BDCP Fish Facilities Technical Team

Technical Memorandum

Fish Facilities Technical Team

Bay Delta Conservation Plan

July 2011

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Acronyms and Units of Measurement

BDCP – Bay Delta Conservation Plan

Reclamation – Bureau of Reclamation

CDFG – California Department of Fish and Game

CER – Conceptual Engineering Report

cfs – cubic feet per second

DHCCP – Delta Habitat Conservation and Conveyance Program

DOE – Division of Engineering

DWR – California Department of Water Resources

EIR/EIS – Environmental Impact Report/Environmental Impact Statement

FFTT – Fish Facilities Technical Team

fps – feet per second

USFWS – U.S. Fish and Wildlife Service

NMFS – National Marine Fisheries Service

NMFS-SWR – National Marine Fisheries Service-Southwest Region

WSE – water surface elevation

The recommendations contained in this memorandum are based on information available at this time (July 2011) and the best professional judgment of the Fish Facilities Technical Team. The team may revise recommendations contained herein if additional information that warrants consideration becomes available.

Summary of Fish Facilities Technical Team Recommendations

1. Diversion structures should be located on-bank.
2. Diversion structures should not exceed 3,000 cfs in capacity at any single location with a total maximum of five diversion structures at five sites on the lower Sacramento River.
3. Diversion structures should be located on hydraulically appropriate sections of the river to optimize screen performance and to avoid sedimentation or scour at the intake.
4. Two potential diversion sites downstream from Steamboat Slough should be considered in addition to five upstream locations. Any potential downstream diversion sites would be in lieu of upstream locations for a total of 5 diversion structures.
5. While locating diversion structures at least 1 mile apart is generally desirable, closer spacing could be acceptable to assure that each location meets the critical siting conditions (e.g., adequate river depth and bank geometry).
6. Provide a positive, physical fish screen barrier between fish and water diversions.
7. Avoid the need to collect, concentrate, and handle fish passing the diversions.
8. Avoid the need for fish bypasses that concentrate fish and increase the risk of predation.
9. Avoid creating areas where predators may congregate or where potential prey would have increased vulnerability to predation.
10. Avoid siting diversion structures at areas of existing riparian habitat.
11. Use the most biologically protective fish screen concepts as the foundation of the proposed designs.

12. Diversion structures should be as short in length as practicable to reduce the duration of fish exposure to the screen surface. Diversions should be designed to operate at an approach velocity of 0.33 fps to minimize screen length, however, to minimize impacts to delta smelt, the diversions should be operated to an approach velocity of 0.2 fps at night if delta smelt are suspected to be present, based on a real-time monitoring program. The diversions may be operated to an approach velocity of 0.33 fps at all other times.
13. Required sweeping velocities for the diversions should be measured adjacent (within twelve inches) to the screen face and should be equal to or greater than the approach velocity criterion (i.e., 0.2 fps or greater when operating at an approach velocity of 0.2 fps, and 0.33 fps or greater when operating at an approach velocity of 0.33 fps).
14. Target the height of fish screen panels to fifteen feet of submerged screen height to operate at 0.33 fps approach velocity at low river stage; taller screens may be appropriate at specific sites for purposes of reducing the length of the diversion structure. If the screens are constructed 40% taller (additional 6 feet), when the river stage exceeds the design minimum, the extra water depth will allow increased diversion capacity while meeting a 0.2 fps approach velocity (during critical times when delta smelt are present). Further refinement of the relationship between screen height and river stage should be addressed during an optimization process associated with final design.
15. Bottoms of screen panels should be elevated three to five feet off the existing river bottom to minimize sediment and bed load impacts, and to limit exposure to benthic-oriented fish species.
16. An approximate distance of 100 feet for spacing between refugia is suggested however, final refugia spacing should be further evaluated prior to final design. In order to

optimize design, construction, operations and maintenance, the refugia should be modular systems that may be installed in any fish screen slot.

17. Dimensions of the fish screens, refugia, and other diversion components should be standardized where possible for all five diversions for economies of scale and operational flexibility.
18. Civil works should be compartmentalized to allow dewatering of some sections for maintenance while other sections are in operation.
19. Flow control baffles should allow diverted flow to be distributed vertically as well as horizontally along the screen face to distribute flow evenly over all operating screen area. Dynamic baffling should be considered to automatically regulate flow through discrete portions of the screen. Selective withdrawal to allow water to be diverted from selected areas of screen (vertically or horizontally) should also be considered.
20. The design of the diversion structures should consider the risk of introduction of quagga and zebra mussels and other invasive species to the lower Sacramento River system, in order to minimize effects to operations and maintenance of the diversion structures and fish screens.
21. Physical and biological studies are necessary to complete diversion facility designs and to evaluate each diversion facility. Recommended pre- and post-construction physical and biological studies are provided in Tables 1 and 2, respectively. Table 1 lists the near-term aquatic study programs needed prior to construction to reduce key uncertainties and improve the diversion and fish screen design. Table 2 identifies the post-construction aquatic studies and monitoring activities needed to ensure screens are meeting

performance criteria and if projects are phased, to allow for design improvements to subsequently-constructed diversion structures.

Introduction

The Bay Delta Conservation Plan (BDCP), Environmental Impact Report/Environmental EIR/EIS and Delta Habitat Conservation and Conveyance Program (DHCCP) teams have been engaged in further developing the intake design concepts and potential facility locations since the release of the draft Fish Facilities Technical Team (FFTT) report in August 2008. New information produced through these efforts led to the reconvening of the FFTT to revisit their initial recommendations. The purpose of the FFTT is to inform agency managers on unresolved issues related to intake location, size, design, and configuration. In January 2011, a formal charge was given to the FFTT by the 5-Agency Group, which included providing agency managers with a technical memorandum of their findings. The 5-Agency Group is made up of representatives from the Department of Water Resources (DWR), California Department of Fish and Game (CDFG), Bureau of Reclamation (Reclamation), US Fish and Wildlife Service (USFWS), and the National Marine Fisheries Service (NMFS). A series of meetings were conducted to address the issues as assigned in the formal charge and to draft this technical memorandum of the team's recommendations and rationale.

2011 Fish Facility Technical Team Participating Agencies

Bay Delta Conservation Plan

Bureau of Reclamation

Department of Fish and Game

Department of Water Resources

National Marine Fisheries Service

US Fish and Wildlife Service

2011 Team Charge

At the request of the 5-Agency group, the FFTT reconvened in 2011 with a focused charge to:

- Examine new information developed since the last FFTT meetings including a Separate Analysis presented to the BDCP Steering Committee and any construction cost estimations for the separate configurations in the Separate Analysis. Based on this information, make recommendations regarding locations, individual size, and configuration of intakes for the benefit of listed and unlisted fish or for water quality. In considering any option for intakes the tech team will consider changes in flood potential (both local and regional), preliminary costs, and constructability for a total 15,000 cfs diversion capacity;
- Develop performance criteria and study programs to evaluate the performance and effectiveness of diversion structures, both individually and collectively. These should include both physical criteria (e.g. NMFS/CDFG criteria for approach and sweeping velocities), and biological criteria (e.g. % survival of out-migrating smolts through the entire reach with screens); and
- Highlight near-term research/monitoring needs, if any, to reduce key uncertainties prior to construction. Also provide advice on research and monitoring tasks and timeframes to ensure an individual screen, or a first set of two screens, is meeting performance measures prior to constructing a second screen or set of screens.

Previous Charge - 2008

The BDCP FFTT was first convened in spring of 2008 to address questions about what types and sizes of fish screening facilities would be appropriate for the BDCP conveyance proposals. The team was asked to review and evaluate different technologies to be used for screening 15,000 cfs of water supply on the Sacramento River between Sacramento and Walnut Grove. In late August, the FFTT issued a draft report of their findings (2008 Draft Technical Memorandum is provided as Appendix A).

Relevant New Information Developed Since Last FFTT Meetings

Since 2008, during the DHCCP evaluation efforts to refine the proposed project, new information came forth resulting in the need for further input from the FFTT. The FFTT was asked to consider the additional information developed since 2008 and revisit their recommendations to confirm or revise as appropriate.

Conceptual Engineering Reports (CERs) – Other New Information

In 2008 the DHCCP began developing several conceptual plans for alignments of conveyance options. In-river designs were used in the development of the CERs for options that consisted of constructing five new north Delta diversion structures. Dimensions for the in-river diversions were estimated in the report to be 30 feet wide by 400 feet long. There was no evaluation of diversion construction methodology and no interior hydrodynamic assessments included in the assumed sizes of the diversions. The DHCCP engineering teams placed the conceptual diversions at the locations agreed upon based on information of the FFTT in 2008 and a Value Planning Study, as well as the integrated considerations of the EIR/EIS team.

Recent Development of Diversion Concepts - DWR "Two Dimensional Hydraulic Modeling Studies of DHCCP Intakes"

DWR's Division of Engineering (DOE) evaluated three types of diversions:

- In-river
- Near bank
- On-bank

Initially, the diversions were evaluated for far-field and near-field impacts. Subsequently, they were evaluated for their size and constructability as determined by their internal hydrodynamics. The near-field analyses provided details of the flow patterns near the diversions. The near-field impacts were defined as the changes in the river hydraulics, particularly creation of a high-velocity region, a no-flow region, and reverse flow zones etc., near the diversion location.

The near-field impacts were modeled by the DWR using a 2-dimensional hydrodynamic model for three diversion types: in-river diversions, in-river near bank diversions, and on-bank diversions. The modeling results showed significant slowing of water immediately downstream of in-river type diversions. These areas of slow moving water are thought to be ideal habitat for predatory fish. The combined effect of pulling water towards the diversion facility and the presence of predatory habitat at the downstream end of the diversion reduces the potential fish benefit of in-river type diversions. The near-bank diversion is also contained fully in the river, but it is sited within an area that is created by setting back the levee a considerable distance. The setback levee was provided to account for the decrease in the flow area due to the construction of the in-river diversion. The modeling results showed that the near-bank diversions would create areas of slow moving water, circulating zones, and areas of reverse flows in the vicinity of diversions. The flow patterns around the near-bank diversion were thought to be less protective to out migrating fish because of the potential to be caught in a circulating pattern of water which would expose the fish to the same screens possibly several times. The slow moving areas are also prone to sedimentation, thereby increasing the need for channel dredging. For these reasons, the near-bank style of diversion was removed from further consideration. The near-field impacts of the on-bank type diversion were minimal and they could be mitigated by streamlining the diversion ends on upstream as well as downstream sides.

In early 2010 the DWR Division of Engineering (DOE) began evaluating the far-field impacts of the potential BDCP diversion facilities on Sacramento River hydraulics. The far-field impact was defined as the cumulative increase in the water surface elevation of the Sacramento River upstream of the diversion location. Far-field evaluations were performed for both the in-river and the on-bank diversions to determine the flood neutrality of the structures. The 1-dimensional hydraulic modeling of in-river type diversions in the Sacramento River reach covering the proposed diversion locations showed increases in the water surface elevation which decreased the levee flood freeboard. The increased flood stages caused by the in-river diversions would require channel widening and/or increased levee height to maintain the same level of flood protection, or flood neutrality. The modeling also showed that the corresponding cumulative increase in the flood stage for the on-bank type diversion was significantly less and did not warrant any mitigation to make it a flood neutral design. DWR modelers determined that the absence of a significant increase in flood stage for the on-bank diversion was due to the fee placement of the structures in the slower water along the bank of the river, which has very little impact on passing flood flow.

In the summer of 2010, DWR started a comparison study of the internal hydrodynamics and sizes of the conceptual in-river diversions to other, existing in-river diversions. DWR found that the width of the conceptual in-river diversions were much narrower than the width of the existing facilities, considering their respective flow capacities. The narrowness of the conceptual in-river diversions creates approach velocities on parts of the screen face that are much faster than the design rate of 0.2 feet per second (fps). DWR determined that to maintain a maximum flow rate of 0.2 fps, the in-river diversions would need to be approximately twice as long as proposed in the CERs and would need to be about 45 feet wide.

Because of these changes in diversion dimensions, DHCCP engineers began evaluating construction methodology to determine if construction of an in-river diversion was practicable at these larger sizes. The following is a short list of potential construction difficulties associated with in-river construction:

- Sheet pile bracing is limited to a width of 60 feet which limits the structure’s width to about 45 feet.
- Uplift from under river forces may limit excavation depth – precluding larger diversion tunnels under the levee and increasing the number of diversion tunnels and valves.

- 100 feet maximum length for sheet pile depth limits the excavation depth and puts construction at risk of flooding.
- A tunnel would be constructed to connect the diversion with the rest of the facility, which requires a means of closure on the river side of the structure to prevent flooding on the land side.
- Tunneling would require low strength soil treatment in the channel outside of coffer structure. This could potentially require hundreds of grout injection shafts at each diversion
- Some low velocity or null zones downstream of each diversion are inevitable.
- Low flow zones alongside the diversions may also occur due to unaligned flow conditions.
- Flood mitigation such as levee setbacks may be necessary prior to construction.

Due primarily to the construction issues associated with in-river diversions, further investigation of this design alternative was considered unwarranted.

Studying Optional Diversion Locations

Since completion of the FFTT draft report of Aug, 2008, DWR has made additional efforts to evaluate and refine the diversion location selection process. At that time, diversion effects on river morphology had not been evaluated. In early 2010, DWR began evaluating near-field hydrodynamic effects and costs associated with constructing five diversions on the Sacramento River. Previous efforts by the FFTT had identified 10 sites as possible diversion locations extending from north of Freeport to Sutter Slough. The two sites located north of Freeport were eliminated from consideration in this hydrodynamic analysis because of potential interference with Sac Regional/Freeport Mutual diversion facilities, possible impacts to Pocket area residents, and mitigation costs. Additionally, further effort by the DHCCP EIR/EIS Team refined the diversion sites proposed by the FFTT. At that time, the in-river diversion configuration was still under consideration. Site visits and land use considerations prompted the EIR/EIS Team to adjust their five proposed sites. The EIR/EIS Team ultimately suggested five specific site locations, with each site capable of diverting 3,000 cfs from the Sacramento River using an in-river diversion configuration. However due to hydraulic characteristics, the specific site locations identified by the EIR/EIS Team for in-river structures are not necessarily appropriate locations for on-bank diversions. Meanwhile, the DWR DOE engineering team obtained bathymetric data for the entire river reach and began evaluating the proposed site locations for appropriate river geometry, resulting in suggested alternative sites for several of the diversion locations. The DWR DOE engineering team also began to examine construction constraints associated with in-river structures of the size contemplated for the diversions. Due primarily to construction issues, the in-river configuration was eliminated from consideration. The FFTT reviewed bathymetric and cross-section data for both the EIR/EIS locations and the alternative locations identified by the engineering team. Potential diversion locations identified by the EIR/EIS team and DWR DOE evaluated by the FFTT are shown on Figure 1. The results of the FFTT evaluation of suitability of the diversion sites for the on-bank configuration based on water depth and river geometry is provided as Appendix B.

In July 2010, the BDCP Steering Committee received a presentation entitled Evaluation of North Delta Intake Locations which addressed potential optional diversion locations, including diversions both upstream and downstream from the five proposed diversion locations suggested by the EIR/EIS Team. The presentation, one of several Separate Analysis evaluations, was discussed with the FFTT in January 2011. Key findings from the presentation were:

- All configurations analyzed, within the reach of upstream of the Sacramento-American River confluence to downstream of Sutter and Steamboat Slough, appear to have similar salinity levels at the intakes.
- Diversion capability appears insensitive to the intake configurations analyzed.
- Operations and operational preference are more important than location of the diversions for effects on tidal dynamics.
- Diversion locations primarily influence exposure risk and to a lesser extent migration pathways.

This presentation indicated that locating two diversions south of Sutter and Steamboat Sloughs may provide a significant benefit to out-migrating smolts. This benefit was based in part on the results of a one dimensional particle tracking model that indicated about half the particles moved down Sutter and Steamboat Sloughs and the other half moved past Walnut Grove. It was noted that fish do not necessarily behave like particles and the actual percentage of downstream migrants entering these sloughs is uncertain.

To aid in the analysis of additional diversion locations south of Sutter/Steamboat Sloughs the FFTT asked DWR to provide some Sacramento River bathymetric plots between the sloughs and Walnut Grove. The FFTT looked at the bathymetric plots as well as some cross sections of two locations in the reach that were more than a mile apart and had a river bottom of about -22 feet, MSL. The team agreed that optional diversion locations south of Sutter/Steamboat Sloughs should be fully analyzed (See Figure 1 for potential diversion locations south of Sutter and Steamboat Sloughs).

Revised Recommendations

General Principles from 2008 Draft Technical Memorandum

The 2011 FFTT agreed to the following general principles to guide development of conceptual fish screening proposals. Many of the recommendations provided in this report build and elaborate upon recommendations by the FFTT in the 2008 draft memorandum. The first numbered list includes general principles identified in the Draft 2008 report that remain the recommendations of the Fish Facilities Technical Team. Additional recommendations from the 2011 FFTT follow as a separate numbered list.

2008 Recommendations:

1. Use the most biologically protective fish screen concepts as the foundation of the proposed designs;
2. Provide a positive, physical fish screen barrier between fish and water diversions;
3. Avoid the need to collect, concentrate, and handle fish passing the water diversion;
4. Avoid the need for fish bypasses that concentrate fish and increase the risk of predation;
5. Avoid creating areas where predators may congregate or where potential prey would have increased vulnerability to predation;
6. Avoid areas of existing riparian habitat

Additional 2011 Recommendations:

1. Diversion structures should be located on-bank.

2. Diversion structures should not exceed 3000 cfs in capacity at a single location with a total maximum of five diversion structures at five sites on the lower Sacramento River.
3. Diversion structures should be located on hydraulically appropriate sections of the river to optimize screen performance and to avoid sedimentation or scour at the diversion.
4. Two potential diversion sites downstream from Steamboat Slough should be considered in addition to five upstream locations. Any potential downstream diversion sites would be in lieu of upstream locations for a total of 5 diversion structures.
5. While locating diversion structures at least 1 mile apart is generally desirable, closer spacing may be acceptable to assure that each location meets the critical siting conditions for hydraulic performance (e.g., adequate river depth and bank geometry).
6. Target the height of fish screen panels to fifteen feet of submerged screen height to operate at 0.33 fps approach velocity at low river stage; taller screens may be appropriate at specific sites for purposes of reducing the length of the diversion structure. If the screens are constructed 40% taller (additional 6 feet), when the river stage exceeds the design minimum, the extra water depth will allow increased diversion capacity while meeting a 0.2 fps approach velocity (during critical times when delta smelt are present).. Further refinement of the relationship between screen height and river stage should be addressed during an optimization process associated with final design.
7. Bottoms of screen panels should be elevated three to five feet off the existing river bottom to minimize sediment and bed load impacts, and to limit exposure to benthic-oriented fish species.
8. Diversion structures should be as short in length as practicable. Diversions should be designed to operate at an approach velocity of 0.33 fps to minimize screen length,

however, to minimize impacts to delta smelt, the diversions should be operated to an approach velocity of 0.2 fps at night if delta smelt are suspected to be present, based on a real-time monitoring program. The diversions may be operated to an approach velocity of 0.33 fps at all other times.

