Subject:	**Intakes Screen Sizing – North Delta Intakes (Final Draft)**
Project feature:	Intakes
Prepared for:	California Department of Water Resources (DWR) / Delta Conveyance Office (DCO)
Prepared by:	Delta Conveyance Design and Construction Authority (DCA)
Copies to:	File
Date/Version:	December 23, 2021
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1. Purpose

The purpose of this technical memorandum (TM) is to document the methodology used for the conceptual sizing of two intake screen type alternatives at the three potential intake locations shown on Figure 1 (attached at end). Intake sizing for configurations using vertical flat plate and cylindrical tee screen systems are described. The results from this TM could be used to size an overall conceptual site footprint for each intake site using each screen alternative.

1.1 Organization

This TM includes the following sections:

- Background
- Summary of Results
- Methodology
- Analysis and Evaluation
- Conclusions
- References
- Document History and Quality Assurance

2. Background

The Delta Conveyance System Project (Project) would use intake structures at up to three sites located on the Sacramento River, each capable of conveying up to 3,000 cubic feet per second (cfs). Diversion rates of 1,500 and 3,000 cfs were considered to allow intake diversion combinations for total Project diversion flows of 3,000, 4,500, 6,000, and 7,500 cfs.

Potential intake sites were identified by the DCA (2021b) and are shown on Figure 1 (attached at end). Some combination of two or three of these intakes would be used to accomplish the overall Project diversion rate.

A large-diameter tunnel would convey flows from the intake structures to a terminal balancing forebay approximately 40 miles downstream, prior to being delivered into the California Aqueduct and possibly the Delta Mendota Canal.

The primary functions of the intakes would be to:

- Provide facilities to accomplish diversions from the Sacramento River
- Provide features for the protection of fish and other aquatic resources
- Manage sediment for the benefit of downstream features
- Provide flow control to meet Project and regulatory requirements

2.1 Fish Protection

Fish protection is provided, in part, using fish screens to prevent fish from being entrained at the intake structure in the diverted water and allow them to safely move past the facility while swimming in the source water body.

Fish screens for the Project would comply with criteria and guidelines issued by the National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS) for salmonids (NOAA 1997, 2018), the California Department of Fish and Wildlife (DFW; formerly Department of Fish and Game, DFG) (DFG, 2010), and the U.S. Fish and Wildlife Service (USFWS). CDFW requirements are applicable to both salmonids and juvenile Delta fish species. USFWS requirements are applicable to juvenile Delta fish species and are typically promulgated via biological opinions versus a published set of criteria. Generally, NMFS requirements acceptable to CDFW and the USFWS, provided the approach velocity is limited for juvenile Delta fish species, as described in this TM.

For salmonids and juvenile Delta fish species at the locations of the proposed intakes, these agencies require fish screens with 1.75-millimeter (mm) (0.069-inch) or smaller openings and with at least a 27 percent open area.

The Project fish screens would be designed to protect juvenile Delta fish species (typically characterized as delta smelt) and salmonids occurring in the river. The determination of providing more stringent protection for Delta smelt versus salmonids depends on the location of the intakes along the river and other environmental considerations developed on a case-by-case basis with resource regulatory agencies.

Regulatory screen sizing criteria limit the maximum approach velocity, as follows:

- Delta smelt protection criteria: 0.2 foot per second (fps) per USFWS requirements as adopted by CDFW.
- Salmonid protection criteria: 0.33 fps per NMFS and CDFW requirements for riverine, lake, and tidal installations (subject to Agency review).

Approach velocity (V_A) is defined as the velocity component of the flow being diverted that is perpendicular to the fish screen face, as close to o the boundary layer of turbulence generated by the screen face as is physically possible (NOAA, 2018), which is typically 3 inches in front of the screen (USBR, 2009). It is determined for design by dividing the diversion flow rate (Q) by the effective wetted screen area (A_s), or:

$$V_A = Q / A_s \qquad \text{(Eq. 1)}$$

The actual area of the fish screen panels must be slightly larger than the computed value to facilitate real-time operational compliance with the limiting approach velocity at the design diversion flow rate.

