g. Halverson *et al.* (1966) found a dietary selenium threshold of about 4.8 µg/g for growth retardation in rats.

All three species of kangaroo rat were probably displaced from historic scrub and grassland habitat that was converted into irrigated crop land in the San Luis Unit with the application of federal water. All three species are not likely to be impacted by selenium in high quality irrigation water delivered to primary fields because (1) such crop land habitat is not favored by kangaroo rats, and (2) this applied water generally has relatively low concentrations of selenium. However, in retired seleniferous land, along drainwater conveyances, near evaporation ponds, and especially in drainwater re-use areas, habitat that is attractive but toxic to kangaroo rats may occur, and individuals may attempt to recolonize the habitat.

Observers performing wildlife surveys at the Atwell Island Land Retirement Program pilot site found a population of the endangered Tipton's Kangaroo Rat (USBR, 2007). The mean selenium concentration in 20 species of plants collected from Atwell Island varied from less than

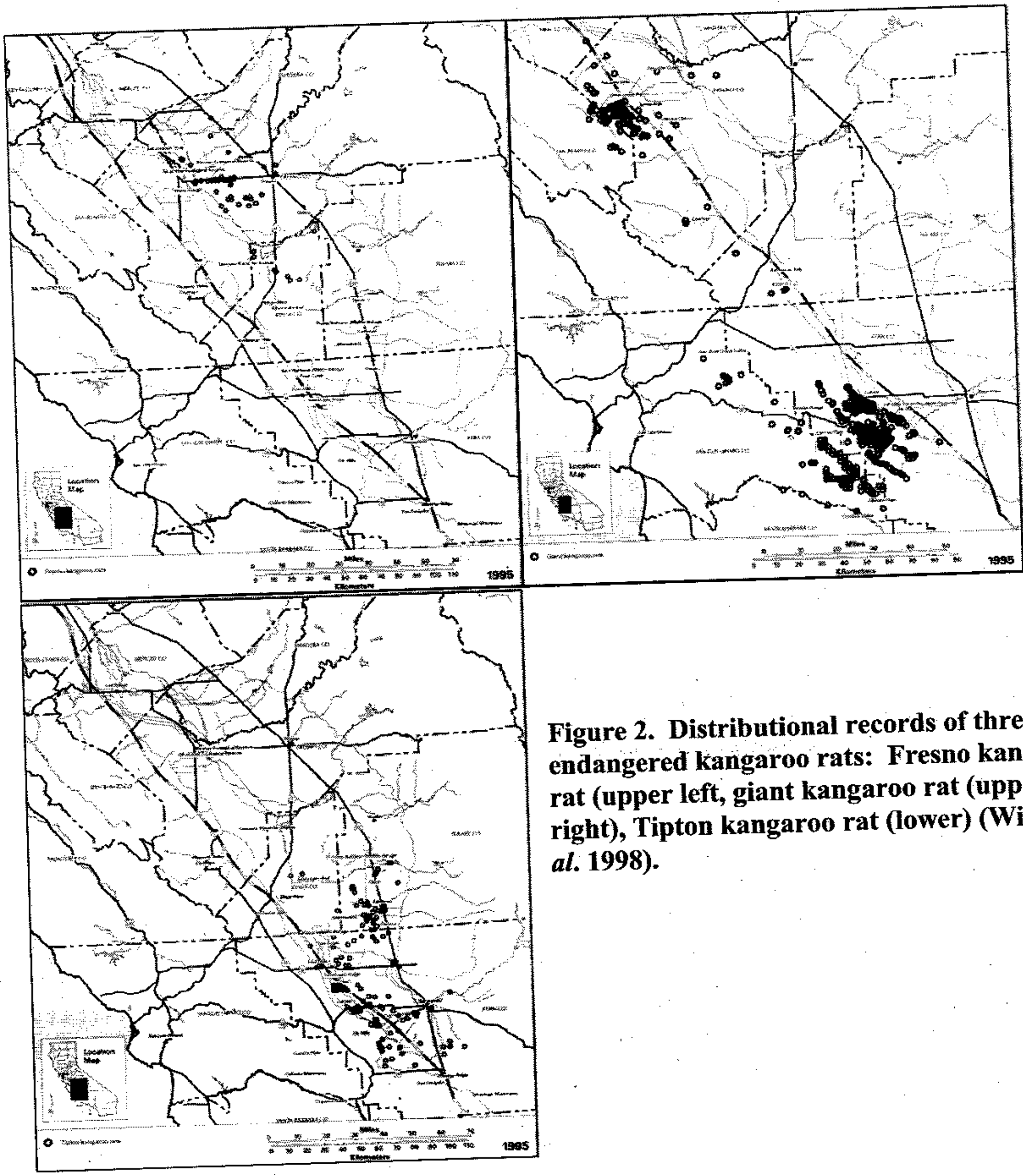

Figure 2. Distributional records of three endangered kangaroo rats: Fresno kangaroo rat (upper left, giant kangaroo rat (upper right), Tipton kangaroo rat (lower) (Williams *et al.* 1998).

0.17 to 0.5 mg/kg and none of the samples were above the 2 mg/kg threshold recommended for the project by the Service (USBR, 2005). There were no discernable differences in the selenium concentration between plant parts (whole, vegetation, fruits) at the Atwell Island site.

Agroforestry projects operated in the western San Joaquin Valley since the 1980's serve as pilot projects for the more extensive drainwater reuse areas that are likely to be established in the San Luis Unit to enable sustained irrigated agriculture there. Monitoring of agroforestry projects by the California Department of Fish and Game indicates that in reuse areas, selenium concentrations in dietary items of kangaroo rats are likely to exceed thresholds for adverse effects (Figure 3 and Figure 4).

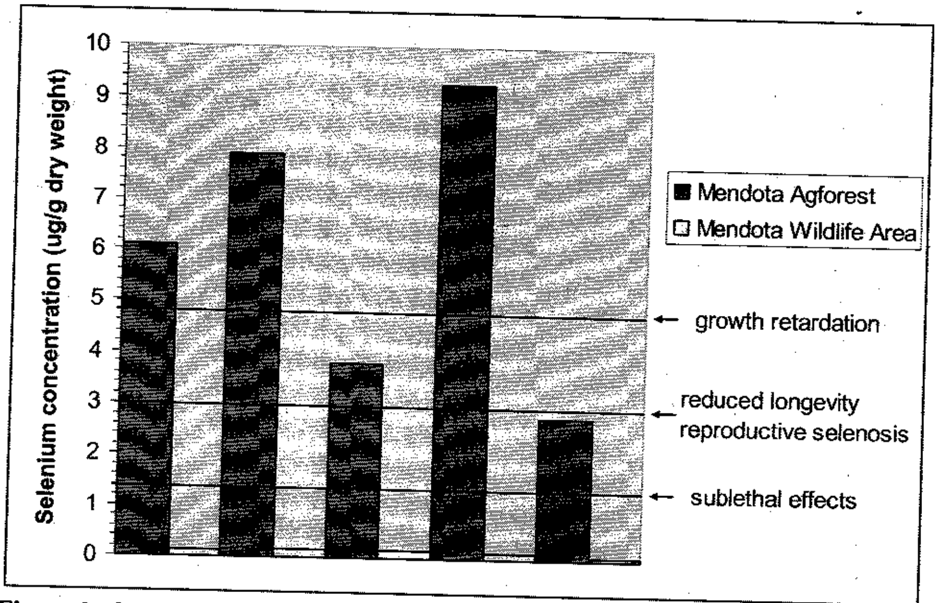

Figure 3. Selenium in rabbitfoot grass (*Polypogon monspeliensis*) collected in the Mendota agroforestry area and the Mendota Wildlife Area in May 1997 (Dunne pers. com.). Effect thresholds for rats (*Rattus norvegicus*) are from Eisler 1985, Olsen 1986, and Halverson *et al.* 1966 (See text).

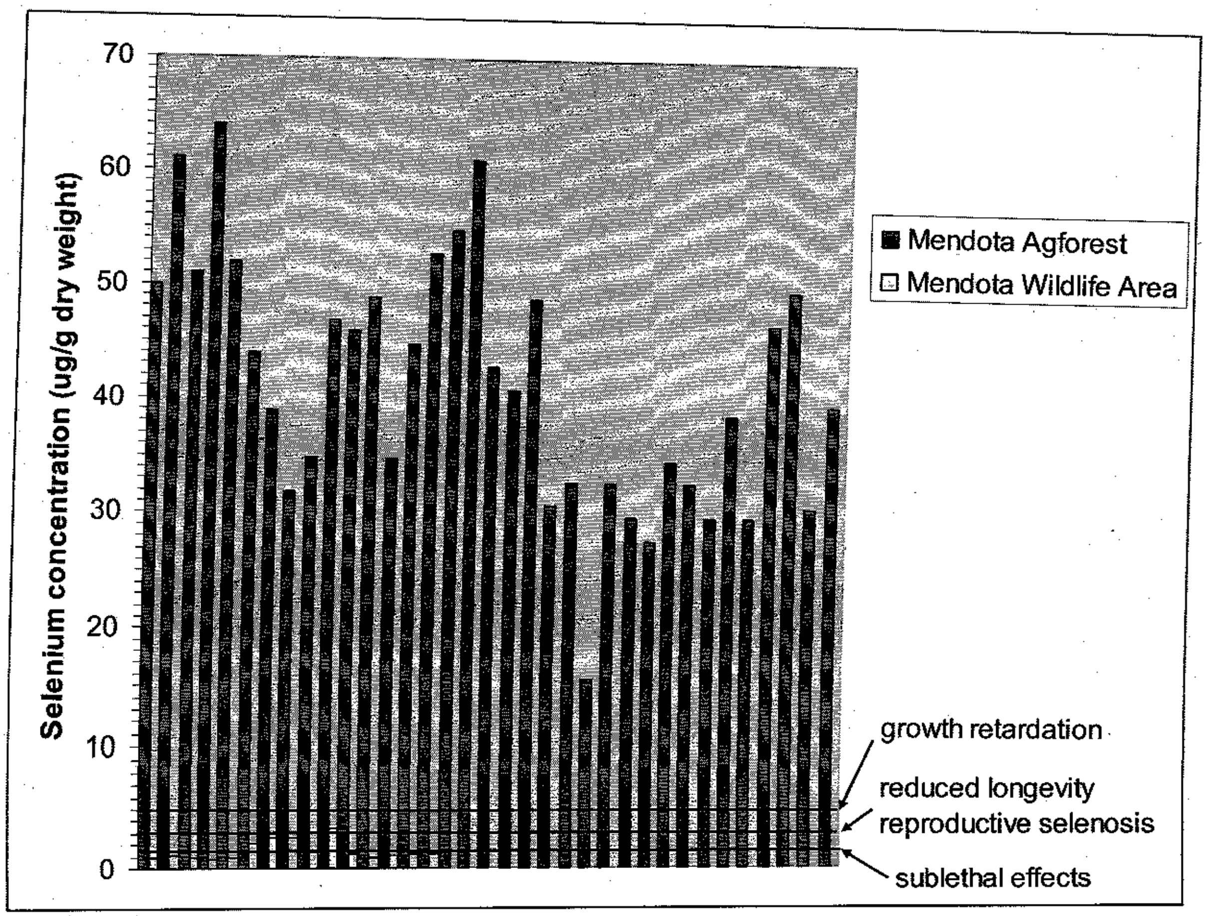

Figure 4. Selenium in sowbugs collected in the Mendota agroforestry area and the Mendota Wildlife Area in 1997 and 1998 (Dunne pers. com.) Effect thresholds for rats (*Rattus norvegicus*) are from Eisler 1985, Olsen 1986, and Halverson *et al.* 1966 (See text).

Giant garter snake (*Thamnophis gigas*)

Status: The giant garter snake was listed as threatened in 1993 (58 FR 54053-54066). It is endemic to the wetlands of the Central Valley from Butte County in the north to Kern County in the south (USFWS 1999). A 5 year review completed in September 2006 recommended no change in the listing status for the snake (USFWS 2006a). Most populations of giant garter snakes are found in the Sacramento Valley while small isolated populations are found in northern San Joaquin Valley (primarily Merced County and western Fresno County).

Life history summary: Fish and amphibians (tadpoles and adults) are the primary food items of giant garter snakes (58 FR 54053-54066). Giant garter snakes prefer marshes, sloughs, ponds, small lakes, and low gradient streams. Currently agricultural wetlands such as irrigation and drainage canals and rice fields provide key habitat for the snake (USFWS 1999). These wetland habitats must include sufficient water through the summer; emergent vegetation for escape cover; grassy banks and openings for basking; and higher elevation uplands for cover and refuge from flood waters (USFWS 1999, 58 FR 54053-54066).

Risk of selenium exposure: Very little research has been done on the toxicity of selenium to reptiles (Hopkins 2000); no such studies have been done on giant garter snakes or on any other species of garter snake (Campbell and Campbell, 2001). Hopkins *et al.* (2002) found that in another species of aquatic snake, the banded water snake (*Nerodia fasciata*), bioaccumulation of dietary selenium was most notable (greatly exceeding toxicity thresholds that have been established for other vertebrates) compared to other elevated trace elements at a site contaminated with coal ash. At the same selenium-contaminated site, Roe et al. (2004) found clutch viability to be reduced in alligators (*Alligator mississippiensis*; viability 30-54%, egg selenium 2.1-7.8 μg/g dry weight) compared to a reference site (viability 67-74%, egg selenium 1.4-2.3 μg/g). Average selenium concentrations in common prey items of alligators (fish and frogs) in the contaminated site ranged from 10 to 27 μg/g (dry weight), with an average concentration of 14.3 μg/g in mosquitofish (*Gambusia affinis*). Average concentrations in the same prey items from the reference site ranged from 1.12 to 3.43 μg/g, with an average concentration of 1.82 μg/g in mosquitofish (Hopkins *et al.* 1999). Other contaminant in prey species varied between the sites, so the role of selenium in reduced clutch viability is not unequivocal.

These data suggest that dietary selenium concentrations of 10 to 27 μg/g may have a negative impact on reptiles that are dependent on an aquatic food chain. It should be noted that interpretation of these field data is confounded by the co-occurrence of other contaminants that could also affect egg viability. However, in such coal ash-contaminated sites, as in subsurface drainwater-contaminated sites, selenium has been implicated as the chief cause of toxicity to wildlife. If, as is most likely, selenium is the principal cause of reduced clutch viability, then the corresponding selenium concentration in prey items must be treated as a dietary LOAEC for a single effect on a single species of aquatic reptile. The actual toxicity threshold for alligators is an unknown amount below this LOAEC value (10 μg/g). Further, any extrapolation of alligator toxicity data to giant garter snakes must include an uncertainty factor to account for the risk that giant garter snakes may be more sensitive than alligators. This accords with findings by a study of dietary selenium effects on the brown house snake (*Lamprophis fulginosus*), a common terrestrial snake found in southern Africa. Female snakes exposed to a diet containing 10 μg/g seleno-D,L-methionine produced about half as many eggs as control females exposed to 1 μg/g (Hopkins *et al.* 2004). Also, the dietary selenium toxicity threshold for the avian descendants of reptiles is about 3 to 7 μg/g (dry weight; Wilber 1980, Martin 1988, Heinz 1996). Therefore, given the above data, an appropriate dietary selenium toxicity threshold for the giant garter snake is probably well below 10 μg/g.

Historical exposure: Open ditches in the Northerly Area of the San Luis Unit have in the past carried subsurface drainwater with elevated concentrations of selenium. Green sunfish (*Lepomis cyanellus*) in this drainwater have been found to have concentrations of selenium ranging from 12 to 23 μg/g (geometric mean: 17.3 μg/g) (Saiki 1998), within the range of concentrations associated with adverse effects on predatory aquatic reptiles (see above). Since 1996, subsurface drainwater has been discharged, via the Grassland Bypass Project, into lower Mud Slough North, where selenium concentrations in small fish, such as mosquitofish, inland silversides (*Menidia beryllina*), red shiners (*Cyprinella lutrensis*), and fathead minnows (*Pimephales promelas*), frequently reach 10-15 μg/g (Beckon *et al.* 2003). Most of the remaining water supply channels such as Salt Slough now have fish selenium levels that are below concern thresholds (Beckon *et al.* 2003).

Potential Project-related exposure: Dietary uptake is the principle route of toxic exposure to selenium in wildlife, including giant garter snakes. Giant garter snakes feed primarily on aquatic prey such as fish and amphibians (Miller and Hornaday 1999). The extent to which they may take aquatic invertebrates is unknown.

Open drainwater ditches may constitute risks of exposure of giant garter snakes to selenium in the aquatic food chain. In addition, these conveyances could provide routes of dispersal of giant garter snakes from existing habitat to evaporation ponds. The drainwater conveyances and ponds of Kesterson Reservoir in the early 1980s serve as the best available prototype for estimation of the effects on giant garter snakes of selenium contamination associated with water deliveries to the San Luis Unit. Mosquitofish were the only fish species that survived in the ponds of Kesterson Reservoir after September 1983 (Saiki 1986). Concentrations of selenium ranged up to 366 μg/g in samples of mosquitofish collected from the San Luis Drain and up to 293 μg/g in the ponds of Kesterson Reservoir in May and August, 1983; aquatic insects collected in these localities had selenium concentrations of up to 326 and 295 μg/g respectively (Saiki 1986). These concentrations are far above dietary selenium concentrations associated with adverse effects in aquatic reptiles (see above).

Gopher snakes (*Pituophis melanoleucus*) collected at Kesterson Reservoir in April-June 1984 and April-July 1985 had liver selenium concentrations ranging from 8.2 to 19 μg/g (dry weight; geometric mean 10.9; Ohlendorf *et al.* 1988). Such a range of liver concentrations corresponds to a selenium concentration range of about 7 to 20 μg/g in eggs in the brown house snake (*Lamprophis fuliginosus*) (Hopkins *et al.* 2005), the closest relative of the giant garter snake for which data are available linking liver and egg concentrations. Therefore the eggs of gopher snakes at Kesterson Reservoir were probably within or above the range (2.1-7.8 μg/g) associated with adverse effects in reptiles (see above). Gopher snakes have a more terrestrial diet than giant garter snakes, but the gopher snake data provide an additional indication that reptiles in an agricultural drainwater evaporation pond environment may be at risk.

Isolation of evaporation ponds from existing giant garter snake habitat may reduce the likelihood that the ponds could serve as attractive population sinks. Such isolation may be accomplished by positioning of drainwater treatment facilities in locations remote from existing habitat and by conveyance of Project drainwater exclusively through closed pipes rather than open ditches. However, it is not known how far giant garter snakes may disperse overland to new aquatic habitats.

Blunt-nosed leopard lizard (*Gambelia sila*)

Status: The Blunt-nosed leopard lizard was federally listed as endangered in 1967 (32 FR 4001). It is endemic to the San Joaquin Valley, and several remaining populations are found in the vicinity of the San Luis Unit (Figure 5).

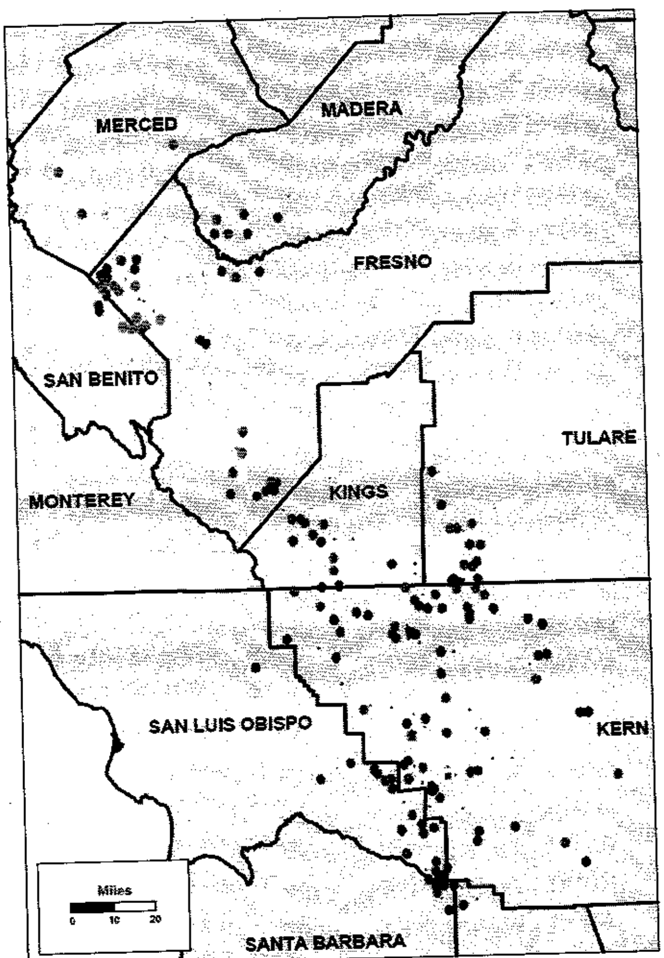

Figure 5. Currently occupied habitat of the blunt-nosed leopard lizard (http://www.cdpr.ca.gov/docs/es/espdfs/bnllall.pdf)

General life history: Blunt-nosed leopard lizards are most commonly found in open vegetated habitats dominated by non-native grasses or by low, alkali-tolerant shrubs of the family Chenopodiaceae, such as iodine bush, and seepweeds, which grow on saline and alkaline soils (Williams *et al.* 1998).

