Appendix B4. Intake Structural Configuration and Fish Screen Type Analysis (Final Draft)

1. Introduction and Purpose

The purpose of this technical memorandum (TM) is to identify potential intake structural configurations and fish screen types and evaluate them for suitability for application as part of the North Delta intakes for the Delta Conveyance Project (Project).

Water diversions at intakes located along the Sacramento River are planned for the Project in the North Delta region between the Towns of Freeport and Courtland. These intakes are required to employ screening systems to protect fish from being entrained in the water diverted at each location.

1.1 Organization

This TM is organized as follows:

- Introduction and Purpose
- Background
- Analysis and Evaluation
- Conclusions and Recommendations
- References

2. Background

The two recommended intake sites, C-E-3 and C-E-5, per the Concept Engineering Report (CER)Appendix B6 *Intake Site Identification and Evaluation*, are used as the setting for this analysis.

The intakes would be located at River Mile (RM) 39.4 and 36.8, along the Sacramento River. The intakes would have a maximum diversion rate of 3,000 cubic feet per second (cfs) per intake for a total Project flow capacity of 6,000 cfs, in accordance with criteria developed by the Bay Delta Conservation Plan (BDCP) Fish Facilities Technical Team (FFTT).

The fish screen systems for the proposed intakes will be subject to compliance with a variety of prescriptive requirements and other considerations needed to implement a workable and maintainable intake system in the Sacramento River environment. Prescriptive requirements are those that result from regulations, guidelines, and direction from aquatic resource agencies of the state and federal governments. Requirements for salmonid species in the Sacramento River are regulated by the National Marine Fisheries Service (NMFS), a division of the National Oceanic and Atmospheric Administration (NOAA) of the U. S. Department of Commerce. Requirements for other juvenile fish species commonly encountered in the North Delta region, including Delta smelt, are regulated by the U.S. Fish and Wildlife Service (USFWS), a division of the U.S. Department of the Interior. Both salmonids and juvenile Delta fish species are also regulated on a state-level by the California Department of Fish and Wildlife (DFW). These regulatory agencies have specific requirements and guidelines related to the type of fish screening systems and related structures that can be used to accomplish the fish protection goals.

A variety of fish screen types are used throughout the United States (U.S.) and California. The specific screen types used for any given diversion depend on the following factors:

- Species to be protected
- Specific project application
- Site conditions
- Diversion size and flow capacity
- Configuration and type of water body water will be diverted from
- In addition to the fish screen systems themselves, the intake structure that contains the fish screen system is also dependent on similar site-specific attributes.

Alternative structural configurations and fish screen types that are potentially applicable to the Project intakes are identified and evaluated in this TM.

3. Methodology

3.1 Basic Methodology

The methodology employed to determine the type of intake structural configuration and associated fish screen types to be further considered for the Project involves the following process:

1) Review potential intake structural configurations and fish screen types.
2) Consider applicable regulatory requirements and guidelines, along with site conditions, similar experience, and engineering judgement, to determine the structural configurations and fish screen types that are considered applicable and viable for the Project intakes.
3) Conduct a comparative evaluation of the alternative structural configurations and fish screen types relative to their applicability to the proposed North Delta intake sites, regulatory compliance, engineering factors, commercial availability, and operations and maintenance (O&M) issues.
4) Determine the structural configurations and fish screen types to be considered further for the Project intakes according to their relative suitability.

3.2 Assumptions

Basic assumptions that apply to identifying and evaluating intake structural configurations and fish screen types include the following:

- Intakes would be located at any of the candidate sites along the Sacramento River identified and recommended in the CER Appendix B6.
- A maximum diversion rate of 3,000 cubic feet per second (cfs) per intake was assumed in accordance with criteria developed by the Bay Delta Conservation Plan (BDCP) Fish Facilities Technical Team (FFTT) (FFTT 2011).
- The intakes will comply with the draft Anadromous Salmonid Passage Design Guidelines (NOAA 2018).
- DFW is assumed to accept the draft NOAA 2018 guidelines.
- The USFWS is assumed to require the intake fish screens be designed to protect juvenile Delta fish species and will require sizing be based on a design approach velocity of 0.2 feet per second (fps). Otherwise, the USFWS is assumed to accept the 2018 NOAA guidelines. Therefore, for concept

design purposes, the intake fish screens will be sized for juvenile Delta fish species protection using a design approach velocity of 0.2 fps.

- The impact of the intake structure(s) on flood flow water surface elevations (WSELs) will be evaluated as part of other analyses supporting the Project environmental documentation. However, it is assumed for this analysis that intake structures that encroach on the river cross section by less than 125 feet from the top of the existing levee will be in compliance with U.S. Army Corps of Engineers (USACE) requirements.

4. Analysis and Evaluation

4.1 Identification of Alternative Structural Configurations and Fish Screen Types

In accordance with the methodology described, structural configurations and fish screen types employed throughout the western U.S. were considered for application to the Project intakes. Three alternative structural configurations and three alternative types of intake fish screens were identified. Table 1 shows a matrix of the structural configurations and fish screen types, as well as their relative compatibility with each other. These alternatives are described in greater detail in the following sections.