To meet approach velocity design and performance criteria, the proposed intake facility will incorporate a number of design measures including: 1) configuring the intake facility in the river to hydraulically distribute the intake flows evenly across the screen surface; 2) providing a screen velocity baffling system behind each screen surface to further evenly distribute the intake flows; and 3) providing an additional screen area allowance factor (F_A) of 5 to 10 percent to lower the overall screen approach velocity due to expected velocity anomalies. During design, physical and/or computational river and intake modeling will be performed to determine the optimal layout and sizing to demonstrate compliance. Post-project field operational testing will also be performed to make any adjustments of the baffling system as necessary. The additional screen allowance factor for each of the proposed intake types was set between these values at this stage in the design. For the vertical flat plate facility design, an F_A of 10 percent was selected to account the larger proportion of screen panel structural members that could influence the flow distribution during operation. A lower F_A of 5-7 percent is warranted for the proposed tee screen facility design due to less screen panel structural member interference, potentially better velocity control due to the smaller individual screen units (100 cfs units verses 500 cfs screen bays), and good velocity performance on similar projects. Specifically, an F_A of 6.75 percent was used for this analysis to maintain 100 cfs for each screen unit using the nominal sizing information presented below. During final design, the length of the vertical plate screens, or the length and diameter of the tee screens, can be slightly modified if a different F_A is selected. Such modification would not be expected to result in significant changes to the overall sizes of the intake systems described in this TM.

Field measurements may be required to verify hydraulic performance during commissioning and/or during post project operations. Screen baffles may be adjusted, if necessary, during these evaluations for compliance purposes.

Because the screens would be designed and constructed to protect the most limiting fish species under consideration, an approach velocity of 0.2 fps was used for this sizing analysis.

For example, a vertical plate fish screen designed for delta smelt protection with a 3,000-cfs diversion flow rate and 10 percent additional area would need to have an effective wetted fish screen panel area of about 16,500 square feet (ft^2) as follows:

$$F_A \times [Q / V_A] = A_s \quad \text{(Eq. 2)}$$

Or, for example:

$$1.1 * [3{,}000 \text{ cfs} / 0.2 \text{ fps}] = 16{,}500 \text{ ft}^2$$

2.2 Intake Structure and Screen Types

Intake sizing was developed for on-bank intake configurations using both cylindrical tee and vertical flat plate fish screen systems in accordance with the intake structure and fish screen types recommended for further consideration (DCA 2021c).

2.3 Controlling Elevations

Water surface elevations (WSELs) pertinent to intake sizing were based on the low design WSELs from DCA (2021a). Similarly, compatible intake depths were determined using the river bottom information from two primary bathymetric evaluations of the river bottom topography in the vicinity of the intake sites (Wood Rogers, Inc. 2010; DWR 2019).

3. Summary of Results

Tables 1 and 2 show the results of the analysis undertaken using the design WSELs, the river bottom elevation, and sill elevation determined for each of the intake locations. For vertical plate screen systems, sizing is shown for maximum screen heights of 20 and 17.5 feet. However, where the effective intake depths are less than 17.5 feet, the actual depths were used to determine the overall intake length. Intake lengths are shown for 1,500, and 3,000-cfs diversion flows at each intake location.

Table 1. Vertical Flat Plate Screen Intake Structure Sizing Results

Intake Site	Design WSEL (ft)	River Bottom EL (ft)	Sill EL (ft)	Effective Screen Height (ft)	Overall Structure Length (ft)[a, b]	
					1,500 (cfs)	3,000 (cfs)
17.5-foot Maximum Screen Height						
C-E-2	3.80	-13	-10	13.38	1,319	1,581
C-E-3	3.72	-25	-17	17.50	1,064	1,275
C-E-5	3.61	-17	-13.5	16.69	1,149	1,377
20 Foot Maximum Screen Height						
C-E-2	3.80	-13	-10	13.38	1,319	1,581
C-E-3	3.72	-25	-17	20.00	979	1,173
C-E-5	3.61	-17	-13.5	16.69	1,149	1,377

[a] Intake length includes screens, columns, screen cleaner landings and other non-screen structural components described in Step 5 of the Methodology section.

[b] Overall structure lengths do not include training walls. Training wall lengths should be estimated as part of upcoming preliminary layout efforts.

Notes:

EL = elevation

ft = foot (feet)

Table 2. Cylindrical Tee Screen Intake Structure Sizing Results

Intake Site	Design WSEL (ft)	River Bottom EL (ft)	Tee Screen Bottom EL (ft)	Overall Structure Length (ft)[a,b]	
				1,500 (cfs)	3,000 (cfs)
C-E-2	3.80	-13	-9.5	469	964
C-E-3	3.72	-25	-13	469	964
C-E-5	3.61	-17	-13	469	964

[a] Intake length includes screens, columns, screen cleaner landings and other non-screen structural components described in Step 5 of the Methodology section.

