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BROWN AND CALDWELL

May 31, 2002

Mr. Peter Mull
Ms. Lynne Galal
United States Army Corps of Engineers
San Francisco District Office
333 Market Street
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11-22459-503/1

Subject: Final Cost Estimate of Napa Salt Marsh Salinity Reduction and Restoration Alternatives

Dear Mr. Mull and Ms. Galal:

We have finalized our analysis and cost estimate of salinity reduction and restoration alternatives for the Napa Salt Marsh. Our evaluation was performed in accordance with the Scope of Work for Engineering Services included as part of the Award Document authorized by the United States Army Corps of Engineers (ACOE) on March 6, 2002. The draft report below summarizes our results, and it includes three main subsections covering costs associated with salinity reduction alternatives, levee repair and maintenance, and restoration alternatives.

Note that this cost estimate is based on a conceptual design of water control structures and restoration components. Further definition of the concepts described herein will allow for the development of more accurate cost estimates for required facilities.

SUMMARY

Estimated total costs for water control structures associated with salinity reduction alternatives are $50.1 million for Alternative 1 (Napa River and Napa Slough Discharge), $56.6 million for Alternative 2 (San Pablo Bay Discharge), and $21.9 million for Alternative 3 (Napa River Discharge via Levee Breaches). These costs do not include those associated with the delivery of reclaimed water to the site.

Initial levee repair is estimated at $1.6 million and peak annual levee maintenance is estimated at $311,000 per year. Annual maintenance costs will decrease slightly during the first few years of the project as some ponds are converted to tidal marsh and their levees no longer require annual maintenance.

Costs associated with restoration components are described in the final section of this report, and can be used to estimate the costs of various restoration alternatives that are currently under development. A generic restoration alternative with 10,000 feet of starter channels, 25 ditch blocks, 10,000 feet of levee lowering, 25 levee breaches, and 40 acres of sediment addition would cost an estimated $8 million. These costs do not include water control structures associated with managed ponds.

INTRODUCTION

In the early 1990s, the Cargill Salt Company ceased the production of salt and sold 9,850 acres of evaporation ponds and associated lands near the mouth of the Napa River to the State of California. The ACOE, the California Coastal Conservancy (CCC), and the California Department of Fish and Game (DFG) are proposing a salinity reduction and habitat restoration project for the site now known as the Napa Salt Marsh. The purpose of this project is to restore tidal salt marsh and ecologically related habitats to support populations of endangered species, migratory waterfowl, shorebirds, and anadromous and native fish. The long-term goal is to produce a natural, self-sustaining habitat that can adjust to naturally occurring changes in physical processes with minimum on-going intervention.

The study area contains 12 ponds formerly used in the salt production process. This process consisted of taking in Bay water at the southern edge of the pond system, allowing evaporation to occur, and then moving the brine to the next pond in the series for further concentration. Water transfers within the pond system occurred through a combination of pumps, tide gates, valves, siphons, and canals.

Salinity Reduction

Removing salts from the ponds is the first step in the habitat restoration process. Once salinity reduction has been achieved, ponds can be opened up to tidal action or maintained as managed ponds, thus increasing their value as wildlife habitat. Salinity reduction is not currently required for Ponds 1, 1A, 2 and 2A. At the present, these ponds are functioning habitat and have salinity levels near ambient conditions. Salinity reduction is required for Ponds 3, 4, 5, 6, 6A, 7, 7A and 8. Currently, these ponds have salinity levels that either preclude use of the ponds by wildlife, or limit use of the ponds to a very small number of species. Based on Spring 2001 data from DFG, Ponds 3, 6, 6A and 7A range from 30 to 65 parts per thousand (ppt). Ponds 4 and 5 range from 150 to 200 ppt. Ponds 7A and 8 are the most saline ranging from 225 to 325 ppt. Salinity levels in most ponds fluctuate to some extent on a seasonal basis.

Three alternatives have been previously developed by Philip Williams and Associates (PWA) to facilitate salinity reduction. These alternatives require construction of water control and conveyance structures, as well as the breaching of levees.

Restoration Alternatives

Restoration alternatives are currently under development and will be implemented in parallel with salinity reduction. Restoration alternatives split the site into two components: ponds that will remain and be managed as ponds over the long-term (managed ponds), and ponds that will be opened to tidal action and be restored to tidal marsh. To date, four alternatives have been developed. Alternative 1 has roughly equal surface area of managed ponds and restored tidal marsh. Alternative 2 emphasizes tidal marsh while alternative 3 emphasizes managed ponds. Alternative 4 emphasizes tidal marsh and includes structural components within the ponds converted to marsh that will accelerate marsh development. Structural components associated with marsh restoration include starter channels, internal berms, ditch blocks, levee lowering, levee breaching, levee construction, sediment addition, and dredging of existing sloughs.

SALINITY REDUCTION ALTERNATIVES

This section summarizes the facility requirements and costs of water control structures associated with the three salinity reduction alternatives. It includes a brief description of the three salinity alternatives, and describes how we sized various water control structures and how they would typically be constructed. Lastly, it discusses some assumptions behind our cost estimates.

Description of Salinity Reduction Alternatives

Each salinity reduction alternative proposes different pond groupings, intake and discharge locations, and number and type of water control structures. Below we briefly describe each alternative, as well as the size and number of water control structures that will be required. In addition to these large-scale facilities, the following small-scale components are included in most alternatives:

- Check valves to ensure one-way flow through intakes or outlets.
- Manual knife valves to control the flow rate through structures.

- Fish screens on intakes to protect fishery resources.
- Diffusers to enhance dilution of pond water into receiving waters.
- Levee breaches to promote water flow from pond to pond and between ponds and the Napa River.

Salinity Reduction Alternative 1 – Napa River and Napa Slough Discharge. For this alternative, the ponds are divided into three operational groups: Pond 3, Ponds 4/5/6/6A, and Ponds 7/7A/8. Pond 3 and Ponds 4/5/6/6A receive freshwater from the Napa River and/or surrounding sloughs and discharge pond water to the Napa River. Ponds 7/7A/8 all discharge to a common mixing chamber that dilutes bittern from Pond 7. Water from the mixing chamber is then discharged to the Napa Slough. Makeup water for Ponds 7A and 8 come from the Napa Slough. However, for Pond 7, our engineering analysis shows that this is not practical. We have assumed herein that reclaimed water will be used for make-up water to Pond 7. Facility structure requirements for each of the operational groups are outlined below.

Pond 3:

- Nine 52-inch-diameter intakes from the Napa River to the northeast corner of Pond 3.
- Three 48-inch-diameter intakes from Dutchman Slough to the southwestern side of Pond 3.
- Two 52-inch-diameter outfalls to allow flow from Pond 3 into the Napa River.

Ponds 4/5/6/6A:

- Seven 54-inch-diameter intakes from Napa Slough to the north-central section of Pond 5.
- Five 52-inch-diameter intakes from Napa Slough to the north-central section of Pond 6A.
- One 52-inch-diameter siphon to convey flow from Pond 6 to Pond 5.
- Two 48-inch-diameter outfalls from Napa Slough to the southeast section of Pond 4.

Ponds 7/7A/8:

- 800 feet of dredged channel plus three 52-inch-diameter intakes from Napa Slough to the southwest corner of Pond 7A.
- One 42-inch-diameter outlet from Pond 8 to the Pond 8 canal.
- One 42-inch-diameter siphon in the Pond 8 canal to cross the slough.
- Mixing chamber at the site of the existing donut structure with inlets from Ponds 7, 7A, and 8 and an outlet to a canal.
- One 42-inch-diameter outfall from the mixing chamber canal to Napa Slough.

Salinity Reduction Alternative 2 – San Pablo Bay Discharge. Under this alternative, salinity reduction in the ponds is divided into two operational groups: Ponds 3/4/5 and Ponds 7/7A/8/1/2/6/6A. Ponds 3/4/5 are interconnected using levee breeches and siphons. These ponds receive freshwater from the Napa River and Napa Slough and discharge pond water to the Napa River. Ponds 7/7A/8 operate as in Alternative 1, but outflow from the mixing chamber is routed to Pond 6A rather then being discharged to the Napa Slough. Water from Pond 6A then flows through Ponds 6, 2, and 1 and out to San Pablo Bay. The salinity reduction process will occur simultaneously for all pond groups. The main difference from Alternative 1 is the greater reliance on siphons to move water from pond to pond and the fact that no water from the highly saline northern ponds is discharged to the Napa River system. Facility structure requirements for each of the operational groups are outlined below.

Ponds 3/4/5:

- Nine 54-inch-diameter intakes from the Napa River to the northeast corner of Pond 3.
- Three 48-inch-diameter intakes from Dutchman Slough to the southwestern side of Pond 3.
- Eleven 54-inch-diameter intakes from Napa Slough to the north-central section of Pond 5.
- One 48-inch-diameter siphon from Pond 3 to Pond 4.
- Two 52-inch-diameter outfalls to discharge flow from Pond 3 into the Napa River.

Ponds 7/7A/8/1/2/6/6A:

- 800 feet of dredged channel plus seven 54-inch-diameter intakes from Napa Slough to the southwest corner of Pond 7A.
- One 42-inch-diameter outlet from Pond 8 to the Pond 8 canal.
- One 42-inch-diameter siphon in the Pond 8 canal to cross the slough.
- Mixing chamber at the site of the existing donut structure with inlets from Ponds 7, 7A, and 8 and an outlet to a canal.
- One 52-inch-diameter siphon from the Mixing Chamber Canal to Pond 6A.
- Two 54-inch-diameter siphons to connect Pond 6 to Pond 2.
- Two 54-inch-diameter siphons to connect Pond 2 to Pond 1/1A.
- One 72-inch-diameter pipe under Highway 37 (in addition to existing pipeline).

Salinity Reduction Alternative 3 – Discharge to Napa River with Controlled Levee Breaches. For this alternative, salinity reduction in the ponds is divided into three operational groups: Pond 3, Ponds 4/5/6/6A, and Ponds 7/7A/8. Salinity reduction in Pond 3 and in Ponds 4/5/6/6A is achieved by breaching levees on the Napa River. Inflow into Ponds 4/5/6/6A comes from an intake between the Napa Slough to Pond 6A. Facilities for Ponds 7/7A/8 are identical to Alternative 1. Facility structure requirements for each of the operational groups are outlined below.

Ponds 4/5/6/6A:

- Ten 54-inch-diameter intakes from Napa Slough to the north-central section of Pond 6A.
- One 52-inch-diameter siphon to convey flow from Pond 6 to Pond 5.

Ponds 7/7A/8 (same as Alternative 1):

- 800 feet of dredged channel plus three 52-inch-diameter intakes from Napa Slough to the southwest corner of Pond 7A.
- One 42-inch-diameter outlet from Pond 8 to the Pond 8 canal.

- One 42-inch-diameter siphon in the Pond 8 canal to cross the slough.
- Mixing chamber at the site of the existing donut structure with inlets from Ponds 7, 7A, and 8 and an outlet to a canal.
- One 42-inch-diameter outfall from the mixing chamber canal to Napa Slough.

Description of Structures

Salinity reduction alternatives use a combination of water conveyance and control structures including intakes, fish screens, outfalls, diffusers, siphons, mixing chambers, and levee breeches. This section briefly describes these facilities, how they were sized, and how they may be constructed. In addition, we briefly describe potential modifications to the structural assumptions used in the previous development of salinity reduction alternatives by PWA.

Intake Structures

Description. Intake structures consist of a pipe or series of pipes penetrating a levee, and convey water from the river and sloughs into ponds during high tide. Pipes will be made of high-density polyethylene (HDPE). Intake pipes range in length from 300 to 600 feet and have diameters ranging from 48 to 54 inches. The number of pipes per intake ranges from 3 to 11, depending on alternatives and location within the site. Peak capacity of individual intake pipes range from 30 to 55 cubic feet per second (cfs) or 20 to 35 million gallons per day (mgd). Pipes will be fitted with check valve on the pond side of the structures that only open when the elevation of the river or slough is above that of the pond. Check valves will prevent backflow from the pond into the river or slough. Manual knife valves will also be included on all pipes within the levees. Fish screens will be installed on the river/slough side of intakes to protect fishery resources.