Table 1. Intake Structural Configuration and Fish Screen Type Matrix

Fish Screen Type	Structural Configuration In-River (Parallel)	Structural Configuration In-Channel (Perpendicular)	Structural Configuration On-Bank (Parallel)
Vertical Flat Plate	Compatible	Compatible	Compatible
Inclined Flat Plate	Possible, but unusual	Possible, but unusual	Compatible
Cylindrical Tee	Possible, but unusual	Possible, but unusual	Compatible

4.2 Structural Configuration and Fish Screen Types Considered but Not Retained Further

The following structural configurations and fish screen types were considered but not carried forward as potentially feasible project alternatives.

- **Conical Screens**—This type of screen is a submerged, cone-shaped screen normally reserved for relatively small diversion rates in shallow depth profile areas. Since the Project intakes are projected to have ample depth and diversion flow rates of 3,000-cfs range per intake facility, cone screens are considered impractical due to size and would be expected to be difficult to properly maintain. Also, these screens are not considered a good choice for stringent, uniform flow performance criteria that may be imposed on the Project.
- **Horizontal Flat Plate Screens**—This type of screen is a horizontal fish screen panel placed on the bottom of the diversion channel. Diverted flow passes downward through the screen, while the remainder of the flow in the diversion channel continues downstream back to the river. This screen type normally depends on flows in the diversion channel to carry debris past the screen. These screens are hard to clean, relative to biogrowth on the screen face, and they tend to collect more bed load sediment than screens higher in the water column. Also, uniform flow through the screen is difficult to achieve. This screen type is not considered practical or applicable to the Project intakes.
- **Coanda-Effect Screens**—This type of screen is normally placed in-river and perpendicular to the river flow. It uses a flat or profile-shaped screen panel inclined down in the direction of river flow,

and normally depends on the river to flow over the upstream end and drop across its face. Water flowing over the screen washes debris and aquatic organisms downstream past the screen. Diverted water passes through the screen and is conveyed away to the downstream system. These screens are normally reserved for smaller, fast-moving water bodies and are not typically submerged in slow-moving rivers. This screen type also collects bed load sediment, and uniform flow through the screen face is difficult to achieve. This screen type is not considered practical or applicable to the Project intakes.

- **End-of-Pipe Screens**—This type of screen is a cylindrical shape on the end of a pipe and is used on small diversions to screen the flow on a diversion pipe situated in the flow stream. These screens are normally reserved for very small diversions and are not practical for the Project intakes.
- **Drum Screens**—Drum screens are a type of cylindrical screen that rotates partially submerged near the water surface in the diversion channel. Drum screens have been effective in many installations but are typically used where the water surface is controlled within a limited range. The wide variation in flow depth at the proposed Project intake locations make these screens impractical. Drum screens were eliminated from further consideration.
- **Traveling Screens**—Traveling screens are a flat plate style screen, and the screen material continually rotates up the front and down the back of the screened area. The screens are cleaned using brushes and high-pressure water jets near the top of the mechanism. Traveling screens can be configured vertically or at an incline parallel or perpendicular to river flow. While traveling screens could be engineered to function properly for the Project intakes, the variable depth and large diversion flow capacity would require extensive, large screen systems with complex mechanical features, likely with high capital costs and O&M needs. Also, full-year operation in the river with potentially high seasonal sediment content and biogrowth is expected shorten service life relative to other alternatives. These factors would lead to a prohibitively costly system to install and maintain, especially on a lifecycle basis. The additional complexity of traveling screens make them a poor choice for the Project, and they were not considered since they are impractical in the proposed project setting.

4.3 Description of Alternative Structural Configurations and Fish Screen Types

4.3.1 Alternative Structural Configurations

4.3.1.1 In-River Screen Structures

In-river screen structures are placed within the river channel and have fish screens on each side parallel to flow. Normally, vertical flat plate screens are used on the sides of in-river structures. It also appears to be possible to use inclined flat plate screens or cylindrical tee screens in a similar configuration, but it would be unusual and without precedence for the size of intakes being contemplated for the Project.

Figure 1 is a photograph of the City of Sacramento's in-river screen structure. It employs vertical flat plate screens permanently attached to a structure below the water level.

The screen structure for in-river intakes is typically placed near the deepest part of the river and is situated with suitable space on each side to facilitate river flows around both sides, providing a sweeping action to help fish move past the screens.

Conveyance conduits connecting to an in-river intake structure's floor are typically used for gravity flow to the riverbank and beyond. Alternatively, pumps inside the structure can also be used for pressure flow via conveyance conduits that run either beneath the river bed or are suspended above the river water surface on a bridge structure.

Source: Lionakis Beaumont, for CH2M HILL (now Jacobs) n.d.

