Public Comment
Desalination Amendments
Deadline: 8/19/14 by 12:00 noon

POSEIDON WATER

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SWRCB Clerk

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Via email to: commentletters@waterboards.ca.gov

Ms. Jeanine Townsend, Clerk to the Board
State Water Resources Control Board
1001 "I" Street, 24th Floor
Sacramento, CA 95814

Re: Comment Letter – Desalination Amendments to California Ocean Plan

Dear Members of the Board:

Poseidon Water LLC ("Poseidon") appreciates the opportunity to provide the following comments on the July 3, 2014 draft Desalination Amendments to the Water Quality Control Plan for Ocean Waters of California ("Ocean Plan") addressing desalination facility intakes and brine discharges (hereafter, "Desalination Amendments"). In addition to the comments provided in this cover letter, we have provided and include herewith a redlined/~~strikeout~~ version of the draft Desalination Amendments (dated August 18, 2014) showing our requested changes to the July 3 draft, along with imbedded comments explaining the premise, rationale and justifications for those requested changes.

At the outset, Poseidon acknowledges the tremendous effort your staff has devoted over the past eighteen months to working with all stakeholders in developing the July 3 draft Desalination Amendments to ensure that they protect ocean water quality, while supporting the development of this important new water supply for California. In particular, we appreciate the discretion granted to the Regional Water Boards to evaluate site-specific factors for each desalination proposal and, where appropriate, to permit alternative intake and brine disposal technologies, and site-specific salinity standards, all in accord with Water Code Section 13142.5(b).

The purpose of the Desalination Amendments is to provide statewide guidance and consistency regarding the permitting of desalination facility intakes and discharges, consistent with Water Code Section 13142.5(b). Poseidon supports this purpose and is committed to working within the process established by the State Water Board to arrive at final Desalination Amendments to facilitate development and operation of desalination projects in California. As you may be aware, Poseidon is extremely interested in seeing the State Water Board adopt final Desalination Amendments to the Ocean Plan in a timely fashion, as they will ultimately govern Poseidon's project currently under construction in Carlsbad that will supply potable water to the San Diego County Water Authority ("SDCWA"), and the project we are currently developing in Huntington Beach. It is perhaps worth noting that these two projects – when completed and operational – will combine to provide more than 100 million gallons per day of ***new water supplies*** to Southern California communities. This equates to approximately 112,000 acre feet each year, every year, and at a time when the State Water Board *may* be considering reductions in Delta water exports *via* its Delta In-Flow standards setting process.

Poseidon believes that the July 3 draft Desalination Amendments represent a strong starting point for establishing appropriate standards for regulating the development of desalination plants on California's coast. However, certain modifications to the draft Desalination Amendments and Substitute Environmental Document (the "SED") are warranted, both to improve the effectiveness of the Desalination Amendments and to ensure its defensibility. This letter and the attachments hereto represent Poseidon's recommended changes to the Desalination Amendments and the SED to accomplish these goals.

Even though the Carlsbad Desalination Project intake and discharge has been fully permitted through the San Diego Regional Water Quality Control Board ("Regional Water Board"), the Desalination Amendments and its requirements will apply to the Carlsbad Desalination Project as a result of recent notification that the Encina Power Station will cease operations as early as June 1, 2017. Because the permit issued by the Regional Water Board for the Carlsbad project is predicated on operation of the power station and associated cooling water flows, the transition to stand-alone operation of the desalination plant will require planned upgrades to the intake system that will be regulated by the Desalination Amendments.

If the draft Desalination Amendments is adopted, Poseidon intends to take the following steps to bring the Carlsbad project into compliance with the Desalination Amendments:

- Revise the Flow, Entrainment and Impingement Minimization Plan approved by the Regional Board in 2009, to describe new technology measures that will be incorporated to comply with the Desalination Amendments and address the 2017 planned closure of the Encina Power Station.

- Relocate the intake providing seawater to the desalination facility from the Encina Power Station discharge to the intake and install new protective fish screen.

- Construct a new 200 MGD low-impact pump station to serve as the source of initial dilution water for the brine discharge and install new fish screens.

- Seek approval for a facility and site-specific brine mixing zone.

- Seek approval of a facility and site-specific salinity standard.

Poseidon's detailed comments on the draft Desalination Amendments, Staff Report, SED, and Appendix G are included in Attachments 1 through 4, respectively. The balance of this letter includes a summary of Poseidon's key concerns with the draft Desalination Amendments as currently drafted, and a summary of additional information that Poseidon requests the State Water Board consider prior to finalizing the Desalination Amendments and SED.

I. **Poseidon's Key Concerns with the Draft Desalination Amendments.** Poseidon's key concerns with the draft Desalination Amendments are summarized in the discussion that follows. Please see Attachment 1 for Poseidon's detailed comments on the draft Desalination Amendments and requested revisions.

A. Water Code 13142.5(b) Determination.

One of the primary purposes of the Desalination Amendments is to provide implementation procedures to the Regional Water Boards for conducting statutorily-mandated "evaluations of the best available site, design, technology and mitigation measures ***feasible*** to minimize the intake and mortality of all forms of marine life at new or expanded desalination facilities." (Water Code § 13142.5(b). Emphasis added). Yet the draft Desalination Amendments fail to provide the Regional Water Boards with direction regarding one of the more contentious aspects of the 13142.5(b) evaluation – the scope of the feasibility assessment. California's Fourth District Court of Appeal effectively resolved this debate in 2012 when it assessed whether the San Diego Regional Water Board complied with Water Code section 13142.5(b) in issuing Order R9-2009-0038 for the Carlsbad Desalination Project. *(Surfrider Foundation vs. California Regional Water Quality Control Board* (2012) 211 Cal. App. 4th 557, 581). The court determined that the Regional Board fully complied with section 13142.5(b) in relying on the definition of "feasible" under CEQA. (*Id.* at pp. 582-583).

Under CEQA, "feasible" means "capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, environmental, social, and technological factors." (Pub. Res. Code, §§ 21061). The California Coastal Act relies on the same definition. (Pub. Res. Code, § 30108 (Coastal Act)). Poseidon believes it is vital for the Regional Water Boards to have clear direction on the scope of the feasibility assessment and respectfully requests the final version of the Desalination Amendments include the definition of feasible that was relied upon by CEQA lead agencies, the San Diego Regional Water Board, and the California Coastal Commission (the "Coastal Commission"), and which was ultimately upheld by the Fourth District Court of Appeal.

B. Seawater Intakes.

Naturally, desalination plants must have seawater to desalinate and create potable water supplies. Water Code Section 13142.5(b) recognizes this by establishing *general* guidelines that govern (not prohibit) how desalination plants are to minimize intake and species mortality. It is critical to understand that the imposition of ***infeasible*** seawater intake conditions will significantly impede (or even prohibit) the development of desalination facilities permitted under the Water Code. The following three examples highlight the need for the State Water Board to ensure that the Desalination Amendments not only comply with Water Code Section 13142.5(b), but do not unreasonably impede the development of desalination projects that provide reasonable water quality and ocean species protection.

1. **Intake Technology Requirements.** The Staff Report supporting the Desalination Amendments carefully – and appropriately – embraces the notion that the Desalination Amendments should be "technology-neutral"; that is to say, not specifically establishing or favoring a specific type of technology as the "default" means of complying with impingement or entrainment standards. Poseidon agrees with this approach for several reasons. First, it complies with the statutory requirements of Water Code Section 13142.5(b) requiring an analysis of the "best available...technology...feasible" to minimize intake and mortality. Second, as State Water Board staff has routinely acknowledged (and the Staff Report/SED specifically states), not all intake

technologies are going to be feasible and appropriate at all desalination project sites. Imposing a "default" intake technology in the Desalination Amendments would contradict this known reality. Third, imposing a "default" intake technology in the Desalination Amendments would stifle and inhibit technological advancements that private companies might develop for desalination projects several years down the road.

The current draft of the Desalination Amendments provide that Regional Water Boards "shall require subsurface intakes" unless the Regional Water Boards make an affirmative finding of infeasibility under Section L.2.a.(2). On its face, this language conflicts with the State Water Board staff recommendation contained on page 58 of the Staff Report.[1] The language in the draft Desalination Amendments needs to be revised accordingly.

In a separate section, the Desalination Amendments provide that a Regional Water Board "may find that a combination of subsurface and surface intakes is the best feasible alternative to minimize intake and mortality of marine life." [L.2.d.(1)(a)ii] Yet, it is fundamentally not practical to expect a desalination facility operator to be able to effectively and feasibly manage the differing water quality and unique operational conditions associated with two completely different water intakes feeding a single desalination facility. This section should be omitted.

2. **Screen Slot Size.** The Desalination Amendments identify subsurface intakes as the preferred intake technology, but appropriately acknowledge the limitations of subsurface intakes and provides an alternative compliance path for those projects such as Carlsbad that utilize a surface intake. The draft Desalination Amendments requires project owners and operators who wish to operate a surface intake to install screens in the front of the intake which have extremely fine openings. A range of screen sizes proposed by staff is 0.5mm to 1.0 mm. The purpose of the small screen size is to reduce the entrainment of fish eggs and larvae.

Poseidon supports inclusion of feasible measures in the Desalination Amendments to reduce entrainment. However, we are concerned that there currently is insufficient operating data to determine the operating efficacy of the proposed screen sizes. The Carlsbad Desalination Project is an important water supply facility to the entire San Diego region. As such, Poseidon and the San Diego County Water Authority are making a significant investment in the design and construction of the facility to ensure the plant can operate at ***full capacity*** during adverse conditions, such as a severe algal bloom. The use of unproven screen technology could inhibit the flow of water and increase the maintenance requirements of the desalination facility, thereby compromising the reliability and efficiency of the plant. We respectfully urge the State Water Board Members to give further, careful consideration to the screen size recommendation to ensure the suitability of this technology for the intended use.

3. **Entrainment study duration.** The draft Desalination Amendments also require project owners and operators who wish to operate surface intakes to conduct an entrainment study of at least 36 consecutive months. A 36 month entrainment study would be excessive and

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[1] The staff recommends subsurface intakes as the "preferred technology for seawater intakes," rather than required technology.

would result in the idling of the Carlsbad project for at least 30 months.[2] The Desalination Amendments should follow the recommendation of the Expert Review Panel convened by the State Board and require 12 months of entrainment data which conforms to the guidelines for entrainment impact assessment included in Appendix E of the Staff Report. These guidelines, written by members of the State Water Board's "Expert Review Panel on Intake Impacts and Mitigation," state that entrainment sampling performed for 12 months is a reasonable period of sampling because the entrainment estimated by the ETM method is "much less subject to inter-annual variation. Therefore, a 12 month study should be adequate to account for variation in oceanographic conditions and larval abundance and diversity such that the abundance estimates are reasonably accurate.

C. Brine Discharge.

Most desalination plants existing in or planned for California use "reverse osmosis" as a means of removing salts from the seawater. The process results in a high-salinity brine byproduct which must be discharged. This is typically done by safely discharging the brine stream back into the ocean. There are a number of potential technologies available for desalination facility operators to safely discharge this brine stream, and the Staff Report does a commendable job of both describing those, and acknowledging that there is no single discharge technology that is considered "best available" for every site.

1. **Technology-neutral brine disposal determination.** The staff recommendation with respect to brine discharge technology is to establish state wide requirements for use of the "most protective brine discharge method after a facility specific evaluation" (Section 8.6.5 Staff Recommendation, page 93). Poseidon agrees with this technology-neutral recommendation, and note that it is specifically mandated under Water Code Section 13142.5(b). However, the draft Desalination Amendments does not carry through with this recommendation. Instead, the draft Desalination Amendments declare that commingling brine with wastewater and multiport diffusers are the "preferred technology" for brine discharge. The Draft Desalination Amendments further provide a streamlined process for owners and operators proposing such technologies. Poseidon has included several comments on the draft Desalination Amendments directed at conforming the draft Desalination Amendments to the staff recommendation (See Attachment 1.)

Fundamentally, however, Poseidon believes that the current draft of the Desalination Amendments should neither establish a "default" preferred technology for brine discharge, nor impose uneven requirements for assessing which discharge technologies are "best available" for a

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[2] The owner of the Encina Power Station recently notified Poseidon of its intent to terminate operation of the cooling water pumps on June 1, 2017. The transition to "stand-alone" operations requires design, permitting, and construction of OPA compliant intake and discharge modifications. Under the draft OPA, the San Diego Regional Water Quality Control Board would not be able to act on the revised report of waste discharge until at least 36 months of entrainment data had been collected and a final report issued. That means the Regional Board would not be able to issue the revised NPDES permit before January 1, 2018. Following the Regional Board approval, we expect that at least an additional six months would be required to secure a Coastal Development Permit, followed by 18 months to construct and commission the intake and outfall modifications. Under this schedule, the desalination plant would be required to curtail operations for approximately two and one-half years following retirement of the Encina Power Station.

given site and related environmental conditions. To this point, if the Desalination Amendments are going to include a requirement that proponents of "flow augmentation" (or in-plant dilution) must demonstrate that the technology provides a comparable level of protection to that of a multi-port diffuser, then the Desalination Amendments must also provide a standard against which flow augmentation proponents can compare their technology and demonstrate equal or better species protection.

2. **Discharge technology compliance standard.** In order to demonstrate a comparable level of environmental protection, the draft Desalination Amendments require that proponents of the alternative discharge technology provide a comparison of the marine life impacts of the proposed technology to that of the "preferred technology" identified by staff. The current draft Desalination Amendments lack guidance on the discharge technology compliance standard to be met under the Desalination Amendments, but there is substantial evidence in the Staff Report to support such an evaluation. Poseidon recommends that the guidance found on page 73 of the Staff Report be incorporated in the Desalination Amendments, "until additional data is available, we assume that larvae in 23 percent of the total entrained volume of diffuser dilution water are killed by exposure to lethal turbulence." This assumption is based on a finding in the State Water Board "Expert Panel Report" (Foster et al 2013) that modeled shearing stress form multiport diffusers and reported that larvae in 23 to 38 percent of the total entrained volume of dilution water may be exposed to lethal turbulence. (Staff Report at 73-74).

D. **Mitigation.** As part of the original San Diego Regional Water Board and Coastal Commission permitting of the Carlsbad Desalination Project, Poseidon was required to develop 55 acres of coastal wetland habitat to mitigate for the marine life impacts of the project that assumes a "stand-alone" operation (*i.e.*, no power plant). As such, the mitigation plan was designed to compensate for 100 percent mortality associated with the intake of 304 MGD of seawater. Poseidon expects to significantly reduce the entrainment mortality associated with the Carlsbad project as part of its transition to stand-alone operation. This would be accomplished through the implementation of the technology measures described at the top of this letter. The draft Desalination Amendments could disrupt the approved mitigation plan, which is already approved and under development.

The wetlands mitigation project for the Carlsbad project has been under development for seven years. After an exhaustive search of available mitigation sites, a location was selected within the National Wildlife Refuge managed by the U.S. Fish and Wildlife Service at the south end of San Diego Bay, where two former salt pond sites will be restored to sub-tidal and inter-tidal wetlands. Currently, Poseidon is working to finalize the environmental documentation as well as the design for the restored wetlands. Construction is expected to begin in mid-2016 and be completed by early 2018. Since the Carlsbad project will be required to comply with the Desalination Amendments, Poseidon is proposing changes to the draft Desalination Amendments to ensure that the mitigation requirements included in the final Desalination Amendments align with the mitigation efforts already under way on the Carlsbad project. We have identified two aspects of the draft Desalination Amendments that could be highly disruptive to Poseidon's mitigation plans if not modified:

1. **Siting of Mitigation Projects.** The draft Desalination Amendments requirement project proponent to locate mitigation within the "source water body" of the feedwater of a desalination facility. This would result in Poseidon having to abandon its current mitigation project and start over, even though it has already been determined that there are no suitable mitigation sites within the source water body. We hope this is an oversight and will be addressed in the final Desalination Amendments.

2. **Calculation of mitigation acreage**. Even though planned improvements to the Carlsbad project will reduce entrainment mortality, the methodology for calculating mitigation acreage requirements for the Carlsbad project under the draft Desalination Amendments would increase the mitigation requirements established by the Coastal Commission from 55 acres to approximately 130 acres. This is due to three provisions in the draft Desalination Amendments that differ from the Commission methodology for establishing mitigation for the entrainment impacts associated with the Carlsbad project:

a. **Mitigation ratio.** The draft Desalination Amendments require 1:1 mitigation of all impacts - regardless of the relative productivity of the habitat impacted - to that of the mitigation habitat provided. Consistent with past APF siting and sizing determinations, the Desalination Amendments should provide the Regional Water Boards sufficient flexibility to adjust the mitigation acreage as needed based on the expected productivity of the type of mitigation to be provided compared to the actual productivity within the facility's source water body. For example, the Coastal Commission determined that 49 acres were needed to mitigate for estuarine species and 64 acres were needed to mitigate for the open ocean species entrained by the Carlsbad project for a total of 130 acres. However, in recognition of the impracticality of creating 64 acres of offshore open water habitat, and recognizing the relatively greater productivity rates per acre of estuarine wetlands habitats, the Coastal Commission allowed the offshore impacts to be "converted" to estuarine mitigation areas. Based on a recommendation from a member of the Coastal Commission's Science Advisory Panel, Dr. Peter Raimondi,[3] the Coastal Commission determined that successfully restored wetland habitat would be ten times more productive than a similar area of nearshore ocean waters. Based on this determination, for every ten acres of nearshore impacted by the project, Poseidon was allowed to mitigate by creating or restoring one acre of estuarine habitat. As a result, 49 acres of estuarine wetlands habitat ("EWH") were required to mitigate for estuarine species, and 64 acres of EWH to mitigate for ocean species, for a total of 55.4 acres. Although this approach would result in "out of kind" mitigation, the Coastal Commission found it would produce overall better mitigation because: (1) it is not practical to create near-shore open water habitat; and (2) that habitat type is already well-represented along the shoreline. The Coastal Commission found that the Carlsbad Mitigation Plan would support a long-recognized need to increase the amount of coastal estuarine habitat in Southern California. (See Attachment 5 – Condition Compliance for Special Condition 8, Poseidon Resources Corporation, Marine Life Mitigation Plan, December 8, 2008.)

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[3] Dr. Raimondi is also a member of the State Water Board's "Expert Review Panel on Intake Impacts and Mitigation" ("ERP").

b. **Mitigation confidence interval.** The Desalination Amendments require that the mitigation acreage calculation be based on a 90 percent confidence level. This proposal has not been reviewed by the ERP. The Coastal Commission found that an 80 percent confidence interval would be acceptable under the site-specific conditions in Carlsbad. The uniform application of a 90 percent confidence interval does not take into consideration the varying levels of uncertainty associated with ETM/APF estimates, and therefore is overly conservative as applied to Carlsbad. Staff's proposal for a 90 percent confidence interval should be submitted to the State Water Board's "Expert Review Panel on Intake Impacts and Mitigation" ("ERP") for peer review.

c. **Requirement of mitigation of area inside the brine mixing zone.** The Desalination Amendments require 1:1 mitigation for the area within the brine mixing zone exceeding 2 ppt. Standard practice under the Ocean Plan is that dischargers do not mitigate for impacts within the zone of initial dilution ("ZID"). The NPDES permit for the Carlsbad project does not require mitigation inside the ZID. It is not clear why staff is recommending desalination facilities mitigate for impacts within the prescribed brine mixing zone, or even how such mitigation could be accomplished. In the case of the Carlsbad Desalination Project, the proposed ZID will be approximately 1000 feet.

E. **Salinity Standard.**

The recommended salinity standard set forth in the draft Desalination Amendments consist of a combination of two options evaluated in the Staff Report. Under Option 4, a receiving water limit of 2 ppt (parts per thousand) above natural background salinity levels would be established, applied at a distance of no greater than 100 meters from the point of discharge. Under Option 6, facility-specific receiving water limits could be established on a case-by-case basis. There are several potential problems with the way both of these options are structured which make it impossible to comply with any technology other than a multiport diffuser. Specifically:

1. **Facility-specific receiving water limit.** Based upon the proposed language in the draft Desalination Amendments, it does not appear possible for an operator to successfully develop a facility-specific receiving water limit:

a. LOEL vs. NOEL. The procedure set forth in the Desalination Amendments for establishing facility-specific receiving water limits uses a *completely different, and more restrictive*, standard of salinity than the standard that is used as a guideline throughout the entire draft Desalination Amendments. Throughout the draft Desalination Amendments, and indeed, throughout Roberts et al. 2012 (upon which much of the draft Desalination Amendments are based), it is stated that red abalone are the most sensitive species tested, with a LOEL (Lowest Observable Effect Level) of 35.6 ppt – or approximately 2.1 ppt above ambient salinity levels (in southern California waters). Thus, it is argued, a maximum regulatory salinity increase of 2 ppt is reasonable because it protects the most sensitive species. However, the language in the draft Desalination Amendments uses a completely different standard, which is NOEL (No Observable Effect Level). The NOEL value, according to Philips et al. (2012) is 34.9 ppt, or approximately *only 1.4 ppt above ambient* salinity levels (in southern California waters). Consequently, an operator that wishes to establish a site-specific receiving water limit under the draft Desalination

Amendments is held to a more restrictive salinity standard. Poseidon requests that the Desalination Amendments provide the facility-specific alternative receiving water standard be based on the same standard that will be used to establish the statewide receiving water limit of 2 ppt – the lowest observed effect level (LOEL).

b. Benthic monitoring study. The Desalination Amendments require that an owner or operator conduct a 36-month baseline biological conditions survey at the discharge location and at reference locations prior to commencing brine discharge. The discharge from the Carlsbad project will start in the 2nd quarter of 2015, so this option is currently not available to the Carlsbad project. In addition, the justification for a 36-month survey period prior to discharge is not clear. Comprehensive testing over a shorter period supported by existing biological data from nearby similar habitat should be sufficient for determining the biological characteristics of the site.

2. **Brine Mixing Zone.** The draft Desalination Amendments propose to limit the salinity increase to a maximum of 2 ppt over natural ocean salinity background, at a fixed distance of 100 meters from the point of discharge. The distance of 100 meters appears to have been selected based on the multiport diffuser. (Staff Report at 98.) The Staff Report states – without a stated basis - that facilities using flow augmentation should also be able to meet 2 ppt above ambient with 100 meters. (Staff Report at 99.) However, this is not correct. Depending on ambient mixing conditions (tides, wind, waves, current, temperature) in the receiving water, the Carlsbad project requires anywhere from 200 meters under good mixing conditions to 500 meters under poor mixing conditions to ensure strict compliance with the proposed 2 ppt standard.

The draft Desalination Amendments' definition of "brine mixing zone" alludes to a mechanism for establishing a larger brine mixing zone: "the brine mixing zone shall not exceed 100 meters ... unless otherwise authorized in accordance with this plan." However, the draft Desalination Amendments does not include a process for establishing a larger brine mixing zone. Failure to include a process for establishing a larger brine mixing zone in the Desalination Amendments would limit the brine discharge options available to the Carlsbad project to the environmentally inferior multiport diffuser. This appears to be an oversight, and we respectfully request that it will be addressed by staff in follow-up revisions.

3. **Definition of salinity.** The definition of salinity in the draft Desalination Amendments is as follows:

> *SALINITY is a measure of the dissolved salts in a volume of water. For the purposes of this Plan, salinity shall be measured as total dissolved solids in mg/l.* (Emphasis added).

Whereas the definition of natural background salinity in the draft Desalination Amendments is as follows:

> *NATURAL BACKGROUND SALINITY is the salinity* at a location that results from naturally occurring processes and is without apparent human influence. Natural background salinity shall be determined by averaging 20 years of historical salinity* data at a location. When historical data are not available, natural background salinity shall be determined by measuring*

salinity at depth of proposed discharge for three years, on a weekly basis prior to a desalination facility* discharging brine,* and the average salinity* shall be used to determine natural background salinity. Facilities shall establish a reference location with similar natural background salinity to be used for comparison in ongoing monitoring of brine* discharges.* (Emphasis added).

These two definitions are potentially at odds with each other depending on the analytical method used to establish the historical salinity data for a particular desalination facility. This is because the definition for Natural Background Salinity seeks to establish a long-term background value, and most of the data collected in the past that would be useful for these purpose measures total dissolved salts, not total dissolved solids ("TDS"). The definition of Salinity in the draft Desalination Amendments, on the other hand, provides that for purposes of determining compliance with the maximum 2 ppt increase over the natural background salinity at the edge of the brine mixing zone (or facility-specific receiving water limit), "salinity shall be measured as total dissolved solids."

As noted in Attachment 6, the Scripps Institution of Oceanography ("SIO") maintains a 30 year historical database of Pacific Ocean salinity that serves as the baseline background salinity for the Carlsbad project.[4] SIO's salinity data base, and most other salinity data bases, measure salinity as total dissolved salts not TDS. This is accomplished using electrical conductivity and reported as the Practical Salinity per PSS-78. This approach is viewed as the most accurate measure of Pacific Ocean salinity because it eliminates the uncharged (neutral) dissolved solids (such as dissolved organic matter) in seawater that are not related to the salinity. The San Diego Regional Water Quality Control Board adopted a similar approach in the order issued for the Carlsbad project. (See Table 5 on page E-8 of Order R9-2006-0065).

For the Carlsbad project, the long-term average Natural Background Salinity, as defined in the draft Desalination Amendments, is 33.5 ppt. The problem with using TDS in the definition of Salinity in the draft Desalination Amendments is that, relative to the historic SIO database measured using electrical conductivity and reported as the Practical Salinity per PSS-78, the TDS measurement is expected to yield a higher reading due to the presence of uncharged (neutral) dissolved solids (such as dissolved organic matter) in seawater that are included in the TDS measurement, but not related to the salinity. To the extent that the TDS measurement is greater than the PSS-78 salinity measurement, and this figure is used to confirm compliance with the 2 ppt increase (or site-specific receiving water limit) over the a historical average of 33.5 measured by the PSS-78 method, then Poseidon is not receiving the full benefit of the 2ppt increase (or site-specific receiving water limit) by the amount of the difference between the TDS and PSS-78 measurements. In order to reconcile this problem, we think the measurement of salinity needs to reflect the same method as that of the historical data base.

The following definition would correct this problem:

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[4] See Attachment 6 for information regarding the SIO historical salinity database and its applicability to the Carlsbad project.

SALINITY is a measure of the dissolved salts in a volume of water. For the purposes of this Plan, salinity shall be measured using electrical conductivity and reported as the Practical Salinity per PSS-78. Other measures of salinity, including absolute salinity as defined per TEOS-10 (in g/kg) , salinity as reflected in total dissolved solids measurements (in mg/L), or the sum of the major anions and cations (chloride, sulfate, bicarbonate, bromide, sodium, magnesium, calcium, and potassium, in mg/L) may also be collected and reported to determine proper correlations with PSS-78 salinity measurements.

4. **Receiving Water Limit for Salinity.** The Desalination Amendments provide that brine discharges from desalination facilities shall not exceed 2.0 parts per thousand above the natural background salinity. Natural background salinity is defined as the 20-year average salinity at the project location. The database that makes up the natural background salinity for the Carlsbad Project shows a mean salinity of 33.5 ppt, a minimum salinity of 27.4 ppt, and a maximum salinity of 34.2 ppt over the last 20 years. Sixty-four percent of daily salinity measurements over the last 20 years are above the 33.5 ppt average. This means that the Carlsbad facility would have to operate at less than a 2 ppt increase over the ambient salinity 64 percent of the time. This operating requirement would severely impact plant reliability. To address this problem, Desalination Amendments should be revised such that the natural background salinity shall be determined by averaging 20 years of historical salinity* data at a location unless the actual salinity measured at the facility intake is greater than the 20 year average salinity, in which case, the natural background salinity shall be the lower of: (1) the actual salinity measured at the intake, or (2) the maximum salinity level measured in the 20 years of historical salinity data (i.e., 33.5 to 34.2 ppt in Carlsbad). (See Attachment 7, Historical Analysis of Salinity for Water Quality Monitoring).

5. **Definition of Brine Mixing Zone.** Project operators would not be able to comply with the proposed prohibition of acutely toxic conditions in the brine mixing zone. The definition of brine mixing zone should include an allowance for acute toxicity consistent with the definition of Acute Toxicity in the Ocean Plan -- "The mixing zone for the acute* toxicity* objective shall be ten percent (10%) of the distance from the edge of the outfall structure to the edge of the [brine mixing zone*]." This appears to be an oversight, and we respectfully request that it will be addressed by staff in follow-up revisions.

II. **Additional information Poseidon requests the State Water Board to consider prior to finalizing the Desalination Amendments.** During the administrative process leading up to the release of the draft Desalination Amendments, Poseidon submitted a number of technical studies and reports to staff for consideration in evaluating the use of low-impact pumps for flow augmentation as a method for brine disposal technology. Included below are a summary of the studies and reports provided and the applicability of that information to the draft Desalination Amendments. Copies of these studies and reports are included as attachments hereto.

A. **U.S. Bureau of Reclamation research on low-impact pumps for transfer of juvenile pumps.** In February 2014, Poseidon provided to State Water Board staff a copies of U.S. Bureau of Reclamation's ("USBR") studies analyzing the low-impact pump technology at the Red Bluff Research Pumping Plant Program (the "RPP") on the Sacramento River. The full-scale pumping plant was constructed to test new fish-protection technology, including Archimedes lifts and internal helical pumps. The research program assessed seasonal patterns of fish entrainment from the Sacramento River, and mortality, injury, and stress of hatchery-reared juvenile Chinook salmon passed through the pumps. The RPP has produced a wealth of studies and peer-reviewed reports on various aspects of the Archimedes Lifts and impacts on juvenile and larval salmonids, all of which are currently available on the USBR website.[5] Of particular interest and value with respect to the State Water Board's evaluation of flow augmentation as a brine disposal technology are the following reports:

Investigations of Fish Entrainment By Archimedes and Internal Helical Pumps at the Red Bluff Research Pumping Plant, Sacramento River, California: February 1997-June 1998, October 1999. A copy of this report is included in Attachment 8.

Wild Fish Entrainment by Archimedes Lifts and an Internal Helical Pump at the Red Bluff Research Pumping Plant, Upper Sacramento River, California: February 1997-May 2000, December 2001. A copy of this report is included in Attachment 9.

B. **Hydrodynamic Impacts on Marine Life Due to Brine Dilution Strategies for Seawater Desalination Plants**. In 2013, Poseidon provided to State Water Board staff a copies a report by Jenkins and Wasyl. This report provided a comparison of the expected entrainment mortality in the dilution water used for flow augmentation and multiport diffusers. Subsequently, Dr. Jenkins revised the report in response to comments received from staff, and submitted it to the *Journal of Environmental Science and Technology* for consideration for publication. A copy of the revised manuscript is included in Attachment 10 of Poseidon's comments on the Desalination Amendments.

Thank you for the consideration given to our prior comments on the Desalination Amendments, as well as the State Water Board's commitment to promoting desalination as a means of augmenting California's potable water supply.

Sincerely,

Peter MacLaggan

Peter MacLaggan
Senior Vice President

Cc: Maureen Stapleton, San Diego County Water Authority

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[5] Information about the research program which staff may find very useful in finalizing the OPA can be found at the following USBR website: http://www.usbr.gov/pmts/tech_services/tracy_research/redbluff/index.html.

List of Attachments

Attachment 1 – Poseidon Comments on Appendix A – Proposed Desalination Amendments to California Ocean Plan.

Attachment 2 -

- **A.** Poseidon Comments on Draft Staff Report;
- **B.** Alden Labs Comments on Draft Staff Report and Substitute Environmental Documentation, Tim Hogen, August 13, 2014;
- **C.** Carlsbad Seawater Desalination Project Energy Minimization and Greenhouse Gas Plan, July 30, 2008, and
- **D.** Poseidon Resources Huntington Beach Desalination Plant Energy Minimization and Greenhouse Gas Plan, April 30, 2010.

Attachment 3 – Latham and Watkins Comments on the Draft Substitute Environmental Documentation, Christopher Garrett, August 13, 2014.

Attachment 4 – Poseidon Comments on Appendix G – Economic Analysis.

- **A.** Option 1 – Screen Open Intake with Flow Augmentation Using Low-Impact Pumps;
- **B.** Option 2 – Screened Intake with Multiport Diffuser;
- **C.** Option 3 – Subsurface Intake with Flow Augmentation Using Low-Impact Pumps, and
- **D.** Option 4 – Subsurface Intake with Multiport Diffuser.

Attachment 5 – Condition Compliance for Carlsbad Desalination Project No. E-06-013 – Poseidon Resources (Channelside), LLC; Special Condition 8 – Submittal of Marine Life Mitigation Plan.

Attachment 6 – Salinity Measurement for Water Quality Monitoring, Ms. Melissa Carter, M.S., Reinhard Flick, Ph.D., August 14, 2014.

Attachment 7 – Historical Analysis of Salinity for Desalination Water Quality Monitoring, Ms. Melissa Carter, M.S., Reinhard Flick, Ph.D., August 18, 2014.

Attachment 8 – Investigations of Fish Entrainment By Archimedes and Internal Helical Pumps at the Red Bluff Research Pumping Plant, Sacramento River, California: February 1997 – June 1998, Sandra Borthwick, Richard Corwin, Charles Liston, October 1999.

Attachment 9 – Wild Fish Entrainment By Archimedes Lifts and Internal Helical Pump at the Red Bluff Research Pumping Plant, Upper Sacramento River, California: February 1997 – May 2000, Sandra Borthwick, Richard Corwin.

Attachment 10 – Hydrodynamic Impacts on Marine Life Due to Brine Dilution Strategies for Seawater Desalination Plants, Scott Jenkins, Dan Cartamil, Joseph Wasyl, Gerald Spain, Alexander Lin.

Attachment 1

Poseidon Comments on Appendix A –

Proposed Desalination Amendments to California Ocean Plan

Public Release
Preliminary Draft
Ocean Plan Desalination Amendment

L. Implementation Provisions for Desalination Facilities*

1. Applicability and General Provisions

   a. Chapter III.L applies to desalination facilities* using seawater.* Chapter III.L.2 does not apply to desalination facilities* operated by a federal agency. Chapter III.L.2, L.3, and L.4 do not apply to portable desalination facilities* that produce less than 0.05 MGD of desalinated water and are operated by a governmental agency. These standards do not alter or limit in any way the authority of any public agency to implement its statutory obligations. The Executive Director of the State Water Board may temporarily waive the application of chapter III.L. to desalination facilities* that are operating to serve as a critical short term water supply during a state of emergency as declared by the Governor.

   b. Definitions of New, Expanded, and Existing Facilities:

      (1) For purposes of chapter III.L, “existing facilities” means desalination facilities* that have been issued an NPDES permit and all building permits and other governmental approvals necessary to commence construction for which the owner or operator has relied in good faith on those previously-issued permits and approvals and commenced construction of the facility beyond site grading prior to [effective date of this Plan]. Existing facilities do not include a facility for which permits and approvals were issued and construction commenced after January 1, 1977, but for which a regional water board did not make a determination of the best site, design, technology, and mitigations measures feasible, pursuant to Water Code section 13142.5, subdivision (b) (hereafter Water Code section 13142.5(b)).

      (2) For purposes of chapter III.L, “expanded facilities” means existing facilities for which, after [effective date of the Plan], the owner or operator does either of the following in a manner that could increase intake or mortality of marine life: 1) increases the amount of seawater* used either exclusively by the facility or used by the facility in conjunction with other facilities or uses, or 2) changes the design or operation of the facility. To the extent that the desalination facility* is co-located with another facility that withdraws water for a different purpose and that other facility reduces the volume of water withdrawn to a level less than the desalination facility’s* volume of water withdrawn, the desalination facility* is considered to be an expanded facility.

(3) For purposes of chapter III.L, “new facilities” means desalination facilities* that are not existing facilities or expanded facilities.

c. Chapter III.L.2 (Water Code §13142.5(b) Determinations for New and Expanded Facilities: Site, Design, Technology, and Mitigation Measures) applies to new and expanded desalination facilities* withdrawing seawater.*

d. Chapter III.L.3 (Receiving Water Limitation for Salinity*) applies to all desalination facilities* that discharge into ocean waters.*

e. Chapter III.L.4 (Monitoring and Reporting Programs) applies to all desalination facilities* that discharge into ocean waters.*

f. References to the regional water board include the regional water board acting under delegated authority. For provisions that require consultation between regional water board and State Water Board staff, the regional water board shall notify and consult with the State Water Board staff prior to making a final determination on the item requiring consultation.

2. Water Code section 13142.5(b) Determinations for New and Expanded Facilities: Site, Design, Technology, and Mitigation Measures Feasibility Considerations

   a. General Considerations

      (1) The owner or operator shall submit a request for a Water Code section 13142.5(b) determination to the appropriate regional water board as early as practicable. This request shall include sufficient information for the regional water board to conduct the analyses described below. The regional water board in consultation with the State Water Board staff may require an owner or operator to provide additional studies or information if needed. Studies and models are subject to the approval of the regional water board in consultation with State Water Board staff.

      (2) The regional water board shall analyze, review and approve~~conduct a~~ the owner or operator’s Water Code section 13142.5(b) analysis of all new and expanded desalination facilities.* A Water Code section 13142.5(b) analysis may include future expansions at the facility. The regional water board shall first analyze separately as independent considerations a range of feasible* alternatives for the best available site, the best design, the best technology, and the best available mitigation measures to minimize intake and mortality of marine life. Then, the regional water board shall consider all four factors collectively, and include the best combination of alternatives feasible*

Comment [PM1]: The stated purpose of the Desalination Amendments are to provide implementation procedures for conducting Water Code section 13142.5(b) “evaluations of the best available site, design, technology and mitigation measures feasible to minimize the intake and mortality of all forms of marine life at new or expanded desalination facilities.” (Emphasis added). Yet the draft Desalination Amendments fail to provide the regional water boards with direction regarding one of the more contentious aspects of the 13142.5(b) evaluation – the scope of the feasibility assessment. The Court of Appeal effectively resolved this debate in 2012 when it assessed whether the San Diego Regional Water Board complied with Water Code section 13142.5(b) in issuing Order R9-2009-0038 for the Carlsbad Desalination Project. *(Surfrider Found. V. Cal. Reg’l Water Quality Control Bd.* (2012) 211 Cal. App. 4th 557, 581). The court determined that the Regional Board fully complied with section 13142.5(b) in relying on the definition of “feasible” under CEQA. (*Id*. at pp. 582-583). Under CEQA, “feasible” means “capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, environmental, social, and technological factors.” (Pub. Res. Code, §§ 21061). The Coastal Act relies on the same definition. (Pub. Res. Code, § 30108 (Coastal Act)). This definition of Feasibility has been included in Poseidon’s suggested revisions to the Definition of Terms section of the Ocean Plan.

Comment [PM2]: It is important that the language here accurately tracks WC section 13142.5(b).

Comment [PM3]: Same comment.

Comment [PM4]: Same comment.

that in combination minimize intake and mortality of marine life. The best combination of alternatives feasible* may not always include the best alternative under each individual factor because some alternatives may be mutually exclusive, redundant, or infeasible in combination.

Comment [PM5]: Same comment.

(3) The regional water board's 13142.5(b) analysis for expanded facilities shall~~may~~ be limited to those expansions or other changes that result in the increased intake or mortality of marine life.~~, unless the regional water board determines that additional measures that minimize intake and mortality of marine life are feasible for the existing portions of the facility.~~

Comment [PM6]: This provision discourages marginal increases in productive capacity of the plant and associated efficiency gains by putting the entire facility at risk of having to come into compliance with technology improvements. As a matter of public policy, the state should encourage the optimal utilization of existing infrastructure.

(4) In conducting the Water Code section 13142.5(b) determination, the regional water boards shall consult with other state agencies involved in the permitting of that facility, including, but not limited to: California Coastal Commission, California State Lands Commission, California Department of Fish and Wildlife, and California Department of Public Health. The regional water board shall consider project-specific decisions made by other state agencies; however, the regional water board is not limited to project-specific requirements set forth by other agencies and may include additional requirements in a Water Code section 13142.5(b) determination.

(5) A regional water board may expressly condition a Water Code section 13142.5(b) determination based on the expectation of the occurrence of a future event. Such future events may include, but are not limited to, the permanent shutdown of a co-located power plant with intake structures shared with the desalination facility* or a reduction in the volume of wastewater available for the dilution of brine.* The regional water board must make a new Water Code section 13142.5(b) determination if the foreseeable future event occurs.

   (a) The owner or operator shall provide notice to the regional water board as soon as it becomes aware that the expected future event will occur, and shall submit a new request for a Water Code section 13142.5(b) determination to the regional water board at least one year prior to the event occurring. If the owner or operator does not become aware that the event will occur at least one year prior to the event occurring, the owner or operator shall submit the request as soon as possible.

   (b) The regional water board may allow up to five years from the date of the event for the owner or operator to make modifications to the facility required by a new Water Code

13142.5(b) determination, provided that the regional water board finds that any water supply interruption resulting from the facility modifications requires additional time for water users to (1) obtain a temporary replacement supply of comparable quantity, quality, and reliability; or (2) the owner of the facility needs to continue operations to receive payments to pay any project specific related financing while modifications are being implemented.

Comment [PM7]: Water agencies are investing in desalination facilities to diversify their water supply portfolio to achieve specific goals with respect to water supply quantity, quality and reliability. Therefore the length of deferral of Section 13142.5(b) modifications should be linked to the ability of the water agency served by the desalination facility to obtain a temporary replacement supply of water with a comparable quantity, quality, and reliability. Similarly, the owner of the facility may have financing that requires the facility continue operating while modifications are implemented (as is the case with the Carlsbad project). The deferral should be available to an owner that needs to continue operations to receive payments to pay any project specific related financing while modifications are being implemented.

(c) If the regional water board makes a Water Code section 13142.5(b) determination for a desalination facility* that will be co-located with a power plant, the regional water board shall condition its determination on the power plant remaining in compliance with the Water Quality Control Policy on the Use of Coastal and Estuarine Waters for Power Plant Cooling.

b. Site is the general onshore and offshore location of a new or expanded facility. There may be multiple potential facility design configurations within any given site. For each potential site, in order to determine whether a proposed facility site best minimizes intake and mortality of marine life, the regional water board shall require the owner or operator to:

(1) Consider whether the identified regional need for desalinated* water identified is consistent with any applicable general or coordinated plan for the development, such as a county general plan, or utilization or conservation of the water resources of the state, ~~such as a county general plan,~~ such as an integrated regional water management plan or an urban water management plan as well as available current and projected water supplies. A design capacity in excess of the identified regional water need for desalinated* water shall not be used by itself to declare subsurface intakes as infeasible.

Comment [PM8]: This sentence should be moved to the technology section.

(2) Analyze the feasibility of placing intake, discharge, and other facility infrastructure in a location that avoid impacts to sensitive habitats* and sensitive species.

(3) Analyze the direct and indirect effects on marine life resulting from facility construction and operation, individually and in combination with potential anthropogenic effects on marine life resulting from other past, present, and reasonably foreseeable future activities within the ~~geographic scope of the~~ area affected by the facility.

Comment [PM9]: Not clear what this means.

(4) Analyze oceanographic, bathymetric, geologic, hydrogeologic, and seafloor topographic conditions within the area affected by the project, so the siting of a facility, including the intakes and discharges, minimize the intake and mortality of marine life.

Comment [PM10]: Clarify scope of analysis.

(5) Analyze the presence of existing infrastructure, and the availability of wastewater to dilute the facility's brine* discharge.

(6) Ensure that the intake and discharge structures are not located within a MPA or SWQPA.* Discharges shall be sited at a sufficient distance from a MPA or SWQPA* so that there are no measurable impacts from the discharge on a MPA or SWQPA* and so that the salinity* within the boundaries of a MPA or SWQPA* does not exceed natural background salinity.* ~~To the extent feasible, intakes shall be sited so as to maximize the distance from a MPA or SWQPA.*~~

Comment [PM11]: It is impossible to demonstrate "no impacts," which potentially exposes the projects to litigation.

Comment [PM12]: The first two sentences adequately address the need to protect MPAs and SWQPAs. Last sentence of this section should be deleted because it is redundant and open to subjective interpretation.

c. Design is the layout, form, and function of a facility, including the configuration and type of infrastructure, including intake and outfall structures. The regional water board shall require that the owner or operator perform the following in determining whether a proposed facility design best minimizes intake and mortality of marine life:

(1) For each potential site, analyze the potential design configurations of the intake, discharge, and other facility infrastructure to avoid impacts to sensitive habitats* and sensitive species.

(2) If the regional water board determines that subsurface intakes are infeasible and surface water intakes are proposed instead, analyze potential designs for those intakes in order to minimize the Area Production Forgone* (APF). The intake shall be designed to minimize entrainment of organisms when operational.

(3) Design the outfall so that the brine mixing zone* does not encompass or otherwise adversely affect existing sensitive habitat.*

(4) Design the outfall so that discharges do not result in dense, negatively-buoyant plumes that result in adverse effects due to elevated salinity* above 2 ppt or above the facility-specific salinity standard (if applicable) or anoxic conditions occurring outside the brine mixing zone.* An owner or operator must demonstrate that the outfall meets this requirement through plume modeling and/or field studies. Modeling and field studies shall be approved by the regional water board in consultation with State Water Board staff.

Comment [PM13]: Clarify intent.

(5) Design outfall structures to minimize the suspension of benthic sediments.

d. Technology is the type of equipment, materials,* and methods that are used to construct and operate the design components of the desalination facility.* The regional water board shall apply the following considerations in determining whether a proposed technology best minimizes intake and mortality of marine life:

(1) Considerations for Intake Technology:

(a) Subject to Section L.2.a.(2), the preferred technology for minimizing mortality of marine life resulting from the intake of seawater is ~~regional water board shall require~~ subsurface* intakes unless the regional water board~~it~~ determines that subsurface* intakes are infeasible based upon an analysis of the criteria listed below, in consultation with State Water Board staff.

i. The regional water board shall consider the following criteria in determining feasibility of subsurface* intakes: geotechnical data, hydrogeology, benthic topography, oceanographic conditions, presence of sensitive habitats,* presence of sensitive species, energy use; construction impacts, impact on recreational resources, freshwater aquifers, local water supply, and existing water users; desalinated* water conveyance, existing infrastructure, co-location with sources of dilution water, design constraints (engineering, constructability, environmental), the ability of being accomplished in a successful manner within a reasonable period of time, and project life cycle cost. Project life cycle cost shall be determined by evaluating the total cost of planning, design, land acquisition, construction, operations, maintenance, mitigation, equipment replacement and disposal over the lifetime of the facility, in addition to the cost of decommissioning the facility. In addition, the regional water board may evaluate other site- and facility-specific factors.

ii. ~~The regional water board may find that a combination of subsurface* and surface intakes is the best feasible alternative to minimize intake and mortality of marine life~~.

Comment [PM14]: The staff recommendation with respect to subsurface intakes presented on page 58 of the Staff Report is: "Option 3: Establish subsurface intakes as the preferred technology for seawater intakes." This change accurately reflects the staff recommendation.

Comment [PM15]: This additional text is needed to complete 13142.5(b) feasibility criteria set established in *Surfrider Found. v. Cal. Reg'l Water Quality Control Bd.* (2012) 211 Cal. App. 4th 552-553.

Comment [PM16]: It is not practical to expect the operator would be able to effectively manage the differing water quality and operational conditions associated with two fundamentally different intakes feeding one treatment facility.

(b) Installation and maintenance of a subsurface* intake shall avoid, to the maximum extent feasible, the disturbance of sensitive habitats* and sensitive species.

(c) If subsurface* intakes are not feasible, the regional water board may approve a surface water intake subject to the following conditions.

i. The regional water board shall require that surface water intakes be screened. Screens must be functional while the facility is withdrawing seawater.*

ii. In order to reduce entrainment, all surface water intakes must be screened with a [*0.5 mm (0.02 in)/ 0.75 (0.03 in)/ 1.0 mm (0.04 in)*] or smaller slot size screen when the desalination facility* is withdrawing seawater.* [*NOTE: The State Water Board intends to select a single slot size, but is soliciting comments on whether 0.5 mm, 0.75 mm, 1.0 mm, or some other slot size is most appropriate to minimize intake and mortality of marine life.*]

iii. An owner or operator may use an alternative method of preventing entrainment so long as the alternative method provides equivalent protection of eggs, larvae, and juvenile organisms as is provided by a [*0.5 mm (0.02 in)/ 0.75 (0.03 in)/ 1.0 mm (0.04 in)*] slot size screen [*see note above*]. The owner or operator must demonstrate the effectiveness of the alternative method to the regional water board. The owner or operator must conduct a pilot study to demonstrate the effectiveness of the alternative method, and use an Empirical Transport Model* (ETM)/ Area of Production Forgone* (APF) approach* to estimate entrainment within the source water body*~~at the pilot study location~~. The entrainment study period shall be at least 12~~36~~ consecutive months and sampling shall be designed to account for variation in oceanographic conditions and larval abundance and diversity such that abundance estimates are reasonably accurate. Samples must be collected using a mesh size no larger than 335 microns and individuals collected shall be identified to the lowest taxonomical level practicable. The ETM/APF analysis* shall be representative of the entrained species. At their discretion, the regional water boards may permit the use of existing entrainment data from the facility to meet this requirement.

Comment [PM17]: Poseidon supports inclusion of feasible measures in the Desalination Amendments to reduce entrainment. However, we are concerned that there currently is insufficient operating data to determine the efficacy of the proposed screen sizes. The Carlsbad Desalination Project is an important water supply facility. As such, Poseidon and the Water Authority are making a significant investment in the design and construction of the facility to ensure the plant can operate at full capacity during adverse conditions, such as a severe red tide event. The use of unproven screen technology could inhibit the flow of water and increase the maintenance requirements of the desalination facility, thereby compromising the reliability and efficiency of the plant. Further consideration should be given to the screen size recommendation to ensure the suitability of this technology for the intended use.

Comment [PM18]: Entrainment sampling needs to be in the source water body of the intake. Whereas, the pilot study would need to be conducted in a laboratory setting to obtain adequate quantities of fish eggs and larval fish to evaluate the low-impact entrainment mortality. Poseidon is working with Hubbs Seaworld Research Institute to evaluate larval fish and fish egg survival associated with the low-impact pump operation. The research facility is well equipped to provide sufficient quantities of larval fish and fish eggs, holding tanks and supervision of appropriately trained marine scientists to oversee the pilot study.

Comment [PM19]: The Desalination Amendments should permit the use of 12 months of entrainment data which conforms to the guidelines for entrainment impact assessment included in Appendix E of the Staff Report. (Guidance Documents for Assessing Entrainment Including Additional Information on the Following Loss Rate Models: Fecundity Hindcasting (FH), Adult Equivalent Loss (AEL) and Area of Production Forgone using an Empirical Transport Model (ETM/APF)). These guidelines, written by members of the SWRCB's Expert Review Panel on Intake Impacts and Mitigation, states that entrainment sampling that is done for 12 months is a reasonable period of sampling because the entrainment estimated by the ETM method is "much less subject to inter-annual variation. (Id. at 97.) Therefore, a 12 month study would be adequate to account for variation in oceanography conditions and larval abundance and diversity such that the abundance estimates are reasonably accurate. All of the intake assessments in California, except one, have been conducted for a period of one year. A 36 month study would be excessive and would result in the idling of the Carlsbad project for two to three years.

(d) In order to minimize impingement, through-screen velocity at the surface water intake shall not exceed 0.15 meters per second (0.5 feet per second).

(2) Considerations for Brine* Discharge Technology:

(a) ~~The preferred technology for minimizing intake and mortality of marine life resulting from brine* disposal is to commingle brine* with wastewater (e.g., agricultural, sewage, industrial, power plant cooling water, etc.) that would otherwise be discharged to the ocean, unless the wastewater is of suitable quality and quantity to support domestic or irrigation uses~~.

(b) ~~Multiport diffusers* are the next best method for disposing of brine* when the brine* cannot be diluted by wastewater and when there are no live organisms in the discharge. Multiport diffusers* shall be engineered to maximize dilution, minimize the size of the brine mixing zone,* minimize the suspension of benthic sediments, and minimize marine life mortality.~~

(c) The regional water board shall require the owner or operator to analyze the brine* disposal technology or combination of brine* disposal technologies that best reduces the effects of the discharge of brine* on marine life due to intake-related entrainment, osmotic stress from elevated salinity,* turbulence that occurs during water conveyance and mixing, and shearing stress at the point of discharge.

(d) Brine* disposal technologies ~~other than~~ such as wastewater dilution and multiport diffusers,* ~~such as~~ and flow augmentation,* may be used if an owner or operator can demonstrate to the regional water board that the technology provides a comparable level of protection. For comparison purposes, the regional water board shall assume that larvae in 23 percent of the total entrained volume of diffuser dilution water are killed by exposure to lethal turbulence until and unless additional data is available. The owner or operator must evaluate all of the individual and cumulative effects of the proposed alternative discharge method on marine life mortality, including (where applicable); intake-related entrainment, osmotic stress, turbulence that occurs during water conveyance and mixing, and shearing stress at the point of discharge. When determining the level of protection provided by a brine* disposal technology or combination of technologies, for purposes of the comparison

Comment [PM20]: The staff recommendation with respect to brine discharge technology is to amend the Ocean Plan to establish state wide requirements for use of the most protective brine discharge method after a facility specific evaluation. (See Section 8.6.5 Staff Recommendation, page 93). Given the technology neutral approach recommended by staff, it is inappropriate to declare commingling brine with wastewater as the "preferred technology" in the Desalination Amendments.

Comment [PM21]: See previous comment. Additionally, the staff report acknowledges that multiport diffusers "may not be the most environmentally protective technology." (See Option 4, page 91 of Staff Report). Given the technology neutral approach recommended by staff, it is inappropriate to declare multiport diffusers as "the next best method for disposing brine" in the Desalination Amendments.

Comment [PM22]: This paragraph accurately reflects the recommendation in the Staff Report. (See Option 5, page 91-92 and Section 8.6.5 Staff Recommendation, page 93 of the Staff Report).

Comment [PM23]: Under the technology neutral approach recommended by staff, wastewater dilution and multiport diffusers should not be excused from having to demonstrate that it is the technology that best reduces the effects of the discharge of brine on marine life.

Comment [PM24]: In order to demonstrate a comparable level of environmental protection, the draft Desalination Amendments require that proponents of the alternative discharge technology provide a comparison of the marine life impacts of the proposed technology to that of the "preferred technology" identified by staff. The current draft Desalination Amendments lack guidance on the discharge technology compliance standard to be met under the Desalination Amendments, but there is substantial evidence in the Staff Report to support such an evaluation. Poseidon recommends that the guidance found on page 73 of the Staff Report be incorporated in the Desalination Amendments: "until additional data is available, we assume that larvae in 23 percent of the total entrained volume of diffuser dilution water are killed by exposure to lethal turbulence." This assumption is based on a finding in the State Board Expert Panel Report (Foster et al 2013) that modeled shearing stress form multiport diffusers and reported that larvae in 23 to 38 percent of the total entrained volume of dilution water may be exposed to lethal turbulence.

described above the regional water board shall require the owner or operator to use empirical studies or modeling to:

i. Estimate intake entrainment impacts using an ETM/APF approach.*

ii. Estimate~~ degradation of~~ marine life mortality from elevated salinity within the brine mixing zone,* including osmotic stresses, the size of impacted area, and the duration that marine life are exposed to the toxic conditions. Consideration~~s~~ shall be given to the most sensitive species located in the brine mixing zone,* and community structure and function.

Comment [PM25]: Clarify intent and make consistent with iii below.

iii. Estimate marine life mortality that occurs as a result of water conveyance, in-plant turbulence or mixing, and waste discharge.

(e) An owner or operator proposing ~~to use flow augmentation* as an alternative~~ brine* discharge technology must:

Comment [PM26]: The purpose of this deletion to conform to technology neutral staff recommendation. Some of the requirements below are, as noted, applicable only to flow augmentation, others should be applied equally to all brine discharge technologies; otherwise, the Desalination Amendments are not technology neutral.

i. For facilities proposing to use flow augmentation, ~~U~~use low turbulence intakes (e.g., screw centrifugal pumps or axial flow pumps) and conveyance pipes.

ii. Convey and mix dilution water in a manner that limits thermal stress, osmotic stress, turbulent shear stress, and other factors that could cause marine life mortality.

iii. Within three years of beginning operation, submit to the regional water board an empirical study that evaluates intake and mortality of marine life associated with~~ flow augmentation.*~~ the brine discharge technology. The study must evaluate impacts caused by augmented intake volume, intake and pump technology, water conveyance, waste brine* mixing, and effluent discharge. The study shall use any acceptable approach for evaluating mortality that occurs due to shearing stress resulting from the facility's discharge, including any incremental increase in mortality resulting from a commingled discharge. Unless demonstrated otherwise, organisms entrained by ~~flow augmentation*~~ brine discharge technology are assumed to have a mortality rate of 100 percent.

Comment [PM27]: Changes are to conform to technology neutral staff recommendation and clarify the type of empirical study the operator is to prepare and submit to demonstrate the marine life mortality of the brine disposal technology.

iv. If the empirical study shows that flow augmentation* is less protective of marine life than a facility using wastewater dilution (if available) or multiport diffusers,* then the facility must either (1) cease using flow augmentation* technology and install and use wastewater dilution (if available) or multiport diffusers* to discharge brine* waste, or (2) re-design the flow augmentation* system to minimize intake and mortality of marine life to a level that is comparable with wastewater dilution or multiport diffusers,* subject to regional water board approval.

v. Facilities proposing to use~~ing~~ flow augmentation* must comply with chapter III.L.2.d.(1).

Comment [PM28]: Question for staff - this is the section regarding consideration of intake technology, which is applicable to all facilities. Why is this needed here?

vi. Facilities proposing to use~~ing~~ flow augmentation* through surface intakes are prohibited from discharging through multiport diffusers.*

(f) Facilities that use subsurface* intakes to supply augmented flow water for dilution are exempt from the requirements of chapter III.L.2.d.(2) if the facility meets the receiving water limitation for salinity in chapter III.L.3.

e. Mitigation for the purposes of this section is the replacement of marine life or habitat that is lost due to the construction and operation of a desalination facility* after minimizing marine life mortality through site, design, and technology measures. The owner or operator may choose whether to satisfy a facility's mitigation measures pursuant to chapter III.L.2.e.(3) or, if available, L.2.e.(4). The owner or operator shall fully mitigate for all marine life mortality associated with the desalination facility.*

(1) *Marine Life Mortality Report.* The owner or operator of a facility shall submit a report to the regional water board projecting the marine life mortality resulting from construction and operation of the facility after implementation of the facility's required site, design, and technology measures.

(a) For operational mortality related to intakes, the report shall include a detailed entrainment study. The entrainment study period shall be at least 12~~36~~ consecutive months and sampling shall be designed to account for variation in oceanographic conditions and larval abundance and diversity such that abundance estimates are reasonably accurate. At their discretion, the regional water boards may permit the use of existing entrainment data from the facility to meet this requirement. Samples must be collected using a mesh

Comment [PM29]: The draft Desalination Amendments require that project owners and operators that wish to operate surface intakes conduct an entrainment study of at least 36 consecutive months. A 36 month entrainment study would be excessive and would result in the idling of the Carlsbad project for 30 months. The Desalination Amendments should permit the use of 12 months of entrainment data which conforms to the guidelines for entrainment impact assessment included in Appendix E of the staff report. (Guidance Documents for Assessing Entrainment Including Additional Information on the Following Loss Rate Models: Fecundity Hindcasting (FH), Adult Equivalent Loss (AEL) and Area of Production Forgone using an Empirical Transport Model (ETM/APF)). These guidelines, written by members of the SWRCB's Expert Review Panel, state that entrainment sampling that is done for 12 months is a reasonable period of sampling because the entrainment estimated by the ETM method is "much less subject to inter-annual variation. (Id. at 97.) Therefore, a 12 month study would be adequate to account for variation in oceanography conditions and larval abundance and diversity such that the abundance estimates are reasonably accurate.

size no larger than 335 microns and individuals collected shall be identified to the lowest taxonomical level practicable. ~~Additional samples shall also be collected using a 200 micron mesh to provide a broader characterization of other entrained organisms~~. The ETM/APF analysis* shall be representative of the entrained species collected using the 335 micron net. The APF* shall be calculated using a ~~90 percent~~ confidence level [consistent with the procedures established by the Intake Expert Review Panel]. An owner or operator with subsurface* intakes is not required to do an ETM/APF analysis* for their intakes and is not required to mitigate for intake-related operational mortality. The regional water boards shall permit the use of existing entrainment data from studies conducted in conformance with the Guidelines for Entrainment Impact Assessment (Appendix E) to meet this requirement.

~~(b) For operational mortality related to discharges, the report shall estimate the area in which salinity* exceeds 2.0 parts per thousand above natural background salinity* or a facility-specific alternative receiving water limitation (see § L.3). The area in excess of the receiving water limitation for salinity* shall be determined by modeling and confirmed with monitoring. The report shall use any acceptable approach for evaluating mortality that occurs due to shearing stress resulting from the facility's discharge, including any incremental increase in mortality resulting from a commingled discharge.~~

~~(c)~~(b) For construction-related mortality, the report shall use any acceptable approach for evaluating the mortality that occurs within the area disturbed by the facility's construction. The regional water board may determine that the construction-related disturbance does not require mitigation because the disturbance is temporary and the habitat is naturally restored.

~~(d)~~(c) Upon approval of the report by the regional water board in consultation with State Water Board staff, the calculated marine life mortality shall form the basis for the mitigation provided pursuant to this section.

(2) The owner or operator shall mitigate for the marine life mortality determined in the report above by choosing to either complete a mitigation project as described in chapter III.L.2.e.(3) or, if an appropriate fee-based mitigation program is available, provide funding for the program as described in chapter III.L.2.e.(4). The mitigation project or the use of a fee-based mitigation program and the amount of the fee that

Comment [PM30]: As noted on page 70 of the Staff Report, the Expert Review Panel III recommended the ETM/APF method that relies on the 335 micron mesh net to calculate mitigation levels because:

- This method has historically been used in California to determine mitigation for entrainment at power plants and is widely accepted in the scientific community,
- Compensates for all entrained species and not just commercially valuable fish taxa, and
- Utilizes representative species (e.g. fish larvae sampled using a 335 micron mesh net) that can be used as proxy species for rare, threatened, or endangered species, which may be challenging to acquire adequate data for. The creation of habitat benefits all species in the food web regardless of whether or not they were assessed in the ETM/APF model.

Comment [PM31]: The Desalination Amendments require that the mitigation acreage calculation be based on a 90 percent confidence level. This proposal has not been reviewed by the ERP. The CCC found that an 80 percent confidence interval would be acceptable under the site-specific conditions in Carlsbad. The uniform application of a 90 percent confidence interval does not take into consideration the varying levels of uncertainty associated with ETM/APF estimates, and therefore is overly conservative as applied to Carlsbad. Staff's proposal for a 90 percent confidence interval should be submitted to the ERP for peer review.

Comment [PM32]: Consistent with Section L2d(1)(c)iii, the Desalination Amendments should allow the use of existing data that meets the guidelines in Appendix E.

Comment [PM33]: Standard practice under the Ocean Plan is that dischargers do not mitigate for impacts within the ZID. Why is staff recommending desalination facilities mitigate for impacts within the prescribed brine mixing zone?

the owner or operator must pay is subject to regional water board approval.

(3) *Mitigation Option 1: Complete a Mitigation Project.* The mitigation project must satisfy the following provisions:

(a) The owner or operator shall submit a Mitigation Plan. Mitigation Plans shall include: project objectives, site selection, site protection instrument (the legal arrangement or instrument that will be used to ensure the long-term protection of the compensatory mitigation project site), baseline site conditions, a mitigation work plan, a maintenance plan, a long-term management plan, an adaptive management plan, performance standards and success criteria, monitoring requirements, and financial assurances.

(b) The mitigation project must meet the following requirements:

i. Mitigation shall be accomplished through expansion, restoration or creation of one or more of the following: kelp beds, estuaries, coastal wetlands, natural reefs, MPAs, or other projects approved by the regional water board that will mitigate for intake and mortality of marine life associated with the facility.

ii. The owner or operator shall demonstrate that the project fully mitigates for intake-related marine life mortality by including acreage that is at least equivalent in size to the APF* calculated in the Marine Life Mortality Report above, unless the regional water board determines that the habitat is of higher productivity than the facility's source water body* (e.g., open ocean vs. estuarine mitigation habitat) in which case, the regional water board shall adjust the quantity of the mitigation acreage such that the productivity of the mitigation habitat provided matches that of the APF times the productivity of the source water body.* The owner or operator shall attempt to locate the mitigation project within the facility's source water body,* and shall do modeling to evaluate the areal extent to which~~of~~ the mitigation project's production area* ~~to confirm that it~~ overlaps the facility's source water body.* Impacts on the mitigation project due to entrainment by the facility must be offset by adding compensatory acreage to the mitigation project. ~~The regional water boards may require additional habitat be mitigated to compensate for the annual entrainment of organisms between 200 and 335 microns.~~

Comment [PM34]: The Desalination Amendments require 1:1 mitigation of all impacts, regardless of the relative productivity of the habitat impacted to that of the mitigation habitat provided. Consistent with past APF siting and sizing determinations, the Desalination Amendments should provide the regional water board sufficient flexibility to adjust the mitigation acreage as needed based on the expected productivity of the type of mitigation to be provided compared to the actual productivity within the facility's source water body. For example, the CCC determined that 64 acres were needed to mitigate for the open ocean species entrained by the Carlsbad project. However, in recognition of the impracticality of creating 64 acres of offshore open water habitat, and recognizing the relatively greater productivity rates per acre of estuarine wetlands habitats, the CCC allowed the offshore impacts to be "converted" to estuarine mitigation areas. Based on a recommendation from a member of the State Water Board's Expert Review Panel on Intake Impacts and Mitigation ("ERP"), Dr. Peter Raimondi, the CCC determined that successfully restored wetland habitat would be ten times more productive than a similar area of nearshore ocean waters. Based on this determination, for every ten acres of nearsho ...

Comment [PM35]: The wetlands project for the Carlsbad project has been under development for seven years and is in the final stages of approval (EIS and CDP scheduled for approval late this year). Construction of the mitigation project is expected to begin late next year. The Desalination Amendments requirement to locate the mitigation within the "source water body" would result in Poseidon and the Water Authority having to abandon their current mitigation project and start over, even though it has already been determined that there are no suitable mitigation sites within the source water body.

Comment [PM36]: See comment 30 above. See also Expert Review Panel Report on Intake Impacts and Mitigation. Specifically page 1 of Appendix 1 which states in part: "The key assumption of APF that makes it useful … it should reflect the impacts to measured and unmeasured resources (e.g., to invertebrate larvae). This is because its calculation assumes that those species assessed [those species captured on the 335 micron mesh] are representative of those not assessed [those species smaller than 335 micron]. Practically, this means that should the amount of habitat calculated using APF be created or substantially restored, the habitat will support species that were assessed as well as those that were not assessed in the ETM. Importantly, that amount of habitat will also compensate for impacts to species only indirectly affected. This means that should the mitigation take place according to APF estimates there will be no net impact."

iii. The owner or operator shall demonstrate that the project also fully mitigates for the discharge-related marine life mortality projected in the Marine Life Mortality Report above. If the regional water board determines that the mitigation habitat is of higher productivity than the facility's source water body (e.g., open ocean vs. estuarine mitigation habitat), the regional water board shall adjust the quantity of mitigation acreage required such that the productivity of the mitigation habitat provided fully mitigates for the discharge-related marine life mortality projected in the marine life mortality report. For each acre of discharge-related disturbance as determined in the Marine Life Mortality Report, an owner or operator shall restore one acre of habitat unless the regional water board determines that a mitigation ratio less~~greater~~ than 1:1 is warranted due to the higher productivity of the mitigation site compared to that of the disturbed area~~needed~~.

Comment [PM37]: See comment 34.

iv. The owner or operator shall demonstrate that the project also fully mitigates for any permanent~~the~~ construction-related marine life mortality identified in the Marine Life Mortality Report above. For each acre of construction-related disturbance, an owner or operator shall restore one acre of habitat unless the regional water board determines that a mitigation ratio less~~greater~~ than 1:1 is warranted due to the higher productivity of the mitigation site compared to that of the disturbed area~~is needed~~. The regional water board may determine that the construction related disturbance does not require mitigation because the disturbance is temporary and the habitat is naturally restored.

Comment [PM38]: Changes are intended to conform with Desalination Amendments section 2.e.(1).(c) which states the regional water board may determine that the construction-related disturbance does not require mitigation because the disturbance is temporary and the habitat is naturally restored.

(c) The Mitigation Plan is subject to approval by the regional water board in consultation with State Water Board staff and with other agencies having authority to permit the project and require mitigation.

(4) *Mitigation Option 2: Fee-based Mitigation Program*. If the regional water board determines that an appropriate fee-based mitigation program has been established by a public agency, and that payment of a fee to the mitigation program will result in the creation and ongoing implementation of a mitigation project that meets the requirements of section L.2.e.(3), the owner or operator may pay a fee to the mitigation program in lieu of completing a mitigation project.

(a) The agency that manages the fee-based mitigation program must have legal and budgetary authority to accept and spend mitigation funds, a history of successful mitigation projects documented by having set and met performance standards for past projects, and stable financial backing in order to manage mitigation sites for the operational life of the facility.

(b) The amount of the fee shall be based on the cost of the mitigation project, or if the project is designed to mitigate cumulative impacts from multiple desalination facilities or other development projects, the amount of the fee shall be based on the desalination facility's fair share of the cost of the mitigation project.

(c) The manager of the fee-based mitigation program must consult with the California Department of Fish and Wildlife, Ocean Protection Council, Coastal Commission, State Lands Commission, and State and regional water boards to develop mitigation projects that will best compensate for intake and mortality of marine life caused by the desalination facility.* Mitigation projects that increase or enhance the viability and sustainability of marine life in Marine Protected Areas are preferred, if feasible.

Comment [PM39]: This is an additional reason the Desalination Amendments should not limit mitigation sites to only those sites that overlap with the source water body.

(5) California Department of Fish and Wildlife, the regional water board, and State Water Board may perform audits or site inspections of any mitigation project.

(6) An owner or operator, or a manager of a fee-based mitigation program, must submit a mitigation project performance report to the regional water board 180 days prior to the expiration date of their NPDES permit.

3. Receiving Water Limitation for Salinity*

a. Chapter III.L.3 is applicable to all desalination facilities discharging brine* into ocean waters,* including facilities that commingle brine* and wastewater.

b. The receiving water limitation for salinity* shall be established as described below:

(1) Discharges shall not exceed a daily maximum of 2.0 parts per thousand above natural background salinity* to be measured as using electrical conductivity and reported as the Practical Salinity per PSS-78 ~~total dissolved solids~~ (mg/L) measured no further than 100 meters (328

Comment [PM40]: The Scripps Institution of Oceanography ("SIO") maintains a 98 year historical database of Pacific Ocean salinity that serves as the baseline background salinity for the Carlsbad project. SIO's salinity data base, and most other salinity data bases, measure salinity as total dissolved salts, not dissolved solids ("TDS"). This is accomplished using electrical conductivity and reported as the Practical Salinity per PSS-78. This approach is viewed as the most accurate measure of Pacific Ocean salinity because it eliminates the uncharged (neutral) dissolved solids (such as dissolved organic matter) in seawater that are not related to the salinity. See definition of SALINITY for more additional discussion on this point.

ft) horizontally from the discharge or the facility specific brine mixing zone authorized in accordance with this plan. There is no vertical limit to this zone.

Comment [PM41]: The draft Desalination Amendments propose to limit the salinity increase to a maximum of 2 ppt over natural background, at a fixed distance of 100 meters from the point of discharge. The distance of 100 meters appears to be based on the multiport diffuser. (Staff Report at 98). The Staff Report states that facilities using flow augmentation should also be able to meet 2 ppt above ambient with 100 meters. (Staff Report at 99). However, this is not correct. Depending on ambient mixing conditions (tides, wind, waves, current, temperature) in the receiving water, the Carlsbad project requires anywhere from 200 meters under good mixing conditions to 500 meters under poor mixing conditions to ensure strict compliance with the proposed 2 ppt standard. The definition for Brine Mixing Zone states that the Desalination Amendments include a mechanism for establishing a larger brine mixing zone: "the brine mixing zone shall not exceed 100 meters … unless otherwise authorized in accordance with this plan." However, the Desalination Amendments currently do not include a process for establishing a larger brine mixing zone. This appears to be an oversight. Failure to include a process for establishing a larger brine mixing zone in the Desalination Amendments would limit the brine discharge options available to the Carlsbad project to the environmentally inferior multiport diffuser.

(2) In determining an effluent limit necessary to meet this receiving water limitation, permit writers shall use the formula in chapter III.C.4 that has been modified for brine* discharges as follows:

Equation 1: Ce= (2,000 mg/l + Cs) + Dm(2,000 mg/l)

Where:

Ce= the effluent concentration limit, mg/L
Co= the salinity* concentration to be met at the completion of initial* dilution= 2,000 mg/l + Cs
Cs= the natural background salinity* mg/L
Dm= minimum probable initial*dilution expressed as parts seawater* per part brine* discharge

(a) The fixed distance referenced in the initial dilution* definition shall be no more than 100 meters, or the facility-specific brine mixing authorized in accordance with this plan (328 feet).

(b) In addition, the owner or operator shall develop a dilution factor (Dm) based on the distance of 100 meters, or the facility-specific brine mixing authorized in accordance with this plan (328 feet) or initial*dilution, whichever is smaller.

Comment [PM42]: See comment 41

(c) The value 2,000 mg/l in Equation 1 is the maximum incremental increase above ambient background salinity* (Cs) allowed at the edge of the brine* mixing zone. A regional water board may substitute an alternative numeric value for 2,000 mg/l in Equation 1 based upon the results of a facility-specific alternative salinity* receiving water limitation study, as described in chapter III.L.3.c below.

c. An owner or operator may submit a proposal to the regional water board for approval of an alternative salinity* receiving water limitation.

(1) To determine whether a proposed facility-specific alternative receiving water limitation is adequately protective of beneficial uses, an owner or operator shall:

(a) Establish baseline biological conditions at the discharge location and at reference locations ~~over a 36-month period~~ prior to commencing brine* discharge. The biologic surveys must characterize the ecologic composition of habitat and marine life using measures established by the regional water board. At their discretion, the regional water boards may permit the use of existing data from the facility to meet this requirement.

Comment [PM43]: The Desalination Amendments require that an owner or operator shall conduct a 36-month baseline biological conditions survey at the discharge location and at reference locations prior to commencing brine discharge. The discharge from the Carlsbad project will start in the 2nd quarter of 2015. This means that the facility-specific alternative receiving water limitation is currently not available to the Carlsbad project. In addition, the justification for a 36-month survey period prior to discharge is not clear. Comprehensive testing over a shorter period supported by existing biological data from nearby similar habitat, should be sufficient for determining the biological characteristics of the site.

(b) Conduct at least the following Whole Effluent Toxicity (WET) tests: germination and growth for giant kelp (*Macrocystis pyrifera)*; development for red abalone (*Haliotis refescens)*; development and fertilization for purple urchin (*Strongleocentrotus purpuratus)*; development and fertilization for sand dollar (*Dendraster excentricus)*; larval growth rate for topsmelt (*Atherniops affinis)*.

(c) The regional water board in consultation with State Water Board staff may require an owner or operator to do additional toxicity studies if needed.

(2) The regional water board in consultation with the State Water Board staff may require an owner or operator to provide additional studies or information in order to approve a facility-specific alternative receiving water limitation for salinity.*

(3) The facility-specific alternative receiving water limitation shall be based on the lowest~~no~~ observed effect level (~~N~~LOEL) for the most sensitive species and toxicity endpoint as determined in the chronic toxicity* studies. The regional water board in consultation with State Water Board staff has discretion to approve the proposed facility-specific alternative receiving water limitation for salinity.*

Comment [PM44]: The procedure set forth in the Desalination Amendments for establishing facility-specific receiving water limits uses a ***completely different, and more restrictive***, standard of salinity than the standard that is used as a guideline throughout the entire draft Desalination Amendments. Throughout the draft Desalination Amendments, and indeed, throughout Roberts et al. 2012 (upon which much of the draft Desalination Amendments is based), it is stated that red abalone are the most sensitive species tested, with a LOEL (Lowest Observable Effect Level) of 35.6 ppt – or approximately 2.1 ppt above ambient (in southern California waters). Thus, it is argued, a maximum regulatory salinity increase of 2 ppt is reasonable because it protects the most sensitive species. However, the language in the draft Desalination Amendments use a completely different standard, which is NOEL (No Observable Effect Level). The NOEL value, according to Philips et al. (2012) is 34.9 ppt, or approximately *only 1.4 ppt above ambient* (in southern California waters). Consequently, an operator that wishes to establish a site-specific receiving water limit under the Desalination Amendments is being held to a more restrictive salinity standard. Poseidon requests that the Desalination Amendments be amended such that the facility-specific alternative receiving water standard be based on the same standard that will be used to establish the statewide receiving water limit of 2 ppt – the lowest observed effect level (LOEL).

(4) The regional water board may eliminate or revise a facility-specific alternative receiving water limitation for salinity* based on a facility's monitoring data, the results from their Before-After Control-Impact study as required in chapter III.L.4 below, or based on any other information that the regional water board deems to be relevant.

d. Existing facilities that do not meet the receiving water limitation at the edge of the brine mixing zone* and throughout the water column by [the effective date of this plan] must either: 1) establish a facility-specific alternative receiving water limitation for salinity* as described in chapter III.L.3.(c); or, 2) upgrade the facility's brine* discharge method in order to meet the receiving water limitation in chapter III.L.3.b in accordance with the State Water Board's

Compliance Schedule Policy, as set forth in (e) below. An owner or operator that chooses to upgrade the facility's method of brine* disposal:

(1) Must demonstrate to the regional water board that the brine* discharge does not negatively impact sensitive habitats,* sensitive species, MPAs, or SWQPAs.

(2) Is subject to the Considerations for Brine* Discharge Technology described in chapter III.L.2.e.(2).

e. The regional water board may grant compliance schedules for the requirements for brine* waste discharges for existing desalination facilities.* All compliance schedules shall be in accordance with the State Water Board's Compliance Schedule Policy, except that the salinity* receiving water limitation set forth in chapter III.L.3.(b) shall be considered to be a "new water quality objective" as used in the Compliance Schedule Policy.

4. Monitoring and Reporting Programs

a. The owner or operator of a desalination facility* must submit a Monitoring and Reporting Plan to the regional water board for approval. The Monitoring and Reporting Plan shall include monitoring of effluent and receiving water characteristics and impacts to marine life. The Monitoring and Reporting Plan shall, at a minimum, include monitoring for benthic community health, aquatic life toxicity, and receiving water characteristics consistent with Appendix III of this Plan and for compliance with the receiving water limitation in chapter III .L.3. Receiving water monitoring for salinity* shall be conducted at times when the monitoring locations are most likely affected by the discharge. For new or expanded facilities the following additional requirements apply:

(1) An owner or operator must perform facility-specific monitoring to demonstrate compliance with the receiving water limitation for salinity,* and evaluate the potential effects of the discharge within the water column, bottom sediments, and the benthic communities. Facility-specific monitoring is required until the regional water board determines that a regional monitoring program is adequate to ensure compliance with the receiving water limitation. The monitoring and reporting plan shall be reviewed, and revised if necessary, upon NPDES permit renewal.

(2) Baseline biological conditions shall be established at the discharge location and at a reference location prior to commencement of construction. The owner or operator is required to conduct Before-After Control-Impact biological surveys that will evaluate the

differences between biological communities at a reference site and at the discharge location before and after the discharge commences. The regional water board will use the data and results from the Before-After Control-Impact surveys for evaluating and renewing the requirements set forth in a facility's NPDES permit.

Add the following new definitions to, and amend existing definitions in, Appendix I of the Ocean Plan.

AREA PRODUCTION FOREGONE (APF), also known as habitat production foregone, is an estimate of the area that is required to produce (replace) the same amount of larvae or propagules* that are removed via entrainment at a desalination facility's* intakes. APF is calculated by multiplying the proportional mortality* by the source water body,* which are both determined using an empirical transport model.* (Raimondi 2014)

BRINE is the byproduct of desalinated* water having a salinity* concentration greater than a desalination facility's* intake source water.

BRINE MIXING ZONE is the area where the salinity* exceeds 2.0 parts per thousand above natural background salinity.* The brine mixing zone shall not exceed 100 meters (328 feet) laterally from the points of discharge and throughout the water column unless otherwise authorized by the regional water board in accordance with this plan. The brine mixing zone is an allocated impact zone where water quality criteria can be exceeded as long as the mixing zone for the acute toxicity objective shall be ten percent (10%) of the distance from the edge of the discharge structure to the outer edge of the brine mixing zone. There is no vertical limit on this zone ~~acutely toxic conditions are prevented and the designated use of the water is not impaired as a result of the brine mixing zone~~. The brine mixing zone is determined through a mixing zone study and the use of applicable water quality models that have been approved by the regional water boards in consultation with State Water Board staff.

DESALINATION FACILITY is an industrial facility that processes water to remove salts and other components from the source water to produce water that is less saline than the source water.

EELGRASS BEDS are aggregations of the aquatic plant species, *Zostera marina*.

EMPIRICAL TRANSPORT MODEL (ETM) is a methodology for determining the spatial area known as the source water body* that contains the source water population, which are the organisms that are at risk of entrainment as determined by factors that may include but are not limited to biological, hydrodynamic, and oceanographic data. ETM can also be used to estimate proportional mortality,* P_m. (Raimondi 2014)

ETM/APF APPROACH or ANALYSIS. For guidance on how to perform an ETM/APF analysis please see Raimondi 2011 and Steinbeck *et al*. 2007.

Comment [PM45]: The draft Desalination Amendments propose to limit the salinity increase to a maximum of 2 ppt over natural background, at a fixed distance of 100 meters from the point of discharge. The distance of 100 meters appears to be based on the multiport diffuser. (Staff Report at 98). The Staff Report incorrectly states that facilities using flow augmentation should also be able to meet 2 ppt above ambient with 100 meters. (Staff Report at 99). Depending on ambient mixing conditions (tides, wind, waves, current, temperature) in the receiving water, the Carlsbad project require greater than 100 meters to ensure strict compliance with the proposed 2 ppt standard. The definition for Brine Mixing Zone alludes to a mechanism for establishing a larger brine mixing zone: "the brine mixing zone shall not exceed 100 meters … unless otherwise authorized in accordance with this plan." However, the Desalination Amendments currently do not include a process for establishing a larger brine mixing zone. This appears to be an oversight. Failure to include a process for establishing a larger brine mixing zone in the Desalination Amendments would limit the brine discharge options available to the Carlsbad project to the environmentally inferior multiport diffuser.

Comment [PM46]: Project operators would not be able to comply with the acute toxicity requirement as drafted. The proposed language tracks the acute toxicity allowance in the Ocean Plan.

FEASIBLE shall mean capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, environmental, social, technological factors.

FLOW AUGMENTATION is a type of in-plant dilution and occurs when a desalination facility* withdraws additional source water for the specific purpose of diluting brine* prior to discharge.

KELP BEDS are aggregations of marine algae of the order Laminariales, including species in the genera *Macrocystis, Nereocystis, and Pelagophycus*. Kelp beds include the total foliage canopy throughout the water column.

MARKET SQUID NURSERIES are comprised of numerous egg capsules, each containing approximately 200 developing embryos, attached in clusters or mops to sandy substrate with moderate water flow. Market squid (*Doryteuthis opalescens*) nurseries occur at a wide range of depths; however, mop densities are greatest in shallow, nearshore waters between ten and 100 meters (328 feet) deep. *D. opalescens* egg nurseries commonly occur within a few hundred meters of the same location every year.

MULTIPORT DIFFUSERS are linear structures consisting of ~~many~~ spaced ports or nozzles that are installed on submerged marine outfalls. Multiport diffusers discharge brine* waste into an ambient receiving water body and enable rapid mixing, dispersal, and dilution of brine* within a relatively small area.

NATURAL BACKGROUND SALINITY is the salinity* at a location that results from naturally occurring processes and is without apparent human influence. Natural background salinity shall be determined by averaging 20 years of historical salinity* data at a location unless the actual salinity measured at the facility intake is greater than the 20 year average salinity, in which case, the natural background salinity shall be the lower of: (1) the actual salinity measured at the intake, or (2) the maximum salinity level measured in the 20 years of historical salinity data. When historical data are not available, natural background salinity shall be determined by measuring salinity* at depth of proposed discharge for three years, on a weekly basis prior to a desalination facility* discharging brine,* and the average salinity* shall be used to determine natural background salinity unless the actual salinity measured at the facility intake is greater than the average salinity, in which case, the natural background salinity shall be the lower of: (1) the actual salinity measured at the intake, or (2) the maximum salinity level measured in the salinity data. Facilities shall establish a reference location with similar natural background salinity to be used for comparison in ongoing monitoring of brine* discharges.

PROPAGULES are structures that are capable of propagating an organism to the next stage in its life cycle via dispersal. Dispersal is the movement of individuals from their birth site to their reproductive grounds.

Comment [PM47]: One of the primary purposes of the Desalination Amendments is to provide implementation procedures for conducting Water Code section 13142.5(b) "evaluations of the best available site, design, technology and mitigation measures feasible to minimize the intake and mortality of all forms of marine life at new or expanded desalination facilities." (Emphasis added). Yet the draft Desalination Amendments fails to provide the regional water boards with direction regarding one of the more contentious aspects of the 13142.5(b) evaluation – the scope of the feasibility assessment. The 4th District Court of Appeal effectively resolved this debate in 2012 when it assessed whether the San Diego Regional Water Board complied with Water Code section 13142.5(b) in issuing Order R9-2009-0038 for the Carlsbad Desalination Project. *(Surfrider Found. V. Cal. Reg'l Water Quality Control Bd.* (2012) 211 Cal. App. 4th 557, 581). The court determined that the Regional Board fully complied with section 13142.5(b) in relying on the definition of "feasible" under CEQA. (*Id.* at pp. 582-583). Under CEQA, "feasible" means "capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, environmental, social, and technological factors." (Pub. Res. Code, §§ 21061). The Coastal Act relies on the same definition. (Pub. Res. Code, § 30108 (Coastal Act)). It is critical that the regional water boards have clear direction on the scope of the

Comment [PM48]: Receiving Water Limit for Salinity. The Desalination Amendments provide that brine discharges from desalination facilities shall not exceed 2.0 parts per thousand above the natural background salinity. Natural background salinity is defined as the 20-year average salinity at the project location. The database that makes up the natural background salinity for the Carlsbad Project shows a mean salinity of of 33.5 ppt, a minimum salinity of 27.4 ppt, and a maximum salinity of 34.2 ppt over the last 20 years. Sixty-four percent of daily salinity measurements over the last 20 years are above the 33.5 ppt average. This means that the Carlsbad facility would have to operate at less than a 2 ppt increase over the ambient salinity 64 percent of the time. This operating requirement would severely impact plant reliability. To address this problem, Desalination Amendments should be revised such that the natural background salinity shall be determined by averaging 20 years of historical salinity* data at a location unless the actual salinity measured at the facility intake is greater than the 20 year average salinity, in which case, the natural background salinity shall be the lower of: (1) the actual salinity measured at the intake, or (2) the maximum salinity level measured in the 20 years of historical salinity data (i.e., 33.5 to 34.2 ppt in Carlsbad). (See Attachment 7, Historical Analysis of Salinity for Water Quality Monitoring).

PROPORTIONAL MORTALITY, P_m, is percentage of larval organisms or propagules* in the source water body* that is expected to be entrained at a desalination facility's* intake. It is assumed that all entrained larvae or propagules* die as a result of entrainment. (Raimondi 2014)

SALINITY is a measure of the dissolved salts in a volume of water. For the purposes of this Plan, salinity shall be measured ~~as total dissolved solids in mg/l~~using electrical conductivity and reported as the Practical Salinity per PSS-78. Other measures of salinity, including absolute salinity as defined per TEOS-10 (in g/kg) , salinity as reflected in total dissolved solids measurements (in mg/L), or the sum of the major anions and cations (chloride, sulfate, bicarbonate, bromide, sodium, magnesium, calcium, and potassium, in mg/L) may also be collected and reported to determine proper correlations with PSS-78 salinity measurements.

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Comment [PM49]: Depending on the analytical method used to establish the historical salinity data for a particular desalination facility the definition of Salinity is potentially at odds with the definition of Natural Background Salinity. This is because the definition for Natural Background Salinity seeks to establish a long-term background value, and most of the data collected in the past that was collected using electrical conductivity and reported as the Practical Salinity per PSS-78. The definition of Salinity, on the other hand, provides that for purposes of determining compliance with the maximum 2 ppt increase over the natural background salinity at the edge of the brine mixing zone (or facility-specific receiving water limit), "salinity shall be measured as total dissolved solids." As noted in Attachment 6, the Scripps Institution of Oceanography ("SIO") maintains a 98 year historical database of Pacific Ocean salinity that serves as the baseline background salinity for the Carlsbad project. SIO's salinity data base, and most other salinity data bases, measure salinity as total dissolved salts, not dissolved solids ("TDS"). This is accomplished using electrical conductivity and reported as the Practical Salinity per PSS-78. This approach is viewed as the most accurate measure of Pacific Ocean salinity because it eliminates the uncharged (neutral) dissolved solids (such as dissolved organic matter) in seawater that are not related to the salinity. The San Diego Regional Board adopted a similar approach in the order issued for the Carlsbad project. (See Table 5 on page E-8 of Order R9-2006-0065). For the Carlsbad project, the long-term average Natural Background Salinity is 33.5 ppt. The problem with the use of of TDS in the definition of Salinity, is that relative to the historic SIO database measured using electrical conductivity and reported as the Practical Salinity per PSS-78, the TDS measurement is expected to yield a higher reading due to the presence of uncharged (neutral) dissolved solids in seawater that are included in the TDS measurement, but not related to the salinity. To the extent that the TDS measurement is greater than the PSS-78 salinity measurement, and this figure is used to confirm compliance with the 2 ppt increase (or site-specific receiving water limit) over the a historical average of 33.5 measured by the PSS-78 method, then the owner or operator is not receiving the full benefit of the 2ppt increase (or site-specific receiving water limit) by the amount of the difference between the TDS and PSS-78 measurements. In order to reconcile this problem, the measurement of salinity should reflect the same method as that of the historical data base (e.g., PSS-78). For more on this point, see Attachment 6 -- Salinity Measurement for Water Quality Monitoring, Ms. Melissa Carter, M.S., Reinhard Flick, Ph.D., August 14, 2014.

SEAWATER is salt water that is in or from the ocean. For the purposes of chapter III.L, seawater includes tidally influenced waters in coastal estuaries and lagoons and underground salt water beneath the seafloor, beach, or other contiguous land with hydrologic connectivity to the ocean.

SENSITIVE HABITATS, for the purposes of this Plan, are kelp beds,* rocky substrate, surfgrass beds,* eelgrass beds,* oyster beds, spawning grounds for state or federally managed species, market squid nurseries,* or other habitats in need of special protection as determined by the Water Boards.

SOURCE WATER BODY is the spatial area that contains the organisms that are at risk of entrainment at a desalination facility* as determined by factors that may include but are not limited to biological, hydrodynamic, and oceanographic data. (Raimondi 2014)

SUBSURFACE, for the purposes of this Plan, is the area beneath the ocean floor or beneath the surface of the earth inland from the ocean.

SURFGRASS BEDS are aggregations of marine flowering plants of the genus *Phyllospadix*.

Attachment 2A

Poseidon Comments on Draft Staff Report

Poseidon Comments on Draft Staff Report
Amendment to the Water Quality Control Plan for Ocean Waters of California
August 18, 2014

Comment #	Page	Section	Comment
1	45	8.3.1	**Subsurface Intakes.** The last sentence of the first paragraph of Section 8.3.1 states that subsurface intakes eliminate the need for pretreatment requirements. This is an over generalization. It would be more accurate to say that depending on the location and design of the subsurface intake, pretreatment requirements may reduced or eliminated. In other locations (e.g., Carlsbad), the quality of the subsurface water may be difficult to treat. See the administrative record that was before the State Board in the Board's consideration of the administrative appeal in *Surfrider Foundation v. Cal. Reg'l Water Quality Control Bd.*, 211 Cal. App. 4th 557 (2012).
2	45	8.3.1	**Subsurface Intakes.** The first sentence of the second paragraph of Section 8.3.1 states that surface intakes result in higher operation costs compared to subsurface intakes. This too is an over generalization. It would be more accurate to say that depending on the location and design of the subsurface intake, the operation costs may reduced or eliminated. In other locations (e.g., Carlsbad), the quality of the subsurface water may be difficult to treat which would increase the operational cost. See the administrative record that was before the State Board in the Board's consideration of the administrative appeal in *Surfrider Foundation v. Cal. Reg'l Water Quality Control Bd.*, 211 Cal. App. 4th 557 (2012).
3	49	8.3.1.2	**Intake Screen Mesh Size.** Several examples are presented in support of the recommended screen size of 0.5 mm to 1.0 mm. The literature referenced by staff for this purpose is poorly cited, resulting in inaccurate representations in the Staff Report as to screen mesh sizes being used, and misleading facts as to when and how the screens are being used. For example, with respect to the three case studies cited that are operating in the marine environment: 1. The first reference is the Big Bend Power Plant in Tampa Bay, FL. The Staff Report states that the power plant intake pipe is equipped with a 0.5 mm fine mesh screens. The 0.5 mm screens are only used seasonally between March 15 and October 15 and only in the intake for Units 3 and 4. The intake for Units 1 and 2 is equipped with 9.5 mm screens. (See Attachment 2B – Alden Research Laboratory Comments at Page 8).

Comment #	Page	Section	Comment
			2. The second reference is the Barney Davis Seawater Cooling Station in Corpus Christi, TX. The Staff Report states that 0.5 mm mesh screens successfully reduced impingement mortality at this location. Poseidon contacted a representative from this power plant who stated the power plant installed 0.7 mm screens, however, those screens were replaced with 1.0 x1.2 mm screens due to the inability to consistently get enough flow through the 0.7 mm screens. 3. The third seawater screen reference is for the Brunswick seawater cooling plant in North Carolina. The staff report states that 0.5 mm fine mesh screens at this facility showed entrainment losses of 84 percent. The actual screen size were 1.0 mm on three of the four traveling screens installed at this facility and 9.t mm on the fourth screen. Additionally, the design of the intake is fairly unique and likely confers a substantial benefit in terms of managing debris. (See Attachment 2B – Alden Research Laboratory Comments at Page 9).
4	54	8.3.2	**Subsurface Intakes.** Paragraph three presents the same problem described in comments 1 and 2 above.
5	55	8.3.2.1.1	**Subsurface Intakes.** California does not have any fractured karstic carbonate aquifers, therefore, the reference to the vertical well in Oman should be removed from the Staff Report.
6	72	8.5.1.2	**Multiport Diffusers.** The Staff Report states that is unclear how Jenkins and Wasyl (2013) estimated entrainment mortality at multiport diffusers to be 16.8 percent of the total entrained volume of dilution water. In response to the comments received from staff, Jenkins et al. significantly revised the subject report and submitted it to the *Journal of Environmental Science and Technology* for consideration for publication. A copy of the revised manuscript is included in Attachment 10 of Poseidon's comments on the Desalination Amendments.

Comment #	Page	Section	Comment
7	88	8.6.2.3	**Flow Augmentation.** Change year of publication of Department of Fish and Game study to 1989. Additional information about flow augmentation studies at Red Bluff was submitted to the State Board in February 2014 during the preparation of the Amendment. This information is being resubmitted and is included as Attachments 8 and 9 of Poseidon's comments on the Desalination Amendments. We hope that in revising the Staff Report, the State Board will consider this information about flow augmentation.
8	88	8.6.2.3	**Flow Augmentation.** The second paragraph of this section states that there are no empirical data that have estimated egg, larvae and small juvenile mortality as low-turbulence pumps. Please see the studies referenced in comment 7 for empirical studies on juvenile fish mortality using low-turbulence pumps. Also see the study referenced in comment 6 for a comparison of the entrainment mortality associated with flow augmentation using low-impact pumps to the entrainment associated with multiport diffusers.
9	99	8.7.3	**Brine Mixing Zone.** The Staff Report incorrectly states that facilities using flow augmentation should also be able to meet 2 ppt above ambient with 100 meters. (Staff Report at 99). Depending on ambient mixing conditions (tides, wind, waves, current, temperature) in the receiving water, the Carlsbad project require greater than 100 meters to ensure strict compliance with the proposed 2 ppt standard.

Comment #	Page	Section	Comment
10	151	12.1.7	**Greenhouse Gases.** The Staff Report incorrectly states that direct and indirect greenhouse gas emissions were not estimated for the Carlsbad facility. Please see Poseidon's Energy Efficiency and Greenhouse Gas Minimization Plans for the Carlsbad and Huntington Beach desalination facilities included in this Attachment 2 to Poseidon's comments on the Desalination Amendments and revise Table 12-17 and associated text in the Staff Report.

Attachment 2B

Alden Labs Comments on

Draft Staff Report and Substitute Environmental Documentation,

Tim Hogan, August 13, 2014

TO: MS. JEANINE TOWNSEND, CLERK TO THE BOARD
STATE WATER RESOURCES CONTROL BOARD
1001 "I" STREET, 24TH FLOOR
SACRAMENTO, CA 95814

FROM: TIMOTHY HOGAN
SENIOR FISHERIES BIOLOGIST
ALDEN RESEARCH LABORATORY, INC.
30 SHREWSBURY STREET
HOLDEN, MA 01520

SUBJECT: COMMENTS ON THE DRAFT STAFF REPORT INCLUDING THE DRAFT SUBSTITUTE ENVIRONMENTAL DOCUMENTATION

DATE: AUGUST 13, 2014

Introduction

Alden was contracted by Poseidon Water to review Section 8.3 (Should the State Water Board identify a preferred method of seawater intake?) of the Draft Staff Report Including the Draft Substitute Environmental Documentation. The overall report describes the State Water Resources Control Board (SWRCB)'s staff rationale and the factors considered in the development and analysis of the Desalination Amendment for the Water Quality Control Plan for Ocean Waters of California (CA Ocean Plan). Alden's review focused primarily on Section 8.3 of the report which provides a summary of the information reviewed on seawater intakes. This Section focuses on the following issues:

- Intake technology considerations for minimizing intake and mortality of marine life
- Surface vs. subsurface seawater intakes

Below are Alden's comments on Section 8.3 of the Draft Staff Report.

Comments

Pg 44, Section 8.3.1 – "*There are instances that occur where surface intakes have to be temporarily shut down because animals (e.g. sea jelly swarms) or other debris clog the intake and prevent source water from entering the facility.*" Though it's true that intakes experience episodic influxes of high debris loads, screens are typically adequate for managing debris. This text may overstate the problem and make intake operators seem passive. In actuality, intake operators continually assess the risk of intake blockages which may result in facility shutdowns and de-rates (each of which has substantial economic impacts and, therefore, incentive for preventing). It is important to understand that there is also a large body of work on the approaches and technologies for forecasting, preparing for, and mitigating anticipated debris events. Some references include:

- Electric Power Research Institute. 2004. Circulating and Service Water Intake Screens and Debris Removal Equipment Maintenance Guide. EPRI, Palo Alto, CA: 2004. 1009672.

- Electric Power Research Institute. 2009. Best Management Practices Manual for Preventing Cooling Water Intake Blockages. EPRI, Palo Alto, CA: 2009. 1020524.
- World Association of Nuclear Operators (WANO). November 2007. Intake Cooling Water Blockage. Significant Operating Experience Report. WANO SOER 2007-2.

Pg 45, Section 8.3.1 – "*The natural filtration process of a subsurface intake eliminates the need for pretreatment requirements. (National Research Council 2008)*" This statement reads too definitively and misrepresents the reference. To be clear, NRC 2008 states, "By taking advantage of the natural filtration provided by sediments, subsurface seawater intakes can reduce (emphasis added) the amount of total organic carbon and total suspended solids, thereby reducing (emphasis added) the pretreatment required for membrane-based desalination systems and lowering the associated operations and maintenance costs."

Pg 45, Section 8.3.1.1.2 – "*Smaller organisms in the water column such as algae, plankton, fish larvae, and eggs, that pass through surface water intake screens are drawn into the facility and will perish when exposed to the high pressure and heat of a cooling water or desalination system.*" A couple of notes regarding this characterization of entrainment:

It is uncommon for algae (micro or macro algae) to be included in the commonly accepted definition of entrainment. The Environmental Protection Agency's (EPA) recently released 316(b) Rule refers to entrainment as "*any life stages of fish and shellfish in the intake water flow entering and passing through a cooling water intake structure and into a cooling water system, including the condenser or heat exchanger.*"

Plankton is a general term which loosely refers to all animal and plant life that floats passively in the water column. As such, plankton includes both zooplankton (early life stages of fish and shellfish) and phytoplankton (plants).

Although it is commonly accepted that entrainment mortality for seawater desalination is 100%, it should be clarified that organisms entrained in water used for dilution purposes (flow augmentation) is not exposed to the same stressors as organisms entrained in the water that undergoes the desalination treatment process. That is, organisms entrained in the dilution flow are not likely to experience 100% mortality.

Pg 46, Section 8.3.1.1.2 – "*Mortality of impinged and entrained organisms is generally assumed to be 100 percent in the absence of site-specific studies. (U.S. EPA 2004; Pankratz 2004)*" Neither the U.S. EPA nor the Pankratz 2004 reference state that impingement mortality is assumed to be 100%. The survival of impinged organisms is commonly accepted and forms the basis of certain compliance alternatives relative to 316(b).

Pg 46, Section 8.3.1.1.2 – "*The entrainment estimate for cooling water intakes provides an example of the scale of entrainment that might occur if desalination efforts expand in California.*" This is hyperbole as the feedwater withdrawn by proposed seawater desalination facilities in CA is substantially less than seawater withdrawn for power plant cooling purposes. According to the 2007 California Energy Commission report "Assessing Power Plant Cooling Water Intake System Entrainment Impacts", the coastal power plants in CA potentially withdraw 17 billion gallons/day. A large seawater desalination facility may draw 100 million gallons/day (if assuming 50% recovery). Since entrainment is proportional to flow, the potential for the scale of entrainment from seawater desalination to reach that of cooling water withdrawals is very unlikely.

Pg 46, Section 8.3.1.2.1 – "*Additional mortality may occur through brine exposure in the mixing process and through predation in conveyance pipes.*" I am not aware of any data on predation in flow conveyance pipes; I would request a reference for this.

Pg 47, Section 8.3.1.2.3 – "*Screened intakes can be placed in areas of high local currents and wave-induced water motion to transport marine debris and organisms off and away from the screens. (Kennedy/Jenks Consultants, 2011)*" Screened intakes are installed everywhere, essentially, with installations onshore, in canals, in bays, in lagoons, etc. This should read "passive screened intakes" as ambient hydrodynamic conditions are key to optimal performance (biological and operational) for these types of screens. The consideration of ambient currents is an issue when considering passive intakes since there is no other means to move debris away from the screen; however, with active screens (e.g., traveling water screens) ambient currents are less of a concern since the screen is designed to collect and remove debris. In addition, Alden co-authored the intake-related portion of the referenced report, specifically the section on the passive screened intake being considered for the SCWD^2 project.

Pg 47, Section 8.3.1.2.3 – "*Studies suggest that the type of screen, size of the screen slot opening, and the method of intake are all factors that influence reductions of marine life mortality.*" It's important to note that there are a number of other factors that influence the biological performance of intake screens. These can include intake location, intake velocities (approach and through-screen), ambient currents, predicted debris loads, life stages and species composition present near the intake location, etc.

Pg 47, Section 8.3.1.2.3 – "*Passive intake screens are not self-cleaning and require manual cleaning either by divers or by retrieving the screen for cleaning and maintenance.*" The paragraph beginning with the previous sentence is poorly structured. Essentially all passive screen manufacturers include features to allow cleaning of screens without the regular need for divers to do manual cleaning. Passive wedgewire screens (such as those made by Bilfinger Water Technologies [formerly US Filter/Johnson Screens] and Hendrick Screen Company) are typically equipped with airburst systems to deliver a high pressure burst of compressed air to the screens to clear it of any accumulated debris. Other manufacturers (such as Intake Screens, Inc) offer passive screens with rotating drums and fixed brushes to clean the screens. In cases where the installation location of far offshore, there can be a need for divers and manual cleaning.

Pg 48, Section 8.3.1.2.3 – "*Coarse bar screens, floating booms, and angled coarse screens*" This section is poorly organized. In general, water enters a shoreline intake through a trash rack (also referred to as a bar rack). This first structure in the flow path is typically coarsely-spaced vertical bars designed primarily to exclude debris. The trash rack is equipped with a cleaning mechanism, typically a trash rake, to keep it clean. I'm not aware of any intakes using clear spacing as low as 2 mm as this would constitute a serious risk of becoming overloaded with debris. Though used at some intakes, floating booms are not used commonly enough to warrant discussion in this section "Angled coarse screens" are not the same at trash racks. Angled screens are used, in some cases, to divert organisms to a collection point (within the intake, not "away from the intake" as stated) where they can be returned to the source waterbody.

Pg 48, Section 8.3.1.2.3 – "*Traveling screens have been shown to substantially reduce impingement mortality. (U.S. EPA 2011) Impingement data from Dominion Power's Surry Station was collected during the 1970s.*" It's important to note that only "modified" traveling water screens provide fish-friendly features that can reduce impingement mortality; conventional traveling water screens do not have these features (fish lifting buckets, low pressure spraywash system, fish return trough, etc.) It's unclear why Dominion Station is called out, there is a plethora of data available on impingement survival on modified traveling water screens throughout the U.S.

Pg 48, Section 8.3.1.2.3 – "*Fine-meshed screens*" Very few would agree that fine-mesh includes sizes up to 9.5 mm. Screens with 9.5 mm openings are generally considered to be coarse-mesh and have been the industry standard for traveling water screens at cooling water intakes in the power industry. In the recently released final 316(b) Rule (particularly in the discussion of the Comprehensive Technical Feasibility and Cost Evaluation Study [§ 122.21(r)(10)]), EPA states, "*The study must include an evaluation of technical feasibility of closed-cycle cooling and fine-mesh screens with a mesh size of 2 mm or smaller…*" In this sense, fine-mesh as it relates to 316(b) compliance must be 2 mm or smaller.

Pg 48, Section 8.3.1.2.3 – "*While fine-meshed screens can reduce entrainment of adult and juvenile fish, they still allow phytoplankton, zooplankton, eggs, and fish and invertebrate larvae to pass through.*" The life stages of fish that are precluded from entrainment depends wholly upon the screening mesh size and morphometric dimensions of the species present; it is not accurate to state that these screens only reduce entrainment of adult and juvenile fish. Meshes of 0.5, 1.0, and 2.0 mm can reduce entrainment of many fish larvae and eggs.

Pg 48, Section 8.3.1.2.3 – "*Wedgewire screens are passive screening systems that act as a physical barrier to prevent organisms from being entrained. The screen slot size must be sufficiently small to physically block passage of an organism in order for wedgewire screens to effectively prevent entrainment. (EPRI 1999)*" This statement is true – that exclusion technologies, such as cyclindrical wedgewire screens, function on the basis that organisms need to be physically large enough to excluded by the screen. However, recent (and some historical) research has demonstrated that larval exclusion is not solely a physical phenomenon; rather, there are hydrodynamic and behavioral components that increase the biological performance of cylindrical wedgewire screens. Among the studies that have demonstrated that exclusion of early life stages of fishes is not solely based on physical size of the organisms are the following:

- EPRI. 2003. Laboratory Evaluation of Wedgewire Screens for Protecting Early Life Stages of Fish at Cooling Water Intakes, EPRI, Palo Alto, CA: 2003. 1005339.
- Heuer, J. H. and D. A. Tomljanovich. 1978. A Study on the Protection of Fish Larvae at Water Intakes Using Wedge-Wire Screening. TVA Technical Note B26.
- Weisburg, S. B., W. H. Burton, F. Jacobs, and E. A. Ross. 1987. Reductions in Ichthyoplankton Entrainment with Fine-Mesh, Wedge Wire Screens. North American Journal of Fisheries Management 7: 386–393.