Sizing. We sized intake structures to meet peak flow requirements predicted from PWA's hydraulic modeling with the limited available head difference between the pond and the receiving waters. Lengths of pipes were determined from digitized topographical maps of the site. We estimated the effective head available to drive flows as the elevation difference between the pond and the river or slough, corrected for headlosses through fish screen and head required to overcome density differences between inlet and outlet waters. Based on discussions with manufactures, we assumed a headloss across fish screens of 0.5 feet at peak flow. Head to overcome salinity differences were estimated based on salinity modeling results provided by PWA. These values were, in some cases, quite substantial. For example, a 50-ppt difference is equivalent to a head differential of approximately 1 foot. After correcting for fish screens and density differences, effective head driving flows through intake structures ranged from 0.5 to 1.3 feet. We then determined the number and diameter of intakes using the hydraulic model H2ONET, which incorporated associated headlosses including entrance, exit, friction, valve, and bend losses.

Note that the design approach outlined above is conservative. Facilities sized herein may decrease in magnitude with more detailed study, which would aim to optimize the sizing of water control structures.

Construction. Construction of the intakes will be conducted using construction equipment brought to the needed location via levee tops and/or barges. A cofferdam will be constructed using sheetpiles on the pond and river/slough side of the levee. The inner areas of the cofferdam will be dewatered during construction as necessary. The levee will then be excavated and a pipe placed in the trench through the levee. A check valve will be fitted to the pond side of the intake pipe and a manual knife valve will be installed within the levee section of the pipe. The levee will then be back filled and compacted and the cofferdams removed. On the river or slough side of the levee, additional pipe will be installed so that the intake elevation is 3 to 4 feet below lower low tide. In areas where the terrain is above high tide, inlet pipes will be installed in a trench dug out by a clamshell digger. Where the pipe is underwater at high tide, it will be attached to support piles driven by a pile driver. On the river/slough side of the pipe, a fish screen will be attached to a flange on the end of the intake using a crane and divers. The intakes will be placed and sized so as to balance between the need to encroach as little as possible into the navigation channel while keeping structures submerged at low tide.

Fish Screens

Description. Each intake pipe will include a cone-shaped fish screen that rests on top of the inlet at the end of the pipe. The fish screens used in this cost estimate are manufactured by Intake Screens Incorporated of Sacramento, California. The screens are self-cleaning using a brush system that intermittently rotates across the outer surface of the screen. The small submersible hydraulic motor that drives the brushes will be powered by a solar panel system. The frequency of cleaning will be set manually to meet field conditions. Screens are made of stainless steel and epoxy coated components that are cathodically protected. Protective piles are installed around the screen to protect them from large floating debris. Ducks Unlimited recently installed a similar screen system on an intake from the Napa River to Pond 8.

Screens for the salinity reduction alternatives must be very large in order to achieve acceptable approach velocities at peak flow. They range in height from approximately 5 to 6 feet and diameter from 16 to 18 feet. Flow rates through fish screens range from 35 to 50 cfs (20 to 35 mgd). To our knowledge, fish screens of this size have not been installed in the local area. Thus, while we did obtain a price quote for these large fish screens from a local company, the cost estimate we developed is preliminary in nature.

Use of fish screens results in substantial headloss (around 0.5 feet) relative to the tidal head (around 2 feet). As a result, facilities with fish screens require more inlets than facilities without fish screens. For example, if fish screens were not used on the inlet from Napa Slough to Pond 3 in Salinity Reduction Alternative 1, the number of 54-inch-diameter inlets would decrease from nine to seven. This would result in a total cost savings of approximately $6.6 million for the fish screens and $1.8 million for the smaller number of inlets.

Sizing. Fish of concern for this project include the Delta Smelt, salmonid smolts, and the Sacramento Splittail. Based on the limiting species, the Delta Smelt, the National Marine Fisheries Service and the State of California Department of Fish and Game require that fish screens be designed with a maximum approach velocity of 0.2 feet per second (fps) and a screen gap of approximately 3/32 inch. We sized all screens to meet these constraints.

Construction. Fish screens will be lowered onto the inlet at the end of an intake structure using a crane and dive crew. The screens will be supported by a number of piles and additional piles will be installed around the screens to protect them from large, floating debris.

Outfall Structures

Description. Outfalls are required for all alternatives to discharge water from ponds to the Napa River and sloughs during low tide. Each outfall runs from a pond or canal, through an external levee and straight out into the receiving water. A manual knife valve is included on the outfall within the levee so that flow through the outfall can be controlled. Outfalls will be constructed of HDPE. Depending on the alternative, outfalls range in length from 300 to 1,000 feet and 42 to 52 inches in diameter and include one or two outfall pipes. Peak capacity through each outfall ranges from 55 to 85 cfs (35 to 55 mgd). The end of each outfall includes a diffuser to enhance the dilution of saline pond water into receiving waters. Diffusers are the same diameter and material as the outfall and are roughly 50 to 100 feet in length. Each diffuser includes eight to ten 6- to 10-inch-diameter ports along its length and one

10- to 14-inch-diameter port at its end. The ports are fitted with flexible neoprene check valves that open only when tidal elevation is lower than pond elevation. Diffusers are anticipated to border navigational channels within the Napa River and will be identified with appropriate signs and lighting.

Sizing. We sized outfalls using DIFF$$, Brown and Caldwell's proprietary diffuser hydraulics program that evaluates the flow distribution along an outfall. Outfalls were designed to meet peak flow requirements predicted from PWA hydraulic modeling based on head difference between the pond and the receiving waters. Maximum head at low tide was approximately 6 to 6.5 feet. Ports were sized to minimize headlosses while maximizing port discharge velocities. Higher velocities lead to greater dilution, but also higher headloss. We estimated peak port discharge velocities generally of about 12 fps.

We also performed dilution modeling of the diffusers using UM, an integral model that solves the equations of conservation of mass and energy as a plume moves away from a diffuser. UM is part of PLUMES, a computer interface that includes United States Environmental Protection Agency dilution models for effluent discharge. Dilution modeling confirms that diffusers achieve a dilution factor of around 1:10 when adequate jet velocity out of the ports was maintained. See Brown and Caldwell's Diffuser and Fish Screens Report dated May 15, 2002, for further details on dilution modeling results.

Construction. Outfalls are constructed in a similar fashion to intakes.

Siphons

Description. Siphons are required in a number of salinity reduction alternatives to move water from one pond to another under sloughs. A number of old siphons that were used during salt production are currently in place. However, the condition of the current siphons and their remaining useful life is somewhat uncertain. As a result, we have assumed that new siphons will be required, and that all siphons (exclude that associated with Pond 8, which will have flow controlled at the pond outlet) will be installed with manually controlled knife valves. Siphons at the site will range in length from 250 to 350 feet and range in diameter from 42 to 54 inches. All siphons will be made of HDPE and flows through siphons range from 12 to 47 cfs (8 to 30 mgd).

Sizing. We sized siphons to meet peak flow requirements predicted from PWA hydraulic modeling with the limited head difference between the ponds (0.1 to 0.6 feet). Lengths of siphons were determined from digitized topographical maps of the site. We then determined the diameter of siphons using the hydraulic model H2ONET which incorporated associated head losses including entrance, exit, friction, valve and bend losses.

Construction. Construction of the siphons will be conducted using construction equipment brought to the needed location via levee tops and/or barges. Cofferdams will first be constructed using sheetpiles on the pond side of the levee on both ponds. The levees between the ponds and the slough will be excavated. A trench will then be excavated with a clamshell dredge across the slough from one levee breach to another. A gravel bed will be placed in the trench and the siphon will be placed on to the bed using divers and a crane. A manual knife valve will be installed on the siphon within one of the levees. Once the siphon and valve are in place, the trench along the bottom of the slough and the levee at each pond will be backfilled. After backfilling is complete, the cofferdams will be removed.

Mixing Chamber

Description. Currently, a round, levee-enclosed structure called a “donut” connects flows from northern Ponds 7, 7A, and 8. For the salinity reduction alternatives, the existing donut structure will be used as a mixing chamber to dilute the highly saline water from Pond 7 with less saline water from Ponds 8 and 7A, and perhaps reclaimed water. To enhance turbulent mixing of the high-density brine with other inflows, new inlet structures from Ponds 7 and 7A will discharge into a 25-foot-diameter inner mixing chamber. Existing inlets that carry flow from Pond 8 will be extended to meet the inner mixing chamber. The mixed flow from the inner chamber will flow up and out into the outer mixing chamber area. It will then flow through outlet structures to a canal and either be discharged to the Napa Slough (Alternatives 1 and 3) or to Pond 6A (Alternative 2). All inlet and outlet structures will be made of HDPE, and all will have manual knife valves within the levee (excluding inlets from Pond 8, which will be controlled at the pond). Based on salinity alternatives developed to date, the mixing chamber is expected to meet a specific dilution ratio of Pond 7 inflow to total inflow from Ponds 7, 7A, 8 and reclaimed water to ensure adequate dilution of Pond 7 bittern prior to discharge to receiving waters.

Sizing. We sized inlet and outlet structures between the ponds and the mixing chamber to meet peak flow requirements predicted from PWA hydraulic modeling with the limited head difference between the ponds and the chamber, and the chamber and the outlet channel. Lengths of inlet structures were determined from a site visit. We then determined the diameter of inlets and outlets using the hydraulic model H2ONET, which incorporated associated headlosses including entrance, exit, friction, and valve losses.

Construction. Installation of inlets and outlets through levees will be similar to the levee penetration scenario described for outlet structures. The inner mixing chamber will be constructed of concrete. Two sets of sheetpiles will be installed in a rough circle. Holes will then be cut in the sheet pile and inlet pipes will be extended into the inner-mixing chamber. Sheetpiles will then also be cut to the appropriate height so that they are just below the water elevation. Concrete will be poured between the sheetpiles after inlet pipes have been positioned through the sheetpiles.

Pipeline under Highway 37

Description. Under salinity reduction Alternative 2, pond water is discharged from Pond 1 to San Pablo Bay via an existing 72-inch-diameter (63-inch-inner-diameter) pipeline and an additional new outlet. This new outlet pipeline is required to pass under Highway 37 to a discharge channel connected to the Bay. The outlet will be made of reinforced concrete and a knife valve will be installed on the pond side of the pipe.

Sizing. We sized the Pond 2 outlet to meet peak flow requirements predicted from PWA hydraulic modeling based on the head difference between Pond 2 and the Bay. Lengths of siphons were determined from digitized topographical maps of the site. We then determined the diameter of inlet, taking into account the capacity of the existing 63-inch outlet, using the hydraulic model H2ONET, which incorporated associated headlosses including entrance, exit, friction, and valve losses.

Construction. The pipeline will be installed using bore-and-jack trenchless construction methods. A geotechnical investigation will first be conducted to confirm that the site is suitable for construction. Cofferdams will be constructed on both the jacking side (Pond 1) and receiving side (the drainage cannel to San Pablo Bay) of the site. The areas will be dewatered and jacking and receiving pits will be excavated. A concrete base will be constructed in the receiving pit and thrust piles will be driven to support jacking. Once pipe installation is completed, a knife valve will be installed on the pond side of the pipe, along with a pile-supported walkway to access the valve.

Internal and External Levee Breaches

Interior and exterior levee breaches would be created using explosives. Typically, explosives are packed into PVC tubes that are drilled into the levee. The quantity of explosives is adjusted in proportion to the volume of levee material. The blast disperses the levee material over a wide area, so no soil movement is required. The flow of water through the levee and subsequent tidal action then opens the levee beyond the size of the initial breech. DFG staff have previously conducted a number of similar levee breaches at the site.

Structural Modifications

During our cost estimate, we determined that there were a handful of structural assumptions that we could modify to allow for more economical construction. These are outlined below.

Pond 5 Inlet from Napa Slough. We moved the inlet roughly 2,500 feet to northwest. This decreased the length of inlet pipes from 2,200 to 500 feet. In addition, deeper channel morphology in the Napa Slough at this point was more was more conducive to fish screen operations.