Figure 1. City of Sacramento In-River Intake Structure

The in-river structural configuration is typically designed similar to a large bridge pier and has hydraulically efficient leading and trailing transition sections to provide relatively smooth flow transitions between the structure and the river. These transitions also minimize flood water surface increases and help control scour. Normally, an access bridge is provided to allow vehicular access from the riverbank to the top of the structure.

4.3.1.2 On-Bank Screen Structures

On-bank screen structures are constructed into the riverbank along the edge of the river channel and have fish screens only on the river side. They are typically placed along straight sections of the river or near the outside of moderate river bends to facilitate sweeping of fish, debris, and sediment past the structure, taking advantage of the deeper side of the river. The configuration along the bank helps the structure blend into the river cross section to minimize flood water surface increases and facilitate sweeping flows past the screens.

Figure 2 is a photograph of the Freeport Regional Water Authority's on-bank fish screen structure. It employs vertical flat plate screens that slide into place from the top of the structure using guide slots.

Source: CH2M HILL n.d.

Figure 2. Freeport Regional Water Authority On-Bank Intake Structure

Conveyance conduits extend from the back of on-bank intake structures and allow flow through the riverbank. Pumps can also be installed inside the structure for pressure flow via the conveyance conduits.

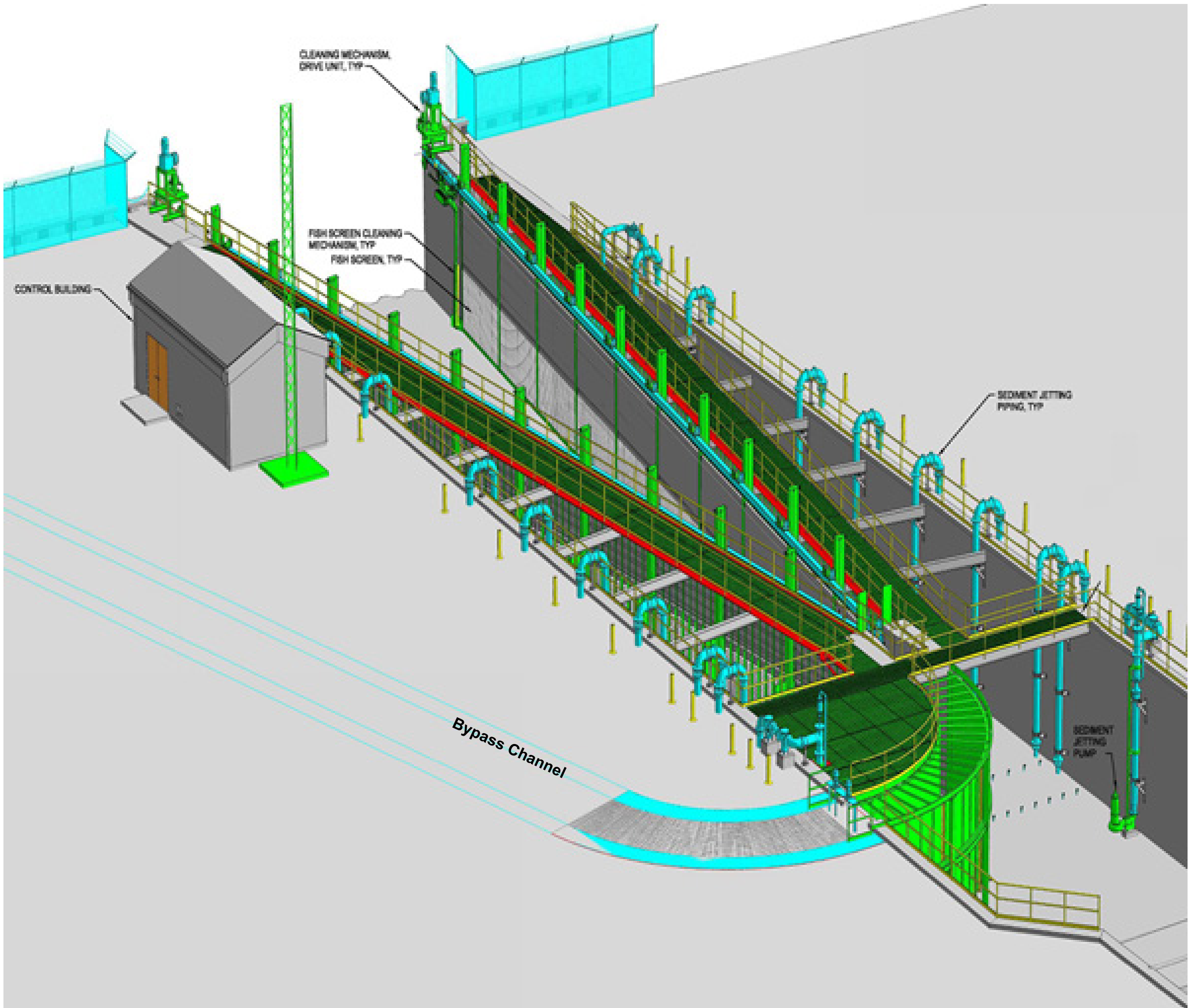
This type of structure is typically designed with curved transitions (training walls), upstream and downstream, that tie the face of the structure to the riverbank side slope. The training walls provide a smooth flow transition in the river. Fill may be placed behind the walls to allow vehicular access to the top of the structure.

