COUNTY of SAN LUIS OBISPO

Steelhead Passage Feasibility Assessment of Lopez Dam

Feasibility Assessment Report

Final
Revision No. 0

McMillen

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Revision Log

Revision	Date	Revision Description
0	09/26/2025	Final Feasibility Assessment Report

Executive Summary

This Feasibility Assessment Report evaluates engineering solutions to enable volitional fish passage for South-Central California Coast steelhead trout at Lopez Dam. The assessment was conducted to inform the development of a draft Habitat Conservation Plan by the San Luis Obispo Flood Control and Water Conservation District and for review of the same by the National Marine Fisheries Service. Through a collaborative, transparent process involving stakeholders and a structured quantitative evaluation, the report identifies and ranks the feasibility of fish passage alternatives based on technical, biological, operational, environmental, and economic criteria.

Five alternatives, two upstream and three downstream, were evaluated using a detailed scoring matrix across seven categories: Biological Efficiency, Constructability, Operation, Design Approach, Environmental Impact, Regulatory Compliance, and Financial Criteria. Among upstream options, a trap-and-haul system ranked highest, while for downstream passage, in-tributary trap-and-haul facilities located in Lopez Canyon and Wittenberg creeks were found to be most viable. Other alternatives were determined to be infeasible due to dam safety risks, excessive water flow requirements, high costs, or lack of proven performance.

Based on these findings, the report recommends as the most practicable option implementation of a seasonal trap-and-haul system for upstream passage using a picket barrier and trap box. For downstream passage, it is recommended to also use a picket barrier and a trap box seasonally in the two tributaries for at least five years to gather performance data and assess the need for a permanent off-channel trapping system. Although these methods are not volitional, they represent the most feasible and lowest risk options currently available for steelhead trout passage at Lopez Dam that could be incorporated into the ongoing development of the Arroyo Grande Creek Habitat Conservation Plan.

1.0 Introduction

This section presents a summary of the Steelhead Passage Feasibility Assessment of Lopez Dam (Project), including contract authorization, purpose, project understanding, background, and report organization.

1.1 Purpose

The purpose of the Project is to conduct a comprehensive steelhead trout passage feasibility assessment that includes potential engineering solutions to enable volitional passage of the South-Central California Coast (SCCC) Distinct Population Segment (DPS) of steelhead trout (*Oncorhynchus mykiss*) at Lopez Dam, both upstream and downstream.

The purpose of this Feasibility Assessment Report is to summarize the study, analysis of alternatives development, and evaluation. The objective is to conclude with sufficient justification that certain volitional passage options (alternatives) may or may not be feasible or practical. This feasibility assessment is intended to inform and support the conservation strategy for the draft Lopez Water Project Habitat Conservation Plan (HCP), which will be reviewed by the National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (USFWS) pursuant to the Endangered Species Act (ESA) section 10(a)(1)(B) and relevant implementing regulations. The objective is achieved by providing science-based, factual evidence, credible and accurate information in an impartial, transparent, and complete evaluation that includes the collaborative development approach solicited during the development of the report. This report presents the findings from the stakeholder process and a ranked list of recommendations for fish passage alternatives that are based on a quantitative assessment process.

This report does not address, establish, or recommend minimum flow release requirements. Any determination of minimum flow releases, including what is necessary to support SCCC steelhead trout, is expressly outside the scope of this report and is addressed in separate documentation prepared for and by the County of San Luis Obispo (County). Flow values referenced herein are presented solely in the context of evaluating certain fish passage alternatives across Lopez Dam and should not be construed as minimum flow recommendations. To the extent that any such values differ from, or exceed, minimum flow thresholds identified by other parties, those discrepancies are solely the responsibility of the County to resolve. For the avoidance of doubt, nothing in this report shall be construed, cited, or relied upon in litigation or other proceedings as establishing, recommending, or endorsing any minimum flow release requirements.

1.2 Authorization

The County has contracted McMillen, Inc. (McMillen) to provide engineering services to assess the feasibility of providing upstream and downstream passage to steelhead trout at Lopez Dam. The County owns and operates Lopez Dam. The contract was authorized on April 8, 2025. The County's Contract number is 552R235006.

1.3 Standard List of Terms and Abbreviations

ACI	American Concrete Institute
ADM	Aluminum Design Manual
AISC	American Institute of Steel Construction
ANSI	American National Standards Institute
AQMD	Air Quality Management District
ASCE	American Society of Civil Engineers
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society of Testing and Materials
AWS	American Welding Society
AWS	auxiliary water supply
CalOSHA	California Occupational Safety and Health Administration
CARB	California Air Resources Board
CBC	California Building Code
CCOR	California Code of Regulations
CDFW	California Department of Fish and Wildlife
CEQA	California Environmental Quality Act
CESA	California Endangered Species Act
CWA	Clean Water Act
DO	dissolved oxygen
DPS	Distinct Population Segment
DSOD	Division of Safety of Dams
EDF	energy dissipation factor
EL	elevation
ESA	Endangered Species Act

ESU	Evolutionarily Significant Unit
FSC	floating surface collector
ft	feet
ft^3	cubic feet
gpm	gallons per minute
HCP	Habitat Conservation Plan
HDPE	high-density polyethylene
HVAC	heating, ventilation, and air conditioning
IBC	International Building Code
IEEE	Institute of Electrical and Electronic Engineers
IESNA	Illuminating Engineering Society of North America
ISA	Instrument Society of America
ITP	incidental take permit
lbs	pounds
LLO	low-level outlet
mm	millimeter
NACE	National Association of Corrosion Engineers
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NEPA	National Environmental Policy Act
NFPA	National Fire Protection Association
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
O&M	Operations and Maintenance
OCSD	Oceano Community Services District
OSHA	Occupational Safety and Health Administration
PGE	Portland General Electric
PLC	programmable logic controller
PVC	polyvinyl chloride
RWQCB	Regional Water Quality Control Board

SCCC	South-Central California Coast
SEI	Structural Engineering Institute
sf	square feet
SHPO	State Historic Preservation Office
SWPPP	Stormwater Pollution Prevention Plan
T	ton
TM	Technical Memorandum
UL	Underwriters Laboratories
USACE	United States Army Corps of Engineers
USACE Ems	United States Army Corps of Engineers Engineer Manuals
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WMP	Watershed Master Plan

1.4 Background

Lopez Dam has been identified as an impassable barrier on the Arroyo Grande Creek, blocking passage for the SCCC steelhead trout. The SCCC steelhead trout was originally listed in 1997 as threatened under the NMFS Evolutionarily Significant Unit (ESU) policy. The listing was reaffirmed in 2006 under the DPS policy. The SCCC steelhead trout are now listed as threatened under the Endangered Species Act (i.e., ESA listed). NMFS identified SCCC steelhead trout in Arroyo Grande Creek as a "Core 1" population in the agency's 2013 Recovery Plan (NMFS 2013). Nearly 40% of the populations in the DPS were designated by NMFS as Core 1. NMFS explained Core 1 populations are the highest priority for recovery based on a variety of factors. NMFS included Arroyo Grande Creek downstream of Lopez Dam and Los Berros Creek in the area designated as critical habitat for the SCCC steelhead trout in 2005 (NMFS 2005; 70 FR 52488).

In the 2000s, the County completed the Lopez Dam seismic remediation project that included changes to the dam and outlet works. The necessary permits and authorizations were obtained, including a permit from the U.S. Army Corps of Engineers and biological opinions from NMFS and the U.S. Fish and Wildlife Service. In Figure 1-5, the cross section of the downstream face shows the seismic retrofit.

Lopez Dam is a vitally important element of water infrastructure for the communities in the County. Its primary purpose is to provide drinking water supply for 50,000 residents. Its ancillary benefits are flood protection for both residences and agricultural lands, groundwater recharge, and recreational opportunities. The dam has been and continues to be a critical infrastructure component for Arroyo Grande Creek and the surrounding communities. Fish passage solutions would need to preserve these functions. The SCCC steelhead trout in Arroyo Grande Creek currently cannot access upstream rearing and spawning habitats. Lopez Dam affects both upstream and downstream migration.

NMFS has asked the County to assess fish passage at Lopez Dam while in the process of developing an HCP. NMFS has communicated that “mechanistic solutions to fish passage impediments can be problematic for a variety of reasons, including: the limitations in the operations during high flows when fish are most likely to be migrating; periodic mechanical failures which result in migration delays, or lost migration opportunities; and the expense of personnel and equipment to maintain such operations” (NMFS 2013, p. 7-9). The County has therefore requested that McMillen assess volitional fish passage feasibility at Lopez Dam.

1.5 Location

The Arroyo Grande Creek Watershed is on the Central California Coast in an arid region with highly variable rainfall and stormwater runoff (Stetson Engineering, Inc. 2004). The watershed is located in southern San Luis Obispo County (Figure 1-1). The watershed also supports permanent agricultural crops (e.g., citrus orchards, vineyards, ranches, and low crops) and seasonal row crops (Stetson Engineering, Inc. 2004). Lopez Dam and Reservoir provide water supply for agricultural and municipal needs by storing stormwater runoff during the winter and early spring and providing managed releases throughout the year to meet downstream demands. Additionally, diversions from the reservoir through a 3-mile pipeline to a water treatment plant provide treated water to the Arroyo Grande, Pismo Beach, Grover Beach, Oceano Community Services District (OCSD), and County Service Area 12 (CSA 12). Each year, 4,530 acre feet (AF) is delivered to the water treatment plant. The watershed drainage rises to a maximum elevation (EL) of approximately 3,100 feet above sea level. Arroyo Grande Creek empties into the Arroyo Grande Lagoon.

Figure 1-1. Arroyo Grande Watershed and Location of Lopez Dam in the San Luis Obispo County, California (Source: County of San Luis Obispo)

1.6 Existing Project Description

Lopez Dam is a zoned earthfill dam constructed in 1968. The dam is 1,120 feet long and has a vertical height of 168.2 feet measured from the crest (EL 538.6[1] min.) to the outlet pipe invert, EL 370.4 on the river side. The dam crest is 40 feet wide and is used as a roadway (Lopez Drive) to connect the town to the southwest to the Lopez Lake Recreation Area.

The dam retains water using a compacted clay core and a cutoff trench keyed into bedrock. The core has a minimum width of 25 feet, and the cutoff trench is keyed in a minimum of 10 vertical feet. The core is buttressed by a compacted sandy gravel layer on the upstream side and a compacted random zone on the downstream side. The dam employs a 10-foot-wide filter zone on both sides of the core, and a 10-foot-wide gravel drain on the downstream side of the core. The gravel drain extends from the core to the downstream toe of the dam where it outlets to a riprap-lined collection area and is conveyed away from the dam. Abutment drainpipes are used to convey seepage along the foundation of the dam to the riprap-lined toe collection area. The upstream portion of the dam is overlayed with a 20-foot-thick layer of

[1] All elevations are in imperial measurements, i.e., feet and NAVD 88.

tuffite (i.e., volcaniclastic) rock and a 10-foot-thick layer of graded tuffite rock for erosion protection. The dam slope is at 3H:1V on both sides of the dam and is benched at EL 450 with an outward slope of 0.05 ft/ft. The bench on the reservoir side is 100 feet long, while the bench on the downstream side is 120 feet long.

Lopez Dam utilizes a concrete spillway to pass storm flows and is equipped with a side channel ogee weir at crest EL 522.6. The spillway chute is linear, and it terminates with a 16-degree launch angle flip bucket with an invert at EL 387.6 to dissipate the flow energy from the spillway. The dam also includes an intake control building, a 42-inch welded steel pipe encased in concrete, an outlet control building (i.e., outlet works), and other appurtenances. The intake structure includes seven inlets that are each connected to a common header at 45 degrees. The inlets are approximately 15 feet apart vertically, and each is equipped with a trashrack and a fish screen. The fish screens have openings of approximately 10 inches by 12 inches, larger than the trashrack openings of 1/2-inch bar at 4 inches on center. We note that this information does not seem correct because the screen should have smaller openings than the trashrack openings. This information is from the 1967 as-builts drawings (sheet 28 of 57). McMillen does not know if the screens have been updated since to meet NMFS and CDFW requirements. The fish screen and the trashrack are both hot-dip galvanized. Figure 1-2 through Figure 1-5 present an overview of Lopez Dam.

During upstream migration (December 1 to May 1), water levels in Lopez Reservoir can fluctuate by up to 69.3 feet. During downstream migration (February 15 to June 15), fluctuations of up to 62 feet can occur. Both represent significant variations.

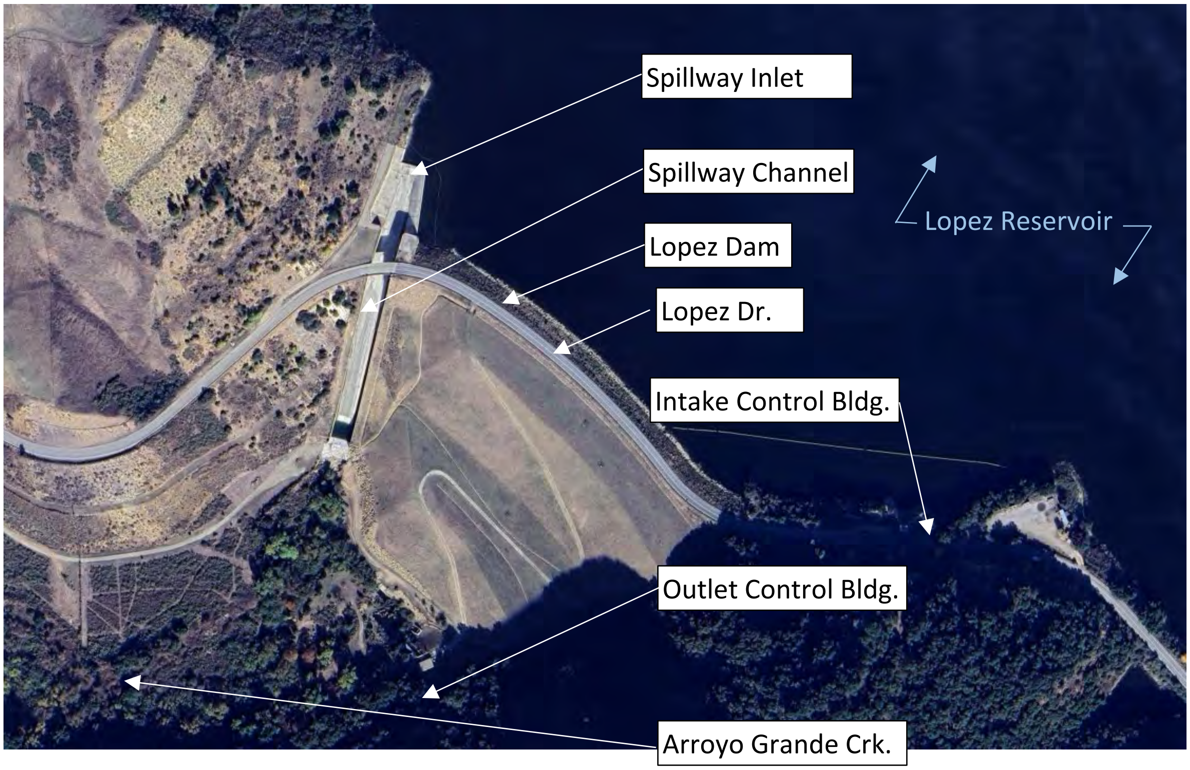


Figure 1-2. Lopez Dam Overview (Source: Google Earth)

Figure 1-3. Lopez Dam on Arroyo Grande Creek, San Luis Obispo County (Source: ForestWatch)

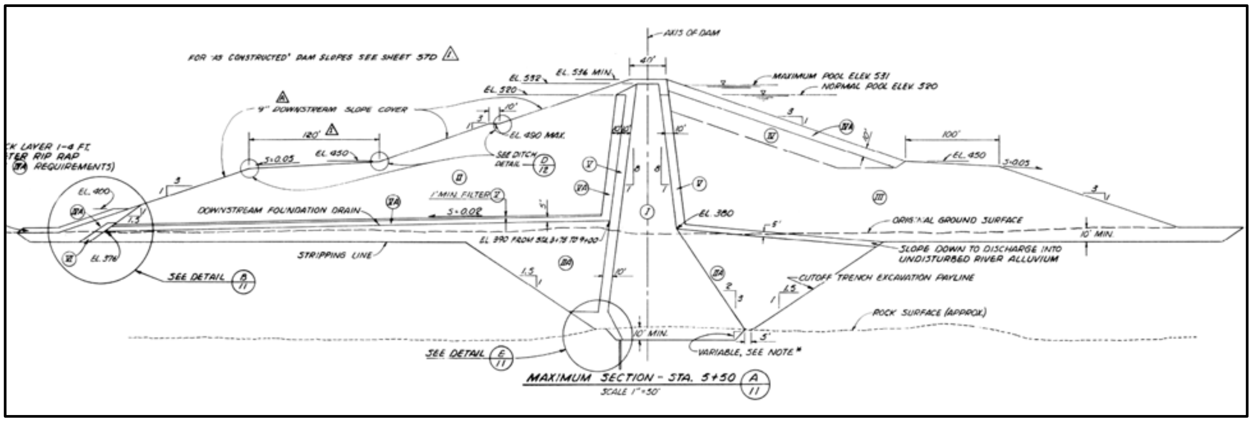


Figure 1-4. Cross Section through Lopez Dam (Source: Koebig & Koebig, Inc. 1967)

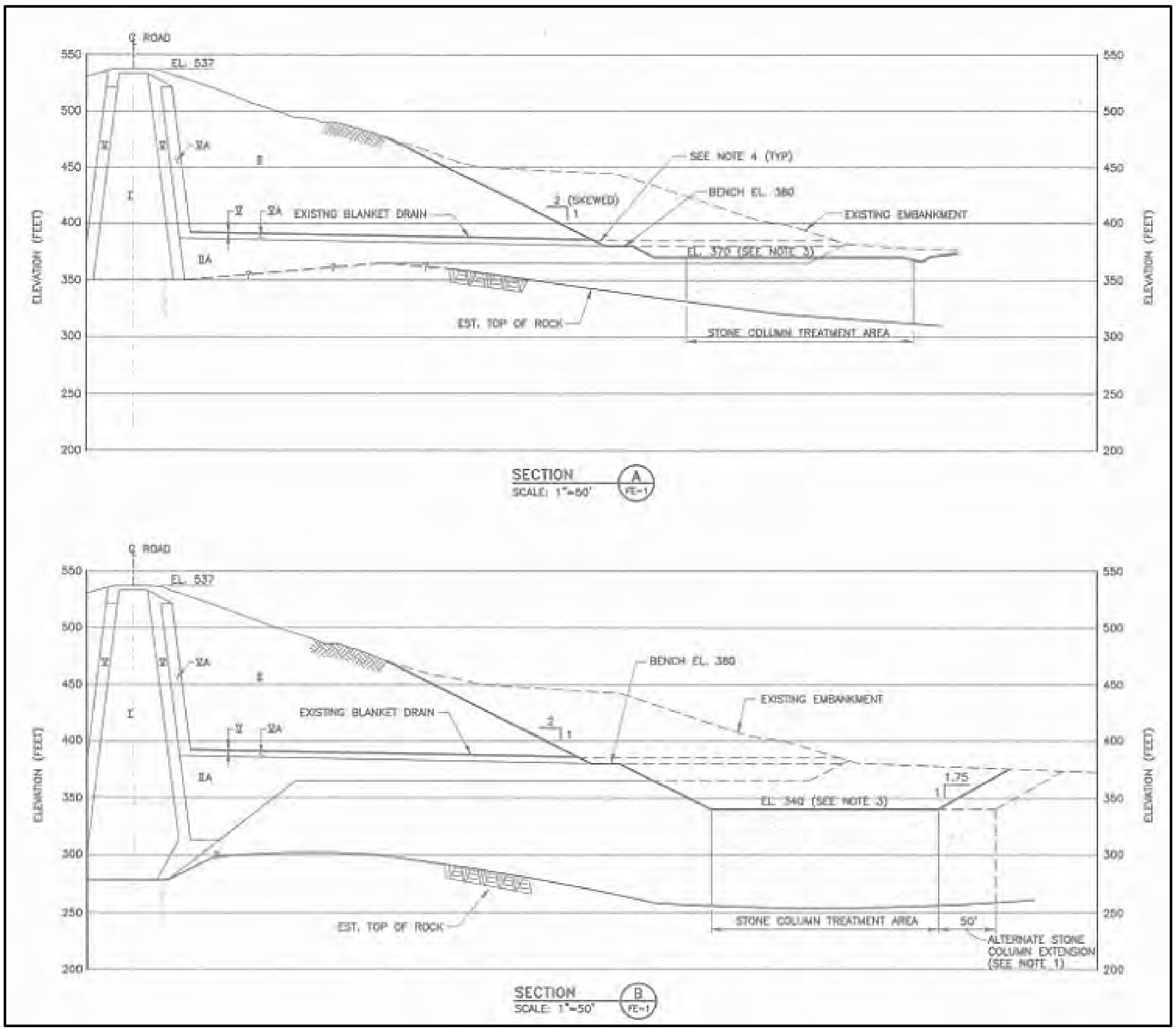


Figure 1-5. Cross Sections of the Downstream Face Showing Seismic Retrofit (Source: URS 2000)

1.7 Report Organization

The major report sections and intended purpose of each are presented in Table 1-1.

Table 1-1. Feasibility Assessment Report Organization

Section	Description	Purpose
1	Introduction	Summarizes the Project authorization, background, existing conditions, purpose, and scope.
2	Design Criteria	Presents the pertinent data and design criteria that are used in the analysis and alternatives development.
3	Initial Screening	Presents upstream and downstream fish passage options that were selected through a collaborative process, which are presented in Appendix B. The limitations of volitional and nature-like fishways, and a summary of options are presented in this section as well.
4	Alternatives Development	Outlines the approach to developing the alternatives and presents a succinct description of each alternative selected for the advancement. For those alternatives being advanced and developed, conceptual drawings were prepared (Appendix C), H&H calculations were performed and documented (Appendix D; Task 2), and an opinion of probable construction cost, Class 5 estimates per the AACE, were developed (Appendix E).
5	Alternatives Evaluation	Presents the evaluation criteria and the findings/evaluation of each alternative that were selected following the initial screening. This section presents the ranking of the alternatives.
6	Conclusion and Recommendations	Presents the conclusions of the alternatives evaluation and McMillen's recommendations.
7	References	Documents the references used in developing this report.
Appendices		
A	TM002 - Design Criteria	Presents the design criteria for the Project.
B	TM003 - Fish Passage Alternatives Pre-Screening Evaluation	Presents the fish upstream and downstream passage options, a pre-screening evaluation, and selection of alternatives to develop. The Evaluation Matrix is in this TM as well.
C	Conceptual Drawings	Presents drawings illustrating the basic conceptual level details (plan and section) of each alternative advanced.
D	Hydrology and Hydraulics Calculations	Presents H&H calculations supporting the conceptual alternatives design development and evaluation.

Section	Description	Purpose
E	Engineering Cost Estimates	Summarizes the Class 5 Construction cost estimates and the Operation and Maintenance estimates prepared for the alternative's evaluation.
F	County and TAC Coordination Meeting Minutes	Meeting documentation with the County and Interagency Technical Advisory Committee (TAC).

2.0 Design Criteria

The design criteria pertinent to the Project have been developed and are documented in Appendix A. The design criteria technical memorandum (TM) 002 (McMillen, Inc. 2025a) includes biological, hydraulic, hydrologic, and engineering criteria that have been used to develop the design.

TM 002 incorporates the most current fish passage criteria issued by NMFS and the California Department of Fish and Wildlife (CDFW), which are commonly applied in the planning and development of fish passage facilities. The TM further references applicable state and federal engineering standards governing the design and construction of water-retaining structures.

The objective of the TM was to collectively establish project-related design criteria with the Project stakeholders. To this end, the design criteria were developed early in the process and were distributed across the Project's team to solicit input and obtain agreement from stakeholders at the Project onset.

3.0 Initial Screening

Technical memorandum 003 (McMillen 2025b) (Appendix B) tabulated all known upstream and downstream fish passage options, regardless of feasibility. For each option, the TM presented a high-level evaluation (i.e., pre-screening assessment), documented pros and cons, and provided a recommendation to advance or not advance, together with a justification. This information was reviewed during a workshop with the County to gain agreement on options to bring to a conceptual level.

This step was necessary to limit re-work and to provide rational reasons why an alternative had not been recommended to be advanced. In addition, the TM presented the fish passage evaluation criteria and Evaluation Matrix that will be applied to the alternatives selected for advancement to the next level of development and evaluation.

This section presents the list of upstream and downstream fish passage options that were selected to advance through this collaborative process. The details and reasoning for each selection are presented in Appendix B.

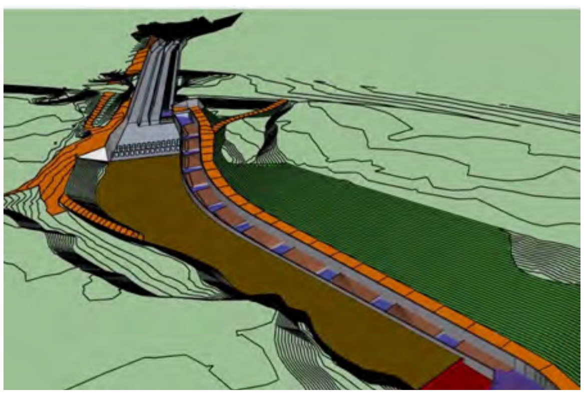
3.1 Volitional Definition and Limitation

The term “volitional” is generally understood to mean that fish have the ability to pass upstream or downstream of their own will, at their own pace, when they desire, with no human interference. Nature-like fishways are generally understood to be volitional, while “technical” fishways can either be volitional or not, depending on if they connect the tailrace to the reservoir hydraulically.

Table 3-1 presents examples of volitional fish passage to provide a visual description of designed and built (or pending construction) projects that include volitional fish passage.

Table 3-1. Volitional Fish Passage Examples

Photo	Description	Total Head; Reservoir Fluctuation (ft)
	Howland Fish Bypass Channel, Piscataquis River, Maine, USA (Source: The Nature Conservancy)	21; ~2
	Nature-like fishway constructed on the Cariboo Dam located on the Brunette River, for Metro Vancouver (Source: NHC)	9; <1
	Nature-like fishway planned for Okanagan Lake Outlet Dam East Salmon Passage, British Columbia (Source: Okanagan Nation Alliance)	<9; <1

Photo	Description	Total Head; Reservoir Fluctuation (ft)
	Opal Springs Volitional Fish Passage, Crooked River, Oregon. vertical slot	30; <3
	Trabuco Creek chute and pool roughened channel fishway across I-5 bridge array – pending construction of a 650-foot-long bypass chute and pool connected to 675-foot transport channel (Source: Caltrout)	N/A; not a reservoir but an instream fishway

In addition, for a volitional system to work effectively (i.e., safe, timely, and effective) within its operational range, the fishway needs to have minimum water level fluctuation in the tailrace and/or reservoir. In other words, it needs stable conditions.

When feasible, volitional passage facilities are preferred (NMFS 2023a, p. 46). Nature-like fishways are typically preferred, when feasible, because they provide volitional passage both upstream and downstream, can provide habitat for multiple aquatic species, and are aesthetically pleasing. Yet, there is a need to also balance client commitments, financial constraints, and fish population recovery goals.

Some of the limitations for volitional and nature-like fishways follow below. While these limitations are known, the list of fish passage options described in this report was purposefully broad and comprehensive in order to provide transparency and a fulsome analysis.

- **Hydraulic connectivity:** There is a risk of losing hydraulic connectivity when the tailrace and/or reservoir have large water level fluctuations. This is because there will be either no water supply at low reservoir levels (i.e., loss of hydraulic connectivity that causes an area to dry up, potentially stranding aquatic species) or too much flow at high reservoir levels that would potentially destabilize the channel structure and create a significant dam safety risk.
- **Reservoir fluctuation and maximum average channel velocity:** NMFS recommends the maximum average channel velocity to be no greater than 5 ft/s (1.5 m/s), regardless of channel slope, in a nature-like fishway (NMFS 2023a). Reservoir fluctuation greatly impacts the average channel velocity, allowing only for a very limited fluctuation level (e.g., ~2 feet), if not using exit pools. Change in reservoir operation would either be so constrictive that Lopez Dam would lose its primary function of providing drinking water or not sufficient enough to make a nature-like fishway function as intended.
- **Dam height:** A nature-like fishway works best when the dam height is less than or equal to 10 feet (3 m) (CETMEF 2008).
- **Exit pool structure:** There needs to be an exit pool structure that includes a large number of gated exit pools to address the fluctuation in the reservoir. Each gate would be operated individually within a bandwidth, and a gate would need to close and then open the adjacent gate when the water level fluctuates out of a gate's bandwidth. The largest constructed exit pool structure known is the Clackamas River North Fork Dam Fishway located in Oregon and operated by Portland General Electric; the pool structure includes 20 exit pools. Note that this exit pool structure is no longer in operation over the full reservoir fluctuation of 20 feet due to a change in reservoir operation.
- **Dam safety:** The fishway needs to be sized for the low reservoir level, necessitating the need for a dam penetration (transport channel) that could result in dam safety risks. See the summary in Section 4.1.1.2.
- **Ambient light and closure gates:** The penetration (transport channel) would need to be large enough to allow ambient light to not limit fish passage. The large tunnel or open trench would need to be regulated with closure gates.
- **Sediment mobilization:** Nature-like fishways work best when connecting to either a small reservoir with limited water level fluctuation or when connecting upstream of the head pool. The reason is that the fishway would then behave similarly to its adjoining reaches, which would allow sediment movement. However, the Lopez Reservoir behaves as a sediment trap which would then limit the ability of the nature-like fishway to aggrade sediment at the rate of sediment erosion. This in itself would require long-term maintenance and an annual sediment augmentation plan.

3.2 Fish Passage Options

The following presents the options selected for advancement following the pre-screening evaluation for upstream and for downstream fish passage. These options are further developed in Section 4.0 of this report.

Upstream fish passage:

- Vertical slot fishway
- Trap-and-haul facility

Downstream fish passage:

- Floating surface collector
- Helical fish passage system
- In-tributaries trap-and-haul facility

4.0 Alternatives Development

This section presents the development of each alternative selected for advancement.

4.1 Upstream Fish Passage

This section presents a description of the two upstream fish passage options selected for further development:

- Vertical slot fishway
- Trap-and-haul facility

4.1.1 Vertical Slot Fishway

This alternative would be a technical pool-type fishway utilizing vertical slots, dam penetration, and an exit pool structure with a series of gated exit pools. The vertical slot ladder would lead from the tailrace to a transport channel through the dam. The transport channel would connect to an exit pool structure. To accommodate the full reservoir variation between the maximum normal reservoir level and minimum normal reservoir level during the upstream fish passage period of December 1 through May 1 (i.e., low and high reservoir levels are 526.6 ft and 457.3 ft, respectively), 70 exit pools would be needed to address the 69.3 feet of vertical variation. The fishway known to have the most exit pools in the world, the Clackamas River North Fork Dam Fishway on the Clackamas River, has 20 exit pools and is no longer in operation. The fishway known to be in operation with the second most exit pools is the Soda Springs fishway, on the North Umpqua River, with 14 exit pools. Both fishways are located in Oregon and have significantly fewer pools than would be required for this design.

To make this alternative viable and to reduce the number of exit pools, it is necessary to narrow the operational range. This is because each exit pool needs to be equipped with a slide gate that must open at a specific reservoir level while all other gates remain closed. To achieve this level-specific control, each slide gate must be motorized and rely on accurate level sensors both inside and outside the fishway pools. All components must function in coordination through a programmable logic controller (PLC) to ensure reliable operation. However, the large number of mechanical and electrical components would significantly increase the risk of equipment failure. Such failures could not only compromise the performance of the fishway but also lead to uncontrolled water releases; though, the occurrence of this risk is considered rare.

Although the lower gates are not designed as low-level outlets (LLOs), they would function similar to LLOs at full reservoir conditions and therefore carry similar risks. As such, they would require periodic inspections, typically every five years, consistent with LLO safety protocols. This risk is identified as it would require review and approval from California Division of Safety of Dams (DSOD).

Upstream migration typically follows a bell-curve pattern rather than a linear one, with the majority of fish migrating during a concentrated window, preceded by a few early arrivals and followed by late stragglers. Therefore, if alternative development efforts concentrate on the peak migration period (between January 1 and March 31) and consider that the bar at Arroyo Grande Lagoon is usually closed in April (restricting upstream fish passage), the operational window could be shortened. In addition, assuming fish passage would be ineffective during extreme dry and wet years, the reduced operational window appears feasible by accommodating a vertical variation of 24.5 feet (from 488.0 ft to 512.4 ft). This would require 25 gated exit pools versus the 70 presented above. The corresponding volume over the 3-month period is approximately 13,564 acre-feet; though, the reservoir would remain available for recharge during that time.

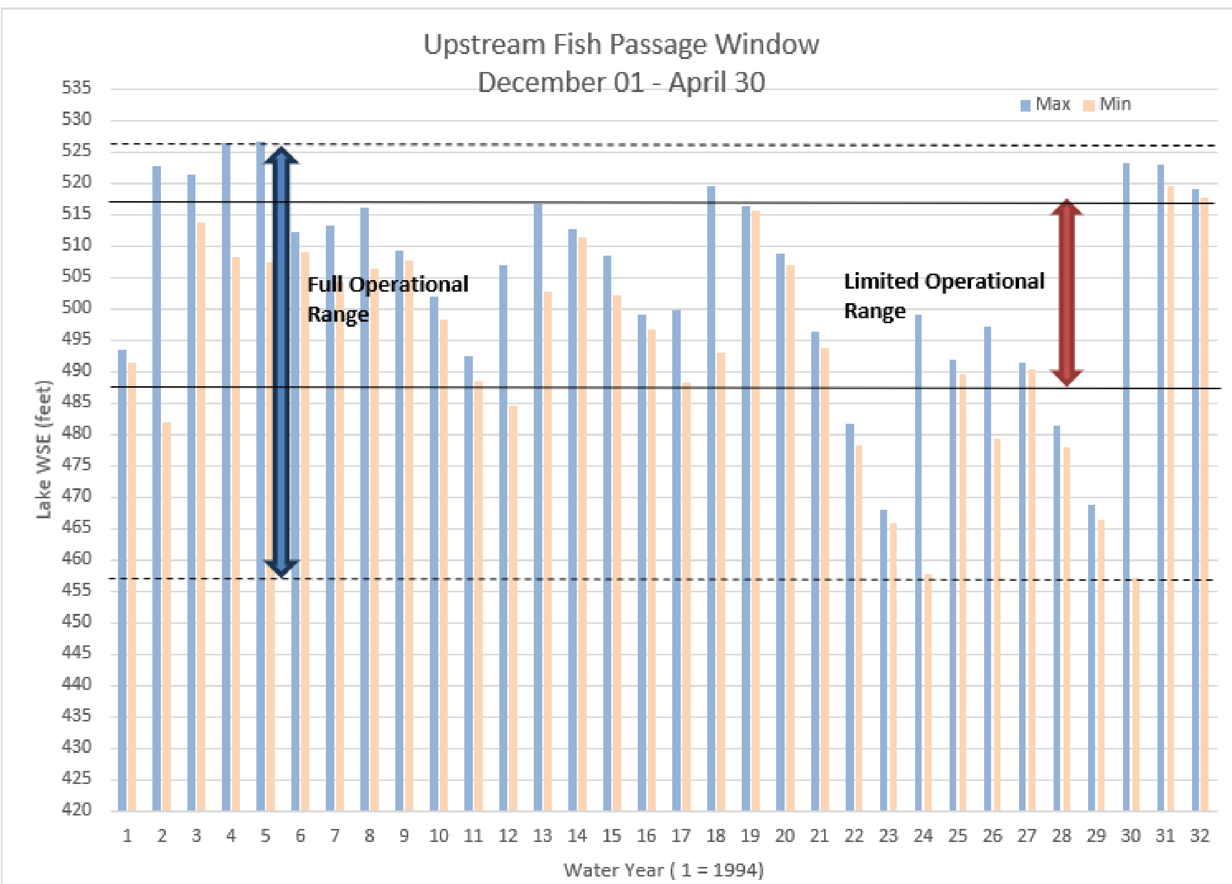


Figure 4-1. Proposed Upstream Fishway Operational Range During Upstream Migration

Creating operational limitation does not necessarily mean that there will be an impact to the reservoir operation. The following scenarios have potential limitation impacts that need to be considered by the County:

- **Scenario 1:** Fishway is fully operational during January 1 to March 31 passage window. The reservoir water level would need to be managed differently as the water level fluctuation would be capped. This would allow upstream passage, but there may be other implications. The limitation in operation would also depend on hydrology, so upstream passage is not truly guaranteed within this scenario. For example, drought conditions where the reservoir could not be kept high enough would impact operability of the fishway; conversely, a wetter year may reduce the duration of time the fishway would be operational because it may be optimal to fill the reservoir above the high operational limit of 512.4 feet.
- **Scenario 2:** Not limiting reservoir operation but understanding that the fishway can only be operational while having the reservoir within a specific bandwidth. Outside of that bandwidth, the fishway could continue operating within a plus/minus 18 inches outside of the criteria and with reduced efficiency. Beyond that bandwidth, the fishway would need to be turned off. This would allow the operator to continue to operate the reservoir as required for drinking water storage, with fish passage provided when the conditions are favorable.

Therefore, it is important to note that the fishway operational limitation does not necessarily limit the operation of the reservoir. The reservoir could continue to be operated as per the current operating procedure. It could be possible to reduce the operation as presented above from 488.0 feet to 512.4 feet, if required to keep the full operation range.

This alternative includes different major components such as a fish ladder, transport channel, and exit pools (Figures 1 and 2 in Appendix C). The following sections present each component in greater detail.

4.1.1.1 Fish Ladder

The fishway is sized following the minimum pool dimensions and energy dissipation factor as presented in McMillen (2025a) TM002. The fishway would be a conventional vertical slot ladder without an auxiliary water supply (AWS) flow. It would have 148 pools, 25 of which would be exit pools (located upstream of the dam in the reservoir, with a total length of 260 feet). It is important to note that some of the largest fishways generally have a maximum of 120 pools. The first 123 pools would be located downstream of the dam, with a total length of 1,297 feet. The vertical slot ladder would have a slot width of 9 inches and no sill within the slot. The sill would make it difficult to maintain the fishway, it would limit fish passage upstream, and limit the ability of the fish to descend the fishway if the water supply to the fishway was lost, which could result in fish kill. This is especially true considering that the sill would be abnormally tall (4.25 feet tall versus the average water depth of 5.5 feet) and would be required to decrease the fishway flow to 7.9 cfs (maximum low flow). Instead, the fishway is sized for standard operation to determine the expected flow rate of the fishway. The fishway flow rate would be 27.1 cfs.

Fish ladders are often used with AWS systems to increase the attraction flow (attraction potential of fish from the tailrace into the fishway). However, because the outflow at Lopez Dam is highly regulated and generally flows are at approximately 5.9 to 7.9 cfs during the fish passage window, AWS flow is not technically required at this site as the ladder flow alone would match the river flow. The ladder flow was calculated to be 27.1 cfs (without a sill or 7.9 cfs with a 4.25-foot-tall sill). Since AWS flow is not used for this alternative, the entrance pool would be a typical ladder pool.

A key design factor for fish ladders is handling fluctuating tailwater levels. To manage this, entrance pools often include a gate to regulate head, and some sites require multiple entrances. At Lopez Dam, however, tailrace levels are stable during the fish passage window, varying by only 8 inches (see Figure 4-2). Therefore, a single orifice entrance with a slide gate is assumed. The gate would mainly serve isolation and maintenance functions, operating either fully open or closed—not for regulating flow or head.

The top of the entrance orifice would sit about 4 inches below the minimum tailwater elevation to maintain submergence and streaming flow, which is preferred over plunging flow to avoid fish injury and poor passage conditions. While not its primary function, the gate could be used to increase velocity at the entrance to deter invasive species. The fishway should allow adjustment of the entrance hydraulic drop between 6 inches and 2 feet, as higher drops can limit passage for some species.

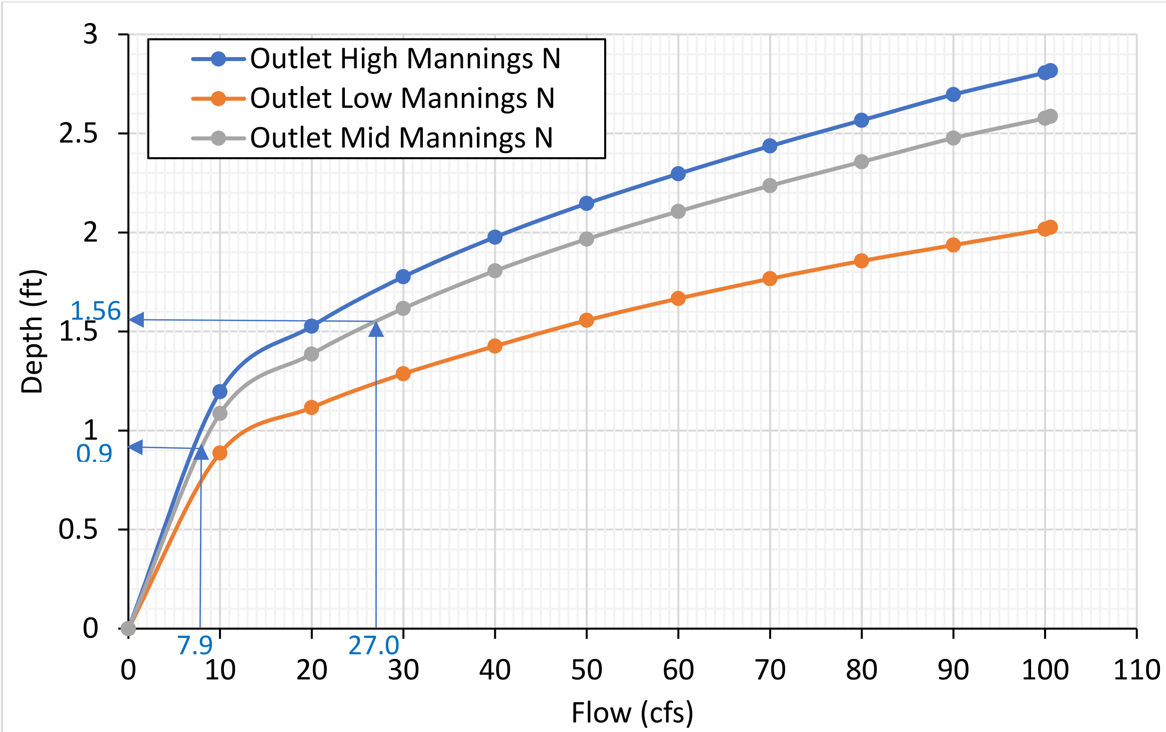


Figure 4-2. Tailwater Rating Curve Near the Outlet

The standard pool size would be 10.5 feet wide by 9.66 feet long and have an average water depth of 5.5 feet. The pool volume is directly dependent on the fishway flow and the hydraulic drop per pool to meet the energy dissipation factor (EDF). For the Project's target species, SCCC steelhead trout, an EDF of 3.13 ft/lbs/ft^3 was selected, as well as larger pools to accommodate two recirculation zones within a pool, which favors resting and thus overall passage efficiency (Wang et al. 2010), especially because this ladder would become one of the longest in the world.

4.1.1.2 Transport Channel

Between Pool 123 and Pool 124, a transport channel would be provided to connect the upstream to the downstream side of the dam. The transport channel would be approximately 640 feet in length with a very gentle slope of 0.03%. To mitigate the lack of ambient light, artificial underwater light could be used. The invert of the penetration through the dam would be approximately 57 feet below the dam's crest and pass through the dam core. The location through the dam as shown (Figures 1 and 2 in Appendix C) was chosen to avoid proximity to the right abutment where the spillway is located, avoid proximity to the left abutment where the intake is located, and to avoid where prior seepage and apparent dissolution of materials was observed, monitored, and remedied through grout curtain injection and extension

(Woodward-Clyde Consultants 1992). The penetration location is also based on the need to locate 25 exit pools in the forebay.

The water depth would be 3 feet. The transport channel would either be a concrete culvert 6 feet tall by 4 feet wide or an HDPE pipe that would be 48 inches in diameter. The material selection would be dependent on the construction method and stability and seepage evaluations. Because the conduit would penetrate the dam, the size of the transport channel would have to be such that the water would not flow in an open channel (which is preferred) and that the pipe would not be pressurized. An observation port or ambient light (or electric light) would not be provided.

An isolation gate would need to be installed just downstream of the exit pool structure. The gate would be a slide gate that is large enough to accommodate the transport channel opening and sized for approximately 52 feet of hydrostatic head.

The following constructability and design concerns to the earthfill dam are to be considered in the alternative evaluation (i.e., dam safety concerns):

- Known prior seepage on the left abutment of the dam. While this was remedied in 1992, any new penetration could create new seepage routes. This would need to be carefully studied and documented with DSOD.
- To stabilize soils during excavation, temporary excavation support would be required. Temporary soil anchors should not be allowed to penetrate the earthfill dam due to the potential risk of fracturing the dam core during the drilling and grouting of the anchors. Other means of soil stabilization would require consideration.
- Some ground movements could occur during excavation. These ground movements, even small, may adversely affect the dam core (e.g., reduction in lateral stress, increased potential for internal erosion, etc.). These changes have the potential to destabilize the dam.
- The transport channel would require seepage and internal erosion mitigation along its outside walls. A grout curtain or a sheet pile wall could be used to minimize seepage, but its installation could negatively impact the dam current configuration.
- The addition of the transport channel could reduce lateral support/stiffness of the dam for both static and seismic loading conditions.
- During or following an earthquake, the exit pool structure gates and the isolation gate may jam or incur operational failure which could lead to an uncontrolled release of the reservoir. Consideration should be given to mechanical solutions such as “fail safe”

operators that close after the loss of main power or by alarm using battery or solar backup.

4.1.1.3 Exit Pool Structure

The exit pool structure would include 25 pools and be approximately 260 feet in length. Each exit pool would have an exit gate (25 total), with all the gates closed apart from the one corresponding to the reservoir level. The gates would be automated and work on level control. They each would have a motor operator at the deck level. The appropriate gate would be open and work within a bandwidth of 1 foot, before closing and having the adjacent gate open and the current one close. Each exit would also be equipped with an isolation gate (25 total). The exit pool structure would be rotated (as shown on Figure 2 in Appendix C) to go along the shoreline. The advantage is to provide vehicular access to each gate for maintenance and operation. Between the exit pool structure and the shoreline, the volume would be filled with structural fill. The top of the exit pool structure would be grated and a handrail provided. The exit pool structure would be located behind the existing log boom to minimize debris accumulation on the fishway exit trashrack. A mechanical rake would not be provided. Access to the trashrack for the higher pools could be completed from the deck; though, access to the lower pools would likely require access from a boat.

4.1.1.4 Capital and O&M Cost Estimate

A Class 5 cost estimate, along with operation and maintenance cost estimates, has been prepared and is provided in Appendix E. All estimates are presented in 2025 dollars. The median construction cost is about $46,614,000 -50%/+100%. The annual O&M cost is about $208,000. The estimated life expectancy of this alternative is 50 years.

4.1.2 Trap-and-Haul Facility

When volitional passage is not feasible, three alternatives could generally be considered for sustaining migratory fish populations: (1) abandon the goal of sustaining migratory fish populations, (2) use below-dam hatcheries to replace the historical contribution of upstream habitats to migratory fish populations, and (3) increase or improve habitat in the rivers below dams (Lusardi and Moyle 2017). Each option has limitations and generally leads to long-term population declines (Lackey et al. 2006; Montgomery 2003). When either one of the three alternatives presented by Lusardi and Moyle are infeasible and not applicable to meet the project goal, a fourth alternative must be considered—providing non-volitional passage. Trap-and-haul systems can provide an engineered alternative to restore aquatic connectivity. These systems involve the physical capture and transport of fish around an obstruction.

Trap-and-haul facilities have many advantages over other fish passage types. The following are some of the advantages:

- Is independent of the size of the dam.
- Is not affected by the reservoir variation.
- Allows a flexible management framework for resource managers.
- Offers passage when other systems fail.
- Provides the ability to move fish upstream of the reservoir, which can decrease predation potential, migration delay, pathogen transmission, and thermal perturbation.
- Provides two-way solutions for resource managers, where both adults and out-migrating juveniles can be captured and transported over dams (Lusardi and Moyle 2017).
- Improves the resilience of fish passages facilities to climate change. For example, trap-and-haul facilities can be used to transport juveniles and adults around river reaches if the stream has insufficient instream flow or warm temperatures, whereas, the natural flow cannot be augmented (NMFS 2022). This advantage may or may not be applied at Lopez Dam dependent on modeled and approved base flows.

Trap-and-haul facilities are, however, not a unique solution, and in fact the term poorly defines the facility's structure and instead only defines its function. The structures can vary greatly in their cost, complexity level, operational need, and construction methodology and schedule. For example, the upstream fish passage can be as simple as a picket barrier spanning the river width that has an in-river trap box (aka, rigid weir):

1. The trap box would get checked daily.
2. A dip net would be used to catch the trapped fish and place them in a 5-gallon bucket of river water.
3. Fish would be transferred to the transport truck using the bucket and placed in the truck.
4. The fish would then be transported using a truck to an upstream release location and released.

In contrast, the upstream fish passage can be a lot more complex:

1. Fish would enter and ascend a technical fishway with multiple entrances that would lead to a pre-sort holding pool.

2. The fish would then be crowded towards a false weir and be distributed using automatic flip gates to sort fish into post-sort holding pools.
3. Fish would then be gathered and transferred to a transport truck using a water-to-water transfer system to minimize fish stress.
4. After transport, to increase survival potential, fish may be kept in acclimation ponds before being released.

For downstream fish passage, the process can be as simple as placing a fyke net across the river in-tributary then checking the trap daily to transport the fish as was done in the above procedure to a more complex system off-channel. Alternatively, a floating surface collector (FSC) in the reservoir with a mooring system and exclusion/guidance nets could be used to attract, trap, sort, and transfer fish from a barge to the shore where a fish transport truck could be used to transport the fish. Or a pipe from the shore to the tailrace could be used to transfer fish to the tailrace. Other options for downstream fish passage are trapping fish in the tributaries, in the reservoir at the dam, or at the head of the reservoir (Askelson et al. 2012), which has its own complexity.

In summary, trap-and-haul facilities can be simple or complex depending on the overall environmental and management goals, number of fish, hydrology and hydraulics, and many more reasons.

For this Project, due to (1) the limited number of SCCC steelhead trout downstream of the dam, (2) the limited instream flow released from the dam, (3) the need for adjustability as the spillway receiving pool and the outlet pool are not the same pool, and (4) the possible need to adjust the location of a trap to be effective (in-river downstream of the connection from both pools), this study proposes a simple in-river trap utilizing a temporary picket barrier and trap. Figures 3 and 4 (Appendix C) and the following sections present each component in greater detail.

The picket barrier and trap may prove to be sufficient. However, if after a minimum of 5 years collecting biological performance data it is found that a more permanent trap is required, this option could be scaled up by integrating a permanent hydraulically driven picket fence (raised during upstream fish passage season and lowered the rest of the time) and installing an off-channel trap. A good example of this is the Lostine River Satellite Facility in Oregon (Figure 4-3). The off-channel option could range from $5M to $15M depending on the project's needs and site selection.

Figure 4-3. Example – Lostine River Satellite Facility in Oregon

4.1.2.1 Picket Barrier

Picket barriers are commonly used in-river for trapping and counting adults. The fences are also used to collect broodstock or for upstream passage. At Lopez Dam, the picket barrier would be located downstream of the confluence of the spillway flow and of the dam outlet flow. The picket barrier would be installed annually before the upstream fish passage window and then would be removed for the rest of the year. The picket barrier would span the Arroyo Grande Creek and be placed in a location with easy access for personnel to bring in the equipment to manage the captured fish. A reach with deeper water would be selected so that the velocity in the trap box is low to minimize fish stress. Due to the small width of the creek, the picket barrier does not need to be complicated. Figure 4-4 presents examples of picket barriers and a trap box.

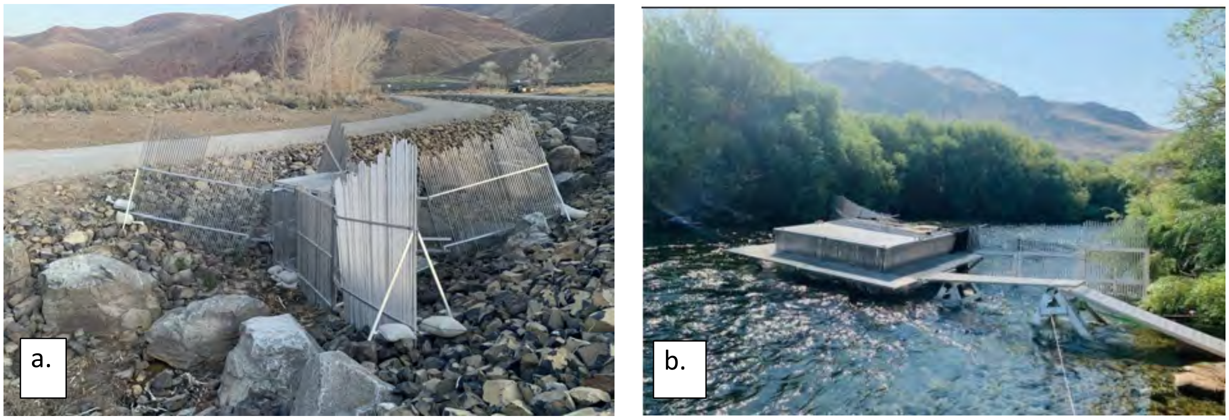


Figure 4-4. Examples of In-River Temporary Traps for Adult Upstream Migration: (a.) Derby Dam Adult Trap, Nevada and (b.) Chelan Falls Adult Trap, Washington

Pickets can be oriented from 30 to 60 degrees from horizontal (as per example “b” in Figure 4-4) or angled to the flow and vertical (as per example “a” in Figure 4-4). In either case, the picket barrier should be designed to lead fish to the trap box. The clear openings between the bars would be less than or equal to 1 inch to exclude anadromous salmonids and less than or equal to 0.75 inch to exclude Pacific lamprey (NMFS 2023a). Smaller openings may be required if resident species are also present that need to be excluded by the facility. The picket diameter would be equal to the selected clear opening to ensure that the picket array has a minimum of 40% open area (NMFS 2023a). While the picket bars can be made of steel, aluminum, or durable plastic, this study recommends aluminum for its durability, lighter weight, and limited corrosion potential. The design flow rate for example “b” is 185 to 235 cfs, and the flow rate for example “a” is < 20 cfs; therefore, a picket barrier of the size and style of example “a” is assumed for the Lopez Dam project.

4.1.2.2 Trap Box

Generally, the trap box would be sized for the number of expected fish to be captured. Because that number is expected to be small, the trap would be sized for an operator to safely work within the trap rather than being sized for the number of fish. The trap would be placed in a river reach where the water depth is a minimum of 2 feet (NMFS 2023a) and where the maximum velocity through the trap box pickets is less than 1.25 fps (NMFS 2023a). The trap box would consist of an aluminum modular design. The trap box could be located closer to a shore (for access) or within the thalweg (deeper water) with the picket directing fish to the trap. The trap would have a floor panel, wall panels, and lid panels that weigh less than 100 lbs each. The trapping mechanism would be an adjustable-throat width vee-trap with cod fingers.

The trap would be 4 feet long by 4 feet wide by 4 or 5 feet deep, which depends on providing a minimum freeboard of 2 feet. A lid panel with a lock would be provided to limit poaching. The temporary trap would be anchored using T-bars and removed annually following the upstream migration window either April 30 or March 31, depending on when the bar at Arroyo Grande Lagoon closes. The installation and removal would be a manual effort requiring a team of two staff for two days. It would not require the use of heavy equipment.

Final upstream release locations have not yet been selected. After being transported, fish should be released in a safe location with sufficient depth and good water quality (NMFS 2023a). Currently, it is assumed that all adult SCCC steelhead trout captured below the dam will not be released in the reservoir but will instead be released in the tributaries. The primary identified release location is in Lopez Canyon Creek just upstream of the downstream trap location. Initially the downstream trap would be a picket barrier and trap box (aka, rigid weir). If this trap system changes to a more permanent system after a few years of operation, it would be recommended to provide passage of adult and kelt at the downstream trap diversion. Another possible release location is in Wittenberg Creek. In either release locations, the reach upstream would need to be surveyed to determine if there are natural barriers that may need to be adjusted to assure upstream movement of fish. For example, there are known constrictions in the lower reach of Wittenberg Creek.

4.1.2.3 Capital and O&M Cost Estimate

A Class 5 cost estimate, along with operation and maintenance cost estimates, has been prepared and is provided in Appendix E. All estimates are presented in 2025 dollars. The median construction cost is about $601,000 -50%/+100%. The annual O&M cost is about $279,000. The estimated life expectancy of this alternative is 10 years.

4.2 Downstream Fish Passage

This section presents a description of the following three downstream fish passage options selected for further development.

- Floating surface collector (including guidance net and either bypass pipe or transport truck)
- Helix
- In-tributaries trap-and-haul facility

4.2.1 Floating Surface Collector

This option would be a combination of an exclusion/guidance net, floating surface collector (FSC), and fish transport features. The FSC is a large floating juvenile collection facility for the purpose of collecting surface-oriented, out-migrant fish. FSC are increasingly being implemented to provide juvenile fish passage at hydroelectric projects with large storage reservoirs in the Pacific Northwest. FSC have been installed in strategic locations in the forebays of hydropower projects where juvenile fish have been known to congregate or where guide nets help guide the fish into the collection system.

The FSC is depicted on Figures 5 and 6 included in Appendix C. The FSC described in this document is based on several fish collectors currently in use including the Upper and Lower Baker FSCs on the Baker River (WA), the Swift FSC on the Lewis River (WA), the North Fork FSC on the Clackamas River (OR), and the Cowlitz North Shore Collector on the Cowlitz River (WA). The following sections describe each component along with the associated benefits and concerns.

4.2.1.1 Debris Boom

The debris type, size, and shape varies throughout the year and is highly dependent on the local reservoir. Understanding the debris load in the reservoir is an important consideration when designing an FSC. Experience with FSCs has shown that debris handling is an important part of operating a fish-safe FSC, not to mention the efforts required by the operations crew. The existing debris boom at Lopez Dam that protects the water intake would need to be relocated to protect both the FSC and the water intake. However, due to the shape of the reservoir not being linear, a guidance net perpendicular to the FSC would need to be installed, similar to the Swift FSC, to increase guidance and trapping efficiency. Because of the guidance boom splitting the reservoir, the relocation of the guidance boom is not straight forward. For this effort, a 2,700 feet log boom was assumed. The debris boom would be designed to be capable of stopping trees, root wads, and other large debris. A fabricated boom by Pacific Netting Products that uses extruded high-density polyethylene (HDPE) would be used for the basis of design and is included for this alternative. The boom features closed joints between the boom's individual HDPE pipe sections and has a 3-foot deep skirt (continuous rubber belt material) along the bottom of the boom that helps to contain more debris than a traditional log boom. It also has a splash guard which creates freeboard that angles back slightly upstream to help prevent debris from overtopping the boom. The system would require new shore anchors and a lake anchor. This type of boom does a good job of excluding large floating debris that would otherwise foul the nets and collector.

4.2.1.2 Exclusion/Guidance Nets

Nets would be an important feature of the FSC to help guide fish to the entrance of the collector and to achieve a high collection efficiency. A flotation/submergence boom is included as part of this alternative. This boom (similar to the system used on the Baker and Lewis River FSCs) would allow the net to be lowered (fully submerged). The FSC and the net would be located away from the spillway to limit potential impact to the net during spill events. The nets would be relatively long with an upper support boom length of 1,500 feet and an estimated depth of 70 feet. In addition, another guidance net perpendicular to the FSC would be provided (similar to the Swift FSC) due to the shape of the nonlinear reservoir to increase fish collection and efficiency. This additional net would be 700 feet long with an estimated depth of 100 feet. The total guidance net area is estimated to be 181,000 ft^2. The wide variation in the lake level would result in a complex mooring system for the netting and would cause the “stranding” of a significant amount of the netting and the support boom on the shore as the lake level drops, exposing it to damage and fouling. The flow velocity in the reservoir towards the collector would be very low (net approach velocity 0.12 fps, or less; based on existing FSCs).

The guidance nets would extend from the shores to the FSC. Assuming that the FSC would be near the intake control building, the guidance nets would extend east and west as shown on Figure 6 in Appendix C.

4.2.1.3 Trashrack and Automated Cleaner

Debris management is important as the pumps used to attract fish to the FSC would also attract debris to the FSC. Therefore, a trashrack with an automated cleaner would reduce debris into the FSC. Less debris reduces the chance of clogging fishways and minimizes the associated reduction in fish collection efficiency and fish injury. The trashrack spacing would be a 4-inch clear opening for the upper 6.5 feet and an 8-inch clear opening below. This would allow fish to enter but would eliminate a majority of the tree branch-sized debris. The total amount of debris (floating and/or suspended; leaves, pine needles, branches, etc.) present at the specific site would determine how this material is handled and/or removed. For reservoirs with relatively little debris, it is sometimes acceptable to remove debris with dip nets from the holding tanks. For installations where the reservoir has a high debris load, it is possible to place a skimmer in front of the vessel to minimize floating debris. A trashrack cleaning machine would be needed to clean the debris from the trashrack.

The proper disposal method for the woody debris varies by site. Common methods include using the spillway and a barge/ backhoe/ dump truck combination, collecting the debris into a pile to be burned in the spring once the burn-season opens, or hauling to a waste management facility, such as the Cold Canyon Landfill for disposal. At Lopez Dam, collection of woody debris into a pile(s) for spring burning is recommended due to infrequent spilling. The basis of design for a trashrack cleaning machine is an Ovivo downward sweeping gripper rake similar to one that is used at the Cowlitz Falls North Shore Collector entrance. This system has proven to be an important debris management feature at fish collector entrances.

Screen cleaners would also be required for both the primary and secondary screens. Screen cleaner options include a brush cleaner, water jet, and air burst systems. Each system has its limitations and should be chosen based on the type of debris anticipated. However, for this alternative development, a brush cleaner is expected, and the basis of design uses the Hydrobrush System HB9100 from Atlas Polar.

4.2.1.4 FSC Vessel

The FSC vessel depicted in Figures 5 and 6 in Appendix C is a 184-foot-long by 69-foot-wide vessel with an entrance flow capacity of 1,000 cfs. The vessel would need to be designed by a naval architect. It would need trim and ballast tanks, and its hull would need regular dive inspections and maintenance. The vessel could be raised or lowered using ballast tanks to perform an inspection and maintenance.

The entrance flow would be split into a two-vee configuration. The screen area for dewatering this flow would be sized to be lower than an approach velocity of 0.4 fps and configured to achieve a capture velocity of 8 fps with gradual acceleration. The fish would enter the FSC through the coarse trashrack at the front of the vessel. The fish then would enter the primary screen section of the collection channel. The collection channel walls would be vertical and angled in a V-shape; the floor would have a slight upward slope. After the primary section, the fish would then enter the secondary screen area that would contain the capture section of the collection channel. The capture section could reach velocities of 6 to 8 ft/s. The floor of the secondary screens would slope upward as the vertical walls continue to narrow in a V-shape. Once the fish enter the collection zone, they would quickly pass to the fish handling area of the vessel. The fish would be further dewatered and sorted into holding tanks. The FSC would include provisions for fish separation (large fish, smolts, and fry), segregated holding, sampling, and loading. The FSC would require anchorage, which is assumed to be independent of the dam structure. The high level of reservoir fluctuation would add cost and operational challenges to anchoring the FSC in a relatively stable location. The FSC can operate well over the wide range of water levels. The FSC would require an approximately 1,000-KVA power service and a means to connect the power to shore to operate the horizontal propeller pumps, which are used to attract fish to and through the structure.

The water would enter through a coarse trashrack at the front of the vessel. A bell mouth entrance could be used to provide a smooth hydraulic flow lines through the trashrack. The primary screens would be V-shaped and would remove 60% to 90% of the water. The geometry for the V-shape width and floor would be chosen to provide a smooth acceleration of the flow and to maintain a safe approach velocity to the screens. The concept of the secondary screens would be similar but would become much narrower as more water is removed. Diffuser plates or baffles would be used directly behind the screens to ensure uniform approach velocities across the screen. From there, the water would enter plenums, which may combine water from several screens. Each plenum would then lead to a large horizontal propeller pump that is submersible and has high flow with low head. The pump outlets could be located either in the wall or the floor of the vessel. The number of attraction pumps required is dependent on the number of collection channels, the operational range of the FSC, and the incremental flow increases that are desired. Water that enters the fish handling area would be pumped separately. This amount of water may vary depending on design needs for species present in the reservoir but is generally 8 to 12 cfs per collection channel. Reducing flows is beneficial for pumping costs and for the vessel's design as related to the largest floodable compartment.

The FSC could be sized for half the flow rate; however, it would be recommended to run a computational fluid dynamic model to determine how much flow is sufficient to attract fish through the FSC. Due to the shape of the reservoir in relation to the FSC, the Swift FSC is the basis of design because of the similarities with Lopez Dam. The Swift FSC has a total flow rate of 1,000 cfs. In addition, all FSCs built to date are located in reservoirs used for hydropower, so in addition to the attraction flow from the FSC, there is also flow to the powerhouse intake guiding fish in the reservoir. Due to the lack of reservoir flow at Lopez Dam, more attraction flow may be needed.

Table 4-1 presents examples of FSCs in the Pacific Northwest. The table includes construction cost, year constructed, the attraction flow rate, and if the fish are transferred downstream using a bypass pipe or a truck.

Table 4-1. Floating Surface Collectors in the Pacific Northwest

ID No.	Name	Owner	Location	Reservoir Fluctuation (ft)	Screen Type[1]	Fish Transport	Flow (cfs)	Construction Cost ($M)	Year Constr.
01	North Fork	PGE	Clackamas River, WA	10	FSC	Bypass Conduit	600/1,000	42	2015
02	Lower Baker	PSE	Baker River, WA	30	FSC	Trap and Transport	500/1,000	50	2013
03	Upper Baker	PSE	Baker River, WA	30	FSC	Trap and Transport	500/1,000	50	2008
04	Cougar	USACE	S. Fork McKenzie River, OR	180.5	FSC	Trap and Transport	1,000	200	In Design
05	Cougar	USACE	S. Fork McKenzie River, OR	180.5	PFFC	Trap and Transport	100	10	2014
06	Swift	PacifiCorp	Lewis River, WA	100	FSC	Trap and Transport	600/800	60	2012
07	Cushman	Tacoma Power	Skokomish River, WA	20	FSC	Trap and Transport	250	24	2015
08	Trail Bridge	EWEB	McKenzie River, OR	NA	FSS	Bypass Conduit	2,000	40	Design Only
09	Round Butte	PGE	Deschutes River, OR	1 to 9	FSS	Trap and Transport	6,000	110	2009
10	River Mill	PGE	Clackamas River, WA	2 to 6	FSS	Bypass Conduit	500/700	12	2012
11	Soda Springs	PacifiCorp	North Umpqua River, OR	14	FSS	Bypass Conduit	1,872	60	2016
12	Cowlitz Falls	Tacoma Power	Cowlitz River, WA	2	FSS	Bypass Conduit	500	32.3	2017
13	Rocky Reach	Chelan PUD	Columbia River, WA	5.52	FSS	Bypass Conduit	6,000	107	2002

[1] *FSC* floating surface collector; *FSS* fish screen structure; *PFFC* portable floating fish collector

4.2.1.5 FSC Access

The FSC would be accessed by a trestle and a mooring tower. The mooring tower would be built upstream of the dam and would be similar in design as the mooring tower of the Swift FSC (see Figure 4-5).

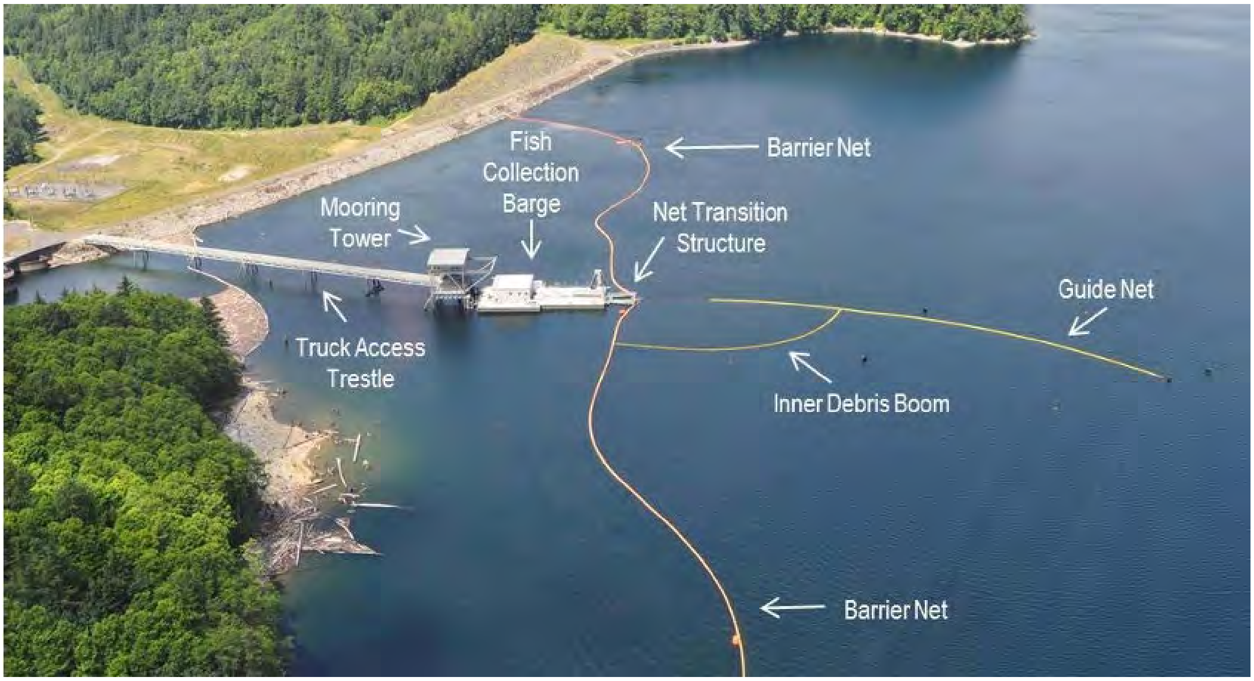


Figure 4-5. Aerial Photo of the Swift Floating Surface Collector (Source: PacifiCorp 2017)

4.2.1.6 Fish Transport and Bypass:

To transfer fish from the FSC vessel to a release site downstream of the dam, there are a couple of options: using a bypass pipe or trucking/hauling the fish.

Bypass Pipe: Fish would be transferred into one of four 94 ft^3 (700 gallon) tanks that would be lowered into a sump on the FSC. After being filled with fish, the tanks would be hoisted up with a jib crane to the trestle deck level, where fish would enter a fish return pipe. The bypass pipe would be an HDPE pipe that is 12 inches in diameter and 0.8 miles long at a 4% slope to have optimum hydraulic conditions in the fish return pipe. The pipe would flow at 40% full, and the flow rate would be 2.5 cfs. The bypass flow would need to be pumped from the reservoir due to the reservoir variation and because the flow cannot be achieved by gravity. The bypass flow (2.5 cfs) may result in a large percentage of the instream flow, that is, 30% to 40% (minimum instream flow; 5.9 – 7.9 cfs). For these reasons, together with the construction cost of the bypass pipe (estimated ~$1.5M), plus operating costs for pumping the bypass flow from the reservoir, a bypass pipe would not be recommended.

Hauling: Hauling fish is more common especially with high reservoir fluctuations, as it removes a step in the process. When the tanks are hoisted up to the trestle deck level, the tank or its contents are transferred to a fish transport truck. The truck is then driven downstream for fish release. Depending on the number of fish, the frequency of the hauling may be a once-a-day event.

Due to the Lopez Reservoir fluctuation, transporting fish in a truck and returning them further downstream may prove to be a cheaper and less limiting option.

4.2.1.7 Capital and O&M Cost Estimate

A Class 5 cost estimate, along with operation and maintenance cost estimates, has been prepared and is provided in Appendix E. All estimates are presented in 2025 dollars. The median construction cost is about $79,371,000 -50%/+100%. The annual O&M cost is about $730,000. The estimated life expectancy of this alternative is 50 years. The annual O&M cost includes ~$300,000 power cost for four months of operation of the attraction pumps, assuming an attraction flow of 1,000 cfs, a pump efficiency of 80%, and a rate of $0.30 per kWh.

4.2.2 Helical Fish Passage System

The only known helical fish passage system, Helix, is the one at the Cle Elum Dam, Washington, that was designed by the U.S. Bureau of Reclamation (USBR). This design includes an intake structure with multiple intakes to accommodate the varying reservoir level and underground helical fish passage, tunnel, and outfall. The Helix represents a groundbreaking design intended to fit a long, gradually sloped channel into a very compact physical space to produce a system that is both technically and economically feasible (USBR 2016). Figure 4-6 and Figure 4-7 present the concept design for the Cle Elum project. The Helix looks and works like a parking structure ramp. The reservoir level determines which intake opening fish enter through. They are six different intakes vertically separated by 11.75 feet that can address a reservoir fluctuation of 63 feet. The Helix is 52 feet in diameter and has a 4- to 5-foot-wide rectangular channel. Fish exit at the bottom of the Helix after traveling a 1,200-foot tunnel into the Cle Elum River. The system was sized for flow rates ranging from 90 to 400 cfs, with an expected flow of 200 cfs. The project involved more than 200 engineers, scientists, architects, and hydraulic modelers and united federal, state, city, tribal, agricultural, and environmental organizations to support the restoration of Sockeye Salmon in the Yakima River basin. The total construction cost was $76 million (2018 dollars) and took four years to build from the spring of 2019 to October 2024. The actual project cost was much larger to validate this approach prior to starting design work.

Figure 4-6. Helix Structure at Cle Elum Dam, Washington

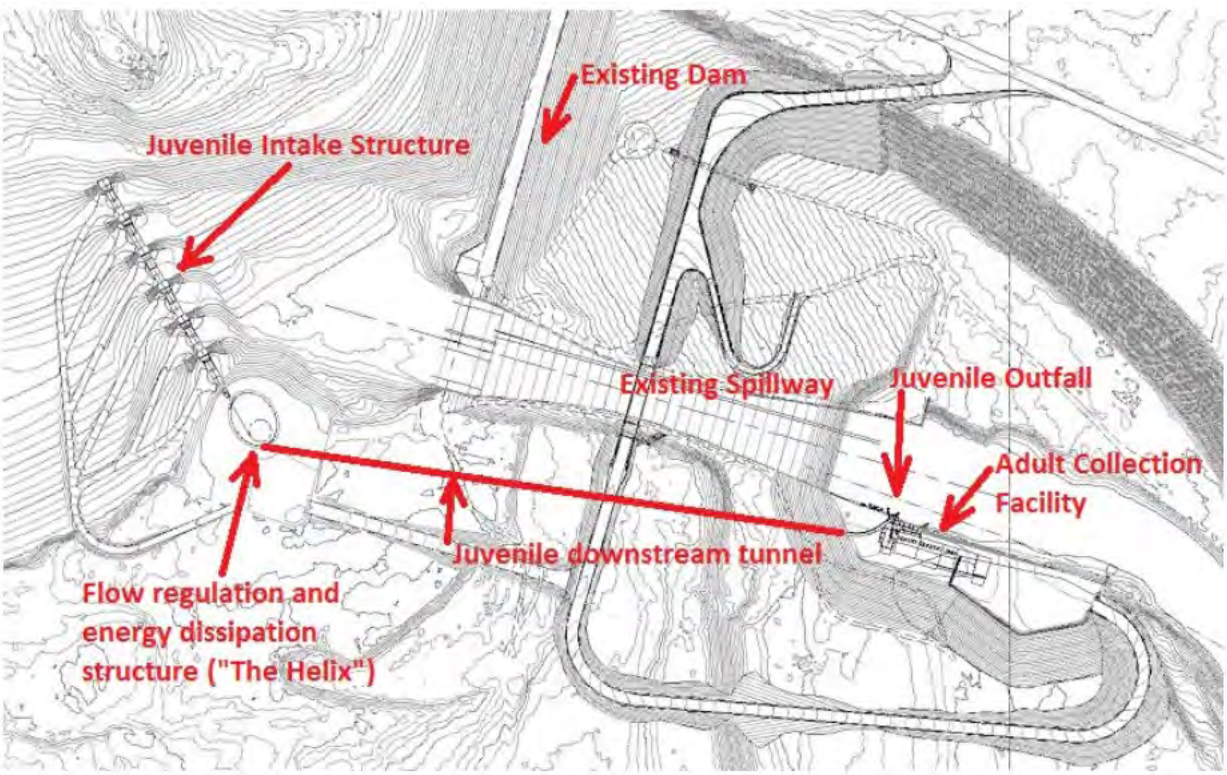


Figure 4-7. Layout of Intake Structure (USBR 2016)

For Lopez Dam, the helical fish passage system is illustrated in Drawings 7 and 8 in Appendix C.

4.2.2.1 Juvenile Intake Structure

The juvenile intake structure at Lopez Dam would effectively replace the dam intake structure. The existing intake structure includes seven intakes, separated vertically by approximately 15 feet, from EL 512.6 to 422.6. During the out-migrating period, the reservoir can vary by 62 feet, from EL 526.6 to 464.6. In other words, some of the lowest existing intakes are up to 42 feet below the low reservoir level during out-migration. Therefore, for constructability, construction period, and redundancy, it is recommended to build a separate juvenile intake structure to allow continued operation during construction and to better match the fishery's need.

Since the Cle Elum juvenile intake structure could accommodate a reservoir fluctuation of 63 feet and the Lopez Reservoir fluctuation is 62 feet, the proposed configuration of the juvenile intakes is to keep the same number of intakes (i.e., six) and the same vertical separation of 11.75 feet as provided at Cle Elum.

In addition, the exiting Lopez Dam intake has an outlet capacity of 150 cfs at minimum pool EL 432.6 (therefore more capacity at higher pool due to increased head differential,) which is also within the same range as Cle Elum. Therefore, the size of the juvenile intakes would be also similar to Cle Elum.

4.2.2.2 Helix

The Helix at Cle Elum has undergone a robust and detailed FLOW-3D analysis to determine the best geometry (diameter of the Helix) and the best hydraulic criteria within the flume (flume shape to minimize turning of the flow, velocity to transport fish, etc.). Because of the similar configuration at Lopez Dam, the Helix geometry proposed for this feasibility assessment is to be the same as Cle Elum, that is, 52 feet in diameter. The Helix would be located in a 110-foot diameter vertical shaft. The shaft would be vertically divided in two, with the Helix on the downstream side. The other side would be used for underground floors corresponding to each intake level. The overall depth would be increased from 94 feet to 165 feet. The Helix would be built at the rocky point, east of the existing intake structure. A geotechnical investigation would be required.

4.2.2.3 Juvenile Downstream Tunnel

The tunnel would be a 5-foot diameter HDPE pipe approximately 2,000 feet long. This tunnel would extend from the bottom of the Helix to a location adjacent to the outlet control building. The tunnel would pass outside of the dam footprint and would therefore not impact the core of the dam. A geotechnical investigation would be required to understand the tunneling means and methods that could practically be used to construct the tunnel.

4.2.2.4 Capital and O&M Cost Estimate

A Class 5 cost estimate, along with operation and maintenance cost estimates, has been prepared and is provided in Appendix E. All estimates are presented in 2025 dollars. The median construction cost is about $237,707,000 -50%/+100%. The annual O&M cost is about $205,000. The estimated life expectancy of this alternative is 75 years.

4.2.3 In-tributaries Trap-and-Haul Facility

In-tributary trapping can be accomplished in several ways, such as the following:

- **Off-channel permanent installation:** An off-channel collector requires a diversion weir, intake works, screening, canal and outfall, fish bypass, fish transfer facility, and upstream fishway (Askelson et al. 2012). It could also include an adjustable weir (e.g., Obermeyer type).
- **In-tributary trap temporary installation:** These traps can vary from picket barriers with trap boxes (similar to Section 4.1.2) to fyke nets, rotary screw traps or incline-plane traps.

Lopez Reservoir is fed by several creeks, which include Rock Falls Creek, Phoenix Creek, Arroyo Grande Creek, Dry Creek, Wittenberg Creek, Lopez Canyon Creek, Big Falls Creek, Vasquez Creek, and a few others. According to Thomas R. Payne & Associates (2011), South-Central California Coast (SCCC) steelhead trout have been observed within the Lopez Canyon, Wittenberg, and Upper Arroyo Grande creeks' sub-basins. Among these, Lopez Canyon and Wittenberg creeks provide the highest quality habitat and support relatively abundant SCCC steelhead trout populations. In contrast, the Arroyo Grande sub-basin is heavily impacted by agricultural and grazing activities, offers limited suitable spawning habitat, is mostly privately owned, and supports a low abundance of SCCC steelhead trout.

Based on the size of the creeks and the information about the tributaries' hydrology that was developed by Stillwater (2023), the need to screen the entire creek flow (to increase capture rate) and for access road availability (the same access road provides access to both proposed sites), installing two in-tributary traps is proposed: one in Lopez Canyon Creek where the mean daily flows during out-migration range from 4.2 to 24.8 cfs and one in Wittenberg Creek where mean daily flows range from 2.1 to 12.6 cfs.

Each trapping system has advantages and disadvantages. Until biological performance data has been gathered for a minimum duration of five years and additional debris loading and sediment movement information that could impact operation has been collected, a picket barrier and trap box is proposed. While the fyke net is the simplest and cheapest solution, the flashy system (i.e., capable of a flash flood) and debris loading would likely overwhelm the nets, and resulting maintenance would be problematic to keep the system functioning effectively. The proposed option can be scaled up if and when required. Using the picket and trap box for a few seasons can inform the operational challenges, site selection, number of fish trapped, survival rate, and the potential need to utilize a different system. The off-channel option could range from $5M to $20M per site depending on the project's needs and site selection.

Once fish are trapped, the operator would check and empty the trap daily, inspect the installation to ensure it remains in proper working condition, transfer the collected fish into the hauling truck, and transport them to a release location downstream of Lopez Dam, and downstream of the adult trap. Figures 9 and 10 in Appendix C present the proposed sites, as well as a schematic the alternative.

Because both sites are accessible through the same access road, there is an inherent risk if the access road is not usable (e.g., flooding, landslide, fallen tree, etc.); therefore, an alternative access plan should be put in place to retrieve trapped fish. For both sites, a backup plan could include the use of 4-wheelers or boats through the Lopez Reservoir.

4.2.3.1 Capital and O&M Cost Estimate

A Class 5 cost estimate, along with operation and maintenance cost estimates, has been prepared and is provided in Appendix E. All estimates are presented in 2025 dollars. The median construction cost is about $909,000, -50%/+100%. The annual O&M cost is $350,000. The estimated life expectancy of this alternative is 10 years.

5.0 Alternatives Evaluation

This section presents the evaluation of the alternatives.