Risk of selenium exposure: Very little is known of the toxicity of selenium to reptiles (see giant garter snake discussion above); even less is known of the effects of selenium on lizards in particular. The effects of selenium on birds are better known, and birds are closely related to reptiles (Hedges 1994; Hedges and Poling 1999). Like birds, most other reptiles are oviparous (egg-laying); therefore, it is likely that in reptiles the maternal transfer of selenium to eggs is critical to the expression of selenium toxicity because the most selenium-sensitive life stage is the development of the embryo in the egg. Some of the mechanisms of maternal transfer of selenium to eggs in lizards are somewhat different from the mechanisms in birds (Unrine *et al.* 2006), but these mechanisms could be at least as efficient in moving selenium from the mother to her eggs. Roe *et al.* (2004) documented maternal transfer of selenium in alligators. Eggs from the contaminated sites had selenium concentrations ranging from 2.1 to 7.8 μg/g and lower viability (30-54 %) compared to reference sites (eggs, 1.4 to 2.3 μg/g: viability, 67 to 74 %). Alligator prey items at the contaminated sites ranged from 10 to 37 μg/g (Roe *et al.* 2004). Female western fence lizards bioaccumulated selenium in their gonads to a level (14.1 μg/g dry weight) that is toxic to bird reproduction after being fed crickets (15 μg/g Se dry weight) that had been fed on commercial feed spiked with seleno-D,L-methione (30 μg/g dry weight) (Hopkins *et al.* 2005). Therefore, lizards foraging in seleniferous habitats must be regarded as potentially at risk to selenium toxicity.

Blunt-nosed leopard lizards are likely to be exposed to selenium by feeding on insects in the vicinity of agricultural drainwater conveyances, evaporation ponds, retired seleniferous land, and re-use areas. At land retirement pilot project lands mean selenium concentrations in crickets ranged from 0.13 to 0.81 mg/kg; in beetles from 0.14 to 1.35 mg/kg; in spiders from 0.25 to 2.24 mg/kg; and in isopods 0.13 to 3.47 mg/kg (USBR 2005). These concentrations are generally within the range for terrestrial invertebrates found in non-seleniferous soils in the western United States (2.5 mg/kg, USDI 1998) although isopods at the Tranquillity site exceeded this range in most years. The selenium levels in all invertebrate groups collected from the land retirement sites are approximately an order of magnitude less than corresponding invertebrate groups collected between 1988 and 1992 in upland habitat at the closed Kesterson Reservoir (USBR 2005). The selenium exposure in invertebrates seen at the closed Kesterson Reservoir may be the best comparison data for drainwater reuse areas. Reuse areas used to grow salt-tolerant grasses and other salt-tolerant forage crops may provide habitat that is attractive to blunt-nosed leopard lizards but so enriched in selenium that it presents a risk of adverse effects.

Bald eagle (*Haliaeetus leucocephalus*)

Status: The bald eagle was federally listed as endangered on February 14, 1978 (43 FR 6233) in all of the conterminous United States except Minnesota, Wisconsin, Michigan, Oregon, and Washington, where it was classified as threatened. On August 15, 1995 (60 FR 36010), the bald eagle was down-listed to threatened throughout its range. On July 9, 2007 the Service, removed the bald eagle in the lower 48 States of the United States from the Federal List of Endangered and Threatened Wildlife (72 FR 37346). The bald eagle remains protected under the Bald and Golden Eagle Protection Act (BGEPA) and the Migratory Bird Treaty Act (MBTA) and a new permitting process will authorize limited take under BGEPA.

General life history: Breeds in coastal and aquatic habitat with forested shorelines or cliffs in North America, including the Pacific Northwest as far south as the northern Sierra Nevada Mountains in California. Wintering areas include coastal estuaries and river systems of northern California (Buehler 2000).

Risk of selenium exposure: Wintering bald eagles have been observed on occasion in the Project area and vicinity (USBR 1991). In addition, bald eagles forage for fish along waterways and the estuary downstream of the Project.

Lillebo *et al.* (1988) derived levels of selenium to protect various species of waterbirds. Based on an analysis of bioaccumulation dynamics and an estimated critical dietary threshold for toxicity of 3 μg/g, they concluded that piscivorous birds would be at substantially greater risk of toxic exposure than mallards (*Anas platyrhynchos*). The calculated water criterion to protect piscivorous birds was 1.4 μg/L as opposed to 6.5 μg/L for mallards. It should also be noted that the 6.5 μg/L calculated criterion for mallards exceeds the actual threshold point for ducks in the wild which is somewhere below 4 μg/L (Skorupa 1998). Thus, the 1.4 μg/L calculated criterion for piscivorous birds may be biased high compared to the wild as well.

Applying an energetics modeling approach, modified from the Wisconsin Department of Natural Resources, Peterson and Nebeker (1992) calculated a chronic criterion specifically for bald eagles. Peterson and Nebeker's estimate of a protective criterion is 1.9 μg/L. Peterson and Nebeker calculated a mallard criterion (2.1 μg/L) that was much closer to their bald eagle criterion than Lillebo *et al.*'s (1988) results would suggest. Peterson and Nebeker's mallard criterion is consistent with real-world data (cf. Skorupa 1998) and therefore their bald eagle criterion may also be reliable.

Even after considerable dilution, waters receiving agricultural drainwater from the west side of the San Joaquin Valley frequently exceed 1.4 μg/L selenium; however, bald eagle dietary exposure to fish from these waters is expected to be low.

California clapper rail (*Rallus longirostris obsoletus*)

Status: The California clapper rail was federally listed as endangered on October 13, 1970 (35 FR 16047-16048).

General life history: The California clapper rail inhabits salt marshes surrounding the San Francisco Bay, California. Principal habitats are low portions of coastal wetlands dominated by cordgrass and pickleweed (USFWS 1984). Nesting habitat in San Francisco Bay is characterized by tidal sloughs, abundant invertebrate populations, pickleweed, gum plant, and wrack in upper zone. Individuals do not migrate far from the breeding grounds (Eddleman and Conway 1998).

Risk of selenium exposure: California clapper rails feed largely on benthic invertebrates, including filter-feeding mussels and clams (Moffitt 1941), a well-documented pathway for bioaccumulation of selenium (Pease *et al.* 1992, Stewart *et al.* 2004). Lonzarich *et al.* (1992) reported that eggs of California clapper rails collected from the north bay in 1987 contained up to 7.4 µg/g selenium. Water data from this time and location are not available. The *in ovo* threshold for selenium exposure that causes toxic effects on embryos of California clapper rails is unknown. For another benthic-foraging marsh bird, the black-necked stilt, the *in ovo* threshold for embryotoxicity is 6 µg/g selenium (Skorupa 1998). The most widely-used biphasic model (Brain and Cousens 1989) applied to Heinz *et al.* (1989) data from laboratory experiments with mallard reproduction indicates that in mallards, a selenium concentration of 7.4 µg/g (dry weight) in the eggs would be associated with a 32 percent reduction in hatchability of the eggs (Figure 6).

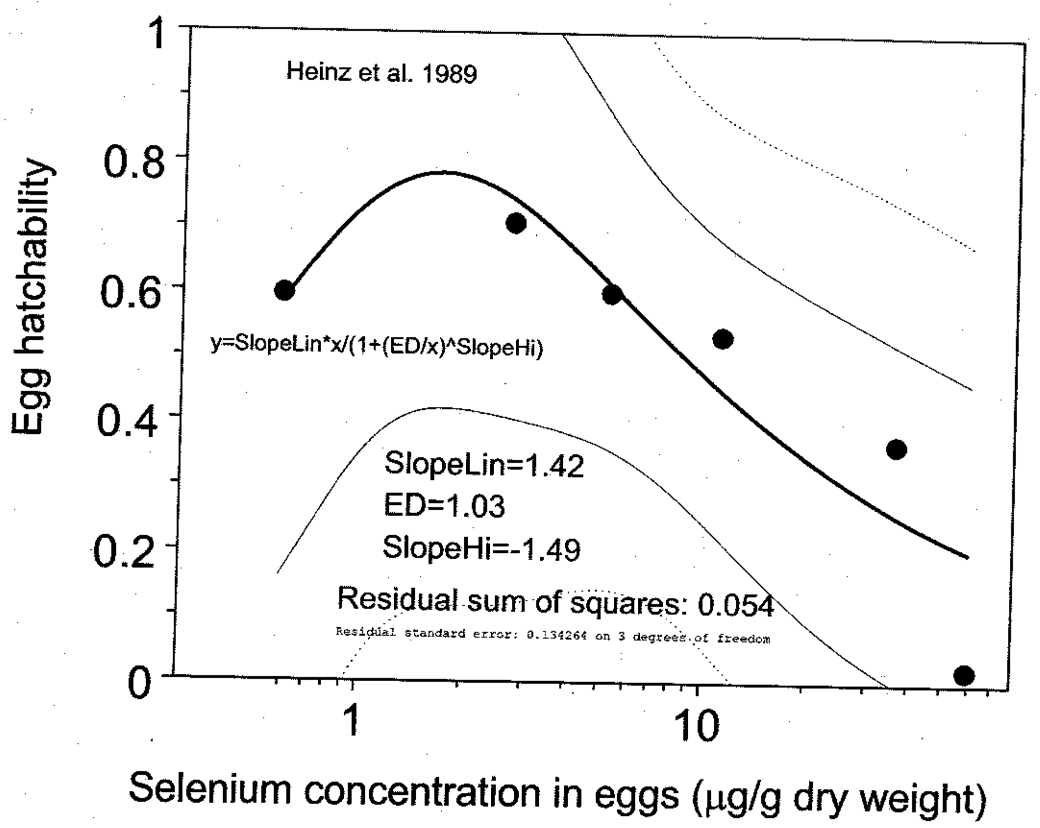

Figure 6. The hatching success of mallard eggs as a function of selenium concentration in the eggs, with the Brain-Cousens biphasic model fitted by least squares regression. Confidence intervals of 95% and 99% are shown.

It has been demonstrated for mallard ducks that interactive effects of selenium and mercury can be super-toxic with regard to embryotoxic effects (Heinz and Hoffman 1998). Lonzarich *et al.* (1992) also reported potentially embryotoxic concentrations of mercury in eggs of California clapper rails. Abnormally high numbers of nonviable eggs, 13.7-22.9 percent (Schwarzbach 1994) and 31 percent (Schwarzbach *et al.* 2006), have also been reported for the California clapper rail.

Based, in part, on the data for California clapper rails, staff technical reports prepared for the San Francisco Bay Regional Water Quality Control Board recommend decreasing current selenium loading to the estuary by 50 percent or more (Taylor *et al.* 1992, Taylor *et al.* 1993). The California clapper rail is particularly vulnerable to any locally elevated effluent concentrations of selenium as the rail generally occupies small home ranges of only a few acres. As selenium loads to the San Joaquin River and hence to the estuary are reduced over time due to implementation of selenium total maximum daily load limits and the Grassland Bypass Project, potential impacts to clapper rails due to delivery of water to the San Luis Unit will diminish.

California least tern (*Sterna antillarum browni*)

Status: The California least tern has been federally listed as endangered throughout its range since 1970 (35 FR 8491-8498, 35 FR 16047-16048). Distributed along the Pacific coast from the San Francisco Bay to Baja California, it is widely separated from the four other subspecies of least tern (Thompson *et al.* 1997). A 5-year review was completed in 2006 which recommended down listing the species to threatened (USFWS 2006b).

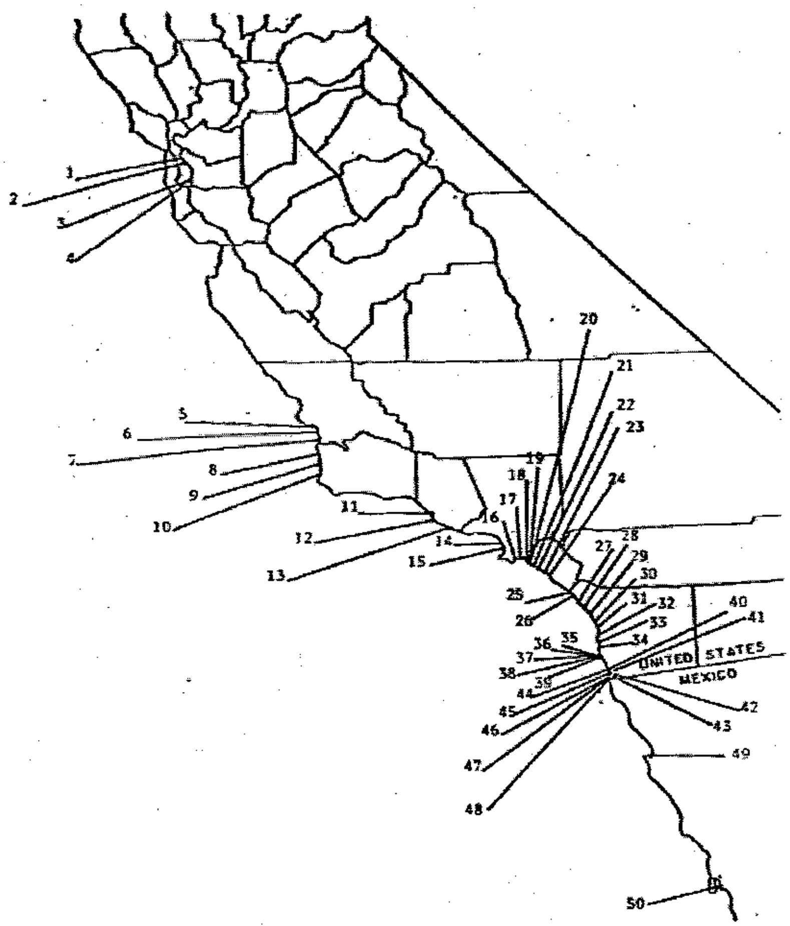

Figure 7. Nesting sites of the California least tern recorded since 1970 (USFWS 1985).

Life history summary: California least terns are migratory, wintering along the southern coast of Mexico (Thompson *et al.* 1997). The primary nesting site in San Francisco Bay is located at the former Alameda Naval Air Station. Least terns primarily eat small fish species that are less than 8 cm in length and small young-of-year fish of larger species. Fish species include northern anchovy (*Engraulis mordax*), top smelt (*Atherinops affinis*), and yellowfin goby (*Acanthogobius flavimanus*). Up to 50 species of fish have been documented in their diet (USFWS 1985).

Risk of selenium exposure: Currently, breeding colonies of California least tern are confined to scattered, isolated locations on beaches along the coast of California and in the San Francisco estuary, where they feed on surface fish in adjacent waters. In these locations any agricultural drainwater from the San Luis Unit is well diluted. Therefore, the current risk of selenium to this bird is probably *de minimis*. However, it is possible that the creation of evaporation ponds for disposal of agricultural drainwater from the San Luis Unit could provide habitat attractive to California least terns. Least terns in North Carolina and the Caribbean are known to eat invertebrates, including shrimp (review in Thompson *et al.* 1997). Although unlikely, California least terns could learn to feed opportunistically on abundant brine shrimp and other invertebrates in evaporation ponds. Concentrations of selenium in evaporation pond invertebrates are likely to be sufficiently elevated to cause reproductive impacts in least terns. Forster's tern eggs from San Joaquin Valley nests at evaporation ponds had an average of 7.1 µg/g dw of selenium (n=10, range 2.6 to 12 µg/g) while Caspian tern eggs averaged 2.4 µg/g (n=7, range 1.9 to 3.3 µg/g) (USFWS unpublished data). Methods of configuring evaporation ponds to discourage shorebird usage (deepening and steepening sides) will be ineffective in deterring foraging by least terns.

Chinook Salmon (*Oncorhynchus tshawytscha*)

Status: The National Marine Fisheries Service (NMFS) has identified 17 Evolutionarily Significant Units (ESUs) of Chinook salmon from Washington, Oregon, Idaho, and California (Myers *et al.* 1998; 63 FR 11482). Three of these use the San Francisco Estuary: the Sacramento River winter-run ESU, the Central Valley spring-run ESU, and the Central Valley fall/late fall-run ESU. The Sacramento River winter-run ESU was listed as endangered on January 4, 1994 (59 FR 440). On September 16, 1999, NMFS listed the Central Valley spring-run ESU as threatened (64 FR 50394). In the same rulemaking, NMFS also determined that the Central Valley fall/late fall ESU is not warranted for listing at that time; however, with recent record declines of salmon fall runs in California listing of this ESU may occur in the future.

Life history summary: Chinook salmon are anadromous and semelparous. That is, as adults they migrate from a marine environment into the fresh water streams and rivers of their birth (anadromous) where they spawn only once and die (semelparous). Juvenile Chinook may spend from 3 months to 2 years in freshwater after emergence before migrating to estuarine areas as smolts, and then into the ocean to feed and mature. The timing and duration of the migratory movements of Chinook salmon are important in assessing their exposure to selenium and estimating consequent risks. Natal streams and estuary rearing habitat vary seasonally in selenium concentration and the salmon evidently vary in sensitivity to selenium across stages in their life histories. A more detailed life history discussion is provided for salmon in order to more clearly define the selenium exposure risks to the various ESUs and to identify the ones at greatest risk to selenium exposure resulting from irrigation deliveries to the San Luis Unit.

Freshwater migration: Once their downstream migration begins, Chinook salmon fry may stop migrating and take up residence in the stream for a period of two weeks to a year or more (Healey 1991).

Use of estuarine habitat: On their migration downstream, many Chinook salmon fry take up residence in the river estuary where they rear to smolt size (about 70 mm fork length) before resuming their migration to the ocean. The proportion of fry that rear in the estuary is not known. On Vancouver Island, BC, about 30 percent of the estimated downstream migrants could be accounted for in the estuary; the fate of the remaining 70 percent is unknown, but they probably suffered mortality due to unknown agents (Healey 1991). The maximum residence time of Chinook salmon fry in the Sacramento-San Joaquin River delta was estimated to be 64 days in 1980 and 52 days in 1981 (Kjelson *et al.* 1981)

Life history types: Chinook salmon exhibit two generalized freshwater life history types (Healey 1983, Healey 1991). "Stream-type" Chinook salmon, enter freshwater months before spawning and reside in freshwater for a year or more following emergence, whereas "ocean-type" Chinook salmon spawn soon after entering freshwater and migrate to the ocean as fry or parr within their first year. Spring-run Chinook salmon exhibit a stream-type life history. Adults enter freshwater in the spring, hold over summer, spawn in fall, and the juveniles typically spend a year or more in freshwater before emigrating. Winter-run Chinook salmon are somewhat anomalous in that they have characteristics of both stream- and ocean-type races (Healey 1991). Adults enter freshwater in winter or early spring, and delay spawning until spring or early summer (stream-type). However, juvenile winter-run Chinook salmon migrate to sea after only four to seven months of river life (ocean-type). Adequate instream flows and cool water temperatures are more critical for the survival of Chinook salmon exhibiting a stream-type life history due to over summering by adults and/or juveniles. The stream-type life history also increases selenium exposure risks during the critical egg development stage of the adult and the growth stage of juveniles.

Runs: Salmon runs (separate ESUs) are designated on the basis of adult migration timing; however, distinct runs also differ in the degree of maturation at the time of river entry, thermal regime and flow characteristics of their spawning site, and the actual time of spawning (Myers *et al.* 1998). Both spring-run and winter-run Chinook salmon tend to enter freshwater as immature fish, migrate far upriver, and delay spawning for weeks or months. For comparison, fall-run Chinook salmon enter freshwater at an advanced stage of maturity, move rapidly to their spawning areas on the mainstem or lower tributaries of the rivers, and spawn within a few days or weeks of freshwater entry (Healey 1991).