- NAI. 2011a. 2010 IPEC Wedgewire Screen Laboratory Study. Prepared for the Indian Point Energy Center, Buchanan, NY.
- NAI. 2011b. 2011 IPEC Wedgewire Screen Laboratory Study. Prepared for the Indian Point Energy Center, Buchanan, NY.

A detailed description of how hydrodynamics and behavior can affect exclusion of early life stages of fishes with cylindrical wedgewire screens is provided beginning on page 23 of the following reference: Barnthouse, L.W., D.G. Heimbuch, M.T. Mattson, and J.R. Young. 2010. Response to Biological Aspects of NYSDEC 401 Certification Letter. http://www.dec.ny.gov/docs/permits_ej_operations_pdf/iprespbioaspect.pdf

Pg 49, Section 8.3.1.2.3 – "The only pilot study that has implemented wedgewire screens on an intake is at West Basin Municipal Water District's (WBMWD) pilot desalination facility." This is incorrect. In CA alone, there have been multiple pilot-scale studies of cylindrical wedgewire screens; they are listed below:

- Marin Municipal Water District – tested a 2.4-mm (3/32-in) cylindrical wedgewire screen
- Santa Cruz and Soquel Creek – tested a 2.0-mm cylindrical wedgewire screen
- West Basin Municipal Water District – currently testing 1.0- and 2.0-mm cylindrical wedgewire screen

In addition to these CA desalination-related pilot-scale studies, the following describes previous pilot-scale studies that have been conducted with cylindrical wedgewire screens:

Weisberg et al. (1987) conducted a field evaluation of cylindrical wedgewire screens (1, 2, and 3 mm) in the Chalk Point Generating Station intake canal in Maryland. The results demonstrated that exclusion was influenced not only by the size of organisms, but also by hydrodynamics, particularly since not all fish small enough to be entrained were always entrained. The biological efficacy of the screens was reported as a reduction in entrainment over an open port. The authors concluded that the entrainment of larger larvae was regularly reduced by 80% over the open port and by 90% over the ambient densities of larvae in the canal. Browne (1997) conducted a field evaluation of cylindrical wedgewire screens (1, 2, and 3 mm) from a floating facility at the Oyster Creek Generating Station on Barnegat Bay in New Jersey. The researchers concluded that the air backwashing feature functioned well in keeping the screens free of debris and that the screens constructed of metals with higher copper contents had the lowest amount of biofouling. Too few organisms were collected in entrainment samples to draw significant conclusions about the biological performance of the screen, though the authors pointed out that fewer fish were entrained through the 1-mm screen than the 2-mm screen or the open port and that those that were entrained through the 1-mm screen were generally smaller. Impingement was negligible. Lifton (1979) conducted a similar evaluation of 1- and 2-mm cylindrical wedgewire screens on the St. John's River in Florida. The data indicated that there was no significant difference in entrainment between the 1- and 2-mm screens. Sixty-five percent of the time, the screened intakes entrained at least 50% fewer organisms. Gulvas and Zeitoun (1979) evaluated entrainment through pilot-scale cylindrical wedgewire screens (2 and 9.5 mm) in Lake Michigan. The results indicated that entrainment densities were much lower than ambient densities of larvae and that no significant differences were seen in entrainment among either screen or the open pipe (control). In addition, no fish were impinged on the screens. EPRI (2005, 2006) completed a comprehensive pilot-scale field evaluation of the exclusion efficiency of 0.5- and 1.0-mm cylindrical wedgewire screens in three different water bodies (ocean, estuarine, and freshwater). The results indicate that 0.5 and 1.0 mm wedgewire screens can effectively exclude eggs and larvae at through-screen velocities of 0.5 and 1.0 ft/sec.

I am also aware of a pilot-scale entrainment study that evaluated biological effectiveness of a 2.0-mm cylindrical wedgewire screen in the Hudson River as part of the evaluation for United Water's Haverstraw Water Supply Project.

The citation for Tenera 2013b is also not germane to WBMWD's desalination pilot facility. It is related to the proposed design of a cylindrical wedgewire intake for the Diablo Canyon Power Plant.

Pg 49, Section 8.3.1.2.3 – "*Another issue in the marine environment is fouling marine organisms. The fouling organisms may impede the structural integrity of the screens or prevent adequate intake flow. Z-alloy screens were found to be the most effective at preventing corrosion or fouling in a one-year study. (Tenera Environmental 2013b)*' This text may understate the magnitude of the O&M risk posed by narrow-slot cylindrical wedgewire screens. There is a much larger volume of work on the topic of wedgewire screens and fouling control. Two relevant studies that address biofouling on narrow-slot wedgewire screens in a marine environment are described below:

- McGroddy, Peter M., Steven Petrich, and Lory Larson. 1981. Fouling and Clogging Evaluation of Fine-Mesh Screens for Offshore Intakes in the Marine Environment. In: Advanced Intake Technology for Power Plant Cooling Water Systems. Proceedings of the Workshop on Advanced Intake Technology. April 22-24, 1981.

  A study was conducted at the Redondo Beach Generating Station to assess fouling and clogging of fine-mesh screens (McGroddy et.al. 1981). This study was done in two parts; the first part looked at debris clogging and the second investigated the propensity of different materials to fouling.

  The debris study was conducted in a small, test tank using an 18 in diameter wedgewire screen. Based on the flow characteristics of this screen, Alden estimates that it had 1.0 mm slot openings. Flow for this tank was provided from behind the existing traveling screens. To provide a cross current an air circulation bubbler was used. This bubbler provided a cross current of between 6 and 9 cm/sec (0.2 and 0.3 ft/sec). Debris obtained from the intake waters was added and the head-loss measured. The results of this study indicated that the screens are prone to fouling and that multiple air-bursts are needed to completely clean the screens. The cleaning is also most effective when the screen is less than 50% blocked, which could require the screens to be air-burst daily or more frequently during high debris loading periods. Additionally, they note that re-impingement of debris on the screens occurs at low cross-screen velocities.

  The second stage of the McGroddy et al. 1981 study compared the rate of biofouling of several potential screening materials. Small material coupons were placed on the intakes for several weeks. The percent covered and head-loss through the material was measured. The materials tested included carbon steel, epoxy-coated steel, copper, and stainless steel. The mesh size of these materials varied from 0.7 mm to 2 mm. Some of these coupons were also subject to a heat treatment to determine the effectiveness of the heat treatment on controlling bio-fouling.

The results showed that stainless steel was the least prone to bio-fouling of all the materials. However, the stainless steel coupons all had larger mesh openings than the other screen types. In addition, there appears to be inconsistencies between the percent covered and headloss through identical meshes. The results of the heat treatment tests indicate that the heat treatment kills attached organisms, but does not remove their shells and that the screens are quickly re-colonized.

- Wiersema, James M., Dorothy Hogg, and Lowell J Eck. 1979. Biofouling Studies in Galveston Bay-Biological Aspects. In: Passive Intake Screen Workshop. December 4-5, 1979. Chicago, IL

The second relevant study was conducted in Galveston Bay, Texas (Wiersema et al. 1979). This study compared the rates of fouling for several small wedgewire screens. All the test screens were 9.5 inches in diameter with 2.0 mm slot openings. The only difference between the screens were their construction materials; one was stainless steel, two were copper-nickel alloys (CDA 706 and CDA 715), and one was a silicon-bronze-manganese alloy (CDA 655). These screens were mounted to a test apparatus that contained pumps and flow meters to measure the flow through each screen during the test period. The total duration of the test was 145 days.

The results indicate that the copper alloys significantly reduce bio-fouling of the screens. At the conclusion of the test period the copper alloy screens remained at least 50% open. The stainless steel screen fouled very quickly and was completely clogged after 2 weeks. In general, the progression of bio-fouling agents was similar for all the screens. First a slime layer formed over the screens which trapped sediments and provided a base for further colonization. After about 4 weeks hydroids began to colonize the screens. The hydroids were the dominant bio-fouling organism until tube-building amphipods appeared. The amphipods were only able to establish themselves on the portions of the screen with significant hydroid cover. This is assumed to be a result of the hydroids providing a buffer between the screens and the amphipods. Throughout the test period there was a small amount of colonization by bryozoans and loosely attached barnacles.

While this study did not include an air backwash, the researchers postulated that an air-burst could be used to break up the slime layer thus retarding the growth of other bio-fouling agents. To date, there have been no studies to determine if an air backwash would effectively remove the slime layer.

In addition to these two studies, the SCWD^2 pilot-scale cylindrical wedgewire study included investigations of biofouling potential of various screen materials (City of Santa Cruz Water Department & Soquel Creek Water District SCWD^2 Desalination Program: Open Ocean Intake Study Effects. ESLO2010-017.1. http://www.scwd2desal.org/documents/Draft_EIR/Appendices/AppendixG.pdf.) It is important to note, however, that this study was limited to the evaluation of screen material coupons and to periodic visual observations of the pilot-scale screen that was intermittently operated for the biological evaluation. It likely does not accurately reflect the magnitude of boifouling that would be expected with a screen through which flow is being continually withdrawn for a full-scale facility.

Pg 49, Section 8.3.1.2.3 – "*It is imperative that the wedgewire screens are maintained so slot-size integrity is maintained, through-screen velocity does not exceed 0.5 ft/s (0.15 m/s), and the facility still has adequate intake flow.*" As a rule of thumb, it is common to assume a degree of blockage in the design a wedgewire screen array. EPA, in the proposed 316(b) Rule, indicated that the 0.5-ft/sec through screen velocity should be under a 15% blocked condition. Therefore, it is common to target approximately 0.43 ft/sec through screen velocity.

Pg 49, Section 8.3.1.2.3 – "*However, other studies have shown that a small screen slot size does not by itself result in significant clogging or cleaning problems. (Taft 2000)*" The referenced paper was written by Alden's former president and inaccurately characterizes the conclusion. The paper states the following about narrow-slot wedgewire screens: "*However, there are major concerns with clogging potential and biogrowth. Since the only two large CWIS to employ wedge-wire screens to date use 6.4 and 10 mm slot openings, the potential for clogging and fouling that would exist with slot sizes as small as 0.5 mm, as would be required for protection of many entrainable life stages, is unknown. In general, consideration of wedge-wire screens with small slot dimensions for CWIS application should include in situ prototype scale studies to determine potential biological effectiveness and identify the ability to control clogging and fouling in a way that does not impact station operation.*"

Pg 49, Section 8.3.1.2.3 – "*Importance of Screen Slot Size.*" The majority of the references cited in this section are secondary sources. It does not appear that the SWRCB staff reviewed the original work for each of the studies and sites that are included in this section.

Pg 49, Section 8.3.1.2.3 – "*Tampa Bay seawater desalination plant*" It is important to note that the co-located desalination plant draws feedwater (approximately 50 MGD) from Big Bend Station's heated effluent (i.e., after it has already been screend and passed through te power plant cooling system). As such, it is the cooling water intake system of the power plant (flow capacity of 1.4 billion gallons/day) that makes use of the 0.5-mm traveling water screens. The 0.5-mm screens are only used seasonally between March 15 and October 15 and only in the intake for Units 3 and 4 (the intake for Units 1 and 2 is equipped with 9.5-mm dual-flow traveling water screens). Low-pressure and high-pressure screen wash pumps provide wash water to the spray nozzle supply headers. Aquatic organisms and debris are rinsed from the fine-mesh screens, collected in a common trough, and routed to a screened sump. The sump incorporates a trash basket to facilitate removal of debris. Three Hidrostal pumps discharge rinsed organisms and debris into one of two 18-inch fiberglass organism return lines. The organism return system is approximately 0.75 miles long and discharges into a natural embayment south of the station discharge canal.

The fine-mesh traveling water screens at Big Bend were considered to be very successful. They were sufficient, in the view of the EPA and the Florida Department of Environmental Regulation, for reducing entrainment at the CWIS for Units 3 and 4. In addition, studies at full-scale installation indicate that the survival of impinged organisms on the fine-mesh screens were comparable to, and in some cases higher than, those achieved during the prototype study. However, the survival of some fragile species/life stages was lower (e.g., bay anchovy).

As part of the evaluation of the fine-mesh screens, an auditing program was established to monitor the conditions of the screens and optimize their screening efficiency. The biggest O&M problem at this site was biofouling (particularly barnacles and mussels). It was found that biweekly manual cleaning of the screens by a two-person crew was effective in preventing damage to the screen mesh and seals. Later studies at Big Bend focused on optimizing the screening.

Pg 49, Section 8.3.1.2.3 – Reference to *Robert Pagano* is outdated (1976); many newer references with better information are available. In addition, "traveling screens" is a general category that includes, among many other designs, the single-entry, double-exit center-flow design at Barney Davis.

Pg 49, Section 8.3.1.2.3 – "*The Tennessee Valley Authority pilot studies showed reductions in striped bass larvae entrainment of up to 99 percent using 0.5 mm screens.*" The TVA studies were conducted in a laboratory with hatchery-reared striped bass; they were not pilot-scale studies as indicated.

Pg 50, Section 8.3.1.2.3 – "*0.5 mm fine mesh screen at the Brunswick seawater cooling Power Plant in North Carolina showed entrainment reductions of 84 percent. Similar results were shown at the Chalk Point Generating Station in Maryland, which also uses seawater for cooling, and the Kintigh Generating Station in New Jersey. (Tetra Tech Inc. 2002)*" Regarding Brunswick, the screens were 1.0-mm mesh and only 3 of the 4 traveling water screens had this mesh size; the fourth screen had standard 9.5-mm mesh. The design of this intake is also fairly unique and likely confers a substantial benefit in terms of managing debris. The intake is comprised of a stationary diversion structure located at the mouth of the intake canal in the river, a traveling water screen structure at the end of the intake canal, and a fish return system. The diversion structure is a stationary, V-shaped screen comprised of 9.4-mm copper-nickel mesh panels. The V-shape was chosen to aid in the sweeping of debris from the screen face during ebb and flood tides. As such, the traveling water screens at the end of the 2.7-mile long intake canal likely experience lighter debris loads than if the screens were adjacent to the estuary.

Regarding Chalk Point, this intake does not have 0.5-mm traveling water screens. They use a double barrier net at the head of an intake canal. The outside mesh is 1.5 in and the inside mesh is 0.75 inch. The traveling water screens at the terminus of the intake canal use 9.5-mm mesh screening. I assume SWRCB staff is referring to the pilot-scale study done in the Chalk Point intake canal with 1.0, 2.0, and 3.0-mm wedgewire screens (Weisburg, S. B., W. H. Burton, F. Jacobs, and E. A. Ross. 1987. Reductions in Ichthyoplankton Entrainment with Fine-Mesh, Wedge Wire Screens. North American Journal of Fisheries Management 7: 386–393.).

Regarding Kintigh, this facility is located on Lake Ontario not in New Jersey. It too, uses 1.0-mm mesh, not 0.5-mm.

Pg 50, Section 8.3.1.2.3 – "*Bestgen et al. 2001*" The referenced study is a laboratory evaluation of a Coanda-effect screen. I am not aware of any seawater intakes using this type of screen; it is typically applied at hydroelectric projects, stormwater outfalls, agricultural diversions, etc.. It is essentially a high velocity inclined profile-wire screen and has a fundamentally different hydraulic design. The following description is from the peer-reviewed paper describing the lab study: "*High velocity profile-bar fish screens differ from traditional positive barrier configurations. Most barrier screen designs couple low approach velocities(velocity through the screen) with high sweeping velocities (across screen) to effect screening….. In contrast, inclined profile-bar screens have water delivered to the top of the screen via an overflow weir, which then flows over the screen face at a high 2–3-m/s velocity….. Thus, unlike* *traditional screens, fish behavior and swimming performance and approach and sweeping velocities are not design considerations for high-velocity inclined profile-bar screens.*" Including a review of this intake type is immaterial as it is an inappropriate technology for a seawater intake.

Pg 50, Section 8.3.1.2.3 – "*Laterally compressed fish like anchovies and flatfish typically will have higher entrainment rates than fish like sculpins or rockfishes of the same length because the anchovies and flatfish have smaller head capsule dimensions.*" Flatfish are not laterally compressed, they are dorsoventrally compressed.

Pg 50, Section 8.3.1.2.3 – "*Another study performed at the facility demonstrated that almost 100 percent of larvae over 10 mm were excluded from entrainment by a 1 mm wedgewire screen (EPRI 2003)*" The EPRI 2003 study was conducted in a laboratory flume at Alden, not in the Chalk Point intake canal in Maryland where the Weisberg et al. study was done.

Pg 50, Section 8.3.1.2.3 – "*Screens with 1 mm slot size reduced entrainment of larvae with large head capsules, but did not reduce entrainment of eggs smaller than 2.3 mm in diameter. (EPRI 2005).*" This is incorrectly cited. The SWRCB staff should have cited Hanson 1979 which was a lab, not a field, study.

Pg 50-51, Section 8.3.1.2.3 – "*Entrainment and impingement were evaluated for 1 mm and 2 mm wedgewire screens on intakes at the Seminole Generating Station in Florida. The study showed there was virtually no impingement of organisms after screens were installed, and that larvae entrainment was reduced by 99 and 62 percent for the 1 mm and 2 mm screens, respectively, when compared to larger (9.5 mm) screen systems. (EPRI 1999)*" This is incorrectly cited. The paper that should be referenced for this study is: Lifton, W. 1979. Biological Aspects of Screen Testing on the St. Johns River, Palatka, Florida. Prepared for Passive Intake Screen Workshop, Chicago, IL, December, 1979. Furthermore, the results described here differ from those in the paper. Namely, Lifton concluded that "*the 1-mm and 2-mm screens offered reductions of 66 and 62 percent of the unscreened (open pipe) intake entrainments, respectively. ….. there was no statistically significant differences between the 1- and 2-mm screens in terms of densities of fish entrained…… Nine (or 75 percent) of the entrainment collections through the 1- and 2-mm screens represented reductions of at least 50 percent over entrainments through the unscreened intake, and 10 (or 83. 3 percent) of the 12 collections showed reductions of more than 30 percent.*"

Pg 51, Section 8.3.1.2.3 – "*Tenera 2013a*" Relative to this reference, it is important to note that the theoretical reductions in entrainment calculated are based solely on physical dimensions of larvae and do not incorporate any benefits conferred by hydrodynamics and fish behavior (e.g., many later larval stages possess the ability to swim – something not accounted for in these estimates of exclusion). As such, the predictions are conservative and, in the field, a wedgewire screen will likely provide greater protection than that which can be estimated based on physical dimensions.

Pg 52, Section 8.3.1.2.3 – "*The general estimates for slot size……*" This paragraph states the very well accepted concept that entrainment is site- and species-specific. Given that the SWRCB staff recognizes this in the Draft Staff Report, it should follow that a one-size-fits all prescription for a certain screen mesh size for all intakes may not be appropriate.

Pg 52, Section 8.3.1.2.3 – "*Additionally, even though wedgewire screens can reduce impingement mortality and entrainment loss of juvenile and adult fish, intake-related mortality will be site and species-specific.*" It is commonly accepted that impingement is essentially eliminated by a wedgewire screen designed for 0.5 ft/sec. The statement of impingement mortality being reduced is immaterial if it has been determined that impingement is essentially eliminated.

Pg 52, Section 8.3.1.2.3 – "*scwd2 2010* and *Tenera Environmental 2012*" I cannot find the full citation for either of these references.

Pg 52, Section 8.3.1.2.3 – "*The portion of organisms that are not entrained because of the wedgewire screen is relatively small compared to the number of organisms in the water. (Foster et al. 2012) Consequently, there is only an approximate one percent reduction in entrainment mortality between screened and unscreened intakes. (Foster et al. 2013)*" It is important to note that although there are smaller organisms in the water column, designing screening systems to keep them out is impractical – mesh sizes can only get so small before head losses are so high as to render any intake infeasible from a design perspective. Raising the question of which species should be included in "entrainment" may be valid; though, being able to calculate the value of these species will be difficult. This is the first I've heard of other components of the plankton being included with "entrainables". Furthermore, if Foster et al (2013) concludes that a 1% reduction in entrainment is the maximum that can be expected for wedgewire intakes, it requires some explanation about which organisms are being included and which mesh size is being used.

Pg 52, Section 8.3.1.2.3 –"*Other passive and active screens*" Regarding the active intake screens – all of the types mentioned are considered modified traveling water screens, they simply represent different vendor-specific designs.

Pg 53, Section 8.3.1.2.4 – "*Velocity Caps*" The description of how a velocity cap is designed to function is wrong. Intake velocities created at the entrance to the velocity cap need to be high enough for fish to sense and avoid; 0.5 ft/sec is not high enough to elicit an avoidance response. Velocity caps in southern California were originally designed with entrance velocities between 2 and 3.5 ft/sec (Weight, R.H. 1958. Ocean Cooling Water System for 800 MW Power Station. Journal of the Power Division of the American Society of Civil Engineers. Paper 1888.). Often, a velocity cap is designed with a series of coarse bars arranged in a vertical orientation around the opening of the cap. These bars act as a very coarse mesh trash rack in addition to providing stability to the cap itself. In southern California, the new OTC policy requires bars spaced at no greater than 9 inches to prevent entrapment of large organisms (e.g., seals, sea lions, and sea turtles). EPA provided a recent clarification regarding velocity caps in Federal Register/Vol. 77, No. 112, Monday, June 11, 2012/Proposed Rules, page 34320: "*EPA is aware that low intake velocity is sometimes confused with velocity cap technologies, and EPA would like to clarify that these concepts are not the same. Most velocity caps do not operate as a fish diversion technology at low velocities, and in fact are often designed for an intake velocity exceeding one foot per second. Thus a velocity cap will not typically meet the low intake velocity impingement mortality limitation. The velocity cap is located offshore and under the water's surface, and uses the intake velocity to create variations in horizontal flow which are recognizable by fish. The change in flow pattern created by the velocity cap triggers an avoidance response mechanism in fish, thereby avoiding impingement.*"

Attachment 2C

Carlsbad Seawater Desalination Project

Energy Minimization and Greenhouse Gas Plan, July 30, 2008

~~GHG Draft Final Oct 08.doc~~**[Revised to be consistent with Findings adopted by CCC on 12/10/08]**

CARLSBAD SEAWATER DESALINATION PROJECT

ENERGY MINIMIZATION
AND
GREENHOUSE GAS REDUCTION PLAN

July 30, 2008

Staff Note:

Key elements of this Plan include:

- *Poseidon's indirect GHG emissions will be calculated using California Air Resources Board (CARB) or California Climate Action Registry (CCAR) methodologies.*

- *Poseidon will be credited with emission offsets that may result from reductions in State Water Project imports.*

- *The offset projects****, except for Renewable Energy Credits (RECs), that*** *Poseidon implements pursuant to this Plan will be ~~those approved by~~****purchased through/from*** *CARB, CCAR, or any California Air Pollution Control District (APCD) or Air Quality Management District (AQMD). Poseidon may also request that the Executive Director approve projects that may be available from other entities.*

- ~~*Poseidon will purchase all offset credits implemented pursuant to this plan through CCAR unless Poseidon requests, and the Executive Director approves, the purchase of credits from other entities.*~~

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CARLSBAD SEAWATER DESALINATION PROJECT

ENERGY MINIMIZATION AND GREENHOUSE GAS REDUCTION PLAN

JULY 30, 2008

INTRODUCTION

In October 2007, Poseidon Resources (Poseidon) ~~made public its voluntary~~**offered as part of its Carlsbad Desalination Project (Project) a** commitment to account for and bring to zero the net indirect Greenhouse Gas (GHG) emissions from the ~~Carlsbad Desalination Project (Project)~~**Project**. Poseidon followed its unprecedented commitment with the development of a Climate Action Plan (CAP), Poseidon's roadmap to achieving its commitment over the 30-year life of the Project. Based on protocols adopted by the California Climate Action Registry (CCAR), the CAP was reviewed by the California Coastal Commission (CCC), the California State Lands Commission (CSLC), the California Air Resources Board (CARB) and, at the request of a Coastal Commissioner, the South Coast Air Quality Management District (SCAQMD).

On November 15, 2007, the CCC approved the Project subject to the condition, among others, that the CCC approve the CAP at a subsequent hearing. Specifically, **Special Condition 10** states that "prior to issuance of the permit, the Permittee shall submit to the Commission a Revised Energy Minimization and Greenhouse Gas Reduction Plan (the Plan) that addresses comments submitted by the staffs of the Coastal Commission, State Lands Commission and the California Air Resources Board. The permit shall not be issued until the Commission has approved a Revised Energy Minimization and Greenhouse Gas Reduction Plan after a public hearing." Since the Special Condition was adopted, Poseidon has reviewed comments from the November 15 hearing as well as CCC staff's draft findings, and continued to work with the CCC, CSLC and CARB to refine the CAP and ensure a complete understanding of the process it sets forth to meet Poseidon's commitments. ~~Poseidon's November 20, 2007 draft of the CAP reflected changes made in response to helpful comments from these agencies and is attached to this document as Appendix A. Poseidon's written responses to numerous questions and comments from the CCC and CSLC about the CAP are attached as Appendix B. More recently, CCC staff issued to Poseidon additional comments and a draft "Greenhouse Gas Emissions Template" (the Draft CCC Template), and instructed Poseidon to revise its CAP in accordance with the template. CCC staff also requested that Poseidon rename the CAP with a new title, the Project's Energy Minimization and Greenhouse Reduction Plan (the Plan). The Draft CCC Template and the most recent comments and Poseidon responses are attached as Appendix C.~~

On May 2, 2008, Poseidon met with representatives of the CCC, CSLC and various agencies in the San Diego region to further discuss details of the Plan and its implementation. The purpose of this document is to present Poseidon's revised Plan in response to the additional comments received, the May 2 meeting, and the draft CCC Template.

1. PROJECT OVERVIEW

The 50 million gallon per day (MGD) Project (Figure 1) is co-located with the Encina generation station, which currently uses seawater for once-through cooling. The Project is developed as a public-private partnership between Poseidon and nine local utilities and municipalities.

In 2006, California legislation introduced the AB 32 Global Warming Solutions Act that aims to reduce the GHG emissions of the state to 1990 levels by year 2020. While it is unlikely that the legislation or its implementing regulations will apply to the Project because the Project only emits significant GHGs indirectly through electricity use,[1] Poseidon applauds the objectives of AB 32 and is committed to helping California maintain its leadership role in addressing the causes of Climate Change. As a result, Poseidon has committed to offset the net indirect GHG emissions associated with the Project's operations. Poseidon's ~~voluntary commitment~~**offer** has been incorporated into the Project's permit through **Special Condition 10**, adopted by the California Coastal Commission and agreed to by Poseidon. According to **Special Condition 10** and CCC staff direction, Poseidon is required to submit a plan for Commission review and approval showing how the Project will minimize its electricity use and reduce indirect GHG emissions resulting from net increases in electricity use over existing conditions.

Figure 1 – Carlsbad Seawater Desalination Facility

[*Note: Figure provided in original.*]

2. CCC DRAFT EMISSIONS TEMPLATE

The draft CCC Template establishes "a protocol for how to assess, reduce, and mitigate the GHG emissions of applicants," and calls for the organization of relevant information into the following three sections:

1. Identification of the amount of **indirect** GHGs ~~emitted from~~ **due to** the Project's **electricity use**,
2. On-Site and Project related measures planned to reduce emissions, and
3. Off-site mitigation options to offset remaining emissions.

After a brief explanation of Poseidon's overall strategy for eliminating the Project's net indirect GHG emissions, this document then organizes the Plan into the CCC's three general categories.

3. OVERVIEW OF THE PROJECT'S GHG REDUCTION STRATEGY

Since offsetting net indirect GHG emissions is an ongoing process dependent on dynamic information, Poseidon's Plan for the assessment, reduction and mitigation of GHG emissions establishes a protocol for identifying, securing, monitoring and updating measures to eliminate

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[1] AB 32's implementing regulations are currently being drafted and will subsequently be released for public comment. AB 32's regulations, when promulgated, will likely target direct emitters of GHGs, including SDG&E (the source of the Project's electricity), rather than indirect emitters such as the Project. In any case, Poseidon will modify its Plan to conform with these regulations to the extent that they are applicable to the Project.

the Project's net carbon footprint. Once the Project is operational and all measures to reduce energy use at the site have been taken, the protocol involves the following steps, completed each year:

1. Determine the energy consumed by the Project for the previous year using substation(s) electric meter(s) readings from San Diego Gas & Electric's (SDG&E) or any other entity from which the Project obtains all or part of its electricity at any time in the future.

2. Determine SDG&E emission factor for delivered electricity from its most recently published CCAR Annual Emissions Report. Reports are issued annually and are accessible on the CCAR's website. Emission factors will be obtained from CARB if and when SDG&E's certified emission factor for delivered electricity is publicly available through CARB's anticipated GHG Inventory program. If at any time in the future the Project obtains all or part of its electricity from an entity other than SDG&E, the appropriate CCAR **or CARB** emission factor for that entity shall be used. While current emissions reports only report CO_2, future reports are expected to include the five additional GHGs (methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride). To the extent that these additional GHGs are included in future reports, they will be converted to carbon equivalents for the Project and offset under the Plan.

3. Calculate the Project's gross indirect GHG emissions resulting from Project operations by multiplying its electricity use by the emission factor.

4. Calculate the Project's net indirect GHG emissions by subtracting emissions avoided as a result of the Project (Avoided Emissions) and any existing offset projects and/or Renewable Energy Credits (RECs). **Each year's amount of net indirect GHG emissions will be determined using CARB or CCAR** ~~**methodologies**~~**emissions factors for SDG&E and the State Water Project.**

5. If necessary, **implement carbon offset projects and** purchase carbon offsets or RECs to zero-out the Project's net indirect GHG emissions~~; provided, however,~~**. Subject to the provisions of Sections III.C, E and F below: (i) Offset projects, except for RECs, implemented pursuant to this Plan will be** ~~**those approved by**~~**purchased through/from CARB, CCAR, or a California APCD or AQMD**~~**. Poseidon will purchase from CCAR any offset credits needed to implement this Plan.**~~ **and (ii) Poseidon may propose** ~~**using**~~**purchasing other offset projects**~~**and credits**~~**, subject to Executive Director** ~~**approval**~~**or Commission approval, in the event that sufficient offsets are not available from CCAR/CARB/California APCD or AQMD at a price that is reasonably equivalent to the price for offsets in the broader domestic market.** ~~that if through the process set forth in Part III of this Plan, it is determined that (i) such offsets or RECs are not reasonably available; (ii) the "market price" for such offsets is not reasonably discernable; (iii) the market for offsets/RECs is suffering from significant market disruptions or instability; or (iv) the market price has escalated to a level that renders the purchase of offsets/RECs economically infeasible to the Project, Poseidon shall pay a fee into an escrow fund, for the purpose of funding GHG offset projects as they become available.~~

Energy efficiency measures and on-site use of renewable resources will be given the highest priority. In addition, through its annual program to offset net carbon emissions for that year, Poseidon will commit the first $1 million spent on this program to fund the revegetation of areas in the San Diego region impacted by wildfires that occurred in the fall of 2007, as discussed in detail in Part III below.[2] **Poseidon will implement this element of the Plan using CARB or CCAR ~~forestry or urban forestry protocols~~Forest Project Protocols or the upcoming CARB/CCAR Urban Forest Project Protocol, depending on the type of project Poseidon selects.**

The following are elements of the Plan organized in accordance with the draft CCC template.

PART I. IDENTIFICATION OF THE AMOUNT OF GHG EMITTED

The Project will produce fresh drinking water using reverse osmosis membrane separation. The treatment processes used at the Plant do not generate GHGs. The desalination process does not involve heating and vaporization of the source seawater and thus does not create emissions of water vapor, carbon dioxide, methane, nitrous oxide, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), or sulfur hexafluoride (SF6). Reverse osmosis membranes do not reject the carbon dioxide, which is naturally dissolved in the source seawater, and this carbon dioxide is retained in dissolved form in the fresh drinking water created by desalination.

The modest number of fleet vehicles used by plant personnel will create a small amount of GHG emissions, but since these emissions make up less than 5% of the Project's carbon footprint, these emissions are considered *de minimis* and are not required to be reported (CCAR General Reporting Protocol of March 2007 (Chapter 5)). The Project will not store or use fossil fuels on site, and will not self-generate electricity that emits GHGs. As a result, Project operations will not create significant direct sources of GHG emissions. There are no direct fugitive emissions from the plant.

The Project's sole significant source of GHG emissions will be indirect emissions resulting from purchased electricity. All of the electricity supply for the desalination plant operations will be provided by SDG&E. Therefore, the complete accounting of significant GHG emissions for the Project will consist entirely of indirect emissions resulting from electricity purchased from SDG&E.[3]

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[2] The California Coastal Commission conditioned the Project's Coastal Development Permit on Poseidon committing the first $1 million spent on this program to the ~~**purchasing $1 million worth of trees for**~~ revegetation of areas impacted by wildfires in the San Diego region.

[3] Typically, GHG emissions from construction of a project are not included in the on-going reporting of GHGs from operations. In fact, GHGs from construction are not typically accounted for in a GHG inventory at all.

Currently, about 65% of the electricity supplied by SDG&E is generated from fossil fuels.[4] As a result, until SDG&E switches to 100% "green" power supply sources, the Project operations will be indirectly linked to the generation of GHGs.

The total net indirect GHG emissions of the Project from the stationary combustion of fossil fuels to generate electricity is dependent on three key factors: (1) how much electricity is used by the Project; (2) sources of energy (fossil fuels, wind, sunlight, etc.) used to generate the electricity supplied to the plant, and (3) the Avoided Emissions, i.e., the amount of energy saved or emissions avoided as a direct result of the Project's operations. These factors will vary over time.

A. ELECTRICITY USE BY THE PROJECT

The Project will operate continuously, 24 hours a day for 365 days per year, to produce an average annual drinking water flow of 50 million gallons per day (MGD). The total baseline power use for this plant is projected to be 31.3 average megawatts (aMW), or 4.9 MWh per acre-foot (AF) of drinking water. The power use incorporates both production of fresh drinking water, as well as conveyance and delivery of the water to the distribution systems of the public water agencies that have contracted to purchase water from the Project. The total annual electricity consumption for the Project Baseline Design is 274,400 MWh/yr.

B. SDG&E'S EMISSION FACTOR

The Project will purchase all of its electricity from SDG&E.[5] Accordingly, the appropriate emission factor to use for the Project's indirect GHG emissions from its electricity use is SDG&E's independently verified and published emission factor for the electricity purchased and consumed during the previous year. The certified emission factor for delivered electricity in 2006 is set forth in the utility's Annual Emissions Report published by CCAR in April 2008. In the published Emissions Report, the current certified emission factor for SDG&E's 2006 delivered electricity is 780.79 lbs of CO_2 per delivered MWH of electricity.

Circumstances will change over the life of the Project. SDG&E's emission factors are updated annually and the amount of energy consumed by the Project may change.[6] As a result, it will be necessary to recalculate the net indirect GHG emissions of the Project on an annual basis using the actual SDG&E emission factor reported to the CCAR (or CARB). Until the mandatory reporting of emission factors under AB 32 is available, the emission factors for SDG&E registered with CCAR are the best available for purposes of planning and permitting this Project.

Statewide initiatives to expand the use of renewable sources of electricity are expected to decrease the emission factors of all California power suppliers in the future. For example, approximately 6% of SDG&E's retail electricity is currently generated from renewable resources

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[4] SDG&E Power Content Label, September 2007.

[5] If at any time in the future the Project obtains all or part of its electricity from an entity other than SDG&E, the appropriate CCAR emission factor for that entity shall be used.

[6] SDG&E Annual Emissions Reports to CCAR have changed each year. For years, 2004, 2005, and 2006 the emissions factors have been 614, 546 and 781 lbs. of CO_2/MWh, respectively.

(solar, wind, geothermal, and biomass).[7] In their most-recent Long-term Energy Resource Plan, SDG&E has committed to increase energy from renewable sources by 1% each year, reaching 20% by year 2017. These and other reductions are expected to further reduce the Project's net indirect GHG emissions over time.

Table 1 summarizes the Project's estimated gross indirect CO_2 emissions from purchased electricity for Project operations, based on the most current information.

Table 1 – Identification of Gross Indirect CO2 Emissions from Purchase of Electricity for Project Operations

Source	**Total Annual Power Use (MWh/year)**	**Total Annual Emissions (metric tons CO_2/year)**
Project Baseline Design	274,400	97,165

PART II: ON-SITE AND PROJECT-RELATED REDUCTION OF GHG EMISSIONS

To determine the Project's indirect GHG emissions, on-site and project-related reductions in emissions must also be considered. These are carbon emission reductions that result from measures that reduce energy requirements (increased energy efficiency, potential onsite solar, recovery of CO_2 and green building design), as well as Project-related emissions that will be avoided (Avoided Emissions) as a direct result of the Project and its various components (coastal wetlands restoration, reduced energy use from water reclamation, and replacing Customers' SWP water with water from the Project). **The total of each year's indirect GHG emissions~~, Project-related reductions, and Avoided Emissions~~ will be determined using CARB- or CCAR-approved ~~methodologies~~emissions factors for SDG&E and the State Water Project.**

A. INCREASED ENERGY EFFICIENCY

Poseidon has committed to implement certain measures to reduce the Project's energy requirements and GHG emissions, and will continuously explore new technologies and processes to further reduce and offset the carbon footprint of the Project, such as the use of carbon dioxide from the ambient air for water treatment. These measures are set forth below.

The Project's high-energy efficiency design incorporates state-of-the-art features minimizing plant energy consumption. One such feature is the use of a state-of-the art pressure exchanger based energy recovery system that allows recovery and reuse of 33.9% of the energy associated with the reverse osmosis (RU) process. A significant portion of the energy applied in the RO process is retained in the concentrated stream. This energy bearing stream (shown with red arrows on Figure 2) is applied to the back side of pistons of cylindrical isobaric chambers, also

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[7] SDG&E Power Content Label, September 2007.

known as "pressure exchangers" (shown as yellow cylinders on Figure 2). These energy exchangers recover and reuse approximately 45% of the energy used by the RO process.[8]

Figure 2 – Energy Recovery System for the Carlsbad Seawater Desalination Plant

[*Note: Figure provided in original.*]

Currently there are no full-scale seawater desalination plants in the US using the proposed state-of-the art pressure exchanger energy recovery technology included in the "High Efficiency Design" (Table 2). All existing seawater desalination projects in the US, including the 25 MGD Tampa Bay seawater desalination plant, which began commercial operation on January 25, 2008, are using standard energy recovery equipment — i.e., Pelton wheels (see Figure 2). Therefore, the Pelton wheel energy recovery system is included in the "Baseline Design" in Table 2.

The pressure exchanger technology that Poseidon proposes to use for the Project is a national technology. The manufacturer of the pressure exchangers referenced in Table 2 of the Project Power Budget is Energy Recovery, Inc., a US company located in San Leandro, California (www.energyrecovery.com).

A pilot-scale seawater desalination plant using the pressure exchanger technology proposed by Poseidon and supplied by Energy Recovery, Inc. has been in operation at the US Navy's Seawater Desalination Testing Facility in Port Hueneme, California since 2005. The overall capacity of this desalination plant is 50,000 to 80,000 gallons per day. The pilot testing work at this facility has been conducted by the Affordable Desalination Collaboration (ADC), which is a California non-profit organization composed of a group of leading companies and agencies in the desalination industry (www.affordabledesal.com). A portion of the funding for the operation of this facility is provided by the California Department of Water Resources (DWR) through the state's Proposition 50 Program. The DWR provides independent oversight of this project and reviews project results. In addition, representatives of the California Energy Commission and the California Department of Public Health are on the Board of Directors of the ADC.

The proposed pressure exchanger technology (i.e., the same pressure exchanger employed at the ADC seawater desalination plant) was independently tested at Poseidon's Carlsbad seawater desalination demonstration plant. More than one year of testing has confirmed the validity of the conclusions of the ADC for the site-specific conditions of the Project. The test results from the Carlsbad seawater desalination demonstration plant were used to calculate the energy efficiency of the pressure exchangers included in Table 2. Poseidon's technology evaluation work at the Carlsbad seawater desalination demonstration plant was independently reviewed and recognized by the American Academy of Environmental Engineers and by the International Water Association, who awarded Poseidon their 2006 Grand Prize in the field of Applied Research.

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[8] The "45% percent energy recovery and reuse" refers to the gross energy recovery potential, while the "33.9% energy recovery and reuse" refers to the actual energy savings associated with the energy recovery system. The difference between gross and actual energy savings is due to mechanical inefficiencies of the recovery system and associated friction losses. Thus, for purposes of calculating the overall energy savings, Table 2 correctly reflects 33.9% savings associated with the pressure exchanger.

Table 2 – Comparison of Baseline and High-Efficiency Power Budget for 50 MGD Water Production Capacity

[*Note: Table provided in original.*]

Figure 3 – Tampa Bay Desalination Plant Pelton Wheel Energy Recovery System

[*Note: Figure provided in original.*]

Table 2 presents a detailed breakdown of the projected power use of the Project under a Baseline Design and High-Energy Efficiency Design. As indicated in this table, the Baseline Design includes high efficiency motors for all pumps, except the largest reverse osmosis feed pumps, and a Pelton wheel energy recovery system, which is the most widely used "standard" energy recovery system today. The total desalination power use under the Baseline Design is 31.3 aMW, which corresponds to a unit power use of 15.02 kWh/kgal[9] (4,898 kWh/AF).[10]

In addition to the state of the art-pressure exchanger system described above, the High-Energy Efficiency Design incorporates premium efficiency motors and variable frequency drives (VFDs) on desalination plant pumps that have motors of 500 horsepower or more. The total desalination plant energy use under the High-Energy Efficiency Design is ~~a~~28.1 ~~MW~~**aMW**, which corresponds to unit power use of 13.488 kWh/kgal[11] (4,397kWh/AF).[12]

The main energy savings result from the use of pressure exchangers instead of Pelton wheels for energy recovery. The pressure exchangers are projected to yield 2,650 hp (2.0 aMW)[13] of power savings, which is 6.3 % reduction of the total power use of 31.3 aMW. Converted into unit power savings, the energy reduction of 2.0 aMW corresponds to 0.95 kWh/kgal[14] (310 kWh/AF)[15]. The installation of premium-efficiency motors and VFDs on large pumps would result in additional 1.2 aMW (4%) of power savings.

The power savings of 0.95 kWh/kgal associated with the use of pressure exchangers instead of Pelton wheels for energy recovery are substantiated by information from several full-scale desalination plants which have recently replaced their existing Pelton wheel energy recovery systems with pressure exchangers in order to take advantage of the energy savings offered by this technology~~ (see Appendix D). Appendix D~~**. Poseidon's submission of this Plan to the**

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[9] 31.3 MWh x 1,000 kW/MW/Average Fresh Water Production Rate of 2083 kg/h.

[10] 15.02 kWh/kgal x 326 kgal/AF.

[11] 28.1 MWh x 1,000kW/MW/2083 kgal/h.

[12] 13.488 KWh/kgal x 326 kgal/AF.

[13] 2650 HP x 0.746 kw/HP

[14] 2.0 x 1000 kw/MW/2083kgal/HR

[15] 0.95 kwh/kgal x 326 kgal/AF

Commission included documentation entitled "Energy Recovery in Caribbean Seawater", which contains energy data for a seawater desalination plant in Mazarron, Spain where a Pelton wheel system was replaced with PX pressure exchangers. As indicated on Table 2 of Attachment 1, the replacement resulted in energy reduction from 3.05 kWh/m^3 to 2.37 kWh/m^3 (i.e., 0.68 kWh/m^3 or 2.57 kWh/kgal). ~~Poseidon will provide for CARB or CCAR verification Tthe~~**The** total actual energy reduction resulting from the use of state-of-the-art desalination and energy recovery technologies and design will be verified by ~~based on~~ direct readings of the total electricity consumed by the desalination plant at the Project's substation(s) electric meter(s) and documented as soon as the Project is fully operational.

B. GHG EMISSION REDUCTION BY GREEN BUILDING DESIGN

The Project will be located on a site currently occupied by an oil storage tank no longer used by the power plant. This tank and its content will be removed and the site will be reused to construct the Project. Because the facility is an industrial facility, LEED-level certification will not be feasible; but to the extent reasonably practicable, building design will follow the principles of the Leadership in Energy and Environmental Design (LEED) program. LEED is a program of the United States Green Building Council, developed to promote construction of sustainable buildings that reduce the overall impact of building construction and functions on the environment by: (1) sustainable site selection and development, including re-use of existing industrial infrastructure locations; (2) energy efficiency; (3) materials selection; (4) indoor environmental quality, and (5) water savings.

The potential energy savings associated with the implementation of the green building design as compared to that for a standard building design are in a range of 300 MWh/yr to 500 MWh/yr. The potential carbon footprint reduction associated with this design is between 106 and 177 tons of CO$_2$ per year. The energy savings associated with incorporating green building design features into the desalination plant structures (i.e., natural lighting, high performance fluorescent lamps, high-efficiency HVAC and compressors, etc.) are based on the assumption that such features will reduce the total energy consumption of the plant service facilities by 6 to 10 %. As indicated in Table 2, the plant service facilities (HVAC, lighting, controls and automation, air compressors and other miscellaneous power uses) are projected to have power use of 760 hp (250 hp + 120 hp +40 hp + 100 hp + 250 hp = 760 hp) when standard equipment is used. The total annual energy demand for these facilities is calculated as follows; 760 hp x 0.746 kW/hp x 0.001 kW/MW x 24 hrs x 365 days = 4,967 MWh/yr. if use of green building design features result in 6 % of energy savings, the total annual power use reduction of the service facilities is calculated at 0.06 x 4,967 MWh/yr = 298.02 MWh/yr (rounded to 300 MWh/yr). Similarly, energy savings of 10 % due to green building type equipment would yield 0.1 x 4,967 MWh/yr = 496.7 MWh/yr (rounded to 500 MWh/yr) of savings. ~~Poseidon will provide for CARB or CCAR verification Tthe~~**The** total actual energy reduction resulting from the use of the green building design will be verified by ~~based on~~ direct readings of the total electricity consumed by the desalination plant at the Project's substation(s) electric meter(s) and documented as soon as the Project is fully operational.

C. ON-SITE SOLAR POWER GENERATION

Poseidon is exploring the installation of rooftop photovoltaic (PV) system for solar power generation as one element of its green building design. Brummitt Energy Associates of San

Diego completed a feasibility study in March 2007 of a photovoltaic system at the Carlsbad Desalination Plant. ~~(The solar feasibility study is attached as Appendix H.)~~ If the solar installation described by Brummitt is implemented, the main desalination plant building would accommodate solar panels on a roof surface of approximately 50,000 square feet, with the potential to generate approximately 777 MWh/yr of electricity. If installed, the electricity produced by the onsite PV system would be used by the Project and therefore would reduce the Project's electrical demand on SDG&E. The corresponding reduction of the Project's indirect emissions would be 275 tons of CO_2 per year. Poseidon is exploring other solar proposals and will update this information as it becomes available. Ultimately, the electricity and corresponding GHG savings of any on-site solar installation will be documented in the Project's annual electricity usage information. Poseidon will use commercially reasonable efforts to implement an on-site solar power project if it is reasonably expected to provide a return on the capital investment over the life of the Project.

If Poseidon proceeds with an onsite PV system, ~~**Poseidon will provide**~~ the total actual energy reductions resulting from the use of on-site solar power generation will be verified by direct readings of the total electricity consumed by the desalination plant at the Project's substation(s) electric meter(s) and documented once the system is fully operational.

D. RECOVERY OF CO_2

Approximately 2,100 tons of CO_2 per year are planned to be used at the Project for post-treatment of the product water (permeate) produced by the reverse osmosis (RO) system. Carbon dioxide in a gaseous form will be added to the RO permeate in combination with calcium hydroxide or calcium carbonate in order to form soluble calcium bicarbonate which adds hardness and alkalinity to the drinking water for distribution system corrosion protection. In this post-treatment process of RO permeate stabilization, gaseous carbon dioxide is sequestered in soluble form as calcium bicarbonate. Because the pH of the drinking water distributed for potable use is in a range (8.3 to 8.5) at which CO_2 is in a soluble bicarbonate form, the carbon dioxide introduced in the RO permeate would remain permanently sequestered. During the treatment process the calcium carbonate (calcite ~~–~~ $CaCO_3$) reacts with the carbon dioxide injected in the water and forms completely soluble calcium bicarbonate as follows:[16]

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[16] This chemical reaction and information presented on Figure 4 are well known from basic chemistry of water. See American Water Works Association (AWWA) (2007) Manual of Water Supply Practices, M46, Reverse Osmosis and Nanofiltration, Second Edition; http://www.chem 1 com!CO/hardwater.html; http:llwww.cotf. eduletelmodules/waterg3lWOassess3b.html. Once the desalinated drinking water is delivered to individual households, only a small portion of this water will be ingested directly or with food. Most of the delivered water will be used for other purposes – personal hygiene, irrigation, etc. The calcium bicarbonate ingested by humans will be dissociated into calcium and bicarbonate ions. The bicarbonate ions will be removed by the human body through the urine (http://www.chemistry.wustl.edu/–courses/genchem/TutorialsIBuffers/carbonic.htm). Since the CO_2 is sequestered into the bicarbonate ion, human consumption of the desalinated water will not result in release of CO_2. The bicarbonate in the urine will be conveyed along with the other sanitary sewerage to the wastewater treatment plant. Since the bicarbonate is dissolved, it will not be significantly impacted by the wastewater treatment process and ultimately will be discharged to the ocean with the wastewater treatment plant effluent. The ocean water pH is in a range of 7.8 to 8.3, which would be adequate to maintain the originally sequestered CO_2 in a soluble form – see Figure 4 above. Other household uses of drinking water, such as personal hygiene, do not involve change in drinking water pH as demonstrated by the fact that pH of domestic wastewater does not differ significantly from that of the drinking water. A portion of the household drinking water would likely be used for irrigation. A significant amount of the calcium bicarbonate in the irrigation water would be absorbed and sequestered in the plant roots

$$CaCO_{3\ (solid)} + CO_{2\ (gas)} + H_20_{\ (liquid)} \rightarrow Ca(HCO_3)_{2\ (liquid\ solution)}$$

At the typical pH range of drinking water (pH of 8.3 to 8.5) the carbon dioxide will remain in the drinking water in soluble form (see Figure 4) and the entire amount (100 %) of the injected carbon dioxide will be completely dissolved.

Figure 4 -- Relationship between free carbon and pH

(Source: http://www.cotf.edu/ete/modules/waterq3/WQassess3b.html)

[Note: Figure provided in original.]

A small quantity of carbon dioxide used in the desalination plant post-treatment process is sequestered directly from the air when the pH of the source seawater is adjusted by addition of sulfuric acid in order to prevent RO membrane scaling. A larger amount of CO_2 would be delivered to the Project site by commercial supplier for addition to the permeate. Depending on the supplier, carbon dioxide is of one of two origins: (1) a CO_2 Generating Plant or (2) a CO_2 Recovery Plant. CO_2 generating plants use various fossil fuels (natural gas, kerosene, diesel oil, etc.) to produce this gas by fuel combustion. CO_2 recovery plants produce carbon dioxide by recovering it from the waste streams of other industrial production facilities which emit CO_2 rich gasses: breweries, commercial alcohol (i.e., ethanol) plants, hydrogen and ammonia plants, etc. Typically, if these gases are not collected via CO_2 recovery plant and used in other facilities, such as the desalination plant, they are emitted to the atmosphere and therefore, constitute a GHG release.

To the extent that it is reasonably available, Poseidon intends to acquire the carbon dioxide from a recovery operation. Use of recovered CO_2 at the Project would sequester 2,100 tons of CO_2 per year in the Project product water. The total annual use of carbon dioxide (i.e., 2,100 tons/CO_2 per year) in the water treatment process was determined based on the daily carbon dioxide consumption presented in Table 4.6-2 of Section 4.6 “Hazards and Hazardous Materials” of the certified Carlsbad desalination project Environmental Impact Report (EIR). The daily consumption of CO_2 in this table is 12,540 lbs of CO_2/day. The annual consumption is calculated as 12,540 lbs/day x 365 days /2,200 lbs/ton = 2,080.5 lbs of CO_2/yr (which was rounded to 2,100 lbs/yr). The daily amount of carbon dioxide in Table 4.6-2 of the EIR was calculated based on the dosage needed to provide adequate hardness (concentration of calcium bicarbonate) in the seawater to protect the water distribution system from corrosion. This amount was determined based on pilot testing of distribution system piping and household plumbing at the Carlsbad seawater desalination demonstration project. The testing was completed using the same type of calcium carbonate chips as those planned to be used in the full-scale operations. Every load of carbon dioxide delivered to the desalination plant site will be accompanied by a certificate that states the quantity, quality and origin of the carbon dioxide and indicates that this carbon dioxide was recovered as a site product from an industrial application

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(http:llwww.Dubmedcentral.nih. gov/paerender.fcgi?artid=54O973&paeindex=1). The remaining portion of calcium bicarbonate would be adsorbed in the soils and/or would enter the underlying groundwater aquifer.

of known type of production (i.e., brewery, ethanol plant, etc.), and that it was purified to meet the requirements associated with its use in drinking water applications (i.e., the chemical is NSF approved). The plant operations manager will receive and archive the certificates for verification purposes. At the end of the year, the operations manager will provide copies of all certificates of delivered carbon dioxide to the independent third party reviewer **(currently the California Center for Sustainable Energy)** responsible for verification **of** facility compliance with the Energy Minimization and Greenhouse Gas Reduction Plan ~~CARB or CCAR as part of the annual review and verification~~.

As noted, verification would be provided through certificates of origin received from suppliers of CO_2 delivered to the Project site indicating the actual amount of CO_2 delivered to the site, date of delivery, origin of the CO2, and the purity of this gas. Poseidon will place conditions in its purchase agreements with CO_2 vendors that require transfer of CO_2 credits to Poseidon and otherwise ensure that the CO_2 is not accounted for through any other carbon reduction program so as to avoid “double counting” of associated carbon credits.

E. AVOIDED EMISSIONS FROM REDUCING ENERGY NEEDS FOR WATER RECLAMATION

The Project will result in Avoided Emissions because it will cause a change in operations by the Carlsbad Municipal Water District (CMWD), which owns and operates a water reclamation facility that includes micro-filtration (MF) and RO treatment for 25% of its water supply. The purpose of the MF/RO system is to reduce the salinity of the recycled water to below 1,000 mg/L so it will be suitable for irrigation. The elevated salinity of the recycled water is due in part to the salinity of the City’s drinking water supply.

The Project will effectively eliminate this problem by lowering the salinity in the source water of the communities upstream of the water recycling facility, thereby eliminating the need for operation of the MFIRO portion of the water recycling process. Implementation of the Project will significantly reduce or possibly eliminate the need to operate the MFIRO system, leading to Avoided Emissions from the lower electricity use by CMWD. This will reduce the carbon footprint of the Carlsbad Water Reclamation Facility as follows: 1,950 MWh/yr x 780.79 lbs of CO_2/MWh = 1,522,541 lbs of CO_2/yr (690 tons of CO_2/yr).

~~Poseidon will provide for CARB or CCAR verification of Tthe~~**The** total actual energy reduction that would result from the higher quality water use upstream of the water recycling facility will be verified annually by CMWD, using actual billing and performance data. This will be accomplished through a comparison of the pre-Project energy use attributable to the RO/MF portion of the water recycling process to the post-Project energy use.

F. AVOIDED EMISSIONS FROM DISPLACED IMPORTED WATER

Another source of Avoided Emissions will result from the Project’s introduction of a new, local source of water into the San Diego area; water that will displace imported water now delivered to Customers from the State Water Project (SWP) – a system with its own significant energy load and related carbon emissions.

One of the primary reasons for the development of the Project is to replace imported water with a locally produced alternative drought-proof source of water supply. Currently, San Diego County imports approximately 90% of its water from two sources – the SWP and the Colorado River. These imported water delivery systems consist of a complex system of intakes, dams, reservoirs, aqueducts and pump stations, and water treatment facilities.

The proposed Project will supply 56,000 acre-feet of water per year to the San Diego region. The Project will provide direct, one-to-one replacement of imported water to meet the requirements of the participating water agencies, thus eliminating the need to pump 56,000 acre feet of water into the region.[17]

The 2003 multi-state Colorado River quantitative settlement agreement forced Metropolitan Water District of Southern California (MWD) to reduce its pumping from the Colorado River by 53% – from 1.20 MAFY to 0.56 MAFY. As a result, MWD now operates its imported water delivery system to base load its Colorado River allotment and draw from the SWP only as needed to serve demand that cannot be met by the lower cost water available from the Colorado River Aqueduct. Consequently, the proposed Project will reduce the Customers demand on the SWP.

The total amount of electricity needed to provide treated water to Poseidon's public agency partners via the SWP facilities is shown in Table 1. The net power requirement to pump an acre-foot of water through the East Branch of the SWP is 3,248 KWh (source: DWR). Approximately 2% of the SWP water pumped to Southern California is lost to evaporation from Department of Water Resources' reservoirs located south of the Tehachapi Mountains (source: DWR). The evaporation loss results in a net increase of 68.3 KWh per acre-foot of SWP water actually delivered to Southern California homes and businesses. Finally, prior to use, the SWP water must be treated to meet Safe Drinking Water Act requirements. The San Diego County Water Authority (SDCWA) entered into a service contract with CH2M Hill Constructors, Inc., to operate its Twin Oaks Water Treatment Plant with a guaranteed electricity consumption of 100 KWh/AF of water treated (source: SDCWA). The electricity required to deliver an acre-foot of treated water to the SDCWA is shown in Table 3.

Table 3 – State Water Project Supply Energy Use

Energy Demand	**KWh/AF**	**Source**
Pumping Through East Branch	3248	DWR
Evaporation Loss	68	DWR
Twin Oaks Water Treatment Plant	100	SDCWA
Total	**3416**	

The reduction of demand for imported water is critical to Southern California's water supply reliability, so much so that MWD not only supports the Project, but has also committed $14 million annually to reduce the cost to Poseidon's customers. Under MWD's program, $250 will be paid to water agencies for every acre-foot of desalinated water purchased from the Carlsbad

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[17] See Poseidon Resources Corporation *Letter to Paul Thayer Re: Desalination Project's Impact on Imported Water Use*, November 8, 2007, including attachments from nine water agencies (Attached as Appendix E).

facility, *so long as the desalinated water offsets an equivalent amount of imported water*. MWD has established "Seawater Desalination Policy Principles and Administrative Guidelines" that require recordkeeping, annual data submittals, and MWD audit rights to ensure that MWD water is offset.[18]

The benefits of a reduction in demand on MWD's system are reflected in, among other things, the energy savings resulting from the pumping of water that – but for the Project – would have to continue. For every acre-foot of SWP water that is replaced by water from the proposed Project, 3.4 MWh of electricity use to deliver water to Customers is avoided, along with associated carbon emissions. And since the Project requires 4.4 MWh of electricity to produce one acre-foot of water, the net electricity required to deliver water from the Project to Customers is 1.0 MWh/AF.

Because the Project will avoid the use of 56,000 AFY of imported water to Customers, once in operation, the Project will also avoid 190,641 MWh/yr of electricity consumption otherwise required to deliver that water to Customers, as well as the GHG emissions associated with pumping, treatment and distribution of this imported water. At 780.79 lbs CO_2per MWh,[19] the total **expected** Avoided Emissions as a result of the Project is 67,506 metric tonsCO_2/yr. **Each year, Poseidon will be credited with Avoided Emissions based on the most recent SWP emission factors and the amount of water Poseidon produces.** ~~**Poseidon will provide for CARB or CCAR verification of those emission factors and the amount of water produced for use in determining the net remaining indirect emissions Poseidon must offset.**~~

G. AVOIDED EMISSIONS THROUGH COASTAL WETLANDS

The Project also includes the restoration and enhancement of marine wetlands. The restoration project will be in the proximity of the Project. These wetlands will be set-aside and preserved for the life of the Project. Once the wetlands are restored, they will act as a carbon "sink" or carbon sequestration project trapping CO_2.

Tidal wetlands are very productive habitats that remove significant amounts of carbon from the atmosphere, a large portion of which is stored in the wetland soils. While freshwater wetlands also sequester CO_2, they are often a measurable source of methane emissions. Coastal wetlands and salt marshes, however, release negligible amounts of greenhouse gases and therefore, their carbon sequestration capacity is not measurably reduced by methane production.

Based on a detailed study completed in a coastal lagoon in Southern California, the average annual rate of carbon sequestration in coastal wetland soils is estimated at 0.033 kg ofC/m^2.yr (a 5,000-year average, Brevick E.C. and Homburg J.A., 2004).[20] In tidal ecosystems, sediment

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[18] MWD's program is documented in a June 22, 2007 letter from its General Manager to Peter Douglas, Executive Director of the California Coastal Commission, as well as various contracts with relevant water agencies.

[19] Since the SWP does not have a published Annual Emissions Report with the CCAR, Poseidon used the certified emission factor for SDG&E system. Poseidon believes this a conservative estimate and will update its calculations when more accurate data is available.

[20] www.slc.ca.gov/Reports/Carlsbad Desalinization Plant Response/Attachment 4.pdf

accumulation rates (via suspended sediment supply, tidal water flooding, etc.) exhort a major control on carbon sequestration rates. Soil carbon sequestration rates determined recently in the Tijuana Estuary on the Mexico/USA border were determined to be 0.343 kg ofC/m^2.yr (Cahoon et. al 1996).[21] (4 = Cahoon, D.R., J.C. Lynch, and A. Powell, Marsh vertical accretion rates in a Southern California estuary, U.S.A., Estuar. Coast. Shelf Sci., 43, 19-32, 1996).

Given that the total area of the proposed wetland project is 37 acres, the carbon sequestration potential of the wetlands is between 4.9 and 51 tons of C/m^2.yr. These numbers are calculated as follows: Sequestration Rate (.033 kg of C/m^2.yr and 0.343 kg of C/m^2.yr) x Area (37 acres = 149,732.5 m^2) x Weight conversion (1000 kg C = 1 metric ton of C) = tons of C sequestered/ m^2.yr (as given above). To get from this unit the standard greenhouse gas unit of tons of CO_2 (not C) of sequestered per year, the conversion factor is 3.664. Therefore, the emissions avoided from the wetlands are estimated to be between 18 and 188 tons of CO_2 per year.

In order to verify the actual soil carbon sequestration rate of the proposed wetland ecosystem, site-specific measurements will need to be made. ~~**Poseidon will provide necessary documentation for CARB or CCAR verification of the total rate and amount of sequestration.**~~ Protocols for wetlands are ~~being~~ currently being developed for inclusion within the Clean Development Mechanism of the Kyoto Protocol, and ~~we~~**Poseidon** will use these protocols until CCAR makes its own wetland protocol available. ~~We anticipate full inclusion wetland protocols to become available within the lifetime of this project. But for the Project, the wetlands mitigation would not occur, and therefore it satisfies the Regulatory Surplus Additionality test. (See, Carbon Offset Projects – Definition (Page 16 herein) for a more detailed discussion of the Regulatory Surplus additionality test.)~~

Table 4 summarizes the **expected** on-site and project-related reductions of GHG Emissions.

Table 4 – Expected On-site and Project-Related Reduction of GHG Emissions

Source	Total Annual Reductions in Power Use (MWh/year saved)	Total Annual Emissions Avoided (metric tons CO_2/ year avoided)
Reduction due to High-Efficiency Design	(28,244)	(10,001)
Green Building Design	(300 to 500)	(106 to 177)
On-site Solar Power Generation	(0 to 777)	(0 to 275)
Recovery of CO2	(N/A)	(2,100)
Reducing Energy Needs for Water Recycling	(1,950)	(690)
Reducing Water Importation	(190,641)	(67,506)
Sequestration in Coastal Wetlands	(N/A)	(18 to 188)
Subtotal On-site Reduction Measures	(N/A)	(80,421 to 80,937)

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[21] www.sfbayjv.orgJtoolslclimatelCarbonWtlandsSummarv 07 Trulio.odf

PART III: IDENTIFICATION OF MITIGATION OPTIONS TO OFFSET ANY REMAINING GHG EMISSIONS

Offsite reductions of GHG emissions that are not inherently part of the Project include actions taken by Poseidon to participate in local, regional, state, national or international offset projects that result in the cost-effective reduction of GHG emissions equal to the indirect Project emissions Poseidon is not able to reduce through other measures.[22] One such offset project – the expenditure ~~**purchase**~~ of one million dollars ~~**worth of trees**~~ to reforest areas burned out by fires in the San Diego region in the fall of 2007 – has been identified by the CCC as the first priority among these measures. **Poseidon will implement this project using the CARB- or CCAR-approved** ~~**protocols.**~~ ~~As set forth in more detail~~**Forest Project Protocol or the upcoming CARB/CCAR Urban Forest Project Protocol, depending on the type of project Poseidon selects. Subject to the provisions of Sections III.C, E and F** below, other carbon offset projects **except for RECs** will be purchased by Poseidon through/from CCAR**, California APCDs / AQMDs,** ~~or~~ CARB ~~approved projects or other approved Third Party Providers of offsets set forth in Section III.C below. Projects available from these Third Party Providers will be consistent with AB 32 principles.[22]~~**or other providers of offsets approved by the Executive Director or Commission (collectively, "Third Party Providers").**[23] The exact nature and cost of the offset projects and RECs will not be known until they are acquired by Poseidon. Offsets or RECs will also be used as the swing mitigation option to "true-up" changes over time to the Project's net indirect GHG emissions, as discussed below.

A. ANNUAL "TRUE-UP" PROCESS

Since the quantity of offsets required will vary from year-to-year, the goal of the annual "True Up" process is to enable Poseidon to meet the subject year's need for metric tons of offsets by purchasing or banking offsets in the short-term, while allowing Poseidon to make long-term purchases and bank offsets to decrease market exposure and administrative costs. To complete the True-Up process, ~~**Poseidon will used CARB's verification and accounting procedures**~~**the third party independent reviewer selected, currently** the California Center for Sustainable Energy (CCSE**),** will obtain the latest SDG&E emission factor from the annual web~~-~~-based CARB or CCAR Emissions Report within 60 days of the end of each calendar year, or the date of publication of the CARB or CCAR Emissions Report on the relevant CARB or CCAR web site, whichever is later. Within 120 days of the end of the prior calendar year or publication of the emission factor (whichever is later), CCSE, with assistance from Poseidon as needed, will gather electricity usage data, relevant data regarding Avoided Emissions, and then calculate the

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[22] This Plan requires Poseidon to join CCAR's Climate Action Reserve, so that it may implement some of this Plan through the Reserve.

~~[22]~~[23] Part 4, Section 38562(d)(1)&(2) states that CARB regulations covering GHG emission reductions from regulated "sources" must ensure that such reductions are "real, permanent, quantifiable, verifiable,. . . enforceable [and additional]". While the Project is not a "source" under AB 32 and the criteria are not currently defined under implementing regulations, Third Party Providers will evaluate potential offset projects against equivalent criteria using their own protocols that employ the same criteria.

necessary metric tons of offsets required for the subject year. The subject year's emissions will be calculated using actual billing data and the emissions factor for the relevant annual period. The subject year's calculated metric tons of net emissions will be compared to the amount of metric tons of offsets previously acquired by Poseidon to determine if Poseidon has a positive or negative balance of net GHG emissions for the subject year, and all of this information will be included in the Annual GHG Report to be submitted to the Commission each year as discussed below. If there is a positive balance of net GHG emissions, Poseidon will purchase offsets to eliminate the positive balance, and provide the Commission with documentation substantiating that purchase, within 120 days of the date the positive balance is identified in the Annual GHG Report. If there is a negative balance of GHG emissions, the surplus offsets may be carried forward into subsequent years or sold by Poseidon on the open market.

Prior to the commencement of Project operations, Poseidon will be required to purchase offsets sufficient to cover estimated net (indirect) GHG emissions for at least the first year of operation (subject to Commission staff concurrence), or to cover a longer period of time at Poseidon's option, based on the most recently published SDG&E emission factor from CARB or CCAR and estimated electricity usage data for the first year of the Project period for which offsets are initially purchased. Poseidon will have the option to purchase offsets for any longer period of time up to and including the entire 30-year life of the Project, subject to Poseidon's above-stated obligation to address any positive balance in net GHG emissions that may subsequently arise. Beginning with the Sixth Annual Report, Poseidon can maintain a negative balance of net GHG emissions over a rolling five-year period. Poseidon will purchase enough GHG reductions measures that conform to the Plan such that it will not incur a positive net GHG emissions balance over any rolling five-year period.

B. CARBON OFFSETS PROJECTS AND CREDITS ~~— DEFINITION~~~~[23]~~[24]

Subject to the provisions of Sections III.C, E and F below, Poseidon will ~~use~~purchase carbon offset projects~~ approved pursuant to AB 32 by~~, except for RECs, through/from CARB, CCAR, or California APCDs / AQMDs~~ and will purchase offset credits through CCAR~~. An offset is created when a specific action is taken that reduces, avoids or sequesters greenhouse gas (GHG) emissions in exchange for a payment from an entity mitigating its GHG emissions. Examples of offset projects include, but are not limited to: increasing energy efficiency in buildings or industries, reducing transportation emissions, generating electricity from renewable resources such as solar or wind, modifying industrial processes so that they emit fewer GHGs, installing cogeneration, and reforestation or preserving forests.

One type of offset project is Renewable Energy Credits (RECs), also known as Green Tags, Renewable Energy Certificates or Tradable Renewable Certificates. Each REC represents proof that 1 MW of electricity was generated from renewable energy (wind, solar, or geothermal). For GHG offsetting purposes, purchasing an REC is the equivalent of purchasing 1 MW of

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~~[23]~~[24] ~~The following two sections are based on information provided by the Climate Trust (http://www.climatetrust.org/)~~

electricity from a renewable energy source, effectively offsetting the GHGs otherwise associated with the production of that electricity. RECs may be sold separately from the electricity.

Except as specified below, offset projects that Poseidon implements pursuant to this Plan will be those approved by CARB, CCAR, or any California APCD / AQMD as conforming to AB 32 requirements~~, and any offset credits purchased pursuant to this Plan Poseidon will obtain through CCAR~~. Poseidon is committed to acquiring cost-effective offsets that meet rigorous standards, as detailed in this Plan. By requiring adherence to the principles, practices and performance standards described here, the Plan is designed to assure that selected offset projects will mitigate GHG emissions as effectively as on-site or direct GHG reductions. Adherence will ensure that the offset projects acquired by Poseidon are real, permanent, quantifiable, verifiable, enforceable, and additional, consistent with the principles of AB 32.

~~**Additionality.** The concept of "additionality" was introduced in Article 12.5 of the Kyoto Protocol, which states that "emission reductions resulting from each project activity shall be... reductions in emissions that are additional to any that would occur in the absence of the certified project activity". The Third Party Providers will assess the additionality of each project proposal on a case-by-case basis. Offset project proposers will be required to demonstrate the additionality of their project. Specifically, the Third Party Providers will perform an initial screening of all proposed offset projects against the following additionality tests before evaluating any other aspects of the proposed project.~~

~~Along with applicable AB 32 criteria, if any, the carbon offset acquisition process will utilize three widely used tests to determine a project's additionality: 1) Regulatory Surplus Test, 2) Barriers Tests, and 3) Common Practice Test. These tests are based on the Kyoto Protocol's Clean Development Mechanism methodology, as well as the World Resource Institute's GHG Protocol for Project Accounting; and are the emerging norms and best practices in the burgeoning offset market in the United States and internationally.~~

~~**Test 1: Regulatory Surplus.** The Regulatory Surplus Test ensures that the project that is proposed is not mandated by any existing law, policy, statute, regulation, or other legal obligations. Otherwise, it is assumed that the project is being developed to comply with the law or regulation and thus cannot be considered additional to the business as usual scenario.~~

~~**Test 2: Implementation Barriers.** The implementation barriers tests are at the heart of the additionality determination process. There are three main implementation barriers tests: 1) Financial, 2) Technological, and 3) Institutional. A project must meet at least one of the following barriers tests in order to be considered additional.~~

~~**Test 2(a): Financial Barriers.** The Financial Barriers Test addresses how offset funding impacts the project in question. Financial barriers tests are generally considered to be one of the more rigorous and stringent tests of additionality. There are two main types of financial barriers a project can face: capital constraint and internal rate of return. The Capital Constraint Test addresses whether a project would have been undertaken without offset funding. Internal rate of return indicates whether or not a project would have met~~

~~established targets for internal rates of return without offset funding. These are not the only acceptable tests of financial barriers, but are the most commonly used.~~

~~Positive economic returns do not necessarily make a project non-additional. There are instances where projects with high rates of return remain unimplemented — the energy efficiency sector is the most well know of these examples. To demonstrate additionality for projects that generate rates of return, it can be useful to describe the barriers faced by the project by including a clear explanation of the project's return rate with a pro forma financial analysis showing both the with and without project case. For example, Company Y typically does not pursue project activities unless they provide a 15% rate of return. An energy efficiency upgrade at the facility will generate a 5% rate of return. The additionality case is that offset funding can be used to increase the return of the efficiency measures to a level that is acceptable to management.~~

~~**Test 2(b): Technological Barriers.** There are several categories of assessment that could fall under this test. If the primary reason for implementing a technology is its GHG reduction benefits, that project is generally considered to be additional. For example, if a more energy efficient, though more expensive to manufacture, model of a hot water heater is available and the additional cost is barring its entry into the market, offset funding can help bridge that gap and bring a technology to market that otherwise would not have been. In this case, the GHG reductions resulting from the deployment of the new technology are clearly above and beyond business as usual.~~

~~**Test 2(c): Institutional Barriers.** Institutional barriers can be organizational, social or cultural. If a GHG reduction project falls outside of the normal purview of a company or organization and there is reluctance to implement a project that is not within that purview or to capitalize a project with uncertain returns, offset funding can often assist in overcoming that barrier.~~

~~**Test 3: Common Practice.** This test is intended to determine whether or not a project is truly above and beyond "business as usual". If a practice is widely employed in a field, it is not considered additional.~~

~~C. THIRD-PARTY ACQUISITION AND VERIFICATION.~~

~~Poseidon may elect to acquire offsets from/through the CCAR or CARB approved projects, as well as offset project certified or offered by any existing member of the Offset Quality Initiative, which includes CCAR, The Climate Trust, Environmental Resources Trust and The Climate Group/Voluntary Carbon Standard (the "Third Party Providers"). Consistent with Staff's recommendation, acquisition of RECs are not limited to purchase from/through CCAR, CARB, or any other Third Party Provider.~~

~~Poseidon may submit a written request to the Executive Director of the CCC requesting that an additional offset provider be designated as a Third Party Provider.~~~~[24]~~~~**[25]**~~ ~~In deciding whether or not~~

~~[24]~~~~**[25]**~~ ~~The fee charged to Poseidon by the Commission for any request to approve additional offset providers pursuant to Section III.C, or to otherwise make the Plan workable by facilitating Poseidon's purchase of offsets/RECs to zero out the Project's net indirect GHG emissions, shall not exceed $5,000.00.~~

~~to approve Poseidon's request, the Executive Director shall consider whether or not the proposed Third Party Provider is an independent and non-affiliated entity that adheres to substantially similar principles and evaluation criteria for high quality offsets as the Third Party Providers listed above. The Executive Director shall determine whether or not to approve Poseidon's request to designate a Third Party Provider within 60 days. Any dispute between Poseidon and Commission Staff regarding the approval or denial of the requested entity may be brought by Poseidon to the CCC for hearing and resolution at the next available hearing date.~~

~~CCSE shall include in its Annual GHG Report, discussed in Section III.D below, an accounting summary and documentation from CCAR, CARB and Third Party Providers, as applicable, which verifies that offsets obtained by Poseidon have been verified by CCAR, CARB or a Third Party Provider.~~

~~D~~C. OFFSET ACQUISITION AND VERIFICATION

Poseidon shall acquire offsets through/from CCAR, CARB or California APCD/AQMD-approved projects. Acquisition of RECs are not limited to purchase from CCAR, CARB, or a California APCD/AQMD.

If sufficient offsets are not available from CCAR, CARB or a California APCD/AQMD at a price that is reasonably equivalent to the price for offsets in the broader domestic market, Poseidon may submit a written request to the Executive Director requesting that an additional offset provider, including without limitation any existing member of the Offset Quality Initiative, which includes CCAR, The Climate Trust, Environmental Resources Trust and The Climate Group/Voluntary Carbon Standard, be designated as a Third Party Provider from/through whom Poseidon may purchase offsets under the Plan.[26] In deciding whether or not to approve Poseidon's request, the Executive Director shall consider whether or not the proposed Third Party Provider is an independent and non-affiliated entity that adheres to substantially similar principles and evaluation criteria for high quality offsets as CCAR, CARB, a California APCD/AQMD or any Third Party Provider previously approved by the Executive Director or the Commission. The Executive Director shall determine whether or not to approve Poseidon's request to designate a Third Party Provider within 60 days. Any dispute between Poseidon and Commission Staff regarding the approval or denial of the requested entity may be brought by Poseidon to the CCC for hearing and resolution at the next available hearing date.

Poseidon's Annual GHG Report, discussed in Section III.D below, shall include an accounting summary and documentation from CCAR, CARB, a California APCD/AQMD and Third Party Providers, as applicable, which verifies that offsets obtained by Poseidon have been verified by CCAR, CARB, a California APCD/AQMD or a Third Party Provider.

D. ANNUAL REPORT

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[26] **The fee charged to Poseidon by the Commission for any request to approve additional offset providers pursuant to Section III.C., or to otherwise make the Plan workable by facilitating Poseidon's purchase of offsets/RECs to zero out the Project's net indirect GHG emissions, shall not exceed $5,000.00.**

~~CCSE will prepare~~ **Poseidon will provide** an Annual GHG Report that will describe and account for Poseidon's annual and cumulative balance of verified net GHG emissions reductions. The Annual GHG Report will ~~analyze~~**include analysis** and ~~validate~~**validation from CCSE of:** (1) the annual GHG emission calculations for the Project, (2) the positive or negative balance in Poseidon's net GHG emissions, (3) the acquisition of offsets and/or RECs in accordance with this Plan, and (4) any other information related to Poseidon's effects to mitigate GHG emissions resulting from the Project's electricity usage. Each year, CCSE will obtain the new emission factor from CCAR or CARB and prepare and submit Poseidon's Annual GHG Report within 180 days of the date of publication of CCAR/CARB emissions reports. The Annual GHG Report shall be submitted to the CCC and the CSLC, with a copy to Poseidon. In the event that the Annual GHG Report indicates that Poseidon has a positive balance of net GHG emissions for a particular year, Poseidon shall purchase offsets, and provide the Commission with documentation substantiating that purchase, within 120 days of the submission of an Annual GHG Report to the Commission. If an approved Annual GHG Report demonstrates that Poseidon possesses a negative balance of net GHG emissions, Poseidon will be free to carry those surplus offsets forward into subsequent years or sell them on the open market. Beginning with the Sixth Annual Report, Poseidon can maintain a negative balance of net GHG emissions over any rolling five-year period. Poseidon will purchase enough GHG reductions measures that conform to the Plan such that it will not incur a positive net GHG emissions balance over any rolling five-year period.

Before commencing Project operations, Poseidon shall submit its first Annual GHG Report for Commission staff review and approval, which will evidence sufficient offsets to zero out the Project's estimated net indirect GHG emissions for the first year. All subsequent reports will cover one calendar year.

~~D. CONTINGENCIES~~

~~**At any time during implementation of this Plan, Poseidon may request the Executive Director approve the use of offset projects provided through entities other than CARB, CCAR, or California APCDs / AQMDs. The Executive Director shall consider whether the proposed offset projects conform to similar principles and evaluation criteria as those used by CARB, CCAR, or the California APCDs / AQMDs. Poseidon may also request the Executive Director approve the use of offset credits from entities other than CCAR if CCAR credits are not available or are not available at a reasonable cost. Further, if any entity initiates a carbon tax or carbon offset program that would allow Poseidon to purchase carbon offsets or pay fees to compensate for GHG emissions, Poseidon may request the Executive Director approve the use of that program in implementing this Plan. Poseidon may also request the Executive Director approve a plan to allow Poseidon to deposit funds in an escrow account instead of purchasing credits if the market price for offset credits is not reasonably discernable or is economically infeasible. Any dispute between Poseidon and the Executive Director may be brought before the Commission for hearing and resolution.**~~

E.- CONTINGENCY IF NO GHG REDUCTION PROJECTS ARE REASONABLY AVAILABLE

At any time during implementation of this Plan, Poseidon may seek a determination from the Executive Director that (i) offset projects in an amount necessary to mitigate the Project's net indirect GHG emissions are not reasonably available; (ii) the "market price" for carbon offsets or

RECs is not reasonably discernable; (iii) the market for offsets/RECs is suffering from significant market disruptions or instability; or (iv) the market price has escalated to a level that renders the purchase of offsets/RECs economically infeasible to the Project. Any request submitted by Poseidon shall be considered and a determination made by the Executive Director within 60 days. A denial of any such request may be appealed by Poseidon to the Commission for hearing and resolution at the next available meeting date. If Poseidon's request for such a determination is approved by the Executive Director, Poseidon may, in lieu of funding offset projects or additional offset projects, deposit money into an escrow account (to be approved by the Executive Director) to be used to fund GHG offset programs as they become available, with Poseidon to pay into the fund in an amount equal to $10.00 per metric ton for each ton Poseidon has not previously offset, adjusted for inflation from 2008.~~[25]~~[27] **The period of time the escrow account contingency may be utilized under this Section shall be determined by the Executive Director or the Commission at the time Poseidon's request to use the contingency is approved, based on circumstances as they exist at the time of the request.** Within 180 days of the Executive Director's determination pursuant to this Section, Poseidon will be required to submit a plan for Executive Director approval that identifies one or more entities who will ~~use~~**utilize** monies deposited into the escrow account to implement carbon offset projects.

F.– CONTINGENCY IF NEW GHG REDUCTION REGULATORY PROGRAM ~~IS~~IS CREATED

If, at any time during the life of the Project ~~any of~~ the SDAPCD, South Coast Air Quality Management District (SCAQMD), **or any other California APCD/AQMD or** the California Air Resources Board (CARB)~~, SDG&E or other relevant entity~~ initiates a carbon tax or carbon offset program that would allow Poseidon to purchase carbon offsets or payment of fees to compensate for GHG emissions**, Poseidon may**, at its option, elect to pay into such a program in order to fulfill all or part of its obligations under the Plan to offset net indirect GHG emissions caused by the Project. By receiving certification from the relevant receiving entity that Poseidon has satisfied its obligations under the applicable regulatory program, Poseidon will be deemed to have satisfied its obligation under the Plan to offset net indirect GHG emissions for the part of the offset obligations under the Plan for which such certification is made. Subject to the approval of the relevant receiving entity, Poseidon may carry over any surplus offsets acquired pursuant to the Plan for credit in the new ~~SDAPCD~~ regulatory program.

~~GE~~**GG**. EXAMPLES OF OFFSET PROJECTS

Offset projects typically fall within the seven major strategies for mitigating carbon emissions set forth below. A similar range and type of offset projects should be expected from a purchase by Poseidon, although it is difficult to anticipate the outcome of Poseidon's offset acquisitions at present.

1. **Energy Efficiency** (Project sizes range from: 191,000 metric tons to 392,000 metric tons; life of projects range from: 5 years to 15 years)
   - Steam Plant Energy Efficiency Upgrade

~~[25]~~[27] $10.00 per metric ton is a conservative figure, as offset credits were trading at $4.90 per metric ton on the Chicago Climate Exchange as of market close on July 2, 2008.

- Paper Manufacturer Efficiency Upgrade
- Building Energy Efficiency Upgrades

2. **Renewable Energy** (Project sizes range from: 24,000 metric tons to 135,000 metric tons; life of projects range from: 10 years to 15 years)
    - Small Scale Rural Wind Development
    - Innovative Wind Financing
    - Other renewable resource projects could come from Solar PV, landfill gas, digester gas, wind, small hydro, and geothermal projects

3. **Fuel Replacement** (Project size is: 59,000 metric tons; life of project is: 15 years)
    - Fuels for Schools Boiler Conversion Program

4. **Cogeneration** (Project size is: 339,000 metric tons; life of project is: 20 years)
    - University Combined Heat & Power

5. **Material Substitution** (Project size is: 250,000 metric tons; life of project is: 5 years)
    - Cool Climate Concrete

6. **Transportation Efficiency** (Project sizes range from: 90,000 metric tons to 172,000 metric tons; life of projects range from: 5 years to 15 years)
    - Truck Stop Electrification
    - Traffic Signals Optimization

7. **Sequestration** (Project sizes range from: 59,000 metric tons to 263,000 metric tons; life of projects range from: 50 years to 100 years)
    - Deschutes Riparian Reforestation
    - Ecuadorian Rainforest Restoration
    - Preservation of a Native Northwest Forest

~~Further details on these projects are set forth in Appendix G.~~

~~HF~~HH. POTENTIAL OFFSET PROJECTS FUNDED BY POSEIDON

Participants at the May 2, 2008 CCC Workshop proposed several potential projects that were suggested to be wholly or partially funded by Poseidon. Proposers were not prepared at that time to provide details for these projects other than generally describing the project concept. As a result, it is not yet possible to evaluate them for consistency with the applicable criteria for valid GHG reduction projects. The projects include the following:

- Reforestation Projects in the San Diego area ravaged by the 2007 fires
- Urban Forestry projects
- Estuary sequestration project
- Wetlands projects
- Fleet Fuel Efficiency Increase & Replacement project
- Accelerated Fleet Hybrid Deployment
- Large-Scale Solar PV project on a covered reservoir

- Mini-Hydro from installing pressure reducing Pelton wheels
- Solar Water Heating for a new city recreation swimming pool
- Lawn Mower Exchange Program (gas exchanged for electric mowers)
- Truck Fleet Conversion (especially older trucks from Mexico)
- School Bus Conversions
- White Tag projects or Energy Efficiency projects

~~Implementation through this Plan of T~~~~t~~**~~hese and~~ Subject to the provisions of Sections III.C, E and F above, Poseidon will purchase these ~~and~~ or other potential offset projects ~~are subject to approval by~~, except for RECs, through/from CARB, CCAR, or any California APCD / AQMD.** ~~must still be acquired through one of the Third Party Providers listed in, or approved pursuant to, Section III.C above, although one project – the San Diego fire reforestation project identified by the CCC and discussed in more detail below – can be identified at this time and Poseidon has already agreed to commit $1 million towards this program. Poseidon is also exploring off-site renewable energy initiatives with some of its water agency partners as described below.~~

~~IG~~II. SEQUESTRATION THROUGH REFORESTATION

The CCC identified as a carbon offset project the reforestation of areas in the San Diego Region impacted by the wildfires that occurred during the fall of 2007. Specifically, at the CCC's request, Poseidon has agreed to invest the initial **~~will purchase~~** $1.0 million **~~worth of trees~~** it spends on offset projects in reforestation activities in the San Diego Region. ~~Any Additionality Requirement should therefore be met, since the CCC directed that a reforestation project take place in the San Diego Region impacted by the 2007 fires.~~ Poseidon ~~will~~ commits to using either the CARB/CCAR Forest Project Protocols or the upcoming CARB/CCAR Urban Forest Project Protocol depending on the type of project Poseidon selects.

~~According to CCSE, the average cost for planting a 15 gallon suitable, drought tolerant shade tree in San Diego neighborhoods affected by the 2007 wildfires is $100 per tree, including staff time and marketing. There is no annual watering and maintenance cost required for the trees after installation, since property owners would cover these expenses. Expected survival rate would be 90%. Poseidon's $1.0 million investment in urban reforestation with shade trees is expected to yield 9,000 mature trees within 10-15 years of planting. At an annual tree sequestration rate of 60 lbs of CO2per tree, the annual carbon footprint reduction associated with the trees would be approximately 245 tons of CO_2 per year (the number could be up to 25% higher if energy demand reductions from trees shading homes were also included in the calculations).~~

~~JH~~JJ. RENEWABLE ENERGY PARTNERSHIPS

Poseidon is exploring the possibility of participating in renewable energy projects with its water agency partners. **~~Any~~Subject to the provisions of Sections III.C, E and F above, any offset projects implemented pursuant to this Plan, except for RECs, will be ~~subject to approval by~~purchased through/from CARB, CCAR, or any California APCD / AQMD ~~as consistent with the requirements of AB 32.~~.** Table 5 presents a summary of some of the project opportunities and associated GHG offsets that are under consideration.

Table 5 – Potential Renewable Energy Partnerships

Desalination Project Public Partner / Location	Green Power Project Description	Annual Capacity of Green Energy Projected to be Generated by the Project (MWh/yr)
City of Encinitas	95 KW Solar Panel System Installed on City Hall Roof	160
Valley Center Municipal Water District	1,000 KW Solar Panel System	1,680
Rainbow Municipal Water District	250 KW Solar Panel System	420
Olivenhain Municipal Water District / Carlsbad Municipal Water District / City of Oceanside	Various solar and hydroelectric generation opportunities	To Be Determined
Santa Fe Irrigation District	Hydropower generation facility at R.E. Badger Filtration Plant	To Be Determined
	Total Renewable Power Generation Capacity (MWh/yr)	2,260

~~The contract terms for each of these potential projects will be specific to the particular project. Typically, the amount paid for each project would be the market price for offsets and not necessarily the full price of the project. The offset projects will be verified through the above criteria to ensure they are real, permanent, quantifiable, verifiable, enforceable, and additional.~~

~~The total currently quantifiable electricity reduction for the proposed projects described in Table 5 is 2,260 MWh/yr, and the net indirect GHG emissions offset for the Project is projected at 800 tons of CO$_2$/year. Should Poseidon decide to proceed with one or more of the potential renewable energy partnerships, the total actual energy reduction that would result would be verified by direct readings of the total electric energy produced by the Project at the partner's electric meter.~~

~~KI~~KK. IMPLEMENTATION SCHEDULE

An illustrative schedule setting forth timing for implementation of Poseidon's Plan elements, assuming regulatory approval is achieved in August 2008, is set forth in the following Implementation Schedule.

Table 6 – Implementation Schedule for the Plan

Measure	Process	Timing
Regulatory Approval		August 2008
Submit First Annual GHG Report	First Annual Report*, submitted to Commission staff	Before operations commence.

	for review and approval, shall be include enough detailed emissions reductions measures to achieve a projected zero net GHG emissions balance.	
Offset and REC Purchases Sufficient to Zero Out Estimated net indirect GHG emissions for first year of operations.	~~**Unless otherwise allowed through Executive Director or Coastal Commission approval**~~**Subject to the provisions of Sections III.C, E and F above, offset projects or credits, except for RECs, will be** ~~Purchased~~ **implemented** through CCAR, CARB or **any California APCDs / AQMDs.** ~~a Third Party Provider, or, in the case of RECs, directly from the provider~~ ~~**and offset credits will be purchased through CCAR**~~.	Before operations commence.
Annual True-Up Process, and all Subsequent Annual GHG Reports	Poseidon will submit its Annual GHG Report to Commission staff for review and approval. Once approved, Poseidon will purchase additional offsets as necessary to maintain a zero net GHG emissions balance, or bank or sell surplus offsets. Poseidon can demonstrate compliance over a rolling 5-year period in the Sixth Annual Report.	Each year, ~~CCSE~~ **Poseidon** will obtain the new emission factor from CARB or CCAR, and prepare and submit Poseidon's Annual GHG Report within 180 days of the date of publication of CCAR/CARB emissions reports. If the report shows a positive net GHG emissions balance, Poseidon is required to purchase offsets, and submit proof of such purchase to Commission Staff, within 120 days from the date of the Annual GHG Report.

* First Annual GHG Report will use projected electricity consumption. All subsequent Annual GHG Reports will use the previous year's electricity consumption data.

~~LJ~~L. THE PROJECT'S ANNUAL NET-ZERO CARBON EMISSION BALANCE

Table 7 presents a summary of the assessment, reduction and mitigation of GHG Emission for the proposed Project. As Shown in the table, up to 83% of the GHG Emissions associated with the proposed Project could be reduced by on-site reduction measures, and the remainder would be mitigated by off-site mitigation projects and purchase of offsets or RECs. It should be noted that on-site GHG reduction activities are expected to increase over the useful life (i.e., in the next 30 years) of the Project because of the following key reasons:

- SDG&E is planning to increase significantly the percentage of green power sources in its electricity supply portfolio, which in turn will reduce its emission factor and the Project's net indirect GHG emissions.

- Advances in seawater desalination technology are expected to yield further energy savings and net indirect GHG Emission reductions. Over the last 20 years, there has been a 50% reduction in the energy required for seawater desalination.

Table 7 – Expected Assessment, Reduction and Mitigation of GHG Emissions

Part I: Identification of GHG Amount Emitted		
Source	**Total Annual Power Use (MWh/year)**	**Total Annual Emissions (metric tons CO_2/year)**
Project Baseline Design	274,400	97,165
Part 2: On-site and Project-Related Reduction of GHG Emissions		
Reduction due to High-Efficiency Design	(28,244)	(10,001)
Green Building Design	(300 to 500)	(106 to 177)
On-site Solar Power Generation	(0 to 777)	(0 to 275)
Recovery of CO2	(NA)	(2,100)
Reducing Energy Needs for Water Recycling	(1,950)	(690)
Reduced Water Importation	(190,641)	(67,506)
Sequestration in Coastal Wetlands	(NA)	(18 to 188)
Subtotal On-site Reduction Measures	(NA)	**(80,421 to 80,937)**
Net GHG Emissions		**16,422 to 16,228**
Part 3: Additional Off-site Reductions of GHG Emissions		
Sequestration Through Reforestation	(NA)	(245)
Potential Renewable Energy Partnerships	(0 to 2,260)	(0 to 800)
Subtotal Off-site Measures	(NA)	(245-1,045)
Offset and REC Purchases	(NA)	**(16,499 to 15, 067)**
Net GHG Emissions		**0**

Attachment 2D

Poseidon Resources Huntington Beach Desalination Plant

Energy Minimization and Greenhouse Gas Plan, April 30, 2010

Poseidon Resources
Huntington Beach Desalination Plant

ENERGY MINIMIZATION
AND
GREENHOUSE GAS REDUCTION PLAN

APRIL 30, 2010

Key elements of this Plan include:

- *Poseidon's indirect GHG emissions will be calculated using California Air Resources Board (CARB) or The Climate Registry (TCR) or California Climate Action Registry (CCAR) methodologies.*

- *Poseidon will be credited with emission reductions associated with the replacement of imported water from the State Water Project (SWP).*

- *The offset projects, except for Renewable Energy Credits (RECs), that Poseidon implements pursuant to this Plan will be purchased through/from CARB, CCAR, or any California Air Pollution Control District (APCD) or Air Quality Management District (AQMD).*

POSEIDON
RESOURCES

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APRIL 30, 2010

INTRODUCTION

Poseidon Resources Surfside LLC (Poseidon) is offering The Huntington Beach Energy Minimization and Greenhouse Gas Reduction Plan (the Plan) as part of its voluntary commitment to account for and bring to zero the net indirect Greenhouse Gas (GHG) emissions from the Huntington Beach Desalination Project (Project). Based on protocols adopted by the California Climate Action Registry (CCAR), the Plan is Poseidon's roadmap to achieving its commitment over the 30-year life of the Project. The Plan is consistent with and based on the Energy Minimization and Greenhouse Gas Reduction Plan (and follows the "CCC Emissions Template") approved by the California Coastal Commission (CCC) and the California State Lands Commission (SLC) for the Carlsbad Desalination Project. The Carlsbad GHG Plan was reviewed by the CCC, SLC, the California Air Resources Board (CARB), and the California Energy Commission (CEC) and at the request of the Coastal Commission, the South Coast Air Quality Management District (SCAQMD).

1. Project Overview.

The 50 million gallon per day (MGD) Project (Figure 1) is co-located with the Huntington Beach generation station, which uses seawater for once-through cooling. The Project is being developed as a public-private partnership between Poseidon and local utilities and municipalities.

Figure 1 - Huntington Beach Seawater Desalination Project

In 2006, California legislation introduced the AB 32 Global Warming Solutions Act that aims to reduce statewide GHG emissions to 1990 levels by year 2020. While the legislation and its implementing regulations do not currently apply to the Project because the Project only generates *de minimis* direct GHG emissions[1], Poseidon applauds the objectives of AB 32 and is committed to helping California maintain its leadership role in addressing the causes of Climate Change. As a result, Poseidon has voluntarily committed to offset the net indirect GHG emissions associated with the Project's operations. For the Carlsbad project, Poseidon's offer was incorporated into the Carlsbad project's Coastal Development Permit through Special Condition 10, adopted by the CCC and agreed to by Poseidon, and incorporated into the Project's SLC lease amendment with minor modifications. According to Special Condition 10 and CCC staff direction, Poseidon

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[1] AB 32's implementing regulations are currently under-going an extensive public review and drafting process. The process is managed by the California Air Resources Board (CARB). The AB 32 Scoping Plan (the "Scoping Plan") was adopted on December 8, 2008 and a majority of the Plan's measures will be adopted by December 31, 2010. CARB anticipates that most of the regulations and initiatives will go into effect on January 1, 2012. AB 32's regulations, when promulgated, are expected to target direct emitters of GHGs, including SCE (the expected source of the Project's electricity), rather than indirect generators such as the Project. Currently, the Scoping Plan does not anticipate regulation of the Project under AB 32.

submitted a plan for CCC review and approval showing how the Carlsbad project will minimize its electricity use and reduce indirect GHG emissions resulting from net increases in electricity use over existing conditions. In addition to offsetting indirect GHG emissions, the SLC required the Carlsbad project to offset a modest amount of direct GHG emissions associated with project construction and operational vehicles, which are considered *de minimis* under applicable reporting protocols. For the Huntington Beach Project, Poseidon voluntarily submits this Plan, which is consistent with the general obligations of the Carlsbad project's GHG plan, as part of its application materials.

2. Emissions Template.

The Emissions Template establishes "a protocol for how to assess, reduce, and mitigate the GHG emissions of applicants," and calls for the organization of relevant information into the following three sections:

1. Identification of the amount of indirect GHGs due to the Project's electricity use;
2. On-Site and Project related measures planned to reduce emissions; and
3. Off-site mitigation options to offset remaining emissions.

After a brief explanation of Poseidon's overall strategy for eliminating the Project's net indirect GHG emissions, this document then organizes the Plan into the three general categories.

3. Overview of the Project's GHG Reduction Strategy.

Since offsetting net indirect GHG emissions is an ongoing process dependent on dynamic information, Poseidon's plan for the assessment, reduction and mitigation of GHG emissions establishes a protocol for identifying, securing, monitoring and updating measures to eliminate the Project's net carbon footprint. Once the Project is operational and all measures to reduce energy use at the site have been taken, the protocol involves the following steps, completed each year:

1. Determine the energy consumed by the Project for the previous year using substation(s) electric meter(s) readings from Southern California Edison (SCE) or any other entity from which the Project obtains all or part of its electricity at any time in the future.

2. Determine SCE's reported emissions factor, described as pounds of CO_2 per MWh from delivered electricity, from its most recently published CCAR or The Climate Registry (TCR) Annual Emissions Report. Reports are issued annually and are accessible on the CCAR's website. Emissions factors will be obtained from CARB if and when SCE certified and reported emissions factor for pounds of CO_2 per MWh from delivered electricity is publicly available through CARB's anticipated GHG Inventory program. If at any time in the future the Project obtains all or part of its electricity from an entity other than SCE, the appropriate CCAR, TCR, or CARB reported emissions factor for that entity shall be used.

3. Calculate the Project's gross indirect GHG emissions resulting from Project operations by multiplying its electricity use by the reported emissions factor.

4. Calculate the Project's net indirect GHG emissions by subtracting emissions avoided as a result of the Project (Avoided Emissions) and any existing offset projects and/or Renewable Energy Credits (RECs). Each year's amount of net indirect GHG emissions will be determined using CARB, TCR or CCAR reported emissions factors for SCE and/or the State Water Project (SWP).

5. If necessary, implement carbon offsets projects and purchase carbon offsets or RECs to zero-out the Project's net indirect GHG emissions. Subject to the provisions of Sections III.C, E and F below: (i) Offset projects, except for RECs, implemented pursuant to this Plan will be purchased through/from CARB, CCAR, or a California APCD or AQMD, and (ii) Poseidon may propose purchasing other offset projects in the event that sufficient offsets are not available from CCAR/CARB/California APCD or AQMD at a price that is reasonably equivalent to the price for offsets in the broader domestic market.

Energy efficiency measures and on-site use of renewable resources will be given the highest priority. In addition to the steps completed each year, Poseidon will quantify direct Project GHG emissions associated with project construction and operational vehicles based on data in the Project's 2010 Draft Subsequent Environmental Impact Report (EIR), which are considered *de minimis* under applicable reporting protocols. All such emissions for the entire 30 years of Project operations are quantified and aggregated in Part I of this Plan, and Poseidon shall purchase carbon offsets or RECs to zero-out these emissions on a one-time basis by the time Poseidon submits the first Annual GHG Report required in Part III of this Plan.

The following are elements of the Plan organized in accordance with the emissions template.

PART I. IDENTIFICATION OF THE AMOUNT OF GHG EMITTED

The Project will produce potable water using reverse osmosis membrane separation. The treatment processes used at the Plant do not generate GHGs. The desalination process does not involve heating and vaporization of the source seawater and thus does not create emissions of water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), or sulfur hexafluoride (SF_6). Reverse osmosis membranes do not reject the carbon dioxide, which is naturally dissolved in the source seawater, and this carbon dioxide is retained in dissolved form in the fresh drinking water created by desalination.

The Project will not store or use fossil fuels on site, nor will it emit GHGs from self-generation of electricity. There are no direct fugitive emissions from the plant. As a result, Project operations will not create direct sources of GHG emissions except for emissions from construction and operational vehicles. The modest number of fleet vehicles associated with plant and the construction emissions will create GHG emissions that make-up less than 5% of the Project's annual carbon footprint, and thus these emissions are considered *de minimis* and are not required to be reported (CCAR General Reporting Protocol of March 2007 (Chapter 5)).

However, Poseidon has calculated these emissions and included them in the overall GHG emissions total for the Project.

Data used in the calculation of the construction and operational emissions are derived from the 2010 Draft Subsequent EIR for the Project. GHG emissions were calculated using emissions factors from the CCAR General Reporting Protocol and the South Coast Air Quality Management District's (SCAQMD) web site which were extrapolated out to 30 years where necessary. Table 1 shows emissions from construction equipment, construction site electricity use, and operational emissions from passenger vehicles and delivery trucks during the 30 year life of the project after completion. These emissions amount to less than one percent of the lifetime emissions of the baseline design Project. Poseidon shall make a one-time purchase of carbon offsets or RECs to zero-out the Aggregate 30-Year Construction and Operational GHG Emissions set forth in Table 1 by the time Poseidon submits the first Annual GHG Report required in Part III of this Plan.

Table 1 – Aggregate 30-Year Construction and Operational GHG Emissions

Emission Source	**MTCO$_2$e**
On-site Construction Equipment & Travel	822
Off-site Construction Equipment & Travel	1,229 to 1,233
Construction Site Electricity	136
Post-Construction Operational Passenger Vehicle and Delivery Truck Emissions	4,128
Total	**6,315 to 6,319**

The Project's on-going source of quantifiable GHG emissions will be indirect emissions resulting from purchased electricity. All of the electricity supply for the desalination plant operations is expected to be provided by SCE. Therefore, with the exception of the offsets or RECs for construction and vehicle operations discussed above, the accounting of GHG emissions for the Project addressed in this Plan will consist entirely of indirect emissions resulting from electricity purchased from SCE.

Currently, about 58% of the electricity supplied by SCE is generated from fossil fuels.[2]. As a result, until SCE switches to 100% "green" power supply sources, the Project operations will be indirectly linked to SCE's generation of GHGs.

The Project's total net indirect GHG emissions from the stationary combustion of fossil fuels to generate electricity is dependent on three key factors: (1) how much electricity is used by the Project; (2) sources of energy (fossil fuels, wind, sunlight, etc.) used to generate the electricity

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[2] SCE 2008 Power Content Label (16% Eligible Renewables, 12% Coal, 7% Large Hydro, 46% Natural Gas, 19% Nuclear)

supplied to the plant, and (3) the Avoided Emissions, i.e., the amount of energy saved or emissions avoided as a direct result of the Project's operations. These factors will vary over time.

A. Electricity Use by the Project.

The Project will almost always operate, 24 hours a day for 365 days per year, to produce an average annual drinking water flow of 50 million gallons per day (MGD). The power use incorporates both production of fresh drinking water, as well as conveyance and delivery of the water to the distribution systems of the public water agencies that will purchase water from the Project. There are four options for the configuration of the project. The project can either be operated "co-located" with the Huntington Beach Generating Station (HBGS) thereby using warm water, or it can be operated "stand alone" mode without the HBGS operating its cooling water system thereby using cold water. In addition, the project has two options for delivery of the water to the distributions systems – the "primary route" and the "optional route." Each option has a different baseline energy use. Table 2 shows the baseline energy use and total annual electricity use for each potential option.

Table 2 – Baseline Electricity Use By Project Option

Option	Baseline Energy Use (aMW)	MWh/AF	MWh/year
Collocated - Primary Route	33.07	5.2	289,715
Stand Alone - Primary Route	35.01	5.5	306,680
Collocated - Optional Route	34.45	5.4	301,779
Stand Alone - Optional Route	36.39	5.7	318,744

B. SCE's Emissions Factor.

The Project currently intends to purchase all of its electricity from SCE.[3] Accordingly, the appropriate emissions factor to use for the Project's indirect GHG emissions from its electricity use is the independently verified and published emissions factor for the electricity purchased and consumed during the previous year. The certified reported emissions factor for delivered electricity in 2007 is set forth in the utility's Annual Emissions Report published by CCAR in the spring of 2009. In the published Emissions Report, the current certified reported emissions factor for SCE's 2007 delivered electricity is 630.89 lbs of CO_2 per delivered MWH of electricity.

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[3] If at any time in the future the Project is able and desires to obtain all or part of its electricity from an entity other than SCE, Poseidon may do so without amending the Plan and the appropriate CCAR reported emissions factor for that entity shall be used.

Circumstances will change over the life of the Project. SCE's reported emissions factors are updated annually and the amount of energy consumed by the Project may change.[4] As a result, it will be necessary to recalculate the net indirect GHG emissions of the Project on an annual basis using the actual SCE reported emissions factor reported to the CCAR (or CARB). Until the mandatory reporting of emissions factors under AB 32 is available, the emissions factors for SCE registered with CCAR are the best available for purposes of planning and permitting this Project.

Statewide initiatives to expand the use of renewable sources of electricity are expected to decrease the emissions factors of all California power suppliers in the future. For example, approximately 16% of SCE's retail electricity is currently generated from renewable resources (solar, wind, geothermal, small hydro and biomass).[5] In their February 2008 SCE Power Bulletin, they stated they hoped to have contracts in place to provide 20% of their customer's energy needs with renewables by 2010. These and other reductions are expected to further reduce the Project's net indirect GHG emissions over time.