5.1 Evaluation Criteria Definition

While the design criteria (McMillen 2025a) are important for the development of feasible alternatives at Lopez Dam, the evaluation criteria are important to distinguish which alternative (Section 4.0) from those options should be recommended for advancement to the conceptual design level as the “highest-ranked” alternative. The proposed evaluation criteria have been grouped into seven categories. Each category has a subset of evaluation criteria. The Evaluation Matrix (Appendix B) presents the framework for the evaluation. Each criterion was given an importance factor (L = Low, M = Medium, H = High). The importance factor was given a relative weight (Low = 1, Medium = 2, High = 3). Each alternative was evaluated against each other within a criterion and a grade between 1 and 10 (1 = worst and 10 = best). When a criterion is expressed in percent, such as passage efficiency, mortality, or fallback risk, the percent value was determined as “good” or “bad.” For example, the smolt mortality can be low percent (good) and survival rate can be high percent (good). In these cases, the grade will be calculated as follows: If smolt mortality is low (e.g., 3%), the grade is 10-0.3 = 9.7, or if the survival rate is high (e.g., 97%), the grade is 9.7. With this quantitative process, each of the seven categories received a combined weighted score for each alternative. The total score was then used to identify which alternative has the most merit. The evaluation criteria have been grouped in the following seven categories:

- **Biological Efficiency** defines the ability of the alternative to attract and collect fish at the fishway entrance and to account whether the fishway is volitional. It also includes criteria such as effort expenditure, stress factor, fish return safety, fall back risk, juvenile and adult passage efficiencies, and smolt and adult mortality risks. The ultimate measure of success is whether the alternative meets the requirements of the design criteria established in the technical memorandum TM-002-Design Criteria (McMillen 2025a) and, more broadly, if the alternative successfully mitigates habitat fragmentation and supports the recovery of SCCC steelhead trout by restoring passage at Lopez Dam.
- **Constructability** identifies the challenges of constructing alternative features. Special consideration is given to site access, cofferdam needs, dewatering difficulties, and utilities availability.
- **Operation** considers potential impacts on existing dam operations and water management objectives. The amount of mechanical equipment and the ease of operation and maintenance of intake screens, pumps, gates, etc. are reviewed. Winter

operation concerns and potential flood impacts are also considered. The ultimate success of the alternative is one that is easy to operate and maintain and limits impacts on existing dam operations and water management.

- **Design approach** is an evaluation criterion that determines the potential complexity of the system designed. Preference is given to an alternative using proven or acceptable technology that has low uncertainty and low risk of not performing as expected, and is compatible with the overall fish passage goals. This criterion is intended to determine which alternatives are the most successful while featuring relatively simple system designs with proven technology. It is also used to evaluate alternatives with the least human intervention required for passage.
- **Environmental impact** considers the alternative's impact on water quality, habitat modification, and the effect on non-target species. This group of criteria should be considered for both the construction period as well as long-term impacts following construction.
- **Regulatory compliance** assesses the permitting requirements and regulatory considerations for each alternative under federal and state law that could impact the alternative's implementation feasibility or cost.
- **Financial** criteria assesses the anticipated construction cost. The intent of this group of criteria is to identify those alternatives that provide the best value (or economic realities) considering all cost aspects. Careful consideration of operation and maintenance costs is required. It includes annualized capital costs (based on the estimated life expectancy of the Project) and annual monitoring (and adaptive management and schedule) costs to compare alternatives on an annual cost to the County.

Each evaluation criterion is further refined in the following sections.

5.2 Evaluation Criteria

This section presents the alternatives evaluation following the evaluation criteria categories and subcategories presented above. The Evaluation Matrix is presented in Table 5-1, and the Ranking Assessment is presented in Table 5-2. The Evaluation Matrix was used to rank all fish passage alternatives.

Table 5-1. Evaluation Matrix

Criterion	Importance Relative (L, M, H)	Upstream Fish Passage		Downstream Fish Passage		
		Vertical Slot Fishway	Trap-and-Haul Facility	Floating Surface Collector	Helical Fish Passage System	In-Tributary Trap-and-Haul
Biological Efficiency						
Volitional passage	H	10	1	1	10	1
Attract and collect fish	M	8	10	5	4	6
Energy expenditure	M	2	10	5	5	10
Stress factor	L	10	2	7	10	5
Fry and smolt survival	L			10	10	10
Juvenile reservoir survival	H			5	5	10
Fish return safety	L			8	10	7
Juvenile passage efficiency	L			9	9	7
Adult survival	H	8	9			
Adult passage efficiency	H	7	9			
Daily passage capacity	M	10	8	8	10	8
Ambient light	H	6	10			
Fallback risk	H	9	9			
Weighted Score		**18.9**	**19.1**	**9.8**	**13.6**	**12.2**
Constructability						
Site access	M	1	10	1	2	10
Cofferdam impact	M	1	10	1	2	10
Dewatering difficulty	M	1	10	1	2	10
Utilities availability	M	1	10	1	2	10
Limited reservoir drawdown requirements	H	1	10	1	2	10
Weighted Score		**2.2**	**22.0**	**2.2**	**4.4**	**22.0**
Operation						
Low mechanical equipment	M	4	9	1	5	10
Site access	M	8	9	1	6	9
Limited screen cleaning effort	M			1	10	3
Limited pump O&M effort	M			1	10	10
Limited gates O&M effort	M	1	10	6	2	10
Low risk (safety)	M	5	6	1	6	6

			Upstream Fish Passage		Downstream Fish Passage		
	Criterion	Importance Relative (L, M, H)	Vertical Slot Fishway	Trap-and-Haul Facility	Floating Surface Collector	Helical Fish Passage System	In-Tributary Trap-and-Haul
	Low winter operation impacts	M	5	5	4	10	8
	Low flood risks	M	10	4	10	10	2
	Low debris management	M	4	7	1	9	6
	Impact to other users	L	10	9	6	2	8
	Weighted Score		**10.5**	**13.6**	**5.8**	**13.8**	**13.6**
Design Approach							
	Proven technology	H	1	10	8	2	10
	Ability to meet fish passage goals	H	1	10	5	5	8
	Simple system	M	1	10	1	2	10
	Low human intervention required for passage	M	9	1	2	10	1
	Design complexity	H	1	10	1	2	10
	Weighted Score		**5.8**	**22.4**	**9.6**	**10.2**	**21.2**
Environmental Impact							
	Limited impact to water quality	M	1	10	1	1	10
	Low impact to habitat	M	5	10	5	5	10
	limited impact on non-target species	M	1	8	10	1	10
	Weighted Score		**4.7**	**18.7**	**10.7**	**4.7**	**20.0**
Regulatory Compliance							
	Low permitting effort	H	1	10	1	1	10
	Low regulatory constraints	H	5	5	5	5	5
	Weighted Score		**9.0**	**22.5**	**9.0**	**9.0**	**22.5**
Financial							
	Capital costs (construction)	H	$46,614,000	$601,000	$79,371,000	$237,707,000	$909,000
	Estimated life expectancy	M	50	10	50	75	10
	Annualized Capital Cost (over life expectancy)	**H**	**$933,000**	**$61,000**	**$1,588,000**	**$3,170,000**	**$90,900**
	Annual operations and maintenance costs	H	$208,000	$279,000	$730,000	$205,000	$350,000
	Total Annualized Cost	H	**$1,141,000**	**$340,000**	**$2,318,000**	**$3,375,000**	**$440,900**

Table 5-2. Ranking Assessment

	Upstream Fish Passage		Downstream Fish Passage		
	Vertical Slot Fishway	Trap-and-Haul Facility	Floating Surface Collector	Helical Fish Passage System	In-Tributary Trap-and-Haul
Biological Efficiency	2	1	3	1	2
Constructability	2	1	3	2	1
Operation	2	1	3	1	2
Design Approach	2	1	3	2	1
Environmental Impact	2	1	2	3	1
Regulatory	2	1	2	2	1
Financial	2	1	2	3	1
Average Rank	2.0	1.0	2.6	2.0	1.3

5.2.1 Biological Efficiency

The biological efficiency evaluation category includes 13 criteria. The results are presented in the Evaluation Matrix (Table 5-1).

5.2.1.1 Criteria for the Upstream Fish Passage Facility

Volitional Passage: The vertical slot fishway would provide passage from the tailrace to the reservoir when fish want to pass by their own means. The vertical slot fishway would be the only upstream volitional fishway and thus was graded 10. The trap-and-haul facility per definition is not a volitional system (grade = 1).

Attract and Collect Fish: Either fishway design would meet the NMFS criteria and would therefore be expected to work effectively. For the trap-and-haul, the whole creek flow would pass through the picket and the trap box located below the spillway and the reservoir outlet pool, capturing all the flow. It is therefore graded higher than the vertical slot fishway for which attraction would be dependent on entrance location, and for which, once built, the entrance location could not be re-adjusted in the field. The alternatives were scored as follows: 8 for vertical slot fishway and 10 for trap-and-haul facility.

Energy Expenditure: Despite design features such as low energy dissipation, resting pools, and oversized pools to support dual recirculation patterns, the vertical slot fishway would still require significant energy expenditure from fish due to the large number of pools (148). In contrast, the trap-and-haul approach—where fish are captured downstream and transported upstream—demands far less energy from the fish. Accordingly, the alternatives were scored 2 for the vertical slot fishway and 10 for the trap-and-haul facility, with the higher score reflecting the lower energy demand.

Stress Factor: Trap-and-haul facilities impose greater stress on fish compared to volitional passage systems. For this reason, the alternatives were scored 10 for the vertical slot fishway and 2 for the trap-and-haul facility. The higher score reflects the lower stress associated with the vertical slot fishway.

Adult Survival Rate: The adult survival rate is aimed to be 95 to 98 percent for either fishway. With proper operations and maintenance, it is expected that either would provide the same survival rate; however, the in-river trap is a much smaller facility to maintain and keep operational. Accordingly, the alternatives were scored 8 for the vertical slot fishway and 9 for the trap-and-haul facility.

Adult Passage Efficiency: The adult passage efficiency will aim for 75 to 95 percent. While a vertical slot fishway typically has a high passage efficiency, the length of it may show a lower passage efficiency compared to shorter fishways; whereas, the trap-and haul facility would have a high efficiency as all target species trapped would be passed upstream. Accordingly, the alternatives were scored 7 for the vertical slot fishway and 9 for the trap-and-haul facility.

Daily Passage Capacity: The vertical slot fishway, being a volitional passage system, would have no capacity limitations. In contrast, the trap-and-haul facility would be constrained by the availability of staff and transport vehicles to cycle fish through the system. Although fish numbers are expected to be low, making staffing and equipment less of a concern, the trap-and-haul alternative still presents operational limitations not present in the vertical slot fishway. As a result, the alternatives were scored 10 for the vertical slot fishway and 8 for the trap-and-haul facility.

Ambient Light: The vertical slot fishway would have a 640-foot-long tunnel through the dam. Fish may reject this structure as there would be a clear change in ambient light. This issue is nonexistent with the trap-and-haul fishway. As a result, the alternatives were scored 6 for the vertical slot fishway and 10 for the trap-and-haul facility.

Fallback Risk: The reservoir is not operated for hydropower or flood control purposes, but instead as storage; therefore, the risk for fallback is very low for either alternative. Accordingly, both alternatives were scored equally at 9.

Overall, for upstream fish passage, the trap-and-haul option scored higher in terms of biological efficiency, despite the vertical slot fishway offering volitional passage.

5.2.1.2 Criteria for the Downstream Fish Passage Facility

Volitional Passage: The FSC is volitional up to the trap. Due to the reservoir fluctuation expected during operation, the system would need to rely on fish transport trucks to transfer fish from the FSC's trap to the tailrace. The helical system, a multiport entrance at different water depths, is volitional. The in-tributaries trap-and-haul is not volitional. Accordingly, the alternatives were scored 1 for the FSC, 10 for the helical fish passage system, and 1 for the in-tributaries trap-and-haul facility.

Attract and Collect Fish: The FSC would use pumps to draw fish from the reservoir into the collection vessel. However, due to the reservoir's nonlinear configuration, attraction efficiency is expected to be low. To address this, the facility was preliminarily sized with a 1,000 cfs attraction flow and a guidance net similar to, but slightly larger than that used at the Swift FSC. The helical fishway, in contrast, would rely solely on system flow (~200 cfs), offering limited attraction. The in-tributaries trap-and-haul option would span two selected creeks, where fish would move downstream with the flow, providing excellent attraction conditions. While the FSC and helical systems offer uniform collection potential across the reservoir, the in-tributaries approach is limited to only two of the many tributaries; though these include Lopez and Wittenberg Creeks, where the highest fish numbers are expected. Based on these factors, the alternatives were scored 5 for the FSC, 4 for the helical system, and 6 for the in-tributaries trap-and-haul.

Energy Expenditure: Fish would generally experience little energy expenditure; however, for those accessing the reservoir they would need to swim to the FSC or the Helix, requiring additional energy when compared to the in-tributaries traps. In addition, for those fish accessing the reservoir, there may be additional expenditure due to predation risk and using their bursting speed to evade predators. Consequently, the alternatives were scored 5 for the FSC, 5 for the helical system, and 10 for the in-tributaries trap-and-haul.

Stress Factor: Fish experience stress every time they experience a situation outside of the ordinary; this includes managing mechanical equipment and being handled. Therefore, the stress factor would be higher for the FSC and the in-tributaries traps, when compared to the helical system. As a result, the alternatives were scored 7 for the FSC, 10 for the helical system, and 5 for the in-tributaries trap-and-haul. The high score for the helical system is because of lower stress. The in-tributaries trap-and-haul was scored lower than the FSC due to operator needing to net fish out of the trap and transferring them to the truck using a bucket.

Fry and Smolt Survival: The fry and smolt survival rate is aimed to be 98 to 99.5 percent for all alternatives. The alternatives were therefore scored the same with a score of 10 each.

Juvenile Reservoir Survival: The juvenile reservoir survival rate would need to meet a minimum survival rate of 75 to 80 percent. Currently the reservoir survival rate is unknown but has been documented as being low. It is possible that the juvenile reservoir survival rate could be lower than 75 percent; thus, for fish expected to enter and navigate through the reservoir to reach the downstream facilities would be expected to have low survival. In contrast for the in-tributaries traps, outmigrants never enter the reservoir and thus the reservoir survival rate would not impact the juveniles. Consequently, the alternatives were scored 5 for the FSC, 5 for the helical system, and 10 for the in-tributaries trap-and-haul.

Fish Return Safety: For the Helix system, fish stay in water the entire time and the fish return pipe would be designed to meet the highest standards of fish safety. The other two alternatives would rely on fish transport in a truck. While fish safety is paramount, air supply to the fish transport truck may fail due to a faulty valve, no oxygen in the tanks, or broken diffusers. In addition, the water temperature could vary from the collection point to the release point, necessitating an acclimation facility before release. As a result, the alternatives were scored 8 for the FSC, 10 for the helical system, and 7 for the in-tributaries trap-and-haul. The score for the in-tributaries traps is lower than for the FSC due to the longer distance required to transport fish and thus greater risk associated with transport.

Juvenile Collection Efficiency: The juvenile collection efficiency is expected to be equal to or greater than 95 percent. Therefore, all alternatives would be scored equally. However, for the in-tributaries traps, only two of the multiple creeks would be equipped with a picket barrier and trap box; therefore, the global efficiency when considering the whole basin would be lower than the other two alternatives. As a result, the alternatives were scored 9 for the FSC, 9 for the helical system, and 7 for the in-tributaries trap-and-haul.

Daily Passage Capacity: The daily passage capacity for the two alternatives relying on trapping and transport would be dependent on the staff and equipment availability, while the Helix system would have no capacity limitation. As a result, the alternatives were scored 8 for the FSC, 10 for the helical system, and 8 for the in-tributaries trap-and-haul.

Overall, for downstream fish passage, the Helix option scores higher in terms of biological efficiency, followed by the in-tributaries trap-and-haul, and then the FSC.

5.2.2 Constructability

The constructability evaluation category includes five criteria. The results are presented in the Evaluation Matrix (Table 5-1).

5.2.2.1 Criteria for the Upstream Fish Passage Facility

Site Access: Lopez Drive can be used for the construction access of both the vertical slot fishway and for the trap-and-haul facility. In addition, for the vertical slot fishway, the lower fishway construction site would need to be accessed through the outlet control building access road that is located approximately 0.72 miles downstream of the spillway. This access road services a private landowner.

At the intersection with Lopez Drive, crossing Arroyo Grande Creek, there is a single lane bridge. The bridge has the following weight limits: 12T for Single Unit Truck (Type 3), 18T for Standard Semi-truck (Type 3S2), 23T for Combination, and Tandem (Type 3-2). In comparison, a concrete truck, when full, weighs approximately 32T. In other words, the bridge is undersized for construction vehicles. The access road is a gravel road from the bridge to the outlet control building.

To build the exit pool structure, there is limited access from the dam's crest. A barge would need to be used. Due to the penetration through the dam for the transport channel, it is assumed that grout injection would be required. The grout injection would be completed from Lopez Drive from the dam's crest, which would impact traffic. A traffic control plan would be required during the drilling and grouting activity.

The construction period would be expected to be a couple of years; therefore, access would be impacted for other users for the duration. In contrast, the trap-and-haul facility (picket barrier and trap box) could be installed in the Arroyo Grande Creek within 2 to 3 days. The trap would be installed and removed annually to be present only during the upstream migration period. The frequency and the duration of the effort provides a lesser impact on access than the other upstream option. The access road located approximately 0.38 miles downstream of the spillway would be used for construction. That access road is also a single lane gravel road that has a turnout, but does not have a bridge, and sees very few users. As a result, the alternatives were scored 1 for the vertical slot fishway and 10 for the trap-and-haul facility.

Cofferdam Impact: To build the vertical slot fishway, two cofferdams would be required: a small one in the tailrace to build the entrance pool and a large one in the reservoir to build the exit pool structure and the penetration through the dam. The cofferdam size can be managed if the reservoir level is controlled. The reservoir drawdown is discussed below. The trap-and-haul facility (picket barrier and trap box) would be installed directly in the creek and do not require cofferdam installation. As a result, the alternatives were scored 1 for the vertical slot fishway and 10 for the trap-and-haul facility.

Dewatering Difficulty: Once the cofferdams are installed for the vertical slot fishway construction, dewatering would need to take place. Dewatering would require pumps that are continually in operation during the construction period behind the cofferdam. The size and number of pumps required would depend on the waterproofing of the cofferdams. Cofferdam design, methodology, and surrounding geology would impact the overall leakage rate. For the trap-and-haul facility, dewatering would not be required. Consequently, the alternatives were scored 1 for the vertical slot fishway and 10 for the trap-and-haul facility.

Utilities Availability: To build the vertical slot fishway, power is required. Contractors often bring in their own power source during construction. This includes generators with fuel tanks. Alternatively, temporary power could be provided from the powerlines. There is no overhead powerline on the crest of the dam. It is assumed that the contractor would thus rely on generators. When working from the barge to complete the exit pool structure, refueling of the generator would be required. This adds an environmental risk factor. In contrast, to install the trap-and-haul facility, only handheld tools (or battery driven tools) would be required. Consequently, the alternatives were scored 1 for the vertical slot fishway and 10 for the trap-and-haul facility.

Limited Reservoir Drawdown Requirements: To control the size of the reservoir cofferdam, size of equipment, and risk of overtopping the cofferdam, the reservoir fluctuation would need to be controlled and the pool would need to be maintained at a low elevation (to be defined by the contractor based on construction risk) for a minimum of one season but possibly two. During that time, the water storage capacity would be affected, as well as the Lopez Lake marina. In contrast, the trap-and-haul facility, located downstream of the dam, would not require any reservoir drawdown. As a result, the alternatives were scored 1 for the vertical slot fishway and 10 for the trap-and-haul facility.

Overall for upstream fish passage, the trap-and-haul option scores higher in terms of constructability. Its constructability is an order of magnitude easier, creates less impact, and is over a much shorter duration.

5.2.2.2 Criteria for the Downstream Fish Passage Facility

Site Access: To build the FSC, there are two main stages: the construction of the trestle bridge to the mooring tower and the construction and assembly of the hull (i.e., FSC vessel). The first stage would require a combination of access from the dam's crest, impacting vehicular access on Lopez Drive (which requires a traffic control plan) and construction from a barge. The second stage, which could take place at the same time, would require on-shore construction. A probable location that could be selected by the contractor would be the swimming area between the marina and the water park on the east shore. During the construction phase of the vessel, which is expected to take 1.5 to 2 years, the swimming area access would be closed to the public.

To build the helical fish passage system, the system would be built on the rocky point east of the existing water intake. It is assumed that the 110-foot-diameter by 165-foot-deep excavation could be built from the rocky point and that the tunneling would be completed from the base of the excavation toward the tailrace, and similarly for the six reservoir taps. In other words, the rocky point would be closed to the public. An additional laydown area would be required for material, which may further impact access to others. The area just west of the spillway pool could possibly be used, limiting the impact to other users.

For the in-tributaries trap-and-haul, the existing access road would be used. The equipment could be transported by a pickup truck and installed within a day. The trap would be installed and removed annually and only be present during the downstream migration period. The frequency and the duration of the effort is an order of magnitude less of an impact on access than the other downstream option. Consequently, the alternatives were scored 1 for the FSC, 2 for the helical system, and 10 for the in-tributaries trap-and-haul. The higher score reflects the lesser site access impact.

Cofferdam Impact: To build the FSC, a cofferdam would be required to build the foundation of the mooring tower, the trestle bridge, and possible piles for the FSC vessel to rest in its low position. In addition, another cofferdam may be required to provide some protection to the work area (assembly of the vessel) from winter storms, dependent on reservoir levels that can be provided/guaranteed during construction.

For the helical fish passage system, cofferdams would be required for the six reservoir taps and for the tailrace discharge. The size of the cofferdams will depend on its type and the approved drawdown during construction. In contrast, for the in-tributaries trap-and-haul, a cofferdam would not be required. As a result, the alternatives were scored 1 for the FSC, 2 for the helical system, and 10 for the in-tributaries trap-and-haul. The lowest score is based on the duration the cofferdam would be utilized.

Dewatering Difficulty: The dewatering difficulty goes hand in hand with the cofferdam type, use, and duration of the installation. Therefore, the alternatives were scored the same as for the cofferdam impact criterion: 1 for the FSC, 2 for the helical system, and 10 for the in-tributaries trap-and-haul.

Utilities Availability: The FSC would require temporary power to build the on-shore structure and the vessel (two different construction sites). The FSC would also require permanent power and would therefore need to tie to existing power. The contractor may select to complete this connection first to support the construction activity, at least for the mooring tower and the trestle bridge.

The construction of the helical system would require heavy machinery such as drill rigs, an excavator, and dump trucks. It is assumed that the contractor would use temporary on-site power using generators that require refueling. In contrast, the installation of the in-tributaries trap-and-haul facilities would be a manual activity requiring handheld and battery powered tools. As a result, the alternatives were scored 1 for the FSC, 2 for the helical system, and 10 for the in-tributaries trap-and-haul.

Limited Reservoir Drawdown Requirements: The FSC would require a reservoir drawdown for construction of the vessel and for the protection of the construction site during winter storms, as well as the construction of the on-shore structures (i.e., trestle bridge and mooring tower). Similarly, the helical structure would require reservoir drawdown during tapping of the six reservoir inlets. In both cases, the drawdown requirement would depend on the cofferdam design. However, for the FSC, the drawdown duration would be expected to be longer than the drawdown duration of the helical system. In contrast, the installation of the in-tributaries trap-and-haul facilities would not require any reservoir drawdown. As a result, the alternatives were scored 1 for the FSC, 2 for the helical system, and 10 for the in-tributaries trap-and-haul.

Overall, for downstream fish passage, the trap-and-haul option scores higher in terms of constructability. Its constructability is an order of magnitude easier, creates less impact, and is over a much shorter duration than that of the FSC and helical system.

5.2.3 Operation

The operation evaluation category contains 10 criteria. The results are presented in the Evaluation Matrix (Table 5-1).

5.2.3.1 Criteria for the Upstream Fish Passage Facility

Low Mechanical Equipment: The vertical slot fishway would include 25 exit pools located in the reservoir plus one entrance pool in the tailrace. The entrance pool would include an adjustable gate for flow control and a slot for a bulkhead gate. Each of the exit pools would include a trashrack, an isolation gate, and an exit gate. Between the section downstream of the dam and the one upstream of the dam, an isolation gate would also be provided. In all, 53 gates and 25 trashracks would be provided. The gates would be controlled by a PLC using water level sensors for input. Each level sensor would have a duty and a backup. In total, 54 level sensors would be required. Even though this alternative is volitional, it relies on a lot of equipment that must function without incident. In contrast, the equipment for the trap-and haul is very basic, with no moving parts, requiring less operational effort or trade knowledge.

As a result, the alternatives were scored 4 for the vertical slot fishway and 9 for the trap-and-haul facility.

Site Access: During operation, the biological staff and the O&M crew must have access to the facility. In the case of the vertical slot ladder, the exit pool structure would be near parallel to Lopez Drive, just west of the existing intake structure. The space between the exit pools and the shore would be filled with material to create an access pullout on the side of the road, providing access to equipment. The access to the entrance pool would be through the existing access road to the outlet control building.

For the trap-and-haul facility, access to the trap would be by truck using the single lane gravel road. A turnout would be built to facilitate loading of the fish. Once fish are in the truck, they would be released at predetermined release site by simply backing up the truck and opening a valve. As a result, access to both options during operation would be high. The vertical slot fishway scored a little lower due to access in maintaining the trashrack from the deck level, requiring a far reach. The alternatives were scored 8 for the vertical slot fishway and 9 for the trap-and-haul facility.

Limited Screen Cleaning Effort: Neither upstream alternative has screens, so no score was provided for either alternative.

Limited Pump Operation and Maintenance Effort: Neither upstream alternative has pumps, so no score was provided for either alternative.

Limited Gates Operation and Maintenance Effort: The vertical slot fishway would have 53 gates to operate and maintain. In contrast the trap-and-haul facility has none. Consequently, the alternatives were scored 1 for the vertical slot fishway and 10 for the trap-and-haul facility.

Low Risk (Safety): Risks to operators must be considered. During design, the risks would be evaluated and either reduced or eliminated through engineering solutions. However, at this level of development, the main risk for operators of the vertical slot fishway would be cleaning the trashrack from the deck level. It would be a long reach, requiring the worker to lean over the handrail. The worker may need to wear a personal flotation device or connect to an attachment point.

For the trap-and-haul facility, workers would need to enter the creek to check the trap. The trap would be in a pool with a minimum of 2 feet of water depth. The workers would need to wear waders and personal flotation devices to access the trap. Similarly, potential solutions to either risk presented here may exist. For example, for accessing the trap, a decking walkway system similar to the one used by Chelan PUD at the Chelan Falls trap may be designed to eliminate the need for a worker to enter the water, resulting in greater safety and more efficient management of the trap. As a result, the alternatives were scored 5 for the vertical slot fishway and 6 for the trap-and-haul facility.

Low Winter Operation Impacts: The upstream fishway alternatives would be in operation from December 1 to May 1, or March 31 if concentrating during the peak migration period and accounting for sand bar formation. In other words, the upstream alternatives would need to be in operation during the winter period. The coldest month of the year in San Luis Obispo is December, with an average low of 41°F and high of 64°F[2]. Therefore, it is not expected for equipment to freeze or winter conditions to create any operational concerns, beyond maybe precipitation and shorter days. Either alternative would be impacted in similar ways and neither one is at greater risk. Consequently, both alternatives were scored the same, with 5 for the vertical slot fishway and 5 for the trap-and-haul facility.

Low Flood Risk: The vertical slot fishway would be sized for a 100-year flood, so the associated flood risk is low. The trap is, however, located in the creek downstream of the spillway and would be at much greater risk to floods. The trap itself would be anchored to resist some loading. However, the anchoring may not be sufficient, and the trap may need to be removed before forecasted floods. Consequently, the alternatives were scored 10 for the vertical slot fishway and 4 for the trap-and-haul facility.

Low Debris Management: The vertical slot fishway exit pool structure would be located downstream of a log boom to minimize debris loading. However, it is expected that some debris would be caught on the trashrack and would need to be maintained to clear debris for optimum fishway operation. In contrast, the trap and picket barrier would collect less debris as it is located downstream of the dam, and the primary water source is through the existing water intake, which is submerged and includes a fish screen and trashrack. If the spillway is activated, a decision would need to be made about possibly removing the trap, in which case debris passing the spillway would not impact the trap. As a result, the alternatives were scored 4 for the vertical slot fishway and 7 for the trap-and-haul facility.

Impact to Other Users: The vertical slot fishway, once built, would not impact other users. The trap-and-haul would minimally impact others during the transport of the fish to their release location when using the road or possibly using the boat ramp. However, the boat ramp during the winter season would have minimal usage, so the overall impact on others should be very

[2] https://weatherspark.com/

low. As a result, the alternatives were scored 10 for the vertical slot fishway and 9 for the trap-and-haul facility.

Overall, for upstream fish passage, the trap-and-haul facility scores higher in terms of operation.

5.2.3.2 Criteria for the Downstream Fish Passage Facility

Low Mechanical Equipment: The FSC is a facility that would contain a lot of mechanical equipment that requires operators 24/7 to manage the debris in nets/booms, ensure the screens are clean and the screen cleaner working as intended, ensure the pumps are working, and that the sorting equipment is functioning as intended. In summary, the FSC is a complex system requiring skilled labor.

The helical system would contain six gates for each reservoir tap but is otherwise relatively simple to operate. The gates would be controlled by level sensors in the reservoir to determine which gate should be opened/closed. In contrast, the in-tributaries trap has no mechanical equipment. Consequently, the alternatives were scored 1 for the FSC, 5 for the helical system, and 10 for the in-tributaries trap-and-haul.

Site Access: The FSC would be accessed from the shore by the mooring tower and a staircase, so that the FSC can be reached at whichever level it floats. The FSC is a vessel, which requires workers to wear personal flotation devices to capture and pass fish.

For the helical system, workers would need minimal access to the facility, as fish entering through the reservoir tap are directed to the tailrace. Access would be required mostly for maintenance. A maintenance staircase and an elevator would be provided to access the bottom of the 165-foot vertical shaft.

For the in-tributaries trap-and-haul facilities, the sites would be accessed by truck utilizing the single lane chip-sealed road. Once fish are in the truck, they would be released at a predetermined release site by simply backing up the truck and opening a valve. As a result, the alternatives were scored 1 for the FSC, 6 for the helical system, and 9 for the in-tributaries trap-and-haul.

Limited Screen Cleaning Effort: The FSC would rely on a minimum of 2,500 sf of intake screen. The screens would be cleaned with a combination of sweeping velocity and brush cleaners that would be activated by a timer or pressure differential built up on the surface of the screens. In addition, the FSC would rely on guidance nets to the entrance of the FSC. These nets need to be kept clean by operators, requiring considerable effort. In contrast, the helical system does not rely on screens, so the cleaning effort is nil. For the in-tributaries traps, the picket barrier would be used to direct and capture juvenile fish in the trap box. Because the picket barrier extends the full width of the creek, the pickets would capture some floating debris, requiring daily observation and maintenance. As a result, the alternatives were scored 1 for the FSC, 10 for the helical system, and 3 for the in-tributaries trap-and-haul.

Limited Pump Operation and Maintenance Effort: The FSC would be equipped with pumps used to attract fish to the screen entrance. The pumps would be sized for 1,000 cfs. While these low-head, high-flow capacity pumps are commonly used and generally require only annual maintenance, access to the pumps would require a ballast system on the vessel to drain some of the ballast tanks and replace them with air to raise the equipment above water level for inspection and maintenance. In contrast, the helical system and the in-tributaries traps do not utilize pumps. Consequently, the alternatives were scored 1 for the FSC, 10 for the helical system, and 10 for the in-tributaries trap-and-haul.

Limited Gates Operation and Maintenance Effort: The FSC and the helical system both would rely on gates. The helical system would include a greater number of gates overall and would thus be scored lower. The in-tributaries traps do not have any gates. Consequently, the alternatives were scored 6 for the FSC, 2 for the helical system, and 10 for the in-tributaries trap-and-haul.

Low Risk (Safety): Risk to operators requires consideration. During design, the risks would be evaluated and either reduced or eliminated through engineering solutions. However, at this level of development, the main risk to operators working on the FSC is working from a floating vessel. Workers would be working above or near water, requiring personal flotation devices and other safety obligations regulated by CalOSHA. In addition, there is risk to operators and maintenance crews keeping the guidance nets and booms clear of debris. The FSC is generally staffed 24/7 during operation. The helical system would require less staff to operate. However, part of the operation would be underground and an exit route, through a staircase, would need to be provided in case of fire. For in-tributaries traps, workers would need to enter the creek to check the trap. The trap would be in a pool with a minimum of 2 feet of water depth. The workers would need to wear waders and personal flotation devices to access the trap. To access the trap, a decking walkway system (similar to the one used by Chelan PUD at the Chelan Falls trap) may be designed to eliminate the need for a worker to enter the water, resulting in greater safety and more efficient management of the trap. As a result, the alternatives were scored 1 for the FSC, 6 for the helical system, and 6 for the in-tributaries trap-and-haul.

Low Winter Operation Impacts: The downstream facilities would be operated from February 15 to June 15. Therefore, the facilities would operate for approximately 5 weeks in winter and the full spring. With December being the coldest month of the year, there is little winter operation impact to the facility. Though, wind, rain, and less daylight would impact operation of the FSC. The helical system should see no difference in operation, and the in-tributaries traps may be harder to reach due to winter driving conditions. Consequently, the alternatives were scored 4 for the FSC, 10 for the helical system, and 8 for the in-tributaries trap-and-haul.

Low Flood Risk: The flood risk with the FSC and the helical system are very low. However, the risks are higher in the creeks and harder to anticipate in comparison to a trap located downstream of the dam. As a result, the alternatives were scored 10 for the FSC, 10 for the helical system, and 2 for the in-tributaries trap-and-haul.

Low Debris Management: The FSC would be prone to debris accumulation and management needs, as the facility works by attracting “things” to it. The debris management for the FSC, the log boom, and the guidance net is therefore high. The debris management for the helical system would be similar to other multiport systems, in that the debris management is generally low. For the in-tributaries trap-and-haul, the picket barrier and the trap box would need to be checked and debris removed daily. As a result, the alternatives were scored 1 for the FSC, 9 for the helical system, and 6 for the in-tributaries trap-and-haul.

Impact to Other Users: The arrangement of the guidance nets and the log boom for the FSC adds elements that recreational boaters would not have had to manage before. While boat passage would not be blocked, it would be impacted. For the helical system, the impact to other users would be any flow release downstream of the dam (200 cfs) and the impact to the storage goal of the dam. For the in-tributaries trap-and-haul facilities, the only impact to others would be the usage of the road. Since the operation of the downstream facility covers the entire spring period, its impact to others would be greater than for the upstream trap-and-haul. Consequently, the alternatives were scored 6 for the FSC, 2 for the helical system, and 8 for the in-tributaries trap-and-haul.

Overall, for downstream fish passage, the helical passage system scores higher in terms of operation, followed closely by the in-tributaries trap-and haul, and far behind by the FSC.

5.2.4 Design Approach

The design approach evaluation category contains five criteria. The results are presented in the Evaluation Matrix (Table 5-1).

5.2.4.1 Criteria for the Upstream Fish Passage Facility

Proven Technology: Vertical slot fishways are a proven and widely used technology, with many successful installations across the globe. However, the proposed exit pool structure at

Lopez Dam—featuring more than 25 exit pools—would be the largest of its kind to date. For context, the largest currently operating exit pool structure is at the Soda Springs Fishway on Oregon's North Umpqua River and contains 14 exit pools. Other examples include the River Mill Dam fishway on the Clackamas River with 5 exit pools and the North Fork Fishway on the Clackamas River that has 20 exit pools. Notably, the North Fork system is no longer operated over the full range of reservoir fluctuations.

To better understand historical performance, the team contacted Portland General Electric (PGE) and interviewed Nick Ackerman, Senior Scientist, regarding the North Fork Dam Fishway. Ackerman explained that the capability to accommodate varying reservoir elevations has not been utilized in nearly 30 years, as the reservoir is no longer operated as a peaking hydroelectric facility. PGE also noted that there is no quantitative data on fishway exit effectiveness from the period when the variable exit system was in use; though, anecdotal evidence suggests sustainable returns may have occurred. In contrast, in-river traps, used seasonally, are a common and well-understood method for capturing fish worldwide. Based on this context, the alternatives were scored 1 for the vertical slot fishway and 10 for the trap-and-haul facility.

Ability to Meet Fish Passage Goals: Vertical slot fishways, when properly designed, can achieve high fish passage efficiency as a volitional system. However, two primary concerns could significantly affect the effectiveness of such a system at Lopez Dam. First, the transport channel through the dam may present a barrier due to abrupt changes in ambient light, which can deter fish movement. Second, the fishway exit structure includes numerous exit pools. While the number of pools is not inherently problematic, the system would rely on the coordinated operation of a large amount of mechanical equipment. If any of this equipment fails, hydraulic conditions within the fishway could be severely disrupted, potentially impeding fish passage. In contrast, in-river traps, used seasonally, are a common and well-understood method for capturing fish worldwide. In addition, the creek's cross section is small in comparison to other installations, so fish would have a high efficiency at finding the trap entrance. Based on this context, the alternatives were scored 1 for the vertical slot fishway and 10 for the trap-and-haul facility.

Simple System: The vertical slot system with the dam penetration, the exit pool structure, and the high level of mechanical equipment would be challenging to design for the geotechnical, structural, mechanical, and instrumentation and control disciplines. In contrast, the picket barrier and trap are very simple systems to design. As a result, the alternatives were scored 1 for the vertical slot fishway and 10 for the trap-and-haul facility.

Low Human Intervention Required for Passage: The vertical slot fishway would be volitional and would not require human intervention apart from keeping the facility operational and completing maintenance activities. The trap-and-haul system would require human intervention to check the trap, net the fish out of the trap, transport to the truck, drive them to the release location, and release them. Consequently, the alternatives were scored 9 for the vertical slot fishway and 1 for the trap-and-haul facility.

Design Complexity: Designing the vertical slot fishway would present significant challenges, particularly in relation to dam penetration, grout injection through the dam's core, and the complexity of the exit pool structure. In contrast, the trap-and-haul facility would involve a relatively straightforward design, with numerous existing examples available to guide development. As a result, the alternatives were scored 1 for the vertical slot fishway and 10 for the trap-and-haul facility.

Overall, for upstream fish passage, the trap-and-haul system scores higher in terms of design approach.

5.2.4.2 Criteria for the Downstream Fish Passage Facility

Proven Technology: There are currently over 11 FSCs in operation throughout the Pacific Northwest, with additional systems, such as the one planned for Cougar Dam, currently in design. These facilities, which came online between 2002 and 2017, have demonstrated strong performance, with collection efficiencies ranging from 85% to 93% (e.g., Upper Baker FSC). In contrast, the helical system at Cle Elum Dam is a novel concept with an expected completion date in 2026. As it has not yet been constructed or tested, no performance data are currently available. However, the Helix represents just one component of a larger multiport collection system that includes multiple intake points at different reservoir depths, which is expected to result in high overall collection efficiency. As for in-tributary trapping, these are used seasonally and are a common, well-understood method for capturing fish worldwide. As a result, the alternatives were scored 8 for the FSC, 2 for the helical system, and 10 for the in-tributaries trap-and-haul.

Ability to Meet Fish Passage Goals: The juvenile collection efficiency target is 95%. FSCs' ability to meet this goal is variable per site, for example the Upper Baker facility has a collection efficiency between 85 and 93%, but the Swift FSC (similar reservoir configuration as Lopez Reservoir) has collection efficiency of 27% for steelhead trout between 2014 and 2019 (Four Peaks 2019). Part of the low efficiency may be due to the reservoir being nonlinear. There are no performance records yet for the helical system at Cle Elum; thus, its ability is unknown but expected to be comparable to FSCs. For the in-tributaries traps, the ability to meet fish passage goals will depend on river conditions, debris management, and the selection of the creeks where the system will be deployed. Assuming that the traps are well maintained and located, their ability to meet fish passage goals is expected to be high. Consequently, the alternatives were scored 5 for the FSC, 5 for the helical system, and 8 for the in-tributaries trap-and-haul.

Simple System: FSCs require a naval architect in addition to all engineering disciplines to design. They are highly complex structures to design. The helical system is simple in nature but unique as well, so engineers would need to learn as they go. In contrast, the picket barrier and trap box is a very simple system. Consequently, the alternatives were scored 1 for the FSC, 2 for the helical system, and 10 for the in-tributaries trap-and-haul.

Low Human Intervention Required for Passage: The FSC system requires regular human intervention for operation. This includes inspecting the holding tank, raising the hopper to deck level, transferring fish to transport vehicles, driving them to the designated release site, and releasing them. In contrast, the helical system is designed to operate passively and would not require routine human intervention for fish passage. For the in-tributary trap systems, similar levels of manual effort are required as with the FSC. Personnel would need to routinely check the traps, handle and transfer the captured fish, and transport them to release locations. Additionally, the nets must be kept free of debris, which is a task that involves ongoing manual maintenance. Consequently, the alternatives were scored 2 for the FSC, 10 for the helical system, and 1 for the in-tributaries trap-and-haul.

Design Complexity: FSCs are complex structures that require specialized expertise, a naval architect, and may take up to two years to design. Design costs are relatively high, often reaching approximately 10% of total construction costs. Similarly, the helical system is a unique and unproven technology that would require extensive physical and computational fluid dynamics (CFD) modeling to validate the design. In addition, the vertical shaft component would necessitate geotechnical engineering support. The estimated design timeline for the helical system would be 1.5 to 2 years, with similarly high design costs anticipated. In contrast, the trap-and-haul facility would involve a relatively straightforward design, with numerous existing examples available to guide development. Consequently, the alternatives were scored 1 for the FSC, 2 for the helical system, and 10 for the in-tributaries trap-and-haul.

Overall, for downstream fish passage, the in-tributary trap-and-haul scores higher in terms of design approach.

5.2.5 Environmental Impact

The environmental impact evaluation category contains three criteria. The following discussion focuses on environmental impact during and post construction for each alternative, including water quality, habitat modifications, and impact on non-target species. The results are presented in the Evaluation Matrix (Table 5-1).

As design studies are further developed, in-depth environmental impact analysis would be conducted. In addition to biological resources and water quality, in the event the County proceeds with the one or more of the fish passage options, the option(s) would be subject to environmental review under the California Environmental Quality Act (CEQA) and National Environmental Policy Act (NEPA).

5.2.5.1 Criteria for the Upstream Fish Passage Facility

Limited Impact to Water Quality: The vertical slot fishway would result in temporary construction impacts including dewatering in Arroyo Grande Creek within the construction footprint of the entrance pool, fish salvage, transportation and release, habitat loss and degradation resulting from structural design requirements to support fish passage structures, ground disturbance due to site grading cut and fill, armoring, with resultant water quality and sediment-related impacts. Construction of permanent structures such as the vertical slot ladder, tunnels, and exit pools would also impact recreational, aesthetics, land use, air quality, and utilities resources and may pose safety hazards. During construction, pouring concrete may impact water quality during placement and setting. As such, best management practices (BMPs) would be used to minimize temporary erosion and sediment impact, and monitoring of water quality would be required to demonstrate that the surrounding water is not being impacted. In contrast, the installation of the picket barrier and trap would have limited impact and in fact is typically done without water quality monitoring and no BMPs. As a result, the alternatives were scored 1 for the vertical slot fishway and 10 for the trap-and-haul facility.

Low Impact to Habitat: The vertical slot fishway would result in both temporary and permanent impacts to habitat due to its large physical footprint and the associated disturbance to existing site conditions during construction. In contrast, the trap-and-haul facility would have minimal habitat impact, limited primarily to the construction of a turnaround area at the end of the existing access road. Furthermore, the trap-and-haul infrastructure would be installed seasonally, and any associated impacts would be confined to the operational period. Consequently, the alternatives were scored 5 for the vertical slot fishway and 10 for the trap-and-haul facility.

Limited Impact on Non-Target Species: As presented in TM002 (Appendix A), there are several native species in the reservoir as well as non-native and invasive species in the reservoir. Species using the fishway would be non-selective; therefore, any fish species, invasive or not, may be able to pass upstream. Therefore, the vertical slot fishway, being volitional, would introduce species in the reservoir, potentially impacting other species in the reservoir. The trap-and-haul facility would be a selective system, where only the target species would be transported upstream and released either in the reservoir or in the tributaries.

Overall, the trap-and-haul facility would create less impact to non-target species. As a result, the alternatives were scored 1 for the vertical slot fishway and 8 for the trap-and-haul facility.

Overall, for upstream fish passage, the trap-and-haul system scores higher in terms of limiting environmental impact.

5.2.5.2 Criteria for the Downstream Fish Passage Facility

Limited Impact to Water Quality: The FSC and the helical system could result in temporary water quality impacts during cofferdam installation, clearing and grubbing activities, ground disturbance due to site grading cut and fill, armoring, excavation, etc. BMPs would be installed to minimize water quality impact prior to starting construction. Additional environmental impacts would be expected such as habitat loss and impact to riparian areas. In contrast, the installation of the picket barrier and trap box would have limited impact and is in fact typically done without water quality monitoring or BMPs. As a result, the alternatives were scored 1 for the FSC, 1 for the helical system, and 10 for the in-tributaries trap-and-haul.

Low Impact to Habitat: The FSC and the helical system would result in both temporary and permanent impacts to habitat due to each system's large physical footprint and the associated disturbance to existing site conditions during construction. In contrast, the in-tributaries trap-and-haul facility would have minimal habitat impact. Furthermore, the in-tributaries trap-and-haul infrastructure would be installed seasonally, and any associated impacts would be confined to the operational period. As a result, the alternatives were scored 5 for the FSC, 5 for the helical system, and 10 for the in-tributaries trap-and-haul.

Limited Impact on Non-Target Species: The FSC is a selective system where an operator can pass the target species only. The helical system is a non-selective system and would pass all fish species downstream, target, non-target, and invasive species alike that enter the system, creating a larger impact to non-target species upstream and downstream of the dam. The in-tributaries trap-and-haul is a selective system where the operator can capture and pass downstream only target species. The trap itself will capture everything that presents itself to it. The operator will need to manage non-target species and pass them downstream of the trap. Consequently, the alternatives were scored 10 for the FSC, 1 for the helical system, and 10 for the in-tributaries trap-and-haul.

Overall, for downstream fish passage, the in-tributary trap-and-haul system scores higher in terms of limiting environmental impact.

5.2.6 Regulatory Compliance

As part of the steelhead trout passage feasibility assessment and HCP development process, the District, McMillen, and others met with NMFS, USFWS, and the CDFW on multiple occasions to discuss regulatory guidance and input on flows, operations, and fish passage. These discussions have informed the design criteria, alternatives screening, and analysis set forth in this report and its supporting materials. This section identifies a list of federal, state, and local permits that may be necessary in order to implement one or more of the fish passage options. Other permits not identified in this report may also be necessary, depending on how passage and flow-related needs for steelhead trout and other species are vetted by permitting agencies.

Federal Permits and Regulations

- Clean Water Act (CWA) 404 Permit, USACE
  - General Orders – Nationwide Permit
- Endangered Species Act (ESA) Section 7 Consultation in connection with USACE approvals (to ensure the activities do not jeopardize ESA-listed species or destroy or adversely modify designated critical habitat)
- Incidental Take Authorization through ESA section 7 or ESA section 10. NMFS for steelhead trout; U.S. Fish and Wildlife Service (USFWS) for red-legged frog (if necessary)
  - Incidental Take Permits (ITP) supported by Habitat Conservation Plan
  - Enhancement of Survival Permit supported by conservation benefit agreement
  - Consistency Determination, NMFS and CDFW (must be consistent with California Endangered Species Act [CESA])
  - Fish and Wildlife Coordination Act, USFWS, or NMFS
  - Incidental Take Statement (ESA section 7)
- National Historic Preservation Act (NHPA) Section 106 Consultation, California State Historic Preservation Office (SHPO)
- National Environmental Policy Act (NEPA)

State Permits and Regulations

- Section 2081(b) Incidental Take Permit (for CESA-listed only species), CDFW
- Scientific Collecting Permit, CDFW
- Special Use Permit, CDFW

- Streambed Alteration Agreement, CDFW
- CWA 401 Water Quality Certification, Regional Water Quality Control Board (RWQCB)
    - Waste Discharge Requirements
    - National Pollutant Discharge Elimination System (NPDES) – Stormwater Pollution Prevention Plan (SWPPP)
- California Division of Safety of Dams (DSOD) – Dam Alteration Application for projects impacting water retaining features of Lopez Dam
- California Clean Air Act, Air Quality Management District (AQMD)
- California Environmental Quality Act (CEQA)

Local Permits and Regulations

- County General Plan – Land Use and Circulation Element, Conservation and Open Space Element, Parks and Recreation Element, Safety Element (2018)
- Countywide Water Conservation Program – Conservation and Open Space Element Supplemental Environmental Impact Report (2015)
- County Biological and Geology Resources (i.e., Arroyo Toad Survey Protocol, Bald Eagle Habitat Evaluation Protocol, California red-legged frog Survey Guidance, Fault-Rupture Hazard Zones in California, Guidelines for Engineering Geology Reports, etc.)

Permitting (Cooperating and Participating) Agencies

- National Marine Fisheries Service (ESA Section 10/ITP, ESA Section 7 – Steelhead)
- U.S. Fish and Wildlife Service (ESA Section 10, ESA Section 7)
- USACE, Los Angeles District (CWA Section 404)
- California Department of Fish and Wildlife Service
- Regional Water Quality Control Board, Region 3 (CWA Section 401 + Waste Discharge Requirements)
- California State Historic Preservation Office
- California Division of Safety of Dams
- County of San Luis Obispo, Planning and Building

5.2.6.2 Regulatory Compliance Criteria

The regulatory compliance evaluation category contains two criteria. The results are presented in the Evaluation Matrix (Table 5-1).

Criteria for the Upstream Fish Passage Facility

- **Low Permitting Effort**: For the vertical slot fishway, the permitting effort would be expected to be high and would also involve coordination and approval from the DSOD for the dam penetration and the resulting dam safety concerns. In contrast, the permitting effort for the trap-and-haul facility would be expected to be low. As a result, the alternatives were scored 1 for the vertical slot fishway and 10 for the trap-and-haul facility. The higher score reflects a lower permitting effort.
- **Low Regulatory Constraints**: Even though interagency coordination has started, the project, independent of the alternative selected, would require significant regulatory coordination effort. As a result, the alternatives were scored equally, 5 for the vertical slot fishway and 5 for the trap-and-haul facility.

Overall, for upstream fish passage, the trap-and-haul system scores higher in terms of regulatory compliance.

Criteria for the Downstream Fish Passage Facility

- **Low Permitting Effort**: For the FSC and the helical system, the permitting effort would be expected to be high. In contrast, the permitting effort for the in-tributaries trap-and-haul would be expected to be low. As a result, the alternatives were scored 1 for the FSC, 1 for the helical system, and 10 for the in-tributaries trap-and-haul.
- **Low Regulatory Constraints**: Even though interagency coordination has started, the project, independent of the alternative selected, would require significant regulatory coordination effort. As a result, the alternatives were scored equally, 5 for the FSC, 5 for the helical system, and 5 for the in-tributaries trap-and-haul.

Overall, for downstream fish passage, the in-tributary trap-and-haul system scores higher in terms of regulatory compliance.

5.2.7 Financial Criteria

The financial evaluation category contains two criteria. The results are presented in the Evaluation Matrix (Table 5-1). The capital and operation and maintenance costs are presented in Appendix E.

5.2.7.1 Criteria for the Upstream Fish Passage Facility

- **Annual Capital Cost**: The annual capital cost is the total construction cost divided by the estimated life expectancy. It is not a true lifecycle cost. The annual capital cost for the vertical slot fishway would be about $933,000 compared to $61,000 for the trap-and-haul.
- **Annual Operational and Maintenance Cost**: The annual O&M cost for the vertical slot fishway would be about $208,000 compared to $279,000 for the trap-and-haul.

Overall, for upstream fish passage, the total annualized cost for the vertical slot fishway would be about $1,141,000 compared to $340,000 for the trap-and-haul. Consequently, the trap-and-haul system scores higher in terms of financial criteria.

5.2.7.2 Criteria for the Downstream Fish Passage Facility

- **Annual Capital Cost**: The annual capital cost for the FSC would be about $1,588,000, $3,170,000 for the helical system, and $90,900 for the in-tributary trap-and-haul.
- **Annual Operational and Maintenance Cost**: The O&M cost for the FSC would be about $730,000, $205,000 for the helical system, and $350,000 for the in-tributary trap-and-haul.

Overall, for downstream fish passage, the total annualized cost for the FSC would be about $2,318,000, $3,375,000 for the helical system, and $440,900 for the in-tributary trap-and-haul. Consequently, the in-tributaries trap-and-haul system scores higher in terms of financial criteria, followed by the FSC, and then the helical system.

5.3 Interagency Coordination

Direct communications with NMFS, USFWS, CDFW, USACE, DSOD, and RWQCB has been documented and shared with the County to facilitate the approach to environmental analyses, regulatory compliance, and closure.

Interagency pre-application and Technical Advisory Committee meetings provided resource agency representatives opportunities to weigh in on draft technical analysis and early alternatives development. Meeting agendas, presentations, and minutes can be found in Appendix F.

5.3.1 Meetings

HCP Interagency Pre-Application Meeting, May 20, 2025: Representatives from USFWS, NMFS, and CDFW asked questions and offered feedback. One suggestion was to ensure decisions are tracked. The following was discussed during the meeting relating directly to the Project:

- A question was asked about the expected timeframe for the passage project implementation. The HCP would need to be complete. The assumption was that it would take year 5 through 10: 5 years for assisted migration to 10 years for completing fish ladder construction. It was noted that timeframes would have to be known before a permit can be issued.

Technical Advisory Committee Meeting, June 24, 2025: Resource agency attendees from USFWS, NMFS, and CDFW attended this second meeting. The following was discussed relating directly to the Project:

- Volitional fish passage options were described, with no substantive comments or questions.

Technical Advisory Committee Meeting, July 22, 2025: The July 22 TAC Meeting was the third of five proposed meetings. The following was discussed relating directly to the Project:

- Volitional fish passage was discussed through the presentation of five fish passage alternatives remaining for consideration after pre-screening over 40 initial options. Constructability, operational requirements, and ancillary facilities of each alternative were presented.

6.0 Conclusion and Recommendations

This section provides conclusions and recommendations for this feasibility assessment.

6.1 Conclusion

This Feasibility Assessment Report provides a comprehensive and objective evaluation of potential engineering solutions to enable volitional passage for SCCC steelhead trout at Lopez Dam. Through a rigorous analysis of alternatives, informed by stakeholder engagement, and a transparent, quantitative assessment process, the study identifies and ranks feasible upstream and downstream fish passage options.

The findings presented herein offer a sound basis for determining which volitional passage alternatives are technically and economically viable, and which are not, under current site conditions and constraints. This report serves as a critical step toward informing the draft HCP for Lopez Dam and supporting the decision-making needs of regulatory agencies, including NMFS.

By integrating engineering, biological, and operational considerations within a collaborative framework, this assessment ensures that the recommendations reflect both scientific credibility and practical applicability. As a result, it provides a strong foundation for advancing conservation efforts for SCCC steelhead trout while guiding future actions to improve ecological connectivity and watershed resilience.

The trap-and-haul system ranked the highest alternative for the upstream fish passage, and the in-tributaries trap-and-haul facilities ranked the highest alternative for the downstream fish passage.

6.2 Recommendations

Based on the findings of this feasibility assessment, a simple trap-and-haul system in the form of a picket barrier and a trap box is recommended to be installed annually during the upstream fish passage period downstream of the dam for upstream migration. For downstream fish passage, it is recommended to also use a picket barrier and a trap box seasonally and install them in Lopez Canyon and Wittenberg creeks. Biological performance data as well as debris loading and sediment movement should be gathered for both upstream and downstream to determine if the options need to be scaled up or not, and to inform the design of the scaled-up options (if required). At this stage, the simple trap-and-haul solutions discussed in this report appear to be the most appropriate to advance as part of the HCP.

As set forth herein, it is the professional judgment of the authors that implementation of a strictly volitional system for either upstream or downstream fish passage at this dam is not feasible or practical, or would present elevated risks to dam safety, which could not safely be mitigated.

The recommendations and professional judgment of this report is based on the information presently available and is subject to revision upon receipt of additional data, further study, or subsequent technical review. Nothing in this report shall be construed as a final determination or binding recommendation, nor shall it be relied upon for purposes other than its intended technical context. The authors expressly disclaim any responsibility or liability for reliance on this judgment in litigation, regulatory proceedings, or other forums outside the scope of this report.

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Appendix A. TM002 - Design Criteria

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Technical Memorandum

To:	David Spiegel County of San Luis Obispo	Project:	Steelhead Passage Feasibility Assessment of Lopez Dam
From:	Wendy Katagi McMillen, Inc.	cc:	
Prepared by:	Vincent Autier, PE McMillen, Inc.	Job No:	25-062
Reviewed by:	John Hollenbeck, PE Hollenbeck Consulting Kevin Jensen, PE McMillen, Inc.	Date:	08/01/25
Subject:	TM 002 - Design Criteria – Attorney-Client Communication		

Revision Log

Revision	Date	Revision Description
A	05/15/25	Draft Design Criteria Memorandum
B	05/28/25	Final Design Criteria Memorandum
C	06/09/25	Final Design Criteria Memorandum (updated)
D	08/01/25	Final Design Criteria Memorandum (updated)

1.0 Introduction

For the Steelhead Passage Feasibility Assessment of Lopez Dam (Project), the design criteria presented here are the general standards required for the State of California. These design criteria will be used in the feasibility assessment.

1.1 Purpose and Objective

The purpose of this Technical Memorandum (TM) is to present a summary of the Project background and to clarify the design criteria specific to the Project. The basis of all design documentation reports, TMs, and feasibility assessments are founded on documenting all design criteria pertinent to the Project. Design criteria may include biological, hydraulic, hydrologic, and engineering criteria that are used to constrain the development of the design.

The objective of this TM is to collectively establish project-related design criteria with the Project stakeholders. To this end, the design criteria are developed early in the process and are distributed across the Project's team to solicit input and obtain agreement from stakeholders at the Project onset. This design criteria TM is a living document and may be updated over the course of the Project if new or revised design requirements mandate a change.

1.2 Authorization

The County of San Luis Obispo (County) has contracted McMillen, Inc. (McMillen) to provide engineering services to assess the feasibility of providing upstream and downstream passage for steelhead trout at Lopez Dam. The contract was authorized on April 8, 2025. The County of San Luis Obispo Contract number is 552R235006.

1.3 Standard List of Terms and Abbreviations

ACI	American Concrete Institute
ADM	Aluminum Design Manual
AISC	American Institute of Steel Construction
ANSI	American National Standards Institute
ASCE	American Society of Civil Engineers
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society of Testing and Materials
AWS	American Welding Society
AWS	Auxiliary water Supply
CARB	California Air Resources Board
CBC	California Building Code
CCOR	California Code of Regulations
CDFW	California Department of Fish and Wildlife
CWA	Clean Water Act
DPS	Distinct Population Segment
DO	dissolved oxygen
EL	elevation
ESA	Endangered Species Act

ESU	Evolutionarily Significant Unit
ft	feet
ft^3	cubic feet
gpm	gallons per minute
HCP	Habitat Conservation Plan
HDPE	high-density polyethylene
HVAC	heating, ventilation, and air conditioning
IBC	International Building Code
IEEE	Institute of Electrical and Electronic Engineers
IESNA	Illuminating Engineering Society of North America
ISA	Instrument Society of America
mm	millimeter
NACE	National Association of Corrosion Engineers
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
OSHA	Occupational Safety and Health Administration
PLC	programmable logic controller
PVC	polyvinyl chloride
SCCC	South-Central California Coast
SEI	Structural Engineering Institute
TM	Technical Memorandum
UL	Underwriters Laboratories
USACE	United States Army Corps of Engineers
USACE EMs	United States Army Corps of Engineers Engineer Manuals
USGS	United States Geological Survey

1.4 Background and Project Goals

Lopez Dam has been identified as an impassable barrier on the Arroyo Grande Creek, blocking passage to the target species, the South-Central California Coast (SCCC) Distinct Population Segment (DPS) steelhead trout (*Oncorhynchus mykiss*). The SCCC steelhead trout were originally listed in 1997 as threatened under National Marine Fisheries Service (NMFS) Evolutionarily Significant Unit (ESU) policy. The listing was reaffirmed in 2006 under the DPS policy. The SCCC steelhead trout are now listed as threatened under the Endangered Species Act (i.e., ESA listed). NMFS identified SCCC steelhead trout in Arroyo Grande Creek as a "Core 1" population in the agency's 2013 Recovery Plan (NMFS 2013). NMFS explained Core 1 populations are the highest priority for recovery based on a variety of factors. NMFS included Arroyo Grande Creek and Los Berros Creek in the area designated as critical habitat for the SCCC steelhead trout in 2005 (NMFS; 70 FR 52488).

Lopez Dam is a vitally important water infrastructure for the communities in the County. Its primary purpose is to provide drinking water supply for 50,000 residents. Its ancillary benefits are flood protection for both residences and agricultural lands, groundwater recharge, and recreational opportunities. The dam has been and continues to be a critical infrastructure component for Arroyo Grande Creek and the surrounding communities. Fish passage solutions would need to preserve these functions. The SCCC steelhead trout in Arroyo Grande Creek currently cannot access upstream rearing and spawning habitats. Lopez Dam affects both upstream and downstream migration.

NMFS has asked the County to assess fish passage at Lopez Dam in the process of developing a Habitat Conservation Plan (HCP). NMFS has communicated that “Mechanistic solutions to fish passage impediments can be problematic for a variety of reasons, including: the limitations in the operations during high flows when fish are most likely to be migrating; periodic mechanical failures which result in migration delays, or lost migration opportunities; and the expense of personnel and equipment to maintain such operations” (NMFS 2013). The County has therefore requested that McMillen assess volitional fish passage feasibility at Lopez Dam.

The goal of the feasibility assessment is to evaluate engineering solutions that enable volitional fish passage, contributing to species conservation and compliance with state and federal environmental regulations, while preserving the dam’s primary functions. The assessment must conclude with sufficient justification that certain volitional passage options may or may not be feasible, so that regulatory agencies, including NMFS, may rely on its findings. The feasibility assessment is intended to inform the conservation strategy for the draft HCP for Lopez Dam.

1.5 Location

The Arroyo Grande Creek Watershed is on the Central California Coast in an arid region with highly variable rainfall and stormwater runoff (Stetson Engineering, Inc. 2004). The watershed is located in southern San Luis Obispo County (Figure 1-1). The watershed also supports permanent agricultural crops (e.g., citrus orchards, vineyards, ranches, and low crops) and seasonal row crops (Stetson Engineering, Inc. 2004). Lopez Dam and Reservoir provide water supply for agricultural and municipal needs by storing stormwater runoff during the winter and early spring and providing managed releases throughout the year to meet downstream demands. Additionally, diversions from the reservoir through a 3-mile pipeline to a water treatment plant provide treated water to the Arroyo Grande, Pismo Beach, County Service Area 12 (CSA 12) - Avila Beach Area, Grover Beach, and Oceano municipalities. The watershed drainage rises to a maximum elevation (EL) of approximately 3,100 feet above sea level. Arroyo Grande Creek empties into the Arroyo Grande Lagoon.

Figure 1-1. Arroyo Grande Watershed and Location of Lopez Dam in the San Luis Obispo County, California (Source: County of San Luis Obispo)

1.6 Existing Project Description

Lopez Dam is a zoned earthfill dam constructed in 1968. The dam is 1,120 feet long and has a vertical height of 168.2 feet measured from the crest (EL 538.6[1] min.) to the outlet pipe invert, EL 370.4 on the river side. The dam crest is 40 feet wide and is used as a roadway (Lopez Drive) to connect the town to the southwest to the Lopez Lake Recreation Area.

[1] All elevations are in imperial measurements, i.e., feet and NAVD 88.

The dam retains water using a compacted clay core and a cutoff trench keyed into bedrock. The core has a minimum width of 25 feet, and the cutoff trench is keyed in a minimum of 10 vertical feet. The core is buttressed by a compacted sandy gravel layer on the upstream side and a compacted random zone on the downstream side. The dam employs a 10-foot-wide filter zone on both sides of the core and a 10-foot-wide gravel drain on the downstream side of the core. The gravel drain extends from the core to the downstream toe of the dam where it outlets to a riprap-lined collection area and is conveyed away from the dam. Abutment drainpipes are used to convey seepage along the foundation of the dam to the riprap-lined toe collection area. The upstream portion of the dam is overlayed with a 20-foot-thick layer of tuffite rock and a 10-foot-thick layer of graded tuffite rock for erosion protection. The dam slope is at 3H:1V on both sides of the dam and is benched at EL 450 with an outward slope of 0.05 ft/ft. The bench on the reservoir side is 100 feet long, while the bench on the downstream side is 120 feet long.

Lopez Dam utilizes a concrete spillway to pass storm flows and is equipped with a side channel ogee weir at crest EL 522.6. The spillway chute is linear, and it terminates with a 16-degree launch angle flip bucket with an invert at EL 387.6 to dissipate the flow energy from the spillway. The dam also includes an intake control building, a 42-inch welded steel pipe encased in concrete, an outlet control building (i.e., outlet works), and other appurtenances. In the 2000s, the County completed the Lopez Dam seismic remediation project, including changes to the dam and outlet works after obtaining necessary permits and authorizations including a permit from the U.S. Army Corps of Engineers and biological opinions from NMFS and U.S. Fish and Wildlife Service (Figure 1-5).

The intake structure includes seven inlets, each connected to a common header at 45 degrees. The inlets are approximately 15 feet apart vertically, and each is equipped with a trash rack and a fish screen. The fish screens have openings of approximately 10 inches by 12 inches, larger than the trash rack openings of 1/2-inch bar at 4 inches on center. The fish screen and the trash rack are both hot-dip galvanized. Figure 1-2 through Figure 1-5 present an overview of Lopez Dam.

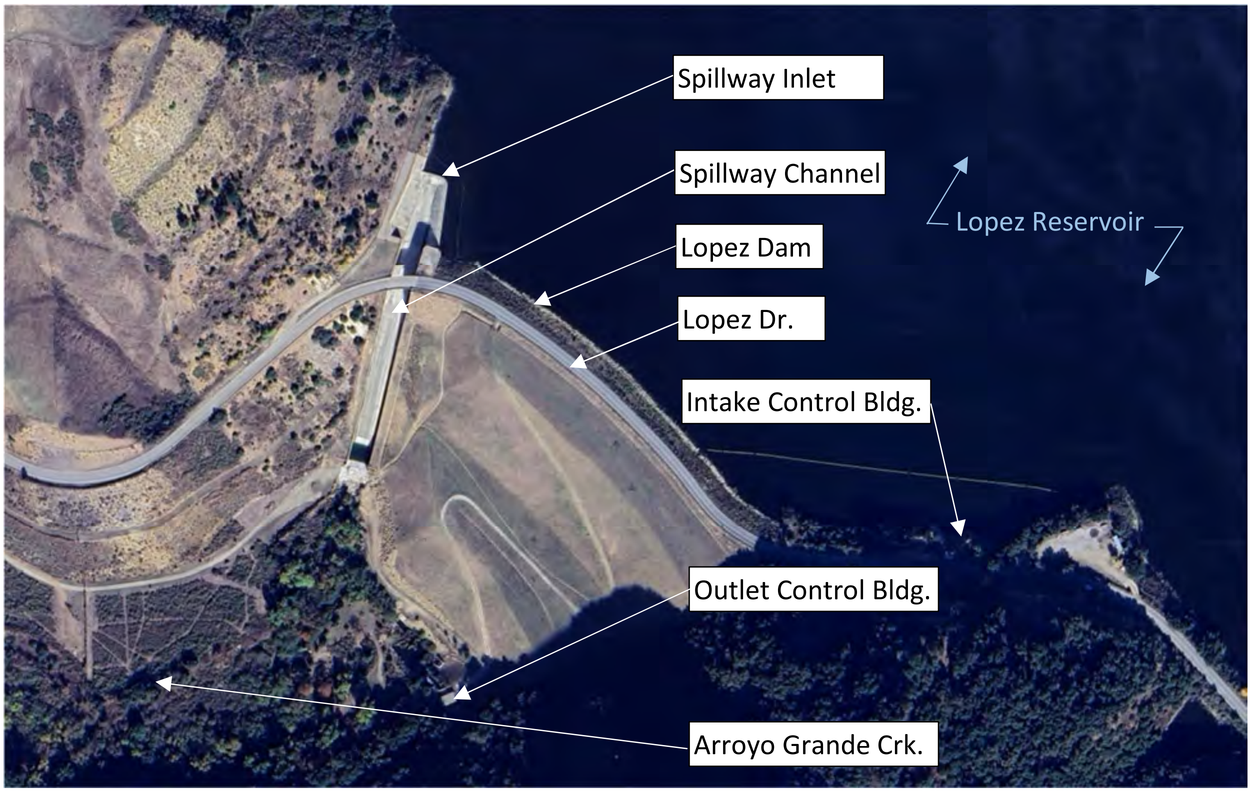

Figure 1-2. Lopez Dam Overview (Source: Google Earth)

Figure 1-3. Lopez Dam on Arroyo Grande Creek, San Luis Obispo County (Source: ForestWatch)

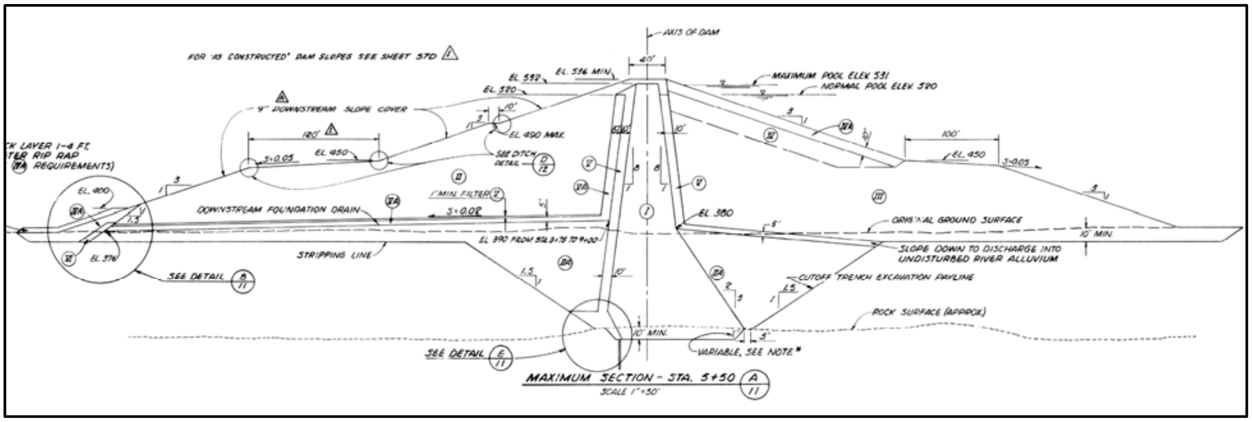

Figure 1-4. Cross Section through Lopez Dam (Source: Koebig & Koebig, Inc. 1967)

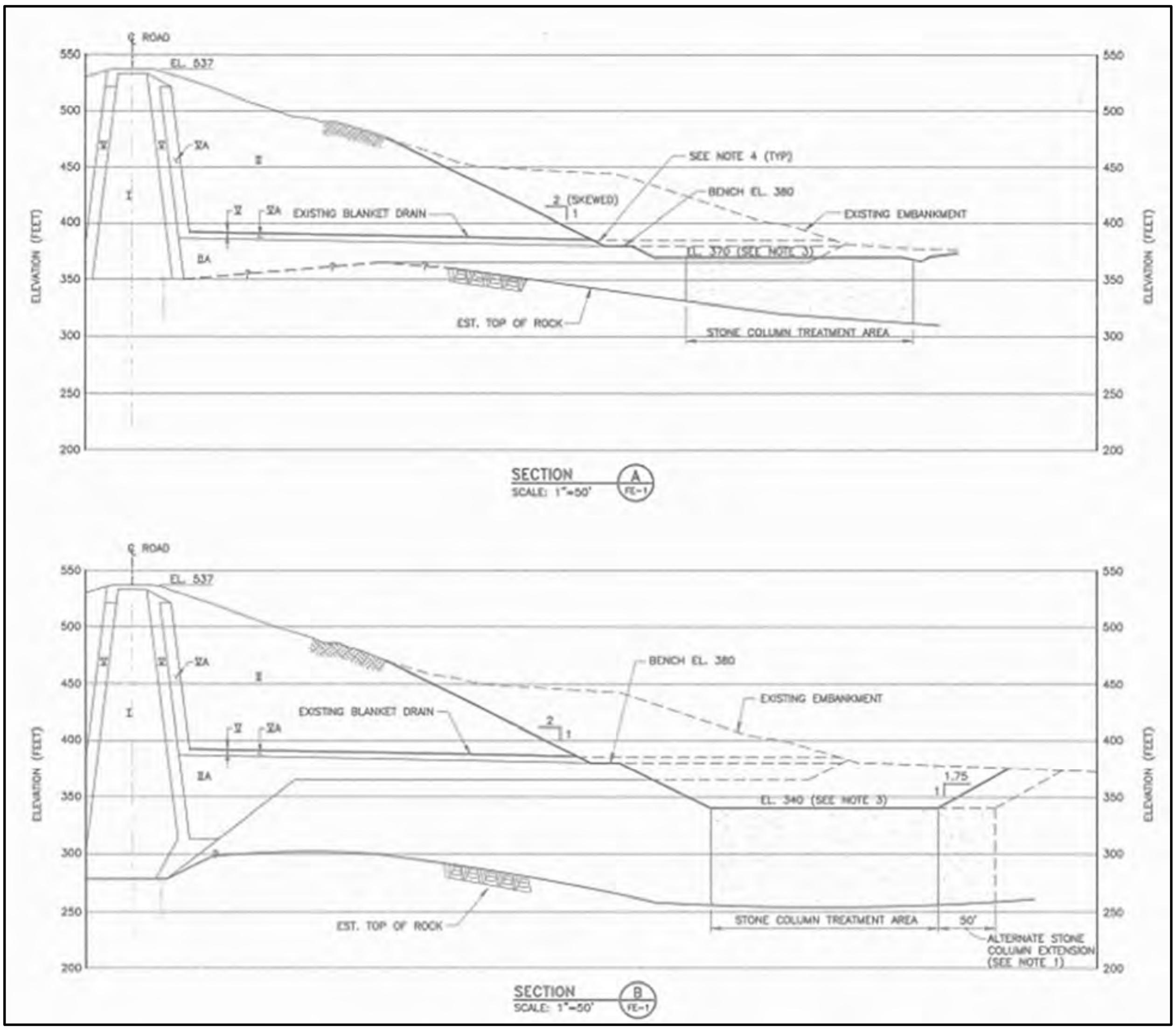

Figure 1-5. Cross Sections of the Downstream Face Showing Seismic Retrofit (Source: URS, 2000)

2.0 Design Criteria

This section presents the design criteria that would be required to design a fishway at Lopez Dam. Section 2.1 presents criteria specific to sizing the fishway, while Section 2.2 presents discipline specific criteria and standards that would be used in later design phases. Section 2.1 is of primary importance for the feasibility assessment for the Project.

2.1 Fishery Design Criteria

This section presents the biological criteria, water quality criteria, hydraulic and hydrologic design criteria, and the fish passage criteria.

2.1.1 Biological

Table 2-1 includes the fish species at Lopez Dam to be included in the passage feasibility assessment, their average size (i.e., length and weight), their corresponding swimming capabilities expressed as burst and prolonged as defined by Powers and Orsborn (1985), and their expected numbers at Lopez Dam.

There are different swimming capability definitions, namely those of Milo Bell (1991)[2] and those of Powers and Orsborn (1985). The Powers and Orsborn definition is used for this TM. They classify swimming capabilities into three categories, which are defined as follows:

1. *Sustained Velocity*: Fish can function normally for long periods of time without fatigue.
2. *Prolonged Velocity*: Velocity can be maintained over long period of time (15 s to 200 min).
3. *Burst Speed*: Velocity can be maintained for short periods (15 s or less) to negotiate falls and high-velocity areas.

Table 2-2 presents the species migration periods per life stage. Note that the migration season from December 1 to June 30 (for upstream and downstream) generally corresponds with the data that is presented in the Preliminary Injunction Order from the U.S. District Court (2024).

Steelhead can exhibit different life history strategies, including anadromy or resident life-history that is commonly referred to as Rainbow Trout. However, the use of the term “Rainbow Trout” is problematic in this context, since the resident life-history adults can

[2] Milo Bell, who also classifies swimming capabilities into three categories, defines those categories as follows: (1) *Cruising*: A speed that can be maintained for long periods of time (hours; 1/6 of Darting Speed), (2) *Sustained*: A speed that can be maintained for minutes (1/2 of Darting Speed), and (3) *Darting*: a single effort, not sustainable. It is important to define those terms especially because the term “sustained” has different definitions depending on the reference used.

produce anadromous smolts and vice versa. They are the same species and are referred to as SCCC steelhead trout in this TM independently of the different life history strategies (Stillwater, 2023).

Table 2-1. Biological Design Criteria

Criteria	Units	Value	Comments / Reference
Species	-		
Target Species			
SCCC steelhead trout	-	Juvenile/Adult	*Oncorhynchus mykiss.* Migratory steelhead spawn and rear within the creek downstream of Lopez Dam. Resident Rainbow Trout spawn and rear in the tributaries upstream of Lopez Lake (Stetson Engineering, Inc. 2004).
Native Species (in Reservoir)			
Hitch	-	Juvenile/Adult	*Lavinia exilicauda*
Speckled Dace	-	Juvenile/Adult	*Rhinichthys osculus*
California Roach	-	Juvenile/Adult	*Lavinia symmetricus*
Three-spined Stickleback	-	Juvenile/Adult	*Gasterosteus aculeatus*
Non-Native and Invasive Species			
Largemouth bass	-	Juvenile/Adult	*Micropterus nigricans* (CCSE 2009)
Black Crappie	-	Juvenile/Adult	*Pomoxis nigromaculatus* (CCSE 2009)
Green Sunfish	-	Juvenile/Adult	*Lepomis cyanellus* (CCSE 2009)
Other Species in Reservoir (introduced)	-	See comment	Lopez Reservoir provides habitat for Sacramento Pikeminnow (*Ptychocheilus grandis*), Channel Catfish (*Ictalurus punctatus*), Blue Catfish *(Ictalurus furcatus)*, brown bullhead (*Ameiurus nebulosus)*, smallmouth bass (*Micropterus dolomieu*), bluegill (*Lepomis macrochirus*), Redear Sunfish (*Lepomis microlophus*) Mosquitofish (Gambusia Sp.), Threadfin Shad (*Dorosoma petenense*), Goldfish (*Carassius auratus*), and Golden Shiner (*Notemigonus crysoleucas*) (Stetson Engineering, Inc. 2004; Woodward 2025)

Criteria	Units	Value	Comments / Reference
Other Species below Dam	-	See Comment	Sacramento suckers (*Catostomus occidentalis*), sculpin (*Cottus spp.)* California roach (*Hesperoleucus symmetricus*), three-spined stickleback (*Gasterosteus aculeatus*), striped mullet (*Mugil cephalus*), steelhead (*Oncorhynchus mykiss*), bullhead catfish (*Hesperoleucus symmetricus*), hitch (*Lavinia exilicauda*), and bass (*Micropterus spp.*). (Stillwater 2024) Pacific Lamprey *(Entosphenus tridentatus;* historical but not present [USFWS 2022])
Fish Size			
Fork Length			
Adult SCCC steelhead trout	mm	460 - 710	Behnke 1992 and Capelli 2024
Juvenile SCCC steelhead trout	mm	96 - 265	Stillwater 2024
Average Fish Weight			
SCCC steelhead trout	grams	2,700 (1,100-5,400)	Professional judgement Behnke 1992
Swimming Capabilities			
Burst Speed			
Adult SCCC steelhead trout	ft/s	20.3	Bell 1991
Juvenile SCCC steelhead trout	ft/s	4.7	Bainbridge 1960
Prolonged Speed			
Adult SCCC steelhead trout	ft/s	10.2	Bell 1991
Juvenile SCCC steelhead trout	ft/s	1.2	Bainbridge 1960
Numbers of Fish			
Adult SCCC steelhead trout	-	14	Below the dam. Stillwater 2024
Juvenile SCCC steelhead trout	Fish per 100 feet	2.9	i.e., 0-10 fish/100 ft avg was 2.9 fish/100 ft. Arroyo Grande Creek downstream of the dam, SHG 2008.
Regulatory Performance Standard			
Juvenile Reservoir Survival Rate	percent	75 to 80	CDFW
Juvenile Collection Efficiency	percent	95	
Fry and smolt survival rates	percent	98 to 99.5	
Adult Passage Efficiencies	percent	75 to 95	
Adult Survival Rate	percent	95 to 98	

Table 2-2 presents the steelhead adult upstream migration and smolt outmigration timing. Since fish passage is not linear and instead follows a bell curve shape, the following bullets present the migration periods:

- Adult Upstream Migration: December 1 to May 1 (Note: the bar at Arroyo Grande Lagoon typically closes in April, reducing the migration season by a month when compared to other watersheds).
- Smolt Outmigration: February 15 to June 15

Table 2-2. Steelhead Adult Migration and Smolt Outmigration Timing (Source: Stetson Engineering, Inc. 2004 and Stillwater Sciences 2023)

Life Stage	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult Migration (Winter-Run)												
Smolt and Kelt Outmigration												

Note: Shading indicates a qualitative measure of migration frequency, with light grey cells representing modest migration instances, dark grey cells representing significant migration instances, and white cells indicating no migration.

2.1.2 Process Water Quality/Quantity

Table 2-3 presents the process water quality and quantity that is dependent on holding duration, number of fish, water quality, and water temperature.

Table 2-3. Process Water Quality/Quantity

Criteria	Units	Value	Comments / Reference
Max River Temperature for Fish in Order to Operate (Holding - River Temp.) Transport	°F/°C	<68°F/ 20°C	The average water temperature of Lopez reservoir between January 2011 and May 2025 was 16.78°C (min 10.3°C; max = 23.8°C). In general, temperatures less than 20°C are considered suitable for juvenile rearing steelhead (Hayes et al. 2008), but a wide range of suitable temperatures have been reported for steelhead throughout their natural range. In locations near their southern extent, steelhead have been reported to maintain high aerobic performance at temperatures exceeding 24°C (Verhille et al. 2016), and steelhead have been observed persisting through the summer in pools where water temperatures exceeded 29°C (Sloat and Osterback 2013).
Max Holding Temperature	°F/°C	<68°F/ 20°C	In holding units, match the tailrace temperature from which the fish are collected.
Minimum DO	% Sat.	Near saturation	May need supplemental oxygen depending on the number of non-target fish in the pre-sort holding pool.
Max Nitrogen Saturation in holding units	% Sat.	<110	There will be some degassing in the fish ladder due to turbulence.
Max Hopper Holding Density	ft^3/lb.	0.15	NMFS 2023a, Section 7.6.1.1.
Short-Term Holding Capacity	ft^3/lb.	0.25	NMFS 2023a, Sections 7.5.5.3 and 7.5.5.5. For holding times <24 hours and DO between 6 and 7 ppm; reduce by 5% for each degree of water temperature above 50°F.
Short-Term Holding Flows	gpm/fish	0.67	NMFS 2023a, Section 7.5.5.3 - Per adult fish based on the vessel holding capacity.
Long-Term Holding Capacity	ft^3/lb.	0.50	NMFS 2023a, Sections 7.5.5.4 and 7.5.5.5 - For holding times between 24 hours and 96 hours; reduce by 5% for each degree of water temperature above 50°F.

Criteria	Units	Value	Comments / Reference
Long-Term Holding Flows	gpm/fish	1.34	NMFS 2023a, Section 7.5.5.4. Per adult fish based on the vessel holding capacity.

2.1.3 Hydraulic and Hydrology

Hydrologic design criteria described in NMFS Section 4.2 and 4.3 provide a bracketed range of fish passage flows by designating both the design low flow and design high flow conditions for fish passage, respectively (NMFS 2023a). The design of low flow for fishways is defined as the average daily streamflow that is exceeded 95% of the time during periods when migrating fish are normally present at the site, while the design of high flow for fishways is defined as the average daily streamflow that is exceeded 5% of the time during periods when migrating fish are normally present at the site (NMFS 2023a). However, per Section 4.0 of NMFS (2023a), significantly different hydrologic conditions in California can necessitate working with NMFS staff to determine appropriate design flow exceedances in California. The California Department of Fish and Wildlife (CDFW) provide different criteria specific to California, as presented in Table 2-4 (2003). These are the hydrologic design criteria adopted for the Project.