Pond 7 Intake from Napa Slough. Perhaps the most significant result of our hydraulic modeling was the fact that there is not enough tidal head to overcome the extreme density gradient between Pond 7 (> 300 ppt salinity) and freshwater in the Napa Slough. Even at high tide, the dense brine from Pond 7 would tend to flow out an open pipe and into the slough. The same phenomena may occur at times in Ponds 4 and 5, which can reach salinity up to 150 to 200 ppt. An additional potential advantage of not installing intakes between Pond 7 and the Napa Slough is a decreased chance for an accidental release of bittern to the slough.

As a result of the above constraints, we have assumed that reclaimed water will be used as makeup water for Pond 7. We have not included any costs with respect to the importation of reclaimed water to the site. For Alternatives 1 and 3, the amount of makeup water required by Pond 7 is approximately 800 acre-feet per year (afy). This is based on evaporation losses of 550 afy and an average flow from the pond into the mixing chamber predicted by PWA hydraulic modeling (250 afy). Makeup water needed for Alternative 2 is 2,400 afy (550 afy plus 1,800 afy).

Cost Estimate for Salinity Reduction Alternatives

Tables 1, 2 and 3 summarize costs associated with the three salinity reduction alternatives. Total estimated costs for Alternatives 1, 2 and 3 are $52.8 million, $56.6 million, and $21.9 million, respectively. Note that we have split out costs associated with fish screens and control valves so that you can evaluate the impact of these structures on total project costs. Below we briefly discuss a number of assumptions that we developed to estimate costs associated with the salinity reduction alternatives.

TABLE 1
Napa Salt Marsh Restoration Project - Preliminary Facility Sizing and Cost Estimates
Alternative 1: Napa River & Napa Slough Discharge

	BASE STRUCTURE					FISH SCREENS		KNIFE VALVES		
Location	Structure Type	Structure length, ft	Number of units	Diameter of units, inches	Base cost, 1,000 dollars	Number of units	Cost, 1,000 dollars	Size and number of valves	Cost, 1,000 dollars	**Total cost, 1,000 dollars**
POND 3										
Napa River to Pond 3	Intake with fish screens	600	9	54	$2,279	9	$3,931	9 @ 54"	$826	$7,036
Dutchman Slough to Pond 3	Intake with fish screens	300	3	48	$503	3	$1,310	3 @ 48"	$210	$2,023
Pond 3 to Napa River	Outfall with diffuser	1,100	2	52	$952	NA	$0	2 @ 52"	$181	$1,133
Pond 3 to Napa River & Slough	External Levee Breach	100	5	NA	$25	NA	$0	NA	$0	$25
PONDS 4/5/6/6A										
Napa Slough to Pond 6A	Intake with fish screens	250	5	52	$697	5	$2,184	5 @ 52"	$437	$3,318
Pond 6A to Pond 6	Internal Levee Breach	100	4	NA	$14	NA	$0	NA	$0	$14
Pond 6 to Pond 5	Siphon	250	1	52	$157	NA	$0	1 @ 52"	$87	$244
Napa Slough to Pond 5	Intake with fish screens	500	7	54	$1,895	7	$3,058	7 @ 54"	$643	$5,596
Pond 5 to Pond 4	Internal Levee Breach	100	4	NA	$14	NA	$0	NA	$0	$14
Pond 4 to China Slough	External Levee Breach	100	2	NA	$10	NA	$0	NA	$0	$10
Pond 4 to Napa River	Outfall with diffuser	1,100	2	48	$895	NA	$0	2 @ 48"	$140	$1,035
PONDS 7/7A/8										
Napa Slough to Pond 7A	Channel & Intake with fish screens	500	3	52	$1,554	3	$1,310	3 @ 52"	$261	$3,125
Pond 8 to Pond 8 Canal	Outlet	200	1	42	$47	NA	$0	1 @ 42"	$91	$138
Pond 8 Canal to Mixing Chamber	Siphon	350	1	42	$147	NA	$0	NA	$0	$147
Mixing Chamber with Inlets and Outlets	Mixing Chamber	NA	NA	NA	$229	NA	$0	1 @ 16", 4 @ 48"	$379	$608
Mix Chamber Outlet Canal to Napa Slough	Outfall with diffuser	300	1	42	$150	NA	$0	1 @ 42"	$90	$240
SUB-TOTAL 1					$9,568		$11,794		$3,345	$24,707
INDIRECT COSTS (15% of Base Cost)					$1,435		$0		$0	$1,435
MOBILIZATION (11% of Base Cost)					$1,210		$0		$0	$1,210
OVERHEAD, PROFIT AND BOND (17%)					$2,076		$2,005		$569	$4,650
SUB-TOTAL 2					$14,290		$13,799		$3,914	$32,002
NPV OF REPLACEMENT COSTS										
Ponds 7/7A, 8 and Mixing Chamber	Valve Replacement				$0		$0		$480	$480
SUB-TOTAL 3					$14,290		$13,799		$4,394	$32,482
CONTINGENCY (40%, 25% for fish screens and knife valves)					$5,716		$3,450		$1,098	$10,264
TOTAL CONSTRUCTION COST					$20,006		$17,248		$5,492	$42,746
ENGINEERING, LEGAL AND ADMINISTRATION (20%, 15% for fish screens and knife valves)					$4,001		$2,587		$824	$7,412
TOTAL ALTERNATIVES COST (2002 dollars)					**$24,000**		**$19,800**		**$6,300**	**$50,100**

TABLE 2

Napa Salt Marsh Restoration Project - Preliminary Facility Sizing and Cost Estimates

Alternative 2: San Pablo Bay Discharge

	BASE STRUCTURE					FISH SCREENS		KNIFE VALVES		
Location	Structure Type	Structure length, ft	Number of units	Diameter of units, inches	Base cost, 1,000 dollars	Number of units	Cost, 1,000 dollars	Size and number of valves	Cost, 1,000 dollars	**Total cost, 1,000 dollars**
PONDS 3/4/5										
Napa Slough to Pond 5	Intake with fish screens	500	11	54	$2,978	11	$4,805	11 @ 54"	$1,010	$8,793
Pond 5 to Pond 4	Internal Levee Breach	100	4	NA	$14	NA	$0	NA	$0	$14
Pond 3 to Pond 4	Siphon	350	1	48	$175	NA	$0	1 @ 48"	$70	$245
Napa River to Pond 3	Intake with fish screens	600	9	54	$2,279	9	$3,931	9 @ 54"	$826	$7,036
Dutchman Slough to Pond 3	Intake with fish screens	300	3	48	$545	3	$1,310	3 @ 48"	$210	$2,065
Pond 3 to Napa River	Outfall with diffuser	1,100	2	52	$952	NA	$0	2 @ 52"	$181	$1,133
PONDS 7/7A/8										
Napa Slough to Pond 7A	Channel & Intake with fish screens	500	7	54	$2,135	7	$3,058	7 @ 54"	$643	$5,836
Pond 8 to Pond 8 Canal	Outlet	200	1	42	$47	NA	$0	1 @ 42"	$91	$138
Pond 8 Canal to Mixing Chamber	Siphon	350	1	42	$147	NA	$0	NA	$0	$147
Mixing Chamber with Inlets and Outlets	Mixing Chamber	NA	NA	NA	$238	NA	$0	1 @ 32", 4 @ 48"	$394	$632
Mix Chamber Outlet Canal to Pond 6A	Siphon	350	1	52	$220	NA	$0	1 @ 52"	$91	$311
PONDS 1/2/6/6A										
Pond 6A to Pond 6	Internal Levee Breach	100	4	NA	$14	NA	$0	NA	$0	$14
Pond 6 to Pond 2	Siphon	300	2	54	$333	NA	$0	2 @ 54"	$186	$519
Pond 2 to Pond 1	Siphon	300	2	54	$333	NA	$0	2 @ 54"	$186	$519
Pond 1 to San Pablo Bay	Inlet/Outlet	200	1	72	$629	NA	$0	2 @ 72"	$208	$837
SUB-TOTAL 1					$11,039		$13,104		$4,096	$28,239
INDIRECT COSTS (15% of Base Cost)					$1,656		$0		$0	$1,656
MOBILIZATION (11% of Base Cost)					$1,396		$0		$0	$1,396
OVERHEAD, PROFIT AND BOND (17%)					$2,396		$2,228		$696	$5,320
SUB-TOTAL 2					$16,487		$15,332		$4,792	$36,611
CONTINGENCY (40%, 25% for fish screens and knife valves)					$6,595		$3,833		$1,198	$11,626
TOTAL CONSTRUCTION COST					$23,082		$19,165		$5,990	$48,237
ENGINEERING, LEGAL AND ADMINISTRATION (20%, 15% for fish screens and knife valves)					$4,616		$2,875		$899	$8,390
TOTAL ALTERNATIVES COST (2002 dollars)					**$27,700**		**$22,000**		**$6,900**	**$56,600**

TABLE 3

Napa Salt Marsh Restoration Project - Preliminary Facility Sizing and Cost Estimates

Alternative 3: Napa River Discharge with Controlled Levee Breaches

	BASE STRUCTURE					FISH SCREENS		KNIFE VALVES		
Location	Structure Type	Structure length, ft	Number of units	Diameter of units, inches	Base cost, 1,000 dollars	Number of units	Cost, 1,000 dollars	Size and number of valves	Cost, 1,000 dollars	**Total cost, 1,000 dollars**
POND 3										
Pond 3 to Napa River	External Levee Breach	100	1	NA	$5	NA	$0	NA	$0	$5
PONDS 4/5/6/6A										$0
Napa Slough to Pond 6A	Intake with fish screens	250	10	54	$1,480	10	$4,374	10 @ 54"	$369	$6,223
Pond 6A to Pond 6	Internal Levee Breach	100	4	NA	$14	NA	$0	NA	$0	$14
Pond 6 to Pond 5	Siphon	250	1	52	$157	NA	$0	1 @ 52"	$87	$244
Pond 5 to Pond 4	Internal Levee Breach	100	4	NA	$14	NA	$0	NA	$0	$14
Pond 4 to Napa River	External Levee Breach	100	1	NA	$5	NA	$0	NA	$0	$5
PONDS 7/7A/8										
Napa Slough to Pond 7A	Channel & Intake with fish screens	500	3	52	$1,554	3	$1,310	3 @ 52"	$261	$3,125
Pond 8 to Pond 8 Canal	Outlet	200	1	42	$47	NA	$0	1 @ 42"	$91	$138
Pond 8 Canal to Mixing Chamber	Siphon	350	1	42	$147	NA	$0	NA	$0	$147
Mixing Chamber with Inlets and Outlets	Mixing Chamber	NA	NA	NA	$229	NA	$0	1 @ 16", 4 @ 48"	$379	$608
Mix Chamber Outlet Canal to Napa Slough	Outfall with diffuser	300	1	42	$150	NA	$0	1 @ 42"	$90	$240
SUB-TOTAL 1					$3,802		$5,684		$1,277	$10,763
INDIRECT COSTS (15% of Base Cost)					$570		$0		$0	$570
MOBILIZATION (11% of Base Cost)					$481		$0		$0	$481
OVERHEAD, PROFIT AND BOND (17%)					$825		$966		$217	$2,008
SUB-TOTAL 2					$5,678		$6,651		$1,494	$13,823
NPV OF REPLACEMENT COSTS										
Ponds 7/7A, 8 and Mixing Chamber	Valve Replacement				$0		$0		$480	$480
SUB-TOTAL 3					$5,678		$6,651		$1,974	$14,303
CONTINGENCY (40%, 25% for fish screens and knife valves)					$2,271		$1,663		$494	$4,428
TOTAL CONSTRUCTION COST					$7,950		$8,313		$2,468	$18,731
ENGINEERING, LEGAL AND ADMINISTRATION (20%, 15% for fish screens and knife valves)					$1,590		$1,247		$370	$3,207
TOTAL ALTERNATIVES COST (2002 dollars)					**$9,500**		**$9,600**		**$2,800**	**$21,900**

Construction Methods. Except for valves on the intakes from Pond 1 to San Pablo Bay and on the existing lines between the Pond 8 channel and the mixing chamber, all knife gates will be installed into connecting pipes within the levee on land. We assume that contractors will have a staging area available in the vicinity of Pond 8, and that all excavation spoils from the project can be spread on adjacent levee banks as part of maintenance operations or in the borrow ditches of ponds. Fish screens in rivers and sloughs will be installed in one continuous operation after the completion of most other construction activities.

