Technical Memorandum

Date	Friday, January 28, 2022
Project:	Chehalis River Basin Flood Damage Reduction Project
To:	Chehalis Basin Flood Control Zone District
From:	Matt Prociv, PE; Rachel Ainslie; Nicole Loo; and Theo Malone, PE
Subject:	DRAFT - Construction Phase Upstream Fish Passage Alternatives Selection

Contents

1.0 Introduction

The Chehalis River Basin Flood Control Zone District (District) is proposing to construct a new flood retention structure and temporary reservoir near the town of Pe Ell, Washington to reduce damage to life and property along the Chehalis River. The development of fish passage alternatives is an integral component of the flood retention structure (Flood Retention Only - Expandable [FRE]) design for both the construction and operational phases. Fish passage options for the permanent FRE facility were advanced to an early, preliminary level of design in collaboration with the Fish Passage Technical Subcommittee[1] (Subcommittee). These options included run-of-river conduits through the FRE facility to provide passage during non-operational periods, and a Collect, Handle, Transfer, and Release (CHTR) fish passage facility for use during flood retention operations (HDR 2018a, 2018b).

Design efforts for the proposed permanent fish passage facility have advanced to a conceptual design level sufficient to assess the effectiveness and performance of the proposed design. Design of the construction phase upstream fish passage facility has not been advanced to the conceptual level. In 2019, Washington state Department of Ecology (Ecology) and the U.S. Army Corps of Engineers (USACE) requested additional information on the anticipated provisions that will be implemented during construction to provide fish passage through the project area. This information would support development of the Draft Environmental Impact Statements (EISs) prepared pursuant to the State Environmental Policy Act (SEPA; Ecology 2020) and National Environmental Policy Act (NEPA; USACE 2020), respectively. In response to these requests, the District advanced conceptual fish passage options for the construction period but did not identify a single recommended design to be incorporated as part of the project.

The District's review of the Draft SEPA EIS found that Ecology had assumed the use of a picket weir as a key component of the construction phase fish passage facility. In August 2021 the District sent Ecology a Technical Memorandum (TM) identifying a velocity barrier as a barrier technology more likely to be employed than a picket barrier. Although the August 2021 Technical Memorandum identified a single barrier technology, the District had yet to develop and evaluate alternatives to provide fish passage during construction. Currently, Ecology and USACE are developing final EIS documents.

1.1 Purpose and Scope of Document

The purpose of this TM is to communicate to Ecology and USACE the District's further conceptual design conclusions regarding the construction phase fish passage facility. This conceptual design will be the basis for more detailed final design development and is recommended to the District for inclusion in the proposed Project Description. This TM presents construction phase upstream fish passage technologies and alternatives to be implemented

[1] The Fish Passage Technical Subcommittee was a collaborative working group consisting of representatives from the National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (USFWS), Washington Department of Ecology (Ecology), Washington Department of Fish and Wildlife (WDFW), and the Quinault Indian Nation (Quinault) that met in 2016 and 2017. Subcommittee meeting notes are found in HDR 2017 Attachment A and HDR 2018b Appendix A.

during the construction phase of the FRE facility for consideration and provides a recommended construction phase upstream fish passage alternative. Downstream fish passage is planned to be accomplished through the diversion tunnels (District 2019, HDR 2018b). This TM focuses on the upstream FP design. Figure 1 presents a process flowchart that was used to develop and evaluate construction phase upstream fish passage alternatives. The descriptions encompass the sections of this TM, with the development of the recommended alternative described in Section 6.0, as next steps.

Figure 1. Process Flowchart for Development and Selection of Construction Phase Upstream Fish Passage Alternative

1.0 Introduction	• Describe purpose and scope of document • Describe the goal and objectives for selection of an alternative for temporary fish passage during construction of the flood retention facility
2.0 Fish Passage Criteria	• Assemble data • Establish project design objectives based on agency criteria and guidelines • Identify data gaps, characterize resources, establish timeline
3.0 Potential Technologies	• Formulate array of potential temporary fish passage and barrier technologies • Describe key features/characteristics of each technology
4.0 Feasibility of Technologies	• Define feasibility criteria • Evaluate feasibility of passage and barrier technologies • Formulate array of fish passage and barrier technologies that meet minimum feasibility requirements
5.0 Alternatives Analysis	• Formulate alternatives from array of fish passage and barrier technologies that meet minimum feasibility requirements and design criteria • Define evaluation factors and develop scoring matrix and comparison methodology • Evaluate alternatives • Identify recommended alternative
6.0 Next Steps	• Gather feedback to determine the recommended alternative • Develop recommended alternative to a 10 percent design level • Develop description of recommended alternative for fish passage during construction in support of the project EIS • Proceed to conceptual and final design of the recommended alternative

1.2 Goal and Objectives

The goal and objectives for the selection of an alternative for construction phase upstream fish passage during FRE facility construction are provided below. The goal describes the future state that is desired to be achieved. The objectives are specific, measurable actions that help define when the goal is achieved. Subsequent sections of this TM refer to this section while discussing the suitability of construction phase upstream fish passage facility alternatives meeting the goal and achieving the objectives.

Goal: Provide construction phase upstream fish passage of the Chehalis Flood Retention Structure for target fish species and life stages.

Objectives:

- Construct and operate a facility in compliance with National Marine Fisheries Service (NMFS) and Washington Department of Fish and Wildlife (WDFW) engineering principals and guidelines.
- Provide reliable upstream passage for target species and life stages of fish in the Chehalis River (described in Section 2.1.1) throughout the anticipated range of operating and environmental conditions during periods when fish are anticipated to migrate during FRE construction.
- Conform to the usual and customary fish passage efficiencies observed at like facilities in operation elsewhere.
- Implement a facility that considers cost effectiveness and limits the anticipated Operations and Maintenance (O&M) effort and level of complexity.
- Accommodate and limit delay or injury to downstream migrating fish that are passed downstream of the construction site through the FRE construction diversion tunnel.
- Limit impact of construction phase fish passage facility on the construction footprint of the permanent flood retention structure.

2.0 Fish Passage Criteria

The biological and technical fish passage criteria used in previous reports and TMs (HDR 2018b, 2021) were refined based on collaboration with WDFW (January 2021). These fish passage criteria are described in the sections below and used to develop evaluation factors and feasible alternatives. These criteria will be used in future design development of the selected construction phase upstream fish passage facility alternative.

2.1 Biological Criteria

Biological fish passage criteria pertinent to the construction phase upstream fish passage facility are presented in previous reports and TMs (HDR 2018b, 2021) and reproduced in the following sections. The two primary types of biological design criteria that most influence facility type, size, and configuration are repeated below:

- **Target species and migration timing:** The species and life stages targeted for fish passage design as well as their seasonality, anticipated hydrologic conditions present during migration, and duration of periods where these target fish species may be expected to migrate upstream and/or downstream of the flood retention structure location.
- **Species abundance:** The annual number of fish that require passage as well as the peak daily rate of migration that influences facility size and operation requirements.

Target species are those species that have been identified as inhabiting or transiting the area of the proposed flood retention structure construction. All designs considered for this facility will consider each of the target species' characteristics (such as swimming ability, size, migration timing, among others) and consider the facility impact on the species.

WDFW asked the District in January 2021 to "set the bar high" early in the design process by providing passage for all species and life stages. Identifying target species by name provides the specificity that is appropriate when moving from conceptual planning into detailed design. Identifying target species meets both the intent and letter of WDFW's request as the list of target species includes "all (aquatic) species present at all mobile life stages" (WAC 2015).

2.1.1 Target Species and Migration Timing

For development of the construction phase upstream fish passage facility alternatives, anadromous and resident species known to occur within the influence of the flood retention structure, in the inundation area of the associated reservoir, and upstream of the reservoir were targeted for upstream passage only. These primary species and their known swimming and leaping abilities influenced specific technical design criteria. Species known to occur downstream of the dam site were selected for consideration but did not directly influence the development of specific technical design criteria. Table 1 provides targeted target fish species and their respective life stages as specified in past reports (HDR 2018b).