4.3.1.3 In-Channel Screen Structures

In-channel screen structures are normally located within a diversion channel off of the main river. The screens are generally positioned diagonally across the channel to screen about 90-95 percent of the diverted flows. The remaining diverted flow is returned to the river in a bypass, along with the fish that were prevented from going through the screens. To minimize the width of the channel structure, screens are arranged diagonally, often with one or more V (chevron) configurations for the screen systems. Normally, vertical flat plate screens are used on in-channel structures. It is also possible to use inclined flat plate screens or cylindrical tee screens in a similar configuration; however, it would be unusual to use those screen types in the V configuration for the size of intakes being contemplated for the Project.

The in-channel screen structures are configured to capture fish after they pass the screens. Protected fish are concentrated at the apex of the V screen (or the end of the diagonal screen) and are collected at the downstream end of the screen panel line-up and returned to the river using bypass facilities (pumped or gravity flow, depending on the specific application).

Figure 3 is a three-dimensional (3D) rendering of the Arroyo Canal Fish Screen structure being implemented by the Henry Miller Reclamation District. It is a single V screen structure that employs vertical flat plate fish screens and a gravity bypass channel.



Source: CH2M HILL 2012

Figure 3. Arroyo Canal In-Channel Fish Screen Structure

The inlet side of V-shaped conveyance channels are sized to maintain adequate sweeping velocity, thereby minimizing exposure time carrying fish and suspended sediment downstream to the bypass facilities. Conveyance conduits or channels extend from the portion of the intake structure downstream of the screens to allow screened water to flow into the downstream conveyance system. Pumps can also be installed behind the screens for pressure flow into the downstream conveyance system.

This type of structure is typically used in a diversion channel where water levels are held relatively constant. Also, the structures are typically designed with transitions that tie the upstream and downstream faces of the structure to the side walls of the diversion channel. These transitions train flows into and out of the facility and can also be configured to allow vehicular access to the top of the fish screen structure.

If there is not sufficient head to drive the bypass flows through the facility, the bypass flows, and fish, must be collected and pumped back the river. That configuration further complicates the complexity of such a facility.

4.3.2 Alternative Fish Screen Types

4.3.2.1 Vertical Flat Plate Screens

Vertical flat plate screen systems have a continuous line-up of vertically placed fish screen panels submerged in the river flow profile. The screen panels are normally arranged parallel to the river flow at a depth where they are almost always submerged. The bottom of the panels are positioned above the portion of the river channel that carries most of the bedload sediment.

Figure 4 shows a portion of a 3D rendering of a typical vertical flat plate screen system.

