Conceptual Fish Passage Designs & Cost Estimates for

Lower Alameda Creek

Prepared for

**Alameda County Water District,
Alameda County Flood Control &
Water Conservation District**

Prepared by

CH2MHILL

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Lower Alameda Creek Fish Passage - Conceptual Designs and Cost Estimates

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The Alameda County Flood Control and Water Conservation District (ACFC&WCD) and the Alameda County Water District (ACWD) have been working closely with the United States Army Corps of Engineers (ACOE) Planning Branch since early 1999 in the hopes that a steelhead fishery could be restored to the Alameda Creek Watershed through a cooperative effort. During this period, the Alameda Creek Fisheries Restoration Workgroup, representing stakeholder, agency, regulatory, and environmental interest groups, was formed to guide restoration efforts, facilitate communication, and initiate studies in the watershed. A number of activities have been initiated, including the investigation of fish passage and protection facilities in the Alameda Creek Flood Control Channel. In July 2000, ACFC&WCD and ACWD contracted with CH2M HILL to look at the feasibility of constructing and operating fishways and fish screens in this area. The purpose of this investigation is to determine if effective fish facilities could be designed in the channel that would (1) minimize operational impacts to the water supply operations, and (2) be constructed in a way that that would not significantly increase the flood hazard in Alameda Creek. Concept drawings and order of magnitude cost estimates were developed for these facilities. This memorandum describes the results of this initial investigation.

1. Background

A report entitled *An Assessment of the Potential for Restoring a Viable Steelhead Trout Population in the Alameda Creek Watershed* was completed in February 2000 for the Alameda Creek Fisheries Restoration Workgroup. Significant study findings were that (1) suitable habitat exists in the watershed, (2) genetic testing indicates that steelhead in the system are members of the federally protected Central California Coast Evolutionarily Significant Unit, (3) in-migration is prevented near the bottom of the watershed by an impassable structure built by the ACOF and severely limited by several other impassable or partial migration barriers, and (4) out-migration may be limited by existing water project operations.

Specific facilities requested to be addressed under the 1135 Program include: (1) fish passage facilities at the flood control drop structure (the “BART weir”) and adjacent inflatable dam ; (2) fish passage facilities at two other inflatable dams located with in the flood control channel; and (3) fish screens at diversion structures located adjacent to the inflatable dams. The BART weir was constructed in 1972 to prevent erosion at the supports for the railroad and BART tracks crossing over the channel. The inflatable dams and diversion structures are water supply facilities that were installed in conjunction with the flood control channel.

These water supply facilities were required, in part, because of the impacts of construction of the flood control channel on groundwater recharge to the underlying Niles Cone Groundwater Basin (a significant source of water supply to the residents and businesses in Fremont, Union City, and Newark).

The design of the flood control and water supply facilities did not provide for fish passage because, at the time of construction of the flood control channel, anadromous fisheries were believed by resource agencies to no longer exist in Alameda Creek. In addition, the design of certain water supply facilities (constructed after the flood control project) did not include provisions for fish passage or protection because the design of the flood control project prevented fish migration in the channel.

2. Proposed Fish Facilities in the Flood Control Channel

The Alameda Creek Flood Control Channel is located near the City of Fremont and west of the Niles Canyon. Within the channel, the Lower Inflatable Dam, BART weir, Middle Inflatable Dam, and Upper Inflatable Dam were identified in the "Assessment Report" as fish passage barriers to migrating steelhead. Fish can not successfully migrate past these facilities due to a number of factors including insufficient water depths, structure heights, high channel velocities, or flow limitations. The report further identified that providing passage facilities in the Flood Control Channel is an important first step in restoring a viable and sustainable steelhead fishery in the watershed where suitable habitat currently exists.

The design of fish passage and protection features in the Flood Control Channel poses several challenges due to site and access constraints, variable water surface fluctuations, inflatable dam operations for water supply, and flood control. The proposed fishway and screen facilities must function within this environment while also functioning within the necessary biological and hydraulic parameters needed for proper fish passage and protection.

As-built drawings from the ACOE, ACFC&WCD, and ACWD were reviewed to collect information on the channel features, structural details, and grade control. Historical data from the U.S. Geological Survey gage at the Niles canyon was used to examine channel flows. The ACOE report, entitled *General Design Memorandum No. 1 for the Alameda Creek Flood Control Project* and dated 1964, was used to assess the flood control capacity and assumed hydrology for the project. Operations information on the inflatable dams and the associated diversion facilities were obtained from ACWD. The inflatable dams and associated diversion facilities are operated based on flow and water quality in the channel as established by the ACFC&WCD, ACOE, Department of Fish and Game (DFG), and ACWD. Typically, the dams are lowered if the projected flow in the channel is at or above 700 cfs. Turbidity is generally the criteria that drives whether a diversion will be used.

The proposed fishways must function during conditions of minimal instream flow as well as during high flow periods, such as when the inflatable dams are deflated. The fishway attraction should be sufficient to allow passage into and through the fishway at flows up to the 90 percent exceedance levels that might occur during the steelhead migration season. Optimally, the fishway attraction flow during these high flow events should be 10 percent of those flows. Many fishway designs function within a limited flow range and therefore require auxiliary water to attract fish to the fishway during high flow events. This adds to the operational complexity and maintenance of the fishways and does not always result in improved passage overall. The flashy nature of the watershed and short duration of extreme flow events (less that 3 days) also limits the benefit of such auxiliary water systems. Upon consultation with fishery agency staff (George Heise, DFG, and Jon Mann, NMFS, pers. communication, September 2000), we determined that the preferred fishway design will size the pools approximately 8 feet wide by 10 feet long, flow at 35 cfs, and not require auxiliary water. This size ladder will function well over a wide channel flow range and reduce the likelihood of debris accumulation or interference in the fishway.

The proposed fish passage features in Lower Alameda Creek include fishways for upstream migrating adults, fish screens to protect outmigrating juvenile fish, and minor channel improvements near each fishway to channelize flows for optimal fishway attraction during low flow periods. Although every effort was made to minimize the hydraulic impacts on the channel, there are several necessary fish protection or fish passage features that will have a minor impact on the channel. Although channel flood capacity appears to be adequate, this analysis has not determined the level of significance or potential measures necessary to mitigate any of the impacts. Most channel impacts would be minimized by cutting the proposed fishways into the existing embankments or by narrowing the fishway, such as at the top of the BART weir. The fish screens will be nearly flush with the existing bank or be removable during flood events. The proposed raised concrete curbs just downstream of each inflatable dam and at the BART weir are necessary to provide sufficient water depth in the fishway and also to protect juvenile fish from passing over each inflatable dam by providing some level of cushioning over the existing concrete sill. Hydraulic impacts due to these features should be minor.

The attached conceptual designs have been discussed with fish passage specialists at the DFG (George Heise), and the National Marine Fisheries Service (Jon Mann) and they have concurred with the concepts presented based on preliminary data. It should be noted that limited, but conservative, criteria was used in developing the proposed designs. Upon further investigation and consultation, the concepts presented may differ from those presented resulting in potentially lower costs. Proposed facilities were developed at each of the below sites:

- Three fishways are proposed -- one around the Lower Inflatable Dam, One around the BART weir and Middle Inflatable Dam, and one around the Upper Inflatable Dam. The rational and basis of design for each type of ladder is described below.
- Seven fish screen sites are proposed at the following water diversion facilities located in the Flood Control Channel:
  - *Locations within the Upper Inflatable Dam Pool*
    Alameda Creek Pipeline Intake – 150 cfs
    B Pond Diversion (gravity) – 20 cfs
  - *Locations within the Middle Inflatable Dam Pool*
    B Pond Pumps (3, 3-cfs pumps) – 10 cfs
    Kaiser Pond AHF Diversion – 50 cfs
    Upper Shinn Pond Diversion (1,2) – 200 cfs
    Lower Shinn Pond Diversion (1,2,3) – 225 cfs

– *Locations within the Lower Inflatable Dam Pool*
  Pit T-1 Diversion – 30 cfs

The basic assumptions used to derive concept level cost estimates are presented in the sections below. The proposed designs represent features that are important to fishway design, flood control, safety of dam considerations, dam operations, site constraints, and maintenance issues. Additional features, such as fishway monitoring, public viewing features, and appurtenance facilities, require further design attention.

Lower Inflatable Dam

When the Lower Inflatable Dam is raised, the 7-to-9 foot high dam (the dam inflates up to 6 feet over the sill) beyond the leaping ability of the steelhead. When the dam is lowered, fish can migrate past the 2-to 3-foot high dam sill without going through a fishway, but passage can be greatly improved during low flow conditions by concentrating flow to one side of the channel and roughening the concrete apron. A small curb (6 inches high) should be constructed to concentrate flows to the right bank for dam down and low flow conditions. Concentrating flow to the right bank may also help form a channel to guide fish to the proposed fishway or roughened sill area.

Instream flows below this dam can vary from several thousand cfs to near zero. Since instream flow requirements have yet to be established, the proposed fishway needs to operate over this wide range of flows. Two fishways (ladders) housed in one structure are proposed:

– a false weir Alaska Steeppass ladder would operate when flows past the lower dam are about 5 to 25 cfs.

– a vertical slot fishway would to operate when channel flows past the dam are above 25 cfs.

During low flow conditions, the upper pool fishways may not have sufficient flow to operate effectively, and therefore the steeppass fishway could be operated as a fish trap for trap and haul operations if necessary. Trapped fish could be transported and released into streams in the upper watershed. This ladder does require a screened water supply of 5 cfs, which may be from the adjacent pool or nearby recharge ponds.

The vertical slot fishway is a self-regulated design that could be operated over a range of water levels according to the inflatable dam height. When the dam is inflated, the ladder should be relatively maintenance free; however, the depressed entrance pool may collect sediments during high flow events and need to be periodically flushed or manually cleaned out. Flow through this ladder will vary from 25 to 40 cfs, but auxiliary water from the reconfigured bypass could be used for additional attraction if available.

Juvenile passage over the Lower Dam can occur safely through the ladder, existing auxiliary bypass, or over the low height inflatable dam.

