# WORK PLAN

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## Intake Design Criteria and Performance Monitoring Development

June 28, 2013

# Work Plan:
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# Contents

# Background and Purpose

Since the release of a draft Fish Facilities Technical Team (FFTT) report in August 2008, the Bay Delta Conservation Plan (BDCP) Environmental Impact Report/Environmental Impact Statement (EIR/EIS) and Delta Habitat Conservation and Conveyance Program (DHCCP) teams continued to engage in further developing the Sacramento River diversion design concepts and potential locations for the BDCP fish facilities. New information produced through those efforts led to the reconvening of the FFTT to revisit their initial recommendations. The purpose of the FFTT was 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 California Department of Water Resources (DWR), California Department of Fish and Wildlife (CDFW), U. S. Bureau of Reclamation (Reclamation), U. S. 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 a technical memorandum of the team's recommendations and rationale. The FFTT completed a draft technical memorandum in July 2011 that outlined 22 technical studies (11 pre-construction studies and 11 post-construction studies) intended to reduce uncertainty and inform facility design.

In July 2012, a Fish Facility Working Team composed of representatives of the above agencies and consultants was convened for the purpose of developing a Work Plan to consolidate agency direction on the FFTT recommendations in consideration of changes in project circumstances and best available science since the technical memorandum was released in 2011, and to provide an implementation framework for the studies. To facilitate the process, the Working Team developed 11 subteams of experts to identify the initial scope, schedule considerations, and estimated costs for each of the studies. These teams convened on several occasions, and this Work Plan represents the consolidated outcome of the Working Team's and subteams' activities. The Work Plan is intended to be used by decisionmakers as the initial basis for prioritizing, scheduling, and funding the studies.

This Work Plan focuses on the 11 pre-construction studies, 8 of which are needed to inform facility design (Part A) and 3 that establish the biological baseline conditions needed to evaluate facility performance in the future (Part B). The scopes of work for each study identified in the Work Plan are prepared in sufficient detail to provide agency confidence that each study addresses the stated purpose, and to serve as the guidance necessary for developing a task order or request for proposals (RFP) that would lead to implementation of the studies.

The Work Plan includes information on schedule; however, because the initiation dates are not currently known, this information is focused on timeframes, the sequencing of tasks, and other schedule considerations that will be useful for decisionmakers. Likely critical path tasks and issues are identified for each of the studies. The cost estimates are based on expert input and are intended to provide a reasonable expectation of the funding needed to complete each study. These initial cost estimates may be influenced by the timing of the studies and the extent to which the studies can take advantage of existing data or be integrated with other ongoing studies.

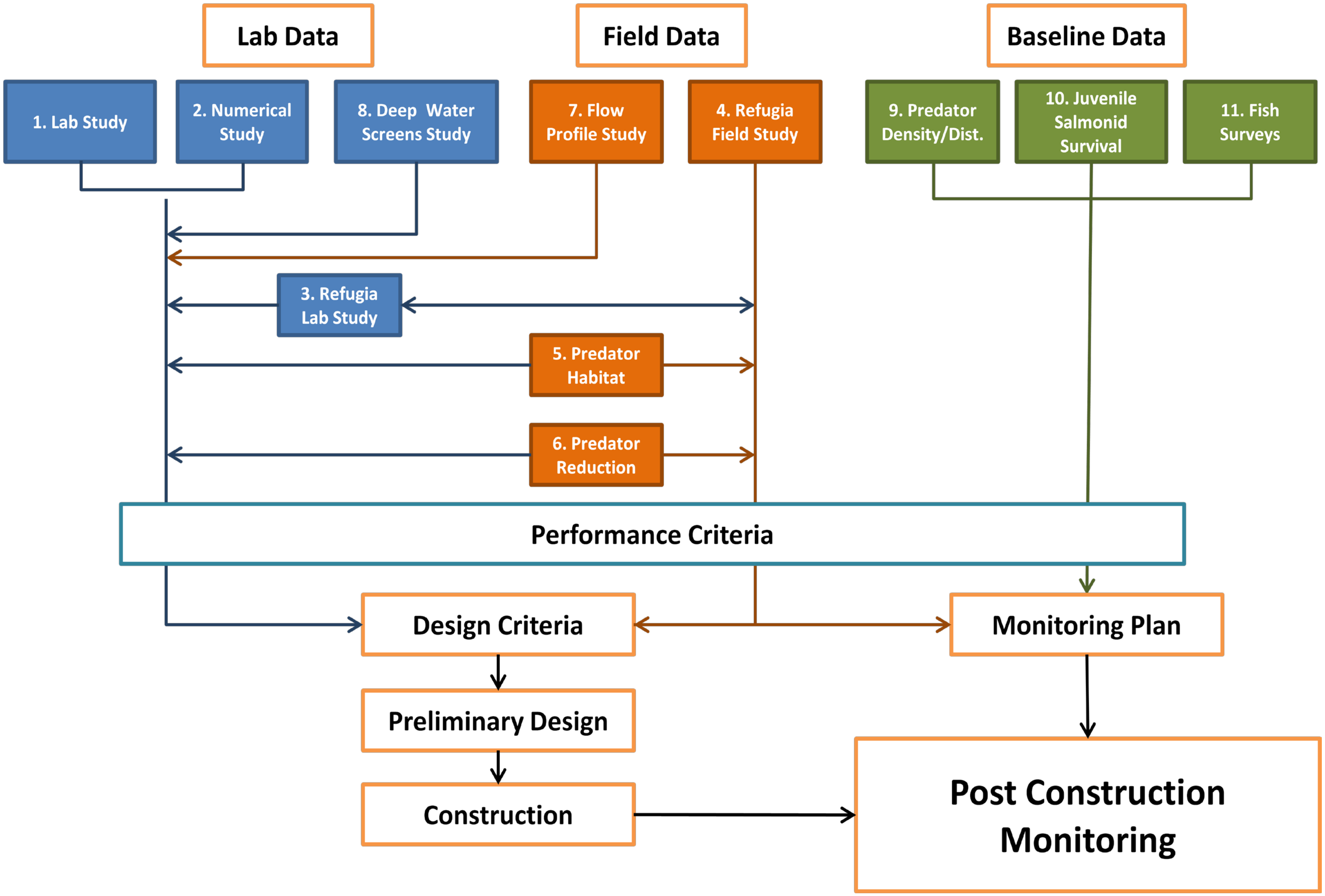
# Study Framework

The 11 pre-construction studies addressed in the Work Plan are described in Table 1. The relationship and linkages of these studies are presented in Figure 1.

TABLE 1
**Purpose of Pre-construction Studies**

| Study | Purpose |
|---|---|
| **Part A: Studies to Inform Facility Design** | |
| 1. Site Locations Lab Study | Optimize hydraulics and sediment transport issues at the selected sites |
| 2. Site Locations Numerical Study | Develop site-specific numerical hydraulic models to characterize the tidal and river hydraulics and the interaction with the intakes under all proposed design operating conditions |
| 3. Refugia Lab Study | Test and verify final recommendations for location, size, and configuration of refugia for the project |
| 4. Refugia Field Study | Evaluate the effectiveness of using refugia as part of intake structure and fish screen design to provide holding habitat for juvenile fish passing the screen to recover from swimming fatigue and to avoid exposure to predatory fish |
| 5. Predator Habitat Locations | Identify the locations and physical and biological characteristics for locations where predatory fish congregate, and develop design and management criteria that would serve to reduce predation risk at the proposed north Delta diversions |
| 6. Predator Reduction Methods | Compile and synthesize information on effective methods to control predation on covered fishes by predatory fish, birds, and mammals |
| 7. Flow Profiling Field Study | Characterize the water velocity distribution at river transects within the proposed river reach under varying flow conditions for calibration of the hydraulic models |
| 8. Deep Water Screens Study | Identify the hydraulic characteristics for deep fish screen panels on the Sacramento River |
| **Part B: Studies to Establish Biological Baselines** | |
| 9. Baseline Predator Density and Distribution | To determine the baseline densities and distribution of predatory fish within the lower Sacramento River where north Delta diversion structures are proposed to be sited and in adjacent control reaches |
| 10. Reach-Specific Baseline Juvenile Salmonid Survival Rates | To determine baseline rates of survival for juvenile Chinook salmon and steelhead within the lower Sacramento River in the vicinity of proposed north Delta diversions |
| 11. Baseline Fish Surveys | To determine baseline densities and seasonal and geographic distribution of all life stages of covered fish species inhabiting the reaches of the Sacramento River where the proposed north Delta diversion structures may be sited |

FIGURE 1
**Framework for Pre-construction Studies**



# Technical Studies

The following describes each of the 11 pre-construction studies, including study objectives, key questions intended to be answered by each study, initial study scope, linkages to other studies, a description of how the results would be used, and schedule. Figure 2 shows the anticipated approximate location of the three new diversion facilities on the Sacramento River.

The descriptions of these studies are intended to serve as the basis for the development of task orders or RFPs to implement the studies. The Working Team anticipates that the first task of each study will be the development of a detailed study design that will be reviewed and accepted by the agencies prior to initiation of the work. It is expected that the study designs will take advantage of available information in the literature as well as coordination with other ongoing studies to the extent reasonable. The study designs for the biological baseline studies (studies 9-11) will be subjected to independent scientific review, likely coordinated through the Delta Science Program. These are anticipated to be desktop reviews by one or two subject-area experts.

In addition, the three biological baseline studies will be structured during the first year as pilot studies. This approach is in response to the current uncertainty about the extent to which collaboration with ongoing studies will be possible and the level of effort needed to meet the specific objectives of the studies. The first-year studies will be specifically designed to confirm the efficacy of the proposed approach and identify opportunities for collaboration and productively sharing resources. These pilot studies also will be used to refine the approach and to develop firm estimates of the level of effort and costs for completing the study.

## 1. Site Locations Lab Study

### Objective

The objective of this study is to optimize the hydraulics and sediment transport issues at the selected diversion sites. In addition to the technical hydraulic and sediment data that will be made available through completion of a physical model, it will also provide a substantial benefit in project understanding and visualization.

### Key Questions

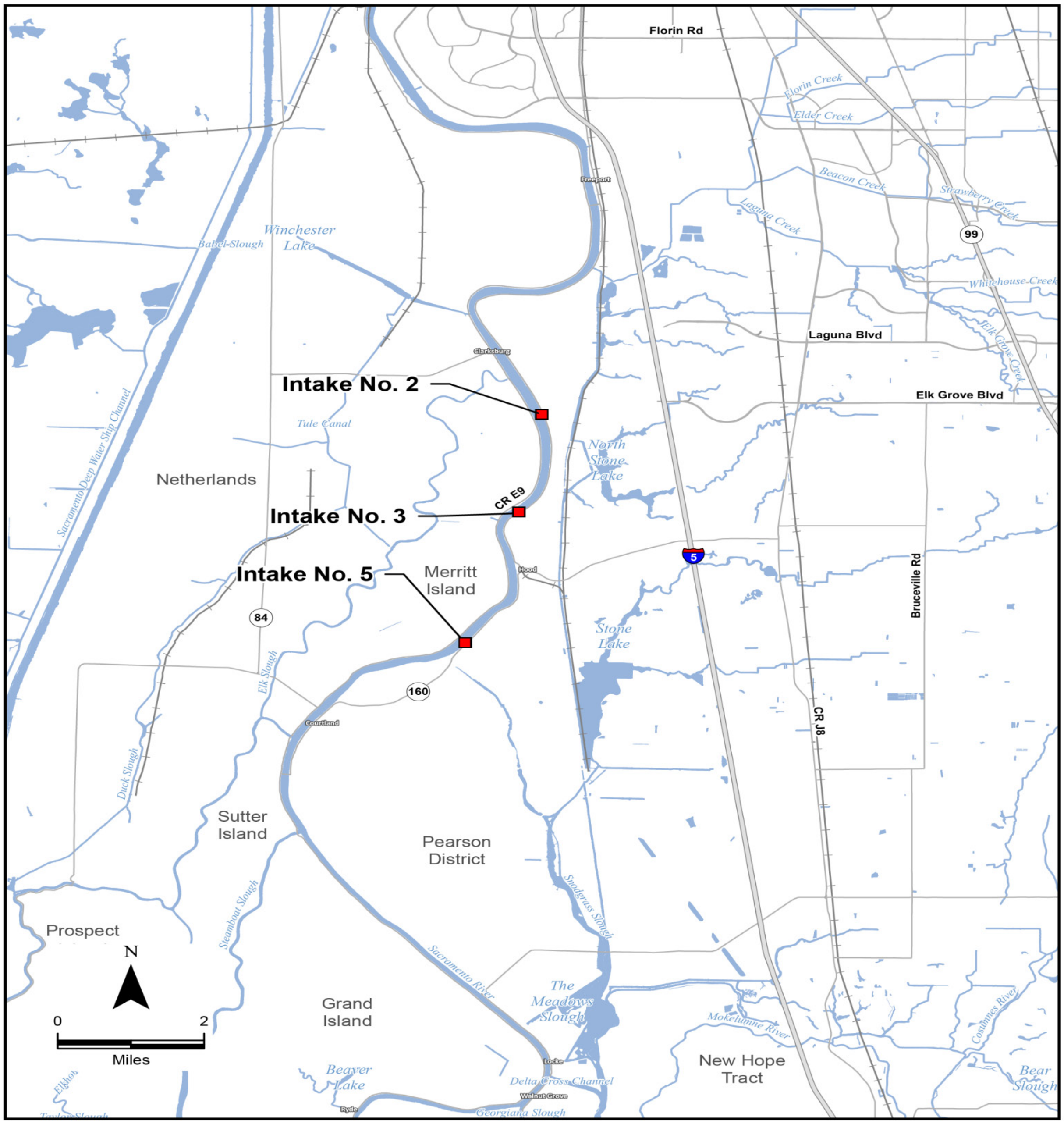
1. How does the screen structure interact with the river hydraulics under different flow and tidal patterns?
2. How do these hydraulic interactions affect sediment transport past the structure and potential sediment scour or deposition in front of the structure?
3. How do the hydraulic impacts of the structure provide or minimize habitat for predators?
4. How would the structure impact navigation?
5. How does sediment move once it is past the fish screens and moving toward the pumps behind the screens?
6. Can baffles be adjusted to provide near-uniform approach velocities at the screen face?
7. Are refugia adequately spaced to limit exposure time based on measured sweeping velocities?
8. Can transition walls, screen geometry, or channel geometry be modified to improve screen performance?