9. Required sweeping velocities for the diversions should be measured adjacent (within twelve inches) to the screen face and should be equal to or greater than the approach velocity criterion (i.e., 0.2 fps or greater when operating at an approach velocity of 0.2 fps, and 0.33 fps or greater when operating at an approach velocity of 0.33 fps).
10. An approximate distance of 100 feet for spacing between refugia is suggested however, final refugia spacing should be further evaluated prior to final design. In order to optimize design, construction, operations and maintenance, the refugia should be modular systems that may be installed in any fish screen slot.
11. Dimensions of the fish screens, refugia, and other diversion components should be standardized where possible for all five diversions for economies of scale and operational flexibility.
12. Civil works should be compartmentalized to allow dewatering of some sections for maintenance while other sections are in operation.
13. Flow control baffles should allow diverted flow to be distributed vertically as well as horizontally along the screen face to distribute flow evenly over all operating screen area. Dynamic baffling should be considered to automatically regulate flow through discrete portions of the screen. Selective withdrawal, to allow water to be diverted from selected areas of screen (vertically or horizontally) should also be considered.

14. The design of the diversion structures should consider the risk of introduction of quagga and zebra mussels and other invasive species to the lower Sacramento River system, in order to minimize affects to operations and maintenance of the diversion structures and fish screens.
15. Physical and biological studies are necessary to complete diversion facility designs and to evaluate each diversion facility. Recommended pre- and post-construction physical and biological studies are provided in Tables 1 and 2, respectively. Table 1 lists the near-term aquatic study programs needed prior to construction to reduce key uncertainties and improve the diversion and fish screen design. Table 2 identifies the post-construction aquatic studies and monitoring activities needed to ensure screens are meeting performance criteria and if projects are phased, to allow for design improvements to subsequently-constructed diversion structures.

Criteria/Principles

The north Delta diversions will be unlike any other screens that have been implemented to date. They may have individual features similar to other screens in terms of length, capacity, river position, or tidal effects, but they will be unique in the combination of these features at this scale. The size (very large), type (on-bank flat plate) and location (tidally influenced) of the north Delta diversion fish screens make it challenging to literally apply sweeping velocity criteria, as well as other aspects of the fish screening criteria, without considering the limitations of that criteria, what each is intended to accomplish, and how best to apply them to maximize fish protection for the target species that may encounter the diversions.

Fish screening criteria are the rules and guidelines that apply to the design and construction of fish screens at water diversions with the intent of minimizing harm to fish species from the diversion operations. Existing guidelines used for evaluating the north Delta diversions include the CDFG *Fish Screening Criteria*, June 19, 2000, and the NMFS-SWR, *Fish Screening Criteria for Anadromous Salmonids*, January 1997. The NMFS-Southwest Region (NMFS-SWR) document states criteria "…are general in nature. There may be cases where site constraints or extenuating circumstances dictate a variance on one or more of these criteria." NMFS and CDFG allow variances from their criteria on a case-by-case basis upon approval of appropriate managers.

Both the CDFG and NMFS-SWR fish screening criteria were derived from criteria developed in the Pacific Northwest for the protection of anadromous salmonids; however, the two documents had different conditions and thresholds for some of the criteria. The 1982 CDFG criteria was patterned after the 1981 state of Washington Department of Fisheries criteria, which emphasized on-bank screens for flowing waters and off shore diversions for lakes and reservoirs. Prior to 1997, NMFS-SWR utilized the NMFS-Northwest Region criteria, which was oriented towards larger in-canal screens and included criteria for fish exposure and fish return bypass systems. In 1996, biologists and engineers from NMFS-SWR and CDFG met to address the differences in the two agencies fish screening criteria, which were intended to protect the same species of fish. The result was issuance of the current NMFS-SWR and CDFG documents in which CDFG defers to NMFS-SWR criteria for on-canal screens utilizing a bypass system to return fish to their migration route. NMFS-SWR adopted the CDFG approach velocity criterion of 0.33 fps for non-canal fish screens in their 1997 criteria document.

NMFS and CDFG criteria were developed to protect salmon and steelhead however, these agencies generally defer to more conservative screen criteria to protect species other than salmon and steelhead when available. While the design criteria adopted by NMFS and CDFG both make reference to a USFWS approach velocity requirement of 0.2 fps for the Sacramento/San Joaquin Estuary/Delta, and although this approach velocity has often been referred to as a "delta smelt criteria", the USFWS does not have a specific approach velocity design criteria for delta smelt. The lack of an adopted USFWS fish screen design criteria for delta smelt was initially due to the lack of research data on delta smelt and their behavior near screens at varying approach velocities and sweeping flows. As additional research data became available for delta smelt, it became clear that fish screen design criteria for delta smelt might be best applied on a project-by-project basis with the potential for different design criteria being most protective of delta smelt based on the size and location of the diversion to be screened. Within recent years, fish treadmill studies by University of California Davis (2010), David White (2007), and Christina Swanson (2005) have provided new information to large-scale projects such as the BDCP.

The FFTT has identified several issues involving the application of fish agency screening criteria to the north Delta sites. Below is guidance provided by the three fish agencies on how to approach these issues:

- The fish agencies recognize that all life stages of all species of concern may not be fully protected from the effects of water diversions even if all fish screen design criteria are met. The current NMFS-SWR and CDFG fish screening criteria were developed for the protection of juvenile anadromous salmonids. These criteria may not be protective of species that have an egg size or juvenile fish size that can be entrained through the screens. They also may not be protective of fish with swimming behaviors that make them more susceptible to the flow field along the screens. For example, the treadmill studies conducted on delta smelt at U.C. Davis suggest that higher sweeping velocities along the screen may be less protective for this species. Other delta fish species may be similarly impacted.

- NMFS-SWR and CDFG fish screen criteria were developed to provide protection for juvenile fish moving in the downstream direction. It is assumed that upstream migrating fish will be of a size and swimming ability that would make them not susceptible to the diversion screens. This may be an invalid assumption for delta smelt and other small delta fish species.
- CDFG fish screen design criteria require a sweeping velocity equal to twice the design approach velocity for on-river screens. Fish agencies revisited that criterion due to the unique issues associated with this project. Those issues include the presence of delta smelt, which have been shown to have higher survival rates at lower sweeping velocities, and the expectation that salmonids exposed to these water intakes will be of a size and age that suggests the in-canal sweeping velocity criterion would provide acceptable protection from impingement on the screens. For these and other reasons, the FFTT recommends that a sweeping flow/approach velocity relationship of 1:1 be considered for the north Delta diversions.
- The point of measurement for sweeping flow velocity is specified as the "water velocity vector component parallel and adjacent to the screen face" in the NMFS-SWR criteria, while no specific location for sweeping velocity measurements is stated in the CDFG criteria. For an on-bank screen, there may be a significant difference between the average

channel velocity and the sweeping velocity along the screen face due to the boundary effect of the river channel. This can be addressed to some degree by selecting screen sites on or just below the outside of river bends and modeling the flow past the screen to optimize the alignment of the screen.

- Sweeping flows along a fish screen serve two purposes; to facilitate the movement of fish past the screen and to transport debris that has been removed by the cleaning device away from the screen. For some fish screens, intermediate bypasses are used to move fish away from the face of the screen to limit the time a fish would be exposed to the screen. Other times, resting areas (refugia areas) are provided in lieu of intermediate bypasses. The spacing of bypasses or refugia is often set by the maximum time a fish would be exposed to the fish screen assuming fish move downstream at the sweeping velocity. At locations where the sweeping velocity may be very low, the number of bypasses or refugia would make constructing the facility infeasible. An approximate distance of 100 feet for spacing between refugia is suggested however, final refugia spacing should be further evaluated prior to final design.

Performance Criteria

The FFTT recognizes that pairing the concept of using multiple on-bank fish screened diversions (in this case five) with protective operating criteria to divert up to 15,000 cfs is imperative to ensure maximum fish protection. Although the proposed fish screen facilities will be state-of-the-art, the FFTT also recognizes that operating to the adopted fish screen design criteria cannot provide full protection to fish eggs and larvae present in the reach of the diversion structures during operation due to the practical limitations in screen mesh sizing and the reduced or lack of mobility of these early life stages. Of the aquatic covered species delta smelt are considered to be the most sensitive. Therefore, it is assumed that by providing protective operating measures for delta smelt it is also protective of other aquatic species, understanding that if there are needs of other covered species not being met by delta smelt protection these measures would be called out as well. The concepts illustrated in this recommendation should be coordinated with other parallel BDCP workgroups (e.g. monitoring, predation, and entrainment) as needed, in an iterative process to evaluate compatibility of proposed operating criteria with fish screening requirements important to the protection and reduction of stressors for covered species. An optimization study would inform more specific design characteristics.

Physical Criteria

Approach velocities

For smaller fish screen projects (under approximately 300 ft in length) within the identified range for delta smelt, the USFWS has typically recommended up-front in the process that the fish screen be designed to operate at a 0.2 fps approach velocity to be most protective of delta smelt. However, for larger fish screen facilities it is important that the design criteria for the project be carefully evaluated by USFWS to determine the most appropriate design criteria for delta smelt based on the site specific location, structure size, and operating criteria. For the BDCP proposed project, the FFTT believe that the 0.33 fps approach velocity criteria established to protect salmonids and steelhead should be used to design the proposed diversions to reduce the overall screen length. The FFTT recommends a design target of 15 feet of submerged screen height to operate at 0.33 fps approach velocity at low river stage. If the screens are constructed

40% taller (additional 6 feet), when the river stage exceeds the design minimum, the extra water depth will allow increased diversion capacity while meeting a 0.2 fps approach velocity (during critical times when delta smelt are present). Further refinement of the relationship between screen height and river stage should be addressed during an optimization process associated with final design.

Rationale

Based on some preliminary calculations by the FFTT, a single diversion structure would be approximately 900 ft long when built to a 0.33 fps approach velocity and 1,400 ft long when built to 0.2 fps, when assuming refugia are included. The concept of incorporating fish screen refugia into the structures is identified as a potential way to limit the uninterrupted duration of fish screen exposure along the screen panels. Refugia are designed to provide resting areas for small fish by providing protected cover between some lengths of fish screens, thereby breaking up long expanses of fish screens. This concept is still in its early stages of application to fish screen projects and benefits to fish have not been quantified. A pre-construction study has been identified (Table 1) to learn more about this concept before incorporation into the final project design.

Many variables can affect the length of the structures themselves; however, the fish screen approach velocity appears to have the greatest influence on screen length. It is due to these large differences in screen length that has led the FFTT to recommend that fish screens for a 15,000 cfs north Delta diversion be designed to a 0.33 fps approach velocity fish screen design criteria. This approach velocity reduces the required length of the fish screen and thereby reduces fish exposure to the diversions, and it also minimizes environmental impacts associated with construction by reducing the sizes of the required diversion structures. Historically, delta smelt have been found as far upstream as the mouth of the American River and continue to be present within the reach of the proposed diversion locations, based on monitoring efforts conducted by USFWS. It is anticipated that there would be less fish mortality associated with the shortened fish screen lengths required by a 0.33 fps approach velocity as compared to a 0.20 fps approach velocity design due to facility impacts attributable to impingement, screen contact, and predation.

Predation at the north Delta diversion structures is a concern for migratory and resident species that utilize these reaches of the Sacramento River. Predation is thought to be one of the major factors in fish mortality associated with screened diversions, in addition to entrainment, impingement, and screen contact. Based on the expected relationship between fish mortality and screen length, the FFTT recommends the screen length be minimized. In addition, fish screen and diversion structures located in the river should be designed to avoid creating areas where predators may congregate or where potential prey would have increased vulnerability to predation. Due to the lack of data on predators associated with fish screen and diversion structures, the need for pre- and post- construction surveys has been identified to evaluate the effect of proposed structures on the distribution and density of predators.

Sweeping velocities

Traditionally in areas where salmonids are present, sweeping velocity criteria for NMFS and CDFG require sweeping velocities to be greater than the approach velocity and should be at least two times the allowable approach velocity for on-river screens. The concept behind maintaining an enhanced sweeping velocity has been to allow salmonids to be quickly transported past the screen and minimize their exposure to the diversion. However, for the BDCP proposed project that occurs in areas where relatively low average sweeping velocities are found , the FFTT recommends an operational criteria that would allow diversions only when sweeping flows are equal to or greater than the approach velocity. The FFTT also recommends measuring the sweeping velocity within 12 inches of the screen face where fish would be subject to the sweeping flows, rather than further into the channel where flows are expected to be faster.

Rationale

In order to provide protection for delta smelt by minimizing screen contact rates, the fish screen designs are focused on minimizing stress to the species by operating at decreased approach velocities when delta smelt are indicated to be present. Within the last ten years in the Hood area, USFWS monitoring efforts have indicated adult delta smelt presence during the months of February through June; with March and April being the most critical in presence. With the goal of developing a sweeping criteria that is conducive to delta smelt, salmonids, and other fish, it was determined that the sweeping velocity requirements be equal to or greater than the approach velocity for pumping from the north Delta diversions to occur. Findings from the UC Davis treadmill studies indicate that delta smelt experience more frequent and severe screen contacts that relate to high injury rates during high approach velocity and high sweeping velocity regimes. By allowing operations to occur at lower approach and sweeping velocity regimes, it will allow pumping to occur during times when delta smelt are thought to incur less severe injuries from contact with the screen. In order to produce a more reliable sweeping flow measurement to determine if operational criteria are being met, the FFTT recommends the sweeping velocity be measured near the fish screen (within about twelve inches).

Operational Parameters

Delta smelt are likely to experience more contact with fish screens during the night than the day based on results from a series of UC Davis Treadmill studies. To address this issue, pumping operations should be regulated at all BDCP diversions such that an approach velocity of 0.2 fps is not exceeded during times of critical delta smelt presence. The FFTT recommends that the fish agency biologists determine the number of delta smelt over a given sampling effort that would trigger pumping at the 0.2 fps approach velocity level. Additional monitoring would need to be integrated into the BDCP to adequately sample for the presence of delta smelt and other fish species.

Rationale

Delta smelt mortality and injury is likely to occur even when operating at a 0.2 fps approach velocity, in part due to the extreme lengths of the diversion structures. At lengths this great, discernable differences in delta smelt mortality between the 0.2 fps and 0.33 fps approach velocity operations for daytime conditions may be difficult to detect. Under night-time conditions when it is dark, delta smelt are found to experience more contact with a screen than during the day when it is visibly light. It is this discernable difference between day and night conditions that causes the FFTT to recommend more protective measures at night under dark conditions during critical delta smelt presence. The differentiation between day and night conditions should be determined during the final design optimization process. These efforts are being recommended to minimize effects to delta smelt during times when they are more vulnerable. Based on recent delta smelt catch data from the USFWS Delta Juvenile Monitoring Program, delta smelt are being caught in low number pulses, followed by catches of few individuals. When delta smelt are no longer caught in critical peaks by the next sampling period within monitoring efforts, actions being taken at night to achieve the 0.2 fps approach velocity would no longer be needed; operations would continue on a daily basis at a 0.33 fps approach velocity until the criteria was met or exceeded again.

The BDCP modeling team is currently evaluating water supply effects under both the 0.2 fps and the 0.33 fps approach velocity, using operational constraints that consider delta smelt presence during specific times of the year and times of day, based on historic data. Operational parameters would be further refined during optimization studies in advance of intake construction.

Biological Criteria

Survivability Comparisons

Several of the biological studies described in Tables 1 and 2 below are designed to evaluate the pre-construction (current) survival rates of salmonids through the proposed diversion reach, and to re-evaluate those survival rates following the construction/operation of one or more diversion structures. In designing and operating the new diversions, the goal should be to achieve no detectable decrease in overall survival of salmonids or other fish as they migrate through the diversion reach. Should post-construction survival estimates indicate survival rates that are below the established baseline rates for the reach, an intensified evaluation of the existing diversion/screening performance would be triggered to determine the source of increased mortality, and potentially a re-evaluation of the design and operational criteria for subsequent diversions.

Rationale

There is a high level of uncertainty as to the type and magnitude of impacts that these new diversions will have on covered fish species that occur within the proposed diversion reach. Much of this uncertainty stems from the fact that these facilities will be approximately ten times larger than the largest diversions/screens that have been constructed in this area thus far and the State of California is proposing to construct five such structures within a relatively short reach of the river. It is also important to note that nearly the entire population of several anadromous species (Sacramento basin salmonids and green sturgeon) must pass through this reach to complete their life cycles.

There are three general sources of potential impacts that may be caused by the new diversion structures and their operations. The first category of impacts are those that can typically result from the operation of large diversions such as entrainment, impingement, and injury of fish that come in contact with the facility as water is being diverted. The second category includes those impacts that may result from the simple existence of large concrete/steel structures in the river, such as increased predation and loss of shoreline habitat features. The third category of impacts are those associated with the actual diversion of large quantities of water from the river, which can affect flow patterns, hydrodynamics, and habitat features/ecological processes that are dependent on river flows.

It is essential that these potential sources of adverse impacts to covered species be thoroughly evaluated and analyzed, and that every effort be made to minimize such impacts by correcting any problems that we can identify through the evaluations described below.

Pre-Construction, Pre-design, and Post-Construction Long-term Monitoring Studies

Near-term studies and research are needed to reduce key uncertainties prior to design and construction of water diversions and fish screens. The scale of this project is uniquely large, both in terms of the total pumping rate and the physical dimensions of diversions and fish screens at each site. The many uncertainties that exist with a project of this size require physical modeling, numerical modeling, and field studies to direct design decisions.

Specific hydraulic and aquatic biological information about the site locations must be collected before design. Some information about screen performance and fish behavior is available at similar sites in the region such as Freeport, Reclamation District 108, Sutter Mutual Water Company, Patterson Irrigation District, and Glenn Colusa Irrigation District, but none of those facilities present the same environmental conditions that will exist at any of the five proposed facilities; therefore additional research is necessary. Baseline studies are required in order to analyze the impacts of the diversions on fish populations.

Long-term aquatic study programs and monitoring are needed after construction to ensure screens are meeting performance criteria, and to determine if biologic losses (juvenile salmonids and other species) attributable to the diversions are within acceptable levels. Standard post-construction evaluations include baffle adjustment to meet hydraulic screen criteria, sediment monitoring, examination of the cleaning mechanism, and entrainment studies. Additional project-specific studies include refugia monitoring and impingement studies. The effects of the project on fish populations can be examined by comparing post-construction biological data to baseline data.

The name, description, purpose, and timeframe for all studies and monitoring needs identified by the team are detailed in Tables 1 and 2. No priority is implied by the order of the studies described in the tables. All studies are necessary to achieve project goals. The FFTT determined that cost estimation requires effort beyond the scope of the team's charge.