Project features are shown on the attached Figures 1 through 3 and briefly described below:

- 9-pool vertical slot fishway (consisting of 8 ft. wide by 10 ft. long pools) cut into right channel embankment (with 2 ft. wide low flow Alaska steeppass ladder adjacent to it).

- Ladder entrance via cut in embankment downstream of dam.
- 60-inch concrete pipe placed under the right dam abutment.
- Small concrete curb downstream of inflatable dam notched on the right side to channelize water and reduce sheet flow over the dam sill when dam is down.
- Bypass modification to increase attraction to ladder and establish low flow channel.
- Roughened concrete surface on the right side of the downstream dam sill to improve passage during dam down operations and low flows.
- False weir ladder to capture fish for trap and haul or for use during low flow conditions when dam is inflated. This ladder would be constructed in the same facility as the vertical slot ladder.

Total cost of the facilities at this location including engineering, environmental mitigation, construction inspection, contract administration, and contingencies is $1,500,000.

BART Weir and Middle Inflatable Dam

The concrete apron of the “BART weir” is an impassable fish barrier due to its steep slope and the high sheeting velocities that occur over its surface. A new fishway would lift fish from the drop structure area to the pool upstream of the Middle Inflatable Dam regardless of whether the dam is inflated or not. This design eliminates the need for two separate ladders and the possibility of fish falling back over the BART weir’s sloping apron.

The lower portion of the fishway is designed as a vertical slot fishway for fish passage when the Middle Inflatable Dam is deflated. This dam is generally deflated during higher flow events when channel depths may fluctuate significantly. The vertical slot design would accommodate this fluctuation and regulate the flow in the fishway. To ensure adequate submergence and minimum ladder flows when the dam is deflated, a two foot high curb placed across the channel and downstream of the ladder exit is necessary. This curb would consist of a fixed concrete lip located just downstream of the Middle Inflatable Dam. This feature could also consist of full or partially adjustable weir elements if necessary for flood control or sedimentation issues. This curb also would serve to protect juvenile migrating fish if they should fall over the dam when it is inflated.

The fishway entrance should be located as close to the apron base as possible. The side channel entrance must be submerged for proper fishway function. This can be accomplished by creating a pool from the backwater created by the Lower Inflatable Dam, or by constructing a notched sill at the end of the energy dissipater when this is not the case. When the backwater from the Lower Inflatable Dam is not available, flows down the channel should be concentrated to the right bank of the channel in a newly formed armored channel. This channel should be cut into the existing grouted stone protection area under the BART bridge to direct fish to the fishway entrance.

The proposed design affords the least channel constriction at the top of the drop structure of options considered. It also can be constructed without compromising the structural integrity of the adjacent retaining walls and bridge footings.

When the Middle Inflatable Dam is inflated, the pool depth upstream of the dam increases up to 11 feet over the channel invert. Then, the upper ladder section consisting of a pool and weir fishway design would be opened and the lower vertical slot exit would be closed. A pool and weir design is used here because the pooled water surface does not fluctuate much and fishways flows can be more closely regulated. Automatic overflow gates should be installed to allow for some water surface fluctuation. Since this portion of the fishway will only operate when the Middle Inflatable Dam is operational, the ladder should remain relatively sediment and debris free.

Project features are shown on the attached Figures 4 through 6 and are briefly described below:

- 13-step Vertical Slot fishway (consisting of 8 ft. wide by 10 ft. long pools) with entrance in the stilling basin. Ladder tied to existing channel walls. No disruption of footings of walls or piers.
- Raised concrete curb with notch at end of dissipater to pool water for ladder entrance and channel more flow to right side of channel.
- Low flow channel cut in grouted riprap.
- 4-foot wide concrete rectangular channel from lower fishway to Middle Inflatable Dam.
- 60-inch pipe culvert under to Middle Inflatable Dam abutment.
- Vertical slot fishway exit upstream of Middle Inflatable Dam with 60-inch gate valve.
- Concrete curb notched on to Middle Inflatable Dam foundation sill.
- 10-step pool and weir ladder (consisting of 8 ft. by 10 ft. pools) cut into right channel embankment when the dam is inflated.
- 3 automatic overflow gates for proper ladder hydraulics due to water level fluctuations.

Total cost of the facilities at this location including engineering, environmental mitigation, construction inspection, contract administration, and contingencies is $2,900,000.

One possible variation of this design would be to connect the Upper Inflatable Dam fishway to the Bart weir and Middle Inflatable Dam fishway via a small (25-35 cfs) conveyance channel. Although this design would likely be as or more expensive, fish would not have to find the entrances of multiple ladders and migration delays could be reduced. It also may be easier to incorporate public viewing and interpretative facilities into this type of configuration. The connecting channel would incorporate small drops within the channel that would make up the 13-foot grade difference between the Middle and Upper Inflatable Dam facilities. In this configuration, a fishway exit would be provided upstream of the Upper Inflatable Dam as well as one just upstream of the Middle Inflatable Dam. The intermediate exit would be operated if the Middle Inflatable Dam was inflated and the Upper Inflatable Dam were deflated.

Upper Inflatable Dam

The Upper Inflatable Dam is a 13-foot high structure when fully inflated. This is well beyond the leaping ability of steelhead and therefore a fishway is necessary. An ACOE grade control sill located about 50 feet below the dam poses another possible migration impediment during low flows, but a minor improvement, including a small curb to concentrate flows, could eliminate any concern here. Unlike the other inflatable dams in the channel, the Upper Inflatable Dam is inflated with air which results in the overflow spills being concentrated in the center of the wide channel. Since the fishway must be constructed on the channel bank, fishway attraction will be important. A notched concrete sill should be constructed that will help guide fish to the ladder entrance.

A pool and weir ladder is proposed installation in the right channel embankment at the base of the Upper Inflatable Dam. Automatic overflow gates would regulate ladder flows and accommodate up to three feet of fluctuations in the pool. The ladder entrance would be positioned at the base of the Upper Rubber Dam on the right abutment. The ladder would gain elevation before passing through a rectangular channel section adjacent to the dam crest. A wall specifically designed to incorporate a ladder design exists in the dam abutment. Therefore, the dam operations should not be disrupted during construction.

Project Features:

- 10-Step pool and weir Fishway (consisting of 8 ft. by 10 ft. pools) cut into right embankment. A nominal ladder flow of 25 cfs would be provided.
- Ladder entrance located at base of the dam.
- Rectangular channel section through dam section.
- 3 automatic overflow gates for proper ladder hydraulics due to water level fluctuations.
- Concrete curb downstream of rubber dam to pond water for ladder entrance and to provide a cushion for juvenile fish falling over dam. Notches would reduce sheet flow over grade control sill and guide fish to fishway entrance.
- Bypass modification to increase attraction to ladder if necessary.

Total cost of the facilities at this location including engineering, environmental mitigation, construction inspection, contract administration, and contingencies is $1,400,000.

Fish Screens

Fish screens will be designed to meet the most current fish screen criteria established by the National Marine Fisheries Service (NMFS) and the California Department of Fish and Game (CDFG) for steelhead fry (See attachment). Consultation on final design criteria should be obtained from NMFS and CDFG prior to the final design of facilities. For purposes of this evaluation, the screen size will be governed by the approach velocity (over the gross screen area) criteria of 0.33 feet per second for continuously cleaned screens. Profile bar screens should be used due to their structural qualities and ease of cleaning. The maximum screen slot openings for profile bar will be 1.75 mm and be at least 27 percent of the open area. Screens will be automatically cleaned when in use with either a brush cleaner or air burst system (except on pump intakes where air entrainment is generally unacceptable).

To standardize design features for maintenance purposes, two screen facility types are proposed. An inclined flat plate fish screen with a wiper brush is proposed for use at the larger gravity diversions (i.e. diversion sites greater than 50 cfs). For the pump screens, and the smaller gravity diversions, a retrievable cylindrical fish screen with a brush cleaner is proposed. Both screen types would be designed to meet operations needs and the established fishery agency criteria for steelhead protection. Figure 9 shows a schematic plan and elevation of the flat plate design. A photograph of a cylindrical screen is shown on Figure 10.

The total cost of the facilities listed below, including engineering, environmental mitigation, construction inspection, contract administration, and contingencies, is $4,100,000.

Alameda Creek Pipeline Intake – 150 cfs

The existing trash rack and the supporting structure would be removed. An enlarged inclined flat plate intake screen would replace the existing trash-rack. A wider screen support structure will be constructed that will protrude several feet into the channel. This design will permit the installation of flow distribution baffling to allow uniform velocities across the screen face. The structure will have smooth transitions to the banks. The existing pipe and gate will continue to function as before.

Project Features:

- 450 sq. ft. of wedgewire screen (15 x 30 long) on inclined plane (2.5:1).
- Baffles behind screen and flow distributor over intake pipe to provide flow uniformity.
- Screen cleaning system with automatic controls.

B Pond Diversion (gravity) – 20 cfs

The existing trashrack structure will be removed. The opening will be covered with a plate and pipe stub that will connect to a cylindrical fish screen manifold. The two screens and manifold will be retrievable so they can be removed during flood events and for maintenance purposes. Screens will be continually cleaned during diversion use using brushes.

Project Features:

- Two cylindrical fish screens with at least 30 sq. ft. of surface area each (42-inch diameter)
- Track system for screen retrievability.

B Pond Pumps (3, 3-cfs pumps) – 10 cfs

Each pump intake will be retrofitted to fit into a larger diameter pipe “sock”. Attached to this pipe will be a submerged, retrievable, cylindrical fish screen. Each screen will be cleaned with an automatic brush system.

Project Features:

- Pipe “sock” and cylindrical fish screen for each pump.
- Track system for screen retrievability.

Kaiser Pond AHF Diversion – 50 cfs

Either a flat plate, inclined fish screen or a cylindrical fish screen arrangement can be installed at this location and constructed as described above.

Project Features:

- Either 150 sq. ft. of wedgewire screen (15 x 10 long) on inclined plane (2.5:1) with baffles behind screen and a flow distributor over the intake pipe to provide flow uniformity;
- Or, four, cylindrical fish screens with at least 38 sq. ft. of surface area each (48-inch diameter screens). Also a track system for screen retrievability.
- Screen cleaning system with automatic controls.