Table 1. Target Fish Species and Life Stages Targeted for Construction Phase Upstream Fish Passage Facility

Species	Upstream Passage
Spring-Run Chinook Salmon	Adult, juvenile
Fall-Run Chinook Salmon	Adult, juvenile
Coho Salmon	Adult, juvenile
Winter-Run Steelhead Trout	Adult, juvenile
Coastal Cutthroat Trout	Adult, juvenile
Pacific Lamprey	Adult
Western Brook Lamprey	Adult
Resident fish, including: River Lamprey, Largescale Sucker, Salish Sucker, Torrent Sculpin, Reticulate Sculpin, Riffle Sculpin, Prickly Sculpin, Speckled Dace, Longnose Dace, Peamouth, Northern Pikeminnow, Redside Shiner, Rainbow Trout, Mountain Whitefish	Adult

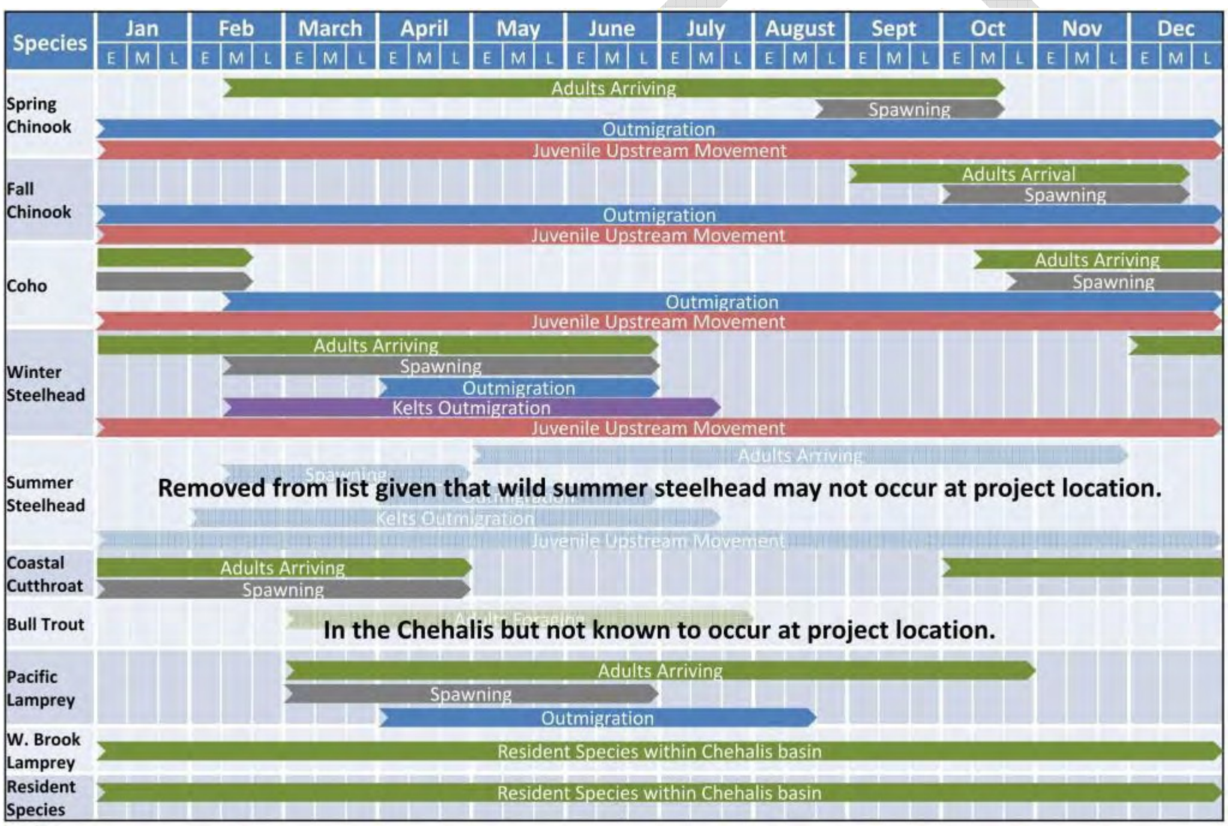
Adapted from CHTR Report (HDR 2018b)

In addition to salmonids and the anadromous Pacific Lamprey, multiple resident fish species and two species of resident lamprey (western brook and river) have been identified to inhabit and transit the proposed flood retention structure area. As such, these resident species are also included as target species. Passage technologies for lamprey are relatively new, and few facilities exist in the western United States that target lamprey for passage or collection and transport above dams. Where applicable, readily available best practices, lessons learned from experimental facilities on the Columbia River, and interviews with researchers who specialize in the understanding of lamprey behavior and navigational capabilities were used to inform lamprey passage facility requirements and anticipated performance.

Bull trout solely occur downstream of the proposed flood retention structure location, so they were removed by the Fish Passage Technical Subcommittee as a target species but remained a species of consideration throughout alternative development and concept design (HDR 2018b).

Fish species migration timing and duration influence the design and operation of proposed fish passage facilities by defining the physical, operational, and environmental conditions expected to occur while passage is required. The migration timing and duration for the target fish species and life stages were discussed at Subcommittee meetings as new information was collected in the field and from literature sources. The resulting conclusions (HDR 2017) were used in fish passage alternative design development (Figure 2).

Figure 2. Anticipated Migration Periods of the Targeted Species and Life Stages (Periodicity)



Reprinted from CHTR Report (HDR 2018b)

2.1.2 Species Abundance

Documents and information provided by WDFW during Subcommittee meetings were used to assess construction phase upstream fish passage facility sizes and capacities (WDFW 2016a, 2016b). Table 2 provides the resulting peak rate of annual migration for adult salmonids moving upstream.

Table 2. Peak Number of Annual Upstream-Migrating Fish

Species	Peak Annual Migration
Spring-run Chinook salmon	1,350
Fall-run Chinook salmon	3,900
Coho salmon	12,900
Winter-run steelhead	5,630

Reprinted from CHTR Report (HDR 2018b)

Numbers for adult upstream migrating Pacific Lamprey, Cutthroat Trout, resident fish, and juvenile salmonids were not available for the construction phase upstream fish passage facility alternatives analysis.

An estimation of peak daily counts was adapted from the CHTR Preliminary Design Report (HDR 2018b) as follows:

> *The peak daily counts of salmon and steelhead migrating upstream were estimated as 10% of the maximum annual run (WDFW 1992), and peak hourly counts were estimated as 20% of the peak daily count based on Bell (1991) and as cited in NOAA Fisheries (2011). Applying both criterion results in the peak hourly count being 2% of the annual run for each species. Using this methodology and based on the run timing information in the periodicity chart (*Figure 2*), a combined peak daily count of roughly 2,000 adult salmonids and a peak hourly count of 400 adult salmonids was used in the consideration of (construction phase) upstream fish passage facilities.*

2.1.3 Resident Fish

The Subcommittee, with support from the U.S. Fish and Wildlife Service (USFWS) representative, assembled relevant biological data for the target resident species, as well as for lamprey and salmonids. A summary of what data was compiled for each species is reproduced in Table 3 (HDR 2018b).

Swim speed and jump height data for resident species will be compared with the same data for the other target species. The construction phase upstream fish passage facility will be designed to accommodate passage of the resident species listed in Table 3 to the extent possible, and without adversely affecting facility performance for listed priority species (salmonids, cutthroat trout, and lamprey).

Table 3. Locomotive and Biological Data Availability

Species		Data Collected*	
Life stage	Common Name	Swim Speed	Jump Height
Adult	Spring-run Chinook Salmon	●	●
Adult	Fall-run Chinook Salmon	●	●

Species		Data Collected*	
Life stage	Common Name	Swim Speed	Jump Height
Adult	Coho Salmon	●	●
Adult	Winter-Run Steelhead Trout	●	●
Adult	Summer-Run Steelhead Trout	●	●
Juvenile	Spring-run Chinook Salmon	●	●
Juvenile	Fall-Run Chinook Salmon	●	●
Juvenile	Coho Salmon	●	●
Juvenile	Winter-Run Steelhead Trout	●	●
Juvenile	Summer-Run Steelhead Trout	●	●
Adult	Coastal Cutthroat Trout	●	●
Adult	Bull Trout	●	●
Adult	Pacific Lamprey	●	Not applicable
Adult	Western Brook Lamprey	●	Not applicable
Adult	River Lamprey	●	Not applicable
Adult	Largescale Sucker	●	
Adult	Salish Sucker	●	
Adult	Torrent Sculpin	Not applicable	
Adult	Reticulate Sculpin	Not applicable	
Adult	Riffle Sculpin	Not applicable	
Adult	Prickly Sculpin	Not applicable	
Adult	Speckled Dace	●	
Adult	Longnose Dace	●	
Adult	Peamouth	●	
Adult	Northern Pikeminnow	●	
Adult	Redside Shiner	●	
Adult	Rainbow Trout	●	
Adult	Mountain Whitefish	●	

Note: ● = Indicates that a data source has been identified
Reprinted from CHTR Report (HDR 2018b)

2.2 Technical Criteria

This section identifies technical design criteria, sources, and guidance relevant to the development of fish passage designs. Technical fish facility design criteria fall into two categories – criteria and guidelines. Criteria are specific standards for fish passage design that require an approved variance from the governing state or federal agency before a design can deviate from the established criteria.