### Scope of Study

For the three previous physical model studies for similar fish screens on the Sacramento River, fixed bed models were selected. Moving bed models are generally more expensive and take more time to complete. The fixed bed models use fine sediment, coal, or walnut shell media to give good qualitative insight into sediment movement. Scour protection is normally designed with the results from the mathematical models (Study 2).

The scope of work should include an analysis of river flow patterns, sedimentation, and screen performance over various flow and tidal scenarios, transition wall geometry, screen geometry, eddy locations, refugia zones, and movement of neutrally buoyant particles representing larval fish. The sweeping velocity in front of the screen face should be compared to the average channel velocity to determine boundary effects at the structure. Approach and sweeping velocities at the screen face should be measured for all screen panels under various flow scenarios. Baffles should be adjusted to achieve regulatory criteria for approach velocities across the screen face. If possible, vertical velocity variations should be measured and baffled appropriately to achieve near-uniform vertical velocities. Sweeping velocities should be examined to determine if refugia are properly spaced to limit exposure time for fish. Channel modification should be considered in the model if river approach conditions do not provide acceptable screen velocities.

FIGURE 2
**Location of Proposed Diversion Facilities**



Ideally, model scale should be selected to cover the entire river reach (bank to bank) plus at least 500 feet upstream and downstream of the proposed structure and should be as large as possible to be consistent with lab space and pump capacity. The site with the deepest bathymetry should be selected for this initial physical model. Then, if needed, the model could be reconfigured to represent the other two more shallow diversion sites.

## Linkage to Other Studies

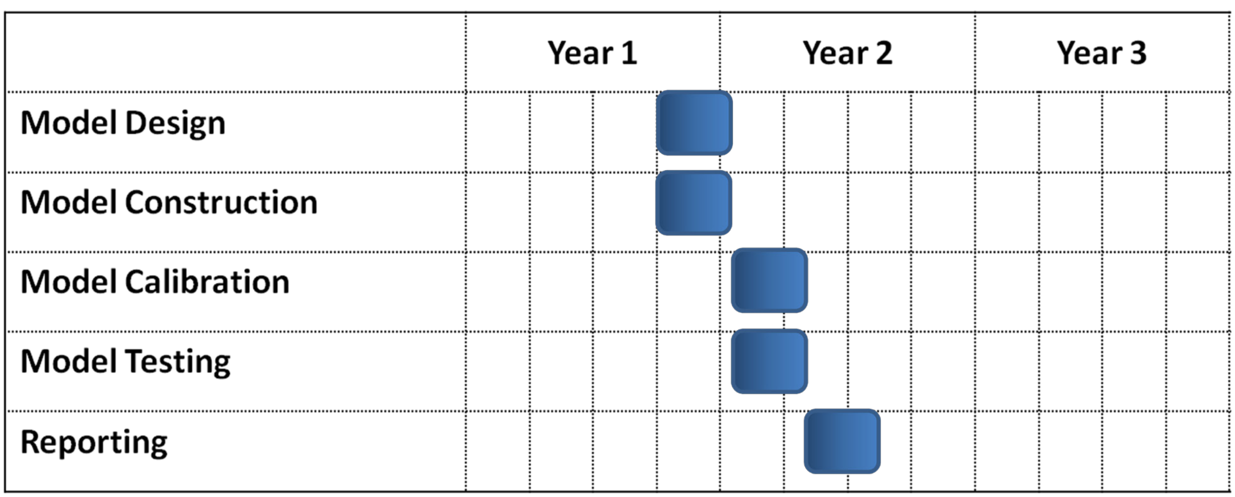
The decision to implement a laboratory study (physical hydraulic model) at any of the sites should be preceeded by substantial preliminary design and mathematical modeling. As a result, the physical model should be used for refinement, optimization, and confirmation of the preliminary design. As such, it should not be an early start task. The decision to proceed with a physical model (and its associated attributes) should follow a careful review of the mathematical model results. Detailed bathymetry, hydraulic data, and bed material information must be provided before physical modeling can begin.

## How Study Results Will Be Used

The results of the physical model study will be used to refine, optimize, and confirm the design of the fish screens and associated elements of the intake facilities.

## Schedule

The development of a physical model study usually comes midway through the preliminary engineering. It should be completed at the same time as preliminary engineering. A physical model of this scale will take approximately 6 to 9 months to design, construct, and test. This study is dependent on the results from Study 7 and Study 2.




# 2. Site Locations Numerical Study

## Objective

The objective of this study is to develop site-specific numerical studies (mathematical models) to characterize the tidal and river hydraulics and the interaction with the intakes under all proposed design operating conditions.

## Key Questions

1. What are the key river hydraulic characteristics in the vicinity of the proposed intakes at the selected sites?
2. How do the proposed intakes interact with the river hydraulics under different flow and tidal patterns?
3. What hydraulic and operations parameters should be explored in Study 1 (Site Locations Lab Study)?

4. How do hydraulic conditions at the intake structure affect the sediment movement and scour at the site?
5. What impact will the diversion hydraulics have on potential predation and survival of covered fish?

## Scope of Study

A 2-dimensional (2-D) mathematical model of the entire river reach containing the proposed diversions will be the key tool to assess the hydraulic interaction among the intakes, the levees, and the river. Model results need to address more than just fish behavior. Understanding of scour, bed movement, flood profiles, flood velocities, levee armoring, and navigation will benefit from the output of the 2-D model. However, the key model output is the detailed spatially varied flow profile under key operational scenarios. This basically describes how much screen area is available and how long the structure needs to be. Prerequisites for this modeling are currently being developed by DWR. These include historical information plus recommendations for model type and the required bathymetric data.

A site-specific 2-D numerical hydraulics model of the Sacramento River reach containing the proposed intakes is required for characterizing the tidal and river hydraulics, and for characterizing the interaction with the proposed intakes under proposed design operating conditions. The spatial domain and resolution for the 2-D model should be determined based on the location of the intakes, initial design of the intakes, run-time for the model and locations of the available inputs for the proposed modeling studies (DSM2 grid).

The bathymetry obtained from the most recent survey should be used in the 2-D model. The stage and flow at the boundary are the major input data for the 2-D model and should be generated using either 1-D HEC-RAS or DSM2 or combination of both models.

The 2-D model should be calibrated and validated in coordination with DWR staff. Available observed data in the vicinity of each proposed intake should be used for this purpose. The observations from flow profile data collected in the Study 7 (obtained from DWR) as well as observed data obtained from other sources such as DWR's CDEC website should be used in the process. The model should be calibrated for the water levels and velocities.

CCHE2D model should be used for developing the Sacramento River 2-D model to assess the hydraulic interaction among the proposed intakes, levees, and the river as well as provide key information related to scour potential, bed movement, flood profiles, flood velocities, levee armoring, and navigation. The CCHE2D is a 2-D depth-averaged, unsteady, flow and sediment transport model developed by the University of Mississippi and is available for free. The FFTT has also requested a more detailed 3-D model to take a closer look at the following issues:

- Changes in the velocity near the screen face
- Characteristics of sweeping velocities
- Development of velocity profiles from the screen face to some distance in the channel
- Identification of likely areas for predation in front of the screen and in the transition structures
- Vertical velocity distributions near the screen face

The 3-D modeling for the project will be performed as part of the Study 8.

All hydraulic modeling efforts need to be part of an iterative process among modelers, designers, and FFTT members. Modeling should be performed for multiple scenarios (at each diversion) including no intake structure, a non-operational intake structure, and a diversion operating at maximum capacity of 3,000 cfs. Up to four operations scenarios that model a range of diversion rates and stream flows recommended by the FFTT should be simulated.

## Linkage to Other Studies

The completion of the detailed mathematical model at each of the proposed diversion sites is one of the most important studies for the successful completion of the preliminary engineering. Without the final design level hydraulics information from this study, final structure sizing cannot proceed. Bathymetric data are necessary before numerical modeling can begin. Results from this study will also inform the design of the physical model (i.e., boundary conditions).

This study may also be related to the environmental permitting process.

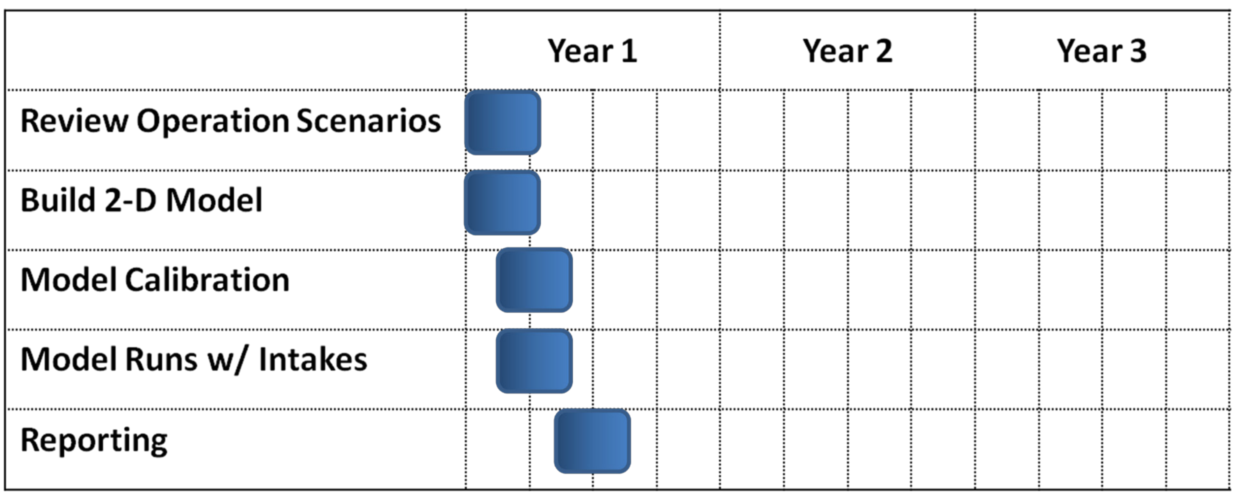
## How Study Results Will Be Used

The results of these detailed site-specific hydraulic studies will form the basis of the sizing of the intakes. The results will also influence the design of the physical model and the 3-D modeling in Study 8. The results will improve understanding of the influences of the facilities on sediment, bed load movement, scour, flood profiles and velocities, navigation, and factors that may influence fish.

The study is required to complete the permitting process. The results from this study can also be used to determine the scouring and sedimentation potential near the intakes.

## Schedule

The mathematical models for all sites study should commence as soon as possible. Given the final design level topographic and bathymetric maps, results from Study 7 and 1-D HEC-RAS model, it should take 3 months to complete the 2-D modeling.




# 3. Refugia Lab Study

## Objective

Refugia (e.g., small depressions in the intake structure with bar racks to exclude larger predatory fish that can act as rest areas and areas to avoid predation) have only recently been added to diversion facilities, and uncertainty remains about the most effective designs. The objective of this study is to test and optimize the final recommendations for refugia that will be required for installation at the north Delta diversion facilities.

## Key Questions

1. What refugia configuration should be used at the north Delta diversion facilities to best optimize fish usage and minimize mortality?
2. How do the results of Study 4 (Refugia Field Study) influence the design of refugia studied in the lab?
3. What are the detailed hydraulics associated with refugia?
4. How do prey and predator fish respond in the physical model?
5. What size do refugia need to be to operate effectively?

6. What is the best location and spacing of refugia along the screen face?
7. What is the best bar rack spacing for refugia to encourage use and reduce predation?
8. Do refugia capture debris and how does the accumulation of debris affect performance?
9. How do differences in fish size and species affect use of refugia?
10. How long do individual fish use refugia before exiting, and does residence time in the refugia influence time of transit across the screen or cause a delay in migration?

## Scope of Study

The Refugia Lab Study requires the development of a physical model to test refugia over a range of conditions and to optimize the selected refugia designs. The model should have the following capabilities and characteristics:

- A flume width five times the depth of the refugia
- Sweeping velocities ranging up to 2 feet per second (fps)
- A minimum water depth of 4 feet, but as high as can be reasonably achieved
- A range of refugia lengths from 2 to 8 feet
- A range of refugia recess depths from 6 inches to 1 feet

The study should initially evaluate two refugia configurations, including (1) the design previously evaluated at the lab in Denver and used at the Red Bluff diversion, but with different flow regimes, and (2) the design used for refugia at RD 2035 diversion. Hydraulic conditions in and around the refugia zones should be measured over a range of flows and other variables. These other variables of interest for the study include refugia length, depth, and the configuration and shape of the exclusion bars.