The FFTT was asked to identify what tasks and timeframes are required to ensure that an individual screen, or a first set of two screens, are meeting performance measures prior to constructing a second screen or set of screens. The FFTT recognizes that there are many factors to weigh when determining whether to phase construction. Phasing construction may result in prolonged construction periods, an increase in overall project cost, potential decreased pumping, and potential loss of revenue from water users. However, there are also potential biological, engineering, and financial benefits to phasing construction for a project of this size and scale. The FFTT agreed that the field and laboratory studies listed in Table 1 should be conducted during the design phase to minimize uncertainties prior to construction. Due to the unprecedented scale of the project and the potential consequences of design decisions to the ecosystem, the FFTT also concluded that there were additional benefits to studying effects of intake construction and operation on a single intake (or a first set of two intakes) before constructing remaining intakes.

The primary benefit of phasing construction is the opportunity to alter design elements of latter diversion structures to increase fish survival and improve whole facility operations and maintenance. Results of post-construction studies listed in Table 2 can be used to evaluate the performance and impacts of the diversion facilities. Benefits that can be achieved by phasing construction are listed in the table. Timeframes necessary to evaluate performance measures on a single screen under ideal hydrologic conditions are also listed. It is understood however, that hydrologic conditions are variable and studies will be greatly affected by the river flow conditions and subsequent project pumping rates. To analyze some performance measures such as hydraulic criteria at the screen face, a worst-case scenario with maximum pumping under a minimum river flow rate is ideal. Other performance measures such as fish survivability require a variety of hydrologic scenarios in order to fully document the impact of the diversion. In order to collect data required to fully determine performance measures, the timeframe for the studies could be longer than the timeframes listed in the table, depending on hydrologic conditions. However, the FFTT believes that any period of time between construction of individual screening facilities can be useful in revising design elements. The FFTT also recommends that the effects of phasing construction be analyzed in the EIR/EIS.

Table 1. List of Near-Term Aquatic Studies Needed Prior to Diversion Structure Construction to Reduce Key Uncertainties.

Study Number*	Study Name	Research Needs Prior to Construction	Study or Studies Needed	Study Purpose	Study Timeframe	Required Completion Time
1	Site Locations Lab Study	Evaluation of proposed screen sites and design features (river flow patterns, transition walls, screen geometry, baffle geometry, eddy locations, macro-refugia, and boundary effects on sweeping velocity)	Physical hydraulic model(s). If site locations are significantly different in terms of river flow conditions or structure geometry, then more than one physical model study is needed.	Physical model provides ability to optimize hydraulics and sedimentation in the chosen river reach. The screening structure and river reach can be modified as needed. Differences between the average channel velocity in the river and sweeping velocity adjacent to the screen face will be identified. Neutrally-buoyant particles will be tracked to provide information on larval fish movement.	Expected duration 6-12 months per model study depending on model scope of work and lab availability	Prior to final design (model can be completed concurrently with "Refugia Lab Study")
2	Site Locations Numerical Study	Evaluation of tidal effects and withdrawals on flow conditions at screening locations	Computational fluid dynamics model	Numerical model will provide information on how tidal changes and flow withdrawals affect flow conditions and sweeping velocities at screening locations. Results can be used in "Site Locations Lab Study" to set boundary conditions and validate physical model results.	Expected duration 6 months depending on model detail and complexity	Prior to final design
3	Refugia Lab Study	Design of refugia areas (macro, micro, and base refugia)	Physical hydraulic model	Physical model provides ability to measure hydraulics and observe fish behavior in a controlled environment. Size/shape of refugia areas can be modified to optimize fish usage. Predators can be added to examine predation behavior near refugia.	Expected duration 6-9 months depending on model scope of work and lab availability	Prior to final design (model can be completed concurrently with "Site Locations Lab Study")
4	Refugia Field Study	Examination of refugia at future fish screens.	Field evaluation of future facilities**	Field evaluation of fish screening facilities using fish refugia will provide important information on their effectiveness and areas for improvement.	1 year study	Prior to final design
5	Predator Habitat Locations	Examine predator habitat locations	Field evaluation of similar facilities***	Identify predator habitat areas at other facilities.	1-2 year study	Prior to final design
6	Predator Reduction Methods	Examine predation reduction methods	Literature search and potential field evaluation of similar facilities***	Identify alternatives for reducing predator habitat.	1 year study	Prior to final design

7	Flow Profiling Field Study	Characterize the water velocity distribution at river transects within the proposed intake reaches for differing river flow conditions.	Field study to measure water velocity distribution across river transects utilizing acoustic Doppler current profiler. Effort to define velocity conditions at channel boundary will be made.	Differences between the average channel velocity in the river and sweeping velocity adjacent to the screen locations need to be identified in order to properly design the screen for sweeping velocity. Water velocity distributions in intake reaches will identify how hydraulics change with flow rate and tidal cycle.	1 year study	Prior to final design
8	Deep Water Screens Study	Effects of deep water screens on hydraulic performance	Computational fluid dynamics model	Proposed screen depth is large. Unique baffling systems and/or creative design elements may be required to address vertical velocity variations at the screen face.	Expected duration 6 months depending on model detail and complexity	Prior to final design
9	Baseline Predator Density and Distribution	Baseline predator density and distribution	Didson camera or other technology and/or acoustic telemetry at 2-3 proposed screen locations; velocity evaluation of eddy zones if needed	Collect baseline predator density and location data for comparison to future post-construction predator data	Important to start studies as soon as possible to collect multiple data sets before construction begins.	Prior to construction
10	Baseline Juvenile Salmon Survival Rates	Baseline survival rates of juvenile salmon	Mark and recapture studies, acoustic telemetry studies, and/or fyke net studies in proposed intake river reaches and control river reaches. Need to collect baseline data at 2-3 proposed screen locations and 2-3 control reaches.	Collect baseline survival data for comparison to future post-construction survival data	Important to start studies as soon as possible to collect multiple data sets before construction begins.	Prior to construction
11	Baseline Fish Surveys	Baseline density and distribution for covered fish species. Targeting all life stages for delta and longfin smelt.	Literature search, trawling, trapping, and beach seining	Enhance current baseline knowledge of covered species through the collection of additional data focused on determining delta and longfin smelt density and distribution within the reach of the proposed intake locations. In addition collect data directly upstream and downstream of the intakes and in close proximity to sloughs and channels.	On-going study to occur during months when delta and longfin smelt are expected to occur in the area. Important to start studies as soon as possible to capture seasonal data.	Prior to construction

NOTES:
* No priority is implied by the order of the studies described in the table. All studies are necessary to meet project goals.
** Future facilities with refugia will include Red Bluff Diversion and Bella Vista.
*** Similar facilities include Freeport, RD108, Sutter Mutual, Patterson Irrigation District, Glenn Colusa Irrigation District, or other suitable screen sites.
**** Additional pre- and post- construction studies/surveys will be needed for terrestrial species.

Table 2. List of Aquatic Studies and Monitoring Needs After Diversion Structure Construction to Ensure Screens are Meeting Performance Criteria

Study Number*	Study Name	Type of Criteria	Study or Monitoring Needs After Construction	Study or Monitoring Needed	Study or Monitoring Purpose	Study Timeframe***	Benefits Achieved by Phasing Construction**
1	Hydraulic Screen Evaluations to Set Baffles	Hydraulic	Post-construction hydraulic evaluation of screen performance to set baffles	Hydraulic field evaluations to measure velocities over a designated grid in front of each screen panel. Repeat as necessary to set initial baffle positions.	Establish initial baffle settings and confirm compliance with design criteria.	Estimated 3 month study (conducted close to maximum diversion rate).	May indicate need to improve design of baffle system, resize screens, or modify operations.
2	Long-term Hydraulic Screen Evaluations	Hydraulic	Long-term hydraulic evaluation of screen performance	Hydraulic field evaluations	Ensure operational criteria are within acceptable tolerances over the long term. Provide changes to baffle settings as needed to accommodate changes in river conditions and diversion rates.	Monitor long-term compliance with criteria. Frequency to be determined, initially annually.	N/A
3	Periodic Visual Inspections	Hydraulic	Identify effectiveness of cleaning mechanism and screen integrity.	Visual inspections (diver and/or camera).	Determine whether cleaning mechanism is effective at protecting the structural integrity of the screen and maintaining uniform flow distribution through the screen. Adjust cleaning intervals as needed to meet requirements.	1 year post-construction study, then periodic evaluation over life of project.	May indicate need to improve design of cleaning mechanism; provides information on required cleaning intervals
4	Velocity Measurement Evaluations	Hydraulic/ Biological	Determine sweeping velocities at the screen facility, and in front of and within refugia areas	Hydraulic field evaluation of sweeping velocities at the screen facility and in front of and within refugia areas over a range of flow conditions	Determine if exposure time is within design criteria for operating flow conditions. Determine if refugia areas are sufficient to meet fish exposure criteria and provide a range of conditions suitable for fish to inhabit the refugia.	1 to 5 year post-construction study, then ongoing evaluation.	Refugia areas may need to be modified. Potential to modify operational triggers.
5	Refugia Effectiveness	Biological	Effectiveness of refugia areas	Didson camera or other technology	Observe fish behavior in refugia areas to ensure that refugia are successful at minimizing screen impingement and near-screen predation.	2 to 5 year post-construction study, then ongoing evaluations to determine if refugia should be modified.	Refugia areas may need to be added, removed, or modified.
6	Sediment Management	Hydraulic	Examine sediment deposition in front of screen base and behind screens	Sonar imaging, acoustic bathymetry, and/or divers	Evaluate effectiveness of sediment management devices in minimizing problematic sediment deposition.	2 to 10 year post-construction study, then ongoing evaluations.	May need to improve sediment management strategies or increase sill height.

7	Screen Impingement	Biological	Evaluation of screen impingement	Didson camera or other technology and/or divers to observe fish activity at screen face. Marked release/recapture to evaluate injury rate. Pull screens to evaluate screen condition.	Observe fish behavior at screen face to ensure that impingement does not occur.	2 to 10 year post-construction study (provided varied river flows and diversion rates).	May indicate need to improve design of baffle system, resize screens, add refugia, or modify operations.
8	Screen Entrainment	Biological	Evaluation of screen entrainment	Larval net study behind screens. Pull screens to evaluate screen condition.	Identify species/size of fish passing through the screen.	2 to 5 year post-construction study (provided varied river flows and diversion rates) then ongoing evaluations.	May indicate that smaller screen openings are preferred.
9	Post-Construction Predator Density and Distribution	Biological	Evaluation of predator density and distribution	Didson camera, electrofishing, or other technology and/or acoustic telemetry; velocity evaluation of eddy zones if needed	Determine density and location of predators. Identify ways to reduce predation at the facilities.	3 to 10 year post-construction study (provided varied river flows and sufficient predator populations).	Designs can be modified to minimize predator holding areas.
10	Post-Construction Juvenile Salmon Survival Rates	Biological	Post-construction survival rates of juvenile salmon	Mark and recapture studies, acoustic telemetry studies, and/or fyke net studies in intake river reaches and control river reaches	Collect post-construction survival data for comparison to baseline survival data. Identify the change in survival rates due to construction/operation of the intakes.	3 to 15 year post-construction study (provided varied river flows and diversion rates).	May indicate need to improve design, resize screens, or modify operations.
11	Post-Construction Fish Surveys	Biological	Post-construction survey for density and distribution of covered fish species.	Trawling, trapping, and beach seining	Collect post-construction survey data for density and distribution of covered fish species for all life stages. Compare to baseline catch data. Identify potential changes due to construction of intakes.	Ongoing evaluations.	N/A

NOTES: * No priority is implied by the order of the studies described in the table. All studies are necessary to meet project goals.
** Modifications to the design and/or operation of the intake facilities identified during post-construction evaluations can be applied to existing and future intake facilities.
*** While many of these monitoring activities are expected to continue beyond any phasing period for project construction, the "years post construction" are intended to indicate the likely range of time periods necessary to ensure the facilities are meeting performance criteria, and to determine necessary design improvements for subsequently constructed intake facilities.
****Additional pre- and post- construction studies/surveys will be needed for terrestrial species.

Diversions

The FFTT reviewed new information developed since 2008 related to diversion size, location, configuration, and potential components of the individual facilities. The following recommendations are provided after discussions of potential benefits and constraints associated with the options considered. The sites considered for north Delta diversions by the FFTT are shown on Figure 1.

Size

- Five points of diversion at 3,000 cfs each. A lower capacity than this equates to greater land use and terrestrial impacts, a higher capacity exceeds the maximum capability of any screened diversions on the Sacramento River.
- Use a modular screen panel design to allow maximum flexibility and exchange of screen components.
- Rough screen length dimensions are shown in Table 3 below.

Table 3. Approximate Screen Dimensions

Screen Height (ft)	Approach Velocity (fps)	Diversion Capacity (cfs)	Screen Length[1] (ft)	Screen Length[2] (ft)
15	0.20	3,000	1,400	1,550
15	0.33	3,000	850	1,000
20	0.20	3,000	1,050	1,200
20	0.33	3,000	625	775

[1] Includes length of 15 ft-wide screen panels plus 15 ft-wide refugia spaced every 100 ft.
[2] Includes "Screen Length" and upstream and downstream transition structures.

Diversion Locations

- Locate diversions downstream of the town of Freeport due to public scoping comments received in March 2009 citing construction impacts in an overly constrained conveyance corridor, historic building conflicts, and precedent set by the Freeport Diversion EIR indicating that diversions in the Pocket area would produce significant impacts.
- Target approximately 1-mile of separation between diversions. Closer spacing may be acceptable to assure that each location meets the critical siting conditions (e.g. adequate river depth and bank geometry).
- Locate diversions within straight reaches of the river or mild outside bends to avoid complex flow patterns, sedimentation, and excessive scour.
- Locate the furthest upstream diversion downstream of where complete mixing is reported to occur from the Sacramento Regional Wastewater Treatment Facility effluent discharge.
- Potential diversion locations identified by the EIR/EIS team and DWR DOE evaluated by the FFTT are shown on Figure 1. The results of the FFTT evaluation of suitability of the diversion sites based on water depth and river geometry is provided as Appendix B.

Potential Diversion Locations South of Steamboat and Sutter Sloughs

The FFTT had several questions and comments on moving diversions below Sutter and Steamboat sloughs. Some comments centered around the potential effects on Sacramento River spawning delta smelt from having diversions further south. One concern is for smelt that spawn in the Sacramento River below Sutter and Steamboat Sloughs, diversions further south could increase the chance of those larval and juvenile smelt being exposed to these diversions. It was also pointed out that smelt spawned *above* Sutter and Steamboat Sloughs would receive the same benefits as salmonids from locating diversions below these sloughs (i.e. a portion of the larvae would be expected to travel down the sloughs and thus avoid exposure to the lower diversions). The benefits of avoiding the lower diversions might be even greater for smelt larvae than they are for salmonids as smelt larvae are much more likely to be entrained through the screens than are salmonids.

The team was also uncertain of the level of benefits to salmonids from placing diversions below Steamboat and Sutter Sloughs. While particle tracking modeling indicates about half the particles move down the sloughs, fish do not necessarily behave like particles and the actual percentage of downstream migrants entering these sloughs is uncertain. An acoustic tracking study conducted by David Vogel (2008) monitored large (107 mm to 181 mm smolt sized) juvenile Chinook salmon as they emigrated through this region of the Delta. Vogel reported that 26% of tagged smolts entered Sutter and Steamboat Sloughs during a series of releases in December, and 37% entered the sloughs during January releases. It is problematic to try to interpret this data to estimate how smaller fish such as larval delta smelt or fry-sized salmonids might behave at these channel junctions as these smaller fish would have much weaker swimming abilities than the larger fish used in Vogel's study.

By placing diversions further south, smelt that spawn in the Sacramento River above the sloughs may have a lower probability of exposure to those diversions. Since a significant proportion of modeled particles traveled down the sloughs, it might be expected that larvae and juvenile smelt spawned in the river above the sloughs would also be diverted in a similar manner. This would result in a portion of the smelt population avoiding exposure to the lower intakes. Since smelt larvae are much more likely to be entrained through a screen than salmonids, the possible benefits associated with avoiding the lower diversions might provide an overall greater benefit for these alternative diversion locations.

The FFTT was also concerned about slower flow velocities past these lower diversions as fish traveling past these diversions could be negatively affected by slower velocities. However, the proposed operational criteria would have these lower diversions operating only during relatively high flow periods and they would be required to shut down any time sweeping velocities were not meeting the minimum deemed to be safe for juvenile salmonids and adult delta smelt.

Concern was also expressed for sturgeon at all of the diversions, regardless of their location. Juvenile sturgeon (along with the other covered fish species) may face higher predation due to the presence of the structures alone (regardless of their operations). The interface between the fish screen facility and the river bottom will need to be evaluated to minimize impacts to sturgeon.

The FFTT agreed that more information was needed to determine the potential effects for each of the covered species from placing structures below the sloughs and recommended that the EIR/EIS should evaluate the option to site diversions below Steamboat and Sutter Sloughs.

Diversion Features

- Flat, wedge wire screen with 1.75 mm max screen material slot width.

- Single diversion structure per site; multiple structures per site are not practical to construct.
- Minimize length of screen to reduce duration of fish exposure to the screen surface.
- Incorporate gravity intake and onshore pumping facilities to minimize in-channel infrastructure and improve accessibility/function of facilities.
- Screens should be designed to provide sufficient wetted screen area to meet or exceed the 0.33 fps approach velocity criterion at the 99% exceedence water surface elevation (WSE). Screens may be designed such that tops of each screen panel are up to 6 feet higher than the 99% exceedence WSE to reduce the effective approach velocity at river stages greater than the 99% exceedence WSE while maintaining maximum pumping capacity (3,000 cfs).
- Offset bottom of screen 3 feet to 5 feet above river floor to minimize dynamic sediment and bed load impacts to available screen area.

Configuration

Previous sessions of the FFTT considered three general screening concepts in various arrangements. The concepts included in-river diversions, similar to the City of Sacramento diversion near the confluence of the American River, on-bank diversions, similar to several existing diversions on the Sacramento River from Freeport to Red Bluff, and diversion clusters of small screens comprised of up to 30 retrievable cylindrical screens along the bank at each diversion location. While some of the other concepts offered desirable conceptual benefits such as shorter screen length and fish exposure times or the simplicity of small cylindrical screens in large numbers, the extrapolation of these screening methodologies by an order of magnitude to achieve the required diversion levels represents a significant uncertainty and risk for fish protection and screen performance. The current state of the art screening technology for large diversions on the Sacramento River is an on-river vertical flat plate screen, utilizing a horizontally traveling brush as the primary screen cleaning mechanism. On-bank diversions are being recommended by the FFTT over in-river diversions for various reasons, including:

- To maintain flood neutrality with an in-river diversion, the river would have to be widened approximately 80 feet;
- Construction of a cofferdam large enough to accommodate the in-river diversion would create a significant amount of disturbance in the river and be very difficult to construct. Also the large amount of bracing required within the cofferdam for the in-river diversion would make construction extremely slow and cumbersome. In-river diversion structure width would be limited to approximately 35 feet requiring the structure to be over 800 feet long;
- Net uplift forces acting under the base slab of the dewatered cofferdam will be enormous. A significant anchorage system will be needed to resist uplift forces during construction of the in-river diversion; and
- A combination of active dewatering, soil anchors and relief vents will be required to construct an in-river diversion.