Table 2-4. High and Low Fish Passage Design Criteria by Species and Life Stage (NMFS 2023b and CDFW 2003)

Species/Life Stage	High Design Flow	Low Design Flow	
	Exceedance	Exceedance	Alternate Minimum Flow (ft^3/sec)
Adult Anadromous Salmonids	**1%**	50%	3
Adult Non-Anadromous Salmonids	5%	90%	2
Juvenile Salmonids	10%	**95%**	**1**
Native Non-Salmonids	5%	90%	1

The migration season for SCCC steelhead trout is December 1 to June 30 (U.S. District Court 2024) and presented in Table 2-2. This migration season was used to produce the low and high fish passage design flows as bounded by the information presented in bold in Table 2-4. Table 2-5 presents these values.

Table 2-5. Hydraulic and Hydrologic Criteria

Criteria	Flow (ft^3/s)	Elevation (ft)	Comments / Reference
Tailwater			
Minimum	0	368.69	Raw daily data (12/1995-03/2025)
95% Exceedance	2.4	368.9	Raw daily data (12/1995-03/2025)
50% Exceedance	5.9	309.4	Raw daily data (12/1995-03/2025)
5% Exceedance	59.6	370.8	Raw daily data (12/1995-03/2025)
1% Exceedance	182	371.2	Raw daily data (12/1995-03/2025)
Maximum	1,130	373.5	Raw daily data (12/1995-03/2025)
Forebay (Reservoir)			
Top of Dam Elevation	-	538.6	Per As-builts, Koebig & Koebig, Inc. 1967, plus datum adjustment.
Maximum Pool Elevation	-	533.6	Per As-builts, Koebig & Koebig, Inc. 1967, plus datum adjustment. This corresponds to 65,830.6 acre-feet.
Outlet Flow Capacity at Normal Maximum EL 522.6	100		The design outlet flow capacity was 237 ft^3/sec (Montgomery Consulting Engineers 1983), yet the outlet pipe has some limitations. The storage is equal to 54, 500.4 acre feet at 522.6. Elevation per As-builts, Koebig & Koebig, Inc. 1967, plus datum adjustment.
Spillway Crest Elevation (i.e., normal maximum elevation)	-	522.6	Per As-builts, Koebig & Koebig, Inc. 1967, plus datum adjustment.
Outlet Flow Capacity at Minimum Pool EL 432.6	150		Outlet Capacity at 4,837 acre-feet. The minimum pool is at 4,000 acre-feet or El 426.0 (Montgomery Consulting Engineers 1983).
Other			
100-year Flow	~19,500	-	Swanson Hydrology & Geomorphology, 2004
Arroyo Grande Peak Flow near Arroyo	4,620 – 5,400		At USGS 11141500 (1940-1986)

Criteria	Flow (ft³/s)	Elevation (ft)	Comments / Reference
Grande, Downstream of Lopez Dam			
Base Flow – Release at the Dam (Minimum instream flow)	5.9 to 7.9	475.00 506.38	5.9 ft³/sec during Dry Water Year (i.e., Lopez reservoir storage <20,000 acre-feet of water on December 1 of that water year) 7.9 ft³/sec during Normal Water Year (i.e., Lopez reservoir storage is between ≥20,000 acre-feet and <40,000 acre-feet of water on December 1 of that water year), and 7.9 ft³/sec during Wet Water Year (i.e., Lopez reservoir storage >40,000 acre-feet of water on December 1 of that water year) per U.S. District Court 2024.

2.1.4 Fish Passage

This section presents general fish passage criteria in a series of tables for volitional and non-volitional fishways.

- Table 2-6. Fish Ladder Design Criteria: Includes drop per pool, energy dissipation, flow range, orifice and slot velocities, length and width, wall height, auxiliary water flows, and ladder type.
- Table 2-7. Nature-Like Fishway Design Criteria: Presents design criteria for Nature-Like Fishways with step-pools and plane-bed morphologies.
- Table 2-8. Fish Screening Facility Design Criteria: Includes maximum approach velocity, transport velocity, time exposure to fish screen, cleaning requirements, and screen opening size.
- Table 2-9. Pre-Sort Holding Pool Criteria: Includes holding density, flow, length, width, depth, wall height, surface spray, and brail floor.
- Table 2-10. Fish Bypass Facility Design Criteria: Includes bypass velocity, impact velocity, pipe size, and pipe material.

Table 2-6. Fish Ladder Design Criteria

Criteria	Units	Value	Comments / Reference
Fishway Entrance			
Configuration and Operations	n/a	See Comment	NMFS 2023a, Section 5.2.2.1. The fishway entrance gate configuration and operation may vary based on site-specific project operations and streamflow characteristics. Entrance gates are usually operated in either a fully open or fully closed position, with the operating entrance dependent on tailrace flow characteristics. Adjustable weir gates that rise and fall with tailwater elevation may be used to regulate the fishway entrance head. Other sites may accommodate maintaining proper entrance head by regulating auxiliary water flow through a fixed geometry entrance gate or variable width entrance.
Location	n/a	See Comment	NMFS 2023a, Section 5.2.2.2. Fishway entrances must be located at points where fish can easily locate the attraction flow and enter the fishway.
Attraction Flow	ft^3/sec	If using 1% Exceedance (182 ft^3/sec): 9.1 to 18.2 If using 5% Exceedance (59.6 ft^3/sec): 3.0 to 5.96	NMFS 2023a, Section 5.2.2.4. Attraction flow from the fishway entrance should be between 5% and 10% of fish passage design high flow for streams with mean annual streamflows exceeding 1,000 ft^3/sec. For smaller streams, when feasible, use larger percentages (up to 100%) of streamflow. During Dry Water Year, 5.9 ft^3/sec corresponds to the low base flow. We would propose the attraction flow to be equal to the base flow as described in Table 2-5.
Hydraulic Head Drop	ft	1 to 1.5	NMFS 2023a, Section 5.2.2.5. The fishway entrance hydraulic drop must be maintained between 1 and 1.5 feet, depending on the species present at the site, and designed to operate from 0.5 to 2.0 feet of hydraulic drop.

Criteria	Units	Value	Comments / Reference
Minimum Width	ft	4	NMFS 2023a, Section 5.2.2.6. The shape of the entrance is dependent on attraction flow requirements and should be shaped to accommodate site conditions. For smaller stream, the ladder entrances should be as large as possible, consistent with available fishway entrance flow, to maximize fish attraction and minimize plugging by debris.
Minimum Depth	ft	6	NMFS 2023a, Section 5.2.2.6. The shape of the entrance is dependent on attraction flow requirements and should be shaped to accommodate site conditions.
Approach Conditions	n/a	See Comment	Bell 1991. Similar to ambient depth, velocity, flow direction, and turbulence.
Additional Entrances	n/a	See Comment	NMFS 2023a, Section 5.2.2.3. If the site has multiple zones where fish accumulate, each zone must have a minimum of one entrance. For long powerhouses or dams, additional entrances may be required. Multiple entrances are usually required at sites where the high and low design flows create different tailwater conditions.
Types of Entrances	n/a	See Comment	NMFS 2023a, Section 5.2.2.7. Fishway entrances may be adjustable submerged weirs, vertical slots, orifices, or other shapes, provided that the requirements specified in Section 5.2.2 are achieved.
Flow Conditions	n/a	See Comment	NMFS 2023a, Section 5.2.2.8. The desired flow condition for entrance weir and/or slot discharge jet hydraulics is streaming flow. Plunging flow induces jumping and may cause injuries, and it presents a hydraulic condition that some species may not be able to pass.
Orientation	n/a	See Comment	NMFS 2023a, Section 5.2.2.9. Generally, low flow entrances should be oriented nearly perpendicular to streamflow, and high flow entrances should be oriented to be more parallel to streamflow.

Criteria	Units	Value	Comments / Reference
Staff Gauges	n/a	See Comment	NMFS 2023a, Section 5.2.2.10. The fishway entrance design must include staff gauges to allow for a simple determination of whether entrance head criterion is met.
Entrance Pools	n/a	See Comment	NMFS 2023a, Section 5.2.2.11. The fishway entrance pool should be designed to combine ladder flow with auxiliary water system (AWS; also known as auxiliary water supply system) flow in a manner that encourages fish to move from the entrances in an upstream direction and optimizes the attraction of fish to lower fishway weirs.
Transport Velocity	ft/s	1.5 to 4.0	NMFS 2023a, Section 5.2.2.12 and Section 5.4.2.1.
Auxiliary Water Supply (AWS) Diffusers			
Velocity	ft/s	See Comment	NMFS 2023a, Section 5.3.2.2. The maximum AWS diffuser velocity must be less than 1.0 ft/s as calculated by dividing the maximum flow by the submerged area of the fine trash rack.
Cleaning Consideration	n/a	See Comment	NMFS 2023a, Section 5.3.2.3. The support structure of the fine trash rack should not interfere with cleaning requirements and should provide access for debris raking and removal.
Edges	n/a	See Comment	All flat-bar diffuser edges and surfaces exposed to fish must be rounded or ground smooth to the touch, with all edges aligning in a single smooth plane to reduce the potential for contact injury.
Bar Spacing	inch	<0.875	NMFS 2023a, Section 5.3.2.1. A fine trash rack should be provided at the AWS intake with clear space between the vertical flat bars of 0.875 or less. If Pacific Lamprey are present, the AWS intake bar spacing should be reduced to 1/2 or 5/8" for exclusion. The diffuser open spacing would be 3/4".
Slope	H:V	1:5	NMFS 2023a, Section 5.3.2.4. The fine trash rack should be at a 1H:5V or flatter slope for ease of cleaning.
Fishway Exit			

Criteria	Units	Value	Comments / Reference
Hydraulic Drop	ft	0.25 to 1.0	NMFS 2023a, Section 5.7.2.1. The exit control section hydraulic drop per pool should range from 0.25 to 1.0 feet.
Length	n/a	See Comment	NMFS 2023a, Section 5.7.2.2. The length of the exit channel upstream of the exit control section should be a minimum of two standard ladder pools.
Design Requirements	n/a	See Comment	NMFS 2023a, Section 5.7.2.3. Exit section design must utilize the requirements for auxiliary water diffusers, channel geometry, and energy dissipation as specified in NMFS Sections 5.3, 5.4, and 5.5.
Closure Gates	n/a	See Comment	NMFS 2023a, Section 5.7.2.4. Any closure gate that is incorporated into the exit control section should be operated either in the fully opened or closed position.
Location	n/a	See Comment	NMFS 2023a, Section 5.7.2.5. In most cases, the ladder exit should be located along a shoreline and in a velocity zone of less than 4 ft/s, sufficiently far enough upstream of a spillway, sluiceway, or powerhouse to minimize the risk of fish non-volitionally falling back through these routes. Distance of the ladder exit with respect to the hazards depends on bathymetry near the dam spillway or crest and associated longitudinal river velocities.
Public Access	n/a	See Comment	NMFS 2023a, Section 5.7.2.6. Public access near the ladder exit should be prohibited.
Fishway Exit Sediment and Debris Management	n/a	See Comment	The fishway Exit Sediment and Debris Management shall meet the NMFS 2023a Section 5.8.
Common Types of Fish Ladder			
Common Types of Fish Ladder	-	See Comment	NMFS 2023a, Section 5.5.2 presents different ladder types such as the vertical slot ladder (5.5.2.1), the pool and weir ladder (5.5.2.2), the weir and orifice ladder (5.5.2.3), the pool and chute ladder (5.5.2.4), and the half Ice Harbor and half-pool and chute ladders (5.5.2.5).

Criteria	Units	Value	Comments / Reference
Hydraulic Drop Between Fish Ladder Pools	ft	1 max	NMFS 2023a, Section 5.5.3.1.
Flow Depth	ft	1 min	NMFS 2023a, Section 5.5.3.2. Fishway overflow weirs should provide at least 1 foot of flow depth over the weir crest.
Minimum Pool Length	ft	8	NMFS 2023a, Section 5.5.3.3.
Minimum Pool Width	ft	6	NMFS 2023a, Section 5.5.3.3.
Minimum Pool Depth	ft	5	NMFS 2023a, Section 5.5.3.3.
Turning Pools	n/a	See Comment	NMFS 2023a, Section 5.5.3.4. Turning pools should be at least double the length of a standard fishway pool, as measured along the centerline of the fishway flow path.
Fish Ladder Pool Energy Dissipation Factor	(ft-lb./s)/ft^3	4 max 3.13	NMFS 2023a, Section 5.5.3.5. Per USFWS 2019, 3.13 is selected for trout and adult Salmonids.
Fish Ladder Pool Freeboard	ft	3 min	NMFS 2023a, Section 5.5.3.6. At high design flow, there should be a minimum of 3 feet.
Orifice Dimensions	inch	15 high 12 wide	NMFS 2023a, Section 5.5.3.7. At sites where large salmonids are expected, the minimum dimensions of the orifice should be 18 inches high by 15 inches wide (Bell 1991), based on the Ice Harbor ladder design dimensions (Section 5.5.3.3). The minimum dimensions of orifices where large salmonids are not expected should be at least 15 inches high by 12 inches wide. The top and sides should be chamfered 0.75 inches on the upstream side and chamfered 1.5 inches on the downstream side of the orifice.
Lighting	n/a	See Comment	NMFS 2023a, Section 5.5.3.8. Ambient lighting is preferred. Abrupt lighting changes must be avoided.
Change in Flow Direction Greater than 60°	n/a	45° vertical miters or 2-foot vertical radius	NMFS 2023a, Section 5.5.3.9.
Transport Velocity	ft/sec	1.5 to 4.0	NMFS, Section 5.2.2.12 and Section 5.4.2.1.

Criteria	Units	Value	Comments / Reference
Orifice Velocities	ft/sec	6.0 or less	Based on fish swimming speed.
Fish Ladder Flow	ft^3/sec	See Comment	Based on transport velocity and energy dissipation criteria.
No. of Ladder Pools	each	TBD	Dependent on alternative development.
Minimum Slope	-	1(V)/10(H)	NMFS, Section 5.5.2.3.
Others			
Predation	n/a	See Comment	Predation prevention shall be included as part of the design (to the extent feasible).

Table 2-7. Nature-Like Fishway Design Criteria

Criteria	Units	Value	Comments / Reference
Maximum Average Channel Velocity	ft/sec	5	NMFS 2023a, Section 5.10.3.1. Maximum average channel velocity at the 5% exceedance flow should be no greater than 5 ft/s, regardless of channel slope.
Pool Depth	ft	4	NMFS 2023a, Section 5.10.3.2. If drop structures are used in the fishway, minimum pool depth should be 4 feet in the receiving pool of each drop structure.
Maximum Hydraulic Drop	ft	1	NMFS 2023a, Section 5.10.3.3. Maximum hydraulic drop is 1 foot for adult salmonids and 0.5 foot for juvenile salmonids.
Maximum Fishway Slope for Step-Pool Morphology	%	5	NMFS 2023a, Section 5.10.3.4. For all salmonid species; CDFW 2009.
Maximum Fishway Slope for Plane-Bed Morphology	%	1.5 to 3.0	CDFW 2009.
Channel Stability	-	See Comment	NMFS 2023a, Section 5.10.3.5. Beds and banks should be designed to be immobile at all anticipated fishway discharges.
Channel Roughness	-	See Comment	NMFS 2023a, Section 5.10.3.6. Actual fishway roughness should produce a maximum 5 ft/s average velocity at the high fish passage design flow.

Table 2-8. Fish Screening Facility Design Criteria

Criteria	Units	Value	Comments / Reference
Design Flow	ft^3/sec	TBD	
Screen Material	-	Stainless steel, aluminum, plastic, or antifouling alloys containing copper and other metals	NMFS 2023a, Section 8.5.8. For this Project, stainless steel is recommended.
Screen Approach Velocity	ft/s	≤0.40 (active) (exposure time <60 sec) ≤0.30 (active) (exposure time >60 sec) ≤0.20 (passive) ≤0.25 (horizontal)	NMFS 2023a, Sections 8.5.1 and 8.8.4.8. Approach velocity is calculated by dividing the maximum screened flow amount by the vertical projection of the effective screen area.
Sweeping Velocity	ft/s	0.8 to 3.0	NMFS 2023a, Section 8.5.3. Screens longer than 6 feet must be angled and must have sweeping velocity greater than approach velocity. For screens longer than 6 feet, sweeping velocity must not decrease along the length of the screen.
Active Screen Cleaning Systems	-	See Comment	NMFS 2023a, Section 8.5.5. All new fish screens should incorporate an automated cleaning system unless the Project meets the requirements for passive screens listed in NMFS 8.5.6.
Active Screen Cleaning Frequency	min	Capable of 5 minutes cycles, min	NMFS 2023a, Section 8.5.5.1. Or triggered by a max head differential of 0.3 ft over clean screen conditions.
Screen Submergence	%	85 max for rotating drum screens 65% min drum diameter	NMFS 2023a, Section 8.5.7.3.
Circular Screen Openings	inch	3/32 max	NMFS 2023a, Section 8.5.8.1.

Criteria	Units	Value	Comments / Reference
Slotted or Rectangular Screen Openings	inch	0.069 max	NMFS 2023a, Section 8.5.8.1. For this Project, slotted or rectangular screen openings are recommended.
Square Screen Openings	inch	3/32 max	NMFS 2023a, Section 8.5.8.1.
Screen Open Area	%	27 min	NMFS 2023a, Section 8.5.8.2.

Table 2-9. Pre-Sort Holding Pool Criteria

Criteria	Units	Value	Comments / Reference
Trapping Mechanism	-	V-trap / Finger Weir	NMFS 2023a, Section 7.5.4.
Holding Density	$ft^{3}/lb.$	0.25	NMFS 2023a, Section 7.5.5.3. See Table 2-3.
Flow	gpm/fish	1.0	NMFS 2023a, Section 7.5.5.3. The trap water supply flow rate should be at least 0.67 gpm/adult fish.
Water Supply	-	Floor or wall diffuser	NMFS 2023a, Section 7.5.5.6.
Water Depth, min.	ft	5	NMFS 2023a, Section 7.5.5.8. Function of fish numbers / size.
Jump Prevention	-	3 feet min / 5 feet optimum	NMFS 2023a, Sections 5.5.3.6 and 7.5.5.9. Extra wall height beyond the freeboard height, removable panels, grating and/or netting.
Cycle Time, min.	hr.	0.5	Cycle time for complete brail operation.

Table 2-10. Fish Bypass Facility Design Criteria

Criteria	Units	Value	Comments / Reference
Fish Return	-	Manual	For non-target fish.
Change in Bypass Channel Velocity	ft/s per linear foot of travel	0.2 Max	NMFS 2023a, Section 8.6.2.8. The rate of increase in velocity between any two points in the bypass channel should be non-negative and should not exceed 0.2 ft/s per foot of travel.

Criteria	Units	Value	Comments / Reference
Bypass Entrance Dimensions	in	18 wide for more than 3 ft^3/sec. 12 wide for less than 3 ft^3/sec.	NMFS 2023a, Section 8.6.2.4.
Bypass Conduit Bends	-	R/D ratio greater than or equal to 5.	NMFS 2023a, Section 8.6.3.11. R/D (center line of radius of curvature/pipe diameter).
Access Points	-	None	NMFS 2023a, Section 8.6.3.13. Spacing access points are to be provided for bypass length greater than 150 feet.
Pipe Size, min.	inch	10	NMFS 2023a, Section 8.6.3.3.
Bypass Flow	%	5% of the total diverted flow amount	NMFS 2023a, Section 8.6.3.4.
Bypass Velocity	ft/s	Between 6 and 12	NMFS 2023a, Section 8.6.3.5.
Minimum Depth	%	40	NMFS 2023a, Section 8.6.3.6. The criterion is 40% of the bypass pipe diameter.
Bypass Outfall Ambient River Velocity	ft/s	4 min	NMFS 2023a, Section 8.6.4.1.
Impact Velocity, Max	ft/s	25	NMFS 2023a, Section 8.6.4.2.
Material	-	HDPE	HDPE pipe segments should be butt welded, and the inner bead shall be removed using a de-beading machine to leave each interior joint smooth to the touch.

2.2 Other Disciplines

This section presents the engineering codes, standards, and/or criteria for other disciplines.

2.2.1 Civil

Table 2-11 provides the codes and standards that will serve as the general civil design criteria.

Table 2-11. Civil Engineering Codes and Standards

Design Class	Standard
Stormwater	Central Coast Post-Construction Stormwater Requirements R3-2013-0032
Erosion Control	Section 4-21 Erosion Control, CalTrans Construction Manual, October 2023
Pollution Control	Section 7-104 Air, Water, and Noise Pollution Control, CalTrans Construction Manual, December 2022
Environmental Protection	Section 7-103 Protection of Environmental Resources, CalTrans Construction Manual, December 2022
Pump Station Design	American National Standard for Pump Intake Design, ANSI/HI 9.8-1998
Rock Slope Protection	California Department of Transportation Construction Manual, 2023 Edition
Drainage Facilities	California Department of Transportation Construction Manual, 2023 Edition
Horizontal Datum	NAD83 2011 (2010.00). The grid projection for coordinates of control and bathymetric data is California State Plane Coordinate Zone 5 (SPC 5).
Vertical Datum	NAVD88 (Conversion factor: NAVD88 = As-Built Datum + 2.6 feet)
Design Truck	Ford F-550

2.2.2 Structural

Table 2-12 and Table 2-13 provide the codes and standards that will serve as the general structural design criteria for the design of the facility and present the structural materials to be used for the new facility, respectively.

Table 2-12. Structural Engineering Codes and Standards

Code	Standard
2021 IBC	2021 International Building Code
2022 CBC	2022 California Building Code
ASCE 7-22	Minimum Design Loads for Buildings and Other Structures

Code	Standard
AISC 360-16	Specification for Structural Steel Buildings
AISC 341-16	Seismic Provisions for Structural Steel Buildings
AISC 370-21	Specification for Structural Stainless Steel Buildings
ACI 318-19	Building Code Requirements for Structural Concrete
ACI 350-20	Code requirements for Environmental Engineering Concrete Structures
ADM-2020	Aluminum Design Manual
AWS D1.1-2020	Structural Welding Code – Steel
AWS D1.2-2014	Structural Welding Code – Aluminum
AWS D1.6-2017	Structural Welding Code – Stainless Steel
AWS D1.8-2016	Structural Welding Code – Seismic Supplement

Table 2-13. Structural Materials

Concrete	
Concrete	4,500 psi normal weight
Rebar	ASTM A615, Grade 60
Structural Stainless Steel	
Hot-Rolled and Extruded Shapes	ASTM A276 Type S30400 or S31600
Plate, Sheet, Strip	ASTM A480, Type S30400 or S31600
Hollow Sections	ASTM A554, Type S30400 or S31600
Structural bolts	ASTM F593 Type 316
Nuts and washers	ASTM F593 Type 316
Anchor bolts	ASTM F593 Type 316
Structural Mild Steel	
Wide Flanges	ASTM A992, Grade 50
Other Shapes, Plates, Angles, and Bars	ASTM A36
Pipe	ASTM A53, Grade B
Hollow Structural Sections (HSS) – Square and Rectangular	ASTM A500. Grade C
Hollow Structural Sections (HSS) – Round	ASTM A500 Grade B
Bolts	ASTM F3125 Grade A325 or A490

Structural Aluminum	
Structural Shapes	ASTM B308 Alloy 6061-T6
Sheet and Plate	ASTM B209 Alloy 6061-T6
Pipe	ASTM B429
High Strength Bolts and Nuts	ASTM F593 and F594
Miscellaneous	
Grating	Aluminum
Stairs	Galvanized steel or Aluminum
Handrails	Galvanized welded steel or Aluminum
Ladders	Aluminum

2.2.3 Mechanical

Table 2-14 provides the standards that will serve as the general mechanical design criteria for the design of the facility.

Table 2-14. Mechanical Engineering Codes and Standards

Applicable Feature	Standard
Gearing	American Gear Manufacturer's Association (AGMA)
Materials, Dimensioning	American Society of Testing and Materials (ASTM)
Materials, Testing, Pumps, Hydraulic Design for Pumps	American National Standards Institute (ANSI)
Gates, Lifting Devices, Pumps, Operating Machinery, Piping, Hydraulic Movers	American Society of Mechanical Engineers (ASME)
Gates, Valves, Operators, Piping	American Water Works Association (AWWA)
Welding	American Welding Society (AWS)
Fire Detection and Protection	National Fire Protection Association (NFPA) International
HVAC	American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)
General Design Guides	U.S. Army Corps of Engineers (USACE) Engineering Manuals
Paint	NACE International (NACE)
Safety Standards	Occupational Safety and Health Administration (OSHA)

2.2.4 Electrical

Table 2-15 and Table 2-16 provide the codes and standards that will serve as the general electrical design criteria and the electrical materials to be used for the design of the facility, respectively.

Table 2-15. Electrical Engineering Codes and Standards

Standard	Description
ANSI	American National Standards Association
CARB	California Air Resources Board
CCOR Title 24	California Code of Regulations
CPUC GO 95	California Public Utilities Commission – General Order No. 95: Overhead Electrical Line Construction
CPUC GO 128	California Public Utilities Commission – General Order No. 128: Construction of Underground Electric Supply and Communication Systems
IEEE	Institute of Electrical and Electronics Engineers
IESNA	Illuminating Engineering Society of North America – Lighting Application Handbook
ISA	Instrument Society of America
NEMA	National Electrical Manufacturers Association
NETA ATS	International Electrical Testing Association Acceptance Testing Specifications
NFPA 70	National Electrical Code (NEC)
NFPA 70E	Standard for Electrical Safety in the Workplace
NFPA 101	Life Safety Code
NFPA 110	Standard for Emergency and Standby Power Systems
OSHA	Occupational Safety and Health Act
UL	Underwriters Laboratories

Table 2-16. Electrical Materials

Material	Standard
Panelboards	NEMA PB 1, UL 67
Transformers, Dry Type	NEMA ST 1, UL 1561, 10 CFR – Part 431 DOE 2016
Circuit Breakers	NEMA AB 1, UL 489
Switches	NEMA KS 1, UL 98
PLCs	NEMA ICS 1, UL 508
Terminal Blocks	UL 1059
Instrumentation Cable: THWN Copper	ASTM B8, NEMA WC 57, UL 13, UL 83, UL 1277
Power Conductors/Cable: THWN Copper; XHHW-2 Copper	ASTM B3, ASTM B8, ASTM B496, NEMA WC 70, UL 83
Splices, Connectors, and Terminations	UL 486A-486B, UL 486C, UL 510
Grounding: Copper	UL 467
Boxes and Enclosures: NEMA 1, 12, 3R, & 4	NEMA 250, UL 514A
Raceway: Rigid Galvanized Steel; Intermediate Metal Conduit; PVC Schedule 80; Liquid-tight Flexible Metal Conduit	NEMA C80.1, NEMA C80.6, NEMA RN 1, UL 6, UL 360, UL 514B, UL 651, UL 1242
Transfer Switches	NEMA ICS 1, NEMA ICS 2, UL 1008
Motors: TEFC or submersible	IEEE 112, NEMA MG 1, UL 2111
Motor Controls	NEMA ICS 2
Wiring Devices	NEMA WD 1, NEMA WD 6
Luminaires: LED	IESNA HB-9, IESNA LM-80, IEEE C62.41.1, UL 1598, UL 2108, UL 8750, U.S. DOE Energy Star
Surge Protective Devices	UL 1449

2.2.5 Instrumentation and Controls

Table 2-17 provides the codes and standards to be used for the instrumentation and controls of the facility.

Table 2-17. Instrumentation and Control Codes and Standards

Code	Standard
IEEE	Institute of Electrical and Electronics Engineers
ISA 5.1	Instrumentation Symbols and Identification
NEMA	National Electrical Manufacturers Association
NFPA 70	National Electrical Code (NEC)
UL	Underwriters Laboratories

3.0 References

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Appendix B. TM003 - Fish Passage Alternatives Pre-Screening Evaluation

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Technical Memorandum

To:	David Spiegel County of San Luis Obispo	Project:	Steelhead Passage Feasibility Assessment of Lopez Dam
From:	Wendy Katagi McMillen, Inc.	cc:	
Prepared by:	Vincent Autier, PE McMillen, Inc.	Job No:	25-062
Reviewed by:	Kevin Jensen, PE McMillen, Inc. John Hollenbeck, PE Hollenbeck Consulting	Date:	08/01/2025
Subject:	TM 003 – Fish Passage Alternatives Pre-Screening Evaluation– Attorney-Client Communication		

Revision Log

Revision	Date	Revision Description
A	05/30/25	Draft Fish Passage Alternatives Pre-Screening Evaluation
B	06/09/25	Draft Fish Passage Alternatives Pre-Screening Evaluation (updated)
C	08/01/25	Final Fish Passage Alternatives Pre-Screening Evaluation

1.0 Introduction

For the Steelhead Passage Feasibility Assessment of Lopez Dam (Project), McMillen, Inc. (McMillen) prepared a comprehensive list of fish passage options for both upstream and downstream passage. This document presents that information.

1.1 Purpose and Objective

The purpose of this Technical Memorandum (TM) is to tabulate all known upstream and downstream fish passage options, regardless of feasibility. For each option, this TM presents a high-level evaluation (i.e., pre-screening assessment), documents pros and cons, and provides a recommendation to advance or not advance, together with a justification. This information will be reviewed during a workshop with San Luis Obispo County (County) to gain agreement on options to bring to a conceptual level.

This step is necessary to limit re-work and to provide rational reasons why an alternative has not been recommended to be advanced. After reviewing the list of passage options, McMillen will be able to develop and evaluate, with confidence, fish passage alternatives that would have merit for the Project.

The second objective of this TM is to present the fish passage evaluation criteria and evaluation matrix, which will be applied to the alternatives selected for advancement to the next level of development and evaluation. Presenting the evaluation criteria and evaluation matrix at this time will facilitate gaining an agreement on the methodology.

1.2 Authorization

The County has contracted McMillen to provide engineering services to assess the feasibility of providing upstream and downstream passage for steelhead trout at Lopez Dam. The contract was authorized on April 8, 2025. The County's Contract number is 552R235006.

1.3 Standard List of Terms and Abbreviations

ACI	American Concrete Institute
ADM	Aluminum Design Manual
AISC	American Institute of Steel Construction
ANSI	American National Standards Institute
ASCE	American Society of Civil Engineers
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society of Testing and Materials
AWS	American Welding Society
AWS	Auxiliary water Supply
CARB	California Air Resources Board
CBC	California Building Code
CCOR	California Code of Regulations
CDFW	California Department of Fish and Wildlife
CWA	Clean Water Act
DPS	Distinct Population Segment

DO	dissolved oxygen
EL	elevation
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit
ft	feet
ft^3	cubic feet
gpm	gallons per minute
HCP	Habitat Conservation Plan
HDPE	high-density polyethylene
HVAC	heating, ventilation, and air conditioning
IBC	International Building Code
IEEE	Institute of Electrical and Electronic Engineers
IESNA	Illuminating Engineering Society of North America
ISA	Instrument Society of America
LLO	Low Level Outlet
mm	millimeter
NACE	National Association of Corrosion Engineers
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
OSHA	Occupational Safety and Health Administration
PLC	programmable logic controller
PVC	polyvinyl chloride
SCCC	South-Central California Coast
SEI	Structural Engineering Institute
TM	Technical Memorandum
UL	Underwriters Laboratories
USACE	United States Army Corps of Engineers
USACE EMs	United States Army Corps of Engineers Engineer Manuals
USGS	United States Geological Survey

WMP	Watershed Master Plan

1.4 Background

Lopez Dam has been identified as an impassable barrier on the Arroyo Grande Creek, blocking passage to the target species, the South-Central California Coast (SCCC) Distinct Population Segment (DPS) steelhead trout (*Oncorhynchus mykiss*). The SCCC steelhead trout was originally listed in 1997 as threatened under the National Marine Fisheries Service (NMFS) Evolutionarily Significant Unit (ESU) policy. The listing was reaffirmed in 2006 under the DPS policy. The SCCC steelhead trout are now listed as threatened under the Endangered Species Act (i.e., ESA listed). NMFS identified SCCC steelhead trout in Arroyo Grande Creek as a "Core 1" population in the agency's 2013 Recovery Plan (NMFS 2013). NMFS explained Core 1 populations are the highest priority for recovery based on a variety of factors. NMFS included Arroyo Grande Creek and Los Berros Creek in the area designated as critical habitat for the SCCC steelhead trout in 2005 (NMFS; 70 FR 52488).

Lopez Dam is a vitally important element of water infrastructure for the communities in the County. Its primary purpose is to provide drinking water supply for 50,000 residents. Its ancillary benefits are flood protection for both residences and agricultural lands, groundwater recharge, and recreational opportunities. The dam has been and continues to be a critical infrastructure component for Arroyo Grande Creek and the surrounding communities. Fish passage solutions would need to preserve these functions. The SCCC steelhead trout in Arroyo Grande Creek currently cannot access upstream rearing and spawning habitats. Lopez Dam affects both upstream and downstream migration.

NMFS has asked the County to assess fish passage at Lopez Dam in the process of developing a Habitat Conservation Plan (HCP). NMFS has communicated that “mechanistic solutions to fish passage impediments can be problematic for a variety of reasons, including: the limitations in the operations during high flows when fish are most likely to be migrating; periodic mechanical failures which result in migration delays, or lost migration opportunities; and the expense of personnel and equipment to maintain such operations” (NMFS 2013; p7-9). The County has therefore requested that McMillen assess volitional fish passage feasibility at Lopez Dam.

1.5 Location

The Arroyo Grande Creek Watershed is on the Central California Coast in an arid region with highly variable rainfall and stormwater runoff (Stetson Engineering, Inc. 2004). The watershed is located in southern San Luis Obispo County (Figure 1-1). The watershed also supports permanent agricultural crops (e.g., citrus orchards, vineyards, ranches, and low crops) and seasonal row crops (Stetson Engineering, Inc. 2004). Lopez Dam and Reservoir provide water supply for agricultural and municipal needs by storing stormwater runoff during the winter and early spring and providing managed releases throughout the year to meet downstream demands. Additionally, diversions from the reservoir through a 3-mile pipeline to a water treatment plant provide treated water to the Arroyo Grande, Pismo Beach, County Service Area 12 (CSA 12) - Avila Beach Area, Grover Beach, and Oceano municipalities. The watershed drainage rises to a maximum elevation (EL) of approximately 3,100 feet above sea level. Arroyo Grande Creek empties into the Arroyo Grande Lagoon.

Figure 1-1. Arroyo Grande Watershed and Location of Lopez Dam in the San Luis Obispo County, California (Source: County of San Luis Obispo)

1.6 Existing Project Description

Lopez Dam is a zoned earthfill dam constructed in 1968. The dam is 1,120 feet long and has a vertical height of 168.2 feet measured from the crest (EL 538.6[1] min.) to the outlet pipe invert, EL 370.4 on the river side. The dam crest is 40 feet wide and is used as a roadway (Lopez Drive) to connect the town to the southwest to the Lopez Lake Recreation Area.

[1] All elevations are in imperial measurements, i.e., feet and NAVD 88.

The dam retains water using a compacted clay core and a cutoff trench keyed into bedrock. The core has a minimum width of 25 feet, and the cutoff trench is keyed in a minimum of 10 vertical feet. The core is buttressed by a compacted sandy gravel layer on the upstream side and a compacted random zone on the downstream side. The dam employs a 10-foot-wide filter zone on both sides of the core and a 10-foot-wide gravel drain on the downstream side of the core. The gravel drain extends from the core to the downstream toe of the dam where it outlets to a riprap-lined collection area and is conveyed away from the dam. Abutment drainpipes are used to convey seepage along the foundation of the dam to the riprap-lined toe collection area. The upstream portion of the dam is overlayed with a 20-foot-thick layer of tuffite rock and a 10-foot-thick layer of graded tuffite rock for erosion protection. The dam slope is at 3H:1V on both sides of the dam and is benched at EL 450 with an outward slope of 0.05 ft/ft. The bench on the reservoir side is 100 feet long, while the bench on the downstream side is 120 feet long.

Lopez Dam utilizes a concrete spillway to pass storm flows and is equipped with a side channel ogee weir at crest EL 522.6. The spillway chute is linear, and it terminates with a 16-degree launch angle flip bucket with an invert at EL 387.6 to dissipate the flow energy from the spillway. The dam also includes an intake control building, a 42-inch welded steel pipe encased in concrete, an outlet control building (i.e., outlet works), and other appurtenances. The intake structure includes seven inlets, each connected to a common header at 45 degrees. The inlets are approximately 15 feet apart vertically, and each is equipped with a trash rack and a fish screen. The fish screens have openings of approximately 10 inches by 12 inches, larger than the trash rack openings of 1/2-inch bar at 4 inches on center. The fish screen and the trash rack are both hot-dip galvanized. Figure 1-2 through Figure 1-5 present an overview of Lopez Dam. In the 2000s, the County completed the Lopez Dam seismic remediation project, including changes to the dam and outlet works after obtaining necessary permits and authorizations including a permit from the U.S. Army Corps of Engineers and biological opinions from NMFS and U.S. Fish and Wildlife Service (Figure 1-2).

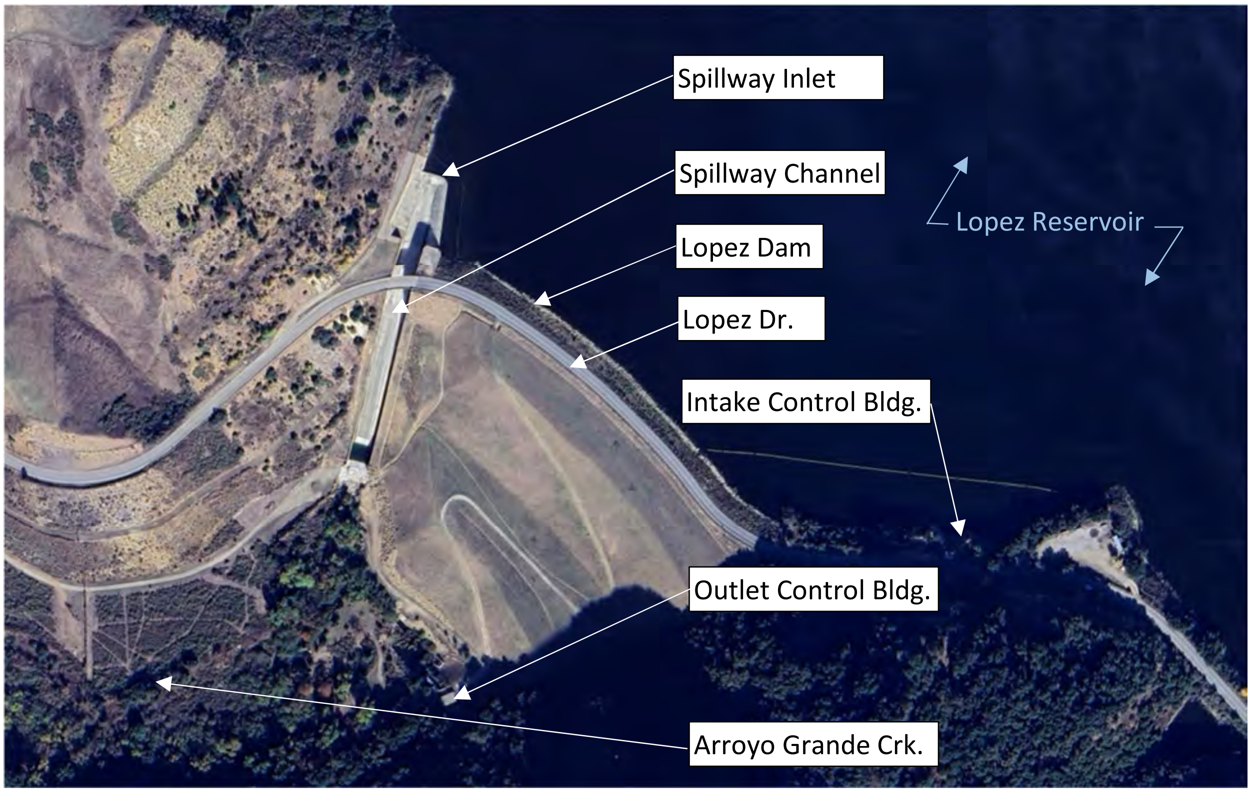


Figure 1-2. Lopez Dam Overview (Source: Google Earth)

Figure 1-3. Lopez Dam on Arroyo Grande Creek, San Luis Obispo County (Source: ForestWatch)

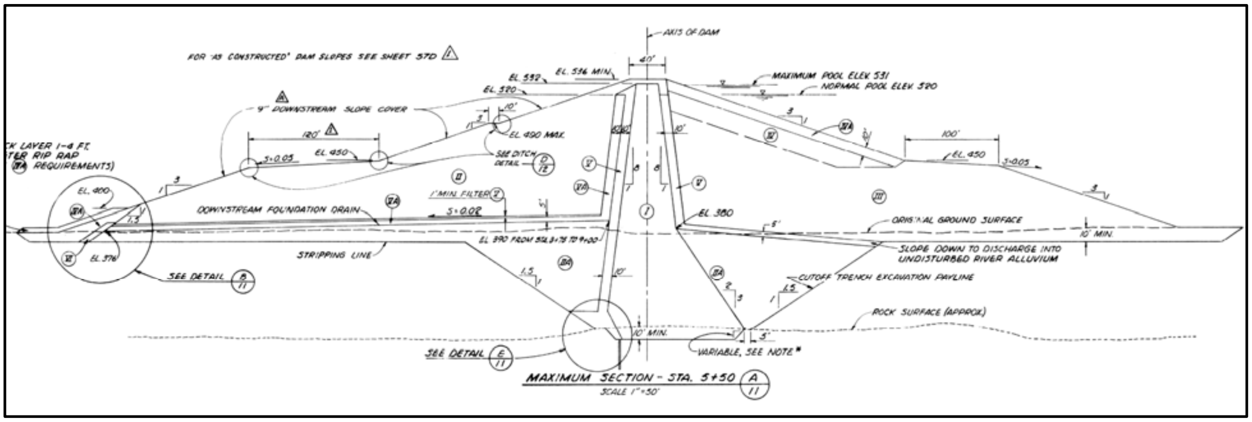


Figure 1-4. Cross Section through Lopez Dam (Source: Koebig & Koebig, Inc. 1967)

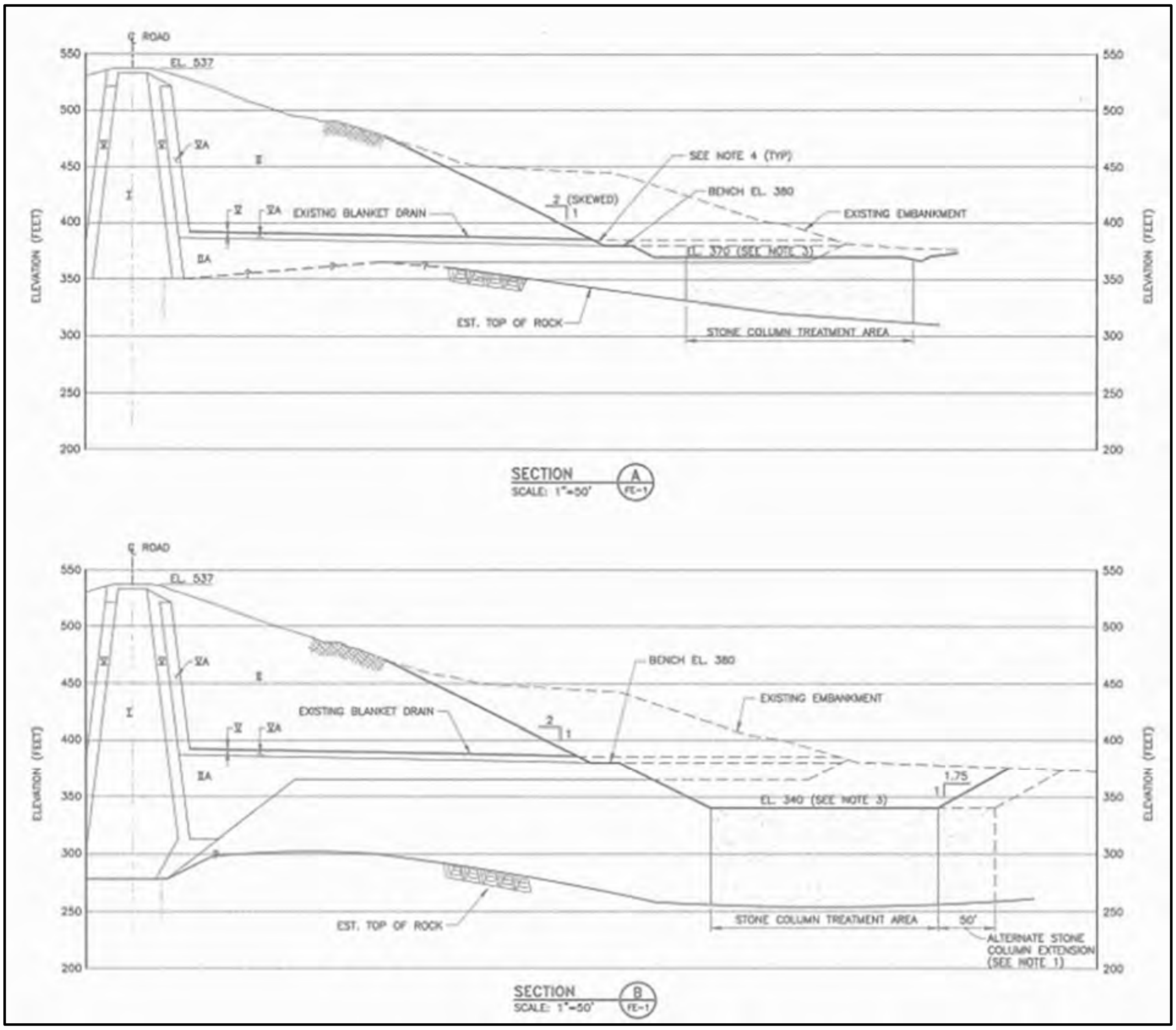


Figure 1-5. Cross Sections of the Downstream Face Showing Seismic Retrofit (Source: URS, 2000)

2.0 Potential Fish Passage Technologies

Fish passage strategies will require the selection and concept development of fish passage technologies best applicable to the site constraints, operational limitation, and overall biological goals. These technologies will provide safe, efficient, and effective fish passage. It is essential to consider the attraction and passability of the fish passage technology and thus rely on previous performance of past technologies. This section will cover three key features: (1) potential upstream fish passage technologies, (2) potential downstream fish passage technologies, and (3) exclusion and guidance technologies. The objective of this section is to succinctly present all potential fish passage technologies, providing a baseline for coordination with the County. The lists of upstream and downstream fish passage technologies will be developed using known and existing technologies as well as County and Stakeholder feedback. These lists will then be used to evaluate suitability for deployment at Lopez Dam using evaluation criteria presented in Section 3.0 of this TM. Though it will become evident that some options are not feasible, all options are documented here to demonstrate that a comprehensive evaluation was completed.

Figure 2-1 presents an overview of the various fish passage technologies commonly used. Fish passage technologies can be “technical” types that can be further categorized as volitional or non-volitional and be used for upstream or downstream fish passage. The term “volitional” in this regard is generally understood to mean fish having the ability to pass upstream at their own will and on their own time. Non-technical fishways are referred to as “nature-like,” such as a roughened channel.

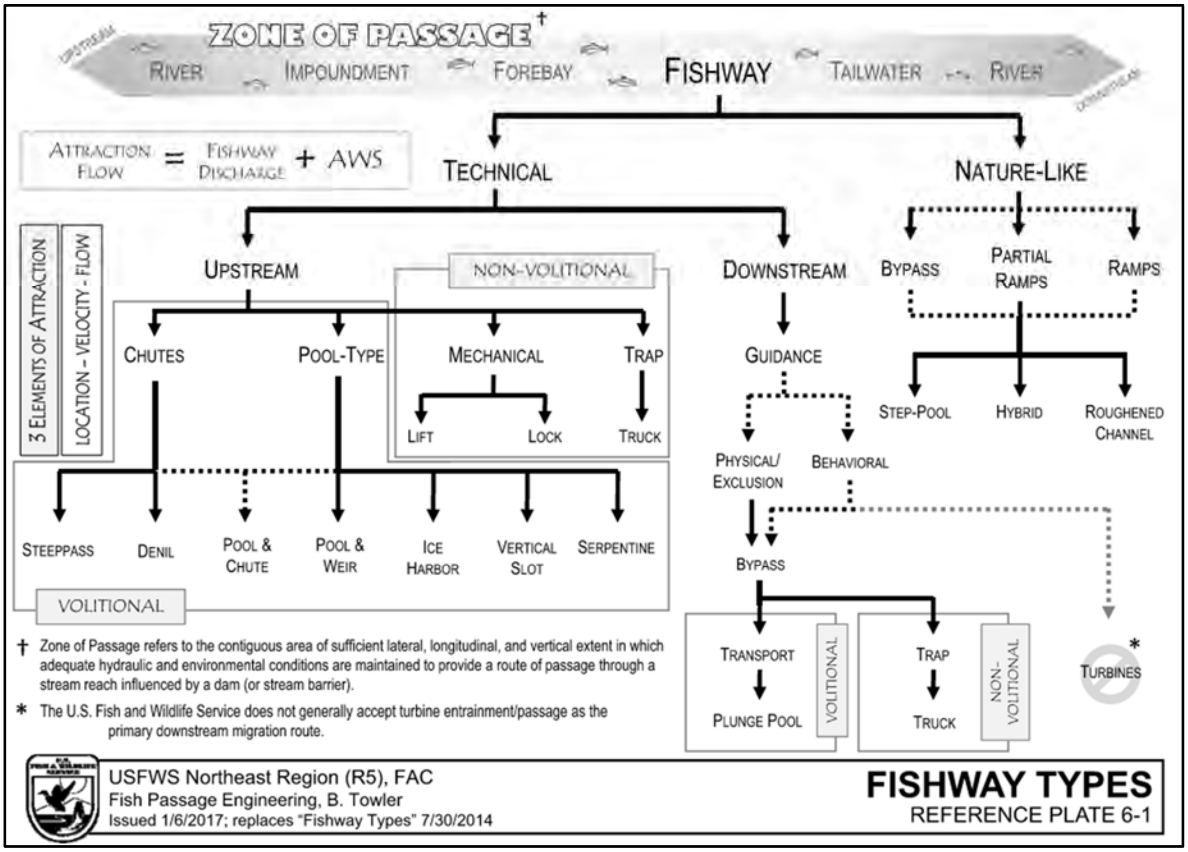


Figure 2-1. Upstream and Downstream Fishway Types (USFWS, R5, 2019)

2.1 Potential Upstream Fish Passage Technologies

Table 2-1 presents known technologies to provide upstream fish passage. These technologies are adapted to the fish species and life stages for which they are designed. They each have advantages and disadvantages that will be further evaluated as part of Section 3.0 of this TM. Numerous configurations and deployment methods are available to suit the physical environment within which they are to be placed. This section provides a description of each option.

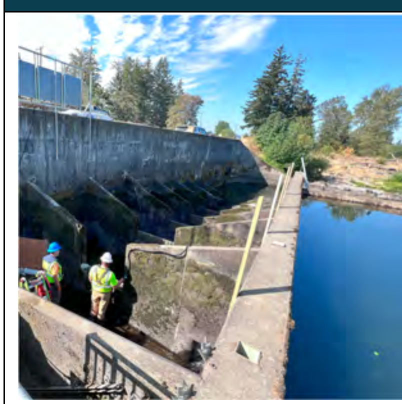
The following presents a list of options further defined in Table 2-1 and evaluated in Table 3-1:

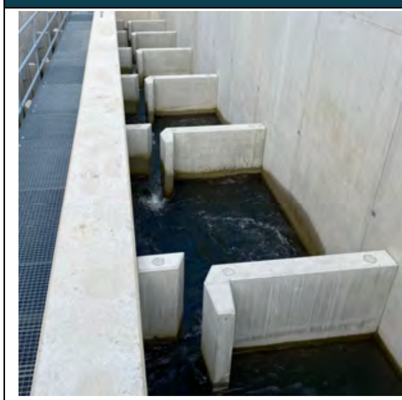
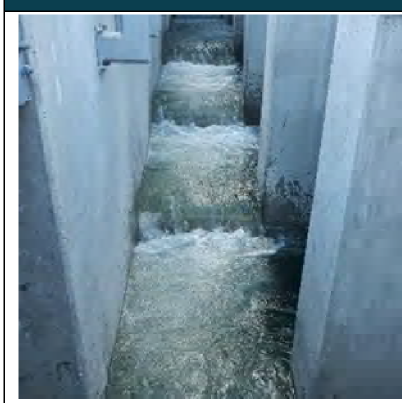
- Chutes
  - Denil
  - Steeppass
  - Fatou
  - Super-Active-Type Bottom Baffles

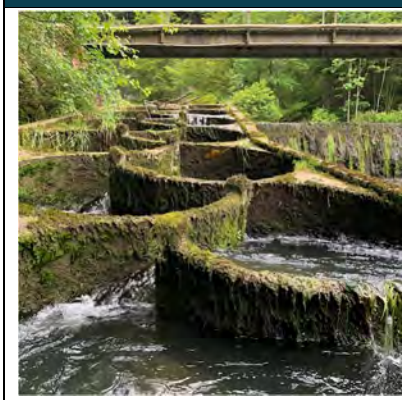
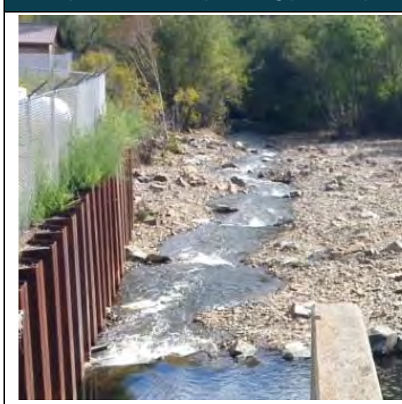
  - Macro-Roughness Elements
  - Pool and Chute
- Pool Types
  - Pool and Weir
  - Vertical Slot
  - Weir and Orifice
  - Deep Side Notch and Submerged Orifice
  - Meander-Type
- Nature-Like
  - Step-Pool Morphology Ramp
  - Plane-Bed Morphology Ramp
  - Bypass
- Others
  - Trap-and-Haul
  - Fish Elevators
  - Fish Locks
  - Archimedean Screw Pumps
  - Pneumatic Fish Transport Tube Systems
  - Tube Fishway

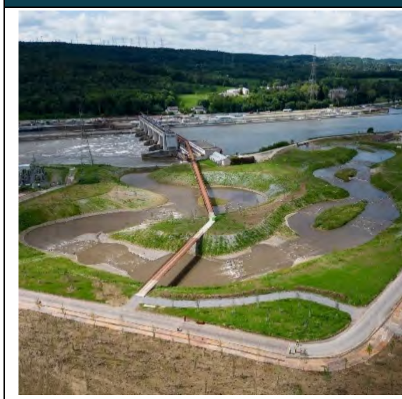
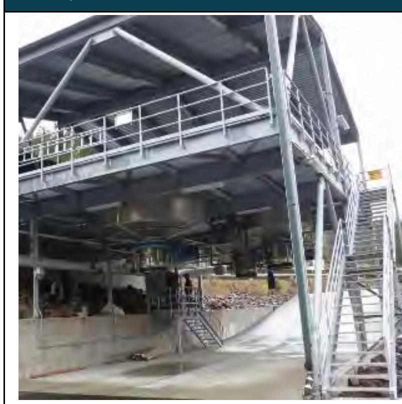
Table 2-1. Description of Potential Upstream Fish Passage Technologies

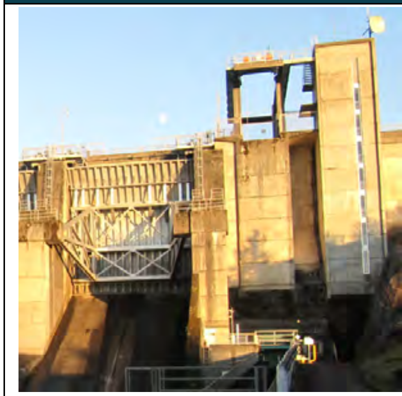
Category, Type & Photo	Description
Chute	
Denil 	The Denil fishway is a Roughened Chute or Baffled Chute as defined by NMFS (Image: Jocko K Canal Diversion, Montana). This type of fishway has excellent fish attraction characteristics when properly sited and provides good passage conditions using relatively low flows. The original design for a Denil fishway was developed in 1909 by the Belgian scientist, Gustave Denil (Denil 1909). It is a successful fishway type that has been refined over the years. The geometry and narrow flow path make this fishway susceptible to debris accumulation; however, when used with a trap the debris issue is limited and the fishway can be used optimally. The Denil fishway is generally designed with slopes ranging from 10% to 20%, with a preference for 15% to accommodate most fish. The width typically ranges from 2 to 4 ft (0.6 to 1.2 m). The horizontal length of the Denil section should be less than 25 ft (7.6 m). The minimum flow depth should be 2 ft (0.6 m).
Steeppass 	Steeppass fishways (aka, Alaska Steeppass) were originally designed with the specific aim of equipping natural waterfalls in Alaska (typically situated in poorly accessible places) with fishways, and where cost-effective construction of concrete fishways was impossible. These fishways are prefabricated in metal shops, typically in 10 ft (3.0 m) standardized lengths, and bolted together by a contractor for on-site installation. In Alaska, the sections can be transported by helicopter and bolted together on site. The steeppass is generally designed with slopes ranging from 25% to 33%, with a preference for 28%. The standard width of the steeppass is narrow, 1.8 ft (0.56 m) (Image: Little Sheep Creek, Oregon). The horizontal length of the steeppass section should be less than 25 ft (7.6 m). The minimum flow depth should be 1.5 ft (0.46 m). It is a sloped trough (usually aluminum) with v-shaped vanes welded along the sides and bottom at regular intervals. The main drawback of the steeppass is that it was designed for strong swimmers (i.e., large salmonids). Once fish start ascending, it must pass all the way upstream and exit the fishway, or risk injury when falling back downstream.
Fatou 	Built upon the Denil prototypes. Energy is dissipated via channel roughness and results in an average velocity compatible with the swimming ability of adult salmonids. It is very efficient at dissipating energy (Image: Elle river, Britanny, France). Slope is typically 20%. The width typically ranges from 2.0 ft (0.6 m) wide for trout to 3.0 ft (0.9 m) for salmon.

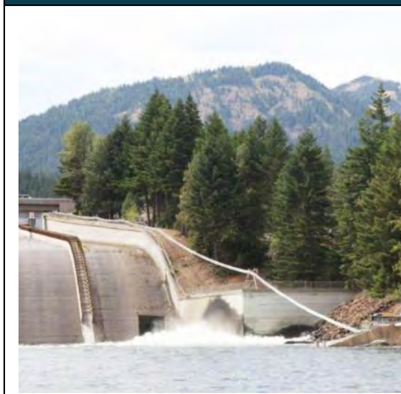
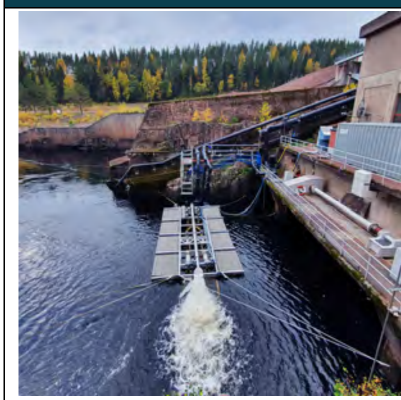
Category, Type & Photo	Description
Super-Active-Type Bottom Baffles (i.e., Larinier) 	This type of fishway consists of a herringbone pattern of thin baffles that are placed on the bottom of the channel only (Image: Aire River, United Kingdom). This type of baffle was developed on hydraulic models (Larinier and Miralles, 1981) inspired by the Riro model (Denil, 1936-1938; Larinier, 1977), which was used at the Roermond Dam on the Meuse River in the Netherlands. It has mainly been used in France, but has recently become quite widespread in Great Britain, and is starting to be used in the USA. The baffles are fabricated from steel and their height generally varies between 3-inch and 8-inch (75 mm and 200 mm). The slope of the Larinier fishway can vary between 10% and 15%. The channel is typically built of concrete with the bottom baffles bolted down to the concrete channel. It is less common to have the channel made of steel as there is no bracing for the steel sidewalls. While there are no known studies evaluating passage in Larinier fishways, the Larinier fishway is designed around smaller-bodied fish (weaker swimmer) versus large anadromous fish. With the super-active-type bottom baffles, the velocity gradient over the depth changes such that a fish can typically find the preferred depth.
Macro-Roughness Elements 	Macro-roughness elements (aka blocks) can be cylindrical, square, or made of rocks (Image: Toorale Station, Darling River, New South Wales, Australia). The elements can be emergent or submerged and the ramp can be full or partial river width. After defining the water depth, ramp slope, block (width, height, and concentration), as well as deciding if the blocks will be emergent or submerged, we need to calculate the vertical velocity profile and velocity between blocks. If the velocity is lower than the fish swimming ability, then we define the total discharge and determine if it is sufficient for attractivity (Cassan and Laurens 2016, Cassan et al. 2014). The slope is generally between 1 and 9% (Larinier et al. 2006).
Pool and Chute 	A pool and chute fishway is a hybrid type of fishway that operates with different flow regimes under different river conditions (Image: Lebanon Dam, South Santiam River, Oregon). This fishway is designed to operate as a pool and weir fishway at low river flows and a baffled chute fishway at higher river flows. This fishway offers an alternative for sites that have fairly low hydraulic drop and must pass a wide range of stream flows with a minimum of flow control features. Placement of stoplogs, a cumbersome and potentially hazardous operation, is required to optimize operation. However, once suitable flow regimes are established, the need for additional stoplog placement may not be required.

Category, Type & Photo	Description
Pool Types	
Pool and Weir 	Pool and weir fishways pass water through successive fishway pools separated by overflow weirs that break the total head into passable increments (Image: Cape Horn Dam Fish Ladder, California). Fish, attracted by the flowing water, move from pool to pool by jumping or swimming (depending on the water depth) until they have cleared the obstruction. Movement between pools usually involves burst speeds. Fish can rest in the pools, if necessary, as they move through the fishway. While simple to construct, the pool and weir is sensitive to fluctuating water levels. When fluctuation of the water surface elevation outside of the design elevation occurs, too much or too little flow enters the fishway. Which leads to operation with fishway pools that are excessively turbulent or provide insufficient flow for adequate upstream passage. The water level drop between pools is usually set at 12-inch (300 mm) for adult salmon and 6-inch (150 mm) for adult resident (non-anadromous) fish. Pool and weir fishways usually have a slope of 10%. Pools are sized to allow energy to be dissipated in the form of turbulence within each receiving pool.
Vertical Slot 	The vertical slot fishway is a pool type fish ladder (Image: Tassebach Weir, Drava River, Austria). The passage corridor is a vertical slot instead of a weir. The slot is typically open from top to bottom, though sometimes a sill is used to maintain the minimal width and to ensure sufficient water depth for energy dissipation. The advantage of the vertical slot ladder is that they self-regulate with fluctuating reservoir and tailwater water surface elevations. This ladder type works well with multiple exits. In addition, they are passable to a larger number of life stages and species that may use the bottom part of the water column. The drawback to this ladder type is that the concrete forming is intricate and typically results in a more expensive fishway. Pool sizing is typically 10 ft. (3.0 m) in length and 8 ft. (2.4 m) wide and typical flow is approximately 30 ft^3/s (0.85 m^3/s).
Weir and Orifice 	The weir and orifice ladder is also a pool type fish ladder (Image: Box Canyon Upstream Fish Ladder, Washington). This ladder type is often referred to as the “half Ice Harbor” ladder. This ladder type was initially developed for use at Ice Harbor Dam on the Lower Snake River in the mid-1960s. The Ice Harbor Dam’s ladder has two orifices and two weirs per pool. An adaptation for lower flow design resulted by taking “half” of the Ice Harbor Ladder, i.e., one weir and one orifice per pool. Similar to the pool and weir ladder, this ladder type does not work well with fluctuating water level in the forebay and is typically designed with an adjustable entrance. This ladder type, like the other pool type fish ladders, works best with an attraction flow system.

Category, Type & Photo	Description
Deep Side Notch and Submerged Orifice 	Notch type fishways are a mix between a vertical slot ladder and a weir and orifice ladder (Image: Le Pont-de-Beauvoisin fishway, Savoie, France). This type of fishway is mostly used for salmonids as the energy dissipation between pools is limited. Its advantages is the smaller footprint and the ability to adjust to different water depth. The traverses between pools consist of side notches with bottom orifices situated opposite of one another (Larinier 2002). A baffle fixed to the upstream face of the wall straightens and stabilizes the flow and also reduces the contraction of the flow at the notch. As there is streaming flow, the width of the notch determines the dimensions of the pools to some extent (namely their minimum length) but their minimum volume depends on the volumetric dissipated power density required.
Meander-Type 	The meander-type fishway is interlinked rounded basins, mounted in a rectangular channel (Helbig 2021); (Image: Sorne River in the Gorges du Pichoux, Switzerland). The basins are generally constructed from pipe segments made of fiberglass reinforced plastic (FRP), with the gaps filled with concrete. There are three basic designs, the main differences between the construction types are the shape and length of the basins, the slope of the rectangular channel and the flow rate. The fishway can be more or less compact with slopes ranging from 4% to 30%. This is a significant difference when compared to traditional fishways which have a slope no greater than 10%. Adding attraction flow to this fishway type is difficult and there are no known such cases.
Nature-Like Fishway	
Step-Pool Morphology Ramp 	Step-pool morphology ramps (aka, rock weirs) are engineered “nature-like” fishway (Image: Little Sheep Creek, Oregon). The streambed material is sized and placed in such a way as to mimic the configuration of a natural streambed. The pools are formed with rocks, providing a structural skeleton, and set hydraulic drops per pool. The steps are typically selected to be between 6-inch to 12-inch (150 mm to 300 mm). USFWS recommends rock ramps slopes to be ≤ 3% (USFWS 2019), while NMFS recommends rock ramps slopes to be ≤ 6% (NMFS 2011), and CDFW recommends slopes to be ≤ 5% to step-pool morphology (CDFW 2009; Larinier et al. 2006). NMFS comments that this is a relatively new technology without a developed and proven design methodology. In other words, while this fishway type seems common sense as it replicates nature, it is difficult to design for durability. The rock weirs are designed for 100-year flow (1% chance of occurrence in any year).

Category, Type & Photo	Description
Plane-Bed Morphology Ramp 	Roughened channel (aka, plan-bed morphology ramp and streambed simulation fishway) is an engineered "nature-like" fishway (Image: Hemphill, Nevada). The streambed material is sized and placed in such a way as to mimic the configuration of a natural streambed. By replicating the natural stream conditions, a wide variety of life stages and species of fish may use the roughened channel for passage. NMFS comments that this is a relatively new technology without a developed and proven design methodology. In other words, while this fishway type seems common sense as it replicates nature, it is difficult to design for durability. CDFW recommends a slope between 1.5% and 3% for a plane-bed morphology (CDFW 2009; Larinier et al. 2006). The streambed material could become mobile during some flow conditions and would rely on the river regenerating the streambed material by natural sediment transport.
Bypass 	Bypass channels can be either made of roughened channel or rock weirs. They are used as an off-channel solution replacing a technical fishway. They can be used for upstream or downstream fish passage, and habitat. They can be used as hydropower facility bypass channels (Image: Ampsin-Neuville Lock, Meuse River, Belgium) or in redeveloping a river reach. They are seldom used to provide passage when barriers exceed 10 ft (3 m) in height, and are never used when the water level in the upstream reach varies significantly, such as in a reservoir with large variation in reservoir levels. This is because there will be either no water supply at low reservoir levels (i.e., the bypass channel loses hydraulic connectivity and dries up, potentially stranding aquatic species), or too much flow at high reservoir levels, which would potentially destabilize the channel structure and create a significant dam safety risk.
Others	
Trap-and-Haul 	Trap-and-haul is a non-volitional fish passage method. This method requires actively collecting, loading, and transporting fish upstream (Kock 2020). Fish are hauled to an approved release site either in or directly adjacent the reservoir. The trapping facility typically includes a conventional fish ladder equipped with an entrance pool and attraction flow (either gravity or pumped). Fish ascend to a holding pool where they are trapped. Based on the need to sort or not, fish are directed to a sorting facility or directly transferred to a fish transport truck using water-to-water transfer via a hopper or elevated holding pool (Image: North Fork, Oregon). As depicted, the fish transport truck is driven under the structure and fish are released into the truck (multiple fish-loading configurations are possible).

Category, Type & Photo	Description
Fish Elevator 	The hopper system is the component of a fish lift (or fish elevator) that contains the fish in the transitory movement. Fish ascend a conventional ladder to the face of the dam, where they enter a holding pool equipped with a finger weir and a crowder. Fish are then crowded into a hopper and lifted to the top of the dam with the use of a hoist system (Image: Foster Dam, Oregon). The hopper then takes fish across the dam with the use of a monorail where they are finally lowered into the forebay and released. The hopper system at Foster Dam was discontinued because of "fall back" through the turbine intake located adjacent to the release location and new sorting requirements. Fall back is the event of a fish attempting to pass but failing to pass by returning to the tailrace.
Fish Lock 	A fish lock is a tower located at the top of a conventional ladder. Fish ascend the ladder to a holding pool where they become trapped. Fish are then crowded into a fish lock and a gate is lowered. Through the action of raising the water level in the fish lock and raising a brail floor, fish are crowded vertically and released at the top of the lock (Image: Box Canyon Upstream Fishway, Washington). Fish can then be directly released in the forebay or into a sorting facility. The fish lock works similarly to a boat lock system.
Archimedean Screw Pump 	This system used an Archimedean screw pump (e.g., Pescalator) to gently lift fish out of the river system (typically from a holding pool, located after a trap) to a release point (Image: Thorne Moors Archimedean screw pump, England). Fish remain in the water at all times to reduce stress and energy expenditure. The screw can be partially open or fully enclosed within a pipe. The pipe material can be made of different material ranging from steel to fiberglass. This type of system is a highly mechanical system which requires additional element to be efficient (such as trap, holding pool, crowder). The vertical rise is limited by the pump length and motor size. The pumps can be used in parallel to increase flow rate. They typically are sized for vertical rise of less than 32.8 ft (10 m).

Category, Type & Photo	Description
Pneumatic Fish Transport Tube Systems 	Whooshh Innovations created the Whooshh system (sometimes referred to as the “fish cannon”) that moves fish through a flexible, pressurized tube, transporting fish from one area to another, including over large vertical obstacles like dams. There are two basic configurations of a Whooshh system considered: 1) a floating platform configuration and 2) a land-based configuration. If the tailwater elevation is stable or there is no land available, the floating platform could be deployed in the summer and removal at the end of the fish passage window without adjustment of the system during the operational period When land space is available, the land-base configuration can be used (Image: Cle Elum Dam, Washington). The discharge tube along the side of the spillway can be seen on the image. In either case a Denil fishway is used for attraction.
Tube Fishway 	Tube fishways are built based upon research completed by Slatick (1970, 1971) who did lab work for the Columbia River dams (Peirson 2024). There are two main companies developing this technology: Tube Fishways Pty. Ltd. from Australia, and Fishheart from Finland (Image: Raasakka Hydropower Station in river Iijoki, Finland). Water supply can be siphoned from the headpond or pumped to a storage tank. The delivery pipe can vary from 1.0 ft to 3.0 ft (0.3 to 0.9 m) diameter. Tube fishway operations are cyclical and rely on fish entering the transfer chamber in less than 2 minutes. During operation, one side of the unit is closed (using valves) to pump fish over the dam while the other side remains open, allowing fish to enter. It uses siphon water from upstream of the dam or pumped tailwater to feed the inlet line and attraction flow. The total flow is less than 10.6 ft^3/s (0.3 m^3/s).

2.2 Potential Downstream Fish Passage Technologies

Downstream fish passage options are classified into (1) physical barriers, (2) behavioral/structural guidance devices, (3) behavioral guidance devices, and (4) others. Table 2-2 presents a short description of each option.

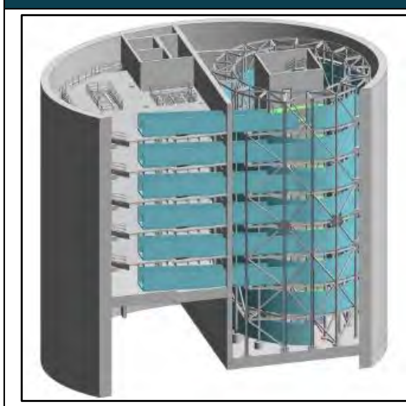
The following presents a list of options further evaluated in Table 3-2:

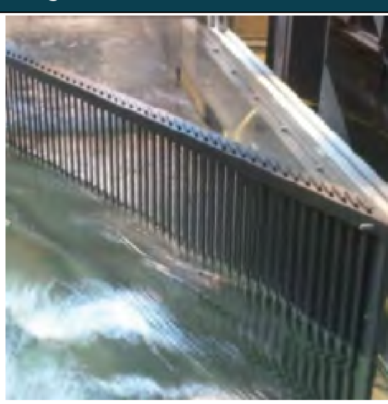
- Physical Barriers
  - Screens
    - Eicher Screens
    - Floating Surface Collectors
    - Fixed Screen Structure

- Fish Bypass System
  - Bypass Pipe
  - Open Channel
  - Helix
  - Transport (truck or barge)
- Behavioral/Structural Guidance Devices
  - Louvers
  - Angled bar and Trash Racks
  - Floating Fish Guidance Boom
  - Hanging Chains
  - Barrier/Guidance nets
  - Removable Spillway Weir
- Behavioral Guidance Devices
  - Lights
  - Sounds (Acoustic)
  - Electric Fields
  - Air Bubble Curtains
  - Hybrid Barriers
- Other Methods
  - Spilling
  - Turbine Passage
  - Trap-and-haul (IN-Tributaries Trap; e.g., Fyke Net))
  - Reservoir Drawdown
  - Dam Removal

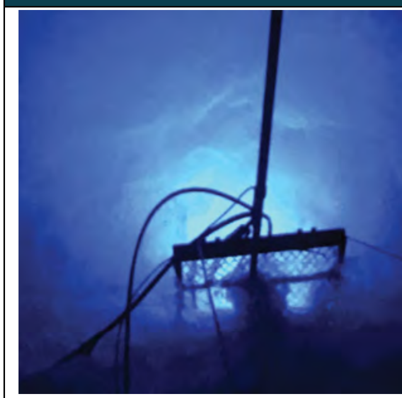
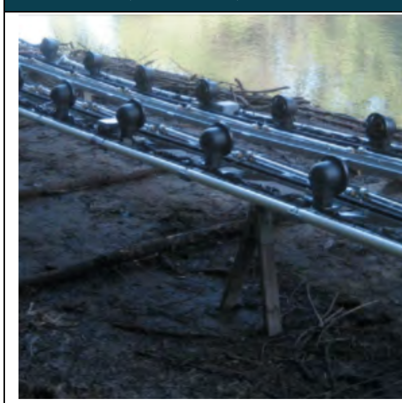
Table 2-2. Description of Potential Downstream Fish Passage Technologies

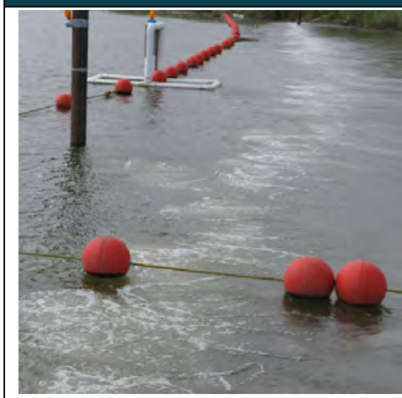
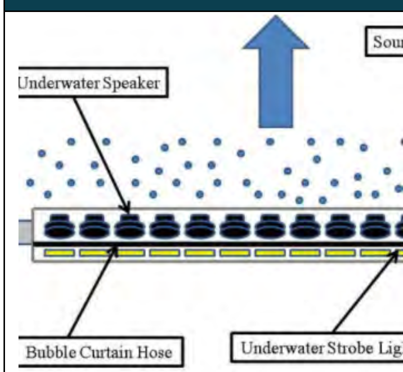
Category, Type & Photo	Description
Physical Barriers	
Eicher Screens 	The first Eicher screen (from George Eicher) was installed in 1980 at the T.W. Sullivan Hydroelectric Project on the Willamette River near Oregon City, Oregon (NPCC, 2016). Eicher screens are elliptical inclined screens that are placed within a closed pipe or conduit and can function in flow velocities up to 8 ft/s (2.44 m/s). The conduit is oftentimes a turbine penstock, a gravity diversion conduit, a pump suction tube, or a submerged intake (USBR 2006); (Image Eicher screen). Most of the flow that enters an Eicher screen passes through the screen and continues on through the conduit, with fish and debris being guided across the screen face to a bypass entrance and bypass conduit positioned at the downstream end of the screen and at the crown of the conduit. The screen is typically mounted on a frame and has a pivot axis that allows it to be rotated and backflushed for cleaning off debris.
Floating Surface Collectors 	Floating surface collectors (FSCs) take advantage of the surface-oriented out-migrant fish species. FSCs are increasingly being implemented to provide juvenile fish passage at hydroelectric projects with large storage reservoirs in the Pacific Northwest (Image: Clackamas River, Oregon). FSCs have been installed in strategic locations in the forebays of a hydropower project where juvenile fish have been known to congregate or where guide nets help guide the fish into the collection system. Typically, FSCs use simple fixed screens and a vee-configuration as a single vee or double vee. Attraction flow is pumped by large submersible horizontal propeller pumps that typically range between 1,000 ft^3/s and 2,000 ft^3/s (28.3 m^3/s and 56.6 m^3/s). FSCs work by collecting juvenile fish using attraction flow and then dewatering into a holding area. If the vertical water level fluctuation in the reservoir is low, fish may be directly transferred to a bypass pipe. However, when the fluctuation is too great, fish are collected into a holding tank and the tank is transferred to a transport truck, or to the dam crest where fish are then transferred into a bypass pipe.
Fixed Screen Structure 	This alternative is very similar to the FSC option, with major exceptions being that 1) attraction flows could be used for power generation (rather than simply pumped attraction flow) and 2) the surface collector is not floating but fixed. This system works well in reservoir with minimum water level fluctuation. The image presents the Round Butte out-migrant collector in the Deschutes River Basin, Oregon.

Bypass Pipe 	By far the most common type of fish bypass system is a bypass pipe. The hydraulic characteristics in the pipe dictate the length and size of the pipe. The pipe can be exceptionally long based on the vertical drop of a high head dam. The pipe material is typically selected as polyvinyl chloride (PVC), high-density polyethylene (HDPE), or welded steel with a smooth interior pipe coating. The image presents the bypass pipe at Rocky Reach Dam, Washington. The Rocky Reach bypass pipe is a steel pipe 9.0 ft (2.75 m) in diameter and extends over 0.87 mile (1.4 km) around the back side of the powerhouse, across the face of the spillway and then on the east side of the Columbia River. It connects the juvenile collector (pumped system) to a monitoring station, and then returns fish to the Columbia River. The vertical drop at the bypass pipe outlet to the river needs to meet NMFS (2023a) design criteria. This system is efficient and works well to pass fish once they have been collected.
Open Channel 	Open channel bypass systems often consist of concrete flumes, which would need to meet the same hydraulic requirements as for a bypass pipe. Concrete trapezoidal or rectangular channels are sometimes used in hatcheries. Open channels can also be natural channels, such as a roughened channel. A roughened channel can often be used for upstream and downstream fish passage, but their length is typically limited to 150.9 ft (46 m) and their slopes to less than 6%, limiting their use at a high head dam. Requirements for natural channels include adequate depth and velocity, sufficient flow volume, protection from predation, and good water quality. The image depicts the open channel bypass used at the Coleman National Fish Hatchery, California.
Helix 	As of this writing, the only known helical fish passage system (Helix) is the installation currently underway at the Cle Elum Dam, Washington, designed by the U.S. Bureau of Reclamation (USBR). This design includes an intake structure with multiple intakes to accommodate the varying reservoir level, helical fish passage, tunnel, and outfall. The Helix represents a ground-breaking design intended to fit a long, gradually sloped channel into a very compact physical space in order to produce a system that is both technically and economically feasible (USBR 2016). The image presents the concept design for the Cle Elum project.

Transport (Truck or Barge) 	Transport-based fish passage systems continue to play a major role in passage of both juvenile and adult fish species. Acknowledging that fish are first collected using one or more of the technologies addressed above, fish are generally transferred to either barge- or truck-mounted tanks (or large-volume containers) that provide a fish-safe environment (proper water temperature, oxygen, aeration, etc.) while fish are transported to release sites. Release sites can range from sites immediately downstream of the fish barrier to sites that are often hundreds of kilometers downstream of the barrier (as in the case of some barge transport systems used on the Columbia River in OR/WA). While transport-based fish passage systems are not considered a volitional form of passage and can temporarily limit environmental cues required in downstream migration (i.e., truck transport; not generally true of barge transport that often provide flow-through water supplies), they often provide greater fisheries management flexibility with regards to release locations, release timing, and environmental conditions at release sites.
Behavioral/Structural Guidance	
Louvers 	Louvers are used to direct juvenile fish toward bypasses and sluiceways at hydropower plants. Louvers consist of an array of vertical slats that are placed on a diagonal structure across a channel at 10 to 15 degrees and are oriented 90 degrees to the flow. Spacing between louver slats is typically larger than the width of the smallest fish that are being excluded. These structural guidance systems are devices that do not physically exclude fish from intakes, but instead create hydraulic conditions in front of the structures. Fish maintain their position off the louver face while the sweeping flow guides the fish along the louver line to the bypass. The success of these systems is dependent on fish response to hydraulic conditions, which means their performance can be poor under changing hydraulic conditions and for fish with weak swimming abilities. Louvers may be considered for sites with relatively high approach velocities, large uniform flow, relatively shallow depths, and for some sites with species requiring reduced levels of protection (OTA 1995). Louvers operate most efficiently when they are designed for larger fish (OTA 1995). The image provides an example of a louver system.
Angled bar and Trash Racks 	Most of the angled bar racks installed to date consist of a single bank of racks placed in front of a turbine intake at a 45-degree angle to flow. Although design can vary from site to site, most racks consist of 1-inch (25.4 mm) spaced metal bars with a maximum approach velocity of 2 ft/s (0.61 m/s). Small fish can pass through the openings; tighter bar spacing is not recommended as they can create the potential for fish impingement and could lead to debris accumulation. The angled bar and trash rack system requires cleaning on a regular basis to remove debris accumulation in front of the bars/racks. Floating trash booms can be used to mitigate debris loading (i.e., large wooden debris). This system is similar to the louver system apart from angle to the flow and spacing.

Floating Fish Guidance Boom 	Worthington, a log boom company, created a physical fish guidance barrier that is essentially a floating fish guidance boom. The fish guidance barrier has a floating element not dissimilar to a log boom, with a panel extending down in the water column generally 5 ft (1.5 m). The image presents an image of the barrier type. Floating fish guidance booms can work efficiently when fish are known to be oriented high in the water column and a safe exit route is provided.
Hanging Chains 	Hanging chains provide a curtain, relying on physical deterrent and sound deterrent. It is assumed that hanging chains would follow a configuration similar to the floating fish guidance boom, but instead of blind panels, chains would be used. It is assumed that they would not work well for weak swimmers. Hanging-chain curtains have shown some success in preventing fish passage under laboratory conditions in flow velocities of less than 1.0 ft/s (0.3 m/s). However, lab results have not been duplicated in the field and research has ceased (OTA 1995).
Barrier / Guidance Nets 	Under the proper hydraulic conditions (e.g., water velocities less than 1.0 ft/s [0.3 m/s]), light debris loads, and minimal wave action, barrier nets have been shown to be effective at blocking fish passage into water intakes. The barrier net is made of nylon or carbon fiber (Dyneema®) material stretched from bank to bank and extending the full water depth. Held in place with cables and weighted net bottoms, these systems can provide protection at a tenth the cost of most alternatives; however, they are not suitable for many sites and are expected to be less effective in blocking fish passage at many hydroelectric projects in the Pacific Northwest because of the higher water velocities and debris loads commonly found at those projects. USACE installed, evaluated, and later discarded barrier nets to help guide fish in the forebays at both Lower Granite Dam on the Snake River and at the Bonneville Second Powerhouse on the Columbia River, which are run-of-river hydroelectric projects. A thorough examination of site-specific environmental and operational conditions is recommended prior to installing barrier nets (NPCC 2016). The image depicts a barrier net used at the Lower Baker FSC, WA.