Table 3 summarizes the Project's estimated gross indirect CO_2 emissions from purchased electricity for Project operations for each configuration option, based on the most current information.

Table 3 - Identification of Gross Indirect CO_2 Emissions from Purchased Electricity for Project Operations

Option	Total Annual Electricity Use (MWh/year)	Total Annual Emissions (metric tons CO_2/year)
Collocated - Primary Route	289,715	82,908
Stand Alone - Primary Route	306,680	87,763
Collocated - Optional Route	301,779	86,360
Stand Alone - Optional Route	318,744	91,215

PART II: PROJECT AND PROJECT-RELATED REDUCTION OF GHG EMISSIONS

To determine the Project's indirect GHG emissions, on-site and project-related reductions in emissions must also be considered. These are carbon emission reductions that result from measures that reduce energy requirements (increased energy efficiency, potential onsite solar, recovery of CO_2 and green building design), as well as Project-related emissions that will be avoided (Avoided Emissions) as a direct result of the Project and its various components

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[4] SCE Annual Emissions Reports to CCAR have changed each year. For years 2004, 2005, 2006 and 2007 the reported emissions factors have been 679, 666, 641, and 631 lbs of CO_2/MWh, respectively.

[5] SCE 2008 Power Content Label. http://www.sce.com/NR/rdonlyres/56AC9CC0-382B-4E1C-BB00-79059037979D/0/2008_SCE_Power_Content_Label.pdf

(replacing Customers' SWP water with water from the Project). The total of each year's indirect GHG emissions will be determined using CARB, CCAR or TCR approved emissions factors for SCE[6] and/or the State Water Project.

A. **Increased Energy Efficiency**.

Poseidon has committed to implement certain measures to reduce the Project's energy requirements and GHG emissions, and will continuously explore new technologies and processes to further reduce and offset the carbon footprint of the Project, such as the use of carbon dioxide from the ambient air for water treatment. These measures are set forth below.

The Project's high-energy efficiency design incorporates state-of-the-art features minimizing plant energy consumption. One such feature is the use of a state-of-the art pressure exchanger-based energy recovery system that allows recovery and reuse of 32.1% of the energy associated with the reverse osmosis (RO) process. A significant portion of the energy applied in the RO process is retained in the concentrated stream. This energy bearing stream (shown with red arrows on Figure 2) is applied to the back side of pistons of cylindrical isobaric chambers, also known as "pressure exchangers" (shown as yellow cylinders on Figure 2). These energy exchangers recover and reuse approximately 45% of the energy used by the RO process.[7]

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[6] Or such other entity from whom Poseidon purchases its electricity.

[7] The "45 % percent energy recovery and reuse" refers to the gross energy recovery potential, while the "32.1 % energy recovery and reuse" refers to the actual energy savings associated with the energy recovery system. The difference between gross and actual energy savings is due to mechanical inefficiencies of the recovery system and associated friction losses. Thus, for purposes of calculating the overall energy savings, Tables 4 through 7 correctly reflects the approximate 32% savings associated with the pressure exchanger.

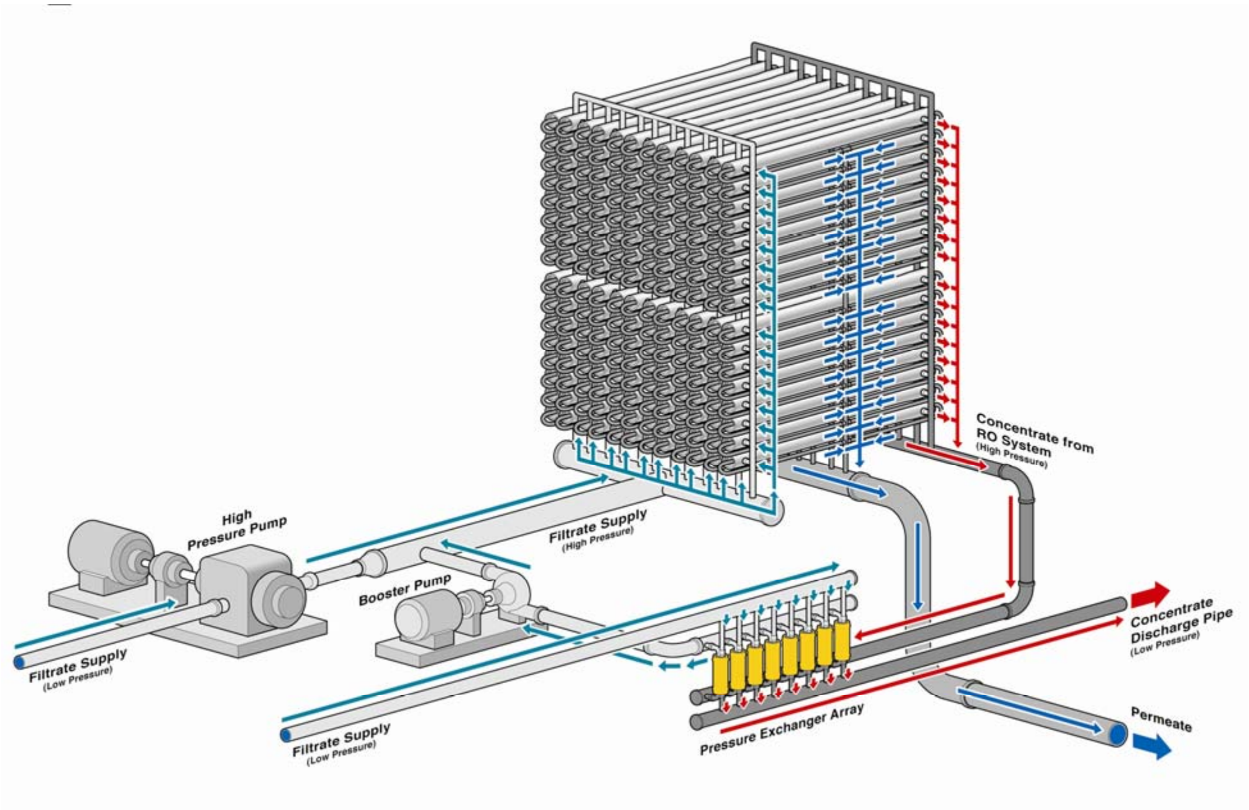

Figure 2 - Energy Recovery System for the Huntington Beach Seawater Desalination Plant

Currently there are no full-scale seawater desalination plants in the US using the proposed state-of-the art pressure exchanger energy recovery technology included in the "High Efficiency Design" (Tables 4 through 7). All existing seawater desalination projects in the US, including the 25 MGD Tampa Bay seawater desalination plant, which recommenced commercial operation in January 2008, are using standard energy recovery equipment – i.e., Pelton wheels (see Figure 3). Therefore, the Pelton wheel energy recovery system is included in the "Baseline Design" in Tables 4 through 7.

The pressure exchanger technology that Poseidon proposes to use for the Project is a national technology. The manufacturer of the pressure exchangers referenced in Tables 4 through 7 of the Project Power Budget is Energy Recovery, Inc., a US company located in San Leandro, California (www.energyrecovery.com).

Figure 3 - Tampa Bay Desalination Plant Pelton Wheel Energy Recovery System

A pilot-scale seawater desalination plant using the pressure exchanger technology proposed by Poseidon and supplied by Energy Recovery, Inc. has been in operation at the US Navy's Seawater Desalination Testing Facility in Port Hueneme, California since 2005. The overall capacity of this desalination plant is 50,000 to 80,000 gallons per day. The pilot testing work at this facility has been conducted by the Affordable Desalination Collaboration (ADC), which is a California non-profit organization composed of a group of leading companies and agencies in the desalination industry (www.affordabledesal.com). A portion of the funding for the operation of this facility is provided by the California Department of Water Resources (DWR) through the state's Proposition 50 Program. The DWR provides independent oversight of this project and reviews project results. In addition, representatives of the California Energy Commission and the California Department of Public Health are on the Board of Directors of the ADC.

The proposed pressure exchanger technology (i.e., the same pressure exchanger employed at the ADC seawater desalination plant) was independently tested at Poseidon's Carlsbad seawater desalination demonstration plant. More than one year of testing has confirmed the validity of the conclusions of the ADC for the site-specific conditions of the Project. The test results from the Carlsbad seawater desalination demonstration plant were used to calculate the energy efficiency of the pressure exchangers included in Tables 4 through 7. Poseidon's technology evaluation work at the Carlsbad seawater desalination demonstration plant was independently reviewed and recognized by the American Academy of Environmental Engineers and by the International Water Association, who awarded Poseidon their 2006 Grand Prize in the field of Applied Research. This technology is the same as the technology used in Poseidon's approved Energy Minimization and Greenhouse Gas Reduction Plan for the Carlsbad Desalination Project.

The following sections describe and compare the baseline design electricity use for each project option to the high efficiency design electricity use for that option. The total actual energy reduction resulting from the use of state-of-the-art desalination and energy recovery technologies and design will be verified by direct readings of the total electricity consumed by the desalination plant at the Project’s substation(s) electric meter(s) and documented as soon as the Project is fully operational.

Colocated Primary Route Option

Table 4 - Comparison of Baseline and High-Efficiency Electricity Budget for 50 MGD Water Production Capacity – Colocated Primary Route Option

	Baseline Design - Power Use			High Efficiency Design - Power Use		
Unit	(Hp)	Equip. Effic.	Equipment Type	(Hp)	Equip. Effic.	Equipment Type
Key Treatment Process Pumps						
Power Plant Intake Pumps (Collocated Operation)	0	NA	NA	0	NA	NA
Seawater Intake Pumps	1,650	70%	Standard Motors - No VFDs	1,445	80%	High Eff. Motors - VFDs
Filter Effluent Transfer Pumps	4,450	82%	High Eff. Motors - with VFDs	4,525	82%	High Eff. Motors - with VFDs
High Pressure Reverse Osmosis Pumps	36,960	82%	High Eff. Motors - No VFDs	34,440	88%	High Eff. Motors - No VFDs
Energy Recovery System – Power Reduction	-9,280	-25.10%	Pelton Wheels	-11,056	-32.10%	Pressure Exchangers
On-site Product Water Transfer Pumps (50 MGD)	5,538	70%	Standard Motors - No VFDs	4,500	80%	High Eff. Motors - No VFDs
Off-site OC-44 Product Water Pump Station (45 MGD)	2,615	65%	Standard Motors - No VFDs	2,125	80%	High Eff. Motors - No VFDs
Off-site Coastal Junction Product Water Pump Station (26 MGD)	462	65%	Standard Motors – No VFDs	375	80%	High Eff. Motors with VFDs
Pretreatment Filter & Residuals Handling Equipment						
Residuals Transfer Pumps	150	65%	Standard Motors - No VFDs	150	65%	Standard Motors - No VFDs
Residuals Dewatering System	600	70%	Standard Motors - No VFDs	600	70%	Standard Motors - No VFDs
Filter Backwash Blowers	250	70%	Standard Motors - No VFDs	250	70%	Standard Motors - No VFDs
Filter Backwash Pumps	150	70%	Standard Motors - No VFDs	150	70%	Standard Motors - No VFDs
Flocculation Mixers	30	70%	Standard Motors - No VFDs	30	70%	Standard Motors - No VFDs
RO Membrane Cleaning System						
Membrane Cleaning Pumps	13	70%	Standard Motors - No VFDs	13	70%	Standard Motors - No VFDs
Scavenger Tank Mixing System	2	70%	Standard Motors - No VFDs	2	70%	Standard Motors - No VFDs
Flush Pumps	17	70%	Standard Motors - No VFDs	17	70%	Standard Motors - No VFDs
Cleaning Chemical System	15	70%	Standard Motors - No VFDs	15	70%	Standard Motors - No VFDs
Sewer System Transfer Pumps	15	65%	Standard Motors - No VFDs	15	65%	Standard Motors - No VFDs
Chemical Feed Equipment						
Polymer Feed System	0.5	65%	Standard Motors - No VFDs	0.5	65%	Standard Motors - No VFDs
Ammonia Feed System	0.5	65%	Standard Motors - No VFDs	0.5	65%	Standard Motors - No VFDs
Calcite Feed System	0.5	65%	Standard Motors - No VFDs	0.5	65%	Standard Motors - No VFDs
Carbon Dioxide Feed System	1	65%	Standard Motors - No VFDs	1	65%	Standard Motors - No VFDs
Sodium Hypochlorite Feed System	0.5	65%	Standard Motors - No VFDs	0.5	65%	Standard Motors - No VFDs
Other Chemical Feed Systems	3	65%	Standard Motors - No VFDs	3	65%	Standard Motors - No VFDs
Service Facilities						
HVAC	70	NA	Standard Equipment	70	NA	Standard Equipment
Lightning	400	NA	Standard Equipment	400	NA	Standard Equipment
Controls and Automation	10	NA	Standard Equipment	10	NA	Standard Equipment
Air Compressors	10	NA	Standard Equipment	10	NA	Standard Equipment
Other Miscellaneous Power Uses	200	NA	Standard Equipment	200	NA	Standard Equipment
TOTAL DESALINATION PLANT HORSEPOWER USE	**44,333**	**Hp**		**38,292**	**Hp**	
TOTAL DESALINATION PLANT POWER USE	**33.07**	**aMW**		**28.57**	**aMW**	

Table 4 presents a detailed breakdown of the projected power use of the Colocated Primary Route option project under a Baseline Design and High-Energy Efficiency Design. As indicated in this table, the Baseline Design includes high efficiency motors for all pumps, except the largest reverse osmosis feed pumps, and a Pelton wheel energy recovery system which is the most widely used “standard’ energy recovery system today. The total desalination power use under the Baseline Design is 33.1 aMW, which corresponds to a unit power use of 15.9 kWh/kgal[8] (5,176 kWh/AF)[9].

In addition to the state-of-the-art pressure exchanger system described above, the High-Energy Efficiency Design incorporates premium efficiency motors and variable frequency drives (VFDs) on desalination plant pumps that have motors of 500 horsepower or more. The total desalination plant energy use under the High-Energy Efficiency Design is 28.6 aMW, which corresponds to

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[8] 33.07 MWh x 1,000 kW/MW/Average Fresh Water Production Rate of 2083 kg/Hr.

[9] 15.9 kWh/kgal x 326 kgal/AF.

unit power use of 13.7 kWh/kgal[10] (4,471 kWh/AF)[11]. This is a reduction of approximately 13.6% from the Baseline Design, for a total of 39,480 MWh/yr.

The main energy savings result from the use of pressure exchangers instead of Pelton wheels for energy recovery. The pressure exchangers are projected to yield 1,776 hp (1.3 aMW)[12] of power savings, which is 4% reduction of the total power use of 32.8 aMW. Converted into unit power savings, the energy reduction of 1.3 aMW corresponds to 0.6 kWh/kgal[13] (207 kWh/AF)[14]. The installation of premium-efficiency motors and VFDs on large pumps would result in additional 1.3 aMW (4.0%) of power savings.

The power savings of 0.6 kWh/kgal associated with the use of pressure exchangers instead of Pelton wheels for energy recovery are substantiated by information from several full-scale desalination plants which have recently replaced their existing Pelton wheel energy recovery systems with pressure exchangers in order to take advantage of the energy savings offered by this technology. Poseidon's submission of the Carlsbad Plan to the CCC included documentation entitled "Energy Recovery in Caribbean Seawater", which contains energy data for a seawater desalination plant in Mazarron, Spain where a Pelton wheel system was replaced with PX pressure exchangers. The replacement resulted in energy reduction from 3.1 kWh/m^3 to 2.4 kWh/m^3 (i.e., 0.7 kWh/m^3 or 2.6 kWh/kgal).

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[10] 28.76 MWh x 1,000 kW/MW/2083 kgal/Hr.

[11] 13.81 kWh/kgal x 326 kgal/AF.

[12] 1776 HP x 0.746 kW/HP

[13] 1.3 x 1000 kW/MW/2083kgal/Hr

[14] 0.64 kWh/kgal x 326 kgal/AF

Stand Alone Primary Route Option

Table 5 - Comparison of Baseline and High Efficiency Electric Budget for 50 MGD Water Production - Stand Alone Primary Route Option

	Baseline Design - Power Use			High Efficiency Design - Power Use		
Unit	**(Hp)**	**Equip. Effic.**	**Equipment Type**	**(Hp)**	**Equip. Effic.**	**Equipment Type**
Key Treatment Process Pumps						
Power Plant Intake Pumps (Collocated Operation)	1,210	70%	Standard Motors - No VFDs	1,210	70%	Standard Motors - No VFDs
Seawater Intake Pumps	1,650	70%	Standard Motors - No VFDs	1,445	80%	High Eff. Motors - VFDs
Filter Effluent Transfer Pumps	4,450	82%	High Eff. Motors - with VFDs	4,525	82%	High Eff. Motors - with VFDs
High Pressure Reverse Osmosis Pumps	38,806	82%	High Eff. Motors - No VFDs	36,160	88%	High Eff. Motors - No VFDs
Energy Recovery System – Power Reduction	-9,740	-25.10%	Pelton Wheels	-11,610	-32.10%	Pressure Exchangers
On-site Product Water Transfer Pumps (50 MGD)	5,538	70%	Standard Motors - No VFDs	4,500	80%	High Eff. Motors - No VFDs
Off-site OC-44 Product Water Pump Station (45 MGD)	2,615	65%	Standard Motors - No VFDs	2,125	80%	High Eff. Motors - No VFDs
Off-site Coastal Junction Product Water Pump Station (26 MGD)	462	65%	Standard Motors – No VFDs	375	80%	High Eff. Motors with VFDs
Pretreatment Filter & Residuals Handling Equipment						
Residuals Transfer Pumps	150	65%	Standard Motors - No VFDs	150	65%	Standard Motors - No VFDs
Residuals Dewatering System	600	70%	Standard Motors - No VFDs	600	70%	Standard Motors - No VFDs
Filter Backwash Blowers	250	70%	Standard Motors - No VFDs	250	70%	Standard Motors - No VFDs
Filter Backwash Pumps	150	70%	Standard Motors - No VFDs	150	70%	Standard Motors - No VFDs
Flocculation Mixers	30	70%	Standard Motors - No VFDs	30	70%	Standard Motors - No VFDs
RO Membrane Cleaning System						
Membrane Cleaning Pumps	13	70%	Standard Motors - No VFDs	13	70%	Standard Motors - No VFDs
Scavenger Tank Mixing System	2	70%	Standard Motors - No VFDs	2	70%	Standard Motors - No VFDs
Flush Pumps	17	70%	Standard Motors - No VFDs	17	70%	Standard Motors - No VFDs
Cleaning Chemical System	15	70%	Standard Motors - No VFDs	15	70%	Standard Motors - No VFDs
Sewer System Transfer Pumps	15	65%	Standard Motors - No VFDs	15	65%	Standard Motors - No VFDs
Chemical Feed Equipment						
Polymer Feed System	0.5	65%	Standard Motors - No VFDs	0.5	65%	Standard Motors - No VFDs
Ammonia Feed System	0.5	65%	Standard Motors - No VFDs	0.5	65%	Standard Motors - No VFDs
Calcite Feed System	0.5	65%	Standard Motors - No VFDs	0.5	65%	Standard Motors - No VFDs
Carbon Dioxide Feed System	1	65%	Standard Motors - No VFDs	1	65%	Standard Motors - No VFDs
Sodium Hypochlorite Feed System	0.5	65%	Standard Motors - No VFDs	0.5	65%	Standard Motors - No VFDs
Other Chemical Feed Systems	3	65%	Standard Motors - No VFDs	3	65%	Standard Motors - No VFDs
Service Facilities						
HVAC	70	NA	Standard Equipment	70	NA	Standard Equipment
Lightning	400	NA	Standard Equipment	400	NA	Standard Equipment
Controls and Automation	10	NA	Standard Equipment	10	NA	Standard Equipment
Air Compressors	10	NA	Standard Equipment	10	NA	Standard Equipment
Other Miscellaneous Power Uses	200	NA	Standard Equipment	200	NA	Standard Equipment
TOTAL DESALINATION PLANT HORSEPOWER USE	**46,929**	**Hp**		**40,668**	**Hp**	
TOTAL DESALINATION PLANT POWER USE	**35.01**	**aMW**		**30.34**	**aMW**	

Table 5 presents a detailed breakdown of the projected power use of the Stand Alone Primary Route option project under a Baseline Design and High-Energy Efficiency Design. As indicated in this table, the Baseline Design includes high efficiency motors for all pumps, except the largest reverse osmosis feed pumps, and a Pelton wheel energy recovery system which is the most widely used "standard' energy recovery system today. The total desalination power use under the Baseline Design is 35.0 aMW, which corresponds to a unit power use of 16.8 kWh/kgal[15] (5,479 kWh/AF)[16].

In addition to the state-of-the-art pressure exchanger system described above, the High-Energy Efficiency Design incorporates premium efficiency motors and variable frequency drives (VFDs) on desalination plant pumps that have motors of 500 horsepower or more. The total desalination plant energy use under the High-Energy Efficiency Design is 30.3 aMW, which corresponds to

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[15] 35.0 MWh x 1,000 kW/MW/Average Fresh Water Production Rate of 2083 kg/Hr.

[16] 16.8 kWh/kgal x 326 kgal/AF.

unit power use of 14.6 kWh/kgal[17] (4,748 kWh/AF)[18]. This is a reduction of approximately 13.3% from the Baseline Design, for a total of 40,917 MWh/yr.

The main energy savings result from the use of pressure exchangers instead of Pelton wheels for energy recovery. The pressure exchangers are projected to yield 1,870 hp (1.4 aMW)[19] of power savings, which is 4% reduction of the total power use of 35.0 aMW. Converted into unit power savings, the energy reduction of 1.4 aMW corresponds to 0.7 kWh/kgal[20] (218 kWh/AF)[21]. The installation of premium-efficiency motors and VFDs on large pumps would result in additional 1.3 aMW (4.0%) of power savings.

The power savings of 0.7 kWh/kgal associated with the use of pressure exchangers instead of Pelton wheels for energy recovery are substantiated by information from several full-scale desalination plants which have recently replaced their existing Pelton wheel energy recovery systems with pressure exchangers in order to take advantage of the energy savings offered by this technology. Poseidon's submission of the Carlsbad Plan to the CCC included documentation entitled "Energy Recovery in Caribbean Seawater", which contains energy data for a seawater desalination plant in Mazarron, Spain where a Pelton wheel system was replaced with PX pressure exchangers. The replacement resulted in energy reduction from 3.1 kWh/m^3 to 2.4 kWh/m^3 (i.e., 0.7 kWh/m^3 or 2.6 kWh/kgal).

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[17] 30.3 MWh x 1,000 kW/MW/2083 kgal/Hr.

[18] 14.6 kWh/kgal x 326 kgal/AF.

[19] 1870 HP x 0.746 kW/HP

[20] 1.4 x 1000 kW/MW/2083kgal/Hr

[21] 0.67 kWh/kgal x 326 kgal/AF

Colocated Optional Route Option

Table 6 - Comparison of Baseline and High Efficiency Electric Budget for 50 MGD Water Production Capacity - Colocated Optional Route Option

	Baseline Design - Power Use			High Efficiency Design - Power Use		
Unit	(Hp)	Equip. Effic.	Equipment Type	(Hp)	Equip. Effic.	Equipment Type
Key Treatment Process Pumps						
Power Plant Intake Pumps (Collocated Operation)	0	NA	NA	0	NA	NA
Seawater Intake Pumps	1,650	70%	Standard Motors - No VFDs	1,445	80%	High Eff. Motors - VFDs
Filter Effluent Transfer Pumps	4,450	82%	High Eff. Motors - with VFDs	4,525	82%	High Eff. Motors - with VFDs
High Pressure Reverse Osmosis Pumps	36,960	82%	High Eff. Motors - No VFDs	34,440	88%	High Eff. Motors - No VFDs
Energy Recovery System – Power Reduction	-9,280	-25.10%	Pelton Wheels	-11,056	-32.10%	Pressure Exchangers
On-site Product Water Transfer Pumps (50 MGD)	4,615	70%	Standard Motors - No VFDs	3,750	80%	High Eff. Motors - No VFDs
Off-site Product Water Pump Station (50 MGD)	5,846	65%	Standard Motors – No VFDs	4,750	80%	High Eff. Motors with VFDs
Pretreatment Filter & Residuals Handling Equipment						
Residuals Transfer Pumps	150	65%	Standard Motors - No VFDs	150	65%	Standard Motors - No VFDs
Residuals Dewatering System	600	70%	Standard Motors - No VFDs	600	70%	Standard Motors - No VFDs
Filter Backwash Blowers	250	70%	Standard Motors - No VFDs	250	70%	Standard Motors - No VFDs
Filter Backwash Pumps	150	70%	Standard Motors - No VFDs	150	70%	Standard Motors - No VFDs
Flocculation Mixers	30	70%	Standard Motors - No VFDs	30	70%	Standard Motors - No VFDs
RO Membrane Cleaning System						
Membrane Cleaning Pumps	13	70%	Standard Motors - No VFDs	13	70%	Standard Motors - No VFDs
Scavenger Tank Mixing System	2	70%	Standard Motors - No VFDs	2	70%	Standard Motors - No VFDs
Flush Pumps	17	70%	Standard Motors - No VFDs	17	70%	Standard Motors - No VFDs
Cleaning Chemical System	15	70%	Standard Motors - No VFDs	15	70%	Standard Motors - No VFDs
Sewer System Transfer Pumps	15	65%	Standard Motors - No VFDs	15	65%	Standard Motors - No VFDs
Chemical Feed Equipment						
Polymer Feed System	0.5	65%	Standard Motors - No VFDs	0.5	65%	Standard Motors - No VFDs
Ammonia Feed System	0.5	65%	Standard Motors - No VFDs	0.5	65%	Standard Motors - No VFDs
Calcite Feed System	0.5	65%	Standard Motors - No VFDs	0.5	65%	Standard Motors - No VFDs
Carbon Dioxide Feed System	1	65%	Standard Motors - No VFDs	1	65%	Standard Motors - No VFDs
Sodium Hypochlorite Feed System	0.5	65%	Standard Motors - No VFDs	0.5	65%	Standard Motors - No VFDs
Other Chemical Feed Systems	3	65%	Standard Motors - No VFDs	3	65%	Standard Motors - No VFDs
Service Facilities						
HVAC	70	NA	Standard Equipment	70	NA	Standard Equipment
Lightning	400	NA	Standard Equipment	400	NA	Standard Equipment
Controls and Automation	10	NA	Standard Equipment	10	NA	Standard Equipment
Air Compressors	10	NA	Standard Equipment	10	NA	Standard Equipment
Other Miscellaneous Power Uses	200	NA	Standard Equipment	200	NA	Standard Equipment
TOTAL DESALINATION PLANT HORSEPOWER USE	**46,179**	**Hp**		**39,792**	**Hp**	
TOTAL DESALINATION PLANT POWER USE	**34.45**	**aMW**		**29.68**	**aMW**	

Table 6 presents a detailed breakdown of the projected power use of the Colocated Optional Route option project under a Baseline Design and High-Energy Efficiency Design. As indicated in this table, the Baseline Design includes high efficiency motors for all pumps, except the largest reverse osmosis feed pumps, and a Pelton wheel energy recovery system which is the most widely used "standard' energy recovery system today. The total desalination power use under the Baseline Design is 34.4 aMW, which corresponds to a unit power use of 16.5 kWh/kgal[22] (5,392 kWh/AF)[23].

In addition to the state-of-the-art pressure exchanger system described above, the High-Energy Efficiency Design incorporates premium efficiency motors and variable frequency drives (VFDs) on desalination plant pumps that have motors of 500 horsepower or more. The total desalination plant energy use under the High-Energy Efficiency Design is 29.7 aMW, which corresponds to

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[22] 34.4 MWh x 1,000 kW/MW/Average Fresh Water Production Rate of 2083 kg/Hr.

[23] 16.5 kWh/kgal x 326 kgal/AF.

unit power use of 14.3 kWh/kgal[24] (4,646 kWh/AF)[25]. This is a reduction of approximately 13.8% from the Baseline Design, for a total of 41,741 MWh/yr

The main energy savings result from the use of pressure exchangers instead of Pelton wheels for energy recovery. The pressure exchangers are projected to yield 1,776 hp (1.3 aMW)[26] of power savings, which is 3.8% reduction of the total power use of 34.4 aMW. Converted into unit power savings, the energy reduction of 1.3 aMW corresponds to 0.6 kWh/kgal[27] (207 kWh/AF)[28]. The installation of premium-efficiency motors and VFDs on large pumps would result in additional 1.3 aMW (3.8%) of power savings.

The power savings of 0.6 kWh/kgal associated with the use of pressure exchangers instead of Pelton wheels for energy recovery are substantiated by information from several full-scale desalination plants which have recently replaced their existing Pelton wheel energy recovery systems with pressure exchangers in order to take advantage of the energy savings offered by this technology. Poseidon's submission of the Carlsbad Plan to the CCC included documentation entitled "Energy Recovery in Caribbean Seawater", which contains energy data for a seawater desalination plant in Mazarron, Spain where a Pelton wheel system was replaced with PX pressure exchangers. The replacement resulted in energy reduction from 3.1 kWh/m^3 to 2.4 kWh/m^3 (i.e., 0.7 kWh/m^3 or 2.6 kWh/kgal).

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[24] 29.7 MWh x 1,000 kW/MW/2083 kgal/Hr.

[25] 14.3 kWh/kgal x 326 kgal/AF.

[26] 1776 HP x 0.746 kW/HP

[27] 1.3 x 1000 kW/MW/2083kgal/Hr

[28] 0.64 kWh/kgal x 326 kgal/AF

Stand Alone Optional Route Option

Table 7 - Comparison of Baseline and High Efficiency Electric Budget for 50 MGD Water Production Capacity - Stand Alone Optional Route

	Baseline Design - Power Use			High Efficiency Design - Power Use		
Unit	(Hp)	Equip. Effic.	Equipment Type	(Hp)	Equip. Effic.	Equipment Type
Key Treatment Process Pumps						
Power Plant Intake Pumps (Collocated Operation)	1,210	70%	Standard Motors - No VFDs	1,210	70%	Standard Motors - No VFDs
Seawater Intake Pumps	1,650	70%	Standard Motors - No VFDs	1,445	80%	High Eff. Motors - VFDs
Filter Effluent Transfer Pumps	4,450	82%	High Eff. Motors - with VFDs	4,525	82%	High Eff. Motors - with VFDs
High Pressure Reverse Osmosis Pumps	38,806	82%	High Eff. Motors - No VFDs	36,160	88%	High Eff. Motors - No VFDs
Energy Recovery System – Power Reduction	-9,740	-25.10%	Pelton Wheels	-11,610	-32.10%	Pressure Exchangers
On-site Product Water Transfer Pumps (50 MGD)	4,615	70%	Standard Motors - No VFDs	3,750	80%	High Eff. Motors - No VFDs
Off-site Product Water Pump Station (50 MGD)	5,846	65%	Standard Motors – No VFDs	4,750	80%	High Eff. Motors with VFDs
Pretreatment Filter & Residuals Handling Equipment						
Residuals Transfer Pumps	150	65%	Standard Motors - No VFDs	150	65%	Standard Motors - No VFDs
Residuals Dewatering System	600	70%	Standard Motors - No VFDs	600	70%	Standard Motors - No VFDs
Filter Backwash Blowers	250	70%	Standard Motors - No VFDs	250	70%	Standard Motors - No VFDs
Filter Backwash Pumps	150	70%	Standard Motors - No VFDs	150	70%	Standard Motors - No VFDs
Flocculation Mixers	30	70%	Standard Motors - No VFDs	30	70%	Standard Motors - No VFDs
RO Membrane Cleaning System						
Membrane Cleaning Pumps	13	70%	Standard Motors - No VFDs	13	70%	Standard Motors - No VFDs
Scavenger Tank Mixing System	2	70%	Standard Motors - No VFDs	2	70%	Standard Motors - No VFDs
Flush Pumps	17	70%	Standard Motors - No VFDs	17	70%	Standard Motors - No VFDs
Cleaning Chemical System	15	70%	Standard Motors - No VFDs	15	70%	Standard Motors - No VFDs
Sewer System Transfer Pumps	15	65%	Standard Motors - No VFDs	15	65%	Standard Motors - No VFDs
Chemical Feed Equipment						
Polymer Feed System	0.5	65%	Standard Motors - No VFDs	0.5	65%	Standard Motors - No VFDs
Ammonia Feed System	0.5	65%	Standard Motors - No VFDs	0.5	65%	Standard Motors - No VFDs
Calcite Feed System	0.5	65%	Standard Motors - No VFDs	0.5	65%	Standard Motors - No VFDs
Carbon Dioxide Feed System	1	65%	Standard Motors - No VFDs	1	65%	Standard Motors - No VFDs
Sodium Hypochlorite Feed System	0.5	65%	Standard Motors - No VFDs	0.5	65%	Standard Motors - No VFDs
Other Chemical Feed Systems	3	65%	Standard Motors - No VFDs	3	65%	Standard Motors - No VFDs
Service Facilities						
HVAC	70	NA	Standard Equipment	70	NA	Standard Equipment
Lightning	400	NA	Standard Equipment	400	NA	Standard Equipment
Controls and Automation	10	NA	Standard Equipment	10	NA	Standard Equipment
Air Compressors	10	NA	Standard Equipment	10	NA	Standard Equipment
Other Miscellaneous Power Uses	200	NA	Standard Equipment	200	NA	Standard Equipment
TOTAL DESALINATION PLANT HORSEPOWER USE	**48,775**	**Hp**		**42,168**	**Hp**	
TOTAL DESALINATION PLANT POWER USE	**36.39**	**aMW**		**31.46**	**aMW**	

Table 7 presents a detailed breakdown of the projected power use of the Stand Alone Optional Route option project under a Baseline Design and High-Energy Efficiency Design. As indicated in this table, the Baseline Design includes high efficiency motors for all pumps, except the largest reverse osmosis feed pumps, and a Pelton wheel energy recovery system which is the most widely used "standard' energy recovery system today. The total desalination power use under the Baseline Design is 36.39 aMW, which corresponds to a unit power use of 17.5 kWh/kgal[29] (5,695 kWh/AF)[30].

In addition to the state-of-the-art pressure exchanger system described above, the High-Energy Efficiency Design incorporates premium efficiency motors and variable frequency drives (VFDs) on desalination plant pumps that have motors of 500 horsepower or more. The total desalination plant energy use under the High-Energy Efficiency Design is 31.5 aMW, which corresponds to

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[29] 36.4 MWh x 1,000 kW/MW/Average Fresh Water Production Rate of 2083 kg/Hr.

[30] 17.5 kWh/kgal x 326 kgal/AF.

unit power use of 15.1 kWh/kgal[31] (4,923 kWh/AF)[32]. This is a reduction of approximately 13.5% from the Baseline Design, for a total of 43,178 MWh/yr.

The main energy savings result from the use of pressure exchangers instead of Pelton wheels for energy recovery. The pressure exchangers are projected to yield 1,870 hp (1.4 aMW)[33] of power savings, which is 3.8% reduction of the total power use of 36.4 aMW. Converted into unit power savings, the energy reduction of 1.4 aMW corresponds to 0.7 kWh/kgal[34] (218 kWh/AF)[35]. The installation of premium-efficiency motors and VFDs on large pumps would result in additional 1.3 aMW (3.8%) of power savings.

The power savings of 0.7 kWh/kgal associated with the use of pressure exchangers instead of Pelton wheels for energy recovery are substantiated by information from several full-scale desalination plants which have recently replaced their existing Pelton wheel energy recovery systems with pressure exchangers in order to take advantage of the energy savings offered by this technology. Poseidon's submission of the Carlsbad Plan to the CCC included documentation entitled "Energy Recovery in Caribbean Seawater", which contains energy data for a seawater desalination plant in Mazarron, Spain where a Pelton wheel system was replaced with PX pressure exchangers. The replacement resulted in energy reduction from 3.1 kWh/m^3 to 2.4 kWh/m^3 (i.e., 0.7 kWh/m^3 or 2.6 kWh/kgal).

B. <u>GHG Emission Reduction by Green Building Design</u>.

The Project will be located on a site currently occupied by an oil storage tank no longer used by the power plant. This tank and its content will be removed and the site will be reused to construct the Project. Because the facility is an industrial facility, LEED-level certification will not be feasible; but to the extent reasonably practicable, building design will follow the principles of the Leadership in Energy and Environmental Design (LEED) program. LEED is a program of the United States Green Building Council, developed to promote construction of sustainable buildings that reduce the overall impact of building construction and functions on the environment by: (1) sustainable site selection and development, including re-use of existing industrial infrastructure locations; (2) energy efficiency; (3) materials selection; (4) indoor environmental quality, and (5) water savings.

The potential energy savings associated with the implementation of the green building design as compared to that for a standard building design are in a range of 300 MWh/yr to 500 MWh/yr. The potential carbon footprint reduction associated with this design is between 86 and 143 tons of CO_2 per year. The energy savings associated with incorporating green building design features into the desalination plant structures (i.e., natural lighting, high performance fluorescent lamps, high-efficiency HVAC and compressors, etc.) are based on the assumption that such

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[31] 31.4 MWh x 1,000 kW/MW/2083 kgal/Hr.

[32] 15.1 kWh/kgal x 326 kgal/AF.

[33] 1870 HP x 0.746 kW/HP

[34] 1.4 x 1000 kW/MW/2083kgal/Hr

[35] 0.67 kWh/kgal x 326 kgal/AF

features will reduce the total energy consumption of the plant service facilities by 6 to 10 %. As indicated in Tables 4 through 7, the plant service facilities (HVAC, lighting, controls and automation, air compressors and other miscellaneous power uses) are projected to have power use of 690 hp (70 hp + 400 hp + 10 hp + 10 hp + 200 hp = 690 hp) when standard equipment is used. The total annual energy demand for these facilities is calculated as follows; 690 hp x 0.746 kW/hp x 0.001 kW/MW x 24 hrs x 365 days = 4,509 MWh/yr. If use of green building design features result in 6 % of energy savings, the total annual power use reduction of the service facilities is calculated at 0.06 x 4,509 MWh/yr = 270.5 MWh/yr (rounded to 270 MWh/yr). Similarly, energy savings of 10 % due to green building type equipment would yield 0.1 x 4,509 MWh/yr = 450.9 MWh/yr (rounded to 450 MWh/yr) of savings. The total actual energy reduction resulting from the use of the green building design will be determined by direct readings of the total electricity consumed by the desalination plant at the Project's substation(s) electric meter(s) and documented when the Project is fully operational.

C. On-Site Solar Power Generation.

Poseidon is exploring the installation of rooftop photovoltaic (PV) system for solar power generation as one element of its green building design. Brummitt Energy Associates of San Diego completed a feasibility study in March 2007 of a photovoltaic system for the Carlsbad Desalination Plant. If a similar solar installation described by Brummitt is implemented in Huntington Beach, the desalination plant buildings would accommodate solar panels on a roof surface of approximately 39,000 square feet, with the potential to generate approximately 606 MWh/yr of electricity. If installed, the electricity produced by the onsite PV system would be used by the Project and therefore would reduce the Project's electrical demand on SCE. The corresponding reduction of the Project's indirect emissions would be 173 tons of CO_2 per year. Poseidon is exploring other solar proposals and will update this information as it becomes available. Ultimately, the electricity and corresponding GHG savings of any on-site solar installation will be documented in the Project's annual electricity usage information. Poseidon will use commercially reasonable efforts to implement an on-site solar power project if it is reasonably expected to provide a return on the capital investment over the life of the Project.

If Poseidon proceeds with an onsite PV system, the total actual energy reductions resulting from the use of on-site solar power generation will be determined by direct readings of the total electricity consumed by the desalination plant at the Project's substation(s) electric meter(s) and documented once the system is fully operational.

D. Recovery of CO_2.

Approximately 2,100 tons of CO_2 per year are planned to be used at the Project for post-treatment of the product water (permeate) produced by the reverse osmosis (RO) system. Carbon dioxide in a gaseous form will be added to the RO permeate in combination with calcium hydroxide or calcium carbonate in order to form soluble calcium bicarbonate which adds hardness and alkalinity to the drinking water for distribution system corrosion protection. In this post-treatment process of RO permeate stabilization, gaseous carbon dioxide is sequestered in soluble form as calcium bicarbonate. Because the pH of the drinking water distributed for potable use is in a range (8.3 to 8.5) at which CO_2 is in a soluble bicarbonate form, the carbon dioxide introduced in the RO permeate would remain permanently sequestered. During the treatment process the calcium carbonate (calcite – $CaCO_3$) reacts with the carbon dioxide injected in the water and forms completely soluble calcium bicarbonate as follows:

$$CaCO_{3\ (solid)} + CO_{2\ (gas)} + H_2O_{\ (liquid)} \rightarrow Ca(HCO_3)_{2\ (liquid\ solution)}$$

At the typical pH range of drinking water (pH of 8.3 to 8.5) the carbon dioxide will remain in the drinking water in soluble form (see Figure 4) and the entire amount (100 %) of the injected carbon dioxide will be completely dissolved.

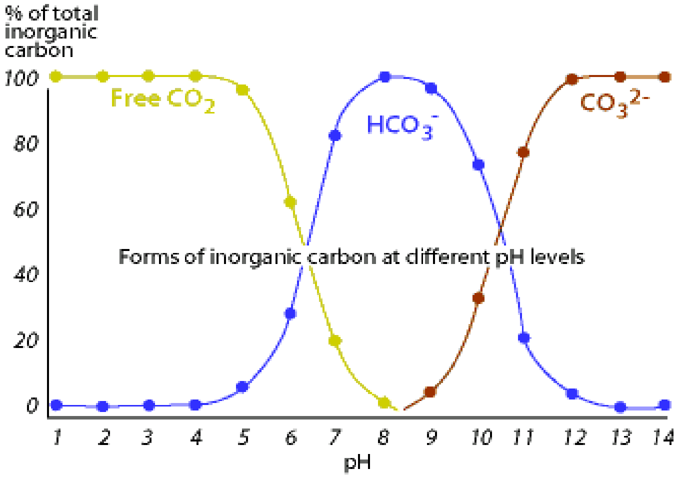

Figure 4 – Relationship between free carbon dioxide in gaseous form and pH

(Source: http://www.cotf.edu/ete/modules/waterq3/WQassess3b.html)[36]

A small quantity of carbon dioxide used in the desalination plant post-treatment process is sequestered directly from the air when the pH of the source seawater is adjusted by addition of

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[36] This chemical reaction and information presented on Figure 4 are well known from basic chemistry of water. *See* American Water Works Association (AWWA) (2007) Manual of Water Supply Practices, M46, Reverse Osmosis and Nanofiltration, Second Edition; http://www.chem1.com/CQ/hardwater.html; http://www.cotf.edu/ete/modules/waterq3/WQassess3b.html. Once the desalinated drinking water is delivered to individual households, only a small portion of this water will be ingested directly or with food. Most of the delivered water will be used for other purposes – personal hygiene, irrigation, etc. The calcium bicarbonate ingested by humans will be dissociated into calcium and bicarbonate ions. The bicarbonate ions will be removed by the human body through the urine (http://www.chemistry.wustl.edu/~courses/genchem/Tutorials/Buffers/carbonic.htm). Since the CO_2 is sequestered into the bicarbonate ion, human consumption of the desalinated water will not result in release of CO_2. The bicarbonate in the urine will be conveyed along with the other sanitary sewerage to the wastewater treatment plant. Since the bicarbonate is dissolved, it will not be significantly impacted by the wastewater treatment process and ultimately will be discharged to the ocean with the wastewater treatment plant effluent. The ocean water pH is in a range of 7.8 to 8.3, which would be adequate to maintain the originally sequestered CO_2 in a soluble form – see Figure 4 above. Other household uses of drinking water, such as personal hygiene, do not involve change in drinking water pH as demonstrated by the fact that pH of domestic wastewater does not differ significantly from that of the drinking water. A portion of the household drinking water would likely be used for irrigation. A significant amount of the calcium bicarbonate in the irrigation water would be absorbed and sequestered in the plant roots (http://www.pubmedcentral.nih.gov/pagerender.fcgi?artid=540973&pageindex=1). The remaining portion of calcium bicarbonate would be adsorbed in the soils and/or would enter the underlying groundwater aquifer.

sulfuric acid in order to prevent RO membrane scaling. A larger amount of CO_2 would be delivered to the Project site by commercial supplier for addition to the permeate. Depending on the supplier, carbon dioxide is of one of two origins: (1) a CO_2 Generating Plant or (2) a CO_2 Recovery Plant. CO_2 generating plants use various fossil fuels (natural gas, kerosene, diesel oil, etc.) to produce this gas by fuel combustion. CO_2 recovery plants produce carbon dioxide by recovering it from the waste streams of other industrial production facilities which emit CO_2-rich gasses: breweries, commercial alcohol (i.e., ethanol) plants, hydrogen and ammonia plants, etc. Typically, if these gases are not collected via CO_2 recovery plant and used in other facilities, such as the desalination plant, they are emitted to the atmosphere and therefore, constitute a GHG release.

To the extent that it is reasonably available, Poseidon intends to acquire the carbon dioxide from a recovery operation. Use of recovered CO_2 at the Project would sequester 1,144 tons of CO_2 per year in the Project product water. The total annual use of carbon dioxide (i.e., 1,144 tons/CO_2 per year) in the water treatment process was determined based on the daily carbon dioxide consumption presented in Table 4.8-1 of Section 4.8 “Hazards and Hazardous Materials” of the Draft Huntington Beach desalination project Subsequent Environmental Impact Report (EIR). The annual consumption of CO_2 in this table is 2,522,000 lbs of CO_2 per year, or 1,144 tons of CO_2 per year (2,522,000 lbs/2,204.5 lbs/ton=1,144 tons).. The daily amount of carbon dioxide in Table 5.8-1 of the EIR was calculated based on the dosage needed to provide adequate hardness (concentration of calcium bicarbonate) in the seawater to protect the water distribution system from corrosion. This amount was determined based on pilot testing of distribution system piping and household plumbing at the Carlsbad seawater desalination demonstration project. The testing was completed using the same type of calcium carbonate chips as those planned to be used in the full-scale operations. Every load of carbon dioxide delivered to the desalination plant site will be accompanied by a certificate that states the quantity, quality and origin of the carbon dioxide and indicates that this carbon dioxide was recovered as a site product from an industrial application of known type of production (i.e., brewery, ethanol plant, etc.), and that it was purified to meet the requirements associated with its use in drinking water applications (i.e., the chemical is NSF approved). The plant operations manager will receive and archive the certificates for verification purposes. At the end of the year, the operations manager will provide copies of all certificates of delivered carbon dioxide to the independent third party reviewer (currently the California Center for Sustainable Energy) responsible for verification facility compliance with the Energy Minimization and Greenhouse Gas Reduction Plan.

As noted, verification would be provided through certificates of origin received from suppliers of CO_2 delivered to the Project site indicating the actual amount of CO_2 delivered to the site, date of delivery, origin of the $CO_{2,}$ and the purity of this gas. Poseidon will place conditions in its purchase agreements with CO_2 vendors that require transfer of CO_2 credits to Poseidon and otherwise ensure that the CO_2 is not accounted for through any other carbon reduction program so as to avoid “double counting” of associated carbon credits.

E. **Avoided Emissions from Displaced Imported Water**.

Another source of Avoided Emissions will result from the Project’s introduction of a new, local source of water into Orange County; water that will displace imported water now delivered to

Customers from the State Water Project (SWP) – a system with its own significant energy load and related carbon emissions.

One of the primary reasons for the development of the Project is to replace imported water with a locally produced alternative drought-proof source of water supply. Currently, Orange County imports over 50% of its water from two sources – the SWP and the Colorado River. These imported water delivery systems consist of a complex system of intakes, dams, reservoirs, aqueducts and pump stations, and water treatment facilities.

In April 2010, the Municipal Water District of Orange County (MWDOC) commissioned a study (Appendix W of the Project's Subsequent Environmental Impact Report) entitled *"Orange County Water Resources Mix and Implications for Desalinated Water Offsets of Imported Water Supplies."*

The Report provides an analysis of the impacts of the delivery of desalinated water supplies from the Project and assesses whether the introduction of Project water into the Orange County's water supply portfolio will result in a net reduction in the demand for imported State Water Project supplies from the Metropolitan Water District of Southern California (Metropolitan). Based on this analysis, the Report reached the following conclusions:

- Consistent with the Metropolitan Board adopted Laguna Declaration of 1952, Metropolitan is the supplemental water supplier to Orange County and is prepared to provide its service area with adequate supplies of water to meet projected demand.

- Given the high costs and challenges associated with the delivery of water supplies that must pass through San Francisco Bay/Sacramento-San Joaquin River Delta (Bay-Delta), State Water Project (SWP) supplies will remain as supplemental supplies for Metropolitan. Thus, any new local supply development that reduces the demand for imported supplies will result in a net reduction in SWP supplies or other supplies from northern California.

- Metropolitan's provides financial incentives of up to $250/AF of water produced for qualifying desalination projects in its service area. To qualify for the incentive, proposed projects must replace an existing demand or prevent a new demand on Metropolitan's imported water supplies.

- To date, there is only one project, with a capacity of 56TAF, within the Metropolitan service area that is currently under construction, which represents just 37% of the 150TAF desalination goal discussed Metropolitan's 2004 Integrated Water Resources Plan (IRP) Update.

- This analysis illustrates that the Project would result in a total net reduction in Metropolitan imported water deliveries of 56,000 AF per year to the Orange County water agencies that purchase water from the Project (Participating Agencies), consistent with the GHG Plan.

- Historical demands for Participating Agencies between FY 1989-1990 and FY 2008-2009 illustrate that these agencies have consistently purchased a minimum of 185,066 AF per year of Metropolitan imported water.

- Historical demands for imported water supplies by the Participating agencies between FY 1989 and FY 2008-2009 exceed potential Project water purchases in all years.

- Projected future demands for imported water supplies by the Participating Agencies total at least 198,119 AF per year, which would be reduced to 142,119 AF per year with Project water purchases.

- Projected demands for each participating agency between 2015 and 2035 illustrate that the projected imported water purchases for each agency exceeds its potential Project water purchase amount in all years.

- Despite significant population growth within Orange County since FY 1989-1990, historical water use has remained relatively consistent due to water conservation. Given the ongoing water conservation efforts and the 20% reduction in urban water use by 2020 mandated under SB x7, it is expected that imported water demand will not increase through 2035. Consequently, imported water from the SWP that is replaced by the Project's water is not expected to be imported into Orange County to satisfy water demand from new or expanded uses developed to accommodate population growth.

As discussed in the Report, the 2003 multi-state Colorado River quantitative settlement agreement forced Metropolitan Water District of Southern California (MWD) to reduce its pumping from the Colorado River by 53% -- from 1.2 MAFY to 0.6 MAFY. As a result, MWD now operates its imported water delivery system to base load its Colorado River allotment and draw from the SWP only as needed to serve demand that cannot be met by the lower cost water available from the Colorado River Aqueduct. Thus new local supply development that reduces the demand for imported supplies will result in a reduction in SWP supplies or other supplies from the Bay-Delta region. It is anticipated that applications will be submitted to Metropolitan's Seawater Desalination Program to make the Project's water eligible for the Program's financial incentives.

The proposed Project will supply 56,000 acre-feet of water per year to Orange County. The Project will provide direct, one-to-one replacement of imported water to meet the requirements of the participating water agencies, thus eliminating the need to pump 56,000 acre feet of water into the region to serve those agencies' demand. Consequently, the proposed Project will reduce the MWD's demand on the SWP to serve the participating water agencies.

The total amount of electricity needed to provide treated water to Poseidon's public agency partners via the SWP facilities is shown in Table 8 below. The net power requirement to pump an acre-foot of water through the East Branch of the SWP into Orange County is 3,036 KWh (source: MWD). Approximately 2% of the SWP water pumped to Southern California is lost to evaporation from Department of Water Resources' reservoirs located south of the Tehachapi Mountains (source: MWD). The evaporation loss results in a net increase of 68 KWh per acre-foot of SWP water actually delivered to Southern California homes and businesses. Finally, prior to use, the SWP water must be treated to meet Safe Drinking Water Act requirements. The MWD Diemer Water Treatment Plant consumes about 30 KWh/AF of water treated (source: MWD).

Table 8 - State Water Project Supply Energy Use

Energy Demand	**KWh/AF**	**Source**
Pumping Through East Branch	3,036	MWD
Evaporation Loss	68	MWD
Diemer Water Treatment Plant	30	MWD
Total	**3,134**	

The reduction of demand for imported water is critical to Southern California's water supply reliability, so much so that MWD not only supports the Project, but has also established a program that could provide $14 million annually to reduce the cost to Poseidon's customers. Under MWD's program, water agencies are eligible for $250 for every acre-foot of desalinated water purchased from the Huntington Beach facility, *so long as the desalinated water offsets an equivalent amount of imported water.* MWD has established "Seawater Desalination Policy Principles and Administrative Guidelines" that require recordkeeping, annual data submittals, and MWD audit rights to ensure that MWD water is offset. These requirements would be memorialized in a binding agreement between MWD and the Project's water agency customers.

The benefits of a reduction in demand on MWD's system are reflected in, among other things, the energy savings resulting from the pumping of water that – but for the Project – would have to continue. For every acre-foot of SWP water that is replaced by water from the proposed Project, 3.13 MWh of electricity use to deliver water to Customers is avoided, along with associated carbon emissions. And since the High-Energy Efficiency Design Project requires 5.2 to 5.7 MWh of electricity to produce one acre-foot of water, the net electricity required to deliver water from the Project to Customers is 2.1 to 2.6 MWh/AF.

Because the Project will avoid the use of 56,000 AFY of imported water to Orange County, once in operation, the Project will also avoid 175,500 MWh/yr of electricity consumption otherwise required to deliver that water to Orange County, as well as the GHG emissions associated with pumping, treatment and distribution of this imported water. At 605.36 lbs CO_2 per MWh, the total expected Avoided Emissions as a result of the Project is 48,190 metric tons CO_2/yr. Each year, Poseidon will be credited with Avoided Emissions based on the most recent SWP emissions factors and the amount of water Poseidon produces. [37]

Table 9 summarizes the expected Project and project-related reductions of GHG Emissions.

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[37] California Department of Water Resources published a 2007 Annual Emissions Report with the CCAR in May 2009 for the SWP.

Table 9 – Expected Project and Project-Related Reduction of GHG Emissions

Source	Total Annual Reductions in Power Use (MWh/year saved)	Total Annual Emissions Avoided (metric tons CO_2/ year avoided)
Reduction due to High-Efficiency Design	(39,500 to 43,200)	(11,300 to 12,360)
Green Building Design	(300 to 500)	(86 to 143)
On-site Solar Power Generation	(0-606)	(0-173)
Recovery of CO_2	(NA)	(1,144)
Reduced Water Importation	(175,500)	(48,190)
Subtotal On-site Reduction Measures	(215,300 to 219,806)	**(60,720 to 62,010)**

PART III: IDENTIFICATION OF MITIGATION OPTIONS TO OFFSET ANY REMAINING GHG EMISSIONS

Offsite reductions of GHG emissions that are not inherently part of the Project include actions taken by Poseidon to participate in local, regional, state, national or international offset projects that result in the cost-effective reduction of GHG emissions equal to the indirect Project emissions Poseidon is not able to reduce through other measures.[38] Subject to the provisions of Sections III.C, E and F below, carbon offset projects, except for RECs will be purchased by Poseidon through/from CCAR, California APCDs / AQMDs, CARB or other providers of offsets approved by the City of Huntington Beach (collectively, "Third Party Providers").[39] The exact nature and cost of the offset projects and RECs will not be known until they are acquired by Poseidon. Offsets or RECs will also be used as the swing mitigation option to "true-up" changes over time to the Project's net indirect GHG emissions, as discussed below.

A. Annual "True-Up" Process

Since the quantity of offsets required will vary from year-to-year, the goal of the annual "True-Up" process is to enable Poseidon to meet the subject year's need for metric tons of offsets by purchasing or banking offsets in the short-term, while allowing Poseidon to make long-term purchases and bank offsets to decrease market exposure and administrative costs. To complete the True-Up process Poseidon will obtain the latest SCE emissions factor from the annual web-based CARB or CCAR Emissions Report within 60 days of the (i) end of each calendar year, or

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[38] This Plan requires Poseidon to join CCAR's Climate Action Reserve, so that it may implement some of this Plan through the Reserve.

[39] Part 4, Section 38562(d)(1)&(2) states that CARB regulations covering GHG emission reductions from regulated "sources" must ensure that such reductions are "real, permanent, quantifiable, verifiable, . . . enforceable [and additional]". While the Project is not a "source" under AB 32 and the criteria are not currently defined under implementing regulations, Third Party Providers will evaluate potential offset projects against equivalent criteria using their own protocols that employ the same criteria.

(ii) the date of publication of the CARB or CCAR Emissions Report on the relevant CARB or CCAR web site, whichever is later. Within 120 days of the end of the prior calendar year or publication of the emissions factor (whichever is later), Poseidon will gather electricity usage data, relevant data regarding Avoided Emissions, and then calculate the necessary metric tons of offsets required for the subject year. The subject year's emissions will be calculated using actual billing data and the emissions factor for the relevant annual period. The subject year's calculated metric tons of net emissions will be compared to the amount of metric tons of offsets previously acquired by Poseidon to determine if Poseidon has a positive or negative balance of net GHG emissions for the subject year, and all of this information will be included in the Annual GHG Report to be submitted to the City each year as discussed below. If there is a positive balance of net GHG emissions, Poseidon will purchase offsets to eliminate the positive balance, and provide the City with documentation substantiating that purchase, within 120 days of the date the positive balance is identified in the Annual GHG Report. If there is a negative balance of net GHG emissions, the surplus offsets may be carried forward into subsequent years or sold by Poseidon on the open market. All documentation that Poseidon will submit to the City pursuant to this Section shall also be submitted to the SLC.

Prior to the commencement of Project operations, Poseidon will be required to purchase offsets sufficient to cover estimated net (indirect) GHG emissions for at least the first year of operation (subject to City staff concurrence), or to cover a longer period of time at Poseidon's option, based on the most recently published SCE emissions factor from CARB or CCAR and estimated electricity usage data for the first year of the Project period for which offsets are initially purchased. Poseidon will have the option to purchase offsets for any longer period of time up to and including the entire 30 year life of the Project, subject to Poseidon's above-stated obligation to address any positive balance in net GHG emissions that may subsequently arise. Beginning with the Sixth Annual Report, Poseidon can meet its net GHG compliance obligations over a rolling five-year period. Poseidon will purchase enough GHG reductions measures that conform to the Plan such that it will never incur a positive net GHG emissions balance over any rolling five-year period.

B. Carbon Offset Projects and Credits

Subject to the provisions of Sections III.C, E and F below, Poseidon will purchase carbon offset projects, except for RECs, through/from CARB, CCAR, or California APCDs / AQMDs. An offset is created when a specific action is taken that reduces, avoids or sequesters greenhouse gas (GHG) emissions in exchange for a payment from an entity mitigating its GHG emissions. Examples of offset projects include, but are not limited to: increasing energy efficiency in buildings or industries, reducing transportation emissions, generating electricity from renewable resources such as solar or wind, modifying industrial processes so that they emit fewer GHGs, installing cogeneration, and reforestation or preserving forests.

One type of offset project is Renewable Energy Credits (RECs), also known as Green Tags, Renewable Energy Certificates or Tradable Renewable Certificates. Each REC represents proof that 1 MW of electricity was generated from renewable energy (wind, solar, or geothermal). For GHG offsetting purposes, purchasing a REC is the equivalent of purchasing 1 MW of electricity from a renewable energy source, effectively offsetting the GHGs otherwise associated with the production of that electricity. RECs may be sold separately from the electricity.

Except as specified below, offset projects that Poseidon implements pursuant to this Plan will be those approved by CARB, CCAR, or any California APCD / AQMD as conforming to AB 32 requirements. Poseidon is committed to acquiring cost-effective offsets that meet rigorous standards, as detailed in this Plan. By requiring adherence to the principles, practices and performance standards described here, the Plan is designed to assure that selected offset projects will mitigate GHG emissions as effectively as on-site or direct GHG reductions. Adherence will ensure that the offset projects acquired by Poseidon are real, permanent, quantifiable, verifiable, enforceable, and additional consistent with the principles of AB 32.

C. Offset Acquisition and Verification

Poseidon shall acquire offsets through/from CCAR, CARB or California APCD/AQMD-approved projects. Acquisitions of RECs are not limited to purchase from CCAR, CARB, or a California APCD/AQMD.

If sufficient offsets are not available from CCAR, CARB or a California APCD/AQMD at a price that is reasonably equivalent to the price for offsets in the broader domestic market, Poseidon may submit a written request to the City's Planning Director requesting that one or more additional offset providers, including without limitation any existing member of the Offset Quality Initiative, which includes CCAR, The Climate Trust, Environmental Resources Trust and The Climate Group/Voluntary Carbon Standard, be designated as a Third Party Provider from/through whom Poseidon may purchase offsets under the Plan.[40] In deciding whether or not to approve Poseidon's request, the City's Planning Director shall consider whether or not the proposed Third Party Provider is an independent and non-affiliated entity that adheres to substantially similar principles and evaluation criteria for high quality offsets as CCAR, CARB, a California APCD/AQMD or any Third Party Provider previously approved by the City's Planning Director or the City Council. The City's Planning Director shall determine whether or not to approve Poseidon's request to designate a Third Party Provider within 60 days. Any dispute between Poseidon and City's Planning Director regarding the approval or denial of the requested entity may be brought by Poseidon to the City Council for hearing and resolution at the next available hearing date.

Poseidon's Annual GHG Report, discussed in Section III.D below, shall include an accounting summary and documentation from CCAR, CARB, a California APCD/AQMD and Third Party Providers, as applicable, which verifies that offsets obtained by Poseidon have been verified by CCAR, CARB, a California APCD/AQMD or a Third Party Provider.

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[40] The fee charged to Poseidon by the CCC for any request to approve additional offset providers pursuant to Section III.C., or to otherwise make the Plan workable by facilitating Poseidon's purchase of offsets/RECs to zero out the Project's net indirect GHG emissions, shall not exceed $5,000.00.

D. Annual Report

Poseidon will provide an Annual GHG Report that will describe and account for Poseidon's annual and cumulative balance of verified net GHG emissions reductions. The Annual GHG Report will include analysis and validation of: (1) the annual GHG emission calculations for the Project, (2) the positive or negative balance in Poseidon's net GHG emissions, (3) the acquisition of offsets and/or RECs in accordance with this Plan, and (4) any other information related to Poseidon's efforts to mitigate GHG emissions resulting from the Project's electricity usage. Each year, Poseidon will obtain the new reported emissions factor from CCAR or CARB and prepare and submit Poseidon's Annual GHG Report within 180 days of the date of publication of CCAR/CARB emissions reports. The Annual GHG Report shall be submitted to the City, and the SLC. In the event that the Annual GHG Report indicates that Poseidon has a positive balance of net GHG emissions for a particular year, Poseidon shall purchase offsets or RECs to cover that balance, and provide the City, CCC and the SLC with documentation substantiating any such purchases, within 120 days of the submission of an Annual GHG Report to the agencies. If an approved Annual GHG Report demonstrates that Poseidon possesses a negative balance of net GHG emissions, Poseidon will be free to carry those surplus offsets forward into subsequent years or sell them on the open market. Beginning with the Sixth Annual Report, Poseidon can comply with its net GHG compliance obligations over any rolling five-year period. Poseidon will purchase enough GHG reductions measures that conform to the Plan such that it will never incur a positive net GHG emissions balance over any rolling five-year period.

Before commencing Project operations, Poseidon shall submit its first Annual GHG Report for review and approval by the City's Planning Director, which will evidence sufficient offsets to zero out the Project's estimated net indirect GHG emissions for the first year, and also shall evidence the one-time purchase of offsets to zero-out the Aggregate 30-Year Construction and Operational GHG Emissions set forth in Table 1 of this Plan (which do not need to be addressed in subsequent reports). All subsequent reports will cover one calendar year.

E. Contingency if No GHG Reduction Projects are Reasonably Available

At any time after submission of its First Annual GHG Report, Poseidon may seek a determination from the City's Planning Director that (i) offset projects in an amount necessary to mitigate the Project's net indirect GHG emissions are not reasonably available; (ii) the "market price" for carbon offsets or RECs is not reasonably discernable; (iii) the market for offsets/RECs is suffering from significant market disruptions or instability; or (iv) the market price has escalated to a level that renders the purchase of offsets/RECs economically infeasible to the Project. Any request submitted by Poseidon shall be considered and a determination made by the City's Planning Director within 60 days. A denial of any such request may be appealed by Poseidon to the City Council for hearing and resolution at the next available meeting date. If Poseidon's request for such a determination is approved by the City's Planning Director or the City Council, Poseidon may, in lieu of funding offset projects or additional offset projects, deposit money into an escrow account (to be approved by the City's Planning Director) to be used to fund GHG offset programs as they become available, with Poseidon to pay into the fund in an amount equal to $10.00 per metric ton for each ton Poseidon has not previously offset, adjusted for inflation from 2008.[41]

The period of time that the conditions giving rise to this contingency remain in effect, and therefore that the escrow account contingency may be utilized under this Section, shall be determined by the City's Planning Director or the City Council at the time Poseidon's request to use the contingency is considered, based on circumstances as they exist at the time of the request. Extensions of the contingency period may be requested and the contingency period shall be extended so long as the conditions giving rise to this contingency period remain in effect. Within 180 days of the City's Planning Director's or the City Council's initial determination pursuant to this Section, Poseidon will be required to submit a plan for the City's Planning Director's approval (the "Contingency Plan") that identifies one or more entities who will utilize monies deposited into the escrow account to implement carbon offset projects. When the escrow account contingency period (together with any extensions thereof) approved by the City's Planning Director or the City Council ends, if the carbon offset projects implemented through the Contingency Plan result in Poseidon having a positive balance of net GHG emissions for the contingency period as calculated under this Plan, then Poseidon shall have three years from the end of the contingency period to purchase offsets or RECs to cover that balance and provide the City, CCC and SLC with documentation substantiating any such purchases.

F. Contingency if New GHG Reduction Regulatory Program is Created

If, at any time during the life of the Project the SCAQMD or any other California APCD/AQMD, or the California Air Resources Board (CARB) or any federal regulatory agency, initiates a carbon tax or carbon offset program that would allow Poseidon to purchase carbon offsets or payment of fees to compensate for GHG emissions, Poseidon may, at its option, elect to pay into such a program in order to fulfill all or part of its obligations under the Plan to offset net indirect GHG emissions caused by the Project. By receiving certification from the relevant receiving entity that Poseidon has satisfied its obligations under the applicable regulatory program, Poseidon will be deemed to have satisfied its obligation under the Plan to offset net indirect GHG emissions for the part of the offset obligations under the Plan for which such certification is made. Subject to the approval of the relevant receiving entity, Poseidon may carry over any surplus offsets acquired pursuant to the Plan for credit in the new regulatory program.

G. Examples of Offset Projects

Offset projects typically fall within the seven major strategies for mitigating carbon emissions set forth below. A similar range and type of offset projects should be expected from a purchase by Poseidon, although it is difficult to anticipate the outcome of Poseidon's offset acquisitions at present.

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[41] $10.00 per metric ton is a conservative figure, as offset credits were trading at $1.20 per metric ton on the Chicago Climate Exchange as of market close on May 28, 2009.

1. Energy Efficiency (Project sizes range from: 191,000 metric tons to 392,000 metric tons; life of projects range from: 5 years to 15 years)

- Steam Plant Energy Efficiency Upgrade
- Paper Manufacturer Efficiency Upgrade
- Building Energy Efficiency Upgrades

2. Renewable Energy (Project sizes range from: 24,000 metric tons to 135,000 metric tons; life of projects range from: 10 years to 15 years)

- Small Scale Rural Wind Development
- Innovative Wind Financing
- Other renewable resource projects could come from Solar PV, landfill gas, digester gas, wind, small hydro, and geothermal projects

3. Fuel Replacement (Project size is: 59,000 metric tons; life of project is: 15 years)

- Fuels for Schools Boiler Conversion Program

4. Cogeneration (Project size is: 339,000 metric tons; life of project is: 20 years)

- University Combined Heat & Power

5. Material Substitution (Project size is: 250,000 metric tons; life of project is: 5 years)

- Cool Climate Concrete

6. Transportation Efficiency (Project sizes range from: 90,000 metric tons to 172,000 metric tons; life of projects range from: 5 years to 15 years)

- Truck Stop Electrification
- Traffic Signals Optimization

7. Sequestration (Project sizes range from: 59,000 metric tons to 263,000 metric tons; life of projects range from: 50 years to 100 years)

- Deschutes Riparian Reforestation
- Ecuadorian Rainforest Restoration
- Preservation of a Native Northwest Forest

H. Implementation Schedule

An illustrative schedule setting forth timing for implementation of Poseidon's Plan elements is set forth in the following Implementation Schedule.

Table 10 - Implementation Schedule for the Plan

Measure	**Process**	**Timing**
Submit First Annual GHG Report	First Annual Report*, submitted to the City's Planning Director for review and approval, shall include enough detailed emissions reductions measures to achieve a projected zero net GHG emissions balance, and shall include offsets to zero-out the Aggregate 30-Year Construction and Operational GHG Emissions set forth in Table 1.	Before operations commence
Offset and REC Purchases Sufficient to Zero Out Estimated net indirect GHG emissions for first year of operations	Subject to the provisions of Sections III.C, E and F above**,** offset projects or credits, except for RECs, will be implemented through CCAR, CARB or any California APCDs / AQMDs and offset credits will be purchased through CCAR.	Before operations commence
Annual True-Up Process and all Subsequent Annual GHG Reports	Poseidon will submit its Annual GHG Report to the City's Planning Director for review and approval. Once approved, Poseidon will purchase additional offsets as necessary to maintain a zero net GHG emissions balance, or bank or sell surplus offsets. Poseidon can demonstrate compliance over a rolling 5-year period in the Sixth Annual Report	Each year, Poseidon will obtain the new reported emissions factor from CARB or CCAR, and prepare and submit Poseidon's Annual GHG Report within 180 days of the date of publication of CCAR/CARB emissions reports. If the report shows a positive net GHG emissions balance, Poseidon is required to purchase offsets, and submit proof of such purchase to the City within 120 days from the date the Annual GHG Report

*First Annual GHG Report will use projected electricity consumption. All subsequent Annual GHG Reports will use the previous year's electricity consumption data.

I. <u>The Project's Annual Net-Zero Carbon Emission Balance</u>

Table 11 presents a summary of the assessment, reduction and mitigation of GHG emission for the proposed Project. As shown in the table, up to 69-75% of the GHG emissions associated with the proposed Project could be reduced by on-site reduction measures, and the remainder would be mitigated by off-site mitigation projects and purchase of offsets or RECs. It should be noted that on-site GHG reduction activities are expected to increase over the useful life (i.e., in the next 30 years) of the Project because of the following key reasons:

- SCE is planning to increase significantly the percentage of green power sources in its electricity supply portfolio, which in turn will reduce its emissions factor and the Project's net indirect GHG emissions.
- Advances in seawater desalination technology are expected to yield further energy savings and net indirect GHG emission reductions. Over the last 20 years, there has been a 50% reduction in the energy required for seawater desalination.

Table 11 – Expected Assessment, Reduction and Mitigation of GHG Emissions

Part 1: Identification of The Amount of GHG Emitted		
Source	**Total Annual Power Use (MWh/ year)**	**Total Annual Emissions (metric tons CO_2/ year)**
Project Baseline Design	**289,715 to 318,744**	**82,908 to 91,215**
Part 2: On-site and Project-Related Reduction of GHG Emissions		
Reduction due to High-Efficiency Design	(39,500 to 43,200)	(11,300 to 12,360)
Green Building Design	(300 to 500)	(86 to 143)
On-site Solar Power Generation	(0-606)	(0-173)
Recovery of CO_2	(NA)	(1,144)
Reduced Water Importation	(175,500)	(48,190)
Subtotal On-site Reduction Measures	**(215,300 to 219,806)**	**(60,720 to 62,010)**
Net GHG Emissions		**22,188 to 29,205**
Part 3: Additional Off-Site Reduction of GHG Emissions		
Offset and REC Purchases	(NA)	**22,188 to 29,205**
Net GHG Emissions		**0**
One-Time Purchase of Offsets for Construction and Operational Emissions		**(6,315 to 6,319)**

Attachment 3

Latham and Watkins Comments on the

Draft Substitute Environmental Documentation,

Christopher Garrett, August 13, 2014

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August 18, 2014

Via email to: commentletters@waterboards.ca.gov

Ms. Jeanine Townsend, Clerk to the Board
State Water Resources Control Board
1001 "I" Street, 24th Floor
Sacramento, CA 95814

Re: Proposed Ocean Plan Amendment for Desalination Facilities

Dear Ms. Townsend:

On behalf of Poseidon Resources, this letter is sent in regard to the State Water Resources Control Board's ("State Board") consideration of the proposed Draft Amendment to the Water Quality Control Plan for Ocean Waters of California Addressing Desalination Facility Intakes, Brine Discharges, and to Incorporate Other Nonsubstantive Changes ("Amendment"). Specifically, this letter addresses the Draft Substitute Environmental Document prepared in connection with the Amendment ("SED"), and is being submitted concurrently with Poseidon's comments on the Amendment.

Poseidon is pleased that its comments and those of other stakeholders were considered during the administrative process leading up to the release of the Amendment. We appreciate the move away from a "one-size-fits-all" strategy for desalination facilities statewide to acknowledge that the Water Code requires the Regional Boards to exercise discretion under Water Code section 13142.5(b) to evaluate site-specific factors for each desalination proposal and, where appropriate, to permit: (1) augmented seawater intake for dilution; (2) open surface intakes; (3) a salinity standard greater than 2 parts per thousand ("ppt") above ambient; and (4) a zone of initial dilution ("ZID") greater than 100 meters.

As explained in these comments, Poseidon believes that certain changes to the SED and the Amendment are warranted, both to improve the Amendment and to ensure its defensibility against any potential legal challenges. However, generally speaking, Poseidon supports the Amendment and believes that it will facilitate the development and operation of Poseidon's Carlsbad and Huntington Beach projects.

On behalf of Poseidon, we request that the State Board consider the entire Water Code section 13142.5(b) administrative record that was before this Board during its consideration of the administrative appeal of the San Diego Regional Board's determination for Poseidon's Carlsbad project, and was also before the Court of Appeal in *Surfrider Found. v. Cal. Reg'l*

Water Quality Control Bd., 211 Cal. App. 4th 557 (2012) ("*Surfrider*"). We believe that the evidence before the State Board at that time continues to be relevant to this proceeding. We believe that the State Board has retained and referred to a copy of the record in this current proceeding, but we would be happy to resubmit another copy to the Board's staff if necessary.

I. THE SED'S DISCUSSION OF "FEASIBILITY" UNDER WATER CODE SECTION 13142.5(B) SHOULD REFERENCE AND INCORPORATE THE COURT OF APPEAL'S ANALYSIS IN THE *SURFRIDER* DECISION

A. Section 13142.5(b) Mandates Only Feasible Measures to Minimize Marine Life Intake and Mortality

Marine life impacts from desalination facilities in California are regulated by section 13142.5(b), which provides:

> For each new or expanded coastal powerplant or other industrial installation using seawater for cooling, heating, or industrial processing, the best available site, design, technology, and mitigation measures feasible shall be used to minimize the intake and mortality of all forms of marine life.

Section 13142.5(b) thus requires a site and project specific determination as to the "best available" measures that are "feasible" for a given project to address intake and mortality of marine life, including by entrainment and impingement.

B. Regional Boards Should Expressly Be Permitted to Conduct Feasibility Analysis That Is Consistent With *Surfrider*

As described in Poseidon's separate letter on the Amendment submitted herewith, one of the primary purposes of the Amendment is to provide procedures for Regional Boards to implement Water Code section 13142.5(b) for desalination facilities. Section 13142.5(b) requires evaluations of "the best available site, design, technology and mitigation measures *feasible*" to minimize the intake and mortality of all forms of marine life at new or expanded desalination facilities. Water Code § 13142.5(b) (emphasis added). However, the Amendment and the SED are silent as to the Court of Appeal's analysis of section 13142.5(b)'s feasibility requirement in *Surfrider*, the only reported decision to interpret section 13142.5(b).

Surfrider addressed a challenge to the San Diego Regional Board's adoption of an NPDES permit for the Carlsbad project, Order No. R9-2006-0065, which applied the California Environmental Quality Act's ("CEQA") definition of "feasible" to the Board's section 13142.5(b) analysis. The *Surfrider* opinion includes specific guidance on the assessment of "feasibility" under section 13142.5(b) and the factors that will support a finding of infeasibility. First, because "feasible" is not defined in the Water Code, the Court of Appeal held that the San Diego Regional Board properly applied the following definition from CEQA: "'feasible' means capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, environmental, social, and technological factors." *Surfrider*, 211 Cal.

App. 4th at 582 (citing Pub. Res. Code § 21061.1). Second, *Surfrider* also recognizes that, as with CEQA, economic considerations generally may be factored into the feasibility analysis. Third, the Court of Appeal affirmed that Regional Boards, like CEQA lead agencies, properly may structure the analysis of alternatives "around a reasonable definition of underlying [project] purpose and need not study alternatives that cannot achieve that basic goal." *Id.* (citing *In re Bay-Delta*, 43 Cal. 4th 1143, 1166 (2008).

The Amendment and the SED should make clear that Regional Boards shall continue to apply CEQA's definition of feasibility to section 13142.5(b) analysis as upheld by the Court of Appeal in *Surfrider*. This would provide clear guidance to the Regional Boards on the implementation of section 13142.5(b) regarding one of the most critical and contentious issues in applying section 13142.5(b), and prevent any misinterpretation or misapplication of the Amendment.

The Amendment and the SED should discuss the *Surfrider* holding and clarify that Regional Boards may conduct their section 13142.5(b) analysis in the same manner that was upheld in that case. If the State Board believes other definitions of feasible also could apply, the SED should identify those definitions and explain why they might be applicable. The State Board should not depart from the interpretation upheld in the only reported decision interpreting section 13142.5(b) without explanation and analysis.

II. THE SED FAILS ADEQUATELY TO ASSESS THE FEASIBILITY OF SUBSURFACE INTAKES

Poseidon does not dispute the SED's conclusion that subsurface intakes—when feasible—are the preferred technology for minimizing intake and mortality during desalination operations, because, if properly constructed, subsurface intakes can eliminate impingement and entrainment. (SED, at 54.) Poseidon also appreciates the SED's determinations that site and facility specific factors need to be evaluated to determine the feasibility of subsurface intakes, and that surface intakes may be permitted where subsurface intakes are infeasible. (SED, at 58.) The SED appropriately recognizes that the feasibility of subsurface intakes is limited by the following factors: (i) favorable geologic conditions, (ii) significant environmental impacts from construction, (iii) limited intake capacity (i.e., inability to provide desired intake volume for large-scale desalination plants), and (iv) aesthetic impacts (for beach wells). (SED, at 54-55.). Poseidon notes that other feasibility considerations that also must be considered include temporary and permanent impacts to recreational resources, and the ability for the subsurface intake to be constructed within a reasonable period of time and in accordance with economic considerations.

The SED should be revised to include a more detailed analysis of the feasibility of subsurface intakes in order to more accurately inform the public about the type of desalination facilities likely to be developed in California, and their environmental impacts. The analysis should, among other things, incorporate findings that were made by multiple regulatory agencies regarding the infeasibility of subsurface intakes for Poseidon's Carlsbad desalination project. Finally, the SED should also address whether subsurface intakes are "available." A key part of the determination of "availability" for crucial equipment in important infrastructure that must perform on a reliable basis is whether the technology can be purchased and installed with a warranty of performance and whether there is a track record of performance at other commercial scale facilities. Section 13142.5(b) requires the best "available" site, design, technology and mitigation that is "feasible." Whether or not an intake technology is available depends in large part on its feasibility.

A. The SED Should Discuss the Findings of Multiple Agencies That a Subsurface Intake for the Carlsbad Project Would Be Infeasible

As described above, the feasibility analysis under Water Code section 13142.5(b) includes "environmental" considerations. Thus, even if a subsurface intake would provide the greatest minimization of intake and mortality during desalination operations, other environmental impacts must be considered and may preclude selecting a subsurface system. The SED, however, does not address these issues. The SED's discussion of impacts from subsurface intakes is cursory, and should be revised to address, at a minimum, the following issues:

- Harm to marine life and coastal habitat during construction, including the potential for such impacts to be permanent;
- The potential for subsurface intakes to draw in water from subsurface formations that is difficult to treat;
- The potential for subsurface intakes to draw water from wetlands or water that is the subject of a more senior water right;
- Aesthetic impacts from siting wells or other infrastructure on the beach;
- Public access and recreation impacts resulting from construction or maintenance of subsurface systems;
- Increased energy usage or greenhouse gas emissions from subsurface intakes; and
- Conversion of seafloor habitat to an engineered filtration system.

As described in greater detail below, requiring a subsurface intake for the already-permitted Carlsbad project—which multiple agencies determined was infeasible—could result in significant environmental impacts. For the reasons described below, the SED should analyze the potential impacts associated with installing a subsurface intake for the Carlsbad project. If there is to be no additional or updated evaluation of subsurface intakes at Carlsbad as part of this SED, then the Board must base its decisions in this proceeding on the existing administrative record also before the Board from the appeal of the San Diego Regional Board's approval of the Carlsbad project to this Board, and the subsequent *Surfrider* case before the Court of Appeal.

1. The SED Must Describe the Existing Environmental Baseline and Potential Direct and Indirect Effects

CEQA requires an EIR to address all reasonably foreseeable consequences of a proposed project, measured against existing baseline conditions. *Laurel Heights Improvement Ass'n v. Regents of Univ. of Cal.*, 47 Cal. 3d 376, 396 (1988). In the context of a regulatory change, the analysis must include a comparison of the physical conditions that exist at the time the regulation is proposed or approved, with forecasts of "reasonably foreseeable future conditions that may occur as a result of the adoption" of the regulation. *Wal-Mart Stores, Inc. v. City of Turlock*, 138 Cal. App. 4th 273, 290-91 (2006), *overruled on other grounds at Hernandez v. City of Hanford*, 41 Cal. 4th 279, 297 (2007); *see also Plastic Pipe & Fittings Assn. v. California Building Standards Commission*, 124 Cal. App. 4th 1390, 1413 (2004) (enactment of regulations allowing the use of certain materials for plumbing uses may result in reasonably foreseeable indirect environmental impacts).

Under CEQA, the impact analysis must include "indirect" environmental effects, or reasonably foreseeable impacts that are caused at a later time or are farther removed in distance from the activity being approved. CEQA Guidelines §§ 15064(d)(2), 15358(a)(2), *compare id.* at § 15064(d)(1) (defining "direct" environmental effects as those "caused by and immediately related to the project."). Indirect effects include secondary effects; that is, if a direct change in the physical environment resulting from a project causes another change in the environment, the secondary effect is treated as an indirect effect of the project. CEQA Guidelines § 15358(a)(2), 15064(d)(3). An EIR's analysis of indirect effects must include actions that are a foreseeable consequence of the project. For example, in *El Dorado Union High School Dist. v. City of Placerville*, 144 Cal. App. 3d 123 (1983), the Court of Appeal held that increased school enrollment that would result from a residential development, leading to overcrowding and the need to construct a new school, was an effect of the project that should have been analyzed in the EIR. *See also Anderson First Coalition v. City of Anderson*, 130 Cal. App. 4th 1173, 1182 (2005) (holding that when there is "evidence" that economic and social effects caused by a project" "could result in a reasonably foreseeable indirect environmental impact," then "the CEQA lead agency is obligated to assess this indirect environmental impact."); *Bakersfield Citizens for Local Control v. City of Bakersfield*, 124 Cal. App. 4th 1184, 1207 (2004) (in assessing indirect impacts, "[t]he lead agency cannot divest itself of its analytical and informational obligations by summarily dismissing the possibility of" indirect impacts as "social or economic effect[s]" of the project.).

Existing physical conditions are referred to as the "baseline," or "the physical environmental conditions in the vicinity of the project, as they exist . . . at the time the environmental analysis is commenced…" CEQA Guidelines § 15125(a). For purposes of the SED's consideration of the Amendment's effect on the Carlsbad project, the "baseline" for environmental review is the existing environment in light of Carlsbad project as permitted and under construction. More generally, for evaluation of the Amendment's impact statewide, the baseline is the existing environment throughout California. *Communities for a Better Env't v. S. Coast Air Quality Mgmt. Dist.*, 48 Cal. 4th 310, 320-21 (2010) (baseline must reflect "existing physical conditions in the affected area"). The SED must therefore evaluate the reasonably foreseeable impacts of the Amendment on the Carlsbad project, including the possible requirement to construct a subsurface impact if feasible. Additional reasonably foreseeable impacts of the Amendment on the Carlsbad project are described throughout this letter.

2. The SED Should Acknowledge Previous Findings on Subsurface Intakes for the Carlsbad Project

In light of the existing baseline described above, the SED should discuss the detailed analysis of subsurface intakes undertaken for the Carlsbad project by the City of Carlsbad, the Coastal Commission, the San Diego Regional Water Quality Control Board, and the State Lands Commission. Each of these agencies found that a variety of subsurface intakes were infeasible for the Carlsbad project on several grounds. Opinions upholding these approvals were issued by multiple reviewing courts, including the San Diego County Superior Court and the Fourth Appellate District. The grounds for each respective agency's determination that subsurface intakes are infeasible for the Carlsbad project are described below.

Coastal Commission. The Coastal Commission concluded that subsurface intakes (offshore infiltration galleries, beach wells, horizontal wells, and an offshore intake) are infeasible and would be more environmentally damaging than "stand-alone" operation of the Project. Subsurface intakes "would result in greater environmental impacts than the proposed project due to destruction of coastal habitat from construction of the intake systems, the loss of public use of coastal land due to numerous intake collector wells that would be located on the beach, and the adverse environmental impact to coastal resources during the construction . . . " (Coastal Commission Findings, at 51.) The Coastal Commission further concluded that subsurface intakes were infeasible at Carlsbad "due to site-specific geologic and/or water quality conditions, which render the water untreatable, and the increased and prohibitive costs of such systems." (*Id.*) The Coastal Commission's findings were upheld in a final decision by the San Diego Superior Court (Case No. 37-2008-00075727), and the State Lands Commission's reliance on the Coastal Commission's findings was upheld by the California Court of Appeal. *San Diego Coastkeeper v. California State Lands Commission*, 2010 Cal. App. Unpub. LEXIS 9797 (2010).

Regional Board. The San Diego Regional Board found subsurface intakes (including vertical and horizontal beach wells, slant wells, and infiltration galleries) infeasible for the Carlsbad project due to (1) limited production capacity of the subsurface geological formation, (2) insufficient sediment depths in the vicinity of the site, (3) poor water quality of the collected source water, (4) economic infeasibility (in light of evidence showing that subsurface intakes would add $400 to $600 million to the construction costs of the plant, frustrating a key project objective of supplying water at or below the cost of imported water supplies). (San Diego Regional Board Order No. R9-2009-0038 (May 13, 2009), at p. 8.) The Regional Board's decision was upheld in the only reported decision interpreting Water Code section 13142.5(b), *Surfrider Found. v. Cal. Regional Water Quality Control Bd.*, 211 Cal. App. 4th 557 (2012).[1]

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[1] The Regional Board's decision was limited to co-located operation of the Carlsbad plant with the Encina Power Station. As described in Poseidon's cover letter on the Amendment, Poseidon is in the process of updating its section 13142.5(b) analysis to seek approve for stand-alone operations.

City of Carlsbad. The City of Carlsbad's certified EIR found alternative intake technologies to be infeasible and lacking in environmental benefit. The EIR concluded that the approved open intake would not cause significant impacts from entrainment or impingement during stand-alone operations because, among other things, the small proportion of marine organisms lost to entrainment and impingement as a result of the project would not have a substantial effect on the species' ability to sustain their populations. (Carlsbad Project EIR, at 4.3-35 to 4.3-36, 4.3-42.) With respect to vertical intake wells, the EIR concluded that the siting, construction and operation of 100 vertical beach wells in Carlsbad was impractical, would not provide environmental benefit, and could cause significant environmental impacts. (Carlsbad Project EIR, at 6-6.) In addition, horizontal beach wells would require 25 large wells along 4 miles of the Carlsbad coastline, causing significant impacts to aesthetics and recreation. (*Id.*) Finally, the EIR determined that the construction of offshore infiltration galleries would cause potentially significant impacts to biological resources. (Carlsbad Project EIR, at 6-6 to 6-7.) A direct challenge to the EIR was dismissed in 2011 by the San Diego County Superior Court in Case No. 37-2009-00061008-CU-TT-CTL.

State Lands Commission. The State Lands Commission's reliance, as a responsible agency, on the Carlsbad EIR's finding that the project would not cause significant marine life impacts during stand-alone operations was upheld by the Court of Appeal against a lawsuit asserting that a Supplemental EIR was required. *San Diego Coastkeeper v. California State Lands Commission*, 2010 Cal. App. Unpub. LEXIS 9797 (2010).

3. The SED Must Disclose the Amendment's Foreseeable Impacts on the Carlsbad Project

It is reasonably foreseeable that one of the outcomes of the adoption of the Amendment is that the Carlsbad project will need to be retrofitted with a subsurface intake. The Amendment applies to desalination facilities, and there is no exception for the Carlsbad plant. Moreover, the Carlsbad plant will be going through a re-permitting process before the San Diego Regional Board in the coming months. Therefore, to the extent that the Amendment may apply to the Carlsbad plant, the SED needs to evaluate the environmental effects of a subsurface intake in Carlsbad. *El Dorado Union High School Dist. v. City of Placerville*, 144 Cal. App. 3d 123 (1983).

Poseidon believes the only potentially technically feasible subsurface approach for Carlsbad is a lagoon-based infiltration gallery. All other subsurface options have already been eliminated as infeasible and environmentally damaging by the evaluations described above. The SED therefore must evaluate the likely environmental impacts of this option, as information on this option has been provided by Poseidon and is in the State Board's record. The layout of the potential subsurface infiltration gallery is shown in Attachment 4. Preliminary investigations show that the footprint of this gallery would cover much of the lagoon east of Interstate 5, as well as the entire middle and outer lagoon. The area that would be affected by the subsurface infiltration gallery is composed of precisely the habitat that produces the fish eggs and larvae that a subsurface intake is intended to protect. Therefore, in order to save the fish in Agua Hedionda Lagoon, Poseidon would have to destroy much of their natural habitat. The SED must therefore analyze the potential biological impacts that would result from requiring a subsurface infiltration gallery for the Carlsbad project, as well as other potentially significant environmental impacts or economic feasibility considerations. For example, even though a shallow gallery may not have water quality impacts, the SED must analyze whether there are any potential impacts from contaminated sediments or minerals that would make a subsurface intake infeasible.

B. The SED's Discussion of the Fukuoka District Desalination Facility Is Misleading

The SED cites to the Fukuoka Desalination Facility in Japan as an example of a feasible existing infiltration gallery with "excellent performance" during its first five years. (SED, at 57.) The Fukuoka infiltration gallery, however, is a one-of-a-kind intake system uniquely set in an embayment with no similar facility in the world. It is a proprietary technology with little performance data available and provides no basis to show the feasibility of infiltration galleries generally. Given the limited opportunities to replicate the one-of-a-kind system in California, and Fukuoka's refusal to provide operating data, the SED should not rely on Fukuoka as evidence that infiltration galleries are feasible. In order to fully evaluate Fukuoka as part of this proceeding, the State Board should seek data on whether any commercial construction companies are willing to provide a warranty of performance for this type of infiltration gallery system. Proceeding forward in reliance on the Fukuoka Desalination Facility is misleading to the public and belies the feasibility issues associated with infiltration galleries, which must be part of infrastructure which must be reliable to provide a long term, reliable water supply to the public.

Likewise, the SED should be revised to include a discussion of the subsurface intake used for a desalination facility at San Pedro del Pinatar in Spain. We understand that the plant had significant fouling problems with the intake and, according to the Coastal Commission's findings, planned to rely on an open ocean intake for its primary source of seawater going forward.

C. The SED Should Assess the Economic Feasibility of Subsurface Intakes

Although Appendix G to the Amendment includes a study purporting to describe the economic costs of complying with the Amendment's proposed policy, the SED does not attempt to assess whether compliance with the Amendment, including its preference for subsurface intakes, will be economically feasible for future projects. As discussed above, economic feasibility must be considered under section 13142.5(b), most notably with regard to whether the costs of constructing and operating desalination plants are such that desalinated water can be competitively priced.[2] Further, Public Resources Code section 21159(c) requires that an

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[2] Although Water Code section 13142.5(b) is separate from Clean Water Act section 316(b), the State Board should consider as persuasive authority caselaw interpreting section 316(b) to permit the use of economics and cost-benefit analysis in deciding whether the benefits achieved under section 316(b) regulations of power plan intake structures are worth the cost. *See, e.g.*, Paul N. Singarella and Marc T. Campopiano, *The Role of Economics in Environmental, Health, and Safety Regulation after Entergy*, 35 ENVIRONS ENVTL. L. & POL'Y J. 101 (2011) (discussing the Supreme Court's decision in *Entergy v. Riverkeeper, Inc.*, 129 S. Ct. 1498

environmental analysis under CEQA take into account economic factors. The estimated cost of the lagoon-based subsurface infiltration gallery is provided in Attachment 4. Preliminary estimates show the cost of this gallery to be approximately $615 million if coupled with a multi-port diffuser to over $793 million if installed in conjunction with brine dilution using flow augmentation. [3]

Desalination plants will not be developed if water cannot be sold at a competitive price using reliable infrastructure built with a warranty of performance. Without assessing the economic feasibility of the subsurface intakes preferred by the Amendment, the SED fails to sufficiently explain their viability or justify their selection as the preferred intake technology.

III. THE SED'S PREFERENCE FOR DIFFUSERS IS NOT SUPPORTED BY SUBSTANTIAL EVIDENCE

A. The Amendment Should Be Consistent With the SED's Technology-Neutral Approach Concerning Brine Discharge

As described in Poseidon's comments on the Amendment, staff's recommendation with respect to brine discharge technology is to amend the Ocean Plan to establish statewide requirements for the use of the "most protective brine discharge method after a facility specific evaluation." (Staff Report at 93.) Poseidon supports staff's technology-neutral approach, which is specifically mandated under Water Code section 13142.5(b). However, the Amendment departs from the staff's recommendation, and proposes multiport diffusers as the second preferred brine discharge technology, following comingling brine with an existing wastewater stream. The Amendment cannot endorse multiport diffusers without substantial evidence supporting preferential treatment for this technology. Pub. Res. Code § 21168.5. Poseidon recognizes that, in some instances, multiport diffusers may be the preferred brine discharge strategy. But there is no basis to presumptively favor diffusers over other strategies, or to impose burdensome compliance requirements only on non-diffuser discharge strategies, when the State Board admittedly has not assessed the entrainment mortality that diffusers will cause.

(2009)); Letter from Michael A. M. Lauffer, Chief Counsel, Office of Chief Counsel, State Water Resources Control Board, to Dorothy Rice, Executive Director, State Water Resources Control Board, dated May 6, 2009 (providing guidance concerning the *Entergy* decision and stating that *Entergy* permits the State Board to use a cost-benefit analysis approach in adopting a policy for coastal cooling water intake structures).

[3] The estimated construction cost for the 100 MGD subsurface intake to be used with the multiport diffuser is $232 million and the estimated construction cost for the multi-port diffuser is $383 million. The estimated construction cost for the 300 MGD subsurface intake to be used with flow augmentation is $793 million, and the estimated construction cost for the low-impact pump station and associated fish screens and bar racks is approximately $43.8 million.

B. The SED Should Clarify That Proposed Brine Discharge Strategies Must Demonstrate That Their Intake and Mortality Is Equivalent to the 23% Estimated Mortality Rate for Diffusers

While Poseidon disagrees that diffusers should be labeled as the preferred technology in all circumstances, if the Amendment is going to do so, it must provide the evidentiary basis for this determination, including detailed evidence regarding the marine life mortality expected from this technology. The SED requires, for any brine discharge strategy other than a diffuser (aside from commingling with existing wastewater), that a proposed facility demonstrate that its technology will be "as protective" as multiport diffusers. (SED, at 92.) Given the stated lack of data on the effectiveness of multiport diffusers, the SED relied on the existing evidence that 23 percent of the total entrained volume of diffuser dilution water are killed by exposure to lethal turbulence. (SED, at 72-73.) Because this estimate is the only estimate presented in the SED, and is the only substantial evidence in the record of diffuser mortality, it should be explicitly established as the target for projects seeking to demonstrate that alternate brine disposal technologies may perform better than multiport diffusers. If staff believes that other estimates may apply, those estimates must be acknowledged and analyzed in the SED, and any substantial evidence supporting those estimates provided.

C. The SED Should Analyze the Impacts of Installing a Diffuser for the Carlsbad Project

The SED should disclose evidence in the administrative record of estimated diffuser impacts for the Carlsbad project. As with subsurface intakes, the SED should analyze the reasonably foreseeable impacts of the Amendment, which may include requiring the installation of a multiport diffuser for the Carlsbad project. *See Laurel Heights Improvement Ass'n v. Regents of Univ. of Cal.*, 47 Cal. 3d 376, 396 (1988); *Wal-Mart Stores, Inc. v. City of Turlock*, 138 Cal. App. 4th 273, 290-91 (2006). The SED and the Amendment do not explicitly exempt the Carlsbad project from the Amendment's brine disposal requirements. Therefore, as described above in the context of subsurface intakes, it is reasonably foreseeable that if the Amendment is adopted, the Carlsbad project may need to be retrofitted with a multiport diffuser. Therefore, the SED must disclose that the only evidence in the record shows that the impacts for diffusers would be much greater than augmented seawater intake, as described below.

The Water Authority and Poseidon have presented the State Board with substantial evidence that high-velocity diffusers are *not* the environmentally preferred option for the Carlsbad project. For example, the studies included in Attachments 8, 9, and 10 show that flow augmentation using low impact pumps, with 200 million gallons per day ("MGD") of dilution water, would injure between 72,600 – 280,000 organisms per day and place at risk 1 – 5 percent of the dilution water to entrainment mortality. By contrast, use of a high velocity diffuser at Carlsbad would require 950 MGD of dilution water, injure 4,415,000 to 9,985,783 organisms per day, and place at risk 16.8 to 38 percent of the dilution water to entrainment mortality. For additional information regarding environmental and economic impacts associated with the construction, installation, and operation of a multiport diffuser in Carlsbad, please refer to Attachment 4.

Additional information about the flow augmentation studies at Red Bluff was submitted to the State Board during the administrative process for the Amendment. See Attachment 8 and 9. A Poseidon representative referenced the need to consider information from the Red Bluff studies at the August 6, 2014 State Board workshop on the Amendment; however, Staff indicated that they had received the information but did not have time to review it. We hope that, in revising the SED, the State Board will add information about flow augmentation technology, which may be best at reducing mortality under Water Code section 13142.5(b).

D. The SED Should Assess the Feasibility of Diluting Brine with Commingled Existing Wastewater Streams

The Amendment proposes as the preferred method of brine disposal commingling with existing wastewater streams from wastewater treatment plant facilities or once-through cooling facilities. (SED, at 92.) Poseidon agrees that, where feasible, this likely is the environmentally preferred strategy under section 13142.5(b). But the SED fails to sufficiently analyze whether this strategy would ever be viable for a desalination facility in California.

The SED concedes that the siting of desalination facilities is “highly specific and may not coincide with the location of an existing wastewater discharge that is willing and able to accept the brine waste.” (SED, at 84.) Further, OTC facilities are being phased out or going to closed-cycle cooling due to the OTC policy, and the limited number of treatment plants and OTC facilities “may restrict locations where desalination facilities are feasible.” *Id.* Commingling also could require miles of pipeline construction and related infrastructure, further limiting its potential use. *Id.* The Amendment also effectively eliminates the use of most municipal wastewater outfalls for dilution of brine with the following provision:

> *The preferred technology for minimizing intake and mortality of marine life resulting from brine* disposal is to commingle brine* with wastewater … unless the wastewater is of suitable quality and quantity to support domestic irrigation use.*

(Amendment, at L.2.d(2)(a).)

While the SED acknowledges the likelihood of successfully using commingled wastewater is low, it fails to undertake any concrete assessment of whether there are any suitable locations where this strategy could be employed. Without such analysis, there is no basis to adopt commingled wastewater as the preferred alternative, because its availability is at best illusory. If there are no suitable locations where commingled wastewater could be used, adopting commingled wastewater as a preferred alternative contradicts the mandate of section 13142.5(b) to use the best “available” technology. In addition, such a preference would also conflict with CEQA’s mandate that mitigation measures must be concrete and capable of being implemented, rather than hypothetical or illusory. *E.g., Sacramento Old City Ass’n*, 229 Cal. App. 3d at 1027 (substantial evidence must support conclusion that mitigation will be effective).

IV. THE SED FAILS TO JUSTIFY ITS PROPOSED MITIGATION REQUIREMENTS, WHICH LACK A RATIONAL BASIS OR ANY REQUIRED NEXUS TO ENVIRONMENTAL IMPACTS

A. The SED Should Permit Regional Boards to Exercise Their Discretion to Select Appropriate Mitigation

The Amendment is intended to provide guidance to Regional Boards in mitigating for desalination-related impacts under section 13142.5(b). (SED at 65-81.) As described in Poseidon's comments on the Amendment, however, certain aspects of the Amendment would be highly disruptive of Poseidon's existing mitigation plans at the Carlsbad project, which is in the final stages of design. As written, the Amendment's mandates would improperly impede the discretion of Regional Boards under section 13142.5(b) to impose appropriate site-specific mitigation, and conflict with other viable approaches, including the approach adopted by the Regional Board (and Coastal Commission) for the Carlsbad project.

For example, the Amendment requires that the mitigation must be located in the source water body. This provision would require that Poseidon abandon its approved mitigation site and begin developing a new site within the source water of Agua Hedionda Lagoon. Poseidon has spent seven years and invested millions of dollars developing the existing mitigation site that is in the final stages of permitting and will be ready to begin construction next year. Given the limited number of suitable mitigation sites, it would be impractical to limit site selection to the facility's source water body.

Consistent with past mitigation siting determinations, the Amendment and the SED should provide Regional Boards with sufficient flexibility to site the mitigation acreage as needed based on the availability of suitable mitigation sites. For example, the Coastal Commission allowed Poseidon to select from a number of suitable sites in the Southern California Bight for its restoration project associated with the Carlsbad project. Following an exhaustive search in and around the Carlsbad project's source water, the Coastal Commission determined that there were no suitable mitigation sites located directly with the project's source water body, and that the best available mitigation site for the Carlsbad project was located within the National Wildlife Refuge at the south end of San Diego Bay, a distance of 50 miles from the facility, where two former salt pools will be restored to sub-tidal and inter-tidal wetlands.[4] The Amendment and the SED should not foreclose the ability of Regional Boards to develop effective, cost-conscious mitigation alternatives for specific facilities. *See, e.g., Surfrider,* 211 Cal. App. 4th 557 (2012) (upholding Regional Board's discretion in selecting and adopting mitigation plan).

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[4] Poseidon notes that, with mitigation, the Carlsbad project was found to have no significant adverse environmental impacts under CEQA. The SED's references to the Carlsbad project should be clarified to confirm that no significant impacts under CEQA would result from the construction and operation of the Carlsbad project.

B. The SED Does Not Provide Substantial Evidence Supporting the Mitigation Requirements Proposed in the Amendment

The SED recommends updating the Ocean Plan to provide statewide guidance on the appropriate methods for determining the nature and size of a mitigation project to ensure that all desalination-related mortality is mitigated for a facility. (SED at 65-81.) While the SED's mitigation goals are laudable, the SED's analysis is wrong insofar as the mitigation requirements it establishes understate the effectiveness of other approaches and ignore substantial evidence in the record (i.e., the findings of the Regional Board, Coastal Commission, and State Lands Commission for Carlsbad) showing that other mitigation approaches are effective under section 13142.5(b). As described in greater detail in Poseidon's comments on the Amendment, Poseidon is particularly concerned that the SED does not provide a basis for requiring (1) a 90% confidence level for calculating the final area of production foregone ("APF"); (2) a 1:1 ratio in all instances; and (3) mitigation for discharge impacts within the zone of initial dilution. If the SED intends to adopt these requirements, it must provide substantial evidence in support of its conclusions. Pub. Res. Code § 21168.5. The SED should also recognize that other mitigation ratios have been determined to be successful at mitigating desalination-related impacts. For example, a mitigation plan that included one acre of estuarine habitat restoration for every 10 acres of open ocean habitat impacted by the project was determined to be appropriate for the Carlsbad project, which restored estuarine wetlands to compensate for open ocean species, because successfully restored wetland habitat is ten times more productive than a similar area of nearshore ocean waters. *See* California Coastal Commission, Revised Condition Compliance Findings for Permit No. E-06-013 (approved December 10, 2008).

C. The SED's Proposed Mitigation Requirements Lack a Nexus or Rough Proportionality to Marine Life Impacts at the Carlsbad Facility

As described above, the San Diego Regional Board already identified the entrainment and impingement impacts at Carlsbad, and found that those impacts will be fully mitigated by the mitigation program selected. It would be inappropriate to require a new approach for the same anticipated losses, since there has been no factual change suggesting that there will be more entrainment and impingement. Moreover, it would be an abuse of discretion for the State Board to make a different conclusion on the same set of facts without any evidence that the existing mitigation for the Carlsbad project would be ineffective. Pub. Res. Code § 21168.5 (a prejudicial abuse of discretion occurs when agency has not proceeded in the manner required by law or if the determination or decision is not supported by substantial evidence).

Poseidon's recent calculations show that the mitigation approach in the Amendment could increase the Carlsbad project's mitigation requirements from 55.4 acres to more than 130 acres. There is thus no nexus nor rough proportionality between the SED's proposed mitigation standard and marine life impacts at the Carlsbad project, particularly in light of the fact that physical conditions at the Carlsbad project have not changed since the Regional Board's determinations. The SED's proposed standard would bear no reasonable relationship to the Carlsbad project's actual impacts, as it would require substantially more mitigation than necessary to fully mitigate impacts from the Carlsbad project. The SED's proposal thus violates mitigation standards under CEQA, and also goes beyond the mandate of section 13142.5(b), which requires best available mitigation feasible to minimize marine life intake and mortality from a project, but nothing more.

Governmental conditions must have a sufficient nexus and be “roughly proportional” to a project’s impacts to meet constitutional requirements. *See Nollan v. California Coastal Comm.*, 483 U.S. 825 (1987); *Dolan v. City of Tigard*, 512 U.S. 374 (1994). For example, *Dolan* held that a city planning commission’s conditional permit approval constituted an unconstitutional taking when it required a property owner seeking to expand an electric and plumbing supply store to dedicate a 7,000 square foot greenway for flood control and a bike path on her property because such conditions were not roughly proportional to the project’s impacts. This “rough proportionality” does not require a precise mathematical calculation, but requires the agency make some sort of an “individualized determination that the required dedication is related both in nature and extent to the impact of the proposed development.” *Dolan*, 512 U.S. at 391; *see also Rohn v. City of Visalia*, 214 Cal. App. 3d 1463 (1989) (conditions must bear reasonable relationship to project impacts).

Here, requiring Poseidon to provide substantially more mitigation than necessary to fully mitigate impacts from the Carlsbad project would not be “proportional” to the Carlsbad project’s impacts on marine life.