To develop appropriate diversion recommendations that will provide meaningful protection for target fish species while meeting the water diversion thresholds identified for the Sacramento River diversions, it's important to recognize the advancements made on large on-bank diversions on the Sacramento River over the past two decades and to limit large deviations from their designs. It is also important to recognize the fundamental differences that the north Delta diversions have from any other screens that have been constructed and the design challenges that they present. Each north Delta diversion will be as large as the largest fish screens on the Sacramento River, will be situated in slower ambient flow condition, and will be subject to weaker swimming fish that don't occur further upstream in the river.

Three Sacramento River screens are of significant relevance to the development of the north delta diversions: the Glenn Colusa Irrigation District (GCID) screens, the Red Bluff Diversion screens (RBD), and the Freeport Diversion Screens (FD). The GCID screen is the largest diversion on the Sacramento River, with a capacity of 3,000 cfs. The GCID screens were reconstructed in the mid-1990s and converted from drum screens to vertical flat plate screens with a length of approximately 1,100 feet. To limit exposure of juvenile salmonids to the long screen surface, the design incorporated intermediate fish bypass to collect fish and return them to the bypass channel below the screen. The bypasses were abandoned due to excessive predation occurring at the water control structure downstream from the screen, a feature necessary to generate head to drive the bypass system. Eliminating the water control structure reduced predation but rendered the bypasses inoperable.

The Red Bluff Diversion screen now under construction is a replacement for the drum screens utilized by the Tehama Colusa Canal Authority and Corning Canal. Diversion through the drum screens required the Red Bluff Diversion Dam to be in place, which causes a variety of significant impacts to fishery resources. To eliminate the need for the diversion dam, the Red Bluff screens were redesigned as an on-river screen. The new screens have a design capacity of 2,500 cfs with approximately 1,100 feet of screen length. Because of the difficulty of implementing intermediate bypasses for on-river screens, the concept of refugia as an alternative to intermediate fish bypasses was developed as part of the RBD fish screen and modeled at the Reclamation Technical Services Center in Denver, Colorado. Refugia can be characterized as a zone along the length of a screen in which a juvenile fish (or other small fish) can escape the flow field in front of the screen and predation from larger fish. This concept was first investigated in a physical model and is being implemented as an element of the RBD fish screen. In its basic form, a refugia is a recessed bay along the length of a fish screen that is covered with a grating flush to the fish screen face that allows small fish to move into and out of the refugia but will not allow larger fish to enter.

The Freeport Diversion was recently completed, but hasn't started operation. While having a much smaller diversion capacity (approximately 290 cfs) it is the closest large flat plate screen to the proposed north Delta diversion sites. Of the three screens mentioned here, the Freeport Diversion is the only one designed to the 0.2 fps approach velocity for delta smelt.

By comparison to the GCID, RBD and FD sites, the following design limitations are recommended for the north Delta diversions:

- Maximum diversion per site should not exceed 3,000 cfs.
- Diversion structures should be as short in length as practicable.
- Resting/Escapement refugia should be considered as an alternative to intermediate bypasses to limit fish exposure to the screen. Fish refugia should be spaced no more than 100 feet apart along the length of each screened intake structure, in lieu of providing intermediate fish bypasses.

- Target the height of fish screen panels to fifteen feet of submerged screen height to operate at 0.33 fps approach velocity at low river stage; taller screens may be appropriate at specific sites for purposes of reducing the length of the diversion structure. If the screens are constructed 40% taller (additional 6 feet), when the river stage exceeds the design minimum, the extra water depth will allow increased diversion capacity while meeting a 0.2 fps approach velocity (during critical times when delta smelt are present).. Further refinement of the relationship between screen height and river stage should be addressed during an optimization process associated with final design. The screen heights for the three reference screens (GCID, RBD and FD) are approximately 10 to 12 feet.

- The large diversions on the Sacramento River north of the delta have been designed using criteria for the protection of downstream migrating juvenile salmonids. The diversions proposed for the BDCP will be required to provide protection for fish species other than salmonids for which there is limited or no criteria for their protection. For this reason, the north Delta diversions should be designed to maximize the potential for collection of data on fisheries impacts and be capable of configuration adjustments to improve fisheries protection efficiency. In this context, adaptability is considered to be the ability of the diversion structure to be reasonably reconfigured or physically modified, to enhance fisheries protection. Flexibility is considered to be the ability to make operation adjustments to enhance fish protection which don’t require physical changes to the diversion structure.

- To optimize the operation of the diversion structures as well as provide for fish protection advancements and transfer of technology from one structure to another, the dimensions of the fish screens, refugia, and other components should be standardized where possible for all five diversions for economies of scale and operational flexibility.

The following are general recommendations for the configuration of fish screens for the north Delta diversions. The FFTT recommends an optimization study to determine appropriate design configurations for each diversion site. An example diversion configuration is provided for information only as Appendix C:

- Each of the five diversions should be comprised of a single diversion structure with a maximum capacity of 3,000 cfs. Each diversion structure should be divided into multiple sections with independent flow control for each of the sections. Each section should be capable of being dewatered for maintenance or repair while the other sections are in normal use.
- The screens should be made up of vertical (or near vertical) flat plate wedge wire panels and utilize a brush type screen cleaning mechanism.

Additional Considerations

Approach Velocity Control – Fish screens are designed under the assumption that velocity of water flowing through the screen is uniformly distributed across the entire screen area. This becomes increasingly difficult to achieve on long and/or tall screens. On long screens, segmenting the screen into shorter sections with screen bay piers and utilizing adjustable baffling or louvers closely behind the screen helps distribute the flow along the length of the screen. However, vertical non-uniformity of flow can still be a concern. To address this issue, the concept of High Definition Approach Velocity Control, where screen bays would be divided into segments with independent flow control, has been suggested for consideration. Details of this concept are provided as Appendix D.

Sampling and Monitoring Options – If the diversions are to be adaptively managed or regulated based on monitoring of fish presence in the vicinity of the screens, sampling will be necessary. Historically, this has been done with beach seining, boat trawls, or screw traps, all of which are manpower intensive. As an alternative, it may be possible to equip one or more refugia with a trapping device for collection and monitoring. This could be accomplished at various levels of sophistication.

Other Potential Refugia – The concept of fish refugia for increased protection efficiency at fish screens is new and is being developed as an alternative to intermediate bypass systems on long screens. Another type of refugia that should be considered for investigation and development for the screens is predation refugia. This type of refugia is composed of escapement features for small fish at locations along the upstream and downstream bank transitions and at the base of the screens. Base refugia are the addition of a physical feature to the base of a fish screen that would allow smaller fish to escape predation. Transition refugia are features added to intake structure transition walls to eliminate predator habitat and provide cover for smaller fish at each end of the diversion structures. Pre-construction studies recommended by the 2011 FFTT will collect data to determine if these refugia concepts are warranted.

Options for Dewatering the Face of the Structure – Consideration should be given to developing a plan and methodology for a cofferdam and dewatering system that will allow portions of the river side of the screen structure to be inspected and serviced without taking the entire structure out of service.

Invasive Mussel Considerations – Consideration should be given to maximizing the ability to isolate and dewater all portions of the screening facilities for management/removal of invasive mussels or other noxious species.

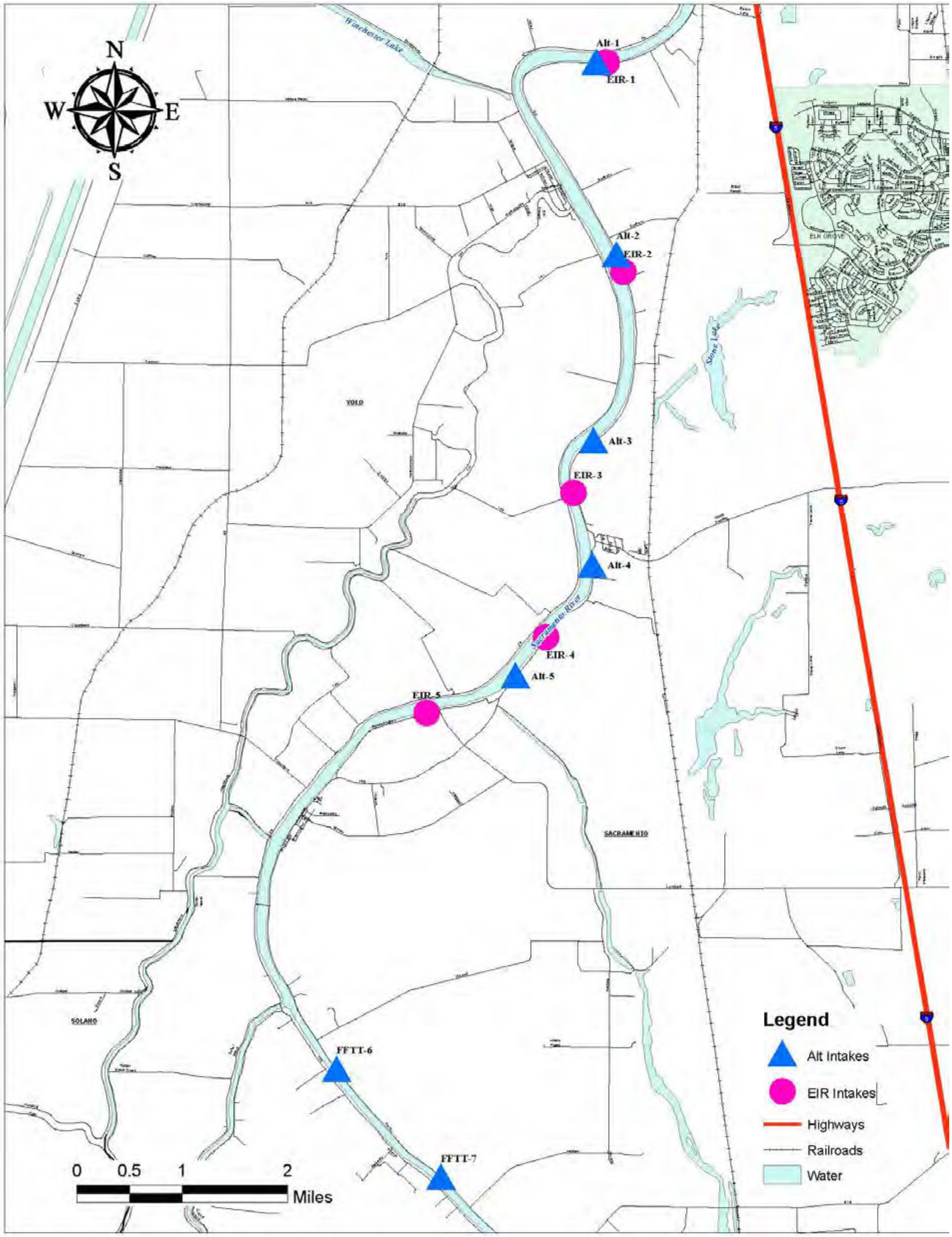

Figure 1. Potential North Delta Diversion Locations Reviewed by the FFTT

1. References

Young, Paciencia S., Swanson, Christina and Cech Jr., Joseph J. (2010) 'Close Encounters with a Fish Screen III: Behavior, Performance, Physiological Stress Responses, and Recovery of Adult Delta Smelt Exposed to Two-Vector Flows near a Fish Screen', Transactions of the American Fisheries Society, 139: 3, 713-726, First published on: 09 January 2011 (iFirst)

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Vogel, David A. (2008). Pilot Study to Evaluate Acoustic-Tagged Juvenile Chinook Salmon Smolt Migration in the Northern Sacramento-San Joaquin Delta 2006-2007. Prepared for California Department of Water Resources, Bay-Delta Office, 1416 9th Street, Sacramento California.

2. List of Appendices

A. 2008 Fish Facilities Technical Team Memorandum

B. Suitability of Diversion Sites Based on Water Depth and River Bend Geometry

C. Example Diversion Facility Arrangement

D. High Definition Approach Velocity Control

Appendix A: 2008 Fish Facilities Technical Team Memorandum

PRELIMINARY DRAFT

Conceptual Proposal for Screening Water Diversion Facilities along the Sacramento River

Fish Facilities Technical Team
Bay-Delta Conservation Plan
August 2008

Conceptual Proposal for Screening Water Diversion Facilities along the Sacramento River

1.0 Introduction

The purpose of this proposal is to document the efforts and current status of the Bay Delta Conservation Plan (BDCP) Fish Facilities Technical Team (FFTT) review and evaluation of approaches to screening a maximum diversion of 15,000 cubic feet per second (cfs) along the Sacramento River between the City of Sacramento and Walnut Grove as part of an isolated conveyance system to route water around the Delta to existing state and federal export facilities in the south Delta. This document is intended to provide the BDCP Conveyance Workgroup initial direction regarding location, composition, and arrangement of fish protective diversion facilities.

The FFTT consists of agency, stakeholder, and consultant representatives charged with developing, analyzing, and proposing concepts on fish screen facilities to the BDCP Conveyance Working Group. The members of the FFTT and the experts providing technical support are listed below:

Team Members:

George Heise, Department of Fish and Game
Richard Wantuck, NOAA National Marine Fisheries Service
Dan Meier, US Fish and Wildlife Service
Steve Hiebert, US Bureau of Reclamation
Tina Swanson, The Bay Institute
Ron Ott, OttH2O
Laura King Moon, BDCP Management Team
Victor Pacheco, Department of Water Resources

Technical Support:

Zaffar Eusuff, Department of Water Resources
Gordon Enas, Department of Water Resources
Ganesh Pandey, Department of Water Resources
Chris McColl, Science Applications International Corporation
Tim Buller, Black and Veatch
Wayne Ohlin, CH2M HILL

This proposal presents the four initial concepts for diversion screening up to 15,000 cfs using one or more screens at multiple locations along the Sacramento River to meet fish protection needs. **The concepts and locations contained in this proposal are for illustration purposes only and require additional discussion and analysis.** These concepts have been developed focusing primarily at the requirements of diverting water from the river and not beyond the limits of the bordering river levees. Additional information will be needed to further develop and refine potential fish screen type; size and number (multiple versus a single intake); configuration and geometry; and locations(s) to support both through and around the Delta conveyance facilities.

2.0 Criteria / Principles

The FFTT recognizes that operating criteria for a maximum diversion of up to 15,000 cfs using multiple diversion facilities will be fundamental to ensure fish protection as they affect the number, types and design of screens. The concepts illustrated in this proposal will need to be coordinated with the Habitat Operations Technical Team (HOTT) and others, as needed, in an iterative process to evaluate compatibility of proposed operating criteria with fish screening requirements important to the protection and reduction of stressors for species of concern. This is one of several pending efforts and issues that will need to be addressed in further developing the proposed concepts as described in Section 5 of this proposal.

The concepts for screening water diversions would be designed in accordance with NMFS, and CDFG design criteria and USFWS guidance for an intake within the Delta where Chinook salmon, delta smelt and other sensitive fish species are present. Adopted fish screen design criteria by CDFG and NMFS have been established primarily to protect salmonids and steelhead. The FFTT recognizes that these criteria may not provide full protection for weakly swimming fish or fish eggs and larvae of non-salmonid fish species and suggests additional information needs in Section 4 of this proposal.

Fish protection criteria and guidelines include, but are not limited to:

Structure Placement
Approach Velocity
Sweeping Velocity/Fish Exposure duration
Screen Material
Screen Opening size
Civil Works and Structural Features
Bypass System
Operations and Maintenance

Fish screen criteria are primarily based on fish swimming ability and behavior to avoid and escape entrainment and impingement. Research has documented the varying swimming ability of several fish species. Fish swimming ability may depend on several factors, including but not limited to:

Fish length
Life stage (adult/juvenile)
Fish swimming behavior
Physical condition of fish
Channel flow condition
Dissolved oxygen concentration
Water temperature
Time of day/light conditions

Site-specific criteria such as screen orientation can also be proposed where opportunities exist to further protect fish species. Variances from an established criterion may be evaluated on a project-by-project basis based on site constraints and operational requirements. For example, the FFTT believes that the 0.33 ft/s approach velocity criteria established to protect salmonids and steelhead should be used to design the proposed facilities and use reduced diversions at these sites in real-time to provide a the 0.2 ft/s approach velocity, as deemed necessary to be more protective of weakly swimming fish and fish eggs or larval life stages, when they are present at the site. Each facility would be engineered to allow variable rate pumping in order to accomplish this operational scheme. This approach reduces the required length of the fish screen and thereby reduces fish exposure to the screen during facility operations, and it also minimizes environmental impacts associated with construction by reducing the size of the required facility.

A list of available fish screen references for the design and operation of fish screen facilities can be found in Section 6 of this proposal.

The FFTT agreed to the following general principles to guide development of conceptual fish screening proposals:

(1) Use the most biologically protective fish screen concepts as the foundation of the proposed designs;

(2) Provide a positive, physical fish screen barrier between fish and water intakes;

(3) Avoid the need to collect, concentrate, and handle fish passing the water intake;

(4) Avoid the need for fish bypasses that concentrate fish and increase the risk of predation;

(5) Eliminate consideration of an 'off-channel screen with a bypass back to the river' alternative because it is ineffective at achieving primary objectives of avoiding fish mortalities as compared to in-channel and on-bank screen alternatives; The off-channel screen approach results in stress and predation related fish mortalities associated with required concentration/handling of fish;

(6) Avoid creating areas where predators may congregate or where potential prey would have increased vulnerability to predation;

(7) Select screening locations that have desirable hydraulic characteristics (uniform sweeping velocities, reduced turbulence);

(8) Select screening locations as far north on the Sacramento River as possible in order to minimize fish exposure to screens by avoiding tidally induced reverse flows or stagnant flow conditions;

(9) Use the best available existing fish screening technology in use such as on-bank vertical flat plate screening systems in place at Sutter Mutual and Reclamation District 108, in-river vertical flat plate screening systems used by the City of Sacramento, or multiple small retrievable screens, such as in place at Reclamation District 999;

(10) Use multiple intakes with modules capable of diverting from 500 cfs to 1,500 cfs per screen face with a combined maximum diversion up to 5,000 cfs at a single location. A single 15,000 cfs diversion was not considered since there is no diversion/screen facility of this size in the Sacramento Valley and it is unknown what hydrodynamic effects would be on the river channel;

(11) Minimize the length of screen intake(s) to reduce the duration of fish exposure to the screen surface;

(12) Select locations on the Sacramento River as far north as practicable to reduce the exposure of delta smelt, longfin smelt, and other estuarine species;

(13) Avoid areas of existing riparian habitat

(14) Cost information was not used in developing concepts, but recognized that it will be a consideration in subsequent development phases and in selection of preferred screening concepts.

The FFTT identified several design issues that require further analysis and discussion. The information needed to further define the fish screening concepts can be found in Section 4 of this proposal.