Unit Costs. Check valve, knife valve and fish screen costs are based on quotes from manufacturers. Breaching costs were based on cost estimates developed by the DFG assuming that DFG staff and explosives experts would be available to perform required breaching. Where work is dependent on tides (e.g., work in sloughs or on the Napa River) costs include a 100 percent markup on standard labor as required by union rules. This accounts for workers having variable starting and finishing times that vary on a daily basis. In addition, a 50 percent markdown on standard equipment costs is included since equipment will not be used during low tide conditions.

Replacement Costs. For Alternatives 1 and 3, we assumed 50 percent valve replacement in the northern pond system (Ponds 7/7A and 8), which is expected to run for a number of decades. No valve replacement costs were included for Alternative 2 since valves are expected to last the life of the 20-year project.

Added Project Costs. A number of additional standard costs were added as a fraction of the base costs. These include:

- 11 percent for mobilization.
- 15 percent for indirect costs.
- 17 percent for overhead, profit and bond costs associated with project construction.
- 40 percent contingency to account for a number of uncertainties associated with the project.
- 20 percent for engineering, legal and administrative fees to cover the design and construction of the project.

Costs not Included. Our cost estimate does not include costs associated with water quality monitoring, restoration monitoring, additional land acquisition, project permitting, or reclaimed water delivery to the site.

Facility Decommissioning. Some existing facilities (e.g., unused siphons) and new facilities associated with salinity reduction (inlets and outlets in ponds converted to tidal marsh) may need to be decommissioned early on in the project. Many of these facilities would be left in place and plugged, and some piping and most check valves and knife valves would be salvaged. We anticipate that fees collected through the sale of salvageable materials will roughly offset costs associated with decommissioning. Thus, we have not included a detailed evaluation of structure decommissioning in this cost estimate.

LEVEE REPAIR AND MAINTENANCE

Levee repair includes an initial effort to upgrade existing levees while long-term maintenance entails ongoing efforts to maintain levees in good condition during both salinity reduction and restoration. Cost estimates associated with levee maintenance and repair are based on a number of assumptions including:

- Required footage of levee repair based on reports from the DFG.
- As noted by DFG, the dimensions of pond levees throughout the site are variable, as are the volumes associated with levee repair. Herein, we have assumed that the volumes required for levee repair and maintenance are equal to 2.5 feet of sediment spread over 30 feet of levee width. These values are based on discussions with DFG and knowledgeable contractors. This is equivalent to 2.8 cubic yards per foot of levee that requires repair or maintenance.
- Long-term maintenance requires repair of 10 percent of the length of levees per year. This value is between those cited by knowledgeable contractors (every 5 to 7 years) and that quoted in the recent report “South Bay Salt Pond Restoration” by Siegel and Bachand. They state that 10 miles of a total 220 miles of levee are maintained each year at the South Bay ponds (Section 14.1.2).
- Sediment from on site is used for levee repair and maintenance.
- Repair base unit costs assume the use of a barge mounted clamshell dredge for half of the repairs and a land-based hydraulic excavator for the other half of the repairs. It also includes the cost of spreading and dressing using a front-end loader.

- Maintenance base unit costs assume the use of a land-based hydraulic excavator and spreading and dressing using a front-end loader.

- Costs include fees for mobilization (5.5 percent for land accessible or 11 percent for non-land accessible), indirect costs (15 percent), overhead and profit (17 percent), and contingency (40 percent).

Cost estimates of levee maintenance are presented in Table 4 on a per pond basis. Initial repair is estimated at $1.6 million ($26.64 per foot of levee) and annual maintenance is around $200,000 to $300,000 per year ($12.66 per foot of levee). Note that these costs per foot of levee are in the range of levee maintenance costs cited in the "South Bay Salt Pond Restoration" report ($10 to $27 per foot). Maintenance costs are also similar to DFG and contractor estimates of $7 to $10 per foot.

Depending on the scope and timing of a given restoration alternative, both repair and maintenance costs can be estimated for applicable ponds and summed to evaluate a given salinity reduction and/or restoration alternative. This is shown in Table 4 for implementation of Salinity Reduction Alternative 1 and draft Restoration Alternative 1. In Year 1, all ponds would require repairs at a total estimated cost of $1.6 million. In the second year, all ponds excluding Pond 3, which would presumably be breached in Year 2, and Pond 2A, which is already open to tidal action, would need maintenance at a cost of $260,000 per year. After Year 3, Ponds 4/5 would be open to tidal action, and levee maintenance costs would drop to $190,000 per year. Maintenance costs would remain at this level for the remainder of the project with ongoing levee maintenance being required for Ponds 1, 1A, 2, 6/6A, 7, 7A and 8. Costs reported herein are in 2002 dollars. These costs can be adjusted to develop the net present value of various combinations of salinity reduction and restoration alternatives.

Some cost savings may be achieved if levee repair is coupled with starter channel construction (see Restoration Alternative section). Rather than sediment from existing borrow ditches, sediment from the starter channels could be used to repair levees. Starter channels have only been proposed in Ponds 3, 4/5, and 6/6A, so cost savings could only be realized in these ponds. Sediment from 1 linear foot of starter channel is roughly equivalent to 4 linear feet of levee repair. Thus, assuming starter channels on the order of 3,000 feet per pond, starter channel sediment volumes would be adequate for repair of all levees in Pond 3 (12,380 feet of repair), Ponds 4/5 (1,210 feet of repair), and Ponds 6/6A (4,180 feet of repair). Note that for Pond 3, if sediment is used for levee repair, none would be available for berm construction.

TABLE 4
Napa Salt Marsh Restoration Project - Levee Repair and Maintenance Costs

		Initial Repair[1]				Long-term Maintenance[2]		Annual cost of long-term maintenance assuming implementation of Salinity Reduction and Restoration Alternatives 1, dollars per year		
Pond	Levee perimeter, feet[3]	Percent of levee footage		Total Footage, feet	Cost, dollars	Footage per year	Annual cost, dollars per year			
		Pass 1	Pass 2					Year 1	Year 2	Year 3+
1	17,750	30%	30%	10,650	$284,500	1,780	$22,700	Repair	$22,700	$22,700
1A	25,250	15%	0%	3,790	$101,300	2,530	$32,300	Repair	$32,300	$32,300
2	30,250	40%	40%	24,200	$646,600	3,030	$38,700	Repair	$38,700	$38,700
3	41,250	15%	15%	12,380	$330,800	4,130	$52,800	Repair	$0	$0
4	33,750	0%	0%	0	$0	3,380	$43,200	-	$43,200	$0
5	24,250	5%	0%	1,210	$32,300	2,430	$31,000	Repair	$31,000	$0
6	18,500	5%	0%	930	$24,800	1,850	$23,600	Repair	$23,600	$23,600
6A	16,250	10%	10%	3,250	$86,800	1,630	$20,800	Repair	$20,800	$20,800
7	12,375	15%	0%	1,860	$47,200	1,240	$15,100	Repair	$15,100	$15,100
7A	15,625	5%	0%	780	$19,800	1,560	$18,900	Repair	$18,900	$18,900
8	10,000	10%	0%	1,000	$25,400	1,000	$12,100	Repair	$12,100	$12,100
Total for all Ponds				60,050	$1,600,000	24,560	$311,000	$1,600,000	$258,000	$184,000
Unit cost, dollars per foot					$26.64		$12.66			

[1] Repair assumes the placement of soil 2.5 feet deep over 30 feet of levee width. Repair costs are based on base cost of $4.60 per cubic yard. This is a composite unit costs assuming use of a barge mounted clamshell dredge for half of the repairs, a land-based hydraulic excavator for half the repairs, and spreading/dressing using a front-end loader on levee. Costs include mobilization (land accessable = 5.5%, non-land accessable = 11%), indirect costs (15%), overhead and profit (17%) and contingency (40%).

[2] Maintenance assumes the placement of soil 2.5 feet deep over 30 feet of levee width. Costs assume 10% per year levee maintenance. Maitenance costs are based on base cost of $2.20 per cubic yard for a land-based hydraulic excavator and spreading/dressing using a front-end loader on levee. Costs include mobilization (land accessable = 5.5%, non-land accessable = 11%), indirect costs (15%), overhead and profit (17%) and contingency (40%).

[3] Repair footage is based on information from DFG (e-mail from Huffman to von Rosenberg, 4/18/02).

RESTORATION ALTERNATIVES

Costs and production rates associated with components for the restoration alternatives are summarized in Table 5, and detailed costs are shown in Table 6. Restoration components include starter channels, ditch blocks, levee lowering, levee breaching, levee construction, sediment addition, and dredging of existing sloughs. Unit costs from Table 5 can be used to estimate the total cost of various restoration alternatives. For example, a restoration alternative with 10,000 feet of starter channels (assuming barge-mounted hydraulic dredging), 25 ditch blocks, 10,000 feet of levee lowering (in addition to that associated with each ditch block), 25 enhanced levee breaches, and 40 acres of sediment addition would cost an estimated $8 million (Table 7). Unit costs include supporting costs (mobilization, indirect costs, overhead and profit, and contingency) as a fraction of a base cost. Those costs exclude costs of water control structures for managed ponds managed as ponds (discussed below), levee maintenance (discussed previously), and restoration monitoring (costs being developed by GAIA with input from PWA).

Table 7. Estimated Costs of Marsh Components of Generic Restoration Alternative

Structure	Unit cost, dollars	Number of units	Cost, $1,000
Starter Channel (hydraulic excavator)	260 per foot	10,000	2,600
Ditch Block	47,700 per ditch block	25	1,200
Levee Lowering	80 per foot	10,000	800
Enhanced Levee Breach	42,800 per levee breach	25	1,100
Sediment Addition	52,200 per acre	40	2,100
Total			7,800

One of the major assumptions associated with the costs developed herein is that access to the site is not dependent on the tides. We assume that access would be achieved through the installation of a temporary floating dock from the levee into the Napa River or sloughs to each pond segment (Pond 3, Ponds 4/5, Ponds 6/6A). This approach allows work crews to access and exit the site during standard working hours and reduces tidal-based labor rates. Costs associated with a floating dock are included in the contingency.

TABLE 5

Napa Salt Marsh Restoration Project - Summary of Restoration Costs and Production Rates

Restoration Component	Excavation production rate, cubic yards per day	Production rate	Estimated unit cost of component, dollars[1]
Starter Channel			
Dynamic Excavation	700	64 ft/day	$180 per foot
Land-based Hydraulic Excavator[2]	1040	64 ft/day	$150 per foot
Land-based Dragline	520	47 ft/day	$120 per foot
Barge-based Hydraulic Excavator	460	42 ft/day	$260 per foot
Ditch Block	1040	6 days/block	$47,700 per ditch block
Levee Lowering	1040	110 ft/day	$80 per foot
Enhanced Levee Breach via Blasting	250	6 days/breach	$42,800 per levee breach
Levee Construction with Clam Shell Excavator	340	31 ft/day	$290 per foot
Sediment Addition using Hydraulic Suction Dredge	460	4 days/acre	$52,200 per acre
Dredging of Existing Sloughs using Hydraulic Suction Dredge	460	460 cy/day	$32 per cubic yard

[1] Unit costs include 40% contingency and 20% engineering/legal/administration cost factors.

[2] Effective production rate is around 700 cubic yards per day because of some double-handling of sediment.