V. THE SED FAILS TO ANALYZE THE ENVIRONMENTAL EFFECTS FROM INCREASED RELIANCE ON OTHER WATER SUPPLY SOURCES THAT COULD BE TRIGGERED BY THE AMENDMENT

The SED’s discussion of environmental impacts is focused exclusively on desalination. The SED fails to assess existing conditions in light of environmental impacts from other current water supply options, including without limitation impacts stemming from transporting water significant distances or water recycling. The SED also fails to analyze the potential effect of the Amendment on the use and demand for alternative water supply sources, and the indirect environmental effects that could occur as a result. By way of example, the SED must analyze the extent to which requirements imposed through the Amendment, such as the preference for subsurface intakes and diffusers, could foreseeably render desalination facilities prohibitively expensive or difficult to permit, such that there would be a greater reliance on imported water or other water supply sources. *El Dorado Union High School Dist. v. City of Placerville*, 144 Cal. App. 3d 123 (1983). The SED should discuss the potential impacts that would result from increased demand for these alternative sources. Among other things, relying on alternative sources of water would result in the need to export more drinking water from the Delta, which could place greater strains on the biology/marine life in the Delta. In addition, greater imports of water from the Delta, the Colorado River, or other distant locations could increase greenhouse gas emissions with resulting climate change impacts. Additional storage and transportation water in the absence of desalination options could also require the construction of water supply infrastructure, with associated environmental impacts.

The SED should be revised to assess the potential of the Amendment to cause increased reliance on other water supply sources and their reasonably foreseeable environmental impacts.

For example, the EIR for the Huntington Beach plant analyzed alternative water supply options in determining the environmentally superior alternative:

> Water planning professionals have forecasted that water demands would increase in the Southern California area, and have specifically identified resource targets to help meet projected demands, including local seawater desalination facilities. . . Consequently, adoption of the "No Project" alternative would result in shifting the obligation for meeting a portion (up to 56,000 acre-feet per year [afy]) of future water demands from the project to: (1) increased conservation efforts (efficiency improvements and reduced consumption); (2) increased use of imported water supplies; (3) increased use of groundwater supplies; (4) construction of additional local water supply projects; and/or (5) construction of seawater desalination projects elsewhere in Orange County. Therefore, in some instances, the environmental impacts associated with the "No Project" alternative may be greater than those associated with the project."

(Huntington Beach Draft Subsequent EIR at p. 6-3.) Thus, increased desalination may be the environmentally superior alternative to other water supply options, and additional restrictions on desalination may result in additional adverse environmental impacts.

The SED should also specifically analyze the impacts that the additional restrictions proposed in the Amendment may have on the Carlsbad plant, which has already been approved by the State Board, is under construction, and will begin producing water in 2016. The SED should analyze the potential impacts associated with a delay in the Carlsbad plant's ability to produce desalinated water, or a disruption in the plant's operations. These impacts would include the loss of 7 percent of the county's water supply and the necessity of resorting to alternative water supplies. More broadly, the SED should consider the unintended consequences of unplanned downtimes for desalination plants, including pulling water from other over-subscribed sources and potential regional water supply impacts.

VI. THE SED DOES NOT PROVIDE ANY BASIS FOR THE 36-MONTH STUDIES REQUIRED IN THE AMENDMENT

The Amendment would require 36-month studies for (1) entrainment data if an applicant is seeking to use an alternative to fine screens on a surface seawater intake, (2) baseline benthic modeling for an applicant seeking a facility-specific salinity standard, and (3) the entrainment study for the mitigation plan. The SED, however, does not evaluate or attempt to support the 36-month duration for these studies, and there is no justification for this time period. The SED is silent as to any scientific basis for a three-year study of baseline benthic modeling to determine if a facility-specific salinity standard is appropriate, and is similarly silent as to any basis for a three-year entrainment study to determine whether larger screens may be used. The SED fails to explain why a three-year entrainment study is required to inform the determination of whether fine screens are beneficial. To the extent the State Board believes a 36-month study is required, the rationale for each study should be assessed in the SED, and be supported by substantial evidence.

The SED must also disclose that requiring 36 months of studies would disrupt or delay urgently needed desalinated water supply sources in the face of an extreme drought.[5] The SED should also clarify whether there is an exception to the 36 months of studies for existing plants. For example, for Poseidon's Carlsbad project, requiring three-year studies would impede Poseidon from fulfilling the timeline for re-permitting Carlsbad in light of the planned 2017 Encina Power Station shut-down and could result in the plant being idle for years. Specifically, Poseidon is conducting an entrainment pilot test to assess whether alternative screens combined with low-impact pumps are beneficial for the Carlsbad plant. Standard protocol for entrainment studies is 12 months. Without substantial evidence that a three-year study is required, the SED should clarify that a Regional Board approved pilot test combined with historic entrainment data relied upon for CEQA review and permitting by the Regional Board and Coastal Commission will suffice for the entrainment study required for the plant's mitigation plan.

In closing, Poseidon appreciates staff's efforts in developing the SED and the Amendment. We look forward to addressing these issues further with the State Board at the August 19, 2014, public hearing.

Very truly yours,

Christopher W. Garrett

Christopher W. Garrett
of LATHAM & WATKINS LLP

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[5] The SED should also analyze other potential delays and disruptions related to the use of smaller screens. Smaller screens may become impacted by red tide algae or other biological contaminants that could result in water fouling and additional plant shutdowns or disruptions.

Carlsbad Desalination Project Intake and Discharge Options
Comparison of Environmental, Schedule and Cost Impacts

Option	**1**	**2**	**3**	**4**
Intake/Discharge Configuration	**Screen Open Intake with Flow Augmentation Using Low-impact Pumps**	**Screened Intake with Multiport Diffuser**	**Subsurface Intake with Flow Augmentation Using Low-Impact Pumps**	**Subsurface Intake with Multiport Diffuser**
Quantity of Water Potentially Exposed to 100% Mortality	120 MGD	281 MGD	0 MGD	181 MGD
Area of Production Foregone	26.4 Acres	140 Acres	0 Acres	118 Acres
Permanent Construction Impacts to Marine Environment	0 Acres	1 Acre	60 Acres	23 Acres
Total Entrainment and Construction Related Mitigation	26.4 Acres[1]	141 Acres[2]	60 Acres[1]	141 Acres[1]
Impacted Habitat	Agua Hedionda Lagoon	Agua Hedionda Lagoon Carlsbad kelp bed Surrounding marine waters	Agua Hedionda Lagoon	Agua Hedionda Lagoon Carlsbad kelp bed Surrounding marine waters
Brine Toxicity Impacts	TBD[3]	TBD[1]	TBD[1]	TBD[1]
Permitting Schedule	1.5 Years	3.0 Years	3.0 Years	3.0 Years
Construction Schedule	2.0 Years	2.0 Years	7.0 Years	4.0 Years
Total Duration	3.5 Years	5.0 Years	10.0 Years	7.0 Years
Construction Cost	$64,000,000	$404,000,000	$793,000,000	$615,000,000

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[1] Mitigation acreage per CA Coastal Commission approval of the Carlsbad Project described in Appendix 5.

[2] Mitigation acreage calculated per the recommendations set forth in the draft Desalination Amendments.

[3] Brine concentrations and exposure times similar across all options, therefore, do not expect to see significant differences in mortality.

Attachment 4A – Option 1

Screen Open Intake with Flow Augmentation

Using Low-Impact Pumps

POSEIDON WATER

State Water Resources Control Board Ocean Plan Amendment
Screened Open Intake with Flow Augmentation Using Low-Impact Pumps

BASIS OF CONCEPTUAL DESIGN

The Carlsbad Desalination Facility (CDF) is currently permitted to operate in conjunction with the Encina Power Station ("EPS") by using the power plant's cooling water discharges as its source water. A permanent shutdown of the EPS will result in the stand-alone operation of the CDF. At such time, the CDF will be considered an "expanded facility" and subject to the provisions of Chapter III.L of the Water Quality Control Plan, Ocean Waters of California ("Ocean Plan").

Stand-alone operation of the CDF will trigger a formal request for a Water Code Section 13142.5(b) determination. In advance of this request, this document seeks to identify a solution for meeting compliance with the intake and discharge provisions of the Ocean Plan.

SCREENED OPEN INTAKE(1)

A new screening structure will be designed to both convey source water to the plant and provide for entrainment reduction in accordance with the Ocean Plan. Design features include:

- Removal of existing trash racks
- Installation of new trash racks with a bar spacing of 2-inches
- Installation of dual flow traveling screens (slot size is not yet determined; however, it will be designed to reduce impingement and entrainment as required by the Ocean Plan)
- Through screen velocities less than or equal to 0.5 feet per second (FPS)

FLOW AUGMENTATION USING LOW-IMPACT PUMPS(2)

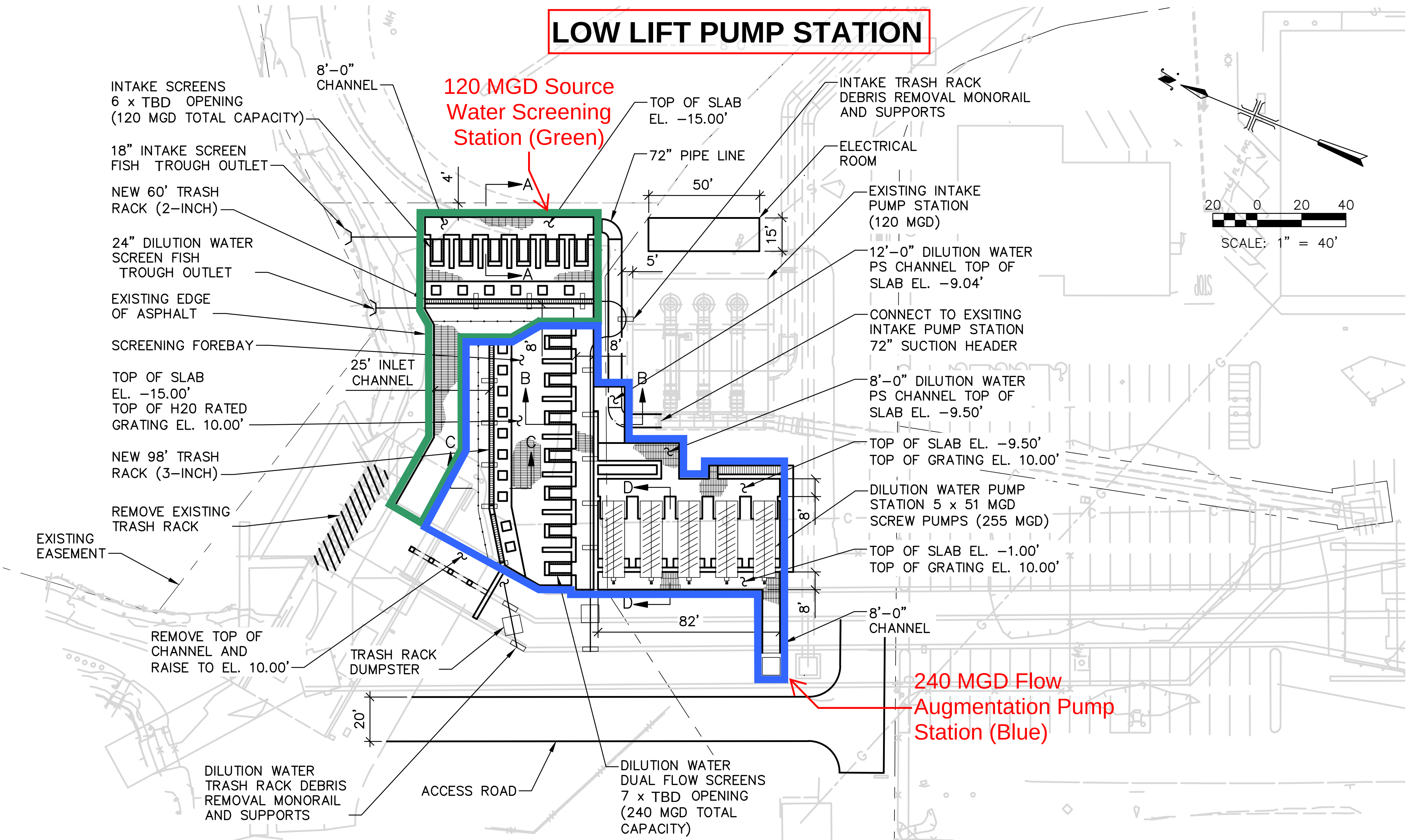
A new flow augmentation structure will be designed to provide a water source for in-plant dilution of brine while minimizing entrainment impacts. Design features include:

- Removal of existing trash racks
- Installation of new trash racks with a bar spacing of 3-inches
- Installation of dual flow traveling screens (slot size is not yet determined; however, it will be designed to reduce impingement and entrainment as required by the Ocean Plan)
- Through screen velocities less than or equal to 0.5 feet per second (FPS)
- Installation of low impact screw pumps

(1) **This option is provided with the understanding that subsurface intakes must first be found not feasible in accordance with the provisions of the Ocean Plan**

(2) **This option is provided with the understanding that flow augmentation must be shown to provide a comparable level of protection as wastewater dilution and multiport diffusers per the provisions of the Ocean Plan**

LOW LIFT PUMP STATION



BASIS OF DESIGN - SCREENING

SOURCE WATER DEMAND: 120 MGD
TRASH RACK DESIGN: 2 INCH SPACING
FINE MESH SCREEN DESIGN: TBD SPACING
THROUGH SCREEN VELOCITY: 0.5 FPS

BASIS OF DESIGN - FLOW AUGMENTATION

SOURCE WATER DEMAND: 240 MGD
TRASH RACK DESIGN: 3 INCH SPACING
FINE MESH SCREEN DESIGN: TBD SPACING
THROUGH SCREEN VELOCITY: 0.5 FPS

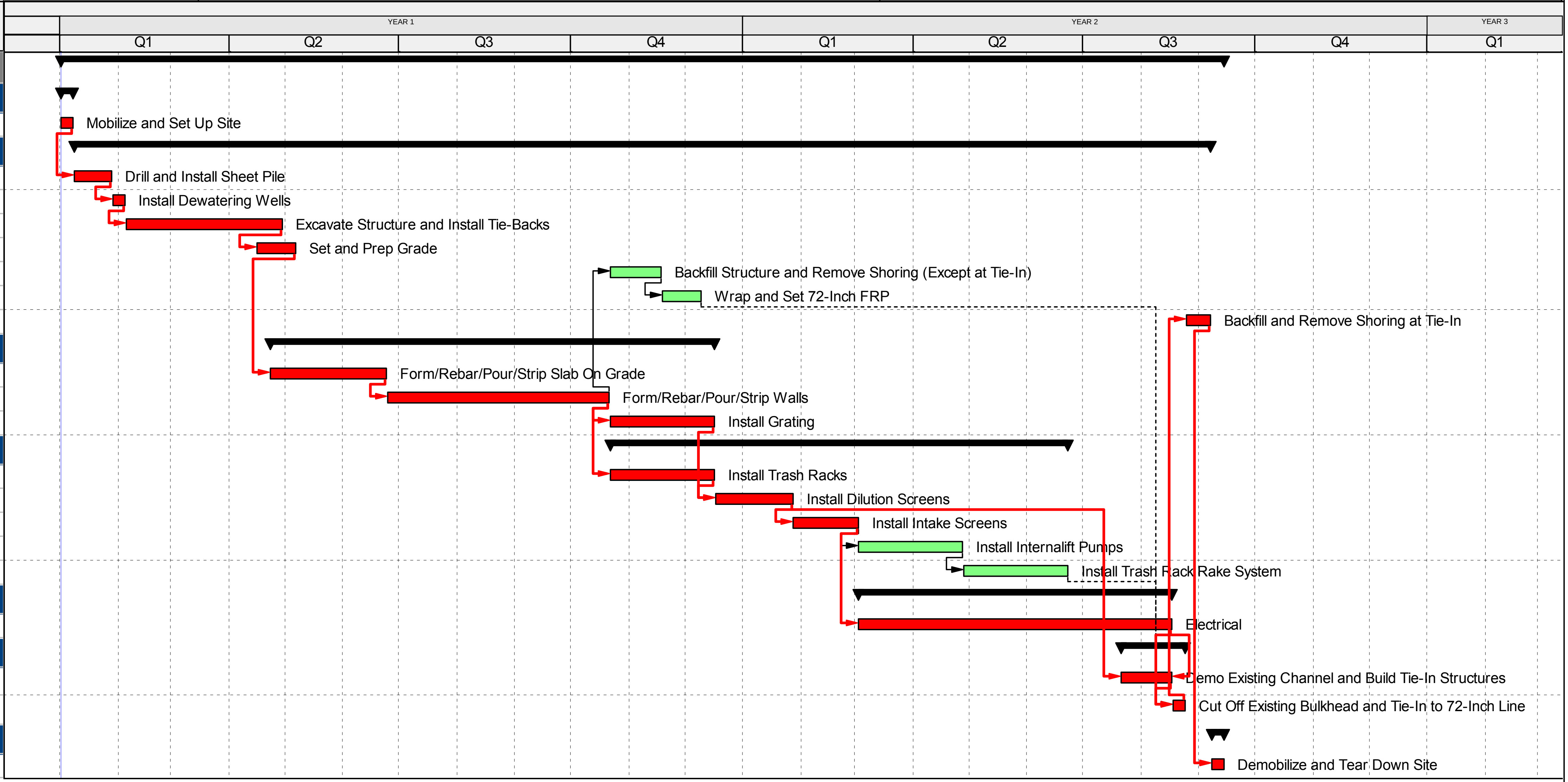
Carlsbad Desalination Facility

Poseidon Water

360 MGD Low Lift Pump Station

Conceptual Construction Schedule

Activity Name	Original Duration
Carlsbad Low Lift Pump Station	445
Mobilization	5
Mobilize and Set Up Site	5
Civil Operations	435
Drill and Install Sheet Pile	15
Install Dewatering Wells	5
Excavate Structure and Install Tie-Backs	60
Set and Prep Grade	15
Backfill Structure and Remove Shoring (Except at Tie-In)	20
Wrap and Set 72-Inch FRP	15
Backfill and Remove Shoring at Tie-In	10
Structures Operations	170
Form/Rebar/Pour/Strip Slab On Grade	45
Form/Rebar/Pour/Strip Walls	85
Install Grating	40
Mechanical Operations	175
Install Trash Racks	40
Install Dilution Screens	30
Install Intake Screens	25
Install Internalift Pumps	40
Install Trash Rack Rake System	40
Electrical Operations	120
Electrical	120
Tie-In Operations	25
Demo Existing Channel and Build Tie-In Structures	20
Cut Off Existing Bulkhead and Tie-In to 72-Inch Line	5
Demobilization	5
Demobilize and Tear Down Site	5



🟦 Actual Work	🟥 Critical Remaining Work	◆ ◆ Milestone
🟩 Remaining Work	🟦 Equipment	▬ Summary

360 MGD Low Lift Pump Station

Description	QTY	Unit	Labor $	Equipment $	Material $	Sub $	Total $
Civil Operations							
Excavate and Set Grade	33,234	CY	$339,201	$850,653	$88,029	$0	$1,277,882
Demo Concrete	429	CY	$13,476	$30,696	$51,500	$0	$95,672
Backfill	16,457	CY	$39,675	$37,276	$745,899	$0	$822,850
L/R/F Base - Roads	473	Ton	$2,666	$2,512	$7,095	$0	$12,272
SUB WORK							
Dewatering	14	EA	$0	$0	$0	$950,400	$950,400
Water Treatment	1	LS	$0	$0	$0	$405,000	$405,000
Sheet Pile	16,763	SF	$0	$0	$0	$1,168,398	$1,168,398
AC Paving	32,537	SF	$0	$0	$0	$97,611	$97,611
Landscaping	875	SY	$0	$0	$0	$65,625	$65,625
Masonry - Retaining Wall and Electrical Bldg.	2,160	SF	$0	$0	$0	$64,800	$64,800
						Civil Total	$4,960,510
Structures Operations							
Concrete	6,299	CY	$2,085,647	$0	$1,804,820	$1,304,100	$5,194,568
Metals							
Temporary Stop Logs	4	EA	$4,554	$0	$200,000	$0	$204,554
Permanent Stop Logs	2	EA	$2,619	$0	$42,615	$0	$45,234
Trash Racks	19	EA	$77,873	$0	$570,000	$0	$647,873
Structures - SUB							
Grating	9,352	SF	$0	$0	$0	$1,870,380	$1,870,380
Painting	1	LS	$0	$0	$0	$150,000	$150,000
Roofing/Metal Studs - Electrical Bldg.	1	LS	$0	$0	$0	$50,000	$50,000
						Structures Operations Total	$8,162,608
Mechanical Operations							
72" FRP	115	LF	$32,619	$12,365	$69,000	$0	$113,984
51 MGD Internalift Pumps	5	Each	$69,622	$0	$6,000,000	$0	$6,069,622
Intake Screens	6	Each	$133,674	$0	$2,400,000	$0	$2,533,674
Dilution Screens	7	Each	$155,953	$0	$2,800,000	$0	$2,955,953
Trash Rack Rake	2	Each	$88,787	$0	$400,000	$0	$488,787
						Mechanical Operations Total	$12,162,021
Miscellaneous							
Schedule Related Equipment	1	LS	$0	$1,411,273	$1,230	$0	$1,412,503
MHR STS	1	LS	$0	$0	$290,914	$0	$290,914
						Miscellaneous Total	$1,703,417
						Sub Total Cost	$26,988,557
Electrical, Instrumentation, and Control						Taken at 25% of Prior Sub Total	$6,747,139
						Sub Total Cost	$33,735,696
Project Management						Taken at 25% of Prior Sub Total	$8,433,924
Insurance and Environmental						Taken at 5% of Prior Sub Total	$1,686,785
Contractor Overhead and Profit						Taken at 25% of Prior Sub Total	$8,433,924
						Sub Total Cost	$52,290,328
Engineering						Taken at 5% of Prior Sub Total	$2,614,516
Legal						Taken at 1.8% of Prior Sub Total	$1,000,000
						Sub Total Cost	$55,904,845
Contingency						Taken at 15% of Prior Sub Total	$8,385,727
						Sub Total Cost	$64,290,571

Note: Proposal Based on Rates Effective August of 2014

Attachment 4B – Option 2

Screened Intake with Multiport Diffuser

POSEIDON WATER

State Water Resources Control Board Ocean Plan Amendment
Screened Open Intake with Multiport Diffuser

BASIS OF CONCEPTUAL DESIGN

The Carlsbad Desalination Facility (CDF) is currently permitted to operate in conjunction with the Encina Power Station ("EPS") by using the power plant's cooling water discharges as its source water. A permanent shutdown of the EPS will result in the stand-alone operation of the CDF. At such time, the CDF will be considered an "expanded facility" and subject to the provisions of Chapter III.L of the Water Quality Control Plan, Ocean Waters of California ("Ocean Plan").

Stand-alone operation of the CDF will trigger a formal request for a Water Code Section 13142.5(b) determination. In advance of this request, this document seeks to identify a solution for meeting compliance with the intake and discharge provisions of the Ocean Plan.

SCREENED OPEN INTAKE(1)

A new screening structure will be designed to both convey source water to the plant and provide for entrainment reduction in accordance with the Ocean Plan. Design features include:

- Removal of existing trash racks
- Installation of new trash racks with a bar spacing of 2-inches
- Installation of dual flow traveling screens (slot size is not yet determined; however, it will be designed to reduce entrainment and as required by the Ocean Plan)
- Through screen velocities less than or equal to 0.5 feet per second (FPS)

MULTIPORT DIFFUSER

A new multiport diffuser system will be designed to maximize dilution, minimize the size of the brine mixing zone, minimize the suspension of benthic sediments, and minimize marine life mortality in accordance with the provisions of the Ocean Plan. Design features include:
- Tie-In to the exiting CDF brine outfall line
- Installation of 8,700 linear feet of 72-Inch conveyance tunnel
- Installation of high pressure multiport diffusers

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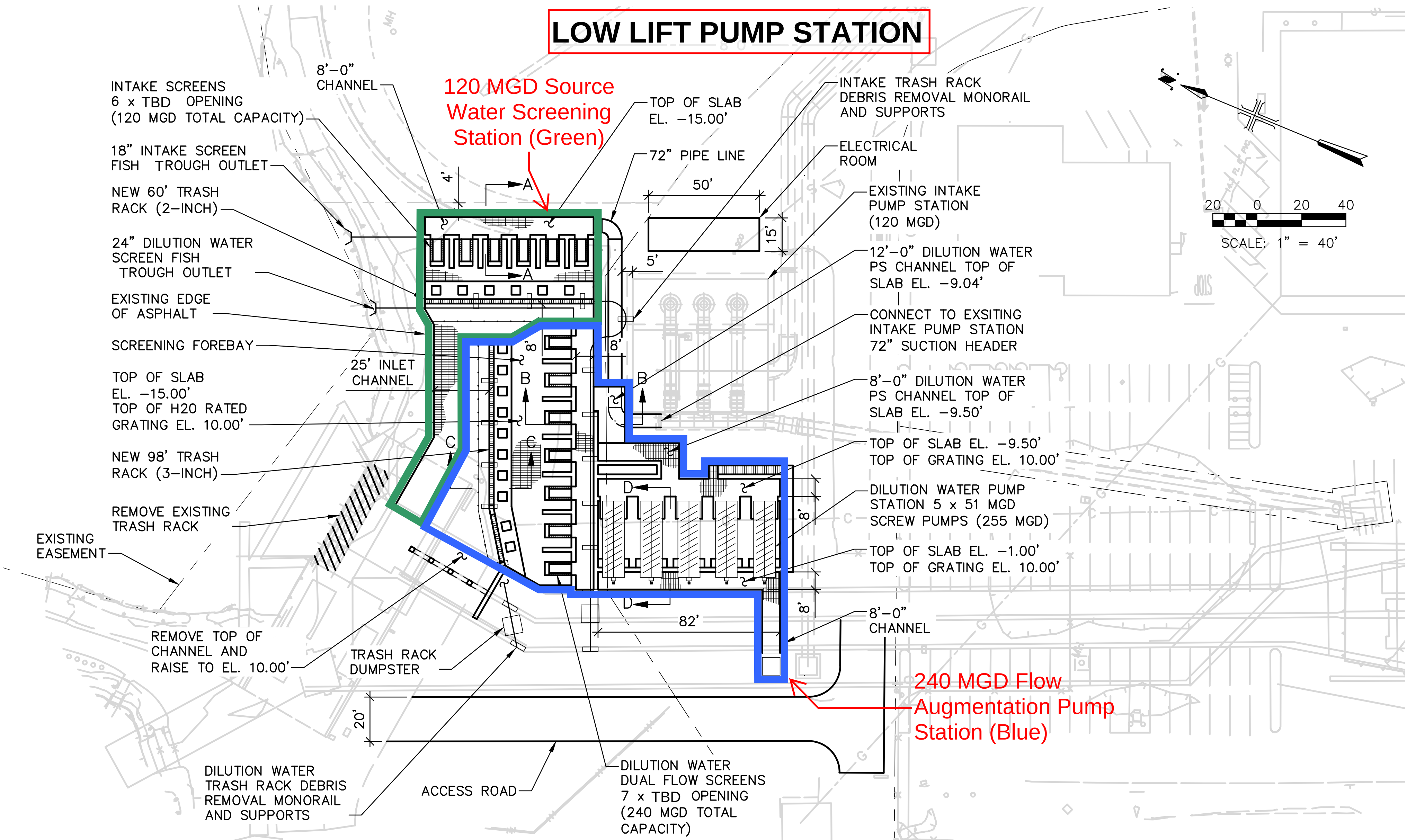
(1) **This option is provided with the understanding that subsurface intakes must first be found not feasible in accordance with the provisions of the Ocean Plan**

LOW LIFT PUMP STATION



BASIS OF DESIGN - SCREENING

SOURCE WATER DEMAND: 120 MGD
TRASH RACK DESIGN: 2 INCH SPACING
FINE MESH SCREEN DESIGN: TBD SPACING
THROUGH SCREEN VELOCITY: 0.5 FPS

BASIS OF DESIGN - FLOW AUGMENTATION

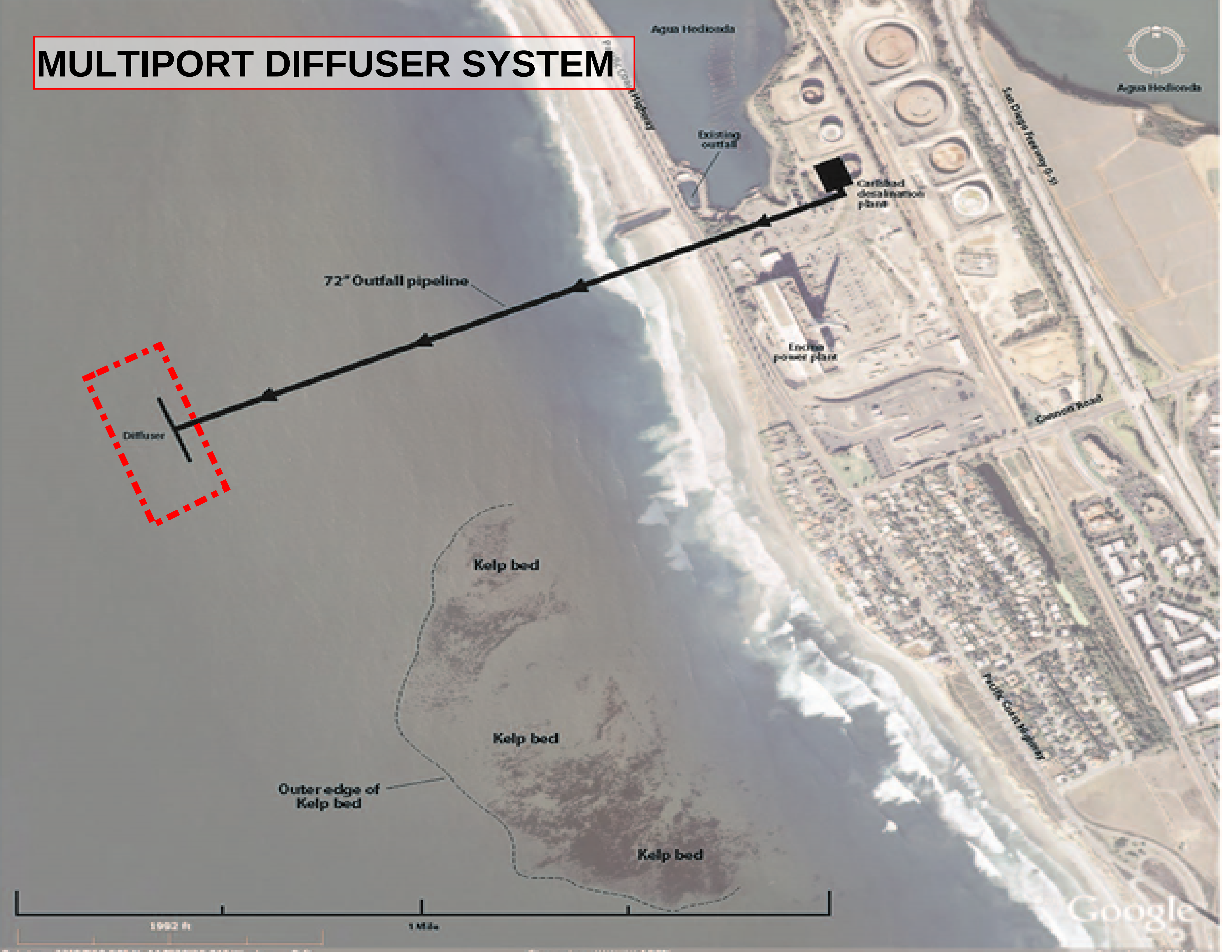
SOURCE WATER DEMAND: 240 MGD
TRASH RACK DESIGN: 3 INCH SPACING
FINE MESH SCREEN DESIGN: TBD SPACING
THROUGH SCREEN VELOCITY: 0.5 FPS

104 MGD Source Water Screening Station

Description	QTY	Unit	Labor $	Equipment $	Material $	Sub $	Total $
Civil Operations							
Excavate and Set Grade	11,078	CY	$113,067	$283,551	$29,343	$0	$425,961
Demo Concrete	429	CY	$13,476	$30,696	$51,500	$0	$95,672
Backfill	5,486	CY	$13,225	$12,425	$248,633	$0	$274,283
L/R/F Base - Roads	473	Ton	$2,666	$2,512	$7,095	$0	$12,272
SUB WORK							
Dewatering	5	EA	$0	$0	$0	$316,800	$316,800
Water Treatment	1	LS	$0	$0	$0	$135,000	$135,000
Sheet Pile	5,588	SF	$0	$0	$0	$389,466	$389,466
AC Paving	32,537	SF	$0	$0	$0	$97,611	$97,611
Landscaping	875	SY	$0	$0	$0	$65,625	$65,625
Masonry - Retaining Wall and Electrical Bldg.	2,160	SF	$0	$0	$0	$64,800	$64,800
						Civil Total	$1,877,490
Structures Operations							
Concrete	2,100	CY	$695,216	$0	$601,607	$434,700	$1,731,523
Metals							
Temporary Stop Logs	4	EA	$4,554	$0	$200,000	$0	$204,554
Permanent Stop Logs	2	EA	$2,619	$0	$42,615	$0	$45,234
Trash Racks	6	EA	$25,958	$0	$190,000	$0	$215,958
Structures - SUB							
Grating	3,117	SF	$0	$0	$0	$623,460	$623,460
Painting	1	LS	$0	$0	$0	$150,000	$150,000
Roofing/Metal Studs - Electrical Bldg.	1	LS	$0	$0	$0	$50,000	$50,000
						Structures Operations Total	$3,020,728
Mechanical Operations							
72" FRP	115	LF	$32,619	$12,365	$69,000	$0	$113,984
Intake Screens	6	Each	$133,674	$0	$2,400,000	$0	$2,533,674
Trash Rack Rake	1	Each	$29,596	$0	$133,333	$0	$162,929
						Mechanical Operations Total	$2,810,588
Miscellaneous							
Schedule Related Equipment	1	LS	$0	$470,424	$410	$0	$470,834
MHR STS	1	LS	$0	$0	$96,971	$0	$96,971
						Miscellaneous Total	$567,806
						Sub Total Cost	$8,276,612
Electrical, Instrumentation, and Control						Taken at 25% of Prior Sub Total	$2,069,153
						Sub Total Cost	$10,345,764
Project Management						Taken at 25% of Prior Sub Total	$2,586,441
Insurance and Environmental						Taken at 5% of Prior Sub Total	$517,288
Contractor Overhead and Profit						Taken at 25% of Prior Sub Total	$2,586,441
						Sub Total Cost	$16,035,935
Engineering						Taken at 5% of Prior Sub Total	$801,797
Legal						Taken at 1.8% of Prior Sub Total	$1,000,000
						Sub Total Cost	$17,837,732
Contingency						Taken at 15% of Prior Sub Total	$2,675,660
						Sub Total Cost	$20,513,391

Note: Proposal Based on Rates Effective August of 2014

MULTIPORT DIFFUSER SYSTEM



54 MGD Outfall with High Energy Diffuser

Description	QTY	Unit	Unit Cost $	Total $
Direct Cost Work				
Tunnel Installation	**8,700**	**LF**	**$10,500**	**$91,350,000**
Pipe Installation	**1**	**LS**	**$50,000,000**	**$50,000,000**
Diffuser Installation	**1**	**LS**	**$15,000,000**	**$15,000,000**
			Direct Cost Total	**$156,350,000**
Project Management	Taken at 25% of Prior Sub Total			**$39,087,500**
Insurance and Environmental	Taken at 15% of Prior Sub Total			**$23,452,500**
Contractor Overhead and Profit	Taken at 25% of Prior Sub Total			**$39,087,500**
			Sub Total Cost	**$257,977,500**
Engineering	Taken at 5% of Prior Sub Total			**$12,898,875**
Legal	Taken at 5% of Prior Sub Total			**$12,898,875**
			Sub Total Cost	**$283,775,250**
Contingency	Taken at 35% of Prior Sub Total			**$99,321,338**
			Sub Total Cost	**$383,096,588**

Note: Proposal Based on Rates Effective August of 2014

Attachment 4C – Option 3

Subsurface Intake with Flow Augmentation

Using Low-Impact Pumps

State Water Resources Control Board Ocean Plan Amendment
SUBSURFACE INTAKE WITH FLOW AUGMENTATION USING LOW-IMPACT PUMPS

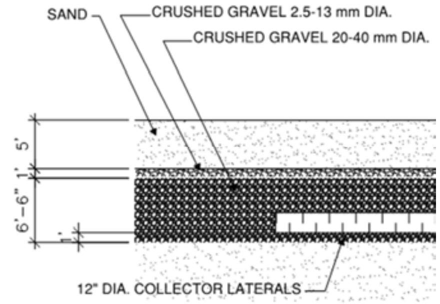
BASIS OF CONCEPTUAL DESIGN

The Carlsbad Desalination Facility (CDF) is currently permitted to operate in conjunction with the Encina Power Station ("EPS") by using the power plant's cooling water discharges as its source water. A permanent shutdown of the EPS will result in the stand-alone operation of the CDF. At such time, the CDF will be considered an "expanded facility" and subject to the provisions of Chapter III.L of the Water Quality Control Plan, Ocean Waters of California ("Ocean Plan").

Stand-alone operation of the CDF will trigger a formal request for a Water Code Section 13142.5(b) determination. In advance of this request, this document seeks to identify a solution for meeting compliance with the intake and discharge provisions of the Ocean Plan.

SUBSURFACE INTAKE

A seafloor infiltration gallery ("SIG"), also known as a subsurface infiltration gallery or seabed infiltration gallery, is a subsurface intake technology. A SIG consists of a submerged collector pipe system installed beneath the seafloor and buried under permeable engineered fill as shown below.



A SIG is sized and configured using the same design criteria as a slow sand filter. The design loading rate (rate at which water will flow through permeable substrate) for a SIG is typically between 0.05 to 0.10 GPM / SQ FT. For the purposes of this conceptual design, we have selected a loading rate of 0.08 GPM / SQ FT (115 GPD / SQ FT = 5 MGD / AC).

Approximately 304 MGD of source water will be obtained from the SIG. Approximately 204 MGD will be used for flow augmentation and approximately100 MGD for desalinating.

FLOW AUGMENTATION USING LOW-IMPACT PUMPS(2)

A new flow augmentation structure will be designed to pump water obtained from the SIG to the existing discharge channel for in-plant mixing of the brine discharges.

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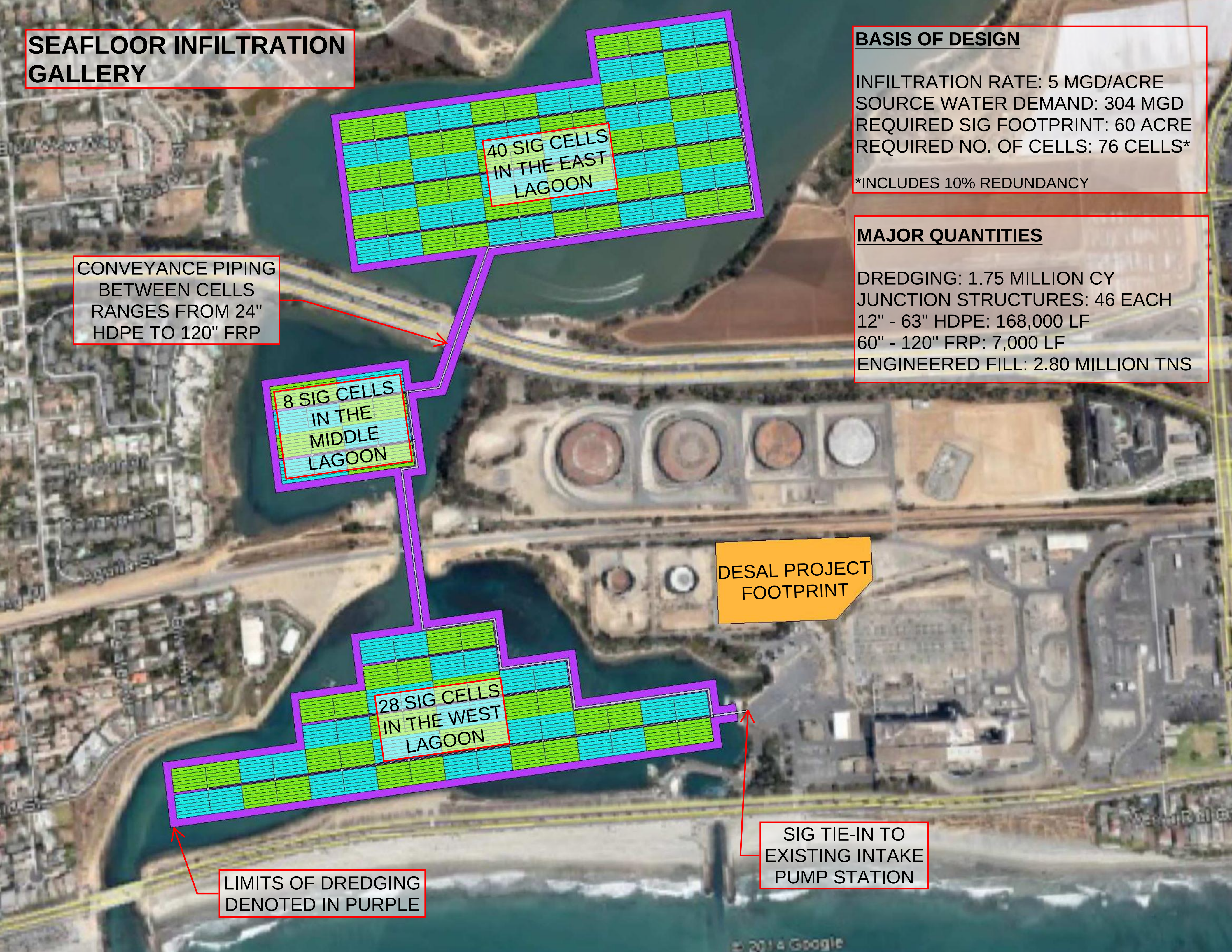
(1) This option is provided with the understanding that flow augmentation must be shown to provide a comparable level of protection as wastewater dilution and multiport diffusers per the provisions of the Ocean Plan

SEAFLOOR INFILTRATION GALLERY



BASIS OF DESIGN

INFILTRATION RATE: 5 MGD/ACRE
SOURCE WATER DEMAND: 304 MGD
REQUIRED SIG FOOTPRINT: 60 ACRE
REQUIRED NO. OF CELLS: 76 CELLS*

*INCLUDES 10% REDUNDANCY

MAJOR QUANTITIES

DREDGING: 1.75 MILLION CY
JUNCTION STRUCTURES: 46 EACH
12" - 63" HDPE: 168,000 LF
60" - 120" FRP: 7,000 LF
ENGINEERED FILL: 2.80 MILLION TNS

CONVEYANCE PIPING BETWEEN CELLS RANGES FROM 24" HDPE TO 120" FRP

LIMITS OF DREDGING DENOTED IN PURPLE

SIG TIE-IN TO EXISTING INTAKE PUMP STATION


12' X 12' PRE-CAST JUNCTION STRUCTURES (TYP)
328'
115'
12" PERFORATED HDPE COLLECTOR PIPE (TYP)
24" HDPE HEADER PIPE (TYP)

CONCEPTUAL DESIGN CONSTRUCTION SCHEDULE

304 MGD SOURCE WATER DEMAND

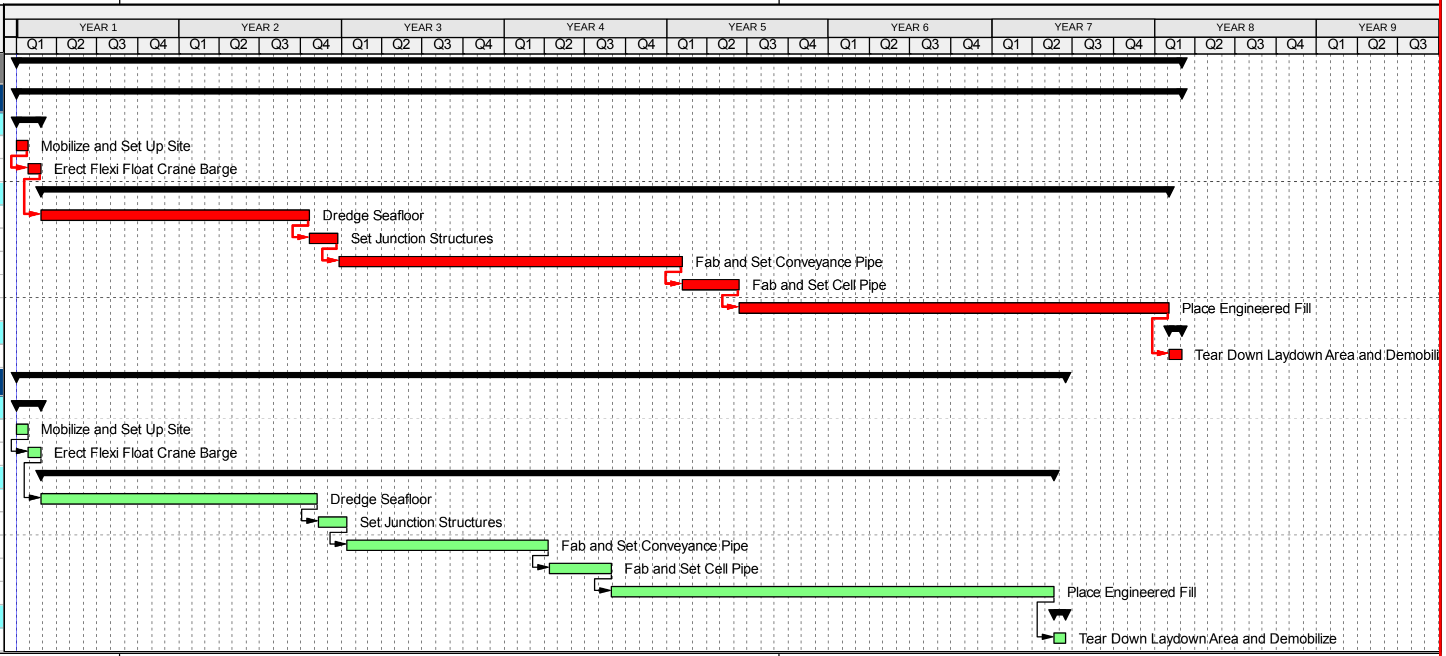
Carlsbad Desalination Facility

Poseidon Water

304 MGD Seafloor Infiltration Gallery (SIG)

Conceptual Construction Schedule

Activity Name	Original Duration
300 MGD Carlsbad Seafloor Infiltration Gallery	1870
West and Middle Lagoon Site	1870
Mobilization	40
Mobilize and Set Up Site	20
Erect Flexi Float Crane Barge	20
SIG Install	1810
Dredge Seafloor	431
Set Junction Structures	46
Fab and Set Conveyance Pipe	553
Fab and Set Cell Pipe	90
Place Engineered Fill	690
Demobilization	20
Tear Down Laydown Area and Demobilize	20
East Lagoon Site	1685
Mobilization	40
Mobilize and Set Up Site	20
Erect Flexi Float Crane Barge	20
SIG Install	1625
Dredge Seafloor	444
Set Junction Structures	46
Fab and Set Conveyance Pipe	325
Fab and Set Cell Pipe	100
Place Engineered Fill	710
Demobilization	20
Tear Down Laydown Area and Demobilize	20



🟦 Actual Work
🟥 Critical Remaining Work
◆ ◆ Milestone
🟩 Remaining Work
▭ Equipment
▼ Summary

304 MGD Seafloor Infiltration Gallery (SIG)

Description	QTY	Unit	Labor $	Equipment $	Material $	Sub $	Total $
Dredging Operations							
SIG Dredging	1,749,290	CY	$9,183,773	$2,604,868	$0	$0	$11,788,641
Export Dredged Material	1,749,290	CY	$3,935,903	$2,736,064	$0	$61,225,150	$67,897,117
						Dredging Total	$79,685,758
Mechanical Operations							
Junction Structures - 46 Each at 12' x 12' x 20'	46	EA	$828,000	$26,422	$14,194,557	$1,000,408	$16,049,387
Fuse 12" & 24" HDPE Pipe for 76 Cells	157,168	LF	$3,420,054	$2,737,411	$36,934,480	$1,943,731	$45,035,677
Set 12" & 24" HDPE Pipe for 76 Cells	76	EA	$1,710,000	$54,568	$0	$2,047,060	$3,811,628
Fuse and Set 24" - 32" HDPE Conveyance Pipe	5,317	LF	$102,126	$81,742	$1,249,495	$58,042	$1,491,405
Fuse and Set 42" - 63" HDPE Conveyance Pipe	5,388	LF	$206,980	$117,820	$3,125,040	$167,654	$3,617,494
Wrap and Set 60" - 120" FRP Conveyance Pipe	6,572	LF	$7,399,125	$236,114	$7,399,125	$8,857,575	$23,891,939
						Mechanical Operations Total	$93,897,530
Engineered Fill							
Make Grade - 1 Foot Thick	209,915	TN	$1,102,054	$30,144	$5,479,411	$1,130,812	$7,742,421
Place Cell 1" Gravel Bedding - 1 Foot Thick	209,915	TN	$1,102,054	$30,144	$5,479,411	$1,130,812	$7,742,421
Place Cell 1" Gravel Zone- 5.5 Feet Thick	1,118,115	TN	$5,870,104	$160,561	$29,186,156	$6,023,286	$41,240,107
Place Cell 3/8" Gravel Backfill- 1 Foot Thick	209,915	TN	$1,102,054	$30,144	$5,168,632	$1,130,812	$7,431,642
Place Cell Sand Backfill- 5 Feet Thick	1,049,574	TN	$5,510,264	$150,719	$24,399,447	$5,654,055	$35,714,485
						Engineered Fill Total	$99,871,076
Tie-In to Plant							
120" Plant Tie-In	1	EA	$45,000	$10,406	$0	$25,500	$80,906
						Tie-In to Plant	$80,906
Schedule Related Equipment							
Liebherr 895 Crawler Crane	4	EA	$0	$28,356,384	$0	$0	$28,356,384
CAT 980 Loader	4	EA	$0	$12,797,236	$0	$0	$12,797,236
Marine Vessel	2	EA	$0	$1,772,274	$0	$0	$1,772,274
Lube Truck	1	EA	$0	$1,859,655	$0	$0	$1,859,655
						Schedule Related Equipment	$44,785,548
						Sub Total Cost	**$318,320,818**
Dilution Water Pump Station						Taken at 8% of Prior Sub Total	**$26,000,000**
						Sub Total Cost	**$344,320,818**
Indirects						Taken at 25% of Prior Sub Total	**$86,080,205**
Insurance and Environmental						Taken at 5% of Prior Sub Total	**$17,216,041**
Contractor Overhead and Profit						Taken at 25% of Prior Sub Total	**$86,080,205**
						Sub Total Cost	**$533,697,268**
Engineering						Taken at 5% of Prior Sub Total	**$26,684,863**
Legal						Taken at 5% of Prior Sub Total	**$26,684,863**
						Sub Total Cost	**$587,066,995**
Contingency						Taken at 35% of Prior Sub Total	**$205,473,448**
						Sub Total Cost	**$792,540,443**

Note: Proposal Based on Rates Effective May of 2014

Attachment 4D – Option 4

Subsurface Intake with Multiport Diffuser

State Water Resources Control Board Ocean Plan Amendment
SUBSURFACE INTAKE WITH MULTIPORT DIFFUSER

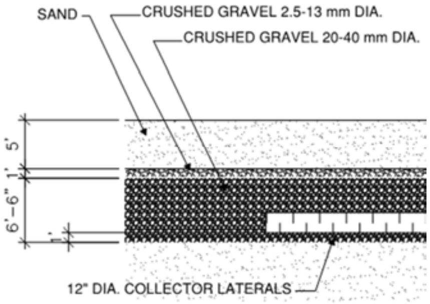
BASIS OF CONCEPTUAL DESIGN

The Carlsbad Desalination Facility (CDF) is currently permitted to operate in conjunction with the Encina Power Station ("EPS") by using the power plant's cooling water discharges as its source water. A permanent shutdown of the EPS will result in the stand-alone operation of the CDF. At such time, the CDF will be considered an "expanded facility" and subject to the provisions of Chapter III.L of the Water Quality Control Plan, Ocean Waters of California ("Ocean Plan").

Stand-alone operation of the CDF will trigger a formal request for a Water Code Section 13142.5(b) determination. In advance of this request, this document seeks to identify a solution for meeting compliance with the intake and discharge provisions of the Ocean Plan.

SUBSURFACE INTAKE

A seafloor infiltration gallery ("SIG"), also known as a subsurface infiltration gallery or seabed infiltration gallery, is a subsurface intake technology. A SIG consists of a submerged collector pipe system installed beneath the seafloor and buried under permeable engineered fill as shown below.



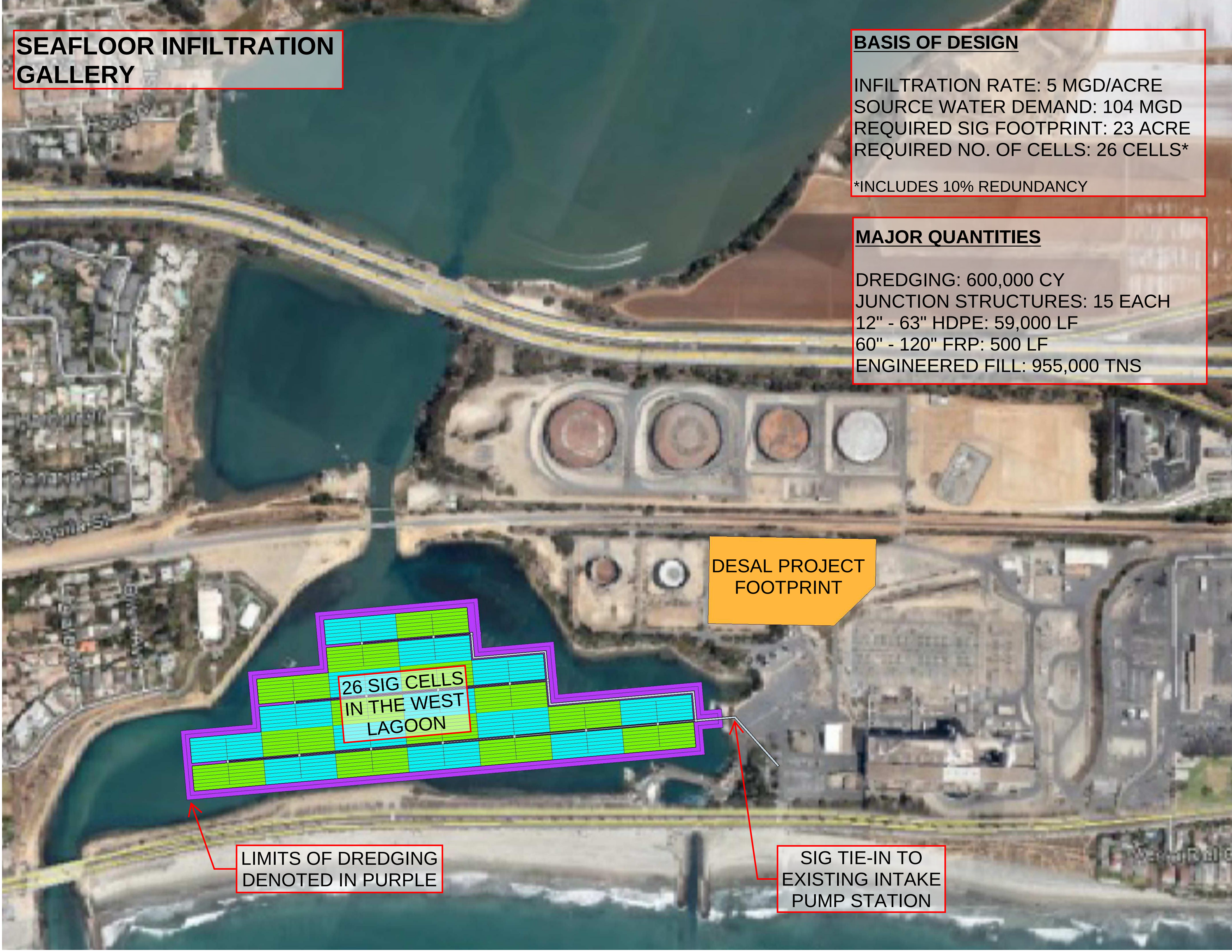
A SIG is sized and configured using the same design criteria as a slow sand filter. The design loading rate (rate at which water will flow through permeable substrate) for a SIG is typically between 0.05 to 0.10 GPM / SQ FT. For the purposes of this conceptual design, we have selected a loading rate of 0.08 GPM / SQ FT (115 GPD / SQ FT = 5 MGD / AC).

MULTIPORT DIFFUSER

A new multiport diffuser system will be designed to maximize dilution, minimize the size of the brine mixing zone, minimize the suspension of benthic sediments, and minimize marine life mortality in accordance with the provisions of the Ocean Plan. Design features include:

- Tie-In to the exiting CDF brine outfall line
- Installation of 8,700 linear feet of 72-Inch conveyance tunnel
- Installation of high pressure multiport diffusers

SEAFLOOR INFILTRATION GALLERY



BASIS OF DESIGN

INFILTRATION RATE: 5 MGD/ACRE
SOURCE WATER DEMAND: 104 MGD
REQUIRED SIG FOOTPRINT: 23 ACRE
REQUIRED NO. OF CELLS: 26 CELLS*

*INCLUDES 10% REDUNDANCY

MAJOR QUANTITIES

DREDGING: 600,000 CY
JUNCTION STRUCTURES: 15 EACH
12" - 63" HDPE: 59,000 LF
60" - 120" FRP: 500 LF
ENGINEERED FILL: 955,000 TNS

DESAL PROJECT FOOTPRINT

26 SIG CELLS IN THE WEST LAGOON

LIMITS OF DREDGING DENOTED IN PURPLE

SIG TIE-IN TO EXISTING INTAKE PUMP STATION


12' X 12' PRE-CAST JUNCTION STRUCTURES (TYP)
328'
115'
12" PERFORATED HDPE COLLECTOR PIPE (TYP)
24" HDPE HEADER PIPE (TYP)

CONCEPTUAL DESIGN CONSTRUCTION SCHEDULE

104 MGD SOURCE WATER DEMAND

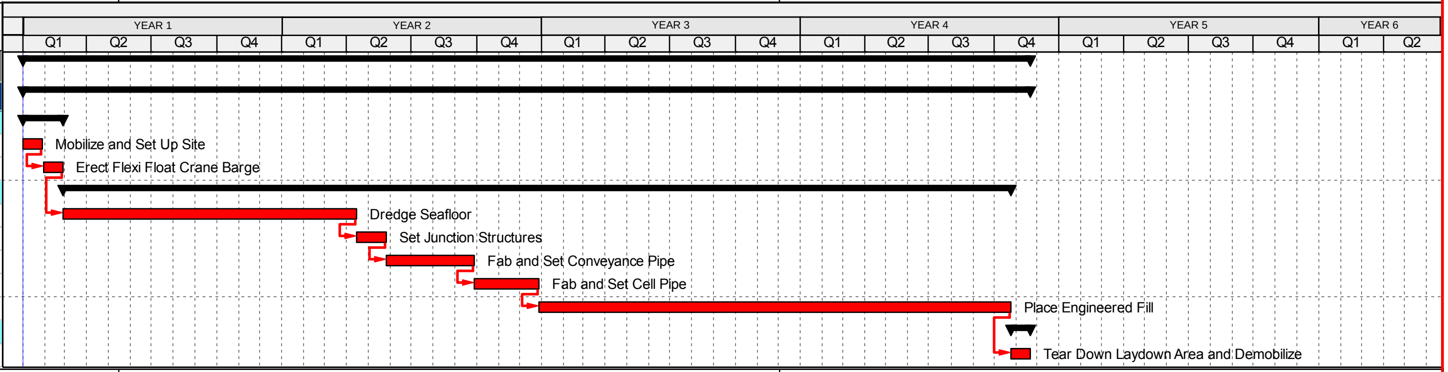
Carlsbad Desalination Facility

Poseidon Water

104 MGD Seafloor Infiltration Gallery (SIG)

Conceptual Construction Schedule

Activity Name	Original Duration
100 MGD Carlsbad Seafloor Infiltration Gallery	1015
West Lagoon Site	1015
Mobilization	40
Mobilize and Set Up Site	20
Erect Flexi Float Crane Barge	20
SIG Install	955
Dredge Seafloor	296
Set Junction Structures	30
Fab and Set Conveyance Pipe	88
Fab and Set Cell Pipe	65
Place Engineered Fill	476
Demobilization	20
Tear Down Laydown Area and Demobilize	20



🟦 Actual Work
🟩 Remaining Work
🟥 Critical Remaining Work
▬ Equipment
◆ ◆ Milestone
▼▬▼ Summary

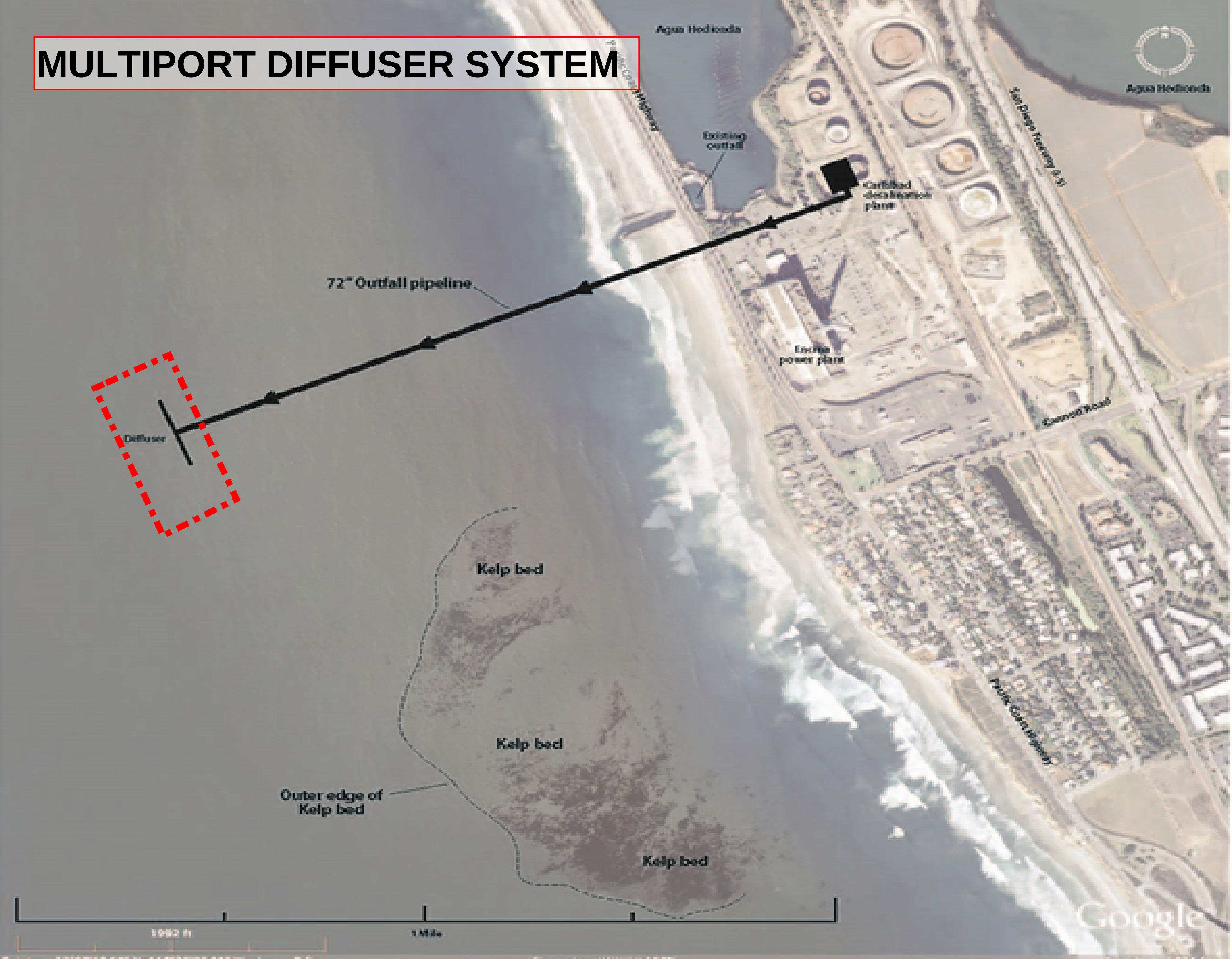
Page 1 of 1

104 MGD Seafloor Infiltration Gallery (SIG)

Description	QTY	Unit	Labor $	Equipment $	Material $	Sub $	Total $
Dredging Operations							
SIG Dredging	592,018	CY	$3,108,095	$881,574	$0	$0	$3,989,669
Export Dredged Material	592,018	CY	$1,332,041	$925,975	$0	$20,720,630	$22,978,646
						Dredging Total	$26,968,315
Mechanical Operations							
Junction Structures - 15 Each at 12' x 12' x 20'	15	EA	$270,000	$8,616	$4,628,660	$326,220	$5,233,496
Fuse 12" & 24" HDPE Pipe for 76 Cells	53,768	LF	$1,170,019	$936,483	$12,635,480	$664,961	$15,406,943
Set 12" & 24" HDPE Pipe for 76 Cells	26	EA	$585,000	$18,668	$0	$700,310	$1,303,978
Fuse and Set 24" - 32" HDPE Conveyance Pipe	2,300	LF	$44,177	$35,359	$540,500	$25,107	$645,143
Fuse and Set 42" - 63" HDPE Conveyance Pipe	2,785	LF	$106,986	$60,900	$1,615,300	$86,658	$1,869,844
Wrap and Set 60" - 120" FRP Conveyance Pipe	500	LF	$562,500	$17,950	$562,500	$673,375	$1,816,325
						Mechanical Operations Total	$26,275,729
Engineered Fill							
Make Grade - 1 Foot Thick	71,042	TN	$372,971	$10,202	$1,854,409	$382,703	$2,620,285
Place Cell 1" Gravel Bedding - 1 Foot Thick	71,042	TN	$372,971	$10,202	$1,854,409	$382,703	$2,620,285
Place Cell 1" Gravel Zone- 5.5 Feet Thick	383,560	TN	$2,013,690	$55,079	$10,012,067	$2,066,238	$14,147,074
Place Cell 3/8" Gravel Backfill- 1 Foot Thick	71,042	TN	$372,971	$10,202	$1,749,232	$382,703	$2,515,108
Place Cell Sand Backfill- 5 Feet Thick	355,211	TN	$1,864,858	$51,008	$8,257,590	$1,913,522	$12,086,978
						Engineered Fill Total	$33,989,730
Tie-In to Plant							
120" Plant Tie-In	1	EA	$45,000	$10,406	$0	$25,500	$80,906
						Tie-In to Plant	$80,906
Schedule Related Equipment							
Liebherr 895 Crawler Crane	2	EA	$0	$8,092,054	$0	$0	$8,092,054
CAT 980 Loader	2	EA	$0	$3,651,944	$0	$0	$3,651,944
Marine Vessel	1	EA	$0	$505,753	$0	$0	$505,753
Lube Truck	1	EA	$0	$1,008,675	$0	$0	$1,008,675
						Schedule Related Equipment	$13,258,426
						Sub Total Cost	**$100,573,106**
Indirects						Taken at 25% of Prior Sub Total	**$25,143,277**
Insurance and Environmental						Taken at 5% of Prior Sub Total	**$5,028,655**
Contractor Overhead and Profit						Taken at 25% of Prior Sub Total	**$25,143,277**
						Sub Total Cost	**$155,888,314**
Engineering						Taken at 5% of Prior Sub Total	**$7,794,416**
Legal						Taken at 5% of Prior Sub Total	**$7,794,416**
						Sub Total Cost	**$171,477,146**
Contingency						Taken at 35% of Prior Sub Total	**$60,017,001**
						Sub Total Cost	**$231,494,147**

Note: Proposal Based on Rates Effective May of 2014

MULTIPORT DIFFUSER SYSTEM



54 MGD Outfall with High Energy Diffuser

Description	QTY	Unit	Unit Cost $	Total $
Direct Cost Work				
Tunnel Installation	**8,700**	**LF**	**$10,500**	**$91,350,000**
Pipe Installation	**1**	**LS**	**$50,000,000**	**$50,000,000**
Diffuser Installation	**1**	**LS**	**$15,000,000**	**$15,000,000**
			Direct Cost Total	**$156,350,000**
Project Management	Taken at 25% of Prior Sub Total			**$39,087,500**
Insurance and Environmental	Taken at 15% of Prior Sub Total			**$23,452,500**
Contractor Overhead and Profit	Taken at 25% of Prior Sub Total			**$39,087,500**
			Sub Total Cost	**$257,977,500**
Engineering	Taken at 5% of Prior Sub Total			**$12,898,875**
Legal	Taken at 5% of Prior Sub Total			**$12,898,875**
			Sub Total Cost	**$283,775,250**
Contingency	Taken at 35% of Prior Sub Total			**$99,321,338**
			Sub Total Cost	**$383,096,588**

Note: Proposal Based on Rates Effective August of 2014

Attachment 5

Condition Compliance for Carlsbad Desalination Project
No. E-06-013 Poseidon Resources (Channelside), LLC;
Special Condition 8 – Submittal of Marine Life Mitigation Plan

STATE OF CALIFORNIA—THE RESOURCES AGENCY ARNOLD SCHWARZENEGGER, *GOVERNOR*

CALIFORNIA COASTAL COMMISSION
45 FREMONT, SUITE 2000
SAN FRANCISCO, CA 94105- 2219
VOICE AND TDD (415) 904- 5200
FAX (415) 904- 5400

W5b

DRAFT E-06-013 MLMP Condition Compliance Dec 08.doc

CONDITION COMPLIANCE

November xx, 2008

To: To Commissioners and Interested Parties

From: Peter Douglas, Executive Director
Alison Dettmer, Deputy Director
Tom Luster, Staff Environmental Scientist

Regarding: **Condition Compliance for CDP No. E-06-013 –** Poseidon Resources (Channelside), LLC; **Special Condition 8**: Submittal of a Marine Life Mitigation Plan

Commissioners on Prevailing Side:

Exhibit 1: xx

Exhibit 2: xx

STAFF NOTE

Staff prepared these recommended Revised Findings to reflect the Commission's August 6, 2008 decision approving a Marine Life Mitigation Plan for the Poseidon desalination facility in Carlsbad, San Diego County. The Plan is required pursuant to ***Special Condition 8*** of Coastal Development Permit #E-06-013. The Commission's approval at the August hearing included modifications to the Plan proposed by both staff and Poseidon. Because the Commission's action differed from staff's recommendation, revised findings are necessary. The recommended Revised Findings herein support the Plan as approved by the Commission and are based on staff's review of the August 6, 2008 hearing transcript and the record before the Commission. Recommended changes from the August 6th document are shown in ~~strikethrough~~ and **bold underline** text.

Please note that the Commission required Poseidon to submit within 60 days of Commission approval a revised Plan for Executive Director review and approval that incorporates the Commission's approved modifications. Poseidon submitted a plan in early October 2008, which is being reviewed by the Executive Director.

SUMMARY

On November 15, 2007, the Commission conditionally approved CDP E-06-013 for Poseidon Resources (Channelside), LLC (Poseidon) for construction and operation of a desalination facility to be located adjacent to the Encina Power Plant in Carlsbad, San Diego County. As part of the Adopted Findings for its approval, the Commission imposed **Special Condition 8**, which required Poseidon to submit for further Commission review and approval, a Marine Life Mitigation Plan **(MLMP, or the Plan)**.[1]

~~On July 7, 2008, Poseidon submitted to Commission staff its proposed Marine Life Mitigation Plan (the Plan). This report provides staff's analysis of the Plan, staff's evaluation of whether the Plan conforms to the Adopted Findings and **Special Condition 8**, and staff's recommendation as to whether the Commission should approve the Plan.~~

~~In brief, staff's analysis shows that the Plan as submitted does not conform to the Adopted Findings and ***Special Condition 8***. However, if modified as described herein, staff believes the modified Plan would conform to the applicable Findings and ***Special Condition 8***. Staff therefore recommends the Commission **approve** the Plan, as modified herein. The modifications staff has identified as being necessary for Plan approval are summarized below and are further detailed in Sections 1.1 and 4.0 of this memorandum.~~ **At its August 6, 2008 hearing, the Commission approved the Plan with modifications. Because the Commission's action differed from staff's recommendation, revised findings are necessary.**

~~Staff recommends the Plan be modified to include the following~~**The Commission modified the Plan as follows**:

1) Poseidon ~~shall~~ **is to** create or restore ~~between~~ 55**.4** ~~and 68~~ acres of coastal estuarine wetland habitat within the Southern California Bight. **For Phase I, within 10 months of issuance of the desalination facility's coastal development permit (CDP), Poseidon must submit proposed site(s) and a Preliminary Restoration Plan for Commission review and approval. Within two years of issuance of the CDP for the desalination facility, Poseidon must submit a complete CDP application to restore at least 37 acres of estuarine wetlands. For Phase II, within five years of issuance of the CDP for the Phase I restoration, Poseidon must submit a complete CDP application to restore an additional 18.4 acres of estuarine wetlands. Poseidon may apply to do all 55.4 acres of restoration during Phase I. Poseidon may request the Commission reduce or eliminate the Phase II restoration requirement if Poseidon adopts technologies that reduce entrainment levels below currently anticipated levels or**

---

[1] The Commission's approval of this CDP also included **Special Condition 10**, which required Poseidon to submit for Commission review and approval an Energy Minimization and Greenhouse Gas Reduction Plan. ~~That Special Condition and Poseidon's submitted plan are evaluated in a separate staff report under Item W5a of the August 6, 2008 Commission hearing.~~ **The Commission approved the Energy Minimization and Greenhouse Gas Emission Reduction Plan at its August 6, 2008 hearing. The recommended Revised Findings for that Plan are on the Commission's December 2008 hearing agenda as Item Xx.**

undertakes dredging in Agua Hedionda Lagoon in a manner that warrants mitigation credit.

2) Poseidon shall implement its Marine Life Mitigation Plan in conformity to the conditions provided in Exhibit 2 of ~~this memorandum~~ **these Findings**.
3) Within 60 days of the Commission's approval of this modified Plan, Poseidon shall submit for the Executive Director's review and approval a revised Plan that includes these modifications.

The first ~~recommendation~~ **modification** is based on a review of Poseidon's proposed Plan by staff and the Commission's independent scientific experts.[2] Poseidon's entrainment study identified impacts that these reviewers believe require more mitigation than Poseidon ~~has~~ **had** proposed. ~~Staff further believes that t~~**T**his amount of mitigation is necessary to ensure the project conforms to **Special Condition 8** and Sections 30230, 30231, and 30260 of the Coastal Act. Based on results from Poseidon's entrainment study, ~~this range in acreage – from 55 to 68 acres – represents the range in statistical confidence that would~~ **55.4 acres of wetland restoration will** provide the Commission with 80% ~~(i.e., 55 acres) to 95%~~ confidence ~~(i.e., 68 acres)~~ that the mitigation would fully mitigate the impacts identified in the study. Section 4.2 of ~~this memorandum~~ **these Findings** provides a more detailed discussion.[3]

The second ~~recommendation is meant to~~ **modification** ensure**s** that mitigation is timely and successful. It ~~would~~ require**s** Poseidon to implement its mitigation subject to the conditions similar to those the Commission required of Southern California Edison at its San Dieguito Restoration Project (see, for example CDPs #183-73 and #6-04-88). Although Poseidon's current Plan does not commit to provide mitigation at a particular site, Poseidon had previously identified a mitigation site in San Dieguito Lagoon adjacent to Edison's as the best location to mitigate for its entrainment impacts. ~~Staff recommends the two projects be held to similar standards.~~ The Commission's scientific experts ~~concur with this recommendation~~ **recommend that the two restoration projects be subject to similar standards**. Section 4.2 provides a more detailed discussion of this ~~recommendation~~ **modification**.

The third ~~recommendation~~ **modification** is ~~meant~~ to help **ensure** Poseidon ~~and the Commission~~ implement**s** the ~~approved~~ mitigation plan **as approved**. Additionally, the 60-day deadline in the recommendation ~~would be~~ **is** consistent with the requirement imposed by the San Diego Regional Water Quality Control Board that Poseidon provide a mitigation plan for Board approval by October 9, 2008.[4]

---

[2] Staff consulted with members of the Commission's ~~Marine Review Committee~~ **Scientific Advisory Panel (SAP)**. Committee members are identified in Section 3.0 of this memorandum.

[3] ~~As an alternative to staff's recommendation, the Commission may wish to require mitigation in a manner similar to past decisions in which it applied a mitigation ratio to the identified level of impact. If the Commission selects this alternative approach, staff recommend mitigation be provided at between a 2:1 to 3:1 ratio, which would result in from 85 to 127.5 acres of coastal estuarine wetland habitat as mitigation.~~

[4] The Regional Board's Order, adopted on April 9, 2008 requires, in part: "*Within six months of adoption of this resolution, Poseidon shall submit to the Regional Board Executive Officer, for approval by the Regional Board an amendment to the Plan that includes a specific proposal for mitigation of the impacts, by impingement and entrainment upon marine organisms resulting from the intake of seawater from Agua Hedionda Lagoon, as required by Section VI.C.2(e) of Order No. R9-2006-0065; and shall resolve the concerns identified in the Regional Board's February 19, 2008 letter to Poseidon Resources, and the following additional concerns:*

~~With these recommended modifications, staff believes Poseidon's Plan would conform to applicable provisions of~~ ~~***Special Condition 8.***~~

TABLE OF CONTENTS

1.0 MOTION & RESOLUTION

Motion:

> *"~~I move that the Commission approve the Marine Life Mitigation Plan attached to the staff recommendation as Exhibit 1 if modified as shown in Section 1.1 below and Exhibit 2 of this memorandum, as compliant with~~ ~~**Special Condition 8**~~ ~~of CDP E-06-013.~~ **I move that the Commission adopt the revised findings in support of the Commission's action on August 6, 2008 to approve the Marine Life Mitigation Plan as compliant with Special Condition 8 of CDP E-06-013.**"*

Resolution to Approve:

> *~~The Commission hereby finds that the compliance plan titled "Marine Life Mitigation Plan" prepared and submitted by the permittee, Poseidon Resources (Channelside) LLC, dated July 3, 2008, if modified as shown in Section 1.1 and Exhibit 2 of the July 24, 2008 Commission staff report, is adequate, if fully implemented to comply with~~ ~~**Special Condition 8**~~ ~~of CDP E-06-013.~~ **The Commission hereby adopts the findings set forth below for the Commission's approval of the Marine Life Mitigation Plan as compliant with Special Condition 8 of CDP E-06-013 on the ground that the findings support the***

---

a) Identification of impacts from impingement and entrainment;
b) Adequate monitoring data to determine the impacts from impingement and entrainment;
c) Coordination among participating agencies for the amendment of the Plan as required by Section 13225 of the California Water Code;
d) Adequacy of mitigation; and
e) Commitment to fully implement the amendment to the Plan.

Commission's decision made on August 6, 2008 and accurately reflect the reasons for it.

Staff Recommendation:

~~Staff recommends a "**YES**" vote, which will result in the **approval** of the modified plan as compliant with the Adopted Findings and **Special Condition 8** and adoption of the motion, resolution, and findings herein. The motion passes only by an affirmative vote of a majority of the Commissioners present. Staff's recommended modifications are provided in Section 1.1 below, and further detailed in Section 4.0 of this memorandum. If these recommended modifications are not incorporated into the Plan, staff recommends the Commission find the Plan, as submitted, does not conform to **Special Condition 8** and staff would therefore recommend the Plan be denied.~~ **Staff recommends a "YES" vote on the motion. Passage of the motion will result in the adoption of revised findings as set forth in this staff report. The motion requires a majority vote of the members from the prevailing side present at the revised findings hearing, with at least three of the prevailing members voting. Only those Commissioners on the prevailing side of the Commission's action are eligible to vote on the revised findings.**

1.1 ~~RECOMMENDED~~ MODIFICATIONS

1) Poseidon shall create or restore ~~between~~ 55**.4** ~~and 68~~ acres of coastal estuarine wetland habitat within the Southern California Bight. **For Phase I, within 10 months of issuance of the desalination facility's coastal development permit (CDP), Poseidon must submit proposed site(s) and a Preliminary Restoration Plan for Commission review and approval. Within two years of issuance of the CDP for the desalination facility, Poseidon must submit a complete CDP application to restore at least 37 acres of estuarine wetlands. For Phase II, within five years of issuance of the CDP for the Phase I restoration, Poseidon must submit a complete CDP application to restore an additional 18.4 acres of estuarine wetlands. Poseidon may apply to do all 55.4 acres of restoration during Phase I. Poseidon may request the Commission reduce or eliminate the Phase II restoration requirement if Poseidon adopts technologies that reduce entrainment levels below currently anticipated levels or undertakes dredging in Agua Hedionda Lagoon in a manner that warrants mitigation credit.**

2) Poseidon shall implement its Marine Life Mitigation Plan in conformity to the conditions provided in Exhibit 2 of ~~this memorandum~~ **these Findings**.

3) Within 60 days of the Commission's approval of this modified Plan, Poseidon shall submit for the Executive Director's review and approval a revised Plan that includes these modifications.

2.0 STANDARD OF REVIEW

The ~~Commission must determine whether the~~ subject plan **must** conform~~s~~ to **Special Condition 8 of CDP E-06-013**, which states:

> *"**Marine Life Mitigation Plan:** PRIOR TO ISSUANCE OF THE PERMIT, the Permittee shall submit to and obtain from the Commission approval of a Marine Life Mitigation Plan (the Plan) that complies with the following:*
>
> *a) Documentation of the project's expected impacts to marine life due to entrainment and impingement caused by the facility's intake of water from Agua Hedionda Lagoon. This requirement can be satisfied by submitting a full copy of the Permittee's Entrainment Study conducted in 2004-2005 for this project.*
> *b) To the maximum extent feasible, the mitigation shall take the form of creation, enhancement, or restoration of aquatic and wetland habitat.*
> *c) Goals, objectives and performance criteria for each of the proposed mitigation sites. It shall identify specific creation, restoration, or enhancement measures that will be used at each site, including grading and planting plans, the timing of the mitigation measures, monitoring that will be implemented to establish baseline conditions and to determine whether the sites are meeting performance criteria. The Plan shall also identify contingency measures that will be implemented should any of the mitigation sites not meet performance criteria.*
> *d) Requires submittals of "as-built" plans for each site and annual monitoring reports for no less than five years or until the sites meet performance criteria.*
> *e) Defines legal mechanism(s) proposed to ensure permanent protection of each site – e.g., conservation easements, deed restriction, or other methods.*
>
> *The Permittee shall comply with the approved Plan. Prior to implementing the Plan, the Permittee shall submit a proposed wetlands restoration project that complies with the Plan in the form of a separate coastal development permit application for the planned wetlands restoration project."*

The Commission's **Permit** Findings supporting **Special Condition 8** state that the Plan is ensure that all project-related entrainment impacts will be fully mitigated and that marine resources and the biological productivity of coastal waters, wetlands, and estuaries, will be enhanced and restored in compliance with Coastal Act Sections 30230 and 30231. The **Permit** Findings further state that the Plan must provide mitigation to the maximum extent feasible through creating, enhancing, or restoring aquatic and wetland habitat and must include acceptable performance standards, monitoring, contingency measures, and legal mechanisms to ensure permanent protection of the proposed mitigation sites.

3.0 PLAN DEVELOPMENT AND REVIEW

On November 15, 2007, the Commission approved CDP No. E-06-013 for Poseidon's proposal to construct and operate a desalination facility in Carlsbad, San Diego County. As part of that approval, the Commission required Poseidon, through **Special Condition 8**, to submit for additional Commission review and approval a Marine Life Mitigation Plan addressing the impacts that will be caused by the facility's use of estuarine water and entrainment of marine organisms.

Since the Commission's project approval in November 2007, staff and Poseidon have worked to develop a Plan that would meet the requirements of ***Special Condition 8*** and would be consistent with the Commission's **Permit** Findings. In March 2008, and as required by ***Special Condition 8***, Poseidon provided a copy of its entrainment study for Commission staff review. Staff provided the study to Dr. Pete Raimondi, an independent scientist with expertise in evaluating entrainment studies, for his review and recommendations (described in more detail in Section 4.0 below).[5] Dr. Raimondi provided the initial results of his review and recommendations to Poseidon in April 2008. In May 2008, staff conducted with Poseidon an interagency meeting with representatives from state and local agencies to determine what mitigation options might be available and feasible for Poseidon to include as part of its Plan.

Attendees include**d** representatives from:

California Department of Fish and Game	City of Carlsbad
California Department of Transportation	City of Vista
California State Lands Commission	U.S. Fish and Wildlife Service
San Diego Regional Water Quality Control Board	

In June 2008, based in part on concerns Poseidon expressed about Dr. Raimondi's review and recommendations, staff asked the Commission's ~~Marine Review Committee (MRC)~~ **Scientific Advisory Panel (SAP)**[6] to review Dr. Raimondi's conclusions and make further recommendations for Poseidon to include in its proposed Plan. The ~~MRC~~ **SAP** review is described in more detail in Section 4.0.

Also in June 2008, staff provided Poseidon a copy of the conditions the Commission had required of Southern California Edison (Edison) for its wetland restoration project at San

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[5] Dr. Raimondi is Professor and Chair of Ecology and Evolutionary Biology at the University of California, Santa Cruz Center for Ocean Health, Long Marine Lab. Dr. Raimondi is considered by many to be California's leading expert on entrainment analysis. He has been a key participant and reviewer of most of the entrainment studies done along the California coast during the past decade, including those done for the Diablo Canyon Nuclear Power Plant, the Huntington Beach Generating Station, Morro Bay Power Plant, and Moss Landing Power Plant. He is also a member of the Coastal Commission's ~~Marine Review Committee~~ **Scientific Advisory Panel (SAP)** responsible for determining mitigation needed for the San Onofre Nuclear Generating Station (SONGS) and providing review and oversight for the SONGS mitigation work at San Dieguito Lagoon.

[6] The ~~Marine Review Committee~~ **SAP** is a team of independent scientists that provides guidance and oversight to the Commission on ecological issues associated with the San Dieguito Restoration Project. That Project is being implemented by Southern California Edison pursuant to requirements of coastal development permits issued by the Commission and is meant to mitigate for marine resources losses caused by the San Onofre Nuclear Generating Station (SONGS). The ~~Marine Review Committee~~ **SAP** consists of ***Dr. Richard Ambrose***, Professor and Director of Environmental Science & Engineering Program, Department of Environmental Health Sciences, University of California Los Angeles; ***Dr. John Dixon***, Senior Ecologist, California Coastal Commission; ***Dr. Mark Page***, Marine Science Institute, University of California at Santa Barbara; ***Dr. Pete Raimondi***, Professor and Chair of Ecology and Evolutionary Biology, University of California at Santa Cruz; ***Dr. Dan Reed***, Marine Science Institute, University of California at Santa Barbara; ***Dr. Steve Schroeter***, Marine Science Institute, University of California at Santa Barbara; and, ***Dr. Russ Schmitt***, Director of Coastal Research Center, University of California at Santa Barbara.

Dieguito Lagoon. Until June, Poseidon had been proposing a site adjacent to Edison's as the best site for its mitigation. Based on the Commission's **Permit** Findings and discussion at the November 2007 hearing, staff recommended to Poseidon that it incorporate modified versions of the Edison conditions into its proposed Plan to ensure the two adjacent mitigation sites would be subject to compatible and consistent mitigation requirements. These conditions are in Exhibit 2.

On July 7, 2008, staff received Poseidon's currently proposed Plan for review by the Commission (see Exhibit 1). On July 14, 2008, staff again consulted with the ~~MRC~~ **SAP** to evaluate changes Poseidon had proposed in this most recent submittal. Poseidon's current proposed Plan, and the results of reviews by staff, Dr. Raimondi, and the ~~MRC~~ **SAP** are described in Section 4.0 below.

4.0 ANALYSIS FOR CONFORMITY TO SPECIAL CONDITION 8

~~Staff's evaluation of the proposed Plan shows that t~~**T**he Plan, as submitted, ~~does~~ **did** not ensure conformity to ***Special Condition 8***. ~~Staff recommends the Plan be modified~~ **The Commission therefore required modifications to the Plan** to address two main areas in which the Plan ~~does not yet~~ **did not** conform to the condition: 1) the adequacy of mitigation proposed in the Plan; and, 2) assurances that the Plan will result in successful mitigation being implemented in a timely manner.

Section 4.1 below describes the submitted Plan's key elements **and the Commission's adopted modifications**. Sections 4.2 and 4.3 evaluate elements of the Plan that ~~staff believes~~ require modification. ~~Staff's recommendations~~ **The modifications** are based on review by staff and by members of the Commission's ~~Marine Review Committee (MRC)~~ **Scientific Advisory Panel (SAP)**, as described in Section 3.0. They also reflect comments received from other agencies, including the U.S. Fish and Wildlife Service and the California State Lands Commission. ~~The discussions below also identify concerns Poseidon expressed about staff's recommendations and staff's response to those concerns. Staff believes its third recommendation~~ **The third modification**, which ~~would~~ require**s** Poseidon to submit a revised Plan that incorporates these modifications, ~~would~~ help**s ensure** ~~the Commission and~~ Poseidon ~~in implementing~~ **implements** the modified Plan.

4.1 PLAN DESCRIPTION

Poseidon's proposed Plan include~~s~~**d** the following main elements:

- **Phased Mitigation Approach:** Poseidon propose~~s~~**d** that it implement necessary mitigation in two phases. Phase I would result in 37 acres of wetland restoration or creation within the Southern California Bight. During this phase, Poseidon would also conduct technology review to determine whether new or developing technologies would be reasonably feasible to reduce entrainment. It would also conduct a new entrainment study ten years after beginning operations to determine whether additional mitigation is needed for the facility's entrainment impacts. Phase I would apply during the time Poseidon's desalination facility operations are concurrent with operations of the power plant's cooling water system.

Phase II would occur if the power plant stops operating or, for three consecutive years, operates at a level that provides less than 15% of the water Poseidon needs to operate the desalination facility (i.e., about 16.6 billion gallons per year)[7]. This amount would be based on the power plant's average water use over any three-year period. Under Phase II, Poseidon would conduct a new entrainment analysis and evaluate potential new technologies, similar to the review described in Phase I. Poseidon would then provide the results of those analyses to the Commission for review. If the Commission determines the analyses show a need for additional mitigation or the evaluations show certain technologies might reduce entrainment impacts, Poseidon would request its Plan be amended to require those changes. If additional mitigation is needed, Poseidon would propose one of the following:

- Assume dredging obligations for Agua Hedionda Lagoon from the power plant and obtain mitigation credit of up to 81 acres of restoration credit for conducting dredging; or,
- Provide additional wetland mitigation of up to 5.5 acres.

- **Suggested Conditions:** ~~The~~ **Poseidon's proposed** Plan include~~s~~**d** suggested conditions that Poseidon would use to implement further studies, evaluate new technologies, select its mitigation site(s), and implement mitigation options. Many of these are modified versions of conditions the Commission required Edison use to implement its mitigation measures for the impacts to marine life from the San Onofre Nuclear Generating Station. These are discussed in Section 4.3 below.

The Commission adopted Poseidon's proposed Plan with a number of modifications, including:

- **Entrainment impacts: The Commission determined that Poseidon's entrainment impacts resulted in a loss of marine organisms equivalent to that produced in a 55.4-acre area of estuarine and nearshore habitat (see Section xx below for details).**

- **Phased mitigation: The Commission required mitigation in up to two phases:**
  - **During Phase I, Poseidon is to create or restore at least 37 acres of coastal estuarine wetland habitat in one or two sites within the Southern California Bight. Within 10 months of issuance of the CDP for the desalination facility, Poseidon is to submit a preliminary site selection and restoration plan for Commission approval, and with 24 months of issuance of that CDP, Poseidon is to submit a complete CDP application for restoration of at least 37 acres of estuarine wetlands. Poseidon may choose to restore the full 55.4 acres of wetlands during Phase I.**

  - **For Phase II, which is to start no later than five years after issuance of the CDP for the Phase I wetland restoration, Poseidon is to submit a complete CDP application to restore an additional 18.4 acres of estuarine wetlands. Alternatively, Poseidon may apply to reduce or eliminate this Phase II restoration requirement by instead**

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[7] Poseidon's average withdrawal of 304 million gallons per day would equal almost 111 billion gallons per year. 15% of that amount is about 16.6 billion gallons, or about 45 million gallons per day.

proposing to adopt technologies that reduce entrainment impacts below currently anticipated levels or by undertaking dredging in Agua Hedionda lagoon in a manner that warrants mitigation credit.

- **Required conditions: Poseidon is to implement its Marine Life Mitigation Plan as modified by the Commission and in conformity to the conditions provided in Exhibit 2 of this memorandum. Those modifications require Poseidon to submit within sixty days of the Commission's August 6, 2008 approval a revised Plan that includes all required conditions and modifications for the Executive Director's review and approval.**

4.2 ANALYSIS – ADEQUACY OF MITIGATION

This section evaluates the following elements of Poseidon's proposed Plan:

Section 4.2.1: Analysis of Poseidon's entrainment study
Section 4.2.2: Determining the mitigation needed to address identified impacts
Section 4.2.3: Analysis of Poseidon's phased approach
Section 4.2.4: Analysis of dredging as proposed mitigation

4.2.1 Analysis of Poseidon's Entrainment Study

Special Condition 8 required Poseidon to submit its entrainment study for Commission staff review. In March 2008, Poseidon submitted data and modeling results from its study. The study was conducted using the Empirical Transport Model (ETM), which is used to identify the level of adverse effect caused by entrainment. The model compares the portion of a population at risk of entrainment to the portion of that population actually entrained. It calculates this proportional mortality for each of the main species subject to entrainment, and uses the source water area of each species – that is, the total volume or area of water in which species are at risk of being entrained – to calculate the Area of Production Foregone (APF), which provides an estimate of the average area of habitat that would be needed to produce the organisms lost to entrainment. As shown below, this APF provides the basis for determining the amount of mitigation needed to address entrainment impacts.

As described in Section 3 above, staff provided Poseidon's data and study results to Dr. Raimondi for review. In reviewing the study, Dr. Raimondi concluded the following:

- **Adequacy of Study:** Dr. Raimondi found that, as submitted, Poseidon's study could not be evaluated for its technical merits or its estimates of impacts. However, by reviewing additional relevant Poseidon documents and documents from the associated power plant's entrainment study, and by working with the consultants that had conducted Poseidon's study (Tenera Consultants), Dr. Raimondi was able to determine that the study's sampling and data collection methods were consistent with those used in other recent studies conducted in California pursuant to the protocols and guidelines used by the U.S. EPA, Regional Water Quality Control Boards, California Energy Commission, and Coastal Commission.

  Dr. Raimondi also found that the study provided adequate data to determine the types and numbers of organisms that would be subject to entrainment and to determine the area of the source water bodies – that is, the area of Agua Hedionda and nearshore ocean waters where entrainable organisms would be subject to entrainment. The study identified a source water area within Agua Hedionda of 302 acres and a nearshore source water area of about 22,000 acres. Poseidon's calculations were generally consistent with those used in other recent studies, although the calculations Poseidon used to determine its source water areas differed from those used in other recent studies to reflect the tidal exchange between Agua Hedionda Lagoon and the nearshore ocean environment.

Determining the Effects of Poseidon's Entrainment: Poseidon concluded that the entrainment caused by 302 MGD of water withdrawal by the desalination facility would result in an Area of Production Foregone (APF) of 37 acres in Agua Hedionda Lagoon. Dr. Raimondi's review revealed that Poseidon's APF calculation was accurate, albeit at the 50% confidence level – that is, the 37-acre APF represented the area for which the study could assure at least 50% confidence that the area reflected the full extent of Poseidon's entrainment impacts in the Lagoon. This calculation is based on applying standard statistical techniques to the error rates Poseidon generated in its study. Dr. Raimondi also used those error rates to calculate APFs at the 80% and 95% confidence levels – that is, the number of acres for which the area of full entrainment impacts could be described with at least 80% or 95% confidence. This resulted in APFs of 49 and 61 acres, respectively.

Poseidon's study did not include an APF for the area of nearshore ocean waters that would be affected by entrainment; therefore, using Poseidon's data, Dr. Raimondi calculated an APF for the entrainment effects Poseidon would cause in these nearshore waters. At the same 50%, 80%, and 95% confidence levels, the APFs would be 55, 64, and 72 acres, respectively. The APFs for both source water areas and each confidence level are shown in Table 1 below.

Table 1: APF Totals

Source water areas:	**APF (in acres) at three levels of confidence:**		
	50%	***80%***	***95%***
Estuarine: 302 acres of source water	37	49	61
Nearshore: 22,000 acres of source water	55	64	72
Total APF	**92 acres**	**113 acres**	**133 acres**

Poseidon raised a number of concerns with staff's and Dr. Raimondi's review (see Exhibit B of the MLMP). In response, and to supplement Dr. Raimondi's review, Commission staff requested that the ~~MRC~~ **SAP** assess the review and respond to Poseidon's concerns.

Poseidon stated its study made a number of conservative assumptions that result in an overestimate of the mitigation needed**.** ~~and that t~~**T**hose ~~conservative~~ assumptions**, and the SAP's response,** include:

- *The study overestimated the number of larvae in the lagoon and assumed a greater amount of entrainable larvae than are actually present.* In response, Dr. Raimondi and the ~~MRC~~ **SAP** noted that this type of study is based on actual sampling data, not estimates. The data reviewed were those Poseidon provided from its sampling efforts, so there should be no overestimate or assumption of a greater number of larvae than were actually sampled. If Poseidon believes the data are incorrect, that would suggest either that the raw data should be re-evaluated or the study should be run again. Further, if Poseidon's contention were true – that is, if the study overstated the number of larvae in the Lagoon – this would result in a higher APF and would therefore result in a need for *more* mitigation.[8]

- *The study assumes the project will render all affected acreage (i.e., the APF) non-functional, even though that acreage would only be partially affected and would continue to allow numerous other species to function*. In response, the ~~MRC~~ **SAP** reiterated that these entrainment studies do not assume the complete loss of ecosystem function within an area of APF; instead, they identify only the area that would be needed to replace the numbers and types of species identified in the study as subject to entrainment. The APF is used to determine impacts to only those species most affected by entrainment, and the mitigation resulting from the APF is meant to account only for those effects.

- *The study protocols assume 100% mortality for entrained organisms; however, Poseidon believes actual mortality will be significantly lower. Poseidon also contends that it should be required to provide less mitigation based on its contention of a lower mortality rate.* In response, the ~~MRC~~ **SAP** noted that the protocols used in these entrainment studies include an assumption of 100% mortality based on guidance from the U.S. EPA and reflecting the practice of California's State and Regional Water Boards, the California Energy Commission, and the Coastal Commission in conducting and evaluating these studies. This assumption applies to these studies regardless of the type of intake and discharge system being evaluated. For example, although each power plant or desalination facility may use different water volumes, have different and variable water velocities and levels of turbulence, use different types of screens, pumps, and other equipment, and draw in a different mix of organisms, all entrainment studies similar to Poseidon's have used this same 100% mortality rate. Further, there are no peer-reviewed scientific studies that support using a lower mortality rate for different types of power plant or desalination systems that cause entrainment. In the case of Poseidon's desalination facility, entrained organisms will be subject to a number of stressors – including high pressures, significant changes in salinity, possible high temperature differences if the power plant is operating, etc. – and they will then be discharged to a different environment than is found in Agua Hedionda. Any one or a combination of these stressors could result in mortality.

  Poseidon's proposed phased mitigation approach, which is based in part on its contention of lower mortality rates, is evaluated in more detail below. One element of this approach, however, is that Poseidon states it might use alternative screening systems to reduce

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[8] To provide a simple example, the APF is based in part on proportional mortality, which is the ratio of the number of organisms entrained compared to those at risk of being entrained. Assuming the number of entrained organisms remains the same, the fewer organisms in the Lagoon, the higher the proportion of those organisms entrained – therefore, Poseidon's contention results in a higher proportional impact area.

entrainment or entrainment mortality. ~~However, staff considers this only speculative at this time, and notes that screening systems that have been tested for reducing entrainment have not been found effective in the marine environment. The current scientific understanding is that entrainment impacts are based on an assumption of 100% mortality of organisms present in the full volume of water drawn into an intake system, and that is the basis of the analysis herein.~~ **Pursuant to the Commission's action, if Poseidon proposes to adopt alternative technologies that would reduce entrainment, it may apply for reduced mitigation requirements as part of its Phase II CDP application.**

Based on the above, and on the reviews conducted by Dr. Raimondi and the SAP, the Commission concurs with the conclusions of the scientific reviews showing that the facility's expected entrainment impacts result in the above-referenced APFs and incorporates those conclusions into its approval of the Plan.

4.2.2 Determining the mitigation needed to address identified impacts

The APFs generated from the study and shown in Table 1 identify the extent of expected entrainment impacts, and also serve as the basis for identifying the type and amount of mitigation needed to address those impacts. Past entrainment studies have generally used the 50% confidence level APF as the basis for mitigation and applied a mitigation ratio (e.g., 1:1, 2:1, 3:1, etc.) to compensate for mitigation occurring at a distance from the affected area, to reflect a temporal loss of habitat functions caused by the impact, to reflect mitigation that provides a different type of habitat than the affected area, or other concerns. This option is described briefly later in this Section.

For this review, however, Dr. Raimondi provided an alternative approach to determine the amount of mitigation needed, based on two main assumptions:

- First, that any mitigation provided would be in the form of restored habitat similar to the types of habitat that produced or supported the affected entrained organisms – that is, that mitigation would consist of tidally-influence salt marsh or shallow water areas similar to those found in Agua Hedionda Lagoon.

- Second, that the mitigation provided would be fully successful – that is, the mitigation site would provide fully functioning habitat that would meet required performance standards, contingency plans, etc., required for such projects to ensure success. This was based on an additional assumption – that Poseidon would be providing mitigation at a site in San Dieguito Lagoon adjacent to Edison's restoration site and would be subject to the same conditions the Commission required of Edison. Dr. Raimondi and the ~~MRC~~ **SAP** believe the conditions required of Edison provide a high level of certainty that Edison's restoration efforts will be successful and that they would provide a similar level of certainty for Poseidon's mitigation at this location.

Using the above assumptions, and using the APF figures noted above, Dr. Raimondi concluded with at least 50% confidence that creating or restoring 37 acres of suitable and fully functioning estuarine habitat would fully replace the lost productivity of Agua Hedionda Lagoon, that 49 acres would be needed to provide an 80% level of certainty, and that 61 acres would be needed to reach a 95% level of certainty. By applying the same approach to the nearshore APFs, Dr.

Raimondi concluded that creating or restoring 55 acres of open water habitat would be needed to provide at least 50% certainty that that entrainment effects in that source water area would be fully mitigated, that 64 acres were needed to provide 80% certainty, and 72 acres would provide 95% certainty. However, in recognition of the impracticality of creating 55 to 72 acres of offshore open water habitat and recognizing the relatively greater productivity rates per acre of estuarine wetland habitats, Dr. Raimondi suggested that these offshore impacts be "converted" to estuarine mitigation areas. That is, by assuming that successfully restored wetland habitat would be ten times more productive than a similar area of nearshore ocean waters, every ten acres of nearshore impacts could be mitigated by creating or restoring one acre of estuarine habitat.[9] Applying this 10:1 ratio to the nearshore APFs results in 5.5, 6.4, and 7.2 acres, respectively. Although this approach would result in "out of kind" mitigation, it is also expected to produce overall better mitigation – not only is it not practicable to create nearshore, open water habitat, that habitat type is already well-represented along the shoreline, whereas creating or restoring coastal estuarine habitat types would support a long-recognized need to increase the amount of those habitat types in Southern California.[10] These totals are shown Table 2 below.

Table 2: Adjusted APF Totals

Habitat Type	**APF (in acres) at three levels of confidence**			**Conversion ratio**	**Resulting APF (in acres) at three levels of confidence**		
	50%	***80%***	***95%***		***50%***	***80%***	***95%***
Estuarine	37	49	61	1:1	37	49	61
Nearshore	55	64	72	10:1	5.5	6.4	7.2
Total Mitigation					**42.5**	**55.4**	**68.2**

In sum, Dr. Raimondi concluded that creating 55.4 to 68.2 acres of fully functioning estuarine habitat similar to habitat in Agua Hedionda Lagoon would provide between 80 to 95% confidence that Poseidon's entrainment impacts would be fully mitigated. This conclusion is also based on Poseidon's mitigation being subject to conditions similar to Edison's, which is discussed in more detail in Section 4.2.3 below.

Poseidon contends that ~~Dr. Raimondi's~~ **staff's** recommendation to apply an 80-95% level of certainty for mitigation is "extraordinary and unprecedented" and would result in excess mitigation for the project's expected impacts. In response, Dr. Raimondi and the ~~MRC~~ **SAP** state that ~~the confidence levels used are based on the error rates Poseidon calculated as part of its study, and generating these calculations is a standard practice for this type of entrainment study~~ **considering uncertainty is a standard practice in data analysis and that such consideration provides a context for understanding the likelihood that a particular amount of mitigation will provide full compensation for identified impacts. Staff notes that Poseidon's entrainment study included error rates that Dr. Raimondi used initially to calculate a higher estuarine APF of 87 acres at the 80% confidence level. Dr. Raimondi then used a**

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[9] This approach – converting offshore entrainment impacts to areas of wetland mitigation – has been used to help determine mitigation in several recent California power plant siting cases, including Huntington Beach (00-AFC-13), Morro Bay (00-AFC-12), and others.

[10] See, for example, the Southern California Wetlands Recovery Project at http://www.scwrp.org/index.htm

different error rate, which he considered more appropriate for this study, to calculate an APF of 49 acres at the 80% confidence level.[11]

Dr. Raimondi's recommendation of using the 80-95% confidence level is "unprecedented" only in that past studies have used the 50% confidence level **to describe the expected impact** and then applied a mitigation ratio, such as 2:1 or 3:1, to reflect the lower confidence level**,** ~~and~~ to include consideration of mitigation that may be "out of kind"**,** ~~or~~ provided at some distance from the affected area**, or may not be fully successful**. Dr. Raimondi's proposal, as supported by the ~~MRC~~ **SAP** and Commission staff, would actually result in less mitigation acreage than that standard mitigation approach, but it would have higher certainty of success.

~~Staff recognizes that the Commission could apply a mitigation ratio to the identified level of impact, consistent with past mitigation determinations for wetland impacts. For example, applying a 2:1 ratio to the 50% 42.5 acre total APF would yield 85 acres of restored coastal wetland habitat, and applying a 3:1 ratio would yield 127.5 acres of habitat. If the Commission selects this approach, staff believes these ratios would be appropriate minimums to apply to reflect that the Plan does not identify specific mitigation sites and the site(s) selected could be more than a hundred miles from the impact site at and near Agua Hedionda.~~

~~However, as described previously, Commission staff believes that Dr. Raimondi's proposed approach of creating 55.4 to 68.2 acres would be an adequate and preferable approach – if Poseidon's proposed Plan is also modified to include staff's other recommended modifications, including the one described in the next section of this memorandum.~~

Based on the discussion above and on the record, the Commisison finds that requiring 55.4 acres of estuarine wetland restoration in the Southern California Bight subject to the conditions provided in Exhibit 2 provides a sufficient degree of certainty that the facility's entrainment impacts will be mitigated and brings the Plan into conformity to Special Condition 8 and the Coastal Act's marine life protection policies.