3.0 Conceptual Proposals

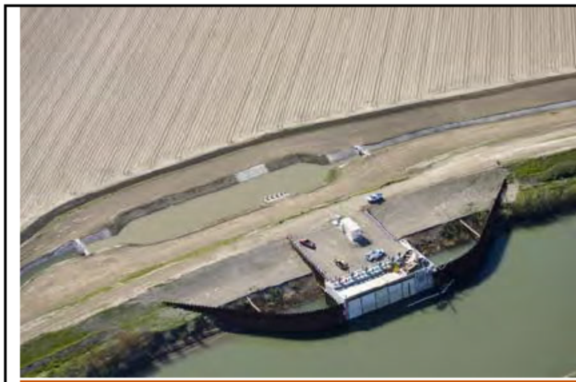
The FFTT has developed four preliminary concepts **for illustration purposes only** in screening up to 15,000 cfs from the Sacramento River which focus on protecting fish based on the criteria and principles described above in Section 2. The FFTT did not analyze additional factors such as; water quality, and aesthetics, on whether 15,000 cfs can be diverted without resulting in significant unavoidable environmental impacts. Screen configurations, locations, and capacities will be determined and refined based on additional analysis of relevant constraints including land use, infrastructure, biological resources and other factors. The additional information needed to further define these concepts is identified in Section 4.

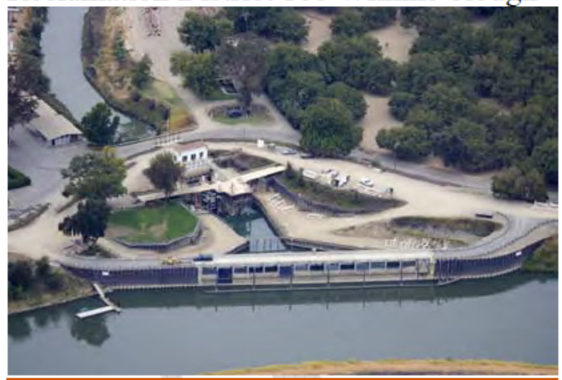
A 15,000 cfs diversion facility at a single location would be five times larger than the biggest existing diversion on the Sacramento River. Hence, a single facility is considered too large to assure fish protection goals of this project would be met. In addition, the uncertainty for local and downstream hydraulic and ecosystem effects led the FFTT to propose the use of smaller diversion facilities at multiple locations. The overall concept is that facilities at several locations on the Sacramento River would be proposed to cumulatively achieve a maximum total diversion of 15,000 cfs. Each diversion facility could consist of one or more screen types to provide optimum protection for fish. All of the proposed concepts adhere to the principles of multiple diversion facilities (intakes) without fish bypasses and/or direct handling of fish.

Each reach of the river between Sacramento and Walnut Grove has unique hydraulic and habitat conditions depending on the time of year and flow and the species to be protected at that location. The location and operation of any diversion facility has an effect on species protection and the level of protection varies for different fish species and life stages. The main differences among the concepts are the proposed number of intakes and type of screens selected to provide optimum fish protection using a single screen type or in combination with other screen types. The three main types of screens include: On-bank screens similar to those used at Reclamation District 108 and currently under construction at Freeport on the Sacramento River, In-river screens similar to those used by the City of Sacramento, and cylindrical screens similar to those used by Reclamation District 999.

Descriptions of conventional screen technologies deemed by the FFTT best suited for this project are as follows:

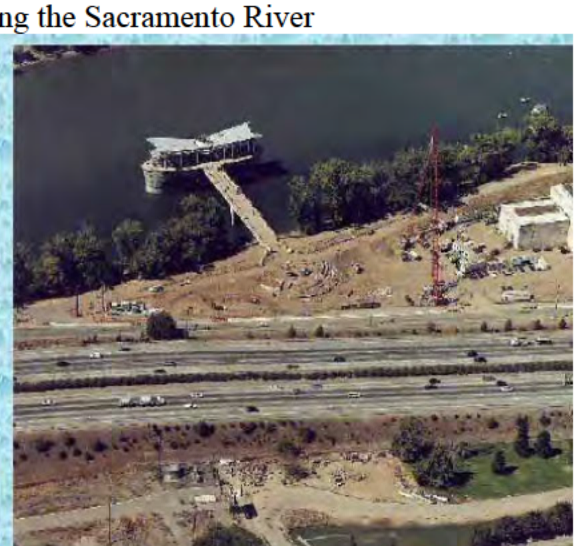
On-bank screens consist of a single plane of flat plate screen panels, either aligned vertically or with an angle of repose. This type of intake configuration is located near and parallel to the bankline, is accessible from the adjacent embankment, and produces little relative projection or silhouette within the water column. Screens would be similar to the many flat plate wedge wire screens operating on the Sacramento River including Sutter Mutual, Princeton-Codura-Glenn/Provident and Reclamation District 108 (Wilkins Slough and Poundstone Pumping Plants). The proposed concepts illustrate the use of one or more on-bank screens at several locations, or in combination with other screen-type facilities. Photographs of on-bank screened intakes are provided below.


Reclamation District 108 Poundstone Pumping Plant

Reclamation District 108 Wilkins Slough


In-river screens consist of a screened diversion constructed in the river, detached from the bankline, and include an aerial bridge span for access. This configuration is a long, narrow, streamlined structure capable of housing dual screen banks at opposing faces. The intake tower with single or dual screen surfaces would be similar to the City of Sacramento's water intakes on the Sacramento River and the American River. The in-river screens have the advantage of being in the deeper part of the river cross-section than the on-bank screens. Therefore, the in-river screens can have a greater depth and can divert a larger flow for the same length of an on-bank screen. In addition, the length would be shorter than a similarly sized on-bank facility due to the use of dual screen surfaces for an in-river facility. The proposed concepts illustrate the use of one or more in-river screens at several locations or in combination with other screen-type facilities. Photographs of the City of Sacramento in-river intake are provided below

City of Sacramento Water Intake Facility along the Sacramento River



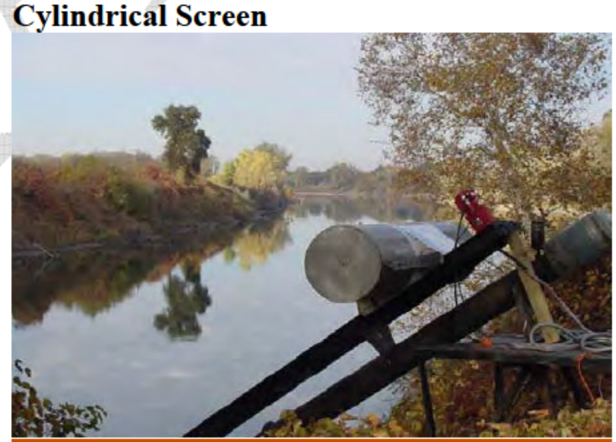
Cylindrical screens would be similar to the many cylindrical screens operating on the Sacramento River. This type of screen is more aptly suited to smaller diversions (100 cfs and less) due to its relatively small screen area. However, multiple units can be combined to provide comparable capacities. Cylindrical screens are pre-manufactured elements assembled in a tee-type configuration with screen elements at each side of a manifold connection. Each module requires above ground superstructure to support an intake conduit/pump casing and guide rails or tracks for guiding the screen into the water body over the conduit inlet.

The advantages of this screen configuration are its relatively low cost, its shallow profile, its retrievable and interchangeable design, and its ability to be constructed in the "wet" without cofferdams and dewatering systems. Obvious drawbacks are the volume of moving parts and hydraulic components, exposure to impact damage from debris/bed load, single-source manufacturing, and potential for producing structure which supports predation. Application of this screened intake concept requires further evaluation but has proven to be viable for other small diversion installations on the Sacramento River.

Examples of this screen type on the Sacramento River are a variety of installations for Reclamation District 999 near Clarksburg and other locations. The proposed concepts require series of cylindrical screens to provide the desired capacity at each location, as well as, in combination with other screen-type facilities. Photographs of cylindrical screened intakes are provided below

Cylindrical Screen

Cylindrical Screen



Sacramento River Cross Sections Evaluated to Date

The FFTT was directed by the Conveyance Workgroup to focus on a reach of the Sacramento River between the City of Sacramento and Walnut Grove for siting fish screen intake facilities. To supplement their working knowledge of this section of the river, the FFTT collected and reviewed a variety of information ranging from aerial images to fishery survey data in order to identify potentially suitable locations. The following is a list of the maps and images used by the FFTT which can be found in Appendix A:

- Delta Map
- Delta Waterways map
- Infrastructure and sensitive natural communities
- Land Elevation layer
- Transportation corridor layers (Highways, local roads, railroads);
- Electrical Transmission and Gas lines and related infrastructure layers;
- Bathymetry layer (latest data available);
- Existing regions of critical habitat that should be avoided within area of interest;

In addition, the FFTT reviewed general fisheries temporal and spatial patterns, critical habitat, and fall mid-water trawl delta smelt data which can be found in Appendix B. However, the FFTT identified the need for more detailed fish species presence, timing, and distribution information for applicable life stages (i.e., eggs, larval, juveniles and adults) within the reach of the Sacramento River between the City of Sacramento and Walnut Grove.

Based on the review of the available information, the team identified twelve potentially suitable locations for placing a diversion facility. These sections were primarily selected to characterize river cross-section geometry based on alignment and to develop a general understanding of water depth and average velocity versus flow. These twelve potentially suitable locations identified by the team for further analysis are shown in Figure 1. Although bathymetry data for each location could be obtained, the most recent data for portions of the reach of interest was obtained in 1997 and some data obtained as far back as 1977 which may not reflect current conditions. In addition, detailed river flow and stage information was unavailable and it was necessary to estimate values for each location based on two existing stations (one at Freeport and one near the Delta Cross Channel). Additional information needs require updated river bathymetry and hydrodynamic information for the reach of interest. The cross sectional information and aerial images can be found in Appendix C.

The FFTT participated in a multi-agency tour of the Sacramento River lead by the US Geological Survey (USGS) on July 29, 2008. The tour provided an opportunity to verify information regarding potentially suitable intake locations, to discuss USGS hydrodynamic and fish tracking studies, to view potentially suitable intake locations firsthand, and to identify potential constraints such as ongoing or proposed levee repair sites and/or riparian habitat restoration areas.

Sacramento River Cross Sections Evaluated to Date

For illustration purposes only,
actual locations would be determined and refined based on additional analysis of relevant constraints including land use, infrastructure, biological resources and other factors.

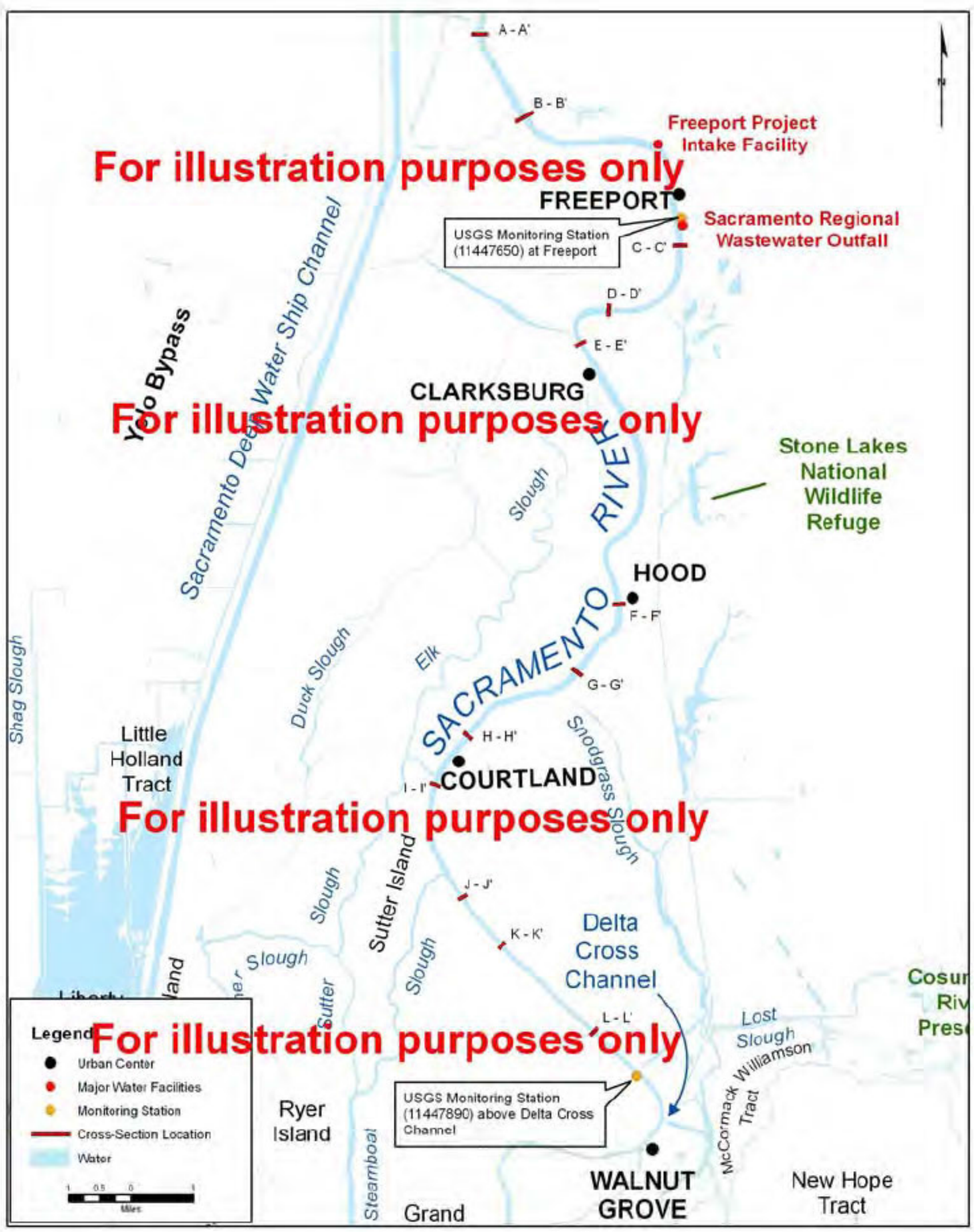


FIGURE 1

Conceptual Proposal A

Concept A consists of a combination of in-river and on-bank screens situated at three locations on the Sacramento River between Freeport and Courtland. Each location would provide a diversion capacity of 5,000 cfs for a combined maximum diversion capacity of 15,000 cfs. The use of multiple locations provides redundancy and increases operational flexibility. Redundancy provided by multiple units and/or facilities provides an opportunity to shift diversions from one location to another, as needed, to protect sensitive species that may be near a given location and/or address maintenance or outages for units or facilities. The use of in-river and on-bank screens eliminates the handling of fish or need for bypass facilities. The screens would be located in a relatively straight stretch of the river to avoid complex flow patterns, scour, and sediment issues associated with river bends.

The length of the screen surface would be kept as short as possible to minimize fish exposure to the screen surface. The in-river screens have the advantage of being in the deeper part of the river cross-section than the on-bank screens. Therefore, the in-river screens have a greater depth and can divert a larger flow for the same length of screen as the on-bank screens. The in-river screens have a screen surface on both sides of the supporting structure allowing for a total screened flow up to 2,500 cfs each. The in-river screened flow would be limited to 2,250 cfs each when they are used in combination with the on-bank screen which would be limited to 500 cfs. In-river screens would be used at each location and on-bank screens would only be used at a location in combination with in-river screens. Configurations for the conceptual layout of these screens are shown in Figures 2, 3, and 4 at representative locations selected by the team for illustration purposes only.

The in-river screens would consist of towers with dual screen surfaces similar to the City of Sacramento's water intakes on the Sacramento River and the American River. The major difference is that the pumps would not be situated on the tower but on the landside of the levee. Water would flow through the screens on the tower, then into pipes buried in the river bottom and under the levee, then into a wet well system where the water would be pumped into a collection channel. A conceptual drawing for illustration purposes only of in-river fish screens is shown in Figure 5.

The on-bank screen would consist of a single screen surface along the bank of the river with transitions at the upstream and downstream ends to achieve uniform sweeping flows and velocities across the screens. The on-bank screen would be used in combination with in-river screens and share common infrastructure (pumps, pipelines, etc…) as described for the in-river screens. A conceptual drawing for illustration purposes only of a combination in-river and on-bank fish screens is shown in Figure 6.

CONCEPT A – Section C-C'

(For illustration purposes only, actual locations would be determined and refined based on additional analysis of relevant constraints including land use, infrastructure, biological resources and other factors.)

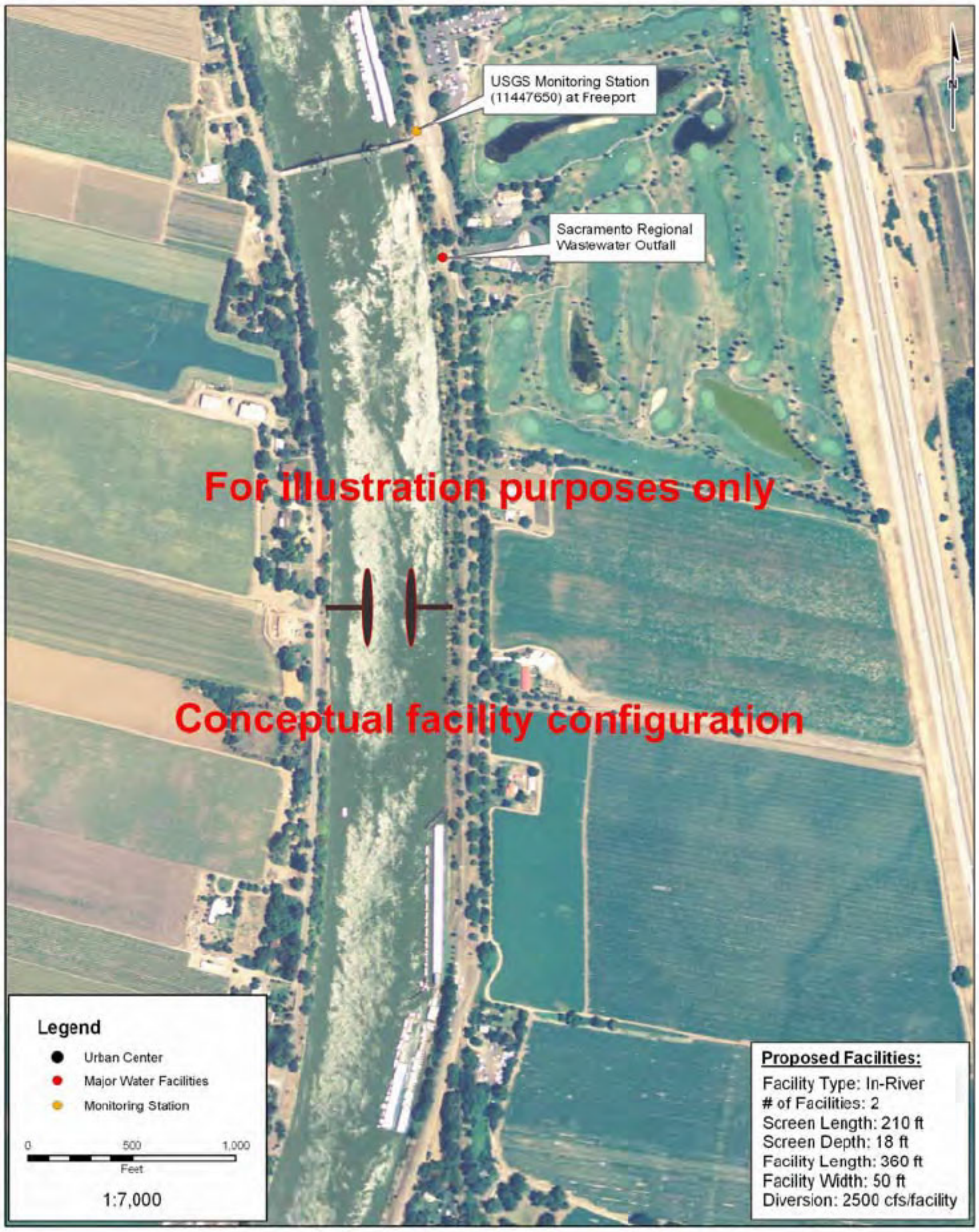


FIGURE 2 - Aerial view showing potential footprint

CONCEPT A – Section F-F'

(For illustration purposes only, actual locations would be determined and refined based on additional analysis of relevant constraints including land use, infrastructure, biological resources and other factors.)