[b] Overall structure lengths do not include training walls. Training wall lengths should be estimated as part of upcoming preliminary layout efforts

Notes:

EL = elevation

ft = foot (feet)

4. Methodology

The vertical flat plate and cylindrical tee fish screen size and associated length of the intake structure were calculated for the intake sites using two flow diversion scenarios: 1,500, and 3,000 cfs.

Calculations for each were performed using the steps described in this section.

4.1 Step 1: Determine Water Surface Elevation

The 99-percentile low WSEL to be used as the planning phase WSEL at each intake location was determined by DCA (2021a).

4.2 Step 2: Determine River Bottom Elevation

Using instream bathymetry (DWR, 2019), cross sectional surface profiles were plotted at each intake location (Figure 2 shows an example) to determine the river bottom elevations to be used for sizing. The 99-percentile low WSELs were depicted on the cross sections. Cross sections were evaluated, and a candidate river bottom elevation was determined.

4.3 Step 3: Size Screen Panels

Screen panel sizes were determined for each intake site as described in this section.

4.3.1 Vertical Flat Plate Screens

4.3.1.1 Screen Height

Vertical flat plate screen heights were determined based on the effective flow depth available in the Sacramento River at each site. This depth was determined on a site-specific basis for each intake site using the design WSEL as the upper limit and a level between 3 and 5 feet above the river bottom elevation as the lower limit. The river bottom is defined as the bottom of the river bank slope at the intake location. In some cases where the river geometry is not uniform, it is selected by inspection. The upper limit was defined to be the same as the top of the effective screen area for each screen panel. The lower limit was defined as the screen panel sill elevation. The bottom of the effective portion of the fish screen panel is slightly above the sill elevation due to the screen panel structural framing thickness (assumed to be 5 inches).

If the available depth resulted in an effective screen height of 17.5 feet or less, the calculated height was used as the effective screen height. For depths that resulted in effective screen heights of more than 17.5 or 20 feet, the effective screen height was limited to 17.5 feet for one case and 20 feet for second case.

4.3.1.2 Screen Width

The effective width of the vertical flat plate screens was assumed to be equal to a 15-foot clear opening between structural columns along the face of the intake structures. Therefore, the effective width is the same regardless of the intake site location or the corresponding screen heights. The actual screen widths are slightly longer due to side frames (assumed to be 5 inches) on both sides.

4.3.2 Cylindrical Tee Screens

4.3.2.1 Screen Diameter

Screen diameter was coordinated with a local cylindrical screen manufacturer with extensive experience in fabricating cylindrical screens in the capacity range being considered. Given the magnitude of the diversion flow rates, the largest practical screen diameter for planning purposed was selected at 8 feet.

4.3.2.2 Screen Length

The length of an individual cylindrical screen unit was also determined in consultation with the same screen manufacturer. Overall screen length was limited to 29.33 feet, maximum.

4.4 Step 4: Determine Individual Screen Panel Flow Capacity and Number of Panels

4.4.1 Vertical Flat Plate Screens

The approach velocity was applied to the effective screen area determined using the height and width from Step 3 to determine the flow capacity of an individual screen panel. This flow capacity was then reduced by 10 percent for overall facility sizing as described above.

The number of screen panels was established per flow control section as the quantity required to achieve a total flow capacity of 500 cfs. The total number of screen panels was determined by multiplying by the number of flow control sections, as follows:

- 1,500 cfs: three 500-cfs sections
- 3,000 cfs: six 500-cfs sections

4.4.2 Cylindrical Tee Screens

Using the fabrication dimensions described and in consultation with the cylindrical tee screen manufacturer, the flow capacity of an individual screen unit was determined. This flow capacity was then reduced by 6.75 percent for overall facility sizing as described above. The resulting screen unit capacity is 100 cfs.

The number of cylindrical screen units was then established by dividing the overall diversion flow rate by 100 cfs.

4.5 Step 5: Determine the Overall Intake Structure Length

4.5.1 Vertical Flat Plate Screens

Using the number of flow control sections and number of screens per section, the overall screen length was determined. The following assumptions were used:

- Each screen panel is separated by a 2-foot-wide structural column, except at the ends of each flow control section.
- A 26-foot-wide section is required upstream of each flow control section for the screen cleaner mechanism.