Removable Spillway Weir 	Removable spillway weirs (RSW) are a structural guidance system placed just upstream of radial gates used for spillways. Without the RSW, juvenile surface-oriented fish must dive down into the water column to exit and pass downstream in applications where gates are opened at the bottom of the gate to release flow. The RSW sits upstream of the radial gate and seals up on the spillway gate piers. The flow passes over the top of the RSW and passes over a "spillway shape of the RSW" then transitions onto the existing concrete spillway. The radial gate is out of the water when the RSW is operating. An important prerequisite is that the spillway should provide safe passage to the fish. Therefore, in cases of high head dams, irregular spillways, large energy dissipators, or flip buckets, the removable spillway weir may not provide the best solution as they only support passage up to the gate, but not through or beyond. The image presents a removable spillway weir installed at the Ice Harbor Dam, Washington.
Behavioral Guidance Devices	
Lights 	Light-emitting diodes (LED) and strobe lights are used as behavioral guidance devices. Many species of fish have well-developed visual systems. Light has a high rate of transmission in water and is not masked by noise. At the same time, the usefulness of light depends upon the clarity of the water as well as upon the contrast between the artificial and ambient light. Strobe lights of specific frequencies and magnitudes can serve as an irritant to direct fish away from a diversion. However, in other cases, mercury lights might be used as an attractant. Work has also been done with numerous other lighting options in attempts to generate attraction or avoidance. Effectiveness of behavioral devices varies with fish species and fish size, site conditions (including layout and flow patterns), and also ambient conditions (including water turbidity and naturally occurring light; USBR 2006).
Sounds (Acoustic) 	Sound has many characteristics that make it suitable for use in the possible modification of fish movement, especially over longer distances or when visibility is marginal. Sound travels at a high rate of speed in water, attenuates slowly, is highly directional, and is not impeded by low light levels or water turbidity (OTA 1995). High noise levels, such as at turbine intakes, may prevent fish from hearing artificially generated sounds in such environments, while high-intensity sounds (produced by any source) might have deleterious effects on fish. In addition, there is some evidence that fish may respond to sounds that are produced in association with human-made structures, such as bypass screens and their cleaning system, including other signals produced as a by-product of hydropower projects (although little is known about the actual behavioral responses to these sounds). A number of vendors may assert that their sound or sonic barriers would have a high level of efficiency; however, these claims are site-, condition-, and fish-specific.

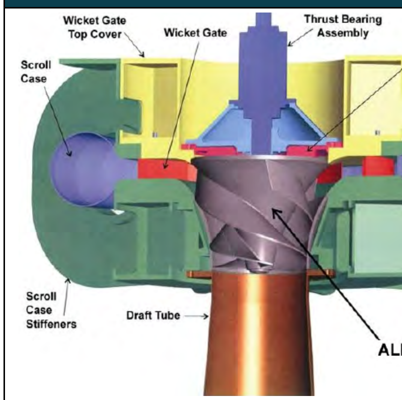
Electric Fields 	While an effective fish passage deterrent in certain applications, electric fields are potentially dangerous to other animal species that may enter the water in the area of the electric field. The electric fields are restricted to regions between electrodes. Thus, they are most effective in shallow streams and relatively narrow regions where sufficient field strength can be set up between opposing electrodes. These systems have been used with some success in limited upstream fish passage of adult migrants. In general, evidence supporting the effectiveness of electrical barriers at supporting the downstream passage of fish is not available (OTA 1995).
Air Bubble Curtain 	Air bubble curtains have been used as a behavioral guidance device with little apparent success. The Electric Power Research Institute (EPRI 1994) concluded that "[t]he results of these studies, combined with conclusions of ineffectiveness from past studies, do not support further testing of air bubble curtains." Not only do they lack effectiveness, but they also require very large compressors, receivers, tanks, control, power and backup power. Other researchers suggest that success with air bubbles may have been associated with the sound that they produce and not necessarily with the bubbles (OTA 1995).
Hybrid Barriers  	Some studies have been done to evaluate the effectiveness of using behavioral barriers in various combinations to increase overall effectiveness, yet the results have been equivocal. Many of the field evaluations have been conducted for application at hydropower projects. Certain researchers have had limited success with combining systems, stating that "the coupling of air bubble curtains with strobe lights can increase strobe light exclusion efficiency" (USBR 2006).

Other Methods

Spilling

A simple and often effective means of bypassing fish around hydropower facilities is to allow or induce them to leave the reservoir via the spillway. Juveniles from most fish species will pass downstream, via spillways, if outlet flow is sufficient. Mortality associated with spillways may result from gas supersaturation in plunge pools, rapid pressure change, rapid deceleration, shearing effects, turbulence, striking force, scraping, and abrasion. Ruggles and Murray (1983) concluded that for dams less than approximately 115 ft (35 m) in height, spilling was generally the safest means of fish passage when compared to either turbine passage or costly fish passage measures such as artificial propagation, interception and transfer, or screening of turbine intakes.

Turbine Passage



Since the early 1990s, extensive research has been completed by the hydropower industry and turbine manufacturers on fish-friendly turbines designed to increase survival of downstream migrants. Turbines generally fall under two designs: reaction and impulse units. Of the two categories, reaction turbines such as Francis or Kaplan units, are more common at low- to medium-head applications with medium to high flow rates. Other reaction units include bulb turbines, pit turbines and the so-called Alden turbine. Francis turbines are inward-flow reaction turbines that combine radial and axial flow and operate at low to high hydraulic head (50 ft to 2,460 ft [15 m to 750 m]). They are some of the commonly used turbines; however, they are also considered less fish-friendly than the Kaplan type. Kaplan turbines are propeller-type turbines with adjustable blades that work in tandem with adjustable wicket gates to achieve high efficiency over a wide range of flow and head. Voith has developed the minimum gap runner technology from a standard axial-flow Kaplan unit as part of the U.S. Department of Energy Advanced Hydropower Turbine System (AHTS) program. The gap is minimized and remains constant across the full range of blade pitch with the objective of reducing injury and mortality to fish and improving turbine operating efficiency. (Image: Alden turbine). Depending on the turbine type, site and environmental conditions, the fish-friendly turbine designs show survival rates between 94% and 100%.

Trap-and-Haul (In-Tributary)

Trap-and-haul can be used in both directions (Lusardi and Moyle 2017). One additional method to provide fish passage is to collect out-migrant fish at the head of reservoirs or in tributaries (e.g., rotary screw traps, fyke nets, diversion and screening), transfer the out-migrants to a fish transport truck, and drive them to their release location. This may be of particular interest when out-migrant who reach the reservoir are considered “lost to the system” due to predation, water quality, or inability to pass downstream of the reservoir.

Reservoir Drawdown 	Drawing down the reservoir may improve fish passage by reducing transit time and additional factors that reduce reservoir transit efficiency and survival. The image shows the Cougar Reservoir drawdown. The Cougar Dam is owned and operated by USACE, Willamette Basin, Oregon. This is only feasible with a low-level outlet.
Dam Removal 	Dam removal is the process of demolishing a dam, returning water flow to the river. Arguments for dam removal consider whether their negative effects outweigh their benefits. The benefits of dams include hydropower production, flood control, irrigation, and navigation. Dam removal is sometimes the best option to provide fish passage for infrastructures that have reached the end of their useful life. This image presents the removal of Glines Canyon Dam (Upper Elwha Dam) on the Elwha River in the Olympic National Park, Washington State.

3.0 Pre-Screening Evaluation

This section presents a high-level evaluation of each fish passage technology, including advantages and disadvantages of each option, and indicates whether each option is recommended to advance to conceptual design based upon the presented justification. Presentation of the information in Table 3-1 and Table 3-2 is inspired by the CETMEF (2008) publication.

3.1 Potential Upstream Fish Passage Technologies

Table 3-1 presents the high-level evaluation of each potential upstream fish passage technology, a recommendation to advance the alternative or not, as well as a justification.

Table 3-1. High-Level Evaluation of Potential Upstream Fish Passage Technologies

Advantages	Disadvantages	Recommendation for Advancement and Justification
Chute		
Denil		Do Not Advance
• Most common type of baffle fishway. • Compact structure. • Simple construction. • Good passage conditions using relatively low flows. • Can use intermediate resting pools for every 12 ft (3.6 m) of vertical rise.	• Devices more particularly adapted to low to moderate < 8.2 ft (2.5 m) fall heights and to small streams. • Generally not used beyond two sections. • Devices adapted for salmonids and species with strong swimming abilities. Does not have resting zones within a section, forcing fish to pass through in one go. • Sensitive to water level variations. • The geometry and narrow flow path make this fishway susceptible to debris accumulation (clogging). • Not considered a substitute for a permanent style of ladder because of their tendency to collect debris and their limited operating range.	• Limited vertical rise • Typically, not used beyond two sections in series; this site would require a very large number of sections. • High water variation at site.
Steeppass		Do Not Advance
• Compact structure. • Simple construction. • Good passage conditions using relatively low flows. • Can use intermediate resting pools for every 12 ft (3.6 m) of vertical rise, though not preferred.	• The main drawback is that it was designed for strong swimmers (i.e., large salmonids). There is no resting place within a given fishway section. Therefore, once a fish starts to ascend, it must pass all the way upstream and exit the fishway, or risk injury when falling back downstream. • Devices more adapted to low to moderate < 8.2 ft (2.5 m) fall heights and to small streams. • Sensitive to water level variations. • The geometry and narrow flow path make this fishway susceptible to debris accumulation (clogging). • Not considered a substitute for a permanent style of ladder because of their tendency to collect debris and their limited operating range.	• Limited vertical rise • Typically, not used beyond one section; this site would require a very large number of sections. • High water variation at site.

Advantages	Disadvantages	Recommendation for Advancement and Justification
Fatou		Do Not Advance
• Hydraulically efficient. • Compact structure. • Good passage conditions using relatively low flows.	• Difficult to build due to the shape of the baffles. • The very high hydraulic efficiency of the baffles limits the kinetic energy of the jet at the entrance of the pass, resulting in a weak attraction at the entrance to the fishway. • Devices more adapted to low to moderate < 8.2 ft (2.5 m) fall heights and to small streams. • Sensitive to water level variations. • The geometry and narrow flow path make this fishway susceptible to debris accumulation (clogging). • Not considered a substitute for a permanent style of ladder because of their tendency to collect debris and their limited operating range.	• Limited vertical rise • Typically, not used beyond one section; this site would require a very large number of sections. • High water variation at site.
Super-Active-Type Bottom Baffles (i.e., Larinier)		Do Not Advance
• Compact structure. • Simple construction. • Good integration in small rise dam. • Devices With the super-active-type bottom baffles, the velocity gradient over the depth changes such that a fish can typically find the preferred depth and is therefore adapted to most fish swimming abilities. • There is considerably less risk of injury during potential fallback downstream than with the Alaska Steeppass. • Less clogging potential. • Adjustable width. • Could be used to pass canoes.	• Devices more particularly adapted to low to moderate < 8.2 ft (2.5 m) fall heights and to small streams. • Generally, not used beyond one section. • Sensitive to water level variations, water levels, and clogging.	• Limited vertical rise • Typically, not used beyond one section; this site would require a very large number of sections. • High water variation at site.

Advantages	Disadvantages	Recommendation for Advancement and Justification
Macro-Roughness Elements		Do Not Advance
• High discharge potential • Lower sensitivity than technical fishways to clogging by floating debris and sediments • Uses the drag of the blocks and the bed roughness for the energy dissipation • Can address variable fishway flows.	• For weirs smaller than 6.5 ft to 10 ft (2 m to 3 m) in vertical height. • High variability in flow, velocities, and attraction dependent on water depth and submergence/emergence of the blocks, impacting the passage efficiency and attraction. • While the concept is simple the mathematical calculations are not.	• Limited vertical rise • High water variation at site. • Typically used with higher flows
Pool and Chute		Do Not Advance
• Very good at passing debris since its open design encourages debris to wash over the weirs and out of the fishway and it is substantially submerged at highest flow. • Good attraction flow, generally not requiring additional AWS flow. Can pass high flows. • Good integration in both urban and urban and natural sites. • Allows fish, canoes and kayaks passage.	• For sites with a low head (less than 6.5 ft [2 m]) that must pass a wide range of streamflow's with a minimum of flow control features. • Placement of stoplogs, in the low flow channel, may be required to optimize operation. This activity can be hazardous and cumbersome. • Design criteria are not well developed. • Known mortality associated with this fishway type. • Sensitive the upstream water level fluctuation. • Low adaptability to land constraints due to a large and straight footprint.	• Limited vertical rise • High water variation at site. • Typically used with higher flows

Advantages	Disadvantages	Recommendation for Advancement and Justification
Pool Types		
Pool and Weir		Do Not Advance
• Simplest style of fish ladder, primarily designed for Salmonids. • Devices adapted to a wide range of total head, less than one meter to tens of meters. • Concrete forming is not as intricate, and therefore typically cheaper than other fishways.	• Fish must leap or swim over the weir flow. Therefore, this style of fishway is not adapted to a large number of fish due to limited access at weir. • Need stable water surface elevation in the forebay pool to function properly. Flow fluctuation may affect upstream passage by causing fishway pools to be excessively turbulent or providing insufficient flow. • To accommodate forebay fluctuations and maintain a consistent flow in the ladder, they are often designed with a fishway exit control section. • To accommodate tailwater fluctuations, they may include an adjustable fishway entrance and an AWS to provide additional flow to meet the channel velocity criterion.	• Primarily limited to surface-oriented fish. • Does not work well with variable water surface. • Pumped system would be expensive to operate.
Vertical Slot		Advance
• Passable to a larger number of life stages and species that may use the bottom part of the water column. • Streaming flow. • Devices adapted to a wide range of total head, less than one meter to tens of meters. • Good adaptation to land constraints due to a great modularity of layout. • Very good adaptation to upstream water level variation. • Self-regulate with fluctuating reservoir and tailwater water surface elevations. • Works well with multiple exits.	• High sensitivity to debris requiring the implementation and installation of trash rack. • Devices requiring a regular maintenance (debris removal). • Limited attraction requiring additional attraction flow. • Concrete forming is intricate and typically results in a more expensive fishway. • Limited landscape integration.	• Adapted to large variation in vertical rise • Adapted to some reservoir water level variations • Can be used as a volitional fishway. • Can be used with flow control exit structure, to adapt to variable water level in the reservoir.

Advantages	Disadvantages	Recommendation for Advancement and Justification
Weir and Orifice		Do Not Advance
• Passable to a larger number of life stages and species that may use the orifice • Streaming flow and plunging flow mix depending on submergence • Devices adapted to a wide range of total head, less than one meter to tens of meters. • Good adaptation to land constraints due to a great modularity of layout. • Concrete forming is not as intricate, and therefore typically cheaper than vertical slot ladders • Works well with multiple exits.	• Need a stable upstream water level. Poor adaptation to upstream water level variation. • Limited attraction requiring additional attraction flow. • Limited landscape integration. • Need strict specification requirements regarding tolerance and accuracy, as the hydraulics are directly dependent on weir elevation, weir length, and orifice size. • Need a competent contractor.	• Similar to vertical slot ladder, but with reduced passability to all fish species. • Less adaptable to reservoir water level variations
Deep Side Notch and Submerged Orifices		Do Not Advance
• Devices adapted to a wide range of total head, less than one meter to tens of meters. • Good adaptability to financial constraints and civil engineering due to high modularity of layout. • Good adaptation to upstream water variability. • Streaming flow. • Adapted to the swimming abilities of a wide range of species. However, they are particularly well-suited to cyprinids and salmonids.	• Specifically adapted to salmonids and cyprinids. • High sensitivity to ice jams and solid transport requiring the upstream protection (trash rack) and possibly cover (gratings) as well as bottom orifices. • Requires regular maintenance to remove debris. • Limited attraction requiring additional attraction flow. • Limited landscape integration. • Suboptimum hydraulic conditions, not taking advantage of the full pool volume. Need to stay within the ratios (L/b) and (B/b) stated above.	• Similar to vertical slot ladder, but with suboptimum hydraulic conditions, not taking full advantage of the pool volume, which would result in fish become tired over a long length fishway. • Challenging to use with flow control exit structure, to adapt to variable water level in the reservoir.

Advantages	Disadvantages	Recommendation for Advancement and Justification
Meander-Types		Do Not Advance
• Passable to a larger number of life stages and species that may use the bottom part of the water column. • Streaming flow, and lower turbulence in the pool. • Devices adapted to a wide range of total head, less than 3 feet to 30 feet plus (less than one meter to tens of meters). • Good adaptation to land constraints due to a great modularity of layout (slope and not linear) • Very good adaptation to upstream water level variation. • Self-regulate with fluctuating reservoir and tailwater water surface elevations.	• High sensitivity to debris requiring the implementation and installation of trash rack. • Devices requiring a regular maintenance (debris removal). • Limited attraction requiring additional attraction flow, but attraction flow would be difficult to provide with a vertical diffuser, forcing horizontal diffuser (hence not acceptable to Lamprey) • Concrete forming is intricate and could result in a more expensive fishway, may need to use other materials • Limited landscape integration. • Lacking approved calculation methodology forcing the use of CFD or physical modeling during planning, the use of factor of safety resulting in larger basins, and measurement during operation.	• Similar to vertical slot ladder, but no known installation in North America. • Lacking approved calculation methodology forcing the use of CFD or physical modeling during planning.
Nature-Like Fishway		
Step-Pool Morphology Ramp		Do Not Advance
• Volitional. • Enhanced passage for multiple species. • Good integration in both urban and natural sites. • Good attraction requiring generally little to no additional flow. • May provide additional benefits to other species such as insects, mollusks, and crustaceans. • Can be used for upstream and downstream passage	• More adapted to a low to moderate fall height (<10ft [2 to 3m]). • Sensitive to upstream water variation; can lose hydraulic connectivity due to forebay fluctuation. • Requires natural system to balance erosion and accretion. i.e., better implemented in a river reach and not connected to a reservoir. • Slopes to be ≤ 5%. • Large footprint. • Need pool volume to dissipate energy. • May be sensitive to flood events, requiring observation and some level of monitoring and maintenance. • Need performance studies. • During construction, if material is not properly compacted, water can go subterranean.	• Operation dependent on forebay water level fluctuation. Can lose hydraulic connectivity. • Lopez Dam is 168.2 feet tall, greater than 10 ft. • The reservoir cannot balance the erosion of streambed material, which will result in long-term maintenance issues.

Advantages	Disadvantages	Recommendation for Advancement and Justification
Plane-Bed Morphology Ramp		Do Not Advance
• Volitional • Enhanced passage for multiple species. • Good integration in both urban and natural sites. • Good attraction requiring generally little to no additional flow. • May provide additional benefits to other species such as insects, mollusks, and crustaceans. • Can be used for upstream and downstream passage	• More adapted to a low to moderate fall height (<10ft [2 to 3m]). • Sensitive to upstream water variation; can lose hydraulic connectivity due to forebay fluctuation. NMFS recommends the maximum average channel velocity to be ≤ 5 ft/s (1.5 m/s) regardless of channel slope (NMFS 2023a) which leads to general acceptable pool variation of ~ 2 ft (0.6m). • Requires natural system to balance erosion and accretion. i.e., better implemented in a river reach and not connected to a reservoir. • Slopes to be ≤ 3%. Large footprint. • May be sensitive to flood events, requiring observation and some level of monitoring and maintenance. • Need performance studies. • During construction, if material is not properly compacted, water can go subterranean.	• Operation dependent on forebay water level fluctuation. Can lose hydraulic connectivity. • The lake variation during upstream migration (Dec 1to May 1) is 69.3 ft. • Lopez Dam is 168.2 feet tall, greater than 10 ft. • The reservoir cannot balance the erosion of streambed material, which will result in long-term maintenance issues. • The slope is even flatter that the step-pool ramp, significantly increasing the footprint.
Bypass		Do Not Advance
• Aesthetics. • Enhances passage for multiple species. • Upstream and downstream passage. • Good attraction. • Can be used as habitat. • Volitional system.	• Need space as it has a large footprint. • Typically require more flow than a technical fishway. • Adequate hydraulic conditions are vulnerable to small alterations to the original design. Some level of monitoring and maintenance will always be necessary. • Need performance studies. • If material is not properly compacted, water can go subterranean. • Does not allow for adaptive management.	• Operation dependent on forebay water level fluctuation. Can lose hydraulic connectivity. • The lake variation during upstream migration (Dec 1 to May 1) is 69.3 ft. • Lopez Dam is 168.2 feet tall, greater than 10 ft. • The reservoir cannot balance the erosion of streambed material, which will result in long-term maintenance issues. • The slope is even flatter than the step-pool ramp, significantly increasing the footprint.

Advantages	Disadvantages	Recommendation for Advancement and Justification
Others		
Trap-and-Haul		Advance
• Low space requirement of the system. • Cost almost independent of the head of the dam. • No sensitivity to reservoir fluctuation. • Possible sorting. • Forebay variation does not impact facilities.	• Significant operating costs. • Requires trained operators. • Possible mechanical issues. • Device not well adapted for small species (e.g., eels). • Requires a fishway and a trap, with possible additional attraction flow. • Need to determine release location. • Not volitional.	• Independent of dam height. • Operation independent from reservoir water level fluctuation. • Would allow for fish sorting (i.e., tool used for meeting fisheries recovery goals). • Release in preferred release location.
Fish Elevators		Do Not Advance
• Low space requirement of the system. • Cost almost independent of the head of the dam • No sensitivity to reservoir fluctuation. • Possible sorting. • Forebay variation does not impact facilities.	• Significant operating costs. • Requires trained operators. • Possible mechanical issues. • Device not adapted for small species (e.g., eels). • Requires a fishway and a trap, with possible additional attraction flow. • Not volitional. • Risk of fall back.	• Earthfill dam profile not conducive to this option
Fish Lock		Do Not Advance
• Low space requirement of the system. • Cost almost independent of the head of the dam • No sensitivity to reservoir fluctuation. • Possible sorting. • Forebay variation does not impact facilities.	• Significant operating costs. • Requires trained operators. • Possible mechanical issues. • Device not adapted for small species (e.g., eels). • Requires a fishway and a trap, with possible additional attraction flow. • Not volitional. • Vertical rise limitation due to head pressure on the fish lock (~50 ft to 60ft [15 m to 20 m])	• Limitation of fish lock height. • Earthfill dam profile not conducive to this option (unless used as a component of a trap-and-haul system).
Archimedean Screw Pumps		Do Not Advance
• Limits fish energy expenditure. • Forebay variation does not impact facilities.	• Significant operating costs. • Requires trained operators. • Possible mechanical issues. • Not volitional. • Vertical rise limitation to 30 ft (10 m).	• Limited vertical rise and not passable to some low priority target species. • No attraction flow. • Could be used as an element of a trap-and-haul facility.

Advantages	Disadvantages	Recommendation for Advancement and Justification
Pneumatic Fish Transport Tube Systems		**Do Not Advance**
• Quick installation. Can be used on a barge or on shore. • Overall installation cost is cheap when compared to other systems. • Provides a lot of information (enumeration, species recognition, photos). • Allows for sorting. • When used with another fishway, providing good attraction, the system can be effective. • The daily passage capacity per lane would be approximately 10,000 adult fish per day (i.e., 28 fish per minute per tube). • No need to holding and hauling fish.	• Height limitation ~165 ft (50 m); (height of Cle Elum Dam where the system was tested). • Not yet used permanently for ESA listed fish species. • Need different tubes for different fish girth. • Often used with a steeppass fishway limiting the passage of stronger swimmers (90% to 100% effective; Geist et al. 2003; Garavelli et al. 2019). Low efficiency for weaker swimmers (30% to 50%). • When used as-is the attraction flow may be insufficient for fish to quickly find the entrance. • Proprietary equipment. $1,000 to $2,000 monthly software license fees. • Requiring experienced staff to operated and maintain.	• Not yet used permanently for ESA listed fish species. • Would release fish in the reservoir, versus in upstream creeks.
Tube Fishway		**Do Not Advance**
• Quick installation using standard pipes and valves. • A complete Tube Fishway costs 20% to 30% of a technical fishway. • The Fishheart system provides a lot of information (enumeration, species recognition, photos). • Allows for sorting before or after the delivery conduit. • No need for holding and hauling fish. No need for multiple pipes to meet fish girth. • Does not use a technical fishway (though it could to address the tailwater variation) • Fully remote system. • Preliminary results seem to be very positive.	• Low attraction (<5% typical attraction flow) that would lead to low efficiency. Velocity may not be compatible to all species. • Very few installations to demonstrate effectiveness. • The Artificial Intelligence (AI) is still learning. • Working from a barge for maintenance versus from the shore; may have some safety concerns (for the Fishheart system). • Need a tailrace pool. • The barge/tube entry is not easily movable to try different entrance locations due to the hard piping. • Holding densities in the transfer chamber is hard to control. • Risk to fish during capture is the possibility of gate closure on fish as they attempt to enter.	• The system is too new and experimental. • Do not have a tailrace pool sufficiently large.

3.2 Potential Downstream Fish Passage Technologies

Table 3-2 presents the high-level evaluation of each potential downstream fish passage technology, a recommendation to advance the alternative or not, as well as a justification.

Table 3-2. High-Level Evaluation of Potential Downstream Fish Passage Technologies

Advantages	Disadvantages	Recommendation for Advancement and Justification
Physical Barriers		
Eicher Screens		Do Not Advance
• Takes no space in the forebay area. • Has low operating costs. • No icing issues. • Not dependent on forebay water levels. • Elwha Hydroelectric Project test results in 1991 showed high passage survival for Coho smolts (98.7%, average length 145 mm), as well as steelhead smolts (99.4%, average length: 174 mm) and Chinook fingerling smolts (98.8%, average length: 99 mm) (Winchell, 1992). • Can use higher approach velocity of up to 8.0 ft/s (2.44 m/s). • Closed conduit screens can be directly incorporated in diversion conduits, which minimizes required civil structures and allows application at sites with little space. • The back-flush cleaning design has proven effective and mechanically simple. • Costs associated with maintaining and operating the facility are low.	• The approach velocity into the screens violates most state and federal screening criteria (OTA, 1995); i.e., 8.0 ft/s (2.44 m/s) versus 0.4 ft/s (0.12 m/s). Higher velocities can lead to fish impingement, descaling with subsequent delayed mortality, etc. These velocities also create significant head loss at the design flow rate. • The concept may be considered developmental/experimental by fisheries resource agencies. • Pressured bypass system not meeting fisheries resource agencies bypass requirements for safe, timely, and efficient fish passage. • Diversion efficiency is lower and mortality higher for fry. • Increased descaling potential with increased velocity. • Eicher screen concepts is patented but patent may have expired. • Bypass flows can be significant for small conduits. Bypass diameters of less than 24 inches (607 mm) have not been field evaluated. • During back-flushing operations, the screen does not exclude fish from the diversion. • Head losses of up to 2.5 ft (0.75 m) may occur with fouling, although under typical operation, head losses of approximately 1 ft (0.3 m) can be expected. • Access to the screen for inspection or maintenance is limited and requires shutdown and dewatering.	• Need a penstock for installation that Lopez Dam does not have.

Advantages	Disadvantages	Recommendation for Advancement and Justification
	• Penstock diameter limitation is 10 ft (3 m). • Structural requirement for the support frame is a concern. • The primary disadvantages of Eicher screens include a lack of information related to the fish passage characteristics of the screen over a broad range of fish species (USBR 2006). • Fishery resource agencies typically do not recommend pressurized bypass pipes. Therefore, while the screen may work efficiently at collecting out-migrants, the design of the bypass pipe becomes challenging and may result in increased fish mortality if the screen is not properly located and hydraulically balanced.	
Floating Surface Collectors		Advance (?)
• Primarily targets the surface-oriented out-migrant and their behavior. They can also be used in combination of a guidance net to help capture deeper oriented fish. • High implementation in the Pacific Northwest and at reservoirs which see a large reservoir water surface fluctuation.	• High pumping and power cost. • Worker safety concerns working from a barge. • High Visual Impact. • Dewatering complexity and requires marine construction. • Often not volitional, as fish are collected in a holding pond. • Highly mechanical. • Large power requirements for attraction flow pumps. • May not be effective in collecting out-migrants without a guidance net.	• Recommend advancing as this technology is made to capture out-migrant. • Though, out-migrant entering the reservoir are essentially “lost” (Stillwater 2023) • A Floating Surface Collector located at the head of reservoir would avoid out-migrant low expected survival rate in the reservoir.
Fixed Screen Structures		Do Not Advance
• Takes advantage of hydropower or Low Level Outlet (LLO) flow. • No separate pumping required for attraction flow. • Round Butte has shown high level of efficiency. • Does not rely on guide nets.	• Fixed surface collector; does not work well with high reservoir fluctuation. • Juvenile fish may be pumped from the holding tank; work best for fry versus smolt. • Construction from a barge and requiring divers and highly technical construction crew. • System can be dewatered using a flotation system which allows the fish collector to be “raised” by pumping out ballast tanks and bring the floor of the	• The reason for not advancing this alternative is that Lopez Dam does not have a LLO and is not a hydropower facility. • Does not work with high reservoir fluctuation.

Advantages	Disadvantages	Recommendation for Advancement and Justification
	structure up out of the water. This exposes all the fish screens, pumps, etc. for inspection and maintenance. A complexity that other system does not have.	
Bypass Pipe		Advance
• Safe, efficient, and effective. • No operational costs. • Very little maintenance.	• Length of pipe at high head dam. • Pipe material can be subject to temperature variation (HDPE), to coating failure (painted steel), or potential issues with pipe joints (PVC). • Does not work well at dams with a large reservoir fluctuation.	• This is the most common way to return fish (once captured) • Can be used with other trapping system with either direct or indirect fish transfer depending on reservoir fluctuation.
Open Channel		Do Not Advance
• Simple technology.	• Limited in length. • Not applicable at high head dam. • Roughened Channel are not the most efficient at providing out-migration. • Possible predation concerns.	• This does not offer advantages over the bypass pipe. • The dam height greatly limits this possibility. • The lake variation during downstream migration (Feb 15 to June 15) is 62.0 ft.
Helix		Advance (?)
• Compact design.	• Only one known application. • Requires significant computational fluid dynamic modeling effort. • Requires multiple intakes to accommodate variation in the forebay.	• Only one project currently being built and not yet operational. • The Lopez Dam outlet works already includes multiple intakes at different depths.
Transport (Truck or Barge)		Advance (?)
• Long history of use; well-developed techniques/ • Many container size/configuration options. • With proper equipment, provides excellent temporary fish holding conditions. • Greater fisheries management flexibility with regards to release site, timing, conditions.	• Not a volitional transport method. Potential for pathogen/parasite transmission with multiple species and increased biomass. • Truck transport does not allow migrational cues (fish removed from water source, imprinting). • Can be challenging in cold climates/conditions. • Increased labor, Capital, and O&M costs.	• This works well but is not efficient. • Adds O&M cost over a bypass pipe. • May be a good and necessary option if collecting out-migrants in the tributaries.

Advantages	Disadvantages	Recommendation for Advancement and Justification
Behavioral /Structural Guidance Devices		
Louvers		Do Not Advance
• Louvers typically operate with higher approach velocities than screens, which leads to reduced overall structure size and cost. • Louvers will pass small debris and sediment, which can reduce debris and sediment handling requirements. • Louvers have a reduced sensitivity to flow blockage caused by debris fouling as compared to fine mesh screens. Consequently, more time is available between required cleaning cycles, and automated cleaners are typically not used. • Louvers offer an effective exclusion option for larger, stronger swimming fish and may provide a reduced-cost fish exclusion option at sites where 100% fish exclusion is not required. • Some examples have been built with maximum flow rates in excess of 8,800 ft^3/s (250 m^3/s).	• Louvers are not absolute fish barriers (not a positive barrier screen). Fish exclusion efficiency varies as a function of fish species, life stage, size, and fish swimming strength. • Some debris types (fibrous aquatic plants and woody plants) will intertwine or embed in the louver, which leads to difficult debris removal and cleaning. • Louvers are not broadly accepted by resource agencies and are typically opposed by resource agencies on the West Coast. • Need attraction and bypass flow for downstream fish passage.	• Need attraction and bypass flow for downstream fish passage, which Lopez Dam does not have. • Not a positive barrier screen.
Angled Bar and Trash Racks		Do Not Advance
• Similar benefits as Louvers.	• Similar disadvantages as Louvers.	• Similar to Louvers.
Floating Fish Guidance Boom		Do Not Advance
• Easy to install and maintain • Can result in high efficiency for sites where fish are in the upper part of the water column.	• Need a bypass route. • Effectiveness depends on fish location in the water column and fish swimming ability. • Need attraction and bypass flow for downstream fish passage.	• Need attraction and bypass flow for downstream fish passage, which Lopez Dam does not have. • Not a positive barrier screen.
Hanging Chains		Do Not Advance
• Easy to install and maintain • Can result in high efficiency for sites where fish are in the upper part of the water column and where the velocities are less than 1 ft/s (0.3 m/s).	• Need a bypass route. • Effectiveness depends on fish location in the water column and fish swimming ability. • No known existing installation. • Visual deterrent would be less effective in turbid conditions and in higher velocities.	• Need attraction and bypass flow for downstream fish passage, which Lopez Dam does not have. • Visual and not physical deterrent.

Advantages	Disadvantages	Recommendation for Advancement and Justification
Barrier/Guidance Nets		Advance
• Provide exclusion to water intake. • Can be used for guidance purpose.	• Difficult to deploy, maintain, and clean. • Barrier nets are not considered to be appropriate at sites where the concern is for entrainment of very small fish, where passage is considered necessary, and/or where there are problems with keeping the net clear of ice and debris. In cases such as downstream fish passage, they could be used in combination with an FSC.	• This solution is typically used in deep reservoir with low velocity, and/or in combination with a floating surface collector. • This may be advanced in combination with an FSC, if selected for advancement.
Removable Spillway Weir		Do Not Advance
• Provides a way for surface-oriented fish to pass downstream of radial gates.	• Site specific; does not work well at high head dam. • Typically deployed at one spillway bay, not all bays. • Highly mechanical system located upstream of spillway. • Marine construction. • Worker safety working from a floating structure. • Limited benefit as it does not provide safe, efficient, and timely fish passage from the forebay to the tailrace, but only through the gate.	• The reason for not advancing this alternative is that Lopez Dam does not have an existing spillway/radial gate, so not applicable.
Behavioral Guidance Devices		
Lights		Do Not Advance
• Light systems have a relatively low capital and maintenance cost. • They are applicable at sites that would otherwise be difficult to screen.	• They do not create an absolute exclusion barrier (not a positive barrier screen). • Exclusion efficiencies can vary with fish species, fish development stage, and ambient conditions (river flow discharge and patterns, fish swimming ability, water quality, and ambient lighting). • They are not generally accepted. • Need an exit route when used as a feature for downstream passage.	• Need attraction and bypass flow (exit route) for downstream fish passage, which Lopez Dam does not have. • Low efficiency. • Cannot ensure that goal will be met.

Advantages	Disadvantages	Recommendation for Advancement and Justification
Sounds (Acoustics)		**Do Not Advance**
• Sound systems have a relatively low capital and maintenance cost. • They are applicable at sites that would otherwise be difficult to screen.	• They do not create an absolute exclusion barrier (not a positive barrier screen). • Exclusion efficiencies can vary with fish species, fish development stage, and ambient conditions (river flow discharge and patterns, fish swimming ability, water quality, and ambient lighting). • They are not generally accepted. • Need an exit route when used as a feature for downstream passage.	• Need attraction and bypass flow (exit route) for downstream fish passage, which Lopez Dam does not have. • Low efficiency. • Cannot ensure that goal will be met.
Electric Fields		**Do Not Advance**
• None	• Risk to other species. Usually used for upstream not downstream fish passage. They are generally not accepted. Likely not effective for smaller juvenile fish (i.e., limited swimming ability to swim away from feature). safety concern for mammals and humans.	• The reason for not advancing this alternative is that physical barriers typically used to impede upstream passage and not for downstream guidance. • Safety concerns
Air Bubble Curtains		**Do Not Advance**
• None	• Research has shown very little effectiveness. • Require large compressor and power. • They are generally not accepted. • Need an exit route when used as a feature for downstream passage. • Exclusion efficiencies can vary with fish species, fish development stage, and ambient conditions (river flow discharge and patterns, fish swimming ability, water quality, and ambient lighting).	• Need attraction and bypass flow (exit route) for downstream fish passage, which Lopez Dam does not have. • Low efficiency. • Cannot ensure that goal will be met.

Advantages	Disadvantages	Recommendation for Advancement and Justification
Hybrid Barriers		Do Not Advance
• Capital and maintenance costs of behavioral systems are relatively low. • They might be applicable at sites that would otherwise be difficult to screen (complex sites with odd configurations that might not be accessible for maintenance).	• Fishery resource agencies will likely not accept behavioral barriers as a fish exclusion alternative or will likely require extensive field evaluation to verify effectiveness. • Need an exit route when used as a feature for downstream passage. • Exclusion efficiencies can vary with fish species, fish development stage, and ambient conditions (river flow discharge and patterns, fish swimming ability, water quality, and ambient lighting).	• Need attraction and bypass flow (exit route) for downstream fish passage, which Lopez Dam does not have. • Hybrid behavioral guidance may have an increased efficiency. • Cannot ensure that goal will be met.
Other Methods		
Spilling		Do Not Advance
• No apparent capital cost for the base flow. • Screening or guidance nets are not required.	• Spill has been very infrequent at Lopez Reservoir and is tied to dam operation. • Would work only for when reservoir is higher than EL 522.6 ft or EL 506 ft (159.3 m or 154.2 m) (if a section of the ogee weir was replaced with an Obermeyer gate). • Spill height from the top of the ogee weir to the tailrace is 168.2 ft (51.3 m) is greater than 115 ft (35 m); Ruggles and Murray (1983) concluded that for dams less than approximately in height 115 ft (35 m) in height, spillway passage is generally considered as the safest means of fish passage.	• Rare spilling events at Lopez Dam. • Dam height is too tall to consider the spillway safe for out-migration.
Turbine Passage		Do Not Advance
• For hydroelectric facility, fish-friendly turbine would be the simplest solution as fish would pass with the flow downstream safely through the fish-friendly turbine.	• Fish-friendly turbines work best for low head hydroelectric dams.	• Lopez Dam is not a hydroelectric facility.
Trap-and-Haul (Rotary Screw Trap)		Advance
• Simple application. • Demonstrated use in Fisheries Management. • Could increase overall survival rate.	• Low collection efficiency. • Does not collect fish in reservoir. • Operationally intensive (but for a short duration). • Collection in tributaries upstream of the reservoir; needing access roads.	• This could result in a simple operation in the main tributaries where SCCC steelhead are located.

Advantages	Disadvantages	Recommendation for Advancement and Justification
Reservoir Drawdown		Do Not Advance
• Simple solution. • Run-of-river. • Passage through the LLO (when one is available)	• No storage capacity; need to align with dam operation requirements. • If the dam was used for hydropower , which it is not, power could not be generated during reservoir drawdown • If there was a LLO, the low point of the reservoir would need to be by the LLO outlet for natural river flow towards the low point. • Loose recreational opportunity during the annual drawdown period. • Loose water supply to 50,000 people during the drawdown.	• The reason for not advancing this alternative is that it would severely impact water supply reliability to 50,000 people dependent on it. • Lopez Dam does not have an LLO.
Dam Removal		Do Not Advance
• Simple solution. • Run-of-river.	• No storage capacity for flood protection. • Loose the primary use of the dam - water storage.	• The reason for not advancing this alternative is that it goes against water storage goal.

4.0 Evaluation Matrix

This section presents the alternatives evaluation tool (Evaluation Matrix). Once the options are selected and the alternatives have been developed to a conceptual design level, the Evaluation Matrix will be used to identify which alternative has the most merit.

4.1 Evaluation Criteria Definition

While the design criteria (McMillen 2025) are important for the development of feasible alternatives at Lopez Dam, the evaluation criteria are important to distinguish which alternative from those options recommended for advancement to conceptual design level (Section 3.0) is the "highest-ranked" alternative. The proposed evaluation criteria are grouped into seven categories. Each category has a subset of evaluation criteria. The Evaluation Matrix (Appendix A) presents the framework for the evaluation, which will be completed later as part of this Project. Each criterion will be given an importance factor (L = Low, M = Medium, H = High). The importance factor will be given a relative weight (Low = 1, Medium = 2, High = 3). Each alternative will be evaluated against each other within a criterion and a grade given between 1 and 10 (1 = worst and 10 = best). When a criterion is expressed in percent, such as passage efficiency, mortality, or fallback risk, the percent value will need to be determine as "good" or "bad". For example, the smolt mortality can be low % (good) and survival rate can be high %

(good). In these cases, the grade will be calculated as follows: if smolt mortality is low (e.g., 3%), the grade will be 10-0.3 = 9.7, or if the survival rate is high (e.g., 97%) the grade will be 9.7. With this quantitative process, each of the seven categories will receive a combined weighted score for each alternative. The total score will then be used to identify which alternative has the most merit. The evaluation criteria are grouped in the following seven categories:

- **Biological Efficiency** defines the ability of the alternative to attract and collect fish at the fishway entrance and to account for whether the fishway is volitional. It also includes criteria such as effort expenditure, stress factor, fish return safety, fall back risk, juvenile and adult passage efficiencies, and smolt and adult mortality risks. The ultimate measure of success is whether the alternative meets the requirements of the design criteria established in the technical memorandum TM-002-Design Criteria (McMillen 2025) and, more broadly, if the alternative successfully mitigates habitat fragmentation and supports the recovery of SCCC steelhead trout by restoring passage at Lopez Dam.
- **Constructability** identifies the challenges of constructing alternative features. Special consideration will be given to site access, cofferdam needs, dewatering difficulties, and utilities availability.
- **Operation** considers potential impacts on existing dam operations and water management objectives. The amount of mechanical equipment and the ease of operation and maintenance of intake screens, pumps, gates, etc. (if used) will be reviewed. Winter operation concerns and potential flood impacts will also be considered. The ultimate success of the alternative would be one that is easy to operate and maintain and limits impacts on existing dam operations and water management.
- **Design approach** is an evaluation criterion needed to determine the potential complexity of the system designed. Preference will be given to an alternative using proven or acceptable technology that have low uncertainty and low risk of not performing as expected compatible with the overall fish passage goals. The criteria will also be used to size the system. This criterion is intended to determine which alternatives are the most successful while featuring relatively simple system designs with proven technology. It will also be used to evaluate alternatives with the least human intervention required for passage.
- **Environmental impact** considers the alternative's impact on water quality, habitat modification, and the effect on non-target species. This group of criteria should be considered for both the construction period as well as long-term impacts following construction.

- **Regulatory compliance** assesses the permitting requirements and regulatory considerations for each alternative under federal and state law that could impact the alternative's implementation feasibility or cost.
- **Financial** criteria assesses the anticipated construction cost. The intent of this group of criteria is to identify those alternatives that provide the best value (or economic realities) considering all cost aspects. Careful consideration of operation and maintenance costs will be required. It will include annualized capital costs (based on the estimated life expectancy of the Project) and annual monitoring (and adaptive management and schedule) costs in order to compare alternatives on an annual cost to the County.

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Appendix A. Evaluation Matrix

Criterion	Performance Measure (Units)	Importance - Relative (L, M, H)	Importance Weighting (H=3; M=2; L=1)	Upstream Fish Passage: *Alternative 1*	Upstream Fish Passage: *Alternative 2*	Upstream Fish Passage: *Alternative 3*	Upstream Fish Passage: *Alternative 4*	Downstream Fish Passage: *Alternative 1*	Downstream Fish Passage: *Alternative 2*	Downstream Fish Passage: *Alternative 3*	Downstream Fish Passage: *Alternative 4*
Biological Efficiency											
Volitional Passage	Degree (1-10)	H	3								
Attract and Collect Fish	Degree (1-10)	M	2								
Energy Expenditure	Degree (1-10)	M	2								
Stress Factor	Degree (1-10)	L	1								
Smolt mortality	Mortality (%)	L	1								
Fish Return Safety	Degree (1-10)	L	1								
Juvenile passage efficiency (if applicable)	Efficiency (%)	L	1								
Adult mortality	Mortality (%)	H	3								
Adult passage efficiency	Efficiency (%)	H	3								
Daily Transport Capacity	Degree (1-10)	M	2								
Fallback Risk	Proportion (%)	H	3								
Weighted Score	Relative Measure			**7.0**	**7.0**	**7.0**	**7.0**	**7.0**	**7.0**	**7.0**	**7.0**
Constructability											
Site Access	Degree (1-10)	H	3								
Cofferdam Impact	Degree (1-10)	M	2								
Dewatering Difficulty	Degree (1-10)	M	2								
Utilities Availability	Degree (1-10)	M	2								
Limited reservoir drawdown requirements	Degree (1-10)	H	3								
Weighted Score	Relative Measure			**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Operation											
Low Mechanical Equipment	Degree (1-10)	H	3								
Limited Screen Cleaning Effort	Degree (1-10)	H	3								
Limited Pump O&M Effort	Degree (1-10)	H	3								
Limited Gates O&M Effort	Degree (1-10)	H	3								
Low Risk (Safety)	Degree (1-10)	H	3								
Low Winter Operation Impacts	Degree (1-10)	H	3								
Low Flood Risks	Degree (1-10)	H	3								
Low Debris Management	Degree (1-10)	H	3								
Weighted Score	Relative Measure			**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Design Approach											
Proven Technology	Degree (1-10)	H	3								
Ability to Meet Fish Passage Goals	Degree (1-10)	H	3								
Simple system	Degree (1-10)	M	2								
Low human Intervention required for Passage	Degree (1-10)	M	2								
Design Complexity	Degree (1-10)	H	3								
Weighted Score	Relative Measure			**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Environmental Impact											
Limited impact to water quality	Degree (1-10)	M	2								
Low impact to habitat	Degree (1-10)	M	2								
limited impact on non-target species	Degree (1-10)	M	2								
Weighted Score	Relative Measure			**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Regulatory Compliance											
Low Permitting Effort	Degree (1-10)	H	3								
Low Regulatory Constraints	Degree (1-10)	H	3								
Weighted Score	Relative Measure			**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Financial											
Capital Costs (Design/Construction)	NPV ($)	H	3								
Estimated Life Expectancy	Years	M	2								
Annualized Capital Cost (over life expectency)	$/yr	**H**	**3**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**
Annual operations and maintenance costs	$/yr	H	3								
Annual NET revenue loss	$/yr	H	3								
Annual monitoring costs	$/yr	H	3								
Total Annualized Cost	$/yr	H	3	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**

RANK ASSESSMENTS

	Upstream Alt 1	Upstream Alt 2	Upstream Alt 3	Upstream Alt 4	Downstream Alt 1	Downstream Alt 2	Downstream Alt 3	Downstream Alt 4
Biological Efficiency	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Constructability	**2**	**1**	**3**	**4**	**2**	**1**	**3**	**4**
Operation	**3**	**2**	**1**	**4**	**3**	**2**	**1**	**4**
Design Approach	**4**	**3**	**2**	**1**	**4**	**3**	**2**	**1**
Environmental Impact	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Regulatory	**2**	**1**	**3**	**4**	**2**	**1**	**3**	**4**
Financial	**3**	**2**	**1**	**4**	**3**	**2**	**1**	**4**
Average Rank (2025)	**2.3**	**1.9**	**2.3**	**3.6**	**2.3**	**1.9**	**2.3**	**3.6**

Appendix C. Conceptual Drawings

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COUNTY of SAN LUIS OBISPO

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COUNTY OF SAN LUIS OBISPO
STEELHEAD PASSAGE FEASIBILITY ASSESSMENT LOPEZ DAM
CALIFORINA

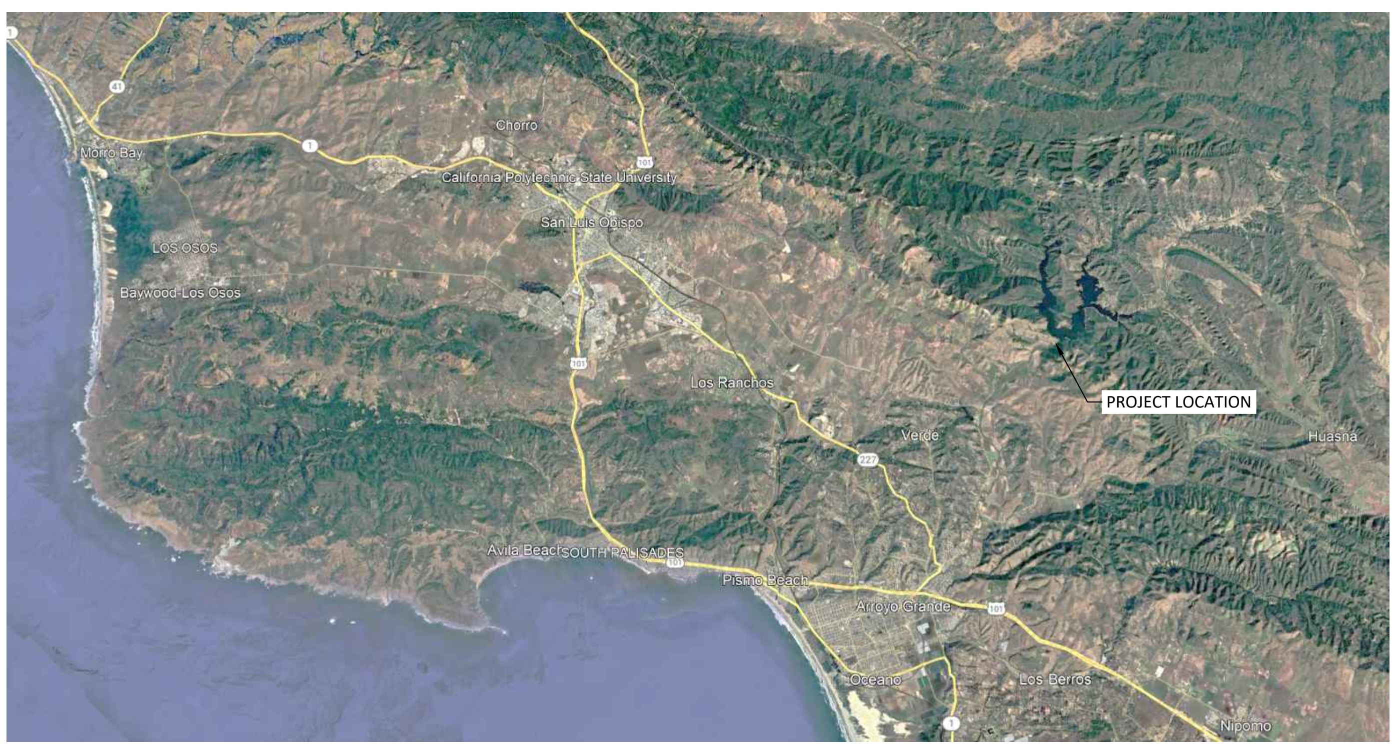
CONCEPTUAL DRAWINGS
SEPTEMBER 2025

FINAL

COUNTY OF SAN LUIS OBISPO

STEELHEAD PASSAGE FEASIBILITY ASSESSMENT LOPEZ DAM CONCEPTUAL DRAWINGS

LOCATION MAP
SCALE: NTS



PROJECT LIMITS
SCALE: NTS

VICINITY MAP
SCALE: NTS

REV	DATE	BY	DESCRIPTION
A	09/26/25	VPA	CONCEPTUAL DRAWINGS

WARNING
0 1/2 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

McMillen

COUNTY of SAN LUIS OBISPO

COUNTY OF SAN LUIS OBISPO
STEELHEAD PASSAGE FEASIBILITY ASSESSMENT LOPEZ DAM

LOCATION MAP, VICINITY MAP, PROJECT LIMITS AND DRAWING INDEX

DESIGNED V. AUTIER
DRAWN C. DOKKEN
CHECKED -
PROJECT DATE 09/26/25

DRAWING
G001

C:\Users\ChadDokken\DC\ACCDocs\McMillen Inc\Lopez Dam Steelhead Passage Feasibility\Project Files\Drawings\G001.dwg

A/C	AIR CONDITIONING
A/E	ARCHITECT/ENGINEER
A	ARCHITECTURAL (DWG DISCIPLINE), AMP
AB	ANCHOR BOLT
ABC	AGGREGATE BASE COURSE
ABAN	ABANDON
AC	ALTERNATING CURRENT
ACST	ACOUSTIC
AD	ADDENDUM, AREA DRAIN
ADDL	ADDITIONAL
ADH	ADHESIVE
ADJ	ADJUSTABLE, ADJACENT
AF	AMP FRAME, AMP FUSE
AFF	ABOVE FINISH FLOOR
AFG	ABOVE FINISH GRADE
AGGR	AGGREGATE
AIC	AMPS INTERRUPTING CAPACITY
ALIG	ALIGNMENT
ALUM	ALUMINUM
ALT	ALTERNATE, ALTITUDE
AMB	AMBIENT
ANC	ANCHOR
AP	ACCESS PANEL
APRX	APPROXIMATE
APVD	APPROVED ARCH ARCHITECTURAL
ASSY	ASSEMBLY
AT	AMP TRIP
ATM	ATMOSPHERE
AUTO	AUTOMATIC
AUX	AUXILIARY
AVE	AVENUE
AVG	AVERAGE
AWG	AMERICAN WIRE GAGE
B/B	BACK TO BACK
BAL	BALANCE
BBD	BULLETIN BOARD
BC	BASE CABINET, BOTTOM CHORD, BOLT CENTER, BOLT CIRCLE
BD	BOARD
BE	BOTH ENDS, BELL END
BF	BOTH FACES, BOTTOM FACE, BLIND FLANGE, BOARD FEET
BFV	BUTTERFLY VALVE
BITUM	BITUMINOUS
BKG	BACKING
BL	BASE LINE
BLDG	BUILDING
BLK	BLOCK
BLKG	BLOCKING
BM	BENCHMARK, BEAM
BOC	BACK OF CURB
BOD	BOTTOM OF DUCT
BOG	BOTTOM OF GRILLE
BOL	BOTTOM OF LOUVER
BOP	BOTTOM OF PIPE
BOR	BOTTOM OF REGISTER
BOT	BOTTOM
BOU	BOTTOM OF UNIT
BP	BASE PLATE
BRG	BEARING
BRGP	BEARING PLATE
BRKT	BRACKET
BS	BOTH SIDES
BTU	BRITISH THERMAL UNIT
BTW	BETWEEN
BTWLD	BUTT WELD
BV	BALL VALVE
BW	BOTH WAYS
BYP	BYPASS
C TO C	CENTER TO CENTER
C&G	CURB & GUTTER
C	CHANNEL SHAPE, CENTIGRADE, CONDUIT, CIVIL (DRAWING DISCIPLINE)
CAB	CABINET
CAP	CAPACITY
CAT	CATALOG
CAV	CAVITY
CB	CATCH BASIN
CCB	CONCRETE BLOCK
CCW	COUNTER CLOCKWISE
CF	CUBIC FEET (FOOT)
CHFR	CHAMFER
CHD	CHORD
CHH	COMMUNICATION HANDHOLE
CI	CURB INLET
CIP	CAST-IN-PLACE
CIPB	CONCRETE INTERLOCKING PAVER BALLAST
CIRC	CIRCULATION, CIRCULAR
CJ	CONSTRUCTION JOINT, CONTROL JOINT
CKT	CIRCUIT
CL	CENTERLINE, CLASS, CLOSE
CLR	CLEAR
CMH	COMMUNICATION MANHOLE
CMU	CONCRETE MASONRY UNIT
CO	CLEAN OUT, CONCRETE OPENING
COL	COLUMN
COM	COMMON
COMB	COMBINATION
COMM	COMMUNICATION
COMP	COMPOSITION, COMPRESSIBLE, COMPOSITE
CONC	CONCENTRIC, CONCRETE
CONN	CONNECTION
CONST	CONSTRUCTION
CONT	CONTINUOUS, CONTINUED
COORD	COORDINATE
CORR	CORROSIVE, CORRUGATED
CP	CHECKER PLATE, CONTROL POINT
CPLG	COUPLING
CSK	COUNTERSINK
CTR	CENTER
CTRL	CONTROL
CU	COPPER, CUBIC
CW	CLOCKWISE
CY	CUBIC YARD
d	PENNY (NAIL MEASURE)
D	DEEP, DIFFUSER
DB	DUCT BANK, DECIBEL, DRY BULB
DBA	DEFORMED BAR ANCHOR
DBL	DOUBLE
DC	DIRECT CURRENT
DEG	DEGREE
DEG C	DEGREE CENTIGRADE
DEG F	DEGREE FAHRENHEIT
DEMO	DEMOLITION
DEP	DEPRESSED
DEPT	DEPARTMENT
DET	DETAIL
DI	DROP INLET, DUCTILE IRON
DIA	DIAMETER
DIAG	DIAGONAL, DIAGRAM
DIFF	DIFFERENTIAL, DIFFERENCE
DIM	DIMENSION
DISCH	DISCHARGE
DIST	DISTANCE, DISTRIBUTION
DIV	DIVISION
DL	DEAD LOAD
DN	DOWN
DP	DEPTH
DS	DOWN SPOUT
DT	DOUBLE TEE, DRIP TRAP ASSEMBLY
DUP	DUPLICATE
DWG	DRAWING
DWL	DOWEL
E	EAST, ELECTRICAL (DWG DISCIPLINE)
EA	EACH, EXHAUST AIR
EC	ELECTRICAL CONTRACTOR
ECC	ECCENTRIC
EDB	ELECTRICAL DUCT BANK
EE	EACH END
EF	EACH FACE
EG	EXISTING GRADE
EGL	ENERGY GRADE LINE
EFF	EFFLUENT, EFFICIENCY
EHH	ELECTRICAL HANDHOLE
EIFS	EXTERIOR INSULATION & FINISH SYSTEM
EJ	EXPANSION JOINT
EL	ELBOW, ELEVATION
ELEC	ELECTRICAL
EMBD	EMBEDDED
EMER	EMERGENCY
EMH	ELECTRICAL MANHOLE
ENCL	ENCLOSURE
ENGR	ENGINEER
ENTR	ENTRANCE
EOP	EDGE OF PAVEMENT
EOW	EDGE OF WATER
EQ	EQUAL
EQUIP	EQUIPMENT
EQUIV	EQUIVALENT
ES	EACH SIDE, EQUAL SPACE, EMERGENCY SHOWER
ESEW	EMERGENCY SHOWER AND EYE WASH
EST	ESTIMATE
EW	EACH WAY, EMERGENCY EYE/FACE WASH
EWC	ELECTRIC WATER COOLER
EWEF	EACH WAY, EACH FACE
EWTB	EACH WAY, TOP AND BOTTOM
EXC	EXCAVATION
EXH	EXHAUST
EXIST	EXISTING
EXP	EXPANSION, EXPOSED
EXT	EXTERIOR, EXTERNAL, EXTENSION
F TO F	FACE TO FACE
FAB	FABRICATE
FBO	FURNISHED BY OWNER
FC	FLUSHING CONNECTION
FCA	FLANGED COUPLING ADAPTER
FCV	FIXED CONE VALVE
FD	FLOOR DRAIN
FDC	FLEXIBLE DUCT CONNECTION
FDR	FEEDER
FE	FLANGED END
FEC	FIRE EXTINGUISHER CABINET
FEXT	FIRE EXTINGUISHER
FF	FAR FACE, FACTORY FINISH, FLAT FACE
FG	FINISHED GRADE
FIG	FIGURE
FH	FIRE HYDRANT
FIN	FINISH
FL	FLOW, FLOW LINE
FLEX	FLEXIBLE
FLG	FLANGE
FLOR	FLUORESCENT
FLR	FLOOR
FLS	FLASHING, FLUSH
FND	FOUNDATION
FNC	FENCE
FO	FINISHED OPENING
FOB	FLAT ON BOTTOM
FOC	FACE OF CONCRETE, FACE OF CURB, FIBER OPTIC CABLE
FOF	FACE OF FINISH
FOM	FACE OF MASONRY
FOS	FACE OF STUDS
FOT	FLAT ON TOP
FPT	FEMALE PIPE THREAD
FR	FRAME
FRP	FIBERGLASS REINFORCED PLASTIC
FS	FLOOR SINK, FAR SIDE
FT	FEET, FOOT
FTG	FOOTING, FITTING FUR FURRED, FURRING
FURN	FURNITURE, FURNISH
FUT	FUTURE
FV	FACE VELOCITY
FW	FIELD WELD, FIRE WALL
FWD	FORWARD
FWE	FURNISHED WITH EQUIPMENT
FXTR	FIXTURE
G	GRILLE, GROUND, GENERAL (DWG DISCIPLINE)
GA	GAGE (METAL THICKNESS)
GAL	GALLON
GALV	GALVANIZED
GB	GRADE BREAK
GD	GUARD
GEN	GENERAL
GFCI	GROUND FAULT CIRCUIT INTERRUPTER
GL	GLASS
GP	GUY POLE
GR	GRADE
GRND	GROUND
GRTG	GRATING
GT	GREASE TRAP
GWB	GYPSUM WALLBOARD
GYP	GYPSUM HARDBOARD
H	HIGH
HB	HOSE BIB
HBD	HARDBOARD
HC	HANDICAPPED, HOLLOW CORE, HORIZONTAL CURVE
HC	HORIZONTAL CENTERLINE
HDR	HEADER
HDW	HARDWARE
HEX	HEXAGONAL
HH	HANDHOLE
HM	HOLLOW METAL
HORIZ	HORIZONTAL
HP	HIGH POINT, HORSEPOWER
HPC	HORIZONTAL POINT OF CURVATURE
HPS	HIGH PRESSURE SODIUM
HPT	HORIZONTAL POINT OF TANGENCY
HR	HOUR
HS	HEADED STUD, HIGH STRENGTH
HSS	HOLLOW STRUCTURAL SHAPE
HT	HEIGHT
HV	HIGH VOLTAGE
HVAC	HEATING, VENTILATION & AIR CONDITIONING
HWD	HARDWOOD
HWL	HIGH WATER LEVEL
HYD	HYDRAULIC HZ HERTZ, CYCLES PER SECOND
I	INSTRUMENTATION (DWG DISCIPLINE)
ID	INSIDE DIAMETER, INTERIOR DIMENSION
IE	INVERT ELEVATION
IF	INSIDE FACE
IH	INTAKE HOOD
IMP	IMPACT
IN	INCH
INC	INCLUDE, INCANDESCENT
INF	INFLUENT
INSTR	INSTRUMENTATION
INSUL	INSULATION
INT	INTERIOR, INTERSECTION
INTR	INTERMEDIATE, INTERIOR
INV	INVERT
IPS	IRON PIPE SIZE
IPT	INTERNAL PIPE THREAD
IRR	IRRIGATION
ISO	ISOMETRIC
JB	JUNCTION BOX
JCT	JUNCTION
JF	JOINT FILLER
JT	JOINT
K	KIP
KB	KNEE BRACE
KCMIL	THOUSAND CIRCULAR MILS
KD	KNOCK DOWN
KO	KNOCK OUT
KSI	KIPS PER SQUARE INCH
L	ANGLE, LENGTH, LAVATORY
LAM	LAMINATE
LATL	LATERAL
LB	LAG BOLT, POUND
LDR	LEADER
LF	LINEAR FOOT
LG	LONG
LH	LEFT HAND
LIN	LINEAR
LIQ	LIQUID
LL	LIVE LOAD
LLH	LONG LEG HORIZONTAL
LLV	LONG LEG VERTICAL
LMLU	LIQUID MARKER LECTURE UNIT
LNG	LONGITUDINAL
LOC	LOCATION
LP	LOW POINT
LPS	LOW PRESSURE SODIUM
LR	LONG RADIUS
LT	LEFT
LTD	LIMITED
LTG	LIGHTING
LTL	LINTEL
LTNG	LIGHTNING
LV	LOW VOLTAGE
LVR	LOUVER
LW	LIGHTWEIGHT
LWC	LIGHTWEIGHT CONCRETE
LWL	LOW WATER LEVEL
M	MECHANICAL (DWG DISCIPLINE)
MA	MIXED AIR
MAINT	MAINTENANCE
MAN	MANUAL
MAOP	MAXIMUM ALLOWABLE OPERATING PRESSURE
MATL	MATERIAL
MAX	MAXIMUM
MB	MACHINE BOLT
MBR	MEMBER
MCJ	MASONRY CONTROL JOINT
MECH	MECHANICAL
MED	MEDIUM
MFR	MANUFACTURER
MH	MANHOLE, METAL HALIDE
MIN	MINIMUM
MIR	MIRROR
MISC	MISCELLANEOUS
MJ	MECHANICAL JOINT
MMB	MEMBRANE
MO	MASONRY OPENING
MOD	MODULAR, MODIFY
MON	MONUMENT
MPT	MALE PIPE THREAD
MSL	MEAN SEA LEVEL
MT	MOUNT
MU	MASONRY UNIT
MULL	MULLION
MV	MEDIUM VOLTAGE
MW	MONITORING WELL
N	NORTH, NEUTRAL
NA	NOT APPLICABLE
NAT	NATURAL
NC	NORMALLY CLOSED
NEG	NEGATIVE
NF	NEAR FACE, NON-FUSED
NG	NATURAL GAS
NIC	NOT IN CONTRACT
NO	NORMALLY OPEN, NUMBER
NOM	NOMINAL
NPS	NOMINAL PIPE SIZE
NPT	NATIONAL PIPE THREAD
NS	NEAR SIDE
NTS	NOT TO SCALE
NWL	NORMAL WATER LEVEL
O TO O	OUT-TO-OUT
OA	OUTSIDE AIR, OVERALL
OC	ON CENTER
OCPD	OVER CURRENT PROTECTION DEVICE
OD	OUTSIDE DIAMETER
OH	OVERHEAD
OPNG	OPENING
OPP	OPPOSITE
OPT	OPTIONAL
ORD	OVERFLOW ROOF DRAIN
ORIG	ORIGINAL
OVFL	OVERFLOW
OVHG	OVERHANG
OZ	OUNCE
P	PAINT, PROCESS (DWG DISCIPLINE)
PAR	PARALLEL, PARAPET
PB	PANIC BAR, PULL BOX
PBD	PARTICLE BOARD
PC	POINT OF CURVE, PIECE, PRECAST
PCC	POINT OF COMPOUND CURVATURE
PCF	POUNDS PER CUBIC FOOT
PCT	PERCENT
PE	PLAIN END
PED	PEDESTAL
PEN	PENETRATION
PERF	PERFORATED
PERM	PERMANENT
PERP	PERPENDICULAR
PF	POWER FACTOR
PH	PHASE
PI	POINT OF INTERSECTION
PKG	PACKAGE
PL	PLATE, PROPERTY LINE
PLBG	PLUMBING
PLF	POUNDS PER LINEAR FOOT
PNEU	PNEUMATIC
POL	POLISH
POS	POSITIVE, POSITION
PP	POLYPROPYLENE, POWER POLE
PRC	POINT OF REVERSE CURVATURE
PREF	PREFINISHED
PREFAB	PREFABRICATED
PRELIM	PRELIMINARY
PREP	PREPARE
PRES	PRESSURE
PROP	PROPERTY
PROT	PROTECTION
PSF	POUNDS PER SQUARE FOOT
PSI	POUNDS PER SQUARE INCH
PSIA	POUNDS PER SQUARE INCH ABSOLUTE
PSIG	POUNDS PER SQUARE INCH GAGE
PT	POINT, POINT OF TANGENCY
PTN	PARTITION
PVC	POLYVINYL CHLORIDE
PVMT	PAVEMENT
PWD	PLYWOOD
PZ	PIEZOMETER
Q	RATE OF FLOW
QTR	QUARTER
QTY	QUANTITY
QUAL	QUALITY
R&R	REMOVE AND REPLACE
R&S	REMOVE AND SALVAGE
R	RADIUS, REGISTER, RISER
RA	RETURN AIR
RB	RESILIENT BASE, ROCK BERM
RCPT	RECEPTACLE
RD	ROOF DRAIN
REC	RECESS
RECD	RECEIVED
RECT	RECTANGULAR
RED	REDUCER
REF	REFERENCE
REINF	REINFORCING
REQD	REQUIRED
RESIL	RESILIENT
RET	RETAINING, RETURN
REV	REVISION, REVERSE
RFL	REFLECTED, REFLECTOR
RGS	RIGID GALVANIZED STEEL
RH	RELIEF HOOD, RIGHT HAND, RELATIVE HUMIDITY
RL	REQUIRED LAP
RND	ROUND
RNG	RENEWABLE NATURAL GAS
RO	ROUGH OPENING
ROW	RIGHT-OF-WAY
RPM	REVOLUTIONS PER MINUTE
RR	RAILROAD
RT	RIGHT
S	SOUTH, SINK, STRUCTURAL (DWG DISCIPLINE)
SA	SUPPLY AIR
SAN	SANITARY
SC	SOLID CORE
SCH	SCHEDULE
SCHEM	SCHEMATIC
SCRN	SCREEN
SE	STEEL/ALUMINUM EDGE
SEC	SECONDARY, SECONDS
SECT	SECTION
SEP	SEPARATE
SF	SQUARE FOOT
SH	SHOWER
SHT	SHEET
SHTG	SHEATHING
SIM	SIMILAR
SL	SLOPE
SLTD	SLOTTED
SLV	SLEEVE
SMLS	SEAMLESS
SOG	SLAB ON GRADE
SP	SOUNDPROOF, STANDPIPE
SPC	SPACING
SPEC	SPECIFICATION
SPLY	SUPPLY
SPT	SET POINT
SQ	SQUARE
SR	SHORT RADIUS
SS	SERVICE SINK
SST	STAINLESS STEEL
ST	STREET
STA	STATION
STD	STANDARD
STIF	STIFFENER
STIR	STIRRUP
STL	STEEL
STOR	STORAGE
STR	STRUCTURAL, STRAIGHT
SUB	SUBSTITUTE
SUC	SUCTION
SUSP	SUSPENDED
SY	SQUARE YARD
SYM	SYMBOL
SYMM	SYMMETRICAL
SYN	SYNTHETIC
SYS	SYSTEM
T&B	TOP AND BOTTOM
T&G	TONGUE AND GROOVE
T	TILE, TREAD
TA	TEMPERED AIR
TAN	TANGENT
TBM	TEMPORARY BENCHMARK
TEMP	TEMPORARY, TEMPERATURE
THK	THICK
THRD	THREAD
THRU	THROUGH
TOB	TOP OF BOLT, TOP OF BANK, TOP OF BEAM
TOC	TOP OF CURB, TOP OF CONCRETE
TOD	TOP OF DUCT
TOF	TOP OF FOOTING
TOG	TOP OF GRATING
TOL	TOLERANCE, TOP OF LEDGER
TOM	TOP OF MASONRY
TOP	TOP OF PLATE
TOPO	TOPOGRAPHY
TOS	TOP OF SLAB, TOP OF STEEL
TOW	TOP OF WALL
TP	TELEPHONE POLE, TOE PLATE, TRAP PRIMER
TPG	TOPPING
TRANS	TRANSITION
TRD	TRENCH DRAIN
TYP	TYPICAL
U	URINAL
UG	UNDERGROUND
ULT	ULTIMATE
UNFN	UNFINISHED
UNO	UNLESS NOTED OTHERWISE
UTIL	UTILITY
V	VENT, VELOCITY, VOLT
VA	VOLT AMPERE
VAC	VACUUM
VAR	VARNISH, VARIABLE, VOLT AMPERES REACTIVE
VB	VAPOR BARRIER, VINYL BASE, VALVE BOX
VC	VERTICAL CURVE
VCT	VINYL COMPOSITION TILE, VERTICAL CENTERLINE
VEL	VELOCITY
VENT	VENTILATION
VERT	VERTICAL
VS	VERSES, VAPOR SEAL
VOL	VOLUME
VPC	VERTICAL POINT OF CURVATURE
VPI	VERTICAL POINT OF INTERSECTION
VPT	VERTICAL POINT OF TANGENCY
VTR	VENT THROUGH ROOF
VWC	VINYL WALL COVERING
W/	WITH
W/O	WITHOUT
W	WATT, WEST, WIDE, WINDOW, WIRE, WIDE FLANGE BEAM
WC	WATER CLOSET, WATER COLUMN
WD	WIDTH
WF	WIDE FLANGE, WASH FOUNTAIN
WG	WIRE GLASS, WATER GAGE
WH	WALL HYDRANT, WEEP HOLE
WL	WATER LEVEL
WLD	WELDED
WM	WIRE MESH
WP	WATERPROOF, WORKING POINT
WTHP	WEATHERPROOF
WS	WATERSTOP, WATER SURFACE
WSEL	WATER SURFACE ELEVATION
WT	WEIGHT, WATER TIGHT
WWF	WELDED WIRE FABRIC
XS	EXTRA STRONG
XXS	DOUBLE EXTRA STRONG
XSECT	CROSS SECTION
YH	YARD HYDRANT
YS	YIELD STRENGTH

AGENCY AND PROJECT ABBREVIATIONS:

SLO	SAN LUIS OBISPO

GENERAL NOTES:

1. THESE ABBREVIATIONS APPLY TO THE ENTIRE SET OF CONTRACT DRAWINGS.
2. LISTING OF ABBREVIATIONS DOES NOT IMPLY ALL ABBREVIATIONS ARE USED IN THE CONTRACT DRAWINGS.
3. ABBREVIATIONS SHOWN ON THIS SHEET INCLUDE VARIATIONS OF THE WORD. FOR EXAMPLE, "MOD" MAY MEAN MODIFY OR MODIFICATION; "INC" MAY MEAN INCLUDED OR INCLUDING; "REINF" MAY MEAN EITHER REINFORCE OR REINFORCING.
4. SCREENING OR SHADING OF WORK IS USED TO INDICATE EXISTING COMPONENTS OR TO DE-EMPHASIZE PROPOSED IMPROVEMENTS TO HIGHLIGHT SELECTED TRADE WORK. REFER TO CONTEXT OF EACH SHEET FOR USAGE.

C:\Users\ChadDokken\DC\ACCDocs\McMillen Inc\Lopez Dam Steelhead Passage Feasibility\Project Files\Drawings\G002.dwg

REV	DATE	BY	DESCRIPTION
A	09/26/25	VPA	CONCEPTUAL DRAWINGS

WARNING

0 1/2 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

McMillen

COUNTY of SAN LUIS OBISPO

COUNTY OF SAN LUIS OBISPO

STEELHEAD PASSAGE FEASIBILITY ASSESSMENT LOPEZ DAM

STANDARD ABBREVIATIONS

DESIGNED V. AUTIER

DRAWN C. DOKKEN

CHECKED -

PROJECT DATE 09/26/25

DRAWING

G002

SHEET SYMBOLS

PLAN
SCALE: 1/2"= 1'-0"
0' 2' 4'
N

SECTION IDENTIFICATION

(1) SECTION CUT ON DRAWING C102:

- A / C103
- SECTION LETTER
- DRAWING WHERE SECTION IS DRAWN

(2) ON DRAWING C103 THIS SECTION IS IDENTIFIED AS:

- SECTION LETTER
- A / S102 **SECTION**
- SCALE: 1/8"= 1'-0" (0' 8' 16')
- DRAWING WHERE SECTION OCCURS*

DETAIL IDENTIFICATION

(1) DETAIL CALL-OUT ON DRAWING C102:

- DETAIL NUMBER
- 1 / C103
- DRAWING WHERE DETAIL IS SHOWN

(2) ON DRAWING C103 THIS SECTION IS IDENTIFIED AS:

- DETAIL NUMBER
- 1 / C102 **DETAIL**
- SCALE: 1"= 2' (0' 2' 4')
- DRAWING WHERE DETAIL OCCURS*

*NOTE: IF PLAN AND SECTION (OR DETAIL CALL-OUT AND DETAIL) ARE SHOWN ON SAME DRAWING. DRAWING NUMBER IS REPLACED BY A LINE.

STANDARD DETAIL IDENTIFICATION

(1) DETAIL CALL-OUT ON PLAN OR SECTION:

- M101
- STANDARD DETAIL NUMBER

(2) ON DETAIL DRAWINGS, IDENTIFIED AS:

- STANDARD DETAIL NUMBER
- M101 **DETAIL**
- SCALE: NTS

ELEVATION/IMAGE IDENTIFICATION

1 / D104

SITE PLAN LINE TYPES

X — X	FENCE LINE
P — P	OVERHEAD POWER
455	MAJOR CONTOUR
456	MINOR CONTOUR
455	EXIST MAJOR CONTOUR
456	EXIST MINOR CONTOUR
	EDGE OF WATERLINE
TOE	TOE OF SLOPE
TOB	TOP OF BANK
SS — SS	SANITARY SEWER
SD — SD	STORM DRAIN
EP — EP	EDGE OF PAVEMENT
EG — EG	EDGE OF GRAVEL
W — W	WATTLE
SF	SILT FENCE
CF — CF	CONSTRUCTION FENCE
GAS	GAS LINE
TC	TURBIDITY CURTAIN
IRR — IRR	IRRIGATION LINE
WTR	WATER LINE
TEL	TELEPHONE LINE
COM	COMMUNICATION LINE
OHP	OVERHEAD ELECTRICAL/POWER
EUG	UNDERGROUND ELECTRICAL
P/L	PROPERTY LINE
OHP	EXISTING OVERHEAD POWER LINE
OHP&T	EXISTING OVERHEAD POWER & TELEPHONE LINE
T	EXISTING OVERHEAD TELEPHONE LINE
BT	EXISTING BURIED TELEPHONE LINE EVIDENCED BY PEDESTALS & WARNING PADDLES
	EXISTING FENCE LINE
	PROJECT BOUNDARY
	TREE PROTECTION FENCE

SITE PLAN SYMBOLS

N	ARROW INDICATES DIRECTION OF PLAN NORTH
	CONIFER TREE: FIR, SPRUCE, LARCH OR PINE, 8" DIAMETER OR LARGER.
	DECIDUOUS TREE: COTTONWOOD, HAWTHORN, ASPEN, 8" DIAMETER OR LARGER.
MH	MANHOLE
EB	ELECTRIC BOX
	STORM DRAIN MANHOLE
FH	FIRE HYDRANT
YH-X	YARD HYDRANT
	SURVEY CONTROL POINT, AS NOTED.
	POLE ANCHOR
	POWER POLE
	LIGHT POLE
	SIGN
	SURVEY HUB
	SECTION CORNER
	BENCH MARK
	EXISTING HEADWALL
	EXISTING MONITORING STATION
X — X	EXISTING FENCE
	STATE PLANE COORDINATE MARKER
	EXISTING TREE LINE
	EXISTING BUILDING, STRUCTURES
	EXISTING SECTION CORNER MONUMENT FOUND AS DESCRIBED
	EXISTING 5/8" REBAR CONTROL POINT MONUMENT, BORING LOCATION
W	EXISTING HOSE BIB
P	EXISTING PORTABLE IRRIGATION WATER PUMP
W	EXISTING 6" WATER WELL
	EXISTING ELECTRICAL OUTLET
P	EXISTING POWER POLE
T	EXISTING TELEPHONE PEDESTAL
	CONTROL POINT
	PUMP
	PUMP
TH	TEST PIT LOCATION

MISCELLANEOUS SYMBOLS

	CHANGE OF PIPE MTL
OR	END OF PIPE
℄	CENTERLINE
Ø	DIAMETER
∠	ANGLE
℘	PLATE
±	PLUS/MINUS

ARCHITECTURAL SYMBOLS

- A101 (1, 2, 3, 4) — ELEVATION IDENTIFICATION; **ELEVATIONS**; SHEET NUMBER
- ROOM NAME / 101 — ROOM NAME; **ROOM IDENTIFICATION**; ROOM NUMBER
- XX — **KEYNOTE** (NUMBER)
- 1i — TYPE NUMBER; **ASSEMBLY TAG (WALL, FLOOR, ROOF)**
- 101A — ROOM REFERENCE; **DOOR IDENTIFICATION**; DOOR LETTER (WHERE APPLICABLE)
- 1t — **WINDOW IDENTIFICATION**; WINDOW TYPE (LETTER OR NUMBER)
- **DATUM POINT** — CONTROL POINT OR WORK POINT

HATCH SYMBOLS

- ROCK, TYPE AS NOTED (PLAN/SECTION)
- BED ROCK
- EXISTING GRADE (SECTION)
- NEW SOIL (SECTION)
- CONCRETE EXISTING (SECTION/PLAN)
- CONCRETE 1ST STAGE (SECTION/PLAN)
- CONCRETE 2ND STAGE (SECTION/PLAN)
- SAND, GROUT (PLAN/SECTION)
- STEEL (SECTION)
- GRATING (PLAN)
- MASONRY (PLAN)
- WOOD, SIZE/TYPE AS NOTED (PLAN)
- WOOD, SIZE/TYPE AS NOTED (SECTION)
- RIP RAP (PLAN/SECTION)
- RIGID INSULATION (SECTION)
- ASPHALT CONCRETE PAVEMENT SURFACE (PLAN/SECTION)
- GRASS/VEGETATION (PLAN)
- BATT INSULATION (SECTION)
- NEW CONSTRUCTION
- EXISTING
- EXISTING TO BE REMOVED OR DEMOLISHED
- CLEARING AND GRUBBING
- ASPHALT
- GRASS/VEGETATION
- GRAVEL

GENERAL NOTES:

1. ALL SYMBOLS ARE NOT NECESSARILY USED. THIS IS A STANDARD DRAWING SHOWING COMMON SYMBOLS ON THIS PROJECT.
2. SCREENING OR SHADING OF WORK IS USED TO INDICATE EXISTING COMPONENTS OR TO DE-EMPHASIZE PROPOSED IMPROVEMENTS TO HIGHLIGHT SELECTED TRADE WORK. REFER TO CONTEXT OF EACH DRAWING FOR USAGE.