Shinn Pond Diversion (1,2, ACP from Upper Inflatable Dam) – 200 cfs

The existing trash rack and the supporting structure will be removed. An enlarged inclined flat plate intake screen will replace the existing trashrack. A wider screen support structure will be constructed that will protrude several feet into the channel. This design will permit the installation of flow distribution baffling to allow uniform velocities across the screen face. The structure will have smooth transitions to the banks. The existing pipe and gate will continue to function as before.

Project Features:

- 600 sq. ft. of wedgewire screen (15 x 40 long) on inclined plane (2.5:1).
- Baffles behind screen and flow distributor over intake pipe to provide flow uniformity.
- Screen cleaning system with automatic controls.

Shinn Pond Diversion (1,2,3) – 225 cfs

The existing trash rack and the supporting structure will be removed. An enlarged inclined flat plate intake screen will replace the existing trashrack. A wider screen support structure will be constructed that will protrude several feet into the channel. This design will permit the installation of flow distribution baffling to allow uniform velocities across the screen face. The structure will have smooth transitions to the banks. The existing pipe and gate will continue to function as before.

Project Features:

- 675 sq. ft. of wedgewire screen (15 x 45 long) on inclined plane (2.5:1).
- Baffles behind screen and flow distributor over intake pipe to provide flow uniformity.
- Screen cleaning system with automatic controls.

Pit T-1 Diversion – 30 cfs

A cylindrical fish screen arrangement can be installed at this location, but water depths may limit the clearances needed for the screens (a minimum of one foot above and below the screens are needed). The existing trashrack structure will be removed. The opening will be covered with a plate and pipe stub that will connect to a cylindrical fish screen manifold. Four screens will be manifolded together and be retrievable during flood events and maintenance purposes. Screens will be continually cleaned during diversion use using brushes.

Alternatives to filling the T-1 pond should be investigated. The existing pond does not fill a significant recharge area and therefore could be filled from a pipeline from the Kaiser Pond or through a pumped intake that would not rely on having sufficient water depth in the Lower Inflatable Dam pool. This may have benefits to passage options at the lower pool also.

Project Features:

- Four, smaller cylindrical fish screens with at least 23 sq. ft. of surface area each (30-inch diameter screens). A track for screen retrievability will be necessary.
- Screen cleaning system with automatic controls.

ATTACHMENT 1

Fish Screening Criteria
June 19, 2000

STATE OF CALIFORNIA
RESOURCES AGENCY
DEPARTMENT OF FISH AND GAME

FISH SCREENING CRITERIA
June 19, 2000

1. STRUCTURE PLACEMENT

A. **Streams And Rivers (flowing water):** The screen face shall be parallel to the flow and adjacent bankline (water's edge), with the screen face at or streamward of a line defined by the annual low-flow water's edge.

The upstream and downstream transitions to the screen structure shall be designed and constructed to match the bankline, minimizing eddies upstream of, in front of, and downstream of, the screen.

Where feasible, this "on-stream" fish screen structure placement is preferred by the California Department of Fish and Game.

B. **In Canals (flowing water):** The screen structure shall be located as close to the river source as practical, in an effort to minimize the approach channel length and the fish return bypass length. This "in canal" fish screen location shall only be used where an "on-stream" screen design is not feasible. This situation is most common at existing diversion dams with headgate structures.

The current National Marine Fisheries Service - Southwest Region criteria for these types of installations shall be used (Attachment A).

C. **Small Pumped Diversions:** Small pumped diversions (less than 40 cubic-feet per second) which are screened using "manufactured, self-contained" screens shall conform to the National Marine Fisheries Service - Southwest Region criteria (Attachment A).

D. **Non-Flowing Waters (tidal areas, lakes and reservoirs):** The preferred location for the diversion intake structure shall be offshore, in deep water, to minimize fish contact with the diversion. Other configurations will be considered as exceptions to the screening criteria as described in Section 5.F. below.

2. APPROACH VELOCITY (Local velocity component perpendicular to the screen face

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

B. **Self-Cleaning Screens:** The design approach velocity shall not exceed:

1. Streams and Rivers (flowing waters) - Either:
   a. 0.33 feet per second, where exposure to the fish screen shall not exceed fifteen minutes, or

b. 0.40 feet per second, for small (less than 40 cubic-feet per second) pumped diversions using "manufactured, self-contained" screens.

2. In Canals (flowing waters) - 0.40 feet per second, with a bypass entrance located every one-minute of travel time along the screen face.

3. Non-Flowing Waters (tidal areas, lakes and reservoirs) - The specific screen approach velocity shall be determined for each installation, based on the species and life stage of fish being protected. Velocities which exceed those described above will require a variance to these criteria (see Section 5.F. below).

(Note: At this time, the U.S. Fish and Wildlife Service has selected a 0.2 feet per second approach velocity for use in waters where the Delta smelt is found. Thus, fish screens in the Sacramento-San Joaquin Estuary should use this criterion for design purposes.)

C. **Screens Which Are Not Self-Cleaning:** The screens shall be designed with an approach velocity one-fourth that outlined in Section B. above. The screen shall be cleaned before the approach velocity exceeds the criteria described in Section B.

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

E. **Screen Area Calculation:** The required wetted screen area (square feet), excluding the area affected by structural components, is calculated by dividing the **maximum** diverted flow (cubic-feet per second) by the allowable approach velocity (feet per second).

Example: 1.0 cubic-feet per second / 0.33 feet per second = 3.0 square feet

Unless otherwise specifically agreed to, this calculation shall be done at the minimum stream stage.

3. SWEEPING VELOCITY (Velocity component parallel to screen face)

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

B. **In Canals:** The sweeping velocity shall exceed the allowable approach velocity. Experience has shown that sweeping velocities of 2.0 feet per second (or greater) are preferable.

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

4. SCREEN OPENINGS

A. **Porosity:** The screen surface shall have a minimum open area of 27 percent. We recommend the maximum possible open area consistent with the availability of appropriate material, and structural design considerations.

   The use of open areas less than 40 percent shall include consideration of increasing the screen surface area, to reduce slot velocities, assisting in both fish protection and screen cleaning.

B. **Round Openings:** Round openings in the screening shall not exceed 3.96mm (5/32in). In waters where steelhead rainbow trout fry are present, this dimension shall not exceed 2.38mm (3/32in).

C. **Square Openings:** Square openings in screening shall not exceed 3.96mm (5/32in) measured diagonally. In waters where steelhead rainbow trout fry are present, this dimension shall not exceed 2.38mm (3/32in) measured diagonally.

D. **Slotted Openings:** Slotted openings shall not exceed 2.38mm (3/32in) in width. In waters where steelhead rainbow trout fry are present, this dimension shall not exceed 1.75mm (0.0689in).

5. SCREEN CONSTRUCTION

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

B. **Corrosion and Fouling Protection:** Stainless steel or other corrosion-resistant material is the screen material recommended to reduce clogging due to corrosion. The use of both active and passive corrosion protection systems should be considered.

   Consideration should be given to anti-fouling material choices, to reduce biological fouling problems. Care should be taken not to use materials deemed deleterious to fish and other wildlife.

C. **Project Review and Approval:** Plans and design calculations, which show that all the applicable screening criteria have been met, shall be provided to the Department before written approval can be granted by the appropriate Regional Manager.

   The approval shall be documented in writing to the project sponsor, with copies to both the Deputy Director, Habitat Conservation Division and the Deputy Director, Wildlife and Inland Fisheries Division. Such approval may include a requirement for post-construction evaluation, monitoring and reporting.

D. **Assurances:** All fish screens constructed after the effective date of these criteria shall be designed and constructed to satisfy the current criteria. Owners of existing screens, approved by the Department prior to the effective date of these criteria, shall not be required to upgrade their facilities to satisfy the current criteria unless:

1. The controlling screen components deteriorate and require replacement (i.e., change the opening size or opening orientation when the screen panels or rotary drum screen coverings need replacing),
2. Relocation, modification or reconstruction (i.e., a change of screen alignment or an increase in the intake size to satisfy diversion requirements) of the intake facilities, or
3. The owner proposes to increase the rate of diversion which would result in violation of the criteria without additional modifications.

E. **Supplemental Criteria:** Supplemental criteria may be issued by the Department for a project, to accommodate new fish screening technology or to address species-specific or site-specific circumstances.

F. **Variances:** Written variances to these criteria may be granted with the approval of the appropriate Regional Manager and concurrence from both the Deputy Director, Habitat Conservation Division and the Deputy Director, Wildlife and Inland Fisheries Division. At a minimum, the rationale for the variance must be described and justified in the request.

Evaluation and monitoring may be required as a condition of any variance, to ensure that the requested variance does not result in a reduced level of protection for the aquatic resources.

It is the responsibility of the project sponsor to obtain the most current version of the appropriate fish screen criteria. Project sponsors should contact the Department of Fish and Game, the National Marine Fisheries Service (for projects in marine and anadromous waters) and the U.S. Fish and Wildlife Service (for projects in anadromous and fresh waters) for guidance.

Copies of the current criteria are available from the Department of Fish and Game through the appropriate Regional office, which should be the first point of contact for any fish screening project.

Region	Address	Telephone Number
Northern California and North Coast Region	601 Locust Street Redding, CA 96001	916-225-2300
Sacramento Valley and Central Sierra Region	1701 Nimbus Drive Rancho Cordova, CA 95670	916-358-2900
Central Coast Region	7329 Silverado Trail/P.O. Box 46 Yountville, CA 94599	707-944-5500
San Joaquin Valley-Southern Sierra Region	1234 E Shaw Avenue Fresno, CA 93710	209-243-4005
South Coast Region	4649 View Crest Avenue San Diego, CA 92123	619-467-4201
Eastern Sierra and Inland Deserts Region	4775 Bird Farms Road Chino Hills, CA 91709	909-597-9823
Marine Region	20 Lower Ragsdale Drive, #100 Monterey, CA 93940	831-649-2870

Technical assistance can be obtained directly from the Habitat Conservation Division; 1416 Ninth Street, Sacramento, CA 95814 - (916) 653-1070.