- The intake structure end walls are 3 feet thick, and the sheet pile cofferdam is 5 feet from the outside of the structure walls.

4.5.2 Cylindrical Tee Screens

Using the number of screen units, the overall screen length was determined. The following assumptions were used:

- The space between cylindrical tee screen units is 1 foot.
- Each tee screen is piped to a 60-inch-diameter gate, piping, and flowmeter assembly housed in a dry-pit structure behind the intake structure face.
- A 20-foot-wide laydown area is required at each end of the structure, beyond the last tee screen assembly to facilitate installation and removal of piping from inside of the structure.
- The intake structure end walls are 3 feet thick, and the sheet pile cofferdam is 5 feet from the outside of the structure walls.

4.6 Assumptions

The following assumptions were used to support the sizing analyses:

- An on-bank intake structure configuration with either a vertical flat plate or cylindrical tee fish screen system would be used for the intakes.
- Controlling elevations would be as described in the Background section.
- Screen sizing assumes the juvenile Delta fish species (Delta smelt) approach velocity criteria (V_A = 0.2 fps) would be required to size the intakes.
- Maximum effective screen height should be limited to either 17.5 or 20 feet, but this dimension would be verified during design.
- Dimensional assumptions are indicated in Step 5 of the Methodology section.
- The same individual screen sizing information was used for all diversion flow rates.
- Overall structure lengths do not include training walls. Training wall lengths should be estimated as part of conceptual layout efforts.

5. Analysis and Evaluation

Tables 3 through 5 show computational data and results of applying the sizing methodology to each intake site for a total diversion capacity of 1,500 and 3,000 cfs at each intake.

Table 3. Computational Data and Results for Intake Site C-E-2

Item	Value		
Design WSEL (ft)	3.8		
River Bottom (ft)	-13		
Screen Sill Elevation (ft)	-10		
Effective River and Flow Depth (ft)	13.38		
Approach Velocity (fps)	0.2		
	Screen Type		
	Cylindrical Tee Screen	**20-ft Vertical Plate**	**17.5-ft Vertical Plate**
Effective Height and Diameter (ft)	8	13.38	13.38
Effective Width (ft)	29.33	15	15
Effective Screen Area (ft^2)	536.17	200.75	200.75
Flow (with allowance factor) cfs	100.0	36.1	36.1
Intake length (ft) at 1,500 cfs[a]	469	795	795
Intake length (ft) at 3,000 cfs[a]	964	1,581	1,581

[a] Intake length includes screens, columns, screen cleaner landings and other non-screen structural components described in Step 5 of the Methodology section.

Table 4. Computational Data and Results for Intake Site C-E-3

Item	Value		
Design WSEL (ft)	3.72		
River Bottom (ft)	-25		
Screen Sill Elevation (ft)	-17		
Effective River and Flow Depth (ft)	20.72		
Approach Velocity (fps)	0.2		
	Screen Type		
	Cylindrical Tee Screen	**20-ft Vertical Plate**	**17.5-ft Vertical Plate**
Effective Height and Diameter (ft)	8	20	17.5
Effective Width (ft)	29.33	15	15
Effective Screen Area (ft^2)	536.17	300	262.5
Flow (with allowance factor) cfs	100.0	54	47.3
Intake length (ft) at 1,500 cfs [a]	469	591	642
Intake length (ft) at 3,000 cfs [a]	964	1,173	1,275

[a] Intake length includes screens, columns, screen cleaner landings and other non-screen structural components described in Step 5 of the Methodology section.

Table 5. Computational Data and Results for Intake Site C-E-5

Item	Value		
Design WSEL (ft)	3.61		
River Bottom (ft)	-17		
Screen Sill Elevation (ft)	-13.5		
Effective River and Flow Depth (ft)	17.11		
Approach Velocity (fps)	0.2		
	Screen Type		
	Cylindrical Tee Screen	**20-ft Vertical Plate**	**17.5-ft Vertical Plate**
Effective Height and Diameter (ft)	8	16.69	16.69
Effective Width (ft)	29.33	15	15
Effective Screen Area (ft^2)	536.17	250.40	250.40
Flow (with allowance factor) cfs	100.0	45.1	45.1
Intake length (ft) at 1,500 cfs [a]	469	693	693
Intake length (ft) at 3,000 cfs [a]	964	1,377	1,377

[a] Intake length includes screens, columns, screen cleaner landings and other non-screen structural components described in Step 5 of the Methodology section.