C:\Users\ChadDokken\DC\ACCDocs\McMillen Inc\Lopez Dam Steelhead Passage Feasibility\Project Files\Drawings\G003.dwg

REV	DATE	BY	DESCRIPTION
A	09/26/25	VPA	CONCEPTUAL DRAWINGS

WARNING
0 1/2 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

McMillen

COUNTY of SAN LUIS OBISPO

COUNTY OF SAN LUIS OBISPO
STEELHEAD PASSAGE FEASIBILITY ASSESSMENT LOPEZ DAM
STANDARD SYMBOLS

DESIGNED V. AUTIER
DRAWN C. DOKKEN
CHECKED -
PROJECT DATE 09/26/25

DRAWING
G003

EXISTING CONDITIONS
SCALE: NTS

N

REV	DATE	BY	DESCRIPTION
A	09/26/25	VPA	CONCEPTUAL DRAWINGS

WARNING
0 1/2 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

McMillen

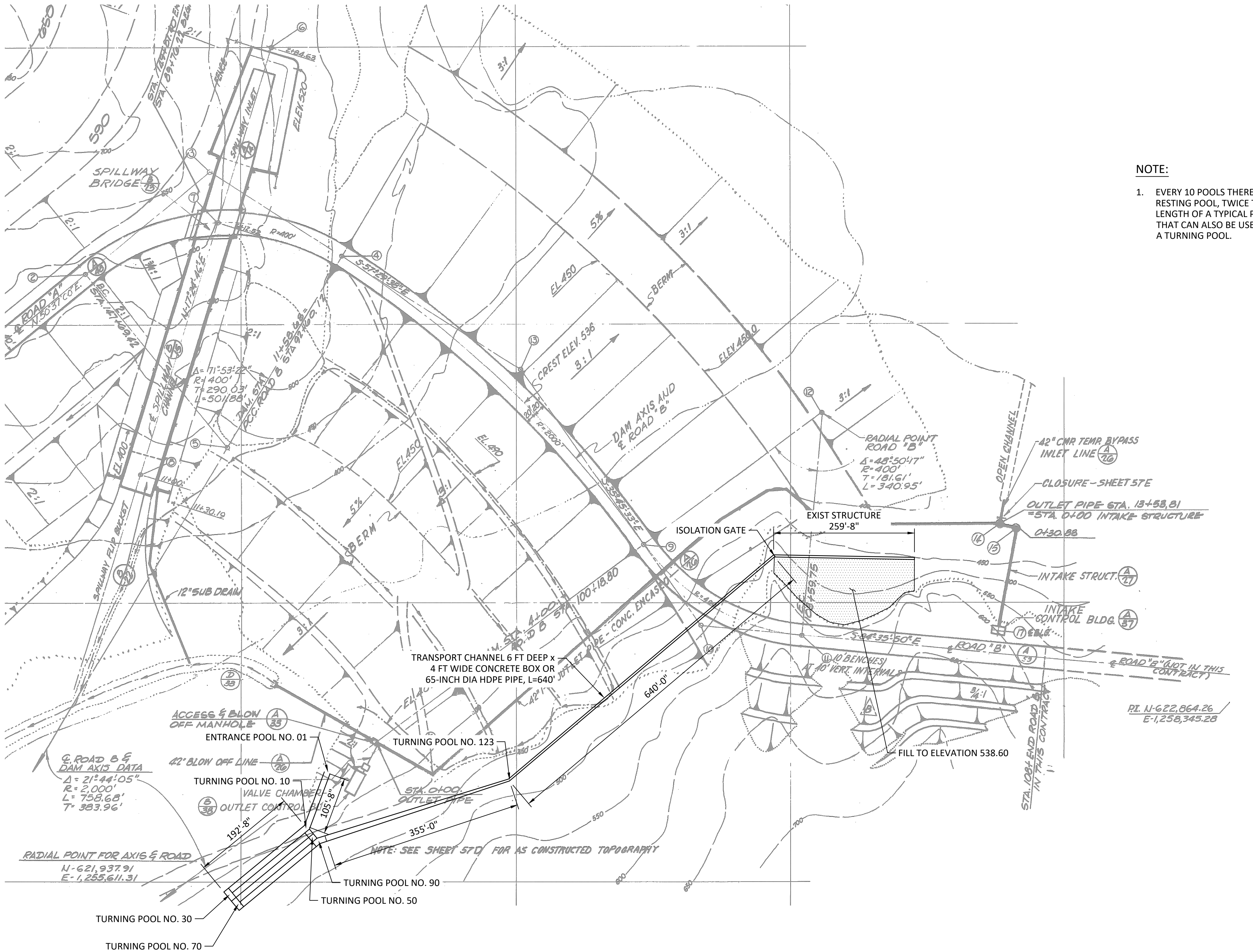
COUNTY of SAN LUIS OBISPO

COUNTY OF SAN LUIS OBISPO
STEELHEAD PASSAGE FEASIBILITY ASSESSMENT LOPEZ DAM
EXISTING CONDITIONS

DESIGNED V. AUTIER
DRAWN C. DOKKEN
CHECKED -
PROJECT DATE 09/26/25

DRAWING
G004

C:\Users\ChadDokken\DC\ACCDocs\McMillen Inc\Lopez Dam Steelhead Passage Feasibility\Project Files\Drawings\G004.dwg



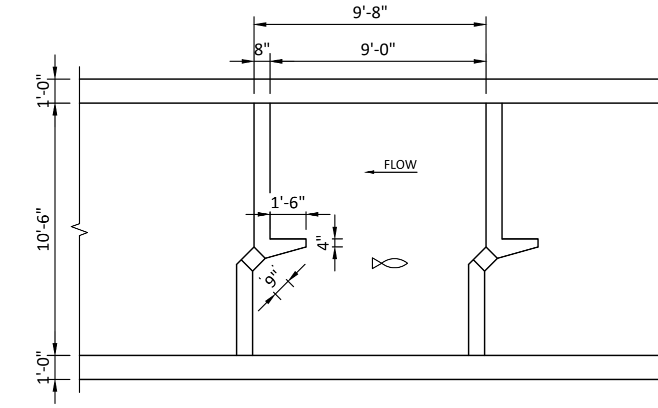
PLAN

SCALE: 1"= 100'

0" 100' 200'

NOTE:

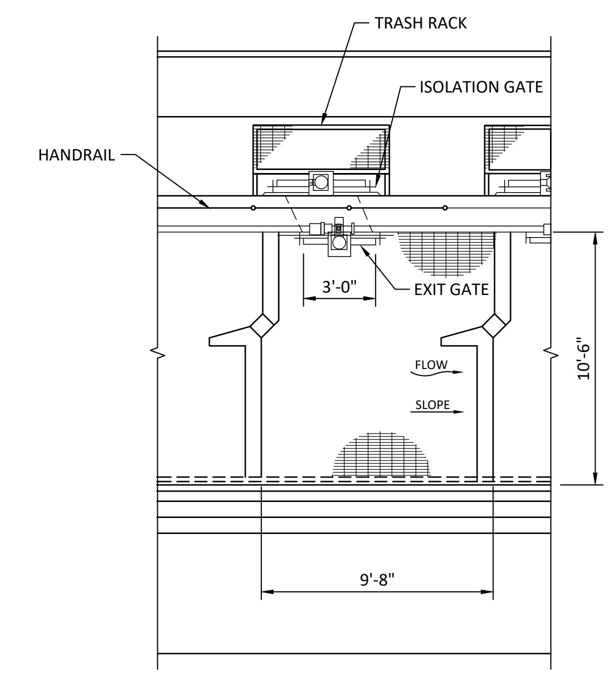
1. EVERY 10 POOLS THERE IS A RESTING POOL, TWICE THE LENGTH OF A TYPICAL POOL, THAT CAN ALSO BE USED AS A TURNING POOL.



TYPICAL VERTICAL SLOT LADDER POOL PLAN

SCALE: 3"= 1'-0"

0" 4" 8"



TYPICAL EXIT POOL PLAN

SCALE: 3"= 1'-0"

0" 4" 8"

REV	DATE	BY	DESCRIPTION
A	09/26/25	VPA	CONCEPTUAL DRAWINGS

WARNING

0 1/2 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

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COUNTY of SAN LUIS OBISPO

COUNTY OF SAN LUIS OBISPO

STEELHEAD PASSAGE FEASIBILITY ASSESSMENT LOPEZ DAM

UPSTREAM FISH PASSAGE VERTICAL SLOT FISHWAY PLAN

DESIGNED V. AUTIER

DRAWN C. DOKKEN

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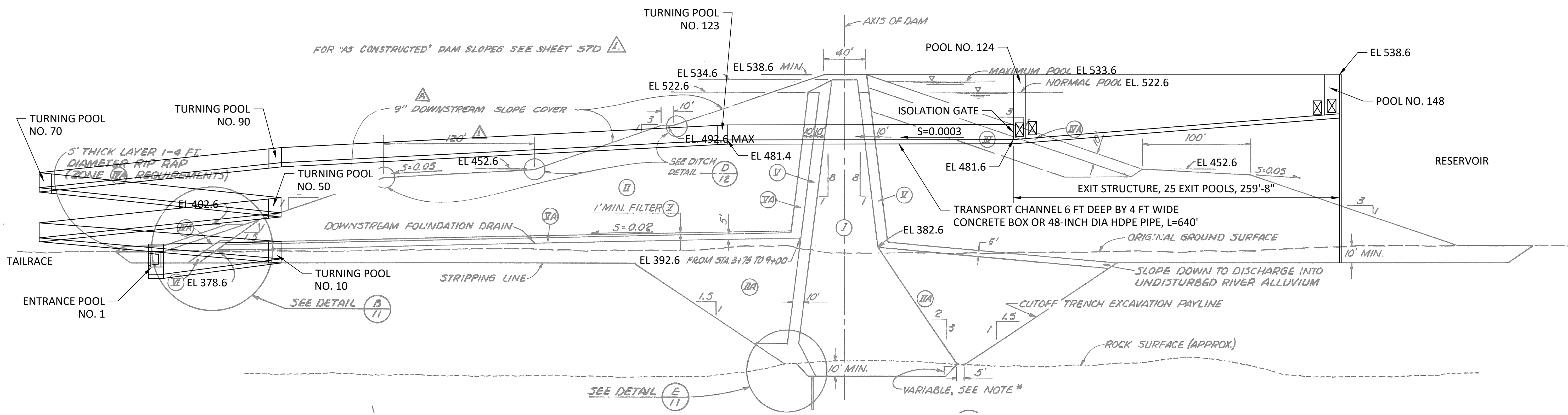
PROJECT DATE 09/26/25

DRAWING

FIG1

C:\Users\ChadDokken\DC\ACCDocs\McMillen Inc\Lopez Dam Steelhead Passage Feasibility\Project Files\Drawings\FIG 1.dwg



SECTION

SCALE: 1"= 40'

0' 40' 80'

N

REV	DATE	BY	DESCRIPTION
A	09/26/25	VPA	CONCEPTUAL DRAWINGS

WARNING

0 1/2 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

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COUNTY OF SAN LUIS OBISPO

STEELHEAD PASSAGE FEASIBILITY ASSESSMENT LOPEZ DAM

UPSTREAM FISH PASSAGE VERTICAL SLOT FISHWAY SECTION

DESIGNED V. AUTIER

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PROJECT DATE 09/26/25

DRAWING

FIG 2

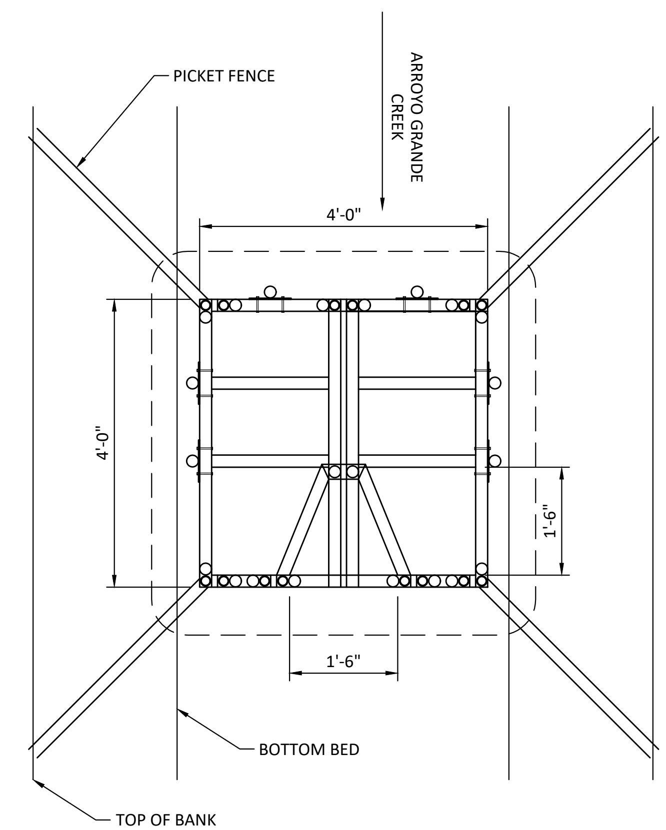
C:\Users\ChadDokken\DC\ACCDocs\McMillen Inc\Lopez Dam Steelhead Passage Feasibility\Project Files\Drawings\FIG 2.dwg

PLAN

SCALE: 1"= 60'

0' 60' 120'

N



VEE TRAP FLOOR PLAN

SCALE: 3/4"= 1'-0"

0' 1' 2'

C:\Users\ChadDokken\DC\ACCDocs\McMillen Inc\Lopez Dam Steelhead Passage Feasibility\Project Files\Drawings\FIG 3.dwg

REV	DATE	BY	DESCRIPTION
A	09/26/25	VPA	CONCEPTUAL DRAWINGS

WARNING

0 1/2 1

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COUNTY OF SAN LUIS OBISPO

STEELHEAD PASSAGE FEASIBILITY ASSESSMENT LOPEZ DAM

UPSTREAM FISH PASSAGE TRAP AND HAUL PLAN

DESIGNED V. AUTIER

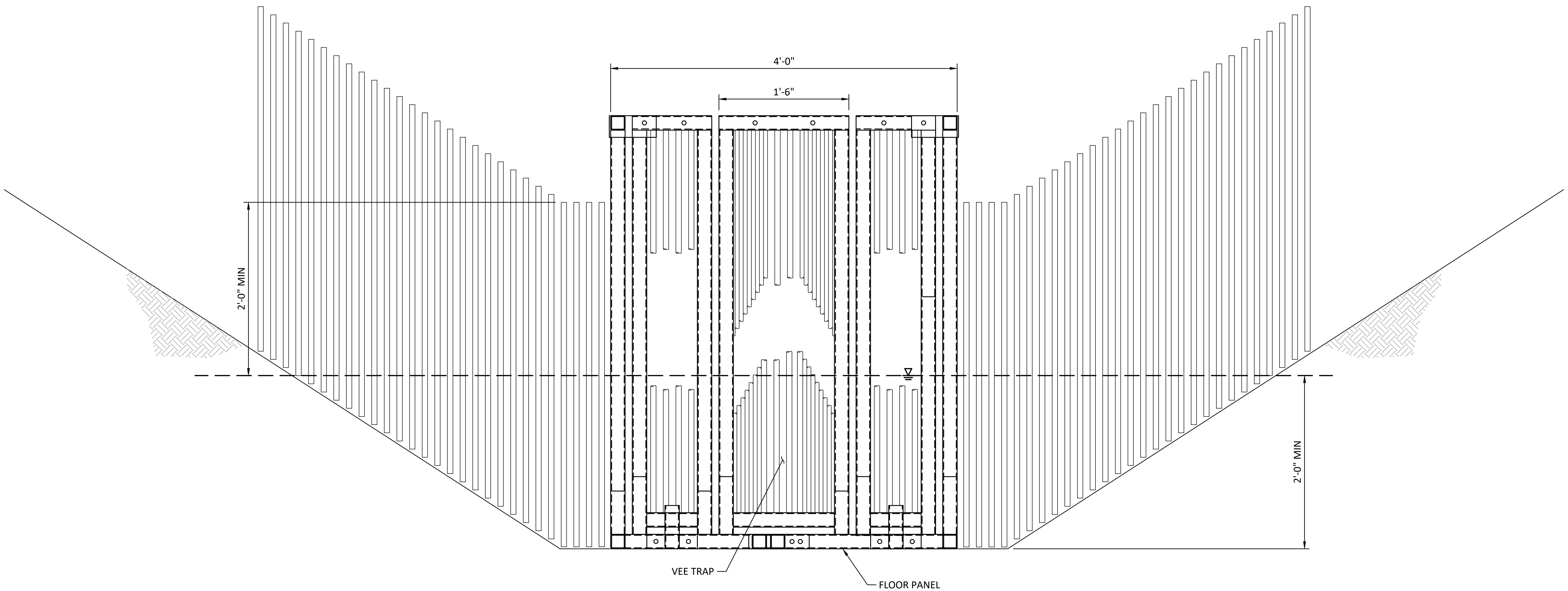
DRAWN C. DOKKEN

CHECKED -

PROJECT DATE 09/26/25

DRAWING

FIG 3



VEE TRAP SECTION

SCALE: 1 1/2"= 1'-0"

0" 8" 16"

C:\Users\ChadDokken\DC\ACCDocs\McMillen Inc\Lopez Dam Steelhead Passage Feasibility\Project Files\Drawings\FIG 4.dwg

REV	DATE	BY	DESCRIPTION
A	09/26/25	VPA	CONCEPTUAL DRAWINGS

WARNING

0 1/2 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

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COUNTY of SAN LUIS OBISPO

COUNTY OF SAN LUIS OBISPO

STEELHEAD PASSAGE FEASIBILITY ASSESSMENT LOPEZ DAM

UPSTREAM FISH PASSAGE TRAP AND HAUL SECTION

DESIGNED V. AUTIER

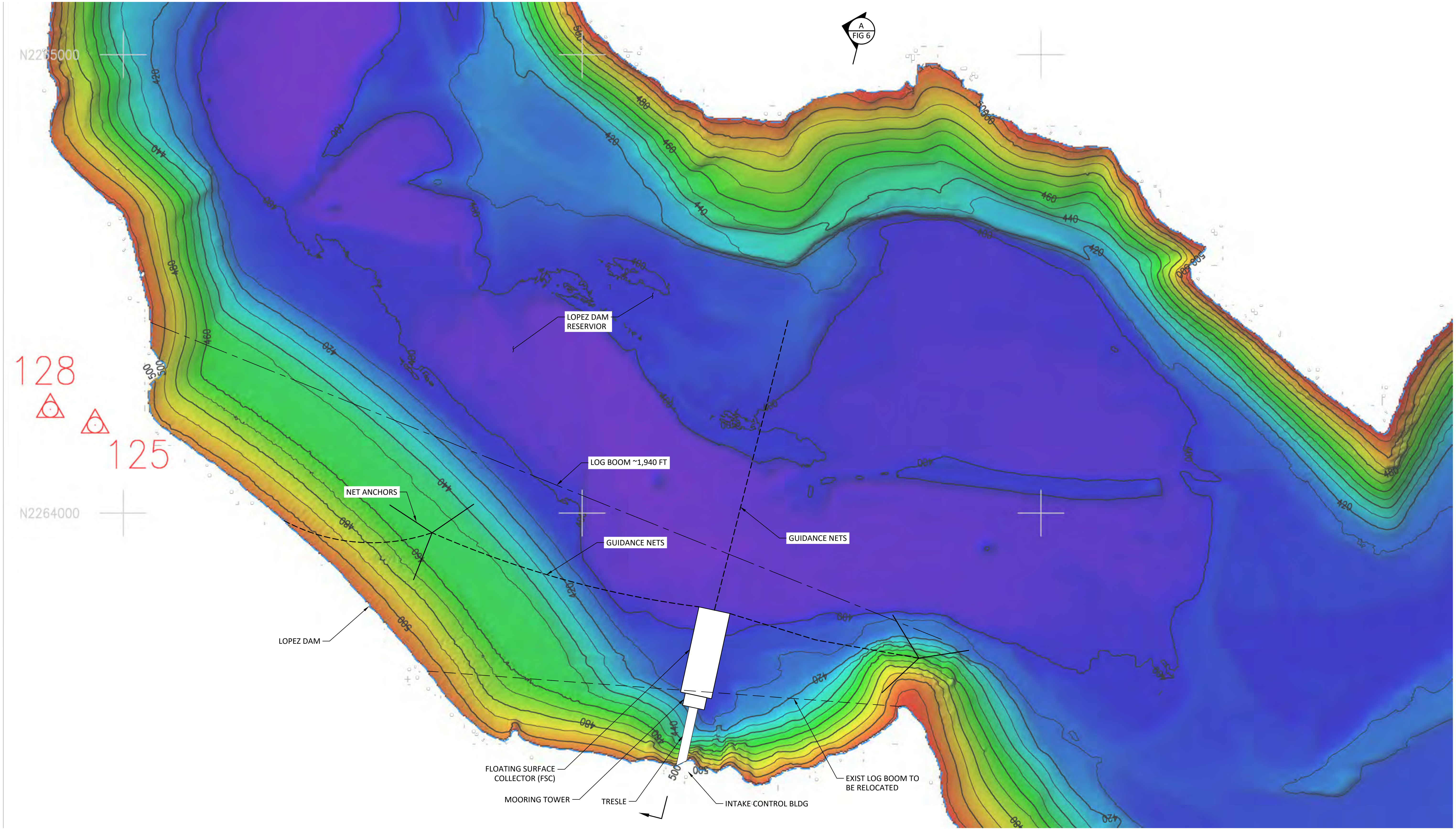
DRAWN C. DOKKEN

CHECKED -

PROJECT DATE 09/26/25

DRAWING

FIG 4



PLAN

SCALE: 1"= 100'

0' 100' 200'

N

C:\Users\ChadDokken\DC\ACCDocs\McMillen Inc\Lopez Dam Steelhead Passage Feasibility\Project Files\Drawings\FIG 5.dwg

REV	DATE	BY	DESCRIPTION
A	09/26/25	VPA	CONCEPTUAL DRAWINGS

WARNING

0 1/2 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

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COUNTY of SAN LUIS OBISPO

COUNTY OF SAN LUIS OBISPO

STEELHEAD PASSAGE FEASIBILITY ASSESSMENT LOPEZ DAM

DOWNSTREAM FISH PASSAGE FLOATING SURFACE COLLECTOR PLAN

DESIGNED V. AUTIER

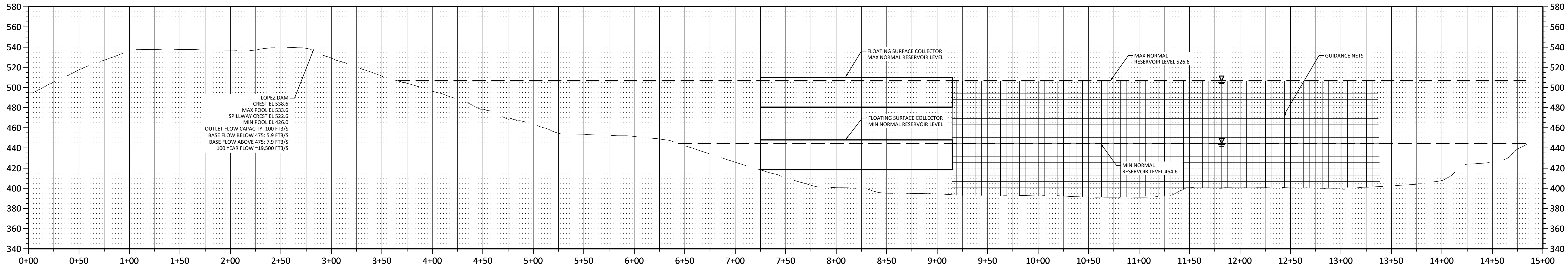
DRAWN C. DOKKEN

CHECKED -

PROJECT DATE 09/26/25

DRAWING

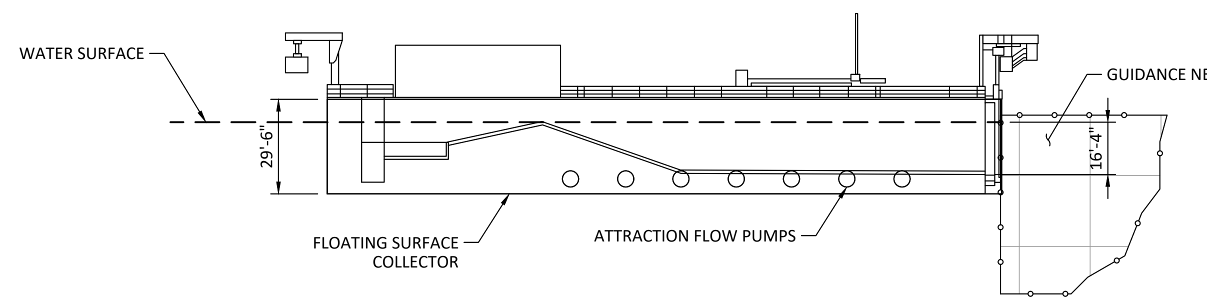
FIG 5



OVERALL PROFILE

SCALE: 1"= 50'

0" 50' 100'

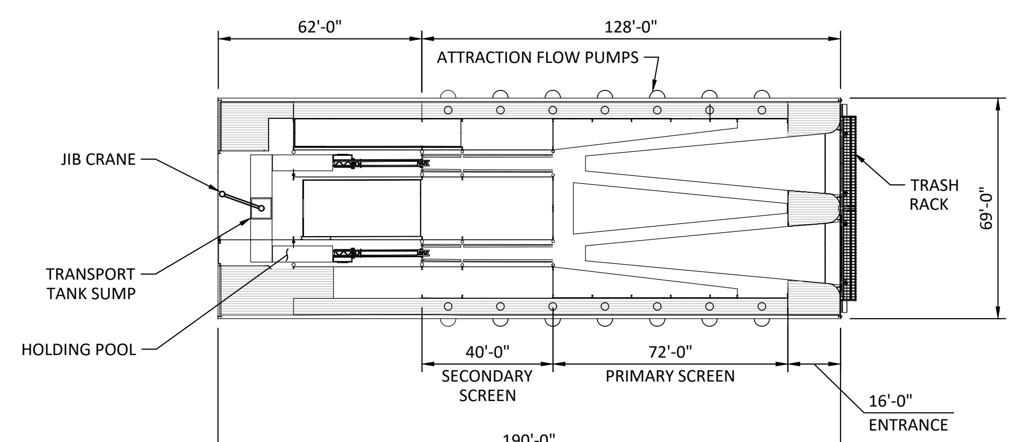


A FIG 5

PROFILE

SCALE: 1"= 30'

0" 30' 60'



PLAN

SCALE: 1"= 30'

0" 30' 60'

REV	DATE	BY	DESCRIPTION
A	09/26/25	VPA	CONCEPTUAL DRAWINGS

WARNING

0 1/2 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

McMillen

COUNTY of SAN LUIS OBISPO

COUNTY OF SAN LUIS OBISPO

STEELHEAD PASSAGE FEASIBILITY ASSESSMENT LOPEZ DAM

DOWNSTREAM FISH PASSAGE FLOATING SURFACE COLLECTOR SECTION

DESIGNED V. AUTIER

DRAWN C. DOKKEN

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PROJECT DATE 09/26/25

DRAWING

FIG 6

C:\Users\ChadDokken\DC\ACCDocs\McMillen Inc\Lopez Dam Steelhead Passage Feasibility\Project Files\Drawings\FIG 6.dwg

PLAN

SCALE: 1"= 60'

0' 60' 120'

N

REV	DATE	BY	DESCRIPTION
A	09/26/25	VPA	CONCEPTUAL DRAWINGS

WARNING

0 1/2 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

McMillen

COUNTY of SAN LUIS OBISPO

COUNTY OF SAN LUIS OBISPO

STEELHEAD PASSAGE FEASIBILITY ASSESSMENT LOPEZ DAM

DOWNSTREAM FISH PASSAGE HELICAL FISH PASSAGE SYSTEM PLAN

DESIGNED V. AUTIER

DRAWN C. DOKKEN

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PROJECT DATE 09/26/25

DRAWING

FIG 7

C:\Users\ChadDokken\DC\ACCDocs\McMillen Inc\Lopez Dam Steelhead Passage Feasibility\Project Files\Drawings\FIG 7.dwg

B
FIG 7

SECTION

SCALE: 1"= 80'

0' 80' 160'

C:\Users\ChadDokken\DC\ACCDocs\McMillen Inc\Lopez Dam Steelhead Passage Feasibility\Project Files\Drawings\FIG 8.dwg

REV	DATE	BY	DESCRIPTION
A	09/26/25	VPA	CONCEPTUAL DRAWINGS

WARNING

0 1/2 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

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COUNTY of SAN LUIS OBISPO

COUNTY OF SAN LUIS OBISPO

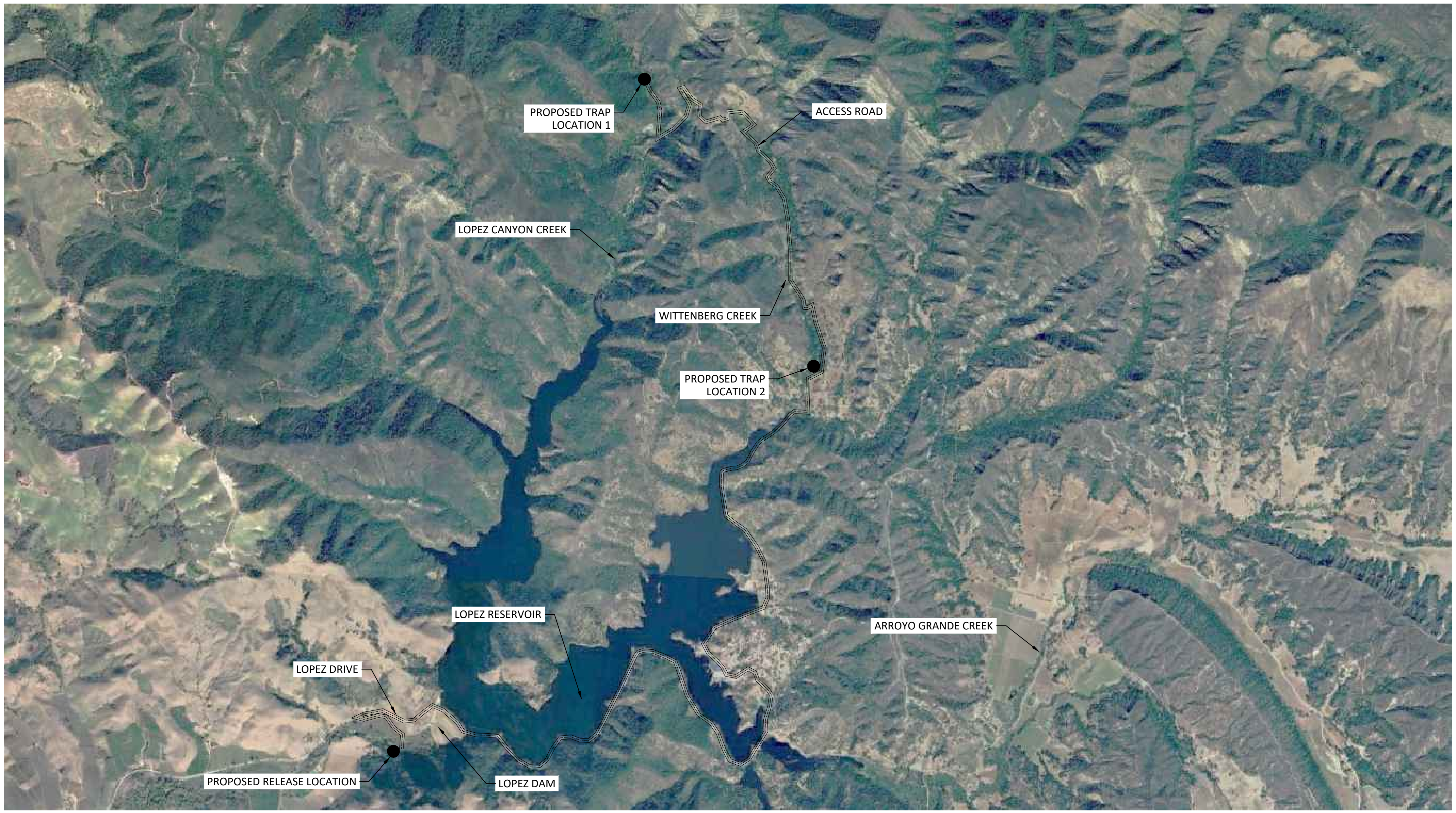
STEELHEAD PASSAGE FEASIBILITY ASSESSMENT LOPEZ DAM

DOWNSTREAM FISH PASSAGE HELICAL FISH PASSAGE SYSTEM SECTION

DESIGNED V. AUTIER
DRAWN C. DOKKEN
CHECKED -
PROJECT DATE 09/26/25

DRAWING

FIG 8



PLAN
SCALE: NTS

N

C:\Users\ChadDokken\DC\ACCDocs\McMillen Inc\Lopez Dam Steelhead Passage Feasibility\Project Files\Drawings\FIG 9.dwg

REV	DATE	BY	DESCRIPTION
A	09/26/25	VPA	CONCEPTUAL DRAWINGS

WARNING
0 1/2 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

McMillen

COUNTY of SAN LUIS OBISPO

COUNTY OF SAN LUIS OBISPO
STEELHEAD PASSAGE FEASIBILITY ASSESSMENT LOPEZ DAM

DOWNSTREAM FISH PASSAGE IN-TRIBUTARY TRAP AND HAUL PLAN

DESIGNED V. AUTIER
DRAWN C. DOKKEN
CHECKED -
PROJECT DATE 09/26/25

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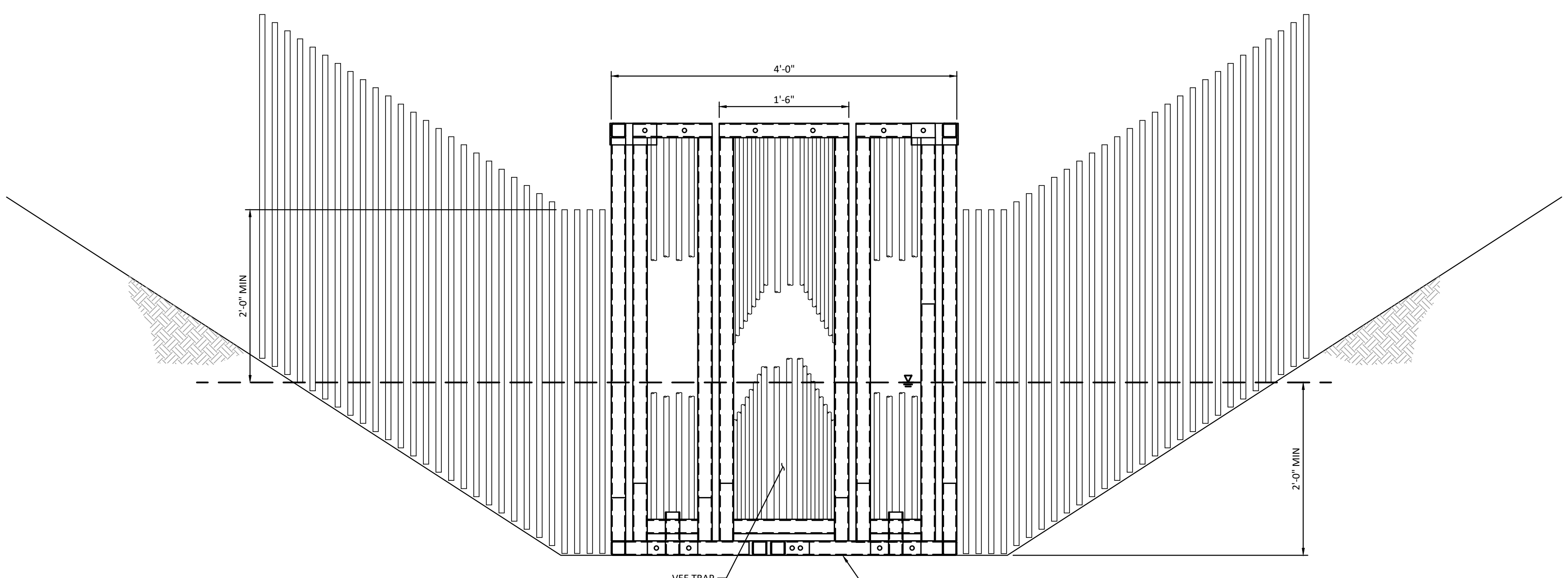

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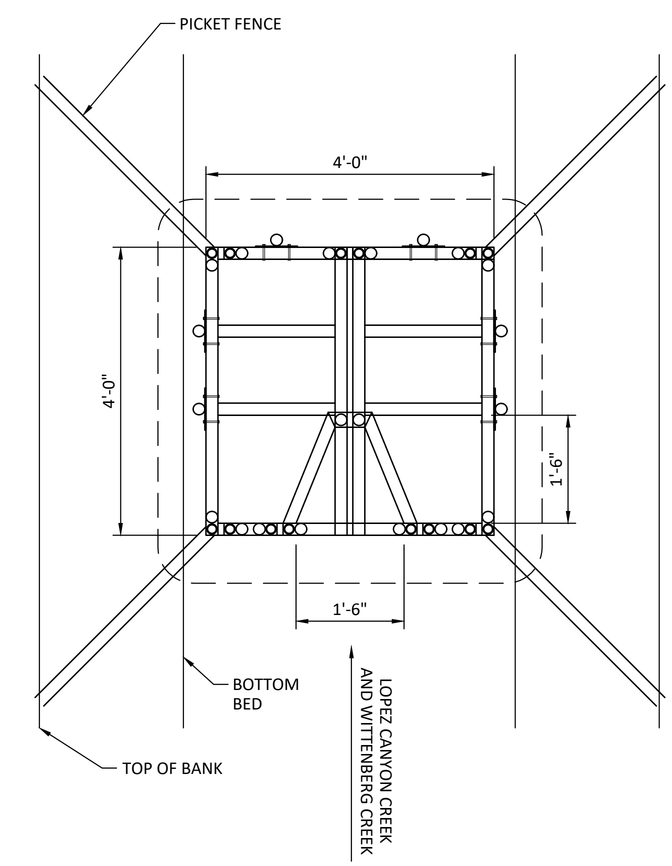

PLAN
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McMillen

COUNTY of SAN LUIS OBISPO

COUNTY OF SAN LUIS OBISPO
STEELHEAD PASSAGE FEASIBILITY ASSESSMENT LOPEZ DAM

DOWNSTREAM FISH PASSAGE IN-TRIBUTARY TRAP AND HAUL DETAILS

DESIGNED V. AUTIER
DRAWN C. DOKKEN
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PROJECT DATE 09/26/25

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FIG 10

Appendix D. Hydrology and Hydraulics Calculations

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Technical Memorandum

To:	David Spiegel County of San Luis Obispo	Project:	Steelhead Passage Feasibility Assessment of Lopez Dam
From:	Wendy Katagi McMillen, Inc.	cc:	
Prepared by:	Marcelo Cerucci, PE McMillen, Inc.	Job No:	25-062
Reviewed by:	Vincent Autier, PE McMillen, Inc.	Date:	07/25/2025
Subject:	TM 004 – Hydraulic Calculations		

Revision Log

Revision No.	Date	Revision Description
0	7/25/2025	Draft for client review

1.0 Introduction

For the Steelhead Passage Feasibility Assessment of Lopez Dam (Project), McMillen, Inc. (McMillen) conducted hydraulic calculations and analysis of reservoir and tailrace water surface elevation (WSE) to support the evaluation of fish passage options for both upstream and downstream passage. This document presents that information.

1.1 Purpose and Objective

The purpose of this Technical Memorandum (TM) is to present a description of the reservoir water surface elevation analysis performed for Lopez Reservoir, development of a tailrace rating curve and hydraulic calculations for the fish passage options.

1.2 Authorization

The County of San Luis Obispo (County) has contracted McMillen to provide engineering services to assess the feasibility of providing upstream and downstream passage for steelhead trout at Lopez Dam. The contract was authorized on April 8, 2025. The County of San Luis Obispo Contract number is 552R235006.

1.3 Background and Project Goals

Lopez Dam has been identified as an impassable barrier on the Arroyo Grande Creek, blocking passage to the target species, the South-Central California Coast (SCCC) Distinct Population Segment (DPS) steelhead trout (*Oncorhynchus mykiss*). The SCCC steelhead trout were originally listed in 1997 as threatened under National Marine Fisheries Service (NMFS) Evolutionarily Significant Unit (ESU) policy. The listing was reaffirmed in 2006 under the DPS policy. The SCCC steelhead trout are now listed as threatened under the Endangered Species Act (i.e., ESA listed). NMFS identified SCCC steelhead trout in Arroyo Grande Creek as a "Core 1" population in the agency's 2013 Recovery Plan (NMFS 2013). NMFS explained Core 1 populations are the highest priority for recovery based on a variety of factors. NMFS included Arroyo Grande Creek and Los Berros Creek in the area designated as critical habitat for the SCCC steelhead trout in 2005 (NMFS; 70 FR 52488).

Lopez Dam is a vitally important water infrastructure for the communities in the County. Its primary purpose is to provide drinking water supply for 50,000 residents. Its ancillary benefits are flood protection for both residences and agricultural lands, groundwater recharge, and recreational opportunities. The dam has been and continues to be a critical infrastructure component for Arroyo Grande Creek and the surrounding communities. Fish passage solutions would need to preserve these functions. The SCCC steelhead trout in Arroyo Grande Creek currently cannot access upstream rearing and spawning habitats. Lopez Dam affects both upstream and downstream migration.

NMFS has asked the County to assess fish passage at Lopez Dam in the process of developing a Habitat Conservation Plan (HCP). NMFS has communicated that “Mechanistic solutions to fish passage impediments can be problematic for a variety of reasons, including: the limitations in the operations during high flows when fish are most likely to be migrating; periodic mechanical failures which result in migration delays, or lost migration opportunities; and the expense of personnel and equipment to maintain such operations” (NMFS 2013). The County has therefore requested that McMillen assess volitional fish passage feasibility at Lopez Dam.

The goal of the feasibility assessment is to evaluate engineering solutions that enable volitional fish passage, contributing to species conservation and compliance with state and federal environmental regulations, while preserving the dam's primary functions. The assessment must conclude with sufficient justification that certain volitional passage options may or may not be feasible, so that regulatory agencies, including NMFS, may rely on its findings. The feasibility assessment is intended to inform the conservation strategy for the draft HCP for Lopez Dam.

1.4 Location

The Arroyo Grande Creek Watershed is on the Central California Coast in an arid region with highly variable rainfall and stormwater runoff (Stetson Engineering, Inc. 2004). The watershed is located in southern San Luis Obispo County (Figure 1-1). The watershed also supports permanent agricultural crops (e.g., citrus orchards, vineyards, ranches, and low crops) and seasonal row crops (Stetson Engineering, Inc. 2004). Lopez Dam and Reservoir provide water supply for agricultural and municipal needs by storing stormwater runoff during the winter and early spring and providing managed releases throughout the year to meet downstream demands. Additionally, diversions from the reservoir through a 3-mile pipeline to a water treatment plant provide treated water to the Arroyo Grande, Pismo Beach, County Service Area 12 (CSA 12) - Avila Beach Area, Grover Beach, and Oceano municipalities. The watershed drainage rises to a maximum elevation (EL) of approximately 3,100 feet above sea level. Arroyo Grande Creek empties into the Arroyo Grande Lagoon.

Figure 1-1. Arroyo Grande Watershed and Location of Lopez Dam in the San Luis Obispo County, California (Source: County of San Luis Obispo)

1.5 Existing Project Description

Lopez Dam is a zoned earthfill dam constructed in 1968. The dam is 1,120 feet long and has a vertical height of 168.2 feet measured from the crest (EL 538.6[1] min.) to the outlet pipe invert, EL 370.4 on the river side. The dam crest is 40 feet wide and is used as a roadway (Lopez Drive) to connect the town to the southwest to the Lopez Lake Recreation Area.

The dam retains water using a compacted clay core and a cutoff trench keyed into bedrock. The core has a minimum width of 25 feet, and the cutoff trench is keyed in a minimum of 10 vertical feet. The core is buttressed by a compacted sandy gravel layer on the upstream side and a compacted random zone on the downstream side. The dam employs a 10-foot-wide filter zone on both sides of the core and a 10-foot-wide gravel drain on the downstream side of the core. The gravel drain extends from the core to the downstream toe of the dam where it outlets to a riprap-lined collection area and is conveyed away from the dam. Abutment drainpipes are used to convey seepage along the foundation of the dam to the riprap-lined toe collection area. The upstream portion of the dam is overlayed with a 20-foot-thick layer of tuffite rock and a 10-foot-thick layer of graded tuffite rock for erosion protection. The dam slope is at 3H:1V on both sides of the dam and is benched at EL 450 with an outward slope of 0.05 ft/ft. The bench on the reservoir side is 100 feet long, while the bench on the downstream side is 120 feet long.

Lopez Dam utilizes a concrete spillway to pass storm flows and is equipped with a side channel ogee weir at crest EL 522.6. The spillway chute is linear, and it terminates with a 16-degree launch angle flip bucket with an invert at EL 387.6 to dissipate the flow energy from the spillway. The dam also includes an intake control building, a 42-inch welded steel pipe encased in concrete, an outlet control building (i.e., outlet works), and other appurtenances. In the 2000s, the County completed the Lopez Dam seismic remediation project, including changes to the dam and outlet works after obtaining necessary permits and authorizations including a permit from the U.S. Army Corps of Engineers and biological opinions from NMFS and U.S. Fish and Wildlife Service (Figure 1-5).

The intake structure includes seven inlets, each connected to a common header at 45 degrees. The inlets are approximately 15 feet apart vertically, and each is equipped with a trash rack and a fish screen. The fish screens have openings of approximately 10 inches by 12 inches, larger than the trash rack openings of 1/2-inch bar at 4 inches on center. The fish screen and the trash rack are both hot-dip galvanized. Figure 1-2 through Figure 1-5 present an overview of Lopez Dam.

[1] All elevations are in imperial measurements, i.e., feet and NAVD 88.

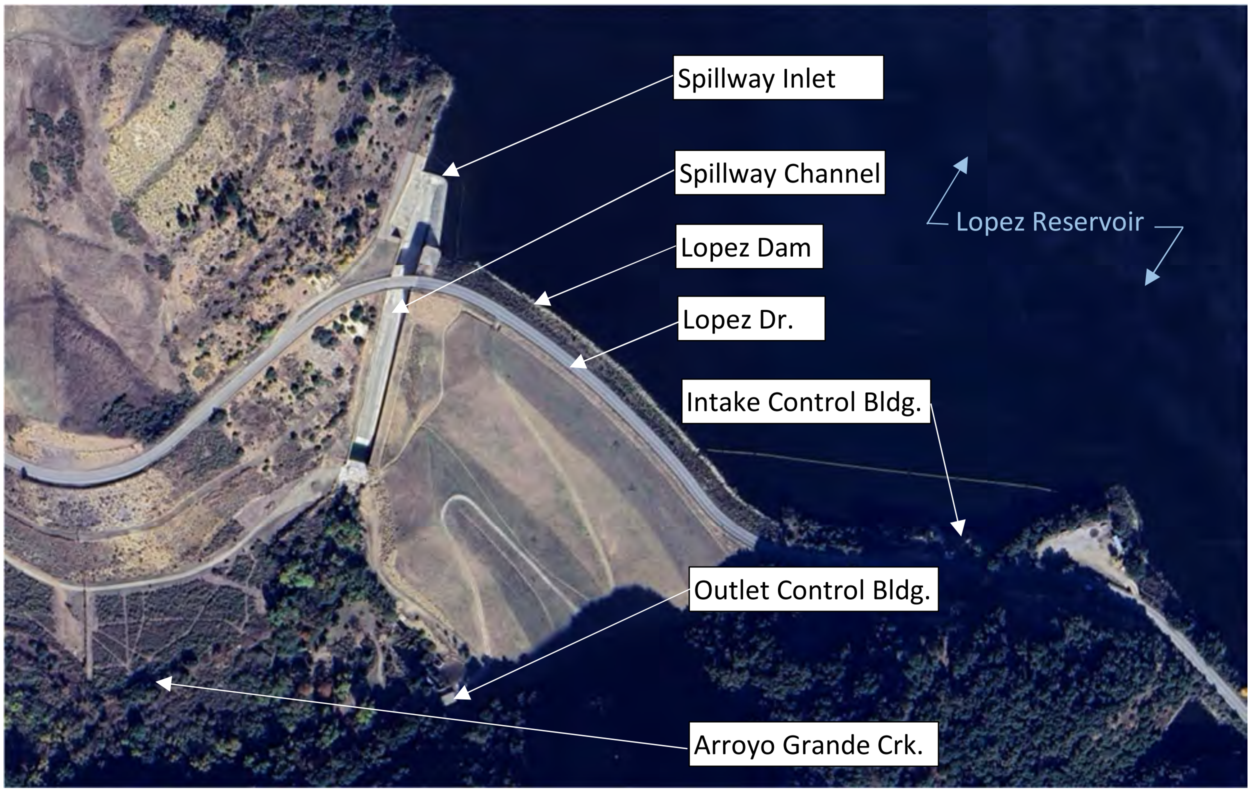


Figure 1-2. Lopez Dam Overview (Source: Google Earth)

Figure 1-3. Lopez Dam on Arroyo Grande Creek, San Luis Obispo County (Source: ForestWatch)

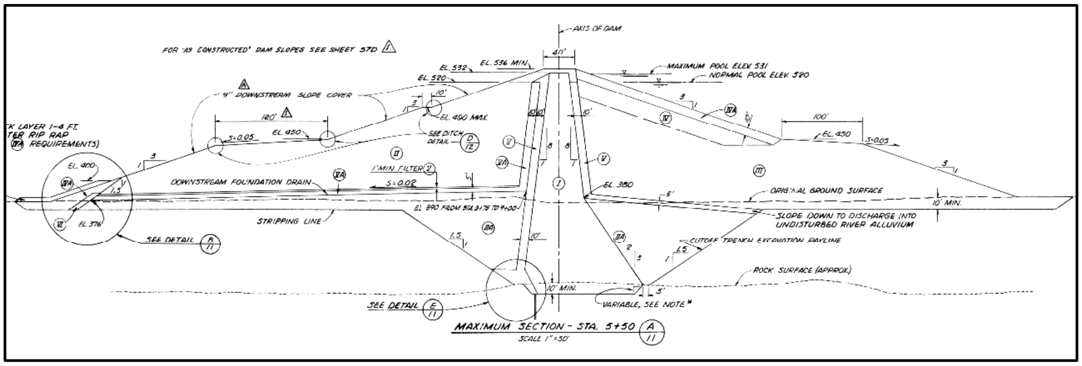


Figure 1-4. Cross Section through Lopez Dam (Source: Koebig & Koebig, Inc. 1967)

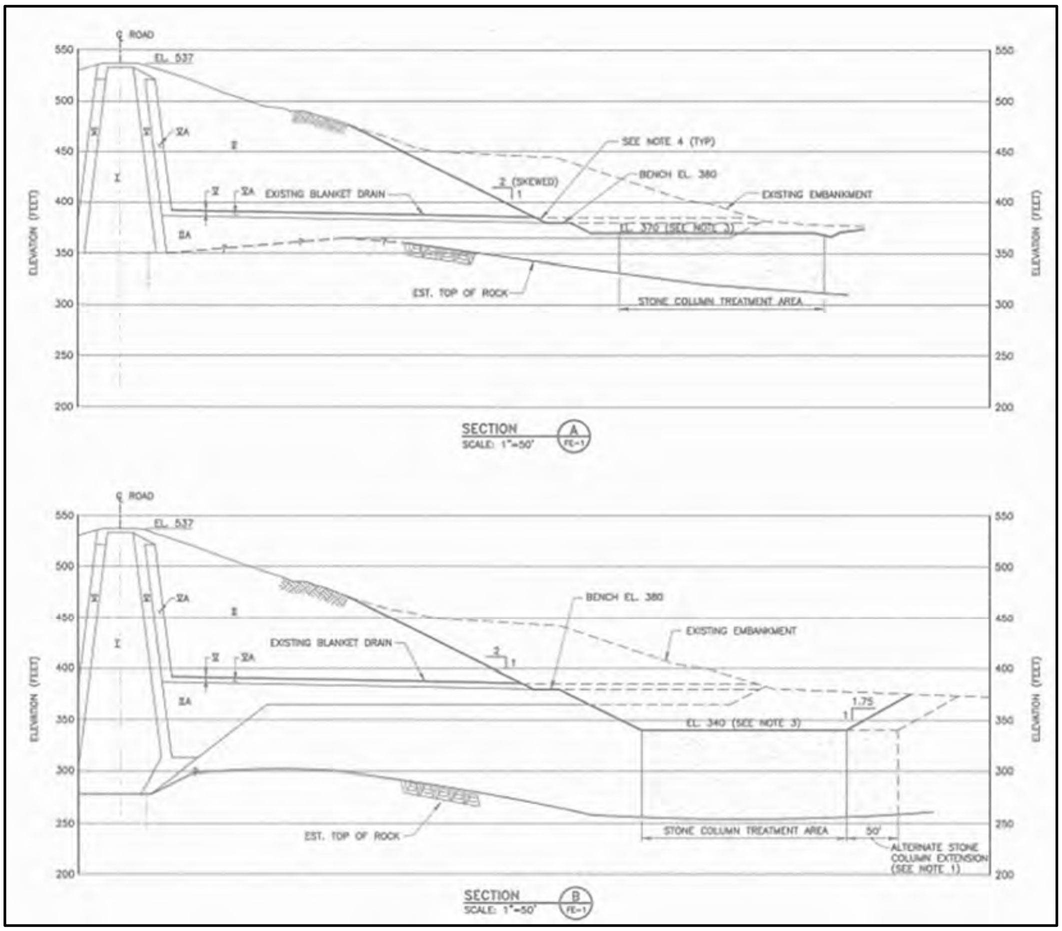


Figure 1-5. Cross Sections of the Downstream Face Showing Seismic Retrofit (Source: URS, 2000)

2.0 Analysis of Lopez Reservoir Flows and Water Surface Elevations for Fish Passage

The analysis of variation of reservoir WSE for the out migration and upstream migration windows is necessary to determine the total number of fishway pools and the number of exit pools (located in the reservoir) for the fish passage structure. The daily data available on the Lopez Dam Operational Report – Compiled Flow Statistics spreadsheet provided by the County was used for the analysis. The data consists of daily WSE, reservoir storage and outflows from the reservoir from December 01, 1993, through March 31, 2025 (approximately 32 years of data). The WSE reported prior to April 1, 2003, is based on an outdated survey. Thus, a correction factor of 5.5 feet was added to WSE before April 1, 2003, to address the survey discrepancy and to provide a consistent stage-capacity dataset. Figure 2.1 presents the adjusted stage-capacity observations for Lopez Reservoir from (12/01/1993 through 03/31/2025).

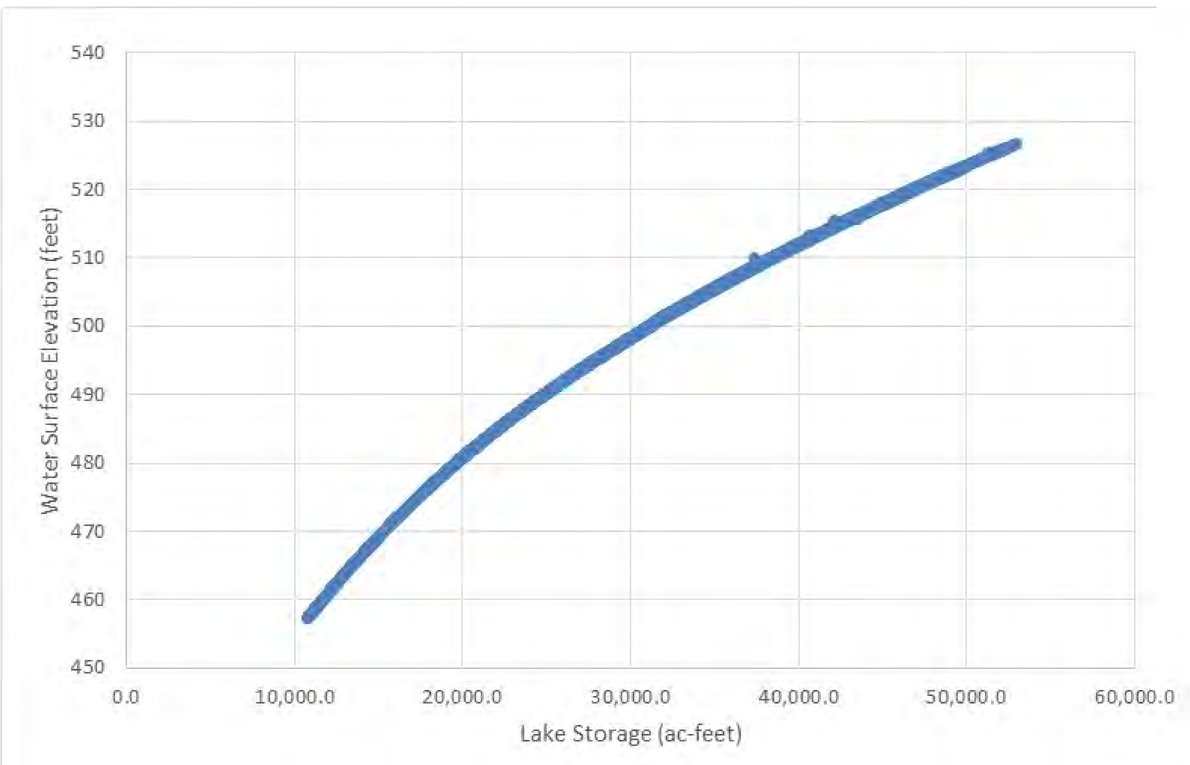


Figure 2-1. Adjusted Reservoir Stage-Storage Data (12/01/1993-03/31/2025)

Frequency analysis of WSE, storage and difference in WSE (**D**H) were calculated for the out-migration period of February 15 - June15 and four different intervals of upstream migration: November 15 – May 30; December 01 – June 30; December 01 – April 30, and January 01-March 31. Multiple intervals of upstream migration were evaluated because fish migration resembles a bell curve (with most fish migrating during a small interval) rather than a linear (constant) process, in addition, upstream migration for this Project is impacted by the annual seasonal formation of a sand bar blocking fish access from the ocean to the Arroyo Grande Creek. Tables 2-1 through 2.5 present the median, 25th percentile, 75th percentile, maximum and minimum WSE, storage and **D**H of Lopez Reservoir for the migration intervals evaluated.

Table 2-1. Frequency Analysis Out Migration 02/15-06/15

	Out Migration (02/15-06/15)		
	WSE (feet)	Storage (acre-feet)	DH (feet)
Median	506.7	36,122	3.6
25th percentile	515.5	43,100	7.8
75th percentile	492.7	26,591	2.3
Maximum	526.6	53,119	29.6
Minimum	464.6	13,371	0.6

Table 2-2. Frequency Analysis Upstream Migration 11/15-05/30

	Upstream Migration (11/15-05/30)		
	WSE (feet)	Storage (acre-feet)	DH (feet)
Median	501.9	32,617	5.0
25th percentile	512.3	40,450	15.3
75th percentile	490.9	25,513	3.0
Maximum	526.6	53,119	66.0
Minimum	457.3	10,837	1.2

Table 2-3. Frequency Analysis Upstream Migration 12/01-06/30

	Upstream Migration (12/01-06/30)		
	WSE (feet)	Storage (acre-feet)	DH (feet)
Median	502.8	33,226	6.0
25th percentile	512.7	40,775	15.3
75th percentile	491.1	25,608	3.6
Maximum	526.6	53,119	66.0
Minimum	457.3	10,837	1.5

Table 2-4. Frequency Analysis Upstream Migration 12/01-04/30

	Upstream Migration (12/01-04/30)		
	WSE (feet)	Storage (acre-feet)	DH (feet)
Median	501.8	32,540	3.6
25th percentile	512.0	40,215	14.9
75th percentile	490.9	25,472	2.3
Maximum	526.6	53,119	66.0
Minimum	457.3	10,837	0.9

Table 2-5. Frequency Analysis Upstream Migration 01/01-03/31

	Upstream Migration (01/01-03/31)		
	WSE (feet)	Storage (acre-feet)	DH (feet)
Median	501.9	32582	2.6
25th percentile	510.8	39229	14.2
75th percentile	490.8	25437	1.2
Maximum	526.6	53119	62.8
Minimum	457.9	11047	0.5

The analysis of WSE indicates that a maximum DH of 66 feet occurs for most upstream migration periods evaluated. The January 01- March 31 interval presents the smallest DH of 62.8 feet, which would still require a great number of exit pools (approximately 63, when considering an hydraulic drop per pool of 1-foot). However, for a fish passage designed to operate approximately between the 25th and 75th percentile (a tighter operational band), the resulting DH is approximately 25 feet. This tighter operational band would require approximately 25 exit pools and could render the vertical slot fish passage alternative hydraulically feasible within operational constraints. Figure 2-2 presents a plot of the maximum and minimum WSE for January 01- March 31 interval starting from 1994 and a proposed limited operational interval between 488 and 512.5 feet (DH of 24.5 feet), which would work for most years except extreme dry and wet years. Table 2-6 presents a summary of maximum and minimum WSE, DH, month of maximum and minimum WSE for the January 01- March 31 upstream migration interval.

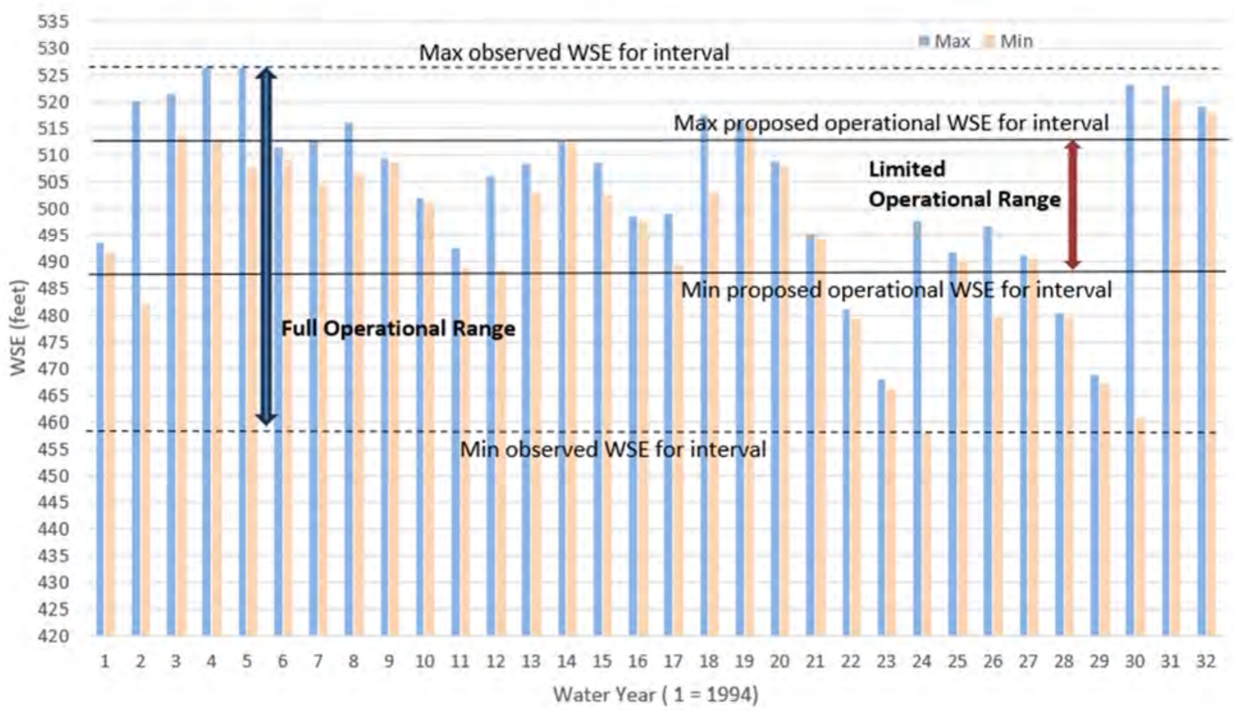


Figure 2-2. Full and Limited Operational Range January 01- March 31

Table 2-6. Annual WSE Maximum and Minimums January 01 – March 31

Year	Max WSE (feet)	Min WSE (feet)	DH (feet)	Month of Max	Month of Min
1994	493.4	491.5	1.9	3	1
1995	520.2	482.0	38.2	3	1
1996	521.6	513.8	7.8	3	1
1997	526.4	512.5	14.0	3	1
1998	526.6	507.7	18.9	3	1
1999	511.3	509.0	2.3	3	1
2000	512.6	504.2	8.4	3	1
2001	516.1	506.4	9.7	3	1
2002	509.2	508.3	0.9	3	3
2003	502.0	501.2	0.8	3	3
2004	492.5	488.7	3.8	3	1
2005	506.0	488.0	18.0	3	1
2006	508.2	503.0	5.2	3	1
2007	512.5	512.1	0.5	3	3
2008	508.5	502.3	6.2	3	1

Year	Max WSE (feet)	Min WSE (feet)	DH (feet)	Month of Max	Month of Min
2009	498.6	497.6	0.9	3	3
2010	499.1	489.3	9.8	3	1
2011	517.5	502.8	14.6	3	1
2012	516.1	515.5	0.5	3	3
2013	508.7	507.6	1.1	3	3
2014	495.5	494.2	1.2	3	2
2015	481.3	479.2	2.1	3	3
2016	468.0	465.9	2.1	3	1
2017	497.9	457.9	40.0	3	1
2018	491.7	489.6	2.1	3	3
2019	496.6	479.3	17.3	3	1
2020	491.3	490.3	1.0	3	3
2021	480.4	479.2	1.2	3	3
2022	468.7	467.2	1.5	3	3
2023	523.3	460.5	62.8	3	1
2024	523.1	520.4	2.8	3	1
2025	519.2	517.6	1.5	3	2

3.0 Tailrace Rating Curve

3.1 Introduction

As a preliminary step to developing potential alternatives for upstream fish passage, the tailwater conditions at the dam required assessment. A hydraulic model was developed for the tailrace to derive the tailwater rating curves at two potential locations for the fishway downstream of Lopez Dam. The first location the tailwater was analyzed is approximately 140 feet downstream of the end of the spillway, which can be considered where the flip bucket terminates. The second location is within the basin downstream of the outlet located near the left embankment of the dam (Outlet). The two locations where the tailwater was assessed are visually represented by the red lines within Figure 3-1.

Figure 3-1. Tailwater Analysis Locations

3.2 Hydraulic Model Data

3.2.1 Terrain Development

The terrain model, shown in Figure 3-2, was developed using U.S. Geologic Survey (USGS) Light Detection and Ranging (LiDAR) point cloud data gathered on 1/18/2019, which is considered the best available topographic data to represent the terrain at the Project area. The point cloud data was converted to a digital elevation model (DEM) with a 1-foot sampling interval to be used as the digital terrain of the hydraulic model. The vertical datum is NAVD88. There was one bridge included in the terrain data within the downstream extents of the terrain model, an unnamed bridge across Arroyo Grande Creek. This bridge was removed from the terrain to allow the water to be routed downstream and was not included within the model as it is not relevant to the tailwater analyses performed.

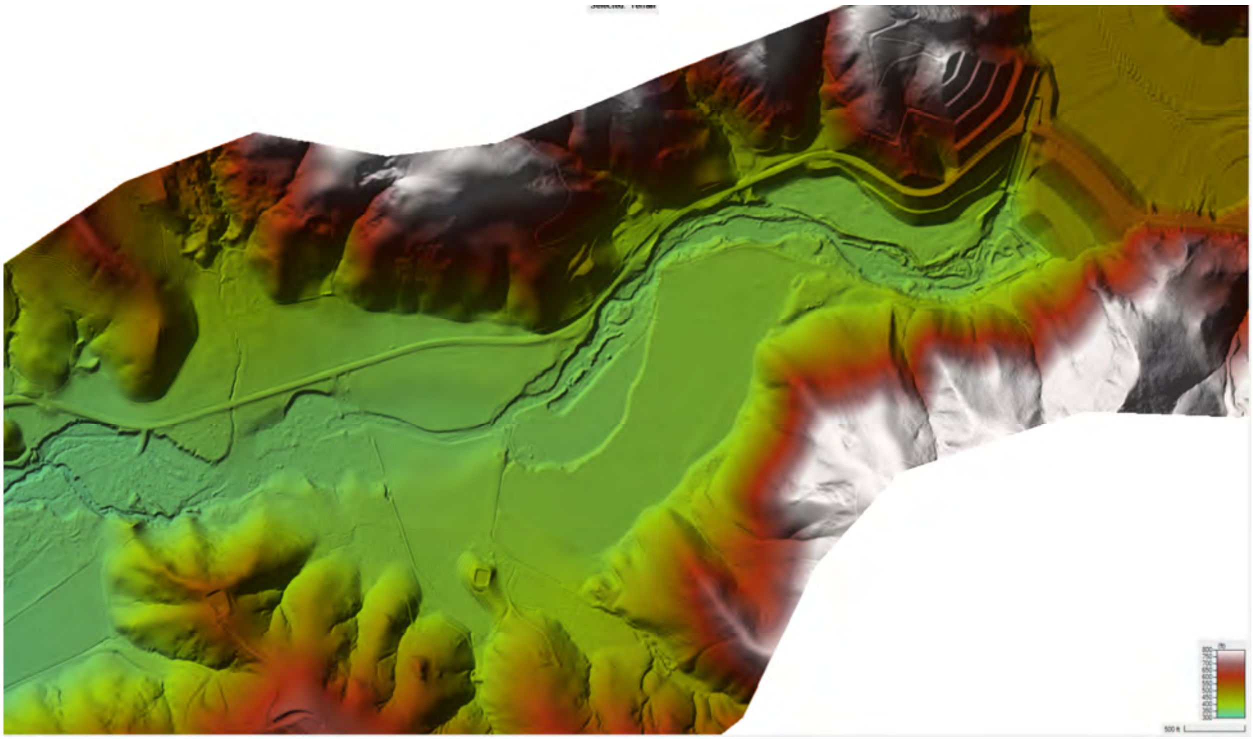


Figure 3-2. HEC-RAS Model Terrain (elevations in feet)

3.2.2 Flow Data

Daily flow data from 1993 to 2025 from the Lopez Dam Operational Report – Compiled Flow Statistics spreadsheet provided by the County was utilized to develop sets of flow conditions to be analyzed at the dam. The Lopez Dam spillway flow rates historically range up to 1,032 cubic feet per second (cfs). Outlet flow rates historically range up to approximately 100 cfs. Three separate flow scenarios were evaluated to gather a rounded understanding of tailwater conditions at Lopez Dam, based on historically observed flow data:

i. Varying Outlet flows up to 100 cfs with no spillway flows.

ii. Varying spillway flows up to 1,032 cfs with minimal outlet flows of 3 cfs. This was the historically observed minimum Outlet flow during active spillway flows.

iii. Varying spillway flows up to 1,032 cfs with maximum outlet flows of 100 cfs. This was the historically observed maximum Outlet flow, which also occurred during the maximum spillway flow of 1,032 cfs.

3.3 Methodology

The tailwater analyses were performed in the Hydrologic Engineering Center River Analysis System (HEC-RAS) version 6.6 through a 2-dimensional model. HEC-RAS software is capable of 1D and 2D unsteady hydrodynamic routing using the Saint-Venant equations or the Diffusion Wave equations. HEC-RAS is an industry-standard software program that is used within the dam safety industry for hydraulic modeling.

3.3.1 Model Geometry

The geometry file for the analysis is made up of a 2D flow area and boundary conditions. The 2D flow area is the computational mesh that combines elevation, slope, roughness, and other information used in the flow calculations.

The 2D flow area for this Project covers an area of approximately 0.22 square miles. Mesh cell sizes within the spillway, Outlet area, and directly downstream of the dam, approximately 460 feet downstream of the spillway, were set equal to a 4-foot cell size. This finer mesh resolution was adopted in the area of interest. The following 750 feet of river reach downstream had a mesh cell spacing of 5-feet. The remaining mile of model reach utilized a 20-foot cell size spacing. The model domain includes approximately one mile of Arroyo Grande Creek downstream of Lopez Dam. Figure 3-5 presents the model domain and numerical mesh adopted for the first 2,600 feet of the reach within the model. Figure 3-4 presents the model domain and numerical mesh for the remaining 2,680 feet of the downstream reach within the model.

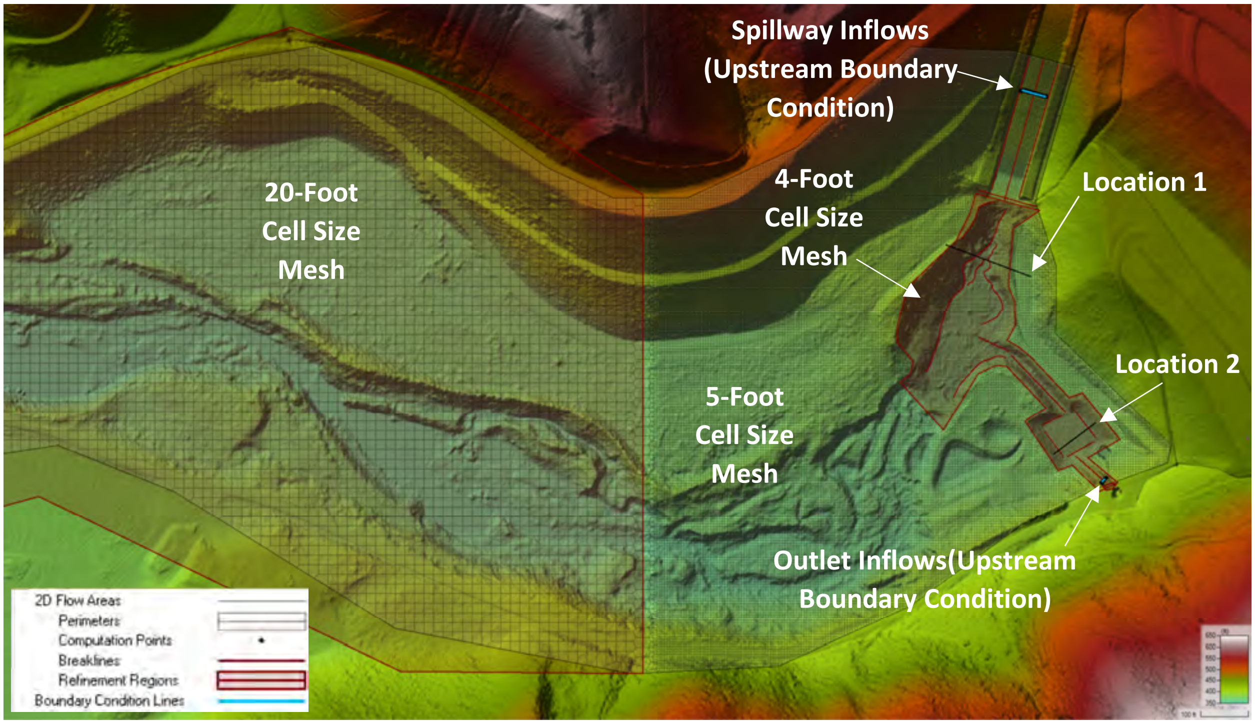


Figure 3-3. HEC-RAS 2D Upstream Model Domain

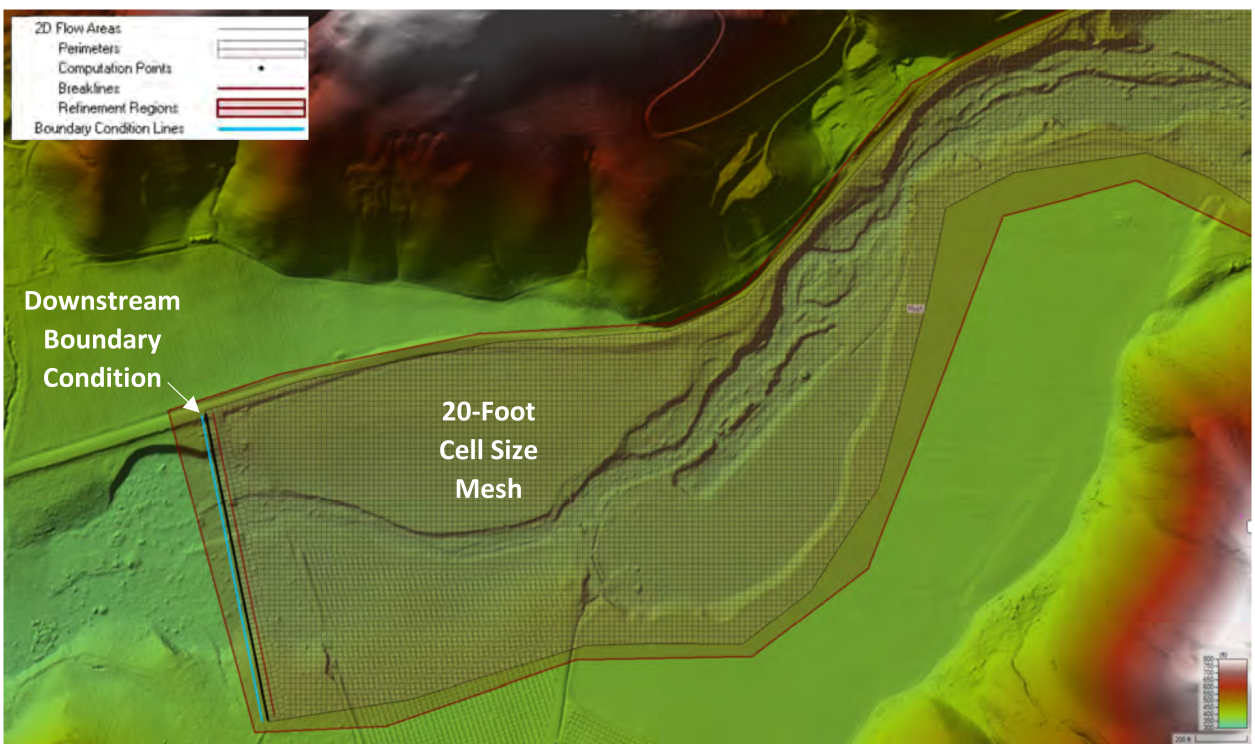


Figure 3-4. HEC-RAS 2D Downstream Model Domain

3.3.2 Boundary Conditions

The inflows for the spillway and Outlet were modeled as internal boundary conditions with flows ramping up over 30-minute intervals for the Outlet and hour-long intervals for the spillway. Flows were increased by increments of 10 cfs for the Outlet analysis, and by 100 cfs for the spillway analysis. The downstream boundary condition, located approximately 1-mile downstream of the dam, utilized a normal depth boundary condition of 0.5%, set to the approximate slope of the river channel in this location. The location of the boundary conditions are shown in Figure 3-3 and Figure 3-4.

3.3.3 Roughness Coefficients and Simulation Times

The Manning's roughness (n-values) adopted for the analysis are generally based on guidance presented in *Open Channel Hydraulics* (Chow, 1959). There are no water depth observations at the dam tailrace. Therefore, the hydraulic simulations were evaluated with three different n-values; 0.035, 0.065, and 0.10 (corresponding to low, medium and high n-values for channels, respectively). The simulations with different n-values provide an uncertainty assessment for tailwater conditions due to the lack of observed data. Manning's n values were applied to the channel and overbank areas of the numerical mesh. A 12-hour simulation time was set for the Outlet tailwater analyses, and a 24-hour simulation time for the spillway tailwater analyses.

3.4 Results

The tailwater ratings curves obtained with the hydraulic model near the Outlet and the spillway for the low, mid and high Manning's n values are presented in Figure 3-5 and Figure 3-6, respectively. The simulations performed with higher Manning's n values result in higher tailrace water depths, which is expected. Simulated water depths near the outlet vary from approximately 1 foot for low outlet flow (10 cfs) and low n-values to 2.75 feet for high outlet flow conditions (100 cfs) and high n-values.

Simulated water depths near the spillway vary according to outlet flow conditions. The predicted water depth is approximately 1.5 foot for spillway flows associated with low outlet flow (3 cfs) and low n-value to 5.4 feet for spillway flows associated to high outlet flow (100 cfs) and high n-values.

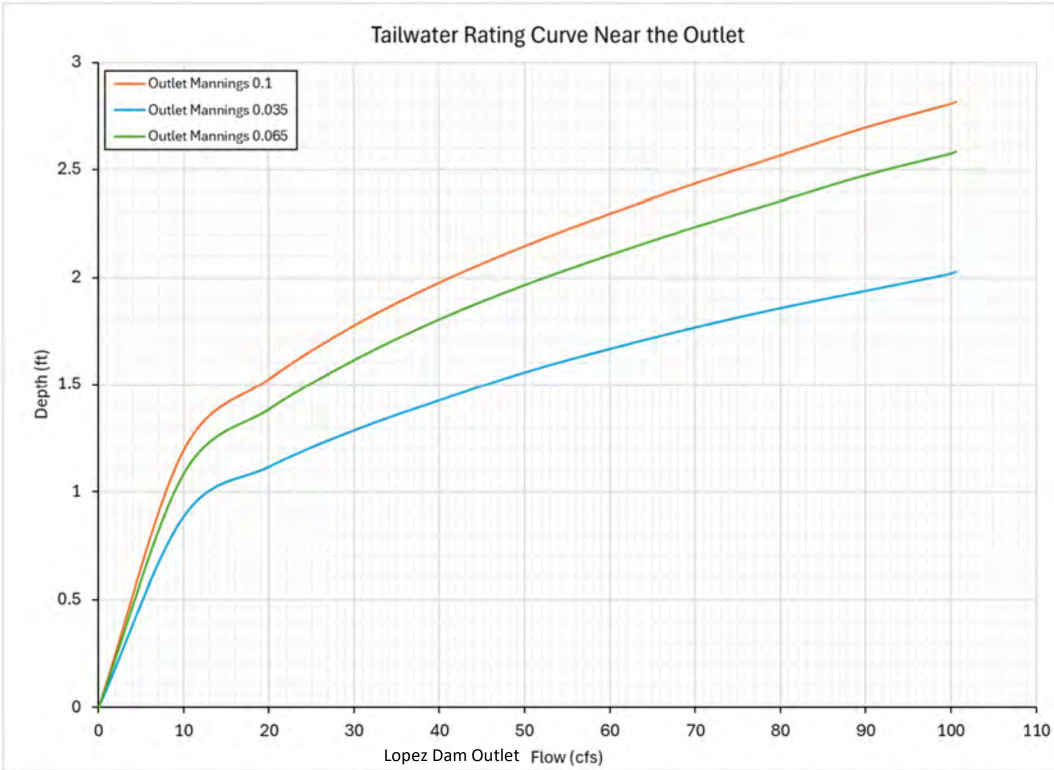


Figure 3-5. Tailwater Rating Curve Near the Outlet

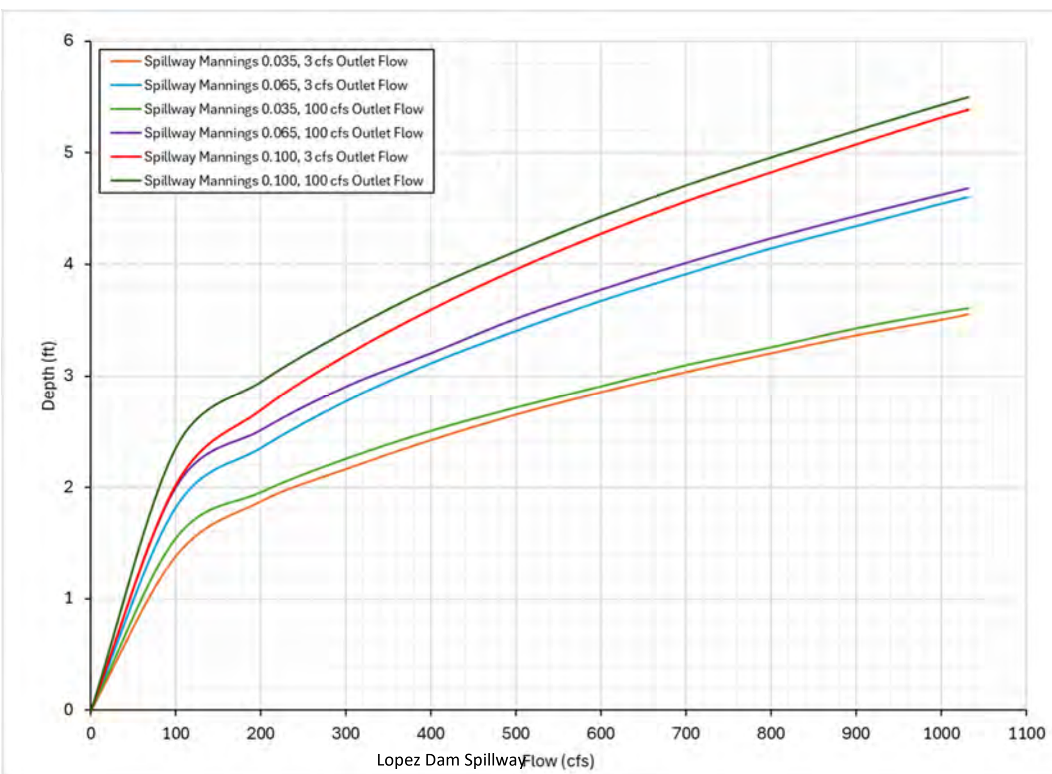


Figure 3-6. Tailwater Rating Curve Near Spillway

Table 3-1 presents a summary of the simulated WSE near the Outlet and the Spillway. The floor elevation near the outlet and spillway were obtained from the LiDAR topography.