The current National Marine Fisheries Service criteria are available from their Southwest Region; 777 Sonoma Avenue, Room 325, Santa Rosa, CA 95402 - (707) 575-6050.

ATTACHMENT 2

Fish Screening Criteria for Anadromous Salmonids
January 1997

National Marine Fisheries Service
Southwest Region
Fish Screening Criteria
for
Anadromous Salmonids
January 1997

Fish Screening Criteria for Anadromous Salmonids [(1)]
National Marine Fisheries Service
Southwest Region
January 1997

Table of Contents

I. General Considerations

This document provides guidelines and criteria for functional designs of downstream migrant fish passage facilities at hydroelectric, irrigation, and other water withdrawal projects. It is promulgated by the National Marine Fisheries Service (NMFS), Southwest Region as a result of its authority and responsibility for prescribing fishways under the Endangered Species Act (ESA), the Federal Power Act, administered by the Federal Energy Regulatory Commission (FERC), and the Fish and Wildlife Coordination Act (FWCA), administered by the U.S. Fish & Wildlife Service.

The guidelines and criteria are general in nature. There may be cases where site constraints or extenuating circumstances dictate a waiver or modification of one or more of these criteria. Conversely, where there is an opportunity to protect fish, site-specific criteria may be added. Variances from established criteria will be considered on a project-by-project basis.

The swimming ability of fish is a primary consideration in designing a fish screen facility. Research shows that swimming ability varies depending on multiple factors relating to fish physiology, biology, and the aquatic environment. These factors include: species, physiological development, duration of swimming time required, behavioral aspects, physical condition, water quality, temperature, lighting conditions, and many others. Since conditions affecting swimming ability are variable and complex, screen criteria must be expressed in general terms and the specifics of any screen design must address on-site conditions.

NMFS may require project sponsors to investigate site-specific variables critical to the fish screen system design. This investigation may include fish behavioral response to hydraulic conditions, weather conditions (ice, wind, flooding, etc.), river stage-discharge relationships, seasonal operations, sediment and debris problems, resident fish populations, potential for creating predation opportunity, and other pertinent information. The size of salmonids present at a potential screen site usually is not known, and can change from year-to-year based on flow and temperature conditions. Thus, adequate data to describe the size-time relationship requires substantial sampling over a number of years. NMFS will normally assume that fry-sized salmonids are present at all sites unless adequate biological investigation proves otherwise. The burden of proof is the responsibility of the owner of the screen facility.

New facilities which propose to utilize unproven fish protection technology frequently require:

1. development of a biological basis for the concept;
2. demonstration of favorable behavioral responses in a laboratory setting;
3. an acceptable plan for evaluating the prototype installation;
4. an acceptable alternate plan should the prototype not adequately protect fish. Additional information can be found in *Experimental Fish Guidance Devices*, position statement of the National Marine Fisheries Service, Southwest Region, January 1994.

Striped Bass, Herring, Shad, Cyprinids, and other anadromous fish species may have eggs and/or very small fry which are moved with any water current (tides, streamflows, etc.). Installations where these species are present may require individual evaluation of the proposed project using more conservative screening requirements. In instances where state or local regulatory agencies require more stringent screen criteria to protect species other than salmonids, NMFS will generally defer to the more conservative criteria.

General screen criteria and procedural guidelines are provided below. Specific exceptions to these criteria occur in the design of small screen systems (less than 40 cubic feet per second) and certain small pump intakes. These exceptions are listed in Section K, Modified Criteria for Small Screens, and in the separate addendum entitled: Juvenile Fish Screen Criteria For Pump Intakes, National Marine Fisheries Service, Portland, Oregon, May 9, 1996.

II. General Procedural Guidelines

For projects where NMFS has jurisdiction, such as FERC license applications and ESA consultations, a functional design must be developed as part of the application or consultation. These designs must reflect NMFS design criteria and be acceptable to NMFS. Acceptable designs typically define type, location, method of operation, and other important characteristics of the fish screen facility. Design drawings should show structural dimensions in plan, elevation, and cross-sectional views, along with important component details. Hydraulic information should include: hydraulic capacity, expected water surface elevations, and flows through various areas of the structures. Documentation of relevant hydrologic information is required. Types of materials must be identified where they will directly affect fish. A plan for operations and maintenance procedures should be included- i.e., preventive and corrective maintenance procedures, inspections and reporting requirements, maintenance logs, etc.- particularly with respect to debris, screen cleaning, and sedimentation issues. The final detailed design shall be based on the functional design, unless changes are agreed to by NMFS.

All juvenile passage facilities shall be designed to function properly through the full range of hydraulic conditions expected at a particular project site during fish migration periods, and shall account for debris and sedimentation conditions which may occur.

III. Screen Criteria for Juvenile Salmonids

A. Structure Placement

1. General:

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

For on-river screens, it is preferable to keep the fish in the main channel rather than put them through intermediate screen bypasses. NMFS decides whether to require intermediate bypasses for on-river, straight profile screens by considering the biological and hydraulic conditions existing at each individual project site.

2. Streams and Rivers:

Where physically practical, the screen shall be constructed at the diversion entrance. The screen face should be generally parallel to river flow and aligned with the adjacent bankline. A smooth transition between the bankline and the screen structure is important to minimize eddies and undesirable flow patterns in the vicinity of the screen. If trash racks are used, sufficient hydraulic gradient is required to route juvenile fish from between the trashrack and screens to safety. Physical factors that may preclude screen construction at the diversion entrance include excess river gradient, potential for damage by large debris, and potential for heavy sedimentation. Large stream-side installations may require intermediate bypasses along the screen face to prevent excessive exposure time. The need for intermediate bypasses shall be decided on a case-by-case basis.

3. Canals:

Where installation of fish screens at the diversion entrance is undesirable or impractical, the screens may be installed at a suitable location downstream of the canal entrance. All screens downstream of the diversion entrance shall provide an effective juvenile bypass system- designed to collect juvenile fish and safely transport them back to the river with minimum delay. The angle of the screen to flow should be adequate to effectively guide fish to the bypass. Juvenile bypass systems are part of the overall screen system and must be accepted by NMFS.

4. Lakes, Reservoirs, and Tidal Areas:

   a. Where possible, intakes should be located off shore to minimize fish contact with the facility. Water velocity from any direction toward the screen shall not exceed the allowable approach velocity. Where possible, locate intakes where sufficient sweeping velocity exists. This minimizes sediment accumulation in and around the screen, facilitates debris removal, and encourages fish movement away from the screen face.

   b. If a screened intake is used to route fish past a dam, the intake shall be designed to withdraw water from the most appropriate elevation in order to provide the best juvenile fish attraction to the bypass channel as well as to achieve appropriate water temperature control downstream. The entire range of forebay fluctuations shall be accommodated by the design, unless otherwise approved by NMFS.

B. Approach Velocity

Definition: *Approach Velocity* is the water velocity vector component perpendicular to the screen face.

Approach velocity shall be measured approximately three inches in front of the screen surface.

1. Fry Criteria - less than 2.36 inches {60 millimeters (mm)} in length.

   If a biological justification cannot demonstrate the absence of fry-sized salmonids in the vicinity of the screen, fry will be assumed present and the following criteria apply:

      Design approach velocity shall not exceed-

      Streams and Rivers: 0.33 feet per second

      Canals: 0.40 feet per second

      Lakes, Reservoirs, Tidal: 0.33 feet per second (salmonids) [(2)]

2. Fingerling Criteria - 2.36 inches {60 mm} and longer

   If biological justification can demonstrate the absence of fry-sized salmonids in the vicinity of the screen, the following criteria apply:

      Design approach velocity shall not exceed -

      All locations: 0.8 feet per second

3. The *total submerged screen area required* (excluding area of structural components) is calculated by dividing the maximum diverted flow by the allowable approach velocity. (Also see Section K, Modified Criteria for Small Screens, part 1).

4. The screen design must provide for uniform flow distribution over the surface of the screen, thereby minimizing approach velocity. This may be accomplished by providing adjustable porosity control on the downstream side of the screens, unless it can be

shown unequivocally (such as with a physical hydraulic model study) that localized areas of high velocity can be avoided at all flows.

C. Sweeping Velocity

Definition: *Sweeping Velocity* is the water velocity vector component parallel and adjacent to the screen face.

1. Sweeping Velocity shall be greater than approach velocity. For canal installations, this is accomplished by angling screen face less than 45 relative to flow (see Section K, Modified Criteria for Small Screens). This angle may be dictated by specific canal geometry, or hydraulic and sediment conditions.

D. Screen Face Material

1. Fry criteria

If a biological justification cannot demonstrate the absence of fry-sized salmonids in the vicinity of the screen, fry will be assumed present and the following criteria apply for screen material:

   a. Perforated plate: screen openings shall not exceed 3/32 inches (2.38 mm), measured in diameter.

   b. Profile bar: screen openings shall not exceed 0.0689 inches (1.75 mm) in width.

   c. Woven wire: screen openings shall not exceed 3/32 inches (2.38 mm), measured diagonally. (e.g.: 6-14 mesh)

   d. Screen material shall provide a minimum of 27% open area.

2. Fingerling Criteria

If biological justification can demonstrate the absence of fry-sized salmonids in the vicinity of the screen, the following criteria apply for screen material:

   a. Perforated plate: Screen openings shall not exceed 1/4 inch (6.35 mm) in diameter.

   b. Profile bar: screen openings shall not exceed 1/4 inch (6.35 mm) in width

   c. Woven wire: Screen openings shall not exceed 1/4 inch (6.35 mm) in the narrow direction

   d. Screen material shall provide a minimum of 40% open area.

3. The screen material shall be corrosion resistant and sufficiently durable to maintain a smooth and uniform surface with long term use.

E. Civil Works and Structural Features

1. The face of all screen surfaces shall be placed flush with any adjacent screen bay, pier noses, and walls, allowing fish unimpeded movement parallel to the screen face and ready access to Bypass routes.

2. Structural features shall be provided to protect the integrity of the fish screens from large debris. Trash racks, log booms, sediment sluices, or other measures may be needed. A reliable on-going preventive maintenance and repair program is necessary to ensure facilities are kept free of debris and the screen mesh, seals, drive units, and other components are functioning correctly.