TABLE 6
Napa Salt Marsh Restoration Project - Restoration Alternatives Component Costs

	Starter Channels (Cost per 1,000 ft of channel)									
		Land-based Excavation								
Cost	Dynamic excavation[1]	Hydraulic excavator	Dragline	Barge-mounted hydraulic dredge	Ditch block, dollars per block	Levee lowering, dollars per 1,000 ft	Enhanced levee breach, dollars per breach[1]	Levee construction, dollars per 1,000 ft	Sediment addition, dollars per acre	Dredging existing sloughs, dollars per 1,000 cubic yards
Base Unit Cost (dollars per cubic yard)	NA	$3.60	$4.40	$9.40	$3.40	$3.40	NA	$10.50	$12.90	$12.90
Base Cost	$65,720	$59,940	$48,840	$104,340	$19,040	$32,300	$15,500	$116,750	$20,808	$12,900
Indirect Costs (15%)	$9,860	$8,990	$7,330	$15,650	$2,860	$4,850	$2,330	$17,510	$3,120	$1,940
Mobilization (11%)	$16,630	$7,580	$6,180	$13,200	$2,410	$4,090	$3,920	$14,770	$2,630	$1,630
Overhead & Profit (17%)	$15,680	$13,010	$10,600	$22,640	$4,130	$7,010	$3,700	$25,340	$4,510	$2,800
Sub-Total	**$107,900**	**$89,500**	**$73,000**	**$155,800**	**$28,400**	**$48,300**	**$25,500**	**$174,400**	**$31,100**	**$19,300**
Contingency (40%)	$43,160	$35,800	$29,200	$62,320	$11,360	$19,320	$10,200	$69,760	$12,440	$7,720
Total Construction Cost	**$151,060**	**$125,300**	**$102,200**	**$218,120**	**$39,760**	**$67,620**	**$35,700**	**$244,160**	**$43,540**	**$27,020**
Engineering, Legal and Admin. (20%)	$30,212	$25,060	$20,440	$43,624	$7,952	$13,524	$7,140	$48,832	$8,708	$5,404
Total Cost	**$181,300**	**$150,400**	**$122,600**	**$261,700**	**$47,700**	**$81,100**	**$42,800**	**$293,000**	**$52,200**	**$32,400**

[1] Mobilization is 22% to account for complexities associated with explosives.

Restoration components are discussed in detail below. In addition, we have included a memorandum from PWA to Brown and Caldwell dated May 2, 2002, which also describes restoration components in some detail. Some text from that memorandum has been incorporated into the discussion below.

Water Control Structures for Managed Ponds

Various water control structures will be needed to control the flow of water into and out of ponds that will be maintained as managed ponds. Inflow to the ponds is needed to makeup for evaporative losses, while outflow is needed to allow for the export of salts to prevent build up in the ponds. The definition of these facilities is under development by others. We understand that these facilities will be constructed in a similar manner to those detailed in the Salinity Reduction section. Interested parties can use costs associated with facilities detailed in the Salinity Reduction section of this report to estimate the cost of new water control structures required for various restoration alternatives.

Starter Channels

Description and Sizing. Starter channels will be excavated in ponds that are planned for restoration to salt marsh. Starter channels are constructed for several reasons that facilitate more rapid and desirable formation of marsh. They help establish a desired channel pattern, typically similar to the historic pattern, which is likely to result in maximum habitat benefits. The starter channels also enhance site drainage, which may increase the rate of vegetation establishment, provide habitat for fish soon after construction, and promote the more rapid formation of smaller channels, which could provide important habitat to biota.

Starter channel dimensions range from 50 to 100 feet wide and 4 to 8 feet deep, with channels becoming smaller as they move into the ponds. The channel cross-section is trapezoidal with side slopes on the order of 5:1. One foot of channel length is roughly equivalent to 5 to 18 cubic yards of material, depending on what end of the channel you evaluate. An average value of 11 cubic yards per foot of channel was used in this cost analysis.

Excavated material could be used to construct berms on the side of starter channels. Berms limit wave generation by limiting reducing the open water fetch lengths, and dissipating waves incident to the berms. Reduced wave action will increase sedimentation rates and will provide a calmer environment conducive to vegetation establishment. Increased sedimentation will facilitate evolution of the site toward higher elevations and vegetated marsh. The berms also locally provide site elevations conducive to vegetation establishment. Berms will be located parallel to starter channels, the excavation of which provides soil for berm construction. The berm elevation would vary around mean high high water (MHHW). The intent is an irregular, wide, low mound with flat slopes and a sinuous path paralleling channels. Berms would be discontinuous to avoid blocking channels.

We have estimated the cost associated with three excavation methods: dynamic excavation using explosives, land-based excavation assuming pond draw down using a hydraulic excavator or a dragline excavator, and barge-based excavation using a hydraulic suction dredge or a clamshell excavator. Each subalternative is detailed below.

Construction - Dynamic Excavation. Explosives are commonly used in agricultural, swamp and marine environments to economically excavate ditches, canals and channels. For example, engineers from the U.S. Army Engineer Waterways Experiment Station report the successful use of explosives in wetlands in the Yazoo National Wildlife Refuge located in north-central Mississippi. They created a series of ditches approximately 1,200 feet long to enhance the ability to control the flow of water through the site and better manage wildlife habitat. (www.wes.army.mil/el/wrtc/wrp/bulletins/v4n4/article2/v4n4a2.html).

In the Napa Ponds, the location of the channels would first be determined and marked. We assume that this can be achieved without drawing down the ponds. To excavate a channel, holes will be drilled from a barge and towboat into the subsurface every 10 feet along the width and length of the desired area to be excavated. Each hole will be lined with plastic or cardboard pipe and filled with explosives. If sediments are soft enough, a pipe could simply be inserted into the sediments and filled with explosives, or the pipe could be pre-filled with explosives prior to insertion. At the end of each day or at a frequency determined feasible and effective by the blasting expert, the explosives will be detonated. It is assumed that blast debris will be spread diffusely out across the ponds in such a way that additional spreading would not be required.

Advantages of the dynamic excavation method include:

- Simple equipment requirements, low labor expenses and high production rates.
- Pond drawdown not required.
- Absence of large spoil banks along the channel, which would require spreading.

Disadvantages of the dynamic excavation method include:

- Location of the historical channels may be difficult to determine.
- Does not allow for the construction of berms along side of the channels.
- Method not conducive with coupling starter channel dredging with restoration components that require sediment such as levee maintenance, levee construction and/or sediment addition.

Construction – Land-Based Excavation. For this method, the ponds will be permitted to temporarily dry up while remaining hydraulically isolated from the Napa River and nearby sloughs. Excavating equipment will be then move into the pond and start the excavation process. This method assumes that dried sediments could support heavy equipment on mud mats. Mud mats are large flat mats that are placed under excavation equipment to redistribute its weight so as to prevent sinking into the mud. Two different types of equipment could be used, a long-reach hydraulic excavator or a dragline excavator.

If a long-reach hydraulic excavator is used, it will first move up on side of the starter channel, excavating half the channel and constructing a berm along the side of the channel. It will then work down the other side of the channel, again piling the spoils along the edge of the channel. A third pass of the excavator will be required to spread the second pile of spoils out over a large enough surface to achieve an acceptable rise in marsh elevation. Because of the limited reach of the excavator, the maximum width of the channel will not exceed 80 feet wide. Based on discussions with excavating contractors and from construction references, a reasonable production rate for a hydraulic excavator in a marsh setting is 1,000 cubic yards per day. But each channel will require double handling of roughly half the spoils.

A land-based dragline excavator could also be used to create starter channels. Compared to the hydraulic excavator, this equipment has a longer reach. This allows for the construction of the channel in only one or two passes and for easier spreading of spoils. The decrease in the number of passes along the channel results in a lower likelihood of problems associated with getting stuck in the mud.

Advantages of the land-based excavation methods include:

- Location of the historical channels may be identified visually.

- Dry environment permits less “sloppy” excavation. Sediment is easier to move around and finished product may be of better quality (this advantage may not be realized if sediments do not thoroughly dry out).
- High production rates.
- Allows for simultaneous construction of berms along side of the channels.

Disadvantages of the land-based excavation methods include:

- Pond draw down is required.
- Risk of getting equipment stuck in sediment during excavation.
- Dry out the sediments may stimulate biochemical processes in the sediment that inhibit the subsequent growth of marsh vegetation.
- Method not conducive with coupling dredging with restoration components that require sediment such as levee maintenance, levee construction and/or sediment addition.

As noted above, there is a level of risk involved with the use of mud mats and the assumption that muddy sediment will be capable of supporting heavy machinery. For example, crossing remnant side-channels filled with softer sediment might prove difficult. While the costs associated with land-based excavation are low, there are a number of issues that need to be closely evaluated to fully access the feasibility of this excavation method.

Construction – Barge-Based Excavation. A barge-mounted hydraulic suction dredge or clamshell excavator could be used to dredge out historical channels without draining the ponds. This approach assumes that the location of the channels could be determined and marked without drawing down the ponds.

Advantages of the barge-based excavation methods include:

- Pond drawdown not required.
- No risk of getting equipment stuck in sediment during excavation.
- Allows for simultaneous construction of berms along side of the channels.

- Method conducive with coupling dredging with restoration components that require sediment such as levee maintenance, levee construction and / or sediment addition.

Disadvantages of the barge-based excavation methods include:

- Location of the historical channels may be difficult to determine.
- Wet environment results in "sloppy" excavation. Sediment is more difficult to move around and finished product may be of lesser quality.
- Lower production rates.

Ditch Block

Description and Sizing. Multiple ditch blocks will be constructed in ponds that will be converted to marshes. The purpose of the ditch block is to inhibit borrow ditches, man-made features located adjacent to levees, from capturing the tidal supply of water and becoming a permanent site feature. Ditch blocks are therefore placed only where existing ditches are located or configured differently than desired, based on a consideration of natural marsh morphology. Nearby levee tops provide earth to build the blocks and provide construction access. Levees are lowered close to MHHW to maximize generation of relative dry earth, while maintaining a bearing surface for construction equipment. Ditch blocks will roughly be 100 feet long, 40 feet wide and 4 feet tall (relative to the pond bottom) with side slopes of 5:1. Assuming that the borrow ditch volume is roughly the same as the levee, and assuming an additional 50 percent in volume to account for losses in the pond waters during construction and subsidence after construction, we estimate that each ditch block will require 5,600 cubic yards of soil. This volume is roughly equivalent to lowering 670 feet of levee by 3 feet.

Construction. Construction of the ditch blocks will take place prior to opening the ponds to tidal action. The blocks will be constructed using land-based equipment and utilizing soil from the top of levees as fill material. Two front-end loaders will collect and transport fill from the top of the levee to a large hydraulic excavator. The excavator will push the soil into the pond and slowly build the ditch block out into the levee.

Levee Lowering

Description and Sizing. Levee lowering, the excavation of the upper portion of the existing levee and partial fill of the adjacent borrow ditch, will be performed along some levees. Levee lowering is applied for several reasons. Levees are unnatural features, and can provide access and habitat for predators that compromise the ecological objectives of restoration. The crest elevation of levees can be lowered to an elevation consistent with marsh vegetation and habitat. We assumed a levee width of 75 feet, levee side slopes of 2:1 on the external side and 5:1 on the internal side, and a lowering distance of 3 feet. This is equivalent to 10 cubic yards of excavation per liner foot of levee lowered.

Construction. Levee lowering will likely be performed after the ponds are open to tidal action in order to avoid the potential for an accidental pond breach. As with ditch block construction, levee lowering will be performed using land-based equipment. Front-end loaders will collect fill from the top of the levee and push it into the borrow ditch of the pond.

Enhanced Levee Breaches

Description and Sizing. As part of the restoration process, levee breaches, termed enhanced levee breaches, will also be created where starter channels meet exterior levees. Unlike breaches associated with salinity reduction, which initially will convey high flow rates, enhanced breaches will experience less scouring action. Thus, we expect that some additional sediment removal on the river or slough side of the breach will be required to ensure that adequate hydraulic connectivity develops between the starter channel inside the levee and the river or slough. Enhanced breaches would include a 100-foot-wide levee breach and up to 100 feet of pilot channel external to the levee, 50 feet wide by 5 feet deep. These breaches would be constructed to mate with starter channels on the interior side of the levee.