4.2.3 Analysis of Proposed Mitigation Phasing

As noted above, Poseidon's Plan includes a proposed phased approach to mitigation, which would be based on changes in power plant operations or possible changes in technology. **Because of the possibility that Poseidon might in the future adopt technologies that reduce entrainment and because of uncertainty regarding future power plant operations, the Commission finds that it is appropriate to allow phasing of the mitigation. For the first phase, Poseidon must submit within two years of the issuance of the CDP for the desalination facility a complete CDP application for wetland restoration of at least 37 acres. Poseidon may apply during Phase I to implement the entire 55.4 acres of wetland restoration. For the second phase, Poseidon must within five years of issuance of the Phase I CDP submit a complete CDP application to restore the additional 18.4 acres of restoration. As part of its Phase II application, Poseidon may request the Commission**

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[11] Poseidon's study included error rates based on source water sampling, which Dr. Raimondi believed were unreasonably high. He instead calculated an error rate based on the proportional mortality of each species being an independent replicate, which he believes better meshes with the logic behind the use of the APF to determine impacts.

reduce or eliminate the amount of required restoration if Poseidon adopts technologies that result in reduced entrainment or if, as explained below, Poseidon performs dredging in Agua Hedionda Lagoon in a manner that warrants mitigation credit. ~~For several reasons, staff recommends the Commission not accept this aspect of the Plan and instead require a specific type and amount of mitigation as described above. The entrainment impacts described in the Commission's Findings were based on Poseidon application to withdraw 304 million gallons per day of estuarine water to operate its desalination facility, and staff recommends the Commission use this as the basis for its decision on the amount of mitigation needed to address this impact.~~

~~Staff believes this phasing approach is speculative in that it is tied to unknown future operations of the power plant. Additionally, information in the record shows that the power plant owner expects to replace the existing power plant within the next few years and to operate the existing plant only at very low levels or on a back-up basis until it is no longer needed to support the regional electrical power grid. More recently, the power plant owner announced that it would consider constructing its own desalination facility to provide water for its proposed new power plant. If built, this facility would use only about one percent of the water Poseidon proposes to use, and so would likely have a relatively minor affect on the overall mitigation needed to adequately address the impacts of both facilities.~~

~~Staff also believes that tying Poseidon's mitigation to power plant operations would be inappropriate for purposes of the coastal development permit and the Commission's Findings. Poseidon's coastal development permit application did not include the power plant owner as a co-applicant, and the Commission has made no determinations about how the power plant should or may operate.~~

4.2.4 Analysis of dredging as project mitigation

~~Similarly, staff recommends the Commission not approve Poseidon's proposal to allow it to use as mitigation during Phase II the dredging activities now being conducted by the power plant owner.~~ Poseidon proposes a formula by which it could obtain up to 81 acres of credit for conducting dredging in Agua Hedionda Lagoon. **The Commission does not accept this formula because it currently does not have sufficient information to evaluate the purpose, nature, or extent of potential dredging, or whether Poseidon would be able to conduct the proposed dredging. It is possible, however, that Poseidon might carry out future dredging in a manner that warrants mitigation credit. Poseidon may therefore apply as part of its Phase II mitigation CDP application for a reduction in restoration requirements in exchange for mitigation credits that the Commission may consider for Poseidon's dredging activities.** ~~However, the Commission has not considered dredging in and of itself to be mitigation. Dredging that the power plant has conducted in the past has been done to maintain its intake channel, and similarly, Poseidon's main purpose for dredging would be to maintain that channel. The Commission has considered habitat benefits resulting from dredging for that primary purpose as merely incidental to the primary purpose of the dredging activities rather than mitigation. Had those dredging activities instead been considered mitigation, the power plant owner may have been required to continue dredging to maintain the area of mitigation, regardless of the need for an intake structure.~~

~~Further, as noted in the Findings, the power plant owner also owns the Lagoon and has expressed its intentions to maintain the Lagoon for the foreseeable future. Additionally, the power plant owner is not a permit co-applicant with Poseidon, and the permit record includes no agreement between Poseidon and the owner regarding dredging, so staff believes it would not be appropriate for the Commission to approve a plan that may create an expectation that Poseidon would take on these activities on the owner's property without landowner approval.~~

~~As Poseidon notes in its Plan, the Commission accepted as part of Edison's San Dieguito restoration project a commitment by Edison to maintain the San Dieguito tidal inlet in an open condition in perpetuity. However, in that instance, dredging was necessary for that project to support the more than 100 acres of restored tidal wetlands Edison had created as a substantial portion of the mitigation required pursuant to its SONGS coastal development permit. The Commission's acceptance of that mitigation element was also based on multiple years of study by the MRC, whose recommendation the Commission used in its decision. The MRC has not made a similar recommendation for Poseidon's proposal. Further, Poseidon has not proposed mitigation within Agua Hedionda that would require dredging.~~

~~Finally, Poseidon's proposal would not meet the provision of **Special Condition 8** requiring mitigation to be in the form of creation, enhancement, or restoration of aquatic and wetland habitat, to the maximum extent feasible. As noted above, there are wetland mitigation opportunities within the Southern California Bight well in excess of the amount needed to mitigate for this project's impacts, and Poseidon has not shown that it would be infeasible to provide the required type of mitigation.~~

4.3 ANALYSIS – ASSURANCE THAT MITIGATION WILL SUCCEED

Until recently, Poseidon had proposed that it provide wetland restoration at a site in San Dieguito Lagoon, adjacent to Edison's restoration project. Review by staff, Dr. Raimondi, and the ~~MRC~~ **SAP** had been based on determining whether that site would provide suitable mitigation. In April 2008, Dr. Raimondi concluded that Poseidon's proposed San Dieguito site would likely provide suitable habitat for the losses of estuarine larvae at Agua Hedionda if the restored habitat was similar to the habitat affected at Agua Hedionda. In June 2008, Dr. Raimondi and the ~~MRC~~ **SAP** also concluded that the San Dieguito site would also provide at least partial mitigation for some species affected in Poseidon's nearshore impact area. Also in June, staff provided Poseidon with a modified version of the conditions the Commission required Edison to meet for conducting its site selection, construction, monitoring, and other aspects of its restoration plan, and recommended that Poseidon include these conditions as part of its proposed Plan. These are provided in Exhibit 2.

~~Since then,~~ **Several weeks before the August 2008 hearing,** Poseidon altered its Plan so that San Dieguito ~~is~~ **was** no longer necessarily Poseidon's preferred site. The Plan instead proposes that Poseidon select a site or sites somewhere within the Southern California Bight that meet conditions shown in Sections 3.1 and 3.2 of the Plan. Those conditions include**d** further modifications to the conditions staff provided in June.

Staff asked the ~~MRC~~ **SAP** to review Poseidon's two proposed changes – that is, its proposal to consider sites other than San Dieguito and the modifications in its Plan to staff's previously recommended conditions. Regarding, staff's proposed conditions, the ~~MRC~~ **SAP** believes those conditions – i.e., Exhibit 2 – would generally provide adequate assurance of success for a restoration project to be implemented in most coastal estuarine areas of Southern California, although a higher degree of assurance would result if specific sites were identified. The ~~MRC~~ **SAP** also determined that the changes Poseidon proposed to staff's conditions and included in its Plan would result in lesser mitigation standards than those required of Edison and would not provide equal assurance of mitigation success. The changes Poseidon proposed include the following:[12]

- Staff recommended that Poseidon submit a complete coastal development permit application for its Final Restoration Plan within 24 months of Commission approval of its Preliminary Plan (i.e., the Plan being reviewed herein). Poseidon **proposed** modif~~ied~~**ying** that recommendation in Section 4 of its Plan to allow submittal of that application either 24 months after issuance of the project coastal development permit or commencement of commercial operations of the desalination facility, whichever is later. This could substantially delay the implementation of mitigation and could result in several years of impacts occurring without mitigation.
- A proposed change to Poseidon's Plan at Section 3.1(d) and at Section 3.2(c) would reduce the required buffer zone at its mitigation sites from no less than 100 feet wide to an average that could **be** much less than 100 feet.
- ~~A proposed change at Section 3.1(i) would allow the Plan to affect endangered species in a way not allowed under the Edison requirements.~~
- Poseidon proposes to change Section 3.3(c) to allow mitigation to occur in up to four sites, rather than up to two sites, as required of Edison, which could fragment the mitigation and reduce its overall value.
- ~~Poseidon also proposed deleting a requirement at Section 5.4 that would require a designed tidal prism be maintained to ensure the wetland mitigation site has adequate tidal action.~~
- ~~Poseidon proposes that any fees it pays for coastal development permits or amendments be credited against the budget needed to implement the mitigation plan.~~

Staff and the ~~MRC~~ **SAP** reviewed these proposed changes and believe they would result in inadequate assurance that successful mitigation would be conducted in a timely manner. ~~Staff's recommendation, therefore, is~~ **The Commission finds** that the Plan be modified to include the conditions in Exhibit 2.

CONCLUSION

The Commission finds that, as modified as described above and with the conditions in Exhibit 2, the Marine Life Mitigation Plan complies with *Special Condition 8* and the marine life protection policies of the Coastal Act.

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[12] For a full comparison, see Section 3 of Poseidon's Plan and Exhibit 2 showing staff's originally recommended conditions.

Attachment 6

Salinity Measurement for Water Quality Monitoring,

Ms. Melissa Carter, M.S., Reinhard Flick, Ph.D., August 14, 2014

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14 August 2014

SALINITY MEASUREMENT FOR WATER QUALITY MONITORING

Mr. Jonathon P. Loveland
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Dear Mr. Loveland:

In response to your request for our expert opinion concerning the definition and measurement of salinity, specifically as applied to the water quality monitoring of a desalination facility, we provide the following recommendation and the analysis that supports this approach. We recommend that salinity be defined and determined as:

> SALINITY is a measure of the dissolved salts in a volume of water. Salinity should be measured using electrical conductivity and reported as the Practical Salinity per PSS-78. Other measures of salinity, including Absolute Salinity as defined per TEOS-10 (in g/kg), salinity as reflected in total dissolved solids measurements (in mg/L), or the sum of the major anions and cations (chloride, sulfate, bicarbonate, bromide, sodium, magnesium, calcium, and potassium, in mg/L) may also be collected and reported to determine proper correlations with PSS-78 salinity measurements.

The concepts of the Practical Salinity Scale, 1978 (PSS-78), Equation of State, 1980 (EOS-80), and the International Thermodynamic Equation of Seawater (TEOS-10) are described below. These reflect the evolution of thought in the oceanographic community on the properties of seawater and the most accurate means to define salinity that has been underway since the early 1900s. For this reason, the application and measurements based on these definitions must be considered. At the present time, the latest TEOS-10 standards recommend salinity to be measured by electrical conductivity and reported as Practical Salinity per PSS-78 in order to maintain continuity with historical measurements.[1]

Traditionally, salinity has been defined as "the total amount of solid materials in grams contained in one kilogram of seawater when all the carbonate has been converted to oxide, the bromine and iodine replaced by chlorine and all organic matter completely oxidized."[2] Salinity units of g/km are expressed as parts per thousand (ppt). Direct determination of salinity according to this definition requires a laboratory evaporation process that is first of all too difficult for routine or continuous monitoring application, and secondly is prone to errors from incomplete drying or sample re-absorption of water.

For these reasons, the more accurate and faster chloride titration method was developed by chemists in the early 1900's to determine "chlorinity" that could then be related to "salinity" empirically.[3] Titration techniques still required laboratory analysis and therefore were not practical for continuous measurement. The modern accurate and practical method of salinity measurement is based on the electrical conductivity of the conservative ionic constituents of seawater. These account for 99.8% of all dissolved material typically in seawater. This led to the Practical Salinity Scale formalized in PSS-78, which has been the standard since 1978, and the revised equation of state (EOS-80).[4, 5, 6] All direct measurements of salinity, chlorinity, and conductivity are based on assumptions about the chemical composition of seawater and reference seawater standards.

The most recent standards for oceanographic salinity, TEOS-10, describes seawater thermodynamics and the concepts of Absolute Salinity and Reference Salinity as they relate to Practical Salinity. The main purpose of TEOS-10 is to provide a better determination of water density, which is the key variable that determines ocean circulation. It also accounts for thermodynamic and heat capacity changes in seawater associated with freshwater content and CO_2 and other gas concentrations.

Absolute Salinity is defined as the mass fraction of dissolved material in seawater, whereas Practical Salinity is a function of the total concentration of the dissolved, inorganic ions (chloride, sulfate, sodium, magnesium, calcium, and potassium). The major difference between these two parameters is that Absolute Salinity more accurately defines the density of seawater since it accounts for all its dissolved constituents. However, at present there are discrepancies in the algorithms to calculate Absolute Salinity, especially in non-standard waters such as estuaries and hydrothermal vents. For this reason, TEOS-10 advises continuing the measurements and reporting of Practical Salinity to national databases of oceanographic data, and the inclusion of density measurements, while Absolute Salinity should be used in scientific journal articles.[1]

For the purposes of monitoring desalination facility water quality and consistency in reporting, grab samples and continuous in-situ measurements should be made using electrical conductivity methods and follow guidelines of the Practical Salinity Scale (PSS-78) within the range of $2 < S_p$ <42. Samples exceeding 42 must be diluted with distilled water to the valid salinity range and adjusted based on water mass added and the conservation of sea salt during the dilution process. Verification of seawater composition and the ratio of these constituents may be necessary to ensure that proportions of conservative ions, specifically KCl, are preserved and the standard calibration seawater are valid for desalination waters.

Conductivity is an accurate direct measure of ionized salt concentration in seawater. Therefore, the use of a conductivity-based salinity measurement protocol for monitoring desalination water quality is further supported if the biggest toxicity concern is osmotic stress from brine discharge.

References:

1 IOC, SCOR and IAPSO (2010). *The international thermodynamic equation of seawater – 2010: Calculation and use of thermodynamic properties*. Intergovernmental Oceanographic Commission, Manuals and Guides No.56, UNESCO, 196 pp.

2 Pickard, G. L. (1963). *Descriptive Physical Oceanography*, Oxford: Pergamon Press LTD., 200 pp.

3 Yoder, L. (1919). Adaptation of the Mohr Volumetric Method to General Determinations of Chlorine." *Industrial & Engineering Chemistry* 11 (8), 755.

4 Unesco (1981). The Practical Salinity Scale 1978 and the International Equation of State of Seawater 1980. *Tech. Pap. Mar. Sci.*, 36

5 Lewis, E. L. (1980). The Practical Salinity Scale and its antecedents. *Journal of Oceanic Engineering*, 5 (1), 3-8.

6 Libes, S. M. (1992). *An Introduction to Marine Biogeochemistry*. New York: John Wiley and Sons, Incorporated, 736 pp.

We would be pleased to provide any further information you may need, or to answer any questions that you may have regarding our findings and recommendation. Our contact information is provided above.

Respectfully,

Melissa Carter, M.S.

Reinhard E. Flick, Ph.D.

Attachment 7

Historical Analysis of Salinity for
Desalination Water Quality Monitoring,

Ms. Melissa Carter, M.S., Reinhard Flick, Ph.D., August 18, 2014

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DRAFT - HISTORICAL ANALYSIS OF SALINITY FOR WATER QUALITY MONITORING

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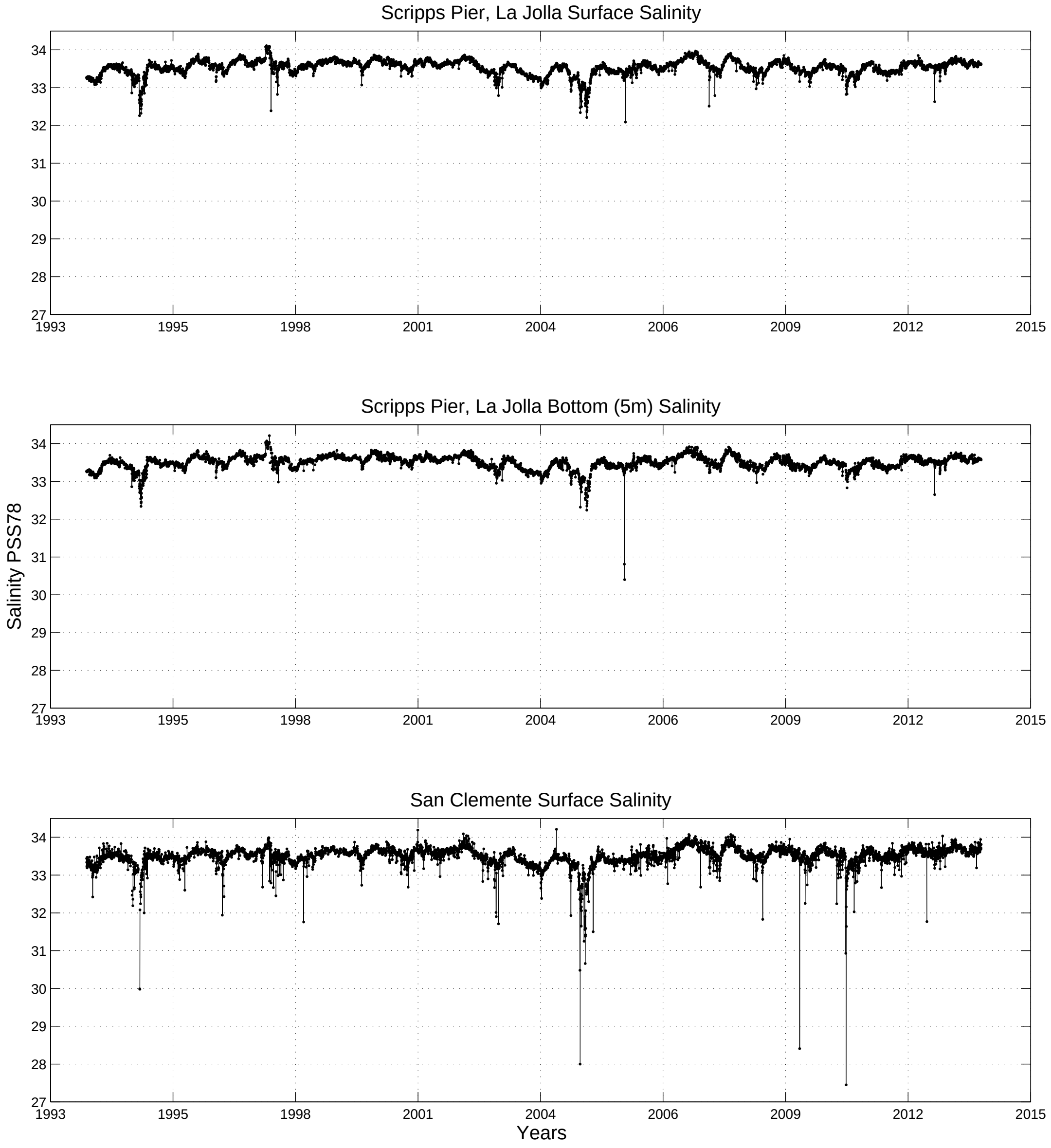
Historical analysis of salinity measurements at two coastal stations, Scripps Pier, La Jolla and San Clemente Pier, San Clemente, and 66 offshore stations, within the southern California region, are used to describe the background salinity conditions during the last 20 years, 1994 to 2013, with respect to two desalination facilities at Carlsbad and Huntington Beach, California. All salinity data discussed herein were measured using electrical conductivity of water samples and reported as Practical Salinity per PSS-78. Historical data from the coastal sites are part of the Shore Stations Program, http://shorestation.ucsd.edu/, a 98 year time series of daily temperature and salinity measurements collected using grab samples since 1916 at Scripps Pier and 49 year time series at San Clemente Pier, since 1965. Offshore stations are part of the California Cooperative Fisheries Investigation, http://calcofi.org/, a long-term time series of quarterly measurements of one meter temperature, salinity and other related oceanographic parameters collected since 1949.

Coastal salinity measurements range between 27.45 and 34.21 (PSS-78) with average salinity at 33.50 to 33.54 (Figure 1, Table 1). In general, both coastal stations show similar patterns in

Figure 1. Daily salinity measurements for the last 20 years (1994-2013) at Scripps Pier surface, Scripps Pier bottom (5m) and San Clemente surface.



salinity variations over the last 20 years, with higher salinity values occurring in summer months when evaporation and temperature are highest, versus fall and winter months when rainfall events decrease surface water salinity and the low salinity California Current moves closer to shore. Low salinity periods are generally short-lived, days to week long events, and are lower at the San Clemente Pier station due to a greater number of freshwaters sources along this portion of the coast. Statistics that encompass the entire time-series for each coastal station show a slight reduction in mean salinity values over time, though salinity measurements remain fairly consistent over the last 40 to 98 years (Table 2).

Table 1. Statistics of daily salinity measurements for the last 20 years (1994-2013) at Scripps Pier (SIO) surface, Scripps Pier bottom (5m) and San Clemente (SC) surface.

	Mean	Median	Standard Deviation	Maximum	Minimum	N
SIO surface	33.54	33.56	0.19	34.11	32.09	6732
SIO 5m	33.50	33.52	0.18	34.21	30.40	6417
SC surface	33.50	33.53	0.27	34.21	27.45	6631

Table 2. Statistics of daily salinity measurements over entire time series at Scripps Pier (SIO) surface (August 1916 – February 2014), Scripps Pier bottom (5m, July 1926 – February 2014), and San Clemente (SC) surface (July 1965 – January 2014).

	Mean	Median	Standard Deviation	Maximum	Minimum	N
SIO surface	33.58	33.60	0.18	34.86	29.64	34149
SIO 5m	33.56	33.58	0.17	34.33	30.40	30059
SC surface	33.53	33.56	0.33	34.89	19.15	16422

Long-term seasonal means of offshore CalCOFI stations, shown in Figure 2, provide a regional perspective of salinity over the last 30 years. Highest salinity values are found inshore during spring and summer within the Southern California Bight due to coastal and isopycnal upwelling, while stations roughly 100-200 km offshore are generally lower due to the influence of the low salinity waters of the California Current. Low standard deviations of salinity (0.1 to 0.2 PSS-78) for both coastal and regional stations for most the year provide an indication of the uniformity of salinity measurements throughout the Southern California Bight (Tables 1-2 and Figure 3).

Pearson's linear correlations between the raw daily salinity measurements of Scripps Pier surface, Scripps Pier bottom and San Clemente surface salinity measurements show significant and strong correlations between these three time-series indicating the high similarity between these three stations. Scripps Pier surface and bottom are highly correlated at R = 0.93, while significant correlations between Scripps Pier surface and San Clemente are R = 0.72, and Scripps Pier bottom and San Clemente are R= 0.70. A more robust statistical study of regional salinity found that Scripps Pier is an excellent proxy for CalCOFI stations (years 1963-2004) with correlations of R = 0.80.[1] Furthermore, salinity and density measurements were in high agreement in the long shore direction than offshore, and decadal variability dominates the salinity variance over time with changes on the order of 0.2 (PSU).[2] Overall, mean coastal conditions at Scripps Pier and San Clemente represent regional salinity variations within the Southern California Bight.

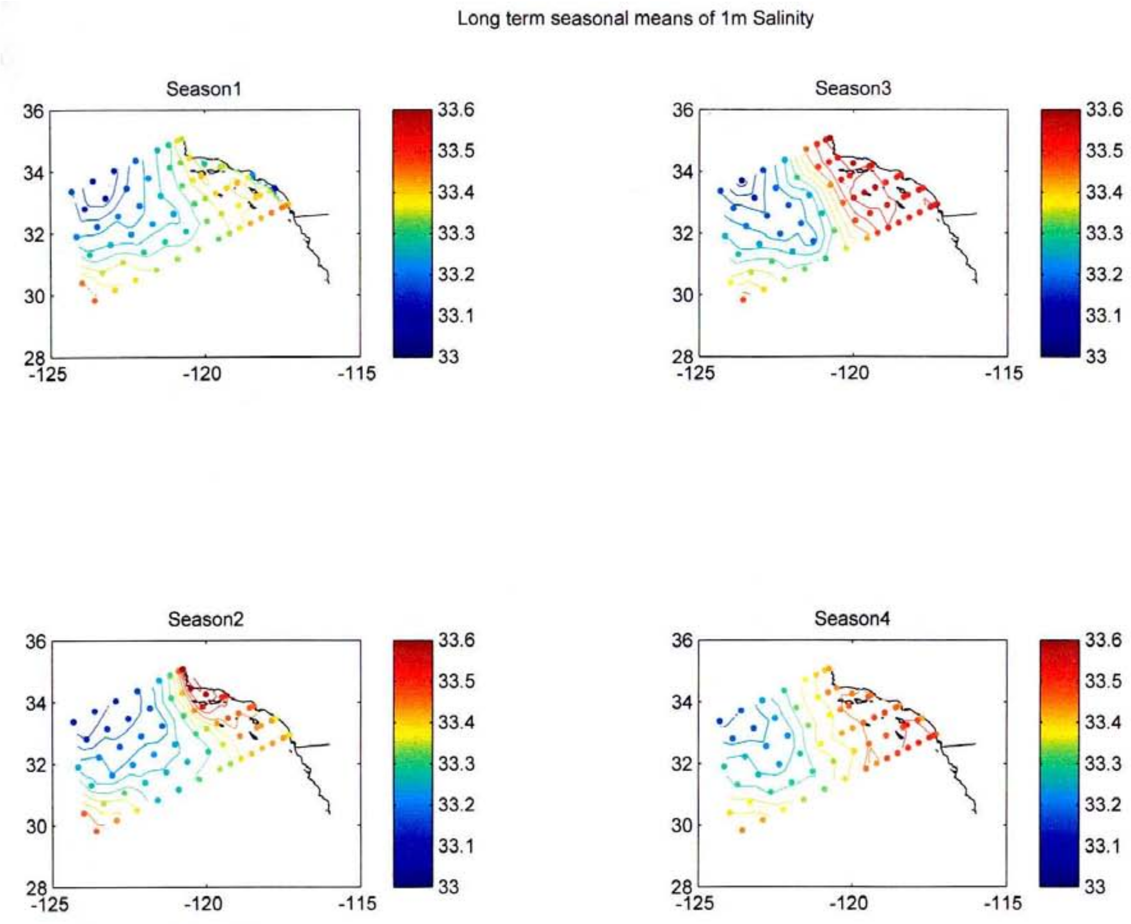


Figure 2. Long-term seasonal means of California Cooperative Fisheries Investigation (CalCOFI) salinity measurements at one meter averaged over years 1984 to 2006. Season 1: December to February (top left), season 2: March to May (bottom right), season 3: June to August (top right), season 4: September to November (bottom right).

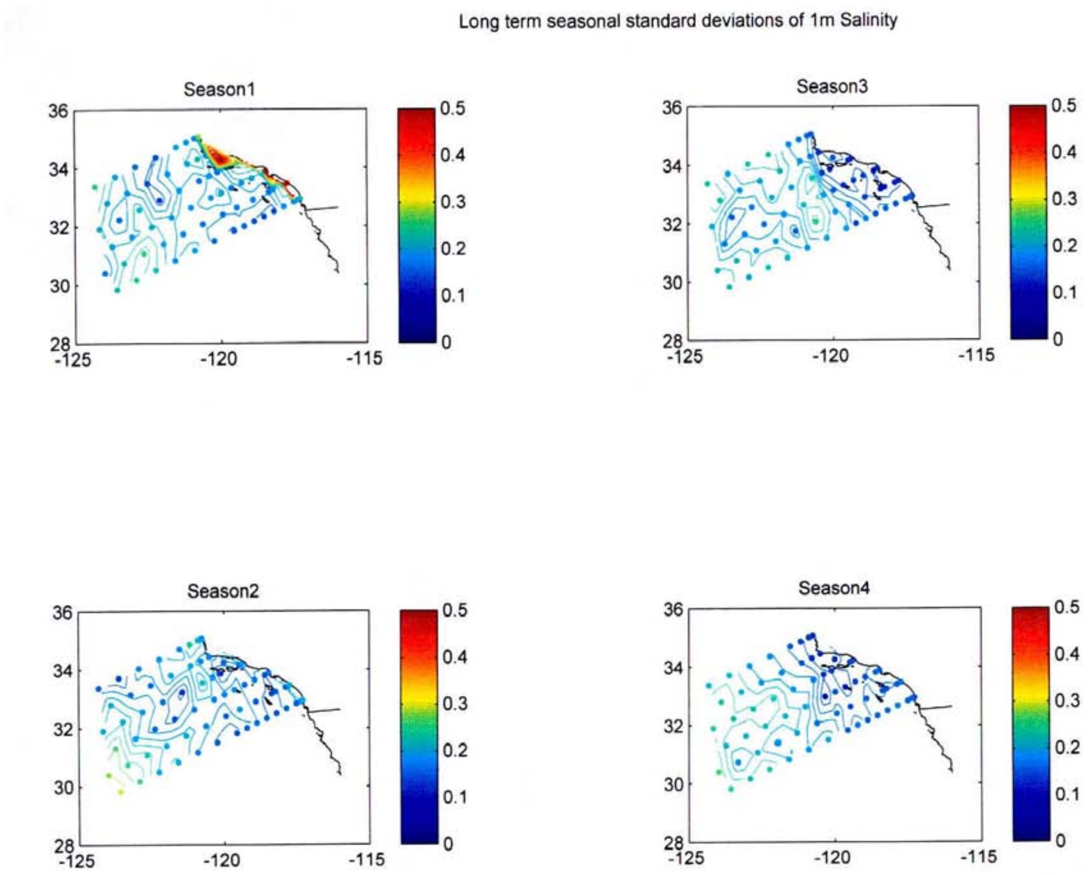


Figure 3. Long-term standard deviation of California Cooperative Fisheries Investigation (CalCOFI) salinity measurements at one meter determined for years 1984 to 2006. Season 1: December to February (top left), season 2: March to May (bottom right), season 3: June to August (top right), season 4: September to November (bottom right).

Cumulative distribution curves of salinity measurements over the last 20 years are shown in Figure 4 to evaluate the percent of time salinity values are greater than mean conditions of 33.5 (PSS-78). For Scripps Pier surface measurements, the percent of time above 33.5 (PSS-78) salinity occurred 62.9% of the time, 54.5% for Scripps Pier bottom, and 55.8% for San Clemente surface (Table 3). The percent of time above 33.55 (PSS-78) salinity occurred 51.6% of the time for Scripps Pier surface, 41.1% for Scripps Pier bottom, and 44.5% for San Clemente surface measurements. In general, all locations have salinity measurements above 33.55 for at least 40% of the time and only rare instances of salinity above 33.8 (PSS-78).

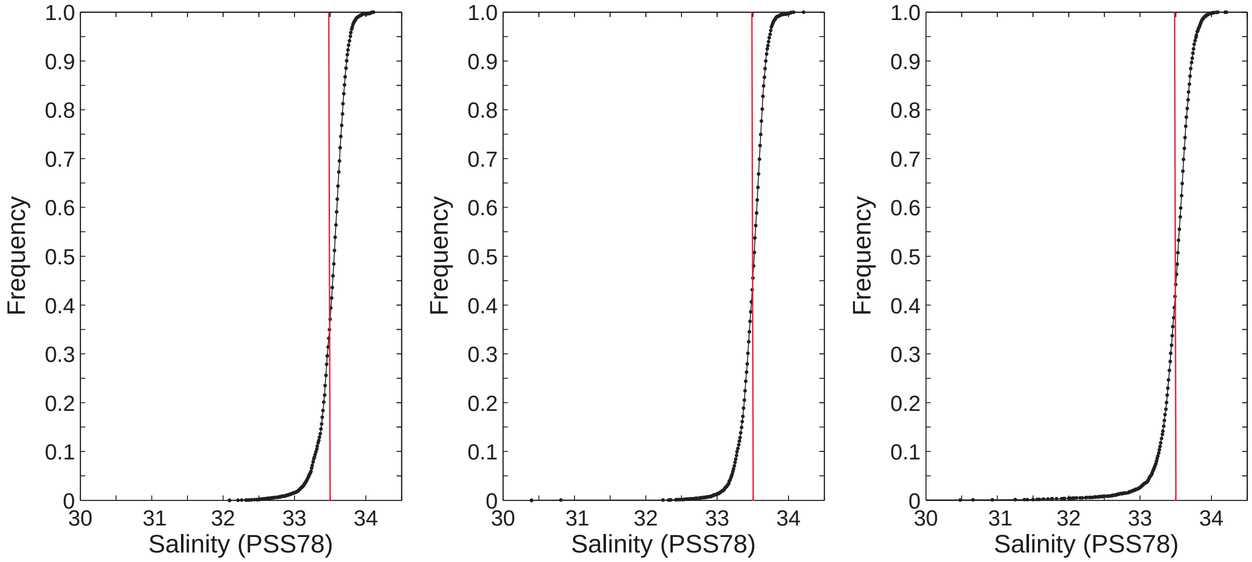


Figure 4. Cumulative distribution of daily salinity measurements for 20 years (1994 - 2013) grouped by location: Scripps Pier, surface (left), Scripps Pier, 5m bottom (center), San Clemente, surface (right). Red line indicates salinity of 33.5 PSS-78.

Table 3. Percent of daily salinity measurements over 33.5 salinity for the last 20 years (1994-2013) at Scripps Pier (SIO) surface, Scripps Pier bottom (5m), and San Clemente (SC) surface.

	% over 33.5	% over 33.6	% over 33.7	% over 33.8	% over 33.9	% over 34
SIO surface	62.9	38.3	14.9	3.5	0.9	0.4
SIO 5m	54.5	27.3	7.51	1.6	0.6	0.3
SC surface	55.8	32.6	13.1	4.0	1.1	0.2

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1. Di Lorenzo E., Fiechter J., Schneider N., Miller A. J., Franks P. J. S., Bograd S. J., Moore A. M., Thomas A., Crawford W. and Pena and Herman A. (2009). Nutrient and Salinity Decadal Variations in the central and eastern North Pacific. *Geophysical Research Letters*, doi:10.1029/2009GL038261.
2. Schneider, N., E. Di Lorenzo, and P. Niiler (2005). Salinity variations in the California Current. *Journal of Physical Oceanography*, 35 (8), 1421-1436.

Respectfully,

Melissa Carter, M.S.

Reinhard E. Flick, Ph.D.

Attachment 8

Investigations of Fish Entrainment By Archimedes and Internal Helical Pumps at the Red Bluff Research Pumping Plant, Sacramento River, California: February 1997 – June 1998,

Sandra Borthwick, Richard Corwin, Charles Liston, October 1999

INVESTIGATIONS OF FISH ENTRAINMENT BY ARCHIMEDES AND INTERNAL HELICAL PUMPS AT THE RED BLUFF RESEARCH PUMPING PLANT, SACRAMENTO RIVER, CALIFORNIA: FEBRUARY 1997 - JUNE 1998

Annual Report
Red Bluff Research Pumping Plant
Report Series: Volume 7

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Disclaimer

The correct citation for this report is:

Borthwick, S.M., R. R. Corwin, and C.R. Liston. 1999. Investigations of fish entrainment by Archimedes and internal helical pumps at the Red Bluff Research Pumping Plant, Sacramento River, California: February 1997 - June 1998. Red Bluff Research Pumping Plant Report Series, Volume 7. U.S. Bureau of Reclamation, Denver, CO.

INVESTIGATIONS OF FISH ENTRAINMENT BY ARCHIMEDES AND INTERNAL HELICAL PUMPS AT THE RED BLUFF RESEARCH PUMPING PLANT, SACRAMENTO RIVER, CALIFORNIA: FEBRUARY 1997 - JUNE 1998

Annual Report

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Abstract. The overall goal of the Red Bluff Research Pumping Plant program is to determine whether Archimedes and/or internal helical pumps can be used to deliver water to canals without harming fish inhabiting the Sacramento River. This report contains results of entrainment monitoring of fish from the Sacramento River during February 1997 through June 1998. Objectives addressed include: determining if differences exist in numbers, species, survival and injury of fish entrained into each of the two types of pumps; and estimating the number of juvenile chinook salmon in each of the four Sacramento River salmon runs entrained annually into the pumps.

Twenty-nine species of fish, 16 native to the Sacramento River, were captured during entrainment monitoring. Juvenile chinook salmon was the most frequently entrained species followed by prickly sculpin, lamprey, Sacramento sucker, Sacramento pikeminnow, and threespine stickleback. These six species comprised 95% of the 17,530 fish entrained. Nearly 90% of the entrained chinook were fall run. Seasonal patterns of chinook salmon entrainment followed those of chinook abundance in the river. Assessment of diel patterns of entrainment revealed that 81% of chinook were entrained at night. This has important implications for pump operations. If it becomes necessary to decrease the number of chinook entrained, a substantial reduction could be made by pumping only during the day.

Ninety-two percent of entrained fish were <100 mm in length. Most chinook salmon (84%) were less than 40 mm fork length. The lowest median fork length for chinook salmon occurred September through October, and December through February reflecting the outmigration of winter and fall chinook fry, respectively.

Because the plant was operated for biological evaluations during all seasons, the number of fish entrained during this study was higher than would occur if the plant were used only for delivering water. Sixty-five percent of the chinook entrained were collected during trials

conducted in December and January, months that the plant would not operate if functioning for water deliveries. The winter of 1997-1998 was wet so the peak of fall chinook outmigration occurred during the winter months and relatively few remained to be vulnerable to spring pumping. In a dry winter, however, spring entrainment rates would be expected to be relatively high since the peak outmigration of fall chinook would be delayed until spring, coinciding with high water demands and continuous pumping.

During this study, 24-hr trials were conducted simultaneously with the U. S. Fish and Wildlife Service's rotary-screw trap sampling to determine the proportion of chinook salmon in the river entrained into the pumping plant during different seasons of the year. Preliminary data from October through December 1997 reveal that the upper estimate of the percentage of riverine chinook entrained into the plant ranged from approximately 0.05 to 0.60. This is well below the the 1.5 to 5.5 percent that was predicted based upon the assumption that chinook are entrained in proportion to the amount of flow diverted into the plant. The low entrainment rate is likely due to the plant intakes being positioned near the bottom of the river whereas the majority of outmigrating chinook salmon inhabit the upper water column.

The number of fish entrained into Archimedes 2 was significantly greater than the number entrained into Archimedes 1 or the internal helical pump, which were not different. Survival of chinook recovered from the holding tanks was 98% for each of the Archimedes pumps and 94% for the internal helical pump. Survival of fish other than chinook was 95% for the Archimedes pumps and 94% for the helical pump. The differences in survival among pumps was not statistically significant for chinook or other species. Percent survival values should not be interpreted strictly as pump passage survival. Captured fish also passed a screening facility, traveled curved bypass channels, up a dewatering ramp, and were routed into a tank where they were held with debris and other fish for up to 14 hours. Factors besides pump passage could affect the survival of entrained fish collected from the holding tanks.

Considering all three pumps, mortality of chinook salmon entrained into the RPP was 3%, and the percentage with sublethal injuries was 2.1. This 5.1 percent mortality and injury is less than anticipated by the Biological Opinion (National Marine Fisheries Service 1993) for the Archimedes pumps (10%) or the internal helical pump (>10%, even as high as 90%). Delayed mortality of chinook was also low, less than or equal to 1 percent for each of the pumps.

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Introduction

Construction of Red Bluff Research Pumping Plant (RPP) was completed in May 1995. The plant is located at river kilometer 391 (river mile 243) on the southwest bank of the Sacramento River just downstream of Red Bluff Diversion Dam (Figure 1). The plant was constructed as a research facility to determine whether two types of experimental pumps could provide water to the Tehama-Colusa and Corning canals without harming fish inhabiting the Sacramento River. Liston and Johnson (1992b) cite 32 species of fish that could be entrained from the river into the RPP. Of particular concern is chinook salmon *Oncorhynchus tshawytscha*. The Sacramento River is unique in supporting four runs of chinook salmon (fall, late-fall, winter, and spring) which are named for the season when the majority of adults enter the river to begin their upstream spawning migration (Vogel and Marine 1991). Populations of all four runs have decreased since the late 1960's although winter chinook have experienced the most dramatic decline (Johnson et al. 1992, Yoshiyama et al. 1998). This prompted the listing of winter chinook as endangered by California in 1989 and by the federal government in 1994.[1] Other runs have also been listed or are proposed for listing.[2] Steelhead *Oncorhynchus mykiss*, another native salmonid in the Sacramento River, was federally listed as threatened in March 1998.[3]

Due to their declining populations, the primary focus of this study has been on monitoring entrainment of juveniles of the four runs of chinook salmon and steelhead. Juvenile chinook salmon migrate past the RPP in each month of the year (Vogel and Marine, 1991). The number of chinook salmon and steelhead entrained into the plant depends upon the water year and the quantity of water requested by users during periods when gates at Red Bluff Diversion Dam (RBDD) are raised. Gates are lowered from May 15 to September 15 creating Lake Red Bluff which allows Sacramento River water to be gravity fed to the canal headworks. Gates are raised from September 15 to May 15; however, water is still needed by irrigators and wildlife refuges during spring and fall months. Therefore, the RPP typically is operated for water deliveries to the canals in the spring (mid-Feb - May 15) and fall (September 15 - October 31) when Lake Red Bluff is dewatered.

Vogel et al. (1988) provide information that can be used to predict seasonal patterns of entrainment of juvenile chinook in wet and dry years. In a wet year approximately 85% of the total annual juvenile out-migration past the RPP occurred during December through March when river discharges were 1133 m^3/s (40,000 ft^3/s) to 2266 m^3/s (80,000 ft^3/s) and reached a

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[1] Winter chinook was listed as endangered by California in 1989 (California Code of Regulations, Title XIV, Section 670.5), and by the federal government in 1994 (National Marine Fisheries Service; 59 FR 440).

[2] Spring chinook was listed as threatened by California in August 1998 (California Code of Regulations, Title XIV, Section 670.5); spring and fall chinook currently are proposed for federal listing (63 FR 11481).

[3] Steelhead was federally listed as threatened in March 1998 (63 FR 13347).

maximum of 3540 m^3/s (125,000 ft^3/s). Most of the juveniles moving at this time of year were small, fall chinook <50 mm fork length. In a dry year when discharges were typically <425 m^3/s (<15,000 ft^3/s) and occasionally peaked at 566 m^3/s (20,000 ft^3/s) during December through June, the annual peak out-migration of fall chinook was delayed until April through June. Juveniles moving at this time of year were large, 60 - 110 mm fork length. Therefore, it could be predicted that in a wet year most juvenile fall chinook would migrate past RBDD before water demands were high and pumping began; therefore, numbers of chinook entrained would be low. In contrast, during a dry year numbers entrained would be higher due to frequent pumping from April through May 15 coinciding with the peak out-migration of juvenile fall chinook. Numbers of out-migrants were consistently low, typically <1 million per month, during July through November (Vogel et al.1988). Therefore, it could be predicted that numbers entrained into the plant would be low.

The goal of this study is to quantify entrainment of juvenile chinook salmon and other species of fish into the RPP during different seasons of the year. Results of the study will be used to help determine whether Archimedes and/or internal helical pumps can operate satisfactorily with minimal harm to fish in the Sacramento River. If the pumps prove benign, their use would continue to facilitate gates-raised operation of RBDD from mid-September to mid-May with the potential for construction of a larger pumping facility that could deliver water to meet needs year-round.

Specific objectives for this study are to:

1. Record rates of entrainment, mortality and injury for chinook salmon and other species of fish entrained from the Sacramento River by Archimedes and internal helical pumps during different seasons of the year.

2. Compare differences in mortality and injury due to passage through the Archimedes versus the internal helical pump.

3. Estimate the number of individuals in each of the four runs of chinook salmon entrained annually by Archimedes and internal helical pumps.

4. Estimate percentages of each of the four runs of juvenile chinook passing Red Bluff that could be entrained annually into the RPP.

This report addresses the first three objectives. The fourth objective is tightly linked to a companion study entitled *Abundance and seasonal, spatial and diel distribution patterns of juvenile salmonids passing the Red Bluff Diversion Dam, Sacramento River, California.* The study is being conducted by personnel of the U.S. Fish and Wildlife Service (USFWS), Northern Central Valley Fish and Wildlife Office in Red Bluff using rotary screw-traps to estimate abundance and distribution patterns of each of the four runs of juvenile chinook salmon and steelhead passing RBDD. Screw-trap sampling and entrainment trials are conducted simultaneously to estimate the proportion of outmigrating juvenile chinook in each of the four runs that are entrained into the pumping plant. Data collection on this objective is on-going; results of this cooperative effort will be reported in a separate document.

Methods

Plant Operations

The Archimedes and internal helical pumps operated intermittently and entrainment trials were conducted opportunistically during 1995 and 1996, while mechanical modifications were made to pumps, screening facilities, and fish bypasses (McNabb et. al, 1998). By February 1997 mechanical problems with the Archimedes pumps were resolved, and they operated reliably throughout this study. This allowed entrainment trials to be conducted more regularly than in the past and throughout the year to assess seasonal entrainment patterns. The internal helical pump was down for modifications and repairs from mid-July through mid-September 1997 and May through June 1998. None of the pumps operated from January 8 - March 8 1998 due to high river discharges.

During each entrainment trial, pumps operated at full speed for 24 hours beginning at sunrise. Each Archimedes pump operated at 26.5 rpm and delivered an average of 2.5 m^3/s (89 to 90 ft^3/s); the internal helical pump operated at 378 rpm and delivered an average of 2.7 m^3/s (96 ft^3/s). The goal was to operate all three pumps simultaneously to allow numbers entrained and survival and injury of fish to be compared among pumps while operated under similar environmental conditions. Due to mechanical problems with the internal helical pump, however, most trials were conducted using only the two Archimedes pumps.

During a trial, dewatering ramps were lowered and the weir beneath the ramp was adjusted to divert approximately 0.02 m^3/s (0.7 ft^3/s) of flow up the ramp and into one of the two holding tanks (McNabb et al.1998). Fish and debris contained in the bypass flows were also diverted into the holding tanks. The 1.2 m square holding tanks contain water to a depth of 0.9 m when full. They operated as a flow-through system with the water in a tank turning over approximately every 1.2 minutes, discharging into the bypass channel. At these flows, ambient river water quality and relatively non-turbulent conditions were maintained in the holding tanks.

Numbers and Characteristics of Entrained Fish

Fish captured in holding tanks during trials were identified to species, measured (fork length for salmonids, total length for others) to the nearest 1.0 mm, assessed for survival and injury, and inspected for tags, fin clips, or dyes that designate them as hatchery-released fish or as fish from other studies. Injury assessment involved visually inspecting each fish for abnormalities to the integument, eyes, head, and fins. Run membership for chinook salmon was determined from a daily fork-length table generated by Green (1992). On the rare occasion when high numbers of juvenile chinook were entrained, the first 100 chinook removed from each holding tank were processed. Additional chinook were counted and recorded as extra dead or extra alive. For other species, the first 30 fish from each holding tank were processed and the remainder counted and recorded as extra dead or alive. After processing, fish were returned to the river via the bypass conduits that exit the pumping plant into the Sacramento River or released directly into the river downstream of the pump intakes. Each time the holding tanks were cleared of fish, debris was removed and measured volumetrically (cc) using displacement of water in a graduated 20 l bucket.

Larval fish <30 mm length were frequently observed in the holding tanks, especially during spring trials. These fish were not efficiently retained because of the relatively large mesh-size (3.2 mm, 1/8 in) of nets used to trap fish in the tanks. Therefore, data on fish <30 mm are not reported here. Numbers and patterns of larval fish entrainment are being assessed in a separate study under Objective N of the RPP evaluation program (Liston and Johnson 1992a).

Environmental Data

Various data were collected at each sunrise and sunset inspection of the holding tanks. River elevation (ft), and speed (hz) and discharge (cfs) of each pump were recorded from control panels within the plant. Water temperature, dissolved oxygen, and total gases were measured from water passing through the holding tanks. Water temperature and dissolved oxygen were measured using a YSI® Model 55 dissolved oxygen meter. Total gases were measured using a Sweeney® Model DS1-A saturometer. Water turbidity was measured with an HF Scientific® continuously monitoring turbidimeter located in the river water fish facility. A HydroLab® DataSonde water quality monitoring probe was deployed in the river on the east side of RBDD to provide hourly measurements of water temperature, dissolved oxygen, conductivity, and pH. Meteorological data, including precipitation, irradiance in the visible portion of the solar spectrum, wind speed and direction, barometric pressure, and air temperature were continuously collected at the project weather station. Estimates of daily river discharge (m^3/s;ft^3/s) past RBDD was provided by Reclamation Operations and Maintenance personnel using data collected at the U. S. Geological Survey's gaging station located near Bend Bridge approximately 24 km upstream.

Rates and Patterns of Entrainment

Data from all entrainment trials, regardless of the number of pumps operated or the length of time they operated, were used to determine seasonal rates of entrainment and diel patterns of entrainment. To assess diel patterns of entrainment, the holding tanks were inspected at sunset and again at sunrise the following day. Times for sunrise and sunset were obtained from the web-site of the U. S. Naval Observatory in Bethesda, Maryland using the coordinates of latitude and longitude for Red Bluff.

Start and end time of each sunrise to sunset and sunset to sunrise monitoring period was recorded. Data on total time monitored along with pump discharge allowed calculation of acre-feet of water pumped during each entrainment trial. Entrainment rates of chinook salmon and other species were estimated for each month as the quotient of the number of chinook salmon entrained divided by the total acre-feet of water pumped during entrainment trials. This data was used to assess seasonal patterns of fish entrainment into the plant.

Estimated Numbers of Fish Entrained

In general, during July 1 - March 31 when juvenile winter chinook may be present in the river near the RPP, two 24-hr trials were conducted each week the pumps operated continuously (i.e., 24 hrs each day). This typically occurred in the spring (March) and fall (September 15 - October 31) when the gates at RBDD were raised yet water was required for agriculture and refuges. At times of the year when pumps were not operated continuously or juvenile winter chinook were not present (April - June), one entrainment trial was conducted each week. These trials were used as samples to estimate, on a weekly basis, the number of chinook in each of the four runs that could be entrained into the pumps. This was done by calculating the number of chinook entrained per hour and multiplying it by the number of hours the pumps operated during the week. Weekly estimates of entrainment were also calculated for steelhead/rainbow trout.

During the period of this study, approximately 26 million juvenile fall chinook were released into Battle Creek from Coleman National Fish Hatchery 56 km upstream of the RPP. Of these, approximately 2 million were coded-wire tagged and adipose fin-clipped resulting in a ratio of 0.083 marked to unmarked fish. This ratio varied somewhat with each release. The ratio from the most recent release was used to estimate the number of hatchery-produced and naturally-produced chinook salmon entrained into the RPP each week. The number of hatchery-produced chinook entrained into the RPP was estimated as the quotient of the number of adipose-clipped fish entrained divided by the ratio of marked to unmarked fish released from Coleman Hatchery. The number of naturally-produced chinook was calculated as the difference between the total number of chinook entrained and the estimated number of hatchery-produced chinook.

Number, Survival, and Injuries of Entrained Fish Compared Among Pumps

Only data from entrainment trials conducted when all three pumps operated simultaneously for 24 hrs were used to compare numbers of fish entrained, and survival and injuries of fish among pumps. This ensured that fish were collected when the three pumps operated under the same water quality and weather conditions, factors which could affect the numbers and condition of entrained fish. The number and survival of fish, by species, entrained into each pump was tabulated and combined for all simultaneous trials. Analysis of variance was used to determine whether numbers entrained or survival differed among pumps for chinook salmon and for all other fish. Injuries were tabulated by type for chinook and all other fish and compared among pumps.

Comparing survival between the two Archimedes pumps was not an objective of this study. During periods when the internal helical pump was inoperable, however, trials were continued using the two Archimedes pumps. Forty-five 24-hr trials were conducted when the two Archimedes pumps operated simultaneously providing an expanded database for assessing numbers and survival of wild fish passed through the Archimedes pumps. This data was tabulated and compared between the two pumps.

Delayed Mortality of Entrained Chinook Salmon

Objective B of the RPP evaluation program is to determine survival and injury to chinook salmon passed through the pumps (Liston and Johnson 1992a). Experiments are conducted using hatchery-reared juvenile chinook salmon as surrogates for wild chinook. Attempts are made to conduct pump passage experiments using *small* (<45mm) and *large* (≥45mm) chinook. After chinook are passed through a pump and collected from a holding tank, they are held in live cages in the river water fish facility for 96 hrs to assess delayed mortality (McNabb et al. 1998). During the period covered in this report, few pump passage experiments were conducted comparing survival of *small* chinook passed through the Archimedes and internal helical pump. Periods when small fish were available from Coleman National Fish Hatchery coincided with periods when the internal helical pump was down for repairs. Therefore, to gain information on delayed mortality of small chinook passed through the two types of pumps, small, wild chinook salmon collected during entrainment trials were held in live cages in the river water fish facility and their survival assessed after 96 hours. Fish collections were not always from simultaneous trials so results are not directly comparable among pumps. A description of the river water fish facility in which the chinook were held can be found in McNabb et al. 1998.

Results

Plant Operations

The study period began with relatively high river discharges in early February 1997 (Figure 2). Rains subsided, however, and discharges decreased to 141 - 425 m^3/s (5,000 - 15,000 ft^3/s) through most of the year. Infrequent storms in late November and December resulted in discharges exceeding 480 m^3/s (17,000 ft^3/s) for short periods. January and February 1998 were very wet with flows frequently between 1020 and 2719 m^3/s (36,000 and 96,000 ft^3/s), peaking near 4276 m^3/s (151,000 ft^3/s) on February 3. Intermittent high flows continued through June. High flows caused the plant to be inoperable from early January through February, mid-to late March and again in mid-May. The proportion of river discharge pumped by the RPP was typically 3 to 4 percent during the low flow spring of 1997 (Figure 2). In contrast, during the high flow spring of 1998, the percent of river flow pumped decreased to 1 to 2 percent. During the study, the percent of river flow pumped was lowest in the spring of 1998 (<1 percent) and highest in late fall (>5 percent) when river flows were typically their lowest.

Information on speed, discharge, and operating time of each pump during this study is provided in Table 1. Both Archimedes pumps were operational except when high river discharges prohibited pumping. Fish entrainment was monitored 27 to 29 percent of the time the Archimedes pumps operated. Forty-nine 24-hr trials were conducted with Archimedes 1 and 52 with Archimedes 2; 45 trials were conducted when both Archimedes pumps operated simultaneously. Due to mechanical problems, the internal helical pump operated for approximately 1500 fewer hours than either of the Archimedes pumps. Entrainment was monitored 30% of the operating time, and thirty-five 24-hr entrainment trials were conducted. Twenty-four 24-hr trials were conducted when all three pumps operated simultaneously allowing survival and injury of fish to be compared among pumps when operated under similar environmental conditions.

Numbers and Characteristics of Entrained Fish

Twenty-nine species of fish were captured during entrainment trials (Table 2). Sixteen species were native to the Sacramento River. Seven species had not been captured during previous entrainment trials. Chinook salmon was the most frequently entrained species followed by prickly sculpin *Cottus asper*, lamprey *Lampetra* spp., Sacramento sucker *Catostomus occidentalis*, Sacramento pikeminnow *Ptychocheilus grandis*, and threespine stickleback *Gasterosteus aculeatus*. These six species comprised 95% of the 17,530 fish captured during entrainment trials.

Ammocoetes comprised 97% of the captured lamprey. The number of ammocoetes entrained was much higher than in previous years (McNabb et al. 1998) due to the pumps operating during all seasons. Fifty-five percent of the ammocoetes were entrained during two trials conducted in late November, a month when trials previously had not been conducted. During these two trials, it appeared that high river flows dislodged ammocoetes from the substrate. Ninety-three percent of the adult lamprey entrained were Pacific lamprey; adults of river and Pacific brook lamprey were entrained less frequently.

Run composition of chinook was 89.3% fall, 6.2% winter, 3.2% spring, and 1.3% late-fall (Table 3). It should be noted that the period covered in this report includes fall and late-fall chinook from brood years 1996 and 1997; winter and spring chinook are from brood year 1997.

Ninety-two percent of fish entrained into the plant were <100 mm in length. Length distributions of the four most frequently entrained species are shown in Figure 3. The majority of chinook salmon (84%) captured were less than 40 mm fork length. Lamprey ammocoetes were all less than 150 mm total length. Total lengths of prickly sculpin were fairly normally distributed with 70% in the 40 to 80 mm range. Most of the entrained Sacramento suckers (56%) were 30-50 mm. The fish most frequently entrained with individuals ≥100 mm in length were lamprey, Sacramento sucker, prickly sculpin, and Sacramento pikeminnow. Of the 97 metamorphosed Pacific lamprey entrained, 76% were greater than 200 mm total length; the remainder were 100 to 140 mm.

The lowest median fork length (mm) for chinook salmon occurred September through October and December through mid-March reflecting the outmigration of winter and fall chinook fry, respectively (Figure 4). The influence of hatchery-released smolts on median fork-length is apparent in April of each year as fork length rises sharply then decreases in May as smolts migrate past Red Bluff. The minimum fork-length was less than 40 mm for most weeks that entrainment was monitored. Maximum fork-length varied widely from week to week, but was typically greater than 60 mm.

Environmental Data

Mean daily water temperatures and dissolved oxygen levels in the Sacramento River during entrainment trials are shown in Figure 5. Mean water temperatures ranged from near 15°C in September and October to less than 7°C in early January. Mean dissolved oxygen values (percent saturation) were typically between 75 and 100 percent. Temperature and dissolved oxygen values measured in the holding tanks were similar to values from the river. Levels of total gases (percent saturation) in the holding tanks were typically between 101 and 104.

Rates and Patterns of Entrainment

The entrainment rate of chinook salmon was less than 0.3 chinook per acrefoot for every month except December and January when the rate increased to 1.3 and 3.4, respectively (Figure 6). This peak corresponded with the fall chinook out-migration. The acre-feet of water pumped in a 24-hr period was approximately 179, 357, and 535 when 1, 2, or 3 pumps were operating, respectively. Figure 7 shows the actual number of chinook salmon entrained per 24 hours of pump operation during each month of this study. The entrainment rate exhibited a seasonal trend being lowest in summer, highest in winter, and intermediate in spring and fall (Figures 6 and 7). Sampling effort varied throughout the year and was highest in the fall when pumps were operated continuously to provide water to the canals and juvenile winter chinook were outmigrating (Figure 6).

The entrainment rate of all fish ranged from 0.1 to 1.4 fish per acre-foot except in January when it reached 3.6. Outmigrating fall chinook comprised the majority (95 percent) of fish entrained in December and January (Figure 6). Chinook salmon comprised the majority of fish entrained in every season except summer when prickly sculpin was the most frequently entrained species. Entrainment rates and patterns of other commonly entrained species is shown in Figure 8.

There was no apparent relationship between entrainment rate and river discharge or turbidity (Figure 9). The greatest factor influencing chinook entrainment rate appeared to be the abundance of chinook in the river. That is, rates were highest in winter during the fall chinook outmigration with small spikes occurring in spring when fall chinook were released from Coleman National Fish Hatchery. A relationship may emerge if entrainment monitoring was conducted more frequently.

The diel entrainment pattern was similar to 1995-1996 with the majority of chinook (81percent) and all other fish (86percent) entrained at night (Table 4). The percent of chinook entrained at night was similar for fall, spring and late-fall chinook; it was somewhat higher for winter chinook. Bluegill and threespine stickleback were the only two frequently captured species that were fairly evenly entrained day and night. This is consistent with previous years' data (McNabb et al. 1998).

Estimated Numbers of Fish Entrained

An objective of this study is to estimate the number of chinook salmon entrained into the RPP. Appendix 1 provides weekly data on the actual number of chinook salmon and steelhead/rainbow trout sampled during entrainment trials and their estimated number entrained based upon the weekly entrainment rate and hours of pump operation. Fall chinook are categorized as naturally or hatchery produced. Figure 10 summarizes this data for the entire reporting period with all pumps combined. Because fall, late-fall, and winter chinook were entrained during periods when the pumps were regularly used to provide water to the canals, the estimated number entrained was much higher than the actual number sampled. In contrast, spring chinook were entrained in the winter when the pumps were operated primarily for entrainment trials. The actual number of chinook sampled and the estimated number entrained into the pumps during this period were 6,523 and 12,432, respectively.

During spring and fall, the estimated number of chinook entrained far exceeded the actual number sampled because the pump hours were high and the proportion of time entrainment was monitored was low. In contrast, during summer and winter the actual number sampled and estimated number entrained were similar because pump hours were low and the proportion of time entrainment was monitored was high (Figure 11).

Differences in pumping regimes and numbers of chinook entrained in a wet versus a dry spring were observed during this study (Figure 11). Spring of 1997 was very dry requiring frequent use of the RPP to provide water to the canals. Therefore, estimated numbers of chinook entrained far exceeded the actual number sampled during entrainment trials. In contrast, the spring of 1998 was very wet with infrequent use of the RPP; pumps were used primarily for entrainment monitoring so estimated number and number sampled are less disparate than in 1997.

Number, Survival, and Injuries of Entrained Fish Compared Among Pumps

Comparisons Among the Three Pumps

Twenty-four 24-hr trials were conducted with all three pumps operating simultaneously. Differences between patterns of entrainment for chinook and all other fish were observed (Table 5). Most juvenile chinook were entrained into Archimedes 2 (54%), followed by Archimedes 1 (28%), and the internal helical pump (18%). In contrast, for fish other than chinook, Archimedes 1 entrained the greatest number (40%) followed by the internal helical pump (33%), and Archimedes 2 (27%) with the fewest fish. Archimedes 2 appears to have a propensity for entraining fish inhabiting the upper water column, and entrains fewer benthic fish. This pattern was also observed in the 1995 and 1996 data (McNabb et al.1998).

The tendency for more chinook to be entrained into Archimedes 2 was fairly consistent occurring in 75% of the trials. It was less consistent when the number of chinook entrained was low (<15). Analyses of variance revealed that the difference among pumps in the percentage of individuals entrained was significant for chinook salmon (*P*=0.0001) but not significant for other fish (*P*=0.66). Tukey's HSD indicated that Archimedes 2 entrained a significantly higher percentage of chinook salmon than Archimedes 1 (*P*=0.001) and the internal helical pump (*P*=0.0001), which were not significantly different (*P*=0.291).

Debris exhibited a similar pattern of entrainment among pumps. Fifty percent of all debris was entrained into Archimedes 2 and 25% into each of the other two pumps. This pattern also was fairly consistent among trials. While conducting experiments and entrainment trials, personnel also observed more larval fish being entrained into Archimedes 2 than into the other two pumps. Studies have not been undertaken to assess why the middle pump entrains more chinook, debris, and larval fish than the other two pumps.

Ninety-four percent of fish entrained during these simultaneous trials were <100 mm in length which is similar to the size distribution of fish entrained in all trials. More than 80% of the chinook salmon entrained were in the 30 - 39 mm size class. Of the four species most commonly entrained during the simultaneous trials, chinook salmon, lamprey, and prickly sculpin exhibited size distributions similar to all trials combined (Figure 12). Sacramento sucker exhibited a more even distribution across size classes with considerably fewer suckers entrained in the 30 to 49 mm size range compared to size distributions from all trials combined (Figures 3 and 12).

Ninety-eight percent of chinook salmon entrained by each of the Archimedes pumps were alive when collected from the holding tanks (Table 5). Survival of chinook collected from the internal helical pump's holding tank was somewhat lower at 94%. Survival of all other fish was 95% for each of the Archimedes pumps and 94% for the internal helical pump. Results of Kruskal-Wallis tests revealed no significant differences among pumps in survival of juvenile chinook salmon or other fish collected from the three pumps' holding tanks (*P*=0.875 and *P*=0.84, respectively).

Percent survival was lowest in the internal helical pump, however, it entrained fewer chinook than the Archimedes pumps. Therefore, it contributed less to the overall mortality of fish entrained into the plant. Considering all three pumps combined, overall survival of chinook entrained into the RPP was 97%; survival of all other fish combined was 95%.

While in the holding tank fish survival may be affected by volume and type of debris, amount of water flowing into the tank, amount of time confined in the tank, and presence of other fish. Regression analysis was conducted to assess the relationship between volume of debris and mortality of chinook salmon recovered from the holding tanks (Figure 13). Although these variables were poorly correlated ($r^2 = 0.113$), the regression was significant (*P*=0.002) suggesting that mortality may be affected by a combination of factors including debris.

The percentage of chinook salmon, dead and alive, removed from the holding tanks servicing Archimedes 1 and Archimedes 2 with injuries was 3.9 and 4.0, respectively (Table 6). The percent injured was higher for chinook removed from the internal helical pump's holding tank (7.9%). This is consistent with the higher mortality rate of chinook passed through the internal helical pump. The percentage of live chinook removed from the tanks with injuries was 2.2, 1.5, and 3.0 for Archimedes 1, Archimedes 2, and the internal helical pump, respectively. Fish other than chinook followed a similar pattern with the highest incidence of injuries in fish removed from the internal helical pump's holding tanks followed by Archimedes 1 and Archimedes 2. For each pump, the frequency of injuries was lower for chinook salmon than for other fish.

The most common injuries to chinook and other fish were observed on the integument (Tables 7 and 8). This was consistent among pumps. These injuries were observed on both live and dead fish. Chinook had fewer injuries than other fish in most injury categories; however, chinook had a higher incidence of abrasions and bulging eyes. Most (97%) of the chinook with bulging eyes were dead. For Archimedes 2 and the helical pump, most of the injuries to chinook salmon were observed in dead fish (65 and 72%, respectively); for Archimedes 1, 48% of the injuries were observed in dead fish. For other fish the incidence of injuries was fairly even between dead and live fish.

Comparisons Between the Archimedes Pumps

Forty-five trials were conducted with the two Archimedes pumps operating simultaneously. This is nearly double the number of trials conducted when all three pumps operated simultaneously. Because most of the additional trials with the Archimedes pumps were conducted in late spring and summer when chinook entrainment rates were low, the number of chinook entrained only increased by 30 and 20 percent for Archimedes 1 and 2, respectively over numbers from trials with all three pumps (Table 9). In contrast, the number of fish other than chinook increased by 70 and 80 percent for Archimedes 1 and 2, respectively, reflecting the high entrainment rate of prickly sculpin during late spring and summer periods.

Survival of chinook salmon was 2 to 4 percent lower than during the simultaneous trials with all three pumps while survival of fish other than chinook was one percent higher for each pump (Table 9). Trials were conducted every month except January and February 1998, covering a wide range of environmental conditions.

Survival of Large Fish (>200 mm) Compared Among Pumps

The majority of fish entrained into the plant were small (<100 mm). There is interest in knowing, however, how effectively these pumps pass large fish (>200 mm) unharmed. The most commonly entrained large fish were hardhead, Pacific lamprey, Sacramento pikeminnow, and Sacramento sucker. Survival of all fish >200 mm during the 24 simultaneous trials was 98, 100, and 96 percent for Archimedes 1, Archimedes 2 and the internal helical pump, respectively (Table 10). Pacific lamprey was the only large species collected dead from the holding tanks.

To increase the sample size, data on survival of all large fish entrained during this study was compiled. Because not all of these trials were conducted when the pumps operated simultaneously under similar environmental conditions, survival among pumps cannot validly be compared. Nevertheless, survival of large fish was similar among the three pumps and slightly higher than data from the simultaneous trials (Table 11). There were no mortalities among the 48 Sacramento pikeminnow or the 87 Sacramento suckers entrained. Of the 256 large fish entrained, four percent were injured. As in small fish, the most common injury was to the integument.

Delayed Mortality of Entrained Chinook Salmon

Chinook salmon <45 mm fork length were not available from Coleman National Fish Hatchery during periods when the internal helical pump was operable. Therefore, entrained wild chinook were used to compare delayed mortality of small chinook between the two types of pumps. Fish collections were not always from simultaneous trials so results are not directly comparable among pumps. The average fork length, however, of chinook passed through each of the three pumps and held for 96 hours was the same (37 mm). Ninety percent were fall chinook entrained in December through March; 6% were winter chinook entrained in September and October, and 4% were spring chinook entrained in December. Because of its higher entrainment rate, the number of chinook held from Archimedes 2 was close to twice that of the other two pumps. Immediate survival of entrained fish was 98% for the Archimedes pumps and 92% for the internal helical pump (Table 12). Fish that survived and were held for 96 hours had greater than 99% survival for each of the experimental pumps.

Discussion

Plant Operations

The Biological Opinion for the RPP predicted that during the juvenile winter chinook outmigration period, 2 percent of the Sacramento River discharge would be diverted into the RPP (National Marine Fisheries Service, 1993). During this study, the average percent of river discharge diverted into the pumping plant was 2.5. The percent was higher, however, during the winter chinook outmigration period. From mid-September through November when 99 percent of the winter chinook were entrained into the RPP, the average percent of river discharge diverted into the plant was 3.8. The higher proportion diverted during this period is due to river discharges at their yearly minimum and water needs at or near their yearly maximum. From mid-September through October all three pumps typically were operated for 24 hours each day to provide water to the canals.

Numbers and Characteristics of Entrained Fish

Because entrainment was monitored for more hours and over a wider range of seasons in this study than in 1995-1996 (McNabb et al. 1998), the number of fish and species entrained was higher. The twenty-nine species entrained represent over 90 percent of the 32 species of Sacramento River fish cited by Liston and Johnson (1992b) as potentially present in the river at Red Bluff. Seven species had not previously been captured during entrainment trials although all, except goldfish *Carassius auratus* had been entrained by rotary screw traps (Johnson and Martin 1997, Martin and Johnson in prep.). Three species collected in screw traps but not in the RPP were black crappie, American shad and redear sunfish.

Juvenile chinook salmon comprised 90% or more of the fish captured in rotary screw traps but only 37% of the fish entrained during trials at the RPP (Johnson and Martin 1997, Martin and Johnson in prep). This difference may be due to the difference in the vertical position of the screw traps and pump intakes in the river. Rotary screw traps sample the top 1.2 m of the water column, whereas the 1.2 m diameter intakes on the RPP pumps are located near the bottom of the river at a depth of approximately 3.6 - 4.8 m.. Studies conducted from 1950 - 1952 by the USFWS in the Sacramento River near Red Bluff assessed the vertical distribution of downstream migrating chinook using a push net to sample at 0.6 m intervals from the surface to a depth of 1.8 m (Azevedo and Parkhurst, 1957). Their sampling revealed that juvenile chinook salmon migrated at all depths, however, the numbers were greatest 0.6 to 1.2 m below the surface and fewest at 1.2 to 1.8 m below the surface. Other studies on outmigrating juvenile Pacific salmon indicate that they generally utilize the entire water column. However, their abundance at different depths within the water column can vary by diel period (McDonald 1960, Edmundson et al. 1968, Wickwire and Stevens 1971), by spatial zone across a river (Dauble et al.1989), by fish size (Wickwire and Stevens 1971), and by water depth (Mains and Smith 1964). Also, results from one river are not necessarily applicable to another. In the Snake River Mains and Smith (1964) found migrating juvenile chinook slightly more abundant in the middle and bottom zones than in the surface zone. However, in the Columbia River they found that chinook favored the surface zone which contained 44% of the catch compared to 27% captured at mid-depth and 29% captured in the bottom zone.

Prickly sculpin and lamprey ammocoetes, both benthic inhabitants, comprised 27 and 22 percent of the entrained fish, respectively, whereas they comprised less than 2% of the fish captured by rotary screw traps. Sacramento pikeminnow comprised 2% of the fish captured by both screw traps and the RPP.

A total of 3,771 lamprey ammocoetes were entrained into the RPP compared to only 123 in 1995-1996. The large increase occurred because trials were conducted during winter high flow periods which appeared to dislodge the ammocoetes from the substrate. In the 1995-1996 study, trials were not conducted during winter.

Eighty-two percent of entrained chinook had fork lengths in the 30-39 mm range compared to only 30% in this size class in the 1995-1996 study. The large increase in the proportion entrained in this size class is attributable to conducting trials during the months of November, December, and January, months that were not sampled in 1995-1996. Also, 1997-1998 was a wet winter so high numbers of post-emergent fall chinook fry were outmigrating during these months (Vogel et al.1988). The next most frequently entrained size class was 70-79 mm which included 6.5% of the chinook. Captures in this size class were influenced by hatchery releases; over 75% were captured in the spring within days of fall chinook smolts being released from Coleman National Fish Hatchery.

The trashracks proved effective at excluding large fish from the RPP. Less than 1.5% of the fish captured during entrainment trials were >200 mm in length. Infrequently, fish that appear too large in girth to pass through the bars on the trashracks have been entrained into the plant. It is believed that these fish gain entry into the sump area during high flows when openings between the trashrack and walkway are submerged.

Rates and Patterns of Entrainment

Excluding February 1998, at least two pumps were operational during each month of this study allowing seasonal patterns of entrainment to be assessed. In general, numbers entrained were low in the summer, increased somewhat in the fall as winter chinook outmigrated, were greatest in the winter as post-emergent fall chinook outmigrated, then decreased through the spring as the fall chinook completed their outmigration. This pattern of entrainment is similar to patterns of chinook abundance observed in the river by Martin and Johnson (in prep). This pattern is also consistent with data on chinook abundance at Red Bluff during a wet winter (Vogel et al. 1988). Heavy rains during December and January of 1996-1997 and 1997-1998 produced high river discharges resulting in the early out-migration of fall chinook salmon at a small size (<50 mm).

Although the entrainment rate of chinook salmon was greatest in December and January, these are months when the plant typically would not be operated if it was functioning only to deliver water. Therefore, it can be predicted that in wet years, most juvenile fall chinook will migrate past the RPP before pumping begins, and the numbers entrained will be low. This occurred in the wet winter of 1997-1998 when fall chinook outmigrated early and few remained in the spring to be entrained into the RPP. In contrast, during a dry winter when the annual peak out-migration of fall chinook is delayed until April through June (Vogel et al. 1988), the number of fall chinook entrained into the plant would be expected to be high due to frequent pumping from April through May 15.

During all seasons of the year except summer, chinook comprised the majority of fish entrained into the plant. Entrainment rates of chinook were lowest from May through August while entrainment rates of other fish, particularly prickly sculpin, were highest during those months. This high entrainment of non-salmonids into the RPP will not occur when the plant is functioning as a water delivery device since it will not be operated from May 15 through September 15 when RBDD gates are lowered.

No apparent relationship existed between entrainment rate and turbidity or discharge in this study. If sampling were conducted more frequently, however, a relationship may emerge. For example, data from USFWS rotary screw traps at RBDD does show a relationship between number of chinook outmigrating and river discharge or turbidity (P. Gaines, USFWS, personal communication.). Screw traps are monitored 5 to 7 days each week while pump entrainment is monitored only once or twice each week. More frequent entrainment monitoring would be necessary to discern such a relationship.

Diel patterns of entrainment were similar to 1995-1996 (McNabb et al. 1998). Most fish were entrained at night. These results are consistent with other studies conducted on migration patterns of juvenile Pacific salmon (McDonald 1960, Mains and Smith 1964, Dauble et al. 1989). McDonald (1960) found that fry of coho, sockeye, pink, and chum salmon initiated downstream movements shortly after dark and terminated these movements as daylight approached. In experiments conducted with sockeye and coho salmon fry, artificial light prevented their normal downstream movement at night.

The diel pattern of entrainment at the RPP has important implications for plant operations. If it was desirable or necessary to reduce the number of fish entrained, it could be accomplished by only pumping during daylight hours. Since 81% of chinook and 86% of all other fish were entrained at night, the numbers entrained would be decreased dramatically.

Results from passage trials conducted with hatchery fish (Objective B) in 1995 and 1996 brought into question whether fish collected from holding tanks accurately reflect diel patterns of entrainment. Preliminary passage trials in 1995 with hatchery fish were conducted during daylight hours. Most chinook salmon released into the pump's intake or outfall resided in the screening facility upstream of the holding tanks for several hours before moving downstream to the holding tanks. When trials were conducted in the 3-4 hours after sunset, chinook moved quickly through the system with over ninety percent of the released chinook recovered within 30 minutes (McNabb et al. 1998). Therefore, it is possible that a fraction of the fish entrained during the day remain upstream of the holding tanks until after sunset at which time they move downstream into the holding tanks. These day-entrained fish would mistakenly be counted as night-entrained fish. Future investigations will assess the percent of chinook entrained into the plant that hold up in the system during the day and move into the holding tanks after sunset.

Estimated Numbers of Fish Entrained

Actual and estimated numbers of chinook entrained into the RPP is related to the hours that the pumps operate. During this study we experienced two very different weather patterns during February - June of 1997 and 1998. After a wet January in 1997, dry conditions prevailed requiring frequent use of the pumping plant. Conditions were so dry by April 1997 that gates of RBDD were lowered for 10 days to allow delivery of water to the canals from Lake Red Bluff. In contrast, wet conditions prevailed through the winter and spring of 1998 keeping water demands low with infrequent use of the plant. This difference in pumping regimes during those two years is reflected in the relatively high actual and estimated numbers of chinook entrained in spring 1997 versus the low numbers in spring 1998. Numbers entrained in April 1997 would have been even higher if the plant had continued to be used rather than lowering the dam gates.

During this study, the RPP was operated for biological evaluations during periods of the year (summer and winter) when it would not be operated if it were being used solely for water deliveries. Therefore, the actual and estimated annual number of chinook salmon and other fish entrained into the plant would be less than determined during this study. Of the 6523 chinook entrained, 65% were collected during trials conducted in December and January, months that the plant would not be operated when functioning for water deliveries to the canals.

The Biological Opinion for the RPP assumed that juvenile chinook salmon would be entrained in proportion to the amount of flow diverted into the plant. Preliminary data from October - December 1997 on the percent of riverine chinook entrained into the RPP refutes this assumption. Based upon 18 entrainment trials conducted simultaneously with the Fish and Wildlife Service's screw trap sampling, the upper confidence interval estimate for percentage of riverine chinook entrained into the plant ranged from approximately 0.05 to 0.60 percent (C.

Martin, USFWS, personal communication). During this period the percent of the river diverted into the RPP ranged from approximately 1.5 to 5.5 percent. As suggested previously, this low entrainment rate may be due to the location of the pump intakes in relation to the vertical distribution of outmigrating juvenile chinook. Another possible explanation is that sweeping velocities along the traskracks in front of the pump intakes deter fish from entering the sump area. The plant was designed to provide a strong sweeping velocity component in front of the trashracks to exclude sediment, debris, and fish. During measurements taken with an acoustic Doppler current profiler in March 1996, sweeping velocities along the trashracks ranged from 2 to 3 ft/s when the two Archimedes pumps were each diverting 93 ft^3/s (Tracy Vermeyen travel report, April 15, 1997).

Number, Survival, and Injury of Entrained Fish Compared Among Pumps

Although there was no statistically significant difference in survival of fish passed through the two types of experimental pumps, percent survival was higher with the Archimedes pumps than with the internal helical pump. Two important differences between these pumps types that may affect fish survival are their speed and the characteristics of the pump's outfall. The helical pump is designed to operate at a much higher speed (350 rpm) than the Archimedes pump (26.5 rpm). During these trials the variable speed drive for the internal helical pump was not functioning and the pump was operated at a higher than optimum speed for pump performance and efficiency (378 rpm). This higher speed may have created conditions that were less fish friendly than if the pump had been operated at the optimum speed. Modifications were made to the pump's gear box in December 1998 to slow the pump speed to 350 rpm which may improve fish survival.

Engineering evaluations have not been made on the pump outfalls, however, there are obvious differences between the discharges of the two pump types (Frizell and Atkinson, 1996). The Archimedes pumps discharge their water in pulses associated with the dumping of water from each flight of the pump. Discharges are centered over the 1.5 m deep channel. Water from the internal helical pump is discharged from a height of approximately 1.0 m above the water surface into the 1.5 m deep channel. The helical pumps' outfall structure is off-center reducing the depth of water that the discharge plunges into to less than 0.5 m on the off-center side. This increases the likelihood that a fish discharged from the pump will strike the channel's concrete substrate. The off-center installation also causes water to slosh from side to side as it travels downstream causing velocity fluctuations along the vertical screens (Frizell and Atkinson 1996).

Survival of fish collected from holding tanks was high for each of the three pumps considering that in addition to passing through a pump, fish in a holding tank traveled the flow stream from the pump outfall to the holding tank. Once in the holding tank, fish were confined for up to 14 hours depending upon when they entered the tank in relation to the sunset or sunrise inspection. While in the holding tank fish survival could be affected by volume and type of debris, amount of water flowing into the tank, length of time confined in the tank, and presence of other fish.

Injuries to fish also may be affected by conditions in the holding tanks. Strikes from debris or predators may account for some of the integument injuries observed. Compared to all other fish, chinook salmon had a higher incidence of bulging eyes, technically known as exophthalmia. This condition has a variety of possible causes including several infectious agents (bacterial and viral) and parasites, nutritional deficiencies, gas supersaturation, kidney functions (increased pressure in the choroid gland), and trauma (Kim True, USFWS, California-Nevada Fish Health Center, personal communication.). Gas supersaturation could likely be ruled out since total gas saturation values measured in holding tanks were below levels found detrimental to fish (Weitkamp and Katz, 1980). However, any of the other causes are possible. Bulging eyes is a symptom of IHN (infectious hematopoietic necrosis), a disease frequently found in fall chinook smolts released from Coleman National Fish Hatchery. However, to avoid handling and adding stress to these diseased fish, entrainment monitoring is generally not conducted when smolts are being released. Therefore, less than 0.3% of chinook entrained with bulging eyes were collected during times when smolts were released from Coleman.

Our data did not show a correlation between debris and chinook mortality in holding tanks. When combined with high flows and/or long holding periods, however, high debris loads may affect survival. Although each entrainment trial began with low flows into the holding tanks, if present, debris impinges on the dewatering ramp decreasing the volume of water passing through the ramp thereby increasing the volume of water going to the holding tanks. Due to the relatively small size of the holding tanks, high flows into the tanks create turbulent conditions which may add to mortality and injuries, especially when coupled with debris and long periods of confinement. Confinement time of individual fish and duration of high flows into the holding tanks were two variables that could not be measured.

Considering all three pumps, overall mortality of chinook salmon entrained into the RPP was 3%. The overall percentage of chinook entrained into the plant with sublethal injuries was 2.1. These rates of mortality and injury are less than the 10% injury and mortality rate expected by the Biological Opinion for Archimedes pumps (NMFS 1993). The Biological Opinion expected the internal helical pump to subject entrained chinook to a "substantially higher rate of injury or mortality", even as high as 90 percent. Although mortality and injury was greater in the internal helical pump, levels were considerably less than expected and not statistically different from the Archimedes pumps.

Experiments conducted under Objective B of the RPP evaluation program provide a better estimate of chinook salmon survival from pump passage than do entrainment trials (McNabb et al. 1998). The condition and history of each treatment group of fish used in these experiments is known and controlled for. Also, during experiments fish are immediately removed from the holding tanks whereas in entrainment trials fish may be held in the holding tanks for several hours and subject to mortality from debris, other fish, or stress of confinement.

Delayed Mortality of Entrained Chinook Salmon

Delayed mortality of wild chinook entrained and held in the river water fish facility was ≤ 1 percent for the Archimedes pumps. This was similar to results with hatchery-produced fish used in Objective B pump passage trials during 1995 - 1996 (McNabb et al. 1998). Delayed mortality was 1 percent in the wild fish passed through the internal helical pump compared to 3 percent in hatchery-produced fish.

Future Monitoring Plans

During this study, 24-hr sunrise to sunrise trials were conducted simultaneously with the FWS screw trap monitoring study to determine the proportion of in-river fish entrained into the RPP. This simultaneous monitoring will continue through 1999. Based upon efficiency trials, FWS has predicted trap efficiency rates which are used with total daily catches to estimate the number of juvenile chinook emigrating past RBDD on any particular day. Ninety percent confidence intervals were constructed around these estimates (Martin and Johnson, in prep). By comparing the number of fish entrained into the RPP to the FWS's estimate of chinook emigrating past RBDD, we will be able to address the final objective of this study. This data will be reported when a sufficient number of trials has been completed to provide reliable estimates during different seasons of the year.

During entrainment monitoring trials in the fall of 1999, efforts will be made to better estimate survival of and injuries to entrained fish. This will be accomplished by monitoring holding tanks at 1 hour intervals for a portion of each sunset to sunrise entrainment period. Because fish will be removed from the holding tanks within at least an hour of entry, pump passage survival and injury will not be confounded with long periods of confinement in a holding tank with debris and other fish.

Trials will be conducted in 1999 to investigate the percent of chinook entrained into the RPP that hold up in the screening facility during the day and move into the holding tanks after sunset. In these trials, hatchery-reared juvenile chinook will be used as surrogates for wild chinook. Samples of 32 fish will be released into the plant intakes at sunrise on day-1. These fish will be dyed with bismarck brown dye to distinguish them from entrained wild chinook. Surrogates will be recovered from tanks at sunset on days-1, and again at sunrise on day-2, and counted. The proportion of fish recovered during the diurnal and nocturnal periods of each entrainment trial will be calculated.

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Table 1. Summary of pump operations and fish entrainment monitoring at Red Bluff Research Pumping Plant, February 1997 - June 1998.

PARAMETER	ARCHIMEDES-1	ARCHIMEDES-2	INTERNAL HELICAL
Pump Speed (rpm)	26.5	26.5	378
Average Discharge (ft^3/s) (Range)	89.4 (79.5 - 94.5)	90.0 (86.0 - 97.5)	96.3 (82.0 - 101.5)
Period of Pump Operation	1997: Feb - Dec 1998: Jan, Mar -Jun	1997: Feb - Dec 1998: Jan, Mar - Jun	1997: Feb - mid-July; Sep - Dec 1998: Jan, Mar - Apr
Total Hrs. Pump Operated	4544	4424	3052
Total Hrs. Entrainment Monitored	1219	1271	908
% of Time Entrainment Monitored	27	29	30
Number of 24 Hr. Trials Conducted	49	52	35

Table 2. Fish species entrained from the Sacramento River and captured in holding tanks at Red Bluff Research Pumping Plant, February 1997 - June 1998.

SPECIES	NUMBER ENTRAINED	PERCENT OF TOTAL
Chinook salmon (*Oncorhynchus tshawytscha*) [1]	6,523	37
Prickly sculpin (*Cottus asper*) [1]	4,710	27
Lamprey ammocoetes (*Lampetra* spp.) [1]	3,771	22
Sacramento sucker *(Catostomus occidentalis)* [1]	941	5
Sacramento pikeminnow *(Ptychocheilus grandis)* [1]	392	2
Threespine stickleback *(Gasterosteus aculeatus)* [1]	265	2
Bluegill *(Lepomis macrochirus)*	202	1
Riffle sculpin (*Cottus gulosus)* [1]	125	<1
Pacific lamprey (*Lampetra tridentata*) [1]	97	<1
Tule perch (*Hysterocarpus traski)* [1]	80	<1
White catfish *(Ictalurus catus)*	68	<1
California roach *(Hesperoleucus symmetricus)* [1]	65	<1
Hardhead *(Mylopharodon concephalus)* [1]	63	<1
Steelhead/Rainbow trout (*Oncorhynchus mykiss)* [1]	62	<1
Mosquitofish (*Gambusia affinis)*	31	<1
Largemouth bass (*Micropterus salmoides)*	28	<1
Threadfin shad (*Dorosoma petenense*) [2]	24	<1
Unidentified adult lamprey (*Lampetra* spp.) [1]	22	<1
Speckled dace (*Rhinichthys osculus*) [1,2]	16	<1
Green sunfish (*Lepomis cyanellus*) [2]	12	<1
River lamprey (*Lampetra ayresi*) [1]	6	<1
Channel catfish (*Ictalurus punctatus*) [2]	6	<1
Brown bullhead *(Ictalurus nebulosus)*	4	<1
Golden shiner (*Notemigonus crysoleucas*) [2]	3	<1
Hitch *(Lavinia exilicauda)* [1]	3	<1
Sturgeon (*Acipenser spp)* [1]	3	<1
Common carp (*Cyprinus carpio*) [2]	2	<1
Smallmouth bass (*Micropterus dolomieui*)	2	<1
Bullhead *(Ictalurus spp)*	2	<1
Goldfish (*Carassius auratus*) [2]	1	<1
Pacific brook lamprey *(Lampetra pacifica)* [1]	1	<1
TOTAL	17,530	

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[1] Species native to the Sacramento River

[2] Species not previously captured during entrainment trials.

Table 3. Run composition of chinook salmon entrained into Red Bluff Research Pumping Plant, February 1997 - June 1998.

RUN	NUMBER ENTRAINED	PERCENT OF TOTAL
FALL	5825	89.3
WINTER	405	6.2
SPRING	209	3.2
LATE-FALL	84	1.3

Table 4. Diel capture of fish most frequently entrained during trials with experimental pumps at Red Bluff Research Pumping Plant, February 1997 - June 1998.

SPECIES	**PERCENT CAPTURED**	
	DAY	**NIGHT**
Chinook Salmon		
Fall	20	80
Late-fall	20	80
Winter	10	90
Spring	17	83
All Chinook	**19**	**81**
Prickly Sculpin	12	88
Lamprey Ammocoetes	12	88
Sacramento Sucker	12	88
Sacramento Pikeminnow	23	77
Threespine Stickleback	44	56
Bluegill	45	55
All Fish Except Chinook	**14**	**86**

Table 5. Total number and percent survival of fish species most frequently entrained into experimental pumps at Red Bluff Research Pumping Plant during 24-hour entrainment trials (N=24) conducted from February 1997 - June 1998 when all three pumps ran simultaneously.[1]

SPECIES	ARCHIMEDES 1		ARCHIMEDES 2		INTERNAL HELICAL	
	Number	% Survival[2]	Number	% Survival[2]	Number	% Survival[2]
Chinook Salmon[3]						
Fall run	831	98	1621	99	549	94
Winter run	48	94	103	90	37	100
Spring run	31	90	70	94	16	81
Late-fall run	8	88	12	92	11	82
All Chinook	**918**	**98**	**1806**	**98**	**613**	**94**
Prickly Sculpin	683	98	420	98	501	95
Lamprey Ammocoetes	175	99	126	99	251	98
Sacramento Sucker	29	97	27	89	19	89
Sacramento Pikeminnow	28	100	40	98	14	86
All Fish Except Chinook	**1098**	**95**	**769**	**95**	**906**	**94**
ALL FISH	**2016**	**96**	**2575**	**97**	**1519**	**94**

[1] Each entrainment trial started at sunrise and continued for 24 hours.

[2] Survival should not be interpreted strictly as pump passage survival. This table represents survival of fish that passed through a pump, then traveled by a screening facility, around curved bypass channels, up a dewatering ramp and into a holding tank. Fish could be held in a holding tank for up to 14 hours depending upon when it arrived in the holding tank in relation to the sunrise or sunset entrainment check. Survival of fish collected from the holding tanks could be affected by the duration it was confined to the tank, the amount of water flowing into the tank, the type and/or volume of debris in the holding tank, or by other fish in the holding tank.

[3] Run membership was determined from a daily fork-length table generated by Sheila Greene, California Department of Water Resources, Environmental Services Office, Sacramento (8 May 1992) from data by Frank Fisher, California Department of Fish and Game, Inland Fisheries Branch, Red Bluff (revised 2 February 1992).

Table 6. Percentage of juvenile chinook salmon and other fish entrained into Red Bluff Research Pumping Plant that exhibited injuries when collected from holding tanks during 24 simultaneous entrainment trials conducted with the three pumps from February 1997 - June 1998. The number of fish examined in each category is shown in parentheses.

Groups of Fish	Archimedes 1	Archimedes 2	Internal Helical
All Chinook[1]	3.9 (565)	4.0 (968)	7.9 (570)
Surviving Chinook	2.2 (543)	1.5 (934)	3.0 (531)
Other Fish[1]	5.8 (834)	5.4 (681)	8.1 (695)
Other Surviving Fish	3.8 (789)	3.2 (649)	4.2 (646)

[1] Includes all fish with injuries, whether individuals were alive or dead at the time of collection.

Table 7. Percentage of dead and alive juvenile chinook salmon with specified injuries. Chinook were collected in holding tanks at Red Bluff Research Pumping Plant during 24 simultaneous entrainment trials conducted with the three pumps, February 1997 - June 1998. The number of fish examined from each pump is shown in parentheses.

Type of Injury[1]	Archimedes 1 (565)		Archimedes 2 (968)		Internal Helical (570)	
	Alive	Dead	Alive	Dead	Alive	Dead
Fins						
Eroded >30%	0	0	0	0	0	0.4
Eroded to base	0.2	0	0.1	0.1	0	0.9
Skin						
Bruise	0.5	0.2	0.1	0.2	0.5	1.1
Partially Deskinned	0.2	0.2	0.4	0.3	0	0
Split or Open Wound	0.9	0	0.1	0.4	1.1	1.1
Abrasion	0.4	0.2	0.7	0.4	0.2	0.4
Hemorrhage	0	0.2	0.1	0	0	0
Eyes						
Bulging	0.2	1.2	0	1.7	0.4	1.9
One missing	0	0	0	0	0	0
Both missing	0	0	0	0	0	0.4
Hemorrhage	0	0.2	0	0.1	0.4	0.4
Head						
One operculum missing	0	0	0	0.1	0.2	0.4
Both operculum missing	0	0	0	0	0	0
Open wound or abrasion	0.4	0.4	0.1	0.1	0.2	0.4
Decapitated	0	0	0	0	0	0
Bruise or hemorrhage	0	0	0.2	0	0	0.2

[1] A fish may have more than one type of injury.

Table 8. Percentage of dead and alive fish other than chinook salmon with specified injuries. Fish were collected in holding tanks at Red Bluff Research Pumping Plant during 24 simultaneous entrainment trials conducted with the three pumps, February 1997 - June 1998. The number of fish examined from each pump is shown in parentheses.

Type of Injury[1]	Archimedes 1 (834)		Archimedes 2 (681)		Internal Helical (695)	
	Alive	Dead	Alive	Dead	Alive	Dead
Fins						
Eroded >30%	0.4	0.4	0.1	0.1	0.4	0.6
Eroded to base	1.1	0.2	0.1	0.4	1.4	0.6
Skin						
Bruise	0.5	0	1.0	0.3	0.9	0.1
Partially Deskinned	0	0.5	0.1	0.4	0.3	0.1
Split or Open Wound	0.7	0.8	0.7	0.4	0.6	1.7
Abrasion	0.1	0.2	0.1	0	0	0
Hemorrhage	0.4	0.4	0.4	0.3	1.0	0.7
Eyes						
Bulging	0.1	0.1	0	1.0	0	0.3
One missing	0	0.1	0	0	0	0
Both missing	0	0.1	0	0.1	0	0
Hemorrhage	0	0	0.1	0	0	0
Head						
One operculum missing	0	0	0	0	0	0.1
Both operculum missing	0	0	0	0	0	0
Open wound or abrasion	0.4	0.2	0.1	0.3	0.1	0
Decapitated	0	0.1	0	0.1	0	0.1
Bruise or hemorrhage	0	0	0	0	0	0

[1] A fish may have more than one type of injury.

Table 9. Total number and percent survival of fish species most frequently entrained into the Archimedes pumps at Red Bluff Research Pumping Plant during 24-hour entrainment trials (N=45) conducted from February 1997 - June 1998 when both pumps ran simultaneously.[1]

SPECIES	ARCHIMEDES 1		ARCHIMEDES 2	
	Number	% Survival[2]	Number	% Survival[2]
Chinook Salmon[3]				
Fall run	1062	95	1858	98
Winter run	158	94	255	88
Spring run	41	93	77	95
Late-fall run	33	82	39	90
All Chinook	**1294**	**94**	**2229**	**96**
Prickly Sculpin	1734	95	1437	99
Lamprey Ammocoetes	717	98	792	100
Sacramento Sucker	406	95	424	88
Sacramento Pikeminnow	135	97	151	98
All Fish Except Chinook	**3628**	**96**	**3758**	**96**
ALL FISH	**4922**	**95**	**5987**	**96**

1 Each entrainment trial started at sunrise and continued for 24 hours.

2 Survival should not be interpreted strictly as pump passage survival. This table represents survival of fish that passed through a pump, then traveled by a screening facility, around curved bypass channels, up a dewatering ramp and into a holding tank. Fish could be held in a holding tank for up to 14 hours depending upon when it arrived in the holding tank in relation to the sunrise or sunset entrainment check. Survival of fish collected from the holding tanks could be affected by the duration it was confined to the tank, the amount of water flowing into the tank, the type and/or volume of debris in the holding tank, or by other fish in the holding tank.

3 Run membership was determined from a daily fork-length table generated by Sheila Greene, California Department of Water Resources, Environmental Services Office, Sacramento (8 May 1992) from data by Frank Fisher, California Department of Fish and Game, Inland Fisheries Branch, Red Bluff (revised 2 February 1992).

Table 10. Survival of large fish (>200 mm) entrained into experimental pumps at Red Bluff Research Pumping Plant during 24-hour entrainment trials (N=24) conducted from February 1997 - June 1998 when all three pumps ran simultaneously.

SPECIES (avg; min-max total length in mm)	ARCHIMEDES 1		ARCHIMEDES 2		INTERNAL HELICAL	
	Number	% Survival	Number	% Survival	Number	% Survival
Pacific Lamprey (541; 395 - 686)	22	95	4	100	15	93
Hardhead (229; 200 - 256)	10	100	14	100	3	100
Sacramento Pikeminnow (235; 202 - 320)	10	100	8	100	5	100
Sacramento Sucker (237; 200 - 305)	2	100	7	100	5	100

Table 11. Survival of large fish (>200 mm) entrained into experimental pumps at Red Bluff Research Pumping Plant during all entrainment trials conducted from February 1997 - June 1998. Pumps were not always operated simultaneously under the same conditions, so results among pumps are not directly comparable.

SPECIES (avg; min-max total length in mm)	ARCHIMEDES 1		ARCHIMEDES 2		INTERNAL HELICAL	
	Number	% Survival	Number	% Survival	Number	% Survival
Pacific Lamprey (536; 307 - 732)	39	95	17	100	18	94
Hardhead (237; 200 - 338)	22	95	20	100	5	100
Sacramento Pikeminnow (251; 202 - 480)	20	100	13	100	15	100
Sacramento Sucker (251; 200 - 432)	35	100	43	100	9	100

Table 12. Percent survival of small chinook salmon (<45 mm) entrained into Red Bluff Research Pumping Plant. Fish that were alive at capture were held in live cages in the river water fish facility for 96 hours to assess delayed mortality. Trials were conducted February 1997 - June 1998.

Pump	Number Entrained	Average Fork Length (mm)	% Survival at Capture	% Survival at 96 hrs
Archimedes 1	1077	37	98.2	99.5
Archimedes 2	2061	37	97.5	99.5
Internal Helical	959	37	92.2	99.2

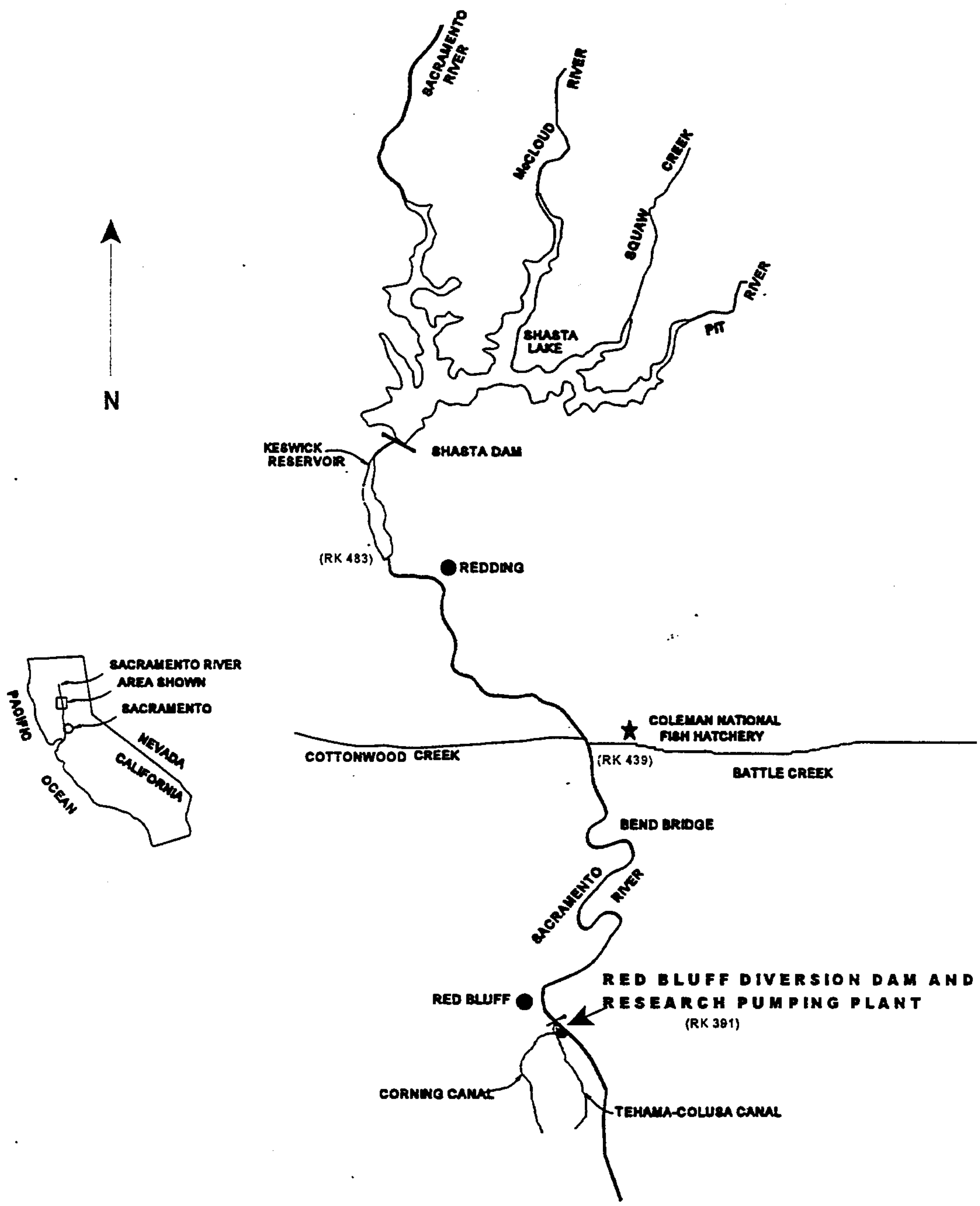

Figure 1. Location of Red Bluff Research Pumping Plant in relation to other features within the upper Sacramento River drainage.

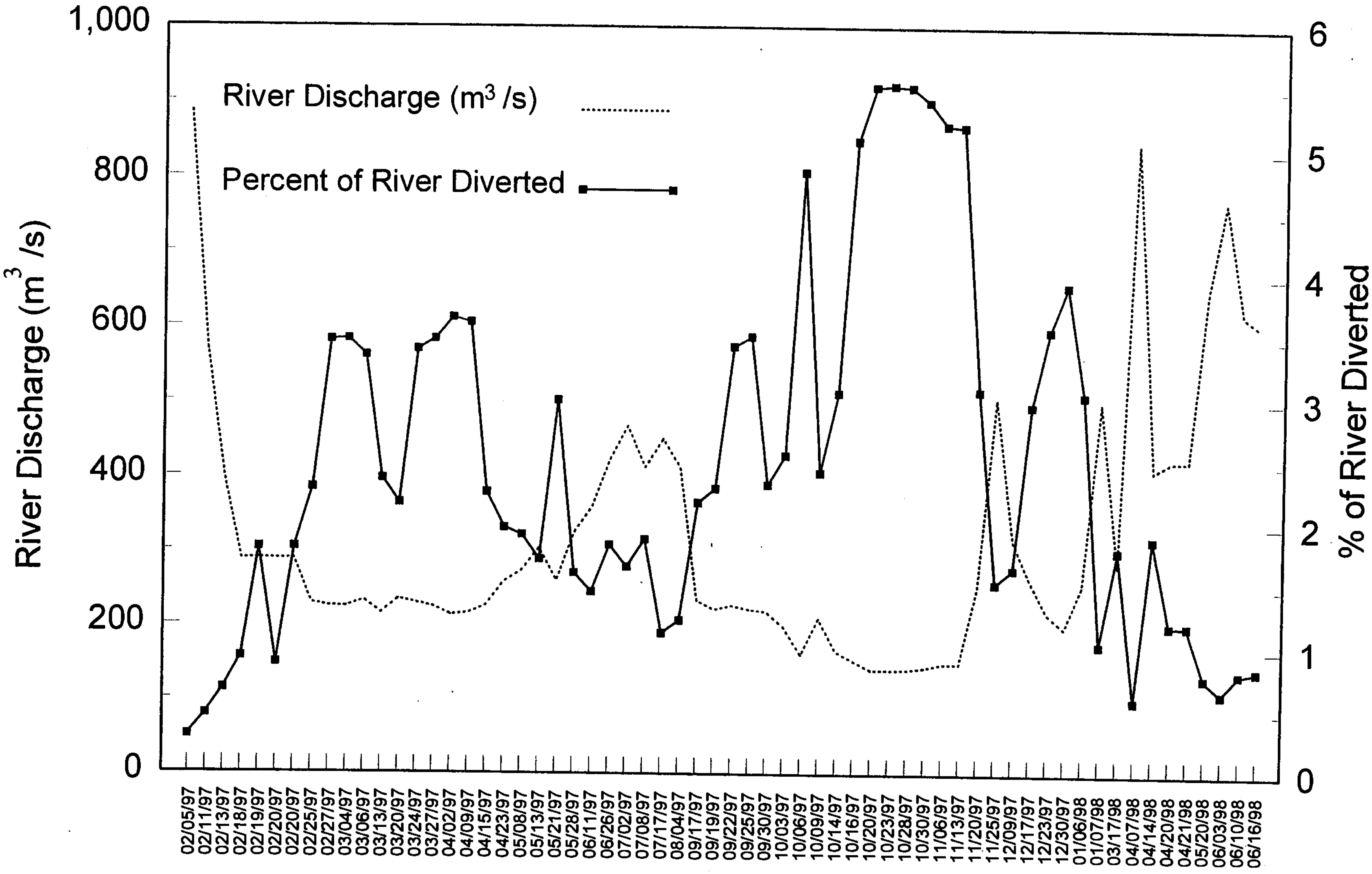

Figure 2. Daily Sacramento River discharge (m^3/s) flowing past Red Bluff Research Pumping Plant and percent of river diverted into the plant during entrainment trials conducted from February 1997 - June 1998.