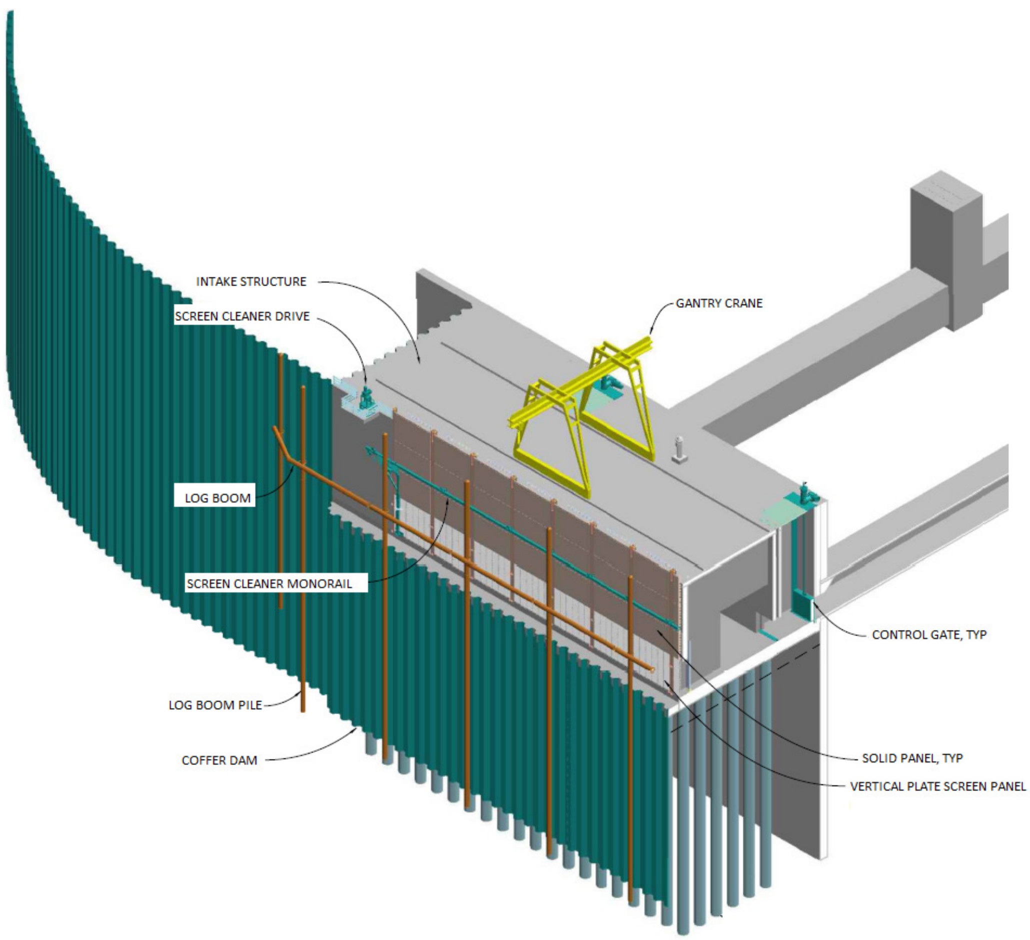


Figure 4. Typical Vertical Flat Plate Screen System

Screen panels are installed from the top of the structure using a fixed or mobile crane system. Screen panels are slid into place using guide slots along the face of the structure. Solid panels are placed above the screen panels using the guide slots. Solid panels block flow and ensure that diverted flows only move through the fish screens.

A supplemental guide slot immediately behind the forward screen and solid panel guide slot can be used to install a removable, perforated, baffle plate system behind the screen panel to help adjust the flow rate through the screen panels. This rear guide slot is also used to store solid panels when screen panels are removed for maintenance. This arrangement keeps the intake structure sealed from fish entrainment at all times.

The vertical screen panels are cleaned by a traveling brush system that moves back and forth across the face of the screen panels. The brush is driven by a cable and pulley system from a drive motor on the top deck of the structure. The brush and drive system can be seen along the left side of the screen panels on Figure 4.

4.3.2.2 Inclined Flat Plate Screens

Inclined flat plate screen systems have a continuous line-up of fish screen panels positioned in an inclined configuration and submerged in the river flow profile. The screens are normally arranged parallel to the river flow. For on-bank screen structures, the inclined configuration allows the fish screen structure to somewhat mimic the slope of the river or streambank. The inclined panel configuration also provides more screen area within the same depth of flow as compared to the vertical flat plate configuration.

Figure 5 shows an inclined flat plate screen at the Buckman Diversion on the Rio Grande River in New Mexico.

Source: CH2M HILL n.d.

Figure 5. Inclined Flat Plate Screen System at Buckman Diversion

Screen panels are normally fixed to the structure in a submerged position in the river flow profile. Some systems have been designed that allow a modified guide slot for placement and retrieval of non-fixed screen panels; however, these systems are typically for short installation settings and are not expected to be feasible at the candidate intake sites being considered for the Project.

Inclined flat plate screen systems require a permanently installed, perforated, baffle plate system behind the screen panels to adjust the flow rate through the screens. A supplemental vertical guide slot can be used to allow solid panel installation to keep the structure sealed from fish entrainment when the screen panels are removed for maintenance. However, that slot would need to be installed behind the back of the top inclined screen panel. Since it is vertical, it cannot be used to position a perforated flow baffle assembly immediately behind the screen panels. Removal and replacement of inclined flat plate screen system normally involves divers and fish rescue from inside the structure and is more difficult and complex than the process for vertical flat plate or cylindrical tee screen systems.

This type of intake structure is normally arranged in the on-bank configuration. Given the greater screen surface area for the same available depth of water, this configuration can result in a shorter diversion structure. The larger screen area can also result in screen panels that are so large they must be divided into multiple subpanels to facilitate handling and cleaning.

Inclined screens are normally cleaned using an air burst system, with air nozzles distributed beneath the screen face to allow air bursts to flow up through the screen panels and remove debris and other accumulated material by agitation. An air compressor and accumulator tank feed an air piping manifold with quick action control valves at each screen panel location. Some brush cleaned installations have been constructed but are not common.

4.3.2.3 Cylindrical Tee Screens

Cylindrical tee screen systems have a continuous line-up of cylindrical screens installed on fabricated tee-type assemblies that convey flow into the intake structure. This system results in a tee configuration with a cylindrical screen section on either side of the central tee manifold.

Figure 6 shows a 3D isometric of the typical configuration for a larger cylindrical tee screen. The screens are normally arranged in the on-bank configuration with the cylinder axis parallel to the river flow.

Screen units are installed from the top of the structure using a fixed or mobile crane system. Screen panels are slid into place using guide slots along the face of the structure. Solid panels are placed using the guide slots above the screen units to block flow and help ensure that diverted flows only move through the fish screens.

A supplemental guide slot immediately behind the front screen unit guide slot is used to hold the solid panels when the screen unit is removed for maintenance. This arrangement keeps the intake structure sealed from fish entrainment at all times.