Construction. Both the levee breaches and the pilot channels would be constructed using explosives. The breaches and associated external channels would be created after salinity reduction is completed either by breaching or by controlled flushing using water control structures. Compared to the breaches associated with salinity reduction, we have increased the cost of levee breaching two-fold to account for an anticipated increase in the depth and complexity of the required levee breaching. In addition, we have added the cost of blasting a pilot channel on the slough or river side of the levee. Costs for channel blasting were based on costs developed for the blasting of internal starter channels (discussed above).

Interior Levee Construction

Description and Sizing. Restoration Alternative 2 calls for an interior levee to be constructed across the narrow width of Pond 2. Half the pond would be a managed pond while the other half would be opened to tidal action. We assumed levee dimensions of 20 feet in width and 5 feet tall with side slopes of 4:1. The estimated length of the levee is 4,200 feet. Assuming an additional 50 percent in volume to account for losses in the pond waters during construction and subsidence after construction, the total volume of sediment to be moved is about 47,000 cubic yards.

Construction. Levee construction will be performed prior to any levee breaching while the pond is full. A barge with a clamshell dredge will be launched into the pond. It will dig a channel and place the spoils along the channel to make the levee. The levee would be constructed in a number of passes with a few months between each pass. This is needed to allow time for the dredged material to consolidate into a well-defined levee structure.

Sediment Addition

Flow rates through the surrounding sloughs may increase after opening ponds to tidal action. This could result in some scouring of sloughs and the loss of some existing fringe wetlands. To make up for this potential loss in habitat, sediment may be added to some areas of ponds to accelerate evolution to a vegetated marsh. Sediment will be placed no higher than MHHW elevation. Presumably, spoils from the dredging of the nearby Napa River, the surrounding sloughs, or starter channel construction would be used.

Cost estimates reported here are based on those developed for starter channels inside of ponds, which are based on published estimates of unit costs associated with hydraulic dredging and pumping/spreading of spoils up to 1,000 feet away. These costs were increased by 50 percent account for the complexity involved with simultaneously dredging out the river or sloughs and spreading out that material to a specific depth within a pond. Assuming one foot of material is spread over one acre, roughly 1,600 cubic yards would need to be moved to make one acre of marsh. Note that some of the cost associated with dredging of the Napa River would likely be shared with other entities that would benefit from the dredging.

Dredging of Existing Sloughs

Dredging of existing tidal sloughs may be required to enhance conveyance to satisfy the increased tidal prism associated with restoration. Dredging would consist of deepening existing channels between fringe marsh vegetation and lowering the grades of mudflats. Sediment could be disposed within the ponds to be restored (see Sediment Addition). The need for this restoration component is still under review. However, costs cited for sediment addition can be used to roughly estimate costs associated with this restoration component.

Brown and Caldwell appreciated the opportunity to work with you on this project.

Very truly yours,

BROWN AND CALDWELL

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M E M O R A N D U M

DATE: May 2, 2002,
revised May 7, 2002

TO: Marc Beutel, B&C

FROM: Bob Battalio

COPY: Michelle Orr

RE: **Description of Restoration Components**
PWA Ref. #: 1595 Napa Salt Ponds Restoration Conceptual Design
Napa Sonoma Marsh Restoration Project

PWA has identified several site features that may be included in the design of the tidal wetland restoration component of the Napa Sonoma Marsh Restoration Project. These components are intended to provide full tidal action and facilitate evolution of the site to tidal marsh. These features are described for the purposes of conceptual engineering estimates of likely construction costs (10% level) being accomplished by Brown and Caldwell under contract with the US Army Corps of Engineers, San Francisco District, and for inclusion in the EIS/R being accomplished by Jones & Stokes under contract with the California State Coastal Conservancy. PWA is developing a conceptual design for the tidal wetland restoration component of the project. The conceptual restoration design will not be completed until after the Draft EIS/R and the 10%-complete engineers estimate are completed. Consequently, the information provided is subject to revision.

The tidal wetland restoration components are listed below along with short descriptions:

- *Breach:* Excavation through an earth levee and adjacent grades, through which tidal action is provided to the site.

- *Pilot Channel:* An excavated channel extending from a breach and through existing vegetated marsh to tidal waters.

- *Starter Channel:* An excavated channel extending from a breach and into a pond.

- *Berm:* An embankment of earth fill located within a pond.

- *Ditch Block:* An embankment of earth fill that crosses an existing borrow ditch to inhibit flow.

- *Levee Lowering:* Excavation of the upper portion of an existing levee, and partial fill of an adjacent borrow ditch or pond with the excavated material

- *Sediment Addition:* Imported earth fill placed in a pond to raise grades, thereby facilitating establishment of marsh vegetation.

- *Channel Dredging:* Dredging of existing tidal sloughs to enhance conveyance to satisfy the increased tidal prism associated with restoration.

The purpose and geometry of each restoration design feature are described below. For all features, it is important to note the difficulties associated with construction in isolated, shallow tidal areas with weak soils. These difficulties are countered somewhat by the very broad construction tolerances typically allowed for dimensions, slopes, and to a lesser degree finished elevations. The location, amount and geometry of these features are often affected by considerations of construction difficulty and cost. However, recent experience with tidal wetland restoration in the San Francisco Bay area generally supports use of these features as described herein.

Breach: Excavation through an earth levee and adjacent grades, through which tidal action is provided to the site. Breaches are sized to approximately correspond to the future equilibrium cross section anticipated for the tidal channel expected to develop in the pond. This is our initial sizing criterion. Breach sizing will be refined in later design. The equilibrium size is estimated using empirical data relating channel cross-section to other geomorphic measures of a tidal marsh in approximate equilibrium. For the NSMR conceptual design, a fourth order channel was assumed. For simplicity at this early stage, the same size is used for all breaches. This is a relative large channel, with a width at mean higher high water (MHHW) of about 100 feet and a thalweg elevation of about –4 feet NAVD. Typically, the constructed cross-section is based on trapezoidal “neat lines” with side slopes about 5:1 (horizontal: vertical), and a bottom width of about 30 feet. The excavation depth is typically below existing site grades on either side of the levee toe, and the excavation therefore extends beyond the levee footprint. Based on experience, it is beneficial to excavate through marsh vegetation that often exists on the outboard side of a levee, so that a channel of adequate size to convey tidal flows can develop rapidly. Likewise, excavation of a starter channel on the inboard side of the levee is beneficial. The extent of channel excavation considered implicit to a breach excavation is limited to practical excavation limits with equipment and techniques associated with breaching. For this study, channel dimensions were selected to be 50 feet wide, 4 feet deep, 50 feet long on the inboard side, and an average of 50 feet long (100 feet maximum) on the outboard side.

Pilot Channel: An excavated channel extending from a breach and through existing vegetated marsh to tidal waters. The pilot channel is intended to facilitate tidal exchange through a breach by providing a small initial flow path and removing erosion –resistant marsh vegetation, so the channel can gradually enlarge through tidal scour. The pilot channel has a minimum depth associated with complete clearing and grubbing of marsh vegetation. A target maximum depth is the same as the breach depth, or about –4 feet NAVD. However, this depth can be exceeded for construction access. To minimize excavation costs and impacts to existing marsh, target width can be less than the breach width. Excavated material, including vegetation, is placed in the salt pond. Given the difficulties and costs associated with this construction, the design reduces the number and length of pilot channels by locating breaches away from wide fringing marshes.

Starter Channel: An excavated channel extending from a breach and into a pond. Starter channels benefit habitat restoration by facilitating more rapid channel and marsh development, and may increase the eventual channel drainage density. Starter channels help established a desired channel pattern, typically similar to the historic pattern, which is likely to result in maximum habitat benefits. Starter channels provide habitat for fish soon after construction, and promote the more rapid formation of smaller channels which may ultimately become habitat for rails and other wildlife. The starter channels also improve site drainage, which may enhance the rates of sedimentation and vegetation establishment. A starter channel typically follows a semi-sinuous path consistent with the historic channel path. The constructed cross section is roughly trapezoidal. The optimal channel size is the estimated equilibrium channel size. However, actual channel dimensions are modified based on construction practicality and costs. For example, a much smaller channel can still provide benefit and a much larger channel can be constructed without adversely impacting the restoration. A trapezoidal cross section is presumed, with side slopes on the order of 5:1. Initial sizing (optimal size as defined above) is based on a fourth order channel at the breach (about 100 feet wide at the top, 7 to 8 feet deep, and 20 feet wide at the bottom) transitioning to a smaller cross section at the other end, consistent with a third order channel (about 50 feet wide at the top, 4 feet deep and 10 wide at the bottom). It is important to note the wide range of sizes of 3rd and 4th order channels found naturally, and the very preliminary nature of the NSMR design.

Berm: An embankment of earth fill located within a pond. Berms directly facilitate rapid development of a diversity of marsh habitat by providing ground elevations conducive to vegetation establishment. Berms also facilitate marsh establishment by serving as dissipaters, creating more sheltered conditions conducive to sedimentation and vegetation colonization. The proposed berm location is parallel to starter channels, the excavation of which provides earth for berm construction. The berm crest elevation would vary around MHHW. The intent is an irregular, wide, low height mound with flat slopes and a sinuous planform roughly paralleling channels. Berms would be discontinuous to avoid blocking channels. The berm would likely be constructed on only one side of the channel, but berms could be constructed on both sides. To avoid double-handling of excavated earth, or other high cost construction methods, berms could be constructed on both sides of the channel or channel and berm dimensions would be reduced. No compaction standards would be applied.

Ditch Block: An embankment of earth fill that crosses an existing borrow ditch or other channel to inhibit flow. The purpose of the ditch block is to inhibit existing borrow ditches from capturing the tidal supply becoming a permanent site feature, and impeding re-establishment of the natural historic channels. Ditch blocks may be constructed on selected channels other than borrow ditches, where these channels are located or configured differently than desired, based on a consideration of natural marsh morphology. Typically, ditch blocks are constructed to block borrow ditches, which are man made features located adjacent to levees. The levees are lowered to provide earth fill and construction access. Levees are lowered close to MHHW to maximize generation of relative dry earth, while maintaining a bearing surface for construction equipment. The earth is “dumped” in a line perpendicular from the levee to form an embankment which is traversed by the equipment. Dimensions selected for this project are 100 feet long, 40 feet wide at the top, a finished grade of about MHHW, and 5:1 side slopes. Compaction is limited to that obtained by dynamic equipment loads.

Levee Lowering: Excavation of the upper portion of an existing levee, and partial fill of an adjacent borrow ditch or pond with the excavated material. Levee lowering as referred to here is in addition to that accompanying the construction of ditch blocks. Levee lowering is applied for several reasons. Levees are unnatural features, and can provide access and habitat for predators that compromise the ecologic objectives of restoration. The crest elevation of levees can be lowered to an elevation consistent with marsh vegetation and habitat. Also, earth generated from levee lowering can be conveniently placed to reduce the size of borrow ditches, while establishing grades conducive to marsh vegetation establishment. Levee lowering consists of moving earth from the upper part of the levee laterally on to the back slope and into the adjacent borrow ditch, if present.

Sediment Addition: Earth fill placed in a pond. The purpose is to accelerate evolution to a vegetated marsh. For larger area fills, earth is placed no higher than one foot below MHHW elevation, in order to facilitate channel development on the new marsh. For smaller area fills (e.g., linear fills or areas not expected to support channels), earth is placed no higher than MHHW, with most at least 0.5 feet lower. Earth can be placed by bucket or hydraulic means. Fill should not be placed in such a way as to create undrained sections of borrow ditch that could trap fish at low tide.

Channel Dredging: Dredging of existing tidal sloughs to enhance conveyance to satisfy the increased tidal prism associated with restoration. Dredging would consist of deepening existing channels between fringe marsh vegetation and lowering the grades of mudflats. Sediment would be disposed within the ponds to be restored (see *Sediment Addition*). Dredging could be accomplished by bucket or hydraulic suction dredging methods. This feature is no longer included in the NSMR alternatives.