Deviating from an agency-established criterion requires establishing a site-specific, biological- or physical-based rationale for the deviation. In contrast, guidelines provide a range of values, or in some instances, specific values that the designer should seek to achieve, but that can be adjusted in light of project-specific conditions, if needed, to achieve the overall fish passage objectives by supporting better performance or solving site-specific issues. Adjustments to a design may be requested from the governing agencies during design development.

The list of criteria provided herein is not intended to be an all-inclusive list used for the design of a construction phase upstream fish passage facility, but that guided alternative formulation and concept development. The following documents provide the criteria and guidelines that were considered during development of the construction phase upstream fish passage facility alternatives. If two or more agencies provide differing guidance on a specific design criterion, the most conservative guidance from a fish passage and protection standpoint was followed. Further design criteria applicable to the recommended technology is provided in Section 5.1.1.

- Anadromous Salmonid Passage Facility Design (National Oceanic and Atmospheric Administration [NOAA] Fisheries 2011)
- Best Management Practices to Minimize Adverse Effects to Pacific Lamprey (USFWS 2010)
- Draft Fishway Guidelines for Washington State (WDFW 2000a)
- Draft Fish Protection Screen Guidelines for Washington State (WDFW 2000b)
- Water Crossing Design Guidelines (WDFW 2013)
- Fisheries Handbook of Engineering Requirements and Biological Criteria (Bell 1991)
- Introduction to Fishway Design (Katopodis 1992)
- Rock Ramp Design Guidelines (U.S. Department of the Interior Bureau of Reclamation 2007)
- Design of Fishways and Other Fish Facilities (Clay 1961)

2.2.1 Hydrologic and Hydraulic Criteria

2.2.1.1 Fish Passage Design Flows

NOAA Fisheries and WDFW provide guidelines for when fish passage facilities must be operated throughout the full range of river flows. Fish passage design flow criteria influences several factors associated with fish passage facility size and complexity. The established guidelines are used to set instream flow depths, flow velocities, debris and bedload conditions, fish attraction requirements, tailwater fluctuations, and numerous other factors that a facility might experience while target fish species are migrating. Fish passage design flows were calculated and reported in the CHTR Preliminary Design Report (HDR 2018b). The following narrative and tables are reproduced from the CHTR Preliminary Design Report (HDR 2018b) for reference:

> *NOAA Fisheries (2011) requires the high fish passage design flow to be the mean daily streamflow that is exceeded 5% of the time during periods when target fish species are migrating. WDFW (2000a) suggests a 10% exceedance flow be used*

as a high design flow. NOAA Fisheries (2011) requires a low fish passage design flow equal to the mean daily streamflow that is exceeded 95% of the time during periods when migrating fish are typically present. WDFW recommends that a low flow be established based upon site- specific conditions.

Mean daily flows for water years 1940 through 2012 from U.S. Geological Survey gage 12020000 near Doty were reduced using basin area and mean annual precipitation to estimate flows at the proposed flood retention structure site. An exceedance analysis was then performed on the estimated flows at the proposed flood retention structure site. The probability for exceedance of mean daily flows is summarized in Table 4*.*

At the flood retention structure site, adjacent to the proposed (construction phase fish) passage facility, 5% and 95% exceedance flows were also calculated for each adult species using their respective upstream migration timing. These results are provided in Table 5*. The lowest 95% exceedance flow and the largest 5% exceedance determined the fish passage design flow for which the selected (construction phase) upstream fish passage facility will be designed. The lowest 95% exceedance flow is the 95% exceedance flow of 16 cfs, which occurs during the fall-run Chinook salmon migration period. The highest 5% exceedance flow is 2,197 cfs, which occurs during the coho salmon migration period. Therefore, (construction phase) upstream fish passage facilities will be designed to operate from a low fish passage flow of 16 cfs to 2,200 cfs.*

Table 4. Annual Flow Exceedance at the Proposed Flood Retention Structure Site

Percent Time Exceeded	Flow (cubic feet per second [cfs])
99	15
95	19
90	24
80	37
75	48
50	171
25	437
10	960
5	1,447
1	2,957

Reprinted from CHTR Report (HDR 2018b)

Table 5. Flow Exceedance during Fish Migration Periods at the Proposed Flood Retention Structure Site

Fish Species	95% Exceedance (cfs)	5% Exceedance (cfs)
Spring-run Chinook salmon	18	882
Fall-run Chinook salmon	16	1,592
Coho salmon	36	2,197
Winter-run steelhead	63	1,724
Coastal cutthroat trout	34	1,908
Pacific lamprey	17	737
Western brook lamprey	19	1,447

Reprinted from CHTR Report (HDR 2018b)

2.2.1.2 River Flood and Exceedance Flows

Anticipated stage fluctuations are significant factors in determining the type, size, and complexity of the construction phase upstream fish passage facility. As stage fluctuations increase, facilities become larger and more complex. Historical river flows were used to calibrate the HEC-HMS simulation model to estimate the flood flows and fish passage design flows (Watershed Science & Engineering 2016). Additional hydraulic modeling will be performed for future design development to estimate water surface elevations within the Chehalis River near the construction phase upstream fish passage facility. To provide an estimated range of stages, the design fish passage flows and select floods associated with their respective tailwater elevations in the FRE facility stilling basin are provided in Table 6. Design fish passage flows were estimated based on efforts described in Section 2.2.1.1

Table 6. Tailwater Elevations for Fish Passage Design Flows and Select Floods

Flow Event	Flow (cfs)	Tailwater Elevation (feet)
Low fish passage design flow	16	417.0
High fish passage design flow	2,200	419.3
2-year flood	7,300	427.4
10-year flood	10,300	430.1
25-year flood	12,200	431.7
100-year flood	15,000	433.9
Probable maximum flood	69,800	444.0

Adapted from CHTR Report (HDR 2018b)

3.0 Potential Technologies

Potential construction phase upstream fish passage technologies were formulated and segregated into five categories: nature-like fishways; fish ladders; fish passes (e.g., elevators, lifts, and locks); pneumatic fish transport tube system (Whooshh); and trap and transport. Section 3.1 provides descriptions of each technology category. The recommended alternative may be comprised of multiple technologies based on their ability to meet the objectives and unique operating environment within which they are to be placed.

Potential fish passage barrier technologies are presented in Section 3.2. All construction phase upstream fish passage alternatives will use a fish passage barrier to prevent fish from attempting to pass upstream through the water diversion tunnel. The fish passage barrier will be installed directly upstream of the construction phase upstream fish passage facility and help direct fish into the facility entrance.

3.1 Passage Technologies

3.1.1 Nature-Like Fishways

Nature-like fishways are composed of constructed concrete or earthen channels configured at lower gradients that provide quasi-natural hydraulic conditions and typically mimic low gradient cascades and runs. In most cases, nature-like fishways use an array of rocks or other objects to add roughness, hydraulic depth, and cross-sectional diversity to create multiple hydraulic navigational pathways for fish to ascend. With typical gradients ranging from 3 to 4 percent, nature-like fishways would be long and likely require large amounts of cut and fill to maintain the targeted slope requirements.

Because nature-like fishways have a shallow fixed cross-section, additional structural and hydraulic control provisions would be needed at the fishway exit to accommodate headwater fluctuations greater than 2 feet. Therefore, a nature-like fishway would require transition back to a technical fish ladder or constructed exit before connecting back to the Chehalis River. Without such a feature, the nature-like fishway on its own would be unable to maintain hydraulic connectivity with a headwater or control flow into the fishway during high flows. As a result, similar to other fishway technologies, complex hydraulic controls and multiple exit ports would be required to maintain hydraulic connectivity and volitional passage during the anticipated migration periods. A nature-like fishway example is shown in Figure 3.

Figure 3. Nature-like fishway on the Oswegatchie River in New York.