In addition to the hydraulic evaluation, covered fish species should be introduced to the model and studied to evaluate their use of the refugia and their behavior in and near the refugia. To the extent available, the lab study should be conducted using juvenile Chinook salmon and steelhead, delta smelt, juvenile sturgeon, and splittail. The target length range for test fish is <100mm for salmonids and up to 150mm for sturgeon; adult delta smelt should be used if available. Experimentation with larger steelhead should be considered. The experiment should also consider introduction of predators (of various sizes) or other stimuli to examine how these stimuli influence the use of refugia by covered fish species.

The study should be conducted during the spring/early summer timeframe over a period of 2 years. Prior to initiation of the second year of study, the results of the first year should be evaluated to determine whether additional study is justified.

## Linkage to Other Studies

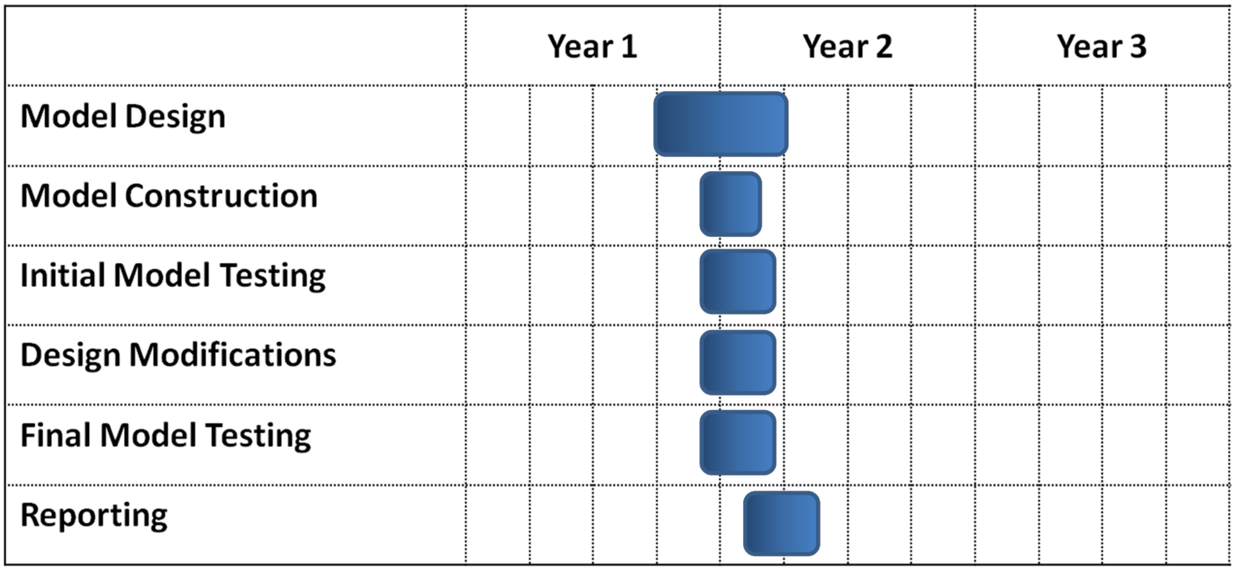
This study is linked to and should be closely coordinated with Study 4 (Refugia Field Study). These two studies are anticipated to be conducted in parallel, with each study potentially providing information that will inform the other. For example, observations in the field may result in hypotheses that can be tested in the lab.

## How Study Results Will Be Used

The results of the Refugia Lab Study will be used to optimize the design selected by the FFTT to best suit the initial needs of the project. Final design will also include adaptive management and post-construction study recommendations so that refugia can be modified as the technology changes.

## Schedule

This study should be conducted following, or in parallel with, the collection of the field data in Study 4 (Refugia Field Study).




# 4. Refugia Field Study

## Objective

Contemporary intake structures such as the new Red Bluff diversion structure and fish screen have been designed to include refugia that allow fish to rest and avoid predation and impingement associated with the fish screen. This is a relatively new element to fish screen design, and the extent of use by fish and the overall effectiveness in reducing fish mortality is uncertain. In consideration of the uncertainty regarding fish use of refugia, the objective of this study is to evaluate the effectiveness of using refugia as part of diversion structure design for the purpose of providing areas for juvenile fish passing the screen to hold and recover from swimming fatigue and to avoid exposure to predatory fish. In addition, the objective is to gain insights (through observation) into the biological benefits of incorporating refugia into diversion structures.

## Key Questions

Questions answered through observation:

1. Do juvenile fish passing an intake screen use refugia?
2. How long do individual fish use the refugia?
3. Do refugia serve as hiding locations and holding areas for predators?
4. Do refugia accumulate debris and increase intake maintenance?
5. What factors seem to influence use of refugia by fish?

Questions answered through inference from observations:

6. Do refugia appear to contribute to increased survival of fish passing an intake structure?
7. Do refugia appear to contribute to reduced risk of impingement on fish screens?
8. Do refugia appear to contribute to a reduced risk of predation mortality associated with intake structures?
9. Does increased surface turbulence associated with refugia appear to increase the risk of impingement or predation?
10. Do refugia appear to contribute to a net biological benefit to improving the overall performance and effectiveness of an intake structure?

11. Do refugia appear to substantially increase the downstream time of transit of fish past the screens?

## Scope of Study

The Refugia Field Study should be designed in two phases, with the first phase focusing on data collection at the Red Bluff facility. The Red Bluff facility was designed to include refugia and incorporated features to facilitate observations. Although the location of this facility in the upper Sacramento River does not fully represent the conditions anticipated at the north Delta diversions, it may provide the opportunity for collecting information quickly that could be used to inform the study of refugia at downstream facilities in the next phase. Accordingly, the second phase of the study should take what is learned from the work at Red Bluff and apply it to a downstream facility that better represents the conditions anticipated at the north Delta diversions (e.g., Freeport or possibly one of the Contra Costa Water District diversions). Based on the results and insight obtained from these observations, Phase 2 should be designed to conduct focused experiments to evaluate the effectiveness of refugia in reducing the risk of impingement and predation.

Phase 1 of the field study should be designed to investigate and confirm the use of refugia by fish at the Red Bluff diversion. A monitoring program that incorporates evaluation of the refugia is currently under development by the Tehama Colusa Canal Authority; therefore, Phase 1 of the study should be coordinated to the extent possible with the monitoring of refugia already in the planning process to determine the feasibility of assessing the effectiveness of refugia at that facility and identify the best approach. To the extent appropriate, observations at the Red Bluff diversion should be conducted for a period of 1 year, with an emphasis on the spring period, to help ensure that observations are made over a range of flow, temperature, and turbidity conditions. Observation at this facility should consider using a DIDSON or ARIS camera with a fixed mount installation to improve the ability to observe fish entering and exiting the refugia. The study also should consider including use of video cameras placed behind the observation panel installed on the screen. Direct observations by divers or other suitable technique (including acoustic detection techniques) should be considered.

To the extent feasible and with agreement from facility owners, similar observations under Phase 2 of the study should be conducted at another existing fish screen that may be more representative of conditions at the proposed north Delta diversion structures. Phase 2 studies can include temporarily replacing an existing screen panel with one or more designs of refugia. Study plans including up to four refugia designs should be developed in cooperation with members of the Working Team. A study plan will be reviewed by, and must be acceptable to, the Working Team.

A technical report should be prepared that includes results of the investigation and provides technical recommendations for the inclusion of refugia into the intake design as well as recommended design modifications intended to make refugia, if they are recommended, more effective in improving the survival of juvenile fish passing the north Delta diversions and the overall effectiveness of the diversion structures and fish screens. The benefits to juvenile Chinook salmon and steelhead should be the primary focus of the investigation; however, information on all fish species should be considered in developing future design recommendations.

## Linkage to Other Studies

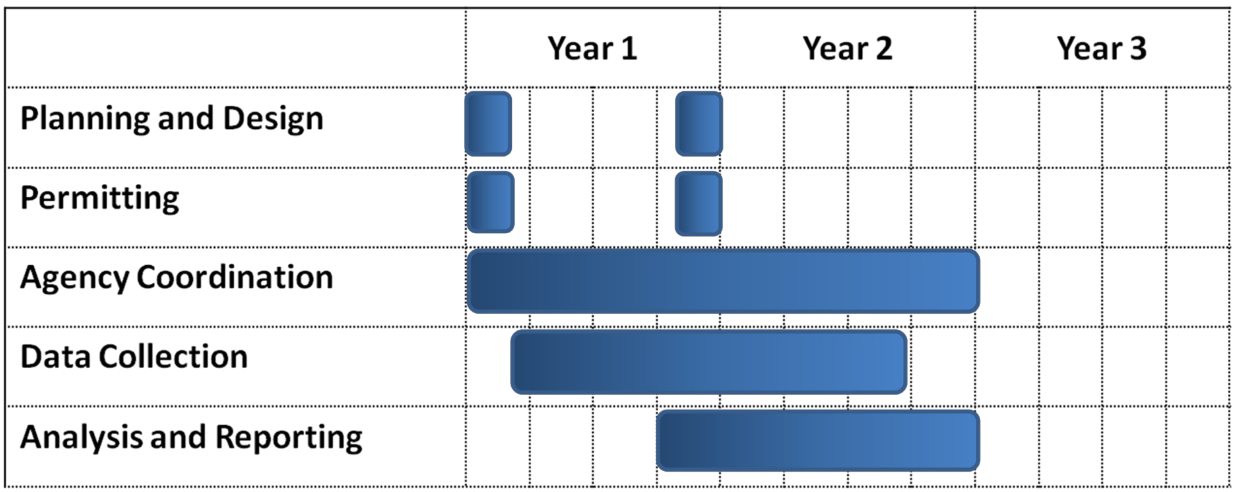
The results of this study are expected to inform the refugia experiments that will be conducted in Study 3 (Refugia Lab Study). Therefore, to the extent possible, this study should be completed prior to or in parallel with Study 3. In addition, this study should be linked and coordinated with the Predator Habitat Locations Study (Study 5) to take advantage of incidental observations of predators at refugia along the screen face.

## How Study Results Will Be Used

The results of the Refugia Field Study will be used to help resolve the uncertainty regarding the effectiveness of refugia and inform the design of the north Delta diversion structure and fish screens. Preliminary information from the study may be incorporated into the physical model constructed for Study 3 (Refugia Lab Study), specifically information regarding the effects of refugia on hydraulic flows across the screen and potential turbulence associated with the refugia that may affect uniformity of sweeping and approach velocities and vulnerability of fish to predation and impingement.

### Schedule

Phase 1 of the study should commence as soon as possible and extend for a period of 1 year. The results of the study will be used to design the experiments needed to evaluate the effectiveness of refugia in Phase 2 and should be summarized and documented in a technical report prepared during the study period.




## 5. Predator Habitat Locations

### Objective

Instream diversion structures in the Sacramento River have the potential to attract and hold predatory fish that prey upon covered fish species by creating conditions that provide cover, favorable water velocities, increased prey densities, and greater access to prey. While it is known that predatory fish congregate at diversion facilities, it is unclear how the proposed north Delta diversion could be designed to reduce the potential to create features that support predators and lead to an increase in predation on covered fish species. The objective of this study is to identify the physical and biological characteristics of locations that attract predatory fish near existing diversion facilities and to identify potential changes that would be expected to reduce predator abundance or prey vulnerability. Based on data from existing and ongoing studies and data collected at existing water diversion structures, the objective also is to identify design and management criteria that would serve to reduce predation risk at the north Delta diversions.

### Key Questions

1. Where do predatory fish congregate at existing diversion structures?
2. Are birds and mammals important predators of covered fish at existing diversion structures?
3. Are there intake structures where predator congregation is most pronounced and other structures where predator congregation does not occur?
4. What are the characteristics of locations of increased predator densities (e.g., scour holes, outside of a bend, in the channel center or along the channel margin, associated with existing structures, and other such characteristics)?
5. What are the flow and bathymetric characteristics at predator congregation sites?
6. Where do prey organisms concentrate and what are the characteristics of those locations?
7. What are the characteristics of cover (e.g., depth, substrate, woody debris) at predator congregation sites?

8. How do built features (fish facility components) contribute to cover used by predators?
9. How are predators distributed relative to refugia sites?
10. Do the characteristics of predator congregation sites differ by species of predatory fishes?

## Scope of Study

Predator studies at diversion and other instream facilities have been conducted in the Sacramento River and other water bodies. In addition, the NMFS Science Center is currently conducting predator studies at the Freeport and Sacramento diversions that may be directly applicable to the Predator Habitat Locations study. The first task of this study should be a review of existing literature on predation at diversion facilities comparable to the proposed north Delta diversions and ongoing predator studies in the Sacramento River to assess and document what is already known about predation at diversion facilities and to identify gaps in the data that need to be filled. This study should focus on resolving the uncertainty about predator use of diversions as it relates to the proposed north Delta facilities. The review of ongoing predator studies at diversion facilities in the Sacramento River should also assess the efficacy of collaborating and coordinating with those current predator studies to improve the usefulness of the collected information. An EndNote® list, or similar bibliographic list, of the reports and studies used in the literature search should be provided.