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BROWN AND CALDWELL
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May 15, 2002

Mr. Peter Mull
Ms. Lynne Galal
United States Army Corps of Engineers
San Francisco District Office
333 Market Street
San Francisco, California 94105 11-22459

Subject: Diffusers and Fish Screens
Napa Salt Marsh Restoration Project

Dear Mr. Mull and Ms. Galal:

We have completed our review of issues related to outfall diffusers and fish screens for the Napa Salt Marsh. Our evaluation was performed in accordance with the Scope of Work for Engineering Services included as part of the Award Document authorized by the United States Army Corps of Engineers (ACOE) on March 6, 2002. We discuss diffusers and fish screens below. Enclosures include hydraulic and dilution modeling results.

OUTFALL DIFFUSERS

Summary

We performed detailed hydraulic and dilution modeling to identify facilities that will provide adequate dilution of saline water discharged from ponds into the Napa River and Napa Slough. Our modeling effort was based on system-wide hydraulic modeling performed by Philip Williams and Associates (PWA). PWA's modeling resulted in predictions of the dynamics of discharge flow rates, elevation differences, and salinity levels of effluent and receiving waters throughout the Napa Salt Marsh under various scenarios.

Brown and Caldwell modeled facility requirements and associated dilution factors for outfalls associated with salinity reduction Alternative 1. This alternative has three points of discharge: Pond 3 to the Napa River, Pond 4 to the Napa River, and combined effluent from the North Ponds to the Napa Slough. Facility requirements and predicted dilution factors at peak flow are summarized in Table 1.

Our dilution modeling confirms that dilution increases with increasing outfall discharge rate and decreasing pond salinity. Our modeling results indicate that a threshold port discharge velocity of approximately 10 feet per second (fps) is needed to achieve a dilution factor of 10:1 at pond salinity levels ranging from 45 to 75 parts per thousand (ppt). To maintain elevated discharge velocity and resulting high dilution factors during non-peak flow rates, the outfalls can be designed to come online in a phased manner. Phasing will be achieved through the use of rubber diffuser-port check valves. The valves can be manufactured with varying stiffness so as to open at varying outfall pressures.

Table 1. Diffuser Requirements Associated with Salinity Reduction Alternative 1

Outfall site	Length, feet	Outer diameter, inches	Number of outfalls	Side ports, number and diameter	End Port, number and diameter	Peak capacity, mgd/cfs[1]	Jet velocity at peak flow, cfs	Dilution at peak flow[2]
Pond 3	1,100	52	2	10 @ 8”	1 @ 14”	40/62	13	11:1
Pond 4	1,100	48	2	10 @ 6”	1 @ 10”	25/39	15	12:1
North Ponds	300	42	1	8 @ 7”	1 @ 10”	25/39	14	12:1

Notes:
[1] mgd - million gallons per day; cfs - cubic feet per second
[2] Assumed salinity difference between pond water and receiving water: 30 ppt for Pond 3, 60 ppt for Pond 4, and 45 ppt for North Pond Outfall.

Diffuser Hydraulics

We evaluated outfall flow distribution using Brown and Caldwell’s proprietary diffuser hydraulics program DIFF$$. Model inputs included diffuser characteristics, flow rate, density of effluent, and density of receiving waters. The number and diameter of ports were designed to maintain a fairly constant discharge velocity along the length of the diffuser under a wide range of flow conditions. Constraints to the design included: low driving head pushing water out of the ponds through the outfall (5 to 6 feet at low tide), variable flow rates with time as tides rise and fall, long outfall lengths that result in high frictional head losses, and the need for high port discharge velocity to promote dilution. The results of hydraulic modeling are included in Appendix 1.

Dilution Calculation

We estimated the near-field or initial dilution factor using the UM dilution model. UM is an integral model that solves equations of conservation of mass and energy as a plume moves away from a diffuser. It is part of PLUMES, a computer interface that supports a number of United States Environmental Protection Agency dilution models for effluent discharge. UM was used because it is the most appropriate model for evaluating dilution in shallow waters and dilution associated with negatively buoyant plumes. Model inputs included flow rate, diffuser section characteristics, and temperature and salinity of effluent and receiving waters.

The dilution model was run under a number of scenarios. Both winter and summer conditions were modeled. For winter conditions, receiving waters were assumed to have zero salinity and a temperature of 12 ^{o}C. Pond temperature was 14 ^{o}C and salinity was varied between 0 and 75 ppt. For summer conditions, receiving waters were assumed to have a salinity of 15 ppt and a temperature of 20 ^{o}C. Pond temperature was 23 ^{o}C and salinity was varied between 15 and 75 ppt. Conservatively, water currents in receiving waters were set to zero to mimics slack water conditions. Actual water currents at the diffusers will likely enhance dilution.

Outfalls were designed with two sections. The first section consists of a row of ports. The second section includes a large port at the end of the outfall to facilitate pond discharge at high flow rates, and to promote the scouring of settleable solids out of the outfall during high flow rates. For each scenario modeled, dilution in each diffuser section was modeled individually. A final dilution factor was then estimated as a flow-weighted average of the two dilution factors. Results of dilution modeling are included in Appendix 2.

Dilution Modeling Results

Pond 3

Discharge from Pond 3 to the Napa River will take place when the river elevation is below the pond elevation. Flow rates generally range from 20 to 50 million gallons per day (mgd) or 30 to 80 cubic feet per second (cfs), and peak at approximately 80 mgd (125 cfs). The associated peak head is around six feet. Based on hydraulic and dilution modeling, two 52-inch-diameter outfalls will be required with ten 8-inch-diameter ports and one 14-inch-diameter end port. Ports will be 10 feet apart.

Tables 2 and 3 below summarize dilution modeling results. Note that dilution is dependent on both outfall discharge rate and pond salinity. As outfall discharge rate increases, port discharge velocity also increases and dilution is enhanced due to more turbulent discharge. As pond salinity increases, dilution decreases as the negative buoyancy of the pond water inhibits turbulent mixing and subsequent dilution. We estimate that a threshold port discharge velocity of approximately 10 fps is needed to achieve a dilution factor of 10:1 throughout the year and at pond salinity of 30 to 45 ppt.

Since dilution increases with increasing flow, low dilution rates will occur during times of low flow. For example, at flows of 20 to 50 mgd (10 to 25 mgd per outfall), and assuming a pond salinity of 30 ppt, winter dilution is around 7:1. However, outfalls can be designed to maximize dilution by coming online in a phased manner as flow increases. This approach will result in high port discharge velocity throughout the tidal cycle, and consistently high dilution factors. Phasing will be achieved through the use of rubber check valves placed on each diffuser port that open only when the outfall is pressurized (i.e., the elevation of the river drops below that of the pond). The valves can be manufactured with varying stiffness so as to open at varying pressures. Thus, the system could be designed so that at flows below 20 mgd, the side port on only one outfall would open. At flows of 20 to 25 mgd, the end port on the outfall would open. As flow increased above 25 mgd, the second outfall would come online, with its end port only opening at flows above 45 mgd.

Table 2. Winter Dilution Factors for Pond 3 Diffuser

Outfall flow		Port velocity, fps	Pond salinity, ppt			
mgd	cfs		0	15	30	45
6.5	10	2	17:1	6:1	5:1	5:1
13	20	4	20:1	7:1	6:1	6:1
26	40	8	21:1	11:1	8:1	8:1
39	60	13	22:1	14:1	11:1	11:1
53	83	17	22:1	16:1	14:1	12:1

Table 3. Summer Dilution Factors for Pond 3 Diffuser

Outfall flow		Port velocity, fps	Pond salinity, ppt			
Mgd	cfs		0	15	30	45
6.5	10	2	NA	14:1	6:1	5:1
13	20	4	NA	17:1	7:1	6:1
26	40	8	NA	19:1	11:1	9:1
39	60	13	NA	20:1	14:1	11:1
53	83	17	NA	21:1	17:1	14:1

Pond 4

As with Pond 3 discharge, discharge from Pond 4 to the Napa River will take place when river elevation is below pond elevation. However, when compared to Pond 3, the discharge rate from Pond 4 is lower and more steady, generally maintaining a rate of roughly 25 mgd (40 cfs) during low tide. Based on our hydraulic and dilution modeling, two 48-inch-diameter outfalls will be required with ten 6-inch-diameter ports and one 10-inch-diameter end port. Ports will be 10 feet apart.

Table 4 summarizes dilution modeling results. Based on our modeling the outfall system will maintain a dilution of greater than 10:1 at pond salinity up to 75 ppt. Based on hydraulic modeling performed by PWA, discharge from Pond 4 will be fairly steady throughout the tidal cycle. Therefore, bringing the outfalls online in a phased manner is not necessary.

Table 4. Dilution Factors for Pond 4 Diffuser

	Outfall flow		Port velocity, fps	Pond salinity, ppt					
Season	mgd	cfs		0	15	30	45	60	75
Winter	25	39	15	35:1	19:1	15:1	13:1	12:1	11:1
Summer	25	39	15	NA	33:1	19:1	15:1	13:1	12:1

North Ponds

Discharge from the North Ponds to the Napa Slough will take place when slough elevation is below pond elevation. Flow rates generally range from 10 to 20 mgd (15 to 30 cfs) and peak at approximately 25 mgd (40 cfs). The associated peak head is 5 feet. Based on hydraulic and dilution modeling, one 42-inch-diameter outfall will be required with eight 7-inch-diameter ports and one 10-inch-diameter end port. Ports will be 10 feet apart.

Tables 5 and 6 below summarize dilution modeling results. As noted with Pond 3, dilution is dependent on outfall discharge rate and pond salinity. A threshold port discharged velocity of approximately 10 fps is needed to achieve a dilution factor of 10:1 throughout the year at pond salinity of 30 to 60 ppt. As with Pond 3 discharge, outfall discharge from Pond 4 will be phased so as to maximize port discharge velocity and dilution throughout the tidal cycle.

Table 5. Winter Dilution Factors for the North Ponds Diffuser

Outfall flow		Port velocity, fps	Pond salinity, ppt				
mgd	cfs		0	15	30	45	60
6	10	4	24:1	8:1	6:1	6:1	6:1
13	19	7	28:1	11:1	9:1	8:1	8:1
25	29	14	31:1	16:1	13:1	12:1	11:1

Table 6. Summer Dilution Factors for the North Ponds Diffuser

Outfall flow		Port velocity, fps	Pond salinity, ppt				
Mgd	cfs		0	15	30	45	60
6	10	4	NA	20:1	8:1	7:1	6:1
13	19	7	NA	25:1	9:1	9:1	8:1
25	29	14	NA	29:1	17:1	13:1	12:1

FISH SCREENS

Introduction

It is the policy of the California Department of Fish and Game (CDFG) and the National Marine Fisheries Service (NMFS) to provide measures to minimize fish losses caused by entrainment or other hazards associated with water diversions. These measures may include the installation of positive barrier fish screens, which are physical devices used to exclude fish from being entrained into a flow diversion. The California Fish and Game Code gives CDFG the authority to require the installation of fish screens to protect vulnerable species from water diversion in public waterways. Section 6100 requires the installation of fish screens on the following structures in salmon and steelhead (anadromous) waters of the State:

- New diversions;
- Intake of any existing diversion that is either enlarged, relocated, or at which the season of use is changed; and,

- Diversions which are located within the essential habitat of a state listed species or the critical habitat of a federally listed species.

Objectives of Fish Screening Criteria

The primary objectives of fish screening criteria are to avoid fish injury and mortality by impingement onto the screen, entrainment through the screen mesh, and predation. Impingement causes bruising, descaling, and other injuries. If it occurs at high velocities, or is prolonged or repeated, it can result in direct mortality. In addition, intake screens can increase predation by stressing or disorienting fish and/or by providing habitat for fish and bird predators. NMFS and CDFG fish screen criteria have been developed to be protective of all fish encounters at the screen site. In general, the guidelines and criteria are protective of the weakest swimming species, in their most vulnerable life stage, under adverse environmental conditions (design species).