3.1.2 Fish Ladders

Technical fish ladders consist of a concrete fish ladder traversing one side of the flood retention structure construction area. The design target hydraulic differential between baffles in the ladder would follow standard agency design guidelines for the upstream passage of adult salmonids. Pool geometry would be established using NMFS 2011 guidelines but would also consider the specific baffle type selected for the ladder. A fish ladder would be composed of typical pools, resting pools, turning pools, and potentially multiple exit pools to account for reservoir stage fluctuations. This technology requires consideration of guidance, attraction, and collection strategies for the fish ladder entrance as well as debris, temperature, and flow control provisions at the entrance. Figure 4 through Figure 6 provide photos of example fish ladder technologies.

Figure 4. Faraday Diversion and North Fork Dams' 2.1-Mile-Long, Half Ice-Harbor Baffle (pool, weir, and orifice) Fish Ladder

Figure 5. River Mill Dam Half Ice-Harbor Baffle (pool, weir, and orifice) Fish Ladder

Figure 6. Crooked River Central Vertical Slot Fishway near Prineville, Oregon

Source: ODFW 2021

3.1.3 Fish Passes

Another means of transporting fish to a point upstream of the flood retention structure construction area is to carry them up over an adjacent hillside in a transportation vessel either suspended from cables or pulled along rail tracks similar to a trolley system via a fish elevator or lift. A fish elevator system would include design and construction of hoists, concrete foundations, rails, structural members, ramps, pumps, and piping. The elevator, or trolley, would require a life support system and means to offload fish in case of mechanical failure while in route. An example of a fish elevator is provided in Figure 7.

Prior to transport, fish would be collected in a similar manner as other trap and transport type technologies and therefore similar guidance, attraction, water control, fish ladder, and holding gallery components would be required.

Figure 7. Skokomish Dam No. 2 Adult Collection Facility Fish Lift

Another type of fish passage technology which uses a mechanical means to lift fish up and over an established structure is called a fish lock. Fish enter the bottom of the lock, water is fed into the lock from the bottom, and fish are crowded upwards with a braille system as the lock slowly fills. As the lock continues to fill, the braille crowds fish upward until they have moved to the top of the water column. Near the top, a gate is opened, and fish are allowed to swim out of the lock.

An example of a fish lock is provided in Figure 8.

Figure 8. Fish Lock at the Trap and Transport Facility on Baker River Operated by Puget Sound Energy

3.1.4 Pneumatic Fish Transport Tube System (Whooshh)

A pneumatic fish transport tube system (also known as "Whooshh") is an experimental technology from the agricultural and fish processing industry that has been adapted over the past decade to provide transport of live fish over distances of 1,700 feet at heights of over 250 feet. The technology is undergoing extensive pilot testing throughout the Pacific Northwest and Northeast on fish species ranging from salmon and steelhead to shad and sturgeon. Overall, the technology is gaining popularity with some resource agencies as a viable and potentially permittable option for safe and timely passage of fish over high- and low-head barriers. The technology is already being used successfully at hatcheries and aquaculture facilities around the world. An example of a pneumatic fish transport tube system is shown in Figure 9.

Figure 9. Six-Lane Pneumatic Fish Transport Tube System (Whooshh) at the Big Bar Emergency Fish Transport Site, Frasier River, British Columbia.

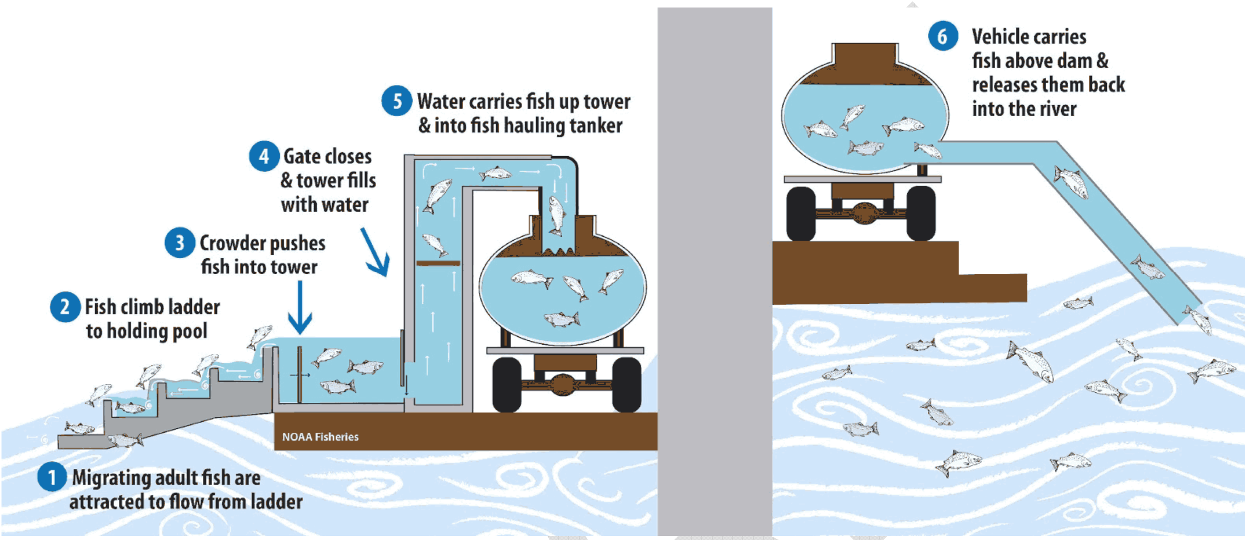
The pneumatic fish transport tube system consists of a flexible plastic tube that is connected to an air pump. A pressure differential of about 1 to 2 pounds per square inch is induced in the tube in front and back of the fish, thus pulling and pushing the fish through the tube. Once in the tube, fish travel at a speed of approximately 15 to 30 feet per second and exit the tube directly into receiving waters. Misters are located within the tube and keep the inside surface of the tube wet and relatively frictionless.

Conventional techniques similar to those used in a fish ladder, trap and transport facility, fish lift, or fish lock are used to provide volitional entry into the pneumatic fish transport tube system. Fish would be attracted to a fish passage entrance; they would enter a short section of fish ladder that leads to a small transition pool. A false weir at the end of the transition pool would lead fish to a transport flume that conveys fish into the entrance of the pneumatic fish transport tube system. Different tube diameters are required to transport different sized fish. Therefore, a system accommodating several species of upstream migrating fish would require a multiple tube system.

3.1.5 Trap and Transport

Trap and transport technologies (Figure 11) are generally composed of five main components that include a barrier or guidance structure; a fish entrance (sometimes consisting of a short fish ladder); a collection, sorting, and holding facility (Figure 12); a vehicle with a transport vessel (tank of water; Figure 13); and a designated release location or locations. For example, a short fish ladder with attraction flow from an auxiliary water system would be used to attract fish and collect them from the river. Migrating fish would ascend the ladder and then stage within the existing holding gallery. Next, fish would be transferred to a vehicle fitted with a transport tank with life support systems. The tank would be transported to a pre-determined release point or points. At the pre-determined release point, fish would be transferred back to a reservoir or the selected tributaries where they would be able to continue their migration upstream.

Figure 10. Trap and Transport Facility Example



Source: NMFS

Figure 11. Lower Baker River Adult Trap and Transport Facility: Barrier Dam and Collection/Crowding Gallery

Figure 12. Overview of Adult Collection and Sorting Facility at North Fork Dam

Figure 13. Trap and Transport Facility: Truck with Fish Transport Vessel

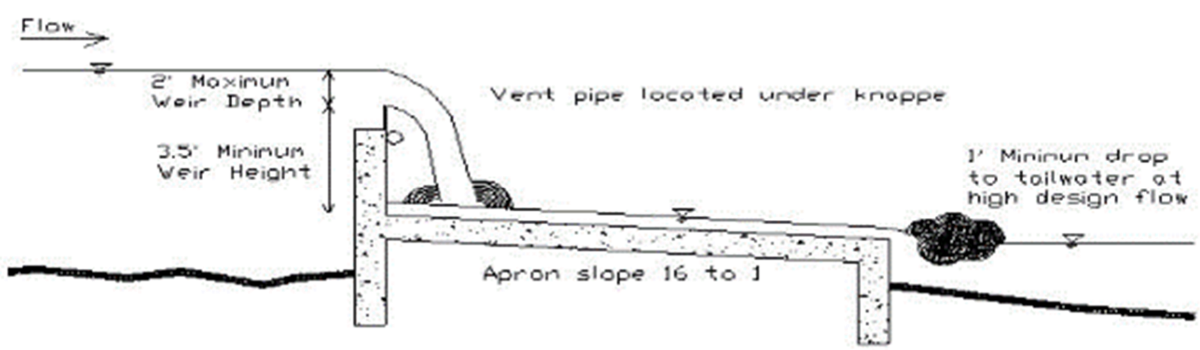
3.2 Barrier Technologies

A fish passage exclusion barrier will be used as part of the construction phase upstream fish passage facility to prevent the upstream migration of aquatic species. A fish passage barrier is necessary for proper performance of all fish passage technologies. The channel-spanning barrier will be located adjacent to the construction phase upstream fish passage facility entrance and help guide fish into, and prevent them from bypassing, the facility. Flow past the barrier can be concentrated near the facility entrance, thereby increasing attraction flow to the facility during the low fish passage design flow. The following sections describe the barrier technologies considered.