Figures 3 and 4 (attached at end) show preliminary conceptual layouts of the on-bank vertical flat plate screen and cylindrical tee screen structures, respectively, including the resulting sizing information for a 3,00 cfs capacity intake.

6. Conclusions

Intake structure sizes were estimated for on-bank intake structures using both vertical flat plate and cylindrical tee screen systems. The resulting overall lengths could be used to site intake structures and layout facilities at the intake sites.

7. References

California Department of Fish and Game (DFG). 2010. “Appendix S, Fish Screen Criteria.” June 19, 2000 version. *California Salmonid Stream Habitat Restoration Manual*. 4th Ed. State of California, The Resources Agency, Wildlife and Fisheries Division.

California Department of Water Resources (DWR). 2019. *Bathymetric survey on the Sacramento River from the confluence with the American River to Courtland*. North Central Region Office, Bathymetry Data Collection Section.

Delta Conveyance Design and Construction Authority (DCA). 2021a. Technical Memorandum River Hydrologic Criteria for Intake Sizing. Final Draft.

Delta Conveyance Design and Construction Authority (DCA). 2021b. Technical Memorandum Intake Site Identification and Evaluation. Final Draft.

Delta Conveyance Design and Construction Authority (DCA). 2021c. Technical Memorandum Intake Structural Configuration and Fish Screen Type Analysis. Final Draft.

National Oceanic and Atmospheric Administration (NOAA). 1997. *Fish Screening Criteria for Anadromous Salmonids*. National Marine Fisheries Service Southwest Region.

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United States Department of the Interior, Bureau of Reclamation (USBR). 2009. Guidelines for Performing Hydraulic Field Evaluations at Fish Screening Facilities. Water Resources Technical Publication. April.

Wood Rogers, Inc. 2010. *Survey of Lower Sacramento River in Support of Hydraulic Model Development Utilizing Multi-Beam Bathymetric and LiDAR Methods*. Submittal of Fugro West, Inc. – Summary Report. State of California, Department of Water Resources, Contract Number 4600007989, Task Order No. 22.

8. Document History and Quality Assurance

Reviewers listed have completed an internal quality review check and approval process for deliverable documents that is consistent with procedures and directives identified by the Engineering Design Manager (EDM) and the DCA.

Approval Names and Roles			
Prepared by	**Internal Quality Control review by**	**Consistency review by**	**Approved for submission by**
Mark Draper / EDM Project Engineer	Phil Ryan / EDM Intakes Lead and Design Manager	Gwen Buchholz / DCA Environmental Consultant	Terry Krause / EDM Project Manager

This interim document is considered preliminary and was prepared under the responsible charge of Philip K. Ryan, California Professional Engineering License C41087.

Note to Reader

This is an early foundational technical document. Contents therefore reflect the timeframe associated with submission of the initial and final drafts. Only minor editorial and document date revisions have been made to the current Conformed Final Draft for Administrative Draft Engineering Project Report version.