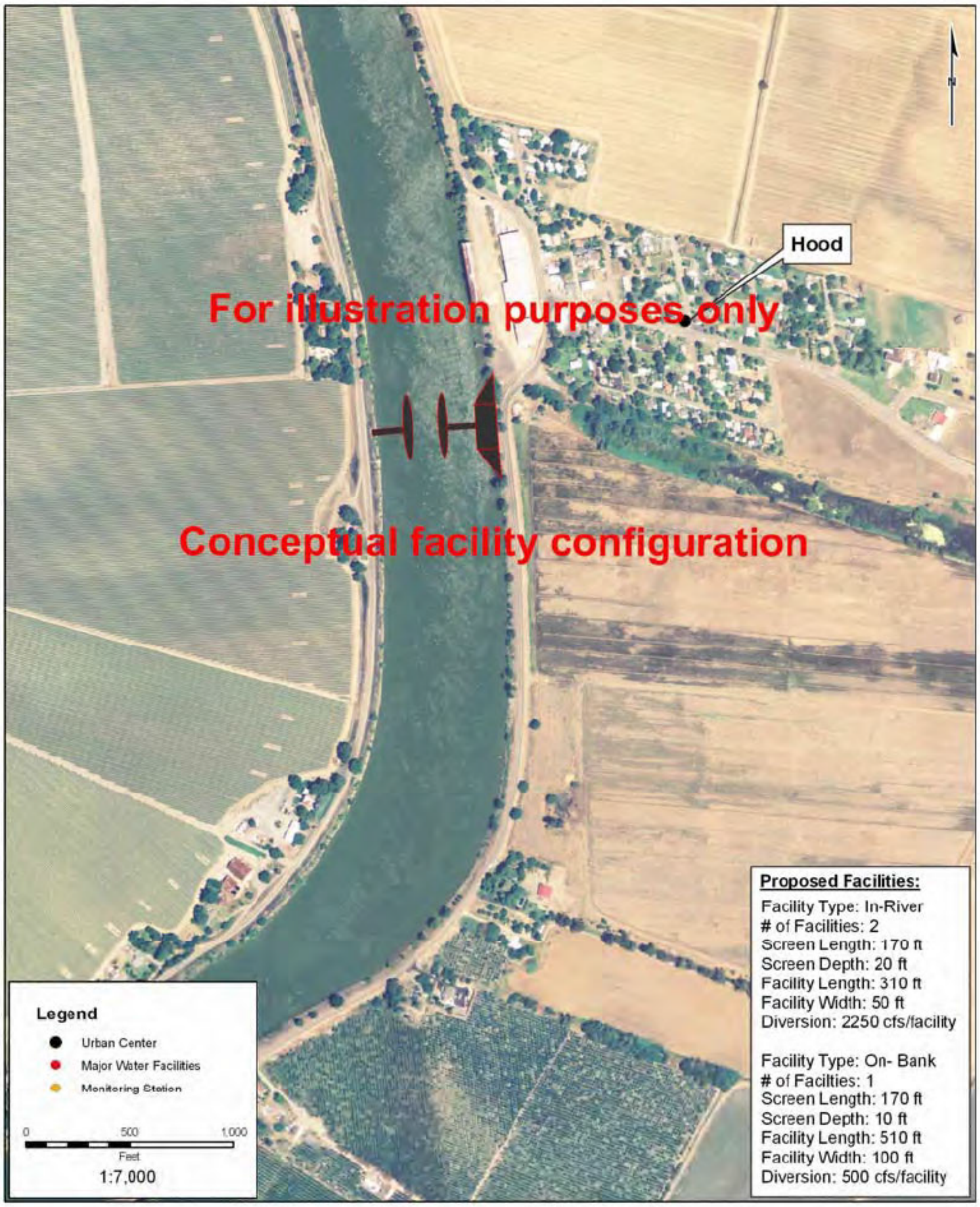


FIGURE 3 – Aerial view showing potential footprint

CONCEPT A – Section H-H'

(For illustration purposes only, actual locations would be determined and refined based on additional analysis of relevant constraints including land use, infrastructure, biological resources and other factors.)

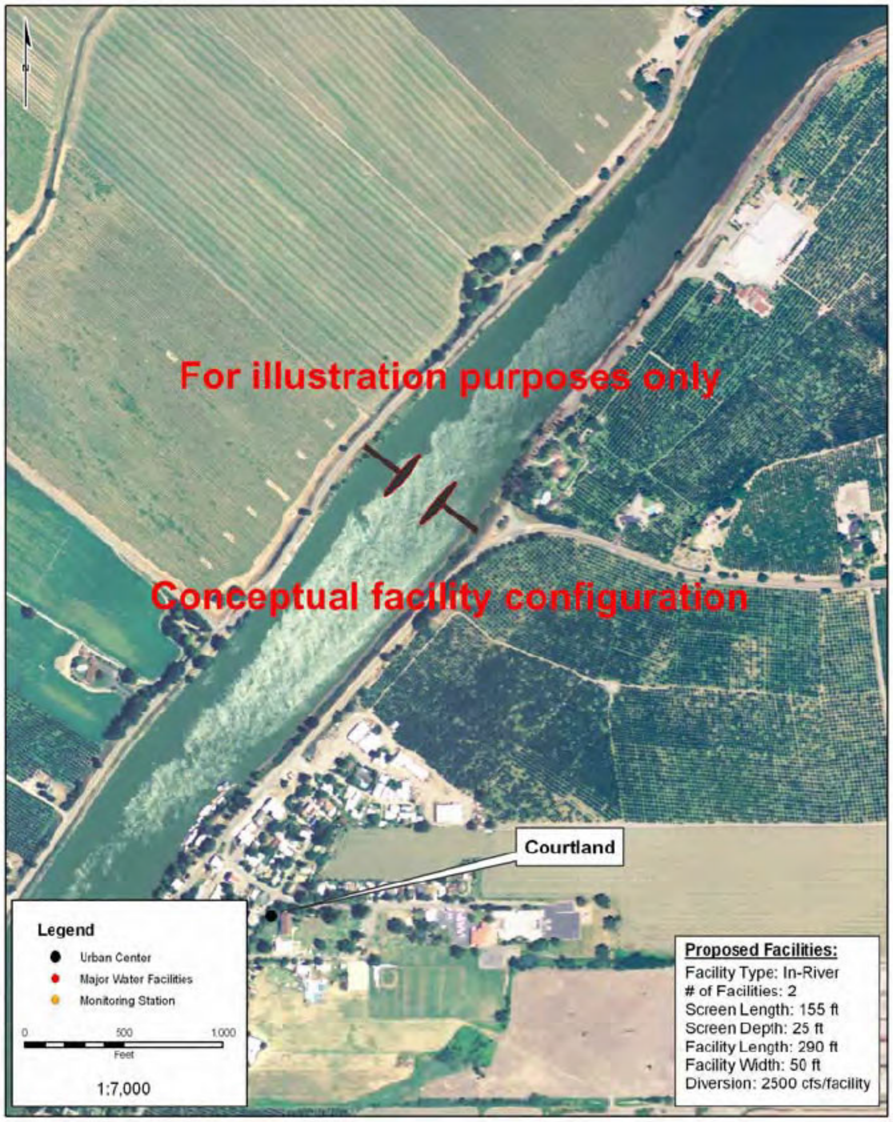


FIGURE 4 - Aerial view showing potential footprint

Figure 5 – Conceptual In-River drawing
(For illustration purposes only)

Figure 6 – Conceptual In-River and On-Bank drawing
(For Illustration purposes only)

Conceptual Proposal B

Concept B consists of a series of cylindrical screens at ten locations along the Sacramento River between the City of Sacramento and Walnut Grove. Each location would consist of fifteen 100 cfs cylindrical screens providing a cumulative diversion capacity of 1,500 cfs. The combined maximum diversion capacity of all ten locations would be 15,000 cfs. The use of ten smaller diversions reduces the potential hydraulic effects and exposure time in comparison to the three larger diversions described in Concept A, and the increased number of smaller diversions provides increased redundancy and operational flexibility. The use of cylindrical screens eliminates the handling of fish or need for bypass facilities. The screens would be located in a relatively straight stretch of the river to avoid complex flow patterns, scour, and sediment issues associated with river bends.

Each cylindrical screen is approximately 7 feet in diameter and 23 feet in length with an estimated screened flow of 100 cfs each. A total of fifteen cylindrical screens at each location will be needed to provide the desired diversion capacity of 1,500 cfs. A total of ten locations will be necessary to achieve a combined maximum diversion capacity of 15,000 cfs. Although removable and retractable features of cylindrical screens provide easy access for maintenance purposes, the increased number of diversions in comparison to Concept A would require greater conveyance infrastructure. Configurations for the conceptual layout of the cylindrical screens are shown in Figure 7 at a representative location for illustration purposes only.

Water would flow through the screens, then into pipes buried in the river bottom and under the levee, then pumped into a collection channel. Alternatively, the flow from each screen could be pumped over the levee and then piped to a collection channel. The cumulative effect of multiple cylindrical screens may cause hydraulic complexities that affect the uniformity of flow through screens and sweeping flows past the screens. Clusters may also create habitat for predatory fish. Cylindrical screens may be more susceptible to impact damage from flood borne debris since they extend into the waterway. A conceptual drawing for illustration purposes only of a multiple cylindrical fish screen layout is shown in Figure 8.

CONCEPT B – Section C-C'

(For illustration purposes only, actual locations would be determined and refined based on additional analysis of relevant constraints including land use, infrastructure, biological resources and other factors.)

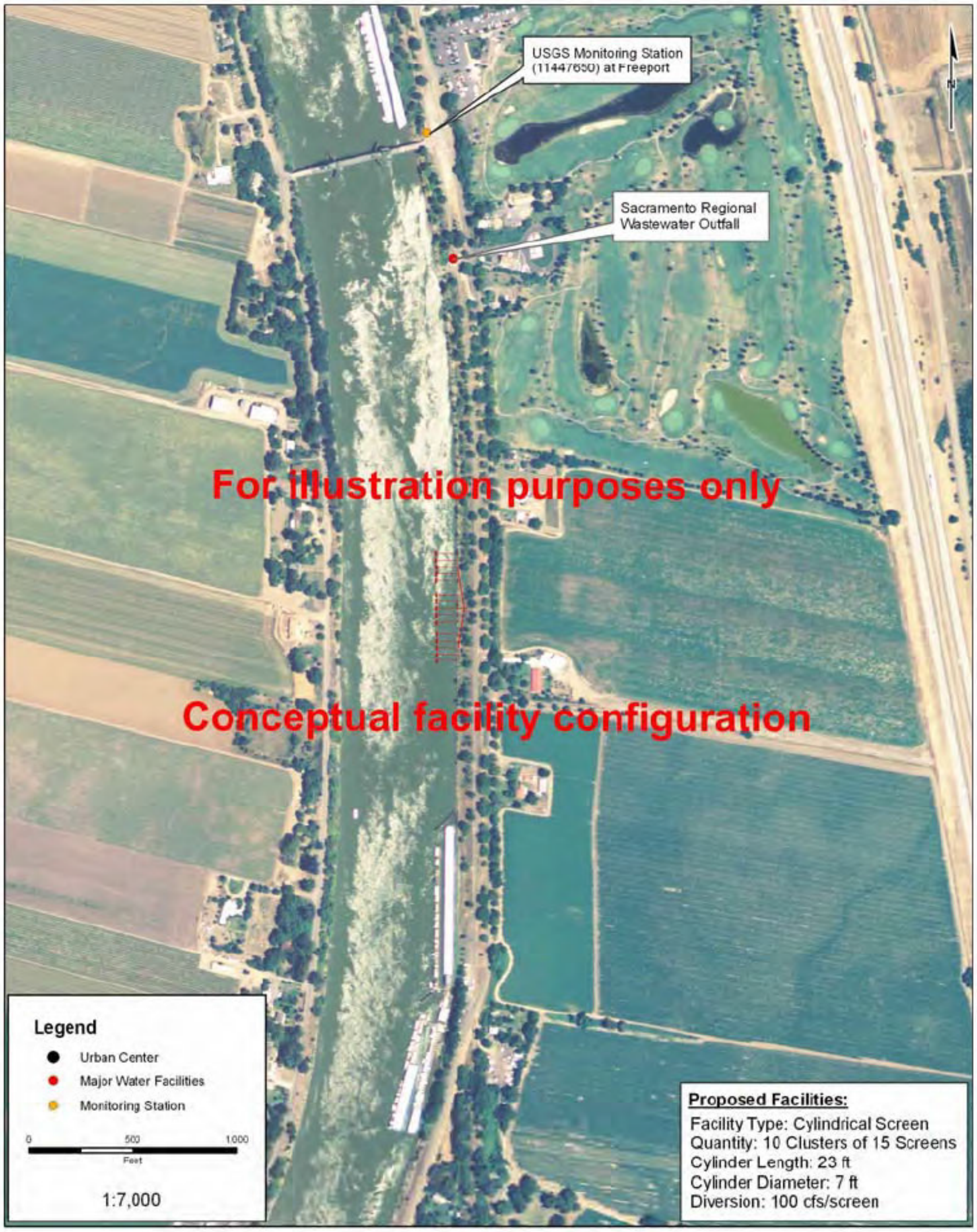


Figure 7 – Aerial view showing potential footprint

Figure 8 – Cylindrical Screen conceptual drawing
(For illustration purposes only)

Conceptual Proposal C

Concept C consists of a combination of on-bank and in-river screens situated at ten locations on the Sacramento River between the City of Sacramento and Walnut Grove. Each location provides a diversion capacity of 1,500 cfs for a combined maximum diversion capacity of 15,000 cfs. The use of ten smaller diversions reduces potential hydraulic effects and exposure time than for the larger diversions described in Concept A, and provides increased redundancy and operational flexibility similar to Concept B. Similar to Concept B, the increased number of diversions in comparison to Concept A would require greater conveyance infrastructure. The use of in-river and on-bank screens eliminates the handling of fish or need for bypass facilities. The use of multiple screen types may require a variety of maintenance and back up screens and material at each site rather than a single type of modular replacement or serviceable screen. The screens would be located in a relatively straight stretch of the river to avoid complex flow patterns, scour, and sediment issues associated with river bends.

The length of the screen surface would be kept as short as possible to minimize fish exposure to the screen surface. The in-river screens have the advantage of being in the deeper part of the river cross-section than the on-bank screens. Therefore, the in-river screens have a greater depth and can divert a larger flow for the same length of screen as the on-bank screens. The in-river screens have a screen surface on both sides of the supporting structure allowing for a total screened flow up to 1,000 cfs each. The in-river screened flow would be limited to 650 cfs each when they are used in combination with the on-bank screen which would be limited to 200 cfs. In-river screens would be used at each location and on-bank screens would only be used at specific locations in combination with in-river screens. Configurations for the conceptual layout of these screens are shown in Figures 9 and 10 at representative locations for illustration purposes only.

The in-river screens would consist of towers with dual screen surfaces similar to the City of Sacramento's water intakes on the Sacramento River and the American River. The major difference is that the pumps would not be situated on the tower but on the landside of the levee. Water would flow through the screens on the tower, then into pipes buried in the river bottom and under the levee, then into a wet well system where the water would be pumped into a collection channel. A conceptual drawing for illustration purposes only of in-river fish screens are shown in Figure 11.

The on-bank screen would consist of a single screen surface along the bank of the river with transitions on the upstream and downstream ends to achieve uniform sweeping flows and velocities across the screens. The on-bank screen would be used in combination with in-river screens and use the infrastructure (pumps, pipelines, etc…) as described for the in-river screens above. A conceptual drawing for illustration purposes only of a combination in-river and on-bank fish screen is shown in Figure 12.

CONCEPT C – Section C-C'

(For illustration purposes only, actual locations would be determined and refined based on additional analysis of relevant constraints including land use, infrastructure, biological resources and other factors.)