Based on the review above, a detailed study design/plan should be developed that describes the actions that would be conducted to meet the above objectives and answer the key questions. The development of the study design/plan should not be initiated until the results of the NMFS Science Center study on predator densities and associated salmonid smolt mortality around water diversions in the Sacramento River are available and considered. The study design/plan should clearly identify the locations where the field activities would be conducted, the scope of data collection activities at each location, the data collection methods, the frequency of sampling, and the data analysis approach that would be applied. The study design would be subjected to an independent scientific review and therefore should be prepared in sufficient detail for the reviewers to determine whether the proposed design would meet the stated objectives. The study design/plan should also include a detailed schedule and estimate of the costs for completing the study.

It is anticipated that field studies of predator densities and distributions during periods when covered fish species are present would be conducted at up to three existing facilities with characteristics similar to the proposed Sacramento River diversions, such as Freeport, Sacramento, Natomas, RD 108, and Sutter Mutual. The study should consider extending for 2 years if needed to obtain information on the seasonal changes in predator distribution at each site for a range of flow and prey abundance conditions. Techniques for collecting predator use information at existing facilities should consider the use of video, DIDSON or ARIS cameras, side-scan sonar, or other survey techniques determined appropriate, including direct observation (e.g., diving).

The study should focus on periods when covered fish species are present and include 24-hour sampling to the extent needed to understand diel patterns of use. In addition, the study should consider fish sampling to confirm the species of fish detected by cameras and the diet of predators congregating near the facility. Where predator congregations are identified, consideration should be given to also detecting juvenile fish that might serve as prey.

A technical report should be prepared that includes results of the investigation and provides technical recommendations for modifications to facility design to reduce the potential for the north Delta diversions to attract and hold predators.

## Linkage to Other Studies

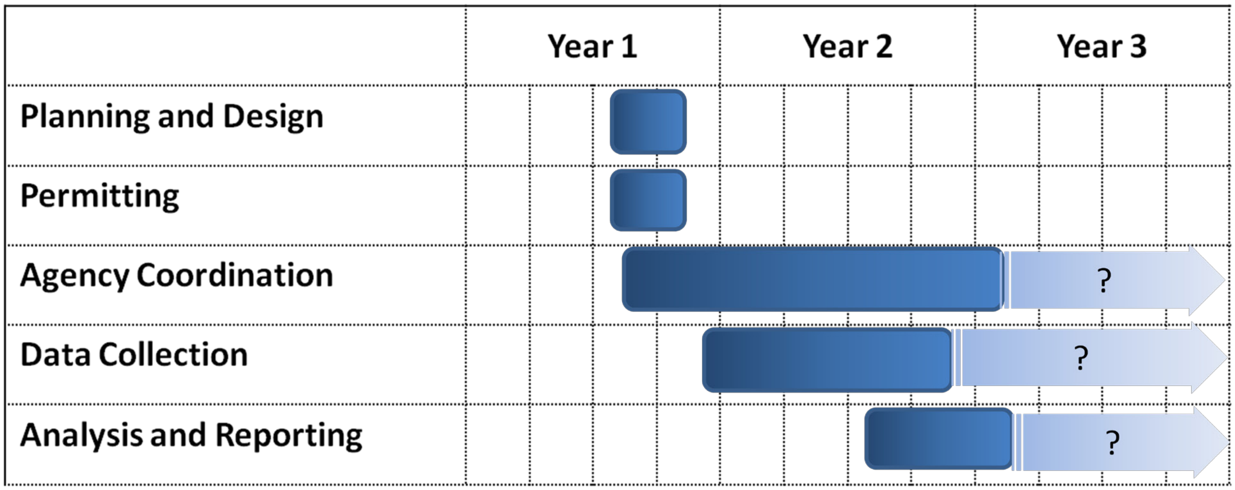
This study should be linked and coordinated with the Refugia Field Study (Study 4), Predator Reduction Methods (Study 6), and Baseline Predator Density/Distribution (Study 9).

### How Study Results Will Be Used

The results of the Predator Habitat Locations Study will be used to inform the design of the north Delta intake facilities such that predation can be minimized. To the extent available, preliminary information from the study will be incorporated into the physical model (Study 1)—specifically, information regarding built features and velocity fields that provide cover for predators or that concentrate prey.

### Schedule

This study should commence as soon as possible following the completion of the NMFS study on predation densities and associated salmonid smolt mortality around water diversions in the Sacramento River, and should extend for a period of 2 years if needed. The results of the study should be evaluated after the first and second years to determine whether an additional year of study would produce meaningful results.




## 6. Predator Reduction Methods

### Objective

Predator control has been used as a management technique on the Columbia River system, Colorado River, and a variety of other locations on a regional scale. Predator control investigations have been performed in the past at Clifton Court Forebay, on the Mokelumne River downstream of Woodbridge Dam, at Glen-Colusa Irrigation District diversion, and at a variety of other locations. The objective if this study is to compile and synthesize information on the methods that have been used successfully and unsuccessfully to control (including the use of deterrents and dispersal methods) predation of covered fishes by predatory fish as well as bird and mammal species. The study is intended to identify the characteristics and elements of successful programs that have controlled predation and improved survival of fish at both a local and regional spatial scale, and to identify the level of effort, estimated cost, long-term maintenance obligations, and monitoring methods used to evaluate program effectiveness.

### Key Questions

1. What methods have been used in an effort to manage and control predation of covered fishes by predatory fish and birds?
2. Have the methods been successful in reducing predation mortality and how was success measured?
3. Was the control program focused on one predatory species or a community of predators?
4. Was the program focused on reducing predator abundance, distribution, or modifications to habitat and structures to reduce predator congregation and prey vulnerability?

5. Was predation mortality localized (e.g., outlet to a fish screen bypass pipe) or extended over a larger regional area (e.g., river reaches or reservoir)?
6. Did the predator control program result in the incidental take of covered fish species?
7. Did the predator control program result in adverse impacts (e.g., economic impacts) to local communities or businesses? Did the program result in beneficial impacts?
8. What was the frequency and level of effort required to implement a successful predator control program on a local and regional scale?
9. Did the program require public involvement and support (such as local tournaments or harvest bounties)?
10. Did the program require changes in local or state fishing regulations to implement?
11. What was the disposition of captured predators (e.g., killed for bounty, relocated and released, given to charity)?
12. What were the approximate sizes of areas managed, level and type of effort, and annual cost?
13. Was the control a one-time effort or did it require frequent maintenance? How frequent and for how long was the control effort required?
14. How was performance of the control methods determined and monitored?
15. Did the program demonstrate a reduction in predation mortality for the prey species? Did the program demonstrate an increase in abundance of the prey species?
16. Was there a change in population abundance or predation by other species (predator release)?
17. Has the program been determined to meet objectives and be a success? Is the program continuing?

## Scope of Study

Data and information from existing predator control programs and investigations available from the peer-reviewed scientific literature, gray literature, and through interviews with state and federal resource agencies, consultants, academic investigators and other knowledgeable parties should be compiled and reviewed for the purpose of identifying potential methods to reduce local predation on covered fish species at the north Delta diversions. This review should take advantage of the similar review conducted by Reclamation in association with the San Joaquin River Restoration. While many of the predator reduction programs focus on removing predators, this review should also consider predator dispersal and deterrent methods as means for reducing predation.

A summary technical report that includes documentation of predator control methods, characteristics of the effectiveness of various alternative control methods, and a synthesis of recommendations for applying results of the survey to the north Delta diversions should be prepared. An EndNote® list, or similar bibliographic list, of the reports and studies used in the literature search should be provided.

## Linkage to Other Studies

This study should be linked and coordinated with the Predator Habitat Location investigation (Study 5).

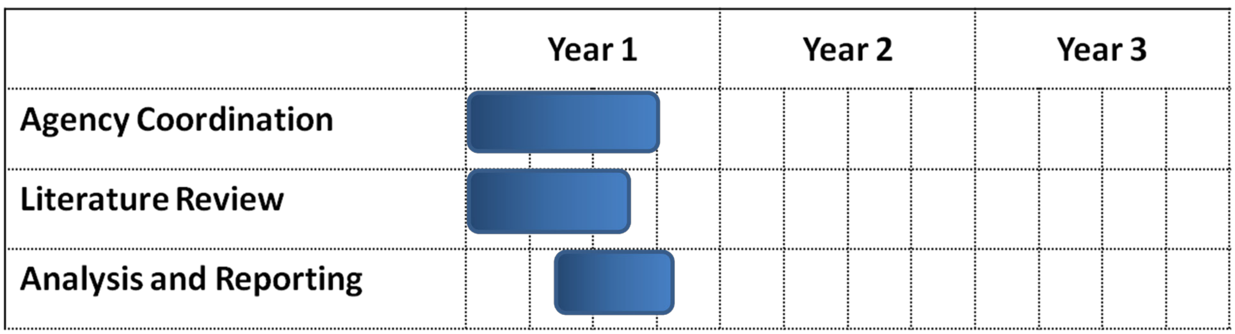
## How Study Results Will Be Used

The results of the Predator Reduction Methods study compilation and synthesis will be used to identify potentially acceptable methods for predator management and reducing the risk of predation at the north Delta diversion locations. This information may also be useful to others conducting habitat restoration projects and other activities in the Delta. The study results will also be used in developing improved estimates of the level of effort and cost associated with implementing a predator control program on a local scale. Recommendations developed through the study may serve as input to others on the design of site-specific field studies to further assess the effectiveness of predator management strategies within the lower Sacramento River and Delta. The study should identify promising approaches and techniques for predator management under various conditions and identify those approaches that have not proven to be successful in previous efforts.

The results of this study also may help inform BDCP Conservation Measure 15, Predator Control, which is intended to reduce the local effects of predators on covered fish species by conducting predator control at "hot spot" locations that have high densities of predators with a disproportionately large adverse effect on covered fish. This study may assist in identifying effective measures for reducing predator abundance that could be applied for that purpose.

### Schedule

This study is not dependent on the results of other studies and can be initiated immediately. This study should be completed within 1 year.




## 7. Flow Profiling Field Study

### Objective

The objective of this study is to characterize the water velocity distribution at river transects within the proposed diversion reaches for differing flow conditions.

### Key Question

1. What is the velocity distribution at various transects at the diversion sites under various river conditions?
2. What are the concentrations and characteristics of the suspended sediment and bed load in the river at the diversion sites?
3. What is the current state of the river cross-sections in the reach at the diversion sites?

### Scope of Study

An acoustic Doppler current profiler should be used to collect data from a boat at approximately 12 transects per intake location. An effort should be made to define velocity conditions at the channel boundary. It is recommended that four data collection efforts be conducted over a range of tidal stages and discharges. The flows recommended by the Study 7 Subteam include: 1) 7,500 cfs, 2) 15,000 cfs, 3) 30,000 cfs and 4) 60,000 cfs. The primary purpose for these velocity data is to calibrate the mathematical model and inform physical model boundary conditions. When the mathematical model is complete, the expected velocities with the proposed structure in place can be assessed.

Channel velocity profiles from the channel bottom to the water surface covering the entire flow depth, across the channel cross section should be collected for each velocity transect at the three intakes. Twelve transects per intake per flow should be performed, including two transects located 500 feet and 1,000 feet upstream, one located 1,000 feet downstream, and nine equally spaced transects along each intake. In addition, two boundary flow transects should be performed, one each at upstream and downstream boundaries of the study reach. The

Subteam also recommended performing a new multibeam bathymetric survey of the river reach from Walnut Grove to the I Street Bridge in Sacramento and collecting sediment samples.

Three types of data should be collected for the sediment sampling: bed load, bottom sediment, and suspended sediment. Ten suspended sediment samples should be collected per sampling location at approximately 5 foot depth intervals to determine the vertical distribution of sediment. Sediment measurements should be collected at four locations at each intake screen location. Two sampling locations should be collected on a transect 1,000 feet upstream of the intake and two more along a transect at the center of the proposed screen. At each transect, one collection point should be on the channel centerline and the other should be 40 feet from the existing shoreline. Suspended sediment samples collected at the channel centerline should be analyzed to determine both the concentration and the particle size distribution.

### Linkage to Other Studies

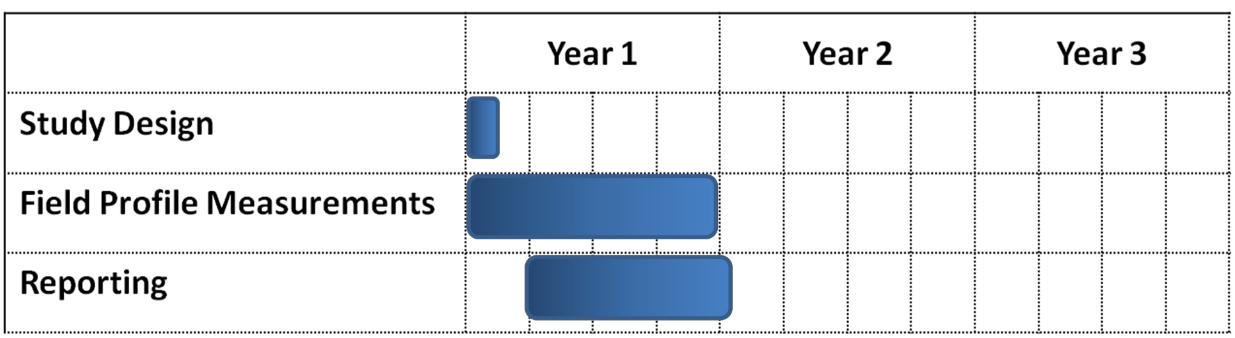
This study should be linked to the required data collected for the development of the mathematical model described in Study 2 and the physical model in Study 1. The results of Study 2 would also be used to provide the data needed for Study 1. It is assumed that DWR has collected (or will collect) the necessary bathymetric data to satisfy the needs of the engineering design phases as well as Studies 1, 2, 3, and 8. To the extent that additional bathymetric surveys are needed, such efforts should be coordinated with the collection of velocity data in Study 7.