The cylindrical shape allows more screen area with lower depth profile requirements than the vertical flat plate systems. This can result in a shorter diversion structure. Screens are cleaned either by rotating the cylindrical screens on each side of the tee manifold over an interior and exterior brush system. Alternatively, screen cleaning using an air burst system similar to the system described for the inclined flat plate screen system is often used for cylindrical tee screens. Air burst systems are not considered effective for screen sizes larger than about 5 feet in diameter due to air flow requirements through the bottom portion of the screen and the difficulty to recharge the compressed air volume to be capable of cleaning screens every 5 minutes. Screens sized to accommodate the Project diversion rate will be on the order of 8 feet in diameter; therefore, only mechanically cleaned (brush) systems are considered viable for the Project. The external brush is visible near the top of the cylindrical screens on Figure 6.

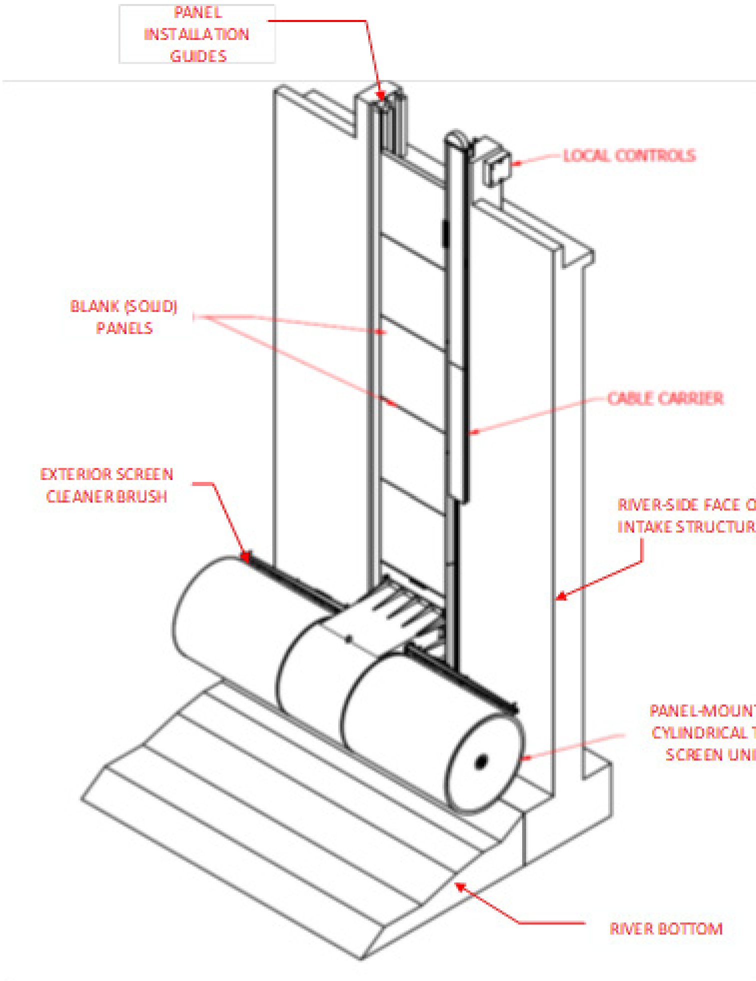


Figure 6. Cylindrical Tee Screen Isometric

4.4 Evaluation of Alternative Structural Configuration and Fish Screen Types

The three alternative structural configurations and the three alternative fish screen types were evaluated for suitability to be used as part of the Project intakes. Initially, several of the alternatives were screened from further consideration, and the remaining alternatives were then compared in additional detail.

4.4.1 Initial Screening

4.4.1.1 Alternative Structural Configurations

In-Channel Screen Structures: The in-channel structural configuration was screened from further consideration because it is incompatible with the Sacramento River site conditions at the proposed intake locations. This configuration would require a lateral diversion channel and would cause migrating fish to enter the channel and need to be captured in a bypass system. The 2018 NOAA guidelines require screens to be constructed at the point of diversion with the screen face parallel to flow, unless it is physically impractical or biologically undesirable. Since the required configuration is physically practical and biologically desirable in the on-bank configuration, the in-channel configuration is not considered a feasible choice for the Project and was eliminated as an alternative. If a Project alternative is developed in the future that requires a lateral diversion channel with limitations on a screen at the point of diversion, this structural configuration can be reconsidered.

In-River Screen Structures: The in-river structural configuration was screened from further consideration because of the following reasons:

- It requires large conveyance conduits to be tunneled beneath the USACE-regulated levees located at all of the intake sites. These tunnels or conduits would be connected to the bottom of the intake structure to provide the conveyance flow path for the diverted water. Diverted flow with sediment would be conveyed to the landside of the levees for sediment collection. This would require that the tunnels or conduits be relatively shallow and small enough to maintain a velocity to keep the sediment in suspension. This configuration is expected to be regulatorily complex given the work in the river and beneath the flood control levees. Also, due to the expected configuration of the conduits or tunnels, the risk of sediment buildup in the conveyance conduits is considered high, especially when diversion flow rates are low.
- Industry experience shows it is more difficult to obtain uniform flow through the screens on in-river structures due to flow irregularities caused by the leading edge of the structure in the river flow path and by the configuration of the connecting conduits inside the structure. This difficulty is compounded by the higher velocity need to keep sediment in suspension in the conduits. Achieving flow uniformity is expected to require the structure be lengthened to mitigate the river flow irregularities and widened and fitted with complex baffling and flow control features to mitigate the effect of the connecting conveyance conduits.
- The structure requires an extensive bridge access system that is likely 200 feet or more in length. The position of the structure in the deepest part of the river with adequate width on each side to encourage sweeping flows will place the structure well out in the river section. The structure itself and access bridge is expected to be costly and cause more visual impacts in the Delta setting than the on-bank alternative.
- The width and position of the structure in the river are expected to result in an unacceptable rise in USACE-regulated flood water surfaces. While definitive river flow modeling results are not available to specifically define the expected rise, modeling for similar structures has demonstrated a higher impact on flood flow levels and an increase in velocity along the river bank from this type of structure (DHCCP, 2010). Also, the cofferdam required for construction would be wider than the finished structure and may be in place for several years. That cofferdam would be expected to have an even greater negative impact on flood levels.

4.4.1.2 Alternative Fish Screen Types

Inclined Flat Plate Screens. The inclined flat plate screen system is not considered a feasible alternative because it is impractical to manage and maintain the screen system from the surface of the intake facility, it is difficult to achieve uniform flow through the screens, and the only practical cleaning system is manual brushing by divers or air burst systems. The 2018 NOAA guidelines require screen cleaning systems to be capable of cleaning the screen’s face every 5 minutes. Therefore, an intake facility cannot practically rely on a team of divers to be present in the water during all diversion periods. An air burst system capable of cleaning the expected number of panels for the Project intakes would require many compressed air and accumulator systems. The total number has not been defined but is expected that an unreasonable amount of equipment would be required to be capable of bursting each panel every 5 minutes.

Further, the 2018 NOAA guidelines also require screen cleaning systems to actively move debris away from the screen face. Air bust systems will blow debris away from the screens, but it is not considered feasible to sequence the air bursts within the 5-minute cleaning time frame to sequentially move all debris downstream past all the screen panels on an intake of the size contemplated for the Project. Therefore, debris blown off one screen panel can be expected to settle on an adjacent panel for some portions of the facility.

Industry experience has also shown that air burst systems cannot effectively remove biogrowth on the screen's wedge wire surfaces (NOAA 2018). Only brushing or high-pressure water jets have proven effective for this aspect of screen cleaning. Therefore, air burst screens can be expected to develop more hotspots where the approach velocity can vary considerably from the required value. This can lead to noncompliance relative to regulatory performance requirements.

To date, there are only a handful of known brush screen cleaning systems used on smaller diversion inclined plate screens. The applicability of these cleaning systems scaled for a project of this magnitude would be unprecedented and very risky.

4.4.2 Comparison of Formal Alternative Fish Screen and Structure Types

After initial screening, the on-bank screen structure and two alternative fish screen types: vertical flat plate and cylindrical tee screens, are still being considered. Combining the structural configuration with the screen types results in two combined structural configuration and fish screen type alternatives, as follows:

1) **On-bank intake structure with vertical flat plate screens:** This system would include a long, concrete structure with a line-up of vertical flat plate screen panels. Each panel would be approximately 15 feet wide and about 12 to 20 feet tall, depending on the overall intake capacity and river depth. Screen panels would be separated by a 2-foot-wide blank area flush with the screen face that consists of a structural column and the screen panel guide slots. Screen panels would be grouped into five to six screen sections, with a total flow capacity between 450 to 500 cfs, depending on the overall intake capacity. Each section would include flow control features to limit the diversion rate for that section. Each section would also include a landing area for the screen cleaning mechanism. Overall, the vertical flat plate screens would result in concrete structures from about 900 feet to about 1,600 feet in length, depending on the river depth and total flow capacity.
2) **On-bank intake structure with cylindrical tee screens:** This system would include a long, concrete structure with a line-up of cylindrical tee screen units. Each unit would enable diversions of up to approximately 100 cfs at 8 feet in diameter and about 30 feet long. Screen units would be separated by a 1-foot clear space between the end of each unit. Each screen unit would be connected to a dedicated conveyance conduit with a flow meter and flow control and isolation valves. These flow control features would limit the diversion rate for that unit. Overall, the cylindrical tee screens would result in concrete structures from about 700 feet to about 960 feet in length, depending on total flow capacity and final configuration.

Both screen systems have shown good performance at multiple locations in the western U.S. The largest existing intake structures on the Sacramento River use vertical flat plate screen systems sized for flows up to 3,000 cfs using the salmonid approach velocity design criteria (NOAA 2018). Given the higher allowable approach velocity, these larger existing diversions are not as large (i.e. in total facility length) as those contemplated for this Project. The Freeport Regional Water Authority fish screens are sized for the Delta smelt approach velocity and perform well. However, the maximum capacity for that facility is only about 325 cfs. Cylindrical tee screens have been used successfully in systems up to about 1,400-cfs capacity under the salmonid design criteria. Table 2 provides a characteristics comparison of the two alternatives.