Run-specific downstream migration: Winter-run Chinook salmon fry begin to emerge from the gravel in late June to early July and continue through October (Fisher 1994). Spring-run Chinook salmon fry emerge from the gravel from November to March and spend about 3 to 15 months in freshwater habitats prior to emigrating to the ocean (Kjelson *et al.* 1981). Post-emergent fry disperse to the margins of their natal stream, seeking out shallow waters with slower currents, finer sediments, and bank cover such as overhanging and submerged vegetation, root wads, and fallen woody debris, and begin feeding on small insects and crustaceans.

When juvenile Chinook salmon reach a length of 50 to 57 mm, they move into deeper water with higher current velocities, but still seek shelter and velocity refugia to minimize energy expenditures. In the mainstems of larger rivers, juveniles tend to migrate along the margins and avoid the elevated water velocities found in the thalweg of the channel. When the channel of the river is greater than 9 to 10 feet in depth, juvenile salmon tend to inhabit the surface waters (Healey 1982). Emigration of juvenile winter-run Chinook salmon past Red Bluff Diversion Dam (RBDD) on the Sacramento River may begin as early as mid-July, typically peaks in September, and can continue through March in dry years (Vogel and Marine 1991; NMFS 1997). From 1995 to 1999, all winter-run Chinook salmon outmigrating as fry passed RBDD by October, and all outmigrating pre-smolts and smolts passed RBDD by March (Martin *et al.* 2001). The emigration timing of Central Valley spring-run Chinook salmon is highly variable (CDFG 1998). Some fish may begin emigrating soon after emergence from the gravel, whereas others over summer and emigrate as yearlings with the onset of intense fall storms (CDFG 1998). The emigration period for spring-run Chinook salmon extends from November to early May, with up to 69 percent of the young-of-the-year fish outmigrating through the lower Sacramento River and Delta during this period (CDFG 1998).

As Chinook salmon fry and fingerlings mature, they prefer to rear further downstream where ambient salinity is up to 1.5 to 2.5 parts per thousand (Healey 1980, 1982; Levings *et al.* 1986). Juvenile winter-run Chinook salmon occur in the Delta from October through early May based on data collected from trawls, beach seines, and salvage records at the Central Valley Project (CVP) and State Water Project (SWP) pumping facilities (CDFG 1998). The peak of listed juvenile salmon arrivals in the Delta generally occurs from January to April, but may extend into June. Upon arrival in the Delta, winter-run Chinook salmon spend the first two months rearing in the more upstream, freshwater portions of the Delta (Kjelson *et al.* 1981, Kjelson *et al.* 1982). Data from the CVP and SWP salvage records indicate that most spring-run Chinook salmon smolts are present in the Delta from mid-March through mid-May depending on flow conditions (CDFG 2000).

Winter-run Chinook salmon fry remain in the estuary (Delta/Bay) until they reach a fork length of about 118 mm (*i.e.*, 5 to 10 months of age) and then begin emigrating to the ocean perhaps as early as November and continuing through May (Fisher 1994; Myers *et al.* 1998). Little is known about estuarine residence time of spring-run Chinook salmon. Juvenile Chinook salmon were found to spend about 40 days migrating through the Delta to the mouth of San Francisco Bay and grew little in length or weight until they reached the Gulf of the Farallones (MacFarlane and Norton 2002). Based on the mainly ocean-type life history observed (*i.e.*, fall-run Chinook salmon) MacFarlane and Norton (2002) concluded that unlike other salmonid populations in the Pacific Northwest, Central Valley Chinook salmon show little estuarine dependence and may benefit from expedited ocean entry. Spring-run yearlings are larger in size than fall-run yearlings and are ready to smolt upon entering the Delta; therefore, they are believed to spend little time rearing in the Delta.

Risk of selenium exposure: Due to water diversions and consequent loss of breeding and migrating habitat, California Central Valley Chinook salmon have been effectively extirpated from the San Joaquin River above the confluence of the Merced River. Planning is underway to restore salmon to this river by increasing flows and restoring habitat. However, seepage and flood flows carrying agricultural drainwater from the San Luis Unit into the San Joaquin River may impact salmon and could impair efforts to restore them to this river.

California Central Valley Chinook salmon evidently are among the most sensitive of fish and wildlife to selenium. They are especially vulnerable during juvenile life stages when they migrate and rear in selenium-contaminated Central Valley rivers and the San Francisco Bay/Delta estuary.

In a laboratory experiment, measurements were made of the selenium bioaccumulation, weight and survival of juvenile (initially swim-up larvae) San Joaquin River fall run Chinook salmon that were exposed for 90 days in fresh water to two parallel graded series of dietary selenium treatments (Hamilton *et al.* 1990). In one series, the food was spiked with seleno-DL-methionine (SeMet); in the other series, the source of selenium was mosquitofish collected from the San Luis Drain (SLD), which carried seleniferous agricultural drainwater from a subsurface tile drainage system in the Westlands Water District in the San Joaquin Valley of California. Although the SLD mosquitofish diets may have included other contaminants, such as pesticides, the results of this experiment indicate that, once selenium is incorporated into fish tissue, there is no difference in the tissue concentration-response relationship due to the different sources of selenium (SLD or SeMet). Therefore, all data from both diet series were combined in the analysis presented here.

The effects of selenium on animals (including fish) are well known to be biphasic (beneficial at low doses; toxic at high doses; see, for example, Beckon *et al.* 2008), and in the Hamilton *et al.* (1990) experiment, the 90-day survival data appear to confirm a biphasic dose-response relationship with respect to the survival endpoint (Figure 8). Therefore, we fitted a biphasic model (Brain and Cousens 1989) to the data by least squares regression. This regression provides a weight-of-evidence estimate of the maximum survival rate (0.7, or 70 percent) of young salmon under these experimental conditions at the estimated optimal selenium concentration in the fish (about 1 µg/g whole body dry weight). It also provides an estimate of the survival rate at any given selenium concentration above the optimum. Any such survival rate estimate can be compared to the maximum survival rate to yield an estimate of the mortality (inverse of survival) specifically attributable to selenium. For example, at a fish tissue concentration of 7.9 µg/g (whole body dry weight) the regression curve predicts a survival of 0.29 (29 percent). As a proportion of the maximum survival this is 0.29/0.7 = 0.41, or 41 percent. Therefore our best weight-of-evidence estimate of the mortality due to selenium toxicity at a tissue concentration of 7.9 µg/g is the inverse of 0.41, which is 0.59, or 59 percent. Similarly, the model predicts that fish with a selenium concentration of 2.45 µg/g (whole body dry weight) after 90 days of exposure would experience 20 percent mortality due to selenium (Figure 8 lower graph).

In the Hamilton *et al.* (1990) experiment, the concentrations of selenium in the food that was provided to the salmon were about the same as the concentrations reached by the salmon themselves. This experiment indicates that, in sloughs that carry agricultural drainwater, concentrations of selenium in invertebrates, small (prey) fish, and larger predatory fish

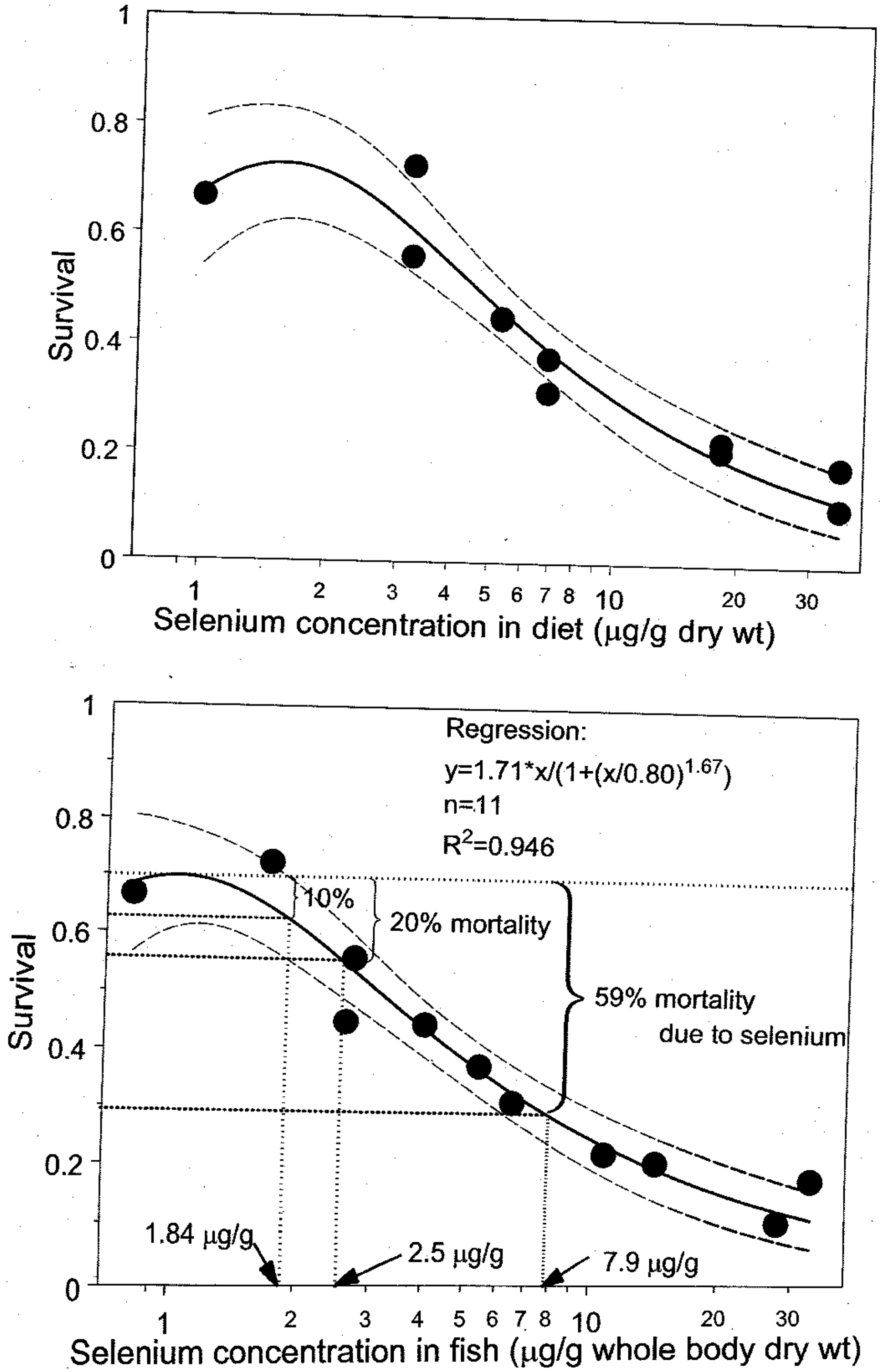

Figure 8. Survival as a function of selenium concentration in diet (above) and tissue (below) of juvenile Chinook salmon after 90 days of exposure to dietary selenium. A biphasic model (Brain and Cousens 1989) was fitted by least squares regression. Dashed lines indicate 95% confidence bands around the regressions.

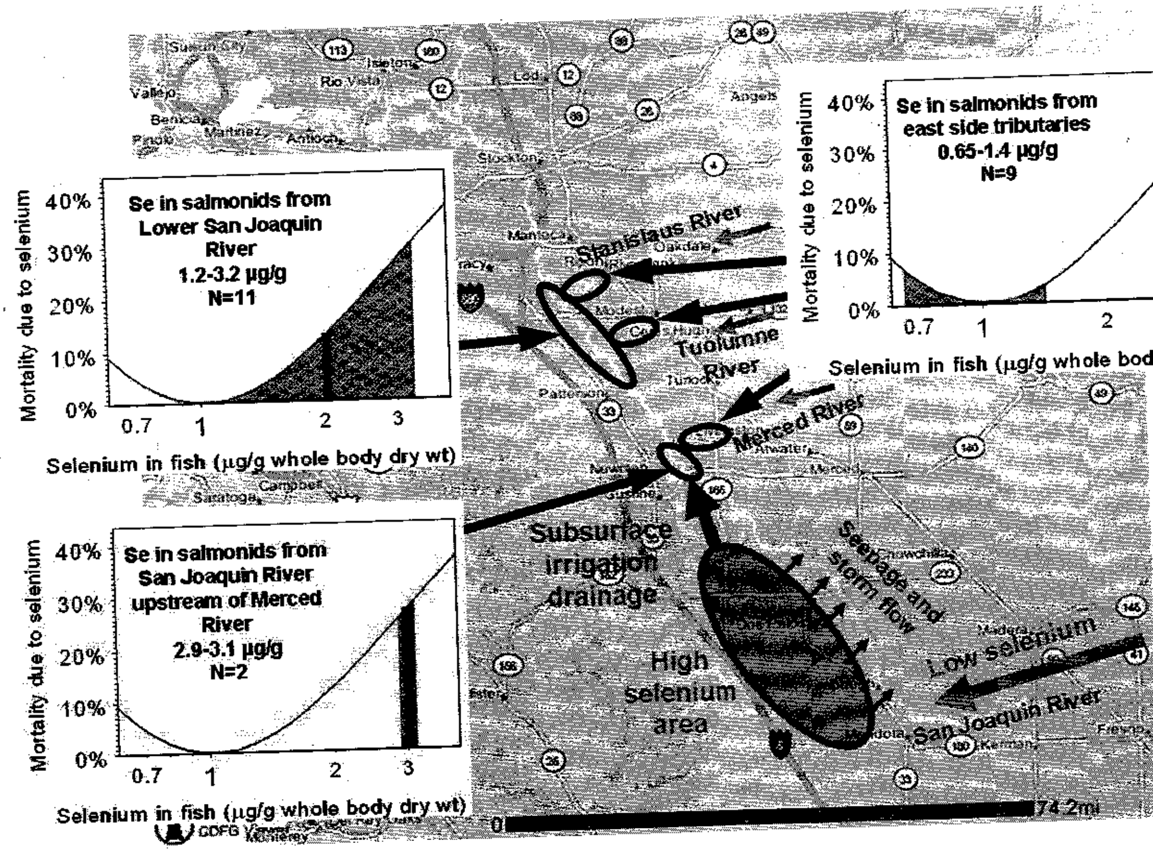

Figure 9. Risk of mortality to juvenile Chinook salmon based on selenium measured in the salmon (Saiki, *et al.* 1991) and the toxicity data shown in Figure 8 (presented here as mortality). Solid red bars represent the geometric mean selenium concentration in sampled fish at each location or cluster of locations. The stippled red areas span the ranges of concentrations in fish at the respective locations.

commonly reach levels (Beckon *et al.* 2003) that could kill a substantial portion of young salmon (Figure 8 upper graph) if the salmon, on their downstream migration, are exposed to those selenium-laden food items for long enough for the salmon themselves to bioaccumulate selenium to toxic levels.

Available data (Saiki *et al.* 1991) confirm that young salmon migrating down the San Joaquin River in 1987 bioaccumulated selenium to levels (about 3 µg/g whole body dry wt.) that were likely to kill more than 25% **(Figure 9)**.

Concentrations of selenium in the San Joaquin River have been reduced since juvenile Chinook salmon were sampled in 1987 (Saiki *et al.* 1991). However, the relationship between selenium in water and in young salmon in 1987 (Figure 10) indicates that there remains a substantial ongoing risk to migrating juvenile Chinook salmon in the San Joaquin River (Figure 11).

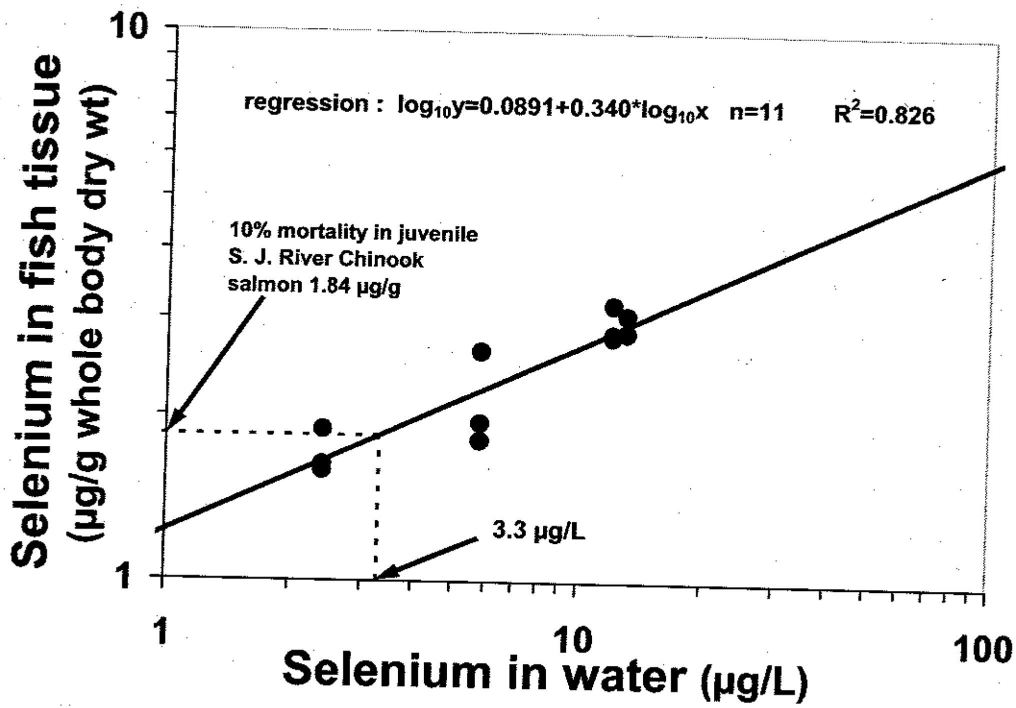

Figure 10. Relationship between selenium in juvenile Chinook salmon (Saiki *et al.* 1991, Saiki pers. com.) and water (Central Valley Regional Water Quality Control Board "Flat File") in the San Joaquin River and its tributaries.

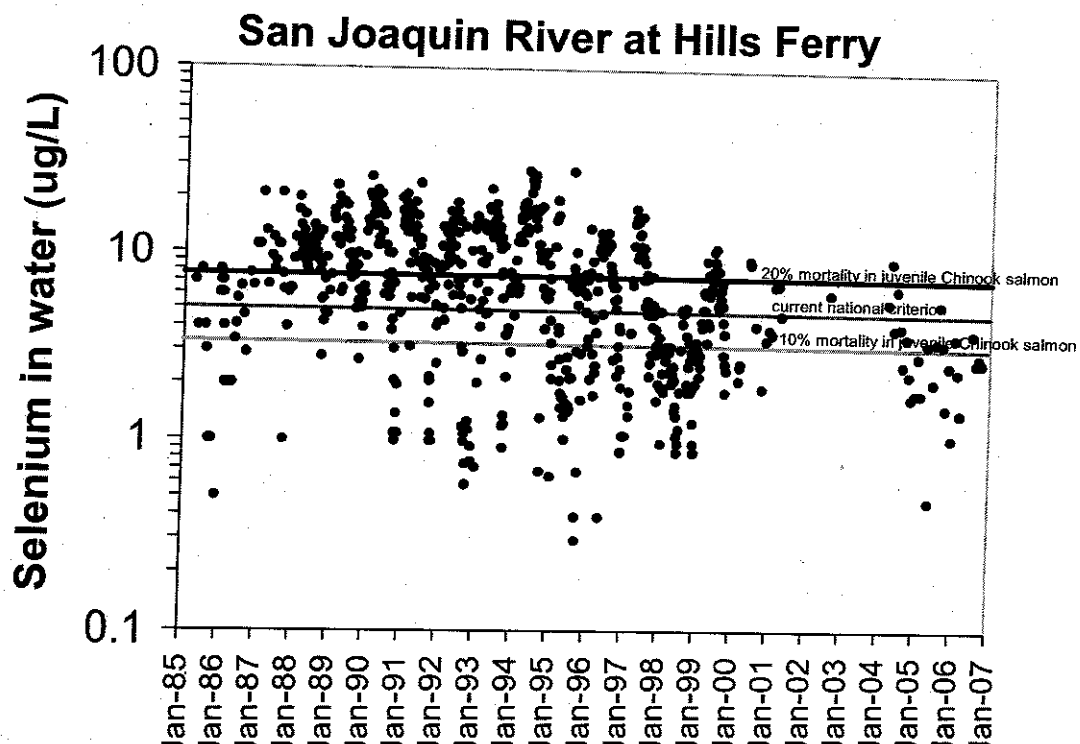

Figure 11. Selenium concentrations measured in the San Joaquin River at Hills Ferry, just upstream of the confluence of the Merced River. The data are from the Central Valley Regional Water Quality Control Board.