### How Study Results Will Be Used

The results of this study will be used to calibrate the Study 2 mathematical model and provide boundary conditions for Study 1.

### Schedule

This study is not dependent on the results of other studies and can be initiated immediately. This study should be conducted concurrently with bathymetric surveys (to the extent possible).




## 8. Deep Water Screens Study

### Objective

The objective of this study is to identify the hydraulic characteristics of deep fish screen panels.

### Key Question

How will deep fish screens perform under varying river conditions and screen-tuning scenarios?

### Scope of Study

The proposed North Delta diversions have fish screens that would be substantially larger than those constructed for previous projects. This study would develop a 3-D computational fluid dynamics (CFD) model to evaluate the need for hydraulic tuning baffles that can be adjusted both in the vertical and horizontal direction.

A requirement for vertical velocity distribution was first encountered during the post-construction tests at RD 108's Poundstone pumping plant. This study will form the basis of developing a much more sophisticated tuning system than previously used.

To closely examine the variation of the horizontal and vertical velocities across the screen face, the study will require a 3-D model of the river reach containing one proposed intake to characterize the 3-D hydraulics in the river and provide boundary conditions to a finer 3-D model of a single screen bay of the intake structure.

Additional CFD models may be required for maximizing the computational efficiency and minimizing the number iterations of the single-bay 3-D model. For example, an analysis of the distribution of the flow in the piping manifold behind the intake screen will be critical because it could have a significant influence on the flow distribution at the intake screen. Another small study should be considered to investigate the effect of the wedge wire on the flow pattern and flow distribution across the screen. A 3-D sectional model representing a slice of the intake screen (a few feet of the larger screen structure) should be developed to determine the impacts of the screen on the flow distribution across the screen. The results from these analyses should be used to fine-tune the parameters for the screen in the single-bay 3-D model.

Considering the need to work closely with the design team, the modeling team should coordinate with the intakes' engineering design team to increase the benefits of this evaluation. For example, during model construction, geometric adjustments that will improve hydraulic performance may be discovered, and these should be shared with the design team. Similarly, features that other studies anticipate (such as materials and configuration of screens) that may affect hydraulic performance may not be shown on preliminary or less-detailed design drawings, so these elements will need to be coordinated among studies and design and modeling efforts. Coordination with the design team is required to determine if recommendations are acceptable and if anticipated features will exist and what dimensions may be representative.

ANSYS® software should be used to build the 3-D CFD model to help determine an acceptable configuration of flow control baffles and its tuning. The boundary conditions needed for the CFD model will be generated using 1-D and/or 2-D model. The study section, mesh size to characterize the structure, modeled parameters, and flow and operations scenarios will be determined to adequately define the flow characteristics of concern and will be developed in coordination with the intake design team.

## Linkage to Other Studies

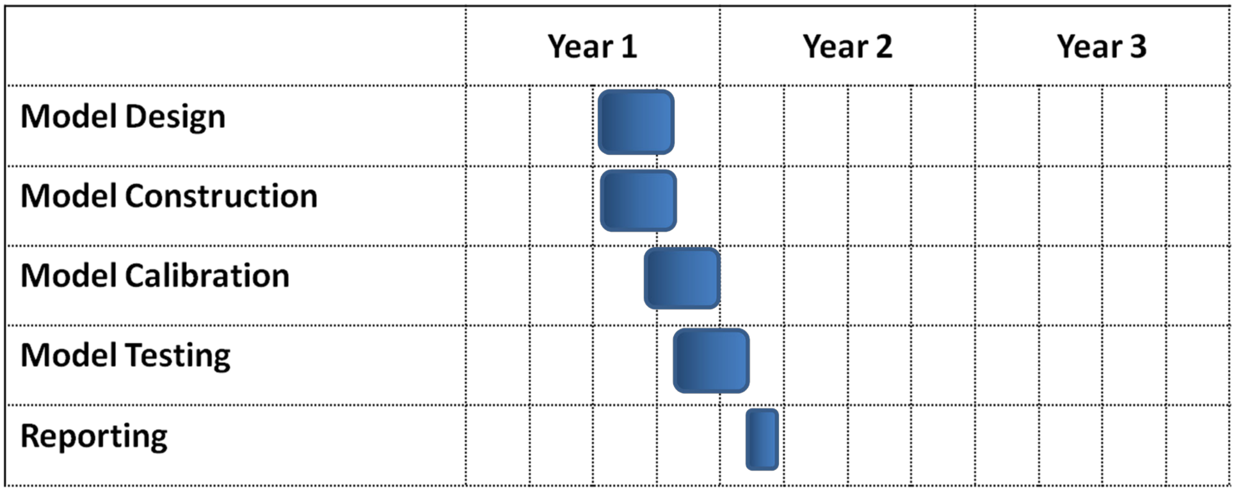
This study is dependent on the results of the Study 2. This study is most directly linked to the preliminary engineering design. Several concepts have been proposed but without this study it is impossible to determine the proper final configuration of the entire screen bay and thus the size of the whole intake structure.

## How Study Results Will Be Used

This hydraulic modeling effort is critical to finalizing the detailed configuration of a typical screen bay. The results will be used to confirm the most appropriate technology for all of the screen bay components.

## Schedule

This study can only start after Study 2 is completed. Without a complete and thorough vetting of all the operations scenarios and their resultant hydraulic profiles, a CFD model of an individual screen bay should not proceed. Likewise, time is needed for the FFTT to work with the engineering team to refine potential technologies to be modeled. The modeling is intended to help confirm the best ideas on how to deal with vertical hydraulic tuning.




# 9. Baseline Predator Density and Distribution

## Objective

Construction and operation of the north Delta diversions have the potential to increase predator populations in that reach of the Sacramento River and increase the rate of mortality for covered fish species relative to the current baseline rate. The objective of this study is to determine the baseline densities, species composition, and seasonal and geographic distribution of predatory fish (and birds and mammals if appropriate) within the Sacramento River in the reaches where the three north Delta diversion structures are proposed to be sited and in adjacent control reaches. Baseline data collected on predator occurrence in the vicinity of each proposed north Delta diversion structure location can then be used in the future to determine changes in predator density and distribution that may be associated with existence and operation of each diversion structure.

## Key Questions

1. What are baseline densities of predatory fish, birds, and mammals in the Sacramento River within reaches where north Delta diversion structures are proposed to be sited?
2. How do predator densities within proposed diversion reaches compare to predator densities in adjacent control reaches?
3. How do predator densities vary by season and in response to changes in Sacramento River flow, water temperatures, turbidity, time of day, and other factors such as water velocity, areas of turbulence, and proximity to shorelines and physical structures within the river?
4. What are the predatory fish and bird species that inhabit the Sacramento River in the vicinity of the proposed north Delta diversion sites?
5. What is the species composition, relative abundance, and length and weight of predatory fish, and how do these metrics vary within and among years and among locations within this reach of the river?
6. What is the diet and selection of prey species for the predators inhabiting the river and how does the diet vary on a species-specific basis, by predator and prey size, and by season?

## Scope of Study

The initial year of activities should be conducted as a pilot study intended to refine and focus the study approach, identify opportunities to share resources and collaborate with other ongoing studies, and develop more reliable estimates of costs. The first task of the pilot study should be a review of ongoing predator studies in the Sacramento River in or near the reach where the north Delta diversion would be located to assess the efficacy of collaborating and coordinating with those studies to avoid duplication of effort and broaden the utility of the collected information. An EndNote® list, or similar bibliographic list, of the reports and studies used in the literature search should be provided.

Based on the review task, a detailed study design/plan should be developed that describes the actions that would be conducted to meet the above objectives and answer the key questions. In addition, it should clearly identify the locations where the field activities would be conducted, the scope of data collection activities at each location, the boundaries of the study reaches, the data collection methods, the frequency of sampling, and the data analysis approach that would be applied. This study design will be subjected to an independent scientific review and therefore should be prepared in sufficient detail for the reviewers to determine whether the proposed design would meet the stated objectives. The study design/plan should also include a detailed schedule and estimate of the costs for completing the study.

The details of the study should be designed in consideration of the following guidance. The study should be conducted within the reach of the Sacramento River where the three north Delta diversion structures are proposed to be sited and adjacent control reaches. Surveys of predators should be conducted at each reach using survey techniques that may include, but would not be limited to, DIDSON/ARIS camera, boat-mounted multibeam hydroacoustics, side-scan sonar, and similar instruments. The surveys should determine the density and distribution of predator-sized fish. The initial surveys should focus on predatory fish; however, if incidental observations of piscivorous birds or mammals suggest that they are causing significant fish mortality, these predators should be considered for inclusion in subsequent surveys. Surveys should be conducted during the day and at night at a frequency necessary to meet study objectives. For each survey, predatory fish should be collected using various methods that may include hook-and-line (including use of artificial lures, dead bait, live bait, and similar), trot lines, gill nets, trammel nets, stationary fyke traps, or other suitable method. Predatory fish collected should be identified to species, length and weight measured, stomach contents sampled by gastric lavage, externally marked (e.g., Floy tag), and released. Data from field surveys should be collected over a 3-year period to reflect a range of Sacramento River flows and other environmental conditions. Results of the field studies are intended to be used to identify the geographic and seasonal distribution of predatory fish within each designated treatment and control reach of the river, species composition, diet, and size composition. The study should consider diet analysis and bioenergetics modeling after the initial year(s) of sampling and whether the additional information is needed to adequately characterize baseline conditions. Bioenergetics models such as that developed to assess potential predation losses at the north Delta diversions as part of BDCP Effects Analysis may be appropriate to estimate the magnitude of reduction in predation mortality.

A revised study design/study plan, including detailed cost estimates and anticipated study duration, should be prepared following completion of the pilot Baseline Predator Density and Distribution Study. The revised study design should be subjected to Working Team and independent scientific review, and modified as appropriate prior to funding subsequent phases of the study.

## Linkage to Other Studies

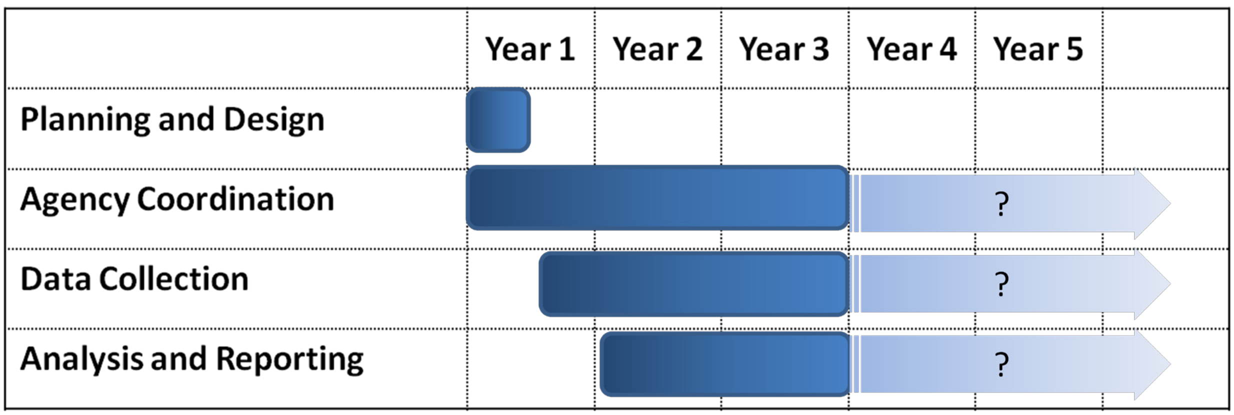
This study should be linked and coordinated with the Predator Habitat Locations Study (Study 5), the Predator Reduction Methods (Study 6), and the Reach-Specific Baseline Juvenile Salmonid Survival Rates Study (Study 10). From an implementation perspective, this study should be closely coordinated with Study 11 (Baseline Fish Surveys) or conducted under the same program because of the considerable overlap in sampling methods and the ability to collect information for both studies simultaneously. This study is not dependent on the results of other studies and can be initiated immediately.

## How Study Results Will Be Used

The results of the Baseline Predator Density and Distribution Study will be used to assess current baseline predator densities, species composition, and seasonal and geographic distribution of predators in the lower Sacramento River in the vicinity of the north Delta diversions. Variation in predator densities and distribution among locations, seasons, and years will be used to determine baseline conditions within the river that can then be compared to predator densities and distribution after the north Delta diversion structures are constructed and operational. Results of the field studies may also contribute to estimating the level of predation mortality occurring for covered species under baseline conditions as well as assessing the magnitude of predator control that may be needed to achieve BDCP biological goals and objectives for covered fish survival. This study may also inform BDCP Conservation Measure 15, Predator Control, and provide information useful in the facility design.