3.2.1 Velocity Barrier

A velocity barrier is a non-mechanical fish barrier that consists of a weir and concrete apron preventing upstream passage by producing a shallow flow depth and high velocity on the apron followed by an impassable vertical jump over the weir (NFMS 2011). There are no moving parts, no systems that require human intervention, nor obstructions that may impede flow or downstream fish movement. During passage conditions (95% to 5% exceedance flow; NMFS 2011, WDFW 2000a), river elevations and flow depths and velocities prevent upstream movement of aquatic species while allowing safe passage for fish moving downstream. At higher flows and flood events, mobilized debris and sediment pass downstream over the barrier without impairing its ability to be a barrier to aquatic species during passage conditions. An example section of a velocity barrier, designed according to NMFS 2011, is depicted in Figure 14.

Figure 14. Velocity Barrier



Source: NMFS (2011)

3.2.2 Jump Barrier

A jump barrier (or vertical drop structure) can function as an exclusion barrier by providing head in excess of the leaping ability of the target fish species (NMFS, 2011). The jump barrier must be a minimum height to prevent fish from leaping over the barrier and a provision must be made to ensure that fish leaping at the jump barrier flow will land in a pool of a minimum depth, without contacting any solid surface. An example of a jump barrier is provided in Figure 15.

Figure 15. Jump barrier on the Baker River operated by Puget Sound Energy

3.2.3 Picket Barrier

Picket barriers diffuse nearly the entire streamflow through pickets extending the entire width of the impassable route, sufficiently spaced to provide a physical barrier to upstream migrant fish (NMFS 2011). Picket barriers include a fixed bar rack and a variety of hinged floating picket weir designs. They have clear openings between pickets and between pickets and abutments, and the picket array must have a minimum percentage of open area.

Figure 16. Picket Barrier on the Okanogan River Operated by the Chief Joseph Hatchery

Source: The Spokesman-Review (2012)

3.2.4 Barrier Nets

Barrier nets are channel-spanning nets suspended from cables attached to floats or anchored adjacent to a waterbody. They are typically only effective under low water velocity and light debris load conditions.

4.0 Feasibility of Technologies

Each technology must meet minimum requirements to be considered viable. Those that do not meet these minimum requirements are considered infeasible and not advanced for further evaluation.

4.1 Feasibility Criteria

For this TM, feasibility is defined by the ability to meet the minimum requirements listed:

- **Anticipated Fish Passage Performance and Survival** – The anticipated fish passage performance and survival of each technology reflects its ability to meet all fish passage performance and survival goals for the target species and life stages. A technology is unable to meet this feasibility requirement if any of the target species or life stages are excluded from passage, or if survival is anticipated to be negatively affected.
- **Cost Effectiveness** – The cost effectiveness of each technology reflects the economic impact of facility construction from a qualitative perspective. A technology is unable to meet the cost effectiveness feasibility requirement when the cost of construction of the construction phase facility rivals the cost of the permanent FRE facility.
- **Environmental and Cultural Impact** – The environmental and cultural impact of each technology reflects the effects of the facility on, and its compatibility with, the surrounding environment. A technology is unable to meet the environmental and cultural impact feasibility requirement when its impact on the surrounding environment rivals that of the permanent FRE facility.
- **Water Supply** – The water supply of each technology reflects the capability of the technology to perform adequately with the available water supply in the river. A technology is unable to meet the water supply feasibility requirement when there is insufficient flow available to meet the function of the technology or the fish passage design criteria.
- **Maintenance and Reliability** – The reliability of the facility reflects the potential of the facility to continuously perform at peak efficiency. A technology is unable to meet the reliability feasibility requirement when the facility is inoperable due to environmental conditions or required maintenance, including following a flood event, for appreciable periods of time.

4.2 Feasibility of Passage Technologies

The feasibility of each construction phase upstream fish passage facility technologies listed in Section 3.0 was qualitatively evaluated and is discussed in the following sections. Technologies that do not meet the minimum requirements of the feasibility criteria outlined in Section 4.1 were not considered for further development or evaluation.

4.2.1 Nature-Like Fishways

A nature-like fishway at the project site would consist of a bypass channel that avoids the flood retention structure construction area and could be located on either the eastern or western bank of the Chehalis River.

Figure 17 shows the approximate location and elevation profile to provide a nature-like fishway as construction phase upstream fish passage on the western (left bank) side of the Chehalis River. The river is at approximate elevation 400 feet at the nature-like fishway entrance. The nature-like fishway could be oriented along the existing alignment of Mahaffey Creek. After 1,500 feet, the alignment would turn south to parallel the Chehalis River upstream. This potential alignment would need to be configured through the hillside via open-cut or tunnel. Open-cut would require an approximately 400-foot-deep excavation at its tallest point. A tunnel would be approximately 1,100 feet long through the hillside. After the tunnel, or open-cut, the topography flattens out and an open-cut would be continued to construct a nature-like fishway approximately 2,400 feet long, where the fishway would rejoin the Chehalis River.

Figure 18 shows the approximate construction footprint required to provide a nature-like fishway as construction phase upstream fish passage on the eastern side of the Chehalis River. The elevation profile provided shows that 3,000 feet of either open-cut construction or a tunnel would be required through the hillside, at depths between 100 and 200 feet, to extend the construction phase upstream fish passage channel past the flood retention structure construction. A nature-like fishway on the eastern (right bank) side of the construction area would also need to avoid the water diversion tunnel.

As displayed in Figure 17 and Figure 18, these potential bypass routes for a construction phase passage facility are both lengthy and expensive. The nature-like fishway could be constructed only through use of a tunnel, or by performing open-cut construction several hundred feet deep, which will be economically impractical for a construction phase upstream fish passage facility. In addition, nature-like fishways will require additional measures to prevent severe flooding of the fishway and provide site safety at the bypass channel. Further, the amount of cut needed for construction of this technology is greater than the cut required for the permanent flood retention structure.

The nature-like fishway technology was removed from consideration because of its inability to meet the environmental and cultural impact and cost effectiveness feasibility criteria. The cut required for open-cut construction of this technology is approximately 400 feet at its deepest point and a length of about 3,000 feet. The footprint of this excavation rivals that of the permanent flood retention structure. The impact of clearing such a large area of vegetation and the substantial changes to the topography caused by a 3000-foot-long, 400-foot-deep excavation render this technology infeasible in terms of environmental and cultural impact for a construction phase technology. In addition, the alternative is infeasible from a cost effectiveness perspective because the cost associated with the extensive volume of excavated material due to the open-cut construction through the hillside would rival that of the permanent facility, violating the cost effectiveness feasibility criteria. Construction of a tunnel would also violate this criteria because tunnel construction would require use of a tunnel boring machine for the same distance of approximately 3,000 feet. The width of the tunnel would need to be greater than that of the diversion tunnel to accommodate upstream fish passage velocity and depth criteria at higher flows, increasing construction cost. In addition, ambient lighting and electrical power would also need to be routed through this tunnel. The cost of this tunnel and its associated elements would rival that of the permanent facility, rendering it infeasible based on the cost effectiveness feasibility criterion.