Steelhead Trout (*Oncorhynchus mykiss*)

Status: Steelhead trout are the anadromous form of the rainbow trout species. Central Valley steelhead were listed as threatened under the ESA on March 19, 1998 (63 FR 13347). This ESU consists of steelhead populations in the Sacramento and San Joaquin River (inclusive of and downstream of the Merced River) basins in California's Central Valley.

The breeding of wild steelhead in the Central Valley is mostly confined to the Sacramento River and its tributaries, including Antelope, Deer, and Mill Creeks and the Yuba River. Populations may exist in Big Chico and Butte Creeks and a few wild steelhead are produced in the American and Feather Rivers (McEwan and Jackson 1996).

Steelhead were thought to be extirpated from the San Joaquin River system. Monitoring has detected small self sustaining populations of steelhead in the Stanislaus, Mokelumne, Calaveras, and other streams previously thought to be devoid of steelhead (McEwan 2001).

General Life History: Steelhead can be divided into two life history types, stream-maturing and ocean-maturing, based on their state of sexual maturity at the time of river entry and the duration of their spawning migration. Stream-maturing steelhead enter freshwater in a sexually immature condition and require several months to mature and spawn, whereas ocean-maturing steelhead enter freshwater with well-developed gonads and spawn shortly after river entry. These two life history types are more commonly referred to by their season of freshwater entry (*i.e.* summer [stream-maturing] and winter [ocean-maturing] steelhead). Only winter steelhead currently are found in the rivers and streams of Central Valley and San Francisco Bay area (McEwan and Jackson 1996).

Winter steelhead generally leave the ocean from August through April, and spawn between December and May (Busby *et al.* 1996). Timing of upstream migration is correlated with higher flow events and associated lower water temperatures. In general, the preferred water temperature for adult steelhead migration is 46 °F to 52 °F (McEwan and Jackson 1996; Myrick 1998; and Myrick and Cech 2000).

Unlike Pacific salmon, steelhead are iteroparous, or capable of spawning more than once before death (Busby *et al.* 1996). However, it is rare for steelhead to spawn more than twice before dying; most that do so are females (Nickleson *et al.* 1992; Busby *et al.* 1996). Iteroparity is more common among southern steelhead populations than northern populations (Busby *et al.* 1996). Although one-time spawners are the great majority, Shapovalov and Taft (1954) reported that repeat spawners are relatively numerous (17.2 percent) in California streams. Most steelhead spawning takes place from late December through April, with peaks from January though March (Hallock *et al.* 1961). Steelhead spawn in cool, clear streams featuring suitable gravel size, depth, and current velocity, and may spawn in intermittent streams as well (Everest 1973; Barnhart 1986).

The length of the incubation period for steelhead eggs is dependent on water temperature, dissolved oxygen concentration, and substrate composition. In late spring and following yolk sac absorption, fry emerge from the gravel and actively begin feeding in shallow water along stream banks (Nickelson *et al.* 1992).

Steelhead rearing during the summer takes place primarily in higher velocity areas in pools, although young-of-the-year also are abundant in glides and riffles. Winter rearing occurs more uniformly at lower densities across a wide range of fast and slow habitat types. Productive steelhead habitat is characterized by complexity, primarily in the form of large and small woody debris. Cover is an important habitat component for juvenile steelhead both as velocity refugia and as a means of avoiding predation (Shirvell 1990; Meehan and Bjornn 1991). Some older juveniles move downstream to rear in large tributaries and mainstem rivers (Nickelson *et al.* 1992). Juveniles feed on a wide variety of aquatic and terrestrial insects (Chapman and Bjornn 1969), and older juveniles sometimes prey upon emerging fry.

Steelhead generally spend two years in freshwater before emigrating downstream (Hallock *et al.* 1961; Hallock 1989). Rearing steelhead juveniles prefer water temperatures of 45° F to 58° F and have an upper lethal limit of 75° F. They can survive up to 81° F with saturated dissolved oxygen conditions and a plentiful food supply.

Juvenile steelhead emigrate episodically from natal streams during fall, winter, and spring high flows. Emigrating Central Valley steelhead use the lower reaches of the Sacramento River and the Delta for rearing and as a migration corridor to the ocean. Some may utilize tidal marsh areas, non-tidal freshwater marshes, and other shallow water areas in the Delta as rearing areas for short periods prior to their final emigration to the sea. Barnhart (1986) reported that steelhead smolts in California range in size from 140 to 210 mm (fork length). Hallock *et al.* (1961) found that juvenile steelhead in the Sacramento River Basin migrate downstream during most months of the year, but the peak period of emigration occurred in the spring, with a much smaller peak in the fall.

Risk of selenium exposure: Planning is underway to restore salmon to the San Joaquin River by increasing flows and restoring habitat. Such restoration efforts would likely improve the small steelhead population in the San Joaquin Valley. However, as with salmon, seepage and flood flows carrying agricultural drainwater from the San Luis Unit into the San Joaquin River may impact steelhead and may confound efforts to restore them to this river.

Because steelhead are regarded as a life-history variant or "form" of the rainbow trout species, studies of the non-anadromous form of rainbow trout may provide a good indication of the risks of the exposure of steelhead to selenium. Such studies indicate that rainbow trout are among the more sensitive of fish to selenium. One of these studies examined the effects of selenium on fry of rainbow and brook trout exposed in streams in Alberta, Canada (Holm 2002, Holm *et al.* 2003). In summary, this study indicates that maternal selenium would result in 20 percent mortality of fry if female rainbow trout have a tissue selenium concentration of 2.93 µg/g wholebody dry weight (Figure 12). The USEPA (2004) has proposed that a fish tissue chronic criterion of 7.9 µg/g selenium (wholebody) would be protective. However, female rainbow trout in the wild with a concentration of about 8 µg/g selenium in their (wholebody) tissue would produce eggs that suffer 44.2 percent mortality by swimup stage (Figure 12). Among the swimup survivors, 96 percent would suffer edema (Figure 13) and 42 percent would have craniofacial deformities (Figure 14) (for details, see USFWS 2005).

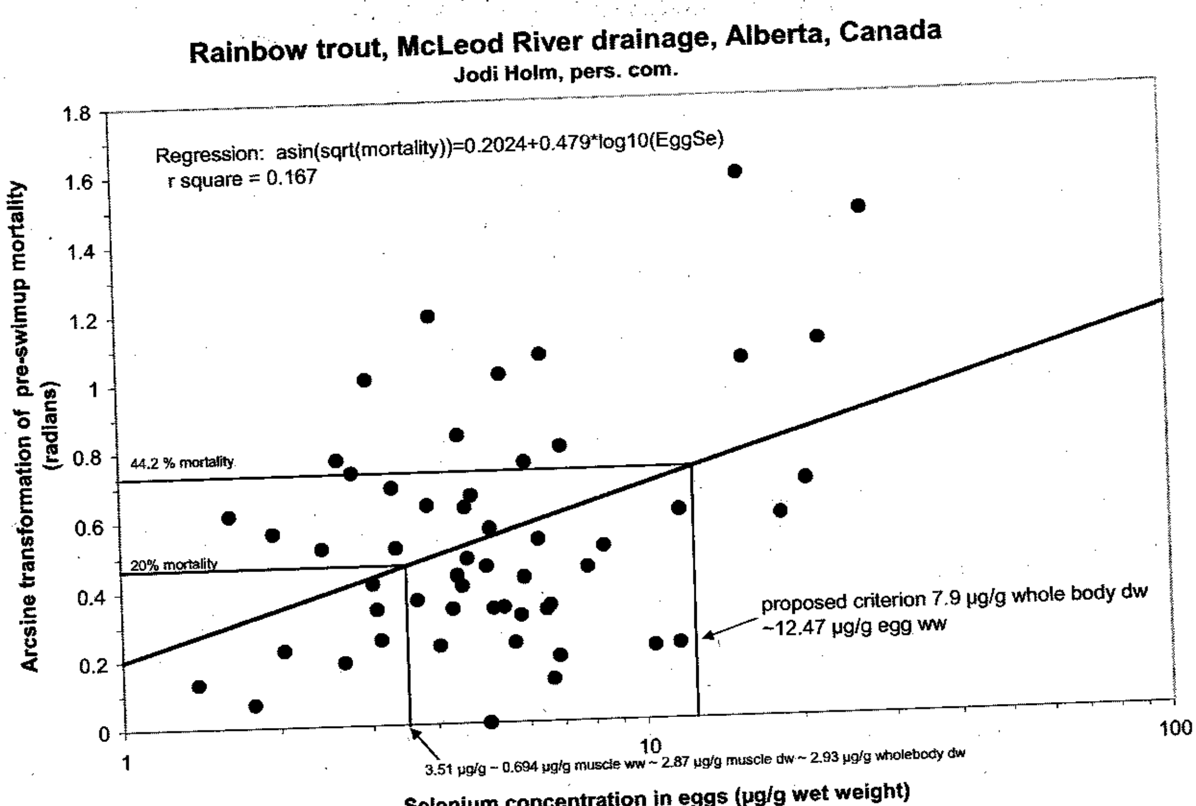

Figure 12. Relationship between selenium in rainbow trout eggs and mortality of eggs and fry by swimup stage. The arcsine transformation is applied to mortality data, as appropriate for linear regressions with percents or proportions (Sokol and Rohlf 1981). Data are from the years 2000-2002.

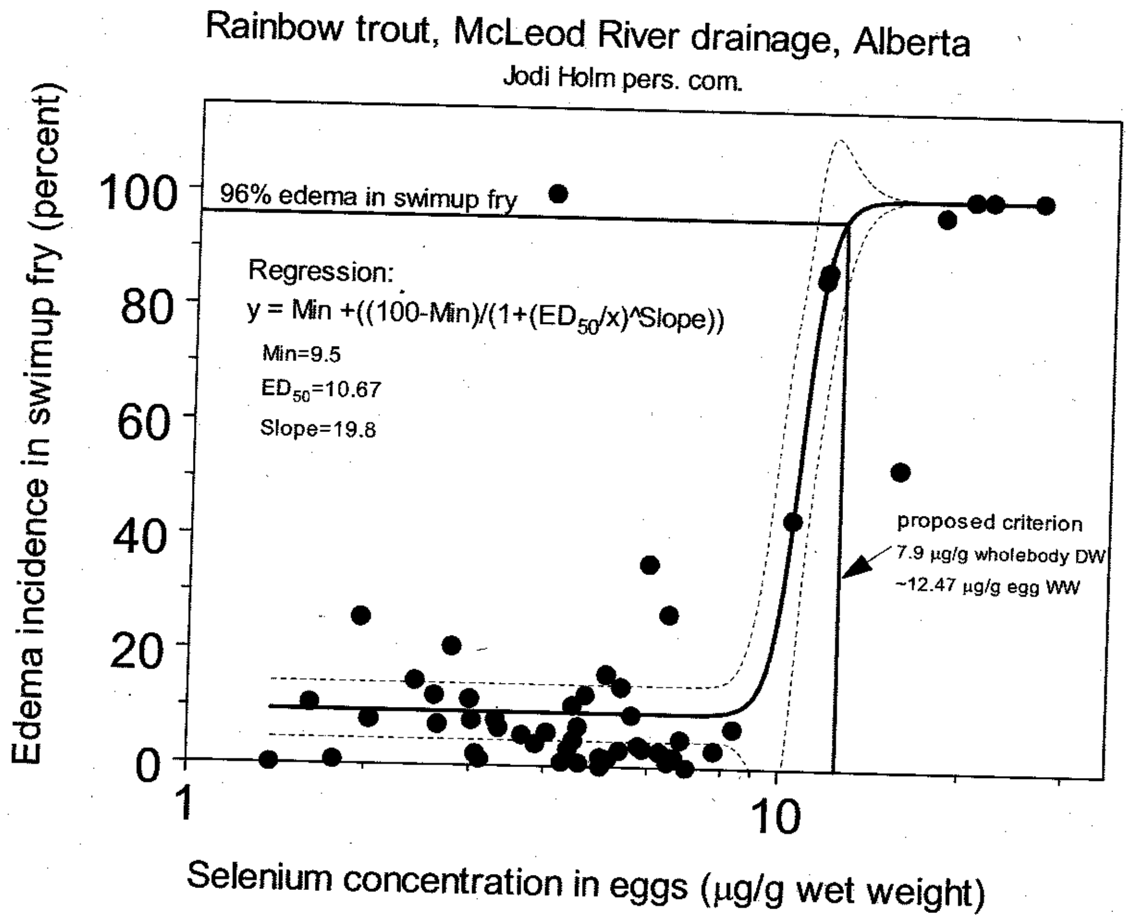

Figure 13. Relationship between selenium in rainbow trout eggs and edema in surviving swimup fry. Data from the years 2000-2002.

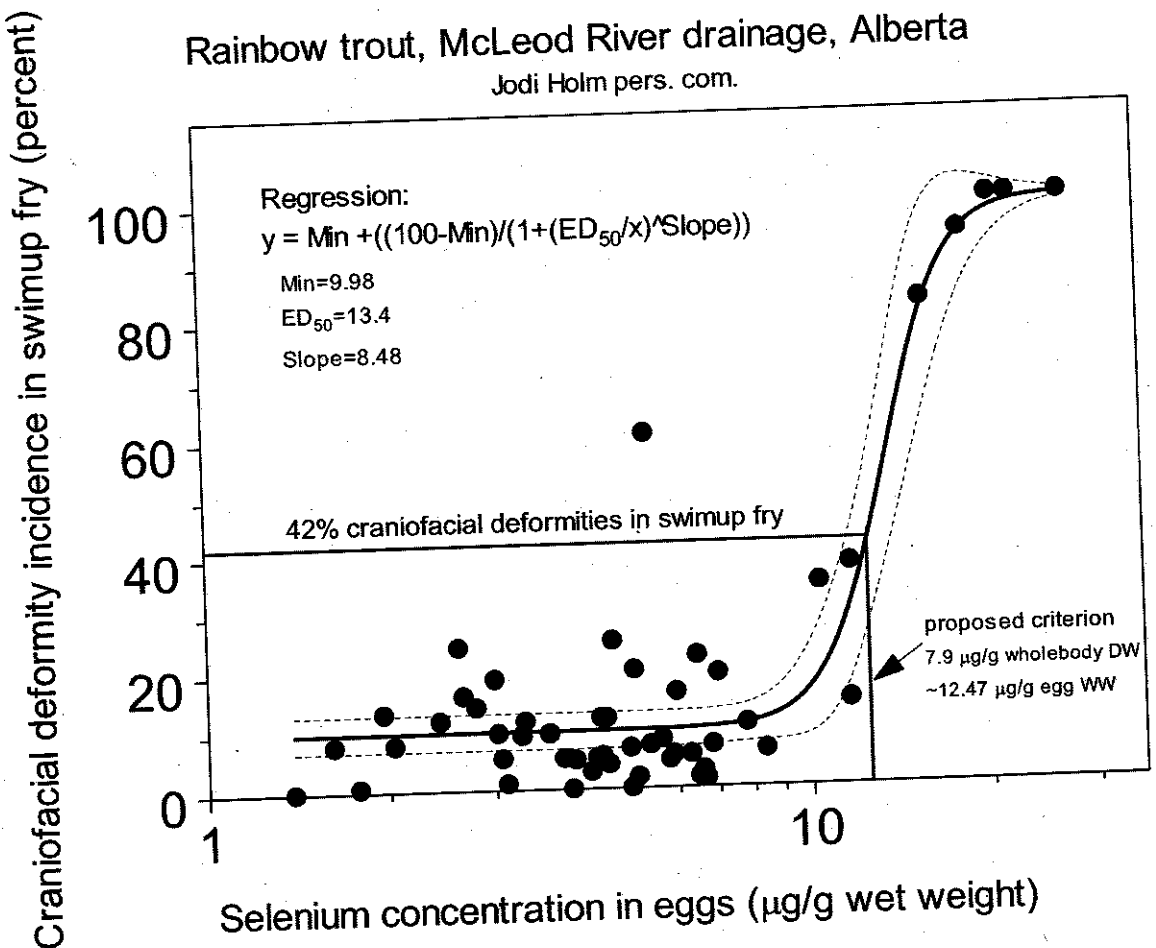

Figure 14. Relationship between selenium in rainbow trout eggs and craniofacial deformities in surviving swimup fry. Data from the years 2000-2002.

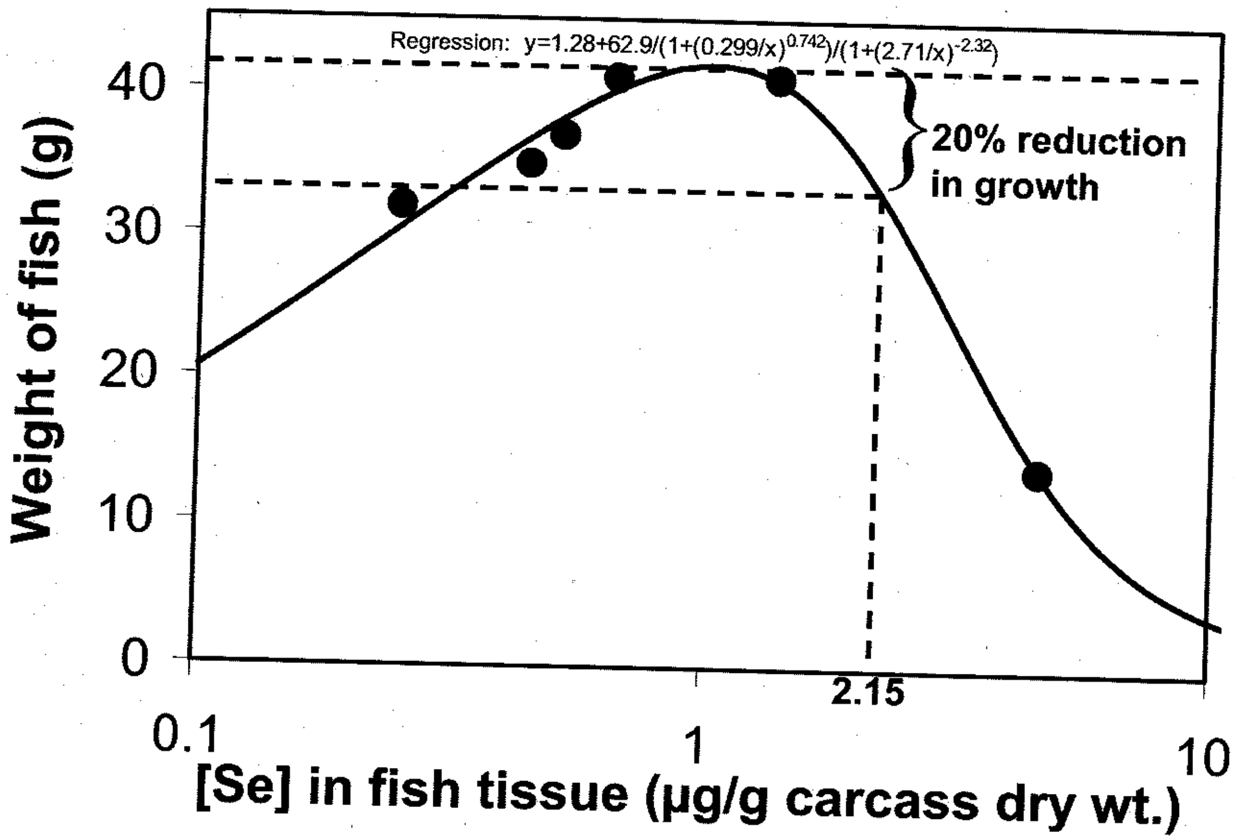

Figure 15. Average weights of juvenile rainbow trout after 20 weeks of exposure to diets spiked with sodium selenite (Hilton *et al.* 1980). The data were fitted with a biphasic model (Beckon *et al.* 2008). In the model it was assumed that at extremely high and extremely low selenium concentrations, the fish would have failed to grow at all, i.e. they would have remained at the initial average weight of 1.28 g. Carcass concentrations are from Fig. 2 of Hilton *et al.* 1980.

A laboratory experiment monitored the growth of juvenile rainbow trout exposed to a diet spiked with selenium in the form of sodium selenite (Hilton *et al.* 1980). This experiment indicates that juvenile rainbow trout that reach a selenium concentration of about 8 µg/g (carcass dry weight) by exposure for 20 weeks to dietary selenium in the form of sodium selenite will experience at least an 86 percent reduction in weight relative to the weight they would gain if their exposure to dietary sodium selenate were optimal (Figure 15). A weight reduction of 20 percent would be associated with a tissue selenium concentration of 2.15 µg/g (carcass dry weight).