Table 3-1. Tailrace Rating Curve Near Outlet

Outlet Flow (cfs)	WSE (feet) n = 0.035	WSE (feet) n = 0.065	WSE (feet) n = 0.1
0	368.69	368.69	368.69
10	369.58	369.78	369.89
20	369.81	370.08	370.22
30	369.98	370.31	370.47
40	370.12	370.5	370.67
50	370.25	370.66	370.84
60	370.36	370.8	370.99
70	370.46	370.93	371.13
80	370.55	371.05	371.26
90	370.63	371.17	371.39
100	370.71	371.27	371.5

Table 3-2. Tailrace Rating Curve Near Spillway

	Outlet Flow 3 cfs			Outlet Flow 100 cfs		
Spillway Flow (cfs)	WSE (feet) n = 0.035	WSE (feet) n = 0.065	WSE (feet) n = 0.100	WSE (feet) n = 0.035	WSE (feet) n = 0.065	WSE (feet) n = 0.100
0	366.70	366.70	366.70	366.70	366.70	366.70
100	368.09	368.53	368.73	368.25	368.71	369.06
200	368.58	369.06	369.40	368.66	369.22	369.65
300	368.87	369.48	369.89	368.96	369.61	370.10
400	369.13	369.82	370.30	369.21	369.91	370.49
500	369.36	370.11	370.66	369.42	370.22	370.82
600	369.56	370.38	370.98	369.61	370.48	371.13
700	369.74	370.62	371.27	369.8	370.72	371.41
800	369.91	370.85	371.53	369.96	370.94	371.66
900	370.07	371.05	371.78	370.13	371.14	371.90
1000	370.21	371.25	372.02	370.27	371.33	372.13
1032	370.26	371.31	372.09	370.31	371.39	372.20

4.0 Fish Passage Calculations

4.1 Introduction

The following sections present the concepts that were used to support the preliminary designs of the upstream and downstream fish passage structures. Calculations were developed to confirm the hydraulic geometry of the facilities conform to empirically verified design parameters presented in the fish passage body of literature. The hydraulic calculations are presented in Attachment A. Preliminary designs were based on a vertical slot fishway for upstream passage and a floating surface collector for downstream passage.

4.2 Upstream Fish Passage – Vertical Slot Fishway

The upstream fish passage design consisted of three components: (1) vertical slot fishway pools that would provide passable flow characteristics for the design species, (2) a transport channel through the dam, and (3) a series of exit pools that allow the fishway to remain operational over the anticipated reservoir fluctuations.

4.2.1 Vertical Slot Pool Geometry

The fishway is sized following the minimum pool dimensions and energy dissipation factor as presented in McMillen (2025a) TM002. The fishway would be a conventional vertical slot ladder without Auxiliary Water Supply (AWS) flow. It would have 148 pools, 25 of which would be exit pools (located upstream of the dam in the reservoir, with a total length of 260 feet). It is important to note that some of the largest fishways generally have a maximum of 120 pools. The first 123 pools would be located downstream of the dam, with a total length of 1,297 feet. The vertical slot ladder would have a slot width of 9-inches and no sill within the slot. The sill would create difficulty to maintain the fishway, limit passage to fish upstream, and limit fish ability to descend the fishway if water supply to the fishway was to be lost, which could result in fish kill. This is especially true considering that the sill would be abnormally tall (4.25 feet tall versus the average water depth of 5.5 feet). A sill would however be required to decrease the fishway flow to 7.9 cfs (maximum low flow). Instead, the fishway is sized for standard operation to determine the expected flow rate of the fishway. The fishway flow rate would be 27.1 cfs.

Fish ladders are often used with AWS systems to increase the attraction flow (attraction potential of fish from the tailrace into the fishway); however, because the outflow at Lopez Dam is highly regulated and generally flows are at approximately 5.9 to 7.9 cfs during the fish passage window, AWS flow is not technically required at this site as the ladder flow alone would match the river flow. The ladder flow was calculated to be 27.1 cfs (without a sill; or 7.9

cfs with a 4.25 ft tall sill). Since AWS flow is not used for this alternative, the entrance pool would be a typical ladder pool.

A key design factor for fish ladders is handling fluctuating tailwater levels. To manage this, entrance pools often include a gate to regulate head, and some sites require multiple entrances. At Lopez Dam, however, tailrace levels are stable during the fish passage window, varying by only 8 inches (see Figure 4-1). Therefore, a single orifice entrance with a slide gate is assumed. The gate would mainly serve isolation and maintenance functions, operating either fully open or closed—not for regulating flow or head.

The top of the entrance orifice would sit about 4 inches below the minimum tailwater elevation to maintain submergence and streaming flow, which is preferred over plunging flow to avoid fish injury and poor passage conditions. While not its primary function, the gate could be used to increase velocity at the entrance to deter invasive species. The fishway should allow adjustment of entrance hydraulic drop between 6 inches and 2 feet, as higher drops can limit passage for some species.

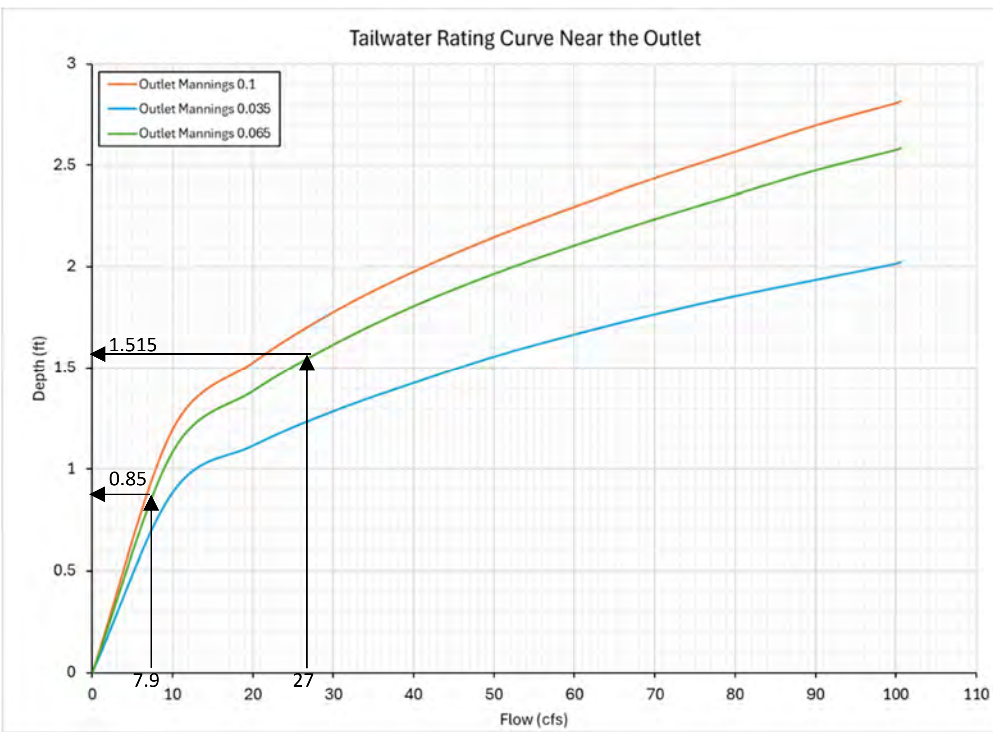


Figure 4-1. Tailwater Rating Curve Near the Outlet

The standard pool size would be 10.5 feet wide by 9.66 feet long and have an average water depth of 5.5 feet. The pool volume is directly dependent on the fishway flow and the hydraulic drop per pool to meet the energy dissipation factor (EDF). For the project target species, SCCC steelhead, an EDF of 3.13 ft.lbs/ft^3 was selected, as well as larger pools to accommodate two recirculation zones within a pool which favors resting and thus overall passage efficiency (wang et al. 2010), especially because this ladder would be the longer than some of the longest.

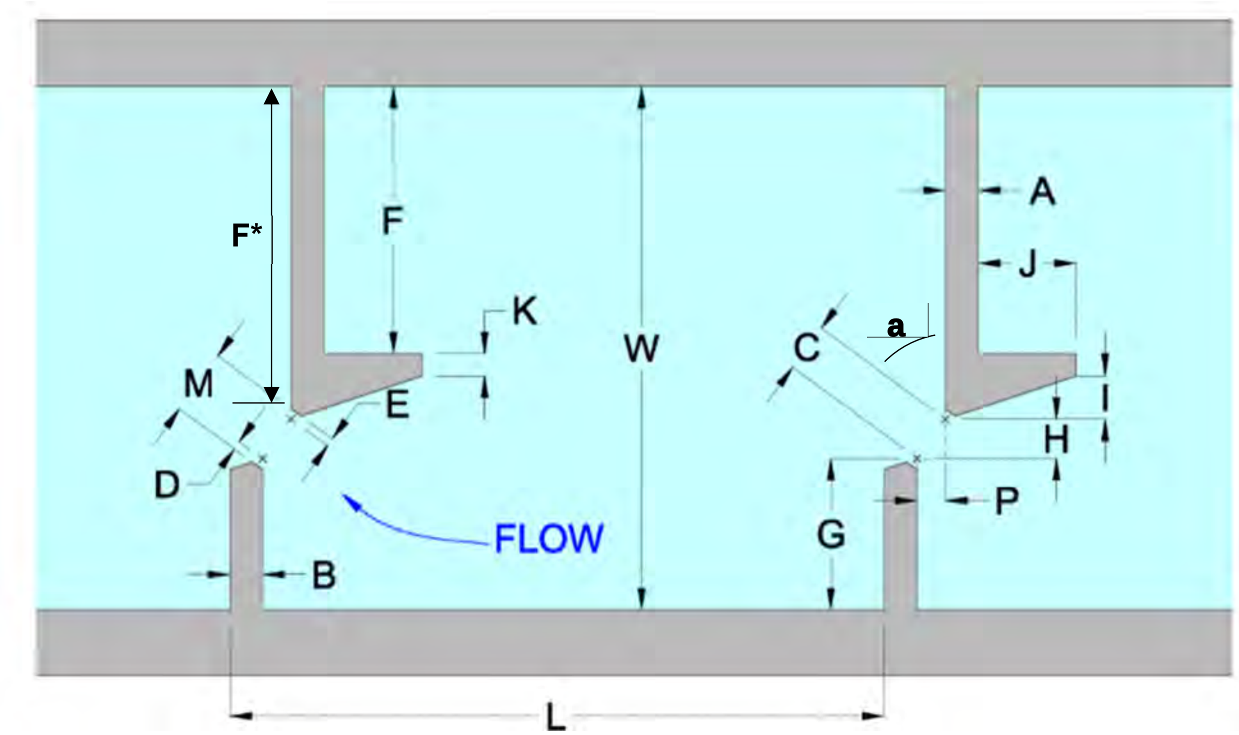


Figure 4-2. Vertical Slot Fishway Layout (Source; NMFS, 2023, Modified)

Table 4-1. Vertical Slot Fishway Dimensions

Dimension Description	Units	Selected Dimension
Pool Width, W	ft	10.50
Pool Length, L	ft	9.67
Min. Pool Depth	ft	5.00
Hydraulic Head per Baffle	in	12
Wall Width, B	in	8
Slot Width, M	in	9
Flow Deflector Length, J	in	18
Baffle Length, F*	in	42
Slot Orientation Angle, **a**	deg	58
Fishway Slope, S	%	10.3

4.2.2 Transport Channel Geometry

A transport channel would provide passage between the vertical slot fishway pools on the downstream side of the dam and the exit pools in the reservoir. The transport channel was designed to meet NMFS (2023) design guidance, and open channel flow calculations were performed using Manning's equation to determine the flow characteristics. Design criteria are summarized in Table 4-2.

Table 4-2. Transport Channel Design Criteria

Criteria	Units	Design Value	Comments
Transport Channel Flow Rate, Q	ft^3/s	27.1	This assumes that the fishway would be designed to meet standard requirements.
Transport Channel Width, W	ft	4.0	4.0' wide minimum, NMFS 5.4.2.2
Transport Channel Depth, D	ft	6.0	5.0' deep minimum, NMFS 5.4.2.2
Transport Channel Slope, S	ft/ft	0.0003	No criterion; see transport velocity
Transport Velocity, V	ft/s	1.75	1.5 – 4.0 ft/s velocity range, NMFS 5.4.2.1

Between Pools 123 and Pool 124, a transport channel would be provided to connect the upstream to the downstream side of the dam. The transport channel would be approximately 640 ft in length with a very gentle slope of 0.03 percent. The invert of the penetration through the dam would be at approximately 57 feet below the dam's crest, and pass through the dam core. The water depth would be 3 feet. The transport channel would either be a concrete culvert 6 feet tall by 4 feet wide, or an HDPE pipe 48-inch in diameter. The material selection would be dependent on construction method, seismic evaluation, and limiting seeping potential. Due to the penetration through the dam, the size of the transport channel is such that the water will not flow in an open channel (preferred), but at the same time the pipe will not be pressurized. Observation port, or ambient light (or electric light) will not be provided.

An isolation gate would need to be installed just downstream of the exit pool structure. The gate would be a slide gate large enough to accommodate the transport channel opening, and sized for approximately 52 feet of hydrostatic head.

The following constructability and design concerns to the earthfill dam are to be considered in the alternative evaluation (i.e., dam safety concerns):

- To stabilize soils during excavation, temporary excavation support will be required. Temporary soil anchors should not be allowed to penetrate the earthfill dam due to potential risk of fracturing the dam core during drilling and grouting of the anchors.

- Some ground movements could occur during excavation. These ground movements, even small, may adversely affect the dam core (e.g., reduction in lateral stress, increase potential for internal erosion etc.). These changes have the potential to destabilize the dam, creating seismic instability and thus dam safety concerns.

- The transport channel would need a means to minimize seepage and internal erosion along its outside walls. A grout curtain or a sheet pile wall could be used to minimize seepage, but its installation could negatively impact the dam core.

- Addition of the transport channel could reduce lateral support/stiffness of the dam for both static and seismic conditions.

- During or following an earthquake the exit pool structure gates and the isolation gate may become un-operational which could lead to an uncontrolled release of the reservoir, though there are mechanical solutions such as “fail safe” operators that close after the loss of main power or by alarm using battery backup.

4.2.3 Exit Pools

As discussed above in Section 2.0, the maximum headwater range for Lopez Dam from December 1 through May 1 is approximately 66 feet which would require nearly 70 exit pools in the reservoir to accommodate the full range of reservoir elevations. Instead, it was elected to focus on the season of January 1 through March 31 for which there would be 25 exit pools. Table 4-3 presents a summary of the upstream fishway, as a whole.

Table 4-3. Upstream Fishway Summary

Design Parameter	Units	Design Value	Comments
95% Exceedance Tailwater Elevation	ft	364.4	Assumed; to be validated
Proposed Lower Limit of Fishway Operation	ft	488.0	Jan 01 – Mar 31, 25th to 75th percentile operational band
Proposed Upper Limit of Fishway Operation	ft	512.5	Jan 01 – Mar 31, 25th to 75th percentile operational band
Number of Pools	#	148	12-inch drop per pool
Number of Exit Pools	#	25	Per headwater operational band and 12-inch drop per pool
Fishway Length	ft	1,557	9.67 per pool length (normal), 18.67 per pool length (rest); transport channel not included

The exit pool structure would include 25 pools and be approximately 260 feet in length. Each exit pool would have an exit gate (25 total), with all the gates closed apart from the one corresponding to the reservoir level. The gates would be automated and work on level control. They each will have a motor operator at the deck level. The appropriate gate would be open and work within a bandwidth of 1 foot, before closing and having the adjacent gate open and the current one close. Each exit will also be equipped with an isolation gate (25 total). The exit pool structure will be rotated to go along the shoreline. The advantage is to provide vehicular access to each gate, for maintenance and operation. Between the exit pool structure and the shoreline, the volume would be filled with structural fill. The top of the exit pool structure will be grated and a handrail provided. The exit pool structure would be located behind the existing log boom, so as to minimize debris accumulation on the fishway exit trashrack. A mechanical rake would not be provided. Access to the trashrack higher pools could be completed from the deck, though access to the lower pools would likely require access from a boat.

4.3 Downstream Fish Passage – Floating Surface Collector

The floating surface collector design consisted of two components: (1) sizing of the vertical V-screens for fish capture, and (2) sizing of the fish return pipe and calculations of the flow characteristics. These are summarized in the following paragraphs.

4.3.1 V-Screen Sizing

The FSC Vessel would be a 184-feet-long by 69-feet-wide vessel with an entrance flow capacity of 1,000 cfs. The vessel would be designed by a naval architect. It will need trim and ballast tanks. Its hull will need regular dive inspections and maintenance. The vessel could be raised or lowered using the ballast tanks, to perform inspection and maintenance.

The entrance flow would be split into a two vee-configuration. The screen area for dewatering this flow is sized to be lower than an approach velocity of 0.4 fps and configured to achieve a capture velocity of 8 fps with gradual acceleration. The fish would enter the FSC through the coarse trash rack at the front of the vessel. The fish then would enter the primary screen section of the collection channel. The collection channel walls would be vertical and angled in a V-shape; the floor would have a slight upward slope. After the primary section, the fish would then enter the secondary screen area that would contain the capture section of the collection channel. The capture section reaches velocities of 6 to 8 ft/s. The floor of the secondary screens would slope upward as the vertical walls continue to narrow in V-shape. Once the fish enter the collection zone, they would quickly pass to the fish handling area of the vessel. The fish would be further dewatered and sorted into holding tanks. The FSC would include provisions for fish separation (large fish, smolts, and fry), segregated holding, sampling, and loading. The FSC would require anchorage, which is assumed to be independent of the dam structure. The high level of reservoir fluctuation would add cost and operational challenges to anchoring the FSC in a relatively stable location. The FSC can operate well over the wide range of water levels. The FSC would require an approximately 1,000-KVA power service in order to operate the horizontal propeller pumps, which are used to attract fish to and through the structure.

The water would enter through a coarse trash rack at the front of the vessel. A bell mouth entrance could be used to provide a smooth hydraulic flow lines through the trash rack. The primary screens would be V-shaped and would remove 60% to 90% of the water. The geometry for the V-shape width and floor would be chosen to provide a smooth acceleration of the flow and to maintain a safe approach velocity to the screens. The concept of the secondary screens would be similar but would become much narrower as more water is removed. Diffuser plates or baffles would be used directly behind the screens to ensure uniform approach velocities across the screen. From there, the water would enter plenums, which may combine water from several screens. Each plenum would then lead to a high flow/low head large submersible horizontal propeller pump. The pump outlets could be located either in the wall or the floor of the vessel. The number of attraction pumps required is dependent on the number of collection channels, the operational range of the FSC, and the incremental flow increases that are desired. Water that enters the fish handling area would be pumped separately. This amount of water may vary depending on design needs for species present in the reservoir but is generally in the 8 to 12 cfs per collection channel. Reducing flows is beneficial for pumping cost and for vessel design related to largest floodable compartment.

The FSC could be sized for half the flow rate, however it would be recommended to run a computational fluid dynamic model to determine how much flow is sufficient to attract fish through the FSC. Due to the shape of the reservoir in relation to the FSC, the Swift FSC is the basis of design because of the similarities with Lopez Dam. The Swift FSC has a total flow rate of 1,000 cfs. In addition, all FSCs built to date are located in reservoirs used for hydropower, so in addition of the attraction flow from the FSC, there is also flow to the powerhouse intake guiding fish in the reservoir. Due to the lack of reservoir flow, more attraction may be needed.

4.3.2 Fish Return Sizing

The fish return pipe will convey entrained fish from the floating surface collector to an outlet in a plunge pool located in the tailrace. The fish return piping was sized in order to meet NMFS design guidance for fish protection. Hydraulic conditions in the pipe were calculated assuming a normal, uniform flow according to Manning's equation. A summary of the fish return piping is provided in Table 4-4.

Table 4-4. Fish Return Pipe Parameters

Design Parameter	Units	Design Value	Comments
Bypass Flow Rate	ft^3/s	2.5	Calculated, to meet parameters below
Pipe Nominal Diameter, D	in	12	NMFS 8.6.3.3, Min 10” 12” SDR 26 HDPE, I.D. 11.77”
Bypass Flow Velocity	ft/s	8.8	NMFS 8.6.3.5, 6 ft/s < V < 12 ft/s; 2 ft/s absolute minimum
Bypass Flow Depth, d	in	4.7	NMFS 8.6.3.6, 40% of pipe diameter
Bypass Pipe Slope, S	ft/ft	0.04	Calculated to meet flow depth/velocity requirements
Bypass Pipe Length, L	ft	4,236	Based on estimated reservoir level and 5% exceedance in tailrace
Impact Velocity, V_j	ft/s	12.1	NMFS 8.6.4.2, $V_j < 25$ ft/s

Based on the above parameters, the fish return piping will consist of approximately 4,250 ft of 12-inch nominal standard dimension ration (SDR) 26 HDPE pipe. Based on an assumed pipe install cost of approximately $300 per foot, the estimated cost for the fish return piping will be approximately $1,275,000.

5.0 References

Chow. 1959. *Open-Channel Hydraulics.* New York: McGraw-Hill.

Stetson Engineering, Inc. 2004. Final Draft Arroyo Grande Creek Habitat Conservation Plan (HCP) and Environmental Assessment/Initial Study (EA/IS) for the Protection of Steelhead and California Red-Legged Frogs. February 2004.

NMFS. 2013. South-Central California Coast Steelhead Recovery Plan. NOAA Fisheries. West Coast Region, California Coastal Office, Long Beach, California.

URS Greiner Woodward Clyde. 2000. Lope Dam Seismic Strengthening Project Drawings. Volume II or IV. June 2000.

Attachment A. Fish Passage Hydraulic Calculations

Calculation Cover Sheet

McMillen

Project: Steelhead Passage Feasibility Assessment of Lopez Dam

Client: County of San Luis Obispo **Proj. No.:** 25-062

Title: Preliminary Hydraulic Calculations

Prepared By, Name: V. Autier

Prepared By, Signature: **Date:** 30-Jun-25

Peer Reviewed By, Name:

Peer Reviewed, Signature:

McMillen

SUBJECT:	County of San Luis Obispo	BY:	V. Autier	CHK'D BY:	
	Steelhead Passage Feasibility Assessment of Lopez Dam	DATE:	6/30/2025		
	Preliminary Hydraulic Calculations	PROJECT NO.:	25-062		

Table of Content

SUBJECT: County of San Luis Obispo
Steelhead Passage Feasibility Assessment of Lopez Dam
Upstream Fish Passage - Vertical Slot Fishway - Fishway Sizing

BY: V. Autier **CHK'D BY:**
DATE: 6/30/2025
PROJECT NO.: 25-062

Purpose

The purpose of this calculation sheet is to size the Vertical Slot Fishway Alternative

References

- *NMFS 2022. Anadromous Salmonid Passage Design Manual. West Coast Region, 2022*
- *Clay 1995. Design of fishways and other fish facilities By Charles H. Clay*
- *Milo Bell Fisheries Handbook Chapter 34.14*
- *Wang, R. W., David, L., Larinier, M. 2010. Contribution of experimental fluid mechanics to the design of vertical slot fish passes. Knowledge and Management of Aquatic Ecosystems (2010) 396, 02. DOI: 10.1051/kmae/2010002.*

Information - Input

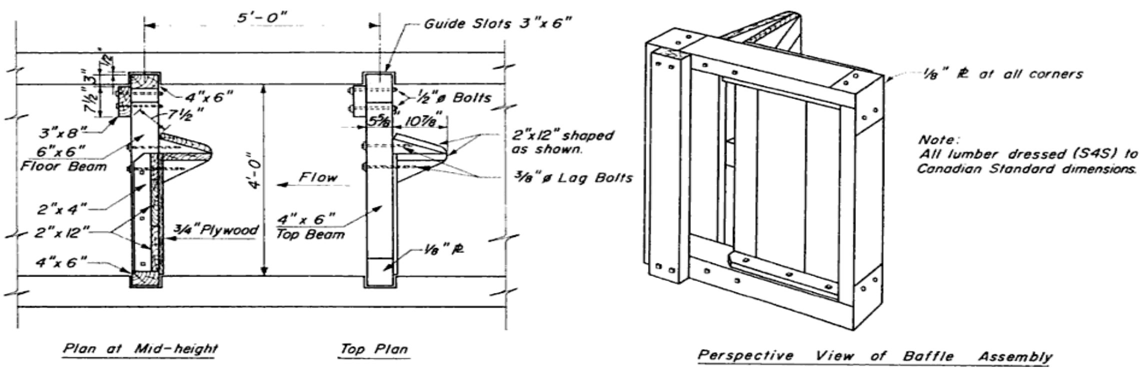


Figure 2.4 **Baffle plan of small fishway for trout using a single vertical slot. This design uses a timber baffle and concrete fishway walls.**

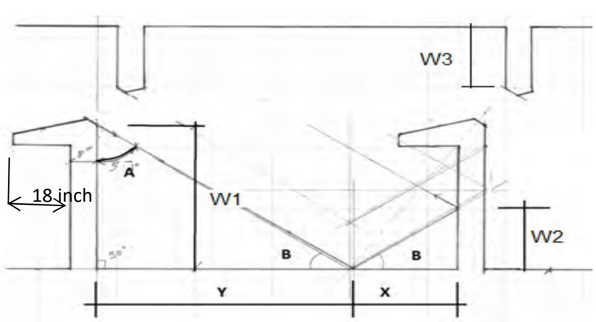
Reference: Design of fishways and other fish facilities By Charles H. Clay 1995

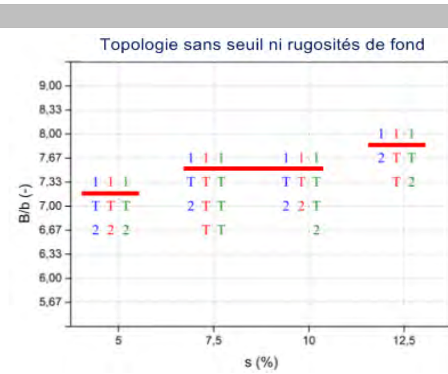
Step 1 - Inputs

Orifice Width =	9 inch	Pool Width =	10.5 feet
Pool Depth =	5 feet	Pool Length (X+Y) =	9 feet
Orifice Sill =	0.00 feet	Wall Thickness =	8 inch
Head per Baffle =	12 inch	Average Water Depth =	5.50 feet

Step 2 - Determine Basic Geometry

Determine Angle A and W1





Wang et al, 2010

						Angle A		Angle B					
Pool Width (ft)	Length* (ft)	Pool Length (X+Y) (ft)	W1 (ft)	W2 (ft)	W3 (ft)	Degree	Rad	Degree	Rad	Y (ft)	X (ft)	Calculated (X+Y) (ft)	Difference (ft)
10.50	9.67	9.00	3.5	1.50	6.60	58.0	1.01	32.0	0.56	5.60	2.40	8.00	1.00

(*) Length is equal to X plus Y plus the wall width.
Note, the dog leg is typically 18-inch long and 4-inch wide at its minimum width.

Determine the number of recirculation zones (1 or 2):

Fishway Slope:	10.3 %
Pool Width (B):	10.5 ft
Orifice Width (b):	0.75 ft
B/b	14
Results:	Type 1 (i.e., 2 recirculation zones; GOOD)

Step 3 - Calculate Ladder Flow

$$Qo = Co \times Ao \times \sqrt{2gh}$$

Co = orifice discharge coefficient	0.75		Per Bell Fisheries Handbook Chapter 34.14, for 6 to 12-inch head per baffle.
Ao = orifice area	4.50	sf	
Orifice width =	9.000	inch	
h1 =	6.000	feet	
Orifice Sill =	0.000	feet	
g = gravitational acceleration	32.2	ft^2/sec	
h = head	12	inch	

Qo = design orifice flow through the weir (cms)

Qo = 0.75*4.5*(2*32.2*12)^0.5

Qo = **27.08 ft^3/s**

Note that the available outflow is only 7.9 ft^3/s.

In order to make this pool type work the vertical slot height would need to be reduced by 4.25 ft (essentially, loosing the benefit of the vertical slot fishway and including a risk if dewatering occurs for fish to escape and could become stranded).

Step 4 - Check Pool Volume

$$EDF = \frac{(Q \times \rho \times H)}{V}$$

Where,

Q =	Pool Inflow	27.08	ft^3/s
ρ =	Density of Water	62.4	lb/ft^3
H =	Inflow Energy Head	12	inch
V=	Volume of Pool		ft^3
	Length	9	ft
	Width	10.5	ft
	Average Water Depth	5.5	ft
	Volume	519.8	ft^3

Maximum EDF =	3.13	$ft.lbs/ft^3$		
Calculated EDF =	3.25	$ft.lbs/ft^3$	< Max EDF	FALSE

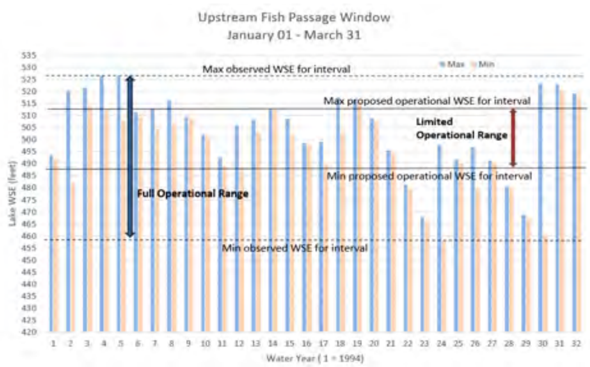
Note the pool volume is not sufficient at the 27.08 cfs flow, however if reducing the flow to 7.9 cfs, the EDF becomes 1.87, and therefore below the maximum. Going below 2.0 would lead to pools being too quiescent and fish not interested to move up. Recommend reducing the size of the pools, for the reduced flow.

McMillen

Pool Dimension Table

Input:

For this option, if using the reservoir fluctuation (min and max) during the upstream fish passage period of December 1 through May 1 (low and high reservoir levels are 526.6 ft and 457.3 ft, respectively) there would be a need of 70 exit pools to address the 69.3 feet of vertical variation. To make this alternative work, there is a need to tighten the operational bend. Upstream migration is not linear. It is more like a bell curve. Knowing this, we focused our evaluation on higher migration days between January 1 to March 31. To further validate this hypothesis, the bar at Arroyo Grande Lagoon typically closes in April, limiting upstream fish passage. In addition, if we can assume the fish passage would not work for extreme dry year and extreme wet years, the Jan 01-Mar31 period looks promising with a 24.5 foot design vertical variation (488-512.4).



95% Exceedance elevation in tailrace 364.4 ft (assumed, need the HEC-RAS model to determine the value)
Proposed Upper Limit of Fishway Operation 488.0 ft
Proposed Lower Limit of Fishway Operation 512.4 ft

Notes: 1. Elevation A is the floor elevation downstream of the pool in concern.
2. Slope 'B' is the dimension in the horizontal hordinate for every vertical meter.
3. Dimension C is the full distance of a pool, from point A to point A.

POOL NO.	NOMINAL SIZE	ELEVATION 'A'	SLOPE 'B'	DIMENSION 'C'	WATER LEVEL*	CHECK	NOTE
1	10.5x9	359.40	9.67	9.67	365.40	6.00	ENTRANCE POOL
2	10.5x9	360.40	9.67	9.67	366.40	6.00	
3	10.5x9	361.40	9.67	9.67	367.40	6.00	
4	10.5x9	362.40	9.67	9.67	368.40	6.00	
5	10.5x9	363.40	9.67	9.67	369.40	6.00	
6	10.5x9	364.40	9.67	9.67	370.40	6.00	
7	10.5x9	365.40	9.67	9.67	371.40	6.00	
8	10.5x9	366.40	9.67	9.67	372.40	6.00	
9	10.5x9	367.40	9.67	9.67	373.40	6.00	
10	10.5x18	368.40	18.67	18.67	374.40	6.00	TURNING POOL/RESTING POOL
11	10.5x9	369.40	9.67	9.67	375.40	6.00	
12	10.5x9	370.40	9.67	9.67	376.40	6.00	
13	10.5x9	371.40	9.67	9.67	377.40	6.00	
14	10.5x9	372.40	9.67	9.67	378.40	6.00	
15	10.5x9	373.40	9.67	9.67	379.40	6.00	
16	10.5x9	374.40	9.67	9.67	380.40	6.00	
17	10.5x9	375.40	9.67	9.67	381.40	6.00	
18	10.5x9	376.40	9.67	9.67	382.40	6.00	
19	10.5x9	377.40	9.67	9.67	383.40	6.00	
20	10.5x18	378.40	18.67	18.67	384.40	6.00	TURNING POOL/RESTING POOL
21	10.5x9	379.40	9.67	9.67	385.40	6.00	
22	10.5x9	380.40	9.67	9.67	386.40	6.00	
23	10.5x9	381.40	9.67	9.67	387.40	6.00	
24	10.5x9	382.40	9.67	9.67	388.40	6.00	
25	10.5x9	383.40	9.67	9.67	389.40	6.00	
26	10.5x9	384.40	9.67	9.67	390.40	6.00	
27	10.5x9	385.40	9.67	9.67	391.40	6.00	
28	10.5x9	386.40	9.67	9.67	392.40	6.00	
29	10.5x9	387.40	9.67	9.67	393.40	6.00	
30	10.5x18	388.40	18.67	18.67	394.40	6.00	TURNING POOL/RESTING POOL
31	10.5x9	389.40	9.67	9.67	395.40	6.00	
32	10.5x9	390.40	9.67	9.67	396.40	6.00	
33	10.5x9	391.40	9.67	9.67	397.40	6.00	
34	10.5x9	392.40	9.67	9.67	398.40	6.00	
35	10.5x9	393.40	9.67	9.67	399.40	6.00	
36	10.5x9	394.40	9.67	9.67	400.40	6.00	
37	10.5x9	395.40	9.67	9.67	401.40	6.00	
38	10.5x9	396.40	9.67	9.67	402.40	6.00	
39	10.5x9	397.40	9.67	9.67	403.40	6.00	
40	10.5x18	398.40	18.67	18.67	404.40	6.00	TURNING POOL/RESTING POOL

41	10.5x9	399.40	9.67	9.67	405.40	6.00	
42	10.5x9	400.40	9.67	9.67	406.40	6.00	
43	10.5x9	401.40	9.67	9.67	407.40	6.00	
44	10.5x9	402.40	9.67	9.67	408.40	6.00	
45	10.5x9	403.40	9.67	9.67	409.40	6.00	
46	10.5x9	404.40	9.67	9.67	410.40	6.00	
47	10.5x9	405.40	9.67	9.67	411.40	6.00	
48	10.5x9	406.40	9.67	9.67	412.40	6.00	
49	10.5x9	407.40	9.67	9.67	413.40	6.00	
50	10.5x18	408.40	18.67	18.67	414.40	6.00	TURNING POOL/RESTING POOL
51	10.5x9	409.40	9.67	9.67	415.40	6.00	
52	10.5x9	410.40	9.67	9.67	416.40	6.00	
53	10.5x9	411.40	9.67	9.67	417.40	6.00	
54	10.5x9	412.40	9.67	9.67	418.40	6.00	
55	10.5x9	413.40	9.67	9.67	419.40	6.00	
56	10.5x9	414.40	9.67	9.67	420.40	6.00	
57	10.5x9	415.40	9.67	9.67	421.40	6.00	
58	10.5x9	416.40	9.67	9.67	422.40	6.00	
59	10.5x9	417.40	9.67	9.67	423.40	6.00	
60	10.5x18	418.40	18.67	18.67	424.40	6.00	TURNING POOL/RESTING POOL
61	10.5x9	419.40	9.67	9.67	425.40	6.00	
62	10.5x9	420.40	9.67	9.67	426.40	6.00	
63	10.5x9	421.40	9.67	9.67	427.40	6.00	
64	10.5x9	422.40	9.67	9.67	428.40	6.00	
65	10.5x9	423.40	9.67	9.67	429.40	6.00	
66	10.5x9	424.40	9.67	9.67	430.40	6.00	
67	10.5x9	425.40	9.67	9.67	431.40	6.00	
68	10.5x9	426.40	9.67	9.67	432.40	6.00	
69	10.5x9	427.40	9.67	9.67	433.40	6.00	
70	10.5x18	428.40	18.67	18.67	434.40	6.00	TURNING POOL/RESTING POOL
71	10.5x9	429.40	9.67	9.67	435.40	6.00	
72	10.5x9	430.40	9.67	9.67	436.40	6.00	
73	10.5x9	431.40	9.67	9.67	437.40	6.00	
74	10.5x9	432.40	9.67	9.67	438.40	6.00	
75	10.5x9	433.40	9.67	9.67	439.40	6.00	
76	10.5x9	434.40	9.67	9.67	440.40	6.00	
77	10.5x9	435.40	9.67	9.67	441.40	6.00	
78	10.5x9	436.40	9.67	9.67	442.40	6.00	
79	10.5x9	437.40	9.67	9.67	443.40	6.00	
80	10.5x18	438.40	18.67	18.67	444.40	6.00	TURNING POOL/RESTING POOL
81	10.5x9	439.40	9.67	9.67	445.40	6.00	
82	10.5x9	440.40	9.67	9.67	446.40	6.00	
83	10.5x9	441.40	9.67	9.67	447.40	6.00	
84	10.5x9	442.40	9.67	9.67	448.40	6.00	
85	10.5x9	443.40	9.67	9.67	449.40	6.00	
86	10.5x9	444.40	9.67	9.67	450.40	6.00	
87	10.5x9	445.40	9.67	9.67	451.40	6.00	
88	10.5x9	446.40	9.67	9.67	452.40	6.00	
89	10.5x9	447.40	9.67	9.67	453.40	6.00	
90	10.5x18	448.40	18.67	18.67	454.40	6.00	TURNING POOL/RESTING POOL
91	10.5x9	449.40	9.67	9.67	455.40	6.00	
92	10.5x9	450.40	9.67	9.67	456.40	6.00	
93	10.5x9	451.40	9.67	9.67	457.40	6.00	
94	10.5x9	452.40	9.67	9.67	458.40	6.00	
95	10.5x9	453.40	9.67	9.67	459.40	6.00	
96	10.5x9	454.40	9.67	9.67	460.40	6.00	
97	10.5x9	455.40	9.67	9.67	461.40	6.00	
98	10.5x9	456.40	9.67	9.67	462.40	6.00	
99	10.5x9	457.40	9.67	9.67	463.40	6.00	
100	10.5x18	458.40	18.67	18.67	464.40	6.00	TURNING POOL/RESTING POOL
101	10.5x9	459.40	9.67	9.67	465.40	6.00	
102	10.5x9	460.40	9.67	9.67	466.40	6.00	
103	10.5x9	461.40	9.67	9.67	467.40	6.00	
104	10.5x9	462.40	9.67	9.67	468.40	6.00	
105	10.5x9	463.40	9.67	9.67	469.40	6.00	
106	10.5x9	464.40	9.67	9.67	470.40	6.00	
107	10.5x9	465.40	9.67	9.67	471.40	6.00	
108	10.5x9	466.40	9.67	9.67	472.40	6.00	
109	10.5x9	467.40	9.67	9.67	473.40	6.00	
110	10.5x18	468.40	18.67	18.67	474.40	6.00	TURNING POOL/RESTING POOL
111	10.5x9	469.40	9.67	9.67	475.40	6.00	
112	10.5x9	470.40	9.67	9.67	476.40	6.00	
113	10.5x9	471.40	9.67	9.67	477.40	6.00	
114	10.5x9	472.40	9.67	9.67	478.40	6.00	

115	10.5x9	473.40	9.67	9.67	479.40	6.00	
116	10.5x9	474.40	9.67	9.67	480.40	6.00	
117	10.5x9	475.40	9.67	9.67	481.40	6.00	
118	10.5x9	476.40	9.67	9.67	482.40	6.00	
119	10.5x9	477.40	9.67	9.67	483.40	6.00	
120	10.5x18	478.40	18.67	18.67	484.40	6.00	TURNING POOL/RESTING POOL
121	10.5x9	479.40	9.67	9.67	485.40	6.00	
122	10.5x9	480.40	9.67	9.67	486.40	6.00	
123	10.5x9	481.40	9.67	9.67	487.40	6.00	Transport Channel through the Dam
124	10.5x9	482.40	9.67	9.67	488.40	6.00	EXIT POOL
125	10.5x9	483.40	9.67	9.67	489.40	6.00	EXIT POOL
126	10.5x9	484.40	9.67	9.67	490.40	6.00	EXIT POOL
127	10.5x9	485.40	9.67	9.67	491.40	6.00	EXIT POOL
128	10.5x9	486.40	9.67	9.67	492.40	6.00	EXIT POOL
129	10.5x9	487.40	9.67	9.67	493.40	6.00	EXIT POOL
130	10.5x18	488.40	18.67	18.67	494.40	6.00	RESTING POOL / EXIT POOL
131	10.5x9	489.40	9.67	9.67	495.40	6.00	EXIT POOL
132	10.5x9	490.40	9.67	9.67	496.40	6.00	EXIT POOL
133	10.5x9	491.40	9.67	9.67	497.40	6.00	EXIT POOL
134	10.5x9	492.40	9.67	9.67	498.40	6.00	EXIT POOL
135	10.5x9	493.40	9.67	9.67	499.40	6.00	EXIT POOL
136	10.5x9	494.40	9.67	9.67	500.40	6.00	EXIT POOL
137	10.5x9	495.40	9.67	9.67	501.40	6.00	EXIT POOL
138	10.5x9	496.40	9.67	9.67	502.40	6.00	EXIT POOL
139	10.5x9	497.40	9.67	9.67	503.40	6.00	EXIT POOL
140	10.5x18	498.40	18.67	18.67	504.40	6.00	RESTING POOL / EXIT POOL
141	10.5x9	499.40	9.67	9.67	505.40	6.00	EXIT POOL
142	10.5x9	500.40	9.67	9.67	506.40	6.00	EXIT POOL
143	10.5x9	501.40	9.67	9.67	507.40	6.00	EXIT POOL
144	10.5x9	502.40	9.67	9.67	508.40	6.00	EXIT POOL
145	10.5x9	503.40	9.67	9.67	509.40	6.00	EXIT POOL
146	10.5x9	504.40	9.67	9.67	510.40	6.00	EXIT POOL
147	10.5x9	505.40	9.67	9.67	511.40	6.00	EXIT POOL
148	10.5x9	506.40	9.67	9.67	512.40	6.00	EXIT POOL

Fish ladder length (ft) = 1556.67

Conclusion

In order to meet the design criteria, the pool depth and length needed to be enlarged.
The fishway from the entrance pool to the last exit pool would include 148 pools, would be approx. 1557 feet in length, and have 25 exit pools.
The resulting flow would be 27 cfs. which is 3.4X as much as the required minimum flow (7.9 cfs). Therefore, a separate system would not be required.
The ladder flow would be provided by gravity.
The ladder would address a reservoir fluctuation of 24.4 ft.

SUBJECT: County of San Luis Obispo
Steelhead Passage Feasibility Assessment of Lopez Dam
Upstream Fish Passage - Vertical Slot Fishway - Transport Channel

BY: V. Autier CHK'D BY: M. Cerucci
DATE: 6/30/2025
PROJECT NO.: 25-062

Purpose

The purpose of this calculation sheet is to size the transport channel between pools 123 and 124.

References

- *NMFS 2022. Anadromous Salmonid Passage Design Manual. West Coast Region, 2022*

Criteria

The transport velocity shall be between 1.5 fps and 4.0 fps per NMFS 5.4.2.1

Inputs

Transport channel width =	4.00	ft
Transport channel Depth =	3.02	ft
Slope =	0.0003	
Length =	640.00	ft

Calculations

Area (A) =	12.06 ft^2
Wetted Perimeter (P) =	10.03
Hydraulic Radius (R) =	1.20 ft^2
Manning's n =	0.013 (concrete)

Based on the Chezy-Manning equation:

$$v = \left(\frac{1.486}{n}\right) R^{2/3}\sqrt{S}$$

Transport Velocity (V) = **2.24 ft/s** 1.5<x<4.0 fps 27.00 cfs

Headloss through channel = 0.192 ft

Entrance Loss

Loss from Pool 124 to the transport channel.

Transport Channel Velocity	2.24 ft/s
Pool velocity	0.47 ft/s
Delta V	1.77 ft/s
Entrance Loss Coeficient	0.1
Head loss is	0.005

Exit Loss

Transport Channel Velocity	2.24 ft/s
Pool velocity	0.47 ft/s
Delta V	1.77 ft/s
Exit Loss Coeficient	0.3
Head loss is	0.015 ft

Total head loss **0.211 ft**

Conclusion

In order to maintain the same water depth as the pools, a transport channel depth of 3 ft and a width of 4 ft were selected.
The slope was selected to be relatively flat at 0.0003.
The transport velocity would be within the allowed transport velocity criteria.
Alternatively, a 48-inch diameter HDPE pipe could be used.

McMillen

SUBJECT:	County of San Luis Obispo	**BY:** V. Autier	**CHK'D BY:** M.Cerucci
	Steelhead Passage Feasibility Assessment of Lopez Dam	**DATE:** 7/1/2025	
	Downstream Fish Passage - Floating Surface Collector Sizing	**PROJECT NO.:** 25-062	

Purpose

The purpose of this calculation sheet is to determine the preliminary sizing for the floating surface collector.

References

- *NMFS 2011. Anadromous Salmonid Passage Facility Design. Northwest Region, July 2011*

Criteria

		Metric Units		Imperial Units		Meets
- Active Screen Approach Velocity	V_n max =	0.122	m/s	0.40016	ft/s	**No**
- Screen Sweeping Velocity	Trans V =	0.24< x<0.91	m/s	0.78<x<2.98	ft/s	**Yes**
- Exposure Time to the Screen	Exp Time <	60	sec			**Yes**

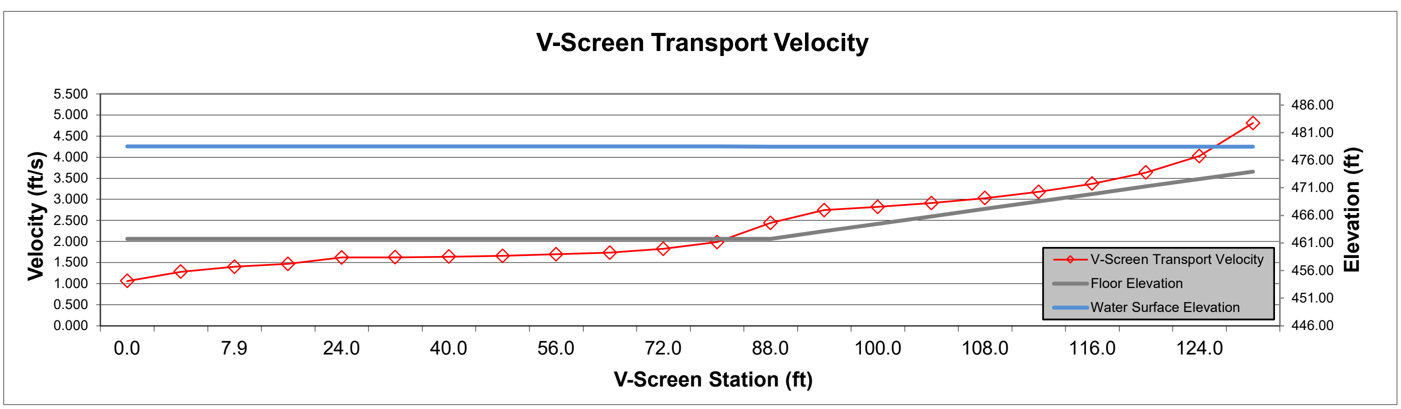
Information - Input

This spreadsheet uses the following assumptions:

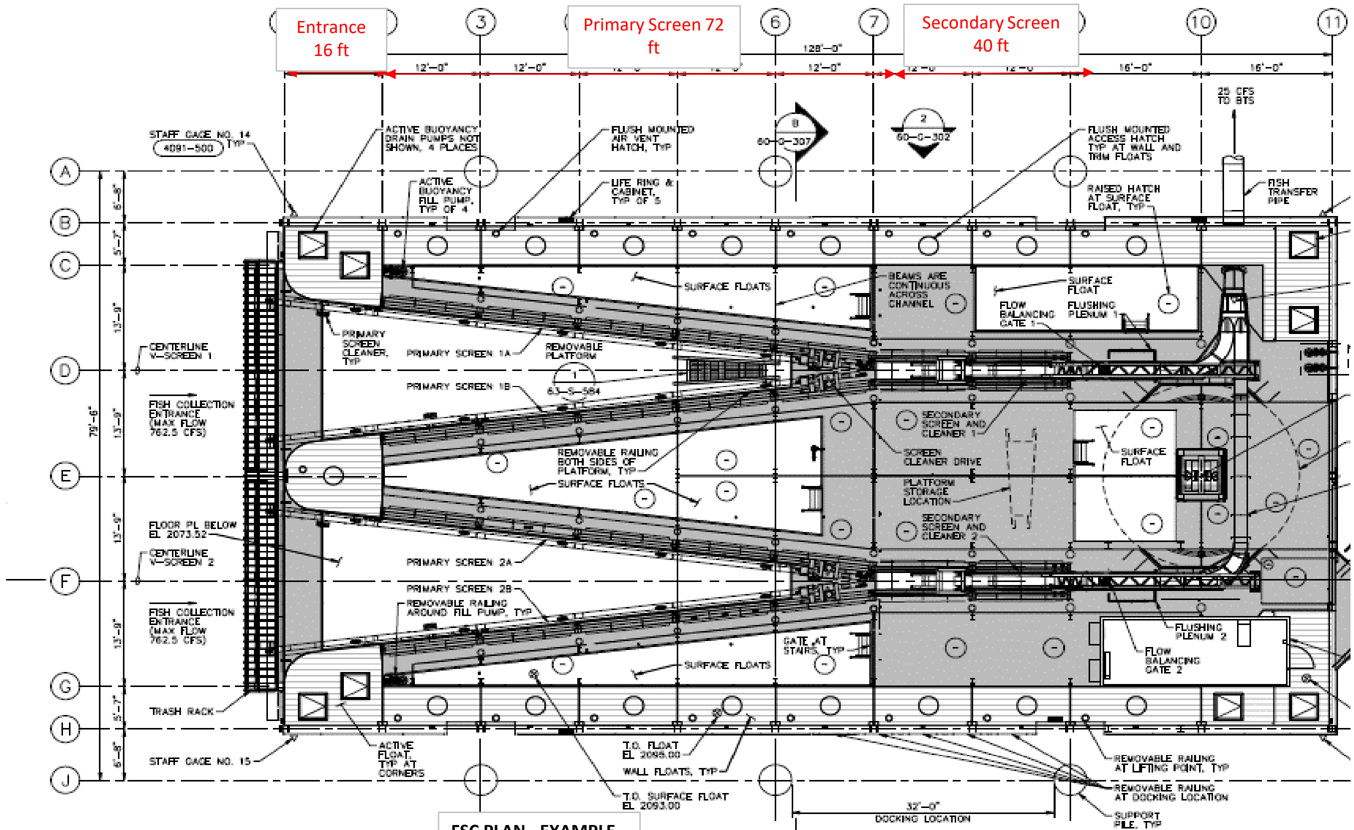
98% stage exceedance	Imperial Units		Metric Units
Maximum intake flow =	1000	cfs	28.32 m^3/s
Primary screen flow =	83.25	%	
Bypass flow =	20.00	cfs	0.566 m^3/s
Primary Wetted Screen Area =	89.98	%	
Secondary Wetted Screen Area =	10.02	%	
Top of screen =	478.64	feet	145.89 m
Screen Height =	16.75	feet	5.11 m
Throat =	24.00	inches	0.61 m
Opening =	20.00	feet	6.10 m
Wall slope =	0.28	rad	
	16.19	Degree	

wall slope 0.242321

ZONE	STA	WATER SURFACE	HGL	FLOOR ELEV	WIDTH	FLOW AREA	Q	TRANS V	Delta Q	Screen Area	Vn	Exposure Time
	ft	ft	m	ft	ft	ft^2	ft^3/s	ft/s	ft^3/s	ft^2	ft/s	Sec
Fish Collector Entrance	0.0	478.52	478.58	461.76	28.00	469	500.0	1.065	0.0	0.0		
Fish Collector Entrance	4.0	478.49	478.56	461.76	23.29	390	500.0	1.283	0.0	0.0		
Fish Collector Entrance	7.9	478.49	478.54	461.76	21.32	357	500.0	1.402	0.0	0.0		
Fish Collector Entrance	16.0	478.49	478.53	461.76	20.38	341	500.0	1.467	0.0	0.0		
Primary Screen	24.0	478.49	478.51	461.76	18.44	308	500.0	1.621	0.0	254.4	0.000	4.9
Primary Screen	32.0	478.49	478.51	461.76	16.50	276	448.8	1.626	51.2	254.3	0.191	9.9
Primary Screen	40.0	478.49	478.50	461.76	14.56	244	399.7	1.641	49.1	254.3	0.183	14.7
Primary Screen	48.0	478.49	478.50	461.76	12.63	211	350.6	1.660	49.1	254.3	0.183	19.6
Primary Screen	56.0	478.49	478.50	461.76	10.69	179	302.9	1.695	47.7	254.3	0.178	24.3
Primary Screen	64.0	478.49	478.49	461.76	8.75	146	253.9	1.735	49.1	254.3	0.183	28.9
Primary Screen	72.0	478.49	478.47	461.76	6.81	114	207.9	1.825	45.9	254.3	0.172	33.3
Primary Screen	80.0	478.49	478.44	461.76	4.87	81	162.0	1.988	45.9	254.3	0.172	37.3
Primary Screen - Throat	88.0	478.45	478.34	461.76	2.93	49	119.7	2.444	42.4	253.8	0.159	40.6
Secondary Screen	96.0	478.45	478.26	463.11	2.00	31	84.2	2.745	35.5	233.2	0.144	43.5
Secondary Screen	100.0	478.45	478.24	464.47	2.00	27.97	78.901	2.821	5.3	53.1	0.100	44.9
Secondary Screen	104.0	478.45	478.21	465.83	2.00	25.26	73.604	2.914	5.3	48.0	0.110	46.3
Secondary Screen	108.0	478.45	478.17	467.18	2.00	22.54	68.307	3.030	5.3	42.8	0.124	47.6
Secondary Screen	112.0	478.45	478.13	468.54	2.00	19.83	63.010	3.177	5.3	37.7	0.141	48.9
Secondary Screen	116.0	478.45	478.06	469.89	2.00	17.12	57.713	3.371	5.3	32.5	0.163	50.0
Secondary Screen	120.0	478.45	477.97	471.25	2.00	14.41	52.415	3.637	5.3	27.4	0.193	51.1
Secondary Screen	124.0	478.45	477.81	472.60	2.00	11.70	47.118	4.028	5.3	22.2	0.238	52.1
Secondary Screen	128.0	478.45	477.46	473.96	2.00	8.99	43.233	4.811	3.9	17.1	0.227	53.0
Weir	128.2	478.45	466.09	477.08	2.00	2.76	43.233	15.692				



Conclusion



FSC PLAN - EXAMPLE

SUBJECT: County of San Luis Obispo
Steelhead Passage Feasibility Assessment of Lopez Dam
Downstream Fish Passage - FSC Fish Return Pipe

BY: V. Autier CHK'D BY: M.Cerucci
DATE: 7/1/2025
PROJECT NO.: 25-062

Purpose

The purpose of this calculation sheet is to design a fish return pipe for which the maximum impact velocity is less than 7.62 m/s.

References

• *NMFS 2011. Anadromous Salmonid Passage Facility Design. Northwest Region, July 2011*

Criteria

- The minimum pipe diameter should not be less than 10 inches.
- Design fish return pipe velocity should be between 6 and 12 ft/s. 13900.64
- To reduce silt and sand accumulation in the return pipe, pipe velocity must not be less than 2.0 ft/s
- The maximum depth should be about 1.97 inch.
- Maximum impact velocity including vertical and horizontal velocity components should be less than 30.0 ft/s.

Information - Input

Top of Earthfill Dam	538.44	ft
Maximum Flood Level	533.46	ft
Maximum Normal Reservoir Level	533.46	ft
Minimum Normal Reservoir Level	522.47	ft
Minimum Flow Minimum Reservoir Elevation	425.91	ft
Minimum Operating Level		
Tailrace 95% Exceedance	364.08	ft
Tailrace 5% Exceedance	363.00	ft

Calculation

Starting elevation of pipe	534.64	ft	(estimated)
Pipe invert elevation	365.08	ft	
WSEL	364.1	ft	
Maximum drop	3.3	ft	

The fish return flume is:

L =	Fish return pipe length	4238	ft	
D =	Fish return pipe diameter	11.81	inches	(> 10 inches)
So =	Slope	0.04		(Assume)
n =	Manning's coefficient	0.012		
Q =	Flume flow	(Solve For)		

Normal depth:

$$Q = \frac{1.49}{n} \cdot A \cdot Rh^{2/3} \cdot So^{1/2}$$

Q = flume flow (solve for) m^3/s
n = Manning's coefficient 0.012
A = Flow aera as function of flow depth (m)

$$A = \left(\frac{D^2}{4}\right)(b - \cos b \times \sin b)$$

Where,

$$b = \cos^{-1}\left(1 - \frac{2Y}{D}\right)$$

D =	Inside diameter of pipe	0.98	ft	
Y =	Flow depth in feet	0.39	ft	(Assume; 40% of water depth in the pipe)
b =	1.369 Radians			
b =	78.46 Degree			

A = 0.28 ft^2

Rh = Hydraulic radius in m =A/WP

Where,

WP = wetted perimeter =**b*** D
WP = 1.348 ft
Rh = 0.211 ft

So = Slope 0.04

Q = 2.50 ft^3/s 0.071 cfs

Calculate the Velocity Vt (in the pipe)

$$v = \left(\frac{1.49}{n}\right) Rh^{2/3}\sqrt{So}$$

Vt =	**8.80** m/s	(6 fps < Vt < 12 fps)

Determine horizontal and vertical velocity components

Vt = Total velocity at pipe exit (fps)

Vx = Horizontal velocity component (fps)

Vx = cos(tan^{-1} (Slope))*Vt

Vx = 8.79 ft/s

Vz = Vertical velocity component (fps)

Vz = sin(tan^{-1} (Slope))*Vt

Vz = 0.35 ft/s

Determine impact velocity

Vj = Jet Impact velocity into pool (fps)

Vjz = Vertical component of jet impact (fps)

$$Vjz = \sqrt{Vz^2 + 2g \times h}$$

where,

h =	fall height	1.075 ft
g =	gravitational acceleration	32.20 m/sec^2

Vjz = 8.33 ft/s

$$Vj = \sqrt{Vjz^2 + Vx^2}$$

Vj =	**12.11** ft/s	(Vj < 25 ft/s)

Conclusion

If reaching for the tailrace 95% exceedance WSEL:
- The average slope shall be 0.04
- The return pipe velocity is in between 6 and 12 ft/s m/s.
- The return pipe flow is 2.5 ft^3/s.
- The pipe length would be 4,236 ft.

Installed cost =	$ 300	US$/ft	of installed 11.81inch DIA HDPE pipe (including support and debidding).
Bypass pipe length =	4238	ft	
Cost =	$ 1,271,400		

McMillen

SUBJECT:	County of San Luis Obispo	**BY:** V. Autier	**CHK'D BY:** 0
	Steelhead Passage Feasibility Assessment of Lopez Dam	**DATE:** 7/1/2025	
	Downstream Fish Passage - Floating Surface Collector Sizing	**PROJECT NO.:** 25-062	

Purpose

The purpose of this calculation sheet is to determine the preliminary sizing for the floating surface collector.

References

• *NMFS 2011. Anadromous Salmonid Passage Facility Design. Northwest Region, July 2011*

Criteria

		Metric Units		Imperial Units		Meets
- Active Screen Approach Velocity	V_n max =	0.122	m/s	0.40016	ft/s	**Yes**
- Screen Sweeping Velocity	Trans V =	0.24< x<0.91	m/s	0.78<x<2.98	ft/s	**Yes**
- Exposure Time to the Screen	Exp Time <	60	sec			**Yes**

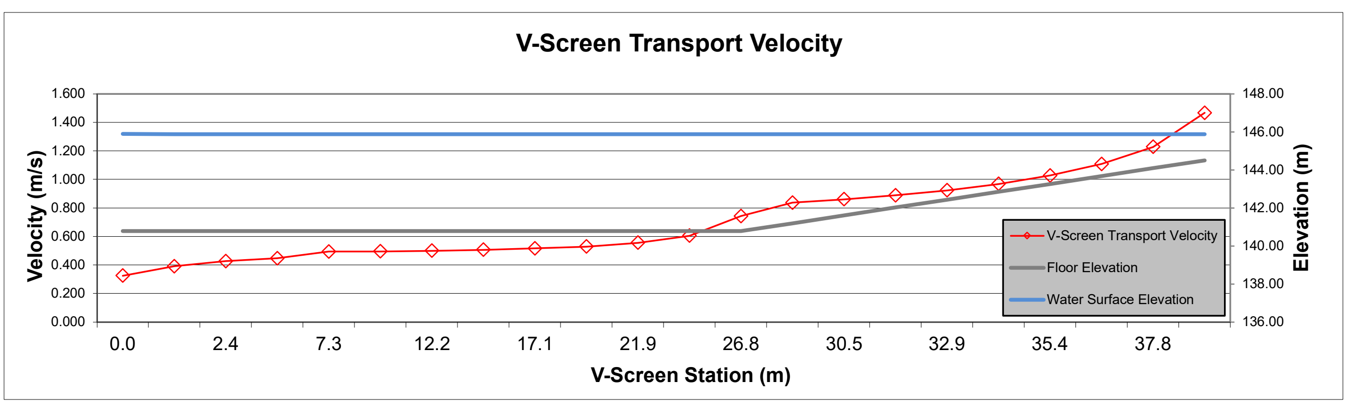
Information - Input

This spreadsheet uses the following assumptions:

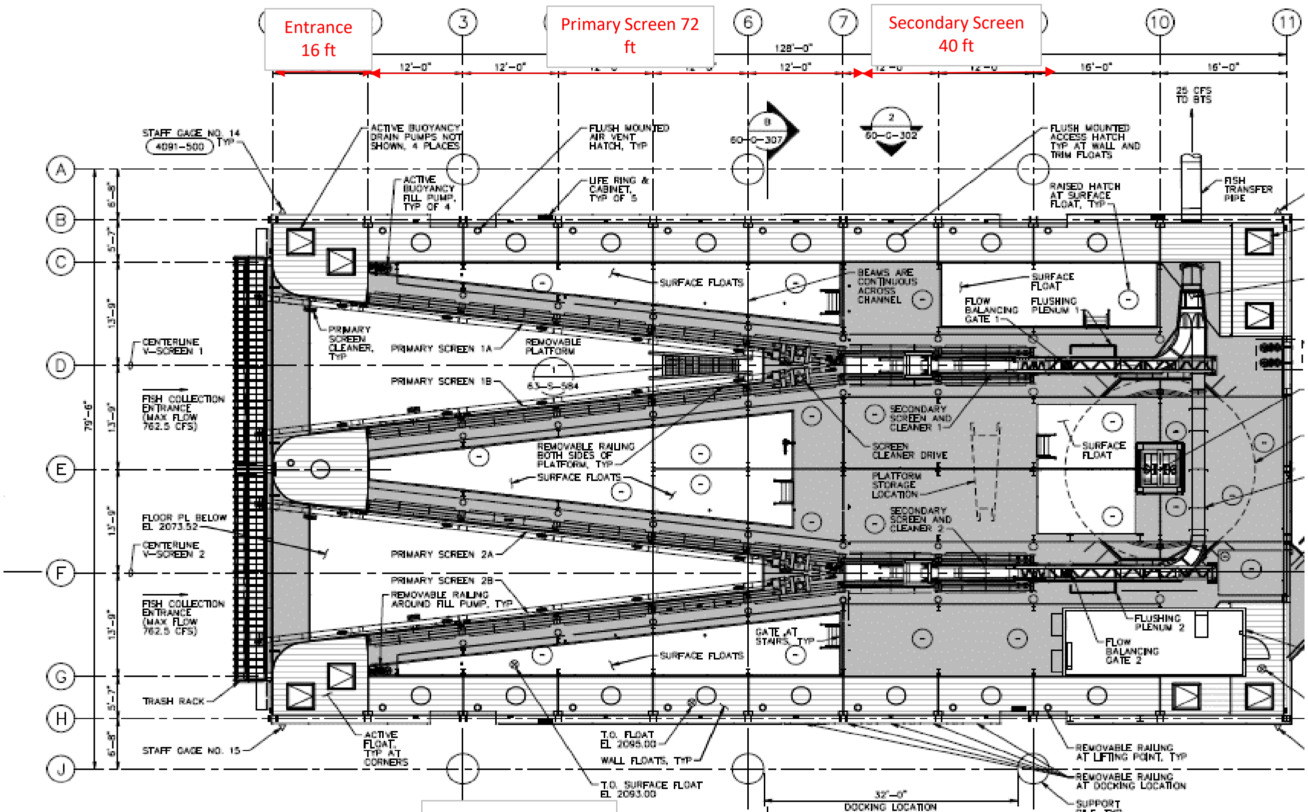
98% stage exceedance	Imperial Units		Metric Units
Maximum intake flow =	1000	cfs	28.32 m^3/s
Primary screen flow =	86.63	%	
Bypass flow =	20.00	cfs	0.566 m^3/s
Primary Wetted Screen Area =	89.98	%	
Secondary Wetted Screen Area =	10.02	%	
Top of screen =	478.64	feet	145.89 m
Screen Height =	16.75	feet	5.11 m
Throat =	24.00	inches	0.61 m
Opening =	20.00	feet	6.10 m
Wall slope =	0.07	rad	
	4.07	Degree	

wall slope 0.242321

ZONE	STA	WATER SURFACE	HGL	FLOOR ELEV	WIDTH	FLOW AREA	Q	TRANS V	Delta Q	Screen Area	Vn	Exposure Time
	m	m	m	m	m	m^2	m^3/s	m/s	m^3/s	m^2	m/s	Sec
Fish Collector Entrance	0.0	145.89	145.88	140.78	8.53	44	14.2	0.325	0.0	0.0		
Fish Collector Entrance	1.2	145.88	145.88	140.78	7.10	36	14.2	0.391	0.0	0.0		
Fish Collector Entrance	2.4	145.88	145.88	140.78	6.50	33	14.2	0.427	0.0	0.0		
Fish Collector Entrance	4.9	145.88	145.88	140.78	6.21	32	14.2	0.447	0.0	0.0		
Primary Screen	7.3	145.88	145.88	140.78	5.62	29	14.2	0.494	0.000	23.628	0.000	4.9
Primary Screen	9.8	145.88	145.88	140.78	5.03	26	12.7	0.495	1.450	23.628	0.058	9.9
Primary Screen	12.2	145.88	145.88	140.78	4.44	23	11.3	0.500	1.390	23.628	0.056	14.7
Primary Screen	14.6	145.88	145.88	140.78	3.85	20	9.9	0.506	1.390	23.628	0.056	19.6
Primary Screen	17.1	145.88	145.88	140.78	3.26	17	8.6	0.516	1.350	23.628	0.054	24.3
Primary Screen	19.5	145.88	145.88	140.78	2.67	14	7.2	0.528	1.390	23.628	0.056	28.9
Primary Screen	21.9	145.88	145.87	140.78	2.08	11	5.9	0.556	1.300	23.628	0.052	33.3
Primary Screen	24.4	145.88	145.87	140.78	1.49	8	4.6	0.605	1.300	23.628	0.052	37.3
Primary Screen - Throat	26.8	145.87	145.86	140.78	0.90	5	3.4	0.743	1.200	23.582	0.048	40.6
Secondary Screen	29.3	145.87	145.85	141.19	0.61	3	2.4	0.836	1.004	21.667	0.044	43.5
Secondary Screen	30.5	145.87	145.85	141.61	0.61	2.60	2.234	0.860	0.150	4.938	0.030	44.9
Secondary Screen	31.7	145.87	145.85	142.02	0.61	2.35	2.084	0.888	0.150	4.459	0.034	46.3
Secondary Screen	32.9	145.87	145.85	142.43	0.61	2.09	1.934	0.923	0.150	3.980	0.038	47.6
Secondary Screen	34.1	145.87	145.84	142.85	0.61	1.84	1.784	0.968	0.150	3.502	0.043	48.9
Secondary Screen	35.4	145.87	145.84	143.26	0.61	1.59	1.634	1.027	0.150	3.023	0.050	50.1
Secondary Screen	36.6	145.87	145.83	143.67	0.61	1.34	1.484	1.108	0.150	2.544	0.059	51.2
Secondary Screen	37.8	145.87	145.81	144.09	0.61	1.09	1.334	1.227	0.150	2.066	0.073	52.2
Secondary Screen	39.0	145.87	145.78	144.50	0.61	0.84	1.224	1.466	0.110	1.587	0.069	53.0
Weir	39.1	145.87	144.72	145.45	0.61	0.26	1.224	4.782				



Conclusion



FSC PLAN - EXAMPLE

McMillen

SUBJECT:	County of San Luis Obispo	**BY:** V. Autier	**CHK'D BY:** 0
	Steelhead Passage Feasibility Assessment of Lopez Dam	**DATE:** 7/1/2025	
	Downstream Fish Passage - FSC Fish Return Pipe	**PROJECT NO.:** 25-062	

Purpose

The purpose of this calculation sheet is to design a fish return pipe for which the maximum impact velocity is less than 7.62 m/s.

References

- *NMFS 2011. Anadromous Salmonid Passage Facility Design. Northwest Region, July 2011*

Criteria

- The minimum pipe diameter should not be less than 254 mm.
- Design fish return pipe velocity should be between 1.8 and 3.6 m/s.
- To reduce silt and sand accumulation in the return pipe, pipe velocity must not be less than 0.61 m/s
- The maximum depth should be about 50 mm.
- Maximum impact velocity including vertical and horizontal velocity components should be less than 7.62 m/s.

Information - Input

Top of Earthfill Dam	164.16	m
Maximum Flood Level	162.64	m
Maximum Normal Reservoir Level	162.64	m
Minimum Normal Reservoir Level	159.29	m
Minimum Flow Minimum Reservoir Elevation	129.85	m
Minimum Operating Level		m
Tailrace 95% Exceedance	111	m
Tailrace 5% Exceedance	110.67	m

Calculation

Starting elevation of pipe	163.00	m	(estimated)
Pipe invert elevation	111.33	m	
WSEL	111.0	m	
Maximum drop	0.3	m	

The fish return flume is:

L = Fish return pipe length	1292	m		4236.94
D = Fish return pipe diameter	300	mm	(> 254 mm)	
So = Slope	0.04		(Assume)	
n = Manning's coefficient	0.012			
Q = Flume flow	(Solve For)			

Normal depth:

$$Q = \frac{1.00}{n} \times A \times Rh^{2/3} \times So^{1/2}$$

Q = flume flow (solve for) m^3/s

n = Manning's coefficient 0.012

A = Flow aera as function of flow depth (m)

$$A = \left(\frac{D^2}{4}\right)(b - \cos b \times \sin b)$$

Where,

$$b = \cos^{-1}\left(1 - \frac{2Y}{D}\right)$$

D = Inside diameter of pipe 0.3 m

Y = Flow depth in feet 0.12 m (Assume; 40% of water depth in the pipe)

b = 1.369 Radians

b = 78.46 Degree

A = 0.03 m^2

Rh = Hydraulic radius in m =A/WP

Where,

WP = wetted perimeter =**b*** D

WP = 0.411 m

Rh = 0.064 m

So = Slope 0.04

Q = 0.07 m^3/s 2.5 cfs

Calculate the Velocity Vt (in the pipe)

$$v = \left(\frac{1.00}{n}\right) Rh^{2/3} \sqrt{So}$$

Vt =	**2.67** m/s	(1.8 m/s < Vt < 3.6 m/s)	8.77 fps	(6 fps < Vt < 12 fps)	8.7710591

Determine horizontal and vertical velocity components

Vt = Total velocity at pipe exit (fps)

Vx = Horizontal velocity component (fps)

Vx = cos($\tan^{-1}$ (Slope))*Vt

Vx = 2.67 m/s 8.76405066

Vz = Vertical velocity component (fps)

Vz = sin($\tan^{-1}$ (Slope))*Vt

Vz = 0.11 m/s 0.35056203

Determine impact velocity

Vj = Jet Impact velocity into pool (fps)

Vjz = Vertical component of jet impact (fps)

$$Vjz = \sqrt{Vz^2 + 2g \times h}$$

where,

h = fall height 0.33 m

g = gravitational acceleration 9.81 m/sec^2

Vjz = 2.55 m/s

$$Vj = \sqrt{Vjz^2 + Vx^2}$$

Vj =	**3.69** m/s	(Vj < 7.62 m/s)	12.11 fps	(Vj < 25 ft/s)

Conclusion

If reaching for the tailrace 95% exceedance WSEL:

- The average slope shall be 0.04
- The return pipe velocity is in between 1.8 and 3.6 m/s.
- The return pipe flow is 0.07 m^3/s.
- The pipe length would be 1,292 m.

Installed cost =	$	984	US$/m	of installed 300 mm DIA HDPE pipe (including support and debidding).
Bypass pipe length =		1292	m	
Cost =	$	1,271,082		

Appendix E. Engineering Cost Estimates

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Technical Memorandum

To:	David Spiegel County of San Luis Obispo	Project:	Steelhead Passage Feasibility Assessment of Lopez Dam
From:	Wendy Katagi McMillen, Inc.	cc:	
Prepared by:	Todd Harper McMillen, Inc.	Job No:	25-062
Reviewed by:	Vincent Autier, PE McMillen, Inc.	Date:	09/26/25
Subject:	Opinion of Probable Construction Cost (OPCC) Estimate (Class 5)		

Revision Log

Revision No.	Date	Revision Description
0	07/28/25	Draft Submittal
1	08/11/25	Revised Draft Submittal with Spreadsheet Corrections
2	09/09/25	Revised Draft Submittal with Format Corrections
3	09/26/25	Final Submittal

1.0 Introduction

1.1 Purpose

The purpose of this technical memorandum (TM) is to present the Opinion of Probable Construction Cost (OPCC) for two upstream and three downstream Steelhead Passage Alternatives at the Lopez Dam Project.

1.2 Estimate Preparation

This OPCC is based on the Fish Passage alternatives detailed in our Feasibility Assessment Report dated September 2025 and illustrated in our Conceptual Drawings dated 09/26/25. When possible, McMillen has utilized historical construction cost data from similar projects, which we have designed or constructed as a self-performing general contractor, as the basis of our OPCC estimate. Quantity takeoffs from the conceptual drawings were not calculated. Line items with quantities shown were calculated by the Engineer. Pricing for the Helical Fish Passage Alternative D-2 was calculated based on the Cle Elum Dam project noted in the feasibility assessment with adjustments for scale (about 1.75 times taller), inflation (constructed between 2019-2024), and State adjustment factor from Washington to California.

2.0 Engineer Cost Estimate

This section presents the estimate class selection of the cost estimate for this Project, the additional cost factors for this opinion of probable construction cost estimate. Operation and Maintenance (O&M) cost estimate has not been considered.

2.1 Estimate Class Selection

The American Association of Cost Engineering (AACE) provides guidelines for development of cost estimates for various levels of project definition (see Table 2-1). For this project, an AACE Class 5 cost estimate has been prepared with an accuracy from -50% to +100%.

Table 2-1. American Association of Cost Engineering Guidelines

	Primary Characteristic	*Secondary Characteristic*			
ESTIMATE CLASS	LEVEL OF PROJECT DEFINITION Expressed as % of complete definition	END USAGE Typical purpose of estimate	METHODOLOGY Typical estimating method	EXPECTED ACCURACY RANGE Typical variation in low and high ranges [a]	PREPARATION EFFORT Typical degree of effort relative to least cost index of 1 [b]
Class 5	0% to 2%	Concept Screening	Capacity Factored, Parametric Models, Judgment or Analogy	L: -20% to -50% H: +30% to +100%	1
Class 4	1% to 15%	Study of Feasibility	Equipment Factored or Parametric Models	L: -15% to -30% H: +20% to +50%	2 to 4
Class 3	10% to 40%	Budget, Authorization, or Control	Semi-Detailed Unit Costs with Assembly Level Line Items	L: -10% to -20% H: +10% to +30%	3 to 10

	Primary Characteristic	*Secondary Characteristic*			
ESTIMATE CLASS	LEVEL OF PROJECT DEFINITION Expressed as % of complete definition	END USAGE Typical purpose of estimate	METHODOLOGY Typical estimating method	EXPECTED ACCURACY RANGE Typical variation in low and high ranges [a]	PREPARATION EFFORT Typical degree of effort relative to least cost index of 1 [b]
Class 2	30% to 70%	Control or Bid/ Tender	Detailed Unit Cost with Forced Detailed Take-Off	L: -5% to -15% H: +5% to +20%	4 to 20
Class 1	50% to 100%	Check Estimate or Bid/Tender	Detailed Unit Cost with Detailed Take-Off	L: -3% to -10% H: +3% to +15%	5 to 100

Notes:

(a) The state of process technology and availability of applicable reference cost data affect the range markedly. The +/- value represents typical percentage variation of actual costs from the dost estimate after application of contingency (typically at a 50% level of confidence) for give scope.

(b) If the range index value of “1” represents 0.005% of project costs, then an index value of 100 represents 0.5%. Estimate preparation effort is highly dependent upon the size of the project and the quality of estimating data and tools.
Source: AACE International Recommended Practice No. 17R-97

2.2 Basis of Cost Estimate

The Class 5 alternative cost estimate is based on the Conceptual Drawings dated 09/26/25. The costs were developed using similar work or features of work from historical projects or cost estimates, as well as utilizing unit price cost ranges as the primary basis for cost. Estimator judgement was used in selecting the unit price based on the standard unit price ranges and factoring similar cost features. Activities with little definition were priced with allowances based on estimator judgement. Quantities were taken off for major scopes such as earthwork and concrete based on dimensions illustrated in the concept site drawings and estimated dimensions not yet detailed.

Class 5 cost accuracy ranges are wide due to the low project definition. Class 5 costs help provide basis for screening alternatives. Pricing is typically reviewed on a large scale for reasonableness based on similar projects, similar features of work, and using judgement in comparing pricing between the scope of each alternative.

The Lopez Dam Steelhead Passage Options alternative cost estimates were based on the following project mark ups:

- **General Contract Requirements (20% & 25%):** This factor includes mobilization/de-mobilization, temporary facilities, erosion control, special testing, and other Division 1 contract requirements. It is applied to the construction cost subtotal including contingency. Alternatives greater than $1M were priced at 20% and projects less than $1M were priced at 25%.
- **Overhead (6%) and Profit (12%):** These factors cover general contractor overhead and profit. They are applied to the construction cost subtotal including contingency.
- **Construction Bond and Insurance Rate (2%)**: A construction bond and insurance rate of 2% was assumed based on other projects of similar size and complexity.
- **Contingency (10%):** A contingency of 10% is added assuming further refinement of the project. Project contingency at this phase of project design can range up to 35% to account for both construction and design contingency. Due to the wide accuracy applied, a 10% contingency is used to account for normal construction contingency only. The estimate accuracy range should include any design contingency.

2.3 Construction Cost Estimate

The OPCC represents a direct supply and install cost with standard general markups add-ons. Table 2-2 provides a summary of the OPCC in 2025 dollars for the Project. The detailed cost estimate is presented in Appendix A. The following was used for the development of the OPCC:

- **Basis of Quantity Calculations:** Conceptual design level drawings were prepared as part of the development of each alternative. The engineer prepared a quantity take off for each element where sufficient information was available. The quantities represent neat line. Wastage was not included in this basis of quantity calculations.
- **Basis of Unit Rates:** The unit rates are based on consultant past projects. For this level of effort, no quotes were gathered, and RS Means pricing was not used.