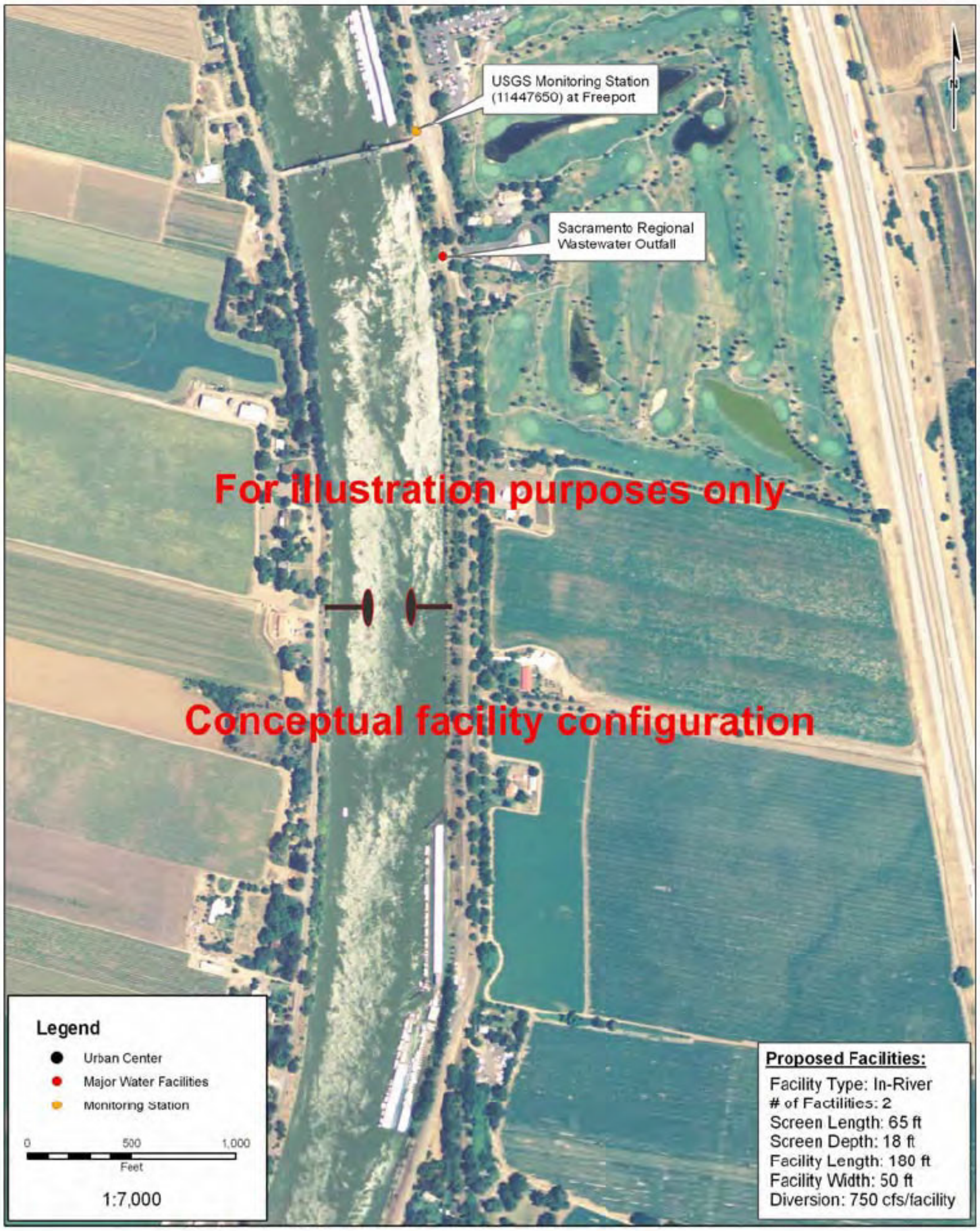


Figure 9 – Aerial view showing potential footprint

CONCEPT C – Section F-F'

(For illustration purposes only, actual locations would be determined and refined based on additional analysis of relevant constraints including land use, infrastructure, biological resources and other factors.)

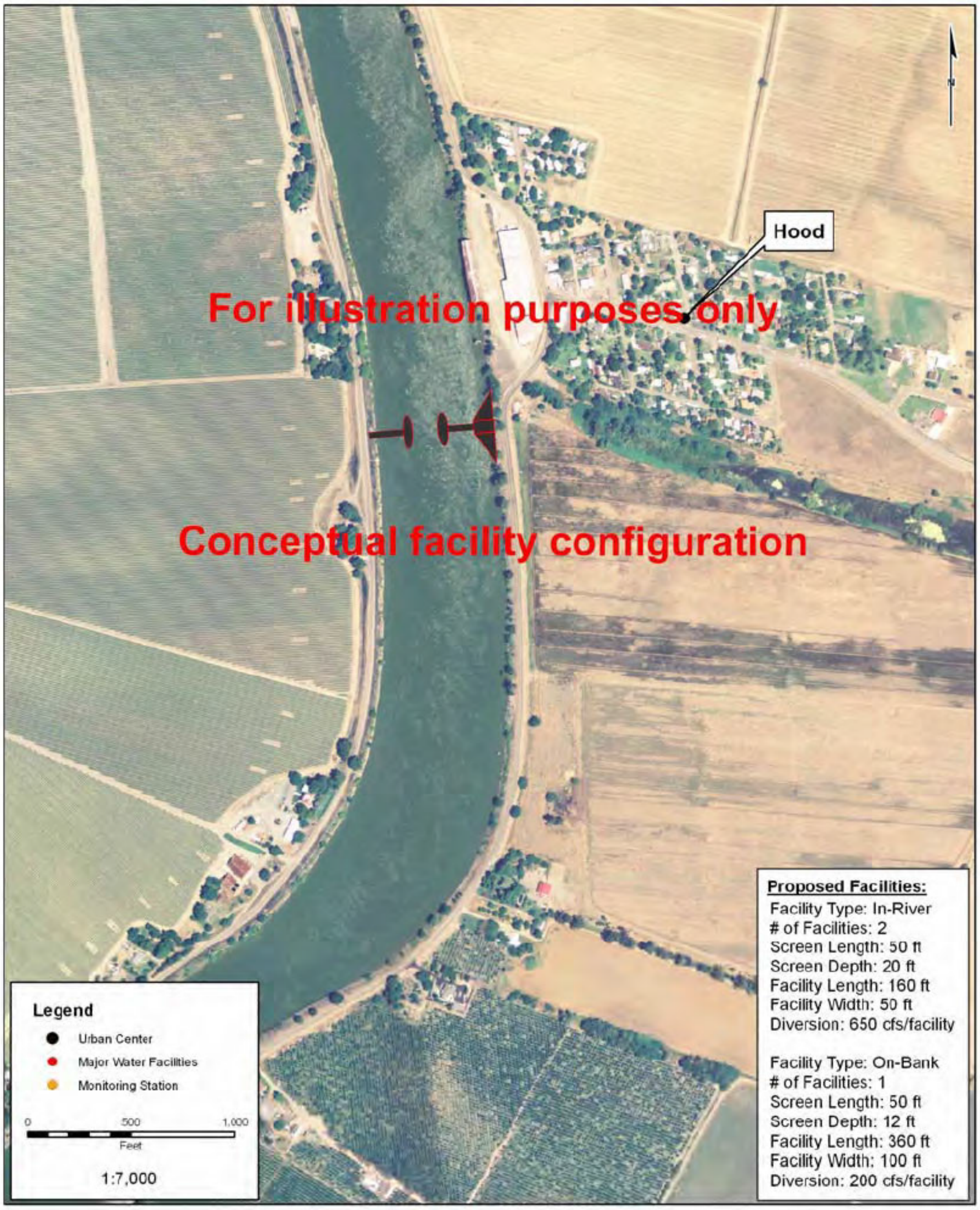


Figure 10 – Aerial view showing potential footprint

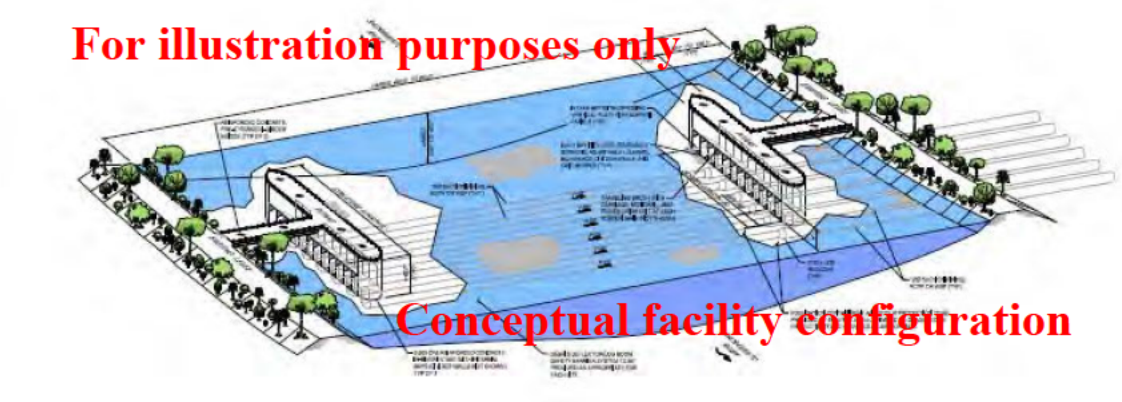


Figure 11 – In-River Conceptual drawing
(For illustration purposes only)

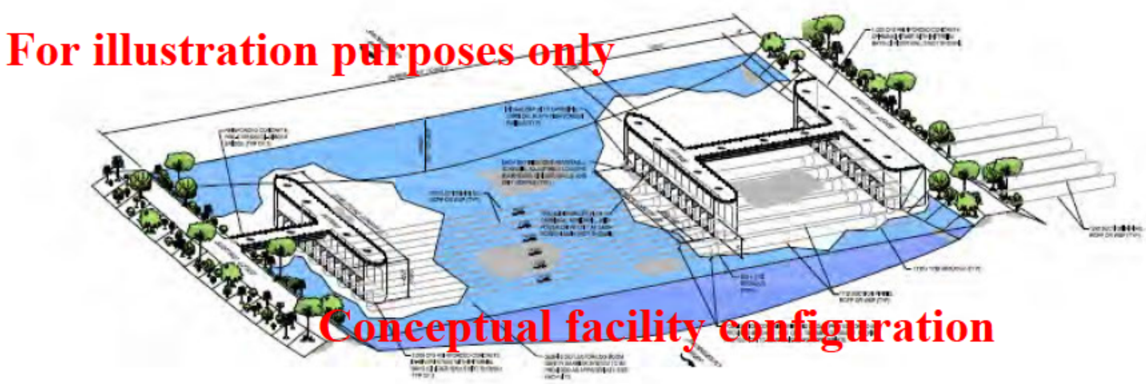


Figure 12 – In-River and On-Bank Conceptual drawing
(For illustration purposes only)

Conceptual Proposal D

Concept D consists of a combination of cylindrical and in-river screens situated at ten locations on the Sacramento River between the City of Sacramento and Walnut Grove. Each location provides a diversion capacity of 1,500 cfs for a combined maximum diversion capacity of 15,000 cfs. The use of ten smaller diversions reduces potential hydraulic effects and exposure time than for the larger diversions described in Concept A, and provides increased redundancy and operational flexibility similar to concepts B and C. However, the increased number of diversions in comparison to Concept A would require greater conveyance infrastructure similar to Concepts B and C. The use of cylindrical and in-river screens eliminates the handling of fish or need for bypass facilities. The use of multiple screen types will require a variety of maintenance and back up screens and material at each site rather than a single type of modular replacement or serviceable screen. The screens would be located in a relatively straight stretch of the river to avoid complex flow patterns, scour, and sediment issues associated with river bends.

The length of the screen surface would be kept as short as possible to minimize fish exposure to the screen surface. The in-river screens have the advantage of being in the deeper part of the river cross-section than the on-bank screens. Therefore, the in-river screens have a greater depth and can divert a larger flow for the same length of screen as the on-bank screens. The in-river screens have a screen surface on both sides of the supporting structure allowing for a total screened flow up to 750 cfs each. The in-river screened flow would be limited to 500 cfs each when they are used in combination with the cylindrical screens which would be limited to 100 cfs each. In-river screens would be used at each location and cylindrical screens would only be used at specific locations in combination with in-river screens. Configurations for the conceptual layout of these screens are shown in Figures 13 and 14 at representative locations for illustration purposes only.

The in-river screens would consist of towers with dual screen surfaces similar to the City of Sacramento's water intakes on the Sacramento River and the American River. The major difference is that the pumps would not be situated on the tower but on the landside of the levee. Water would flow through the screens on the tower, then into pipes buried in the river bottom and under the levee, then into a wet well system where the water would be pumped into a collection channel. A conceptual drawing for illustration purposes only of in-river fish screens is shown in Figure 15.

The cylindrical screens would be used in combination with in-river screens and use the infrastructure (pumps, pipelines, etc) as described for the in-river screens above.
Each cylindrical screen is approximately 7 feet in diameter and 23 feet in length with an estimated screened flow of 100 cfs each. A total of five cylindrical screens will be needed to provide the desired diversion capacity of 500 cfs at selected locations. The removable and retractable features of cylindrical screens provide easy access for maintenance purposes. A conceptual drawing for illustration purposes only of a combination cylindrical and in-river fish screens is shown in Figure 16.

CONCEPT D – Section C-C'

(For illustration purposes only, actual locations would be determined and refined based on additional analysis of relevant constraints including land use, infrastructure, biological resources and other factors.)

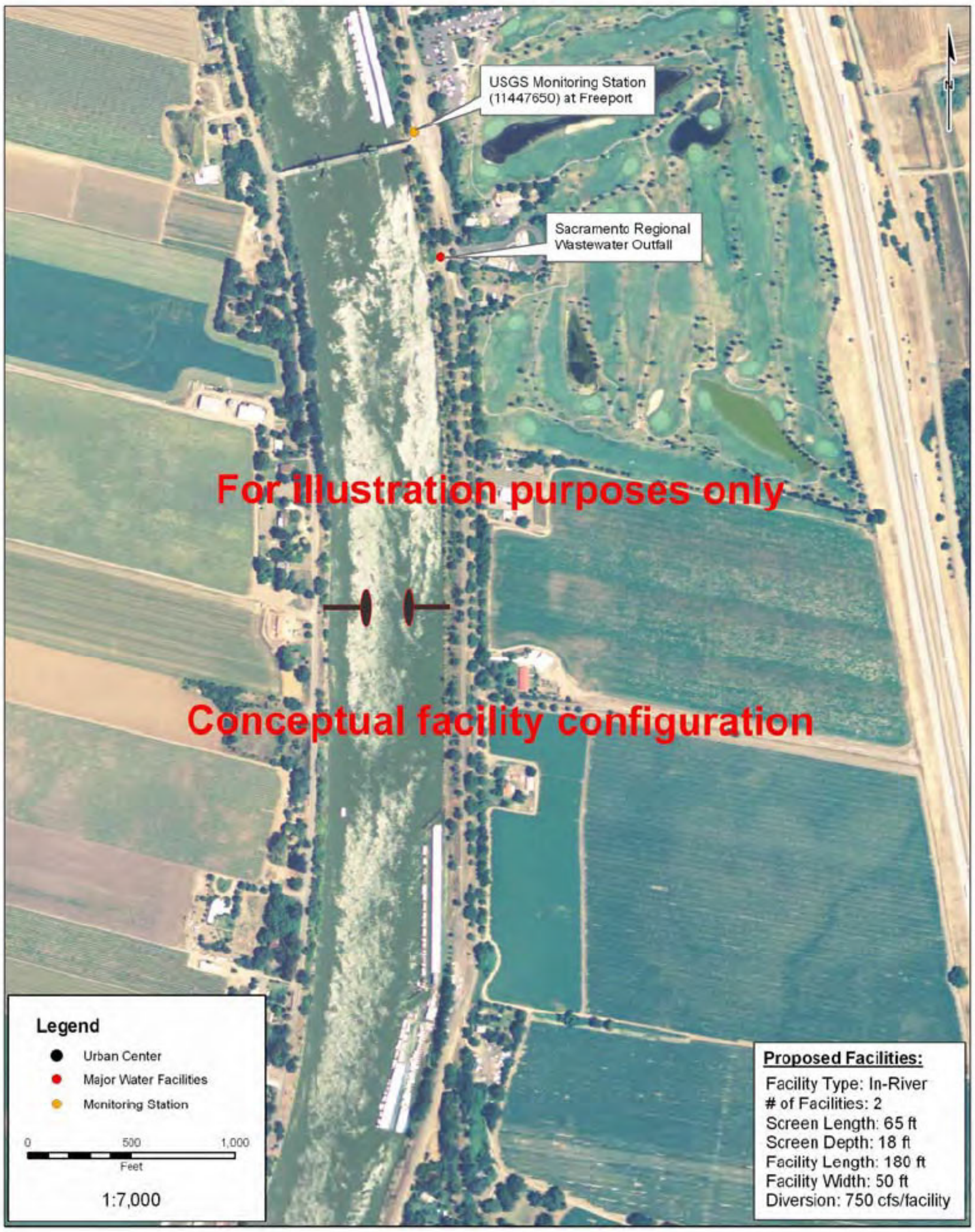


Figure 13 – Aerial view showing potential footprint

CONCEPT D – Section F-F’

(For illustration purposes only, actual locations would be determined and refined based on additional analysis of relevant constraints including land use, infrastructure, biological resources and other factors.)

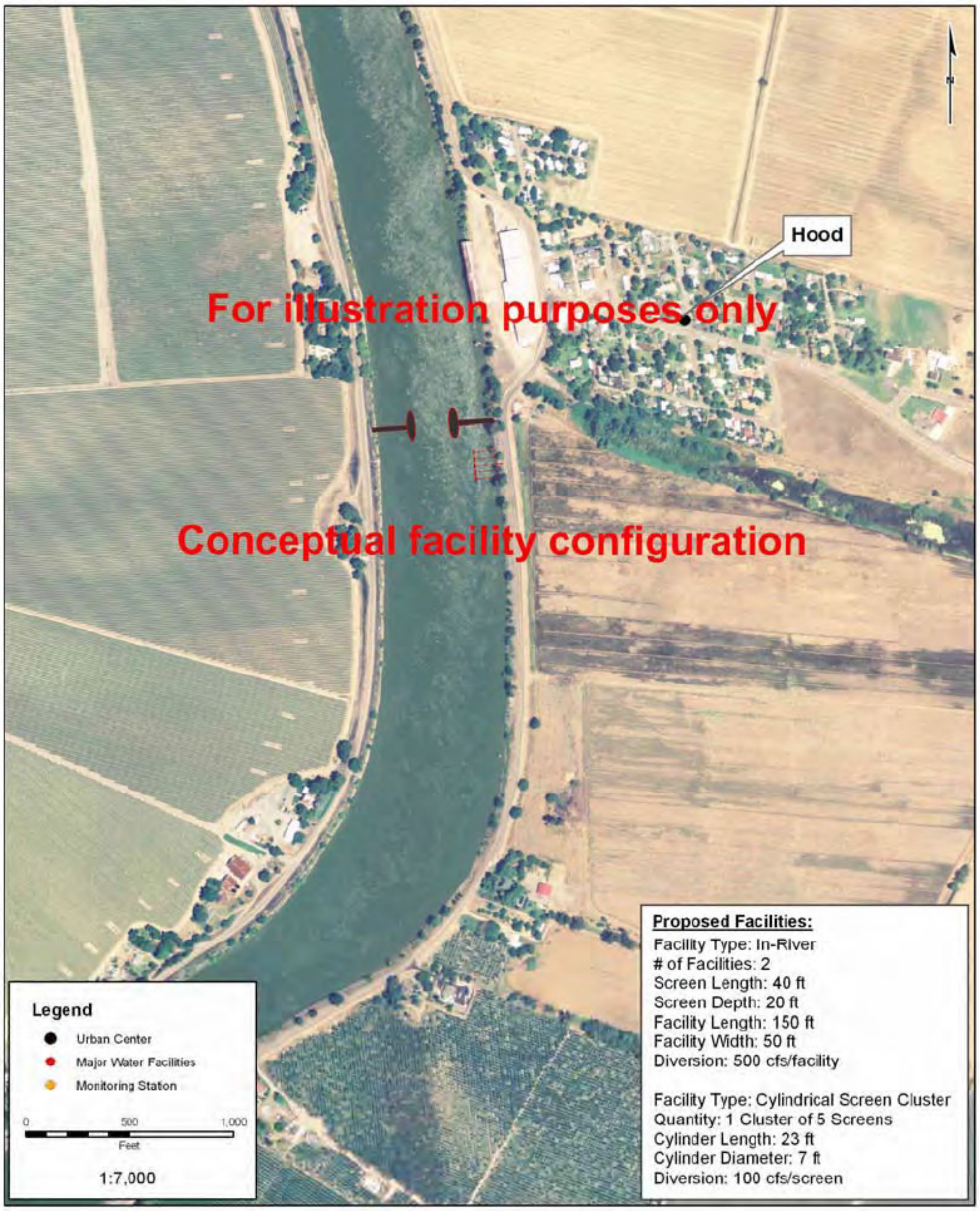


Figure 14 – Aerial view showing potential footprint

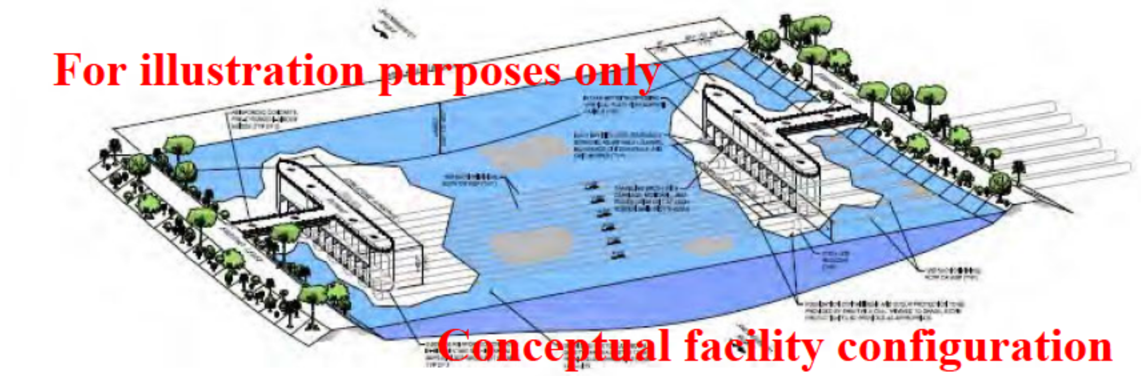


Figure 15 – Conceptual drawing (For illustration purposes only)