Figure 17. Nature-Like Fishway and Fish Ladder Potential Construction Footprint, Western Alignment

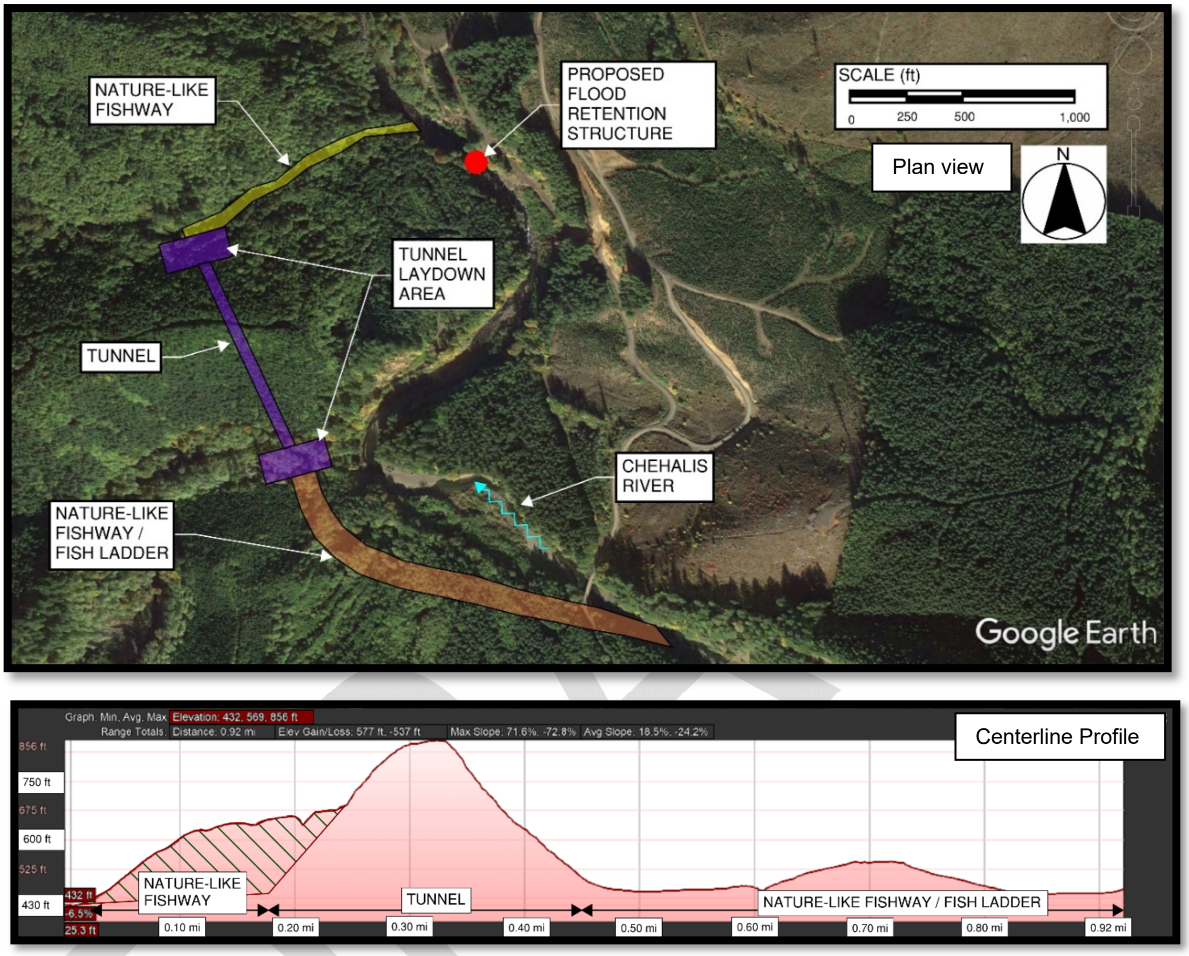
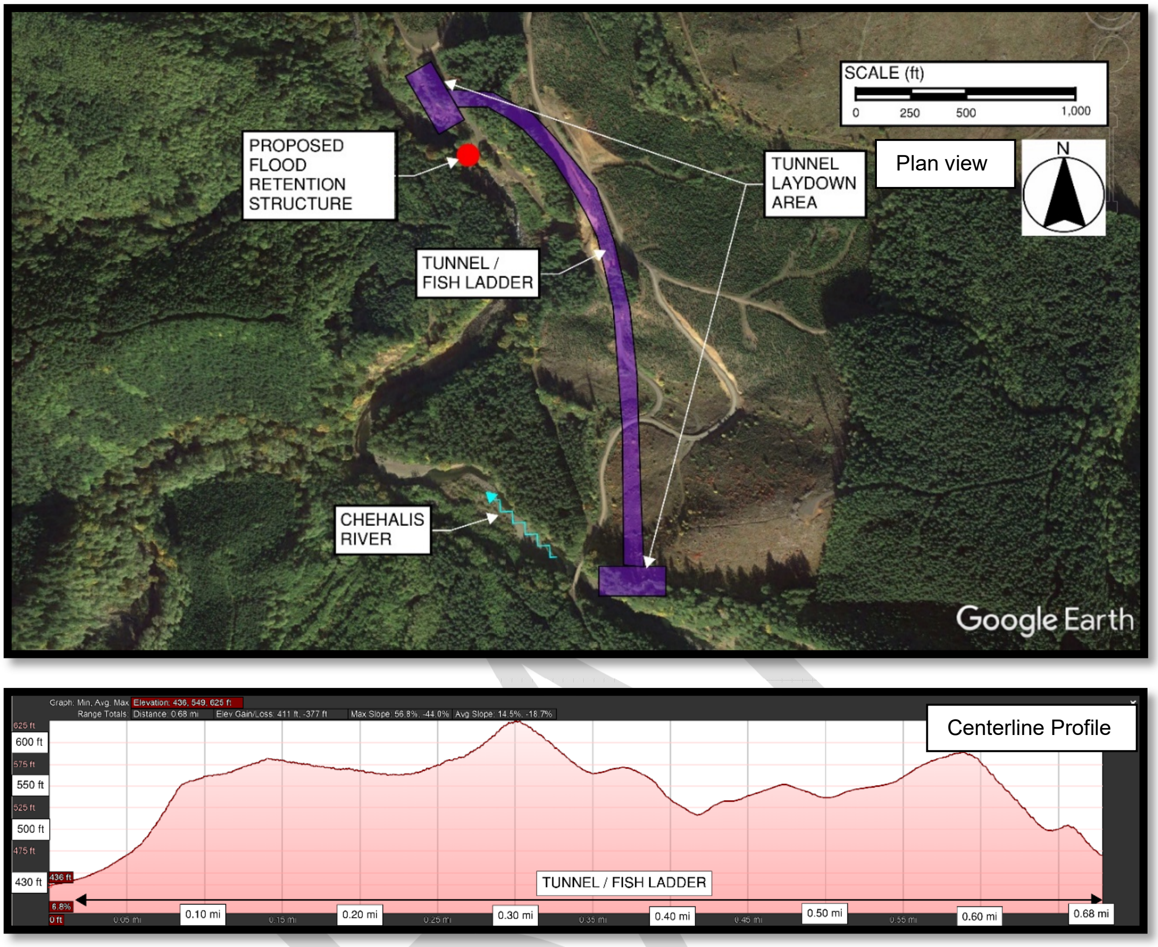


Figure 18. Nature-Like Fishway and Fish Ladder Potential Construction Footprint, Eastern Alignment



4.2.2 Fish Ladders

Research was conducted for several of the fish passage technologies to determine if there was data available for the passage rates of species beyond adult salmonids. Research of Pacific Northwest fish ladders shows no documented evidence of passage rates for resident and juvenile fish, though several references identified visual observations of these fish in the ladders. Low bottom swimmers such as resident fish find it difficult to pass through longer fish ladders because of the higher velocities requiring different criteria to accommodate the wide variety of expected fish species and life stages. If a ladder was designed for a broader range of species and life stages, identification of appropriate design criteria would require additional research. For example, one limiting factor requiring vertical slot ladder design analysis is the maximum slot velocity. If the slot velocity is reduced to accommodate weaker swimmers and the hydraulic differential per pool is reduced to 0.4 feet (~5 inches), the conceptual ladder would be 1,100 to 1,200 feet long to accommodate an approximately 40-foot hydraulic differential between the fishway entrance and exit. The 40-foot hydraulic differential value was estimated from bathymetry data as a surrogate for water surface elevation (EL 405 ft to EL 447 ft NAVD88).

A construction phase fish ladder would also need to bypass the construction site, using the same routes as outlined above in Figure 17 and Figure 18 for the nature-like fishway technology. A conceptual fish ladder would require navigational channel sections linking the ladder segments, entrance, and exit together, and extending the fish passage far enough upstream to bypass the flood retention structure construction activities. Those navigational channel sections could be sloped, nature-like fishway sections or simple constructed channels. Figure 17 and Figure 18 show potential fish ladder alignments on the west and east sides of the river.

To determine whether or not the Maintenance and Reliability criterion is met, the water supply needs of the fish ladders and lamprey ramp for the permanent CHTR facility (HDR 2018b)_are listed in Table 7. At this stage of design, it is assumed that the same water supply would be required for a construction phase fish ladder as for a permanent fish ladder.