3. Screens located in canals - surfaces shall be constructed at an angle to the approaching flow, with the downstream end terminating at the bypass system entrance.

4. The civil works design shall attempt to eliminate undesirable hydraulic effects (e.g.- eddies, stagnant flow zones) that may delay or injure fish, or provide predator opportunities. Upstream training wall(s), or some acceptable variation thereof, shall be utilized to control hydraulic conditions and define the angle of flow to the screen face. Large facilities may require hydraulic monitoring to identify and correct areas of concern.

F. Juvenile Bypass System Layout

Juvenile bypass systems are water channels which transport juvenile fish from the face of a screen to a relatively safe location in the main migratory route of the river or stream. Juvenile bypass systems are necessary for screens located in canals because anadromous fish must be routed back to their main migratory route. For other screen locations and configurations, NMFS accepts the option which, in its judgement, provides the highest degree of fish protection given existing site and project constraints.

1. The screen and bypass shall work in tandem to move out-migrating salmonids (including adults) to the bypass outfall with minimum injury or delay. Bypass entrance(s) shall be designed such that out-migrants can easily locate and enter them. Screens installed in canal diversions shall be constructed with the downstream end of the screen terminating at a bypass entrance. Multiple bypass entrances (intermediate bypasses) shall be employed if the sweeping velocity will not move fish to the bypass within 60 seconds [(3)] assuming the fish are transported at this velocity. Exceptions will be made for sites without satisfactory hydraulic conditions, or for screens built on river banks with satisfactory river conditions.

2. All components of the bypass system, from entrance to outfall, shall be of sufficient hydraulic capacity to minimize the potential for debris blockage.

3. To improve bypass collection efficiency for a single bank of vertically oriented screens, a bypass training wall may be located at an angle to the screens.

4. In cases where insufficient flow is available to satisfy hydraulic requirements at the main bypass entrance(s), a *secondary screen* may be required. Located in the main screen's bypass channel, a secondary screen allows the prescribed bypass flow to be used to effectively attract fish into the bypass entrance(s) while allowing all but a reduced residual bypass flow to be routed back (by pump or gravity) for the primary diversion use. The residual bypass flow (not passing through the secondary screen) then conveys fish to the bypass outfall location or other destination.

5. Access is required at locations in the bypass system where debris accumulation may occur.

6. The screen civil works floor shall allow fish to be routed to the river safely in the event the canal is dewatered. This may entail a sumped drain with a small gate and drain pipe, or similar provisions.

G. Bypass Entrance

1. Each bypass entrance shall be provided with independent flow control, acceptable to NMFS.
2. Bypass entrance velocity must equal or exceed the maximum velocity vector resultant along the screen, upstream of the entrance. A gradual and efficient acceleration into the bypass is required to minimize delay of out-migrants.
3. Ambient lighting conditions are required from the bypass entrance to the bypass flow control.
4. The bypass entrance must extend from floor to water surface.

H. Bypass Conduit Design

1. Smooth interior pipe surfaces and conduit joints shall be required to minimize turbulence, debris accumulation, and the risk of injury to juvenile fish. Surface smoothness must be acceptable to the NMFS.
2. Fish shall not free-fall within a confined shaft in a bypass system.
3. Fish shall not be pumped within the bypass system.
4. Pressure in the bypass pipe shall be equal to or above atmospheric pressure.
5. Extreme bends shall be avoided in the pipe layout to avoid excessive physical contact between small fish and hard surfaces and to minimize debris clogging . Bypass pipe centerline radius of curvature (R/D) shall be 5 or greater. Greater R/D may be required for supercritical velocities.
6. Bypass pipes or open channels shall be designed to minimize debris clogging and sediment deposition and to facilitate cleaning. Pipe diameter shall be 24 inches (0.610 m) or greater and pipe velocity shall be 2.0 fps (0.610 mps) or greater, unless otherwise approved by NMFS. (See *Modified Criteria for Small Screens*) for the entire operational range.
7. No closure valves are allowed within bypass pipes.
8. Depth of flow in a bypass conduit shall be 0.75 ft. (0.23 m) or greater, unless otherwise authorized by NMFS (See Modified Criteria for Small Screens).
9. Bypass system sampling stations shall not impair normal operation of the screen facility.
10. No hydraulic jumps should exist within the bypass system.

I. Bypass Outfall

1. Ambient river velocities at bypass outfalls should be greater than 4.0 fps (1.2 mps), or as close as obtainable.

2. Bypass outfalls shall be located and designed to minimize avian and aquatic predation in areas free of eddies, reverse flow, or known predator habitat.
3. Bypass outfalls shall be located where there is sufficient depth (depending on the impact velocity and quantity of bypass flow) to avoid fish injuries at all river and bypass flows.
4. Impact velocity (including vertical and horizontal components) shall not exceed 25.0 fps (7.6 mps).
5. Bypass outfall discharges shall be designed to avoid adult attraction or jumping injuries.

J. Operations and Maintenance

1. Fish Screens shall be automatically cleaned as frequently as necessary to prevent accumulation of debris. The cleaning system and protocol must be effective, reliable, and satisfactory to NMFS. Proven cleaning technologies are preferred.
2. Open channel intakes shall include a trash rack in the screen facility design which shall be kept free of debris. In certain cases, a satisfactory profile bar screen design can substitute for a trash rack.
3. The head differential to trigger screen cleaning for intermittent type systems shall be a maximum of 0.1 feet (.03 m), unless otherwise agreed to by NMFS.
4. The completed screen and bypass facility shall be made available for inspection by NMFS, to verify compliance with design and operational criteria.
5. Screen and bypass facilities shall be evaluated for biological effectiveness and to verify that hydraulic design objectives are achieved.

K. Modified Criteria for Small Screens (Diversion Flow less than 40 cfs)

The following criteria vary from the standard screen criteria listed above. These criteria specifically apply to lower flow, surface-oriented screens (e.g.- small rotating drum screens). Forty cfs is the approximate cut off; however, some smaller diversions may be required to apply the general criteria listed above, while some larger diversions may be allowed to use the "small screen" criteria below. NMFS will decide on a case-by-case basis depending on site constraints.

1. The required screen area is a function of the approach velocity listed in Section B, Approach Velocity, Parts 1, 2, and 3 above. Note that "maximum" refers to the greatest flow diverted, not necessarily the water right.
2. Screen Orientation:
   a. For screen lengths six feet or less, screen orientation may be angled perpendicular to the flow.
   b. For screen lengths greater than six feet, screen-to-flow angle must be less than 45 degrees. (See Section C Sweeping Velocity, part 1).
   c. For drum screens, design submergence shall be 75% of drum diameter. Submergence shall not exceed 85%, nor be less than 65% of drum diameter.

d. Minimum bypass pipe diameter shall be 10 in (25.4 cm), unless otherwise approved by NMFS.

e. Minimum pipe depth is 1.8 in (4.6 cm) and is controlled by designing the pipe gradient for minimum bypass flow.

Questions concerning this document can be directed to NMFS Hydraulic Engineering Staff at:

National Marine Fisheries Service

Southwest Region

777 Sonoma Ave. Room 325

Santa Rosa, CA 95402

Phone: 707-575-6050

Adopted,

Date: February 24, 1997

Authorizing Signature:

1. Adapted from NMFS, Northwest Region

2. Other species may require different approach velocity standards, e.g.- in California, the U.S. Fish & Wildlife Service requires 0.2 fps approach velocity where delta smelt are present in the tidal areas of the San Francisco Bay estuary.
3. In California, 60 second exposure time applies to screens in canals, using a 0.4 fps approach velocity. Where more conservative approach velocities are used, longer exposure times may be approved on a case-by-case basis, and exceptions to established criteria shall be treated as variances.

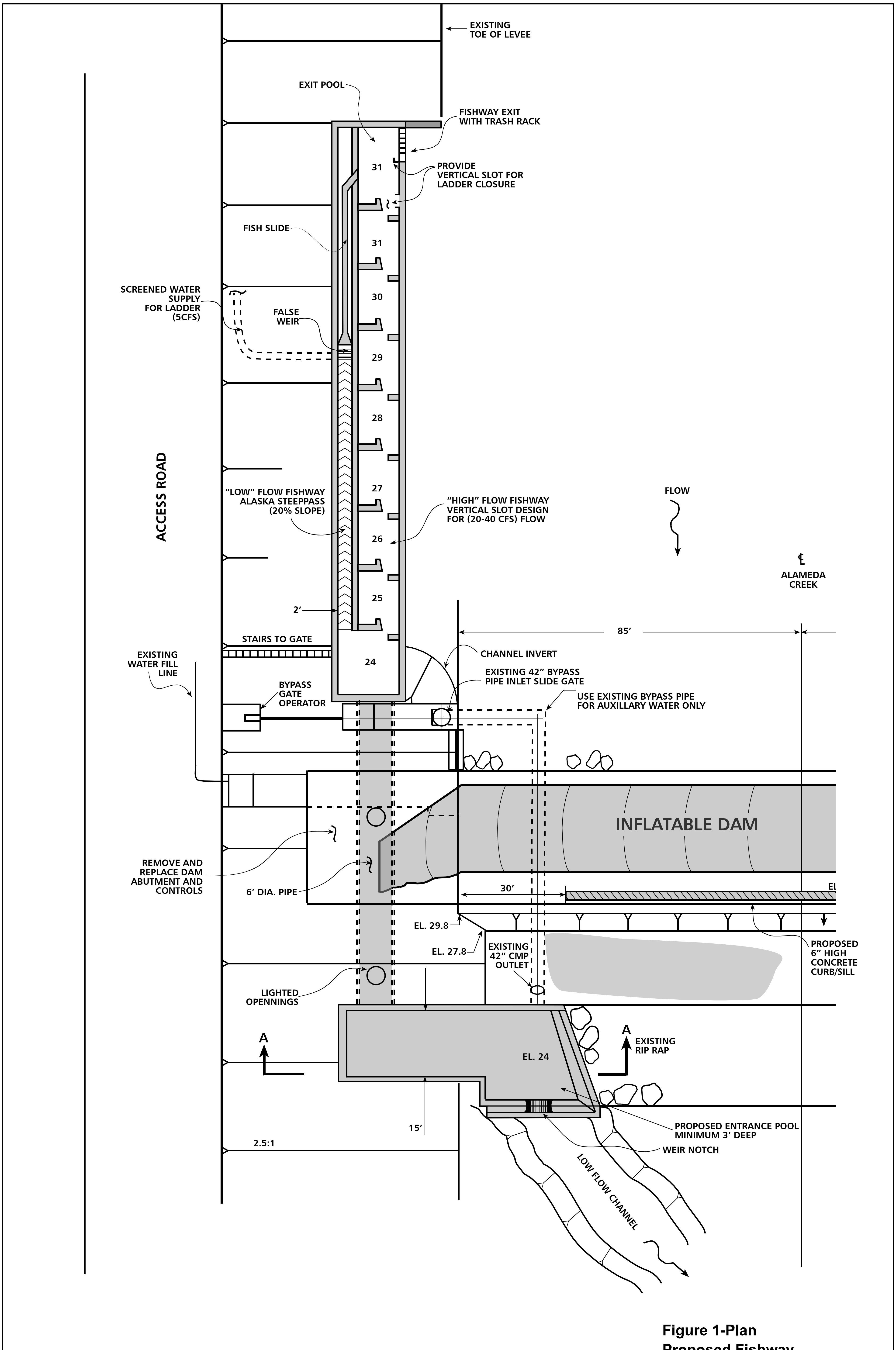


Figure 1-Plan
Proposed Fishway
at the Lower Inflatable Dam
Alameda Fish Creek Passage