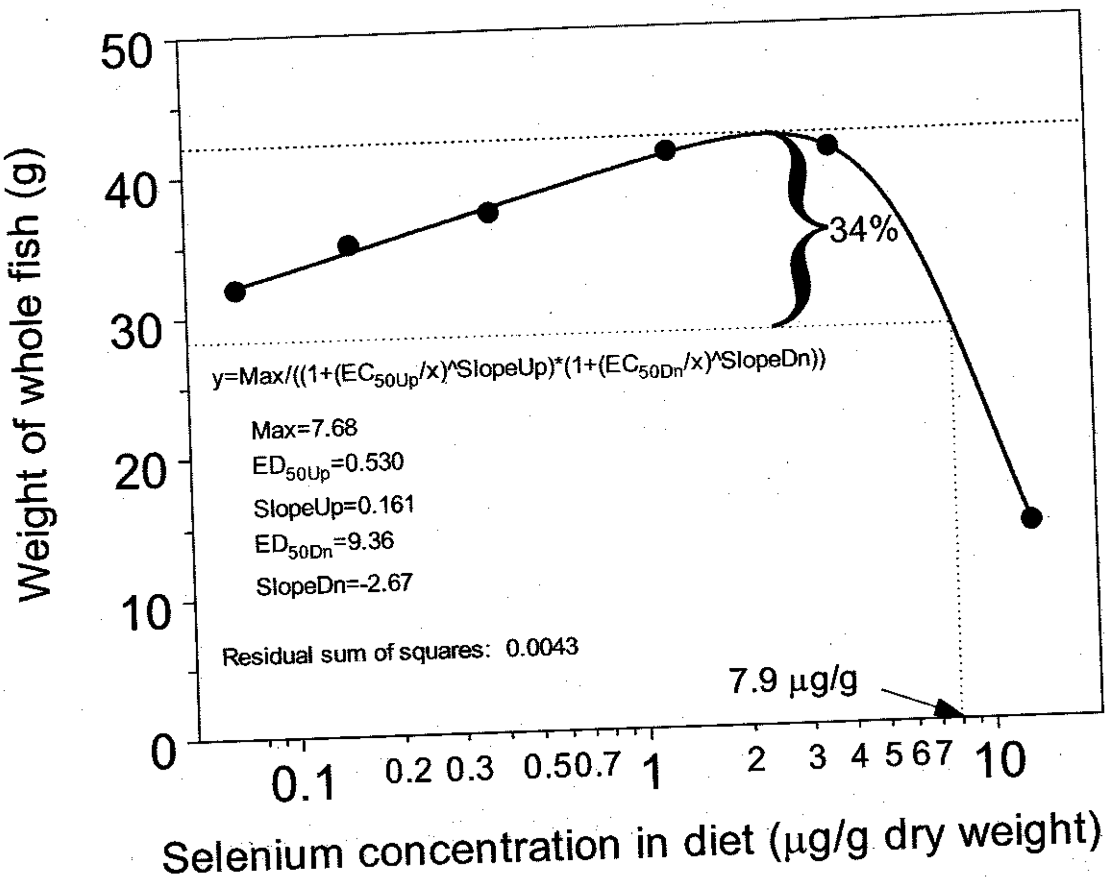

Figure 16. Average weights of juvenile rainbow trout after 20 weeks dietary exposure to sodium selenite (Hilton *et al.* 1980). A biphasic model (Beckon *et al.* 2008) is fitted to the data by least squares non-linear regression.

This experiment also indicates that if young rainbow trout feed on tissue that has a selenium concentration of about 8 µg/g (in the form of sodium selenite) they will suffer a reduction in growth of about 34 percent (Figure 16). Because the form of selenium administered to the fish in this experiment was sodium selenite, this analysis may yield an underestimate of the adverse effects of the more bioavailable organic forms of selenium that fish consume in the wild.

The experiments summarized above indicate that the larval survival and the health and growth of young steelhead trout would be impaired by a concentration of selenium (about 8 µg/g) commonly exceeded in invertebrates, small (prey) fish, and larger predatory fish in waterways that carry agricultural drainwater in the vicinity of the San Luis Unit (Beckon *et al.* 2003).

Green sturgeon (*Acipenser medirostris*)

Status: The southern distinct population segment, or DPS, of north American green sturgeon was federally listed as threatened under the Endangered Species Act on Apr. 7, 2006 (71 FR 17757). The range of the southern DPS extends southward from the Eel River, in northern California, and includes the green sturgeon inhabiting the San Francisco Bay/Delta estuary.

General life history: The ecology and life history of the anadromous green sturgeon have received comparatively little study, evidently because of their generally low abundance and their low commercial and sport-fishing value in the past. The adults are more marine than white sturgeon, spending limited time in estuaries or fresh water.

Green sturgeon migrate up the Klamath River between late February and late July. The spawning period is March-July, with a peak from mid-April to mid-June (Emmett *et al.* 1991). Spawning times in the Sacramento River are probably similar, based on times when adult sturgeon have been caught there. Spawning takes place in deep, fast water. Female green sturgeon produce 60,000-140,000 eggs (Moyle 1976). Based on their presumed similarity to white sturgeon, green sturgeon eggs probably hatch around 196 hours (at 12.7 degrees Celsius [54.9 degrees Fahrenheit]) after spawning, and larvae should be 8-19 millimeters (0.3-0.7 inch) long. Juveniles likely range in size from 2.0-150 centimeters (1-59 inches) (Emmett *et al.* 1991). Juveniles migrate out to sea before 2 years of age, primarily during summer-fall (Emmett *et al.* 1991). Length-frequency analyses of sturgeon caught in the Klamath Estuary by beach seine indicate that most green sturgeon leave the system at lengths of 30-70 centimeters (12-28 inches), when they are up to 4 years old, although a majority leave as yearlings (USFWS 1996). They remain near estuaries at first, but can migrate considerable distances as they grow larger (Emmett *et al.* 1991). Individuals tagged by DFG in San Pablo Bay (part of the San Francisco Bay system) have been recaptured off Santa Cruz, California, in Winchester Bay on the southern Oregon coast, at the mouth of the Columbia River and in Gray's Harbor, Washington (Chadwick 1959; Miller 1972). Most tags for green sturgeon in the San Francisco Bay system have been returned from outside that estuary (D. Kohlhorst, DEG, personal communication, cited in USFWS 1996).

Risk of selenium exposure: Little is known of the risk of selenium to green sturgeon, but white sturgeon (*Acipenser transmontanus*), a representative surrogate species for the green sturgeon, have been the subject of detailed studies within the San Francisco Bay estuary. See the discussion for white sturgeon below.

White Sturgeon (*Acipenser transmontanus*)

Status: According to the World Conservation Union (Duke *et al.* 2004), in general the white sturgeon species is not threatened, but some subpopulations are endangered (Kootenai River and Upper Fraiser River) or critically endangered (Nechako River, Upper Columbia River). The Kootenai River population of the white sturgeon in Montana and Idaho was federally listed as endangered under the Endangered Species Act on September 6, 1994 (59 FR 45989). The California Department of Fish and Game (CDFG) established a daily bag and possession limit of one fish, which must be between 46 and 72 inches total length (CDFG 2007). Temporary (120 days) emergency regulations issued by the CDFG in March 2006 restricted fishing in California to individuals between 46 and 56 inches total length.

General life history: Like green sturgeon, white sturgeon are anadromous, but the adults are less marine than green sturgeon, spending more time in estuaries or fresh water. At sea, white sturgeon have been found from Ensenada, Baja California (Mexico) to the Gulf of Alaska (Fry 1973). The majority of white sturgeon rear in the Columbia-Snake River and Sacramento-San Joaquin basins (Duke *et al.* 2004). White sturgeon have been the subject of detailed studies within the San Francisco Bay estuary (e.g., Kohlhorst *et al.* 1991, Linares *et al.* 2004, Linville 2006). White sturgeon are long-lived, large-bodied, and demersal (bottom-dwelling) fish. For most species of sturgeon, females require several years for eggs to mature between spawnings (Conte *et al.* 1988). White sturgeon in the San Francisco Bay estuary congregate in Suisun and San Pablo Bays where they remain year-round except for a small fraction of the population that moves up the Sacramento River, and to a lesser extent the San Joaquin River, to spawn in late winter and early spring (Kohlhorst *et al.* 1991).

Risk of selenium exposure: Many individuals of this species remain year-round in San Pablo Bay, the part of the San Francisco Bay estuary with the highest selenium concentrations (up to 2.7 µg/L). Clams predominated in the esophageal and stomach contents of white sturgeon caught by anglers in San Pablo Bay (213 fish) and Suisun Bay/Carquinez Strait (142 fish) in 1965-1967 (McKechnie and Fenner 1971). More recently with the change in the benthic food structure of the estuary (Feyrer *et al.* 2003) white sturgeon may depend more on the introduced Asian clam, *Potamocorbula amurensis*, which is an extraordinarily efficient bioaccumulator of selenium (Stewart *et al.* 2004). The median concentration of selenium in Asian clams from San Pablo Bay was found to be above 10 µg Se/g (Stewart *et al.* 2004). Based on histopathological alterations in the kidney, Tashjian *et al.* (2006) estimated that for juvenile white sturgeon a threshold dietary selenium toxicity concentration lies between 10 and 20 µg Se/g. It is uncertain at what point in their life white sturgeon begin feeding on Asian clams.

Linares *et al.* (2004) found concentrations of selenium as high as 46.7 µg/g in gonads of 39 white sturgeon captured in the San Francisco Bay. Kroll and Doroshov (1991) reported that developing ovaries of white sturgeon from San Francisco Bay contained as much as 71.8 µg/g selenium or 7-times the threshold for reproductive toxicity in fish (Lemly 1996a, 1996b) of 10 µg/g. An effect threshold in white sturgeon eggs has been estimated to be between 9 µg/g and about 16 µg/g in experiments in which seleno-L-methionine was injected into yolk sac larvae of white sturgeon (Linares *et al.* 2004). Linville (2006) showed that significant developmental defects and mortality occurred in white sturgeon eggs at a threshold of around 11–15 µg/g selenium. A hazard threshold of around 3–8 µg/g in developing white sturgeon was suggested by Linville (2006).

Sampling of pallid sturgeon (*Scaphirhynchus albus*) in the Missouri River system suggests that normal selenium levels in sturgeon eggs are 2-3 µg/g (Ruelle and Keenlyne 1993) as has been found for many other fish species (see review in Skorupa *et al.* 1996 and in USDI-BOR/FWS/GS/BIA 1998). Thus, white sturgeon in the San Francisco Bay estuary are producing eggs with as much as 35-times normal selenium content. Based on studies regarding toxicity response functions for avian and fish eggs (e.g., Lemly 1996a, 1996b; Skorupa *et al.* 1996;

USDI-BOR/FWS/GS/BIA 1998) and assuming that sturgeon are as sensitive to selenium as birds and other fish, it is highly probable that these fish are reproductively impaired due to selenium exposure. For example, bluegill embryos resulting from ovaries containing 38.6 μg/g selenium exhibited 65 percent mortality (Gillespie and Bauman 1986).

Considering the high bioaccumulation efficiency of Asian clams and their importance in the diet of white sturgeon any selenium reaching the estuary from upstream sources likely contributes to the exposure risk of white sturgeon. As selenium loads to the San Joaquin River and hence to the estuary are reduced over time due to implementation of selenium total maximum daily load limits and the Grassland Bypass Project, potential impacts to sturgeon due to delivery of water to the San Luis Unit should diminish.

Delta smelt (*Hypomesus transpacificus*)

Status: Delta smelt were federally listed as a threatened species on March 5, 1993, (58 FR 12854). The Service completed a 5-year review in March 2003 (USFWS 2003) and recommended no change in its listing status; however, there has been a recent dramatic decline in Delta smelt numbers since 2005.

Life History: Delta smelt of all sizes are found in the main channels of the Delta and Suisun Marsh and the open waters of Suisun Bay where the waters are well oxygenated and temperatures relatively cool, usually less than 20°-22° C in summer. When not spawning, they tend to be concentrated near the zone where incoming salt water mixes with out flowing freshwater (mixing zone). This area has the highest primary productivity and is where zooplankton populations (on which delta smelt feed) are usually most dense (Knutson and Orsi 1983; Orsi and Mecum 1986). At all life stages delta smelt are found in greatest abundance in the top two meters of the water column and usually not in close association with the shoreline.

Delta smelt inhabit open, surface waters of the Delta and Suisun Bay. In most years, spawning occurs in shallow water habitats in the Delta. Shortly before spawning, adult smelt migrate upstream from the brackish-water habitat associated with the mixing zone to disperse widely into river channels and tidally-influenced backwater sloughs (Radtke 1966; Moyle 1976, 2002; Wang 1991). Some spawning probably occurs in shallow water habitats in Suisun Bay and Suisun Marsh during wetter years (Sweetnam 1999 and Wang 1991). Spawning has also been recorded in Montezuma Slough near Suisun Bay (Wang 1986) and also may occur in Suisun Slough in Suisun Marsh (P. Moyle, UCD, unpublished data).

The spawning season varies from year to year, and may occur from late winter (December) to early summer (July). Pre-spawning adults are found in Suisun Bay and the western delta as early as September (DWR and USDI 1994). Moyle (1976, 2002) collected gravid adults from December to April, although ripe delta smelt were common in February and March. In 1989 and 1990, Wang (1991) estimated that spawning had taken place from mid-February to late June or early July, with peak spawning occurring in late April and early May.

Delta smelt spawn in shallow, fresh, or slightly brackish water upstream of the mixing zone (Wang 1991). Most spawning occurs in tidally-influenced backwater sloughs and channel edgewaters (Moyle 1976, 2002; Wang 1986, 1991; Moyle *et al.* 1992). Laboratory observations have indicated that delta smelt are broadcast spawners (DWR and USDI 1994) and eggs are demersal (sink to the bottom) and adhesive, sticking to hard substrates such as: rock, gravel, tree roots or submerged branches, and submerged vegetation (Moyle 1976, 2002; Wang 1986). Growth of newly-hatched delta smelt is rapid and juvenile fish are 40-50 mm long by early August (Erkkila *et al.* 1950; Ganssle 1966; Radtke 1966). By this time, young-of-year fish dominate trawl catches of delta smelt, and adults become rare. Delta smelt reach 55-70 mm standard length in 7-9 months (Moyle 1976, 2002). Growth during the next 3 months slows down considerably (only 3-9 mm total), presumably because most of the energy ingested is being directed towards gonadal development (Erkkila *et al.* 1950; Radtke 1966). There is no correlation between size and fecundity, and females between 59-70 mm standard lengths lay 1,200 to 2,600 eggs (Moyle *et al.* 1992). The abrupt change from a single-age, adult cohort during spawning in spring to a population dominated by juveniles in summer suggests strongly that most adults die after they spawn (Radtke 1966 and Moyle 1976, 2002). However, in El Nino years when temperatures rise above 18° C before all adults have spawned, some fraction of the unspawned population may also hold over as two-year-old fish and spawn in the subsequent year. These two-year-old adults may enhance reproductive success in years following El Nino events.

In a near-annual fish like delta smelt, a strong relationship would be expected between number of spawners present in one year and number of recruits to the population the following year. Instead, the stock-recruit relationship for delta smelt is weak, accounting for about a quarter of the variability in recruitment (Sweetnam and Stevens 1993). This relationship does indicate, however, that factors affecting numbers of spawning adults (*e.g.*, entrainment, toxics, and predation) can have an effect on delta smelt numbers the following year.

Risk of selenium exposure: The Recovery Plan for the Sacramento/San Joaquin Delta Native Fishes (USFWS 1996) states that Delta Smelt are ecologically similar to larval and juvenile Striped Bass (*Morone saxitilis*). Saiki and Palawski (1990) sampled juvenile striped bass in the San Joaquin River system including three sites in the San Francisco Bay estuary. Striped Bass from the estuary contained up to 3.3 µg/g whole-body selenium, a value just below Lemly's 4 µg/g toxicity threshold, even though waterborne selenium typically averages <1 µg/L (ppb) and has been measured no higher than 2.7 µg/L (ppb) within the estuary (Pease *et al.* 1992). Striped Bass collected from Mud Slough in 1986, when the annual median selenium concentration in water was 8 µg/L (ppb) (Steensen *et al.* 1997), contained up to 7.9 µg/g whole-body selenium and averaged 6.9 µg/g whole-body selenium.

Delta smelt, salvaged from the Chipps Island area during the springs of 1993 and 1994, had whole-body selenium concentrations of 1.5 µg/g dw (n=41, range 0.7 - 2.3 µg/g) (Bennett *et al.* 2001). Delta Smelt spawning sites are almost entirely restricted to the north-Delta channels associated with the selenium-normal Sacramento River and are nearly absent from the south-Delta channels associated with the selenium-contaminated San Joaquin River (USFWS 1996). Therefore, Delta smelt would appear to be at low risk to selenium exposure.

Sacramento splittail (*Pogonichthys macrolepidotus*)

Status: The Sacramento splittail was listed as threatened on February 8, 1999 (FR 64:5963). The listing was challenged in Federal District Court, and rescinded on September 22, 2003 (FR 68:55139). However, they remain a species of concern and are included in the report.

Sacramento splittail are endemic to certain waterways in California's Central Valley, where they were once widely distributed (Moyle 1976, Moyle 2002). Sacramento splittail currently occur in Suisun Bay, Suisun Marsh, the San Francisco Bay-Sacramento-San Joaquin River Estuary (Estuary), the Estuary's tributaries (primarily the Sacramento and San Joaquin rivers), the Cosumnes River, the Napa River and Marsh, and the Petaluma River and Marsh.

General life history: Splittail are relatively long-lived (about 5-7 years) and are highly fecund (up to 100,000 eggs per female). Their populations fluctuate on an annual basis depending on spawning success and strength of the year class (Daniels and Moyle 1983). Both male and female splittail mature by the end of their second year (Daniels and Moyle 1983), although occasionally males may mature by the end of their first year and females by the end of their third year (Caywood 1974). Fish are about 180-200 millimeters (7-8 inches) standard length when they attain sexual maturity (Daniels and Moyle 1983), and the sex ratio among mature individuals is 1:1 (Caywood 1974).

There is some variability in the reproductive period, with older fish reproducing first, followed by younger fish that tend to reproduce later in the season (Caywood 1974). Generally, gonadal development is initiated by fall, with a concomitant decrease in somatic growth (Daniels and Moyle 1983). By April, ovaries reach peak maturity and account for approximately 18 percent of the body weight. The onset of spawning seems to be associated with increasing water temperature and day length and occurs between early March and May in the upper Delta (Caywood 1974). However, Wang (1986) found that in the tidal freshwater and euryhaline habitats of the Sacramento-San Joaquin estuary, spawning occurs by late January and early February and continues through July. Spawning times are also indicated by the salvage records from the SWP pumps. Adults are captured most frequently in January through April, when they are presumably engaged in spawning movements, while young-of-year are captured most abundantly in May through July (Meng 1993). These records indicate most spawning takes place from February through April.

Splittail spawn on submerged vegetation in flooded areas. Spawning occurs in the lower reaches of rivers (Caywood 1974), dead-end sloughs (Moyle 1976) and in the larger sloughs such as Montezuma Slough (Wang 1986). Larvae remain in the shallow, weedy areas inshore in close proximity to the spawning sites and move into the deeper offshore habitat as they mature (Wang 1986).

Strong year classes have been produced even when adult numbers are low, if outflow is high in early spring (e.g., 1982, 1986). Since 1988, recruitment has been consistently lower than expected, suggesting this relationship may be breaking down (Meng 1993). For example, both 1978 and 1993 were wet years following drought years, yet the young-of-year abundance in 1993 was only 2 percent of the abundance in 1978.

Risk of selenium exposure: Like white sturgeon, splittail are likely to be relatively vulnerable to selenium contamination because of their estuarine habitat, bottom-feeding habits, and high bioaccumulation rates of Asian clams. The Asian clam and other mollusks constituted 34 percent of the splittail diet (Feyrer and Matern 2000, Feyrer *et al.* 2003).