Table 2. Comparison of Vertical Flat Plate and Cylindrical Tee Screens Characteristics in an On-Bank Structural Configuration

Comparison Factor	Vertical Flat Plate Screens	Cylindrical Tee Screens
Screen Cleaning	• Counterweighted brush moves both directions on wire rope and pulley system. The horizontal travel portion of the pulley system is set above the top of the screen panels. In higher river flows, the wire rope and its supports may operate in a submerged condition. • Effective cleaning if properly maintained and adjusted. • High maintenance requirements; frequent adjustments needed. • "Striping" is common; this is bands on the screen face that are not fully cleaned. • Biofouling, especially on the downstream side of the screen panels will require more O&M. • Subject to debris collection and damage.	• Cylinders rotate forward and backward on interior and exterior brushes. • Superior cleaning as long as brushes are maintained in good condition. Fewer hot spots. • Better biofouling performance, and less O&M effort. • Minor debris collection potential on external brushes.
Fish Protection	• Flat structure surface, and little opportunity for predator holding. • Requires longer structures; therefore, longer juvenile fish exposure – possibly too long for Delta smelt. • Opportunities for refugia limited to brush cleaner "parking areas" and pier areas, unless adding additional structure length.	• Space between screen cylinder units (about 1 foot) is a potential predator holding area. Some mitigation may be possible. • Area on downstream side of tee connection to structure is a potential predator holding area. • Substantially shorter structure and related exposure time than vertical flat plate system. • High refugia opportunity along structure face, but minimal along screens.
Flow Control	• Adjustable baffle plates help provide uniform approach velocity through each screen panel. • Flow control in approximately 450- to 500-cfs sections, with large control gates and flow meters in box conduit extending behind structure to sediment basins. • Uniform flow performance dependent on adjustable baffles; can vary with river depth, tidal conditions, and diversion rate. • Accurate flow control highly dependent on downstream sedimentation basin level control to facilitate fine flow control at screens and intake structure sections using baffles and large gates.	• Flow control for individual screen units better than individual vertical flat plate screen panels. • More difficult to use adjustable baffles for individual units, but screen uniformity easier to laboratory test and adjust. • Very accurate flow control for each 100-cfs screen unit using in-line flow control and flow meter; results in very accurate total intake facility flow control. • Only minor dependency on downstream sedimentation basin level control because of in-line control valve and meter.

Comparison Factor	Vertical Flat Plate Screens	Cylindrical Tee Screens
O&M	• Screen removal frequency relatively high (approximately every 3 months). • Screen removal relatively simple. • Screen cleaner more complex. • Fewer motors, and none submerged. • Sediment jetting system required to resuspend settled sediment for transport from wet pit intake structure behind screens into the sediment basins.	• Screen removal frequency less (approximately 6 months). • Screen removal is similar to vertical plate screen panels, but involves substantially more weight; therefore, larger crane or hoist equipment is needed. • More motors, all submerged but accessible when screen unit raised; generally low-maintenance motors. • Possibly more debris collection. • Industry experience shows that cylindrical screen systems require less routine maintenance than vertical flat plate systems. • No sediment jetting system required because intake structure is dry pit.
Other Factors	• Requires wet pit structure to distribute screened flow to sediment basins. • Best screen material is manufactured by one firm in Kentucky. • Known regulatory acceptance for proposed large intakes. • Screen panel can be repositioned to a higher setting in the future, but screen cleaner mechanism would also need to be relocated. • Expected to result in higher cost intake facilities.	• Screens directly piped to sediment basins; no wet pit structure required. • Currently, single local supplier (located in Freeport, CA) may limit competition and may not have capacity, depending on schedule. • Regulatory acceptance is good for other installations, but unknown for proposed large intakes. • Screen unit can be easily repositioned to a higher setting in the future with minimal modifications. • Expected to result in lower cost intake facilities.

5. Conclusions and Recommendations

5.1 Alternative Structural Configuration and Fish Screen Types

Intake structural configurations and fish screen types typically used in the western U.S. were reviewed and considered for applicability and suitability for use on the Project. Three alternative structural configurations and three alternative types of intake fish screen systems were identified, as described in Table 1.

After initial screening, an on-bank intake structure was determined to be the preferred structural configuration for the Project intakes. Two fish screen systems were determined to be viable alternatives: vertical flat plate and cylindrical tee screens. Each fish screen alternative has various advantages and disadvantages relative to their specific characteristics. Review of both alternatives were discussed with regulators and cylindrical tee screens were selected.

6. References

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Photo references include the following:

- Lionakis Beaumont for CH2M HILL n.d. City of Sacramento project construction photo
- CH2M HILL. n.d. Buckman Diversion project construction photo.
- CH2M HILL. n.d. Freeport Regional Water Authority project construction photo.
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