CH2MHILL

SAC-W-160108.ZZ.03 Figure 1. 11-21-00 tiffany

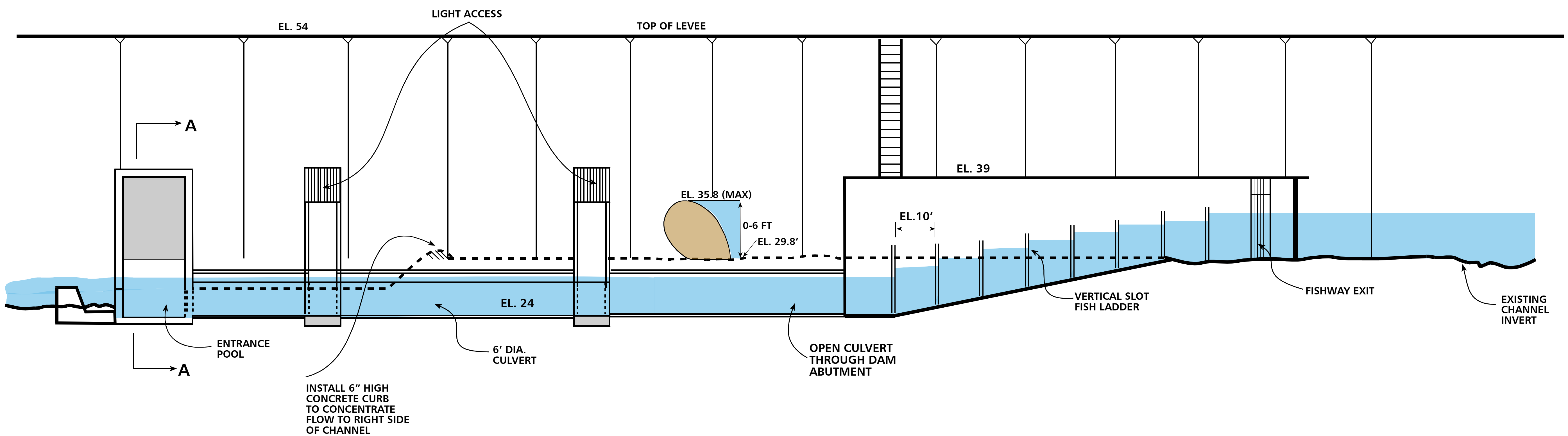
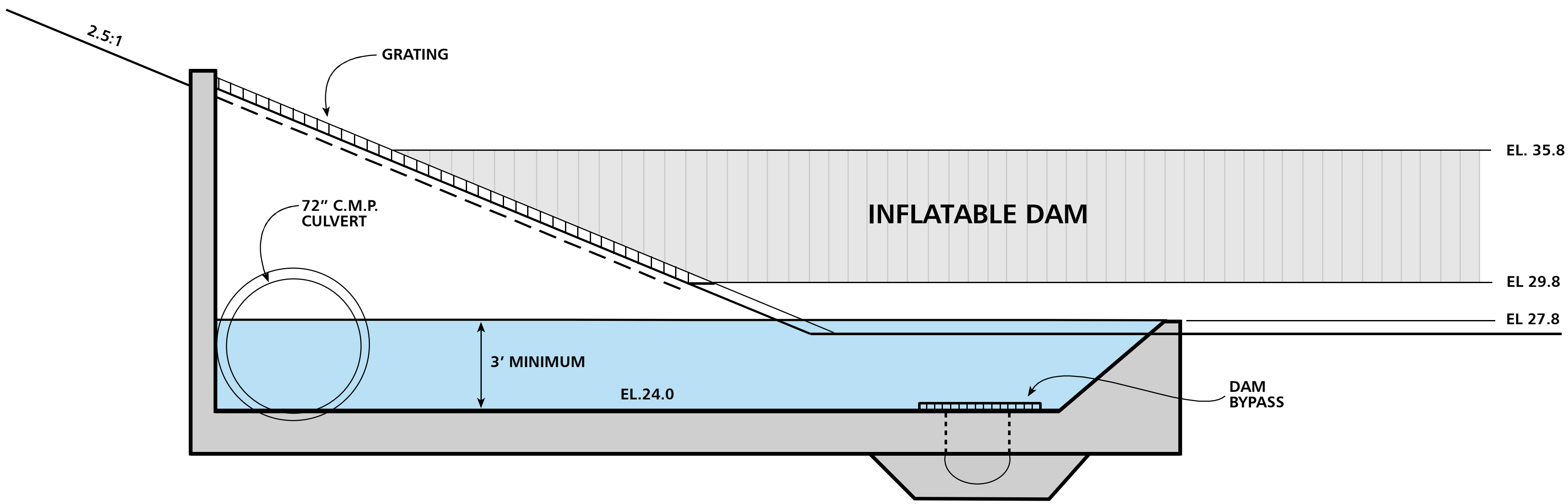