The median selenium liver level in splittail from the Suisun Bay area of the estuary was about 13 μg/g dw (Stewart *et al.* 2004) while background liver concentrations in fish are generally less than 5 μg/g (USDI-BOR/FWS/GS/BIA 1998). Deformities typical of Se exposure have been seen in splittail collected from Suisun Bay (Stewart *et al.* 2004). Teh *et al.* (2004) found that juvenile splittail are impacted (liver lesions) by chronic exposure (nine months) to a diet of 6.6 μg/g selenium.

In 1998, an above normal rainfall year type, splittail were collected from Mud and Salt Sloughs within the San Luis National Wildlife Refuge during quarterly fish sampling for the Grassland Bypass Project (GBP)(Beckon *et al.* 1999). This was the only time in the 14 year life of the project (1993-2007) that splittail were documented in these two sloughs. Selenium levels in splittail composite whole-body samples at the three Mud Slough sites were all above the GBP concern threshold of 4 μg/g dw with the site immediately downstream of the San Luis Drain having 7.1 μg/g dw (Beckon *et al.* 1999). At Salt Slough where drainwater no longer is discharged into the slough the splittail whole-body composite concentration was 3.1 μg/g dw (Beckon *et al.* 1999).

Considering the high bioaccumulation efficiency of Asian clams and their importance in the diet of splittail any selenium reaching the estuary from upstream sources likely contributes to the exposure risk of splittail. As selenium loads to the San Joaquin River and hence to the estuary are reduced over time due to implementation of selenium total maximum daily load limits and the Grassland Bypass Project, potential impacts to splittail due to delivery of water to the San Luis Unit should diminish.

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ENTRIX
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Attachment D
Response to USFWS Comment 10, from FEIR, Appendix I, Page I-59

APPENDIX I

Public Comments and Responses

ability to manage one system as opposed to hundreds of smaller systems. All options will continue to be evaluated to accomplish the project goals including the completion of the Westside Plan (see discussion in the EIS/EIR on pages 1-3, 1-5, 2-8, 2-20, 2-21, 2-33 and 8-15).

The Use Agreement deals with the situation that would result in selenium loads exceeding load values including the assessment of incentive fees if monthly or annual salt or selenium loads are exceeded (see Appendix H of the Use Agreement, page 41.)

In addition the Use Agreement incorporates termination provisions in Section VII on page 21.

USFWS-9

Scientific studies on mercury contamination in the DMC sumps are not a part of this EIS/EIR. However, the GBD agreed in 2006 to participate with the Regional Board on a mercury source study. So far the Regional Board has not developed or implemented that study. The GBD propose to add mercury testing at Site B to determine compliance with applicable water quality objectives. In addition the GBD will participate in an overall mercury source study when requested by the Regional Board. Also see response USEPA-3.

USFWS-10

The Service asks that the Final EIS/EIR include an evaluation of effects of GBP selenium discharges on anadromous fish including the proposed San Joaquin River Restoration runs of Chinook salmon and steelhead. The response elaborates on material contained in the EIS/EIR.

The effects of the GBP on existing anadromous fish and their habitats were discussed in Section 6 of the EIS/EIR for the alternatives as follows:

- **No Action:** pages 6-29 to 6-33
- **Proposed Action:** pages 6-38 to 6-40
- **Alternative Action:** pages 6-45 to 6-46

Impacts to the proposed anadromous runs of Chinook salmon and steelhead under the SJRRP were described qualitatively in Section 6.2.3, Cumulative Effects, page 6-52. This discussion has been expanded as described below, but this does not affect the determination that the GBP would not result in cumulatively significant effects with the SJRRP.

Cumulative Effects of GBP and SJRRP

The SJRRP will restore flows and habitat in the SJR below Friant Dam beginning in 2009 and Chinook salmon will begin to be re-introduced in fall 2012. The ultimate goal is to establish a run of spring-run Chinook salmon in the river[1]. Per the terms of the Settlement Agreement, the spring-run Chinook salmon introduced to the SJR as part of the SJRRP will be an "experimental population" and as such will not be listed under the ESA. Wild steelhead may take advantage of the improved conditions in the upper San Joaquin River and these fish would potentially experience greater contact with the Project Area than they do under existing conditions. Once these populations become established, juvenile Chinook salmon will migrate downstream from

[1] A run of fall-run Chinook salmon may also be established if there is sufficient habitat to accommodate both races.

the spawning and rearing areas below Friant, downstream past the Grasslands area, where they would be exposed to elevated concentrations of selenium from the project, and then on to the Delta and the ocean. Returning adult spring-run Chinook salmon would also pass through the affected area during their upstream migration 2 to 5 years later.

The effects of this exposure would depend upon the duration of exposure, the mechanisms by which exposure occurs, and the concentrations of selenium in the environment.

Salmonid Use of the Project Area

Adult spring-run Chinook salmon would migrate upstream from April through August, although water temperatures would likely be too warm to allow migration beginning sometime in June or July. Based on the first introductions of Chinook salmon into the river in late 2012, the first adults would be expected to return in about 2014. These adults would migrate upstream rapidly, to holding areas in large, cold pools below Friant Dam, likely in Reach 1 and 2A. These fish would not be expected to remain within the 3 mile reach maximally affected by the project, between the mouths of Mud Slough and the Merced River, for more than a day or two and would not be expected to remain in the affected reach of the San Joaquin River (from Mud Slough to Crows Landing) for more than a few days. Adult steelhead migrate upstream from December through April. Steelhead may be able to begin colonizing the upper San Joaquin as soon as passage is provided past several barriers between the Merced River and Mendota Pool. Like spring-run Chinook salmon, adult steelhead tend to migrate rapidly upstream as far as they can to spawn. They would also be expected to be in the area affected by the project for only a few days. Adult Chinook salmon and steelhead do not eat after entering freshwater. Based on their short duration in the affected area and limited pathway of exposure to selenium, effects on adult salmon would likely be minimal to non-existent.

Spawning for both species would occur in Reaches 1 and 2A, well upstream of the project area in a location that would not be affected by Se from the project.

Emergent fry and young Chinook salmon would rear in the SJR for a period of several months before emigration. Steelhead would rear for one to two years prior to emigration. It is anticipated that the primary areas for juvenile rearing would be in Reaches 1 and 2A, about 100 miles upstream of the Grassland Project Area (Stillwater Sciences 2003[2]). The suitability of rearing habitat would decrease with distance downstream from Friant Dam, due to changes in thermal regime and habitat structure.

Emigration for spring-run Chinook salmon would occur from January through mid-May, with a peak in January through March, based on the timing of emigration from Butte Creek (Ward et al. 2004) and limited historic information on the SJR (SJRRP TAC 2009). The timing for steelhead would be similar. A few individuals might be observed at any time of year when temperatures are suitable, however. Based on a review of the literature, Williams (2006) reports migration rates for Chinook salmon range from 1 to 20 miles (2 to 32 km) per day. The rate of migration appears to be related to fish size, time of year, suitability of foraging habitat, and temperature, with migration rates increasing with increasing values of all of these parameters. Migration rates for Central Valley steelhead are not well-documented (Williams 2006), and rates are assumed to

[2] *Stillwater Sciences. 2003. Draft Restoration Strategies for the San Joaquin River. Prepared for the Friant Water Users Authority and the Natural Resources Defense Council. February.*

be similar to Chinook salmon. Suitability of foraging habitat may also affect emigration rates, as described below.

Juvenile Chinook salmon have been observed to use favorable habitat to grow during their emigration for periods exceeding two months, however (Ward et al. 2004). The SJRRP TAC (Feb 2009) cites historical CDFG information indicating that SJR Chinook salmon might have migrated slowly, rearing and growing along the way. This information indicates a peak migration past Mendota Dam in February and March 1946 and peak migration past Mossdale in April and May 1939-1941. The SJRRP TAC indicate this shows a potential 2 months spent in the river between these two points. However, it must be noted that these data are not from the same year and reflect peaks of migration, not movements of specific fish. Indeed, the data from Mendota Dam is from a time after Friant Dam was completed, while the data from Mossdale was from before Friant Dam was completed. Thus the difference between these peaks may reflect differences in timing due to hydrologic conditions due to closure of Friant Dam or meteorologic conditions between these years, runs from intervening tributaries, or other factors.

Suitable rearing and foraging habitat for juvenile Chinook salmon is strongly associated with floodplain habitat (SJRRP 2008, SJRRP TAC 2009, Williams 2006, Ward 2004). As described by the SJRRP TAC (2009), It is unknown what flows would be required in the SJR to connect the river to it floodplains. Assuming the river would be connected to its floodplains only during normal-wet or wet years, and the migration rates in the main channel are the 1 to 20 miles per day described above, then the downstream migrant fish might be expected to be within the Project Area for only a few days. In wetter years, if salmonids were able to access the floodplains, they might be expected to spend more time migrating downstream, perhaps as much as a couple of months. The wetland areas in the vicinity of the project are relatively extensive, but anadromous salmonids have rarely been observed using these areas (Saiki 1998). It is unclear whether this area would be used more extensively once the SJRRP and GBP are implemented. The portion of the SJR maximally affected by the project represents less than 1 percent of the total length of the SJR between its confluence with the Sacramento River and Friant Dam. Thus a only small proportion of the total population would be expected to use this area for prolonged periods, unless this area provided substantially better habitat than other areas of the SJR. As described in Section 6.1.2.1.6 of the EIS/EIR, the habitat in the project area is largely degraded.

Selenium Concentrations under Existing Conditions and the Proposed Action

The likely selenium concentrations that would be present in the SJR between Mud Slough and the Merced River (Site H) with the GBP in place were evaluated based on calculated selenium concentrations in 2005, a normal-wet year, and 2008, a critical-high year (using the terminology of the SJRRP), taking into account the flow and selenium concentration reductions that would occur as a result of the GBP, and imposing the SJRRP flows upon those concentrations. Selenium concentrations were projected for 2012 through 2017.

The Regional Board stopped monitoring at Site H (on the SJR between Mud Slough and the Merced River) in 1999 because they determined that the floodplain in this reach of the River is subject to overflow from the Merced River and there was not a single site that could be monitored without possible influence from Merced River flows. Therefore the Waste Discharge Requirements for the Grassland Bypass Project do not require, and the RWQCB does not require sampling at Site H. It is sampled (by the Grassland Basin Drainers-GBD) and sent in to S.

Dakota State University (by GBD) for analysis and that information is sent to the San Francisco Estuary Institute (SFEI) for inclusion in the Grassland Bypass Project reports.

Existing data were used to estimate flows and selenium concentrations at Site H. Since there is no flow station at Site H, upstream gages and diversion were used to calculate the flows at Site H. These locations are depicted on the attached map (at end of this response) and include:

- San Joaquin River at Hwy 165
- Salt Slough at Hwy 165
- Mud Slough at Site D
- Los Banos Creek at Hwy 140
- Diversions from Los Banos Creek to the Newman Land Co.

Under SJRRP, releases from Friant Dam are made for the benefit of downstream fish resources. The volume and timing of these releases varies with water year type (NRDC vs. Rogers 2006)[3]. Review of the SJRRP criteria and discussion with modelers familiar with the hydrology indicated that 2005 would be typical of a Normal-Wet year and 2008 would be typical of a Critical-High year. Although these two year types are not the maximums from the SJRRP year types, they were two recent year types in which the best data were available and they were representative of high and low flow periods. The section of the SJR between Mud Slough and Merced River is within Reach 5 as identified by the SJRRP, and additional flows were specified accordingly. It was determined that the first year that salmon would be introduced to the upstream reaches of the San Joaquin River would be 2012, and the first year juveniles would migrate out through this reach would be in the Spring of 2013. In order to estimate what the selenium concentrations at Site H would be under the proposed new Use Agreement, the modeled concentration at Site B (discharge from the San Luis Drain) and the calculated Site H flow were used. There would be no change in loads for 2012-2014, and loads would be ramped down starting in 2015. For the years 2012 – 2016 projections were made for Critical-High and Normal-Wet water year types as defined by the SJRRP, and for 2017 a projection was made for the Normal-Wet water year type in order to bracket the range of expected selenium concentrations. After 2016 the selenium loads allowed under the new Use Agreement reduce sharply and the impacts at Site H would reduce accordingly.

The attached Figures (Site H 2012-2014 Critical-High, 2015 Critical-High, 2016 Critical-High, 2012-2014 Normal-Wet, 2015 Normal-Wet, 2016 Normal-Wet and 2017 Normal-Wet) present the analysis of Site H present the analysis of Site H. The information shown on the figures is as follows:

- **Restoration flows** - it was determined there would be additional flows in this reach of the river starting in 2013. (These are given as CFS per day in the restoration program agreement documents).
- Two year types are shown using 2005 and 2008 as a basis. 2005 was determined to be a "Normal-Wet" year type per the river restoration criteria and 2008 a "Critical-High" year.

[3] *NRDC et al. vs. Rogers et al. 2006.* Notice of Lodgement of Stipulation of Settlement. U.S. District Court, Eastern District of California (Sacramento Division). Case No. CIV S-818-1658 LKK/GGH.

Adjustments were then made to selenium loads and river restoration flows to project into future years.

- **Site H (cfs)**-calculation of the actual flows at Site H using upstream gages as shown on the attached map.
- **Se calculated concentration**-using the selenium load at Site B (discharge from the San Luis Drain) and the calculated Site H flow.
- **Se measured Conc @ H**-weekly samples are taken at Site H but the Regional Board has noted the sampling location is subject to overflow from the Merced River. Therefore, these concentrations would be equal to or less than the calculated concentrations. Therefore these concentrations are not used except to compare for verification the calculated Site H concentrations.
- **New Site H flow** - (for the year indicated on the figure), adjusted for the addition of river restoration flows and an adjustment for changes in Site B flows. Site B flows were proportionally reduced in the future based on loads in the base years compared to loads in the future years. Then river restoration flows were added. (As future Site B loads are monthly numbers, the daily load for the future years is the monthly load divided by the days in the month).
- **New Site H Conc** - (for the year indicated on the figure), using the new Site H flows and the Site B load values for the years indicated selenium concentrations were calculated.

Year 2013 is the first year that restoration flows are due at Site H so this was the first year calculated (2012 and 2014 would look identical to 2013, and 2012 water concentrations were used to calculate the 1-3 month prior time averaged concentrations for 2013.). Projections were then made to future years to see what the lower loads did to the concentrations. In 2013 for both year types the concentrations during the spring period and several months before are low. In normal-wet years the summertime concentrations get higher. This is mainly because the allowable loads are higher and the flows in summer are pretty consistent between wet and dry years. In 2016, the concentrations are below 3.3 µg/L in critical-high years. Concentrations are below 3.3 µg/L in normal-wet years by 2017. The summertime concentrations are projected to be below 5 by 2016 in normal-wet and below 5 in critical-high in 2013.

Selenium Concentration in Fish

The comment references an analysis by Beckon and Maurer (2008) that concluded there is a substantial ongoing risk to migrating juvenile Chinook salmon and steelhead in the San Joaquin River due to selenium bioaccumulation. This analysis relies on data from a laboratory study done by Hamilton et al (1990) that measured the survival of juvenile Chinook salmon after exposure to various levels of dietary selenium for 90 days. This study and other cited in the comments suffer from several weaknesses, some of which are noted by Beckon and Maurer (2008) and USEPA (2004). In addition, the control exhibited significant mortality between 60 – 90 days. However, the full data set was used by Beckon and Maurer in their analysis of potential effects.

While the evidence of selenium-related effects to salmonids and selection of appropriate toxicity thresholds for coldwater species is controversial, it is recognized that there is significant uncertainty regarding potential effects to salmonids. For this reason, it was assumed in the Draft EIS/EIR that there could be potential negative impacts to Chinook salmon and steelhead under the Proposed Action and Alternative Action, independent of the SJRRP (see Table 6-8). However, in response to USFWS comments we have compared the predicted selenium concentrations at Site H (described above) to the potential effects thresholds cited in the comments.

As shown in Appendix E2 (where the original analysis of historical data was done by Bill Beckon of USFWS for the 2001 EIS/EIR, and updated by URS for the 2009 EIS/EIR to incorporate more recent data), historical data indicate that the best prediction of fish selenium equilibrium concentrations (and hence toxicity to fish) is provided by the logarithmic transformation of selenium concentrations in water averaged over the period one to seven months prior to collection of the fish sample. This analysis was based on all species of fish collected in the Grasslands region, and Se uptake and bioaccumulation in these fish is not necessarily representative of salmonids. Bill Beckon of USFWS has recently done similar analyses evaluating existing data on species that may be more similar to salmonids (large mouth bass and sunfish) and found that the lag time for Se bioaccumulation is much longer for these species (approximately 300 days for large mouth bass) (Beckon 2009 – personal communication). Because large mouth bass become piscivorous approximately a month after hatching, the bioaccumulation lag time for this species is likely to be longer than that for fish that feed at lower trophic levels.

At this time there is not sufficient data to evaluate appropriate Se bioaccumulation lag times and averaging windows for anadromous fish such as salmonids, and the analysis is complicated by migration patterns because individuals are exposed to different concentrations in different locations. However, in order to address the concerns raised by commentors an attempt was made to make a reasonable prediction of the juvenile salmon exposure to Se during migration through SJR downstream of the Grasslands region.

It is assumed that juvenile salmon would receive the highest Se exposure during the time they remain in the Grasslands region, as Se water concentrations upstream and downstream are generally lower. It is recognized that most Se uptake in fish occurs through the diet rather than through direct uptake from water. While the Se bioaccumulation lag time for juvenile salmonids has not been determined due to insufficient data, it may be somewhat longer than the 1 month lag time for the "all resident fish" category used for the regression analysis presented in Appendix E, which includes some species of lower trophic level, but it likely to be shorter than the lag time for large mouth bass, which feed at a higher trophic level. Because the period of interest for this analysis is the time that juvenile salmonids remain in the Grasslands region during migration, the approach taken was to use an water concentration averaging window expected to represent bioaccumulation of the prey the salmon would consuming during this time.

An averaging window of 2 months (30 to 90 days prior) was selected for the following reasons:

- For invertebrates (which are expected to comprise the bulk of the diet of juvenile salmonids as they migrate through the Grasslands region), the best predictor of invertebrate selenium equilibrium concentration was found to be a shorter period (30 to 60 days prior to measurement of Se in invertebrate tissue). Using a longer period (30 to 90 days) is more conservative because it includes higher concentrations predicted to occur earlier in the fall.
- The toxicity data referenced in comments received on the Draft EIR was generally based on exposure periods of about 60 to 90 days.

- As discussed above, it is unlikely that juvenile salmonids would remain in the area of concern longer than about 2 months and it is likely that they would be in the area of concern for only a few days. Therefore, it seems reasonable to use a time-averaged concentrations of 2 months for comparison to the lowest survival threshold cited in the comments received (3.3 μg/L, level associated with 10 percent mortality in juvenile Chinook salmon).

As discussed above, available evidence indicates that juvenile salmon migrate through the area of concern between January and May. The attached table labeled Site H Selenium Concentrations presents the calculated 2 month running average concentrations for 1 – 3 months prior to each date shown.

Instantaneous selenium concentrations in blue font are greater than or equal to the 3.3 μg/L value cited for coldwater fish, concentrations in red font are greater than or equal to the 4 μg/L level of concern for warm water fish, and concentrations in pink font are greater than or equal to the 5 μg/L existing water quality objective. However, the 1-3 month prior time-averaged concentrations for the Jan – May periods are all lower than 3.3, the lowest juvenile mortality threshold cited. As discussed above, the number of juveniles that do linger in this area and may be affected is likely to be very low. Due to the low probability of extended exposure and the low time-averaged concentrations, it is unlikely that there will be significant effects to juvenile salmon migrating through this reach. However, as discussed above, there is considerable uncertainty in this analysis due to lack of data on Se bioaccumulation and toxicity in salmonids as well as limited data on likely exposure periods. Due to this uncertainty, it was assumed in the Draft EIS/EIR that there could be potential negative impacts to Chinook salmon and steelhead under the Proposed Action and Alternative Action, independent of the SJRRP

Conclusions

The available information indicates that Chinook salmon and steelhead reintroduced by the SJRRP would likely have some exposure to selenium as they pass through the Project Area during emigration and immigration. The GBP would reduce the selenium exposure from what these fish might encounter under existing conditions, and with the Project, selenium concentrations would decrease over time. The amount of time these fish would be exposed to the selenium would likely be short, for upstream migrant adults, a few days; for downstream migrant juveniles a few days to a few weeks. Adults would have limited pathways to exposure, as they do not eat after they enter freshwater, and so are not expected to be affected by their limited exposure. Juveniles may be exposed through the food chain. However, selenium concentrations are low during the time the juveniles are most likely to be present and most juveniles would not reside in the affected area long enough to receive a biologically meaningful dose.