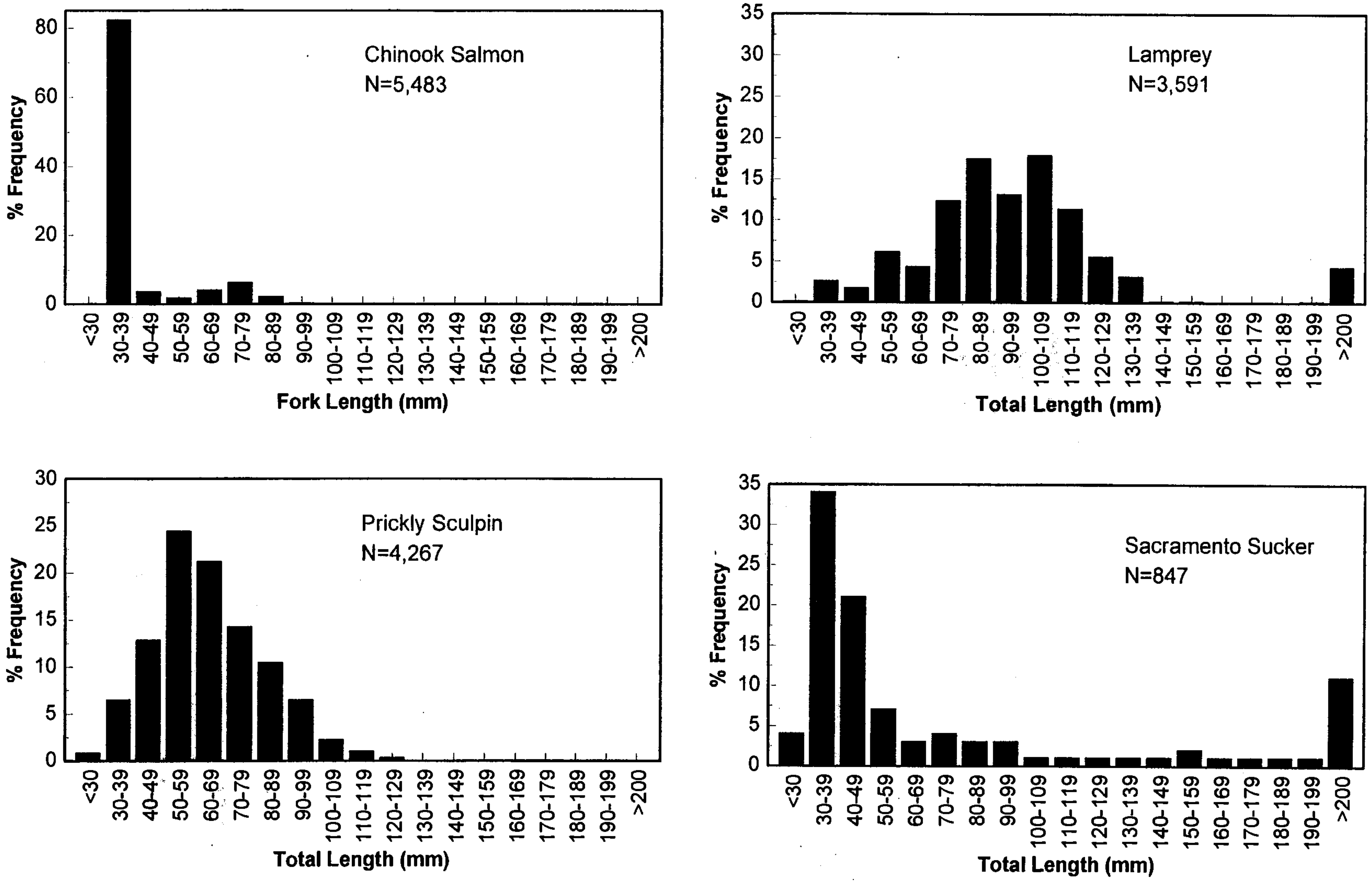

Figure 3. Size-frequency distribution of chinook salmon, lamprey, prickly sculpin, and Sacramento sucker entrained into Red Bluff Research Pumping Plant during entrainment trials conducted February 1997 - June 1998.

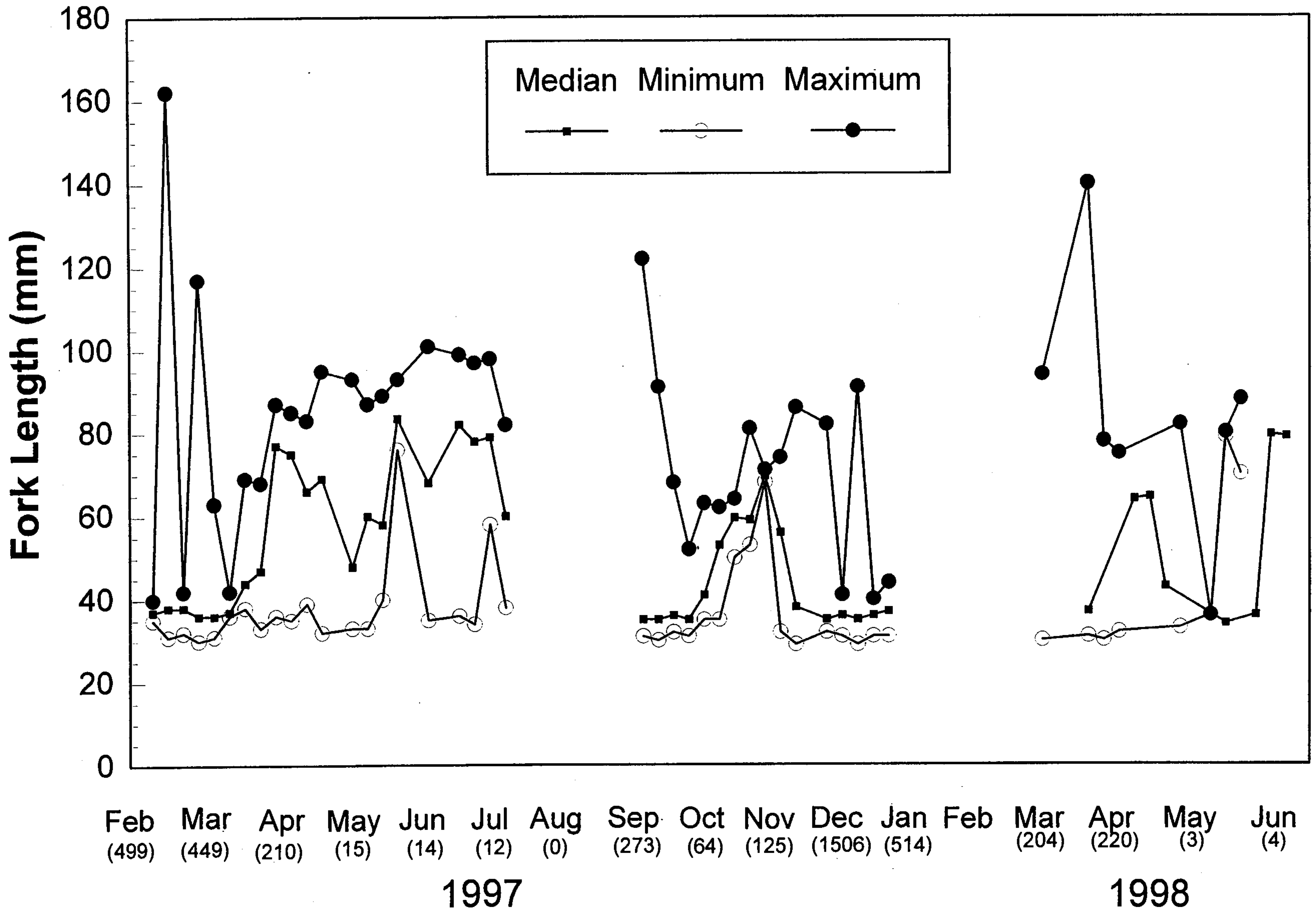

Figure 4. Weekly median, minimum and maximum fork lengths of juvenile chinook salmon entrained into Red Bluff Research Pumping Plant during February 1997 - June 1998. Number of fish measured each month is shown in parentheses. Breaks in the graph indicate weeks when entrainment monitoring was not conducted (February 1998) or chinook salmon were not entrained (all other breaks).

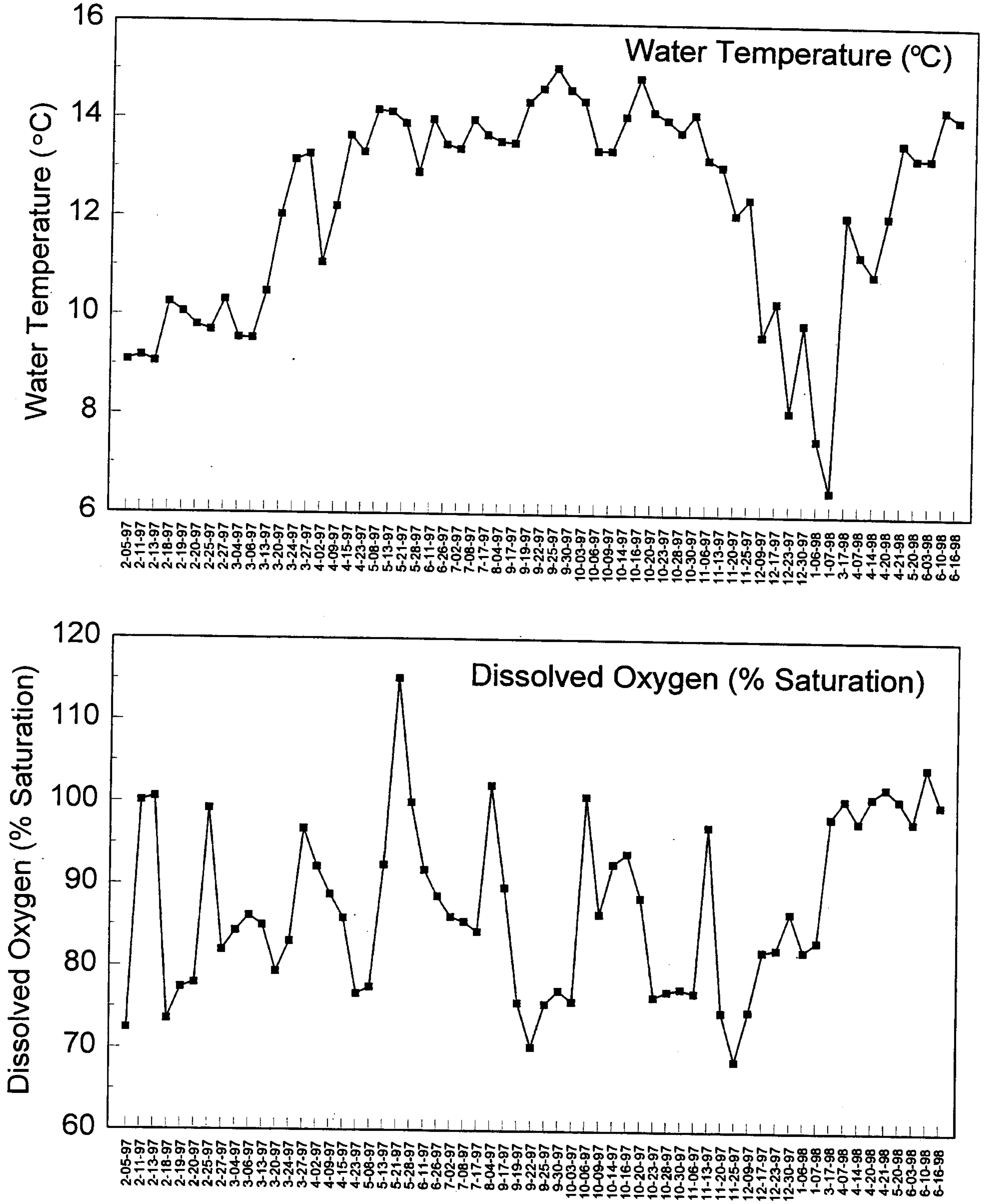

Figure 5. Mean daily water temperature and dissolved oxygen values in the Sacramento River during entrainment trials conducted at Red Bluff Research Pumping Plant from February 1997 - June 1998. Hourly measurements were taken with a Hydrolab Datasonde T water quality probe situated in the river near the east side of Red Bluff Diversion Dam.

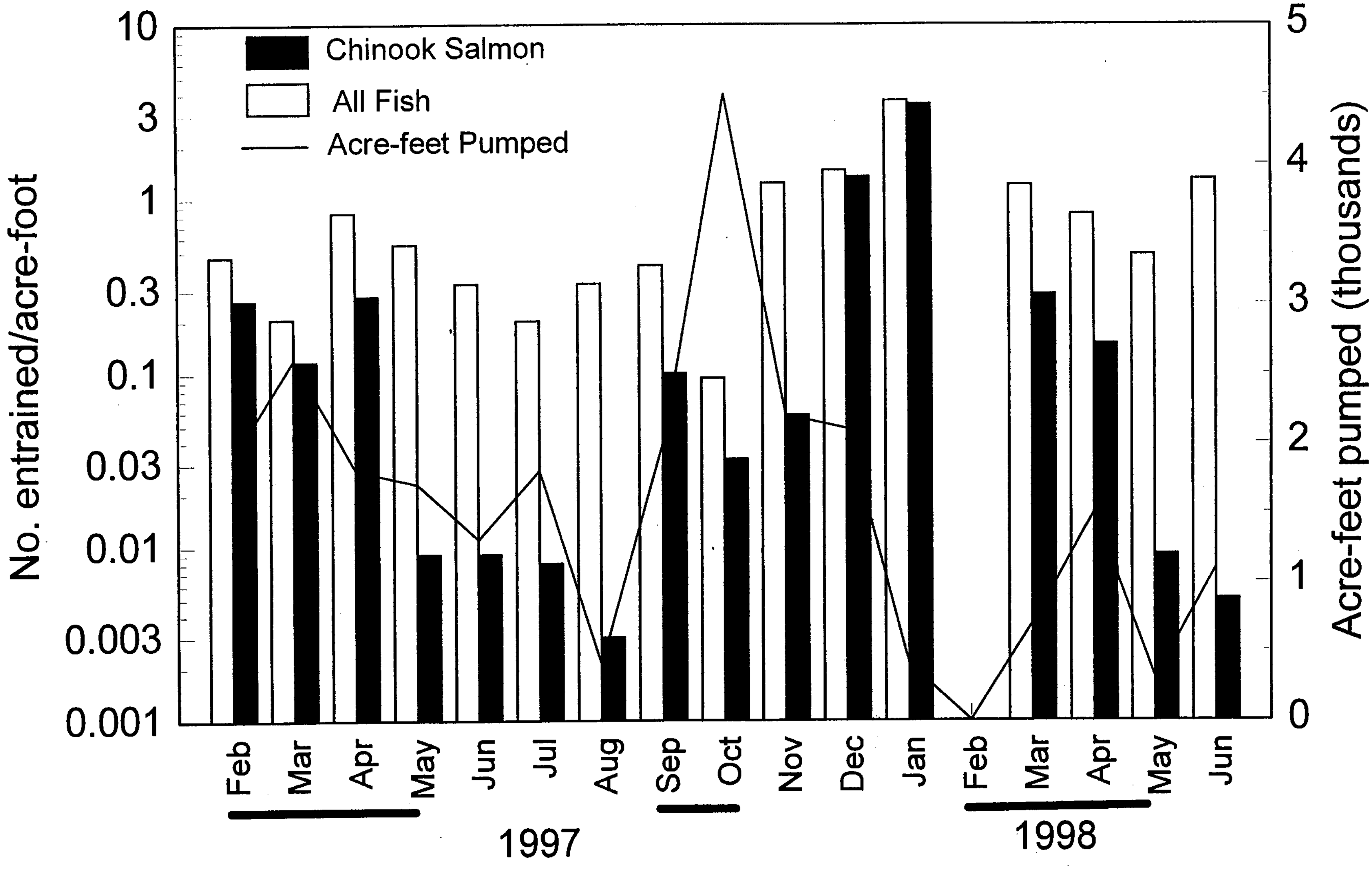

Figure 6. Monthly entrainment rates of chinook salmon and all fish into Red Bluff Research Pumping Plant during trials conducted February 1997- June 1998. Sampling effort is indicated by the number of acre-feet pumped during entrainment trials each month. The pumps did not operate in February 1998. Lines beneath the months indicate periods when the plant is typically operated to provide water to the canals. A log scale is used on the y-axis because of the large range in no. entrained/acre-foot.

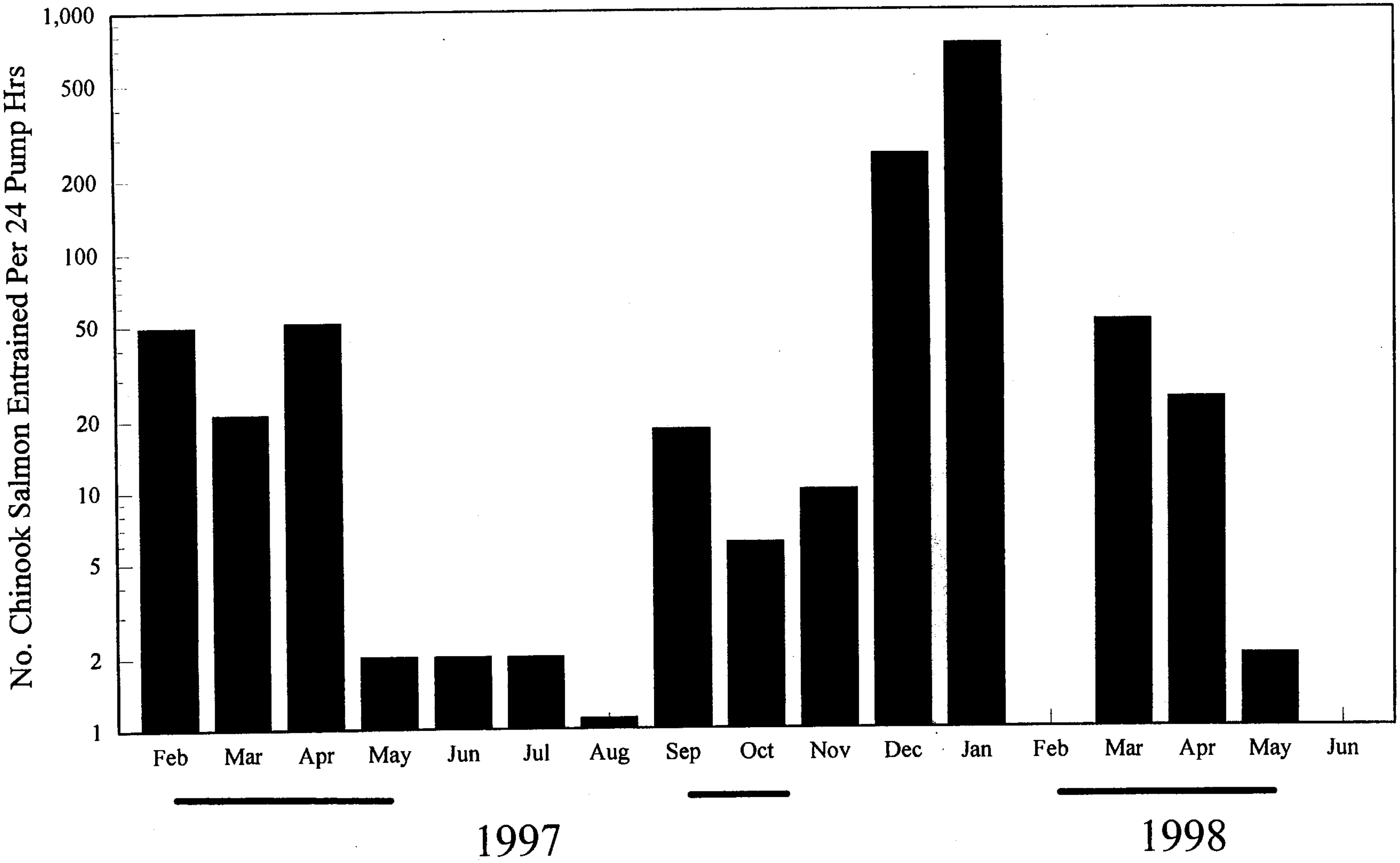

Figure 7. The number of chinook salmon entrained into Red Bluff Research Pumping Plant per 24 hours of pump operation during February 1997 - June 1998. None of the pumps operated in February 1998. Lines beneath the months indicate periods when the plant would typically be used to provide water to canals. A log scale is used on the y-axis because of the large range in number entrained per 24 hours.

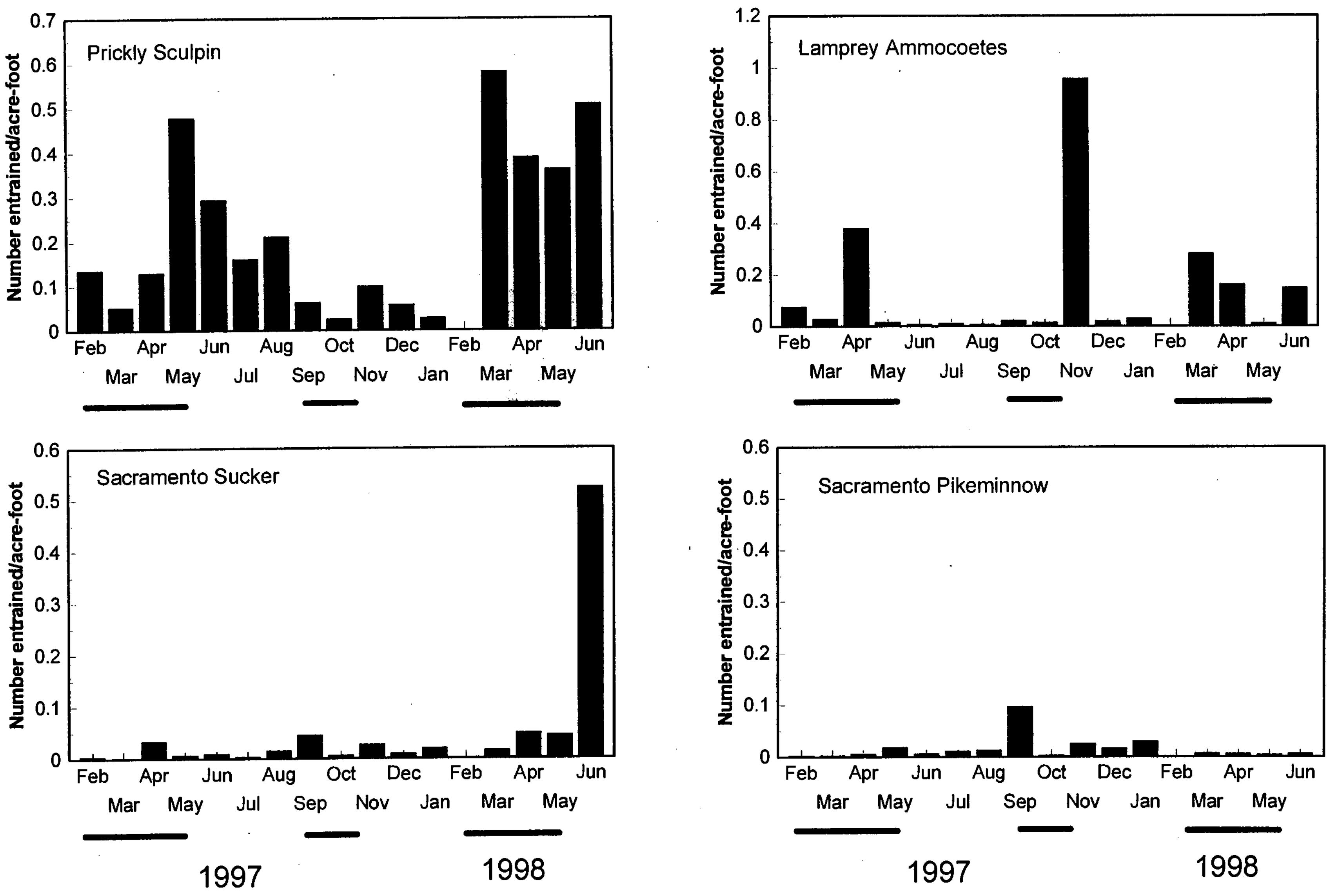

Figure 8. Monthly entrainment rates of four species frequently entrained into Red Bluff Research Pumping Plant, February 1997 - June 1998. The pumps did not operate in February 1998. Lines beneath the months indicate periods when the plant is typically operated to provide water to the canals.

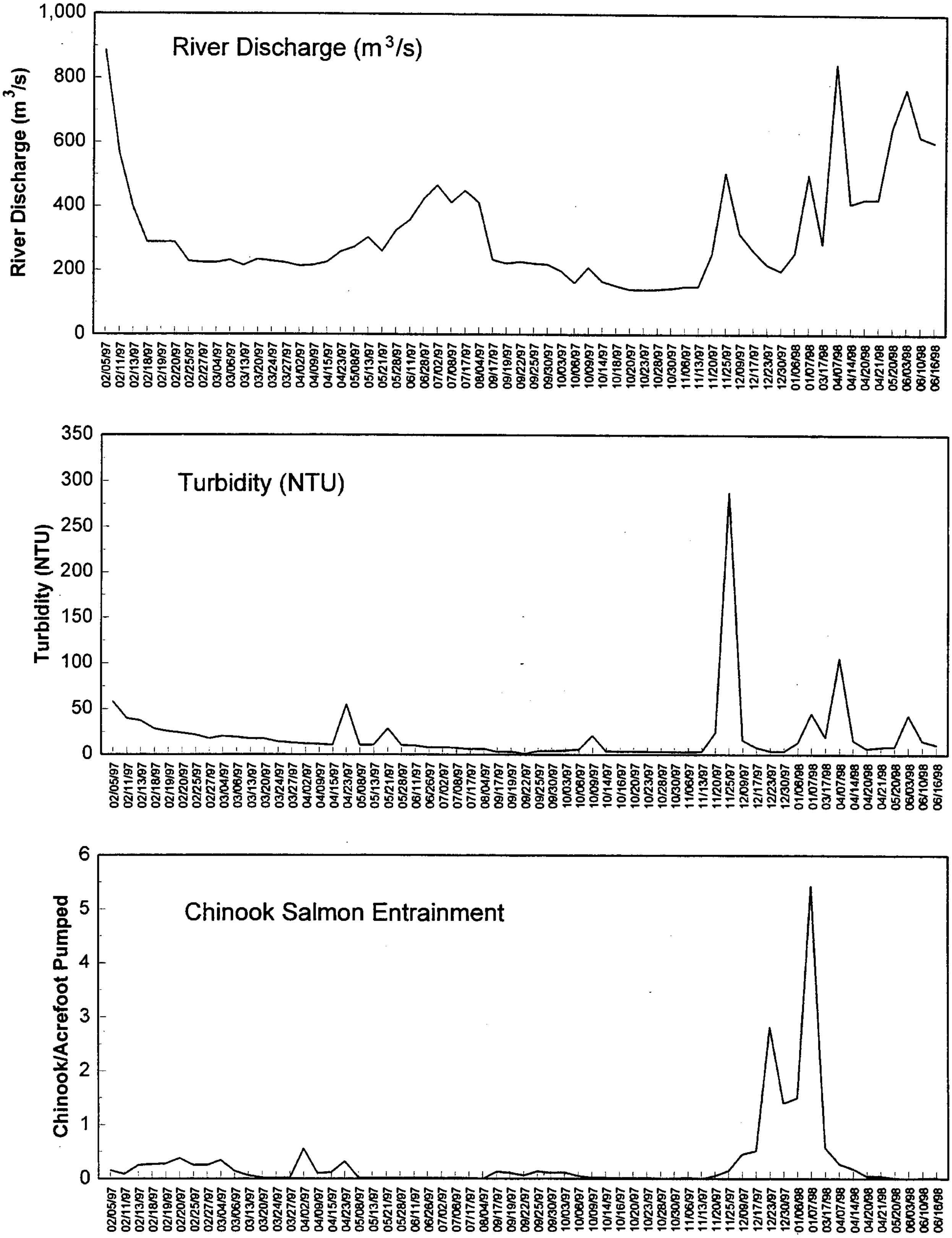

Figure 9. River discharge, turbidity, and entrainment rate of juvenile chinook salmon into Red Bluff Research Pumping Plant on each date that trials were conducted during February 1997 - June 1998.

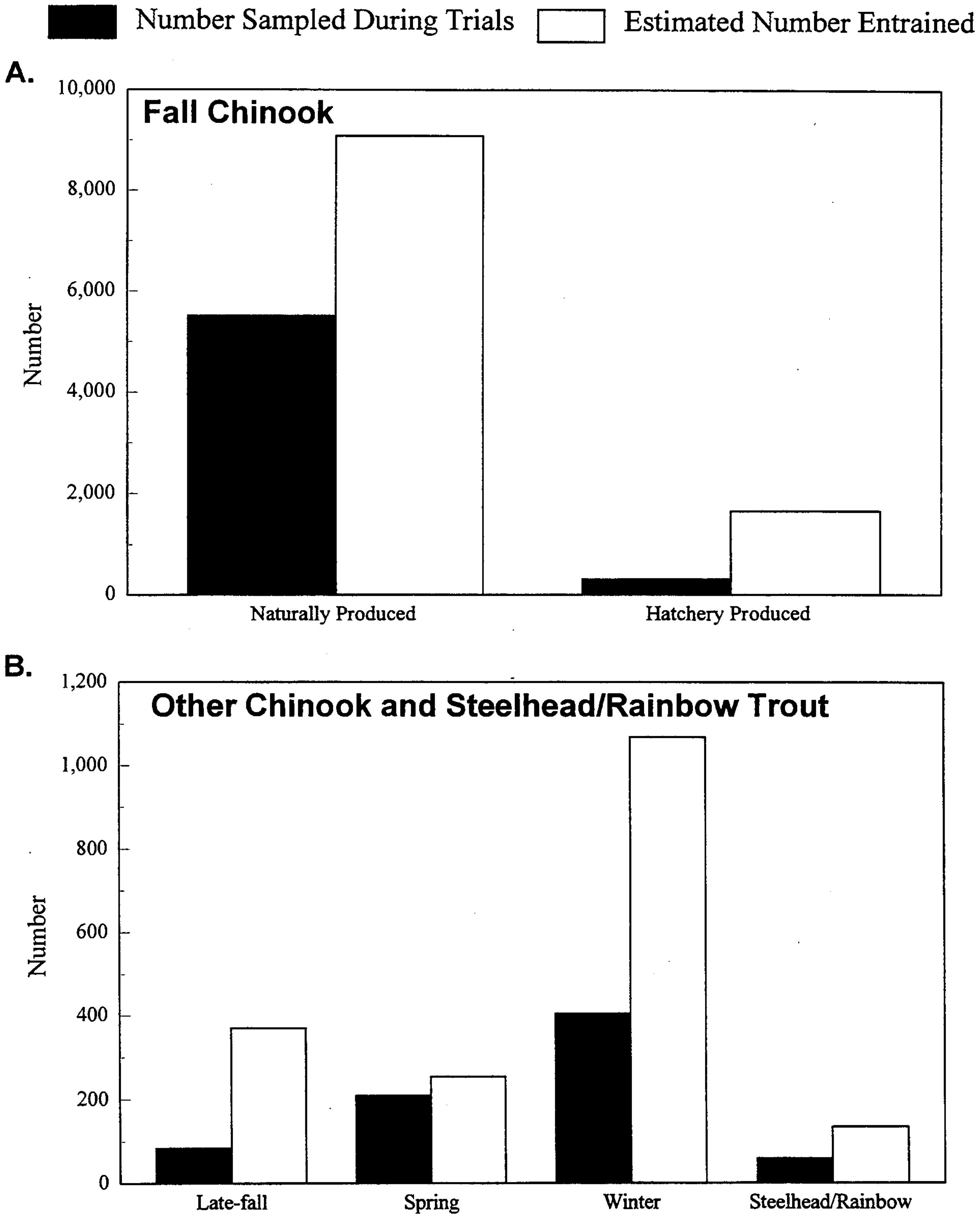

Figure 10. Number of chinook salmon, by run, sampled during entrainment trials and estimated number entrained into Red Bluff Research Pumping Plant, February 1997 - June 1998. A. Fall chinook are designated as naturally or hatchery produced based upon entrainment of adipose-clipped chinook. B. A distinction could not be made between juvenile steelhead and rainbow trout.

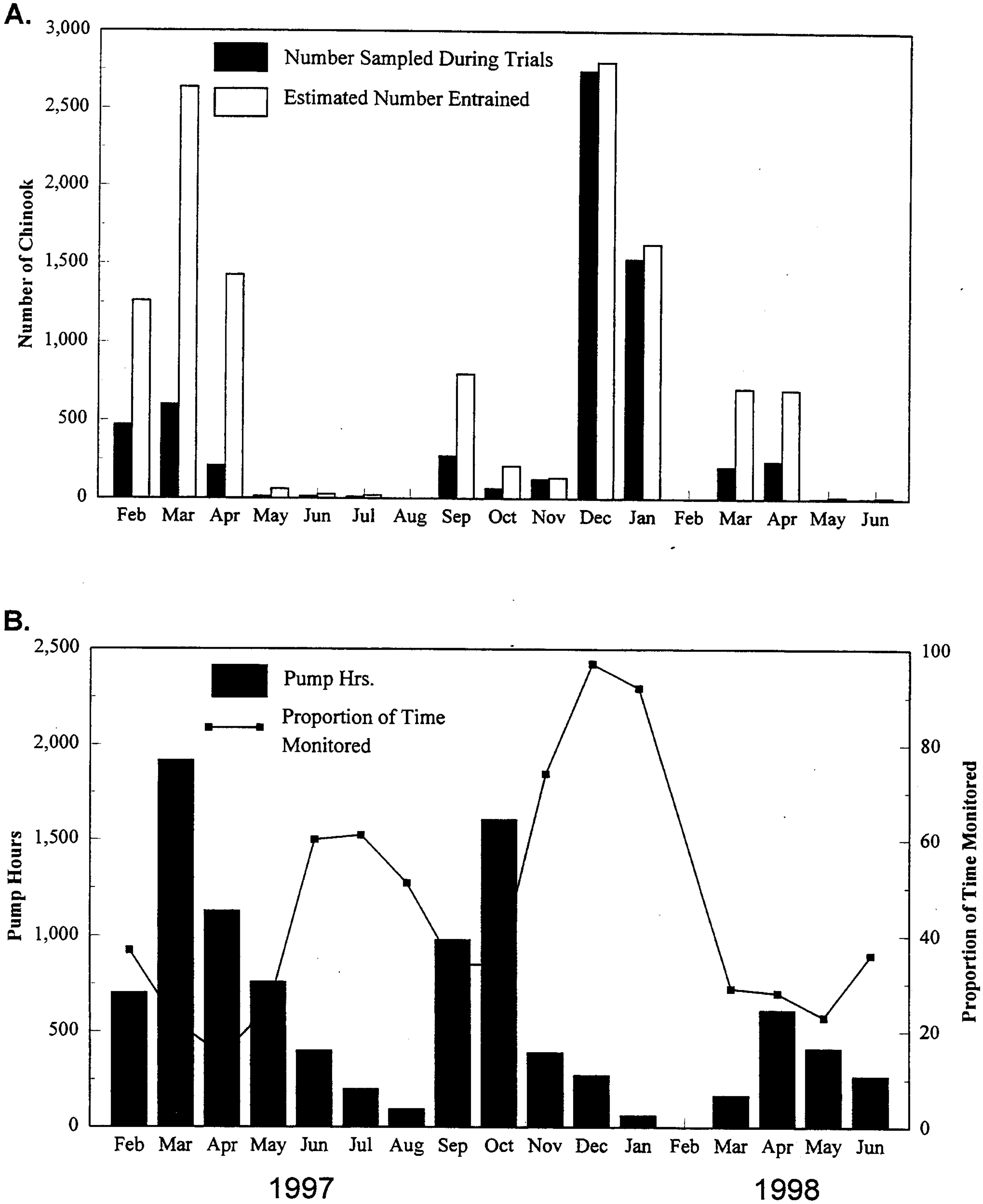

Figure 11. A. The number of chinook salmon sampled and the estimated number entrained into the Red Bluff Research Pumping Plant during each month from February 1997 - June 1998. The pumps were not operated in February 1998. B. The total pump hours and the proportion of time that entrainment of fish into the pumps was monitored each month.

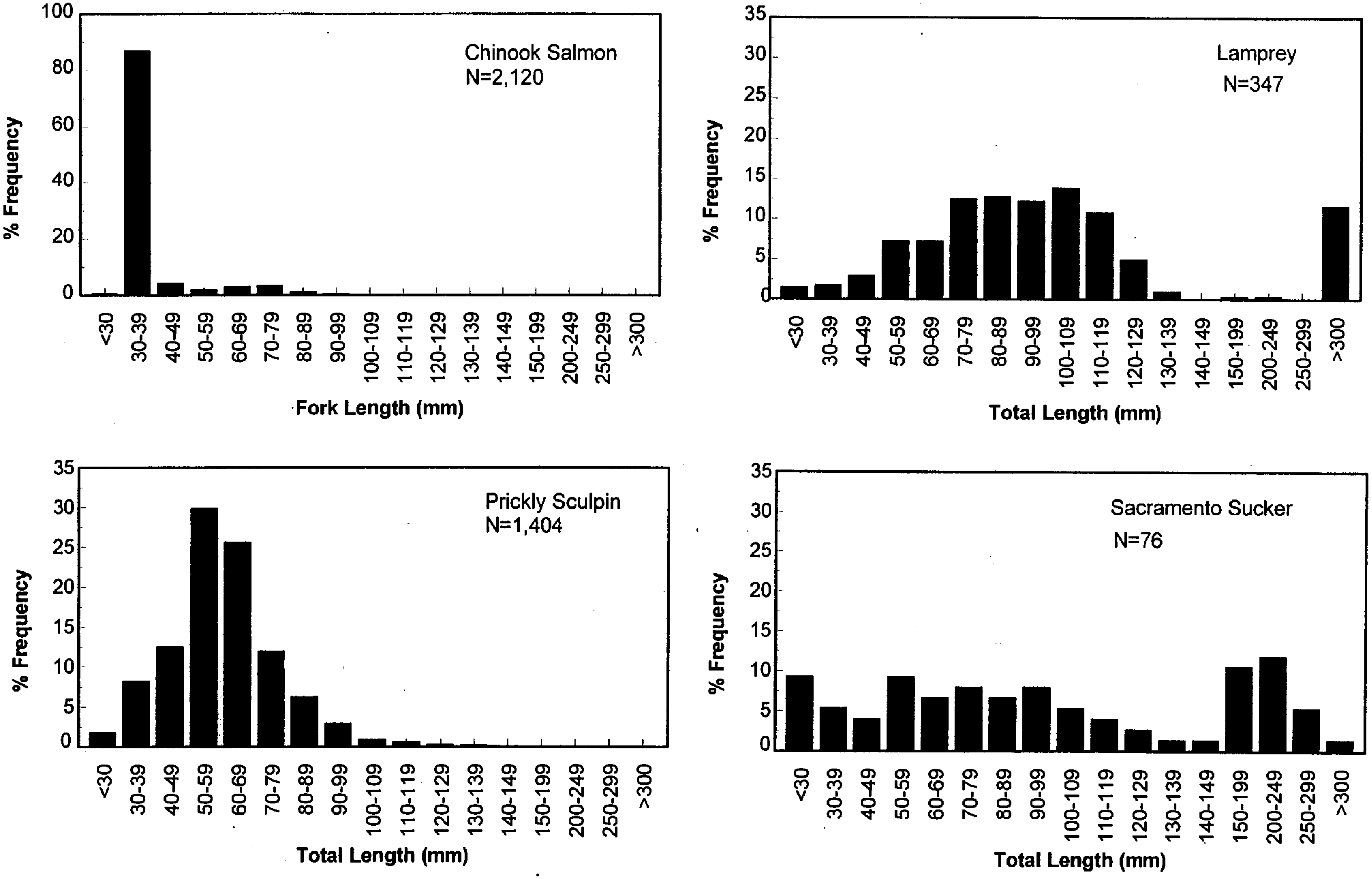

Figure 12. Size-frequency distribution of chinook salmon, lamprey, prickly sculpin, and Sacramento sucker entrained into Red Bluff Research Pumping Plant during 24 entrainment trials conducted when all three pumps operated simultaneously, February 1997 - June 1998.

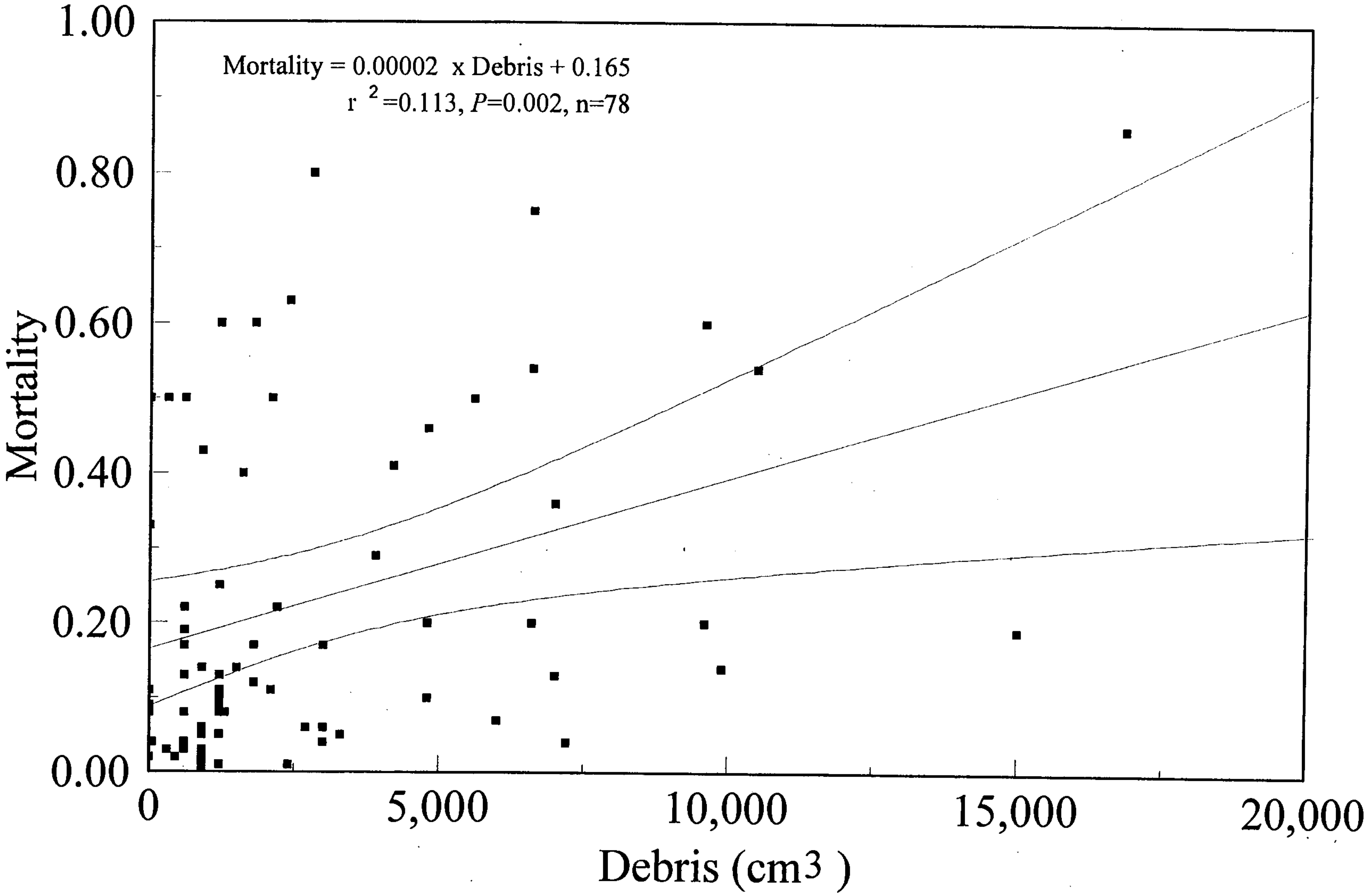

Figure 13. Mean daily mortality of chinook salmon entrained into Red Bluff Research Pumping Plant versus volume of debris entrained during trials conducted from February 1997 through June 1998.

Appendix 1. Weekly summary data for hours each pump operated, hours entrainment was monitored, number of chinook salmon and steelhead/rainbow trout sampled, and estimated number entrained into each pump, February 1997 - June 1998.

Week's Start Date	Pump	Hours Operated	Hours Monitored	NUMBER SAMPLED DURING ENTRAINMENT TRIALS						ESTIMATED NUMBER ENTRAINED					
				CHINOOK SALMON						CHINOOK SALMON					
				Natural Fall[1]	Hatchery Fall[1]	Latefall	Spring	Winter	Trout[2]	Natural Fall[1]	Hatchery Fall[1]	Latefall	Spring	Winter	Trout[2]
2/02/97	3	33	10.25	13	0				1	41.9					3.2
2/09/97	3	113.5	39.56	56		1			4	160.7		2.9			11.5
2/16/97	2	70.5	48	103					1	151.3					1.5
2/16/97	3	104.5	48	98					1	213.4					2.2
2/23/97	1	134	23.95	31						173.4					
2/23/97	2	134	48	112			2		1	312.7			5.6		2.8
2/23/97	3	111.5	38.75	83						238.8					
3/02/97	1	113.5	46.6	77						187.5					
3/02/97	2	135	46.6	106			1			307.1			2.9		
3/02/97	3	166.5	46.6	71					1	253.7					3.6
3/09/97	1	163	24	10					1	67.9					6.8
3/09/97	2	162	24	12						81					
3/16/97	1	160	24	3						20					
3/16/97	2	160	24	4			1			26.7			6.7		

[1] The number of hatchery-produced fall chinook was estimated as the quotient of the number of adipose-clipped fish entrained divided by the ratio of clipped and unclipped fish released from Coleman National Fish Hatchery. The number of naturally-produced chinook was calculated as the difference between the total number of chinook entrained and the estimated number of hatchery-produced chinook.

[2] Unable to distinguish between juvenile rainbow trout and steelhead.

Appendix 1. Weekly summary data for hours each pump operated, hours entrainment was monitored, number of chinook salmon and steelhead/rainbow trout sampled, and estimated number entrained into each pump, February 1997 - June 1998. Continued.

Week's Start Date	Pump	Hours Operated	Hours Monitored	NUMBER SAMPLED DURING ENTRAINMENT TRIALS						ESTIMATED NUMBER ENTRAINED					
				CHINOOK SALMON						CHINOOK SALMON					
				Natural Fall[1]	Hatchery Fall[1]	Latefall	Spring	Winter	Trout[2]	Natural Fall[1]	Hatchery Fall[1]	Latefall	Spring	Winter	Trout[2]
3/23/97	1	168	48	3					1	10.5					3.5
3/23/97	2	168	48	9						31.5					
3/23/97	3	136	24	5						28.3					
3/30/97	1	121	24	4	22					20.2	110.9				
3/30/97	2	121	24	5	144	3				25.2	726	15.1			
3/30/97	3	143	24	65	55					387.3	327.7				
4/06/97	1	168	24	17		1				119		7			
4/06/97	2	168	24	18		0				126					
4/06/97	3	168	24	17						119					
4/13/97	1	144	24	12	11					72	66				
4/13/97	2	144	24	7	11		1			42	66		6		
4/13/97	3	141.5													
4/20/97	1	168	24	24	11	7			1	168	77	49			7
4/20/97	2	168	24	30	32	11			1	210	224	77			7

[1] The number of hatchery-produced fall chinook was estimated as the quotient of the number of adipose-clipped fish entrained divided by the ratio of clipped and unclipped fish released from Coleman National Fish Hatchery. The number of naturally-produced chinook was calculated as the difference between the total number of chinook entrained and the estimated number of hatchery-produced chinook.

[2] Unable to distinguish between juvenile rainbow trout and steelhead.

Appendix 1. Weekly summary data for hours each pump operated, hours entrainment was monitored, number of chinook salmon and steelhead/rainbow trout sampled, and estimated number entrained into each pump, February 1997 - June 1998. Continued.

Week's Start Date	Pump	Hours Operated	Hours Monitored	NUMBER SAMPLED DURING ENTRAINMENT TRIALS						ESTIMATED NUMBER ENTRAINED					
				CHINOOK SALMON						CHINOOK SALMON					
				Natural Fall[1]	Hatchery Fall[1]	Latefall	Spring	Winter	Trout[2]	Natural Fall[1]	Hatchery Fall[1]	Latefall	Spring	Winter	Trout[2]
5/04/97	2	165.8	24	1		3			1	6.9		20.7			6.9
5/04/97	3	168	24	2						14					
5/11/97	1	118.5													
5/11/97	2	116.5	24	1		1				4.9		4.9			
5/11/97	3	118.4	24						1						4.9
5/18/97	1	35.4	24	1						1.5					
5/18/97	2	35.1	24	1		1				1.5		1.5			
5/25/97	1	46.1	24	1						1.9					
5/25/97	3	73	24	3						9.1					
6/08/97	1	48.25	24	1		1			1	2		2			2
6/08/97	3	60	24	3		1				7.5		2.5			
6/15/97	1	44.5	24						1						1.9
6/15/97	3	40	24												
6/22/97	1	46.25	24	1		1				1.9		1.9			
6/22/97	2	26.25	24						1						1.1

[1] The number of hatchery-produced fall chinook was estimated as the quotient of the number of adipose-clipped fish entrained divided by the ratio of clipped and unclipped fish released from Coleman National Fish Hatchery. The number of naturally-produced chinook was calculated as the difference between the total number of chinook entrained and the estimated number of hatchery-produced chinook.

[2] Unable to distinguish between juvenile rainbow trout and steelhead.

Appendix 1. Weekly summary data for hours each pump operated, hours entrainment was monitored, number of chinook salmon and steelhead/rainbow trout sampled, and estimated number entrained into each pump, February 1997 - June 1998. Continued.

Week's Start Date	Pump	Hours Operated	Hours Monitored	NUMBER SAMPLED DURING ENTRAINMENT TRIALS						ESTIMATED NUMBER ENTRAINED					
				CHINOOK SALMON						CHINOOK SALMON					
				Natural Fall[1]	Hatchery Fall[1]	Latefall	Spring	Winter	Trout[2]	Natural Fall[1]	Hatchery Fall[1]	Latefall	Spring	Winter	Trout[2]
6/22/97	3	24.25	24	2		1				2		1			
6/29/97	1	25.25	24												
6/29/97	2	46.25	24	2		1				3.9		1.9			
6/29/97	3	37.25	24												
7/06/97	1	48.5	24	6						12.1					
7/06/97	2	33.25	24			2			1			2.8			1.4
7/06/97	3	33	24	2						2.8					
7/13/97	1	56.25	24	1		1				2.3		2.3			
7/13/97	2	25.5	24												
8/03/97	1	24	24			1						1			
8/03/97	2	69.25	24						2						5.8
9/14/97	1	88.55	47.7					40						74.3	
9/14/97	2	88.55	47.7	1				43	3	1.9				79.8	5.6
9/21/97	1	168	48					21	1					73.5	3.5
9/21/97	2	168	48					59						206.5	

[1] The number of hatchery-produced fall chinook was estimated as the quotient of the number of adipose-clipped fish entrained divided by the ratio of clipped and unclipped fish released from Coleman National Fish Hatchery. The number of naturally-produced chinook was calculated as the difference between the total number of chinook entrained and the estimated number of hatchery-produced chinook.

[2] Unable to distinguish between juvenile rainbow trout and steelhead.

Appendix 1. Weekly summary data for hours each pump operated, hours entrainment was monitored, number of chinook salmon and steelhead/rainbow trout sampled, and estimated number entrained into each pump, February 1997 - June 1998. Continued.

Week's Start Date	Pump	Hours Operated	Hours Monitored	NUMBER SAMPLED DURING ENTRAINMENT TRIALS						ESTIMATED NUMBER ENTRAINED					
				CHINOOK SALMON						CHINOOK SALMON					
				Natural Fall[1]	Hatchery Fall[1]	Latefall	Spring	Winter	Trout[2]	Natural Fall[1]	Hatchery Fall[1]	Latefall	Spring	Winter	Trout[2]
9/21/97	3	129.5	48			4		24				10.8		64.8	
9/28/97	1	168	48			1		19				3.5		66.5	
9/28/97	2	168	48					61						213.5	
10/05/97	1	165.45	48					10						34.5	
10/05/97	2	168	48					16						56	
10/05/97	3	99	35.4					6						16.8	
10/12/97	1	168	48.2					3	1					10.5	3.5
10/12/97	2	168	48.2					7						24.4	
10/12/97	3	88	24												
10/19/97	1	168	48					7						24.5	
10/19/97	2	168	48					7						24.5	
10/19/97	3	127.75	48					2						5.3	
10/26/97	1	105.7	48					2						4.4	
10/26/97	2	105.7	48					2						4.4	
10/26/97	3	75.2	48					2						3.1	

[1] The number of hatchery-produced fall chinook was estimated as the quotient of the number of adipose-clipped fish entrained divided by the ratio of clipped and unclipped fish released from Coleman National Fish Hatchery. The number of naturally-produced chinook was calculated as the difference between the total number of chinook entrained and the estimated number of hatchery-produced chinook.

[2] Unable to distinguish between juvenile rainbow trout and steelhead.

Appendix 1. Weekly summary data for hours each pump operated, hours entrainment was monitored, number of chinook salmon and steelhead/rainbow trout sampled, and estimated number entrained into each pump, February 1997 - June 1998. Continued.

Week's Start Date	Pump	Hours Operated	Hours Monitored	NUMBER SAMPLED DURING ENTRAINMENT TRIALS						ESTIMATED NUMBER ENTRAINED					
				CHINOOK SALMON						CHINOOK SALMON					
				Natural Fall[1]	Hatchery Fall[1]	Latefall	Spring	Winter	Trout[2]	Natural Fall[1]	Hatchery Fall[1]	Latefall	Spring	Winter	Trout[2]
11/02/97	1	29.5	24					2						2.5	
11/02/97	2	29.5	24			1		6				1.2		7.4	
11/02/97	3	69.5	24					2						5.8	
11/09/97	1	28.1	24					1						1.2	
11/09/97	2	26.6	24					1						1.1	
11/09/97	3	56	24												
11/16/97	1	25	24				3	6	1				3.1	6.3	1
11/16/97	2	25	24				6	10					6.3	10.4	
11/16/97	3	25	24				1	3					1	3.1	
11/23/97	1	24.5	24				9	11	2				9.2	11.2	2
11/23/97	2	24.5	24				20	9	2				20.4	9.2	2
11/23/97	3	24.5	24				15	19	2				15.3	19.4	2
12/07/97	1	24.5	24	58			29	2		59.2			29.6	2	
12/07/97	3	24.5	24	47			29			48			29.6		
12/14/97	1	24.75	24	55			14			56.7			14.4		

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[1] The number of hatchery-produced fall chinook was estimated as the quotient of the number of adipose-clipped fish entrained divided by the ratio of clipped and unclipped fish released from Coleman National Fish Hatchery. The number of naturally-produced chinook was calculated as the difference between the total number of chinook entrained and the estimated number of hatchery-produced chinook.

[2] Unable to distinguish between juvenile rainbow trout and steelhead.

Appendix 1. Weekly summary data for hours each pump operated, hours entrainment was monitored, number of chinook salmon and steelhead/rainbow trout sampled, and estimated number entrained into each pump, February 1997 - June 1998. Continued.

Week's Start Date	Pump	Hours Operated	Hours Monitored	NUMBER SAMPLED DURING ENTRAINMENT TRIALS						ESTIMATED NUMBER ENTRAINED					
				CHINOOK SALMON						CHINOOK SALMON					.
				Natural Fall[1]	Hatchery Fall[1]	Latefall	Spring	Winter	Trout[2]	Natural Fall[1]	Hatchery Fall[1]	Latefall	Spring	Winter	Trout[2]
12/14/97	2	24.75	24	124			24			127.9			24.8		
12/14/97	3	25.5	24	50			9			53.1			9.6		
12/21/97	1	24.5	24	408			5	1		416.5			5.1	1	
12/21/97	2	24.2	24	887			23			894.4			23.2		
12/21/97	3	24.5	24	210			4			214.4			4.1		
12/28/97	1	24.75	24	206						212.4					
12/28/97	2	24.75	24	423			1			436.2			1		
12/28/97	3	24.75	24	136						140.3					
1/04/98	1	10.7	7.92	96					1	129.7					1.4
1/04/98	2	25	24	609					6	634.4					6.3
1/04/98	3	25	24	827			1		13	861.5			1		13.5
3/15/98	1	82.75	24	112			8		1	386.2			27.6		3.4
3/15/98	2	82.75	24	82			2		2	282.7			6.9		6.9
4/05/98	1	50.5	24	21	11	1				44.2	23.1	2.1			
4/05/98	2	24	24	56		6	1	1		56		6	1	1	

[1] The number of hatchery-produced fall chinook was estimated as the quotient of the number of adipose-clipped fish entrained divided by the ratio of clipped and unclipped fish released from Coleman National Fish Hatchery. The number of naturally-produced chinook was calculated as the difference between the total number of chinook entrained and the estimated number of hatchery-produced chinook.

[2] Unable to distinguish between juvenile rainbow trout and steelhead.

Appendix 1. Weekly summary data for hours each pump operated, hours entrainment was monitored, number of chinook salmon and steelhead/rainbow trout sampled, and estimated number entrained into each pump, February 1997 - June 1998. Continued.

				NUMBER SAMPLED DURING ENTRAINMENT TRIALS						ESTIMATED NUMBER ENTRAINED					
				CHINOOK SALMON						CHINOOK SALMON					
Week's Start Date	Pump	Hours Operated	Hours Monitored	Natural Fall[1]	Hatchery Fall[1]	Latefall	Spring	Winter	Trout[2]	Natural Fall[1]	Hatchery Fall[1]	Latefall	Spring	Winter	Trout[2]
4/12/98	1	100.5	24	44		6				184.3		25.1			
4/12/98	2	75.5	24	19		7				59.8		22			
4/12/98	3	55	24		14	6					32.1	13.8			
04/19/98	1	168	24	13		9				91		63			
04/19/98	2	136	24	2		3				11.3		17			
5/17/98	1	59.5	24			1			1			2.5			2.5
5/17/98	2	79	24	1		1				3.3		3.3			
5/31/98	1	136.5	24						1						5.7
5/31/98	2	136	24			1						5.7			
6/07/98	1	96	24												
6/07/98	2	102.25	24	2						8.5					
6/14/98	1	33.5	24	1						1.4					
6/14/98	2	33.5	24	1					1	1.4					1.4
TOTALS		10,376.8	3343.3	5514	311	84	209	405	59	9085.8	1652.9	369.5	254.4	1068.8	133.7

1 The number of hatchery-produced fall chinook was estimated as the quotient of the number of adipose-clipped fish entrained divided by the ratio of clipped and unclipped fish released from Coleman National Fish Hatchery. The number of naturally-produced chinook was calculated as the difference between the total number of chinook entrained and the estimated number of hatchery-produced chinook.

2 Unable to distinguish between juvenile rainbow trout and steelhead.

Attachment 9

Wild Fish Entrainment By Archimedes Lifts and Internal Helical Pump at the Red Bluff Research Pumping Plant, Upper Sacramento River, California: February 1997 – May 2000,

Sandra Borthwick, Richard Corwin

WILD FISH ENTRAINMENT BY ARCHIMEDES LIFTS AND AN INTERNAL HELICAL PUMP AT THE RED BLUFF RESEARCH PUMPING PLANT, UPPER SACRAMENTO RIVER, CALIFORNIA: FEBRUARY 1997 - MAY 2000

Red Bluff Research Pumping Plant
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WILD FISH ENTRAINMENT BY ARCHIMEDES LIFTS AND AN INTERNAL HELICAL PUMP AT THE RED BLUFF RESEARCH PUMPING PLANT, UPPER SACRAMENTO RIVER, CALIFORNIA: FEBRUARY 1997 - MAY 2000

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Abstract-The overall goal of the Red Bluff Research Pumping Plant (RPP) biological evaluation program was to determine whether Archimedes lifts and internal helical pumps could be used to deliver water to the Tehama-Colusa canal without harming fisheries resources in the Sacramento River, with emphasis on chinook salmon. From February 1997 through May 2000, 133 trials were conducted to evaluate species, numbers, and characteristics of fish entrained from the river into the RPP. Trials lasted 24 hours and were segmented into diurnal and nocturnal periods. After passing through a lift or pump, fish were captured in downstream holding tanks, identified, measured (length), and assessed for mortality and injury. The specific objectives addressed in this study were: 1) determine diel and seasonal patterns of entrainment, 2) compare mortality and injury to fish passed through Archimedes lifts and the internal helical pump, 3) estimate the number of chinook salmon entrained annually, and 4) estimate the fraction of juvenile chinook salmon passing Red Bluff Diversion Dam that were entrained into the RPP.

Twenty-eight species of fish were captured during entrainment trials. Juvenile chinook salmon were most frequently entrained followed by prickly sculpin, lamprey, Sacramento sucker, Sacramento pikeminnow, and riffle sculpin. These six species comprised 94% of the 26,220 fish captured. Ninety-four percent of entrained fish were <100 mm in length. Nocturnal entrainment of chinook salmon exceeded diurnal entrainment in 33 of 35 months. Other fish species were also entrained more frequently at night. Seasonal patterns of chinook salmon entrainment followed patterns of abundance in the river, peaking in winter as fall-run juvenile chinook salmon outmigrated.

Mortalities and injuries of fish were compared among pumps during eighty 24-h trials and fifteen 2 to 3-h trials when all three pumps operated simultaneously. In the short-duration trials fish were removed from the tanks every 10-15 minutes. The objective of the short-duration trials was to minimize mortality due to confinement in holding tanks. In both 24-h and short-duration trials, mortalities and injuries were not due solely to pump passage. On their way to the holding tanks, fish traveled past screens with motorized brushes and into concrete channels where dewatering ramps were used to adjust the amount of flow into the tanks. Once in the holding tanks, fish were subject to turbulence and debris. Also, condition of the fish prior to entrainment was unknown. Therefore, frequency of mortality and sub-lethal injury obtained in this study for wild entrained fish are assumed to be overestimates of that due to pump passage alone.

Mean percent mortality of chinook salmon in the short-duration trials was 0.9, 0.6, and 1.2 for Archimedes 1, Archimedes 2, and the internal helical pump, respectively, compared to 2.8, 2.9, and 4.9 in the 24-h trials. Mortality did not differ significantly among the three pumps for the short-duration or the 24-h trials. Percent frequency of chinook salmon with sub-lethal injuries was < 0.3% for each of the three pumps during short-duration trials and <1.8% in the 24-h trials.

The total number of chinook salmon entrained during trials was consistently less than 5,000 each year. The estimated number entrained was calculated weekly for each pump as the product of the number entrained per hour during trials and the hours the pump operated. The estimated total number of chinook salmon entrained was consistently less than 10,000 each year. During this study the RPP was operated for biological evaluations during all seasons. Therefore, the number of fish entrained was higher than would occur if the plant was used solely to meet water needs of the Tehama-Colusa and Corning canals. Forty-nine percent of chinook salmon entrained were collected during trials conducted in December and January, months that the plant typically would not be operated to supply water to the canals.

During this study, 24-h trials were conducted simultaneously with the U. S. Fish and Wildlife Service's rotary screw trap sampling in the Sacramento River to determine the fraction of chinook salmon in the river entrained into the RPP during different seasons of the year. The screw trap sampling provided daily estimates of the total number of juvenile chinook salmon passing Red Bluff Diversion Dam (RBDD). The fraction of fish passing RBDD that were entrained into the RPP was consistently less than the fraction of river discharge diverted. During 84 trials, the fraction of daily passage entrained ranged from 0.00007 to 0.0138 and averaged 0.0022 (0.22%). The highest fraction entrained occurred during the winter outmigration of fall chinook salmon. The fraction of winter chinook salmon entrained averaged 0.0017 and ranged from 0.00008 to 0.0066. The small fraction of salmon entrained likely was due to the position of the pump intakes near the bottom of the river whereas the majority of outmigrating chinook salmon inhabited the upper water column. The small fraction of chinook salmon entrained into the RPP, combined with the low frequency of mortality and sub-lethal injury to all fish passed through the pumps, supports the conclusion that the RPP can be operated with little harm to fishery resources, including chinook salmon, in the Sacramento River at Red Bluff.

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Introduction

Populations of anadromous salmonid fishes in the Pacific Northwest have been reduced by anthropogenic alterations of streams, rivers and their riparian landscapes over the last 150 years. Many consider hydroelectric and water diversion dams to be major factors in the decline of salmonid fishes due to juvenile and adult passage delays, entrainment of juveniles within associated pumping facilities and canals, and loss of habitat (Hallock 1959; Rainey 1985; Pearce and Lee 1991; Liston et al. 1994; Yoshiyama et al. 1998; Black 1998). In California, large water diversions and pumping projects on the upper mainstem of the Sacramento River, including the Glenn-Colusa Irrigation District (GCID), Anderson-Cottonwood Irrigation District (ACID), and Red Bluff Diversion Dam (RBDD) have contributed to the decline of chinook salmon *Oncorhynchus tshawytscha* populations (Ward 1989, Vogel et al. 1988). Winter and spring runs of chinook salmon in the Sacramento River are listed as protected under the *Endangered Species Act of 1973* (59 FR 440; 64 FR 50393, respectively). Steelhead *Oncorhynchus mykiss*, another native salmonid in the Sacramento River, is also federally listed (63 FR 13347).

Prior to installation of the rotary drum screens in 1975, GCID's pumping facility (river km 332; Figure 1) entrained and killed an estimated 800,000 to 9,100,000 juvenile chinook salmon annually (Ward 1989; USA v GCID 1992). Further upstream, ACID's diversion dam (river km 480; Figure 1) also entrained juvenile chinook salmon into its Bonneyview Pump Diversion Facility. According to California Department of Fish and Game (CDFG), ACID's unscreened pumps entrained between 1.23% and 2.45% of the 1991 annual winter-run emergent fry by September of that year (CDFG v. ACID 1992). As a result of these findings, a cylindrical fish screen was installed on this pump facility in 1992.

Completion of Red Bluff Diversion Dam (RBDD; river km 391; Figure 1) in 1964 and lowering of the dam gates in 1966 to supply water to the Tehama-Colusa canal (TCC) posed another threat to outmigrating juvenile chinook salmon in the Sacramento River. From 1982 through 1987 the annual entrainment of outmigrating chinook salmon into the canal headworks varied from 0.2 to 0.6 million (Vogel et al. 1988). The fish louver and bypass system, original components of RBDD, were ineffective at diverting entrained juveniles back to the Sacramento River, and injured 1.6% to 4.1% of the migrants passing through the facility. As a result, in 1990 the louvers and bypass system were replaced with rotary drum screens and a new fish bypass system. The new facilities proved to be successful at returning entrained juveniles to the river unharmed (Bigelow and Johnson 1996).

Since the Federal listing of winter-run chinook salmon as endangered in 1994, the gates on RBDD have been raised each year from September 15th through May 15th to accommodate fish passage. In 1995 the Bureau of Reclamation (Reclamation) completed construction of Red Bluff Research Pumping Plant (RPP) near Red Bluff Diversion Dam (Figure 1; McNabb et al. 1998, Frizell and Atkinson 1999). This project was part of Reclamation's commitment to improve fish passage at the dam and to deliver water to the Tehama-Colusa canal as needed during the eight-month gates-raised period. The plant has two Archimedes lifts and an internal helical pump

(Figure 2a). The lifts and pump were developed to attempt to pass fish with minimal injury or mortality. Because all three pump intakes are unscreened, fish from the Sacramento River are entrained into the plant. Fish pass through a trash rack with 5 cm (2 in) spacings that exclude large debris and most large fish from the pumps. Vertical wedgewire screens designed to contain fish but pass water are located downstream of the pump outfalls (Figure 2b). About 90% of the flow passes through the screens to the TCC while about 10% of the flow, along with entrained fish and debris, continues into an open, curved bypass channel (Figure 2c). Flows in the bypass channel can be diverted into holding tanks (Figure 2d) or returned to the river downstream of RBDD via underground conduits (Figure 3) .

If the Archimedes lifts and helical pump at the RPP are to be part of the ultimate solution to fish passage problems at RBDD, they must be able to provide water to the TCC without harming fishery resources in the Sacramento River. To evaluate the plant's ability to do this, Reclamation and interagency cooperators developed a biological evaluation program for the RPP to be conducted over several years (Liston and Johnson 1992). Work presented in this report addresses entrainment of adult and juvenile fish from the Sacramento River into the plant, with an emphasis on juvenile chinook salmon (Objective I). Results of this study will be used to help determine whether Archimedes lifts and internal helical pumps can operate satisfactorily with minimal harm to fish populations in the Sacramento River. If the pumps prove benign, their use would continue to facilitate gates-raised operation of RBDD from mid-September through mid-May with the potential for construction of a larger pumping facility that could deliver water to meet needs year-round.

The overall purpose of this study was to quantify and characterize entrainment of juvenile chinook salmon and other fish species into the RPP during different seasons of the year. The specific study objectives were to:

1. Record diel and seasonal patterns of entrainment for chinook salmon and other fish species entrained into the RPP from the Sacramento River.

2. Estimate the number of individuals in each of the four runs of chinook salmon entrained annually into the RPP.

3. Compare percent frequencies of mortality and sub-lethal injury to fish passed through Archimedes lifts versus the internal helical pump.

4. Estimate the fraction of wild juvenile chinook salmon passing Red Bluff Diversion Dam that are entrained into the RPP during different seasons of the year.

Methods

Plant Operations

The Archimedes lifts, manufactured by Wheelebrator/CPC, consist of 11.5 m (38 ft) long, 3.0 m (10 ft) diameter rotating cylinders with three helical flights continuously welded along the length of the cylinder's inside walls. The lifts are unique in having a rotating, sealed inlet at their lower end allowing them to operate over a wide range of river elevations. During this study each Archimedes lift operated at 26.5 revolutions per minute (rpm), delivering water at an average rate of 2.5 m^3/s (89 to 90 ft^3/s; Table 1). The hydraulic lift ranged from about 3.0 - 4.3 m (10 - 16 ft), depending upon river elevation. The internal helical pump, manufactured by Wemco-Hidrostal, has an inlet diameter of 91 cm (36 in) and is the largest of its type ever constructed (Frizell and Atkinson 1999). It has a single-vane impeller cast with a rotating conical shroud. From February 1997 through April 1998 the internal helical pump operated at 378 rpm and delivered an average of 2.7 m^3/s (96 ft^3/s; Table 1). In September 1998 the speed was reduced to 350 rpm using the variable speed drive. In December 1998 a smaller gear box was installed on the helical pump to permanently reduce the maximum speed to 350 rpm which was used for the remainder of the study. This reduced speed resulted in a decrease in pump discharge to 2.3 m^3/s (82.6 ft^3/s). The hydraulic lift ranged from about 3.8 - 5.5 m (12.5 - 18.5 ft).

The Archimedes lifts operated reliably during this study, and both lifts were operated a similar number of hours (Figure 4). The helical pump operated fewer hours than the Archimedes lifts because of repairs in 1997 and 1998. However, after its speed was reduced in September 1998, the helical pump operated with the same reliability and during the same periods as the Archimedes lifts (Table 1). In some years all three pumps were inoperable in winter and spring due to high river levels.

Fish entrainment was monitored 30% and 32% of the time that Archimedes 1 and Archimedes 2 operated, respectively (Table 1). The number of 24-h trials conducted was 118 and 122, respectively. The helical pump operated for approximately 1500 fewer hours than the Archimedes lifts. Entrainment was monitored 30% of the operating time, and ninety-four 24-h trials were conducted. Eighty 24-h trials were conducted when all three pumps operated simultaneously.

Entrainment Trials

24-h Trials

To address the study objectives, 133 24-h trials were conducted to monitor entrainment of fish from the Sacramento River. During 80 of these trials, all three pumps were operated simultaneously for 24 continuous hours. These trials were termed *complete trials.* Data from these trials were used to compare mortality and sub-lethal injury of fish among pumps since they were operated under similar environmental conditions.

Incomplete trials were those 24-h trials in which mechanical problems or high water levels caused one or more of the pumps to be inoperable or to shut down before the trial was completed. Fifty-three incomplete trials were conducted. Data from all 24-h trials (complete and incomplete) were used to tabulate numbers of fish entrained, to assess species composition and characteristics, to determine diel and seasonal entrainment patterns, and to estimate and project the number of chinook salmon entrained. Data from 84 trials, including complete trials and incomplete trials in which at least two pumps operated continuously for 24 h, were used to assess the fraction of wild chinook salmon entrained based upon data collected simultaneously with the Fish and Wildlife Service's screw trap monitoring.

Wild fish entrained from the river passed through a pump, were discharged into a concrete channel, traveled past vertical wedge-wire screens with motorized brushes and into an open, concrete bypass channel (Figure 3). During trials, wedge-wire screen dewatering ramps on each pump's bypass channel were lowered and the weir beneath the ramp was adjusted to divert approximately 0.02 m^3/s (0.7 ft^3/s) of flow up the ramp and into one of two holding tanks. Fish and debris contained in the bypass flows were also diverted into the holding tanks. The 1.2 m^2 holding tanks contained water to a depth of 0.9 m when full. They operated as a flow-through system with a water replacement rate of 1.2 minutes; discharge flowed into the bypass channel. At these flows, ambient river water quality and relatively non-turbulent conditions were maintained in the holding tanks.

Each 24-h trial began at sunrise and lasted 24 h unless an unscheduled shutdown of the pumps occurred. Fish and debris were removed from the holding tanks twice during these trials; at sunset and the following sunrise. This allowed diel entrainment patterns to be assessed. Times for sunrise and sunset were obtained from the website of the U. S. Naval Observatory in Bethesda, Maryland using the coordinates of latitude and longitude for the pumping plant. Each time tanks were cleared of fish, physiochemical data of water and pumping conditions were recorded, volume of debris in each holding tank was measured, and each fish was identified, measured, and assessed for mortality and injuries. Debris was measured volumetrically (cc) using displacement of water in a graduated 20 L bucket. Fish were returned to the river via the bypass conduits that exit the pumping plant into the Sacramento River or released directly into the river downstream of the pump intakes.

To assess seasonal patterns of entrainment, trials were conducted year-round when possible. Trials could not be conducted when river flows exceeded about 991 m^3/s (35,000 ft^3/s) during winter and spring storms. Under such high flows, pumps were shut down and pinch valves in the underground fish bypass conduits were closed to prohibit flooding of the plant. When river levels allowed, at least one 24-h trial was conducted each week throughout the year. From July 1 through March 31 of each year when juvenile winter chinook salmon could be in the river near the RPP, two 24-h trials were conducted each week that the pumps operated continuously (i.e., 24 h each day). This typically occurred in the spring (March) and fall (September 15 - October 31) when the gates on RBDD were raised out of the river yet water was required for agriculture and refuges.

Short-duration Trials

Data from complete 24-h trials were used to compare mortality and sub-lethal injury of fish among the three pumps. However, fish collected during these trials were confined in holding tanks for up to 14 h depending upon when they arrived in the tank in relation to the sunrise or sunset entrainment check. Conditions within the holding tanks could affect fish survival. High debris loads, high water flows into the tanks, long periods of confinement, and presence of other fish in the holding tank all could contribute to fish mortality and injury. Therefore, the 24-h trials included confinement and other effects, and likely over-estimated mortality and injury to fish entrained into the RPP. To obtain better estimates of mortality and injury of wild, entrained fish, 15 *short-duration trials* were conducted in winter and spring 2000 when high numbers of juvenile fall chinook salmon were entrained. During these 2 to 3-h entrainment trials, fish were removed from holding tanks, measured, and assessed for injury and mortality every 10 to 15 minutes. Therefore, mortality was not confounded with long-term confinement or conditions in the holding tanks. However, in both 24-h and short-duration trials, the condition of fish prior to entrainment was unknown. Entrained fish were transported to the river water facility and held for 96 h to assess delayed mortality. Data from the short-duration trials were used to compare mortality and sub-lethal injury among pumps and to evaluate length frequencies of entrained fish; data were not used to assess diel or seasonal entrainment patterns.

Environmental Data

Measurements of river elevation (m;ft), and speed (hz) and discharge (m^3/s; ft^3/s) of each pump were automated and continuously recorded on a computer in the pumping plant's automation facility. Water temperature (°C), dissolved oxygen (ppm, percent saturation), and total gases (% saturation) were measured from river water passing through the holding tanks. Water temperature and dissolved oxygen were measured with a YSI® Model 55 dissolved oxygen meter. Total gases were measured with a Sweeney® Model DS1-A saturometer. An HF Scientific® continuously-monitoring turbidimeter located in the river water fish facility associated with the RPP was used to measure turbidity (NTU).

In 1997 a HydroLab® DataSonde water quality monitoring probe deployed in the Sacramento River on the east side of RBDD provided hourly measurements of water temperature, dissolved oxygen, conductivity, and pH. Each month, data were downloaded, and probes were cleaned and calibrated. In 1998, Reclamation's Northern California Area Office replaced the Hydrolab with a YSI 6820 probe which provided hourly readings of water temperature and dissolved oxygen. These data were accessed through the California Department of Water Resources Data Exchange Center website. Reclamation's Operations and Maintenance personnel provided estimates of daily river discharge (m^3/s; ft^3/s) past RBDD based on data from the U. S. Geological Survey's gaging station near Bend Bridge, approximately 24 km upstream.

Numbers and Characteristics of Entrained Fish

Data from all 24-h trials were used in tabulating and characterizing entrained fish. Fish captured in holding tanks during trials were identified to species, measured (fork length for salmonids, total length for others) to the nearest 1.0 mm, assessed for mortality and injury, and inspected for tags, fin clips, or dyes that designate them as hatchery-released fish or as fish from another study. Injury assessment involved visually inspecting each fish for abnormalities to the integument, eyes, head, and fins. Run designation for chinook salmon was determined from a daily fork-length table generated by Green (1992). When high numbers of juvenile chinook salmon were entrained, the first 100 removed from each holding tank were measured. Additional chinook salmon were counted and recorded as extra dead or extra alive. For other species, the first 30 fish from each holding tank were measured and the remainder counted and recorded as extra dead or extra alive.

Larval fish <30 mm length were frequently observed in the holding tanks, especially during spring trials. These fish were not efficiently retained because of the relatively large mesh-size (3.2 mm, 0.13 in) of nets used to hold fish in the tanks. Therefore, data on fish <30 mm are not reported here. Numbers and patterns of larval fish entrainment were assessed in a separate study under Objective N of the RPP evaluation program (Liston and Johnson 1992; Borthwick and Weber 2001).

Seasonal and Diel Patterns of Entrainment

Data from all 24-h entrainment trials, regardless of the number of pumps operated, were used to determine seasonal and diel patterns of entrainment. However, trials that included only day or only night data were not included in analysis of diel patterns. Start and end times of each diurnal and nocturnal monitoring period were recorded for each trial. Total operating time and pump discharge were used to calculate acre-feet of water pumped during each diel period for each trial. In a 24-h period, approximately 175, 350, and 525 acre-feet of water was pumped when 1, 2, or 3 pumps operated, respectively. The number of fish entrained per acre-foot of water pumped was calculated monthly for each diel period. Monthly comparisons of the number entrained per acre-foot between nocturnal and diurnal periods were made for chinook salmon and other frequently entrained species.

Entrainment trials were conducted in all but five months between February 1997 and May 2000, allowing seasonal patterns of entrainment to be assessed over this three and one-half year period. The number entrained per acre-foot each month was used to assess seasonal patterns of entrainment for chinook salmon and other fish species.

Estimated and Projected Numbers of Chinook Salmon Entrained

Twenty-four hour entrainment trials were used as samples to estimate and project the number of chinook salmon, by run, entrained into the pumps each week. The *estimated* number entrained each week was the product of the number of chinook salmon entrained per hour during trials and the number of hours the pumps operated. The *projected* number entrained each week was the product of the number of chinook salmon entrained per hour during trials and the total hours in a week (i.e., 168). The estimated number was based upon actual operating time and, therefore, provided the best estimate of the number of chinook salmon entrained each week. The projected number was based upon pumps always operating 24 h a day, and therefore was the maximum number that could have been entrained, based upon our sample. Since the estimates and projections were based upon actual weekly entrainment rates, they were only calculated in weeks that trials were conducted. The particular weeks that entrainment trials were conducted, the number of trials that were conducted, and the number of hours pumps operated varied among years. The weekly estimated and projected numbers were summed each year to obtain annual estimates and projections of chinook salmon entrainment.

During trials conducted in 1997 and 1998, juvenile fall chinook salmon released into Battle Creek from Coleman National Fish Hatchery 56 km upstream of the RPP were entrained into the plant. During these years, a total of approximately 26 million juvenile fall chinook salmon were released into Battle Creek. Of these, approximately 2 million were coded-wire tagged and adipose fin-clipped resulting in a ratio of 0.08 marked to unmarked fish. The ratio varied somewhat with each release. The ratio from the most recent release was used to determine the number of hatchery-produced and naturally-produced chinook salmon entrained into the RPP each week. The number of hatchery-produced chinook salmon entrained into the RPP was calculated as the number of adipose-clipped fish entrained divided by the ratio of marked to unmarked fish released from Coleman Hatchery. The number of naturally-produced chinook salmon was calculated as the difference between the total number of chinook salmon entrained and the estimated number of hatchery-produced chinook salmon. Entrainment trials in 1999 and 2000 did not correspond with releases of hatchery-produced chinook salmon. Of the more than 8,000 fall chinook salmon entrained during this study, 3.6% were hatchery-released fish.

Number, Mortality, and Injury of Entrained Fish Compared Among Pumps

Data from the 80 complete, 24-h trials conducted when all three pumps operated concurrently were used to compare number, mortality, and injury of entrained fish among pumps. This ensured that fish collected from the three pumps experienced similar water quality and weather conditions, factors which could affect the number and condition of entrained fish. Each trial included a day and a night sample collected from each of the three pumps. The number and percent mortality of each fish species entrained into each pump was tabulated and calculated for each trial. Due to the non-normal distribution of the data, Kruskal-Wallace tests were used to determine whether %-frequency of mortality differed significantly among pumps for chinook salmon and for all other fish species combined. Percent frequency of injuries, by pump, was calculated for chinook salmon and all other fish species combined. Injuries were also tabulated by type for chinook salmon and all other fish species combined for each of the three pumps. Data from the 15 short-duration trials, which were conducted in an attempt to obtain better estimates of mortality and injury of wild entrained fish, were analyzed similarly. In addition to direct mortality, delayed mortality was assessed in the short-duration trials.

In both 24-h and short-duration trials, frequencies of mortality and sub-lethal injury of wild entrained fish were assumed to be overestimates of pump passage mortality since condition of fish prior to being entrained was unknown. Also, other factors may contribute to mortality. On their way to the holding tanks fish traveled past screens and brushes, in concrete channels, and up a wedge-wire dewatering ramp. In the holding tanks, fish could be subjected to turbulence and debris, especially in the 24-h trials.

Fraction of Riverine Chinook Salmon Entrained

This portion of the study was tightly linked to a companion study entitled *Abundance and seasonal, spatial, and diel distribution patterns of juvenile salmonids passing the Red Bluff Diversion Dam, Sacramento River, California.* This study was conducted by personnel of the U. S. Fish and Wildlife Service (USFWS), Red Bluff Fish and Wildlife Office (Johnson and Martin 1997, Gaines and Martin 2001, draft). From July 1994 through June 2000, up to four rotary screw traps were deployed in the Sacramento River just downstream of RBDD. Data on fish captured in the screw traps were used to estimate abundance and distribution patterns of each of the four runs of juvenile chinook salmon passing RBDD. Population estimates for juvenile salmon were made using the trap efficiency method (Thedinga et al. 1994). Trap efficiency was estimated for each trap by mark and recapture techniques and was calculated as the quotient of the number of recaptures in a trap divided by the number of marked fish released upstream (Martin et al. 2001, draft). Results of the efficiency trials were used to develop a model which predicated daily trap efficiency using percent of river discharge sampled as the primary variate (Martin et al. 2001, draft). Daily passage estimates of the number of juvenile salmon migrating downstream past RBDD on any given day of sampling were then calculated as the number of chinook salmon captured in screw traps divided by trap efficiency. Details on methods used to develop the daily passage estimates are described in Martin et al. (2001, draft).

From fall 1997 through spring 2000, simultaneous data on the number of juvenile chinook salmon captured in rotary screw traps and in holding tanks at the RPP were collected during eighty-four 24-h periods. Three pumps operated on 72 of the dates and two pumps operated on 12 dates. Monitoring was segmented into diurnal and nocturnal periods. Simultaneous monitoring allowed us to estimate the fraction (± 90% CI) of the daily total number of juvenile salmonids passing RBDD that were entrained into the RPP on each of the 84 dates. The fraction entrained was calculated for each date as the number entrained into the RPP divided by the estimated number passing RBDD based on screw trap sampling.

Comparisons were made between fractions entrained during the day and night. Relationships were assessed between the fraction of chinook salmon entrained and 1) the percent of river discharge pumped; 2) turbidity; and 3) mean fork length of chinook salmon. Wilcoxan signed-rank tests were used to assess differences in fork length between chinook salmon entrained in the RPP versus those captured in the screw traps for day and night samples. The mean catch per acre-foot of the five most frequently entrained species was calculated and compared between the RPP and screw traps. The Pearson correlation coefficient was calculated to determine how well entrainment rates of chinook salmon into the RPP were correlated with capture rates of chinook salmon in screw traps.

Holding Tank Efficiency Trials

The purpose of these trials was to determine a mean %-efficiency at which holding tanks sample juvenile chinook salmon entrained from the river. Trial results would provide an estimate of the percentage of chinook salmon entrained from the river that were recovered in the holding tanks within a 24-h period. Fish not recovered may have escaped to the river via the bypass channels or may have resided in low velocity zones within the plant.

Hatchery-reared juvenile chinook salmon were used as surrogates for riverine salmonids in these trials. During a trial all three pumps were operated simultaneously. A sample of 32 juvenile chinook salmon was released into the intake of each pump using methods described by McNabb et al. (1998). Fish in each sample were marked with an upper or lower caudal fin-clip to differentiate them from wild entrained chinook salmon.

Eight trials were conducted between March and July, 1999. All trials began about one-half hour after sunrise. Mean fork length of juvenile chinook salmon samples ranged from 48 to 60 mm. Eight trials were also conducted between March and early May, 2000. Four trials began about one-half hour after sunrise and four began about one-half hour after sunset to assess whether %-efficiency was related to diurnal or nocturnal release. A trial started at sunset was followed by a trial started at sunrise the next day so fish in the two trials experienced similar environmental conditions. In 2000, juvenile chinook salmon samples had mean fork lengths ranging from 39 to 68 mm.

Each trial lasted 24 h with holding tanks checked at sunrise and sunset. The percentage of fish recovered during each diel period was calculated for each trial. The mean percent recovered at each diel period was then calculated for all sixteen trials. In addition to being checked at sunset and the following sunrise, holding tanks were checked 0.5, 1, 2, and 6 h after release in six trials conducted in 1999. These trials provided data on travel time of fish between the pump intakes and the holding tanks.

Results

Plant Operations and Environmental Data

In each year of this study, river flows were highest from January through March and lowest from September through November (Figure 5). El Nino storms in 1998 resulted in the highest flows, exceeding 1000 m^3/s (35,340 ft^3/s) from mid-January through February and peaking near 4570 m^3/s (161,000 ft^3/s) on February 3. Intermittent high flows continued through mid-June. Data collected during entrainment trials revealed an inverse relationship between river discharge and the percent of the Sacramento River pumped into the RPP (Figure 6). The percentage pumped ranged from less than 1 to 5.5. The percent of river pumped was lowest in summer, but highest each fall due to low river flows coupled with regular use of all three pumps to meet water needs.

Mean daily water temperatures (°C) and dissolved oxygen concentrations (percent saturation) collected from Sacramento River water flowing through the holding tanks during entrainment trials are shown in Figure 7. Mean water temperature ranged from 8 to 9 °C each winter to between 14 and 15 °C each summer or fall. Mean temperatures also exceeded 14 °C in early

April 2000 which was unusually warm. Mean dissolved oxygen in the holding tanks was consistently greater than 80% and usually exceeded 90% saturation.

On average, mean daily water temperatures collected from the holding tanks and from the multi-parameter probes placed in the Sacramento River were within 1.5% of each other. Mean daily dissolved oxygen concentrations from the two locations were within 1% of each other in 1998, 1999, and 2000. In 1997, however, dissolved oxygen values from the holding tanks averaged 13% higher than those collected from the river. Apparently, the river probe was giving inaccurate readings since the installation of the new probe at that site in 1998 resulted in similar readings between the river and holding tank data. The similarity in temperature and dissolved oxygen values between the holding tanks and the river indicated that fish in the holding tanks were held in ambient river water conditions. Total gas saturation measured in the holding tanks averaged 102%, and ranged from 97% to 107%.

Numbers and Characteristics of Entrained Fish

Twenty-eight species of fish were identified during entrainment trials (Table 2). Sixteen species and 98% of all fish captured were native to the Sacramento River. Chinook salmon was the most frequently entrained species followed by prickly sculpin *Cottus asper*, lamprey ammocoetes *Lampetra* spp., Sacramento sucker *Catostomus occidentalis*, Sacramento pikeminnow *Ptychocheilus grandis*, and riffle sculpin *Cottus gulosus*. These six species comprised 94% of the 26,220 fish captured during entrainment trials. Run composition of chinook salmon was 83.6% fall, 12.1% winter, 2.4% spring, and 1.9% latefall. The period covered in this report included brood years 1996 through 1999 for fall run, 1997 through 2000 for latefall run, and 1997 through 1999 for spring and winter-run chinook salmon.

The lowest mean monthly fork length (mm) for chinook salmon occurred from January through March and from August through October each year, reflecting the outmigration of fall and winter chinook salmon fry, respectively (Figure 8). Mean fork length in these months was typically less than 44 mm. The exception was September 1999 when the mean fork length was 55 mm due to an unusually high proportion (35%) of the chinook salmon entrained being large-sized fall and latefall chinook salmon with mean fork length 93 mm (Figure 9). In September of 1997 and 1998, fall and latefall chinook salmon comprised less than 4% of the chinook salmon entrained. Length distributions of the most frequently entrained species are shown in Figures 9 and 10 for each month of this study.

Ninety-four percent of fish entrained into the plant were <100 mm in length. Length frequency distributions of the four most frequently entrained species are shown in Figure 11. The majority of chinook salmon (81%) entrained were less than 40 mm fork length. Approximately 70% of the lamprey ammocoetes ranged from 70 to 119 mm in total length. Of the 273 metamorphosed Pacific lamprey entrained, 74% were greater than 300 mm total length; the remainder ranged from 100 - 139 mm. Interestingly, there were no Pacific lamprey in the >150 to 299 mm range (Figure 10). Five of the six river lamprey entrained, however, were in that size range. Total length of prickly sculpin was approximately normally distributed with over 80% in the 40 to 90 mm range. Sacramento sucker were represented in all size classes from 30 mm to >200 mm. The majority, however, were less than 60 mm total length, and the size class with the highest %-frequency was 30 to 39 mm. Six and eight percent of the lamprey and Sacramento suckers, respectively, were greater than 200 mm total length. The species most frequently entrained with individuals greater than 100 mm in length were lamprey, Sacramento suckers, prickly sculpin, and Sacramento pikeminnow.

Seasonal and Diel Patterns of Entrainment

Sampling effort was measured in terms of acre-foot of water pumped during entrainment trials (Figure 12). This effort was most intensive each fall (mid-September into October) when typically all three pumps were used to supply water to the canals, and estimates of winter chinook salmon take into the RPP were required (National Marine Fisheries Service 1993). During each week that pumps operated for 24 h a day, on each of the seven days, two 24-h entrainment trials were conducted to provide a sample for estimating the weekly take of winter chinook salmon. By mid-to-late October, the demand for water decreased, and pumping and entrainment monitoring was reduced.

The number of juvenile chinook salmon entrained per acre-foot of water pumped exhibited a seasonal trend being lowest in summer, highest in winter, and intermediate in spring and fall (Figure 12). This pattern was consistent each year, although summer entrainment rates were higher in 1999 and were similar to fall entrainment rates. The number of chinook salmon entrained was less than 0.3 per acre-foot pumped in every month except December, January, and February when it usually exceeded 0.3 and ranged up to 3.5 salmon per acre-foot pumped in January 1998. These winter peaks in entrainment corresponded with the outmigration of fall chinook salmon fry. Figure 13 shows the number of chinook salmon entrained per 24 h of pump operation during 24-h entrainment trials conducted each month.

Generally, entrainment for all other fish species combined was lowest in fall and winter, and highest in spring and summer (Figure 12). The high spring and summer entrainment was due to high numbers of prickly sculpin entrained (Figure 14). An exception to the low fall entrainment occurred in November 1997 when more than 1 fish per acre-foot was entrained. Most of those were lamprey ammocoetes apparently dislodged from the sediment as a result of high river flows following a storm (Figure 14). The only other month that entrainment exceeded 1 fish per acre-foot was June 1998 due to unusually high numbers of Sacramento suckers and lake species such as bluegill and largemouth bass (Figure 14). High river flows in late May required that gates on RBDD be raised causing fish residing in Lake Red Bluff to move downstream. Consequently, an entrainment trial conducted on June 3 and 4 entrained more lentic species and individuals than typical for that time of year.

The relationships between chinook salmon entrainment, river discharge, and turbidity are shown in Figure 15. River discharge and turbidity influenced entrainment during winter months when juvenile chinook salmon were abundant in the Sacramento River near the RPP. At other times of the year, however, increases in discharge or turbidity did not result in an increase in number entrained per acre-foot because few juvenile chinook salmon were in the river.

Nocturnal entrainment of juvenile chinook salmon exceeded diurnal entrainment in 33 of the 35 months that entrainment was monitored (Figure 16). In the two months when diurnal entrainment was higher, sample sizes were small (3 and 15 fish). There was no apparent seasonal pattern in the degree of differences between nocturnal and diurnal entrainment. Greater entrainment at night also held true for other species (Table 3). The mean monthly nocturnal entrainment of juvenile chinook salmon was nearly five times greater than the mean monthly diurnal entrainment. Fall chinook salmon had the lowest nocturnal to diurnal entrainment ratio (2.7) while winter run had the highest (16.5). For fish other than chinook salmon, nocturnal entrainment was eight times greater than diurnal entrainment.

Estimated and Projected Numbers of Chinook Salmon Entrained

An objective of this study was to estimate the number of individuals in each of the four runs of chinook salmon entrained into the RPP annually. The estimated number entrained was calculated weekly based upon the entrainment rate (i.e., number per hour), derived from the week's entrainment trial(s), and the hours of pump operation. The number of chinook salmon that would be entrained annually if the pumps operated continuously each week that entrainment was monitored was projected (Figure 17). Actual and projected numbers of chinook salmon decreased each year while estimated numbers varied with hours of pump operation (Figure 17). Estimated numbers were lowest in 1998 and 2000 due to low pump hours. High river flows made pumps inoperable during much of spring and early summer of 1998, while the 2000 data only extends through May. The highest actual and projected numbers entrained were 4,535 and 28,312, respectively in 1997. The highest estimated number entrained was 9,520 in 1999.

The actual, estimated, and projected numbers of chinook salmon entrained varied among brood years for each run (Figure 18). Typically, the number of hours the pumps operated was much greater than the number of hours entrainment was monitored, resulting in large differences between the actual and estimated numbers of chinook salmon entrained. An exception to this occurred in brood year 1997 for spring and fall run chinook when actual and estimated numbers were similar. During the winter of 1997-1998, one 24-h entrainment trial was conducted each week. Because the pumps only operated each week to conduct these entrainment trials, the actual and estimated numbers entrained were similar. High numbers of chinook salmon were entrained during those 24-h trials, resulting in the projected number entrained being several times greater than the actual number entrained for both fall and spring run.

Number, Mortality, and Injury of Entrained Fish Compared Among Pumps

24-h Trials

Eighty 24-h trials were conducted with all three pumps operating simultaneously allowing comparisons among pumps to be made. Most juvenile chinook salmon were entrained into Archimedes 2 (50%) followed by Archimedes 1 (30%) and the internal helical pump (20%; Table 4). This was consistent with the entrainment pattern among pumps reported by McNabb et al. (1998) and Borthwick et al. (1999). The tendency for more chinook salmon to be entrained into Archimedes 2 was fairly consistent occurring in 61% of the trials. For all other fish combined, Archimedes 1 entrained the greatest percentage (40%) followed by Archimedes 2 and the internal helical pump each with 30%.

Mortality of juvenile chinook salmon entrained into Archimedes 1 and Archimedes 2 and collected in the holding tanks was 2.8% and 2.9%, respectively (Table 4). Mortality of chinook salmon collected from the internal helical pump's holding tank was higher at 4.9%. Results of Kruskal-Wallis tests revealed no significant difference among the three pumps in mortality of juvenile chinook salmon collected from pump holding tanks (P=0.07). Considering all three pumps combined, overall mortality of chinook salmon entrained into the RPP was 3.3%

The percent mortality of all fish except chinook salmon combined was 4.5% for Archimedes 1, 4.9% for Archimedes 2, and 5.1% for the internal helical pump. Percent frequency of mortality for the ten most commonly entrained species is shown in Table 4. Mortality was relatively high for Sacramento suckers. Nearly 50% of those entrained were small (<50mm; Figure 11). Other species with high frequencies of mortality tended to have relatively small sample sizes. Considering all three pumps combined, overall mortality of fish other than chinook salmon was 4.8%.

While in the holding tanks fish survival may be affected by volume and type of debris, amount of water flowing into the holding tank, amount of time confined in the tank, and presence of other fish (Figure 19). Regression analysis was conducted for each pump to assess the relationship between volume of debris and mortality of chinook salmon recovered from the holding tanks (Figure 20). Although these variables were poorly correlated for each pump ($r^2 < 0.15$), the regressions were highly significant (P<0.001) suggesting that mortality may be affected by a combination of factors including debris.

The percentage of injured chinook salmon (dead and alive) removed from the holding tanks servicing Archimedes 1 and Archimedes 2 was 3.1 for each of the lifts (Table 5). The percentage injured was higher for chinook salmon removed from the internal helical pump's holding tank (4.9). The percentage of live chinook salmon removed from the holding tanks with sub-lethal injuries was 1.2, 0.8, and 1.7 for Archimedes 1, Archimedes 2, and the internal helical pump, respectively. Fish other than chinook salmon followed a similar pattern with the highest frequency of injuries in fish removed from the internal helical pump's holding tanks (5.7%) followed by the Archimedes lifts (5.0 for each; Table 5). For each pump, the frequency of injuries was lower for chinook salmon than for other fish combined. For all three pumps combined, the percent frequency of sub-lethal injuries to chinook salmon was 1.2%. The most frequent injuries to chinook salmon and other fish occurred on the skin (Tables 6 and 7). Open wounds, abrasions, and bruises were the most common skin injuries. Bulging eyes were commonly observed on dead fish but rarely on live fish. Damage to fins was less frequent on chinook salmon than on other fish. Head injuries were relatively infrequent for all fish.

Short-duration Trials
Mortality of juvenile chinook salmon and all other fish combined was much lower in the 2 to 3-h entrainment trials than in the 24-h trials (Table 8). Mortality of chinook salmon ranged from 0.6 to 1.2% in the short-duration trials compared to 2.8 to 4.9% in the 24-h trials. Similarly, mortality of all other fish combined was 0 to 0.9% in the short-duration trials compared to 4.5 to 5.1% in the 24-h trials. As in the 24-h trials, there were no significant differences among pumps in percent mortality of chinook salmon (Kruskal-Wallace test, $P = 0.23$) or of all other species combined ($P = 0.21$). The percent frequency of chinook salmon with sub-lethal injuries was 0.2 for each of the Archimedes lifts and 0.1 for the helical pump. For all other fish combined, the frequency of fish with sub-lethal injuries was 0.5% for Archimedes 1, 1.2% for Archimedes 2, and 1.1% for the helical pump. Considering the RPP as a whole, percent frequency of mortality and sub-lethal injuries for chinook salmon was 0.8 and 0.2, respectively. For all other species combined percent frequency of mortality and sub-lethal injuries was 0.6 and 0.9, respectively.

Chinook salmon removed alive from the holding tanks during these trials were held in the river water laboratory for 96 h to assess delayed mortality. The percentage of fish that died during the 96-h observation period was 2.2, 0.9 and 2.7 for Archimedes 1, Archimedes 2, and the internal helical pump, respectively.

Mortality of Large Fish (>200 mm)
There is interest in knowing if Archimedes lifts and internal helical pumps can pass large fish unharmed. During entrainment trials 1.9% of all fish collected exceeded 200 mm in length. The four most commonly entrained large fish, in decreasing order, were Pacific lamprey *Lampetra tridentata*, Sacramento sucker, Sacramento pikeminnow, and hardhead *Mylopharodon concephalus* (Table 9). Large fish frequently slid across the fish separator bars at the end of the dewatering ramp and were captured in a metal box at the end of the bars rather than in the holding tanks (Figure 3). The metal box was 89 cm long, 38 cm wide, and 76 cm deep (35 in x 15 in x 30 in) and contained river water. Unlike the holding tanks, the box was not a flow-through system. Conditions within the box were not always amenable to fish survival, particularly during periods with high debris and flow, and may have contributed to fish mortality and injury.

Archimedes 1 entrained the most large fish (226) followed by Archimedes 2 (179) and the internal helical pump (96). None of the large fish passed through Archimedes 2 died, while 2.2% and 4.2% of the large fish passed through Archimedes 1 and the internal helical pump, respectively, were dead when collected from the holding tank or the metal box. Because not all of these trials were conducted when the three pumps operated simultaneously under similar environmental conditions, mortality among the three pumps was not directly comparable. Overall mortality of the 501 large fish entrained into the plant and collected in a holding tank or a metal box was 1.8%. Of the 492 large fish entrained alive, 3.6% were injured. Percentage injured by pump was 4.5, 1.7, and 3.3 for Archimedes 1, Archimedes 2, and the internal helical pump, respectively. Most of the injuries were abrasions or open wounds on the skin.

Fraction of Riverine Chinook Salmon Entrained
Between September 1997 and May 2000, 24-h samples were collected simultaneously from the RPP and the rotary screw traps on 84 dates. Based on screw trap estimates of daily total numbers of chinook salmon passing the dam, the fraction entrained from the river into the RPP on the 84 dates ranged from <0.0001 (<0.01%) to 0.0138 (1.38%, Figure 21) with an average of 0.0022 (0.22%). The fraction entrained was less than 0.005 in 89% of the samples and was consistently less than the fraction of river discharge pumped (Figure 21). The fraction of river discharge pumped represented the expected fraction of salmon entrained if the fish were uniformly distributed and entrained in proportion to density. The upper 90% confidence interval of the fraction entrained exceeded the fraction of river discharge pumped on only one sampling date. The Pearson correlation between the fraction of river discharge pumped and the fraction of chinook salmon entrained was 0.287 indicating factors other than the fraction of river pumped were responsible for changes in entrainment patterns.

The chinook salmon run that experienced the highest fraction entrained was the fall run averaging 0.0036 and ranging from 0.0002 to 0.0138. The fraction of winter chinook salmon entrained averaged 0.0017 and ranged from 0.00008 to 0.0066. Spring and latefall chinook salmon were only entrained in combination with salmon from other runs. Therefore, their fractions entrained could not be determined. However, the fraction of chinook salmon entrained was consistently less than 0.002 in samples that contained spring and latefall chinook salmon.

For each of the three pumps, about 30% of the samples collected during simultaneous trials with the screw traps contained no chinook salmon (Figure 22a). Disregarding the large number of samples with no chinook salmon, the histogram of the natural log of the fraction of chinook salmon entrained was approximately normally distributed for each of the three pumps. For both Archimedes lifts, the most frequent fraction of chinook salmon entrained was 0.0009 to 0.0014 (0.09% to 0.14%). For the helical pump, it was 0.0015 to 0.0022 (0.15% to 0.22%).

The Delta distribution, which adjusts estimates for the probability of catching no fish, was used to compare the fraction of fish entrained in day versus night samples for each of the three pumps (Figure 22b). The fraction entrained was higher during the day for Archimedes 1. For Archimedes 2 and the internal helical pump the fractions entrained day and night were very similar. Among the three pumps, the internal helical pump had the lowest fraction of fish entrained in both day and night samples.

There was no relationship between fraction of chinook salmon entrained into the RPP and river turbidity ($r^2 = 0.001$, $P = 0.770$, n = 317). Similarly, there was no relationship between fraction of chinook salmon entrained and mean fork length of entrained salmon ($r^2 = 0.006$, $P = 0.098$, n = 314). When comparing the mean fork length of chinook salmon captured in screw traps and the RPP, lengths of fish captured in screw traps were significantly greater in night samples (Wilcoxan signed-rank test, $P<0.001$, n=203) and in day samples (Wilcoxan signed-rank test, $P = 0.016$, n = 109; Figure 23).

The number of fish captured per acre-foot in the screw traps and the RPP is shown in Table 10 for the five species most frequently entrained into the pumps. Chinook salmon were captured in higher densities in the traps with a pump to trap ratio of 0.22. There was a strong, positive correlation between the number of chinook salmon captured per acre-foot in the rotary screw traps and in the RPP on the 84 dates when simultaneous samples were collected (Pearson correlation coefficient = 0.824). The correlation was stronger for day samples (0.855) than for night samples (0.640) when typically more fish were captured in both traps and the RPP.

Sacramento pikeminnow and Sacramento sucker were entrained in higher densities in the RPP with ratios of 4 and 3, respectively. Lamprey ammocoetes and prickly sculpin, both benthic species, were entrained in much higher densities in the RPP than in the screw traps (ratios of 202 and 114, respectively). It should be noted that these ratios are somewhat conservative since fish <30 mm (excluding salmonids) were not tabulated from RPP samples, however, they were tabulated in screw trap samples.

Holding Tank Efficiency Trials

Results from all sixteen trials combined revealed that on average 10 to12% of the juvenile chinook salmon released into the pump intakes were not recovered in the holding tanks within 24 h of release (Table 11). There were no significant differences among the three pumps in the percentage of fish recovered at 24 h (ANOVA; P=0.80). There also were no significant differences between the percentage of sunrise and sunset released fish recovered for any of the pumps although sample size was small (n=4; $P \geq 0.05$; two-sample t-tests). In 1999 six trials were conducted in which travel time was monitored at 0.5, 1, 2, 6, 14, and 24 h after release. All trials began at sunrise. Table 12 shows time-in-travel during these trials for juvenile chinook salmon released into each of the three pumps. The pump with the highest mean percentage recovered varied by hours post-release.

Discussion

Plant Operations

The Biological Opinion for the RPP predicted that during the juvenile winter chinook salmon outmigration period, 2.0% of the Sacramento River discharge would be pumped into the RPP (National Marine Fisheries Service 1993). The actual average percent pumped during the winter run outmigration period was 3.5%, with a high of about 5.5% occurring in fall 1997. During the mid-September through October portion of the winter-run outmigration, gates at RBDD were raised yet TCC water demands were high requiring frequent use all three pumps. Also, during this period river discharges were typically at their yearly minimum. While the percentage of the river pumped was highest in the fall, it was lowest in the summer when flows were relatively high and use of the pumps was low. Overall, during this studies' entrainment trials, the average percent of river discharge pumped into the RPP was 2.6.

Numbers and Characteristics of Entrained Fish

Twenty-eight fish species were identified during entrainment trials. All twenty-eight species were previously reported entrained in similar proportions during February 1997 through June 1998 (Borthwick et al. 1999). Gaines and Martin (2001, draft) reported capturing thirty-nine species in rotary screw traps deployed near the RPP from July 1994 to June 2000. Twelve species collected in rotary screw traps but not entrained in the RPP during our trials were spotted bass *Micropterus punctulatus*, redear sunfish *Lepomis microlophus*, black crappie *Pomoxis nigomaculatus*, white crappie *Pomoxis annularis*, Kokanee/sockeye *Oncorhynchus nerka*, brown trout *Salmo trutta*, American shad *Alosa sapidissma*, striped bass *Morone saxatilis*, fathead minnow *Pimephales promelas*, Sacramento splittail *Pogonichthys macrolepidotus*, black bullhead *Ictalurus melas*, and Sacramento blackfish *Orthodon microlepidotus*. The greater diversity of species captured in the screw traps compared to the RPP was likely due to a much more intensive screw trap sampling effort. While entrainment of fish into the RPP was monitored for one or two 24-h periods each week, screw traps were typically monitored for four to seven 24-h periods each week. Another plausible reason for differences in the diversity of species captured is that the RPP and screw traps sampled different portions of the river's water column.