Table 7 Permanent Facility Fish Ladder Conceptual Design Water Supply

Water Supply Need	Flow Requirement (cfs)
Adult fish ladder	25
Adult fish ladder AWS	0-200
Juvenile fish ladder	18
Juvenile fish ladder AWS	0-50
Lamprey ramp	3.6
Total required for ladder	46.6 – 296.6

Water supplied to the CHTR facility is gravity-fed from the temporary reservoir upstream of the flood retention structure when it is available[2]; however, the construction phase facility does not provide the same large impoundment of water to pull from upstream. The fish passage design flows, as discussed in Section 2.1, range from 16 cfs to approximately 2,200 cfs. As a result, at the low fish passage design flow of 16 cfs, a fish ladder as an upstream passage technology would be inoperable because of insufficient water supply to support adult and juvenile ladders as well as the lamprey ramp. This technology application does not meet the water supply criteria because the amount of water required is greater than the lower range of target design flows for fish passage.

The fish ladder was removed from consideration because of its inability to meet the environmental and cultural impact, cost effectiveness, and water supply criteria. As stated in Section 4.2.1, this technology requires cut of about 400 feet at its deepest point for a length of about 3,000 feet through the hillside on either the right or left bank of the Chehalis River. The footprint of this excavation rivals that of the permanent flood retention structure. The impact of

[2] The CHTR facility is fed both by gravity when sufficient water is impounded and from a pump station below the flood retention structure the rest of the time the CHTR is operating (HDR 2018b).

clearing such a large area of vegetation and the substantial changes to the topography caused by a 3000-foot-long, 400-foot-deep excavation render this technology infeasible in terms of environmental and cultural impact for a construction phase technology. In addition, the alternative is infeasible from a cost effectiveness perspective because the cost associated with the extensive volume of excavated material due to the open-cut construction through the hillside would rival that of the permanent facility, violating the cost effectiveness feasibility criteria. Thirdly, the alternative is infeasible from a water supply perspective because the required water for fish ladder operation (46.6 cfs) is higher than the available river flow at the low fish passage design river flow (16 cfs). Therefore there would be insufficient flow to meet the function of the technology.

The possibility of a short fish ladder in conjunction with a construction phase trap and transport technology was also investigated and is further discussed in Section 4.2.5.

4.2.3 Fish Passes

Fish passes (e.g., elevators, lifts, and locks) are typically used to transport fish over an established flood retention structure. At the FRE project site, a construction phase fish elevator, lift, or lock would need to bypass the construction site by ascending an adjacent hillslope on the western or eastern bank of the Chehalis River using similar routes as the nature-like fishway and fish ladder technologies described in Sections 4.2.1 and 4.2.2. These types of fish passes would also likely be combined with a natural gravity channel.

Prior to transport, fish would be collected in a similar manner as other trap and transport facility type technologies with similar required guidance, attraction, water control, fish ladder, and holding gallery components.

Figure 19 shows an example configuration of a fish pass system incorporated with a nature-like fishway/fish ladder on the western bank of the Chehalis River. Figure 20 shows an example of a similar configuration on the eastern bank.

Figure 19. Fish Elevator/Lift/Lock to Nature-like Fishway/Fish Ladder Potential Construction Footprint, Western Alignment

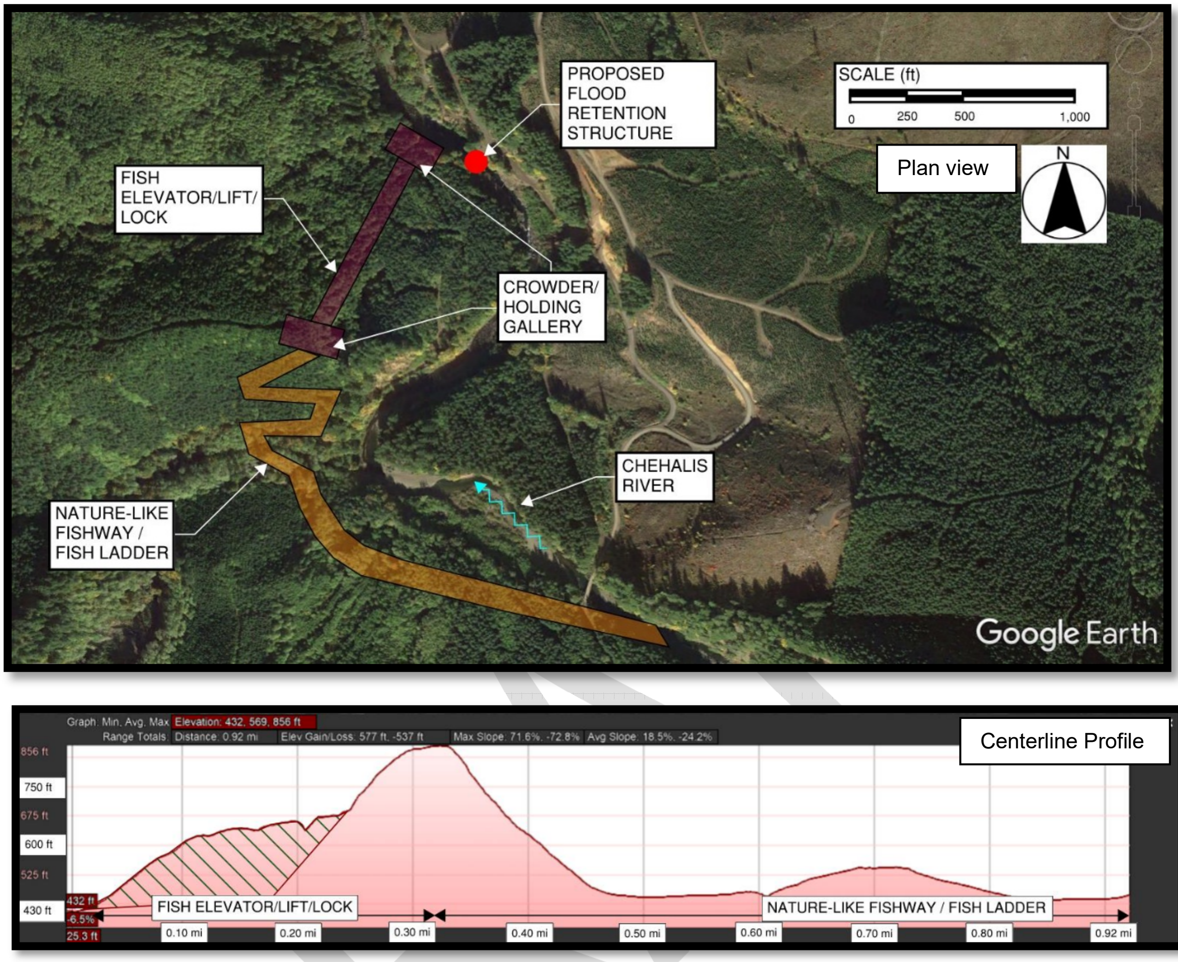
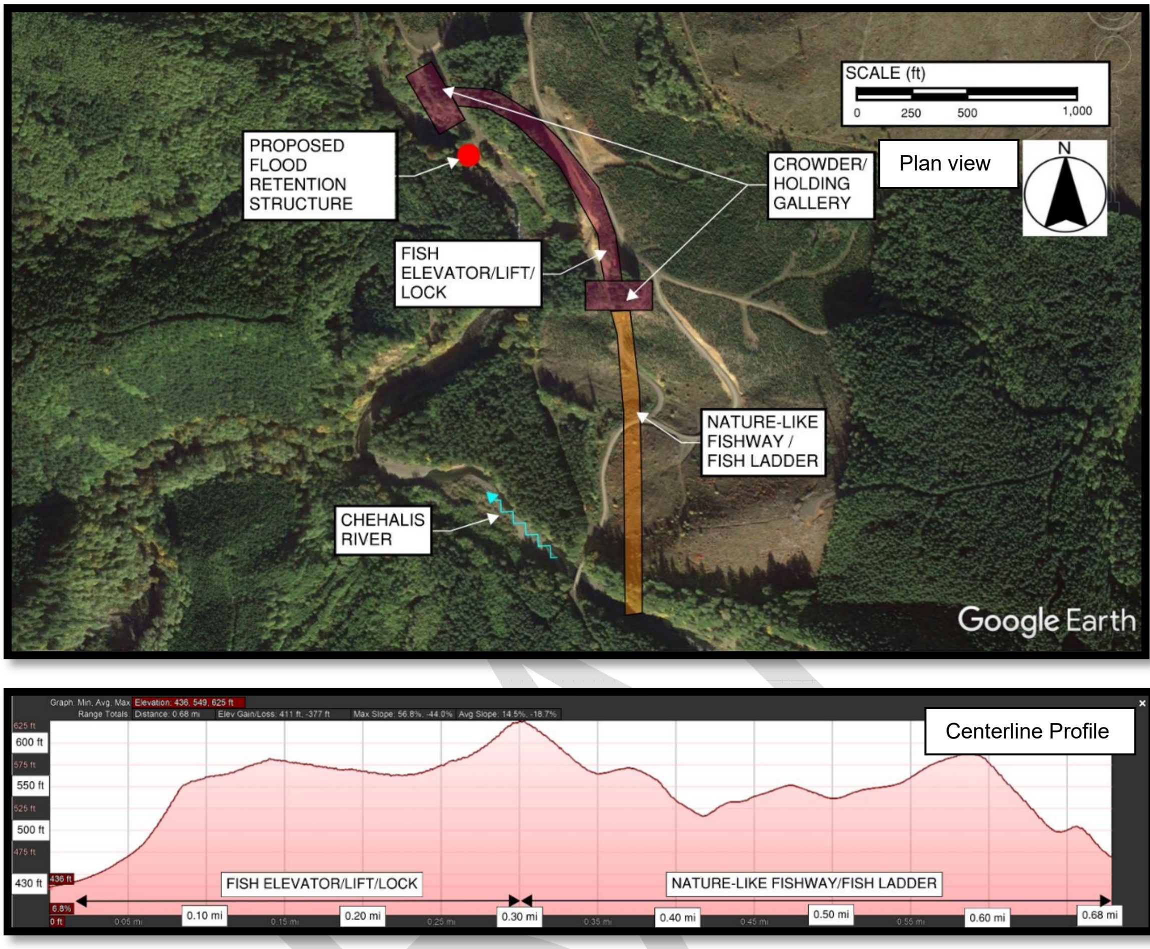