This information indicates that the GBP is unlikely to have a significant impact on the fish reintroduced as part of the SJRRP. Because both projects would be expected to improve conditions for salmonids in the SJR and, therefore, they would not have a cumulatively significant impact.

USFWS-11

The comment is concerned with the cumulative impacts of reductions in flow associated with tailwater recovery by the Exchange Contractors in non-critical water years on water quality in Mud and Salt Sloughs combined with discharges from non-GDA properties to wetland supply channels, from the additional lands mentioned in comment 1. Concerning the Exchange Contractors' 10-year water transfer program EIS/EIR in 2004, your comments are noted and considered to the extent appropriate for the Grassland Bypass Project.

The Exchange Contractors' tailwater does not contain high levels of Se. Concerning salt, the refuge water balance modeling conducted for the 10-year program, which included acquisition of transfer water for delivery to the wildlife refuges, found that more salt was discharged from the wetlands than was in the receiving water supply, that salt was being leached from the wetlands into the San Joaquin River due to the provision of additional water to the refuges from the 10-year transfer. This relates to the commenter's assertion that water quality of the combined 10-year and 25-year programs needs to be addressed in comment 12. See response USFWS-12 below.

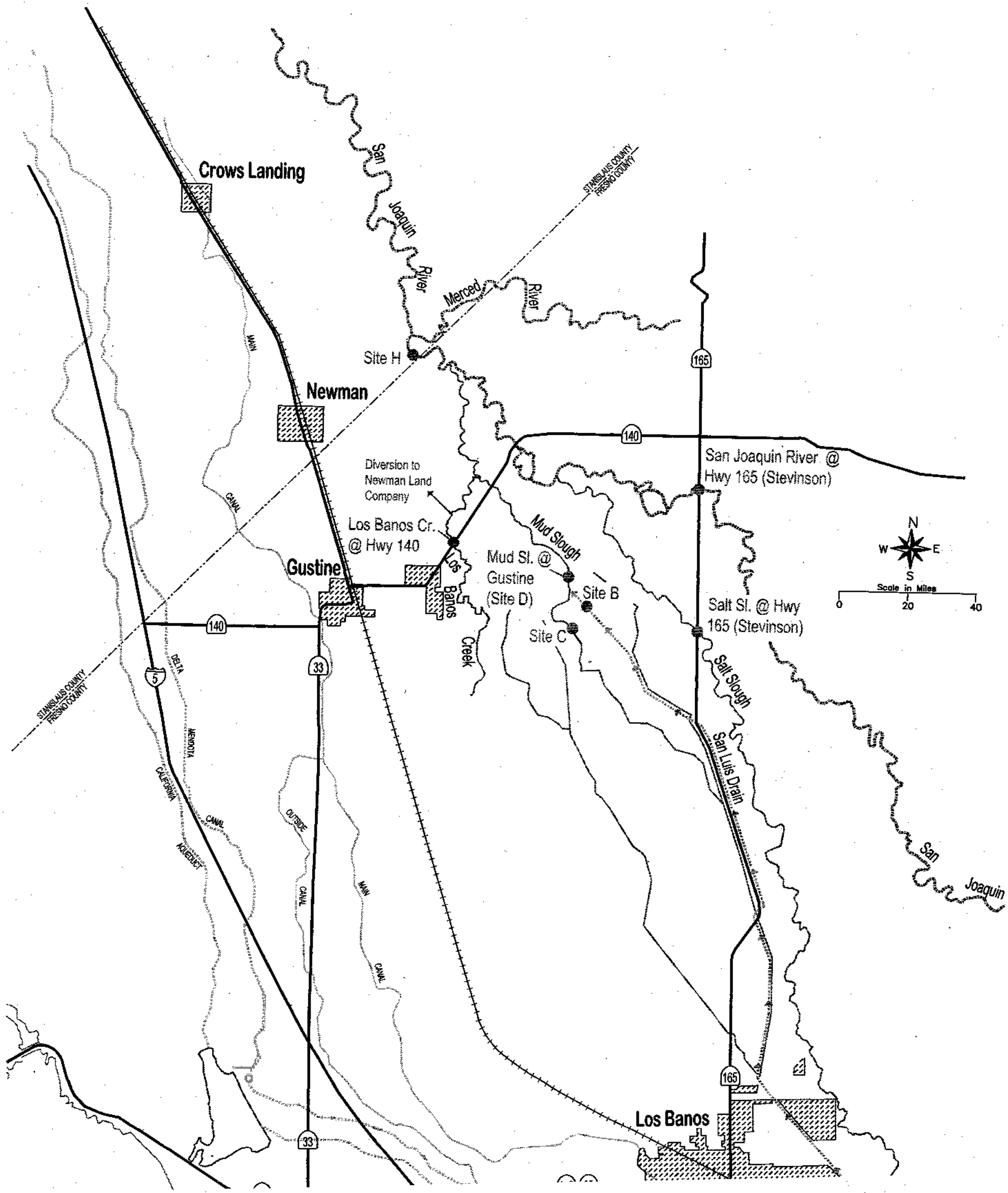
The analysis for the Grassland Bypass Project EIS/EIR would have included the Exchange Contractors transfer project's reduced flows from tailwater recovery in the baseline data described in Section 4.1.5.7 and then in Section 4.1.5.8 for the San Joaquin River downstream to Crows Landing. Additional analysis of water quality (Se concentrations) at Site H is provided for response USFWS-10, and no further analysis is warranted.

USFWS-12

The commenter states that the Exchange Contractors' 25-year groundwater pumping and water transfer program will degrade groundwater, reduce the quality of water delivered to the Grasslands wetlands, and further reduce dilution flows in the wetlands channels and result in further water quality degradation; and he wants these 'impacts" addressed in the cumulative impacts analysis. The 25-year program utilizes groundwater pumping, conservation, and/or land fallowing to generate the substitute water for transfer to other water users. It did not propose additional tailwater recovery or delivery of water to the wildlife refuges.

First of all, these issues were addressed in responses to comments on the Exchange Contractors' EA/IS in October 2007 (Exchange Contractors 2007). Highlights of those responses include the following:

- The wells are to be designed to tap lower salinity water in the profile below a depth of about 150 feet and above the Corcoran Clay, as opposed to shallower poor quality groundwater.
- Selenium is not a constituent that would be introduced into water deliveries from this project. Concerning other constituents, e.g., TDS, the project would not directly cause the CVP to exceed suitability objectives.
- The EA/IS illustrates that there would be no effect to the users that receive waters from the Main Canal upstream of O'Banion Bypass, including the refuges.
- While past and present projects will need to meet current salt TMDLs, reasonably foreseeable plans and projects on the San Joaquin River point to improved water quality (Grassland Bypass Project, San Joaquin River Restoration Program, potential Basin Plan amendments) over time. The indirect localized incremental effect to the Grasslands refuges caused by delivery of the blended water to CCID using the Outside Canal is further offset by reductions in poor quality drainage that would otherwise be discharged as part of the Grassland Bypass Project to Mud Slough.



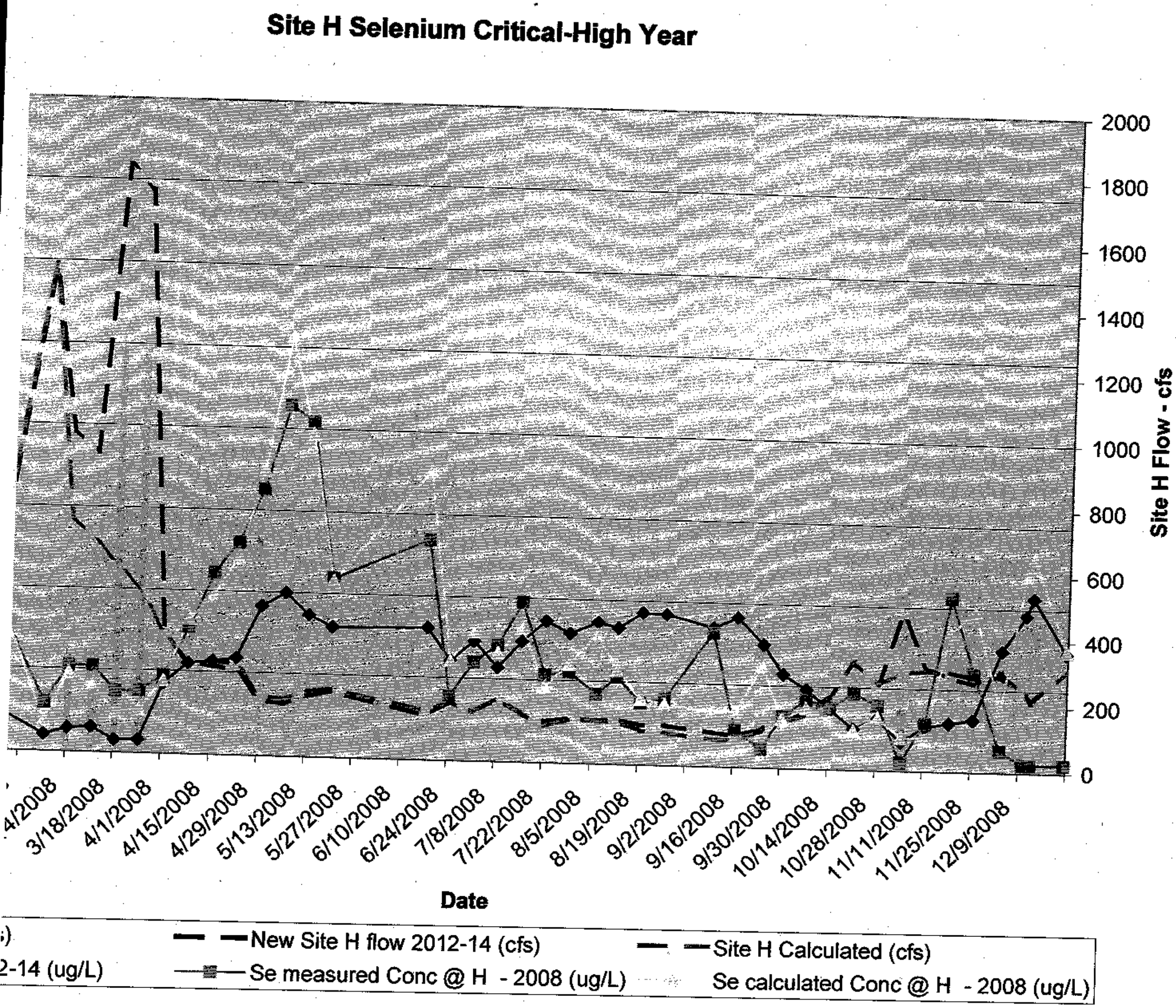
Crows Landing
Newman
Gustine
Los Banos
San Joaquin River
Merced River
Site H
Diversion to Newman Land Company
Los Banos Cr. @ Hwy 140
Los Banos Creek
Mud Slough
Mud Sl. @ Gustine (Site D)
Site B
Site C
San Joaquin River @ Hwy 165 (Stevinson)
Salt Sl. @ Hwy 165 (Stevinson)
Salt Slough
San Luis Drain
San Joaquin
165
140
33
5
STANISLAUS COUNTY
FRESNO COUNTY
MAIN CANAL
DELTA MENDOTA CANAL
CALIFORNIA AQUEDUCT
OUTSIDE CANAL
N
W
E
S
Scale in Miles
0
20
40

Concentrations for Normal-Wet Water Year Types

New Site H Se Conc 2015 (ug/L)		New Site H Se Conc 2016 (ug/L)		New Site H Se Conc 2017 (ug/L)	
Predicted Instantaneous Concentration	Average 1-3 months prior	Predicted Instantaneous Concentration	Average 1-3 months prior	Predicted Concentration	Average 1-3 months prior
0.47	**3.32**	0.34	2.66	0.21	1.96
0.17	2.99	0.12	2.39	0.08	1.76
0.74	2.57	0.54	2.04	0.34	1.50
1.30	2.60	0.95	2.06	0.59	1.52
2.03	2.33	1.49	1.85	0.93	1.35
2.28	1.85	1.67	1.46	1.04	1.07
0.71	1.58	0.52	1.25	0.33	0.91
0.93	1.17	0.68	0.91	0.42	0.65
1.11	1.10	0.81	0.84	0.50	0.58
0.70	1.16	0.51	0.85	0.31	0.53
0.59	1.10	0.43	0.81	0.27	0.50
0.71	1.17	0.53	0.85	0.33	0.53
0.60	1.30	0.43	0.95	0.27	0.59
0.60	1.29	0.44	0.95	0.27	0.59
4.76	1.19	**3.54**	0.87	2.25	0.54
2.85	1.01	2.08	0.74	1.30	0.46
2.20	0.79	1.60	0.58	1.00	0.36
0.64	0.77	0.46	0.56	0.29	0.35
0.27	1.30	0.20	0.96	0.12	0.60
0.63	1.33	0.46	0.98	0.29	0.62
1.36	1.54	0.99	1.14	0.62	0.71
2.75	1.76	2.04	1.29	1.28	0.81
3.63	1.70	2.69	1.25	1.70	0.79
3.90	1.57	2.90	1.15	1.85	0.72
4.54	1.66	**3.41**	1.22	2.19	0.77
6.18	1.93	**4.72**	1.42	3.09	0.89
5.29	1.53	**4.02**	1.12	2.60	0.70
4.95	1.64	**3.71**	1.21	2.36	0.76
4.26	1.88	3.19	1.39	2.03	0.86
4.62	2.44	**3.48**	1.81	2.23	1.15
5.49	2.91	**4.12**	2.17	2.64	1.39
4.73	**4.46**	**3.51**	**3.35**	2.23	2.16
6.64	**4.67**	**5.01**	**3.51**	3.24	2.25
4.85	**4.90**	**3.63**	**3.69**	2.32	2.37
3.53	**5.05**	2.61	**3.81**	1.65	2.45
3.30	**5.07**	2.48	**3.82**	1.59	2.45
2.58	**5.07**	1.92	**3.82**	1.23	2.46
1.88	**5.12**	1.37	**3.84**	0.86	2.45
1.86	**5.08**	1.35	**3.81**	0.85	2.43
2.63	**4.97**	2.07	**3.73**	1.30	2.38
2.75	**4.75**	2.03	**3.56**	1.28	2.28
2.55	**4.27**	1.87	3.19	1.17	2.04
1.35	**3.93**	1.00	2.93	0.62	1.87
1.75	**3.52**	1.29	2.63	0.80	1.68
1.35	**3.43**	1.00	2.56	0.63	1.63

Projected Instantaneous and Time-Averaged Concentrations for Critical-High Water Year T

Date	New Site H Se Conc 2012-2014 (ug/L)		New Site H Se Conc 2015 (ug/L)		New Site H Se Conc 2016 (ug/L)	
	Predicted Instantaneous Concentration	Average 1-3 months prior	Predicted Instantaneous Concentration	Average 1-3 months prior	Predicted Instantaneous Concentration	Average 1-3 months prior
1/8/08	0.94	1.37	0.74	1.37	0.54	1.09
1/15/08	2.31	1.95	1.83	1.95	1.33	1.56
1/22/08	2.77	2.17	2.20	2.17	1.60	1.73
2/12/08	1.01	2.48	0.79	2.46	0.58	1.95
2/26/08	0.40	2.86	0.32	2.68	0.23	2.09
3/4/08	0.56	2.84	0.44	2.63	0.32	2.04
3/11/08	0.60	2.23	0.47	1.92	0.34	1.45
3/18/08	0.31	1.99	0.24	1.70	0.17	1.27
3/25/08	0.32	1.76	0.25	1.39	0.18	1.01
4/1/08	1.74	1.49	1.33	1.18	1.02	0.86
4/8/08	2.27	1.41	1.74	1.12	1.34	0.81
4/15/08	2.34	1.07	1.79	0.84	1.37	0.61
4/22/08	2.43	0.58	1.87	0.45	1.44	0.33
4/29/08	**3.76**	0.53	2.90	0.42	2.23	0.30
5/6/08	**4.00**	0.71	3.15	0.55	2.33	0.41
5/13/08	**3.45**	0.89	2.73	0.69	2.02	0.52
5/20/08	3.16	1.07	2.52	0.82	1.88	0.62
6/17/08	3.21	2.54	2.55	1.97	1.87	1.49
6/24/08	2.42	2.89	1.93	2.25	1.42	1.70
7/1/08	2.87	3.06	2.34	2.39	1.73	1.80
7/8/08	2.23	3.19	1.81	2.49	1.32	1.88
7/15/08	2.88	**3.36**	2.36	2.63	1.74	1.98
7/22/08	**3.39**	**3.52**	2.62	2.77	2.11	2.07
7/29/08	3.10	3.25	2.53	2.58	1.87	1.91
8/6/08	**3.44**	3.02	2.76	2.41	2.05	1.78
8/12/08	**3.31**	2.78	2.67	2.23	2.00	1.64
8/19/08	**3.71**	2.72	3.06	2.20	2.34	1.62
8/26/08	**3.68**	2.83	3.07	2.30	2.39	1.70
9/9/08	**3.38**	2.94	2.84	2.39	2.17	1.77
9/16/08	**3.64**	2.96	3.02	2.40	2.27	1.78
9/24/08	3.00	3.12	2.44	2.54	1.80	1.90
9/30/08	2.28	3.22	1.87	2.63	1.39	1.98
10/7/08	1.92	**3.36**	1.56	2.75	1.17	2.07
10/14/08	1.46	**3.43**	1.17	2.82	0.86	2.13
10/21/08	1.00	**3.47**	0.79	2.85	0.58	2.16
10/28/08	1.27	**3.45**	1.00	2.84	0.73	2.15
11/4/08	0.71	3.29	0.56	2.71	0.41	2.05
11/11/08	1.08	3.09	0.87	2.55	0.64	1.93
11/18/08	1.18	2.77	0.93	2.28	0.68	1.72
11/25/08	1.28	2.36	1.00	1.96	0.73	1.46
12/3/08	2.96	2.24	2.37	1.84	1.77	1.37
12/10/08	**3.84**	1.91	3.06	1.55	2.27	1.15
12/12/08	**4.27**	1.82	**3.42**	1.48	2.56	1.09
12/22/08	2.92	1.64	2.32	1.24	1.72	0.92



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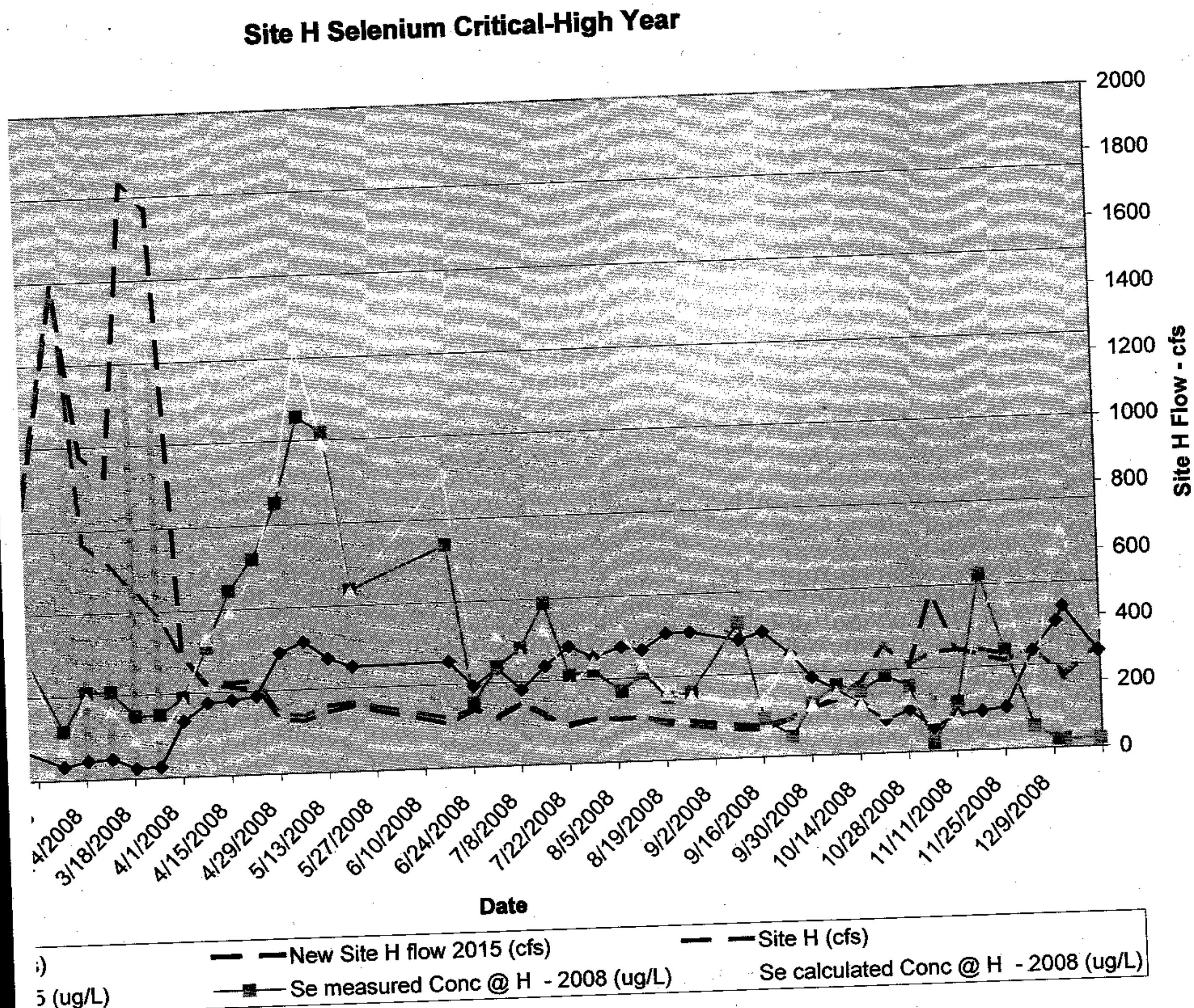