Juvenile chinook salmon comprised 87% of the fish captured in the rotary screw traps (Gaines and Martin 2001, draft) but only 40% of the fish captured in the RPP during entrainment trials. This difference is likely due to the traps and the RPP sampling a different strata of the water column. Rotary screw traps sample the top 1.2 m of the water column whereas the 1.2 m diameter intakes on the RPP pumps are located near the bottom of the water column at a depth of approximately 3.6 - 4.8 m (12 - 16 ft). Studies conducted from 1950 - 1952 by the USFWS in the Sacramento River near Red Bluff assessed the vertical distribution of downstream migrating chinook salmon using a push net to sample at 0.6 m intervals from the surface to a depth of 1.8 m (Azevedo and Parkhurst 1957). Their sampling revealed that juvenile chinook salmon migrated at all depths, however, numbers were greatest 0.6 to 1.2 m below the surface and fewest at 1.2 to 1.8 m below the surface. Other studies on outmigrating juvenile Pacific salmon indicate that they generally utilize the entire water column. However, their abundance at different depths within the water column can vary by diel period (McDonald 1960, Edmundson et al. 1968, Wickwire and Stevens 1971), by spatial zone across a river (Dauble et al.1989), by fish size (Wickwire and Stevens 1971), and by water depth (Mains and Smith 1964). Also, results from one river are not necessarily applicable to another (Mains and Smith 1964).

Other evidence that the rotary screw traps and the RPP sampled different strata of the river's water column was in the relative percentage of benthic species captured. Prickly sculpin and lamprey ammocoetes comprised 28% and 18% of the fish entrained into the RPP, respectively, but 1% or less of the fish captured by rotary screw traps (Gaines and Martin 2001, draft). Sacramento sucker and Sacramento pikeminnow comprised similar proportions in the RPP (6% and 2%, respectively) and in the rotary screw traps (4% for each species; Gaines and Martin 2001, draft).

Eighty-one percent of entrained chinook salmon were less than 40 mm fork length which was also the most abundant size class sampled in rotary screw traps (Gaines and Martin 2001, draft). The mean monthly fork length of chinook salmon captured during entrainment trials was consistently less than 40 mm in December, January, and February reflecting the outmigration of fall chinook salmon fry (Vogel et al. 1988). Mean fork lengths were <45 mm during August, September, and October when winter-run chinook salmon were outmigrating. The largest fork lengths occurred in May, June, and July. The number of chinook salmon entrained in the summer, however, was low (<22 each month), except in 1999 when relatively high numbers of large fall and late-fall chinook salmon continued to be entrained through September. Lower river flows in winter and spring 1999 than in the previous two years may explain why larger chinook salmon remained in the river through September (Vogel et al. 1988).

Nearly 50% of Sacramento suckers entrained into the plant were less than 50 mm total length. Length frequencies of Sacramento suckers captured in rotary screw traps were similarly skewed to the small size classes (Gaines and Martin 2001, draft). The percent frequency of sucker entrainment into the RPP gradually decreased with increasing length, leveling off near 2% for each of the 10 mm size classes between 100 mm and 200 mm. Percent frequency increased to 8% for suckers >200mm in length. Similarly, most lamprey (including ammocoetes) were less than 140 mm, however, a rise in percent frequency to 6% occurred in the >200 mm size class due to entrainment of adult Pacific lamprey.

Prickly sculpin exhibited an approximately normal length frequency distribution, most ranging from 50 to 70 mm. Percent frequency gradually decreased for size classes less than 50 mm and greater than 70 mm. The largest size class was 120-129 mm. Prickly sculpin captured in rotary screw traps exhibited a very similar size frequency distribution (Gaines and Martin 2001, draft) Many prickly sculpin and Sacramento suckers less then 30 mm in length were entrained during our trials. Because they were not efficiently retained by the relatively large mesh-size (3.2 mm, 1/8 in) of nets used to hold fish in the tanks, these small fish were not enumerated. However, they were abundant, particularly during the spring. In a separate study addressing entrainment of larval fish, prickly sculpin and Sacramento sucker comprised 87.5% and 11.5% of the larval fish entrained into the plant, respectively (Borthwick and Weber 2001).

The trash racks proved effective at excluding most large fish from the RPP. Only 1.9% of the fish captured during entrainment trials were ≥200 mm in length. Occasionally, fish that appeared too large in girth to pass through the 5.1 cm (2 in) openings between the bars of the trash racks were entrained into the plant. These fish may have entered the sump area during high flows when openings between the trash rack and walkway were submerged, or they may have increased in size while residing in the sump area.

Seasonal and Diel Patterns of Entrainment

For juvenile chinook salmon, entrainment was consistently highest in the winter months of December, January, and February coinciding with the outmigration of post-emergent fall chinook salmon near Red Bluff (Vogel et al.1988; Gaines and Martin 2001, draft). The highest density of fish entrained was 3.5 per acre-foot in January 1997. Typically, if the plant was functioning only to deliver water, it would not be operated in these winter months. High river levels often preclude use of the RPP during winter when water demands generally are low. Excluding winter months, entrainment of chinook salmon consistently was less than 0.3 fish per acre-foot, or less than 60 fish per 24 pump hours.

Patterns of entrainment were similar in 1997 and 1998 with the highest number entrained per acre-foot pumped in winter and spring, decreasing in summer, then increasing again in fall as juvenile winter-run chinook salmon outmigrated. In 1999, summer entrainment was greater than in the previous two years, and similar to fall entrainment. River flows in the winter of 1997 and winter and spring of 1998 were higher than in 1999 possibly resulting in earlier outmigration of fall chinook salmon at a small size (<50 mm). This pattern is consistent with data on chinook salmon abundance at Red Bluff during a wet winter (Vogel et al. 1988). The relatively low river flows in the winter of 1999 may have encouraged fry to remain longer in the upper Sacramento River. Based upon Vogel et al. (1988), it can be predicated that in wet years such as 1998, most juvenile fall chinook salmon will migrate past the RPP before pumping begins in the spring. In contrast, in drier years such as 1999 when the annual peak outmigration of fall chinook salmon was delayed until April through June (Vogel et al. 1988), more salmon would be vulnerable to entrainment into the RPP when pumping begins in the spring. These fish would pass the RPP at a larger size (Gaines and Martin 2001, draft) so may not be entrained as easily as smaller fish that pass in the winter.

There was no consistent seasonal entrainment pattern among years for all other fish combined. Entrainment was less than 1.0 fish per acre-foot pumped in every month except November 1997 and June 1998. Most fish entrained in November 1997 were lamprey ammocoetes, which may have been dislodged from the substrate during high river flows making them vulnerable to entrainment. In rotary screw traps, the number of ammocoetes captured per acre-foot of water sampled was also highest in November 1997 (Gaines and Martin 2001, draft). Sacramento suckers and prickly sculpin composed most of the fish entrained in June 1998. Prickly sculpin entrainment was consistently high in June of each year. Sucker entrainment was unusually high in June 1998 due to atypical gate operations at RBDD prompted by high river flows. Each year gates were lowered from May 15 through September 15. In 1998 gates were lowered on May 15th, but high river flows required that they be raised on May 28th. When the gates were raised, suckers residing in Lake Red Bluff appeared to move downstream in unusually high numbers resulting in high numbers being entrained during a single trial conducted in early June. The number captured per acre-foot of water sampled in rotary screw traps that month was also the highest in the 5.5 years of sampling (Gaines and Martin 2001, draft). Capture was near 0.5 suckers per acre-foot in both screw traps and the RPP. In all other months, entrainment of Sacramento suckers into the RPP was less than 0.1 fish per acre-foot pumped.

Prickly sculpin exhibited a seasonal pattern of entrainment with rates consistently highest in late spring and summer each year. Although the number captured per acre-foot was much lower in rotary screw traps, the seasonal pattern was very similar (Gaines and Martin 2001, draft).

Sacramento suckers and prickly sculpin less than 30 mm were not enumerated in this study, but were addressed in a separate study on larval fish entrainment (Borthwick and Weber 2001). Seasonal entrainment patterns of larval suckers and prickly sculpin (i.e., those < 30 mm) were similar to that of juvenile and adults, however, the number of larval fish entrained per acre-foot pumped was dramatically higher. For prickly sculpin, entrainment of larval fish ranged from about 26 to 220 fish per acre-foot pumped in the late spring and summer period. In contrast, entrainment of juveniles and adults was consistently less than 0.6 fish per acre-foot pumped. Similarly, for Sacramento suckers entrainment of larval fish ranged from 0 to 65 fish per acre-foot during the study period while entrainment of juveniles and adults ranged from 0 to 0.5 fish per acre-foot.

Seasonal entrainment patterns of juvenile chinook salmon appeared to be due to a combination of seasonal abundance patterns and river conditions (Figure 15). Entrainment consistently peaked in the winter when the abundance of outmigrating juvenile chinook salmon was typically the greatest (Gaines and Martin 2001, draft). In 1999 and 2000, these peaks in entrainment corresponded with peaks in river discharge and slight rises in turbidity. In 1998, peak entrainment preceded peak river flows and turbidity which occurred in the spring and early summer. A spike in river turbidity and discharge in November 1997 did not result in increased entrainment because few juvenile chinook salmon were present in the river. Similarly, the spike in river discharge in February 1997 occurred without a corresponding peak in juvenile chinook salmon entrainment, presumably because few chinook were present in the river. River discharges exceeded 2266 m^3/s (80,000 ft^3/s) from 12/31/96 through 1/5/1997, with a peak of over 3398 m^3/s (120,000 ft^3/s) on January 1, 1997 (Figure 5). These high flows likely pushed most of the chinook salmon fry out of the upper Sacramento River by February when entrainment monitoring began.

The diel pattern of entrainment was similar to earlier findings (McNabb et al.1998, Borthwick et al. 1999) with mean monthly nocturnal entrainment of chinook salmon on average nearly five times greater than diurnal entrainment. This is consistent with findings from rotary screw traps where catch per acre-foot of juvenile chinook salmon emigrating past RBDD showed distinct diel patterns of abundance, being greatest at night (Johnson and Martin 1997, Gaines and Martin 2001, draft). A study conducted from 1982 through 1987 revealed that entrainment of juvenile chinook salmon through the Tehama-Colusa canal headwork louvers was also consistently greater at night than during the day (Vogel et al. 1988). Results from the Sacramento River are consistent with studies conducted elsewhere on migration patterns of juvenile Pacific salmon (McDonald 1960, Mains and Smith 1964, Dauble et al. 1989). McDonald (1960) found that fry of coho, sockeye, pink, and chum salmon initiated downstream movements shortly after dark and terminated those movements as daylight approached. In experiments conducted with sockeye and coho salmon fry, artificial light prevented their normal downstream movement at night.

Our holding tank efficiency trials and other studies at the RPP (Borthwick et al. 2000, McNabb et al. 2000) revealed that a fraction (about 1 to 12%) of chinook salmon passed through the pumps resided in the plant for several hours or days before moving downstream to the holding tanks. The percentage of fish holding up was consistently greater for fish released through the pumps during the day than for those released at night. Because all our 24-h entrainment trials began at sunrise, it's likely that some fraction of fish entrained during the day did not move into the holding tanks until night. Therefore, day entrained fish would be counted as night entrained fish resulting in a bias in our night to day entrainment ratios. However, due to the relatively small number of chinook salmon passing RBDD during the day compared to night (Johnson and Martin 1997), this bias is likely small.

On average, the monthly nocturnal entrainment of all species other than chinook salmon combined was eight times greater than diurnal entrainment. For the five most frequently entrained species, prickly sculpin had the greatest propensity for night entrainment while Sacramento pikeminnow had the lowest. Entrainment of larval fish also was significantly greater at night than during the day or crepuscular periods for prickly sculpin, Sacramento sucker, and all species combined (Borthwick and Weber 2001). These findings on greater nocturnal entrainment of fish into the RPP have important implications for plant operations. If it becomes desirable or necessary to reduce the number of fish entrained, pumping could be restricted to daylight hours.

Estimated and Projected Numbers of Chinook Salmon Entrained

The actual number of chinook salmon entrained into the RPP during entrainment trials decreased each year from 1997 through 2000. This was due to a decrease in sampling effort (i.e., fewer entrainment trials) and/or sampling during periods of lower fish density in the river. In 1998, after exceptionally high entrainment in early January, high river levels precluded use of the plant from mid-January through early March, in late March, and in late May. Therefore, during much of the fall chinook salmon outmigration period, entrainment monitoring was not conducted. Actual numbers entrained decreased slightly more in 1999. Entrainment was monitored for more hours in 1999 than in 1998, however, fewer fish were entrained per acre-foot. Actual number entrained was lowest in 2000 because only data from January through May was included.

The estimated number entrained is the number entrained extrapolated to include fish entrained while the pumps were running but entrainment was not monitored. It is based upon the entrainment rate (number entrained per hour) and the number of hours the pumps operated. The estimated number was highest in 1997 and in 1999, about 9,500 chinook salmon. Low pump hours resulted in low estimated numbers entrained in 1998 and 2000 (nearly 4500 to 4800). There also was interest in projecting the number of chinook salmon that would be entrained if the pumps ran continuously, 24 hours a day. Because a constant multiplier (i.e., 168 hours) was used with the actual number entrained per hour each week, the projected numbers followed a pattern similar to the actual numbers, being highest in 1997 (near 28,000) and lowest in 2000 (near 6,500). Therefore, the estimated number provided the best assessment of the number of chinook salmon entrained into the RPP during actual pump operations. The projected number provided an assessment of the maximum number of chinook salmon that could have been entrained into the plant had it operated continuously during the weeks that entrainment trials were conducted.

Brood year 1997 had the highest actual and projected numbers entrained for fall and spring-run chinook salmon due to high entrainment in the winter of 1997 - 1998. Because the pumps were not operational in December of 1998 or 1999, the actual and projected number of fall and spring chinook salmon entrained was considerably less for brood years 1998 and 1999. When the pumps did operate in December and January, it was for the sole purpose of conducting biological evaluations. The plant typically would not be operated in these months if functioning solely to deliver water to the Tehama Colusa and Corning canals. Therefore, the high actual and projected numbers of fall and spring-run chinook salmon entrained would be far fewer than determined during this study. Of the more than ten thousand chinook salmon entrained during trials, 49% were entrained in December and January.

Brood year 1998 had the highest actual, estimated, and projected numbers of latefall and winter-run chinook salmon entrained. Actual, estimated, and projected numbers of winter chinook salmon were near 500, 1500, and 3000, respectively.

This study and others have revealed that about 1 to 15% of chinook salmon entrained into the RPP are not recovered in the holding tanks within a 24-h period. Therefore, the actual, estimated, and projected numbers entrained based upon our 24-h entrainment trials were conservative.

Mortality and Injury of Entrained Fish Compared Among Pumps

24-h Trials

Consistent with previous studies at the RPP (McNabb et al.1998, Borthwick et al. 1999), each of the Archimedes lifts entrained more chinook salmon and had lower frequency of mortalities and sub-lethal injuries than the internal helical pump. The difference in mortality between the two pump types however, was not statistically significant. Besides pump configuration, two important differences between these pump types that may affect fish mortality are their speed and the characteristics of the pump's outfall. The helical pump is designed to operate at a much higher speed (350 rpm) than the Archimedes lift (26.5 rpm). The faster pump speed may contribute to the higher frequency of mortalities. Prior to May of 1998 the helical pump operated even faster, at 378 rpm. Although we have entrainment data to compare mortality of entrained chinook salmon when the pump operated at 378 versus 350 rpm, other variables such as debris loads, water quality and size of entrained fish confound these comparisons. Systematic trials under similar environmental conditions with similar sized fish would need to be conducted to accurately assess whether this difference in pump speed affected fish survival. Trials conducted by Helfrich et al. (2000) using a 41 cm diameter internal helical pump revealed that survival of both Sacramento splittail and chinook salmon was unrelated to pump speed over the range of 461 to 601 rpm tested ($R^2 = 0.01$, $p = 0.867$)

Engineering evaluations have not been made on the pump outfalls, however, there are obvious differences between the discharges of the two pump types (Frizell and Atkinson 1999). The Archimedes lifts discharge water in pulses associated with the dumping of water from each flight of the pump. Discharges are centered over the 1.5 m deep channel. Water from the internal helical pump is discharged from a height of approximately 1.0 m above the water surface into the 1.5 m deep channel. The helical pump's discharge structure is off-center reducing the depth of water that the discharge plunges into to less than 0.5 m on the off-center side. This increases the likelihood that a fish discharged from the pump could strike the channel's concrete substrate. The off-center installation also causes water to slosh from side to side as it travels downstream causing velocity fluctuations along the vertical screens (Frizell and Atkinson 1999).

Experiments using hatchery-reared juvenile chinook salmon were conducted in winter and early spring of 2000 to evaluate the effect on mortality of the plunge fish experience when discharged from the internal helical pump (McNabb et al. 2000). Experiments compared mortality of fish released through a port in the top of the pump's discharge structure with mortality of fish released downstream of the pump's discharge. Both groups of fish were collected in the holding tanks. Results showed no significant difference in mortality between the two release groups indicating that plunging from helical pump's discharge structure into the channel did not contribute significantly to mortality. However, as stated in McNabb et al. (2000), these experiments did not answer the question of whether fish passed through the pump travel safely through the discharge structure and into the channel in the same manner as those that were inserted in the port at the top of the pump's discharge structure.

During our study, the frequency of mortality and sub-lethal injury of fish collected from holding tanks was low for each of the three pumps considering that the condition of fish prior to being entrained was unknown. Also, in addition to passing through a pump, fish traveled the lengthy flow stream from the pump's discharge to the holding tanks (Figure 3). Once in the holding tank, fish were confined for up to 14 h depending upon when they entered the tank in relation to the sunset or sunrise check. While in the holding tank fish mortality could be affected by type and amount of debris, amount of water flowing into the tank, length of time confined in the tank, and presence of other fish. Therefore, our frequencies of mortality and injury to wild fish passed through the Archimedes lifts and helical pump are assumed to be overestimates.

Our data did not show a correlation between debris and chinook salmon mortality in holding tanks for any of the pumps (Figure 20). Whether a given amount of debris affects survival was likely confounded with the type of debris, the amount of time the fish was exposed to the debris, and the amount of water flowing into the holding tank. High flows caused turbulent conditions that increased the likelihood of debris striking a fish. Although each entrainment trial began with low flows into the holding tanks, debris impinged on the dewatering ramp decreased the volume of water passing through the ramp thereby increasing the volume of water going to the holding tanks (Figure 19). Due to the relatively small operating volume of the holding tanks (about 1370 L; 360 gal), high flows into the tanks created turbulent conditions which may have contributed to mortality and injury, especially when coupled with debris and long periods of confinement. Confinement time of individual fish and duration of high flows into the holding tanks were two variables that could not be measured.

Sub-lethal injuries to fish also may be affected by conditions in the holding tanks. Strikes from debris or predators may account for some of the integument injuries observed. Small-sized suckers tended to be less hardy than similar-sized chinook salmon to tolerating turbulence and debris in the holding tanks. Compared to all other fish, chinook salmon had a higher incidence of bulging eyes, exophthalmia. This condition has a variety of possible causes including several infectious agents (bacterial and viral) and parasites, nutritional deficiencies, gas supersaturation, kidney functions (increased pressure in the choroid gland), and trauma (Kim True, USFWS, California-Nevada Fish Health Center, personal communication.). Gas supersaturation was unlikely since total gas saturation values measured in holding tanks were below levels found detrimental to fish (Weitkamp and Katz 1980). Bulging eyes also are a symptom of IHN (infectious hematopoietic necrosis), a disease frequently found in fall chinook smolts released from Coleman National Fish Hatchery. To avoid handling and adding stress to these diseased fish, entrainment monitoring was generally not conducted when diseased smolts were released. Therefore, less than 0.1% of chinook entrained with bulging eyes were collected during times when IHN infected smolts were released from Coleman National Fish Hatchery.

Considering all three pumps, overall mortality of chinook salmon entrained into the RPP and recovered from holding tanks was 3.3%. The overall percentage of chinook salmon recovered from the holding tanks with sub-lethal injuries was 1.2. The Biological Opinion for the pumping plant (National Marine Fisheries Service 1993) expected a "substantially higher rate of injury or mortality" to entrained fish passed through the internal helical pump compared to the Archimedes lift. Although frequency of mortality and sub-lethal injury to entrained chinook salmon was greater with the internal helical pump, levels were considerably less than expected and not statistically different from the Archimedes lifts.

Short-duration Trials

Experiments conducted under Objective B of the RPP evaluation program (McNabb et al. 1998, 2000) provided a better estimate of chinook salmon mortality from pump passage than did entrainment trials. The condition and history of each treatment group of fish used in the experiments was known. Also, during experiments fish were immediately removed from the holding tanks and therefore were not subjected to mortality from debris, other fish, or stress of confinement. However, the experiments used hatchery-reared chinook salmon. The short-duration entrainment trials conducted during our study were intended to provide an estimate of mortality of wild chinook salmon entrained from the Sacramento River. The intent was to avoid the confounding mortality factors previously mentioned in our 24-h entrainment trials. While the condition of the fish prior to entrainment was unknown, fish were removed from holding tanks every 10 to15 minutes as in experiments. Percent mortality in the short-duration trials was similar to that reported by McNabb et al. (2000) in the pump passage experiments. Direct mortality of chinook salmon passed through the Archimedes lifts ranged from 0.4 to 0.8% in the passage experiments and 0.6 to 0.9% in the short-duration trials. For the helical pump, percent mortality was lower for chinook salmon in the short-duration trials (1.2%) than for salmon from the passage experiments (2.8%). The low frequencies of mortalities are consistent with low levels of stress found in fish passed through the lifts and pumps (Weber and Borthwick 2000).

Compared to the 24-h entrainment trials, mortality of entrained chinook salmon and all other fish combined was less in the short-duration trials for each of the pumps. Although the lower mortality could be attributed to many things including smaller sample size, different sized fish, and different environmental conditions, the lack of confinement in the holding tanks with debris and high flows likely contributed a great deal towards the lower mortality.

Mortality of chinook salmon held for 96 h was greater in the short-duration trials (0.9% - 2.7%) compared to experiments (0.7% - 1.0%; McNabb et al. 2000) and compared to previous trials in which entrained juvenile chinook salmon were held for 96 h (0.5 - 0.8%; Borthwick et al. 1999). In the short-duration trial with the greatest number of chinook salmon entrained, fish were inadvertently held at high densities in 20 L buckets for a long period before being transferred to the river water laboratory. This was suspected of contributing to the relatively high delayed mortality.

Mortality of Large Fish

Entrainment of large fish (≥200 mm) during trials suggested that both pump types, but particularly the Archimedes lifts, were capable of passing large fish with low incidence of mortality and injury. Mortality among more than 400 large fish passed through the Archimedes lifts was lower than mortality of small fish (1.2% and 3.0%, respectively). Mortality of nearly 100 large fish passed through the helical pump was slightly higher (4.2%) than mortality of small fish (3.8%). However, the sample size for large fish passed through each pump was much less than for small fish. The largest fish passed through each type of pump was a 730 mm (24 in) Pacific lamprey which was collected alive from the holding tanks. Excluding Pacific lamprey, the largest fish passed through an Archimedes lift during entrainment trials was a 480 mm (19 in) Sacramento pikeminnow. The largest passed through the internal helical pump was a 432 mm (17 in) Sacramento sucker. Both were collected alive.

Fraction of Riverine Chinook Salmon Entrained

The biological opinion for the RPP (National Marine Fisheries Service 1993) assumed that juvenile chinook salmon would be uniformly distributed in the Sacramento River and entrained in proportion to the fraction of river discharge pumped into the plant. Our data do not support this assumption with a low correlation between the fraction of chinook salmon entrained and the fraction of river pumped (Pearson correlation = 0.287). The fraction of salmon entrained was consistently less than the fraction of discharge pumped. The upper 90% confidence interval (CI) for fraction entrained only exceeded the fraction of river discharge pumped on one of 84 sampling dates (1/7/98). Rotary screw trap sampling also revealed that chinook salmon were not uniformly distributed in the Sacramento River (Gaines and Martin 2001, draft).

The highest fraction of daily chinook salmon passage that was entrained into the RPP occurred on 12/24/97 with 0.0138 (1.38%) and an upper 90% CI of 0.0339 (3.99%). Half of the fourteen sample dates with a 90% CI exceeding 0.01 were collected in winter (Dec - early Feb) when the plant typically was not used to provide water to the TCC. Winter samples were collected specifically for our study. The highest entrainment rates corresponded with the outmigration of fall chinook salmon.

Most winter chinook salmon outmigrated past RBDD during August through November (Martin et al. 2001, draft). During those months, the fraction of chinook salmon passing RBDD that were entrained into the RPP on each date sampled averaged 0.0017 and ranged from 0.00007 to 0.0066. The fraction entrained was much less than the fraction of river discharge pumped on each sampling date (Figure 21).

The low ratio of chinook salmon per acre-foot captured in the RPP versus the rotary screw traps (0.22) is another indication that relatively few riverine salmon were entrained into the RPP. As suggested previously, this low frequency of entrainment may be due to the location of the pump intakes in relation to the vertical distribution of outmigrating juvenile chinook salmon. Another possible explanation is that sweeping velocities along the trash racks in front of the pump intakes deter fish from entering the sump area. The plant was designed to provide a sweeping velocity component in front of the trash racks to exclude sediment, debris, and fish. During measurements taken with an acoustic Doppler current profiler in March 1996, sweeping velocities along the trash racks ranged from 0.6 to 0.9 m/s (2 to3 ft/s) when the two Archimedes lifts were each pumping 2.6 m^3/s (93 ft^3/s; Tracy Vermeyen travel report, April 15, 1997).

Because the number of juvenile chinook salmon passing Red Bluff was greatest at night (Gaines and Martin 2001, draft), more salmon were entrained into the RPP at night than during the day. The fraction of riverine chinook salmon entrained into the RPP, however, was very similar between day and night samples for each of the three pumps. This suggests that the vulnerability of chinook salmon to entrainment was similar day and night. Turbidity also did not influence the fraction of fish entrained into the RPP. Due to their position at about 3.6 m (12 ft) below the water surface, low light conditions likely exist near the pump intakes at all times. This may explain why the fraction entrained was similar day versus night and was not influenced by turbidity.

There was no relationship between fork length and fraction of chinook salmon entrained. However, mean fork lengths of chinook salmon captured in traps were significantly greater than mean fork lengths of chinook salmon captured in the RPP. The RPP, located along the river margin, may have sampled younger fish which used the margins as rearing habitat. Rotary screw traps located in the main channel may have sampled older fish that were actively migrating downstream.

During the eighty-four dates when 24-h samples were collected simultaneously from the screw traps and the RPP, there was a strong, positive correlation between the number of chinook salmon captured per acre-foot in the traps and in the RPP. Although they likely have different efficiencies, a positive correlation between the RPP and traps was expected since they are fixed sampling methods located in the same general vicinity. The high correlation indicates that the number captured per acre-foot in the traps was a good predictor of the number entrained per acre-foot into the RPP, and vice versa.

Densities of two benthic inhabitants, prickly sculpin and lamprey ammocoetes, captured in the RPP were more than 100 and 200 times greater than in the screw traps, respectively. As with chinook salmon, this skewed ratio is thought to be related to the vertical distribution of these species in relation to the portion of the water column that the RPP and screw traps sample. Densities of juvenile Sacramento suckers and Sacramento pikeminnow captured in the RPP were 3 and 4 times greater than in the screw traps, respectively. In large streams juvenile Sacramento suckers and pikeminnow occupy areas along the stream margins which may make them more vulnerable to capture in the RPP than in the screw traps (McGinnis 1984).

Holding Tank Efficiency Trials

The purpose of these trials was to determine how effective our method of tabulating the number of fish collected in the holding tanks during a 24-h period was at evaluating the number of riverine chinook salmon entrained into the RPP. Our results suggest that on average, 10 - 12% of the chinook salmon entrained into the RPP were not captured in holding tanks within 24 h. Therefore, our actual, estimated, and projected numbers of chinook salmon entrained based upon our 24-h trials likely are conservative. Also, because fish may reside in the plant for several hours before moving downstream to the holding tanks, our diel patterns of entrainment may be skewed towards greater night entrainment. Another consideration when interpreting this data is that 81% of chinook salmon entrained into the plant were < 40 mm fork length, while only about 18% those used in our efficiency trials were <40 mm fork length. Size of fish may be an important consideration when assessing holding tank efficiencies.

The 10 to 12% of the chinook salmon not recovered within 24 h in our study was higher than reported by McNabb et al. (2000). During their study, chinook salmon released for pump passage experiments were frequently captured after a trial was completed, either during another trial the same night or while collecting fish at a subsequent sunrise or sunset check of the holding tanks for a 24-h entrainment trial. Occasionally, these fish were never recovered and were designated as *holdouts.* Investigations indicated that holdouts resided near pump outfalls or in the screening facilities. The percentage of fish released into the pump intakes that were holdouts ranged from 7 to 8 in 1998 and 1999 when velocities in the screening facilities were similar to conditions during our trials. In trials conducted to evaluate travel time of chinook salmon through the plant, 3% to 12% of fish released into pump intakes were not recovered in holding tanks within 24 h (Borthwick et al. 2000). Travel time and the percentage recovered were influenced by light conditions (i.e., day or night release) and turbidity of the water at release. Work during this study also revealed that fish not captured were holding up near pump outfalls or in the screening facilities. The difference in the results among various studies is likely a function of size of chinook salmon, water quality conditions, and velocities within the screening facility.

Frizell and Atkinson (1999) suggest that passage delays in the screening facility are due to the ramp located at the downstream end creating a recirculating eddy preventing flow from accelerating into the open bypass channel. The ramp created a zone of deceleration with sweeping velocities near the bottom very low, ranging from approximately 0.12 to 0.61 m/s (0.4 to 2.0 ft/s) for a distance of 2.4 m (8 ft) upstream of the bypass entrance (Frizell and Atkinson 1999). Juvenile salmon of the size used in our holding tank efficiency trials can maintain their position in these velocities (Bell 1991). Therefore, the screening facility can provide a refuge for chinook salmon. Also, juvenile salmonids can sense changes in velocity, and may avoid moving from one gradient to another, especially from a lower to a higher gradient (Bell 1991). Therefore, chinook salmon that encounter low velocity zones in the screening facility likely resist moving back into high velocity waters.

Summary

- The fish most frequently entrained into the RPP, in decreasing order, were chinook salmon, prickly sculpin, lamprey ammocoetes, Sacramento sucker, Sacramento pikeminnow, and riffle sculpin. These six species comprised 94% of the fish entrained. Ninety-four percent of entrained fish were <100 mm in length.

- Seasonal patterns of chinook salmon entrainment followed patterns of abundance in the river, peaking in winter when fall chinook salmon were outmigrating.

- Mean percent mortality of chinook salmon in the short-duration (2 to 3-h) trials was 0.9, 0.6, and 1.2 for Archimedes 1, Archimedes 2, and the internal helical pump, respectively, compared to 2.8, 2.9, and 4.9 in the 24-h trials. Mortality did not differ significantly among the three pumps for the short-duration or the 24-h trials.

- In both 24-h and short-duration trials, frequencies of mortality and sub-lethal injury of wild entrained fish were assumed to be overestimates of pump passage mortality since other factors may have contributed to mortality. Fish traveled past screens and brushes, in concrete channels, and up a wedge-wire dewatering ramp on their way to the holding tanks. In the holding tanks, fish were subjected to turbulence and debris, especially during 24-h trials. Also, condition of fish prior to entrainment was unknown.

- The fraction of the estimated daily total number of juvenile chinook salmon passing RBDD that were entrained into the RPP on 84 trial dates averaged 0.0022 (0.22%) and ranged from 0.00007 to 0.0138. The fraction entrained was consistently less than the fraction of river discharge pumped into the RPP.

- The greatest number and fraction of chinook salmon entrained during 24-h trials occurred in winter months (December through early February) when fall chinook salmon were outmigrating. During this winter period the plant typically would not be operated if used solely to deliver water to the Tehama-Colusa canal.

- The fraction of the estimated daily total number of winter chinook salmon passing RBDD that were entrained into the RPP averaged 0.0017 and ranged from 0.00008 to 0.0066.

- There was a positive correlation (Pearson correlation coefficient = 0.824) between the number of chinook salmon captured per acre-foot in the screw traps and in the RPP on the 84 dates when simultaneous samples were collected.

- The number of chinook salmon entrained per acre-foot into the RPP was greater at night than during the day in 33 of the 35 months that entrainment was monitored. However, the fraction of riverine chinook salmon entrained was similar between day and night suggesting that vulnerability to entrainment during those two diel periods was similar.

- Trials conducted with hatchery-reared chinook salmon revealed that 10 to 12% of fish released into the pumps were not collected in the holding tanks within 24 h of release. This suggests that entrainment trials underestimated the actual number of chinook salmon entrained into the RPP.

- The number captured per acre-foot of prickly sculpin and lamprey ammocoetes, both benthic species, was much higher (100-200 times) in the RPP than in rotary screw traps. This large difference was likely due to the RPP sampling the bottom of the water column while screw traps sampled the upper 1.2 m of the water column. Catch per acre-foot of chinook salmon, which migrate in the upper water column, was higher in the screw traps than in the RPP.

- In conclusion, the low fraction of chinook salmon entrained into the RPP, combined with the low frequency of mortality and sub-lethal injury to all fish passed through the pumps, supports the conclusion that the RPP can be operated with minimal harm to Sacramento River fishery resources near Red Bluff, including chinook salmon.

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Table 1. Summary of pump operations and fish entrainment monitoring at Red Bluff Research Pumping Plant, February 1997 - May 2000.

PARAMETER	ARCHIMEDES-1	ARCHIMEDES-2	HELICAL
Pump Speed (rpm)	26.5	26.5	378 and 350[1]
Average Discharge (m^3/s) (Range)	2.5 (2.1 - 2.7)	2.5 (2.0 - 2.8)	@378: 2.7 (2.3 - 2.9) @350: 2.3 (2.1 - 2.7)
Period of Pump Operation	1997: Feb - Dec 1998: Jan, Mar - Dec 1999: Feb - Oct 2000: Feb - May	1997: Feb - Dec 1998: Jan, Mar - Dec 1999: Feb - Oct 2000: Feb - May	1997: Feb - mid July Sep - Dec 1998: Jan, Mar - Apr Sep - mid-Nov 1999: Feb - Oct 2000: Feb - May
Total Hrs. Pump Operated	9922	9647	8145
Total Hrs. Entrainment Monitored	2974	3045	2461
% of Time Entrainment Monitored	30	32	30
Number of 24-h Trials Conducted	118	122	94

[1] Pump speed was 378 rpm from Feb 1997 - Apr 1998. Thereafter, pump speed was 350 rpm.

Table 2. Fish species entrained from the Sacramento River and captured in holding tanks at Red Bluff Research Pumping Plant during 24-h entrainment trials, February 1997 through May 2000.[1]

SPECIES	NUMBER ENTRAINED	PERCENT OF TOTAL
Chinook salmon (*Oncorhynchus tshawytscha*)[2]	10,412	40
Fall run	(8,704)	(83.6)
Winter run	(1,255)	(12.1)
Spring run	(252)	(2.4)
Latefall run	(201)	(1.9)
Prickly sculpin (*Cottus asper*)[2]	7,305	28
Lamprey ammocoetes (*Lampetra spp.*)[2]	4,580	18
Sacramento sucker (*Catostomus occidentalis*)[2]	1,497	6
Sacramento pikeminnow (*Ptychocheilus grandis*)[2]	511	2
Riffle sculpin (*Cottus gulosus*)[2]	357	1
Pacific lamprey (*Lampetra tridentata*)[2]	273	1
Threespine stickleback (*Gasterosteus aculeatus*)[2]	228	<1
Bluegill (*Lepomis macrochirus*)	220	<1
Tule perch (*Hysterocarpus traski*)[2]	172	<1
White catfish (*Ictalurus catus*)	144	<1
Steelhead/Rainbow trout (*Oncorhynchus mykiss*)[2]	114	<1
Hardhead (*Mylopharodon concephalus*)[2]	86	<1
California roach (*Lavinia symmetricus*)[2]	86	<1
Mosquitofish (*Gambusia affinis*)	31	<1
Common carp (*Cyprinus carpio*)	40	<1
Largemouth bass (*Micropterus salmoides*)	18	<1
Speckled dace (*Rhinichthys osculus*)[2]	25	<1
Unidentified adult lamprey (*Lampetra spp.*)[2]	25	<1
Threadfin shad (*Dorosoma petenense*)	24	<1
Green sunfish (*Lepomis cyanellus*)	15	<1
Unidentified sunfish (Centrarchidae)	14	<1
Channel catfish (*Ictalurus punctatus*)	9	<1
Brown bullhead (*Ictalurus nebulosus*)	7	<1
River lamprey (*Lampetra ayresi*)[2]	6	<1
Smallmouth bass (*Micropterus dolomieui*)	6	<1
Sturgeon (*Acipenser spp.*)[2]	4	<1
Golden shiner (*Notemigonus crysoleucas*)	2	<1
Hitch (*Lavinia exilicauda*)[2]	2	<1
Bass sp. (*Micropterus spp.*)	3	<1

Table 2.–Continued.

Bullhead sp. *(Ictalurus spp)*	1	<1
Western brook lamprey *(Lampetra richardsoni)* [2]	1	<1
Goldfish (*Carassius auratus*)	1	<1
Minnow sp. (Cyprinidae)	1	<1
TOTAL	26,220	

[1] Includes all chinook salmon, steelhead/rainbow trout, and sturgeon entrained. For other species, includes individuals ≥ 30 mm total length.

[2] Species native to the Sacramento River.

Table 3. Mean monthly number of fish entrained per acre-foot of water pumped for nocturnal and diurnal periods. Includes the five most frequently entrained fish species, and all fish species except chinook salmon combined. Trials were conducted at the Red Bluff Research Pumping Plant from February 1997 through May 2000.

Species	Mean Monthly Number Entrained per Acre-foot Pumped		Nocturnal:Diurnal
	Nocturnal	Diurnal	
Chinook salmon			
Fall	0.388	0.146	2.7
Latefall	0.003	0.001	3.3
Spring	0.021	0.003	7.0
Winter	0.028	0.002	16.5
All Salmon	**0.428**	**0.090**	**4.8**
Prickly sculpin	0.352	0.029	12.1
Lamprey ammocoetes	0.135	0.017	7.9
Sacramento sucker	0.078	0.008	9.8
Sacramento pikeminnow	0.014	0.005	2.8
All fish except salmon	0.642	0.080	8.0

Table 4. Total number and percent mortality of fish species most frequently entrained into experimental pumps at Red Bluff Research Pumping Plant during 24-h entrainment trials (N=80) conducted when all three pumps ran simultaneously; February 1997 through May 2000. Each entrainment trial started at sunrise and continued for 24 h.

	ARCHIMEDES 1		ARCHIMEDES 2		INTERNAL HELICAL	
SPECIES	Number	% Mortality[1]	Number	%Mortality [1]	Number	% Mortality[1]
Chinook salmon[2]						
Fall run	1730	2.4	2929	2.4	1243	5.0
Winter run	267	3.7	458	4.6	97	1.0
Spring run	43	11.6	89	5.6	24	12.5
Late-fall run	40	2.5	50	12.0	42	7.1
All chinook salmon	**2080**	**2.8**	**3526**	**2.9**	**1406**	**4.9**
Prickly sculpin	1657	1.7	1076	1.4	1153	3.9
Lamprey ammocoetes	367	0.5	348	0.9	498	1.2
Sacramento sucker	204	17.2	174	23.6	125	15.2
Sacramento pikeminnow	62	4.8	84	1.2	25	16.0
Riffle sculpin	102	0.0	81	1.1	78	0.0
Threespine stickleback	78	30.8	45	31.1	39	33.3
Pacific lamprey	95	3.2	66	1.5	53	1.9
Bluegill	21	19.0	30	20.0	12	16.7
White catfish	45	17.8	18	33.3	32	6.3
All fish except chinook	**2744**	**4.5**	**2048**	**4.9**	**2094**	**5.1**
ALL FISH SPECIES	**4824**	**3.8**	**5574**	**3.6**	**3500**	**5.0**

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[1] Mortality should not be interpreted strictly as pump passage mortality. This table represents mortality of fish that passed through a pump, then traveled by a screening facility, around curved bypass channels, up a dewatering ramp and into a holding tank. Fish could reside in a holding tank for up to 14 h depending upon when they arrived in relation to the time of collection at sunrise or sunset. Mortality of fish collected from the holding tanks could be affected by the duration it was confined to the tank, the amount of water flowing into the tank, the type and/or volume of debris in the tank, or by other fish in the tank. Also, the condition of fish in the river prior to being entrained was unknown.

[2] Run membership was determined from a daily fork-length table generated by Sheila Greene, California Department of Water Resources, Environmental Services Office, Sacramento (8 May 1992) from data by Frank Fisher, California Department of Fish and Game, Inland Fisheries Branch, Red Bluff (revised 2 February 1992).

Table 5. Percentage of juvenile chinook salmon and other fish entrained into experimental pumps at Red Bluff Research Pumping Plant that exhibited injuries when collected from holding tanks during 24-h entrainment trials (N=80) conducted when all three pumps operated simultaneously; February 1997 through May 2000.

Groups of Fish	Percent Injured		
	Archimedes 1	Archimedes 2	Helical
All Chinook[1]	3.1	3.1	4.9
Surviving Chinook	1.2	0.8	1.7
Other Fish[1]	5.0	5.0	5.7
Other Surviving Fish	2.9	2.8	2.6

[1] Includes all fish with injuries, whether individuals were alive or dead at the time of collection.

Table 6. Percentage of alive and dead juvenile chinook salmon with specified injuries. Chinook salmon were collected in holding tanks at Red Bluff Research Pumping Plant during 24-h entrainment trials (N=80) conducted when all three pumps operated simultaneously; February 1997 through May 2000.

Type of Injury[1]	Archimedes 1		Archimedes 2		Helical	
	Alive	Dead	Alive	Dead	Alive	Dead
Fins						
Eroded >30%	0	1.7	0	3.3	0	4.3
Eroded to base	0	0	0	1.1	0	1.4
Hemorrhage or Bruise	0.07	0	0	1.1	0	1.4
Missing	0	0	0	0	0	1.4
Skin						
Bruise	0.20	3.4	0.19	3.3	0.17	8.7
Partially Deskinned	0	1.7	0.14	4.3	0	1.4
Split or Open Wound	0.48	8.6	0.09	8.7	0.33	13.0
Abrasion	0.14	5.3	0.28	18.5	0.42	20.3
Hemorrhage	0.14	3.4	0.09	0	0.08	1.4
Eyes						
Bulging	0.07	20.7	0	21.7	0.25	18.8
One Missing	0	1.7	0	4.3	0.17	5.8
Both Missing	0	0	0	1.1	0	4.3
Hemorrhage	0	3.4	0	5.4	0.42	8.7
Head						
One operculum missing	0	0	0	3.3	0	0
Open wound or abrasion	0.14	1.7	0	3.3	0	2.9
Decapitated	0	0	0	0	0	5.8
Bruise or hemorrhage	0	3.4	0.05	4.3	0.08	4.3

[1] A fish may have more than one type of injury.

Table 7. Percentage of alive and dead fish other than juvenile chinook salmon with specified injuries. Fish were collected in holding tanks at Red Bluff Research Pumping Plant during 24-h entrainment trials (N=80) conducted when all three pumps operated simultaneously; February 1997 through May 2000.

Type of Injury[1]	Archimedes 1		Archimedes 2		Helical	
	Alive	Dead	Alive	Dead	Alive	Dead
Fins						
Eroded >30%	0.30	6.6	0.06	12.0	0.24	8.5
Eroded to base	0.25	3.3	0.28	8.0	0.18	3.8
Hemorrhage or Bruise	0.40	0.8	0.11	1.0	0.30	0
Missing	0.05	0.8	0.11	0	0.24	0.9
Skin						
Bruise	0.60	1.6	0.74	2.0	0.54	1.9
Partially Deskinned	0.05	6.6	0.11	4.0	0.12	1.9
Split or Open Wound	0.40	8.9	0.40	13.0	0.18	11.3
Abrasion	0.20	10.6	0.23	7.0	0.24	2.8
Hemorrhage	0.60	4.9	0.91	5.0	0.71	6.6
Eyes						
Bulging	0.05	1.6	0.06	11.0	0	7.5
One Missing	0	3.3	0	3.0	0	0.9
Both Missing	0	0.8	0	1.0	0	0.9
Hemorrhage	0.05	0.8	0	0	0	0.9
Head						
One operculum missing	0	0	0	0	0	2.8
Open wound or abrasion	0.05	1.6	0.06	0	0	2.8
Decapitated	0	1.6	0	2.0	0	1.9
Bruise or hemorrhage	0.05	4.1	0.06	3.0	0.06	2.8

[1] A fish may have more than one type of injury.

Table 8. Results of short-duration (2 to 3-h) entrainment trials (N=15) conducted from January through March, 2000. Entrained fish were removed from holding tanks every 10-15 minutes. The objective of these trials was to obtain a better estimate of mortality of entrained fish by minimizing mortality due to confinement in tanks and interactions with debris and other fish. Mean fork length of chinook salmon entrained during these trials was 38 mm.

	ARCHIMEDES 1		ARCHIMEDES 2		INTERNAL HELICAL	
SPECIES	Number	% Mortality	Number	% Mortality	Number	% Mortality
Chinook salmon[1]	468	0.9	1045	0.6	782	1.2
Lamprey ammocoetes	319	0	253	0.4	198	0
Prickly sculpin	27	0	33	0	47	0
Pacific lamprey	18	0	12	0	16	0
Sacramento sucker	8	0	11	0	3	0
Steelhead/Rainbow trout	7	0	7	0	5	0
Threespine stickleback	6	50	5	20.0	0	--
White catfish	2	0	0	--	0	--
Sacramento pikeminnow	3	0	9	0	4	0
Riffle sculpin	4	0	6	0	4	0
Mosquito fish	0	--	3	33.3	0	--
Bluegill	0	--	2	0	0	--
California roach	0	--	1	0	0	--
Hardhead	0	--	1	0	4	0
All fish except salmon	394	0.8	343	0.9	281	0
All fish combined	**862**	**0.8**	**1388**	**0.6**	**1063**	**0.8**

[1] Surviving chinook salmon were held in the river water lab for 96 h to assess delayed morality. Despite high handling mortality which occurred during counting and measuring fish in one trial with high numbers entrained (>300/pump), percent mortality at 96 hours for fish passed through Archimedes 1, 2, and the helical pump was 2.2, 0.9 and 2.7, respectively.

Table 9. Mortality of large fish (≥200 mm) entrained into experimental pumps at Red Bluff Research Pumping Plant during 24-h and short-duration entrainment trials conducted from February 1997 through May 2000. Pumps were not always operated simultaneously.

SPECIES (avg; min-max total length in mm)	ARCHIMEDES 1		ARCHIMEDES 2		HELICAL	
	Number	% Mortality	Number	% Mortality	Number	% Mortality
Pacific lamprey (566; 307 - 732)	109	2.8	58	0	42	2.4
Sacramento pikeminnow (249; 202 - 480)	32	3.1	26	0	20	5.0
Sacramento sucker (251; 201 - 432)	47	0	51	0	12	8.3
Hardhead (235; 203 - 338)	29	3.4	26	0	10	0
White catfish (271; 232 - 345)	3	0	6	0	1	0
Steelhead\Rainbow trout (250; 205 - 375)	4	0	6	0	7	14.3
Channel catfish (271; 211 - 334)	0	-	3	0	1	0
Bass (275; 210 - 380)	1	0	2	0	2	0
River lamprey (246; 216 - 275)	1	0	0	--	1	0
Common carp (255; 255 - 255)	0	--	1	0	0	--
ALL LARGE FISH	**226**	**2.2**	**179**	**0**	**96**	**4.2**

Table 10. Results from simultaneous collections of fish passed through pumps at the Red Bluff Research Pumping Plant and from rotary screw traps placed in the Sacramento River near the pumping plant from September 1997 through May 2000. N is the number of samples collected.

Species	Mean Number (SD) Captured Per Acre-foot of Water Sampled		Capture ratio pumps/traps
	Pumps (N = 467)	Rotary Screw Traps (N = 168)	
Chinook salmon	0.1708 (0.5671)	0.7690 (1.2989)	0.22
Lamprey ammocoetes	0.0404 (0.4034)	0.0002 (0.0011)	202
Prickly sculpin	0.0228 (0.1357)	0.0002 (0.0005)	114
Sacramento pikeminnow	0.0016 (0.0041)	0.0004 (0.0015)	4
Sacramento sucker	0.0042 (0.0058)	0.0015 (0.0084)	3

Table 11. Results of 16 holding tank efficiency trials conducted at Red Bluff Research Pumping Plant in 1999 and 2000. All three pumps were operated during each trial.

Pump	No. Fish per Trial	Mean (SD) % of Fish Recovered 24 h After Release[1]		
		All Trials (N=16)	Sunrise Release Trials (N=4)	Sunset Release Trials (N=4)
Archimedes 1	30 - 32	88 (8)	84 (11)	90 (8)
Archimedes 2	31 - 32	90 (6)	94 (4)	88 (15)
Internal Helical	31 - 32	88 (12)	82 (13)	85 (14)

[1] Mean trial duration was 23.6 h. In 1999, all samples were released at sunrise. In 2000, samples were released at sunset on day one and at sunrise the next day to assess if release time affected percent of fish recovered.

Table 12. Time-in-travel for chinook salmon (52 mm mean fork length) released in pump intakes and collected from holding tanks. Six trials were conducted, and all three pumps were used in each trial. Experimental fish were released at sunrise.

Hours Post-Release	Mean Percent Recovered (SD)		
	Archimedes 1	Archimedes 2	Internal Helical
0.5	38 (19)	40 (20)	32 (24)
1.0	46 (16)	53 (29)	40 (25)
2.0	67 (16)	59 (26)	55 (23)
6.0	78 (13)	72 (24)	75 (28)
14.0	87 (6)	76 (20)	82 (25)
24.0	90 (5)	88 (7)	98 (7)

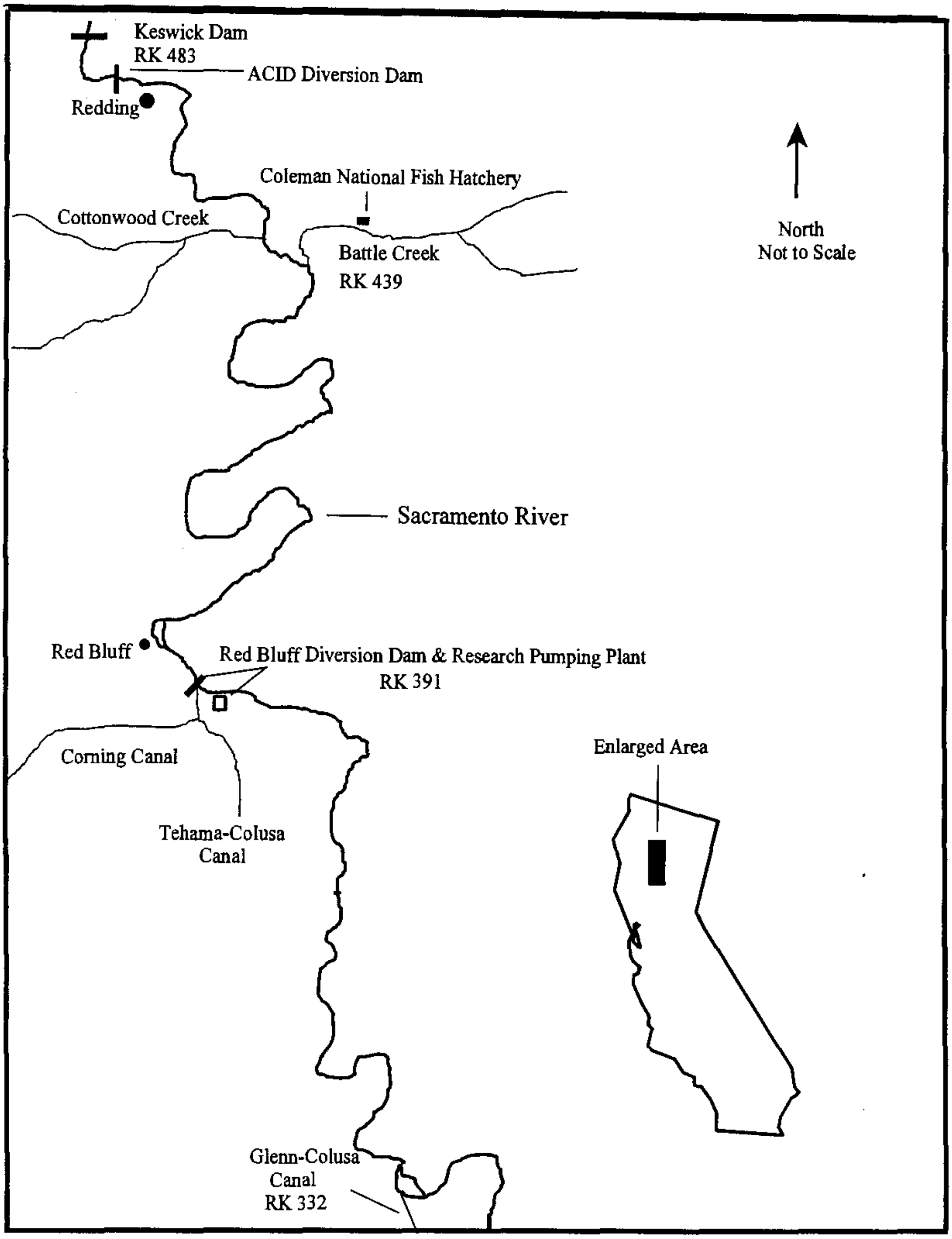

Figure 1. Location of Red Bluff Research Pumping Plant on the Sacramento River at river kilometer 391 (river mile 243).

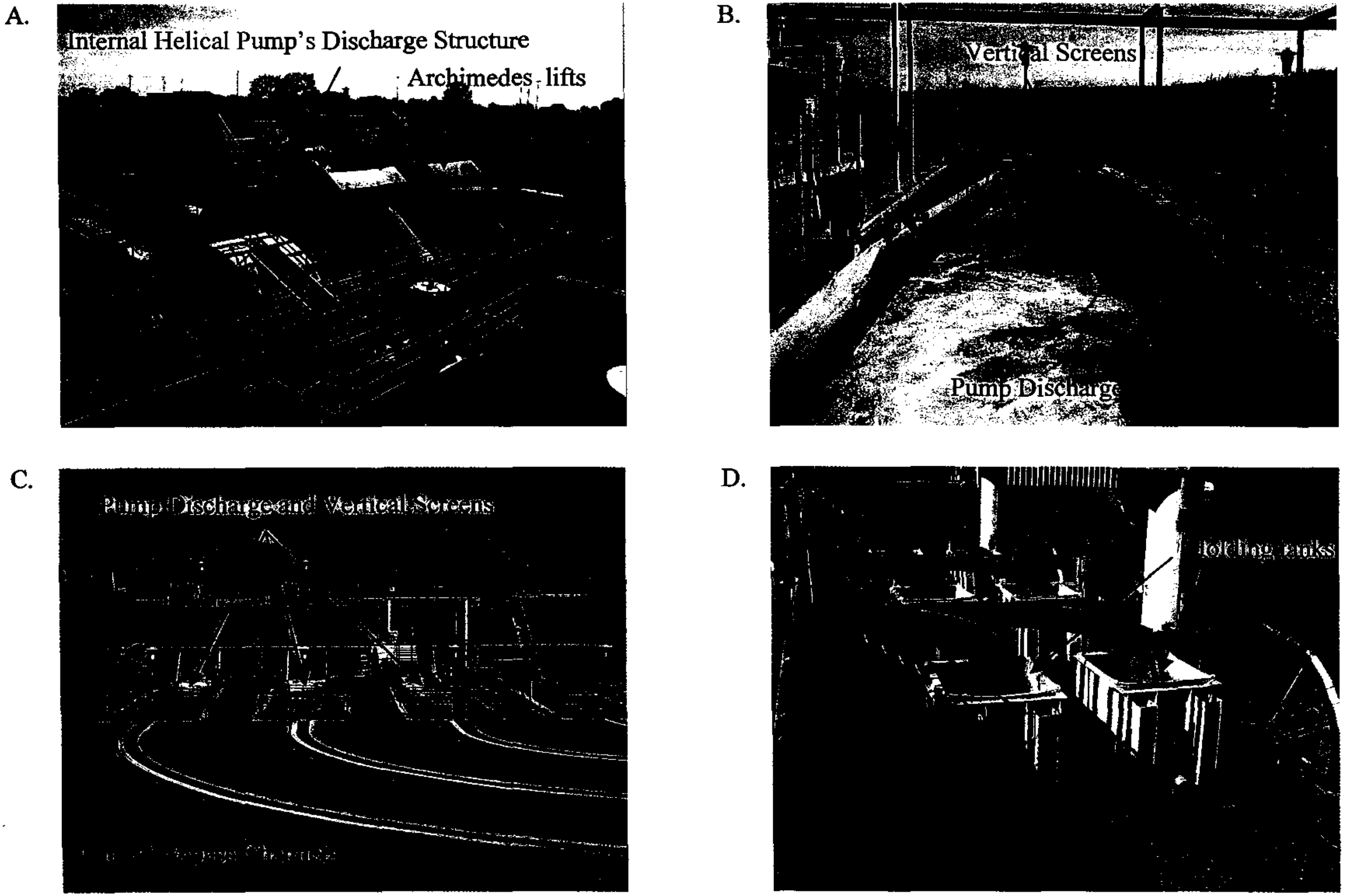

Figure 2. Features of Red Bluff Research Pumping Plant. (A) The two Archimedes lifts and the discharge structure of the internal helical pump. (B) Vertical wedge-wire screens downstream of the pump discharge. (C) Curved open bypass channels downstream of the vertical screens. (D) Holding tanks downstream of the curved bypass channels.

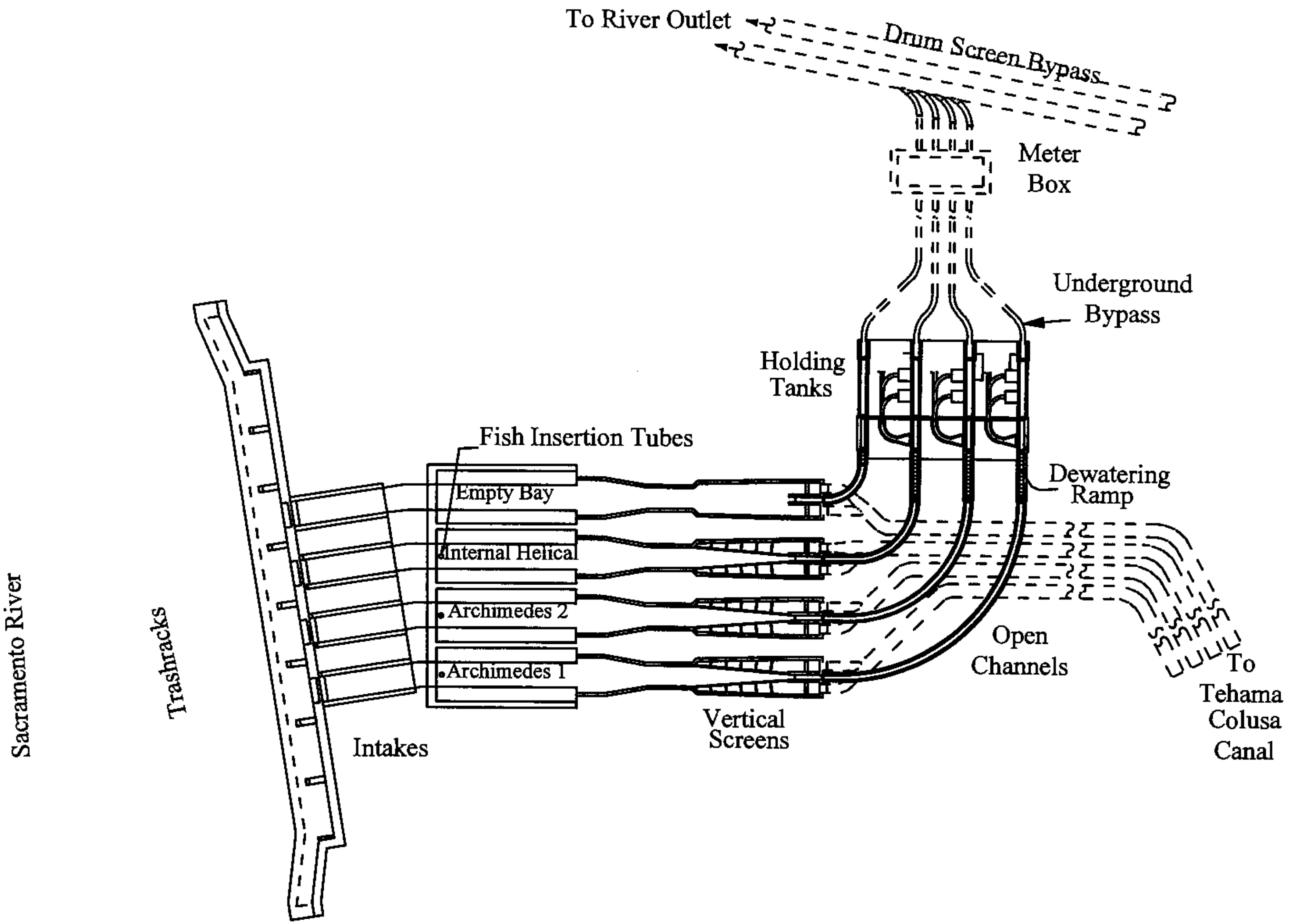

Figure 3. Schematic of Red Bluff Research Pumping Plant showing pathways of movement for fish entrained from the Sacramento River. During trials fish were collected in holding tanks.

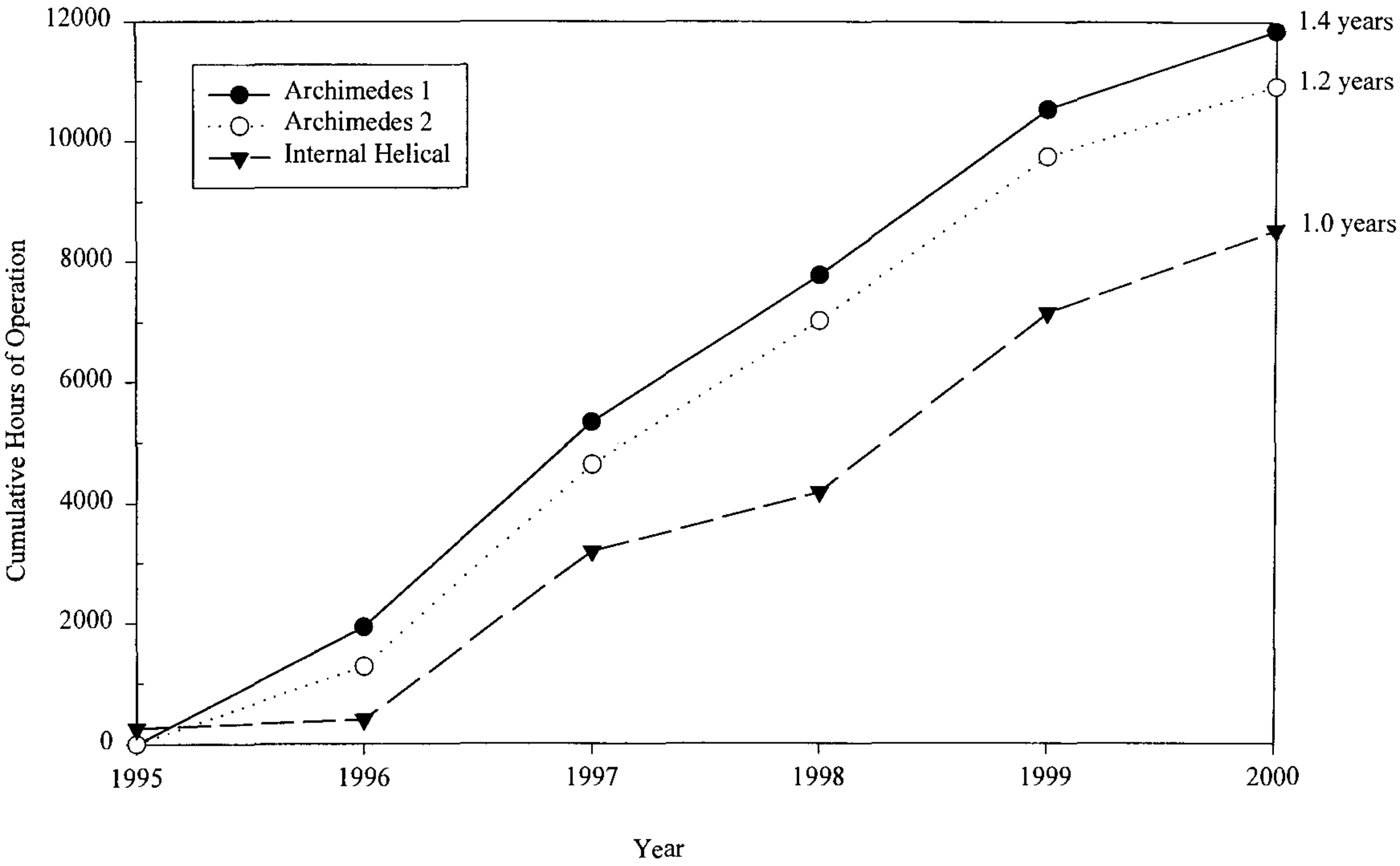

Figure 4. Cumulative hours of operation, by year, for the Archimedes lifts and the internal helical pump at Red Bluff Research Pumping Plant from May 1995 through May 2000.

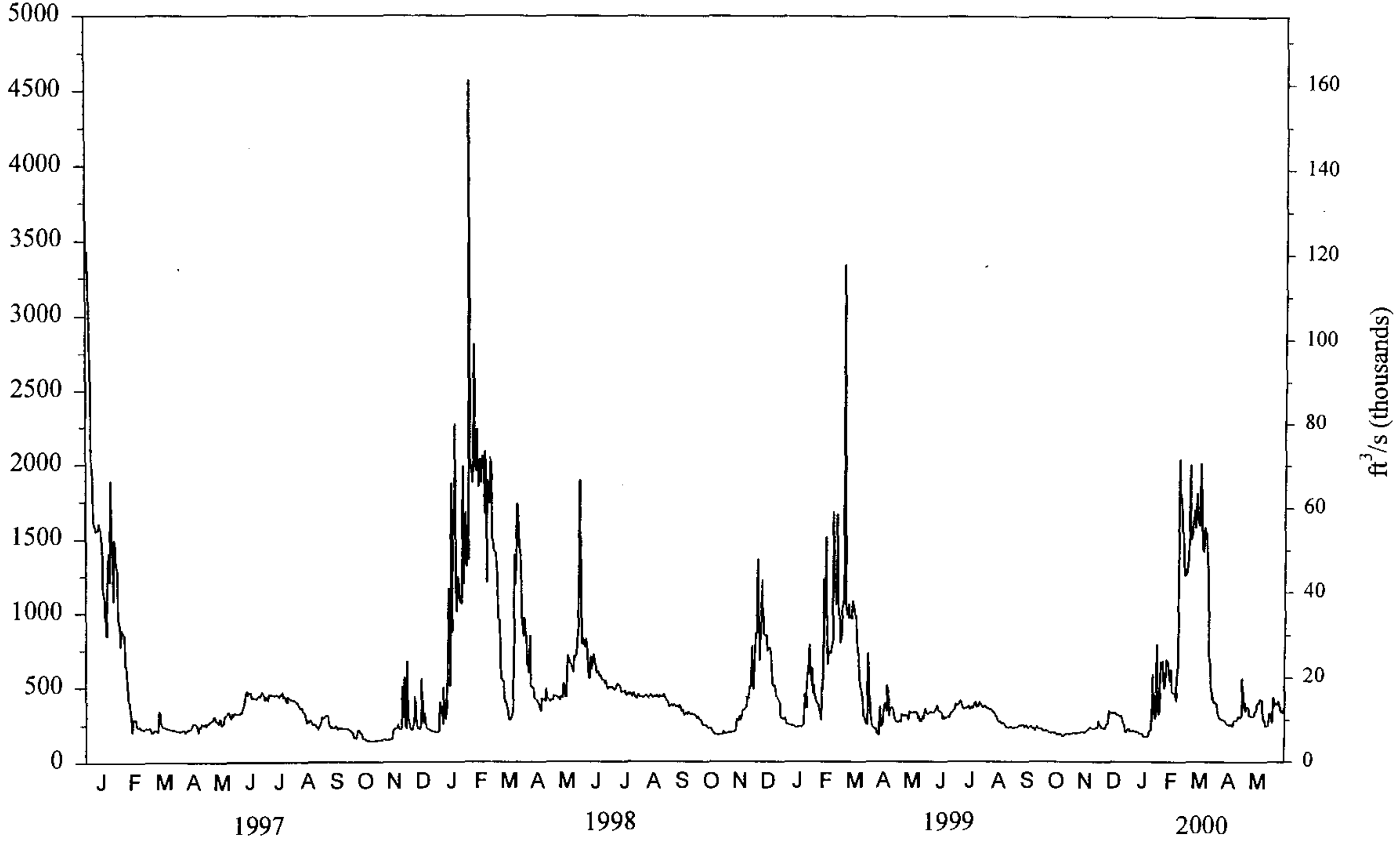

Figure 5. Daily Sacramento River flows past Red Bluff Diversion Dam (RBDD) from January 1997 through May 2000. Flows were estimated by Bureau of Reclamation personnel based upon U. S. Geological Survey flow data collected at Bend Bridge approximately 24 river km upstream of RBDD.

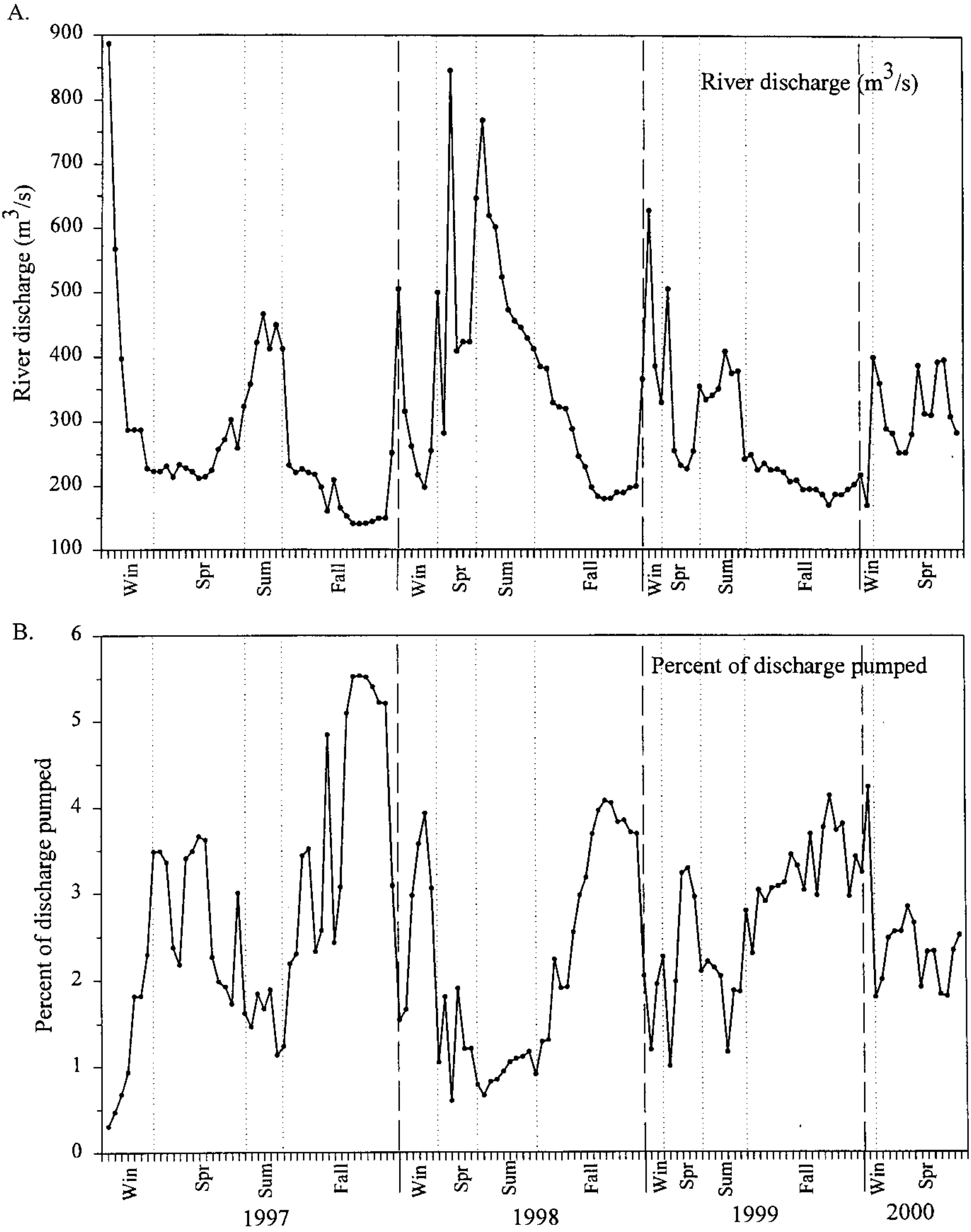

Figure 6. (A) Daily Sacramento River discharge (m^3/s) flowing past Red Bluff Research Pumping Plant on dates that entrainment trials were conducted. (B) Percent of discharge pumped into the plant during entrainment trials; February 1997 - May 2000. Seasons are defined as Win=Dec-Feb; Spr=Mar-May; Sum=Jun-Aug; Fall=Sep-Nov.

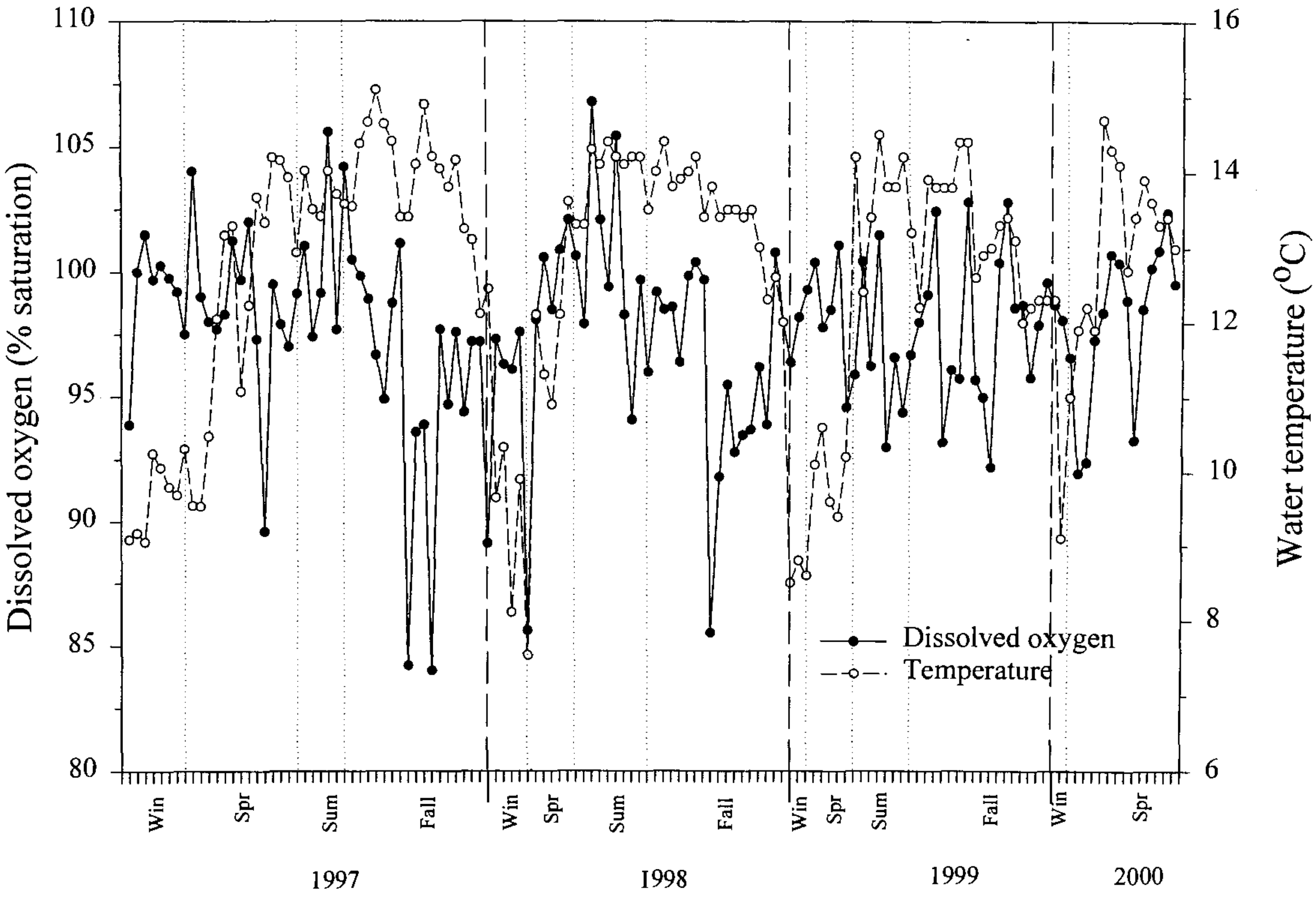

Figure 7. Mean water temperature and dissolved oxygen (% saturation) during entrainment trials conducted at Red Bluff Research Pumping Plant from February 1997 through May 2000. Measurements were collected from Sacramento River water flowing through holding tanks using a YSI dissolved oxygen meter. Seasons are defined as follows: Win = Dec - Feb; Spr = Mar - May; Sum = Jun - Aug; Fall = Sep - Nov.

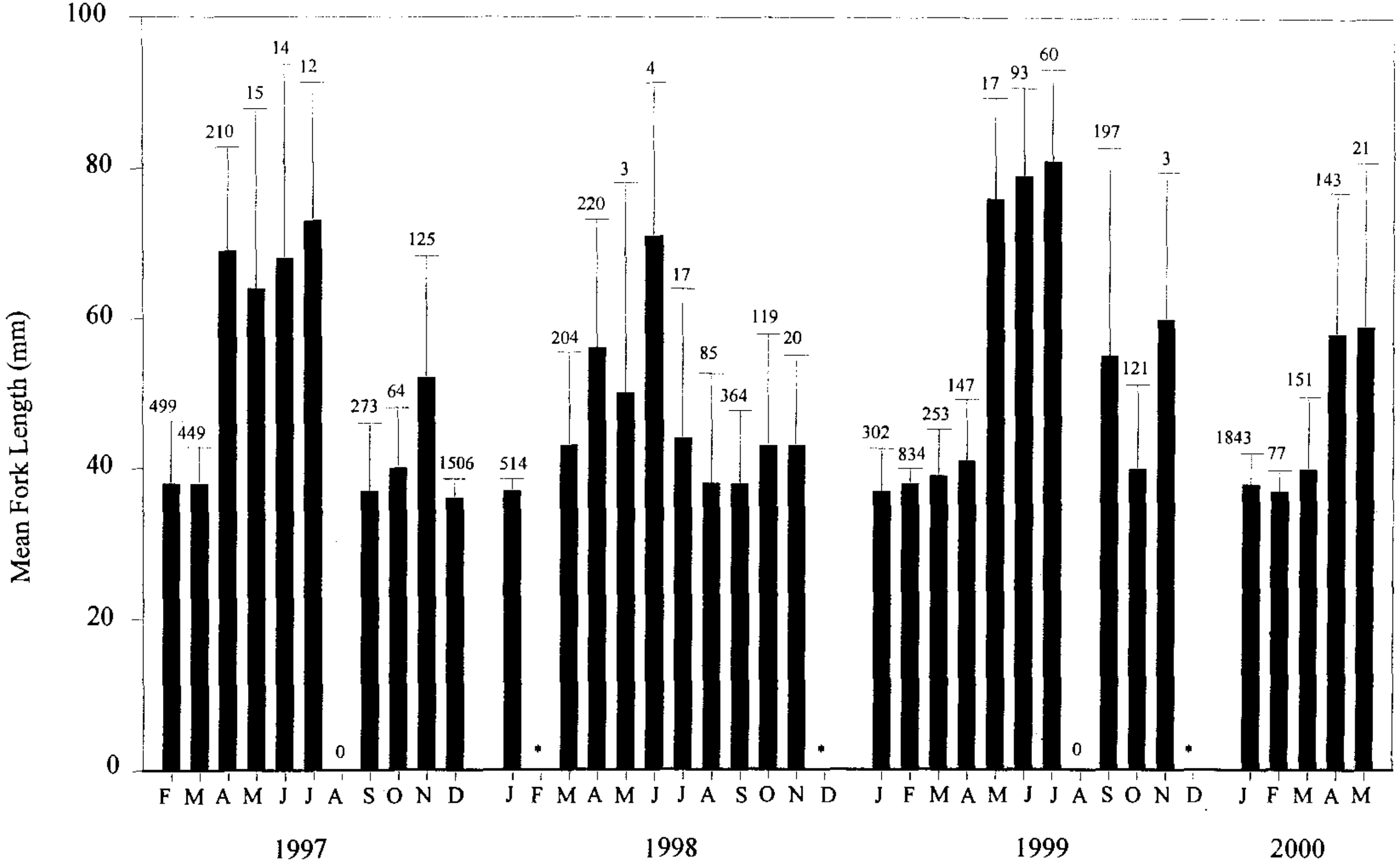

Figure 8. Monthly mean fork length (+ SD) of juvenile chinook salmon entrained into Red Bluff Research Pumping Plant during 24-h and short-duration entrainment trials; February 1997 through May 2000. Number of fish measured each month is shown above each bar. Asterisks indicate months when entrainment monitoring was not conducted.

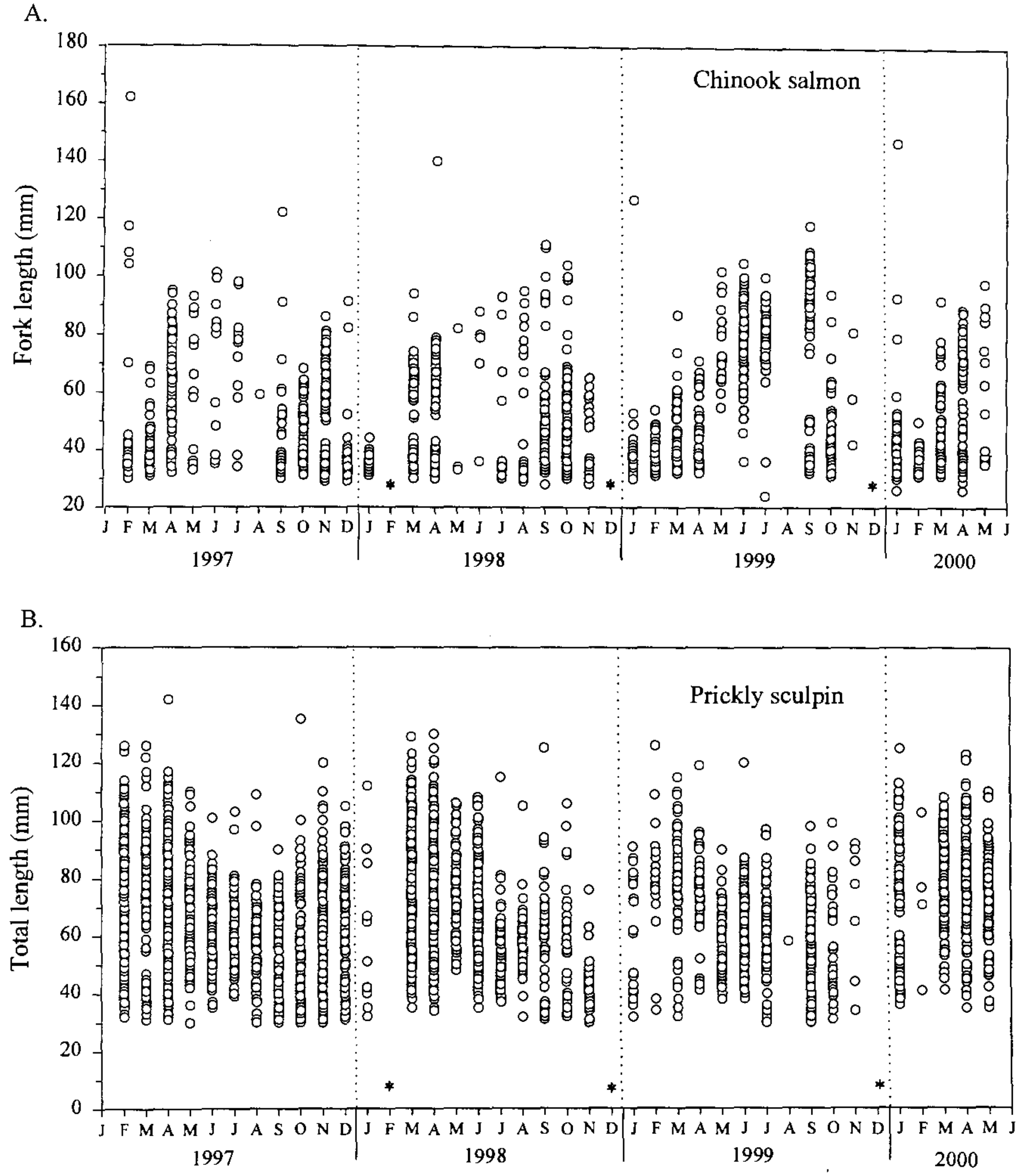

Figure 9. Monthly length distributions of (A) chinook salmon and (B) prickly sculpin entrained into Red Bluff Research Pumping Plant during 24-h and short-duration entrainment trials; February 1997 through May 2000. Asterisks indicate months when entrainment trials were not conducted.

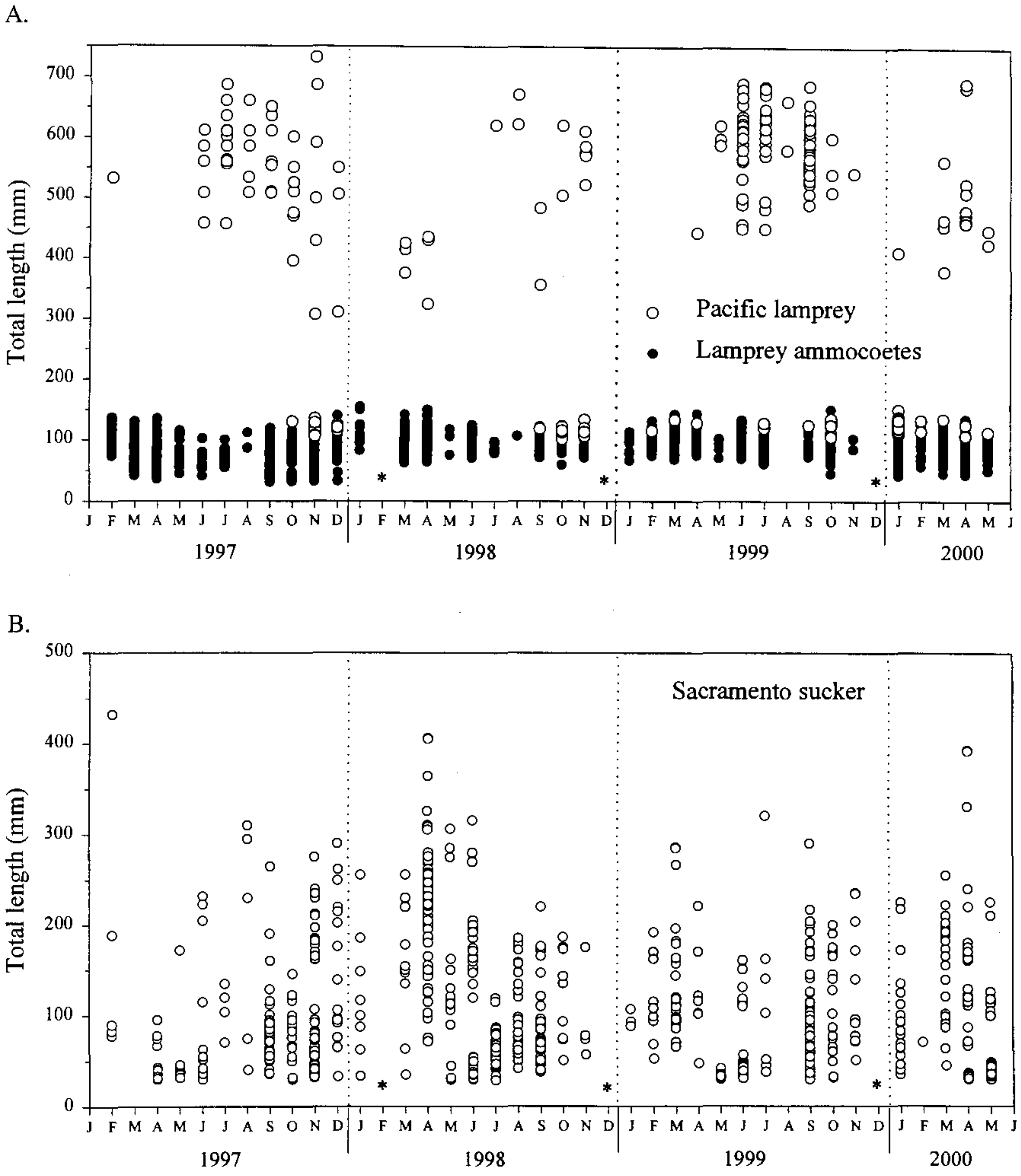

Figure 10. Monthly length distributions of (A) lamprey ammocoetes and Pacific lamprey and (B) Sacramento suckers entrained into Red Bluff Research Pumping Plant during 24-h and short-duration entrainment trials; February 1997 through May 2000. Asterisks indicate months when entrainment trials were not conducted.

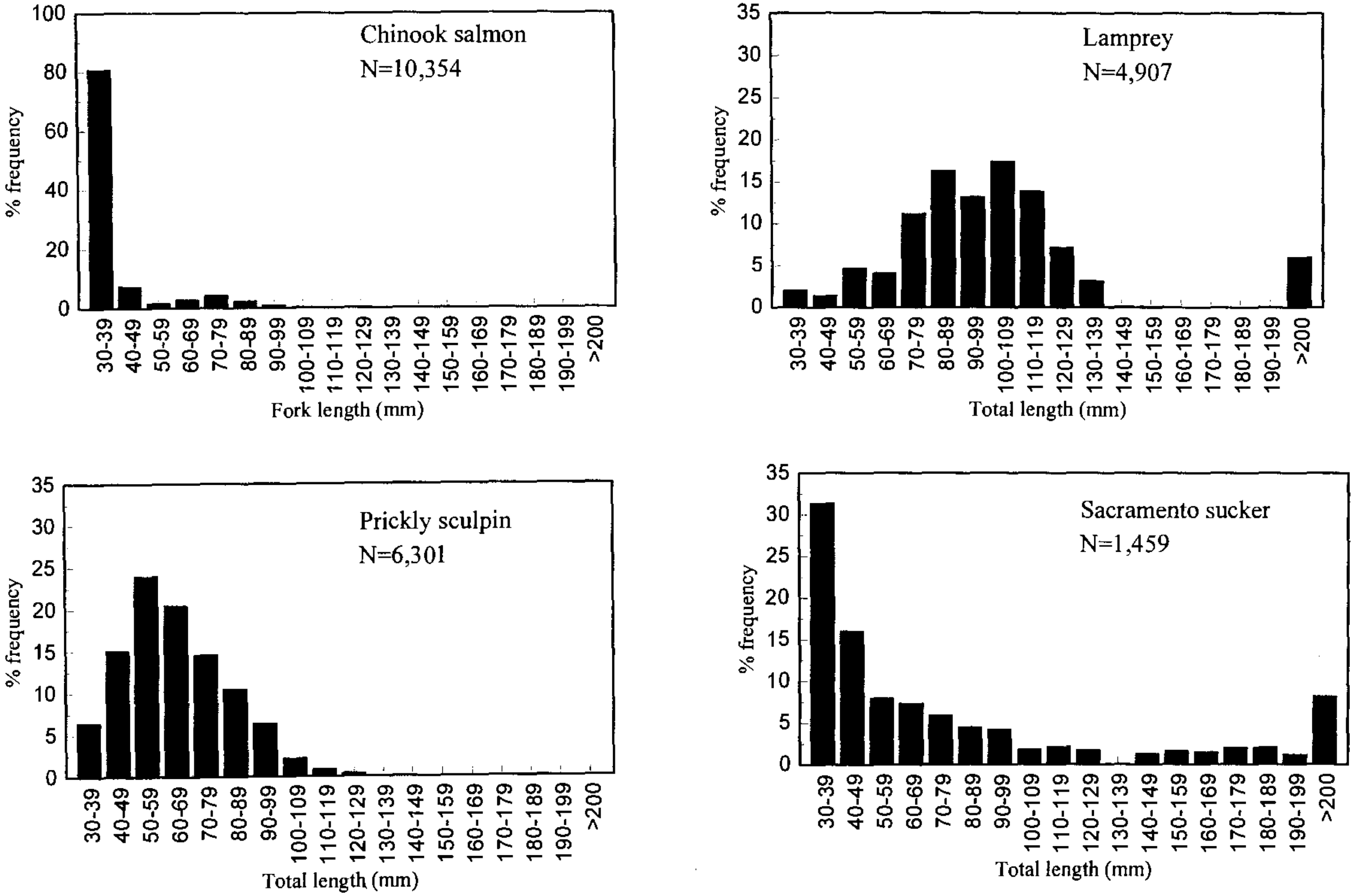

Figure 11. Size-frequency distribution of chinook salmon, lamprey, prickly sculpin, and Sacramento sucker entrained into Red Bluff Research Pumping Plant during 24-h and short-duration entrainment trials; February 1997 through May 2000.

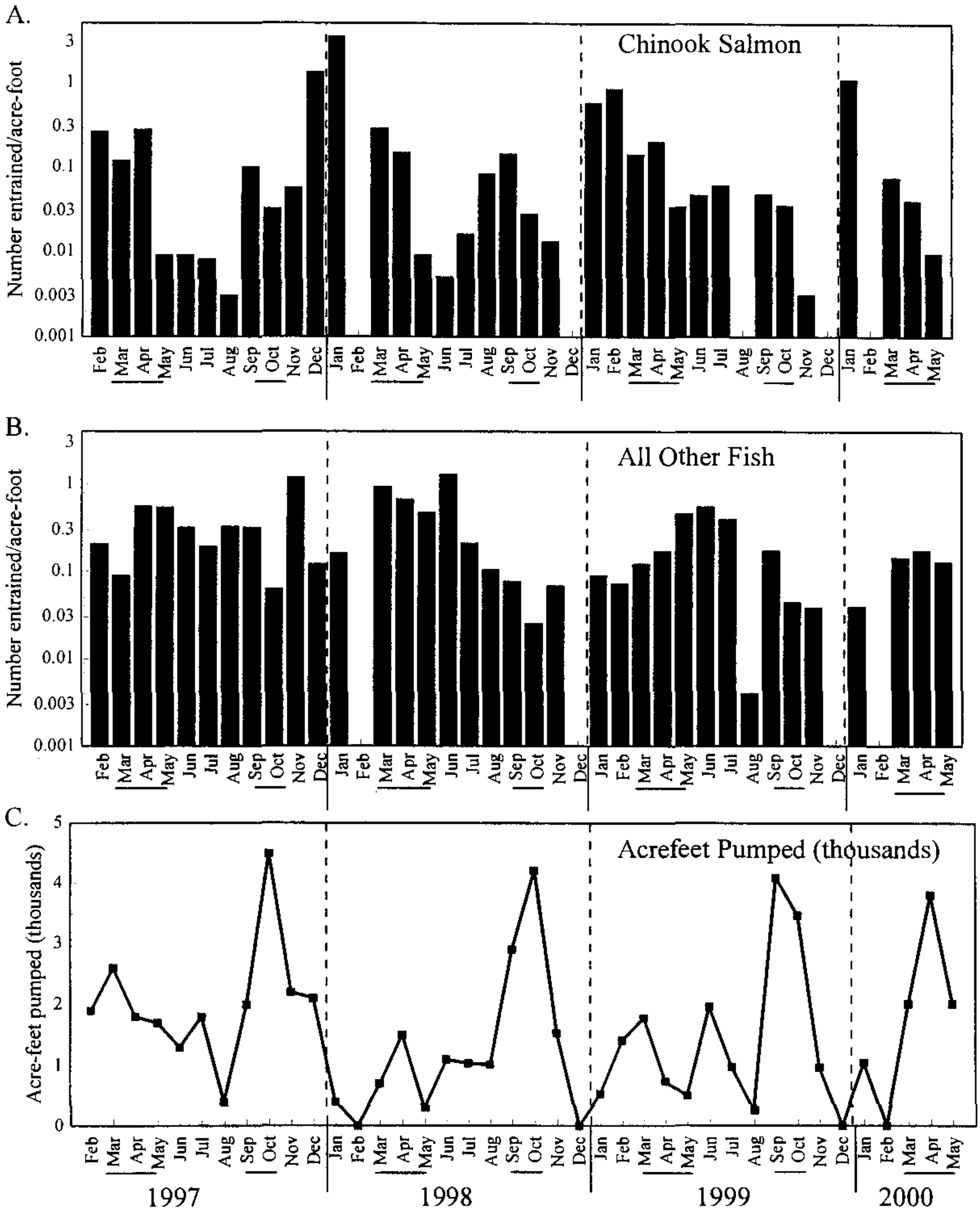

Figure 12. Seasonal entrainment patterns of (A) chinook salmon and (B) all other fish into Red Bluff Research Pumping Plant during 24-h entrainment trials; February 1997 through May 2000. (C) Sampling effort is indicated by acre-feet of water pumped during entrainment trials each month. Lines beneath months indicate periods when the plant would typically be operated to provide water to the canals. A log scale is used on the y-axis in A and B because of the large range in number entrained per acre-foot.

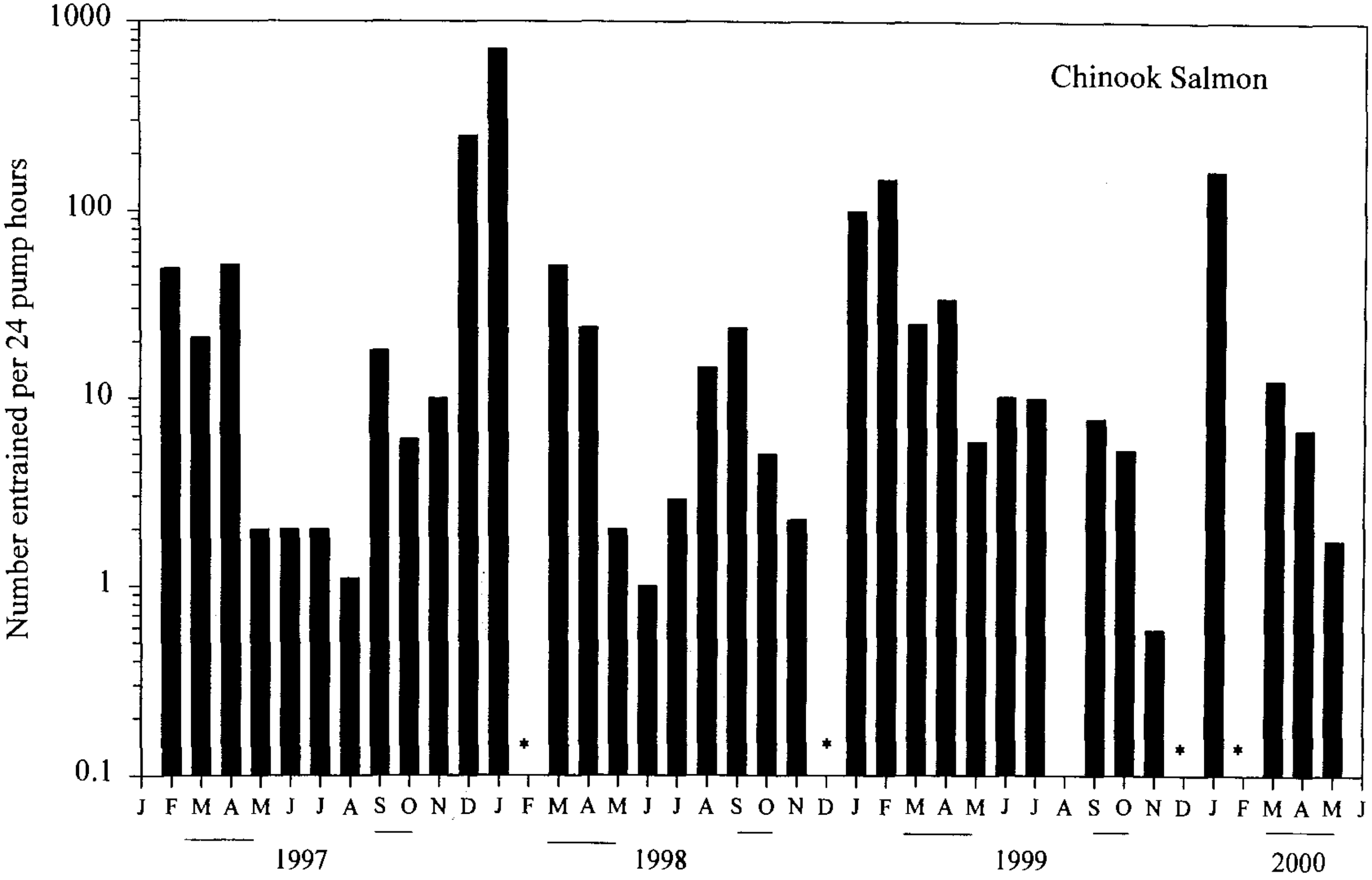

Figure 13. Number of chinook salmon entrained into Red Bluff Research Pumping Plant per 24 h of pump operation during 24 h entrainment trials; February 1997 through May 2000. Askerisks indicate months when trials were not conducted. Lines beneath the months indicate periods when the plant would typically be operated to provide water to canals. A log scale was used on the y-axis because of the large range in number entrained per 24 h.

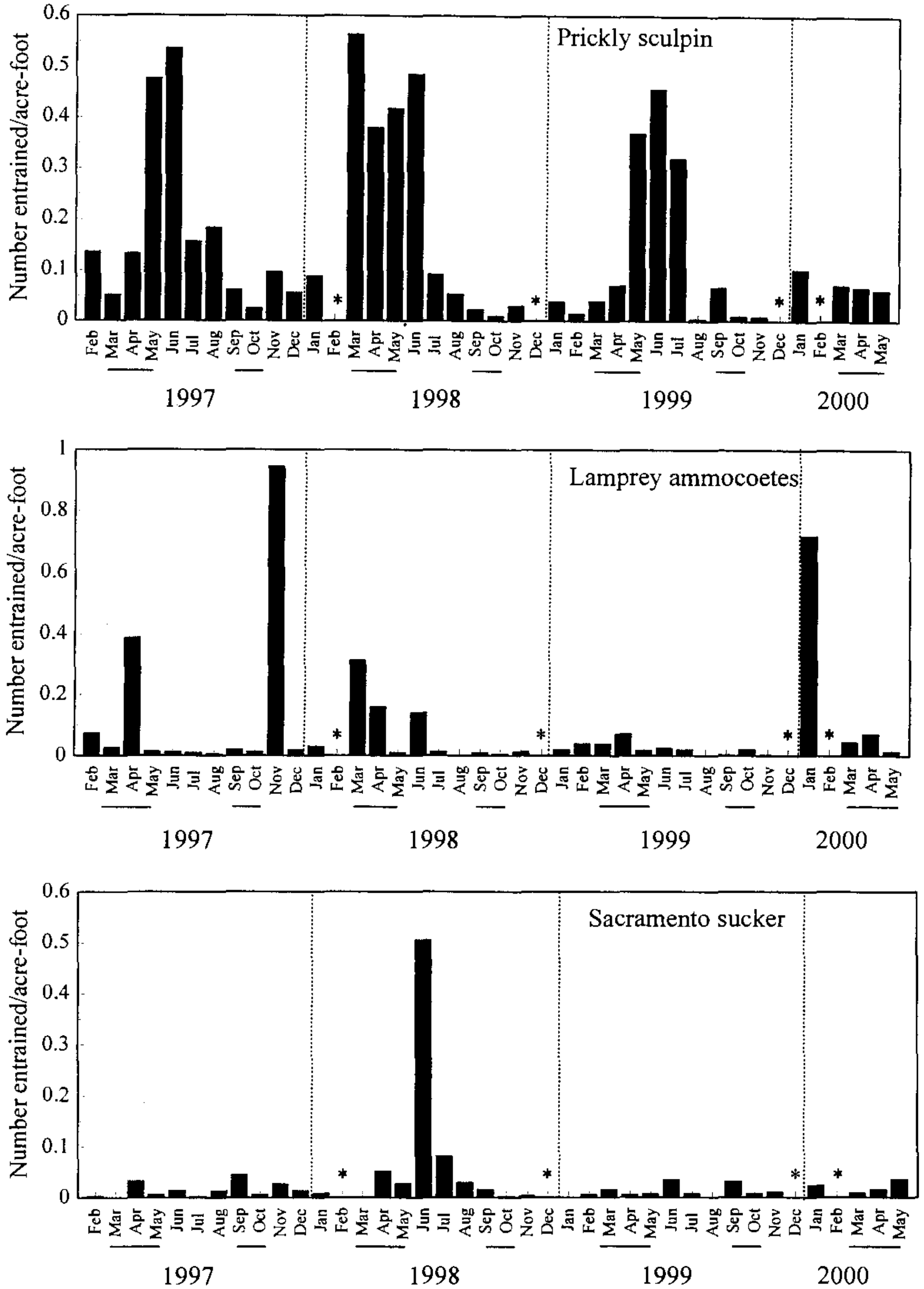

Figure 14. Seasonal entrainment patterns of three species frequently entrained into Red Bluff Research Pumping Plant during 24-h entrainment trials; February 1997 through May 2000. Asterisks indicate months when entrainment monitoring was not conducted. Lines beneath the months indicate periods when the plant would typically be operated to provide water to the canals.