### Schedule

This pilot study should commence as soon as possible. The study should extend for a period of at least 3 years to reflect a range of Sacramento River flows and other environmental conditions within the river that may affect covered fish species survival in the lower Sacramento River. The results of the study should be evaluated after each year and the experimental design refined as needed. The study may need to be extended if an appropriate range of baseline conditions cannot be adequately established during the initial years of study.




## 10. Reach-Specific Baseline Juvenile Salmonid Survival Rates

### Objective

The primary objective of this study is to determine baseline rates of survival for juvenile Chinook salmon and steelhead within the Sacramento River in the vicinity of proposed north Delta diversion sites for comparison to post-project survival in the same area, with sufficient statistical power to detect a 5 percent difference in survival. Results of previous acoustic tag studies conducted in the Sacramento River have detected relatively high mortality rates for juvenile salmon migrating through the Delta. Concern has been expressed that operation of the three proposed north Delta diversion structures would increase direct mortality (e.g., predation) of juvenile salmonids in this reach of the river.

### Key Questions

1. What is the baseline (current) survival of juvenile Chinook salmon and steelhead migrating downstream in the Sacramento River where the proposed north Delta intakes would be located, and how much does survival vary within and among years and by species?
2. What is the sample size of acoustically tagged juvenile salmonids that would be required to detect a 5 percent change in survival over the reach as a result of north Delta operations?
3. Do fish size, season, species, flow, velocity, turbidity, tidal phase and/or migration rates predict juvenile salmonid inter-reach or intra-reach survival rates?
4. Does survival, through the treatment reaches and in comparison to control reaches, differ by more than 5 percent under various environmental and biological conditions?
5. Can results of these pre-construction survival studies be used as a baseline for detecting changes in juvenile salmonid survival that may be attributable to the diversion structures and operations under BDCP?

6. What is the distribution of juvenile salmonids within the river channel and how does the location and migratory path change in response to variation in factors such as river flow, species, and time of day?
7. Are hatchery-produced juvenile Chinook salmon and/or steelhead a suitable surrogate for wild fish in assessing changes in survival in the future as a function of north Delta intake operations?

## Scope of Study

The three basic tasks and associated objectives for the study are outlined below.

The initial task of this study (Task 1) should be the development of a detailed study design/plan, which will be subjected to independent scientific review. At a minimum, the design/plan should include the following:

- A conceptual model of the potential mechanisms through which the physical structure and water diversion operations of the proposed north Delta intake structures (three flat plate on-bank intakes with a diversion capacity of 3,000 cfs each) could affect the migration and survival of juvenile Chinook salmon and steelhead. The conceptual model should address, but not be limited to, direct immediate effects such as predation mortality and delayed effects such as swimming fatigue that lead to increased predation mortality some distance downstream of the intake structures. The conceptual model will be used, in part, as the basis for the experimental design and data analysis.
- (1) A review of the relevant literature on past and current salmonid survival studies conducted in the Sacramento River and elsewhere, (2) identification of specific reaches of the river that would serve as control and treatment reaches (see Figure 2), including control reaches upstream of all diversions that would not be affected by the diversions or their operations and a reach sufficiently downstream of the diversions to assess potential delayed mortality or other effects (the farthest downstream reach would terminate at or upstream of the confluence with Sutter Slough), (3) a statistical power analysis (potentially using data from past acoustic tag studies such as the Georgiana Slough non-physical barrier study) to determine the appropriate sample size for detecting a 5 percent change in juvenile salmonid survival across the three diversion reaches and downstream control reaches, (4) identification of an appropriate upstream release location accounting for acclimation time in the river and in-river losses, (5) identification of an appropriate acoustic tag type and size for use in the juvenile salmon and steelhead and associated tag detection array configuration (single or multiple tag technologies may be used for various purposes as appropriate), (6) adherence to the Standard Operating Procedures for Acoustic Tagging developed by USGS[1] with control to assess tagger effects, and (7) identification of the proposed approach for data management, QA/QC, and modeling/statistical analysis of results to address the key questions.

In addition, the study design/plan should include:

- Identification of all metrics that would need to be collected or measured as part of the study including, but not limited to, acoustic telemetry, river flow and velocity, turbidity, ambient light levels, basic water quality measurements, and other appropriate metrics identified through the conceptual model and analytical framework proposed for the investigation. The source of each data set should be identified if current data collection is proposed to be used (e.g., average daily river flow in cfs measured at the Hood Gage and available on CDEC, model velocities, and similar data sources) or if separate instrumentation is needed (e.g., recording turbidity meter or velocity meters) to support the study and analysis of results.
- Plan for transporting hatchery salmonids from the hatchery and the collection and transport of wild salmonids to the tagging location.

[1] Liedtke, T. L., J. W. Beeman, and L. P. Gee. 2012. *A Standard Operating Procedure for the Surgical Implantation of Transmitters in Juvenile Salmonids.* U.S. Geological Survey Open-File Report 2012-1267, 50 p. http://pubs.usgs.gov/of/2012/1267/.

- Identification of and plan for obtaining all necessary permits and approvals needed to collect and tag wild salmonids.
- A recommended list and quantity of all equipment that will need to be purchased or fabricated.
- An annual breakdown of anticipated costs for labor, equipment, travel, and other expenses.

It is anticipated that the study design for this investigation would include installation of tag detectors at upstream and downstream boundaries of reaches encompassing each of three potential north Delta diversion locations as well as additional river reaches (one upstream and one downstream of each potential diversion reach). These detectors would continuously monitor the passage of acoustically tagged salmonids released at an upstream location.

During the first year of the investigation, it is anticipated that late fall-run Chinook salmon and yearling steelhead produced at the Coleman National Fish Hatchery would be used in the study (fish in the first year likely would range in length from approximately 110 to 150 mm) and would be released into the Sacramento River at a location determined appropriate in the experimental design.

Results of the first year of the survival study should be used to estimate the variance in survival rates and for use in a statistical analyses (power analysis) to determine the sample size requirements in subsequent years to detect a cumulative reduction in juvenile salmonid survival of 5 percent within the river reach where the three north Delta diversions are to be sited compared to adjacent control reaches.

The study could potentially be expanded in subsequent years as part of a separate task (Task 2) to include the application of 3-D tag detection at selected potential diversion sites to determine predation on salmon smolts and where fish moving through the reach are positioned in the channel. More advanced information on the actual migratory pathway, location in the water column, response to changes in water velocities, and location relative to channel margins, could be developed using more advanced 3-D acoustic tagging technologies. The 3-D acoustic tracking systems provide high-resolution mapping of the actual distribution and pathway of fish movement within the river channel and may be appropriate for use in identifying juvenile salmonids that have been preyed upon by larger fish and for providing detailed information on the location and movement patterns of juvenile salmonids as they migrate downstream through discrete reaches where the diversion structures are proposed to be constructed. Application of high-resolution 3-D acoustic tracking technology would provide additional information regarding fish location within the channel and movement patterns would assist in the design of the diversion structures.

The study may be expanded after the first year to include a comparative study of wild and hatchery-produced juvenile Chinook salmon and/or steelhead. A third separate task (Task 3) would potentially involve conducting comparative studies of survival and migration rate through each of the treatment and control reaches for wild vs. hatchery-produced juvenile Chinook salmon and/or steelhead. Prior survival and migration studies have used hatchery stock as a surrogate for wild salmonids migrating in the Sacramento River. Task 3 would be designed to validate or refute the use of hatchery-produced salmonids as surrogates for wild salmonids. Hatchery-produced juvenile salmon and steelhead could be provided by the Coleman and/or Feather River fish hatcheries. Wild fish could be captured and tagged as part of a study using rotary screw traps or other suitable methods.

The initial year of activities should be conducted as a pilot study intended to refine and focus the study approach, identify opportunities to share resources and collaborate with other ongoing studies, and develop more reliable estimates of costs. The pilot also should be used to determine whether to proceed with optional tasks 2 and 3.

### Geographic Scope

The specific reach of the lower Sacramento River where survival of juvenile salmonids would be assessed encompasses the area where the proposed north Delta diversions are to be located (see Figure 2). The reach extends from Freeport to Hood with potential control reaches located as far downstream as the confluence with Sutter Slough.

As part of the experimental design for this baseline investigation, it is anticipated that each of the potential north Delta diversion locations would be used to identify the mid-point of a treatment reach extending upstream and downstream of each potential diversion structure. Tag detectors could be located at the upstream and downstream boundary of each designated reach (multiple tag detectors may be used at each reach boundary to assess tag detection probabilities for each treatment and control reach and/or provide redundancy). Control reaches would be identified upstream and downstream of each diversion reach. Beacon tags may be deployed at each reach boundary for use in validating the performance of each tag detector throughout the study period. The control and treatment reaches would represent conditions in the Sacramento River channel for each of the potential diversion sites representing where survival would be determined.

It is anticipated that acoustically tagged salmonids would be released a sufficient distance upstream of the control and treatment reaches to allow acclimation to the river and orientation to the river channel (specific release locations should be identified as part of the experimental design). Continuous monitoring should occur as tagged salmonids migrate downstream through each designated control and treatment reach. The results would be used to estimate the probability of reach-specific survival. Confidence intervals should be developed for each survival estimate. Reach-specific survival may be modeled statistically to evaluate the contribution of other covariates that may affect survival, such as river flow, tidal phase, water temperature, turbidity, and time of day (e.g., day vs. night).

### Temporal Scope

Survival tests should be conducted by releasing acoustically tagged juvenile salmonids over the period extending from as early as October through May to characterize conditions within the Sacramento River during the seasonal period of primary juvenile Chinook salmon and steelhead downstream migration. The experimental design should include a recommended release strategy that is compatible with the proposed data analysis methods. The study is anticipated to be conducted each year over a 3-year period to represent a variety of hydrologic (river flow) and seasonal conditions (although the study period may need to be extended beyond 3 years in the event that the range of desired flow conditions is not met). The first year of the study will serve as a pilot for the full study.

### Test Fish

It is anticipated that the survival studies in the first year will be conducted using late fall-run Chinook salmon and yearling steelhead produced in the Coleman National Fish Hatchery. Table 2 lists the fish species and sizes likely available for use in the study.

TABLE 2
**Potential Sources of Hatchery Fish for Survival Study**

| Test Species | Source | Size Range |
|---|---|---|
| Late fall-run Chinook | Coleman Hatchery | 110–150 mm |
| Fall-run Chinook | Feather River Hatchery | 80–90 mm |
| Winter-run Chinook | Livingston Stone Hatchery | ~90-110 mm |
| Spring-run Chinook | Feather River Hatchery | 80-100 mm |
| Fall-run Chinook | Coleman Hatchery | 80-90mm |
| Steelhead | Coleman Fish Hatchery | 125–150 mm |

It is anticipated that test fish would be transported by truck from each hatchery to an on-site holding and tagging facility located near the proposed release location. Test fish would be held in live-cars for acclimation and to reduce stress associated with handling and transport prior to tagging. Test fish may be tagged surgically using standard procedures developed by USGS,[2] held for post-tagging recovery, and subsequently released into the Sacramento River. As part of the study implementation and documentation, additional groups of salmon and steelhead associated with each release may be tagged and held to assess battery life and post tagging survival.

### Data Analysis

Statistical analysis of reach-specific survival for both acoustically tagged Chinook salmon and steelhead may be consistent with the analytical methods used for survival estimation in the Vernalis Adaptive Management Plan and Six-Year steelhead study being performed on the lower San Joaquin River and the NMFS regional study or using alternative methods proposed by the preparer of the study design. Statistical models and other analytical methods may be proposed in the study design to evaluate the contribution of various environmental and biological covariates in determining reach-specific survival rates. Differences in survival rates between treatment and control reaches would also be analyzed statistically.

### Documentation/Reporting

The first-year report should present the findings of the pilot and include a revised study design/study plan that refines the approach, cost estimates, and anticipated study duration. An EndNote® list, or similar bibliographic list, of the reports and studies used in the literature search should be provided. The revised study design should be subjected to Working Team and independent scientific review, and modified as appropriate prior to funding subsequent phases of the study. The revised study plan should anticipate that draft and final technical documentation reports would be prepared annually describing the methods and results of testing each year. The study is expected to be conducted over a 3-year period, which may be extended to a longer time period. Each annual report should synthesize results of prior year investigations as well as present results of current tests.

## Linkage to Other Studies

This study should be linked and coordinated with the Site Locations Study (Study 2) and with the Predator Habitat Locations Study (Study 5). In addition, this study should consider acoustic tag studies recently conducted in the Sacramento River by DWR, NMFS, and others that provide the technical foundation for the design of a large multi-year experimental study of juvenile salmonid migration and survival. For example, DWR has conducted extensive acoustic tag salmonid survival and migration studies in the Sacramento River in 2011 and 2012 as part of the Georgiana Slough non-physical barrier investigations. In addition, NMFS and other collaborators are initiating an acoustic tag study this year that is designed to test survival of fall-, winter-, and spring-run Chinook salmon as well as provide a comparison of survival and migration between hatchery and wild salmonids. Detectors will be deployed as part of the NMFS study throughout the migration corridor on the Sacramento River through northern San Francisco Bay to the Golden Gate Bridge to monitor fish movement and survival on a regional scale over a 3-year period. DWR is also planning to test an experimental fish guidance fence to reduce migration of juvenile salmonids into Georgiana Slough in 2014. These and other studies offer information on salmonid migration and survival in the Sacramento River and can potentially be used collaboratively with the design of this study to gain greater sample sizes, statistical power, and cost efficiencies.