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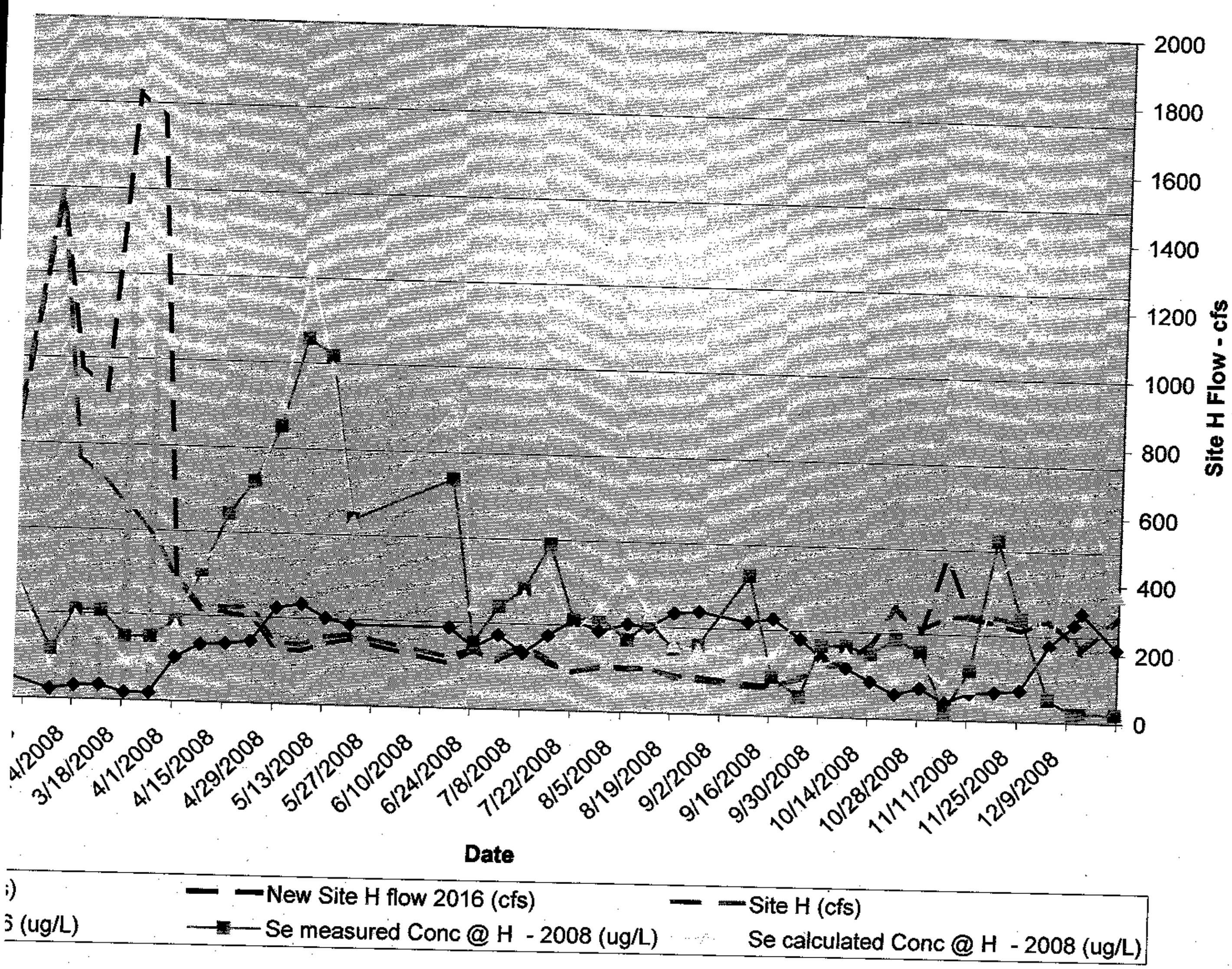
Site H Selenium Critical-High Year



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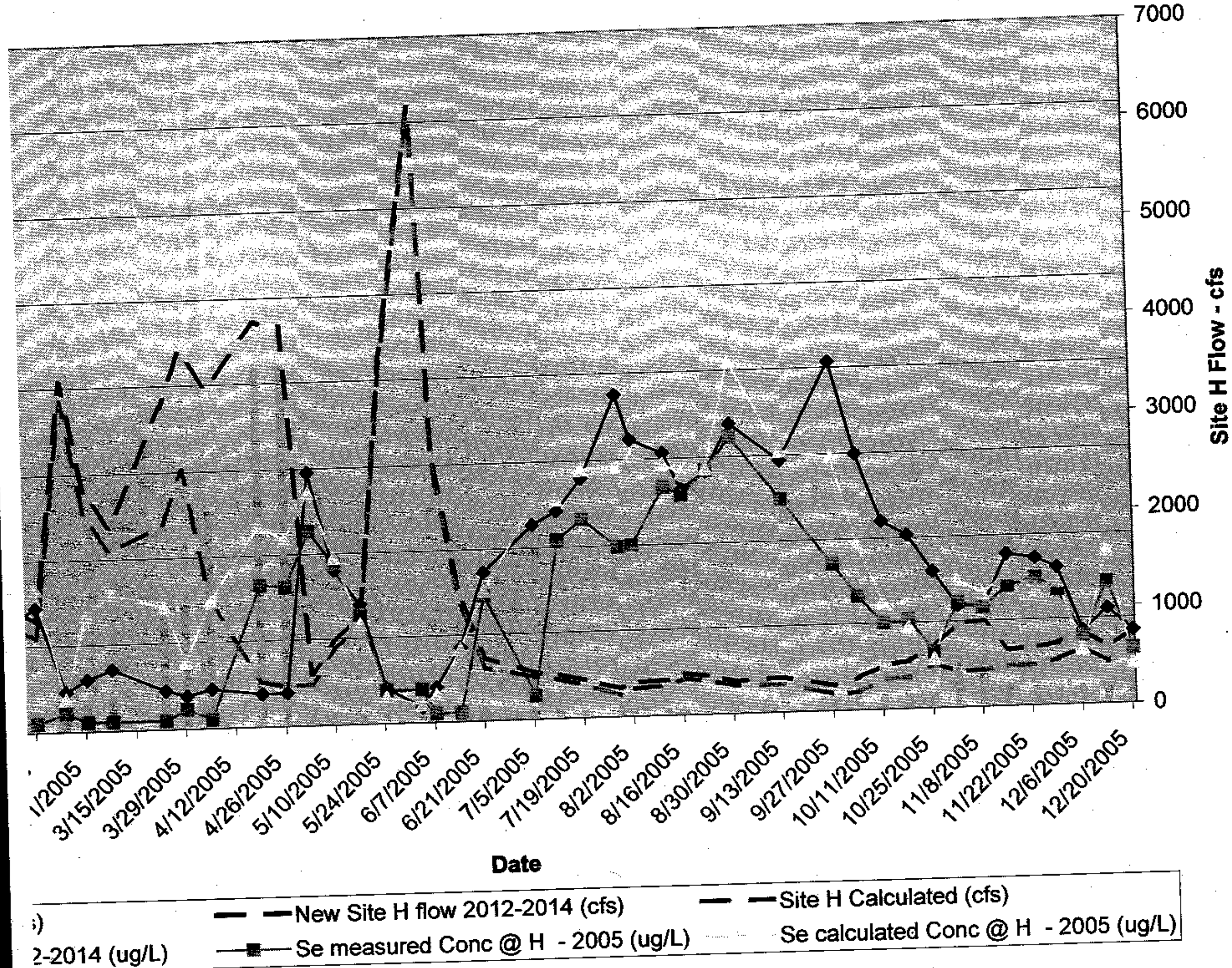
Site H Selenium Normal-Wet Year



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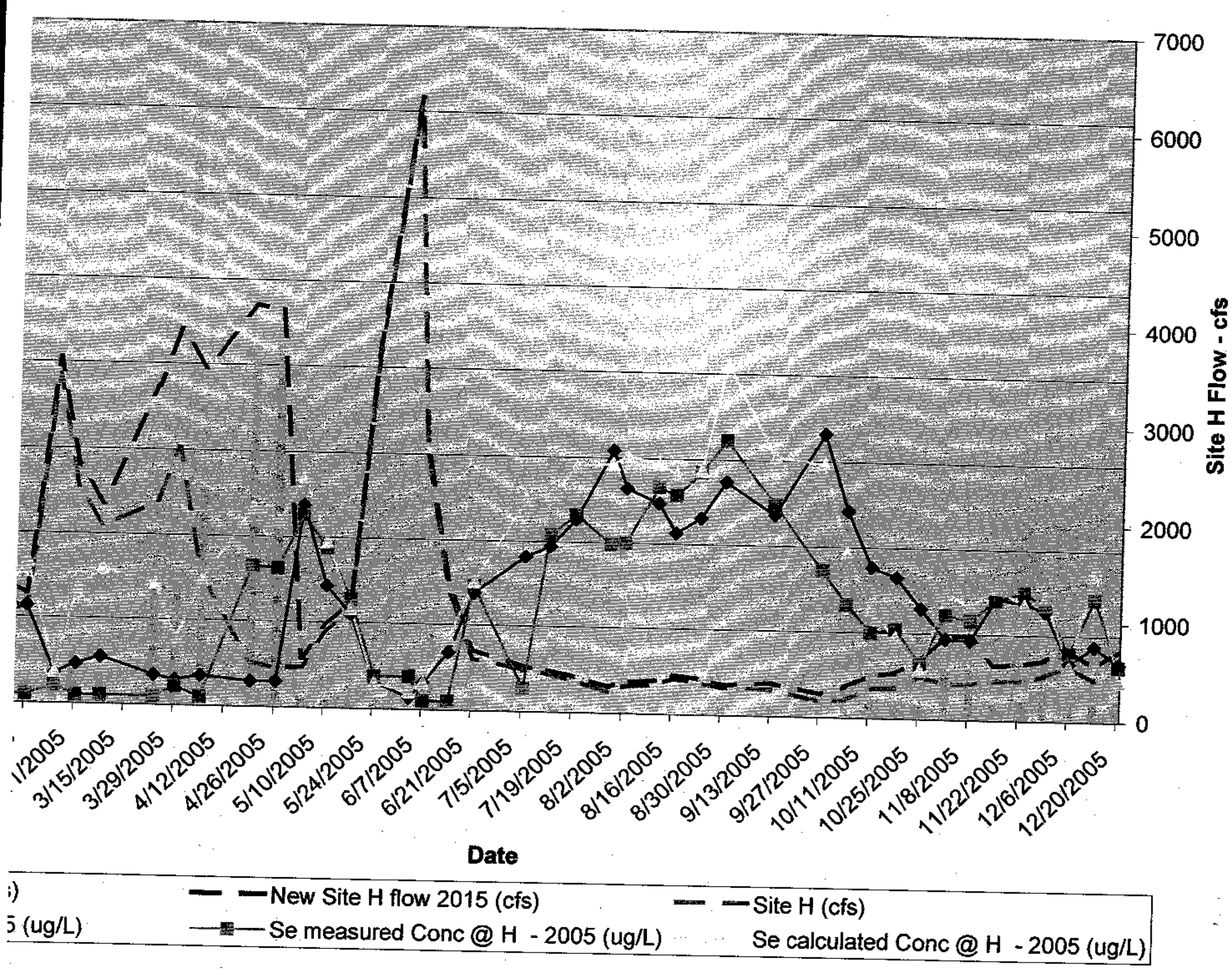
Site H Selenium Normal-Wet Year



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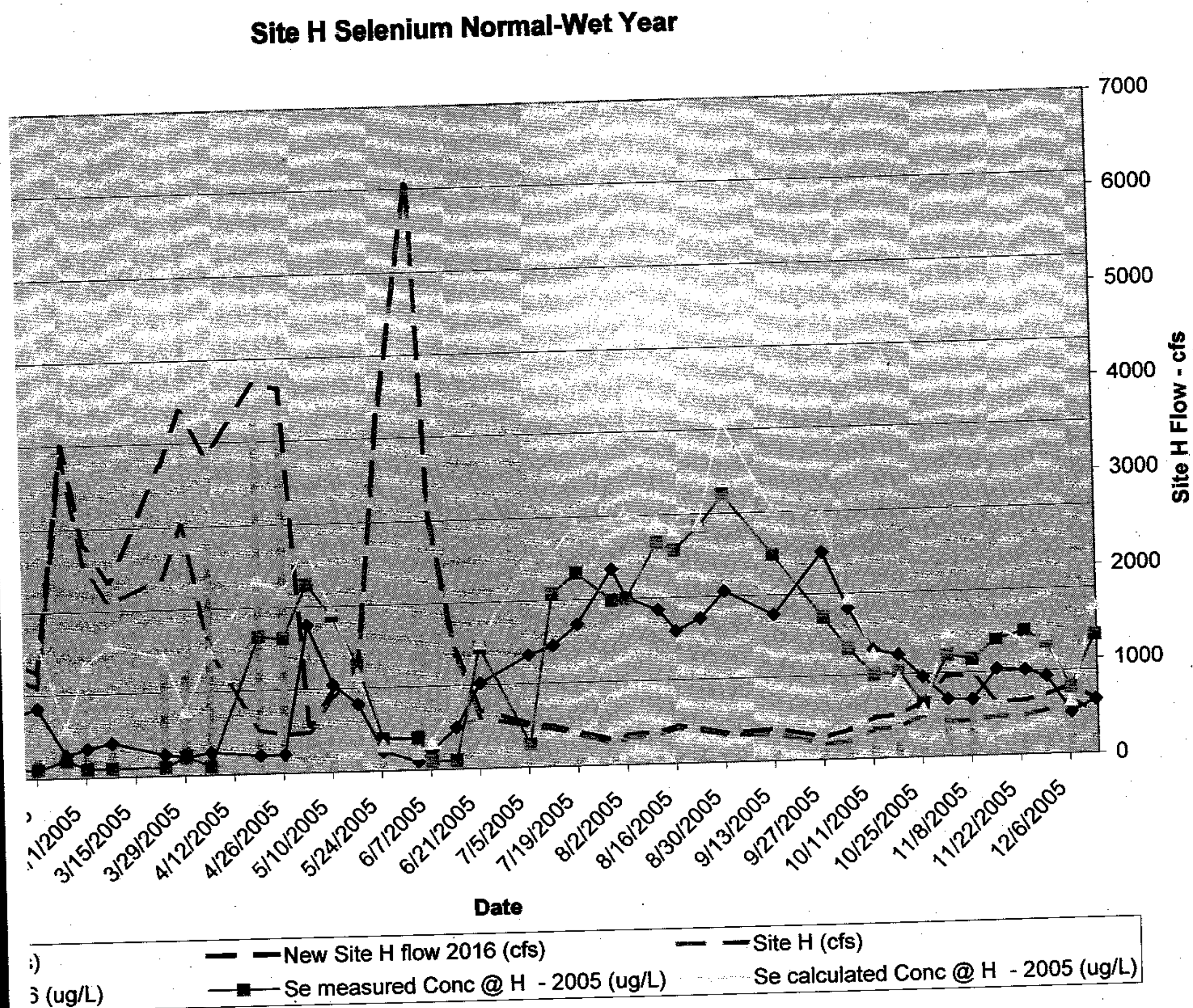

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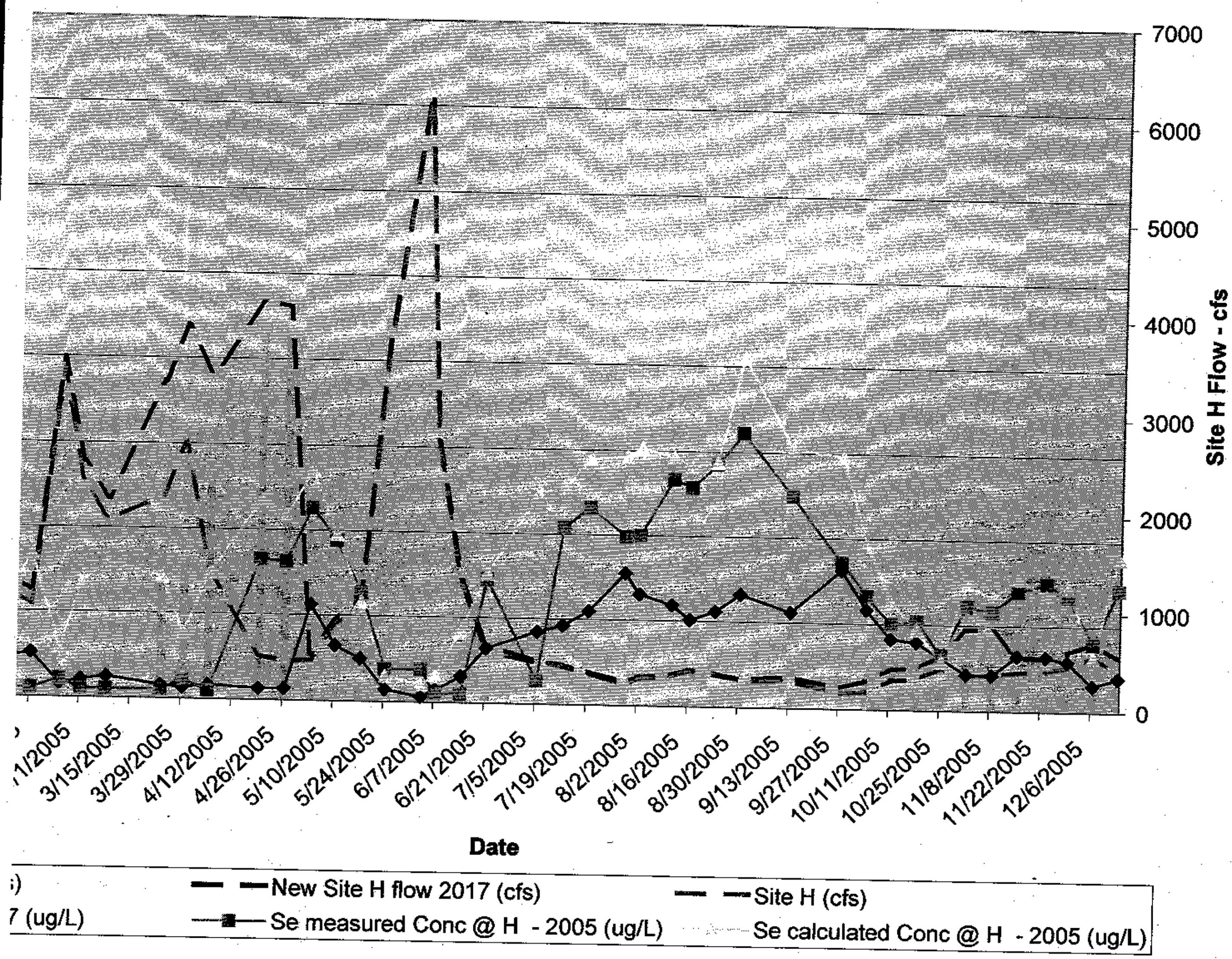
Site H Selenium Normal-Wet Year



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