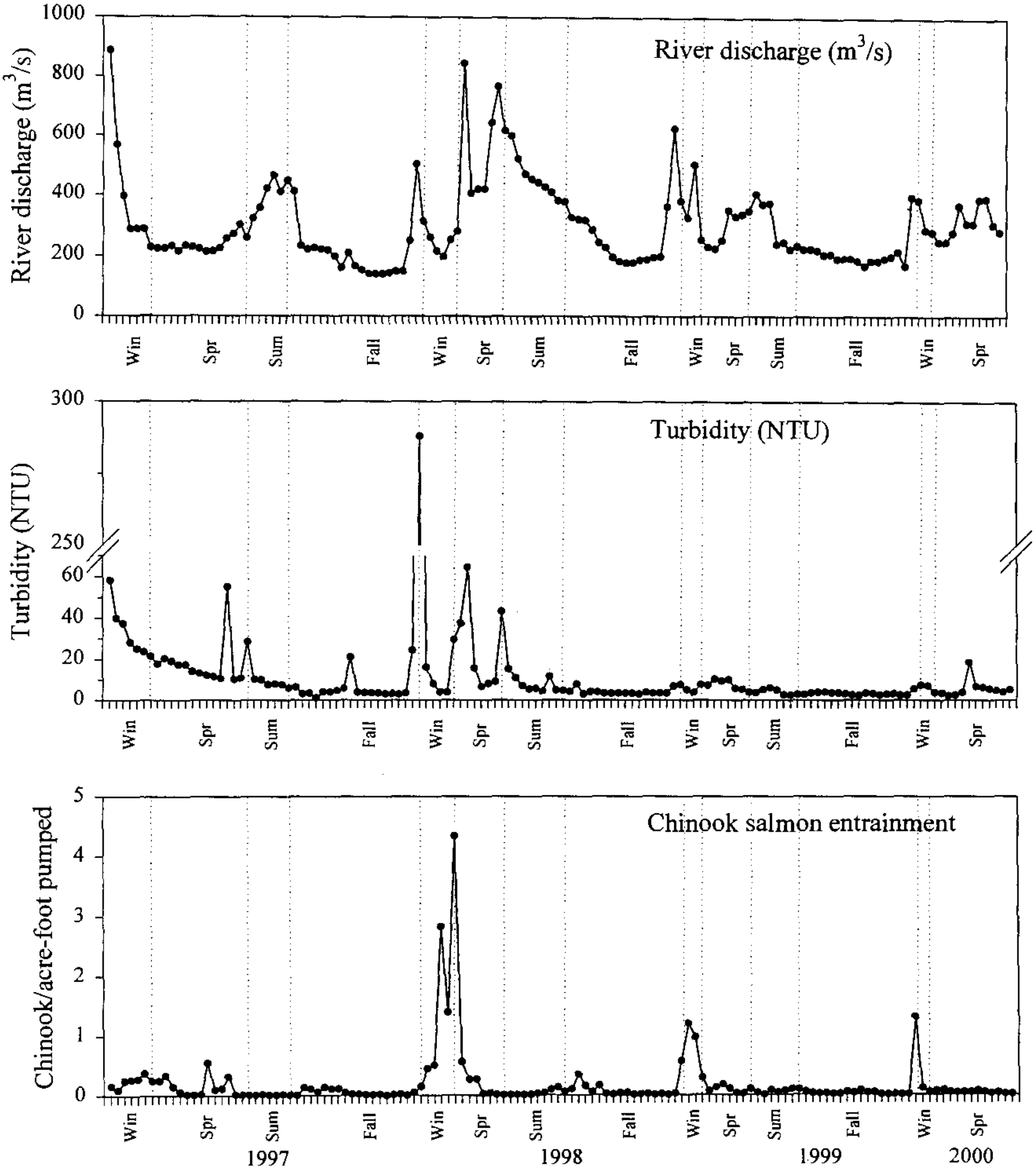

Figure 15. River discharge, turbidity, and number of chinook salmon entrained per acre-foot into Red Bluff Research Pumping Plant on each date that 24-h entrainment trials were conducted; February 1997 through May 2000. Seasons are defined as follows:
Win = Dec - Feb; Spr = Mar - May; Sum = Jun - Aug; Fall = Sep - Nov.

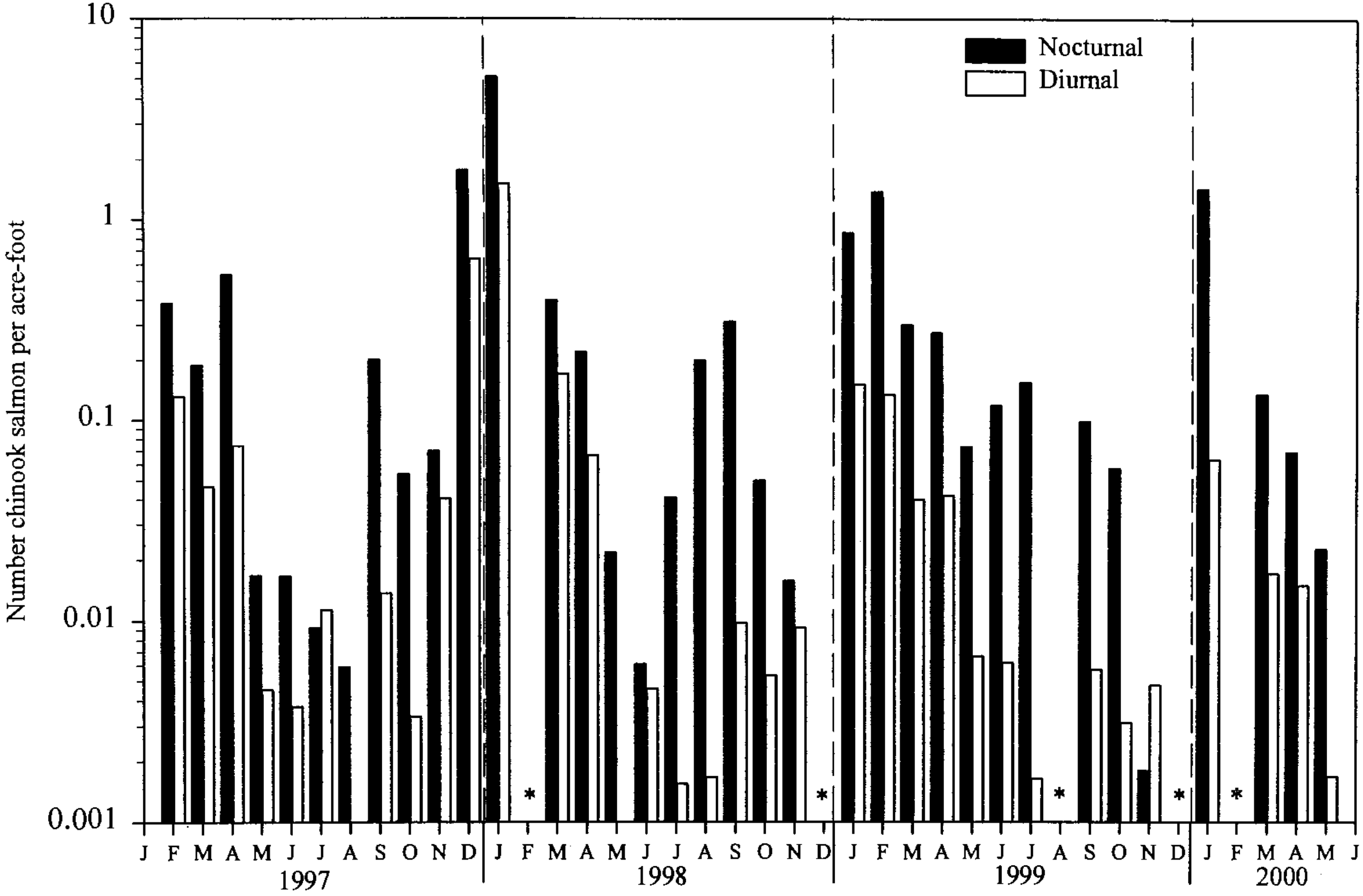

Figure 16. Monthly number of juvenile chinook salmon entrained per acre-foot during nocturnal and diurnal entrainment trials conducted at the Red Bluff Research Pumping Plant; February 1997 through May 2000. Asterisks indicate months when 24-h entrainment trials were not conducted. A log scale was used on the y-axis.

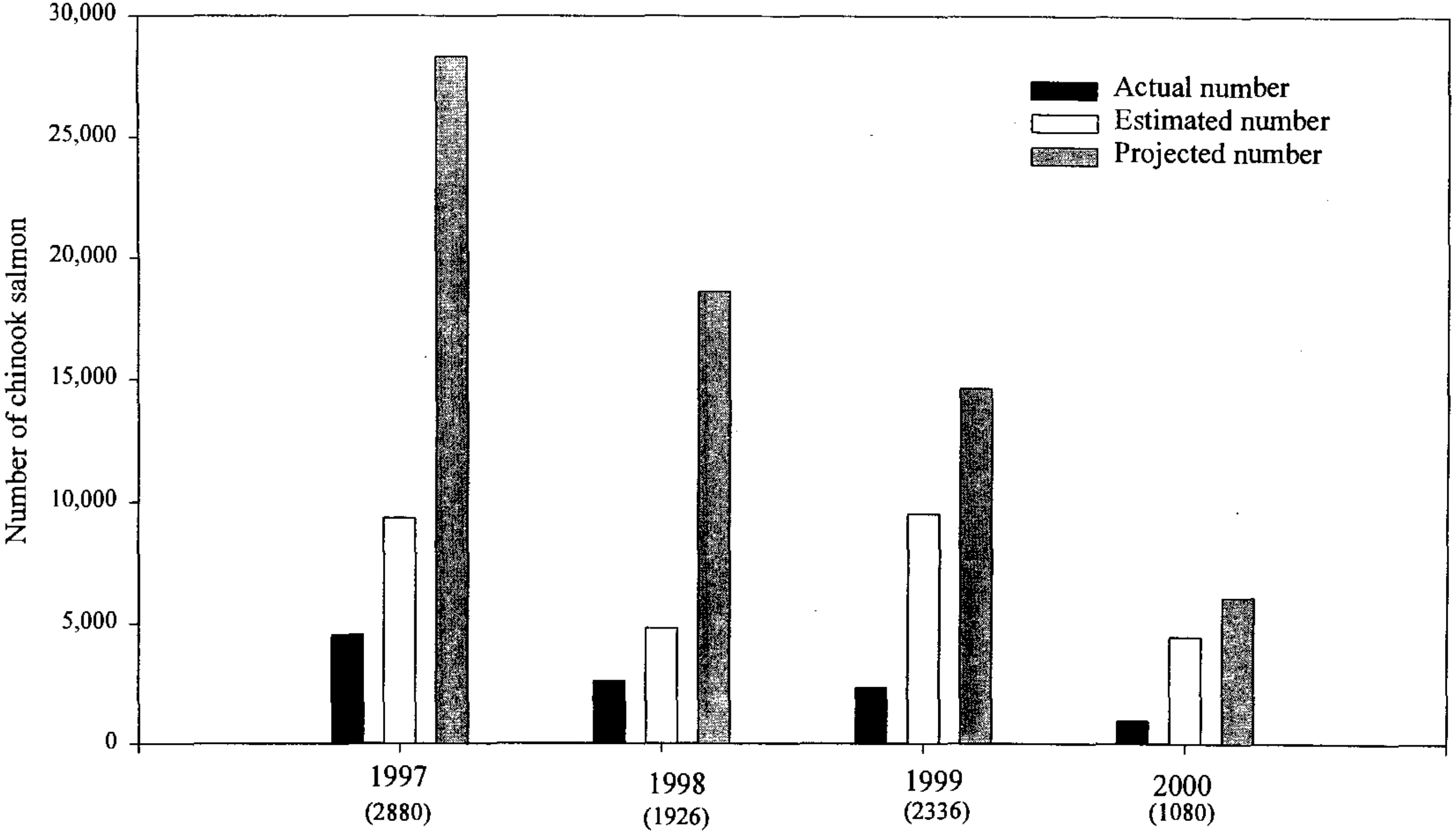

Figure 17. Actual, estimated, and projected number of juvenile chinook salmon entrained annually based on data from weekly 24-h trials; February 1997 through May 2000. See text (page 6) for definitions of estimated and projected numbers. Numbers in parentheses are the total hours pumps operated each year during entrainment trials.

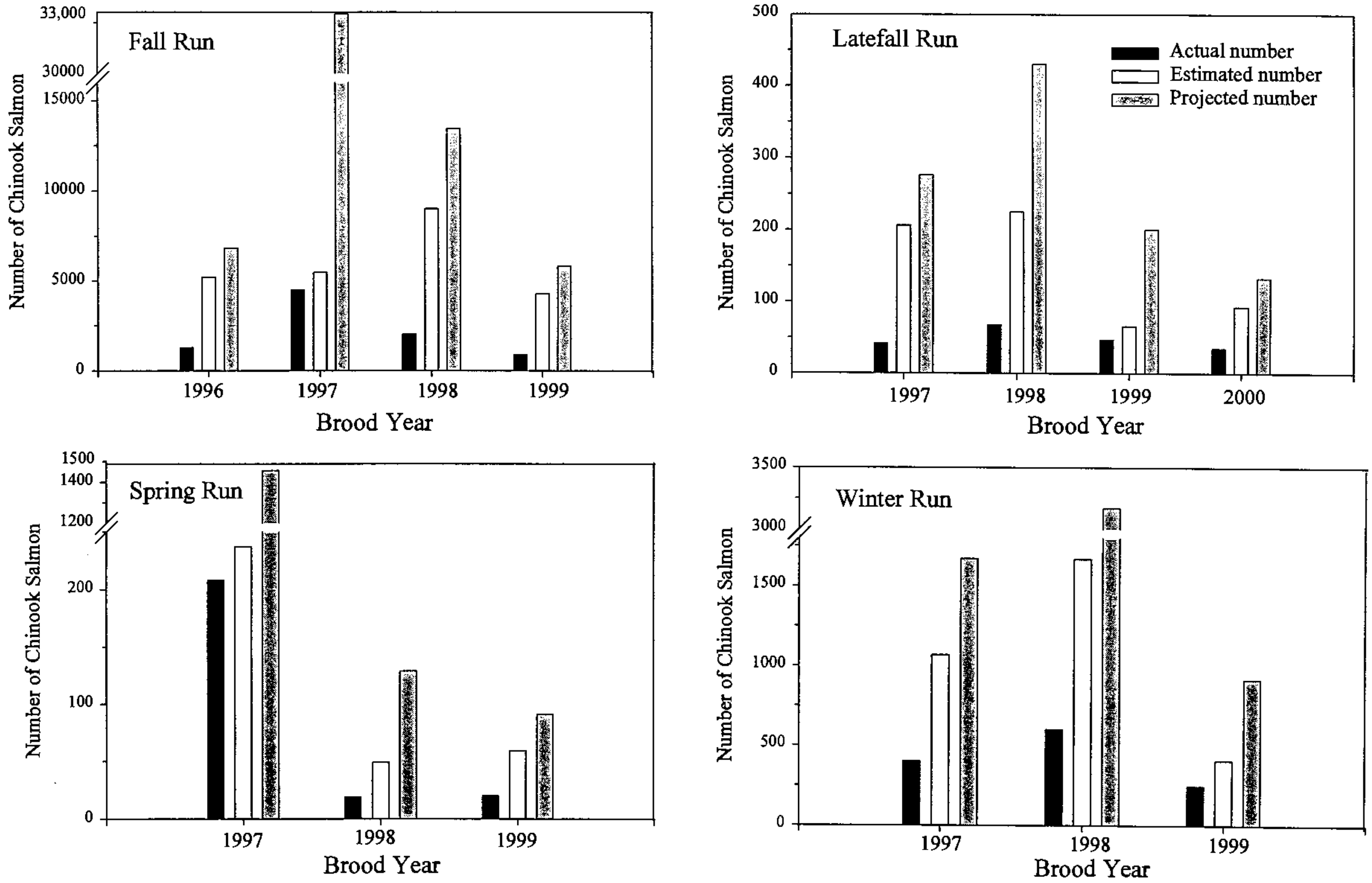

Figure 18. Actual, estimated, and projected number of juvenile chinook salmon, by run and brood year, entrained annually based on data from weekly 24-h trials; February 1997 through May 2000. See text (page 6) for definitions of estimated and projected numbers.

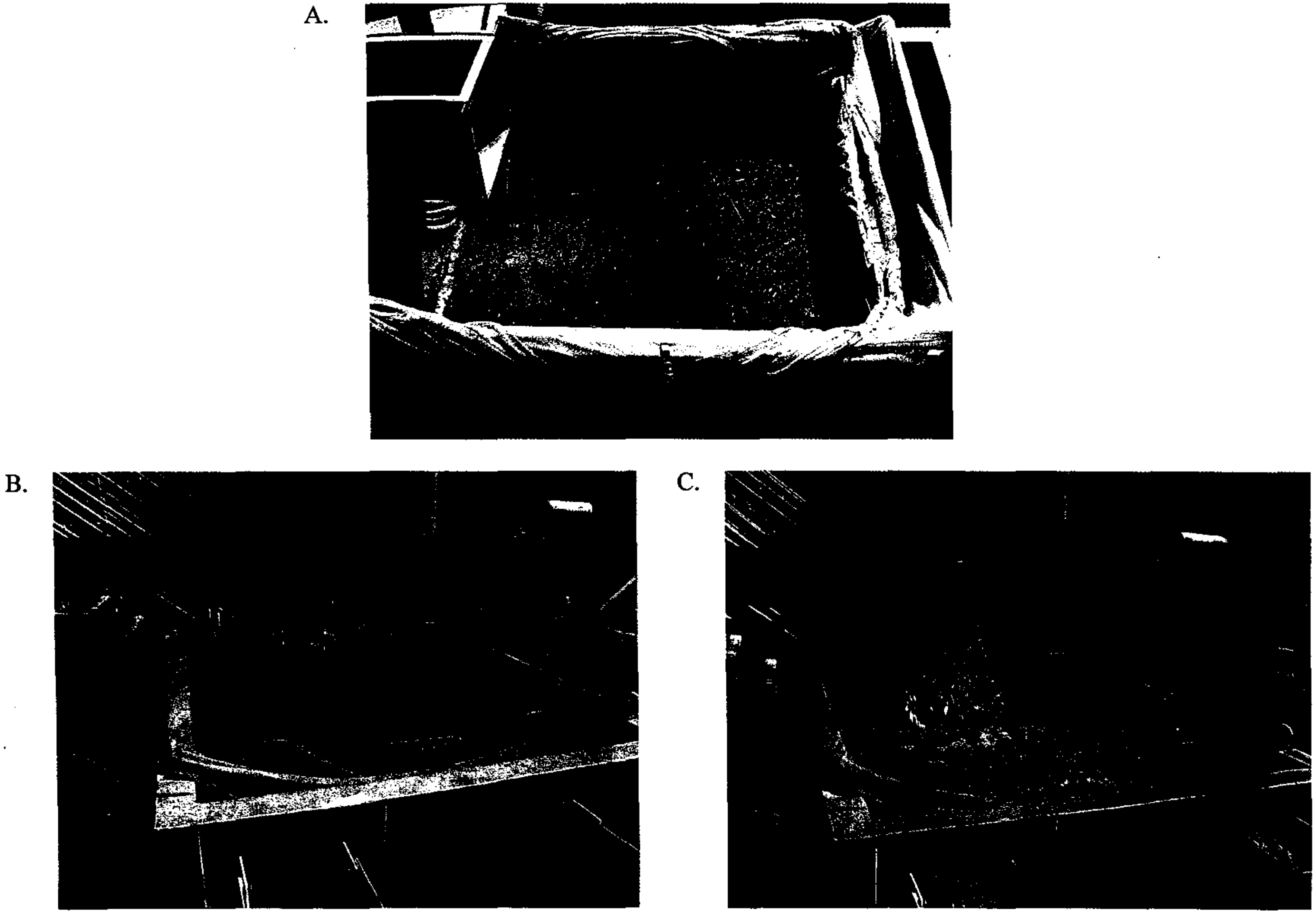

Figure 19. (A) Debris-laden holding tank at Red Bluff Research Pumping Plant. (B) Typical low flows into a holding tank at the beginning of an entrainment trial. (C) High, turbulent flows into a holding tank caused by debris obstructing water flow through the dewatering ramp screen.

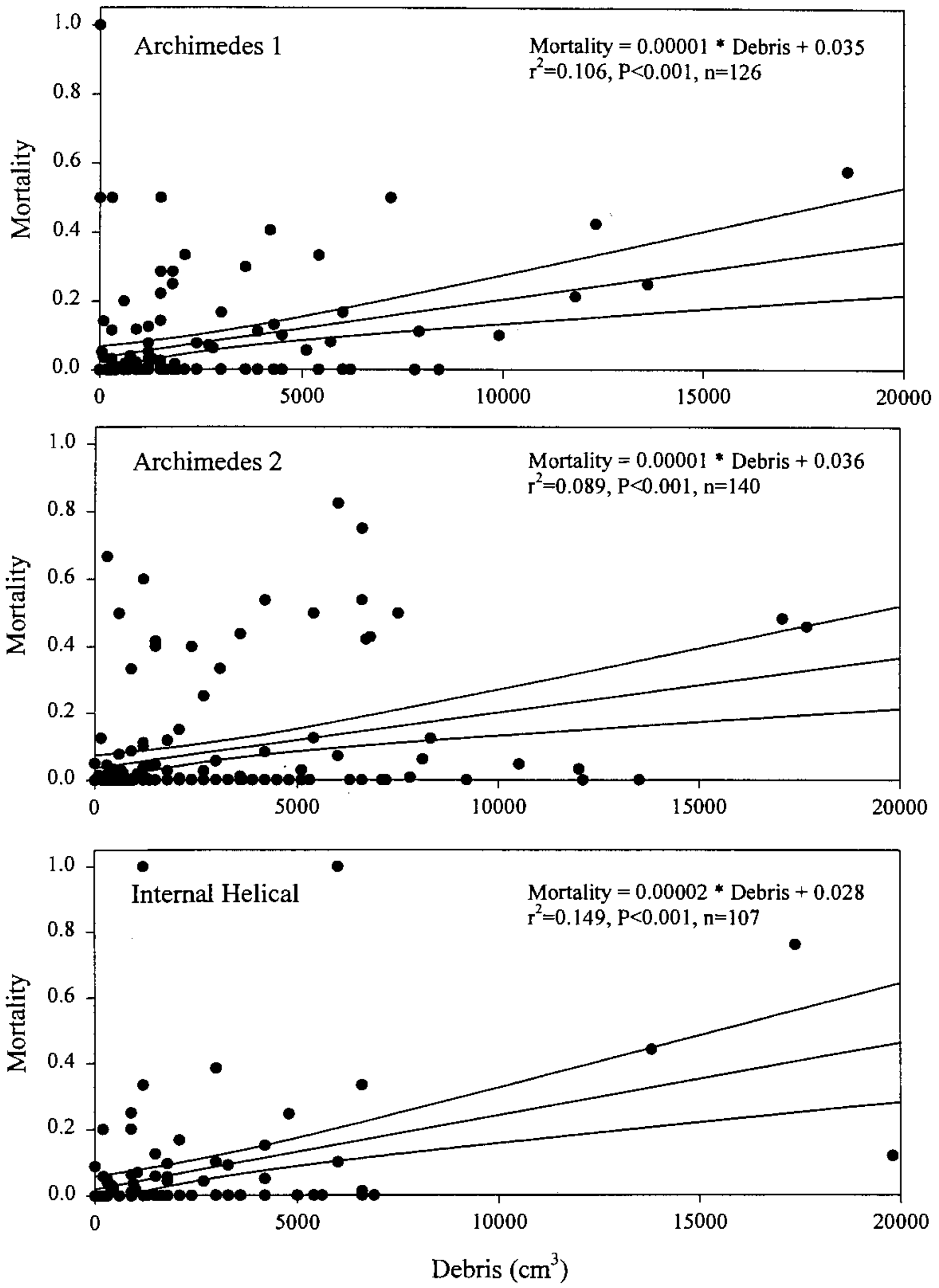

Figure 20. Mortality of juvenile chinook salmon entrained versus the volume of debris entrained for each 24-h entrainment trial conducted with each of the three pumps at Red Bluff Research Pumping Plant; February 1997 through May 2000. The confidence interval is 95%.

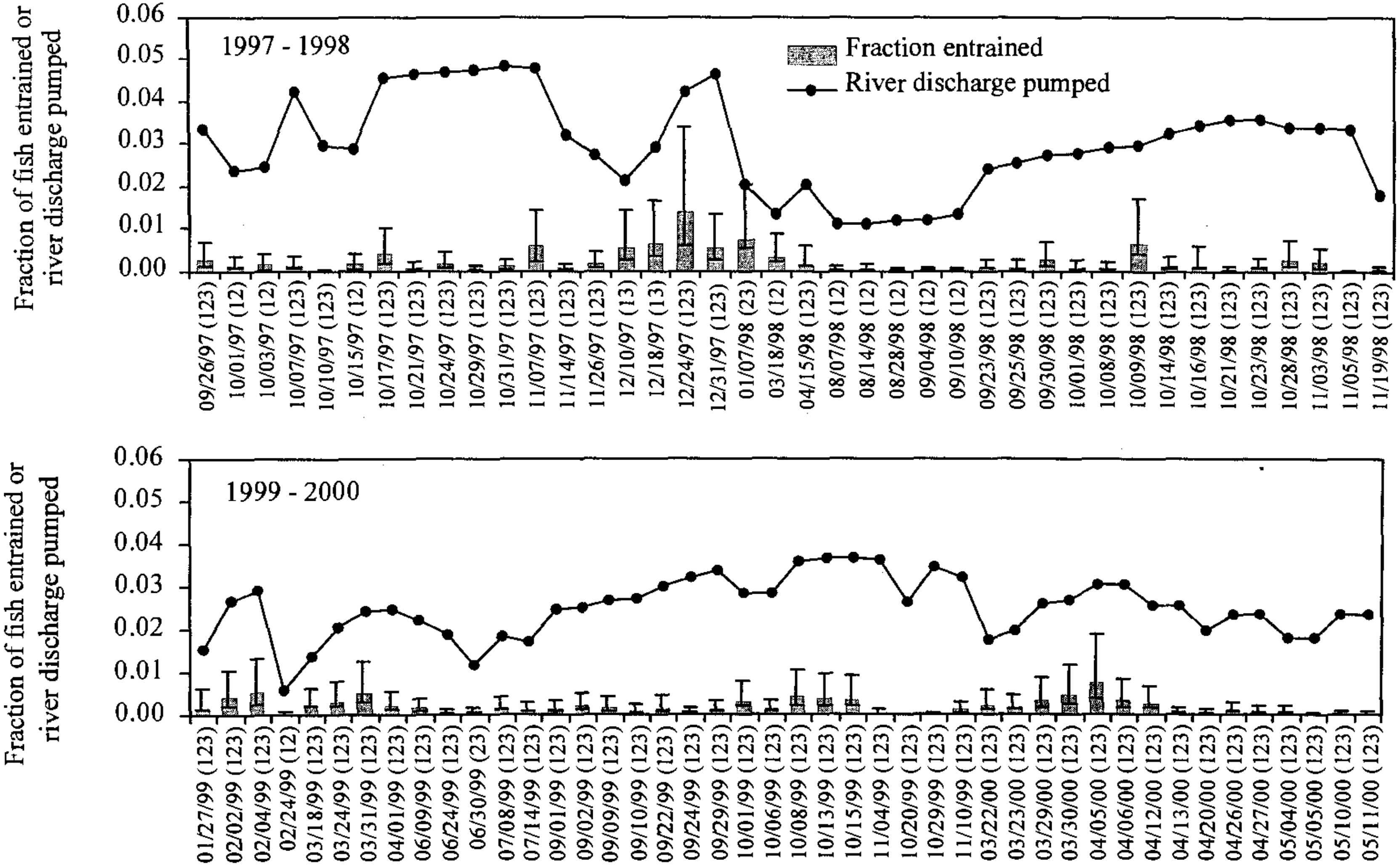

Figure 21. Fraction of riverine chinook salmon (±90% CI) entrained into Red Bluff Research Pumping Plant. Fraction entrained was calculated from catch in pumps divided by number passing RBDD each day as estimated by rotary screw traps. Numbers in parentheses after dates are the pumps that were operated; 1=Archimedes 1, 2=Archimedes 2, 3=internal helical pump. The fraction of river discharge pumped by the plant is the expected fraction of fish entrained if fish were uniformly distributed and entrained in proportion to density.

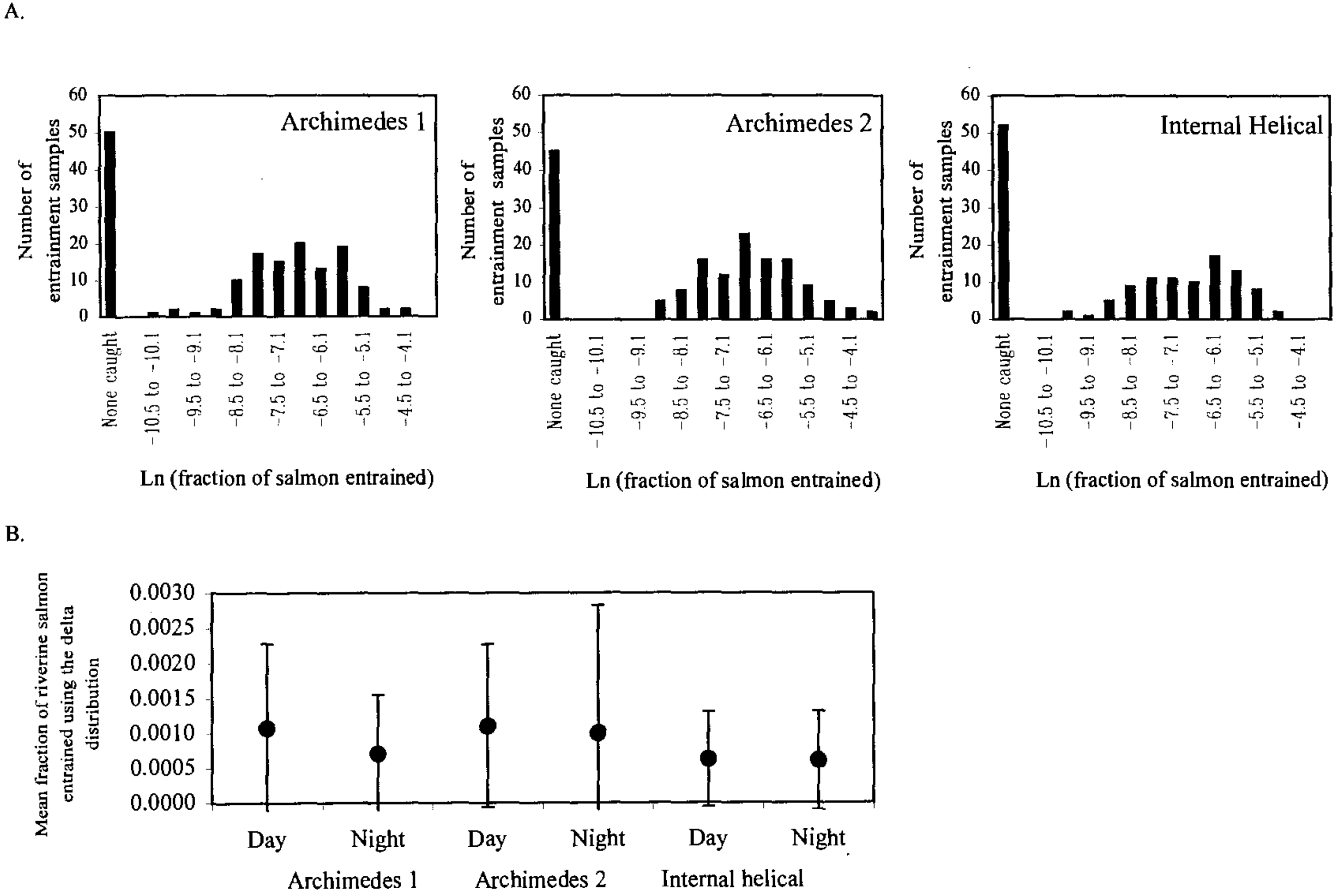

Figure 22. (A). Histogram of the natural log of the fraction of riverine chinook salmon entrained into each pump at Red Bluff Research Pumping Plant. Samples where no salmon were caught are indicated by the left-most bar. (B) Mean fraction of riverine salmon entrained per acre-foot (± 95% CI) for each pump and diel period using the delta-distribution which adjusts estimates for the probability of catching no fish.

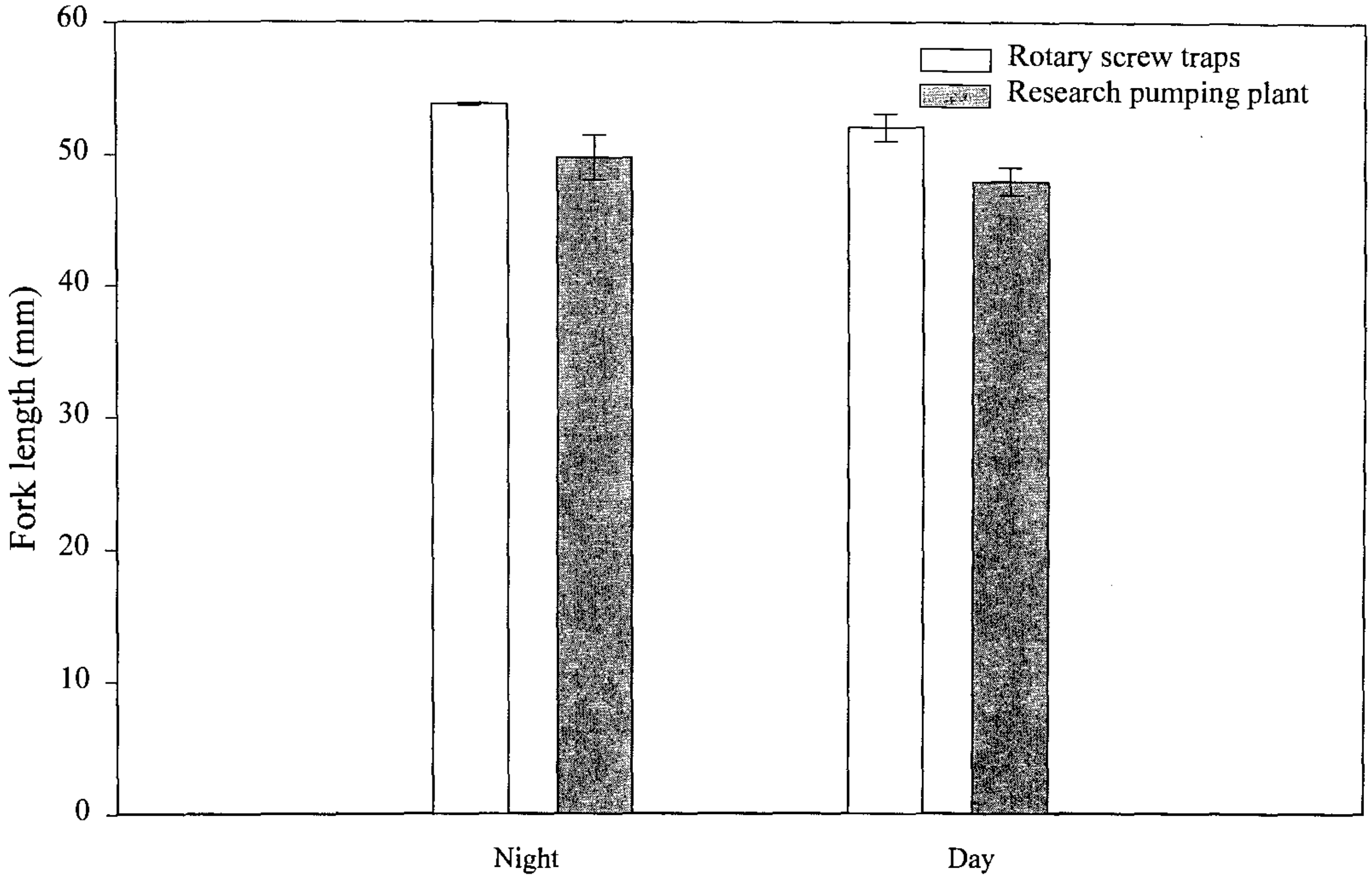

Figure 23. Diel length distributions (mean, SE) for chinook salmon captured in the Research Pumping Plant and rotary screw traps at Red Bluff Diversion Dam. Salmon entrained into the pumps were significantly smaller in length than salmon captured in rotary screw traps (Wilcoxan sign-ranked test, Day, $P = 0.016$, n=109; Night, $P < 0.001$, n=203).

Attachment 10

Hydrodynamic Impacts on Marine Life Due to Brine Dilution Strategies for Seawater Desalination Plants,

Scott Jenkins, Dan Cartamil, Joseph Wasyl, Gerald Spain, Alexander Lin

Hydrodynamic Impacts on Marine Life Due to Brine Dilution Strategies for Seawater Desalination Plants++

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++Feature Article submission to the Journal of Environmental Science and Technology

ABSTRACT: It is commonly assumed that marine life impacts associated with brine discharges from ocean desalination are limited to hyper-salinity toxicity. Consequently, industry regulations have focused primarily upon requiring some minimum level of brine dilution to limit the exposure of marine organisms to hypersaline conditions beyond their physiological tolerance. A less well-recognized, but potentially important, impact is that of *hydrodynamic mortality*, which is related to violent physical forces arising from the dilution process that may be injurious to small entrained marine organisms. This paper analyzes and compares the potential hydrodynamic mortality associated with the two most common brine-dilution strategies: in-plant dilution and high velocity diffusers. Using comprehensive data bases from the Carlsbad Desalination Project (California, USA) as an analytic proxy, we show that in-plant dilution utilizing low-rpm screw pumps reduces hydrodynamic mortality by a factor of 7-to-10 times relative to conventional diffuser technology, but is limited by the requirement for low-relief

shore-side topography. Thus, desalination industry discharge regulations should consider site-specific conditions and hydrodynamic mortality, in addition to hypersalinity toxicity.

INTRODUCTION:

In response to the pressures of a growing global population, climate change, and dwindling water supplies, there is increasing interest in ocean water desalination as an alternative to traditional water sources. As part of this process, large volumes of seawater are removed from the ocean. Reverse osmosis (RO) technology is used to extract fresh water from seawater, and the resultant hyper-saline concentrate (approximately twice the salinity of the original seawater) is discharged into receiving waters offshore of the desalination facility. However, concerns have been voiced about the effects of hypersaline discharge on marine life[1].

In California, USA, members of the legislature, industry, and conservation groups are currently debating regulatory standards for desalination plants along the state's coastline[1]. Although there is limited scientific data on the hyper-salinity tolerances of local marine organisms. some studies on southern California marine fish and invertebrates report short-term toxicity thresholds to be approximately 20% to 35% over ambient salinity[22,51,52,55]. The environmental permits of at least one desalination plant (the Carlsbad Desalination Project, or CDP) are based upon the lower threshold of this value. However, data on long-term, sub-lethal hypersalinity exposure (that may cause injuries that typically limit growth or reproduction) are virtually non-existent[2-14]. Given this paucity of *chronic toxicity* data, a more conservative water quality objective has been recently proposed, that would limit brine discharges to 5% over ambient salinity at the limit of a regulatory mixing zone measuring 100 m in radius from the discharge point[1].

There are two commonly employed strategies to meet dilution standards. The first is '*in-plant dilution',* which involves the blending of raw brine effluent with an additional quantity of dilution water in order to meet a particular water quality objective. This strategy typically involves co-locating the desalination facility with a coastal power plant and taking advantage of the power plant's once-through cooling system to provide source water and intake/discharge infrastructure. In the case of the CDP, which was originally permitted for in-plant dilution, hyper-saline discharge circuits through the Encina Power Station (EPS), and is eventually channeled into the ocean surf zone, where it is passively dispersed via physical mixing and gravity.

The second strategy is the use of 'high-velocity diffusers', whereby hypersaline brine is discharged through high-pressure jets at a maximum velocity of approximately 3 to 5 m second^{-1}, (Figure 1). This results in rapid dilution and mixing as ambient water is entrained by turbulent vortices created by viscous shear stresses along the boundary of the discharge jet (Tenera 2012). High-velocity diffusers are a mature technology that has been deployed worldwide to provide dilution of treated wastewater and thermal effluent, and has been deployed in several very large desalination projects, notably at Perth Australia [21]. When optimized for dilution using conventional engineering practice, high-velocity diffusers can easily satisfy even highly conservative water quality objectives, achieving brine dilution to less than 5% over ambient salinity within 10 meters from the discharge point.

Both dilution strategies have environmental impacts related to exposure of organisms to hypersaline conditions beyond their physiological tolerances[1]. However, another important, but often overlooked regulatory consideration, is that of potential injury imposed by the strong hydrodynamic forces organisms may be exposed to during the dilution process [20]. Both lethal and sub-lethal injuries resulting from these hydrodynamic forces are generally referred to as *hydrodynamic mortality*. The marine life impact resulting from the hydrodynamic effects of either strategy may be expressed by the same equation based upon mass conservation:

$$I_{total} = \frac{\tilde{C}\,Q_{product}}{R} + I_{dilution} \qquad (1)$$

Where:

$$I_{dilution} = \tilde{K}_i\,\tilde{C}\,Q_{dilution}$$

$$Q_{dilution} = Q_{brine}(\psi - 1) = Q_{product}\ (\psi - 1)\left(\frac{1}{R} - 1\right)$$

Here I_{total} is the total marine life injury rate due to desalination operations with an open ocean intake, measured in terms of either injured biomass or numbers of injured organisms per day, depending on the units of the concentration of entrained organisms, $\tilde{C}$, where $\tilde{C}$ is measured either as biomass per unit volume or numbers of organisms per unit volume. $I_{dilution}$ is the marine life injury rate due solely to dilution processes; $Q_{product}$ is the product water production rate of the desalination plant; R is the product water recovery ratio from the RO process; $Q_{dilution}$ is the entrainment rate of dilution water required to satisfy a particular water quality objective; $\tilde{K}_i$ is the integrated injury factor representing the proportion of the population of entrained organisms in the dilution water, integrated over size, that would be affected by either lethal or sub-lethal injury from hydrodynamic forces during the dilution process; Q_{brine} is the brine discharge rate from the desalination plant and ψ is the dilution factor required to satisfy a particular water quality objective.

With either high-velocity diffusers or in-plant dilution, the marine life impact represented by the first term on the right, $I_{total} = \frac{\tilde{C}\,Q_{product}}{R} + I_{dilution}$, is the same. This term represents the injury/mortality associated with the amount of source water that enters the RO system, as required to produce any given amount of product water for a given recovery ratio. Virtually every ocean intake is now equipped with screens or velocity caps to reduce entrainment of larger organisms. However, these screens are generally ineffective against entrainment of small, sub-mesh size organisms such as ichthyoplankton and juvenile fish, which are consequently lost in the pre-treatment train of the RO system. The subject of this paper, then, is the second term on the right, $I_{dilution}$, which represents marine life injury rate due *solely to dilution processes*. The decisive question addressed is: which dilution strategy, in-plant dilution or high-velocity diffusers, can minimize this term (i.e., offers the smallest potential $\tilde{K}_i$), thereby minimizing the overall environmental impact of the desalination facility?

Review of the literature and physical concepts.

When equation (1) is applied to in-plant dilution and co-location with power plants, both terms on the right-hand side of equation (1) have been referred to as *entrainment impacts*; meaning mortality to micro-organisms entrained through the intake pipe that are subsequently exposed to thermal shock, biocides and hydrodynamic forces in the confined flows of the once-through sea water circulation systems of power plants[28,29]. Few studies, however, have examined the component stresses of thermal power plant entrainment independently, by quantifying effects of turbulence and shear forces on fish early life stages without concomitant thermal and biocidal stresses [30]. These empirical studies indicate that the shear stresses caused by average bulk flow velocities through a cold power plant condenser system (the most likely operating condition for a co-located desalination plant in the future) are unlikely to cause injury or mortality among fish or ichthyoplankton. For example, seven species of freshwater fish larvae were rapidly passed through 2.2-cm-diam condenser tubing at velocities of up to 5.8 m/s, with less than 5% mortality[30]. Similarly, striped bass larvae exposed to shear in condenser tubes at velocities as high as 3.0 m/s suffered no significant mortality[31]. In another study, several species of freshwater fish larvae and juveniles were subjected to the combined stresses of moderate pressure changes (56 to 146 Pa) and shear forces associated with passage through 3.2-cm-diam pipes at velocities of 2.4 m/s, with insignificant mortalities [32]. In addition, the effect of turbulence was studied in the field by Jessopp[24], who found that even turbulent tidal flows produce significantly increased mortality to thin-shelled veliger larvae of gastropods and bivalves. In fresh water species, turbulence and shear-induced mortality has been demonstrated in laboratory flumes for zebra mussel veligers[25,26], and yolk-sac larvae of paddlefish[27].

There are three major physical forces which could inflict mechanical damage to entrained organisms during brine dilution; these are 1) pressure gradient forces, 2) inertia forces associated with acceleration, and 3) shear stresses and friction forces arising from velocity shear. For this assessment, we will necessarily draw upon the sparse field of quantitative bio-engineering data describing injury and survival of aquatic organisms subjected to these forces, much of which has been developed primarily by hydro-electric industries and resource agency laboratories. We submit that this data is relevant so long as the ratio of these forces during brine dilution is in dynamic similitude with literature measurements, and that the size of the affected organisms remains small in relation to the details of the flow boundary conditions.

Pressure Gradient Forces. Small organisms without swim bladders have a high tolerance for large, in-water pressure changes[28, 33, 34,36], even surviving shock waves from underground nuclear explosions,[35].The reason for such tolerance is that aquatic organisms predominantly consist of, and have nearly the same density as, water. Consequently, these organisms are essentially incompressible and have little acoustic impendence contrast with the surrounding water mass. Shock waves and pressure impulses propagating through the water mass merely pass through the bodies of these organisms, causing little if any distortion, while the organisms themselves tend to move synchronously with the pressure-induced water particle motions. Because of the neutral buoyancy of most small aquatic organisms, pressure gradients cause little if any relative velocity between the organism and the surrounding water particles, and therefore pressure gradient forces likely constitute a negligible component of hydrodynamic mortality.

Inertial Forces from Acceleration: Indirect effects from pressure gradients can be substantial and arise from the fact that pressure changes over short distances will cause the organism and surrounding fluid to accelerate. Acceleration induces inertial forces on the organism referred to as *virtual mass forces*[59] that can be expressed as:

$$F_m = \rho V_0 \frac{d\bar{u}}{dt} + \rho c_a V_0 \left(\frac{dU_0}{dt} - \frac{d\bar{u}}{dt} \right) \tag{2}$$

Where ρ is the fluid density, V_0 is the volume of the individual organism proportional to the cube of its size, c_a is the added mass coefficient equal to 3/2 for a spherical approximation to an icthyoplanktonic organism; du/dt is the mean acceleration of the fluid induced by pressure gradients; and dU_0/dt is the acceleration of the organism in response to pressure gradients and shear stresses in the fluid.

The greatest virtual mass forces occur when an organism moving in the fluid subsequently impacts a solid surface, giving rise to inertial forces that can damage the organism, either immediately, or in later development[28, 33, 34]. The most detailed information arising from rapid accelerations pertains to juvenile fish and ichthyoplankton impacting turbine blades and pump impellors, a phenomenon referred to as *blade strike*. Blade strike is the leading order mechanism of entrainment mortality associated with in-plant dilution strategies, occurring during pump passage.

The size of an entrained organism has been found to be one of the most important variables determining blade strike mortality. For example, in testing trout passed through a Francis turbine, it was found that mortality increased approximately proportional to fish length[37]. A similar size dependence was identified via multiple regression analysis of survival data from 95 tests of axial flow turbines[38,39,40]. These experiments confirmed a probability relationship expressed as [41]:

$$P_b = \frac{\lambda\, n\, \Omega\, a \cos\alpha}{Q} \qquad (3)$$

Here P_b is the probability of blade contact; λ is the characteristic size of entrained organism; n is the number of turbine or pump impeller blades; Ω is the pump rotation rate; a is the cross-sectional area of the pump or turbine case; α is the impeller or turbine blade angle; and Q is the turbine or pump discharge rate. While often the strike probability has closely matched empirically derived mortality estimates, technically, the strike formula alone does not account for all the variables known to affect sub-lethal injury. A regression equation that estimates the sub-lethal injury to strike ratio (ξ) was developed by (42) that yields an injury factor due to blade strike given by:

$$K_i(\lambda)=P_b\,\xi \qquad (4)$$

Where: $\xi = 0.153\ \log_e(\lambda/\lambda_0) + 0.12$

Here $\log_e$ is the natural logarithm, and λ_0 is the reference size of the smallest entrained organisms, typically taken as 0.1 mm. Applying equations (3) & (4) to centrifugal pumps typical of those used at EPS, that turn 273 rpm and move 157 mgd of dilution water, gives a predicted blade-strike injury factor K_i of 0.40 for a 100 mm juvenile fish, 0.12 for a 10 mm juvenile fish, and 0.008 for 1 mm eggs or larvae.

Impact injury and mortality due to blade strike also increase with pump rpm. Thus, several studies have focused on reducing mortality by using ultra-low rpm pump options, which rely on an Archimedes screw to thread through and gently push water along a hydraulic pathway [46, 47, 48]. Low-speed pump tests by (46) in which juvenile salmon (averaging 100 mm in length) were lifted 2.15 vertical m (at pump speeds of up to 24 rpm) resulted in no discernable mortality. In another study[49] of 26,220 fish (primarily Chinook salmon) entrained into a pumping station with

Archimedes lifts and internal helical pumps, average mortality was 0.6 to 0.9 % for short term trials and 2.8 to 2.9 % for 24 h trials. The % frequency of chinook salmon with sub-lethal injuries was < 0.3% during short-duration trials and < 1.8% for 24 h trials. Using the dimensions and test data listed in Tables 4-9 of (48) to calibrate equations (3) & (4), we obtain an injury factor relationship shown as the red curve in Figure 2 for a screw pump pushing 58.2 mgd with a rotation rate Ω = 26.5 rpm. The predicted injury factor K_i is 0**.**029 for a 100 mm juvenile fish, 0.02 for a 10 mm juvenile fish, and 0.0012 for 1 mm eggs or larvae.

Turbulent Shear Stress. Shear stresses and friction forces arise from the action of viscosity that produces *velocity shear* in the fluid flow. Velocity shear is simply a change in mean velocity $\bar{u}$ over some cross-stream distance, r. Velocity shear in turbulent flow produces shear stresses, τ, of the form;

$$\tau = \rho \varepsilon \frac{\partial \bar{u}}{\partial r} = \rho l^2 \left| \frac{\partial \bar{u}}{\partial r} \right| \frac{\partial \bar{u}}{\partial r} \tag{5}$$

Where ρ is the fluid density, ε is the eddy diffusivity (also referred to as virtual kinematic viscosity), l is the mixing length associated the largest turbulent eddies; and $\varpi = \partial \bar{u} / \partial r$ is the mean rate of shear or strain rate.

In the bio-engineering literature, lethal and sub-lethal injury thresholds are reported almost exclusively in terms of shear stress or strain rate. For striped bass (*Norone saxatilis*) and white perch (*N. Americana*), LD_{50} (the dose of shear stress required to kill half an experimental population) during 1 min exposures was generally on the order of τ =385 to 450 dynes/cm^2 (38.5 to 45 Pa) for eggs; τ =435 to 540 dynes/cm^2 (43.5 to 54 Pa) for larvae; and τ =1,600 dynes/cm^2

(160 Pa) for a composite of juvenile fish[20, 33]. LD_{50} thresholds for longer 4 min exposures (as typical of passage time through power plant conduits) were lower, on the order of $\tau = 150$ dynes/cm^2 to 170 dynes/cm^2 (15 Pa to 17 Pa) for eggs; $\tau = 310$ to 365 dynes/cm^2 (31 to 365 Pa) for larvae; and $\tau = 1{,}000$ dynes/cm^2 (100 Pa) for a composite of juvenile fish[42].

In the most comprehensive experimental measurements on turbulence mortality to date, four different species of freshwater juvenile fish measuring 10 cm in length and 2 cm in width were exposed to a submerged jet having exit velocities of up to 21.3 m/s, providing estimated exposure strain rates up to 1,185 per second[43,44]. There was no apparent size-related trend in susceptibility to entrainment into the diffuser jet[44]. Injuries and mortalities increased for American shad at strain rates greater than 397/s (corresponding to a jet velocity $\bar{u} \cong 5$ m/s); and for all species of fish at strain rates greater than 495/s (a jet velocity $\bar{u} \cong 6.1$ m/s). The portion of the test population experiencing sub-lethal injuries or worse was found to obey the following best-fit analytic relation:

$$K_c = \frac{\exp\left(\beta_0 + \beta_1 \varpi\right)}{1 + \exp\left(\beta_0 + \beta_1 \varpi + \beta_2 \varpi^2\right)} \qquad (6)$$

where K_i , represents the proportion of the population incurring sub-lethal (minor) injury; $\varpi = \partial \bar{u} / \partial r$ is the strain rate, and $\beta_0, \beta_1, \beta_2$ are empirical best-fit parameters derived from Tables 1-3 in (44). These results can be transposed to a function of shear stress based on the mixing length of the largest turbulent eddies varying with distance x from the jet nozzle according to the relation[54] $l \cong 0.003\,(x/d)^{4/3}$, where d = 6.4 cm is the jet diameter. Based on these experimental dimensions, equation (6) can be restated in terms shear stress as:

$$K_c = \frac{\exp\left(\beta_0 + \gamma_1 \tau^{1/2}\right)}{1 + \exp\left(\beta_0 + \gamma_1 \tau^{1/2} + \gamma_2 \tau\right)} \quad (7)$$

where $\gamma_1 = \beta_1/(l\,\rho^{1/2})$; and $\gamma_2 = \beta_2/(l^2\rho)$.

The shear stress dependence of sub-lethal injury factor due to exposure of 100 mm long juvenile fish to a turbulent diffuser jet are plotted as the black curve in Figure 3. These results show LC-10 values (10% of the population incurring sub-lethal injury or worse) corresponding to shear stresses of between 1500 dynes/cm^2 and 1600 dynes/cm^2 (150 to 160 Pa), which is consistent with the earlier published results[20, 33]. We will refer to shear stresses that correspond with LC-10 values as critical shear stress for sub-lethal injury threshold, represented as τ_c .

Dynamic scaling laws for size adaptation allow these results[44] to be extrapolated to the relevant species sizes and diffuser discharge velocities. The basis for this scaling principle is the well-known *2/3-Power Law*, which teaches that the size of a swimming or flying organism is limited by its tensile strength, or the maximum stress that a membrane or epidermis can withstand while being stretched or deformed by external (hydrodynamic) forces before failing[56,57]. In this case, Tensile strength balances shear stress at the onset of injury whence the critical shear stress decreases with size as $\tau_c \propto \lambda^{2/3}$. Since we already know the shear stresses that cause injury for a given size of size juvenile fish, $\lambda = \lambda_0 =$ 100 mm after (43) and (44), we can rescale those results for an arbitrary size of smaller organism, λ_i , by:

$$K_i(\tau, \lambda_i) = \frac{\exp\left(\beta_0 + \delta_1 \tau^{1/2}\right)}{1 + \exp\left(\beta_0 + \delta_1 \tau^{1/2} + \delta_2 \tau\right)} \quad (9)$$

where $\delta_1 = \gamma_1 \left(\lambda_i/\lambda_0\right)^{1/3}$; and $\delta_2 = \gamma_2 \left(\lambda_i/\lambda_0\right)^{2/3}$. The curves in Figure 3 plot sub-lethal injury factors due to diffuser jet turbulence exposure for typically sized juveniles, larvae and eggs of marine fishes. The rescaled results show that LC-10 values drop to a critical jet shear stress τ_c of 350 dynes/cm^2 for a 10 mm juvenile fish, 75 dynes/cm^2 for a 1mm size egg or larvae, and 16 dynes/cm^2 for sub-mm sized ichthyoplankton. Notably, LC-10 for a 10 mm juvenile marine fish occurs at jet discharge velocities of 4.2 m/s while for 1mm eggs and larvae LC-10occurs at jet discharge velocities of about 2.5 m/s, both within the operating domain of conventional diffuser systems (Figure 3).

The critical shear stress, τ_c, for sub-lethal injuries reported in (43) and (44) was incurred at a distance of 10 cm downstream of the jet nozzle. However, smaller shear stress occur in the jet further downstream as the turbulent eddies mix the jet momentum into the interior of the surrounding fluid. Consequently, non-swimming eggs, larvae and ichthyoplankton can be injured at greater distances from the jet nozzle than swimming juvenile fishes. An important factor in the decay of jet induced shear stress (particularly in the case of diffusers) is the proximity of the bottom plane of the seabed, which influences both the coherent entrainment flow patterns (Figure 1) as well as the extinction rate of the jet shear stress by the action of bottom friction. Laboratory and field measurements of shear stresses in a turbulent jet discharging across the seabed were reported in (60), yielding the following relation for shear stress decay with distance x from the jet nozzle:

$$\tau = 120\,\rho\,\bar{u}_0^{\,2}\,\mathrm{Re}_j^{\,-0.4}\left(\frac{d}{x}\right)^{2.4} \qquad (10)$$

where $\bar{u}_0$ is the jet discharge velocity at $x = 0$, d is the jet diameter at the discharge nozzle, and $\mathrm{Re}_j = \bar{u}_0 d / \nu$ is the jet Reynolds number. The distance downstream from the jet nozzle X_c where the jet-induced shear stress decays to the LC-10 injury threshold τ_c for some particular size of organism can be written:

$$X_c = d \left(\frac{\tau_c \,\mathrm{Re}_j^{\,0.4}}{120\, \rho \bar{u}_0^2} \right)^{-0.417} \tag{11}$$

while the critical radius of the plume, r_c, where the jet-induced shear stress decays to the LC-10 injury threshold τ_c was found to be about $r_c \cong X_c / 3$.

Micro-Mechanics of Turbulence Mortality It has been suggested that turbulence mortality is greatest when the size of the organism is comparable to small-scale *Komogorov* eddies,[45,58]. However, there is no direct evidence to support this hypothesis, which appears to be based on the fact that most of the dissipation of turbulent energy into heat occurs at the *Komogorov* eddy scales[61]. However, it has been incorrectly presumed that strain rates and shear stresses are also largest at these small eddy scales[45]. In fact, almost all turbulent energy is concentrated at the large eddy scales of the energy spectra[62]. The structure of the turbulence at these large eddy scales is determined by the mean flow, $\bar{u}$, which supplies the energy [62], and it is the size of these large eddies l that control the turbulent diffusion of momentum, the size of the eddy diffusivity $\varepsilon = l^2 \left| \frac{\partial \bar{u}}{\partial r} \right|$, and ultimately the size of shear stress that injures the organisms (cf. equation 5). While energy dissipation spectra (distribution of energy dissipation vs eddy size) may peak at the

Komogorov eddy scales[63,64], energy dissipation causes a negligible change in water temperature, owing to the high heat capacity of water[65] and therefore does not directly injure organisms. In addition, the *Komogorov Hypothesis* is based on the small scale eddies being decoupled from the mean flow, and completely independent of the large energy-containing eddies [61,]. However, organisms entrained into a turbulent jet will simultaneously be exposed to a range of sizes of turbulent eddies across the energy spectra, and it is impossible to separate the injurious effects of one size of eddy from another.

Shear Sorting: Another micro-scale flow phenomena that could influence turbulence mortality is the *Magnus effect*, the generation of a lift stress, τ_L on an organism that acts perpendicular to the mean flow as a result of action of velocity shear, $\varpi = \partial \bar{u} / \partial r$ in that flow, expressed as[59]:

$$\tau_L = \frac{\rho \bar{u} \varpi A_0}{\lambda} = 1/2 \rho C_L (\bar{u} - U_0)^2 \tag{12}$$

Where A_0 is the cross sectional area of the organism, U_0 is the velocity of an entrained organism, and C_L is the lift coefficient. Lift stress will act to displace an entrained organism into the higher velocity region of a shear flow[53], and has different consequences for different dilution strategies. With in-plant dilution, shear flows occur inside conduits and pump casings, where shear induced lift forces displace the organisms into the higher velocity regions near the center of the pipes and conduits. Here, damaging strain rates and shear stresses become vanishingly small, while this action also reduces the likelihood of organisms impacting the pipe wall and suffering abrasion and impact mortality. The reverse is true in the turbulent jet of a high velocity diffuser, where the action of shear sorting will tend to displace the organisms into the higher velocity regions of the core of the jet where accelerations and turbulent energy are high and injury is more likely.

Comparisons of hydrodynamic mortality from two brine dilution strategies at the Carlsbad Desalination Project

The Carlsbad Desalination Project (CDP), co-located at the Encina Power Station (EPS), Carlsbad, CA (Figure 4) is used as a proxy for prototype comparisons of hydrodynamic impacts on marine life due to the brine dilution strategies of in-plant dilution and high velocity diffusers. CDP is the most data rich desalination project of its kind, with fully certified Environmental Impact Reports, NPDES discharge and Coastal Development (CDP) permits, and Clean Water Act (CWA) Section 316(b) Entrainment and Impingement Studies to characterize diversity and abundance of marine life in the source and receiving waters [22, 66, 67, 68, 69]. This hydrodynamic impact analysis will consider only those injuries and mortalities to marine life associated with the dilution water. Analyses of impacts arising from in-plant dilution are based on utilizing screw pumps to blend brine with the dilution water (Figure 5a), whereas impacts arising from high velocity diffusers are based on linear diffuser designs utilizing Tideflex duckbill diffuser nozzles (Figure 5b). Hydrodynamic marine life impacts associated with these two dilution technologies will made for dilution water requirements under both the plant's presently *Permitted Standard* (20% over ambient salinity; $\psi = 5$); as well as under the potential future dilution standard, *The 5% Rule* (5% over ambient salinity; $\psi = 20$).

Marine Organism Size and Abundance: Size and abundance data for eggs, larvae and juvenile fish in the source waters and receiving waters around the EPS and Carlsbad Desalination Project

(Figure 4) were monitored from June 2004 through May 2005[69]. The traveling intake screens at EPS reject all juvenile fish larger than 10 mm. During the one-year entrainment monitoring period (concurrent with power generation by EPS), a total of 3.63 x10^9 fish larvae and 162,000 invertebrate larvae were entrained. Entrainment of 1.82 x 10^7 fish larvae and eggs occurred daily. The probability density function of abundance as a function of size $p\ (\lambda)$ was found to fit a fifth order polynomial with a coefficient of determination of $r^2 = 0.96$:

$$p\ (\lambda) = \frac{1}{\Delta\lambda}\left(c_0 + c_1\lambda + c_2\lambda^2 + c_3\lambda^3 + c_4\lambda^4 + c_5\lambda^5\right) \qquad (13)$$

Here λ is the size of the organism in mm, $\Delta\lambda$ is the sampling interval (bin width)[69]; and the polynomial coefficients are: c_0 = 0.00013, c_1 = .1744146362, c_2 = -07003183448, c_3 = 01107751102, c_4 = -0.0007744442227, and c_5 = 0.00001998643897. Based on Equation 13, the median organism size in the source and receiving waters was $\tilde{\lambda}$ = 2.4 mm. The average seawater intake rate over the monitoring period was 658 mgd, yielding a mean concentration of $\tilde{C}$ = 2.766 x 10^4 organisms per mgd of dilution water.

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Marine Life Impacts due to In-Plant Dilution: The CDP is permitted for harvesting 304 mgd of screened source water from Agua Hedionda Lagoon (Figure 4). From this, 200 mgd of intake flow enters a discharge channel for in-plant dilution of the brine discharge, and is presently propelled by high rpm centrifugal pumps (black curve in Figure 2). However, new CWA Section 316(b) regulations are requiring coastal power plants to convert to newer technologies, giving the Carlsbad Desalination Project the opportunity to convert to low-impact screw pumps for powering its in-plant dilution operations. The use of screw pumps is the basis on which comparisons of marine life impacts at CDP will be made between in-plant dilution and high-velocity diffuser strategies. This conversion will utilize high-flow rate, low-rpm screw pumps connected in parallel in a pump box (Figure 5a). Under the Permitted Standard, the four screw pumps will rotate at 20 rpm rotation rate, providing a combined flow rate of 204 mgd for in-plant dilution. These pumps are nearly identical in design and operating rpm to those used by (49), and calculate to nearly the same injury factor as a function organism size (dashed blue curve in Figure 2). If t*he 5% Rule* is adopted, then in-plant dilution will require 950 mgd of dilution water, and the 4 screw pumps will have to be up-sized to produce 251 mgd of flow rate each, at 20 rpm rotation rate. Accounting for the physical dimensions of these largest Spaans-Babcock screw pumps, injury factors as a function of organism size calculate to slightly higher values than the those in (49), based on equations (3) and (4) (dashed green curve in Figure 2).

Under the Permitted Standard, the 1.3% of the organisms in 200 mgd of dilution water that would suffer lethal or sub-lethal injuries. The size integrated injury factor $\tilde{K}_i$ is a joint probability of blade strike P_b after equation (2); and the organism size probability density $p(\lambda)$ for the organisms that pass through the intake screens[69] according to equation (13). This joint probability is in turn a function of the slope of the dashed blue curve in Figure 2. With a concentration of $\tilde{C}$ = 2.766 x 10^4 organisms per mgd of dilution water, 72,600 eggs, larvae and sub-centimeter juveniles will suffer lethal or sub-lethal injuries daily (Table 1).

Under the 5% Rule, $\tilde{K}_i = \int \frac{\partial K_i(\lambda)}{\partial \lambda} d\lambda = 2.4\%$. This larger integrated injury factor (relative to the Permitted Standard), it also ccurs in a larger volume (950 mgd) of dilution water, resulting in a dilution impact of 631,000 eggs, larvae and sub-centimeter juveniles suffering lethal or sub-lethal injuries daily (Table 1).

Screw pumps are low pressure pumps, capable of providing vertical lift of only about 2 to 3 m. They are also unable to hold pressure if they stop turning for any reason (e.g., maintenance, cleaning, or power interruption). Therefore, the screw pump is not a viable option if discharging below the sea surface more than several meters below MLLW tide levels is required. In the prototype case of the CDP at the EPS, the use of screw pumps is ideal, as no more than 2 m of vertical lift are needed to by-pass the dilution water around the desalination facilities. This underscores the necessity of considering site-specific conditions when selecting a brine dilution strategy.

Marine Life Impacts due to Dilution with High-Velocity Diffusers: To evaluate potential marine life impacts due to implementation of the high velocity diffuser strategy at CDP, we pose the offshore hydraulic layout in Figure 4. This layout utilizes a buried 72 inch diameter pipeline to transport 54 mgd of of hypersaline brine to a depth of at least 10m MSL, in order to avoid direct discharge into existing kelp beds. At the end of this pipeline, we pose a conventional linear diffuser, consisting of five discharge risers at 20 m spacing that extend above the seabed from a buried manifold pipe (Figure 5b). Each riser is fitted with a Tideflex duckbill nozzle, angled upward at a 60 degree angle, and standing 2.13 m above the seafloor (to protect against burial effects, damage from contact with bottom debris, and surge). Herein we evaluate two different sizes of nozzles, specific to the two dilution standards in question. For the Permitted Standard, the nozzles are sized for 0.5 m diameter riser pipes to produce discharge velocities of 3 m/s. For the 5% Rule, nozzles are sized for 0.4 m diameter riser pipes with discharge velocities of 5 m/s.

Four distinct hydrodynamic models were used to evaluate the 54 mgd linear diffuser. The basic riser and diffuser internal flow simulations were performed using *COSMOS/ FLowWorks*. The subsequent turbulence kinetics of the discharge plume was evaluated using a $\bar{v}^2 - f$ mode computational fluid dynamics model, *Star-CD ,* Version 3.1, with *QUICK* space discretization for the mean flow and first order up-winding of the turbulence equations [70,71]. It was used herein to compute the jet core velocities, shear stress, strain rates. Nearfield dilution performance of the hypothetical diffuser design was evaluated using *Visual Plumes* (reference). Finally, the fully 3-dimensional far field dispersion model *SEDXPORT* [22] was used to assess the large scale trajectory of the brine plume and plume-induced sediment re-suspension. This model is a processed-based stratified flow model with the complete set of littoral transport physics including tidal transport, and wind & wave induced transport and mixing.

Numerical integration of the 3-dimensional shear stress field around the diffuser allows computations of the stress-integrated injury factor, $\tilde{K}_i$. Because jet-induced injury is a function of both the shear stress and the sizes of the organism after equation (8); and because the shear stress around the diffuser varies in 3-dimensional space (x, y, z), this computation is performed from the total derivative of $K_i(\tau, \lambda)$ according to:

$$\tilde{K}_i(\tau,\lambda) = \int \frac{\partial K(\tau,\tilde{\lambda})}{\partial \tau} d\tau = \int \left(\frac{\partial K_i}{\partial \tau} \right)_{\tilde{\lambda}} \frac{\partial \tau}{\partial x} dx + \int \left(\frac{\partial K_i}{\partial \tau} \right)_{\tilde{\lambda}} \frac{\partial \tau}{\partial y} dy + \int \left(\frac{\partial K_i}{\partial \tau} \right)_{\tilde{\lambda}} \frac{\partial \tau}{\partial z} dz \qquad (16)$$

Where $\partial K_i / \partial \tau$ is evaluated from equation (9) for the median size organism $\lambda = \tilde{\lambda}$ = 2.4 mm; and shear stress gradients ($\partial \tau / \partial x$, $\partial \tau / \partial y$, $\partial \tau / \partial z$) are evaluated from the *Star-CD* model .

Under Permitted Standard, 10.7 % (592,000 eggs, larvae and sub-centimeter juveniles per day) of entrained organisms would suffer lethal or sub-lethal injuries from the 5-jet linear diffuser,

The 5% Rule scenario would necessitate the entrainment of 950 mgd of dilution water with jet discharge velocities of $\bar{u}_0$ = 5 m/s, resulting in shear stresses of up to 500 dynes/cm^2 (50 Pa) (Figure 6). The percentage of entrained organisms that would suffer lethal or sub-lethal injuries in this scenario is 16.8%, which corresponds to 4,415,000 eggs, larvae and sub-centimeter juveniles fishes. These values represent a 7 to 9.5 times greater marine life impact then was found for in-plant dilution using screw pump by-pass technology to meet the 5% Rule dilution standard (Table 1). It should be noted that this impact is not necessarily limited to sub-centimeter juvenile fish, because the offshore receiving waters are not pre-screened before the resident organisms are subjected to potentially damaging turbulence. It has been suggested that organisms can avoid the diffuser turbulence, because entrainment velocities associated the large high energy turbulent eddies are only on the order of 2 cm/sec. However, many planktonic organisms and juvenile fishes cannot perform sustained swimming speeds of 2 cm s^{-1}, nor would they necessarily know which direction to swim toward to avoid a diffuser jet. Diffuser jets are very narrow, sharp edged, high-velocity current streams that have no naturally occurring counterpart in the ocean.

Bottom Turbidity Layers due to Dilution with High-Velocity Diffusers: A brine diffuser system at CDP could introduce artificially high levels of bottom turbulence to offshore areas of seafloor. Dense brine plumes from a diffuser jet will fall onto the seabed under force of gravity and spread as *turbulent spreading layers*[72]. If the seabed sediments do not have adequate grain size to resist onset of motion due to these high turbulence levels, then those sediments will be scoured and re-suspended, forming a bottom turbidity layer[60]. The concern for potential marine life impacts arises from the fact that these re-suspended sediments can cause reductions of ambient light levels near the bottom that subsequently leads to failure of kelp to recruit at neigboring kelp beds [73], such as those found in the nearshore waters at CDP (Figure 4).

The flux of sediment that is scoured, resuspended and entrained in a turbulent jet near the seabed is given by [60]:

$$E_j = \frac{\mathrm{Re}\left[\dfrac{9a^3\,k_0^{\;3}\,(\tau-\tau_0)^{3/2}\,(m+z_0)}{\omega_0^2\,z_0\,\sqrt{\rho_m}}\log_e\left(\dfrac{m+z_0}{2z_0}\right)\right]}{\left(1-\rho/\hat{\rho}_s\right)} \qquad (19)$$

where E_j is the jet-induced entrainment flux of sediment; Re is the real-part operator; a is the Peclet number; k_0 is von Karman's constant; τ is the jet-induced shear stress; τ_0 is the critical shear stress that induces threshold of motion of the bottom sediments (incipient motion shear stress); ω_0 is the settling velocity of the sediment; m is the height of the diffuser jet nozzle above the seabed; z_0 is the bottom roughness height (ripple height); ρ_m is the density of the fluid-sediment mixture given as:

$$\rho_m = \rho_q\,C + (1-C)\,\rho \quad \text{and} \quad \hat{\rho} = \rho_q\,C \qquad (20)$$

Here, ρ_q is the density of quartz (2.65 g/cm^3); ρ is the fluid (seawater) density; $\hat{\rho}$ is the density of the sediment component of the fluid sediment suspension mixture (dry bulk sediment density, or excess density); and C is the sediment particle number concentration (volume concentration) in the fluid-sediment suspension mixture; and $\hat{\rho}_s$ is the dry bulk density of the sediments that comprise the seabed. The optical properties of the water depend on the particle number concentration, C, which can be derived from the jet-induced entrainment flux of sediment E_j for any arbitrary elevation z above the bottom at $z = z_0$ according to [60]

$$C(z) = \frac{9a^2 k_0{}^2 (\tau - \tau_0)}{\rho_q \,\omega_0^2 \log_e{}^2 \left[(z + z_0)/2z_0\right]} + \frac{\hat{\rho}_s}{\rho_q} \exp\left[\frac{(z-m)}{(h-m)} \log_e\left(\frac{\rho}{\hat{\rho}_s}\right)\right] \tag{21}$$

Where h is the distance between the seabed and the sea surface.

Equations (19) and (21) indicate that both the sediment flux entrained by a diffuser jet and the suspended sediment concentration profile within the turbulent brine plume depend strongly on the excess shear stress $(\tau - \tau_0)$, (i.e., how much the jet-induced shear stress exceeds the threshold of motion shear stress of the bottom sediments). The offshore sediments around the hypothetical linear diffuser in Figure 4 are comprised of 50% fine particles, consisting of silts and clays,with a median grain size of 52 microns[74, 79]. The threshold of motion shear stress required to scour and re-suspend these native bottom sediments is 70 dynes/cm^2 (7 Pa)[74, 75]. and the average speed of near-bottom currents in the vicinity of the diffuser is approximately 5 cm/s, with a persistent southeastward net drift.

The shear stress outputs from the *Star-CD ,* Version 3.1 CFD model were used to drive Vortex Lattice scour simulations on a broad-scale seabed[76]. Figure 7 shows solutions for the shear-stress scour trails on the seabed due to the 5 jet, linear diffuser array operating in a 5 cm/s mean southerly current under The 5% Rule, with discharge velocities of $\bar{u}_0$ = 5 m/s. Outside the scour trails, native sediments appear in equilibrium with the longshore current. However, the addition of diffuser jet-induced shear stresses induces large super-critical shear stress areas, 5 to 20 Pa over ambient bottom shear stress, particularly in the nearfield of the diffuser risers. These shear stress hotspots induce scour and re-suspension of seabed sediments and form a bottom turbidity layer that drifts with the ambient currents. Sediments settling rates are only1 to 10 cm hr^{-1}, and the bottom turbidity layer will travel as far as 2.1 km down-coast toward the southeast before resettling.

To evaluate the effect of diffuser-induced sediment scour and turbidity on optical properties of the near-bottom water mass, we invoke the Coastal Water Clarity Model[77, 78]. This model combines the sediment flux and concentration profile relations from equations (19) – (21) with *Mei-scattering* physics to solve for the diffuse attenuation coefficient, k_d , for photosynthetically available irradiance (PAR; the light spectrum between 400 and 700 nm) according to:

$$k_d = \left[C^2(z) + 0.256 \;\; C(z)\, b(D) \;\; \right]^2 \tag{22}$$

where *b(D)* is the slope of the suspended sediment particle size distribution curve in the silt and clay regime after equation (21).

In the absence of the diffuser, the Coastal Water Clarity Model typically calculates a diffuse attenuation coefficient of $k_d = 0.60$ cm^{-1} and a visibility distance of 5m over the sandy/silty seabed, while over the rocky bottom in the kelp beds, $k_d = 0.51$ cm^{-1} with a visibility distance of 5.9 m. Based on inputs of 28,328 realizations from ADCP current measurements [74] made between November 2011 and November 2012, the modeled sediment concentrations from jet-induced bottom shear stresses produce a worst-case (under The 5% Rule) k_d of 27 cm^{-1} with a visibility distance of 11 cm in the nearfield of the diffuser and a k_d of 3 cm^{-1} with a visibility distance of 100 cm in the kelp beds (Figure 8). Bottom turbidity under The 5% Rule operating parameters would reduce PAR in the Carlsbad kelp beds by as much 85% (worst case current conditions), and by 15% for average current conditions. Under the Permitted Standard, PAR reductions in the CDP kelp beds would be less, with 63% reductions in PAR for worst case, and 11% for average case. Extrapolating from well documented turbidity impacts observed near the diffuser of the closely situated San Onofre Nuclear Generating Station[73], persistent 11 % to 15% reductions in PAR would likelycause reduced recruitment and general degradation of CDP kelp beds and their associated biotic communities.

In contrast, turbidity impacts to the CDP kelp beds are negligible with the in-plant dilution strategy that discharges pre-diluted brine effluent into the surfzone. This is because turbulent bottom stresses from surf zone wave action have winnowed away the fine grained sediments. The median grain size of this beach material is 2.5 to 4 times coarser than that of the offshore sediments[79], and this size class of sediments simply does not cause turbidity.

CONCLUSIONS:

Analytic comparisons of potential hydrodynamic marine life impacts associated with in-pipe (or in-plant) dilution and high velocity diffusers were performed for 50 mgd brine discharges from ocean desalination, using the Carlsbad Desalination Project as an analytic proxy. These comparisons are summarized in Table-1 and were made for two sets of dilution standards: the presently permitted brine dilution standard of 5-to-1; and a proposed future dilution standard of 20-to-1, referred to as the 5% Rule. Analytic comparisons were made based on algorithms derived from the literature data on lethal and sub-lethal injuries to juvenile fish that were subsequently rescaled to smaller eggs, larvae and immature juveniles of sub-centimeter scale, capable of passing through the intake screens of the Carlsbad Desalination Project, co-located at the Encina Power Station (EPS) in Carlsbad, CA.

Lethal and sub-lethal injuries to small entrained marine organisms occurs primarily during pump passage with in-plant dilution as a consequence of the organisms experiencing large accelerations and virtual mass forces when colliding with pump impellor blades. The literature teaches that this form of injury (referred to as *blade-strike* or *impact mortality*) scales with pump rpm. It can be reduced to as little as 1.3 % of the organisms entrained in the dilution water under the presently permitted dilution standard; and as little as 2.4% under The 5% Rule; if the in-plant dilution facility is fitted with low-rpm screw pump by-passing technology. These percentages represent 72,600 eggs, larvae and sub-centimeter juveniles suffering lethal or sub-lethal injuries daily under the presently permitted dilution standard that requires 200 mgd of dilution water; and 631,000 lethal or sub-lethal injuries daily to these same organism under The 5% Rule, where 950 mgd of dilution water is required.

Marine life impact numbers were found to be 7 to 9.5 times greater using high velocity diffusers to affect brine dilution with jet discharge velocities ranging from 3 m/s to 5 m/s. The lethal and sub-lethal injuries incurred with diffusers arises from the organisms being entrained by the coherent flow structures surrounding the jet and by the large high-energy turbulent eddies within the jet that subject the organisms to large shear stresses and strain rates. Using scalable injury algorithms derived by the Pacific Northwest National Laboratory from experiments with a prototype scale diffuser jet, it was determined that 10.7 % of the eggs, larvae and juvenile fish entrained by a 5-jet linear diffuser with discharge velocities of 3 m/s would suffer lethal and sub-lethal injuries daily under the presently permitted dilution standard ; and that 16.8% to 23% of those organisms would suffer the same kinds of injuries under The 5% Rule, where diffuser jet discharge velocities must be increased to 5 m/s to insure compliance. These diffuser injury percentages represent 592,000 eggs, larvae and juvenile fish suffering lethal or sub-lethal injuries daily under the presently permitted dilution standard; and 4,415,000 to 6,044,000 lethal or sub-lethal injuries daily to these organism under The 5% Rule. These numbers are not necessarily limited to sub-centimeter juvenile fish, because the offshore receiving waters are not pre-screened before the resident organisms are subjected to potentially damaging turbulence. In addition, it was demonstrated with computational fluid dynamic (CFD) modeling that high velocity diffusers can generate turbidity layers when the native bottom sediments are not sufficiently course to resist scour and re-suspension by diffuser-induced bottom stress and turbulence. Using monitoring data on currents and sediment grain sizes in the vicinity of the hypothetical linear diffuser offshore of the Carlsbad Desalination Project, it was found that diffusers operating under parameters of The 5% Rule would reduce the photosynthetically available radiation in the nearby kelp beds by as much 85% (worst case current conditions), and by 15% for average current conditions. Under the presently permitted dilution standard, reductions of PAR in the neighboring kelp beds would be less, with 63% reductions in PAR for worst case, and 11 % for average case. Experience at San Onofre Nuclear Generating Station has shown that persistent reductions in PAR of this order can cause co-lateral damage to adjacent marine communities (kelp beds) by impairing the ability of kelp to recruit.

Table 1: Impacts of brine dilution strategies using in-plant dilution vs. high velocity diffusers with ocean desalination plants, based on 50 mgd water production. PAR = Photo-synthetically Available Radiance. * eggs, larvae, and sub-centimeter juveniles

	In-Plant Dilution for *Permitted Standard*	**In-Plant Dilution for *5% Rule***	**Diffuser Dilution for *Permitted Standard***	**Diffuser Dilution for *5% Rule***
Required Flux of Dilution Water	**200 mgd**	**950 mgd**	**200 mgd**	**950 mgd**
Integrated Injury Factor	**1.3%**	**2.4%**	**10.7%**	**16.8 % to 23 %**
# Organisms Injured per day*	**72,600**	**631,000**	**592,000**	**4,415,000 to 6,044,000**
Impacted Domain	**In –pipe From source water body**	**In-pipe From source water body**	**End-of-pipe In receiving water body**	**End-of-pipe In receiving water body**
Co-lateral Environmental Damage	**none**	**none**	**Turbidity increases from diffuser turbulence**	**Turbidity increases from diffuser turbulence**
Co-lateral Damage	**none**	**none**	**Reduction in PAR** 65% max, 11% mean**	**Reduction in PAR** 85% max, 15% mean**
Co-lateral Impact Zone	**none**	**none**	**Kelp Beds and dependent marine community**	**Kelp Beds and dependent marine community**

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FIGURE CAPTIONS:

Figure 1: Hydrodynamic simulation of outflow and entrainment regions in the nearfield of a high-velocty diffuser jet with TideFex duckbill nozzle. The total discharge per nozzle is 10 mgd of 65 ppt brine.

Figure 2: Proportion of entrained organism population subjected to sub-lethal injury or worse during passage through centrifugal versus screw pumps**.**

Figure 3: Sub-lethal injury factor re-scaled for relevant sizes of marine juvenile fish, larvae and eggs using the 2/3-Power Law.

Figure 4: Site layout with neighboring source and receiving water bodies for the Carlsbad Desalination Project, co-located at the Encina Power Station (EPS), Carlsbad, CA. Also shown is an overlay of a hypothetical offshore discharge pipeline with diffuser system for brine dilution.

Figure 5: A) One of 4 Spaans-Babcock screw pumps that will be used at the CDP. B) Physical example of the linear diffuser concept posed for the CDP. Five discharge risers at 20 m spacing will extend above the seabed from a buried manifold pipe. Each riser pipe is fitted with a Tideflex duckbill nozzle.

Figure 6: Simulation of shear stress field using the *Star-CD* , Version 3.1 CFD model showing the nearfield of a diffuser fitted with a TideFlex duckbill nozzle sized for the 5% Rule dilution standard using a discharge velocity $\bar{u}_0$ = 5 m/s. Five such nozzles will discharge 10.8 mgd each of brine at 65 ppt salinity.

Figure 7: Vortex lattice simulation scour simulation model output showing bottom shear stress induced by hypothetical offshore diffuser system for the CDP. Based on 5-riser/Tideflex nozzles in a linear diffuser. Shear stress contours in look-down horizontal plan view with a 5 cm/s southward flowing longshore current. North is toward the top of the figure and onshore is toward the right hand side of the figure.

Figure 8: Histogram (probability density) and cumulative probability of percent reductions in photosynthetically available radiation at the centroid of the Carlsbad kelp beds due to CDP brine diffuser-generated bottom turbidity layers.

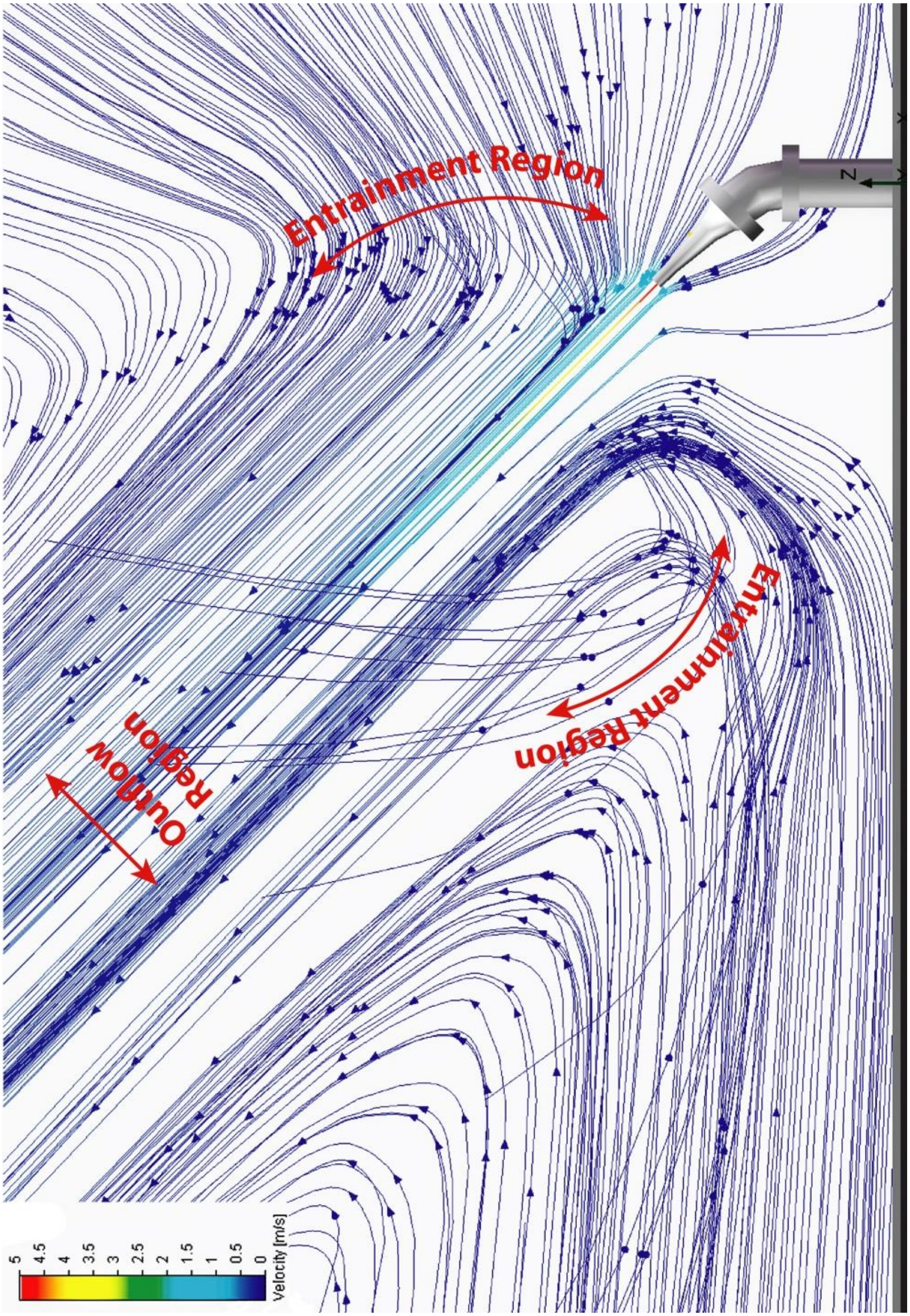
Entrainment Region
Entrainment Region
Outflow Region
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Velocity [m/s]
Z

Figure 1

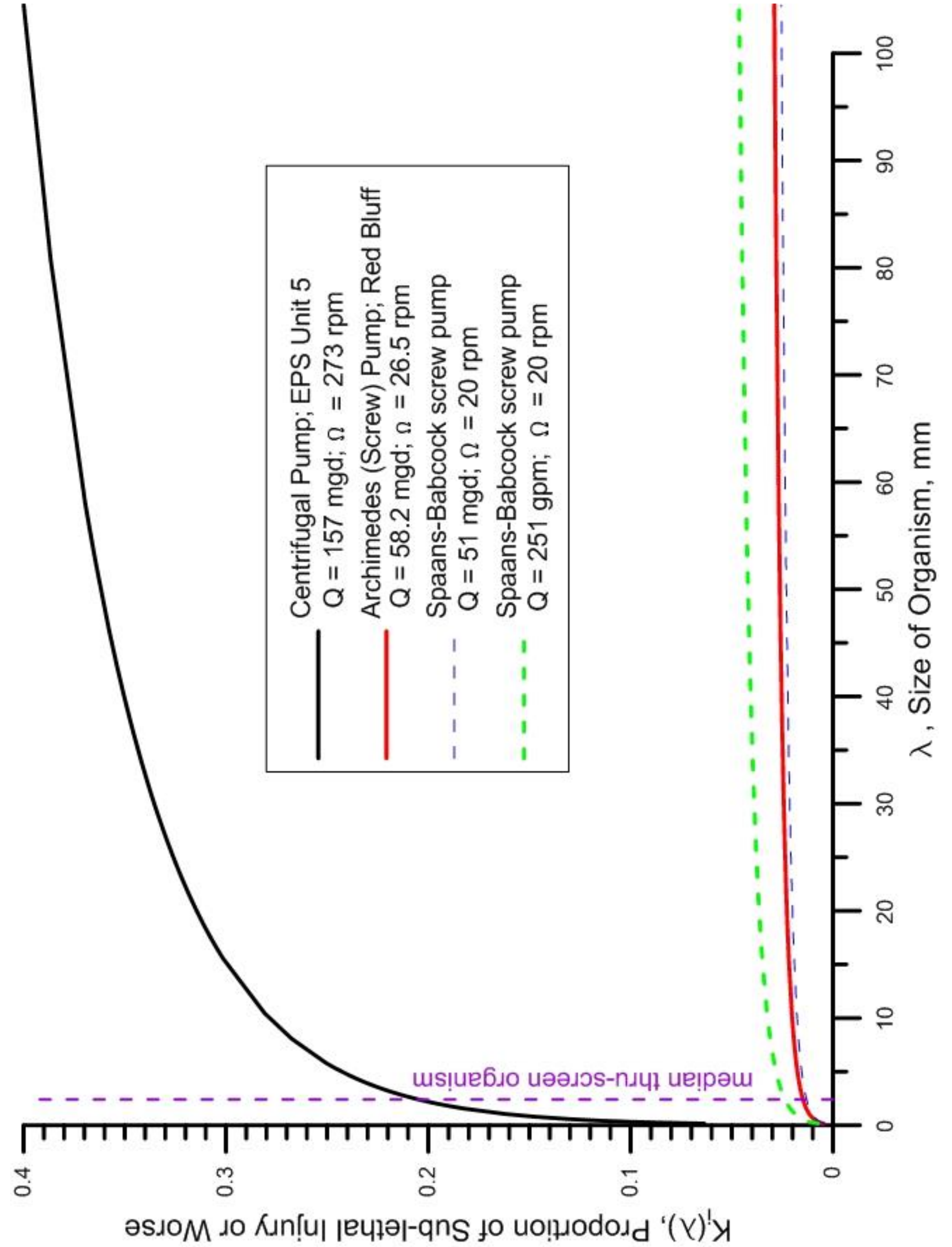
Centrifugal Pump; EPS Unit 5
Q = 157 mgd; Ω = 273 rpm
Archimedes (Screw) Pump; Red Bluff
Q = 58.2 mgd; Ω = 26.5 rpm
Spaans-Babcock screw pump
Q = 51 mgd; Ω = 20 rpm
Spaans-Babcock screw pump
Q = 251 gpm; Ω = 20 rpm
median thru-screen organism
$K_i(\lambda)$, Proportion of Sub-lethal Injury or Worse
0
0.1
0.2
0.3
0.4
λ , Size of Organism, mm
0
10
20
30
40
50
60
70
80
90
100

Figure 2

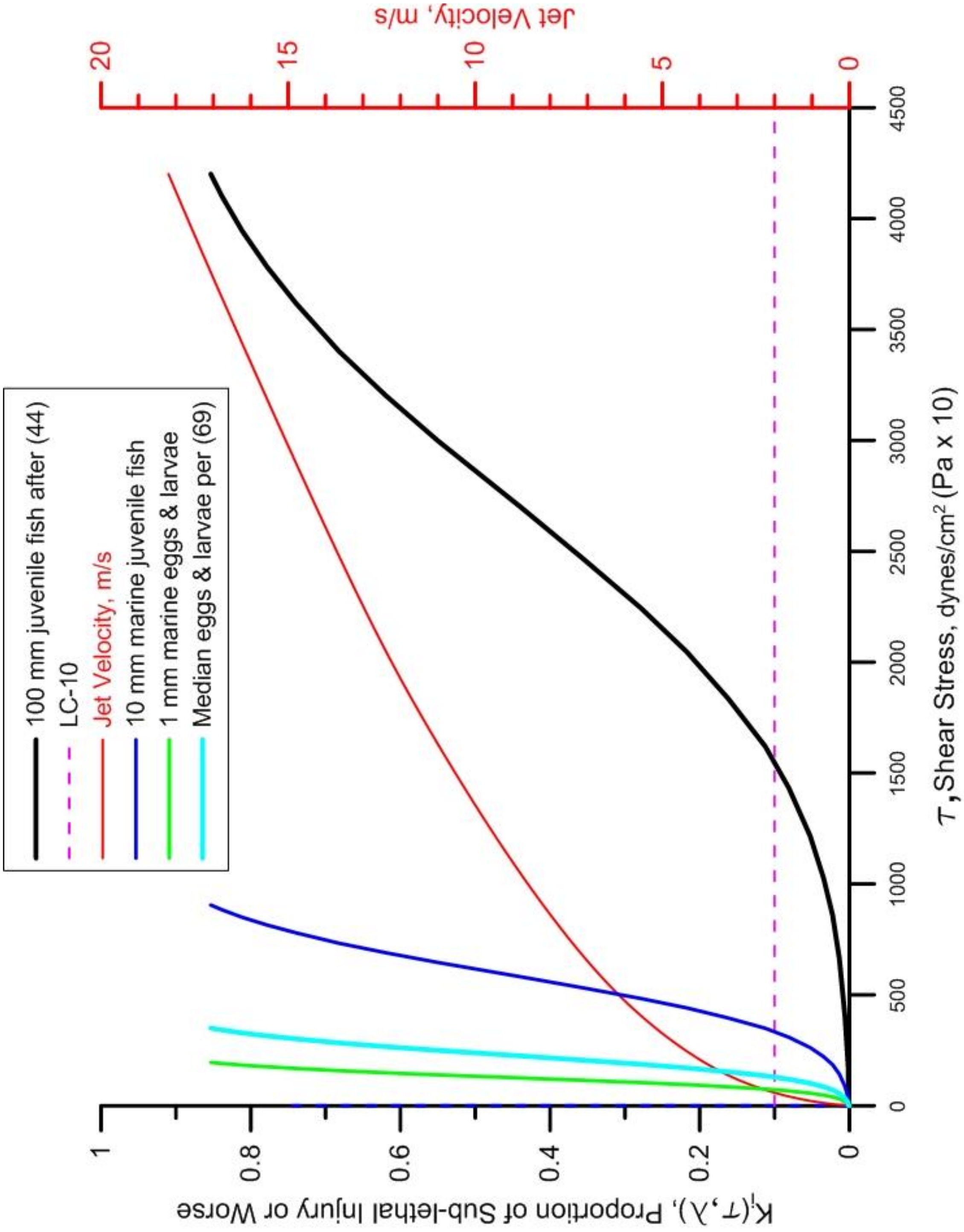
100 mm juvenile fish after (44)
LC-10
Jet Velocity, m/s
10 mm marine juvenile fish
1 mm marine eggs & larvae
Median eggs & larvae per (69)
K_i(τ,λ), Proportion of Sub-lethal Injury or Worse
0
0.2
0.4
0.6
0.8
1
τ, Shear Stress, dynes/cm² (Pa x 10)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Jet Velocity, m/s
0
5
10
15
20

Figure 3

Ocean Outfall/Diffuser System

Figure 4


Tideflex
Technologies

Figure 5a (upper); and Figure 5b (lower)

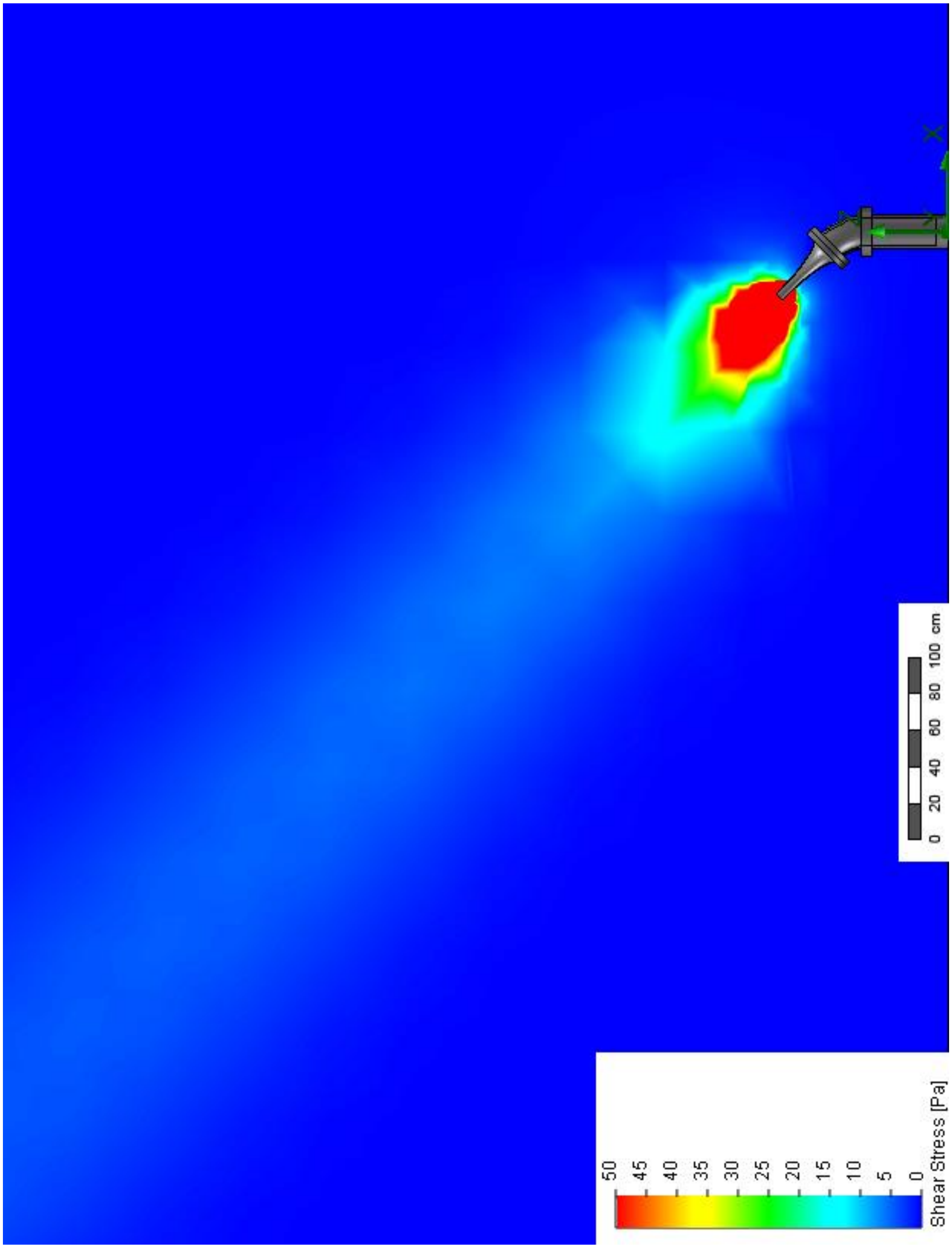

Figure 6

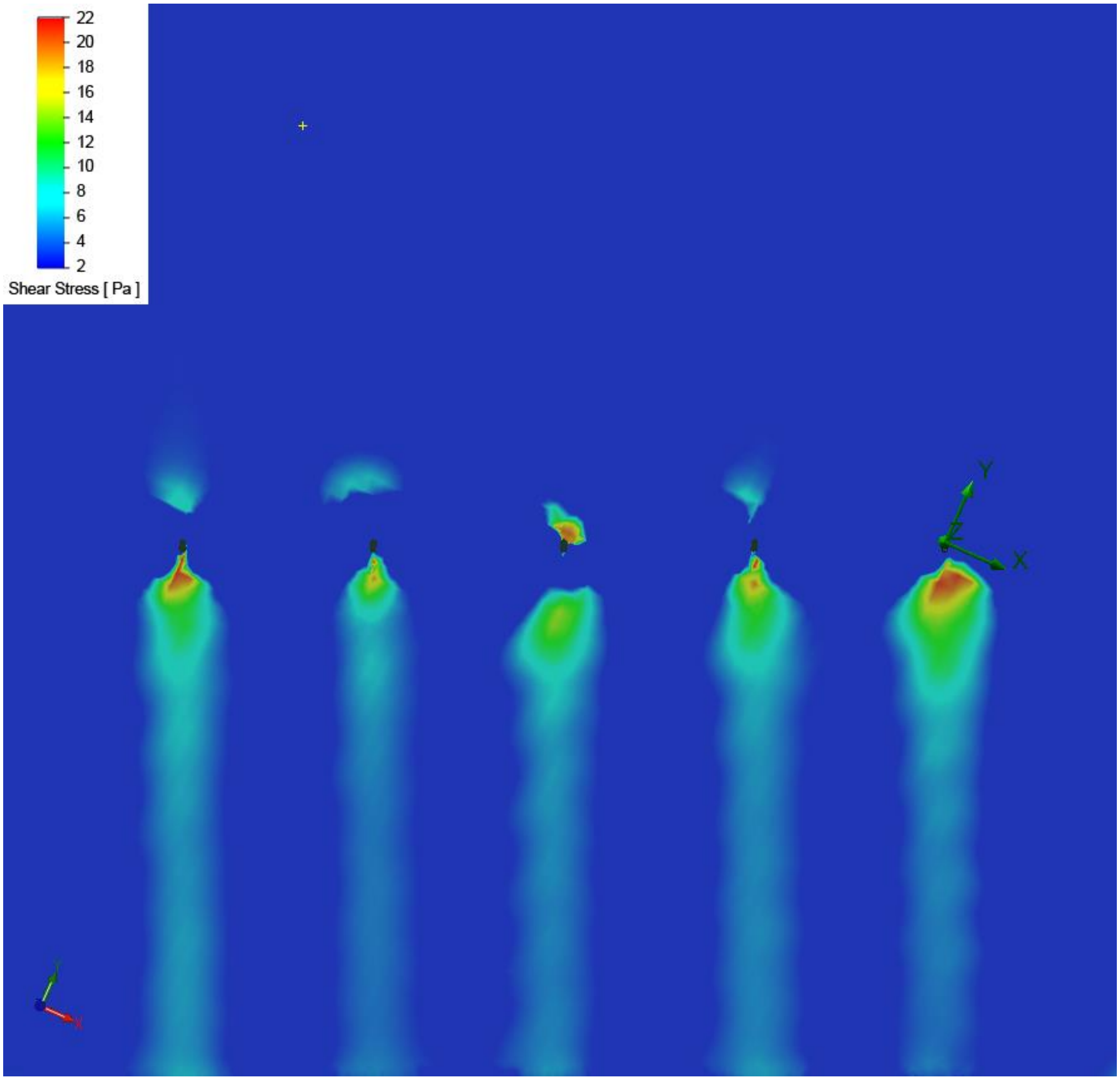

Figure 7:

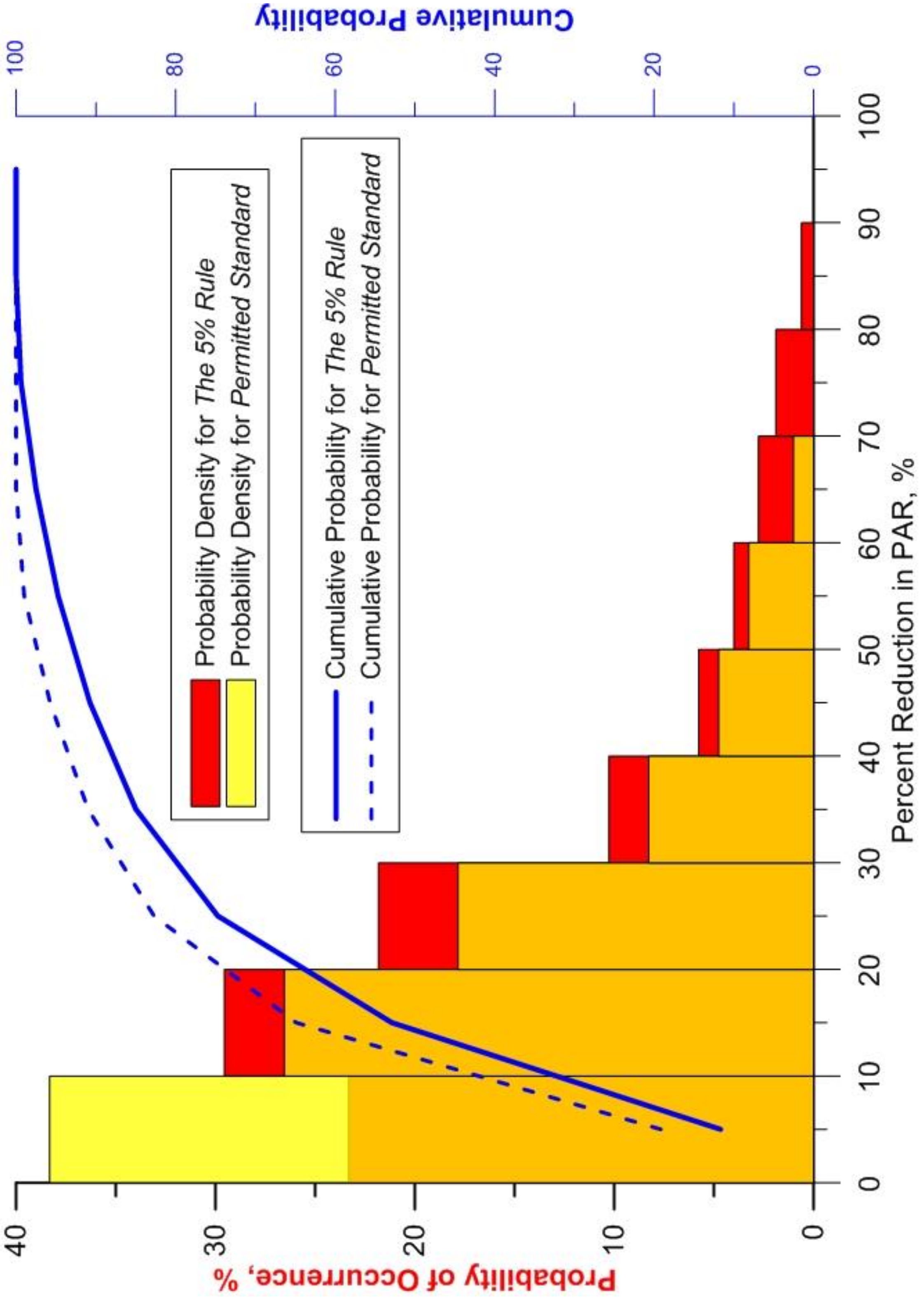
Cumulative Probability
0
20
40
60
80
100
Probability of Occurrence, %
0
10
20
30
40
Percent Reduction in PAR, %
0
10
20
30
40
50
60
70
80
90
100
Probability Density for The 5% Rule
Probability Density for Permitted Standard
Cumulative Probability for The 5% Rule
Cumulative Probability for Permitted Standard

Figure 8