Figure 2-Elevation

Proposed Fishway at the Lower Inflatable Dam

Alameda Creek Fish Passage

CH2MHILL



SECTION A-A

Figure 3-Section
Inflatable Dam Ladder Entrance
Alameda Creek Fish Passage

CH2MHILL

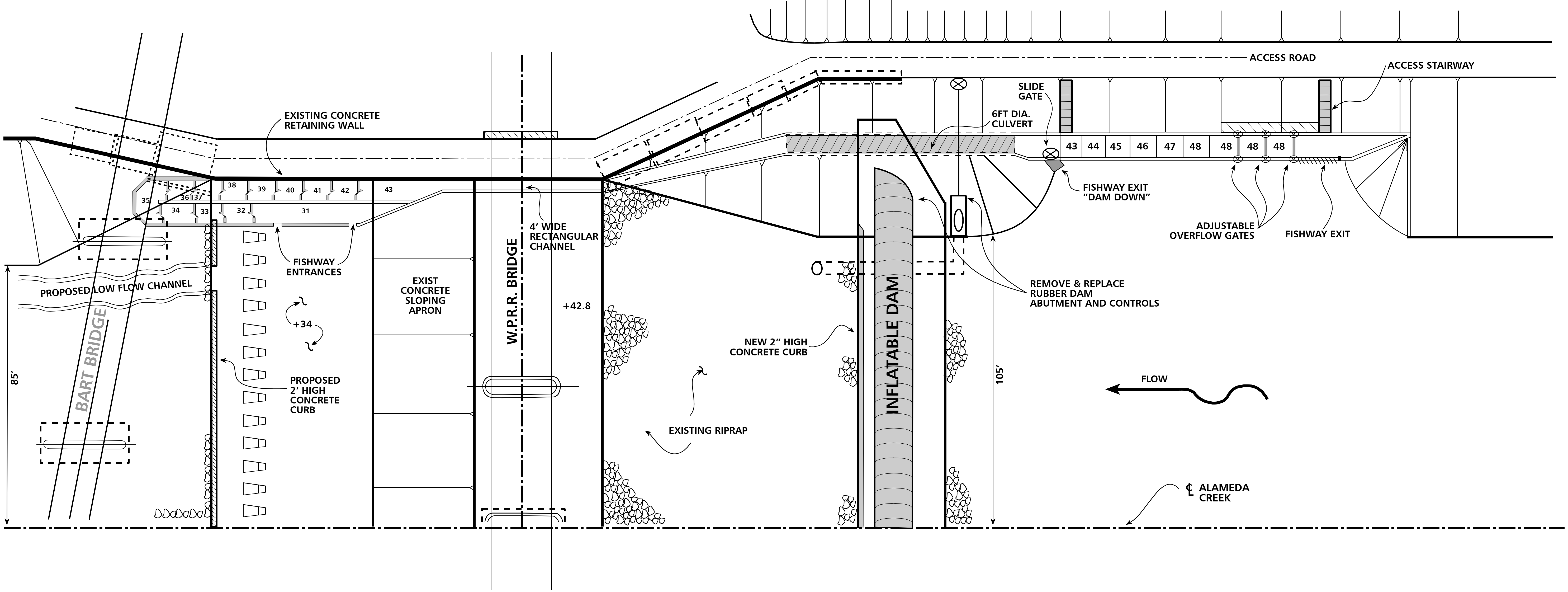


Figure 4-Plan

Proposed Fishway at B.A.R.T. WEIR and Middle Inflatable Dam

Alameda County Water District

CH2MHILL

SAC-W-160108.ZZ.03 Figure 4. 11-21-00 tiffany

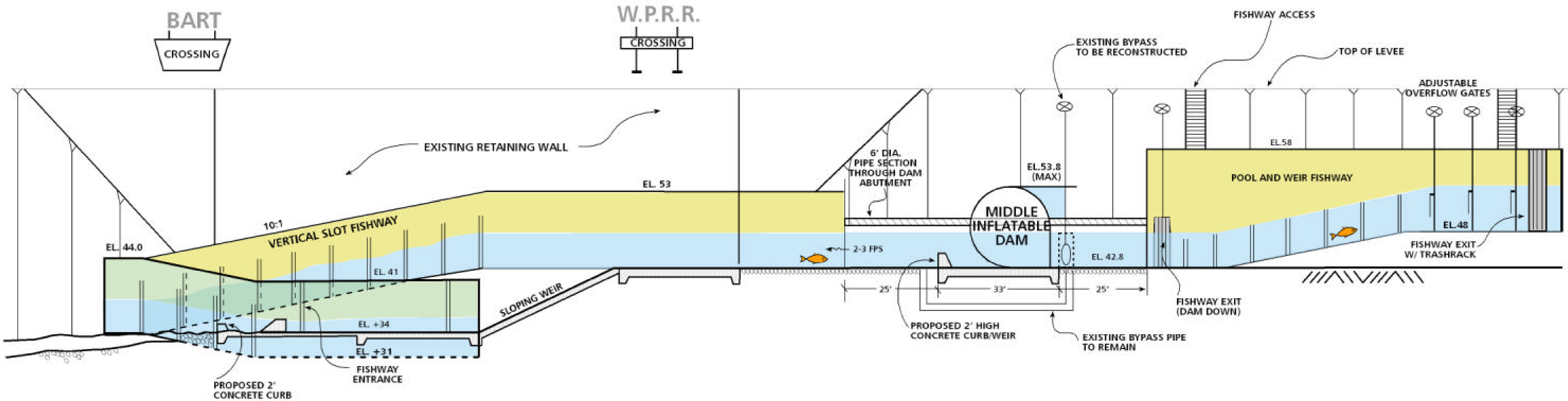


Figure 5-Elevation
Proposed Fishway at BART WEIR and Middle Inflatable Dam
Alameda Creek Fish Passage

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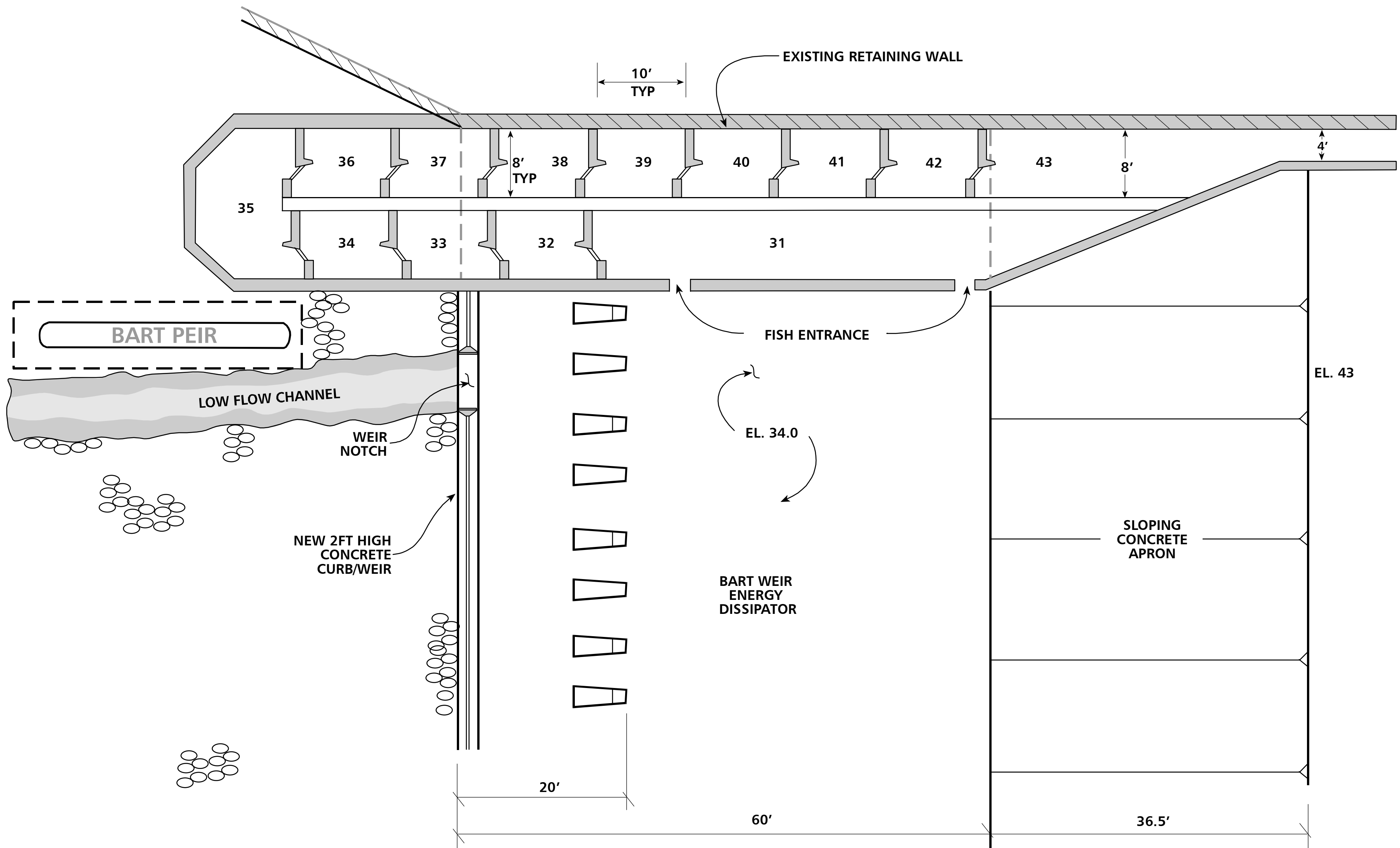

Figure 6-Detail Plan

Proposed Fishway at B.A.R.T. WEIR and MIDDLE Inflatable DAM

Alameda Creek Fish Passage

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SAC-W-160108.ZZ.03 Figure 6. 10-02-00 tiffany

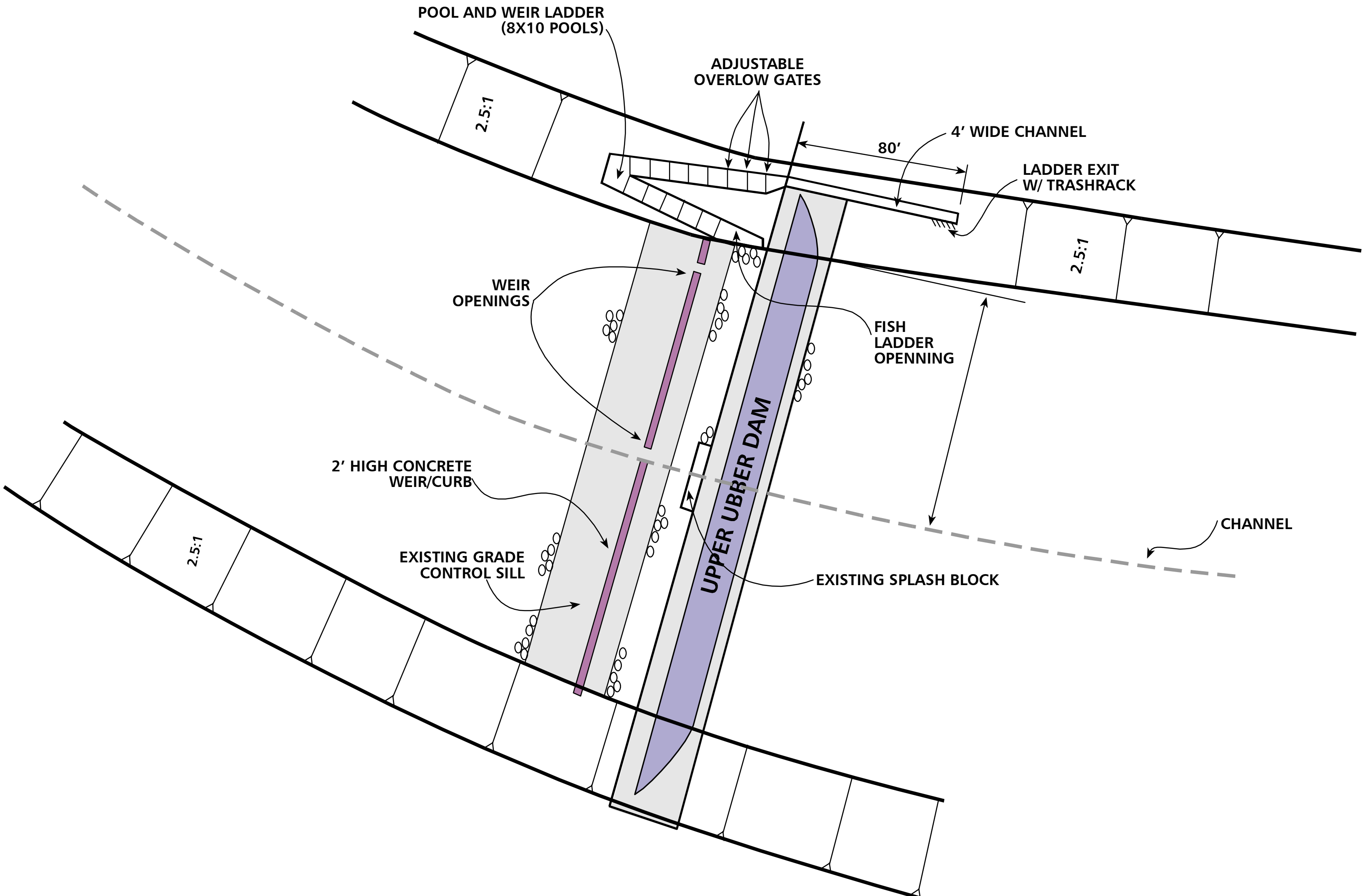

Figure 7-Plan
Proposed Fishway at the Upper Rubber Dam Fish Ladder
Alameda Creek Fish Passage

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SAC-W-160108.ZZ.03 Figure 7. 11-21-00 tiffany