Design Species

The endangered or threatened fish of concern for the Napa Salt Marsh project include the Delta smelt, Chinook salmon, and the Sacramento splittail. The design species for this project is the Delta smelt. The Delta smelt was listed as a threatened species by the U.S. Fish and Wildlife Service and the California Fish and Game Commission in 1993. Delta smelt are considered environmentally sensitive due to their short life span, low fecundity, limited diet, and primary residence in the interface between salt and freshwater.

Delta smelt are found only in the Sacramento-San Joaquin Estuary, extending downstream as far as San Pablo Bay. The Delta smelt are small, slender-bodied fish that live in brackish water ranging from 2 to 14 ppt. Delta smelt are fast growing and short-lived. The seasonal movement occurs within a short section of the upper estuary. During the late winter to early spring, Delta smelt migrate to the fresher waters of dead-end sloughs and lower reaches of the Sacramento and San Joaquin rivers to spawn. Eggs sink to the bottom, attach to the substrate, and hatch within 10 to 14 days. Planktonic larvae float downstream and develop at the interface between salt and fresh water. Juvenile Delta smelt (20-50 millimeters (mm) in length) move downstream to San Pablo Bay and Carquinez Straight before turning back to Suisun Bay for spawning. Delta smelt reach maturity after their first year, and most of the adults (50-100 mm in length) die after spawning.

Fish Screen Design Criteria

Fish screens must not only exclude juvenile fish from entrainment through the screen, but also allow fish to swim away from the screens, thereby avoiding impingement onto the screens. Both of these goals are achieved by matching the biomechanics and behavior of the design species with the hydraulics of the screen site and the fish screen design. The following section presents CDFG and NMFS fish screening criteria (Fish Screening Criteria, June 19, 2000) including hydraulic design, construction, structure placement, and operations and maintenance of fish screens. The CDFG may issue supplemental criteria for a project to accommodate new fish screening technology or to address species-specific or site-specific circumstances.

Hydraulic Design Criteria

Hydraulic design criteria have been developed for the approach velocity, the velocity component perpendicular to the screen face, and the sweeping velocity, the velocity component parallel to the screen face. The approach velocity must be less than the sustained swimming speed of the juvenile fish design species. The approach velocity is measured about three inches in front of the screen face, or at the edge of the boundary layer at the screen face. Criteria for approach velocity include:

- **Flow Uniformity**: The design of the screen shall distribute the approach velocity uniformly across the face of the screen. Provisions shall be made in the design of the screen to allow for adjustment of flow patterns. The intent is to ensure uniform flow distribution through the entire face of the screen as it is constructed and operated.

- **Self-Cleaning Screens**: In streams and rivers (flowing waters) the design approach velocity shall not exceed 0.2 fps for use in waters where the Delta smelt is found. Thus, fish screens in the Sacramento-San Joaquin Estuary should use this criterion for design purposes.

- **Non Self-Cleaning Screens**: The screens shall be designed with an approach velocity one-fourth that outlined above (i.e. 0.05 fps). The screen shall be cleaned before the approach velocity exceeds the criteria described above.

- **Frequency of Cleaning:** Fish screens shall be cleaned as frequently as necessary to prevent flow impedance and violation of the approach velocity criteria. A cleaning cycle once every 5 minutes is deemed to meet this standard.

- **Screen Area Calculation:** The required wetted screen area (square feet), excluding the area affected by structural components, is calculated by dividing the maximum diverted flow (cubic-feet per second) by the allowable approach velocity (fps). Unless otherwise specifically agreed to, this calculation shall be done at the minimum stream stage.

As noted above, the sweeping velocity is the local velocity component parallel to the screen face that assists in moving fish along the screen face. The sweeping velocity can be varied by adjusting the angle between the screen face and the direction of flow. Steeper angles provide a larger sweeping velocity component. Approach velocity criteria include:

- **In Streams and Rivers**: The sweeping velocity should be at least two times the allowable approach velocity.

- **Design Considerations**: Screen faces shall be designed flush with any adjacent screen bay piers or walls, to allow an unimpeded flow of water parallel to the screen face.

Screen Construction Criteria

Screen face material must be selected to prevent fish entrainment, de-scaling or injury, and must be smooth, without projections or gaps. Screen construction criteria include:

- **Material Selection**: Screens may be constructed of any rigid material, perforated, woven, or slotted that provides water passage while physically excluding fish. The largest possible screen open area which is consistent with other project requirements should be used. Reducing the screen slot velocity is desirable both to protect fish and to ease cleaning requirements. Care should be taken to avoid the use of materials with sharp edges or projections which could harm fish.

- **Corrosion and Fouling Protection**: Stainless steel or other corrosion-resistant material is recommended for screens to reduce clogging due to corrosion. The use of both active and passive corrosion protection systems should be considered. Consideration should be given to anti-fouling material choices to reduce biological fouling problems. Care should be taken not to use materials deemed deleterious to fish and other wildlife.

- **Porosity**: The screen surface shall have a minimum open area of 27 percent. CDFG recommend that the maximum possible open area be consistent with the availability of appropriate material and structural design considerations. The use of open areas less than 40 percent shall include consideration of increasing the screen surface area to reduce slot velocities and assist in both fish protection and screen cleaning.

- **Round Openings**: Round opening in the screening shall not exceed 3.96 mm (5/32 inches).

- **Square Openings**: Square openings in screening shall not exceed 3.96 mm (5/32 inches) measured diagonally.

- **Slotted Openings**: Slotted openings shall not exceed 2.38 mm (3/32 inches) in width.

- **Perforated Plate**: Screen openings shall not exceed 3/32 inches, measured in diameter.

- **Profile Bar**: Screen openings shall not exceed 0.0689 inches in width.

- **Woven wire**: Screen openings shall not exceed 3/32 inches, measured diagonally.

Structural Placement Criteria

Structural placement criteria include:

- **Streams and Rivers (flowing water):** The screen face shall be parallel to the flow and adjacent bankline (water's edge), with the screen face at or streamward of a line defined by the annual low-flow water's edge. The upstream and downstream transitions to the screen structure shall be designed and constructed to match the bankline, minimizing eddies upstream of, in from of, and downstream of, the screen. When feasible, this "on-stream" fish screen structure placement is preferred by the CDFG.

- **Small Pumped Diversions**: Small pumped diversions (less than 40 cfs) which are screened using "manufactured, self-contained" screens shall conform to the NMFS-Southwest Region criteria.

- **Water Withdrawal elevation**: The screened intake shall be designed to withdraw water from the most appropriate elevation, considering juvenile fish attraction, appropriate water temperature control downstream or a combination thereof. The design must accommodate the expected range of water surface elevations.

- **Debris Protection:** Structural features shall be provided to protect the integrity of the fish screens from large debris. Trash racks, log booms, sediment sluices, or other measures may be needed.

- **Screen Face**: The face of all screen surfaces shall be placed flush with any adjacent screen bay, pier noses, and walls, allowing fish unimpeded movement parallel to the screen face and ready access to bypass routes.

- **Screen Orientation**: Based on the NMFS Modified Criteria for Small Screens-diversion flow less than 40 cfs:
  a. For screen lengths of six feet or less, screen orientation may be angled perpendicular to the flow.
  b. For screen lengths greater that six feet, screen-to-flow angle must be less that 45 degrees.
  c. For drum screens, design submergence shall be 75 percent of drum diameter. Submergence shall not exceed 85 percent, nor be less than 65 percent of drum diameter.

Operations and Maintenance Criteria

Operations and maintenance criteria include:

- **Preventative Maintenance**: A reliable on-going preventative maintenance and repair program is necessary to ensure facilities are kept free of debris and the screen mesh, seals, drive units, and other components functioning properly.

- **Cleaning Frequency**: Fish screens shall be automatically cleaned as frequently as necessary to prevent accumulation of debris. The cleaning system and protocol must be effective, reliable, and satisfactory to NMFS. Proven cleaning technologies are preferred.

- **Head Differential**: The head differential to trigger screen cleaning for intermittent type systems shall be a maximum of 0.1 feet unless otherwise agreed to by NMFS.

Fish Screens and Napa Salt Marsh Intakes

We evaluated fish screen design options based on CDFG and NMFS fish screening criteria, design species, and site-specific design constraints. The tidal/marsh environment of the Napa Salt Marsh has a number of site specific design constraints that need to be considered with respect to fish screens. They include:

- Small channel cross sections and shallow depth in sloughs;
- Variable magnitude of intake flows;
- Variable magnitude and direction of tidal flows;
- Limited access to power and for maintenance of structures;
- Minimal hydraulic head available to drive intake flow;
- Excessive debris and high sedimentation load; and
- Highly corrosive, hyper-saline environment.

Design Options

Pre-manufactured fish screens designed to meet CDFG and NMFS fish screening criteria are available in a variety of configurations. These screens are designed to prevent impingement onto the screen by providing low velocities normal to the screen face and sufficient sweeping velocities to move fish past the screen. Screen shape options include barrel or cone. Types of screen face material include perforated plate, woven wire, and bar screens. Screens can be configured to be self-cleaning or non-self cleaning. Common mechanisms for cleaning include rotation of brushes across the screen surface or the release of a burst of compressed air inside the screen. Power sources used to provide energy to cleaning systems include electric motors and compressors powered by electricity or solar power. Finally, corrosion resistant systems and materials (e.g., cathodic protection, epoxy coated, stainless steel components) may need to be used in high-corrosion environment

One fish screen design identified as potentially appropriate for this project is a brushed cone screen with solar powered brush cleaning mechanism. These screens are manufactured by Intake Screens, Inc. of Sacramento, California, and two cone screens were recently installed on an intake from Mud Slough to Pond 8. The following features of the cone screen make this screen design superior to cylindrical screens in the shallow, silty, marsh environments typical at the project site.

Construction:

- The cone shape is very strong and has a uniform surface that enhances the sweeping brush arms ability to clean its surface;
- Cone is made of stainless steel perforated plate screen material with a standard hole size on screen surface of 3/32 inches;
- Carbon steel and epoxy coated components are cathodically protected;
- Reasonable headloss of approximately 0.5 feet across screen structure;
- Pre-manufactured screen sizes can accommodate flows up to 70 cfs;
- Adjustable internal flow controller is designed to eliminate velocity hotspots;
- Meets the approach velocity requirement of 0.2 fps for Delta smelt (tested by NMFS and CDFG) over all portions of the screen face in tidal environments (ebb and flow).

Brush Cleaning System:

- Sweeping brushes clean the screen face with only one moving part;
- Positive brushing action prevents debris buildup and biofouling;
- Low energy requirements for remote locations;
- Hydraulic motor at control panel can run directly from a solar panel with a 24-volt battery pack or with standard line voltage;
- Hydraulic line runs from motor to cone to operate brush cleaning system;
- The hydraulic system uses food grade hydraulic oil;
- A Programmable Logic Controller regulates the cleaning cycle;

- Cleaning cycle can be set to run continuously or once a day depending on the amount of debris or silt present (a minimum or one cleaning cycle per day is suggested to inhibit biofouling and silt build-up);

- Typical cleaning cycle would be 4 revolutions for one minute in the counter clockwise direction, and 4 revolutions for one minute in the clockwise direction.

Simplicity of Installation:

- Screen base installation requires limited excavation, depending on depth and consistency of bottom material;

- The screen base in lowered onto supports that are set at a pre-determined level above the sediments;

- The screen is installed on its base by lowering the screen into a flanged recess and is held in place by gravity.

Silt Build-up:

- No build-up of silt will occur around the base or inside of the screen;

- Over 50 percent of the screen surface is within the lowest foot on the cone screen. Therefore, even in low tide, when the top portion of the cone may be exposed, the greatest portion of the screen surface will still be submerged.

- As water passes through the perforated metal holes in the screen face the face velocity/slot velocity increases to up to about 0.5 fps. The water velocity further increases to about 4 fps as it converges on the centrally located pipe in the center of the screen. These uniform flows and high velocities as the surface and inside the screen prevent silt buildup inside the screen.

Brown and Caldwell appreciates the opportunity to work with you on this project. Please call us with any questions.

Very truly yours,

BROWN AND CALDWELL

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Enclosures