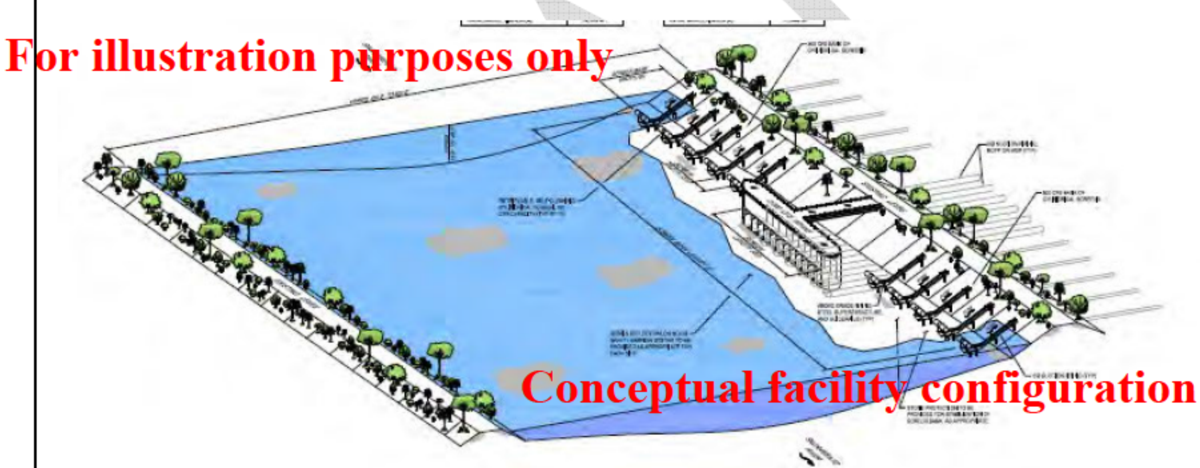


Figure 16 – Conceptual drawing (For illustration purposes only)

4.0 Information/Study Needs and Additional Considerations

During the process of developing the concepts in this proposal, the FFTT identified the need for additional information for the reach of the Sacramento River being considered for diversion facility locations. The information pertaining to river hydrology and hydraulics and fisheries information includes:

- Need for detailed bathymetry data;
- Need for river depth and velocity profile data for various locations;
- Need to further understand current hydro-dynamics ;
- The need to model the estimated changes to hydro-dynamics with the addition of the proposed diversion;
  - Effects of facility on the river channel flood flow carrying capacity
  - Additional analysis may include hydraulic and hydro-dynamic modeling, physical modeling, sediment modeling, 2-dimensional testing of baffle systems ('dynamic baffling'), and further analysis of delta smelt and green sturgeon interaction with fish screen designs.
  - Effects on the near and far field velocity patterns as they affect the amount of water going into Steamboat, Sutter, and Georgiana Slough as well as the Delta Cross Channel. This information will be needed to address many of fish migration issues in the north Delta.
- Need to consider future hydrologic conditions associated with climate-change;
- Fish species presence, timing, and distribution for applicable life stages;
- Need for any applicable navigational and flood conveyance regulations established by the U.S. Coast Guard and U. S. Army Corps of Engineers that could affect placement of in-river structures.
- Restrictions or variances for construction of piping through flood control levees.
- Anticipated facility/system operations.

The above information will contribute to defining operations (timing, volume/rate, percentage of river flow) of the facility, subsequent location and design of proposed facilities, and to determine the effect on flows downstream of proposed diversion locations.

Additional factors for consideration in selecting diversion facility locations, screen types, and associated conveyance includes:

- Land use – existing and proposed land use.
- Infrastructure – existing and proposed infrastructure (highways, railroads, transmission lines).
- Other biological resources in addition to fish resources.

5.0 Next Steps

There are several pending efforts and issues that will need to be addressed in further developing the proposed concepts above for screening a maximum diversion of 15,000 cubic feet per second (cfs) along the Sacramento River between the City of Sacramento and Walnut Grove. These efforts and issues include:

- Operating Criteria for Diversions
  The overall concept in this proposal is a maximum diversion of up to 15,000 cfs using multiple diversion facilities. While placing the diversions at several locations on the Sacramento River could offer the most flexibility to provide protection for fish, each diversion, as well as the combination of all the diversions will need criteria beyond the screening criteria discussed in this proposal to define their individual and combined operations. These operating criteria will need to be determined as they affect the number, types and design of screens. While the focus of the FFTT has been on the criteria for design and operation of the individual fish screens, a physical approach in meeting proposed operating criteria was discussed by the FFTT. This facility design approach would provide technical safeguards and physical assurances that water diversion rates operate within agreed upon limits is referred to as "Selective Withdrawal". This approach is based on the concept that ecosystem protection and water export limitations must be guaranteed during periods of low river flows, while at the same time offering opportunities to significantly increase water diversion flow rates during high flow. Physical design features (and control and instrumentation) can be incorporated into the structure(s) to always allow diversion of a limited "base flow" from the lower portion of the water column. In order to divert "surplus flows" (stage 2, 3, etc.) additional intake points would be situated at incrementally higher elevation(s) in the water column- corresponding to higher flows in the river. Alternatively, the use of retrievable cylindrical screens as a single facility or in combination with other facilities as described in this proposal could be implemented to achieve similar objectives. Either approach could be used to physically curtail export capacities at times when additional pumping would cause ecosystem degradation and fish losses, but would allow the facilities to divert and export high flows at high pumping rates so that conveyance and storage facilities capture the water for later delivery.

- Investigate Material types
  A variety of materials are available for use in constructing fish screens. The team has identified the advantages and disadvantage of stainless steel, copper-nickel, and plastic and will need to further discuss the type of materials most appropriate for the specific site conditions of proposed locations. The FFTT may consider the need for additional field studies of coated materials to complement previous studies of commonly used materials.

- Investigate Cleaning Mechanisms
  A variety of cleaning mechanisms are available for use in cleaning fish screens. The team has identified the advantages and disadvantage of air burst systems, and mechanical arm/brushes and will need to further discuss the type of cleaning system most appropriate for the specific site conditions of proposed locations.

- Investigate Biofouling and Introduced Mussel Infestation/Cleaning
  Quagga and Zebra mussels are spreading through the west and it appears it is simply a matter of time before many screening facilities become infested. Both Quagga and Zebra mussels have been recently found in California and the potential exists for these to move into the Delta and Sacramento River system via unauthorized or accidental introductions. At the large diversion concept facilities, use of traveling screens, anti- fouling alloys and coatings, and alternative cleaning systems or other methods should be investigated as alternatives to the commonly used stainless steel flat plate screens. On smaller concepts, alloys and alternative cleaning systems should be investigated for use.

6.0 References Related to Fish Screen Facilities

1) DFG Fish Screen Criteria, 2000
http://www.dfg.ca.gov/fish/Resources/Projects/Engin/Engin_ScreenCriteria.asp

2) NMFS Fish Screen Criteria, 1997
http://swr nmfs.noaa.gov/hcd/fishscrn.pdf

3) NMFS Fish Screen Criteria, 1995
http://www.ser.org/sernw/pdf/NOAA_fish_screen_guidance.pdf

4) Bureau of Reclamation Water Resources Technical Publication
Fish Protection at Water Diversions
A Guide for Planning and Designing Fish Exclusion Facilities, April 2006
Note: Fish Screen Chapter: Chapter IV. Positive Barrier Screens
http://www.usbr.gov/pmts/hydraulics_lab/pubs/manuals/fishprotection/index.html

5) Fish Screening and Fish Passage Analysis of the CALFED Bay-Delta Program,
Phase II Delta Conveyance Alternatives
July, 1997

6) Debris Rack: Debris Capture and Fish Passage; March, 2008
(DWR Technical Memorandum)
http://baydeltaoffice.water.ca.gov/ndelta/fishery/documents/DWR_memo_031008_UCD_TDF_Debris%20rack%20study.pdf

7) A Pilot Study on the Bio-fouling Resistance of 304 and 316 Stainless Steels and Copper Nickel Metal; July 2005
(A DWR Study Report)
http://baydeltaoffice.water.ca.gov/ndelta/fishery/documents/BiofoulingStudyFinal.pdf

7.0 List of Appendices

Appendix A: Maps (Bathymetry, Habitat, Infrastructure, etc…)

- Urban land use layer;
- Land Elevation layer;
- Transportation corridor layers (Highways, local roads, railroads);
- Electrical Transmission and Gas lines and related infrastructure layers;
- Bathymetry layer (latest data available);
- Existing regions of critical habitat that should be avoided within area of interest;
- Parcel Data.

Appendix B: Spatial / Temporal Patterns of Fish in the Sacramento River

Appendix C: Cross Sections and Aerial Imagery Data

Appendix D: Fish Screen Component Matrix

Appendix B: Suitability of Diversion Sites Based on Water Depth and River Bend Geometry

The following is a subjective cursory evaluation of potential north Delta diversion sites based on anticipated water depth for screening and position of the site relative to river geometry. The sites include the EIR/EIS (EIR) Sites 1 through 5, the Alternate (Alt) Sites 1 through 5 as refined by DWR-DOE for the FFTT, and the two sites below Steamboat Slough, FFTT Sites 6 and & 7, identified by the FFTT. All the screen sites are on the left bank looking down stream. This evaluation is based only on the position of the site as located on a Google Earth map, and river bathymetric transects provided by DWR in the vicinity of each site. Land side issues were not considered.

For this evaluation, it is assumed that the screens will be on-bank flat plate screens structures with a screen height of approximately15 feet. Sites on or just below an outside bend in the river are preferable. It is anticipated that these sites will be deeper, have higher sweeping flow velocities, and be less subject to sedimentation. Conversely, it is anticipated that sites on or just below the inside of a river bend will be shallower, have slower sweeping flow velocities, and be more susceptible to sedimentation.

EIR-1:

- Depth: The bed elevation along the toe of the left bank ranges from approximately -22’ to -30’. The bed is deepest along the toe of left bank.
- River Geometry: The site is at the downstream end of an outside curve.
- Rating: Good.

Alt-1:

- This site is located approximately 270’ downstream of EIR-1 and is essentially the same as EIR-1.
- Rating: Good.

EIR-2:

- Depth: The bed elevation along the toe of the left bank ranges from approximately -19’ to -13’. The bed is deepest on the left bank.
- River Geometry: The site is towards the middle of a gentle outside river bend.
- Rating: Marginal for depth, moderate for curvature.

Alt-2:

- This site is located approximately 70’ upstream from, and is essentially the same as EIR-2.

EIR-3:

- Depth: The bed elevation along the toe of the left bank ranges from approximately -15’ to -20’ with the deepest part of the channel at approximately -40 along the toe of the right bank.
- River Geometry: The site is at the downstream end of a relatively sharp inside river bend.
- Rating: Poor due to location relative to river bend.

Alt-3:

- Depth: The bed elevation along the toe of the left bank ranges from approximately -26’ to -31’. The bed is deepest along the toe of the left bank.
- River Geometry: The site is at the downstream end of an outside curve.
- Rating: Good.

EIR-4:

- Depth: The bed elevation along the toe of the left bank ranges from approximately -13’ to -22’ with the deepest part of the channel at approximately -23 along the toe of the right bank.
- River Geometry: The site is at the downstream end of a short inside river bend.
- Rating: Poor due to location relative to river bend.

Alt-4:

- Depth: The bed elevation along the toe of the left bank ranges from approximately -22’ to -25’. The bed is deepest along the toe of the left bank.
- River Geometry: The site is at the downstream end of a gentle outside river bend.
- Rating: Good.

EIR-5:

- Depth: The bed elevation along the toe of the left bank ranges from approximately -12’ to -28’. The deepest part of the channel crossed over from the toe of the left bank at the upstream end of the site to the toe of the right bank at the downstream end of the site with a bed elevation of approximately -30.
- River Geometry: The site is at the downstream end of a short inside river bend.
- Rating: Poor to Moderate due to location relative to river bend.

Alt-5:

- Depth: The bed elevation along the toe of the left bank ranges from approximately -27’ to -34’. The bed is deepest along the toe of the left bank.
- River Geometry: The site is near the upstream end of a gentle outside river bend.
- Rating: Good to Moderate due to location relative to river bend.

FFTT-6:

- Depth: The bed elevation along the toe of the left bank ranges from approximately -15’ to -20’ with the deepest part of the channel at approximately -25 along the toe of the right bank.
- River Geometry: The river at this site has a very slight curvature to the left, with the screen site on the inside of the curve. The river bed is nearly flat along this site, so the influence of river geometry may have little effect at this location.
- Rating: Moderate.

FFTT-7:

- Depth: The bed elevation along the toe of the left bank ranges from approximately -20’ to -25’ with the deepest part of the channel crossing over from the right bank to the left bank moving in the downstream direction. The bed elevation along the toe of the right bank is similar as the thalweg crosses from right to left.
- River Geometry: The river is nearly straight at this location, but has a slight offset to the left just upstream of the site.

- Rating: Poor at the upstream end of the site, but improves to Moderate or Good along the lower end of the reach.

Appendix C: Example Diversion Facility Arrangement

The following is an example of a diversion configuration utilizing the recommendations of the FFTT:

- The design approach velocity for sizing the structure is assumed to be 0.33 fps at maximum diversion and will utilize flow reduction for lower approach velocities as warranted for fish protection.
- The top of the screens should be set at the minimum water elevation that occurs under river flow conditions that would allow maximum diversion through all intake structures. For the five sites identified, as well as the two sites identified below Steamboat Slough, a screen height of 15 feet should be possible. At Site 2, a 15-foot high screen may place the bottom of the screen within a few feet of the riverbed.
- The screen bays should be approximately 15 feet wide, similar to the new RBD screens.
- Refugia should be spaced not farther than 100 feet apart.

Each diversion structure would be substantially the same and configured as follows:

- Assuming a screen height of 15 feet, each bay would have an open width of 15 feet per bay.
- Each bay should be separated by a pier wall of sufficient length (est. 20'±) to prevent lateral flow from one bay to the adjacent bays.
- The back of each bay should be capable of isolation from the wet wells leading to the diversion pipes without interfering with the diversion through the adjacent bays.

- The structural dimensions and components of each bay should be the same. Each bay should be equipped with the same arrangement of vertical wall slots (stoplog slots) that would allow each bay to be interchangeably configured as a screen bay, a refugia bay, or a monitoring bay. This would allow the number and/or location of refugia bays to be changed in the future.
- The initial configuration should consist of 45 screen bays and 8 refugia bays. This would make every sixth bay a refugia bay, with a spacing of approximately 84 feet between refugia. Initially, the refugia would be at bays 6,12,18,24, 36, 42, and 48.
- The back of bays 18 and 36 would have a divider wall extending to the back wall of the wet well and dividing the wet well into 3 equal compartments. The back of each of the three wet well units should be equipped with a minimum of two gated outlet pipes to deliver flow to the pump forebay/settling pond.
- The length of the diversion structure, as described here, is approximately 900 feet, plus the upstream and downstream bank transition walls.

Flow control – Flow through the diversion structure should be controllable at the following points:

- Stoplogs behind the screens to allow removal or replacement of screen panels.
- Adjustable baffles within the screen bay to allow for approach velocity flow adjustments vertically and along the length of the diversion structure.
- Stoplogs or slide gate at the back of each bay to isolate the bay from the wet well, if needed for inspection or maintenance.

- Gates at the entrance to the discharge pipes at the back of the wet wells, to regulate the water level in the wet wells.
- A minimum of two variable speed pumps at the pump station. The rest can be fixed speed pumps.

Appendix D: High Definition Approach Velocity Control

To address the issue of vertical non-uniformity of flow across a fish screen, the concept of High Definition Approach Velocity Control was suggested. The basic concept is to divide a screen into individual sections called flow pixels. Each flow pixel would have independent flow control in the form of baffles, louvers or other flow regulating device. In the lowest resolution of this concept the flow pixel would be represented by a full height screen bay with louvers or baffles. The next level of resolution would be to divide a screen bay into an upper pixel and lower pixel, which would allow flow through the upper or lower half of the screen, independently of the other half. This could possibly enhance fish protection efficiency and allow for additional methods of adaptive management of the diversion. The next level of flow resolution would be to divide each bay into four quadrants in a 2X2 arrangement to yield four flow pixels per bay. The total number of flow pixels would be the number of pixels per bay times the number of screen bays. The greater the number of flow pixels, the greater the control over the approach velocity distribution on the face of a long and tall screen.

The basic level of operation for this concept would be the manual setting of the flow control baffles for each pixel based on approach velocity measurements on the face of the screen. The next level of refinement would be to have a flow velocity measuring device between the back of the screen and the baffles that would eliminate the need for measurements in front of the screens. Next would be baffles that could be remotely operated from a control room that would, also, have the digital readouts from the pixel flow meters. The final level of refinement would be an automated system in which an operator could set a target flow velocity, and the baffles would be automatically adjusted to maintain that flow, based on feedback from the flow meter for that pixel.

All the flow pixel equipment for a single bay would be manufactured into a single unit that would fit into the bay wall slots and could be installed and removed from the screen structure deck.