Figures

DCA DELTA CONVEYANCE DESIGN & CONSTRUCTION AUTHORITY

N

0 1.25 Miles

Figure 1.
Potential Intake Sites for Central and Eastern Corridors

Data Source: DCA

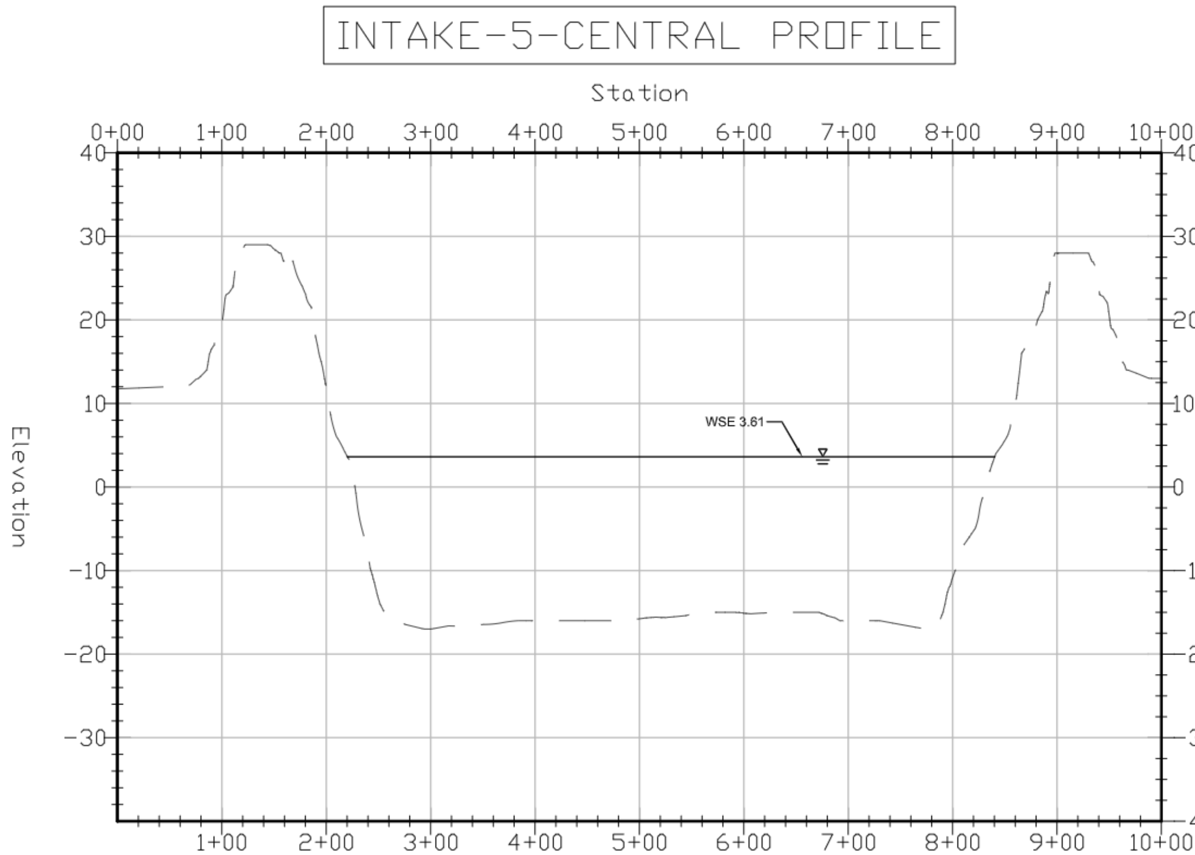


Figure 2. River Cross Section Example, Intake Site C-E-5

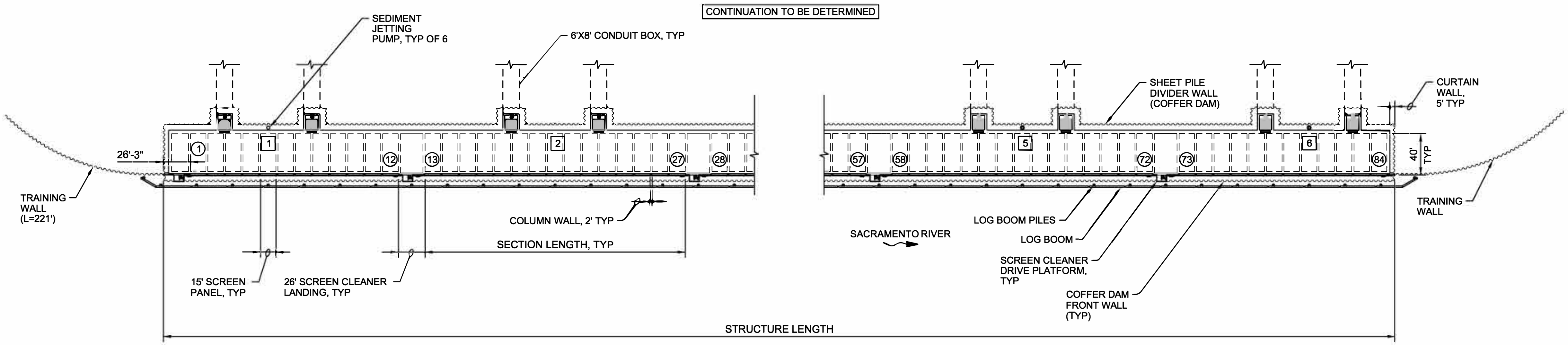
LEGEND

[#] INTAKE SECTION NO.

(#) SCREEN BAY NO.