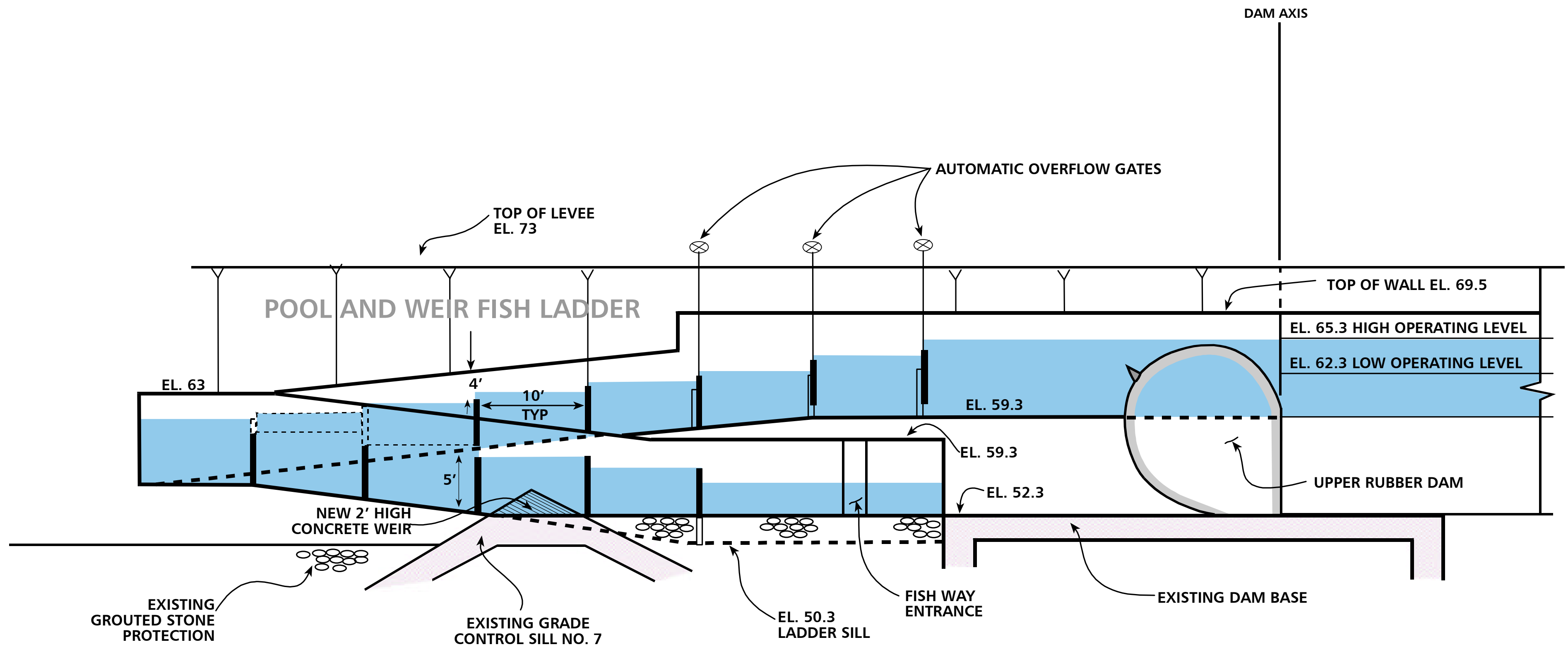

Figure 8-Elevation
Proposed Fishway at Upper Rubber Dam Fish Ladder
Alameda Creek Fish Passage

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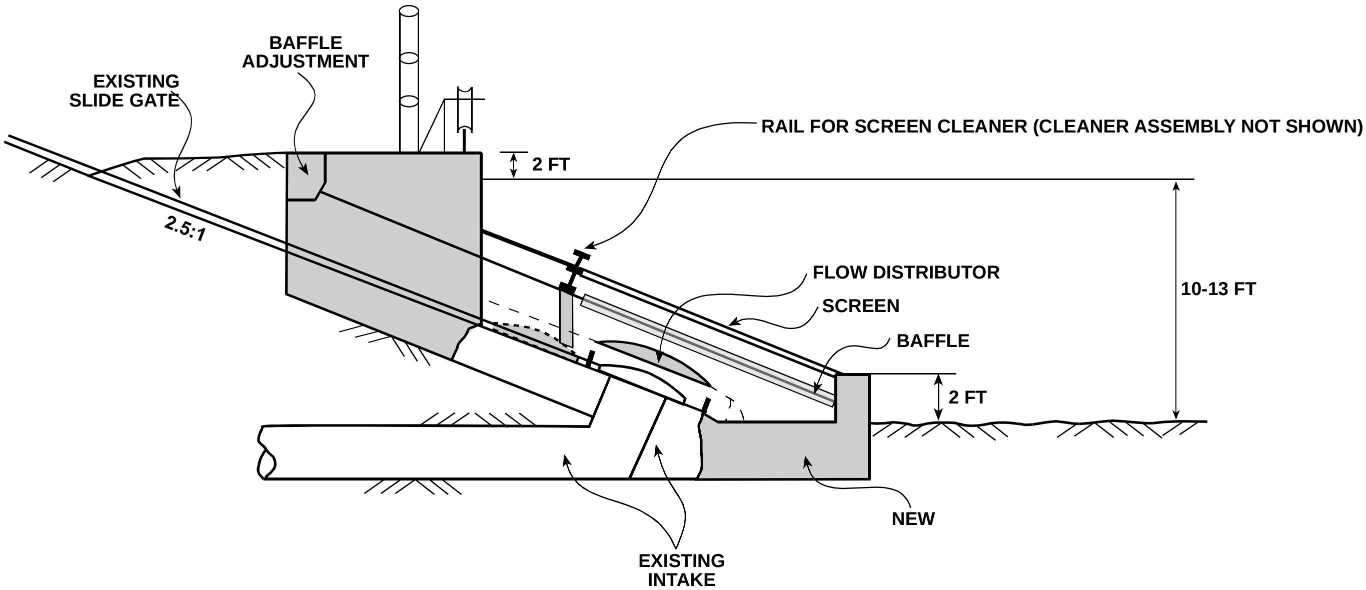
SAC-W-160108.ZZ.03 Figure 8. 10-02-00 tiffany



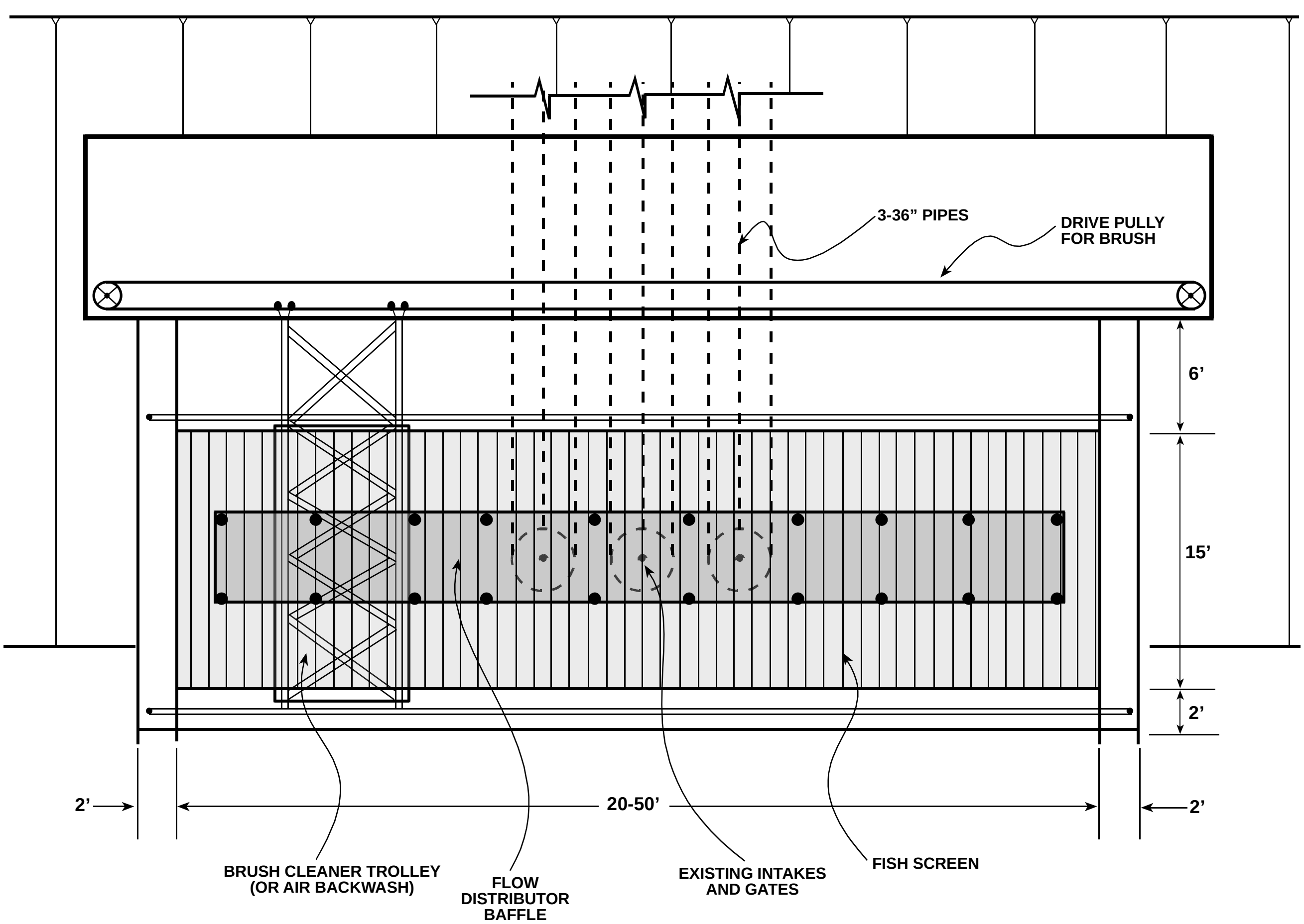


Figure 9
Flat Plate Fish Screen
Alameda Creek Fish Passage

CH2MHILL

SAC-W 160108 Figure 9 11-22-00 tiffany