Table 2-2. Engineer's Cost Estimate

Line Item	Upstream Fish Passage		Downstream Fish Passage		
	Alt U-1	Alt U-2	Alt D-1	Alt D-2	Alt D-3
	Vertical Slot Fishway	Trap and Haul	Floating Surface Collector	Helical Fish Passage System	In-Tributaries Trap and Haul
GC's & Mobilization	$6,541,812	$90,875	$4,760,295	$29,457,000	$137,500
Existing Conditions	$45,000	$25,000	$50,000	$120,000	$50,000
Concrete	$12,866,240	$0	$0	$54,360,000	$0
Metals	$6,062,500	$95,000	$0	$2,718,000	$190,000
Equipment	$0	$175,000	$5,963,500	$21,744,000	$175,000
Special Construction	$912,500	$0	$27,795,721	$14,496,000	$0
Electrical	$741,000	$0	$6,000,000	$7,248,000	$0
Instrumentations and Controls	$727,500	$0	$500,000	$1,268,000	$0
Plumbing	$0	$0	$0	$906,000	$0
Earthwork	$6,070,296	$47,500	$0	$18,120,000	$95,000
Exterior Improvements	$9,000	$21,000	$0	$3,624,000	$40,000
Utilities	$3,200,000	$0	$1,314,400	$10,000,000	$0
Marine and Waterway	$2,075,025	$0	$13,695,354	$12,681,000	$0
Total Construction Price	**$39,250,873**	**$454,375**	**$60,079,270**	**$176,742,000**	**$687,500**
Taxes, Overhead, Profit & Bond					
Overhead - 6%	$2,355,052	$27,263	$3,604,756	$10,604,520	$41,250
Profit - 12%	$4,710,105	$54,525	$7,209,512	$21,209,040	$82,500
Construction Bonds and Insurance - 2%	$832,119	$9,633	$1,273,681	$3,746,930	$14,575
Total Construction Cost	$7,897,276	$91,420	$12,087,949	$35,560,490	$138,325
Contingency					
Contingency - 10%	$4,714,800	$54,600	$7,216,700	$21,230,200	$82,600
Median Construction Cost	**$46,613,627**	**$600,395**	**$79,370,708**	**$237,706,781**	**$908,425**
Construction Cost Range (-50%)	$23,307,000	$300,000	$39,685,000	$118,853,000	$454,000
Construction Cost Range (+100%)	$93,227,000	$1,201,000	$158,741,000	$475,414,000	$1,817,000

Appendix A. OPCC Calculation Spreadsheets

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McMillen

Lopez Dam Upstream Fish Passage - Vertical Slot Fishway

				McMillen, Inc.		
Line Item	Item	Quantity	Unit	Unit Price	Price	Sub Total
	Division 01 - General Requirements					**$6,541,812**
1	GC's & Mobilization (20% of Direct Costs)	1	LS	$6,541,812	$6,541,812	
	Division 02 - Existing Conditions					**$45,000**
2	Clearing & Grubbing	1	LS	$15,000	$15,000	
3	Temporary Access Roads, Lay Down & Storage	1	LS	$30,000	$30,000	
	Division 03 - Concrete					**$12,866,240**
4	Fish Ladders	2,023	CY	$2,500	$5,058,363	
5	Resting Pools	390	CY	$2,500	$974,350	
6	Exit Pools	2,733	CY	$2,500	$6,833,528	
	Division 05 - Metals					**$6,062,500**
7	Grating	190,000	SF	$25	$4,750,000	
8	Handrail	3,700	LF	$150	$555,000	
9	Sheetpiles	10,000	SF	$72	$720,000	
10	Trash Rack	25	EA	$1,500	$37,500	
	Division 11 - Equipment					**$0**
11	NONE					
	Division 13 - Special Construction					**$912,500**
12	Utility Enclosure	450	SF	$250	$112,500	
13	Grout injection (to protect the dam core)	200	CY	$4,000	$800,000	
	Division 26 - Electrical					**$741,000**
14	Electrical Service, 480V, 3 Phase	1	LS	$602,000	$602,000	
15	Standby Generator	1	EA	$75,000	$75,000	
16	Automatic Transfer Switch	1	EA	$10,000	$10,000	
17	Disconnect Switches	18	EA	$3,000	$54,000	
	Division 26 - I&C					**$727,500**
18	SCADA PLC Cabinet with Auto Dialer	1	LS	$350,000	$350,000	
19	Miscellaneous Material	1	LS	$50,000	$50,000	
20	Level Sensors/Misc Instrumentation	50	EA	$5,000	$250,000	
21	Phone Line	1	EA	$2,500	$2,500	
22	Commissioning Support	30	DAYS	$2,500	$75,000	
	Division 22 - Plumbing					**$0**
23	NONE					
	Division 31 - Earthwork					**$6,070,296**
24	Site Grading	1	LS	$50,000	$50,000	
25	Cofferdam (Tailrace)	1	LS	$250,000	$250,000	
26	Cofferdam (Forebay)	1	LS	$1,250,000	$1,250,000	
27	Dewatering	1	LS	$35,000	$35,000	
28	Fill for Fish Ladder	1	LS	$300,000	$300,000	
29	Excavation for Exit Structure	1	LS	$200,000	$200,000	
30	Excavation & Shoring for Trench	1	LS	$350,000	$350,000	
31	Trench (Dam) Zoned Fill Material	1	LS	$500,000	$500,000	
32	Site Restoration	1	LS	$75,000	$75,000	
33	Large fill area along the exit structure	21,859	CY	$140	$3,060,296	
	Division 32 - Exterior Improvements					**$9,000**
34	Asphalt Paved Access Road	600	SF	$15	$9,000	
	Division 33 - Utilities					**$3,200,000**
35	65-inch DIA HDPE Pipe (Transport channel)	640	LF	$5,000	$3,200,000	
	Division 35 - Waterway and Marine Construction					**$2,075,025**
36	Fishway Entrance 2'X2' Slide Gate (manual)	1	EA	$15,000	$15,000	
37	Exit Gates and Operator (4' x 5')	25	EA	$40,000	$1,000,000	
38	Isolation Gates in exit pools	25	EA	$40,001	$1,000,025	
39	Isolation Gate (6' x 6') with Operator	1	EA	$60,000	$60,000	
	Total Direct Cost					**$39,250,874**

McMillen

Lopez Dam Upstream Fish Passage - Trap and Haul

Line Item	Item	Quantity	Unit	Unit Price	Price	Sub Total
				McMillen, Inc.		
	Division 01 - General Requirements					**$90,875**
1	GC's & Mobilization	1	LS	$90,875	$90,875	
	Division 02 - Existing Conditions					**$25,000**
2	Clearing & Grubbing	1	LS	$10,000	$10,000	
3	Temporary Access Roads, Lay Down & Storage	1	LS	$15,000	$15,000	
	Division 03 - Concrete					**$0**
4	NONE			$0	$0	
	Division 05 - Metals					**$95,000**
5	Picket Barrier (Materials & Installation)	1	LS	$30,000	$30,000	
6	Trap Box (Materials & Installation)	1	LS	$65,000	$65,000	
	Division 11 - Equipment					**$175,000**
7	Live Fish Transport Truck	1	EA	$175,000	$175,000	
	Division 13 - Special Construction					**$0**
8	NONE			$0	$0	
	Division 26 - Electrical					**$0**
9	NONE			$0	$0	
	Division 26 - I&C					**$0**
4	NONE			$0	$0	
	Division 22 - Plumbing					**$0**
5	NONE			$0	$0	
	Division 31 - Earthwork					**$47,500**
6	Site Grading	1	LS	$40,000	$40,000	
7	Site Restoration	1	LS	$7,500	$7,500	
	Division 32 - Exterior Improvements					**$21,000**
8	Access Road	4,200	SF	$5	$21,000	
	Division 33 - Utilities					**$0**
9	NONE			$0	$0	
	Division 35 - Waterway and Marine Construction					**$0**
10	NONE			$0	$0	
	Total Direct Cost					**$454,375**

McMillen

Lopez Dam Downstream Fish Passage - Floating Surface Collector						
				McMillen. Inc.		
Line Item	Item	Quantity	Unit	Unit Price	Price	Sub Total
	Division 01 - General Requirements					**$4,760,295**
1	General, Mobilization and Demobilization	1	LS	$4,760,295	$4,760,295	
	Division 02 - Existing Conditions					**$50,000**
2	Clearing & Grubbing	1	LS	$10,000	$10,000	
3	Temporary Access Roads, Laydown & Storage	1	LS	$40,000	$40,000	
	Division 03 - Concrete					**$0**
4	NONE					
	Division 05 - Metals					**$0**
5	NONE					
	Division 11 - Equipment					**$5,963,500**
6	Shore Anchors - Debris Boom	2	EA	$300,000	$600,000	
7	Lake Anchor - Debris Boom	1	EA	$100,000	$100,000	
8	Continuous HDPE Boom w/ Skirt and angled freeboard	2,700	LF	$390	$1,053,000	
9	Boat Gate (for debris Boom)	2	EA	$165,000	$330,000	
10	Shore Anchors - Netting	2	EA	$75,000	$150,000	
11	Lake Anchors - Netting	2	EA	$80,000	$160,000	
12	Continuous Bottom Anchor	2,700	LF	$55	$148,500	
13	Guidance nets	181,000	SF	$9	$1,629,000	
14	Floatation Boom	2,700	LF	$250	$675,000	
15	Lowering/Raising System,	1	LS	$450,000	$450,000	
16	Boat Gate (for exclusion/guidance nets)	2	EA	$50,000	$100,000	
17	Fish Transport Tanks	4	EA	$52,000	$208,000	
18	5 Ton Transport Jib Crane	2	EA	$30,000	$60,000	
19	Transport Hoist Structure	18,000	LB	$7	$126,000	
20	5 Ton Transport Hoist and Trolley	1	EA	$20,000	$20,000	
21	Tank Guides	22,000	LB	$7	$154,000	
	Division 13 - Special Construction					**$27,795,721**
1	Floating Surface Collector (Barge)	1	LS	$22,884,000	$22,884,000	
2	Mooring Tower and Trestle	1	LS	$1,500,000	$1,500,000	
3	Anchors	3	EA	$300,000	$900,000	
4	Chain and Rope	2,200	LF	$100	$220,000	
5	Screen Supports	5,651	SF	$210	$1,186,721	
6	Fish Separator Bars	2	EA	$15,000	$30,000	
7	Holding Tanks	5	EA	$50,000	$250,000	
8	Crowders	5	EA	$25,000	$125,000	
9	Sampling Facility	1	LS	$700,000	$700,000	
	Division 26 - Electrical					**$6,000,000**
10	General	1	LS	$6,000,000	$6,000,000	
	Division 26 - I&C					**$500,000**
11	Testing and Startup	1	EA	$500,000	$500,000	
	Division 22 - Plumbing					**$0**
12	NONE					
	Division 31 - Earthwork					**$0**
13	NONE					
	Division 32 - Exterior Improvements					**$0**
14	NONE					
	Division 33 - Utilities					**$1,314,400**
15	Fish Return Pipe	4,240	LF	$310	$1,314,400	
	Division 35 - Waterway and Marine Construction					**$13,695,354**
16	Screen Panels and Baffles	5,650	SF	$250	$1,412,500	
17	Screen Cleaner System	2	EA	$2,700,000	$5,400,000	
18	Dewatering Pumps	1	LS	$5,000,000	$5,000,000	
19	FSC Trashracks	950	SF	$656	$622,854	
20	Trash Rake (Cleaners)	2	EA	$630,000	$1,260,000	
	Total Direct Cost					**$60,079,271**

McMillen

Lopez Dam Downstream Fish Passage - Helical Fish Passage System						
				McMillen. Inc.		
Line Item	Item	Quantity	Unit	Unit Price	Price	Sub Total
	Division 01 - General Requirements					**$29,457,000**
1	General, Mobilization and Demobilization	1	LS	$29,457,000	$29,457,000	
	Division 02 - Existing Conditions					**$120,000**
2	Clearing & Grubbing	1	LS	$20,000	$20,000	
3	Temporary Access Roads, Lay Down & Storage	1	LS	$100,000	$100,000	
	Division 03 - Concrete					**$54,360,000**
4	Concrete	1	LS	$54,360,000	$54,360,000	
	Division 05 - Metals					**$2,718,000**
5	Metals	1	LS	$2,718,000	$2,718,000	
	Division 11 - Equipment					**$21,744,000**
6	Equipment	1	LS	$21,744,000	$21,744,000	
	Division 13 - Special Construction					**$14,496,000**
7	Special Construction	1	LS	$14,496,000	$14,496,000	
	Division 26 - Electrical					**$7,248,000**
8	Electrical	1	LS	$7,248,000	$7,248,000	
	Division 26 - I&C					**$1,268,000**
9	Testing & Startup	1	LS	$1,268,000	$1,268,000	
	Division 22 - Plumbing					**$906,000**
10	Plumbing	1	LS	$906,000	$906,000	
	Division 31 - Earthwork					**$18,120,000**
11	Earthwork	1	LS	$18,120,000	$18,120,000	
	Division 32 - Exterior Improvements					**$3,624,000**
12	Exterior Improvements	1	LS	$3,624,000	$3,624,000	
	Division 33 - Utilities					**$10,000,000**
13	Juvenile Downstream Tunnel	2,000	LF	$5,000	$10,000,000	
	Division 35 - Waterway and Marine Construction					**$12,681,000**
14	Waterway and Marine Construction	1	LS	$12,681,000	$12,681,000	
	Total Direct Cost					**$176,742,000**

McMillen

Lopez Dam Downstream Fish Passage - In-Tributaries Trap-and-Haul						
				McMillen, Inc.		
Line Item	Item	Quantity	Unit	Unit Price	Price	Sub Total
	Division 01 - General Requirements					**$137,500**
1	GC's & Mobilization (25% of Direct Costs)	1	LS	$137,500	$137,500	
	Division 02 - Existing Conditions					**$50,000**
2	Clearing & Grubbing (Limits TBD)	2	EA	$10,000	$20,000	
3	Temporary Access Roads, Lay Down & Storage	2	EA	$15,000	$30,000	
	Division 03 - Concrete					**$0**
4	NONE			$0	$0	
	Division 05 - Metals					**$190,000**
5	Picket Barrier (Materials & Installation)	2	EA	$30,000	$60,000	
6	Trap Box (Materials & Installation)	2	EA	$65,000	$130,000	
	Division 11 - Equipment					**$175,000**
7	Live Fish Transport Truck	1	EA	$175,000	$175,000	
	Division 13 - Special Construction					**$0**
8	NONE			$0	$0	
	Division 26 - Electrical					**$0**
9	NONE			$0	$0	
	Division 26 - I&C					**$0**
10	NONE			$0	$0	
	Division 22 - Plumbing					**$0**
11	NONE					
	Division 31 - Earthwork					**$95,000**
12	Site Grading	2	EA	$40,000	$80,000	
13	Site Restoration	2	EA	$7,500	$15,000	
	Division 32 - Exterior Improvements					**$40,000**
14	Access Road improvements (Limits TBD)	2	EA	$20,000	$40,000	
	Division 33 - Utilities					**$0**
15	NONE			$0	$0	
	Division 35 - Waterway and Marine Construction					**$0**
16	NONE			$0	$0	
	Total Direct Cost					**$687,500**

Project: Lopez Dam - Fish Passage Evaluation - Cost Estimate
Location: California
Date: 17-Sep-25

Operation & Maintenance Cost — **Amount**

	Vertical Slot Fishway	Trap-and-Haul Facility	Floating Surface Collector	Helical Fish Passage System	In-Tributary Trap-and-Haul
Personnel	$ 134,650	$ 195,200	$ 237,500	$ 127,500	$ 230,600
Transportation	$ -	$ 8,720	$ 8,720	$ -	$ 17,440
Power	$ 20,000	$ -	$ 310,195	$ 25,000	$ -
Materials	$ 5,000	$ 10,500	$ 5,000	$ 5,000	$ 21,000
Expenses	$ -	$ -	$ -	$ -	$ -
Subtotal	$ 159,650	$ 214,420	$ 561,415	$ 157,500	$ 269,040
Contingency @ 30%	$ 47,895	$ 64,326	$ 168,424	$ 47,250	$ 80,712
Total	$ 207,545	$ 278,746	$ 729,839	$ 204,750	$ 349,752

Notes:
All costs are order-of-magnitude costs for comparative purposes only.

Vertical Slot Fishway

Line Item	Item	Quantity	Unit	Unit Cost (2025)	Cost	Total Cost
1	**Personnel**					**$ 134,650**
2	**Operation**					
3	Project Manager	0.5	FTE	120000	$ 60,000	
4	(1) Field Biologist	0.33	FTE	105000	$ 34,650	
5						
6	**Maintenance**					
7	Electrician	160	hr	125	$ 20,000	
8	Mechanic	160	hr	125	$ 20,000	
9						
10	**Transportation**					**$ -**
11	NONE					
12						
13	**Power**					**$ 20,000**
14	General Site Consumption	1	LS	20000	$ 20,000	
15						
16	**Materials**					**$ 5,000**
17	Consumables	1	LS	5000	$ 5,000	
18						
19	**Expenses**					**$ -**
20	None					
21						
22	**Project Subtotal**					**$ 159,650**
23						
24	**Contingency**	30%	LS			**$ 47,895**
25						
26	**Project Total**					**$ 207,545**

Trap-and-Haul

Line Item	Item	Quantity	Unit	Unit Cost (2025)	Cost	Total Cost
1	**Personnel**					**$ 195,200**
2	**Operation**					
3	Project Manager	0.75	FTE	120000	$ 90,000	
4	(2) Field Biologists/Drivers	0.99	FTE	105000	$ 103,950	
5						
6	**Maintenance**					
7	Electrician	0	hr	125	$ -	
8	Mechanic	10	hr	125	$ 1,250	
9						
10	**Transportation**					**$ 8,720**
11	Truck Cost per kilometer	9600	ML	$ 0.700	$ 6,720	
12	Truck maintenance per year	1	LS	$ 2,000	$ 2,000	
13	**Power**					
14	None					
15						
16						
17	**Materials**					**$ 10,500**
18	Oxygen Tanks	1	LS	$ 3,000	$ 3,000	
19	Pump and Oxygen Diffusers Parts	1	LS	$ 1,000	$ 1,000	
20	Lock/Equipment	1	LS	$ 500	$ 500	
21	Monitoring and Evaluation	1	LS	$ 500	$ 500	
22	Building Supplies	1	LS	$ 500	$ 500	
23	Consumables	1	LS	$ 5,000	$ 5,000	
24						
25						
26						
27						
28	**Expenses**					**$ -**
29	NONE					
30						
31	**Project Subtotal**					**$ 214,420**
32						
33	**Contingency**	30%	LS			**$ 64,326**
34						
35	**Project Total**					**$ 278,746**

Floating Surface Collector

Line Item	Item	Quantity	Unit	Unit Cost (2025)	Cost	Total Cost
1	**Personnel**					**$ 237,500**
2	**Operation**					
3	Project Manager	0.5	FTE	120000	$ 60,000	
4	(2) Field Biologists/Drivers	1.5	FTE	105000	$ 157,500	
5						
6						
7	**Maintenance**					
8	Electrician	80	hr	125	$ 10,000	
9	Mechanic	80	hr	125	$ 10,000	
10						
11	**Transportation**					**$ 8,720**
12	Truck Cost per kilometer	9600	ML	$ 0.700	$ 6,720	
13	Truck maintenance per year	1	LS	$ 2,000	$ 2,000	
14						
15	**Power**					**$ 310,195**
16	Pumps	1	LS	300195	$ 300,195	
17	General Site Consumption	1	LS	10000	$ 10,000	
18						
19	**Materials**					**$ 5,000**
20	Consumables	1	LS	5000	$ 5,000	
21						
22	**Expenses**					**$ -**
23	NONE					
24						
25	**Project Subtotal**					**$ 561,415**
26						
27	**Contingency**	30%	LS			**$ 168,424**
28						
29	**Project Total**					**$ 729,839**

Helical Fish Passage System

Line Item	Item	Quantity	Unit	Unit Cost (2025)	Cost	Total Cost
1	**Personnel**					**$ 127,500**
2	**Operation**					
3	Project Manager	0.5	FTE	120000	$ 60,000	
4	(1) Field Biologist	0.5	FTE	105000	$ 52,500	
5						
6	**Maintenance**					
7	Electrician	60	hr	125	$ 7,500	
8	Mechanic	60	hr	125	$ 7,500	
9						
10	**Transportation**					**$ -**
11	NONE					
12						
13	**Power**					**$ 25,000**
14	General Site Consumption	1	LS	25000	$ 25,000	
15						
16						
17	**Materials**					**$ 5,000**
18	Consumables	1	LS	5000	$ 5,000	
19						
20	**Expenses**					**$ -**
21	NONE					
22						
23	**Project Subtotal**					**$ 157,500**
24						
25	**Contingency**	30%	LS			**$ 47,250**
26						
27	**Project Total**					**$ 204,750**

In-tributary Trap-and-Haul

Line Item	Item	Quantity	Unit	Unit Cost (2025)	Cost	Total Cost
1	**Personnel**					**$ 230,600**
2	**Operation**					
3	Project Manager	0.75	FTE	120000	$ 90,000	
4	(2) Field Biologists/ (2) Drivers	1.32	FTE	105000	$ 138,600	
5						
6	**Maintenance**					
7	Electrician	0	hr	125	$ -	
8	Mechanic	16	hr	125	$ 2,000	
9						
10	**Transportation**					**$ 17,440**
11	Truck Cost per kilometer	19200	ML	$ 0.700	$ 13,440	
12	Truck maintenance per year	2	LS	$ 2,000	$ 4,000	
13	**Power**					
14	None					
15						
16						
17	**Materials**					**$ 21,000**
18	Oxygen Tanks	2	LS	$ 3,000	$ 6,000	
19	Pump and Oxygen Diffusers Parts	2	LS	$ 1,000	$ 2,000	
20	Lock/Equipment	2	LS	$ 500	$ 1,000	
21	Monitoring and Evaluation	2	LS	$ 500	$ 1,000	
22	Building Supplies	2	LS	$ 500	$ 1,000	
23	Consumables	2	LS	$ 5,000	$ 10,000	
24						
25						
26						
27						
28	**Expenses**					**$ -**
29	NONE					
30						
31	**Project Subtotal**					**$ 269,040**
32						
33	**Contingency**	30%	LS			**$ 80,712**
34						
35	**Project Total**					**$ 349,752**

Appendix F. County and TAC Coordination Meeting Minutes

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Public Works Department

Lopez HCP Interagency Pre-Application Meeting Agenda

Tuesday May 20, 2025 @ 3:00PM

Location – 1120 Mill St, San Luis Obispo and via TEAMS

COUNTY of SAN LUIS OBISPO

Participants

County of San Luis Obispo, USFWS, NOAA/NMFS

Meeting Objective(s)

Establish Pre-Application Consultation Process for Lopez HCP

Discuss Covered Species, Plan Duration, Covered Activities

Present Overview of Conservation Measures

Meeting Agenda	Time
1. Introductions and Agency Administrative Updates	15 minutes
2. Preliminary Injunction a. Establish recurring meeting schedule for June/July/August/September ahead of court-ordered October 1, 2025 Draft HCP submittal b. Confirm pre-application consultation process of draft sections provided for agency review 2 weeks prior to each meeting for real time iterative feedback/Q&A occuring during meeting c. Establish process for elevating or tabling conflicts for future meetings as needed	20 minutes
3. Draft HCP Scope Components a. Outline Overview b. Plan Area/Covered Area- Lower Arroyo Grande Creek from Lopez Dam to Leveed portion of creek c. Covered Species-Steelhead, CRLF, Tidewater Goby, Least Bell's Viero, Others? d. Plan Duration-50 years	35 minutes
4. Conservation Measures Overview	20 minutes

Next Meeting Topics

a. Tabled Items
b. Conservation Measures
c. Biological Goals and Objectives
d. Existing Conditions

Meeting Minutes

To:	Project Team/File	Date:	05/20/2025
From:	Blair Hurst	Job no:	25-062
cc:			
Project:	Lopez Dam Steelhead Passage Feasibility Assessment		
Subject:	HCP Pre-Application Meeting		

This memorandum documents the HCP Pre-Application meeting held on May 20, 2025. The meeting started at 4:00 p.m., Mountain Standard Time (MST) and was adjourned at approximately 5:30 p.m. The following people attended the meeting:

Name	Organization
Kate Ballentine	County of San Luis Obispo
Nola Engelskirger	County of San Luis Obispo
Lisa Bugrova	County of San Luis Obispo
David Spiegel	County of San Luis Obispo
Kate Shea	County of San Luis Obispo
Ethan Bell	Stillwater Sciences
Rebecca Hays Barho	Nossaman LLP
Rob Thornton	Nossaman LLP
Wendy Katagi	McMillen
Blair Hurst	McMillen
Sharon Hsu	H.T. Harvey
Joseph Brandt	USFWS
Kirby Bartlett	USFWS
Zachary Crum	CDFW
Krissy Atkinson	CDFW
Mandy Ingham	NMFS
Matt McGoogan	NMFS

The meeting was conducted according to the agenda prepared by the County of San Luis Obispo (County) and presented the County's Power Point slide deck "Final Draft Lopez HCP Interagency Pre-Application Meeting 1 5.20.2025". The agenda and sides are attached to the meeting minutes.

1.0 Introductions and Agency Administrative Updates

This section of the meeting was dedicated to talking about the Lopez Dam Preliminary Injunction (PI) Plans and how they relate to the Lopez Dam Habitat Conservation Plan (HCP), and how the County is going to work through preparing the HCP by October 1, 2025. The County plans on regular meetings with this group to gain consensus at critical milestones.

The project schedule was presented, organized by Draft HCP component, and included meeting dates and review windows ahead of each meeting:

Month 1 (May 20) –

- PI Plans and Conservation Strategy Overview
- Covered Species
- Covered Lands

Month 2 (June 24) –

- Covered Activities: Flow Enhancement/Water Management
- Conservation Strategy: Biological Goals and Objectives

Month 3 (July 22) –

- Conservation Strategy:
    - Instream Restoration and Enhancement
    - Off-Channel/Backwater Habitat Creation
    - Erosion Control BMPs
    - Riparian Vegetation Enhancement

Month 4 (August 26) –

- Conservation Strategy: Fish Passage Feasibility

Month 5 (September 16) –

- Adaptive Management

- Monitoring
- Issues Previously Tabled

Joseph – Ambitious schedule. The devil in the details as to whether it is feasible. Kirby will have other projects; can't dedicate staff to this project. **Kate** – we will rely upon previous work/studies to help expedite/decrease load. The County WILL meet legal obligations for 10/1. There will be an opportunity for review after 10/1 draft submittal.

Joseph – How will we treat info/study gaps? **David** – we will track and build these into the schedule; will adaptively manage moving forward in transparent way.

Joseph – Appreciate meeting, verbal communication (since not doing formal drafts and comments response), and need to make sure there is a decision record; tracking decisions being made and discussed to take care of any legal challenges that may arise. **Kate** – County will be taking notes at the meetings, track decisions and outcomes. Avoid providing section, getting formal comment letter back and forth – keep more flexible, verbal and document, plus provide to the group

Mandy – Injunction driven deadline of Oct 1. At what point would you want the section 10A permit in hand? **Kate** – ASAP.

2.0 Preliminary Injunction

Plans required due to the preliminary injunction:

- Flow Release Plan
- Steelhead Monitoring Plan*
- Biddle Park Culvert Monitoring Plan*
- Spillway Fish Screen Plan*
- Passage Barriers Plan*
- Sediment BMP Plan*
- Volitional Passage Plan*
- Habitat Conservation Plan
- Predator Removal Plan*

- Habitat Restoration Plan*

Elements of plans with an asterisk (*) will be incorporated as Conservation Measures in the HCP.

The County has prepared and submitted all plans to NMFS, except the Passage Barrier Plan.

3.0 Draft HCP Scope Components

Consultation process for draft HCP sections – review in advance, real-time Q&A during meetings.

Draft HCP Components-Outline Overview for Agency Input

Month 1:

- Covered Lands/Area
- Covered Species

Covered Area

Blue outline on slide is where County has Section 7 consultation for flood control (waterway management program area). Ethan confirmed description provided. Can influence creek most in upper reaches of watershed

Flow releases intended to coincide with natural events in the watershed to ensure suitable migration conditions upstream to Lopez dam. Releases all through winter.

Joseph – is water released affecting tidewater gobi? Appropriate to have "those things" in agreement. **David** – water release from Lopez influences water levels in lagoon. If there's a compelling case that covered activities could result in take – then would want to include.

Joseph – is lagoon breach a covered activity? **David** – Year-round releases would not be used to break lagoon. **Joseph** – relying on natural breach of lagoon? **David** – Yes. Will include assessment of bar breaching.

Joseph – Evaluated flows to assess migration … spawning and rearing year-round? **David** –Yes, including water temperature consideration.

Mandy – for covered area – reaches where have effects AND areas where have conservation benefit too.

Quick review of land ownership – District owns minimal land from the reservoir to the outlet. It is a challenge to commit to activities on private property. Will propose – and must work through issues.

Flow release plan is a part of the preliminary injunction. It will not be part of the HCP.

Covered species

- Steelhead – occurs in covered area, certain covered activities reasonably likely to result in take
- California red-legged frog – occurs in covered area, certain covered activities reasonably likely to result in take
- Tidewater gobi – occurs downstream of HCP covered area, operation and maintenance of Lopez Dam not reasonably certain to result in take
- Least Bell's vireo – has not been reported in Arroyo Grande Creek watershed, HCP covered activities not reasonably certain to result in take

Matt – Regarding the red legged frog, has the County/consultants considered how take will be documented? **Kate** – we will need to capture/relocate frogs for restoration activities

David – The creek can see up to 1000 cfs at flood stage. Flow released out of dam are on the order of 5-10-20 maybe 50 cfs. These flows are not expected to wash away red-legged frogs. **Joseph** – agreed. And the project will provide lift in conditions. State parks do red-legged frog surveys on their property downstream.

HCP Duration is 50 years. Based on research, agency commentor suggest longer (commentor not noted)

Mandy – is finalizing 30-year HCP for Santa Cruz (multi-species: anadromous steelhead, coho). Some red flags of 50-year duration: 50-yr analysis can't account for climate change. If have residual effects, point to conservation strategy, need to show funding available for 50 years, a major financial commitment. Tough analysis.

Joseph – given that it is looking like effects to the frog are on the conservation side, not overly concerned with duration.

4.0 Conservation Measures Overview

1. 3 buckets of measures/approaches to HCP:

a. Lopez flow releases – schedule to benefit steelhead migration and spawning

b. Instream restoration – gravel augmentation, large wood for cover. Removal of invasives included

c. Fish passage feasibility – feasibility of connecting to upstream habitat

Mandy – good examples of types of restoration looking for to mitigate effect, BUT looking at 30–50-year timeline, will need more. Set up structure for funding, meeting with agencies on how to implement/handle adaptive management.

David – recognize ongoing effect, consider other ongoing measure to address – gravel augmentation, temperature, flows. Largest ongoing activity to address

Joseph – echo Mandy's idea. SW pond turtles. Proposed species – include due to longevity of project. Include now will streamline process should they become listed

Mandy – WHEN expect to get passage project implemented? **David** – McMillen is contracted to do a fish passage feasibility study. No project will be in place until the HCP is done – roughly year 5- 10 (5 for assisted migration to 10 for fish ladder) **Mandy** – would have to know this before permit can be issued.

5.0 Next Meeting Topics

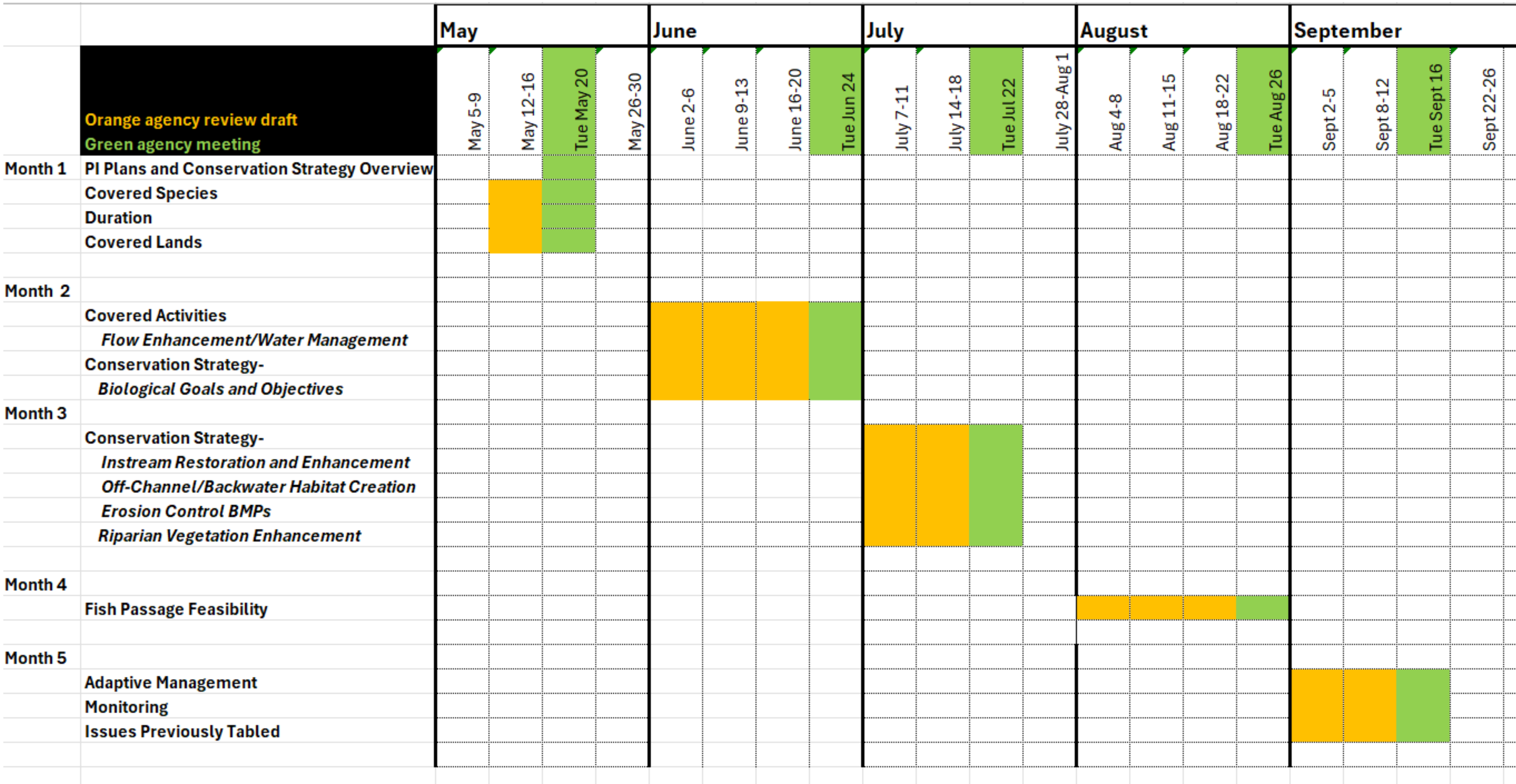
- Green blocks in schedule are proposed meeting dates
- Kate to send invite for June 24 date
- Expect to see draft flow measures and conservation strategies – biological goals for review before the meeting. Alignment on species included.

COUNTY OF SAN LUIS OBISPO

Interagency Pre-Application Coordination Meeting for the Lopez HCP

Introductions and Agency Administrative Updates

Proposed Pre-Application Schedule



Preliminary Injunction Process

Male and female steelhead trout. Credit: NOAA Fisheries

- Pre-Application coordination process:

Summer/Fall Iterative feedback/Q&A Meetings

- PI Plans relation to HCP

PI Plans Overview

Flow Release Plan- Does not provide sustainable yield, or appropriate seasonal fluctuations. Will **not** be incorporated into HCP

Steelhead Monitoring Plan- Recurring critical riffle, flow, redd, and spawning gravel surveys will be incorporated as ***Conservation Measures***. Permanent lifecycle monitoring will be considered as a potential opportunity to increase understanding of the AG Creek SCCC steelhead population and its evolution.

Biddle Park Culvert Monitoring- Recurring monitoring for blockages will be incorporated as a ***Conservation Measure***

Spillway Fish Screen Plan-Fish screen to prevent game fish from entering creek during high runoff over top of reservoir will be incorporated as a ***Conservation Measure***

Passage Barriers Plan-Identification and plans for removal of County-owned passage barriers will be incorporated as a ***Conservation Measure***

PI Plans Overview ctnd.

Sediment BMP Plan- Formation of public/private partnerships to reduce sediment loading will be incorporated as a ***Conservation Measure.***

Volitional Passage Plan- Engineering analysis, feasibility study, and alternatives will be incorporated into the HCP and considered as potential ***Conservation Measure*** opportunities.

Habitat Conservation Plan-A draft HCP will be formally submitted for agency consideration by October 1, 2025.

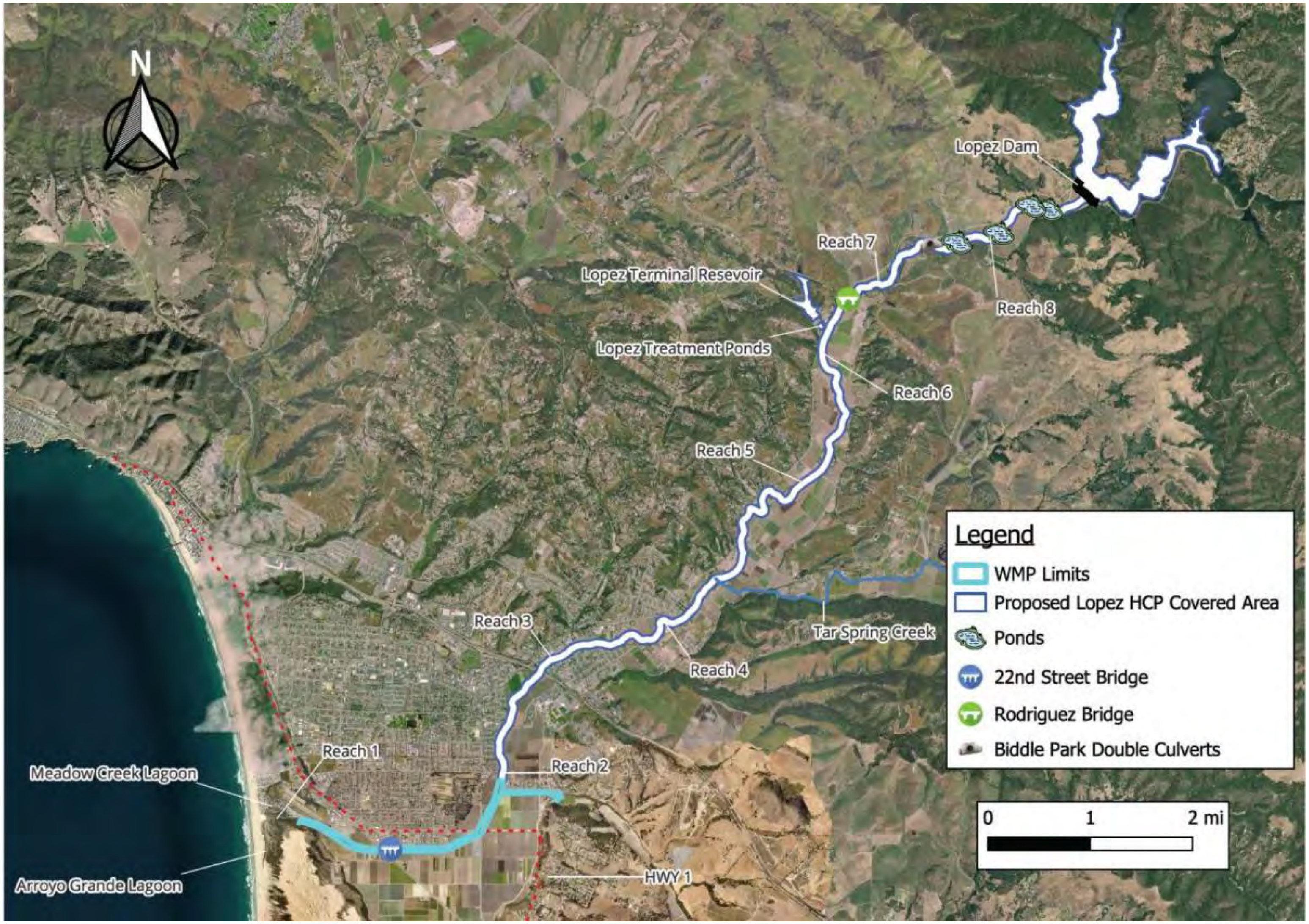
Predator Removal Plan-eDNA and visual surveys conducted will inform potential ***Conservation Measure*** opportunities.

Habitat Restoration Plan-Include project(s) with landowner consent as potential ***Conservation Measure*** opportunities.

Draft HCP Components-Outline Overview for Agency Input/Section Pre-Application Review

- **Covered Activities Focus**
  - Flow Enhancement/Water Management
- **Conservation Strategy Focus**
  - Biological Goals and Objectives
  - Instream Restoration and Enhancement Opportunities
  - Off-Channel/Backwater Habitat Creation
  - Erosion Control BMPs
  - Riparian Vegetation Enhancement
  - Fish Passage Feasibility
- **Adaptive Management**
- **Monitoring**
- **Additions?**

Covered Area



Covered Area

Species Considered for Coverage

Species	Federal Status	Ca Status	Designated Critical Habitat	Critical Habitat within Covered Lands?
South-central California Coast DPS Steelhead *(Oncorhynchus mykiss)*	Threatened	SSC*	Yes	Yes
California red-legged frog *(Rana aurora draytonii)*	Threatened	SSC	Yes	No
Tidewater goby *(Eucyclogobius newberryi)*	Endangered	SSC	Yes	No
Least Bell's vireo *(Rana aurora draytonii)*	Endangered	Endangered	Yes	No

Covered Species
Why are we addressing with agencies?

Southern Steelhead

- Occurs in the covered area, specifically, in Arroyo Grande Creek downstream of Lopez Dam to the Pacific Ocean and in tributaries to Arroyo Grande Creek
- Certain covered activities are reasonably likely to result in take of steelhead

Figure 8. Juvenile steelhead (*O. mykiss*) from lower Arroyo Grande Creek c. 15cm. 2-15-21. Photo: Courtesy of D. Rischbieter.

NMFS 2024

California red-legged frog

- Occurs in the covered area, specifically, Arroyo Grande Creek downstream of Lopez Dam to the Lagoon and in tributaries to Arroyo Grande Creek
- Certain covered activities are reasonably likely to result in take of red legged frog

USFWS

Additional Covered Species
Why are we considering addressing with agencies?

Tidewater goby

- Operation and maintenance of Lopez Dam not reasonably certain to result in take
- Occurs in the lagoon only, which is downstream of HCP covered area (Lopez Dam to upstream end of WMP)
- Winter flow releases from Lopez are likely to occur when other tributaries (Tar Springs, Los Berros) are providing discharge into AGC, therefore Lopez winter release flows are unlikely to cause the berm to breach or negatively affect

Source: USFWS

Least Bell's vireo

- HCP covered activities not reasonably certain to result in take
- Has not been reported in Arroyo Grande Creek watershed
- HCP not proposing to address vegetation management as a covered activity, therefore should not affect the riparian habitat that they could use

Source: USFWS

Plan Duration 50 years

General Conservation Measures Development Process

Types of Conservation Measures

Lopez Flow Release

- Winter releases for migration and spawning
- Summer releases for rearing
- Adapted to water year type
- Water quality
- Geomorphic flows

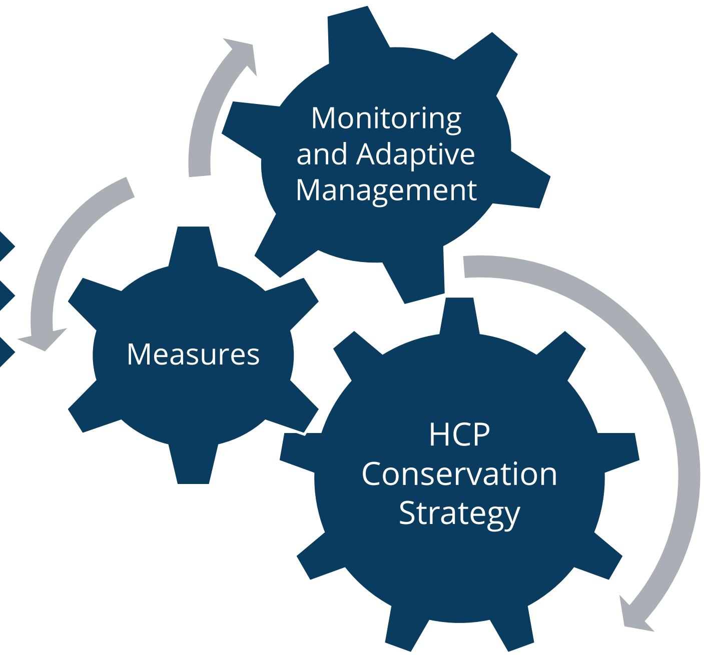
Instream Restoration

Improve AGC habitat downstream of Lopez Dam

* Gravel Augmentation
* Large wood

Fish Passage Feasibility

Feasibility of connectivity with habitat upstream of Lopez Dam



*Measures to be evaluated and considered in combination with one another

Focused Discussion- In Stream Habitat Restoration Potential Opportunity 1

LOCATION: Remnant Gravel Pits/In-Stream Ponds downstream of Lopez Dam. Pond Conversion to Stream Habitat-filling ponds with native material, planting native riparian and emergent aquatic vegetation, installation of anchored large wood (LW) structures. High benefit potential by restoring riverine conditions for spawning, fry and juvenile rearing, and reducing habitat suitability for non-native predators.

Pond 3

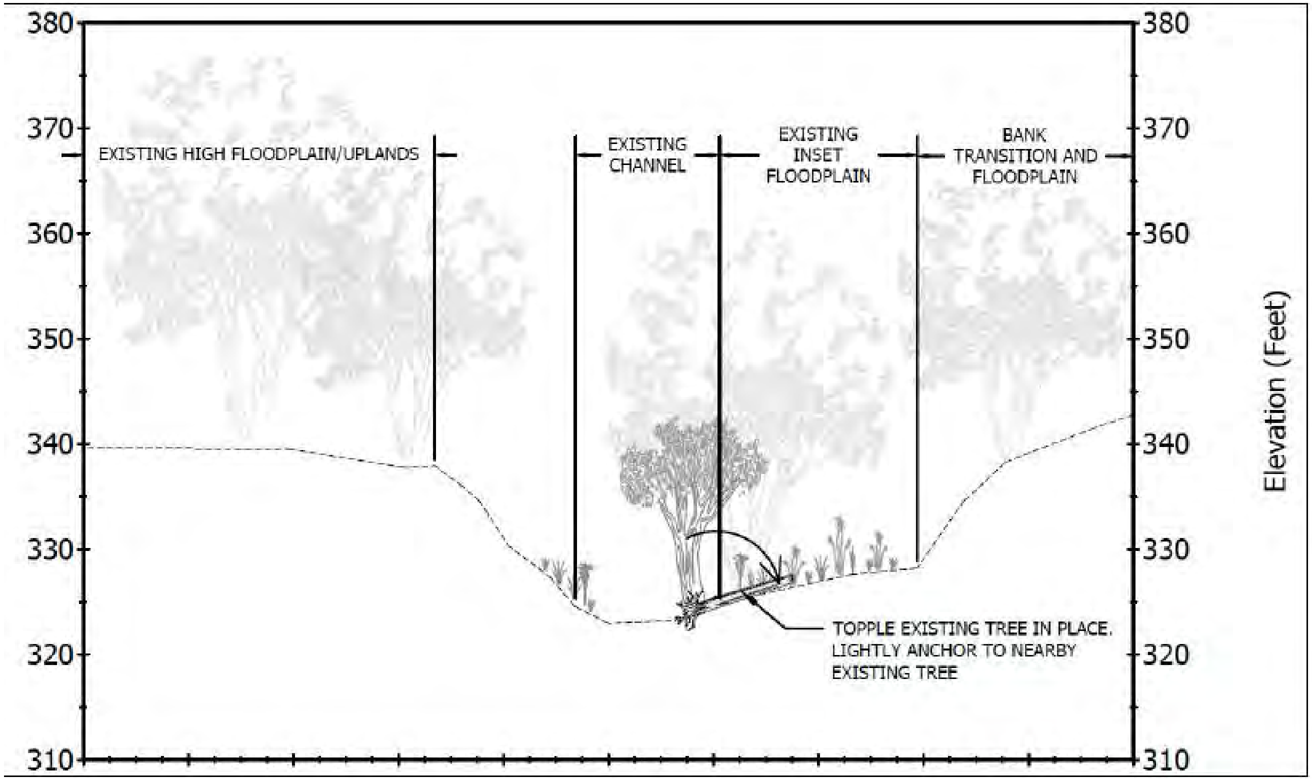
Focused Discussion- In Stream Habitat Restoration Potential Opportunity 2

LOCATION: Biddle Park Reach. Large Wood (LW) Inputs, Sediment Augmentation and Excavation-introducing LW features, paired with sediment placement (gravel or other native bed materials) and in channel grading (secondary channels, alcoves, and bank setbacks). Moderately high benefit potential by improving uniform and/or incised stream channels with increased habitat diversity, overhead cover, low velocity zones, steelhead spawning and rearing bed material, and floodplain activation.

AG Creek in Biddle Park, upstream of culvert

Focused Discussion- In Stream Habitat Restoration Potential Opportunity 3

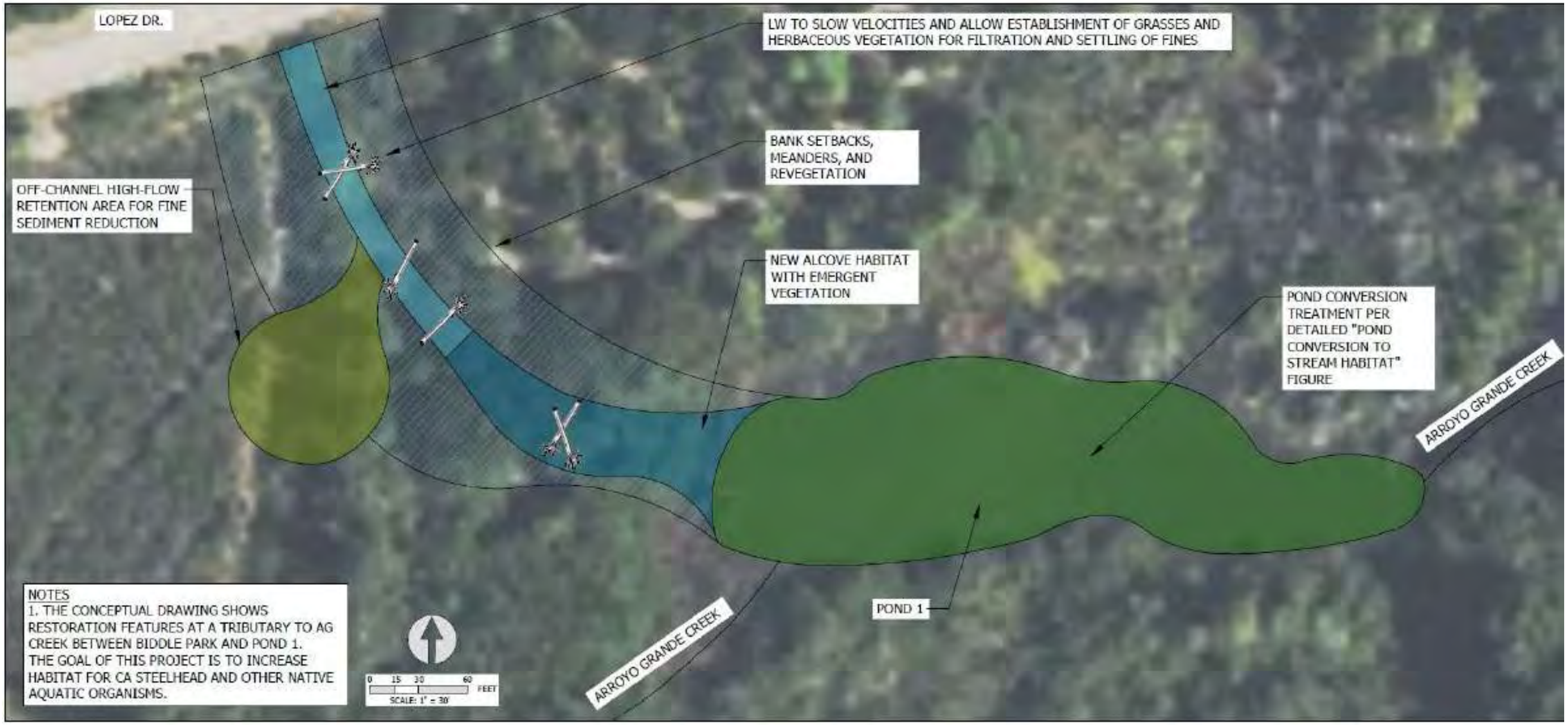
LOCATION: Biddle Park Reach and other reaches. Large Wood Anchored in Place- felling existing trees, reorienting to maximize habitat and geomorphic benefits, and anchoring in place. Low benefit potential by improving uniform and/or incised stream channels with increased habitat diversity, overhead cover, low velocity zones, and floodplain activation.



Large Wood in creek-topple
Existing tree and anchor in place

Focused Discussion- In Stream Habitat Restoration Potential Opportunity 4

LOCATION: Tributary between AG Creek between Biddle Park and Pond 1 and others. Tributary Habitat Enhancement- introducing LW features, paired with sediment augmentation and in channel grading in the form of secondary channels, alcoves, and bank setbacks where a tributary meets the AG Creek mainstem or up the tributary itself. Moderately high benefit potential by improving uniform and/or incised stream channel with increased habitat diversity, overhead cover and low velocity zones. Reduced turbidity and fine sediment deposition on spawning gravels downstream of tributary treatment.



Conceptual Tributary enhancement integrated with pond conversion to stream habitat

Next Meeting Topics

Tabled Items

Conservation Measures

Biological Goals and Objectives

Existing Conditions

Public Works Department

Lopez HCP Interagency Pre-Application Meeting Agenda

Tuesday June 24, 2025 @ 1:30PM

Location – 1120 Mill St, San Luis Obispo and via TEAMS

COUNTY of SAN LUIS OBISPO

Invitees

County of San Luis Obispo: Kate Ballantyne, David Spiegel, Lisa Bugrova, Kate Shea, Nola Engelskirger

County of SLO Consultant/Legal Team: Ethan Bell,Sharon Shu, Sharon Kramer, Rebeca Hays Barho, Wendy Katagi, Blair Hurst, Vincent Autier

USFWS: Joseph Brandt, Kirby Bartlett

NOAA/NMFS: Mandy Ingham, Matt McGoogan Jean Castello

CDFW: Kristine Atkinson, Zach Crum

Jeff Meyer
Eileen Kataga
John O'Brien
Katherine Ayres

Meeting Objective(s)

Discuss Proposed Flow Enhancement/Water Management

Discuss Proposed Volitional Passage Study Screening Analysis

Meeting Agenda	Time
1. Agency Updates	5 minutes
2. Covered Activities-Flow Enhancement/Water Management	55 minutes
3. Conservation Strategy- Volitional Fish Passage Feasibility	60 minutes

Next Meeting Topic

a. Covered Activities
b. Conservation Strategies

Public Works Department

Lopez HCP Interagency Pre-Application Meeting Agenda

Tuesday June 24, 2025 @ 1:30PM

Location – 1120 Mill St, San Luis Obispo and via TEAMS

COUNTY of SAN LUIS OBISPO

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McMillen

Meeting Minutes

To:	David Spiegel San Luis Obispo County	Date:	06/26/2025
From:	Wendy Katagi, CEP McMillen, Inc.	Job no:	25-062
cc:	Meeting Attendees		
Project:	Steelhead Passage Feasibility Assessment of Lopez Dam		
Subject:	Lopez HCP Interagency Pre-Application Meeting Agenda		

1.0 Introduction and Roll Call

This memorandum documents the Interagency Pre-Application Meeting held on June 24, 2025. The meeting started at 1:30 p.m., Pacific Standard Time (PST) and was adjourned at approximately 3:30 p.m. The following people attended the meeting:

Name	Organization
Kate Ballantyne	County of San Luis Obispo
David Spiegel, PE	County of San Luis Obispo
Lisa Burgova	County of San Luis Obispo
Kate Shea	County of San Luis Obispo
Nola Engelskirger	County of San Luis Obispo
Ethan Bell	Stillwater Sciences
Jeff Meyer	Stillwater Sciences
Sharon Shu	H.T. Harvey & Associates
Sharon Kramer	H.T. Harvey & Associates
Rebeca Hays Barho	Nossaman LLP
Wendy Katagi, CEP	McMillen Inc.
Vincent Autier, PE	McMillen Inc.
John O'Brien	
Joseph Brandt	USFWS
Kirby Bartlett	USFWS
Mandy Ingham	NOAA/NMFS
Matt McGoogan	NOAA/NMFS

Name	Organization
Jean Castello	NOAA/NMFS
Kristine Atkinson	CDFW
Zach Crum	CDFW
Jeff Wilkinson	
Katherine Ayres	

2.0 Agency Updates

None

3.0 Covered Activities – Flow Enhancement/Water Management

1. Stillwater Sciences (Jeff Meyer and Ethan Bell) presented the Preliminary Draft Lopez Downstream Release Plan, including Baseflows, Migration Flows, and Constraints

- Baseflows are established for each season
- Migration flows (up to 2 in the winter, 10-day duration) are synchronized with natural flow events illustrated by sand bar/berm at beach being open
- Constraints preclude migration flow releases if reservoir is below 20,000 acre-feet

2. Hydrologic model runs for low, median, and high discharge water years were presented and show the number of pulse releases and spills in each condition.

3. Ethan explained goals for steelhead:

- Support adult migration and increased spatial distribution of adult steelhead by increasing migration opportunities and timing
- Synchronize with watershed events
- Habitat value, suitability, and water temperature all goals for steelhead

4. Release Plan Methodology models steelhead migration in response to proposed flow; includes:

- Qualitative habitat and flow assessment
- Comparative temperature and hydrograph analyses
- California Environmental Flows Framework (CEFF) considerations
- Scenarios:
    - Pre-Dam

  - Existing Conditions (Baseline)
  - Proposed Operations
- To include adult migration opportunities and spatial distribution and sensitivity analysis

5. Questions/discussion of the methodology and modeling:

- The model is an R program, developed with Chris Caudel, University of Idaho.
- CDFW SOPs are being followed and critical riffles will be included/part of an adaptive management plan
- Flow models have not been verified given timelines, but available data was used to create unimpaired hydrology that is the best available data
- Ethan offered that they could share an outline draft of the monitoring program, including a table that captures key metrics for monitoring
- Will not have different water year types for downstream releases – Arroyo Grande gage indicates whether berms open up
- The sandbar is tricky and sometimes hard to describe if open or closed with high tide being a factor as well
- Discussion of what daily averages represent and how far in a day we can deviate from the daily averages. Zach prefers something different if legally mandated, as its good to be clear the model isn't cranking flow up to meet minimum criteria, compliance, and adequate stream flow

4.0 Conservation Strategy – Volitional Fish Passage Feasibility

Problem & Goal Statements:

- Problem: Lopez Dam in an impassable barrier on Arroyo Grande Creek, blocking fish passage
- Goal: The purpose of the Project is to identify and describe technically feasible upstream and downstream fish passage options for the South-Central California Coast (SCCC) Distinct Population Segment (DPS) steelhead trout while preserving the dam's primary function
- Goal: Assess volitional fish passage feasibility at Lopez Dam

Vincent emphasized the importance of reviewing all options, that there are no bad ideas at this time. Options will be assessed for what is volitional or not.

Two technical memorandums (TM) were prepared and provided to the TAC on June 9 for review and input. The purpose of this presentation is to receive feedback on the TMs:

- TM002 – Design Criteria:
  - Biological – fish species, migration season
  - Lopez Reservoir Fluctuation – large water surface differentials during migration
    - About 70' during upstream migration
    - About 62' during downstream migration
  - Hydrology & Hydraulics – hydraulic drop, swimming strength
  - Others provided in TM; all shown because we don't yet know what alternatives may look at
- TM003 – Alternatives: tabulated all known fish passage options and provided high-level evaluation and recommendations
  - Additional feedback/options are welcomed
- Volitional & Nature-Like Fishways were discussed and examples presented:
  - Clackamas River North Fork Dam Fishway includes 20 exit pools (no longer in operation)
  - Soda Springs Fishway has 14 exit pools
  - To accommodate Lopez Dam water surface fluctuations, 70 exit pools would be required
  - Examples of successful volitional fishways were provided, noting the total head and water surface fluctuation are on a much smaller scale than Lopez Dam (e.g., 9 to 30 ft total head with 1 to 3 ft fluctuation compared to 168 ft total head with 60 to 70 ft fluctuation).
- Technologies for upstream and downstream passage were reviewed. Technologies recommended to advance include:
  - Upstream:

    - Vertical Slot – pre-looked at potential reduction in number of exit pools; still have 168 pools. Need agency guidance on flow rates (typically about 30 cfs per vertical slot; we have about 10 times that)
    - Trap and Haul
  - Downstream:
    - Bypass Pipe – use floating surface collector to get fish before putting them in the bypass pipe. Earth fill profile of the dam will put collector further away. About 1000- 2000 cfs attraction flow is needed, which will require pumps.
    - Barrier/Guidance Nets – e.g., Helix system by USBR. Estimated $1M.
    - Trap and Haul – In-tributary trapping with Fyke nets; need to divert river into a barrier/screen to trap and collect
- Selected technologies will be developed and evaluated using a rigorous quantitative process
  - This is a collaborative process
- The updated version of the slide deck (presented at the meeting) will be distributed. This version includes the Clackamas River
- Wendy provided her email address for additional questions or feedback on the alternatives: katagi@mcmillen.com

Steelhead Passage Feasibility Assessment of Lopez Dam

Design Criteria & Alternatives Pre-Screening Evaluation for TAC Review

9 JUNE 2025 (UPDATED 23 JUNE 2025

McMillen

Presentation Purpose

Purpose: To receive feedback and input on the design criteria, alternatives pre-screening evaluation, and evaluation matrix.

Outline

A. Project Background, Problem and Goal Statements
B. Overview of
   1. Draft Design Criteria Technical Memorandum (TM002)
   2. Draft Fish Passage Alternatives Pre-Screening Evaluation Technical Memorandum (TM003)
C. Technical Advisory Committee Feedback Process & Next Steps

Project Background

- Lopez Dam is an earthfill dam constructed in 1968/69.
- The dam is 1,120 feet long and has a vertical height of 168.2 feet.
- Lopez Dam is a vitally important element of water infrastructure for the communities in the County. Its primary purpose is to provide drinking water supply for 50,000 residents.

Problem & Goal Statements

PROBLEM

- Lopez Dam is an impassable barrier on Arroyo Grande Creek, blocking fish passage.

GOAL

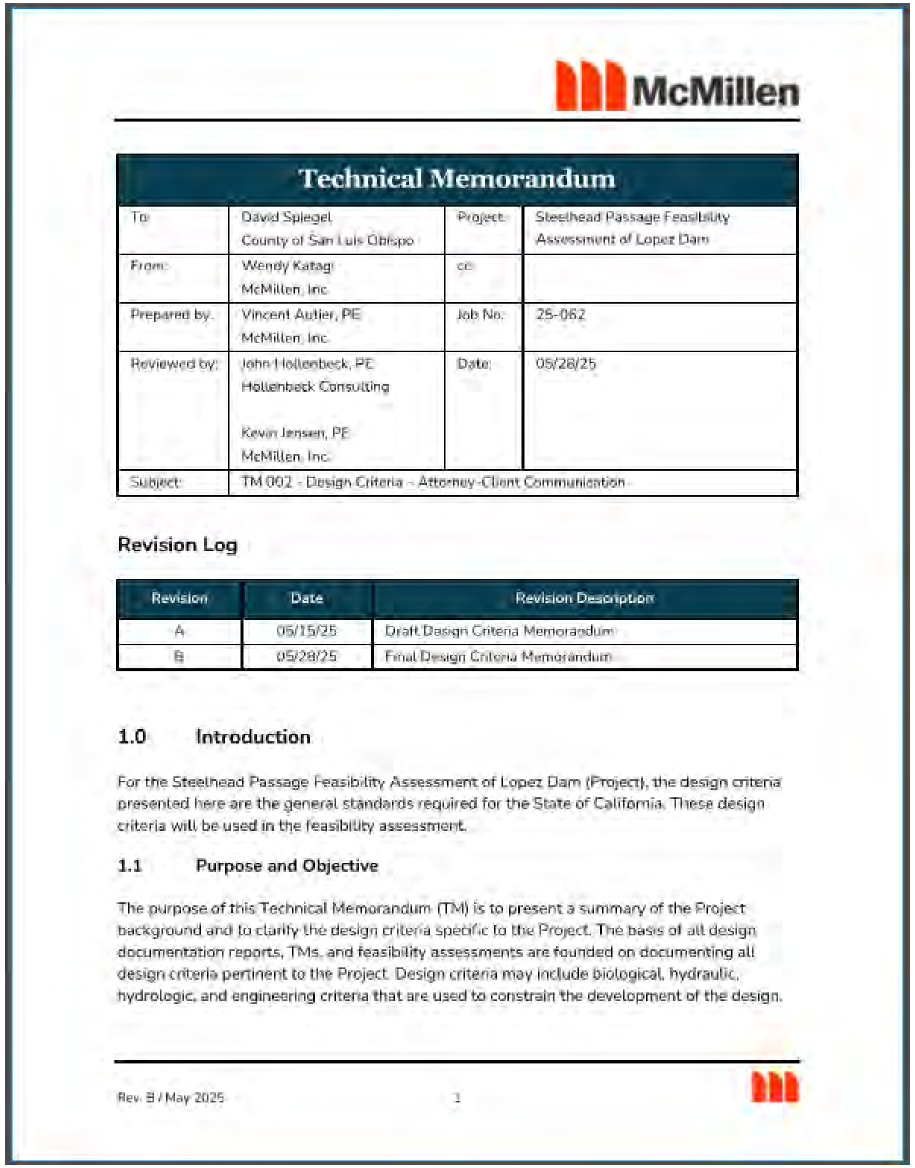
- The purpose of the Project is to identify and describe technically feasible upstream and downstream fish passage options that support the threatened South-Central California Coast (SCCC) Distinct Population Segment (DPS) steelhead trout (*Oncorhynchus mykiss*), contributing to species conservation and compliance with state and federal regulations, using technologies and operations that are proven within the specific context of the Lopez Dam, while preserving the dam's primary functions.
- Assess volitional fish passage feasibility at Lopez Dam.

Design Criteria DRAFT (TM 002)

Design Criteria TM Introduction

Purpose and Objective

- The purpose of this TM is to present a summary of the Project background and to clarify the design criteria specific to the Project.
- The objective of this TM is to **collectively** establish project-related design criteria with the Project stakeholders.
- To this end, the design criteria are developed early in the process and are distributed across the Project's team to **solicit input and obtain agreement** from stakeholders at the Project onset.



McMillen

Technical Memorandum

To:	David Spiegel County of San Luis Obispo	Project:	Steelhead Passage Feasibility Assessment of Lopez Dam
From:	Wendy Katagi McMillen, Inc.	cc:	
Prepared by:	Vincent Autier, PE McMillen, Inc.	Job No.:	25-062
Reviewed by:	John Hollenbeck, PE Hollenbeck Consulting Kevin Jensen, PE McMillen, Inc.	Date:	05/28/25
Subject:	TM 002 - Design Criteria – Attorney-Client Communication		

Revision Log

Revision	Date	Revision Description
A	05/15/25	Draft Design Criteria Memorandum
B	05/28/25	Final Design Criteria Memorandum

1.0 Introduction

For the Steelhead Passage Feasibility Assessment of Lopez Dam (Project), the design criteria presented here are the general standards required for the State of California. These design criteria will be used in the feasibility assessment.

1.1 Purpose and Objective

The purpose of this Technical Memorandum (TM) is to present a summary of the Project background and to clarify the design criteria specific to the Project. The basis of all design documentation reports, TMs, and feasibility assessments are founded on documenting all design criteria pertinent to the Project. Design criteria may include biological, hydraulic, hydrologic, and engineering criteria that are used to constrain the development of the design.

Rev. B / May 2025 1

Two Key Categories of Fishery Design Criteria

*What are the Key Ecological **Structures and Functions** Necessary for Successful Fish Passage?*

- Biological
- Hydraulic & Hydrology

Table 2-1

Fishery Design Criteria: Biological

<u>Target Species:</u> South-Central California Coast (SCCC) Distinct Population Segment (DPS) steelhead trout (*Oncorhynchus mykiss*).

Size, Swimming Speeds, fish numbers, etc. can be found in Table 2-1 of the TM002.

Criteria	Units	Value	Comments / Reference
Species	-		
Target Species			
SCCC steelhead trout	-	Juvenile/Adult	*Oncorhynchus mykiss.* Migratory steelhead spawn and rear within the creek downstream of Lopez Dam. Resident Rainbow Trout spawn and rear in the tributaries upstream of Lopez Lake (Stetson Engineering, Inc. 2004).
Native Species (in Reservoir)			
Hitch	-	Juvenile/Adult	*Lavinia exilicauda*
Speckled Dace	-	Juvenile/Adult	*Rhinichthys osculus*
California Roach	-	Juvenile/Adult	*Lavinia symmetricus*
Three-spined Stickleback	-	Juvenile/Adult	*Gasterosteus aculeatus*
Non-Native and Invasive Species			
Largemouth bass	-	Juvenile/Adult	*Micropterus nigricans* (CCSE 2009)
Black Crappie	-	Juvenile/Adult	*Pomoxis nigromaculatus* (CCSE 2009)
Green Sunfish	-	Juvenile/Adult	*Lepomis cyanellus* (CCSE 2009)
Other Species in Reservoir (introduced)	-	See comment	Lopez Reservoir provides habitat for Sacramento Pikeminnow (*Ptychocheilus grandis*), Channel Catfish (*Ictalurus punctatus*), Blue Catfish (*Ictalurus furcatus*), brown bullhead (*Ameiurus nebulosus*), smallmouth bass (*Micropterus dolomieu*), bluegill (*Lepomis macrochirus*), Redear Sunfish (*Lepomis microlophus*) Mosquitofish (Gambusia Sp.), Threadfin Shad (*Dorosoma petenense*), Goldfish (*Carassius auratus*), and Golden Shiner (*Notemigonus crysoleucas*) (Stetson Engineering, Inc. 2004; Woodward 2025)

Fishery Design Criteria: Biological

- Overall Migration season:

  December 1 – June 30 (U.S. District Court 2024)

- Adult Upstream Migration:

  December 1 to May 1 (Note: the bar at Arroyo Grande Lagoon typically closes in April, reducing the migration season by a month when compared to other watersheds).

- Smolt Outmigration:

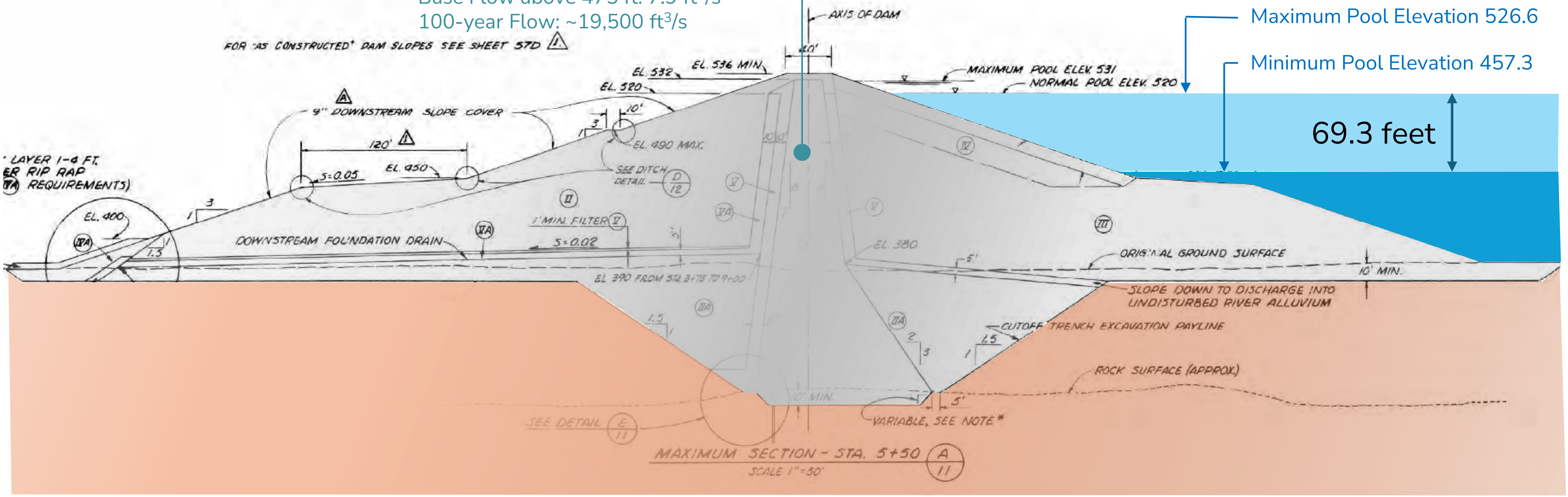
  February 15 - June 15

Lopez Reservoir Fluctuation

During Upstream Migration

Lopez Dam
Crest Elevation: 538.6 ft
Maximum Pool Elevation: 533.6 ft
Spillway Crest Elevation: 522.6 ft
Minimum Pool Elevation: 426.0 ft
Outlet Flow Capacity: 100 ft^3/s
Base Flow below 475 ft: 5.9 ft^3/s
Base Flow above 475 ft: 7.9 ft^3/s
100-year Flow: ~19,500 ft^3/s

	Upstream Migration (12/01-04/30)		
	WSE (feet)	Storage (ac-feet)	ΔH (feet)
Median	501.8	32540	3.5
25 percentile	512.0	40215	14.9
75 percentile	490.9	25472	2.3
Max	526.6	53119	66.0
Min	457.3	10837	0.9



Lopez Reservoir Fluctuation
During Downstream Migration

	Out Migration (02/15-06/15)		
	WSE (feet)	Storage (ac-feet)	ΔH (feet)
Median	506.7	36122	3.6
25th percentile	515.5	43100	7.8
75th percentile	492.7	26591	2.3
Max	526.6	53119	29.6
Min	464.6	13371	0.6

Lopez Dam
Crest Elevation: 538.6 ft
Maximum Pool Elevation: 533.6 ft
Spillway Crest Elevation: 522.6 ft
Minimum Pool Elevation: 426.0 ft
Outlet Flow Capacity: 100 ft^3/s
Base Flow below 475 ft: 5.9 ft^3/s
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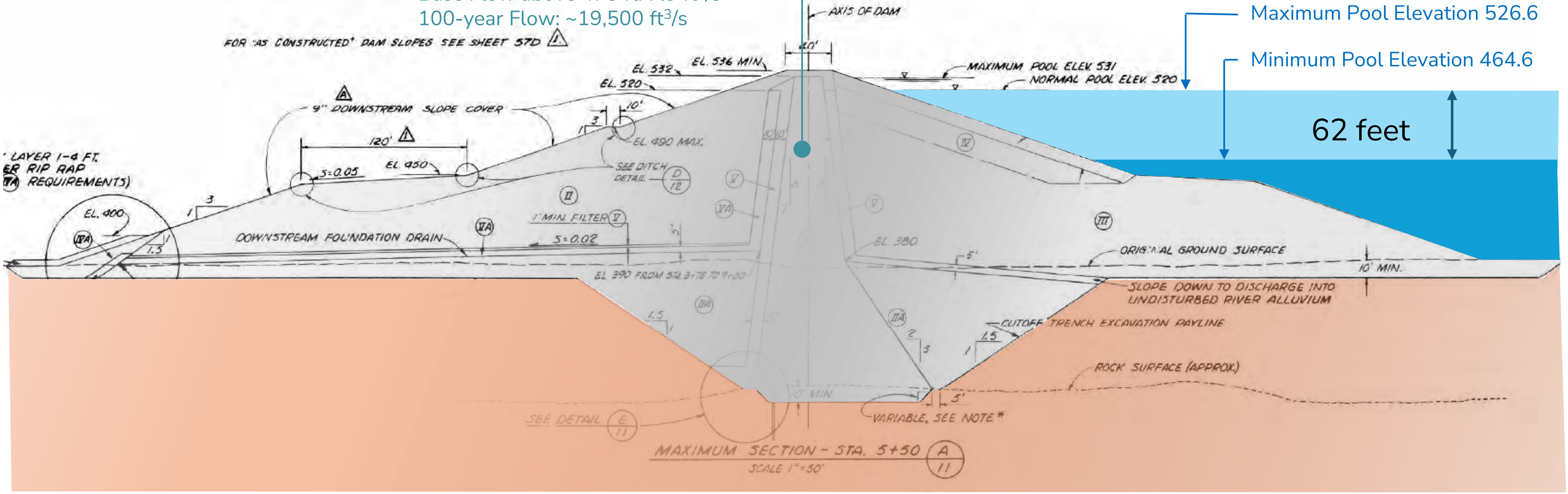


Fishery Design Criteria: Hydraulic and Hydrology

Table 2-4. High and Low Fish Passage Design Criteria by Species and Life Stage (NMFS 2023b and CDFW 2003)

Species/Life Stage	High Design Flow	Low Design Flow	
	Exceedance	Exceedance	Alternate Minimum Flow (ft^3/sec)
Adult Anadromous Salmonids	**1%**	50%	3
Adult Non-Anadromous Salmonids	5%	90%	2
Juvenile Salmonids	10%	**95%**	**1**
Native Non-Salmonids	5%	90%	1

Attraction Flow:

- If using 1% Exceedance (182 ft^3/sec): 9.1 to 18.2 ft^3/sec
- If using 5% Exceedance (59.6 ft^3/sec): 3.0 to 5.96 ft^3/sec

Ichthyo Mechanics

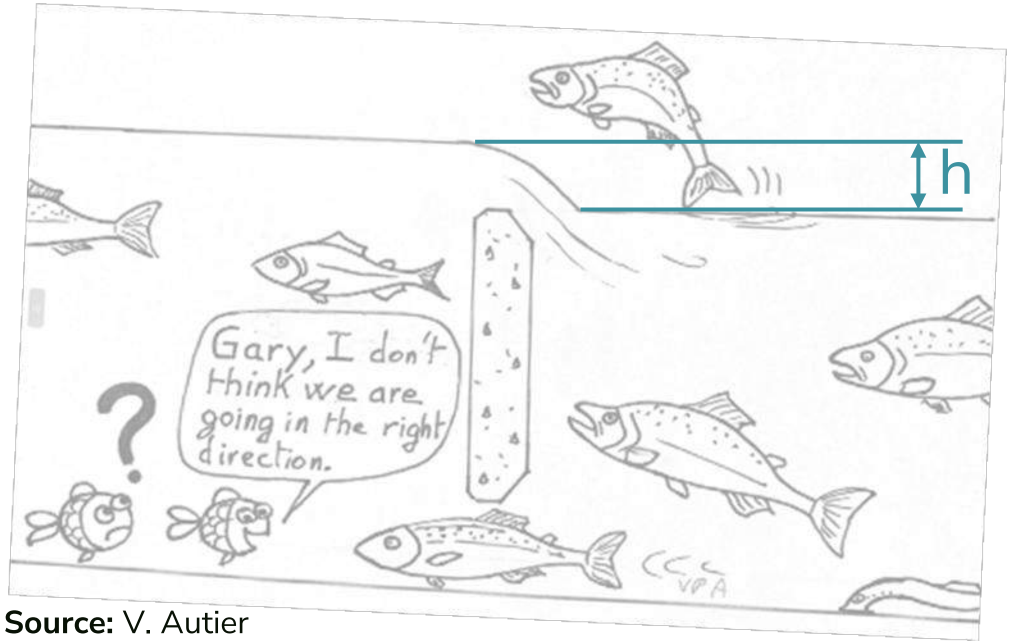
The drop per pool is selected as a function of the fish swimming and leaping capacities. Swimming speeds and endurance vary with species and body morphology, fish length, water temperature and other variables.

'h" is directly influencing the maximum water velocity. For that reason, the following "h" is often used:

h = 300 mm (12 inch) for Anadromous Salmonid (strong swimmer); ~2.4 m/s (7.9 ft/s)

h = 230 mm (9 inch) for Bull Trout; ~2.1 m/s (6.9 ft/s)

h = 150 mm (6 inch) for small resident species (weak swimmer); ~1.7 m/s (5.6 ft/s)



Source: V. Autier

$$V = \sqrt{2gh}$$

Where:

V = maximum velocity created by the hydraulic drop h (m/s or ft/s)
g = gravitational acceleration (9.81m/s^2 or 32.2 ft/s^2)
h = hydraulic drop per pool (in m or ft)

For the weir and orifice velocities, a coefficient is used based on the weir and orifice shape.

Pool Volume

It is harder for fish to pass when the turbulence and aeration levels in the pools are high. The Energy Dissipation Factor (EDF) is a good representation of those conditions, ((ft.lbs)/s)/ft^3. It can also be expressed as the Volumetric Dissipated Power, Pv (watts/m^3) in metric.

EDF:

- 4 ((ft.lbs)/s)/ft^3 for salmon and sea trout
- 3.13 ((ft.lbs)/s)/ft^3 for SCCC Steelhead
- 3 ((ft.lbs)/s)/ft^3 for Bull Trout

Pv:

- 200 watts/m^3 for salmon and sea trout
- 150 watts/m^3 for shad and riverine species

Imperial System:

$$EDF = \frac{(Q \times \gamma \times h)}{V}$$

Where:

Q = fishway flow, ft^3/s
γ = unit weight of water, 62.4 lb per ft^3
V = Pool Volume, ft^3/s
h = hydraulic drop per pool, ft
EDF = energy dissipation factor, ((ft.lbs)/s)/ft^3

SI Units:

$$Pv = \rho\, g\, Q\, h/V$$

Where:

Pv = volumetric dissipated power, watts/m^3
ρ = density of water, 1000 kg/m^3
g = gravitational acceleration, 9.81m/s^2
Q = fishway flow, m^3/s
h = hydraulic drop per pool, m
V = Pool Volume, ft^3/s

Note: 1 watt/m^3 = 0.020885432 ((ft.lbs)/s)/ft^3

Fish Passage Design Criteria (Table 2-6)

Fish Ladder	Drop per pool, energy dissipation, flow range, orifice and slot velocities, length and width, wall height, auxiliary water flows, and ladder type.
Nature-Like Fishway	Nature-Like Fishways with step-pools and plane-bed morphologies.
Fish Screening Facility	Maximum approach velocity, transport velocity, time exposure to fish screen, cleaning requirements, and screen opening size.
Pre-Sort Holding Pool	Holding density, flow, length, width, depth, wall height, surface spray, and brail floor.
Fish Bypass Facility	Bypass velocity, impact velocity, pipe size, and pipe material.

Fish Passage Alternatives Pre-Screening DRAFT (TM 003)

Design Criteria TM Introduction

Purpose and Objective

- The purpose of this TM is to:
    1. Tabulate all known upstream and downstream fish passage options, regardless of feasibility.
    2. Present a high-level evaluation (i.e., pre-screening assessment), documents pros and cons, and provides a recommendation to advance or not advance, together with a justification.
    3. Present the evaluation matrix which will be used to then evaluation alternatives that will be advanced.
- The objective of this TM is to **collectively** review fish passage options, pre-screen, and select alternatives to further develop.
- TM003 is distributed early to the Project's team to **solicit input and obtain agreement** from stakeholders.

McMillen

Technical Memorandum

To:	David Spiegel County of San Luis Obispo	Project:	Steelhead Passage Feasibility Assessment of Lopez Dam
From:	Wendy Katagi McMillen, Inc.	cc:	
Prepared by:	Vincent Autier, PE McMillen, Inc.	Job No:	25-062
Reviewed by:	Kevin Jensen, PE McMillen, Inc. John Hollenbeck, PE Hollenbeck Consulting	Date:	05/30/25
Subject:	TM 003 – Fish Passage Alternatives Pre-Screening Evaluation– Attorney-Client Communication		

Revision Log

Revision	Date	Revision Description
A	05/30/25	Draft Fish Passage Alternatives Pre-Screening Evaluation

1.0 Introduction

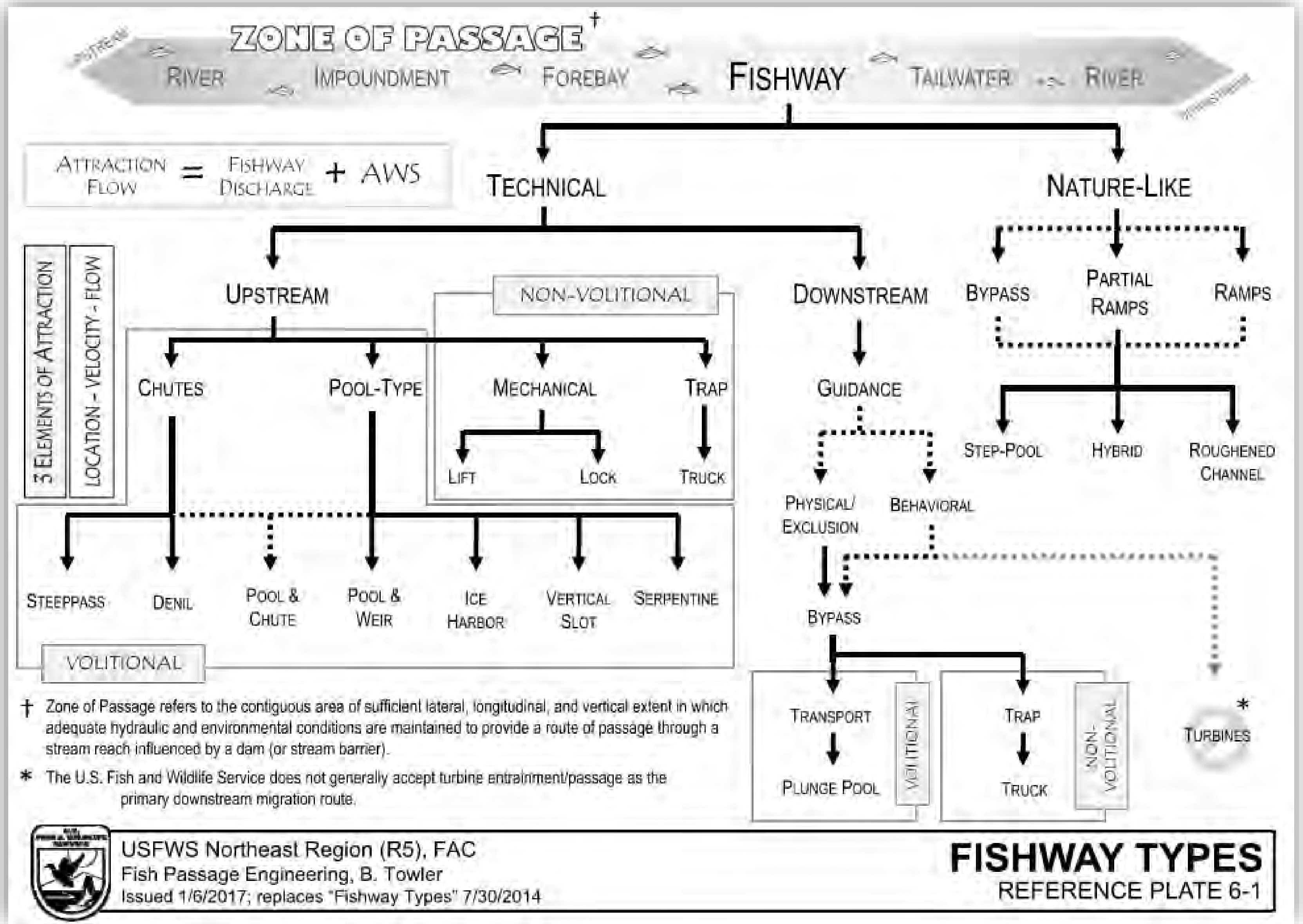
For the Steelhead Passage Feasibility Assessment of Lopez Dam (Project), McMillen, Inc. (McMillen) prepared a comprehensive list of fish passage options for both upstream and downstream passage. This document presents that information.

1.1 Purpose and Objective

The purpose of this Technical Memorandum (TM) is to tabulate all known upstream and downstream fish passage options, regardless of feasibility. For each option, this TM presents a high-level evaluation (i.e., pre-screening assessment), documents pros and cons, and provides a recommendation to advance or not advance, together with a justification. This information

Potential Fish Passage Technologies

Upstream & Downstream Fishway Types



Volitional Definition

The term "*volitional*" is generally understood to mean that fish have the ability to pass upstream or downstream of their own will, at their own pace, when they desire, with no human interference.

As such, fishways requiring auxiliary power source or human intervention to operate (e.g., pumps, gates, intake screens) are not considered to be volitional. *Nature-Like Fishways* are generally understood to be volitional, while "technical" fishways can either be volitional or not, depending on if they connect the tailrace to the reservoir hydraulically.