SITE	DESIGN WSE (FT)	RIVER BOTTOM (FT)	SILL EL (FT)	SCREEN HEIGHT (FT)	STRUCTURE LENGTH (FT) 3000 (CFS)
C-E-2	3.80	-13	-10	13.4	1581
C-E-3	3.72	-25	-17	17.5	1275
C-E-5	3.61	-17	-13.5	16.7	1377

SITE	DESIGN WSE (FT)	RIVER BOTTOM (FT)	SILL EL (FT)	SCREEN HEIGHT (FT)	STRUCTURE LENGTH (FT) 3000 (CFS)
C-E-2	3.80	-13	-10	13.4	1581
C-E-3	3.72	-25	-17	20	1173
C-E-5	3.61	-17	-13.5	16.7	1377



TYPICAL VERTICAL SCREEN INTAKE STRUCTURE

1 PLAN
1"=60'
STO6-SM-1015IT

VERIFY SCALE
BAR IS ONE INCH ON ORIGINAL DRAWING.
0 1"

REV	DATE	DESCRIPTION	SUB.	APPD

DESIGNED: P RYAN
DRAWN: J SMITH
CHECKED:
APPROVAL RECOMMENDED:
APPROVAL BY:

DCA
DELTA CONVEYANCE DESIGN & CONSTRUCTION AUTHORITY

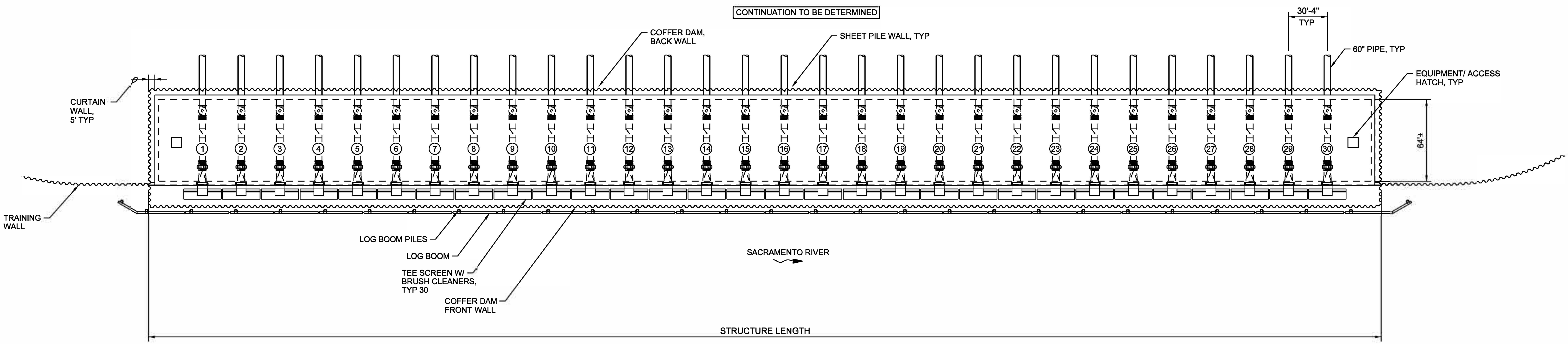
INTAKE STRUCTURE TYPICAL PLAN

PROJECT NO. W8X97000
SHEET NO. FIGURE 3
REV
SEQUENCE NO.

LEGEND

(#) SCREEN BAY NO.

SITE	DESIGN WSE (FT)	RIVER BOTTOM (FT)	TEE SCREEN BOTTOM (FT)	STRUCTURE LENGTH (FT) 3000 (CFS)
C-E-2	3.80	-13	-9.5	964
C-E-3	3.72	-25	-13	964
C-E-5	3.61	-17	-13	964



TYPICAL TEE SCREEN INTAKE STRUCTURE

2 PLAN
1"=40'
STO6-SM-1015IT

VERIFY SCALE
BAR IS ONE INCH ON ORIGINAL DRAWING.
0 1"

REV	DATE	DESCRIPTION	SUB.	APPD

DESIGNED: P RYAN
DRAWN: J SMITH
CHECKED:
APPROVAL RECOMMENDED:
APPROVAL BY:

DCA
DELTA CONVEYANCE DESIGN & CONSTRUCTION AUTHORITY

INTAKE STRUCTURE
TYPICAL PLAN

PROJECT NO. W8X97000
SHEET NO. FIGURE 4
REV
SEQUENCE NO.