## How Study Results Will Be Used

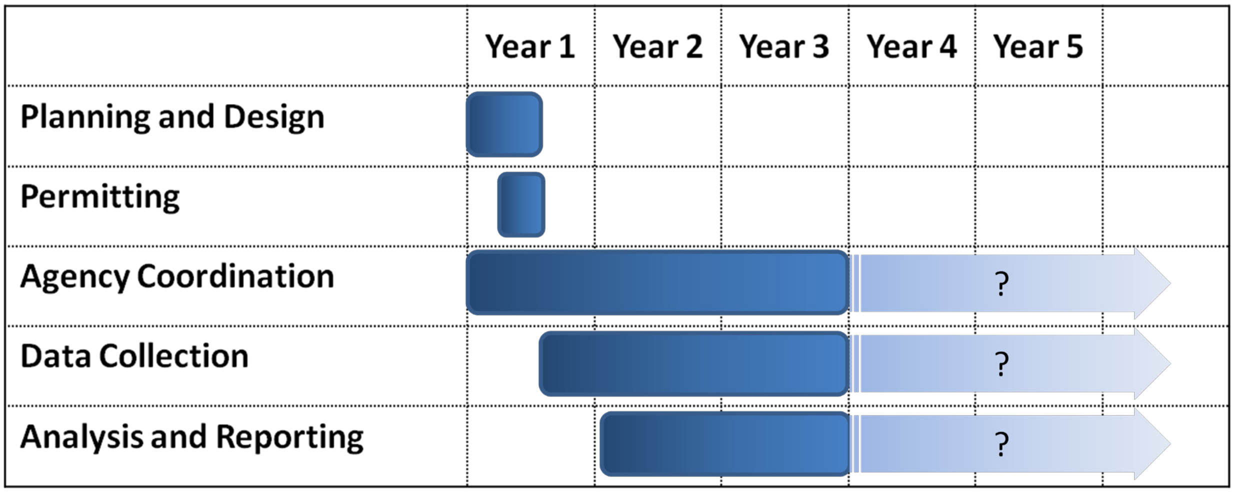
The results of the juvenile salmonid survival study will be used to establish baseline measurements for post-construction survival studies designed to evaluate incremental reductions (5%) in salmonid survival within river reaches where north Delta diversion structures are located.

## Schedule

This pilot study should commence as soon as possible and the study should extend for a period of 3 years or more to reflect a range of Sacramento River flows and other environmental conditions within the river that may

[2] Liedtke, T. L., J. W. Beeman, and L. P. Gee. 2012. *A Standard Operating Procedure for the Surgical Implantation of Transmitters in Juvenile Salmonids*. U.S. Geological Survey Open-File Report 2012-1267, 50 p. http://pubs.usgs.gov/of/2012/1267/.

affect juvenile salmonid survival in the Sacramento River. The results of the study should be evaluated after each year and the experimental design refined as needed. The annual reviews should also be used to determine whether additional study is needed to adequately establish baseline survival rates. This study also requires lead time to obtain necessary test fish and tags.




# 11. Baseline Fish Surveys

## Objective

Determine baseline densities and seasonal and geographic distribution of all life stages of delta and longfin smelt and other aquatic species covered by the BDCP inhabiting reaches of the lower Sacramento River where proposed north Delta diversion structures may be sited.

## Key Questions

1. What is the seasonal and geographic distribution of each life stage of covered species in the vicinity of the proposed north Delta diversion locations?
2. What are the densities of each life stage of covered fish species inhabiting the lower Sacramento River adjacent to each of the proposed north Delta diversion sites?
3. What is the fish length frequency distribution of all life stages of covered fish species observed at each of the proposed diversion sites?
4. Is the distribution of each life stage of covered fish species inhabiting the lower Sacramento River uniform within the river water column and laterally across the channel width, or does the distribution vary spatially? Does the spatial distribution vary between day and night?
5. How do the distribution and densities of covered fish species respond to variation in Sacramento River flow and other environmental conditions such as turbidity, water temperature, tidal cycle, and dissolved oxygen?

## Scope of Study

The initial year of activities should be conducted as a pilot study intended to determine the level of effort necessary for gathering baseline data within the vicinity of the proposed intake locations. The first year will involve determining existing research and monitoring efforts that occur within the reach, identifying where there are gaps in data collection for target species, and identify sampling needs under Study 11. There should be a review of the ongoing research and monitoring studies of covered fish species in the Sacramento River in or near the river reach where the north Delta diversion would be located to assess the efficacy of collaborating and coordinating with those current studies to avoid duplication of efforts and broaden the utility of the collected information. This review should also be used to standardize data collection and evaluation protocols with these other studies to the extent possible, including the concept of recording data for all species captured. Future efforts under Study 11 will refine and focus the study approach, identify opportunities to share resources and collaborate with other ongoing studies, and develop more reliable estimates of costs. Collaborating and coordinating with existing long-term projects is highly recommended for Study 11. Determining overlap and collaborating with long-term programs such as the USFWS' Delta Juvenile Fish Monitoring Program is essential to gather data efficiently.

Based on the review above, a detailed study design/plan should be developed that describes the actions that would be conducted to meet the above objective and answer the key questions. In addition, it should clearly identify the locations where the field activities would be conducted, the scope of data collection activities at each location, the boundaries of the study reaches, the data collection methods, the frequency of sampling, the data analysis approach that would be applied, and methods for making data available on a timely basis. This study design will be subjected to an independent scientific review and therefore should be prepared in sufficient detail for the reviewers to determine whether the proposed design would meet the stated objectives. The study design/plan should also include a detailed schedule and estimate of the costs for completing the study.

The fish surveys should be conducted in the reach of the Sacramento River where the three diversion facilities are proposed and phased to adjust the level of sampling effort seasonally and based on results of the presence of covered fish species in the area.

The baseline surveys should determine the occurrence, densities, and seasonal and geographic distribution of each life stage of covered fish species at each proposed diversion site. Capture techniques should be sufficiently broad to capture all target species, including sturgeon, which may require methods such as the use of otter trawls and trammel nets.

The study may need to accommodate additional focus on delta and longfin smelt if it appears that the presence and timing of these species at the diversion sites could influence operations. This additional sampling, if needed, should focus on providing additional information on the detailed seasonal distribution, variation in occurrence in response to Sacramento River flows or other factors, length frequency distribution, and spatial distribution within the river water column in the immediate vicinity of the proposed diversion site. Sampling effort should be coordinated with other fishery monitoring programs in the area to reduce the potential for increased incidental take of protected fish species.

The first-year report should present the findings of the pilot and include a revised study design/study plan that refines the approach, cost estimates, and anticipated study duration. The revised study design should be subjected to Working Team and independent scientific review, and modified as appropriate prior to funding subsequent phases of the study. The study should be conducted for a minimum of 3 years, with the results of these years of study used to determine how much additional effort would be needed to establish the baseline. The results of first year of survey should also be used to focus the scope of subsequent surveys. Low level annual monitoring may be required until the diversion facilities are constructed.

Results of the compilation and analysis of existing data and additional field sampling efforts should be documented in annual technical reports. The incidental take and sampling design and results would be critically reviewed annually and revised as needed.

## Linkage to Other Studies

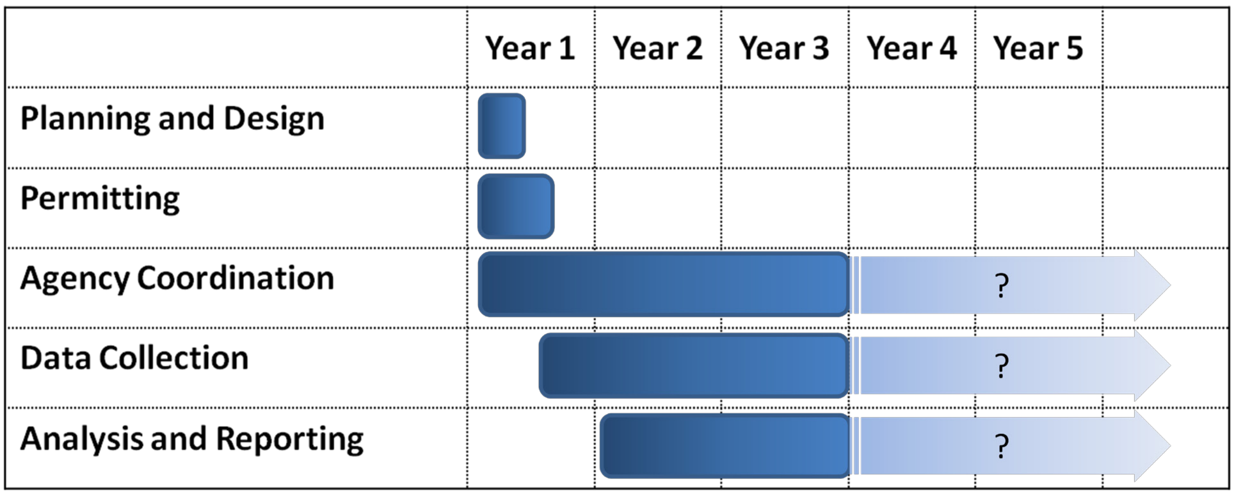
This study should be linked and coordinated with the Baseline Predator Density and Distribution (Study 9) and Reach-Specific Baseline Juvenile Salmonid Survival Rates (Study 10). Coordination and collaboration with other current studies to increase technical and cost efficiency is encouraged. This study is not dependent on the results of other studies and can be initiated immediately.

## How Study Results Will Be Used

The results of the surveys will be used to establish baseline conditions for covered fish species within the reaches of the river where the north Delta diversions will be sited. This information may help inform operations of the north Delta intakes structures to reduce and avoid entrainment and impingement risk for covered fish species. Information on the occurrence of delta smelt and longfin smelt in the lower Sacramento River can be used to prioritize the preferential operation of north Delta diversions (e.g., operate the most upstream diversion first) as well as provide information on design approach velocities and other diversion design features. Results of the studies can also be used to assess seasonal operations to reduce or avoid entrainment risk for covered fish species as well as to determine the potential magnitude of fish species incidental take as a result of north Delta diversion operations.

## Schedule

This study should commence as soon as possible and extend for a period of 3 years or more to reflect a range of Sacramento River flows and other environmental conditions within the river that may affect the distribution and density of various life stages of covered fish species in the lower Sacramento River. The surveys should be conducted year round, but the frequency of sampling is expected to increase in the December through June period. This study will require incidental take authorization, which will likely extend the schedule for initiation of the study.



# Study Coordination

As indicated in Figure 1, most of the pre-construction studies described above are linked and should be closely coordinated. Opportunities may exist to improve the cost and technical efficiency of studies by combining them with other study efforts, sharing elements of the study (e.g., use the same tagged fish for multiple purposes and combining permits), and sharing equipment and staff resources. This coordination would sequence studies and tasks to help ensure that information flows efficiently from one study to the other and would maximize the sharing of resources (e.g., equipment) among the studies. The coordination element should also include collaboration and coordination with similar ongoing studies conducted in the Sacramento River, particularly for the baseline biological studies. Collaborating and coordinating with organizations, such as other state, federal, and academic programs that have historically gathered data within the vicinity of the proposed intakes, is necessary to avoid duplication of effort and broaden the utility of the collected information. The team implementing pre-construction studies 1 through 11 should enlist the assistance of the Interagency Ecological Program (IEP), as necessary, in carrying out the pre-construction monitoring programs to ensure compatibility with future post-construction BDCP efforts and existing IEP efforts. Also, the level of scientific independent review will vary among studies, but will require coordination with the Delta Science Program prior to the review.

Although focused on collecting information needed for the north Delta diversions, these studies are anticipated to produce information that has incidental value to other studies and programs. Therefore, an important component of the coordination will be the collection of data using established protocols to the extent possible and managing the data in a way that provides accessibility.

It is envisioned that the BDCP Fish Facility Working Team convened for the purpose of developing and refining the pre-construction studies would continue to play a role in study coordination. Members of this group are engaged in similar studies conducted in the area and will be able to provide insights into the larger context of other BDCP and related studies. Similarly, the technical subteams would continue to engage to help ensure coordination at the specific study level.

# Performance Criteria

The performance criteria recommended by the FFTT are presented in Table 3 along with some discussion about the linkages with the proposed studies and a status update regarding any changes and/or decisions since July 2011.