Volitional & Nature-Like Fishways Limitations

For a volitional system to work effectively (i.e., safe, timely, and effective) within its operational range, the fishway needs to have:

- **Hydraulic Connectivity:** Risk of losing hydraulic connectivity when the tailrace and/or reservoir have large water level fluctuation.
  - For Nature-Like Fishway, a small variation of 2 feet can greatly impact the fishway flow and the Maximum Average Channel Velocity.
  - For technical fishways, the use of exit pools is required when the forebay is not constant.
- **Dam Height:**
  - *Nature-Like Fishway* works best when the dam height is less than or equal to 10 feet.
  - Technical fishways are typically used when the dam height is less than or equal to 120 feet.

Volitional & Nature-Like Fishways Limitations

- **Exit Structure:** to accommodate the reservoir variation (69.3 ft) during upstream migration 70 exit pools would be required.
- The largest constructed exit structure known is the Clackamas River North Fork Dam Fishway located in Oregon and operated by Portland General Electric which includes 20 exit pools. We note that this exit structure is no longer in operation.
- The second fishway known to be in operation with the most exit pools is the Soda Springs Fishway on the North Umpqua River, with 14 exit pools. Both fishways are located in Oregon.

Volitional & Nature-Like Fishways Limitations

- **Dam Safety:** Need to size the fishway for the low reservoir level, necessitating the need for a dam penetration (transport channel), which could result in dam safety risks:
  - To stabilize soils during excavation, temporary excavation support will be required. Temporary soil anchors should not be allowed to penetrate the earthfill dam due to potential risk of fracturing the dam core during drilling and grouting of the anchors.
  - Some ground movements could occur during excavation. These ground movements, may adversely affect the dam core (e.g., reduction in lateral stress, increase potential for internal erosion etc.). These changes have the potential to destabilize the dam, creating seismic instability and thus dam safety concerns.
  - The transport channel would need a means to minimize seepage and internal erosion along its outside walls. A grout curtain or a sheet pile wall could be used to minimize seepage, but its installation could negatively impact the dam core.
  - Addition of the transport channel could reduce lateral support/stiffness of the dam for both static and seismic conditions.
  - During or following an earthquake the exit structure gates and the isolation gate may become un-operational which could lead to an uncontrolled release of the reservoir.

Volitional & Nature-Like Fishways Limitations

- **Ambient Light and Closure gates:** The penetration (transport channel) would need to be large enough to allow ambient light and thus not limit fish passage. The large tunnel or open trench would need to be regulated with closure gates.
- **Sediment Mobilization:** *Nature-Like Fishways* work best when connecting to either a small reservoir with limited water level fluctuation or when connecting upstream of the head pool. The reason is that the fishway would then behave similarly to its adjoining reaches, which would allow sediment movement. However, the Lopez Reservoir behaves as a sediment trap which would then limit the ability of the *Nature-Like Fishway* to aggrade sediment at the rate of sediment erosion. This in itself would require long-term maintenance and annual sediment aggradation plan.

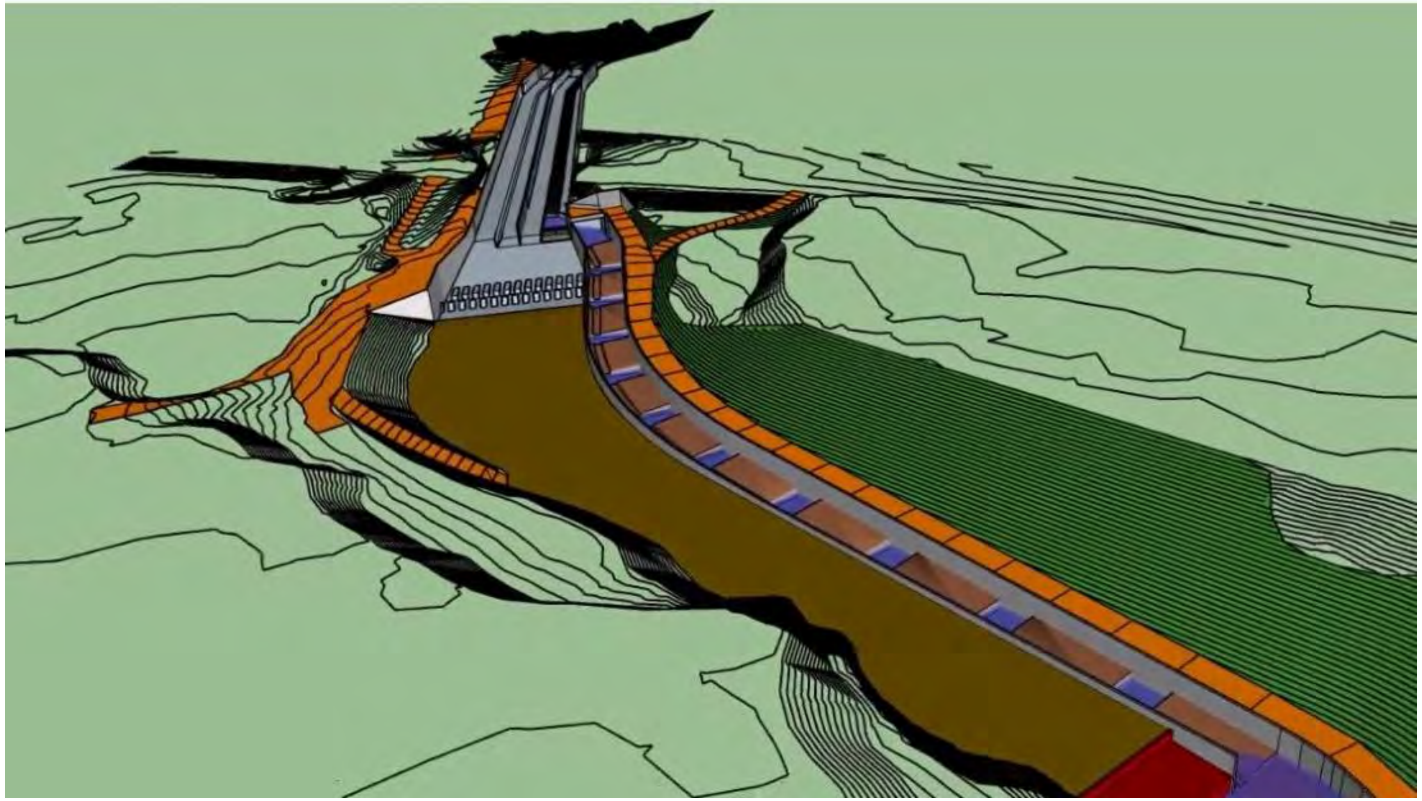
Example of Volitional Fishways

Photo	Description	Total Head (ft) and Reservoir Fluctuation (ft)
	Howland Fish Bypass Channel, Piscataquis River, Maine, USA (Source: The Nature Conservancy)	21; ~2
	Nature-Like Fishway Constructed on the Cariboo Dam Located on the Brunette River, for Metro Vancouver (Source: NHC)	9; <1

Example of Volitional Fishways

Photo	Description	Total Head (ft) and Reservoir Fluctuation (ft)
	Okanagan Lake Outlet Dam East Salmon Passage, British Columbia.	<9; <1
	Opal Springs Volitional Fish Passage, Crooked River, Oregon. Vertical Slot.	30; <3

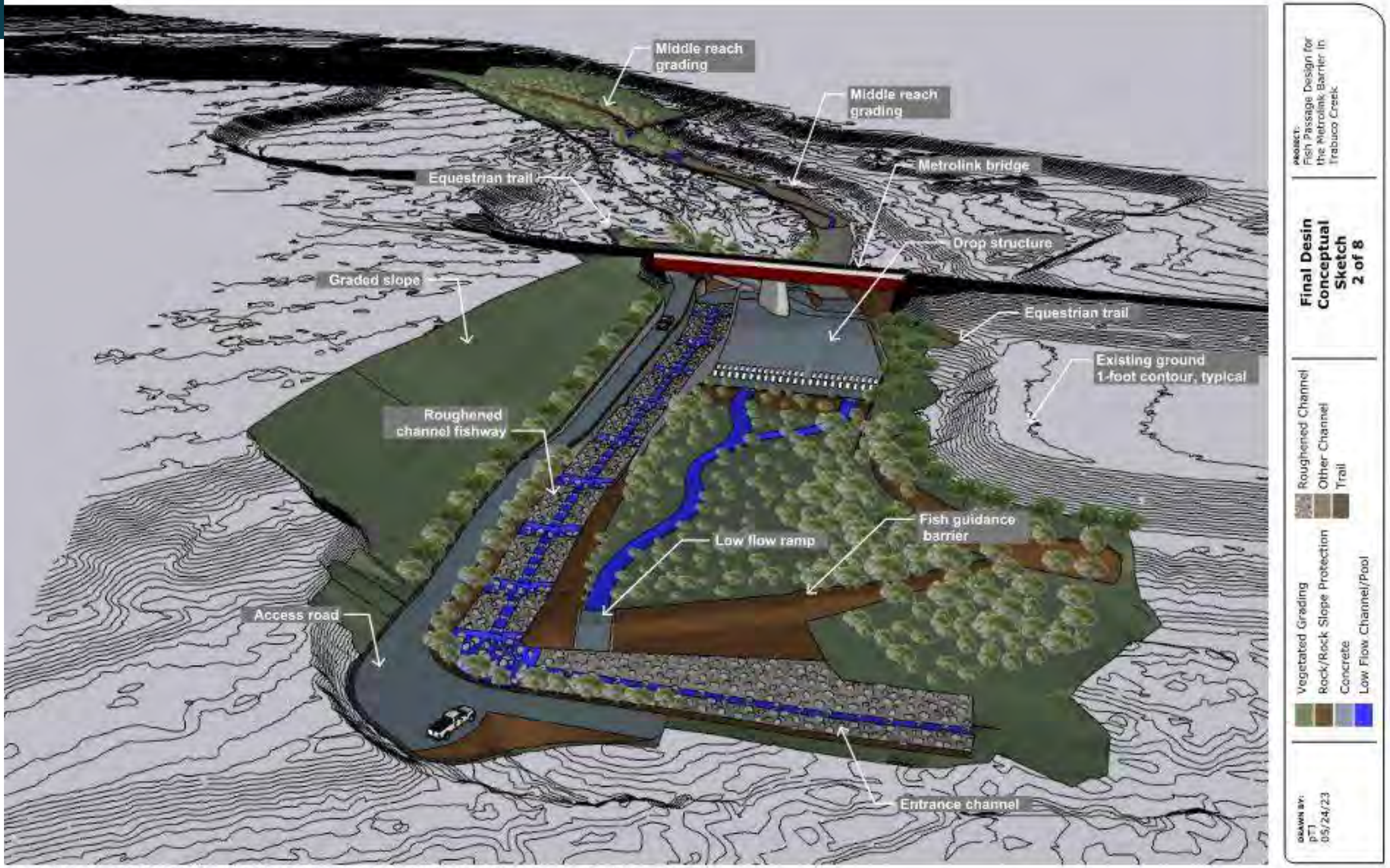
Example of Volitional Fishways



Trabuco Creek Chute and Pool Roughened Channel Fishway across I-5 Bridge Array
650-foot long bypass chute and pool connected to 675-foot transport channel (Source: Caltrout)

Example of Volitional Fishways

Trabuco Creek at Metrolink Rail Roughened Ramp Fish Passage (Source: Caltrout)



erspective view of 3D rendering showing the proposed project and existing contours, looking upstream

Lopez Reservoir – Summary

Dam Height = 168.2 ft > 120 ft
Reservoir Fluctuation = 69.3 ft > ~2 ft
Required No. of Exit Pools = 70 > 20

Lopez Dam
Crest Elevation: 538.6 ft
Maximum Pool Elevation: 533.6 ft
Spillway Crest Elevation: 522.6 ft
Minimum Pool Elevation: 426.0 ft
Outlet Flow Capacity: 100 ft^3/s
Base Flow below 475 ft: 5.9 ft^3/s
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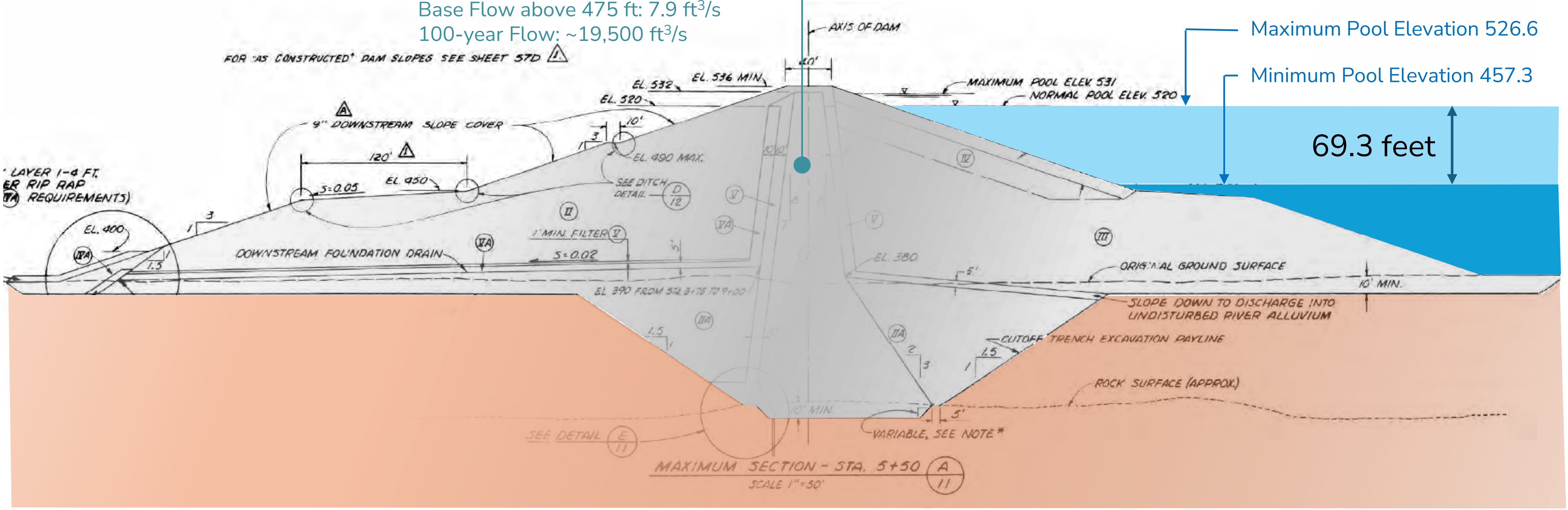


Fish Passage Technologies: UPSTREAM Categories

Chutes

- Denil
- Steeppass
- Fatou
- Super-Active-Type Bottom Baffles
- Macro-Roughness Elements
- Pool & Chute

Pool Types

- Pool & Weir
- Vertical Slot
- Weir & Orifice
- Deep Side Notch & Submerged Orifice
- Meander-Type

Nature-Like

- Steep-Pool Morphology Ramp
- Plane-Bed Morphology Ramp
- Bypass

Others

- Trap-and-Haul
- Fish Elevators
- Fish Locks
- Archimedean Screw Pumps
- Pneumatic Fish Transport Tube Systems
- Tube Fishway

Volitional

Chutes – Denil
Source: CSKT – Jocko K Canal
Photo Courtesy: V. Autier

Chutes – Steeppass
Source: USFWS – Little Sheep Creek
Photo Courtesy: V. Autier

Chutes – Fatou
Source: Elle river, Britanny, France
Photo Courtesy: Larinier, 2002

Chutes – Larinier
Source: Saltaire Weir UK
Photo Courtesy: EnvAgencyYNE

Chutes – Macro-Roughness Elements
Source: Toorale Station, Darling River, Australia
Photo Courtesy: NSW Government

Chutes - Pool and Chute
Source: USACE – Lebanon Dam
Photo Courtesy: F. Khan

Pool and Weir
Source: PG&E – Cape Horn Dam
Photo Courtesy: V. Autier

Vertical Slot
Source: Tassebach Weir, Drava River, Austria
Photo Courtesy: Martin Schletterer

Weir and Orifice
Source: Pend Oreille PUD – Box C.
Photo Courtesy: V. Autier

Deep Side Notch / Orifice
Source: HydroWatt Pont de Beauvoisin
Photo Courtesy: M. Larinier

Nature-Like

Step-Pool morphology ramp
Source: USFWS – Little Sheep Creek
Photo Courtesy: V. Autier

Plane-bed Morphology Ramp
Source: NID, Hemphill, Nevada, USA
Photo Courtesy: Jon Burgi

Bypass
Source: Ampsin-Neuville Lock,
Meuse River, Belgium
Photo Courtesy: Sofico

Meander-Type
Source: Pichoux Gorge, Switzerland
Photo Courtesy: reddit

Non-Volitional


Fish Elevator
Source: USACE – Foster Dam
Photo Courtesy: V. Autier


Fish Lock
Source: Pend Oreille PUD – Box C.
Photo Courtesy: V. Autier


Archimedean Screw Pump
Source: Thorne Moors PS UK
Photo Courtesy: Aquatic Control Eng.


Trap and Haul
Source: PGE - Clackamas
Photo Courtesy: M. McMillen


Pneumatic Fish Tubes
Source: USBOR – Cle Elum Dam
Photo Courtesy: Whoosh


Tube Fishway
Source: Raasakka Hydropower Plant Iijoki River, Finland
Photo Courtesy: Fishheart

Fish Passage Technologies: DOWNSTREAM Categories

Physical Barriers

- Screens
  - Eicher Screens
  - Floating Surface Collectors
  - Fixed Screen Structure
- Fish Bypass System
  - Bypass Pipe
  - Open Channel
  - Helix
  - Transport (truck or barge)

Behavioral Guidance Devices (Structural)

- Louvers
- Angled Bar & Trash Racks
- Floating Fish Guidance Boom
- Hanging Chains
- Barrier/Guidance Nets
- Removable Spillway Weir

Behavioral Guidance Devices (Non-Structural)

- Lights
- Sounds (Acoustic)
- Electric Fields
- Air Bubble Curtains
- Hybrid Barriers

Other Methods

- Spilling
- Turbine Passage
- Trap-and-Haul
- Reservoir Drawdown
- Dam Removal

Source: Cleveland Dam, BC. North Shore News.

Screens

Eicher Screens
Source: Sullivan Hydroelectric
Photo Courtesy: Fish Screen Oversight Committee

Floating Surface Collectors
Source: North Fork, Clackamas, OR
Photo Courtesy: PGE

Fixed Screen Structure
Source: Round Butte, Oregon
Photo Courtesy: CH2M HILL

Fish Bypass System

Bypass Pipe
Source: Chelan PUD, Rocky Reach
Photo Courtesy: V. Autier

Open Channel
Source: USFWS, Coleman NFH
Photo Courtesy: V. Autier

Helix
Source: USBOR, Cle Elum Dam

Transport Truck
Source: Chelan PUD, Eastbank
Photo Courtesy: V. Autier

Removable Spillway Weir
Source: USACE, Ice Harbor
Photo Courtesy: USACE

Behavioral Guidance (Structural)

Louvers
Source: ETH Zurich
Photo Courtesy: Dr. Meister

Angled Bars
Source: Publication
Photo Courtesy: S. Raynal

Floating Fish Guidance
Source: Worthington

Hanging Chains
Source: NA

Guidance Nets
Source: Upper Baker FSC
Photo Courtesy: PGE

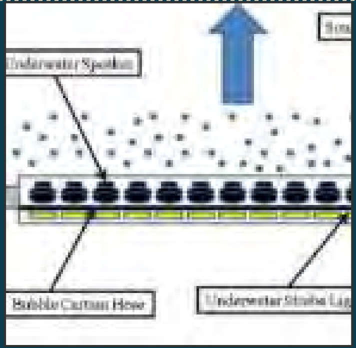
Behavioral Guidance (Non-Structural)

Lights
Source: Hydro Review
Photo Courtesy: P. Patrick

Sounds (Acoustics)
Source: power mag
Photo Courtesy: Ovivo USA

Electric Fields
Source: Elysian Lake, MN
Photo Courtesy: Smith-Root

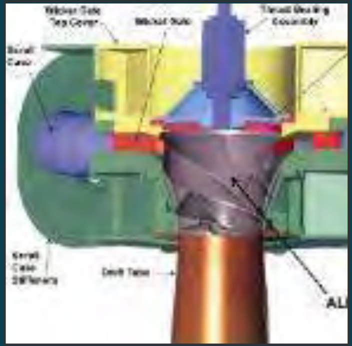
Air Bubble Curtains
Source: Canadianpond.ca
Photo Courtesy: Canadian Pond



Hybrid Barriers
Source:
Image Credit:

Other Methods

Spilling
Source: BC Hydro, Alouette Dam



Turbine Passage
Source: Alden Turbine Runner
Image Credit: EPRI

In-Tributary Trap (Fyke)
Source: AFS
Photo Courtesy: Duluth Nets

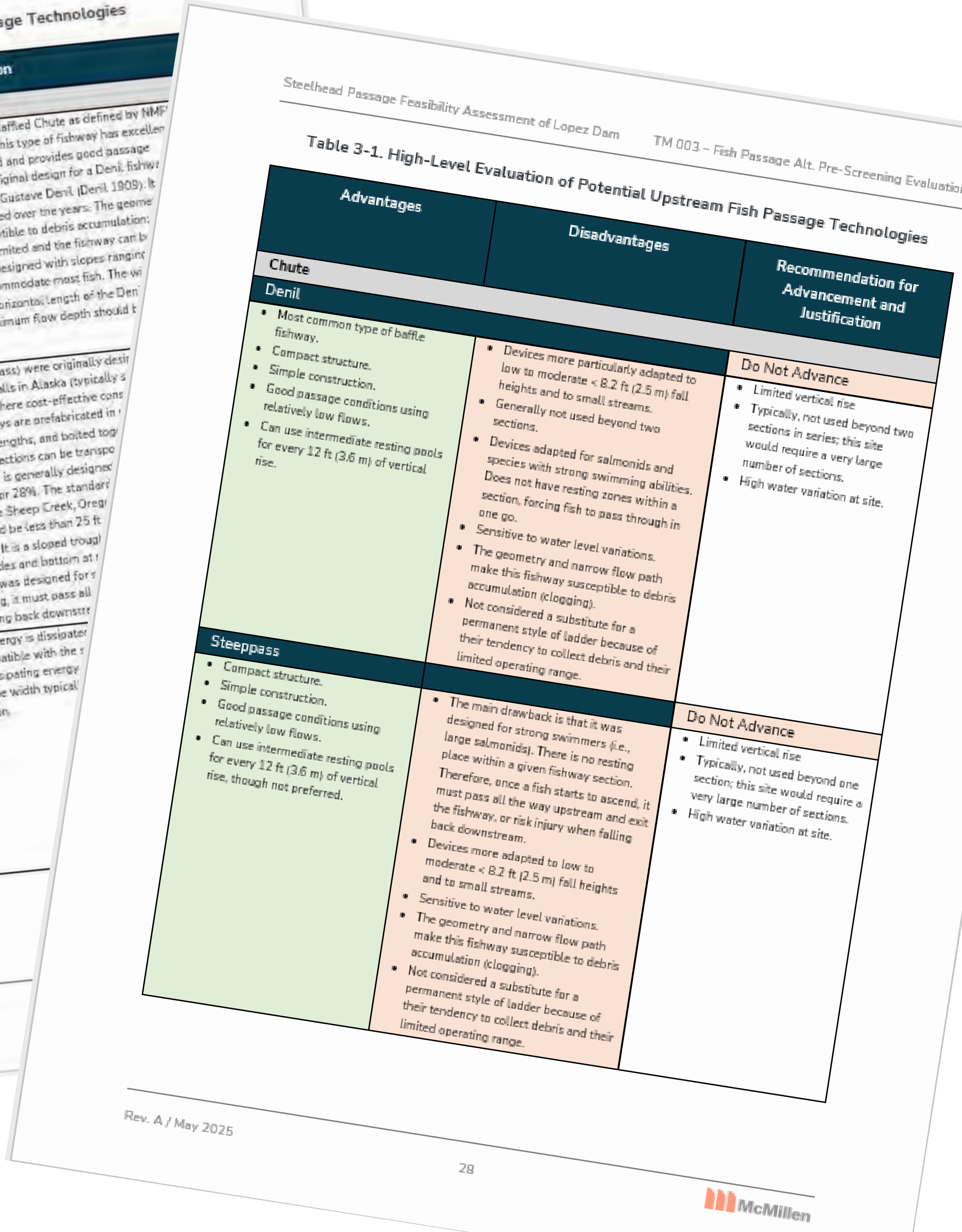
Reservoir Drawdown
Source: Fall Creek, OR
Photo Courtesy: USACE, Portland

Dam Removal
Source: Glines Canyon Dam, WA
Photo Courtesy: U.S. NPS

Pre-Screening Evaluation

TM003 presents:

- a summary description of each option (Tables 2-1 and 2-2).
- a pre-screening evaluation with a recommendation for advancement (Tables 3-1 and 3-2)



High-Level Evaluation of Potential Upstream Fish Passage Technologies

	Upstream Technology	Recommendation
Chute	Denil	Do Not Advance
	Steeppass	Do Not Advance
	Fatou	Do Not Advance
	Super-Active-Type Bottom Baffles (i.e., Larinier)	Do Not Advance
	Macro-Roughness Elements	Do Not Advance
	Pool and Chute	Do Not Advance
Pool Types	Pool and Weir	Do Not Advance
	Vertical Slot	Advance
	Weir and Orifice	Do Not Advance
	Deep Side Notch and Submerged Orifices	Do Not Advance
	Meander-Types	Do Not Advance
Nature-Like	Step-Pool Morphology Ramp	Do Not Advance
	Plane-Bed Morphology Ramp	Do Not Advance
	Bypass	Do Not Advance
Others	Trap-and-Haul	Advance
	Fish Elevators	Do Not Advance
	Fish Lock	Do Not Advance
	Archimedean Screw Pumps	Do Not Advance
	Pneumatic Fish Transport Tube Systems	Do Not Advance
	Tube Fishway	Do Not Advance

High-Level Evaluation of Potential Downstream Fish Passage Technologies

	Downstream Technology	Recommendation
Physical Barriers	Eicher Screens	Do Not Advance
	Floating Surface Collectors	Advance (?)
	Fixed Screen Structures	Do Not Advance
	Bypass Pipe	Advance
	Open Channel	Do Not Advance
	Helix	Advance (?)
	Transport (Truck or Barge)	Advance (?)
Behavioral-Structural	Louvers	Do Not Advance
	Angled Bar and Trash Racks	Do Not Advance
	Floating Fish Guidance Boom	Do Not Advance
	Hanging Chains	Do Not Advance
	Barrier/Guidance Nets	Advance
	Removable Spillway Weir	Do Not Advance
Behavioral-Non-Struct.	Lights	Do Not Advance
	Sounds (Acoustics)	Do Not Advance
	Electric Fields	Do Not Advance
	Air Bubble Curtains	Do Not Advance
	Hybrid Barriers	Do Not Advance
Others	Spilling	Do Not Advance
	Turbine Passage	Do Not Advance
	Trap-and-Haul (In-Tributaries Trap e.g., Fyke Net)	Advance
	Reservoir Drawdown	Do Not Advance
	Dam Removal	Do Not Advance

Alternatives Evaluation Matrix (Draft)

Evaluation Criteria

Once alternatives are selected, they will be developed and evaluated using a rigorous quantitative evaluation process.

The evaluation criteria are grouped in 7 categories:

- Biological Efficiency
- Constructability
- Operation
- Design approach
- Environmental impact
- Regulatory compliance
- Financial

Criterion	Performance Measure (Units)	Importance - Relative (L, M, H)	Importance Weighting (H=3; M=2; L=1)	Upstream Fish Passage				Downstream Fish Passage			
				Alternative 1	*Alternative 2*	*Alternative 3*	*Alternative 4*	*Alternative 1*	*Alternative 2*	*Alternative 3*	*Alternative 4*
Biological Efficiency											
Volitional Passage	Degree (1-10)	H	3								
Attract and Collect Fish	Degree (1-10)	M	2								
Energy Expenditure	Degree (1-10)	M	2								
Stress Factor	Degree (1-10)	L	1								
Smolt mortality	Mortality (%)	L	1								
Fish Return Safety	Degree (1-10)	L	1								
Juvenile passage efficiency (if applicable)	Efficiency (%)	L	1								
Adult mortality	Mortality (%)	H	3								
Adult passage efficiency	Efficiency (%)	H	3								
Daily Transport Capacity	Degree (1-10)	M	2								
Fallback Risk	Proportion (%)	H	3								
Weighted Score	Relative Measure			7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Constructability											
Site Access	Degree (1-10)	H	3								
Cofferdam Impact	Degree (1-10)	M	2								
Dewatering Difficulty	Degree (1-10)	M	2								
Utilities Availability	Degree (1-10)	M	2								
Limited reservoir drawdown requirements	Degree (1-10)	H	3								
Weighted Score	Relative Measure			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Operation											
Low Mechanical Equipment	Degree (1-10)	H	3								
Limited Screen Cleaning Effort	Degree (1-10)	H	3								
Limited Pump O&M Effort	Degree (1-10)	H	3								
Limited Gates O&M Effort	Degree (1-10)	H	3								
Low Risk (Safety)	Degree (1-10)	H	3								
Low Winter Operation Impacts	Degree (1-10)	H	3								
Low Flood Risks	Degree (1-10)	H	3								
Low Debris Management	Degree (1-10)	H	3								
Weighted Score	Relative Measure			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Design Approach											
Proven Technology	Degree (1-10)	H	3								
Ability to Meet Fish Passage Goals	Degree (1-10)	H	3								
Simple system	Degree (1-10)	M	2								
Low human Intervention required for Passage	Degree (1-10)	M	2								
Design Complexity	Degree (1-10)	H	3								
Weighted Score	Relative Measure			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Environmental Impact											
Limited impact to water quality	Degree (1-10)	M	2								
Low impact to habitat	Degree (1-10)	M	2								
limited impact on non-target species	Degree (1-10)	M	2								
Weighted Score	Relative Measure			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Regulatory Compliance											
Low Permitting Effort	Degree (1-10)	H	3								
Low Regulatory Constraints	Degree (1-10)	H	3								
Weighted Score	Relative Measure			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Financial											
Capital Costs (Design/Construction)	NPV ($)	H	3								
Estimated Life Expectancy	Years	M	2								
Annualized Capital Cost (over life expectancy)	$/yr	H	3	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Annual operations and maintenance costs	$/yr	H	3								
Annual NET revenue loss	$/yr	H	3								
Annual monitoring costs	$/yr	H	3								
Total Annualized Cost	$/yr	H	3	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Evaluation Matrix

Each criterion, within each category, will be given an importance factor (L, M, H). The importance factor will be given a relative weight (L=1, M=2, H =3).

Each alternative will be evaluated against each other within a criterion and a grade given between 1 and 10 (1 = worst and 10 = best).

With this quantitative process, each of the seven categories will receive a combined weighted score for each alternative. The total score will then be used to identify which alternative has the most merit.

Biological Efficiency	
CRITERION	**PERFORMANCE MEASURE (Units)**
Volitional Passage	Degree (1-10)
Attract and Collect Fish	Degree (1-10)
Energy Expenditure	Degree (1-10)
Stress Factor	Degree (1-10)
Smolt mortality	Mortality (%)
Fish Return Safety	Degree (1-10)
Juvenile passage efficiency (if applicable)	Efficiency (%)
Adult mortality	Mortality (%)
Adult passage efficiency	Efficiency (%)
Daily Transport Capacity	Degree (1-10)
Fallback Risk	Proportion (%)

Constructability	
CRITERION	**PERFORMANCE MEASURE (Units)**
Site Access	Degree (1-10)
Cofferdam Impact	Degree (1-10)
Dewatering Difficulty	Degree (1-10)
Utilities Availability	Degree (1-10)
Limited reservoir drawdown requirements	Degree (1-10)

TAC Feedback Process

Alternatives Development Package

1. Technical Memorandum “Design Criteria” (TM 002) (.PDF)
2. Technical Memorandum “Fish Passage Alternatives Pre-Screening Evaluation” (TM 003) (.PDF)
3. TAC Feedback Form (.XLS)
4. Presentation Slidedeck (.PDF)
5. Pre-Recorded Presentation by Vincent Autier, PM (.MP4)

Feedback Form Instructions

By June 20, 2025 provide **FEEDBACK** to design criteria, alternatives and preliminary screening results and justification in feedback form (excel spreadsheet in distribution packet)

Please include your name, contact information, specific page/section/table number as reference, comment category, and comment.

Indicate if you concur/non-concur with screening results, and provide rationale for non-concur and alternative recommendation

What other ideas did we NOT include?**

By June 20, 2025, **RETURN** feedback to Vincent Autier, McMillen, cc TAC and County. Emails provided in County distribution.

If possible, **SHARE** and discuss your feedback with fellow TAC member prior to June 24 meeting

Next Steps

I. **REVIEW** presentation and Technical Memorandums

II. By June 20, 2025, provide **FEEDBACK** to design criteria, alternatives and preliminary screening results and justification in feedback form (excel spreadsheet)

   A. Please include your name, contact information, specific page/section/table number as reference, comment category, and comment

   B. Indicate if you concur/non-concur with screening results, and provide rationale for non-concur and alternative recommendation

   C. **What other ideas did we NOT include?****

III. By June 20, 2025, **RETURN** feedback to Vincent A., McMillen, cc TAC and County. Emails provided in County distribution.

IV. If possible, **SHARE** and discuss your feedback with fellow TAC member prior to June 24 meeting

V. **ATTEND** June 24, 2025 TAC meeting with County and McMillen

Thank you.

McMillen

Public Works Department

Lopez HCP Interagency Pre-Application Meeting Agenda

Tuesday July 22, 2025 @ 1:30PM

Location – 1120 Mill St, San Luis Obispo and via TEAMS

COUNTY of SAN LUIS OBISPO

Invitees

County of San Luis Obispo: Kate Ballantyne, David Spiegel, Lisa Bugrova, Kate Shea, Nola Engelskirger

County of SLO Consultant/Legal Team: Ethan Bell, Sharon Kramer, Sharon Hsu, Rebeca Hays Barho, Wendy Katagi, Blair Hurst, Vincent Autier

USFWS: Joseph Brandt, Kirby Bartlett

NOAA/NMFS: Mandy Ingham, Matt McGoogan

CDFW: Kristine Atkinson, Zach Crum

Meeting Objective(s)

Discuss Effects of Flow Proposal

Discuss Conservation Strategies, Monitoring and Adaptive Mangement

Receive Federal Agency Feedback

Meeting Agenda	Time
1. Effects of flow proposal Improvements in baseflows Improvements in migration flows Fish migration modeling results	1:30pm-2:00pm
2. Other Conservation Strategies Pond conversion restoration Gravel augmentation Volitional Fish Passage	2:00pm-2:30pm
3. Monitoring and Adaptive Management Monitoring goals, measurable objectives, methods, management action	2:30pm-3:00pm
4. Federal Agency Feedback on Previously Covered Topics Covered Species Permit Area Permit Term	3:00pm-3:30pm

Next Meeting Topics

a. Fish Passage Alternatives
b. Conservation Strategies

Public Works Department

Lopez HCP Interagency Pre-Application Meeting Agenda

Tuesday July 22, 2025 @ 1:30PM

Location – 1120 Mill St, San Luis Obispo and via TEAMS

COUNTY of SAN LUIS OBISPO

Meeting Minutes

To:	Project Team/File	Date:	07/22/2025
From:	Blair Hurst	Job no:	25-062
cc:			
Project:	Lopez Dam Steelhead Passage Feasibility Assessment		
Subject:	Lopez HCP Interagency Pre-Application Meeting		

This memorandum documents the HCP Pre-Application meeting held on July 22, 2025. The meeting started at 2:30 p.m., Mountain Standard Time (MST) and was adjourned at approximately 4:30 p.m. The following people attended the meeting:

Name	Organization
Lisa Bugrova	County of San Luis Obispo
David Spiegel	County of San Luis Obispo
Ethan Bell	Stillwater Sciences
Terra Dressler	Stillwater Sciences
Rebecca Hays Barho	Nossaman LLP
Rob Thornton	Nossaman LLP
Wendy Katagi	McMillen
Blair Hurst	McMillen
Brent Welton	McMillen
Sharon Hsu	H.T. Harvey
Sharon Kramer	H.T. Harvey
Joseph Brandt	USFWS
Kirby Bartlett	USFWS
Zachary Crum	CDFW
Kristine Atkinson	CDFW
Jeanne Costillo	NMFS
Matt McGoogan	NMFS
Mark Gard	CDFW
Peter William	Oceanu.

The meeting followed the agenda prepared by the County of San Luis Obispo (County) and presented the County's meeting materials "July 22nd Meeting Materials_merged"

1.0 Effects of Flow Proposal

The last meeting discussed what the proposed flow release program is. This meeting will present the effects of proposed program.

Hydrology & Migration

Slide 1 – Summer season shows a proposed reduction in base flow compared to existing conditions. Flow bumps up in the fall and even more in the winter. This is more in line w pre-dam hydrology

Slide 2 – Summary of migratory opportunities. Flow releases to provide adult and smolt migration opportunities. During migration season, seeing dramatic increase in flow across wet, dry, and average conditions at Cecchetti Road RM 12.2 and City of Arroyo Grande RM 5.7 (for period of record (POR) 1968- 2024).

Zach – describe how pre-dam flows were calculated and water-year type criteria were developed. Ethan – for pre-dam, took out all flow removed by diversion at dam location (absence of dam and any operations related to dam). For calculating dry/average/wet years, take total volume of water, rank all years on record, split by thirds.

Mark Gard – dry/average/wet years: are those based on end of September storage in Lopez or total flow for year? Ethan – based on total flow in watershed; not storage in Lopez (different from what was in Stillwater report (instream flow study report) – which was based on storage). Mark – were there flow records before the dam? Ethan doesn't think so.

Ethan – proposed operation doesn't vary by water year type because we don't know what type the year will be. Operation is based on minimum flow released, migration flow releases.

Ethan – flow proposal for HCP is different from instream flow study report, which was a look at habitat conditions, requirements for passage at critical riffles

Slide 3 – Ethan – a decrease in summer baseflow, and increase in winter and spring baseflows... what does this mean for Steelhead? Shows overall increase in days with flows supporting adult steelhead migration, especially upstream of Tar Spring Creek Confluence to Lopez Dam.

Modeling Effects of Flow Operations on Adult Steelhead

Slide 1 – Summary – Modeled movement paths for 100 simulated adult steelhead under pre-dam, existing, and proposed operations. Model assumptions include annual connectivity between the estuary and ocean during the full migration window. Commentor – connectivity assumption is not consistent with experience. Ethan – a lot of years in POR indicate the sandbar is open in January and February. Connectivity provided by the sandbar is included in the sensitivity analysis, but the key question is whether there is a difference between the alternative scenarios

Movement Rules Slide – this slide presents flows required to move fish through reach and the rate of movement for each reach. The model routes the population through a reach based on these rules. Mark – are you assuming any losses between Reaches 2 and 1, and 4 and 3? Ethan – yes, there is some loss of groundwater, and accretion, depending on the year and scenario

Results –

Bar graphs show simulated fish migration paths with percent of fish that have access to various locations along the reach for wet, average, and dry years.

Tables 1 and 2 show the percent of fish that have access to various locations along the migration route across all years

An increase in the percent of fish with access to various locations is seen from baseline/existing conditions to proposed conditions under all flow regimes. The HCP will present results and the full suite of ways to look at results.

Mark – in flow proposal, how many pulse flows? Ethan – don't recall, but it increases and overall, seeing increase in fish with access to upper watershed

Zach – assumption lagoon is open Dec 1 – April 30 – what would results look like if this was not the case? How would it limit passage opportunities. Ethan – Would see fewer fish at tails of migration, most at peak. So doesn't affect too much. The key is to compare results across 3 scenarios: pre-dam, existing, proposed. This is an issue that will be called out in documents.

Ethan – in next meeting, would like to talk about the sensitivity of results and which parameters are most sensitive

Matt McCoogin – what does baseline represent/where does data come from? Ethan – baseline is existing condition, based on how Lopez flow releases are going prior to court ordered injunction. Currently in interim flow condition that is a little higher than baseline. Migration flows are higher than baseline. Baseflows in the flow proposal differ from flows prescribed by the injunction; migration flows too. Not much analysis of what is happening with injunction because it is not part of baseline or proposed condition. Flows Prior to Jan 15, 2025 – was no seasonal variation.

2.0 Other Conservation Strategies

The strategies of pond conversion/habitat restoration and volitional fish passage were discussed.

Pond Conversion – Concept-level plans to convert remnant gravel pits/ponds on Arroyo Grande Creek to riverine habitat were presented. This would reduce water temperatures and increase habitat complexity, rearing habitat, and feeding opportunities for juveniles.

Commentor – was sediment testing done to see what might be accumulated at the bottom of the ponds? Ethan – No.

Kirby – have biological surveys been completed in the ponds (e.g., for the SW pond turtle)? Ethan – No. Surveys were done in the past but not recently. Future work would include geotechnical/sediment sampling and biological surveys, and technical input from agencies.

Volitional Fish Passage – five fish passage alternatives, remaining for consideration after pre-screening over 40 initial options, were discussed. Constructability, operational requirements, and ancillary facilities of the five alternatives were presented:

Vertical slot – reservoir level fluctuations require 25 exit pools, gates, actuators, power, and trash racks at each. Minimal natural light at high water due to 52' depth may limit attraction.

Trap and haul upstream – need road access for transport trucks; land ownership could be a challenge.

Helix – large complex structure is best if built concurrently with dam. Only one exists and is still under construction.

Floating surface collector (FSC) – Construction would span multiple passage seasons. Need several ancillary structures. Manned operations and managing nets/debris booms are labor-intensive.

Trap and haul downstream – same considerations as trap and haul upstream.

Commentor – why go with a big structure if we don't have fish number? Start with trap and haul. Brent agreed and explained ways to scale-up trap and haul as fish numbers increase (e.g., Fyke nets to picket leads or screens that can be raised and lowered; evaluate based on labor).

Mark – suggest looking at FSC at Los Padres Dam on (Carmel?) River as it is much smaller. Brent – smaller FSC have less flow signature for juveniles to identify not always deep enough.

Jeanne Costillo – have locations been identified where would adults be released? Ethan – Lopez Creek is the best habitat, so presumably there and Wittenburg Creek. There is access at Wittenburg already.

David reminded the group of McMillen's TM003 documenting all known upstream and downstream passage technologies**. David requested any final comments or questions on fish passage solutions by the end of the week (July 25)**.

3.0 Monitoring and Adaptive Management

Goals, measurable objectives, methods, and management actions for each management action were presented. Each management action corresponds to a section in the HCP.

Mark G – is critical riffle data available? Ethan – data is continuing to be collected, will be reported when complete

Commentor – are the locations where flow levels are to be maintained shown? Ethan – yes, release rate is shown. Commentor – discussion of flows at each location will need to be included. Ethan – will have maintenance of rating curves at locations.

Zach – how were locations and flows determined? Ethan – determined with the goal of providing habitat, increasing migratory opportunities.

Zach – there was mention of low and moderate densities of juveniles – how do we define these terms and adaptive management that may come? Ethan – good point, no specific answer. Could be relative to other reaches.

Zach – would there be reference to densities upstream in the watershed? Ethan – not comparable to d/s

Commentor – typically there is a survey to inform baseline. Is that in the plans? Ethan – agree, good approach, would be at discretion of County to do, get permitted. Could be index monitoring. Mark G – could estimate abundances, estimate survival, calculate population.

4.0 Federal Agency Feedback on Previously Covered Topics

Inclusion of the tidewater goby, Least Bell's vireo, and the southwestern pond turtle is still to be determined.

The permit term is still to be determined, with potential durations ranging from 20 to 50 years. The duration will be based on the estimated time required to increase steelhead population density within the framework of the HCP.

Matt McGoogan – revisiting area covered: Is it accurate that the levee portion is not covered? County – Yes, because it is covered under the 2017 Biological Opinion NMFS Section 7, is within WMP. Matt – do wonder how USFWS will have to write BO for permit. Action area may be different from permit area. Action area is dam out to the mouth.

Jeanne – regarding permit term: for (another project) in operation now that has a permit, does that have a timeline? Does that timeline end while ours is going? County – think WMP is a 17-year term.

Matt – NMFS is compiling comments from presentation in June – for fish passage and flow proposals. County – hard internal deadline is this Friday 7/25 for feedback on Tech Memo 003.

5.0 Next Meeting Topics

Fish Passage Alternatives

Conservation Strategies

Anticipated Effects of Lopez Dam Release Program (LDRP)

All materials are draft proposals, and will be revised when/if included in HCP application

Average daily flows in Arroyo Grande Creek at Lopez Dam (RM 13.8) and near the City of Arroyo Grande (AG Gage, RM 5.7)

Season	Water Year Type[1]	**Average Daily Flows (cfs)**					
		Lopez Dam (RM 13.8)			City of Arroyo Grande (RM 5.7)		
		Pre-Dam	Existing Conditions	***Proposed Operations***	Pre-Dam	Existing Conditions	***Proposed Operations***
Summer (July–September)	Dry	0.1	4.0	***2.5***	0.2	4.8	***3.4***
	Average	0.3	4.0	***2.7***	0.4	4.9	***3.6***
	Wet	3.6	4.3	***2.9***	4.5	6.1	***4.7***
	All years	1.4	4.1	***2.7***	1.7	5.3	***3.9***
Fall (October – December)	Dry	1.1	4.9	***4.7***	2.0	6.1	***5.9***
	Average	4.7	5.1	***5.0***	6.1	6.9	***6.9***
	Wet	11.3	7.9	***8.4***	15.5	12.5	***13.1***
	All years	5.7	6.0	***6.0***	7.9	8.6	***8.6***
Winter (January–March)	Dry	10.0	3.1	***6.6***	11.7	4.9	***8.5***
	Average	28.0	6.2	***9.7***	36.4	14.8	***18.3***
	Wet	136.2	67.3	***70.1***	182.8	114.0	***116.8***
	All years	58.6	25.9	***29.2***	77.7	45.1	***48.4***
Spring (April – June)	Dry	4.5	4.5	***4.7***	5.0	5.5	***5.7***
	Average	6.3	3.2	***3.8***	7.5	4.9	***5.5***
	Wet	31.6	19.3	***18.7***	39.3	27.5	***26.8***
	All years	14.2	9.1	***9.2***	17.5	12.8	***12.8***

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Summary of migration flow during the migration season (December-April); Average days greater than 6 cfs at Arroyo Grande Creek at Cecchetti Road (RM 12.2) and average days greater than 15 cfs near the City of Arroyo Grande (AG Gage, RM 5.7). (adult upstream steelhead migration is achieved at 6 cfs at Cecchetti Road, and 15 cfs at City of Arroyo Grande)

Season	Water Year Type	Annual average days with flows greater than 6 cfs at Cecchetti Road (RM 12.2)			Annual average days with flows greater than 15 cfs at City of Arroyo Grande (AG Gage, RM 5.7)		
		Pre-Dam	Existing Conditions	**Proposed Operations**	Pre-Dam	Existing Conditions	**Proposed Operations**
Migration Season (December–April)	Dry	30	3	**46**	18	4	**7**
	Average	68	16	**73**	54	19	**26**
	Wet	98	65	**95**	108	81	**91**
	Average for all years	65	28	**71**	59	35	**41**

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LDRP summary:

- Overall decrease in summer baseflows, more closely mimicking natural California coastal hydrograph;
- Overall increase in winter and spring baseflows, more closely mimicking natural California coastal hydrograph; and
- Overall increase in days with flows supporting adult steelhead migration, especially upstream of Tar Spring Creek Confluence to Lopez Dam.

Modeling Effects of Flow Operations on Adult Steelhead

All materials are draft proposals, and will be revised when/if included in HCP application

Model Summary:

- Adult steelhead upstream migration was simulated for 3 modeled flow scenarios: pre-dam, baseline (current operations), and LDRP (proposed operations) over 56 water years (1969-2024).
- For each year of flow data, movement paths of 100 adult steelhead were simulated.
- Main model assumptions
  - Fish require a minimum of 15 cfs to swim through the lower reaches from the ocean to the confluence with Tar Springs Creek (RM 6.3)
  - Fish require a minimum of 6 cfs to swim through the upper reaches of the mainstem from the confluence with Tar Springs to Lopez Dam (RM 12.2)
  - Fish move at an average rate of 6.3 miles/day (0.26 mi/hr)
  - Fish arrival to Arroyo Grande Creek from the ocean follows a normal distribution between December 1st and April 30th (mean arrival date is February 14th; the same distribution was applied across all years and all scenarios)
  - There is connectivity between the estuary and the ocean during the entire migration window each year.
  - If a fish gets "stuck" due to low flows, it can "wait" up to 5 days for an additional flow event. Fish that have to wait more than 5 days are assumed to stop and spawn where they are.

Reach		Movement rule(s): move if true, else wait	Movement rate
	Arroyo Grande Creek Entry from the ocean RM 0	Assumption: estuary is generally open during migration season, doesn't have a specific triggering flow	N/A ; this is an entry point so fish either move into the estuary or not
1 Flow too low? Wait	Estuary to 22nd Street Bridge RM 1.3	Q_22 > Q_{min} (15 cfs)	**6.3 mi/day = 0.3 mi/hour**
2 Flow too low? Wait	22nd Street Bridge to Tar Springs RM 6.3	Q_Tar > Q_{min} (15 cfs)	**6.3 mi/day = 0.3 mi/hour**
3 Flow too low? Wait	Tar Springs to Cecchetti Road RM 8.14	Q_Cecchetti > Q_{min} (6 cfs)	**6.3 mi/day = 0.3 mi/hour**
4 Flow too low? Wait	Cecchetti Road to Dam RM 12.2	Q_Dam > Q_{min} (6 cfs)	**6.3 mi/day = 0.3 mi/hour**

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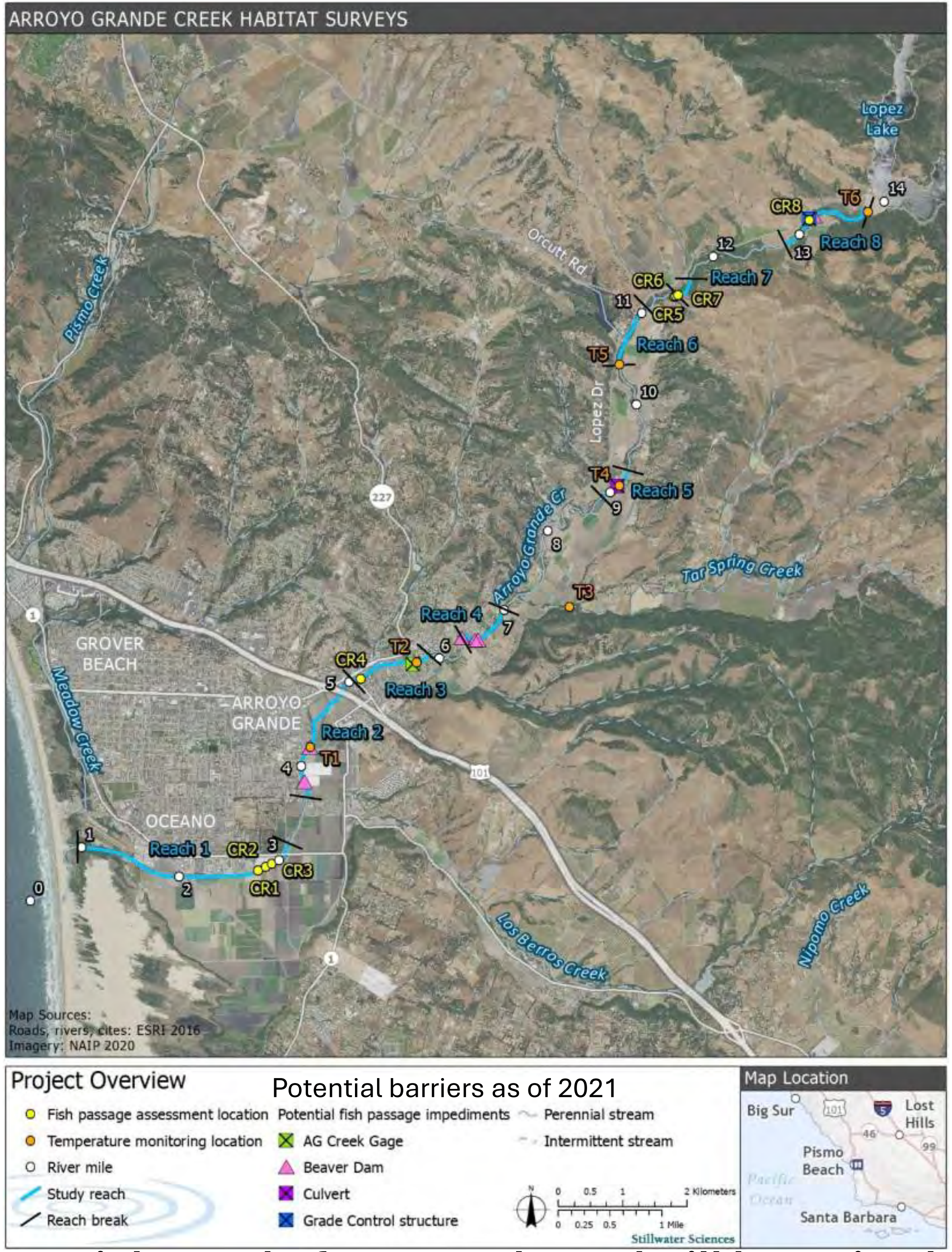

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Figure 1: An example of simulated fish migration paths (top row) and modeled flows at Tar Springs Creek and at Lopez Dam (bottom row) for all scenarios during a wet water year (1996).

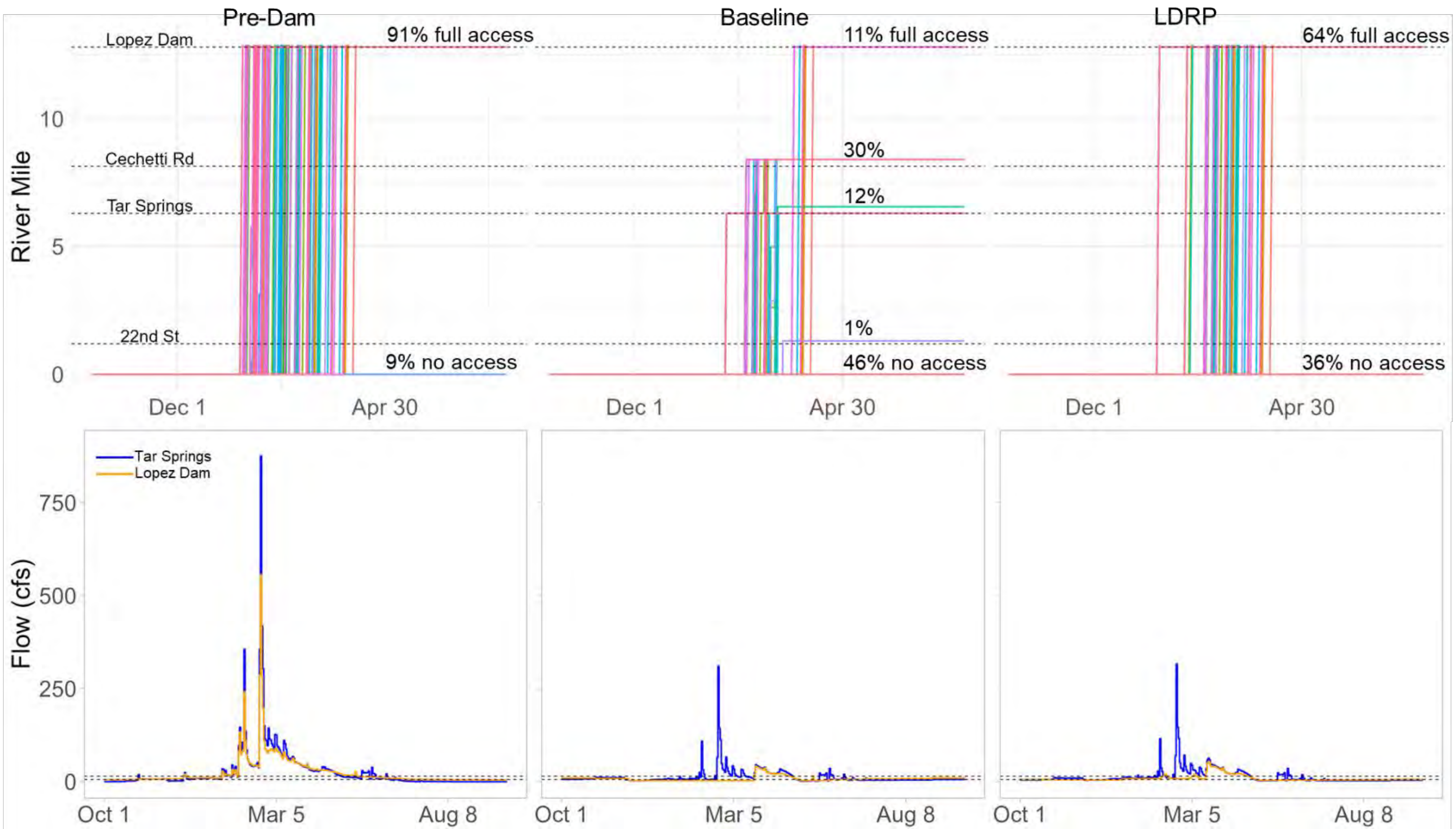

Figure 2: An example of simulated fish migration paths (top row) and modeled flows at Tar Springs Creek and at Lopez Dam (bottom row) for all scenarios during a median water year (2010).

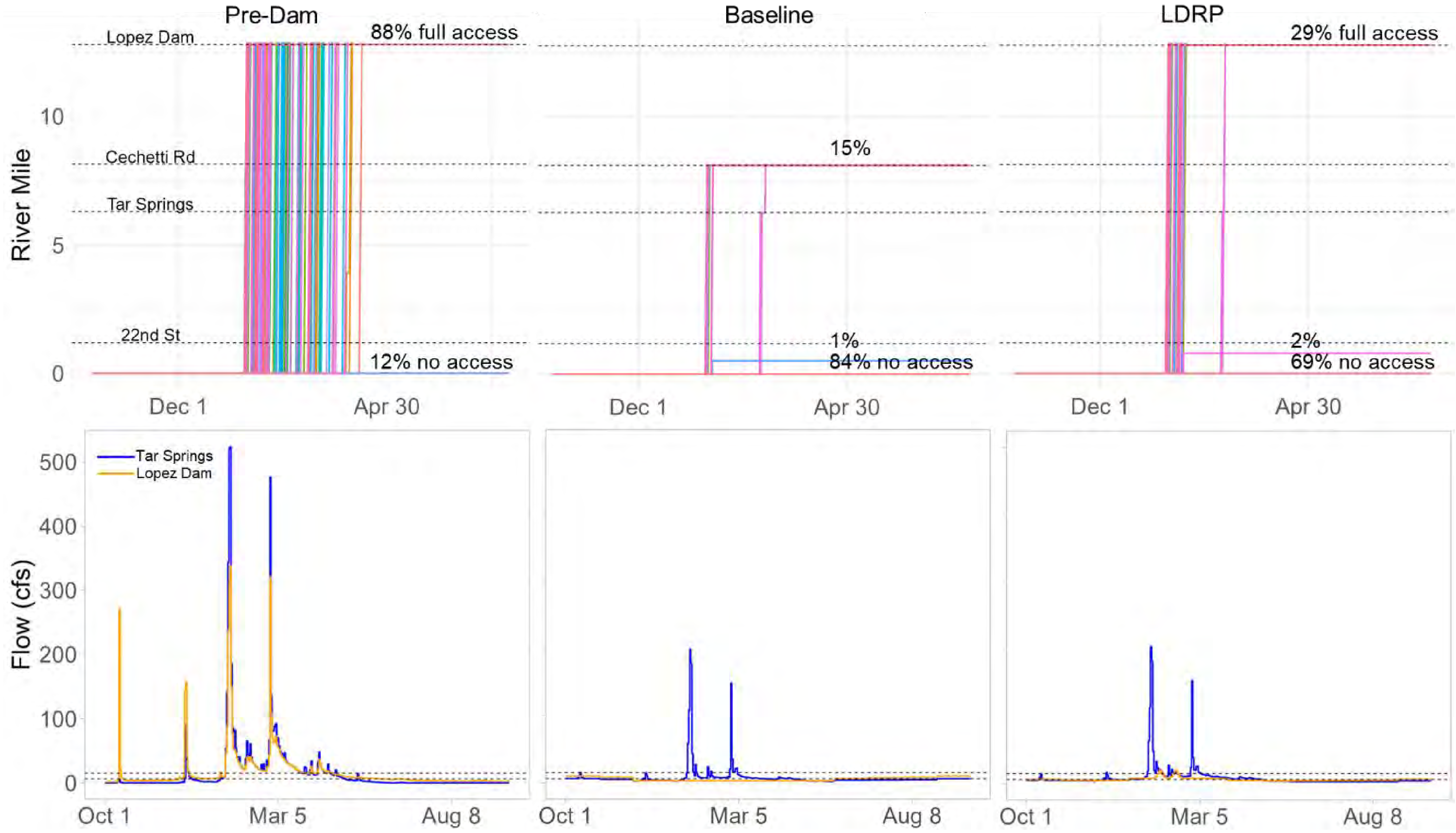

Figure 2: An example of simulated fish migration paths (top row) and modeled flows at Tar Springs Creek and at Lopez Dam (bottom row) for all scenarios during a dry water year (1994).

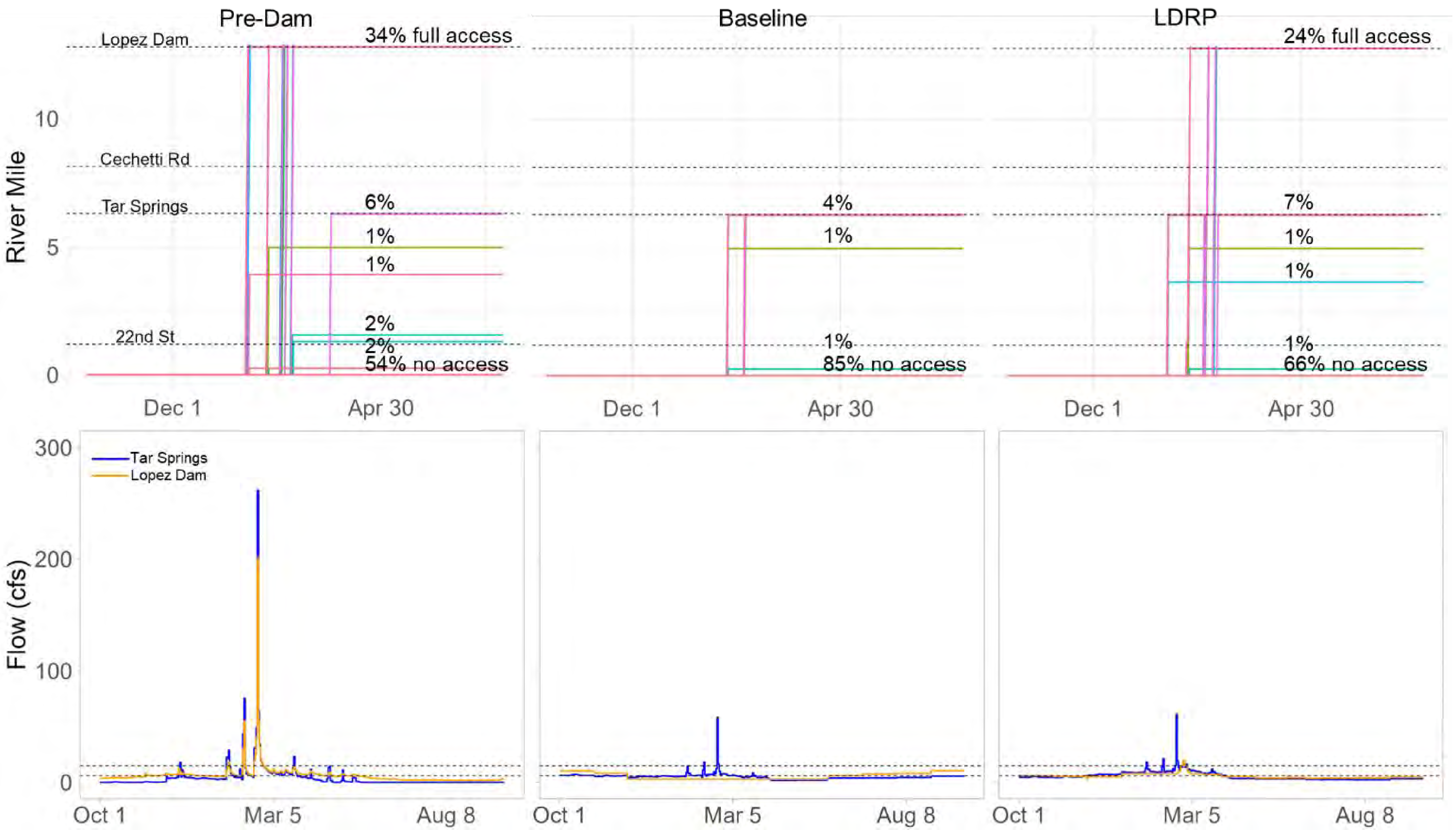

Table 1: Average proportion (across water years) of simulated fish to reach various locations along the migration route.

	Pre-Dam	Baseline	LDRP
Lower Mainstem (below Tar Springs)	58%	31%	37%
Tar Springs Confluence	54%	28%	34%
Cechetti Road Crossing	54%	25%	33%
Lopez Dam	54%	11%	33%

Table 2: Proportion of modeled years where adult fish had no access to Arroyo Grande Creek, where at least 50% of adult fish were able to enter Arroyo Grande Creek, and where at least 50% of adult fish had full access to Arroyo Grande Creek from the ocean to Lopez Dam.

	Pre-Dam	Baseline	LDRP
No Access	7%	27%	20%
≥50% Access	59%	32%	39%
≥50% Full Access	55%	9%	36%

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Modeled Effects Summary:

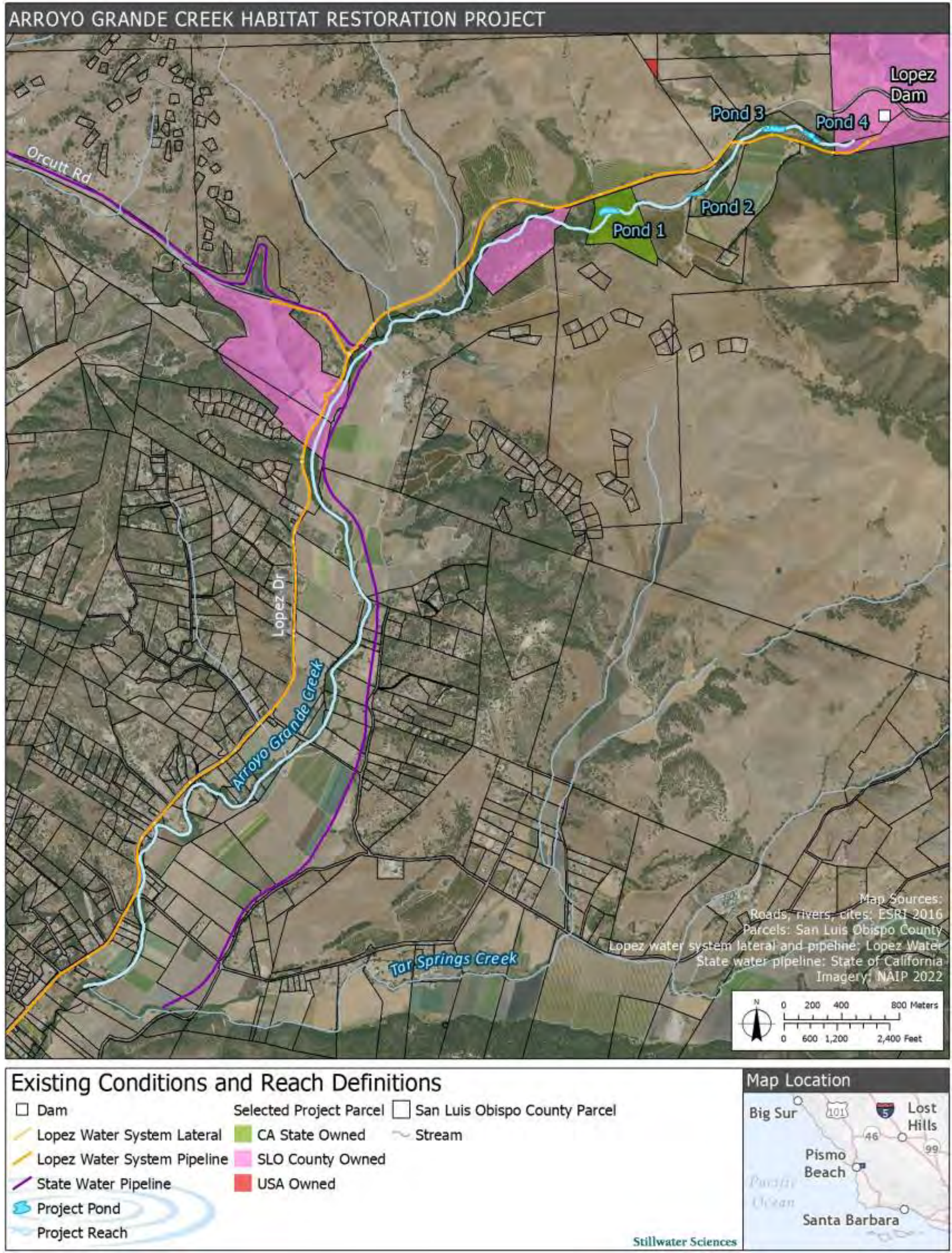
- Overall increase in the number of simulated fish than can access AG Creek Watershed; and
- Substantial increase in the number of simulated fish than can access and spawn in habitat upstream of Tar Spring Creek confluence to Lopez Dam.

Conservation Program-
Habitat Restoration Projects

All materials are draft proposals, and will be revised when/if included in HCP application

- Remnant gravel pits have been “captured” by Arroyo Grande Creek, resulting in ponds.
- Ponds slow water velocity and reduce suitable steelhead habitat:
    - increasing water temperatures,
    - reducing cover,
    - eliminate cobble riffle habitat.

- Restoration of riverine habitat within the ponds would:
    - Reduce water temperatures,
    - increase spawning habitat,
    - providing cover from increased habitat complexity,
    - increasing shallow water fry rearing habitat,
    - increased productive macroinvertebrate habitat within substrate, and
    - increased feeding opportunities for juveniles from increased water velocities adjacent to resting pools.
    - Decreasing suitable warm water habitat for bull frogs (plus removal) would also improve conditions for native CRLF.



Existing Pond 3 downstream of Lopez Dam.

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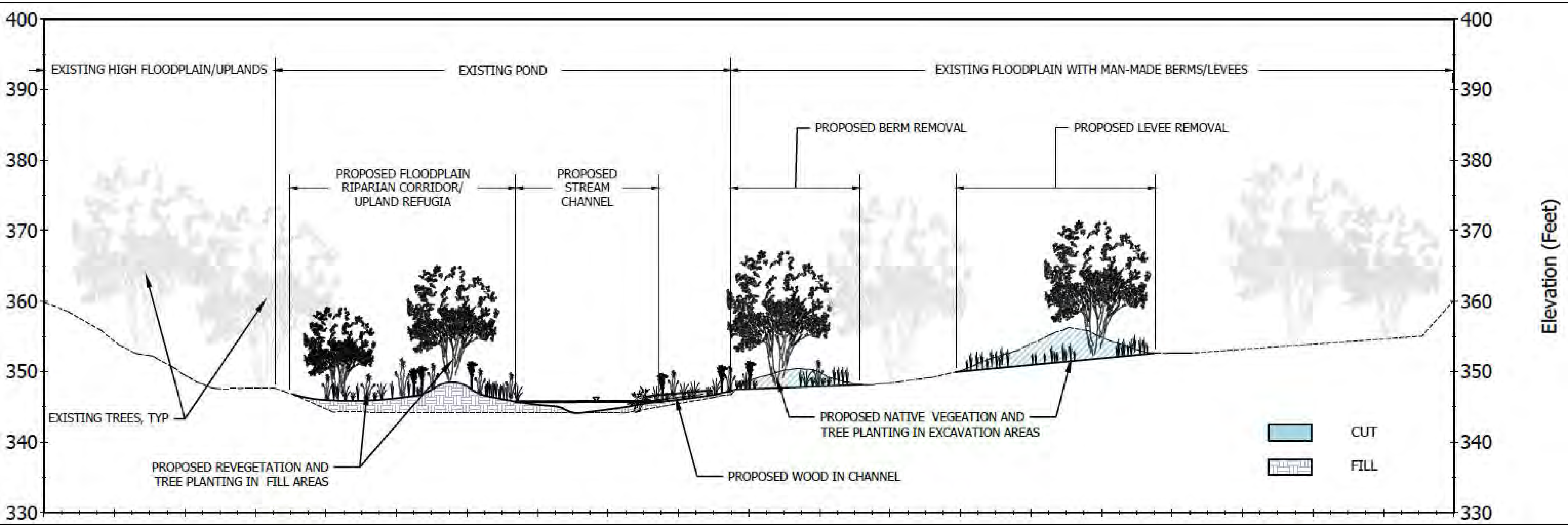

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Monitoring Program Summary

(included as separate PDF)

All materials are draft proposals, and will be revised when/if included in HCP application

Table 8-1. Monitoring components and associated HCP goals, objectives, triggers, and potential management actions.

Action (HCP Section)	Goals	Objectives	Monitoring type and methods	Triggers	Potential management actions	Monitoring period and frequency
Lopez Release Plan (6.4.1)	Maintain flows in AG Creek that support steelhead year-round	Maintain minimum of 3 cfs during summer, 5 cfs during fall, 8 cfs during winter, and from 4 to 7 cfs during spring	Compliance monitoring. Monitor Lopez flow releases year-round. (**MM-01**)	Minimum flows not met on required dates	TWG[1] evaluates annual monitoring information, and District may modify operations protocols to comply with minimum flows.	Continuous year-round gage monitoring; annual reporting.
	Provide steelhead migration flows	Up to 2 migration flow releases each winter, each release is at least 10 days in duration, ranging in flow from 10 to 20 cfs from Lopez Dam.	Compliance monitoring. Monitor flow releases from Lopez Dam, AG gage, and 22nd Street Bridge. (**MM-01**)			
		Increase in minimum number of adult upstream passage days to Lopez Dam over baseline.	Effectiveness monitoring. Monitor streamflow at Cecchetti and AG Gage from December to April; assumes that flows greater than 6 cfs at Cechetti and flows greater than 15 cfs at AG provide passage to Lopez Dam. (**MM-02**)	Objectives for minimum migration passage days not met.	TWG evaluates annual monitoring information for a minimum of 7 years or the period necessary to obtain information about wet, normal and dry years. Based on that evaluation, the District may modify flow release management such as magnitude, frequency, or duration or adjust the migration	Continuous monitoring during adult migration flow release period (December through April); annual reporting.

[1] Technical Workgroup

Table 8-1. Monitoring components and associated HCP goals, objectives, triggers, and potential management actions.

Action (HCP Section)	Goals	Objectives	Monitoring type and methods	Triggers	Potential management actions	Monitoring period and frequency
					flow release to attain measurable objectives.	
	Provide sufficient water depth during adult migration	Migration flows releases for attraction and migration (>6 cfs upstream of Tar Springs, >15 cfs Tar Springs to Lagoon) provide water depth >0.7 ft over 25% of entire channel cross section and 10% of continuous cross section at critical riffles.	Effectiveness monitoring. Following CDFW SOP at TWG identified critical riffles in AG Creek. (**MM-02**)	Adult migration water depth objectives not met during migration flow releases.	TWG evaluates migration flow monitoring information for HCP implementation for Years 1, 3, 5 and 10 after implementation, and after any modification to migration flow regime. Based on that evaluation, the District may identify refinements to attraction flow magnitude, including modify Lopez releases for steelhead migration, or modify passage obstacles.	Within 1 year of implementation and/or when a migration flow is released, in Years 1, 3, 5, and 10 of HCP and after any modification to migration flow magnitude or duration for the duration of the HCP.
	Avoid stranding	*In process*	Compliance monitoring. Monitor streamflow at X gage at 15-minute intervals during flow recessions. (**MM-03**)	Flow recessions in excess of objectives	TWG to evaluate flow ramping criteria annually. Based on evaluation, the District may identify and make annual refinements to ramping rate measurable objectives or implementation.	Immediately after implementation, annually for the duration of the HCP during flow recessions.

Table 8-1. Monitoring components and associated HCP goals, objectives, triggers, and potential management actions.

Action (HCP Section)	Goals	Objectives	Monitoring type and methods	Triggers	Potential management actions	Monitoring period and frequency
Water Quality (7.1.4)	Maintain suitable water quality during the summer baseflow period	Suitable water temperature (< 23°C); Dissolved oxygen (< X mg/l) downstream of Lopez Dam to Tar Spring	Compliance monitoring. Monitor water quality parameters at the outlet at Lopez Dam. (**MM-02**)	Water temperature in excess of criteria, DO less than criteria	TWG to evaluate water quality criteria annually. Based on evaluation, the District may identify and make annual refinements to flow releases, or elevation of flow releases.	Immediately after implementation, annually for the duration of the HCP.
Lopez Ponds Restoration CM (6.4.2.1)	Restore riverine function, enhance rearing habitat, BMI habitat, and reduce habitat for non-native species	Restore over X ft of channel. Maintain over X ft2 of suitable juvenile rearing habitat, and over X ft of fry rearing habitat at typical spring flows (5 cfs). Over X ft2 of suitable spawning habitat at typical winter flows (8 cfs).	Effectiveness monitoring. Annual monitoring at design flows to determine the success of the project at achieving restoration objectives, and to inform maintenance. (**MM-05**)	Rearing or spawning habitat less than objectives.	TWG to evaluate annual monitoring information for a period of at least 10 years to determine if habitat measurable objectives continue to be met. Based on evaluation, the District may implement Sediment Augmentation program or other appropriate maintenance or restoration activities to maintain habitat measurable objectives.	Annual monitoring for ten years following implementation.
Sediment Augmentation (6.4.2.3)	Supplement sediment and spawning gravels downstream of Lopez Dam	Augment at least X cy of sediment within the CWMZ.	Effectiveness monitoring. Monitor augmentation location and replenish to initial volume at least every five years. (**MM-06**)	Sediment transport is occurring and volume at augmentation site is less than X cy or sediment	TWG to evaluate annual monitoring information for a period of at least 5 years to determine if augmented gravel is mobilizing and being transported downstream. Based on evaluation, District may	Monitored annually and replenished to initial volume at least every five years.

Table 8-1. Monitoring components and associated HCP goals, objectives, triggers, and potential management actions.

Action (HCP Section)	Goals	Objectives	Monitoring type and methods	Triggers	Potential management actions	Monitoring period and frequency
				transport is not occurring.	replenish sediment to initial volume, adjust geomorphic flows, or conduct other maintenance or restoration activities to maintain the measurable objectives.	
Geomorphic Flows (6.4.1.5)	Transport sediment, scour vegetation, maintain spawning gravel and BMI quality	Release X cfs at least every X years	Compliance monitoring. Monitor daily average streamflow at Cecchetti and AG gages Effectiveness monitoring. Monitor volume of gravel transported. (**MM-06**)	Sediment transport is not occurring.	TWG to evaluate annual monitoring information for a period of at least 5 years to determine if gravel is mobilizing and being transported downstream. Based on evaluation, District may adjust geomorphic flows, or conduct other maintenance or restoration activities to ensure geomorphic processes	Within two years of sediment augmentation and/or when a spill occurs or a geomorphic flow is released, for the duration of the HCP.
Population Health (8.5.1.3)	Individual and population diversity	Spatial diversity of spawning and rearing from Lopez Dam downstream to lower AG Creek	Biological monitoring. Monitor spawning abundance and distribution. (**MM-07**) Monitor juvenile rearing distribution. (**MM-08**)	Infrequent or no spawning or rearing observed upstream of Tar Spring	TWG to evaluate annual monitoring information for a period of at least 5 years to determine where spawning and rearing is or is not occurring. Based on evaluation, District may adjust restoration efforts,	Within one year after implementation, and annually for the duration of the HCP

Table 8-1. Monitoring components and associated HCP goals, objectives, triggers, and potential management actions.

Action (HCP Section)	Goals	Objectives	Monitoring type and methods	Triggers	Potential management actions	Monitoring period and frequency
					flows, gravel augmentation, or barrier remediation.	
		Multiple age classes of rearing juveniles	Biological monitoring. Monitor fall juvenile rearing relative abundance at index sites. (**MM-08**)	Low abundance of age 0+ and 1+, and infrequent 2+ or older juveniles observed.	TWG to evaluate annual monitoring information for a period of at least 5 years to evaluate juvenile rearing. Based on evaluation, District may revise restoration efforts, or other actions.	Within one year after implementation, and annually for the duration of the HCP
		Support anadromous and resident life histories	Biological monitoring. Monitor spawning. (**MM-07**)	Evidence of only one life history observed	TWG to evaluate annual monitoring information for a period of at least 5 years to determine life history of spawning activity. Based on evaluation, District may adjust restoration efforts, or gravel augmentation.	Within one year after implementation, and annually for the duration of the HCP
		Native steelhead genetics occur, without hatchery introgression	Biological monitoring. Assess genetics of *O. mykiss* population upstream and downstream of Lopez Dam. (**MM-10**)	Little to no native *O. mykiss* genetics observed	TWG to evaluate genetics of population and consider implications for fish passage, hatchery stocking practices, and other management in the watershed.	Within one year after implementation.

Table 8-1. Monitoring components and associated HCP goals, objectives, triggers, and potential management actions.

Action (HCP Section)	Goals	Objectives	Monitoring type and methods	Triggers	Potential management actions	Monitoring period and frequency
	Successful reproduction	Spawning by anadromous and resident adults	Biological monitoring. Monitor evidence of spawning (e.g., observations of adults, redds, fry) by anadromous and resident adults. (**MM-07; MM-09**)	Infrequent or no anadromous or resident spawning observed	TWG to evaluate annual monitoring information for a period of at least 5 years to determine if spawning is occurring. Based on evaluation, District may adjust restoration efforts, or gravel augmentation.	Within one year after implementation, and annually for the duration of the HCP
	Population abundance	Moderate densities of multiple age classes of juveniles, increasing abundance of adults	Biological monitoring. Monitor fall juvenile rearing densities at index sites. (**MM-08**)	Low densities of juveniles observed.	TWG to evaluate annual monitoring information for a period of at least 5 years to evaluate juvenile rearing. Based on evaluation, District may revise restoration efforts, or other actions.	Within one year after implementation, and annually for the duration of the HCP
	Individual growth	Moderate individual growth rates and large smolts	Biological monitoring. PIT tag mark and capture, and migrant trap monitoring. (**MM-08**)	Low growth rate of juveniles, and/or small smolts observed.	TWG to evaluate annual monitoring information for a period of at least 5 years to evaluate growth rates. Based on evaluation, District may revise restoration efforts, or other actions.	Within one year after implementation, and annually for at least five years

Table 8-1. Monitoring components and associated HCP goals, objectives, triggers, and potential management actions.

Action (HCP Section)	Goals	Objectives	Monitoring type and methods	Triggers	Potential management actions	Monitoring period and frequency
		Improving BMI production between Lopez Dam and Tar Springs	Biological monitoring. Regular monitoring of BMI production. (**MM-11**)	Continued poor BMI production	TWG to evaluate annual monitoring information for a period of at least 5 years to evaluate BMI production. Based on evaluation, District may revise restoration efforts, or other actions.	Within one year after implementation, and annually for at least five years
	Species composition	Increase in native species relative to non-native	Biological monitoring. Annual monitoring of species composition in index reaches, and eDNA sampling. (**MM-12**)	Continued low abundance of native species relative to non-native species	TWG to evaluate annual monitoring information for a period of at least 5 years to evaluate species composition. Based on evaluation, District may revise predator removal programs, restoration efforts, or other actions.	Within one year after implementation, and annually for at least five years