TABLE 3
**Fish Facility Technical Team (FFTT 2011) Performance Recommendations and Criteria**

| Recommendation/Criterion | Linkage to Studies | Status |
|---|---|---|
| 1. Diversion structures should be located on-bank. | | Design is proceeding with diversion structures located on-bank. |
| 2. Diversion structures should not exceed 3,000 cfs in capacity at any single location with a total maximum of three diversion structures at three sites on the lower Sacramento River. | | Diversion structures will be constructed at three diversion structures instead of five. |
| 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. | This optimization process will proceed during pre-construction studies 1 (Site Locations Lab Study), 2 (Site Locations Numerical Study), and 7 (Flow Profiling Field Study). | |
| 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 three diversion structures. | | The EIR/EIS will evaluate alternatives with 1 to 5 diversion facilities and up to 12 diversion sites. |
| 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). | | This recommendation was based on early evaluation of multiple sites. The current facility locations are located more than 1 mile apart. |
| 6. Provide a positive, physical fish screen barrier between fish and water diversions. | | Facility design proceeding with positive, physical fish screen barriers. |
| 7. Avoid the need to collect, concentrate, and handle fish passing the diversions. | | Facility design proceeding with structures that will not collect, concentrate, or require handling of fish passing the diversions. |
| 8. Avoid the need for fish bypasses that concentrate fish and increase the risk of predation. | | Facility design proceeding without the use of fish bypasses. |

TABLE 3
**Fish Facility Technical Team (FFTT 2011) Performance Recommendations and Criteria**

| Recommendation/Criterion | Linkage to Studies | Status |
|---|---|---|
| 9. Avoid creating areas where predators may congregate or where potential prey would have increased vulnerability to predation. | The selected sites will be evaluated for predators primarily by way of pre-construction studies 5 (Predator Habitat Locations) and 9 (Baseline Predator Density and Distribution). Studies 1 (Site Locations Lab Study), 2 (Site Locations Numerical Study), 3 (Refugia Lab Study) and 4 (Refugia Field Study), 6 (Predator Reduction Methods), 7 (Flow Profiling Field Study), and 10 (Reach-Specific Baseline Juvenile Salmon Survival Rates) may also inform this design recommendation. | Recommendation still valid; the design will incorporate facility features based on the results of identified studies. |
| 10. Avoid siting diversion structures at areas of existing riparian habitat. | | Current facility locations have taken this recommendation into consideration. |
| 11. Use the most biologically protective fish screen concepts as the foundation of the proposed designs. | | This is still the goal; need to clarify current thinking on elements of the most protective fish screen. |
| 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. | Study 11 (Baseline Fish Surveys) may inform this recommendation by documenting the timing of delta smelt presence within the diversion reach. | Recommendations 12, 13, and 14 were the subject of focused technical group discussions to reconcile screen length/approach velocity with initial design activities. Initial design will proceed with strategies to accommodate as much flexibility as practicable while meeting approach and sweeping velocity criteria, consistent with Recommendation 16. |
| 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). | | Recommendations 12, 13, and 14 were the subject of focused technical group discussion to reconcile screen length/approach velocity with initial design activities.<br><br>Initial design will proceed with strategies to accommodate as much flexibility as practicable while meeting approach and sweeping velocity criteria, consistent with Recommendation 16. |

TABLE 3
**Fish Facility Technical Team (FFTT 2011) Performance Recommendations and Criteria**

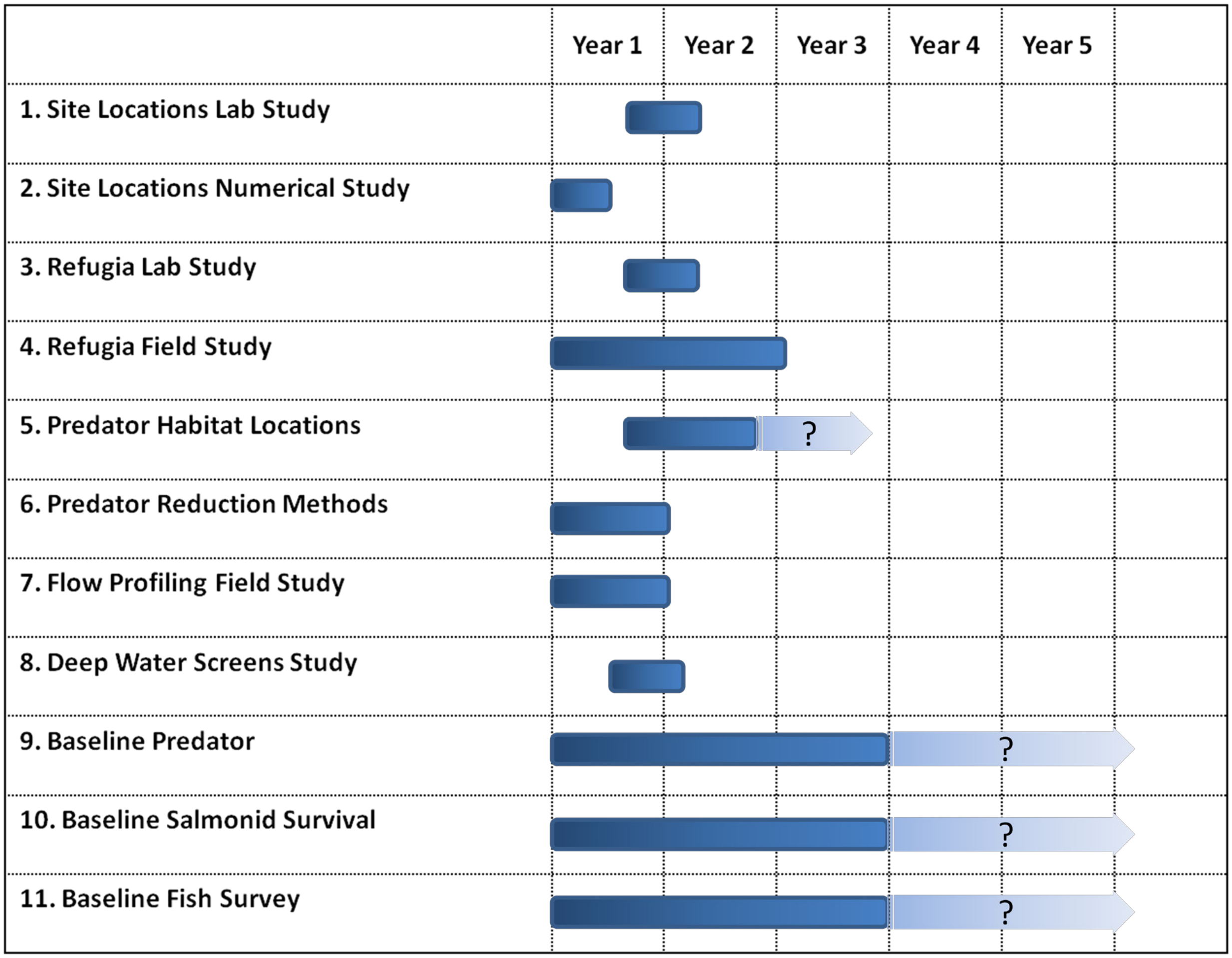
| Recommendation/Criterion | Linkage to Studies | Status |
|---|---|---|
| 14. Target the height of fish screen panels to 15 feet of submerged screen height to operate at 0.33 fps approach velocity at low river stage; taller screens may be appropriate at specific sites for purposes of reducing the length 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. | Study 8 (Deep Water Screens Study) will inform this recommendation by clarifying the effects of deep water screens on hydraulic performance. | Recommendations 12, 13, and 14 were the subject of focused technical group discussion to reconcile screen length/approach velocity with initial design activities.<br><br>Initial design will proceed with strategies to accommodate as much flexibility as practicable while meeting approach and sweeping velocity criteria, consistent with Recommendation 16. |
| 15. Bottoms of screen panels should be elevated three to 5 feet off the existing river bottom to minimize sediment and bed load impacts, and to limit exposure to benthic-oriented fish species. | The depth of screen panels relative to the river bottom will be informed primarily by studies 1 (Site Locations Lab Study) and 2 (Site Locations Numerical Study); studies 7 (Flow Profiling Field Study) and 8 (Deep Water Screens Study) also may inform the selection of the appropriate depth. | |
| 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. | Final details to be determined as part of pre-construction studies 1 (Site Locations Lab Study), 2 (Site Locations Numerical Study), 3 (Refugia Lab Study) and 4 (Refugia Field Study). | No change, although this recommendation should be discussed by the technical subteams addressing studies 10 and 11 following completion of the refugia studies. |
| 17. Dimensions of the fish screens, refugia, and other diversion components should be standardized where possible for all three 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. | This design will require detailed hydraulic analysis as described in pre-construction studies 2 (Site Locations Numerical Study), 7 (Flow Profiling Field Study), and 8 (Deep Water Screens Study). | Defer decision on baffling technique until after 3-D modeling is complete; consider incorporating flexibility in the design to accommodate improved baffling techniques in the future. |
| 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. | | No change to recommendation; consider designing in flexibility to dewater individual bays to facilitate cleaning of the screens. |

TABLE 3
**Fish Facility Technical Team (FFTT 2011) Performance Recommendations and Criteria**

| Recommendation/Criterion | Linkage to Studies | Status |
|---|---|---|
| 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. | The 11 pre-construction studies and 11 post-construction studies address this recommendation. | |

# Schedule

The preliminary schedule for the pre-construction studies is presented here, along with the anticipated sequence of studies. The schedule does not show actual calendar dates because it is not currently known when these studies would be approved and funded. Although the timing of study implementation will be influenced by several factors, the general priority and sequence of studies should remain the same.



# Preliminary Cost Estimates

In the course of developing this Work Plan, initial cost estimates were developed for planning purposes. These estimates will be updated and revised as the studies are further developed and refined. The preliminary estimates are provided in Tables 3 and 4.

TABLE 3
**Preliminary Cost Estimates for Part A, Pre-construction Studies to Inform Facility Design**

| Pre-Construction Study | Preliminary Cost Estimate | Cost Assumptions |
|---|---|---|
| 1. Site Locations Lab Study | $575,000 to $900,000 | Assumes one physical model with option to modify for two additional configurations |
| 2. Site Locations Numerical Study | $210,000 | Anticipates 2-D modeling |
| 3. Refugia Lab Study | $350,000 | Assumes construction of a physical model |
| 4. Refugia Field Study | $325,000 | Assumes study of up to three existing facilities |
| 5. Predator Habitat Locations | $815,000[a] | Assumes 2 years of study at up to three existing facilities |
| 6. Predator Reduction Methods | $125,000 | Assumes literature review only; no field work |
| 7. Flow Profiling Field Study | $295,000 | Assumes collecting velocity profiles, sediment sampling, and bathymetry. |
| 8. Deep Water Screens Study | $280,000 | Assumes CFD model of single screen bay |
| **Part A Total (Total Study Costs)** | **$2,975,000 to $3,300,000** | |

[a] Study costs may be less if current predator studies by NMFS sufficiently answer some of the key questions.

TABLE 4
**Preliminary Cost Estimates for Part B, Pre-construction First-year Pilot Studies**

| Pilot Study | Preliminary Cost Estimate[a] | Cost Assumptions |
|---|---|---|
| 9. Baseline Predator Density and Distribution | $425,000 | **Estimate reflects the cost of conducting the first-year pilot study only.** Detailed level of effort and cost for subsequent years of study will be developed as part of the pilot study. Study costs could range to as much as $520,000 per year. |
| 10. Reach-Specific Baseline Juvenile Salmon Survival Rates | $2,400,000[b] | **Estimate reflects the cost of conducting the first-year pilot study only.** Detailed level of effort and cost for subsequent years of study will be developed as part of the pilot study. Study costs could range to as much as $4,000,000 per year. |
| 11. Baseline Fish Surveys | $420,000 | **Estimate reflects the cost of conducting the first-year pilot study only.** Detailed level of effort and cost for subsequent years of study will be developed as part of the pilot study. Study costs could range to as much as $485,000 per year. |
| **Part B Total (First-year cost)** | **$3,245,000** | **Estimate reflects the cost of conducting the first-year Part B pilot studies only.** |

[a] The identified costs for the baseline biological studies are for the first-year pilot study only; studies could extend for 3 years or more.
[b] The first-year cost of this study could be reduced significantly if it can be combined with DWR's Georgiana Slough non-physical barrier study.

The preliminary cost estimates were based on initial calculations using consulting rates and the anticipated costs associated with study equipment and other expenses. The estimates of costs do not account for possible savings that might be realized by collaborating with other ongoing studies. These preliminary estimates were modified by input from agency Working Team and subteam participants based on the expert opinion of those with recent or current experience conducting similar studies. For example, the estimate for Study 1 was provided by Reclamation staff based on their recent experience constructing and testing a physical model to evaluate the fish screens at the Red Bluff facility. The scopes of the studies associated with Part A are generally better defined than those for the baseline biological studies. Accordingly, the Working Team has greater confidence that the preliminary cost estimates for the Part A studies will reasonably reflect actual costs. Because of the greater uncertainty regarding the level of effort and scope of the baseline biological studies (e.g., the number of tagged fish that will be needed for Study 10), these studies are initially structured as pilot studies intended in part to refine the scope, period of study, and costs of the overall study. The preliminary cost estimates provided in Table 4 identify the anticipated cost for conducting the first-year pilot for each baseline study. The Working Team anticipates that the baseline studies could take 3 years or more to complete. The annual costs associated with conducting these studies will be influenced by the ultimate scope of the study determined by the pilot study and the extent to which the studies can be coordinated during implementation to efficiently share staff resources and equipment, and collaborate with other ongoing studies in the area. Estimates of the maximum annual costs for conducting the baseline studies reflect the experience of agency staff working on similar studies.