Figure 20. Fish Elevator/Lift/Lock to Nature-like Fishway/Fish Ladder Potential Construction Footprint, Eastern Alignment



A fish lift system would require construction of hoists, concrete foundations, rails, structural members, ramps, pumps, and piping. The elevator, or trolley, would also require a life support system and means to offload fish in case of mechanical failure when in route.

A fish lock system would also require extensive space and infrastructure to be built and construction of a lock chamber, concrete foundations, structural members, gates, pumps, and piping. A fish lock system alone would not be able to transport fish to the upstream release location; therefore, a fish ladder or nature-like fishway would need to be constructed with similar impacts as described in previous sections.

The fish pass was removed from consideration because of its inability to meet the environmental and cultural impact and cost effectiveness criteria. As described, this technology would need to bypass the construction site by ascending approximately 400 feet at the highest point on an adjacent hillslope on the western bank or eastern bank of the Chehalis River using similar routes as the nature-like fishway and fish ladder technologies described above in Sections 4.2.1 and 4.2.2. These routes require an extensive footprint and significant excavation of the hillside to accommodate the required infrastructure. The area of vegetation removal and change to the topography rivals that of the permanent flood retention structure. Thus, this technology is considered infeasible in terms of environmental and cultural impact. Additionally, costs associated with the technological elements and the extensive excavation associated with the open-cut construction through the hillside would rival that of the permanent flood retention facility, making this technology infeasible from a cost effectiveness perspective

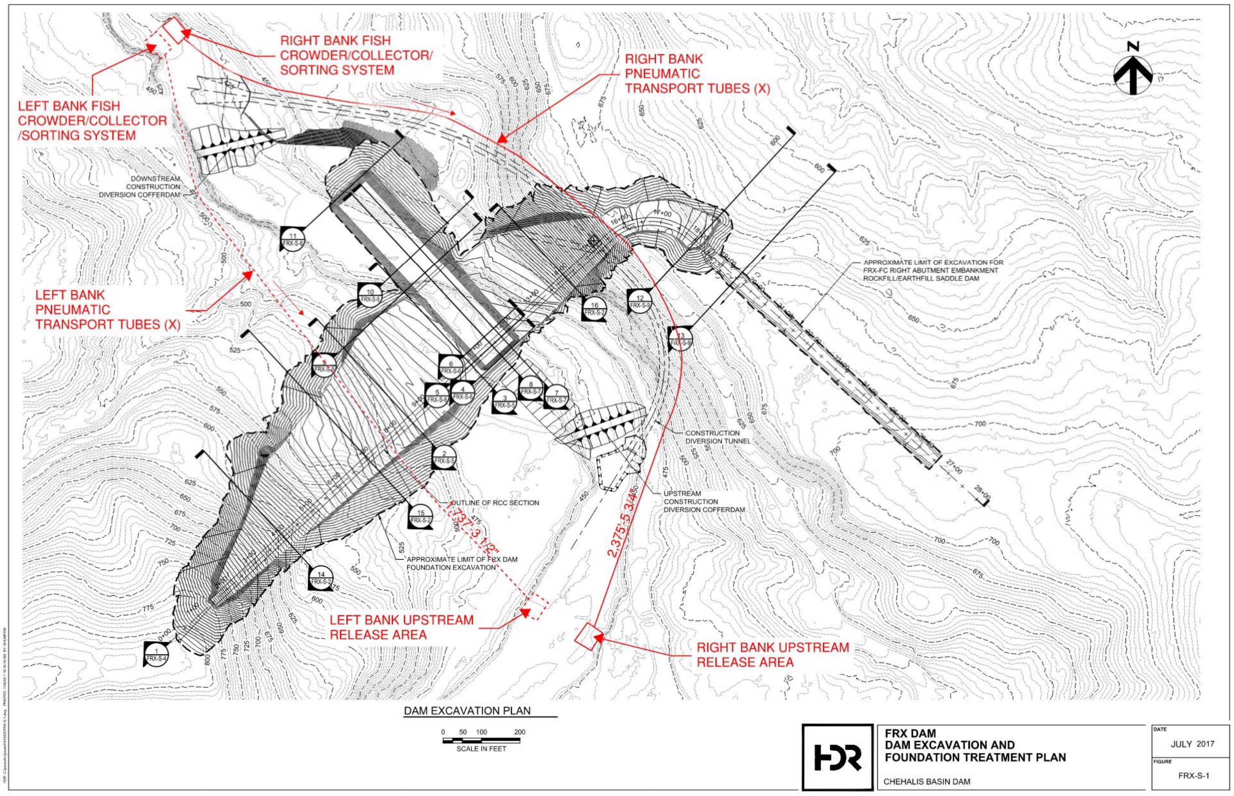
While this technology is not be feasible for a primary passage method, a fish elevator, lift, or lock may be employed as part of a trap and transport system to carry fish to a sorting facility.

4.2.4 Pneumatic Fish Transport Tube System (Whooshh)

A pneumatic fish transport tube system (Whooshh) implemented at the FRE project site could be located on either the eastern or western bank of the river. Figure 21 depicts the approximate extents of the potential Whooshh systems on either bank. Each system would consist of a downstream fish crowder/collector/sorting system, a series of pneumatic transport tubes, and an upstream release area. The flexible pneumatic transport tubes would go up and over the flood retention structure construction area, following the natural topography. The left or right bank options allow the transport system to be moved and placed on either bank depending on construction sequence timing to prevent the transport system from impeding construction activities.

Different tube diameters are required to transport different fish sizes; therefore, a system accommodating several species of upstream migrating fish would require a multiple tube system. The upstream release location for this passage technology differs from the previously discussed technologies. Because space requirements for the tube transport system release location differ from the requirements for the nature-like fishway or fish ladder, the release location for this technology was chosen as the most downstream possible location to minimize travel distance and required tube length. Based on river bathymetry, the hydraulic differential is approximately 30 feet between the downstream and upstream capture and release points (EL 405 ft to EL 436 ft NAVD 88). The tubes for the right bank system would span approximately 2,500 feet and ascend a height of approximately 250 feet before descending approximately 210 feet to the release point. The tubes for the left bank system would span approximately 2,000 feet and ascend a height of approximately 100 feet before descending approximately 60 feet to the release point.

Figure 21. Pneumatic Fish Transport Tube System (Whooshh) Schematic with Flood Retention Structure Excavation and Foundation Plan



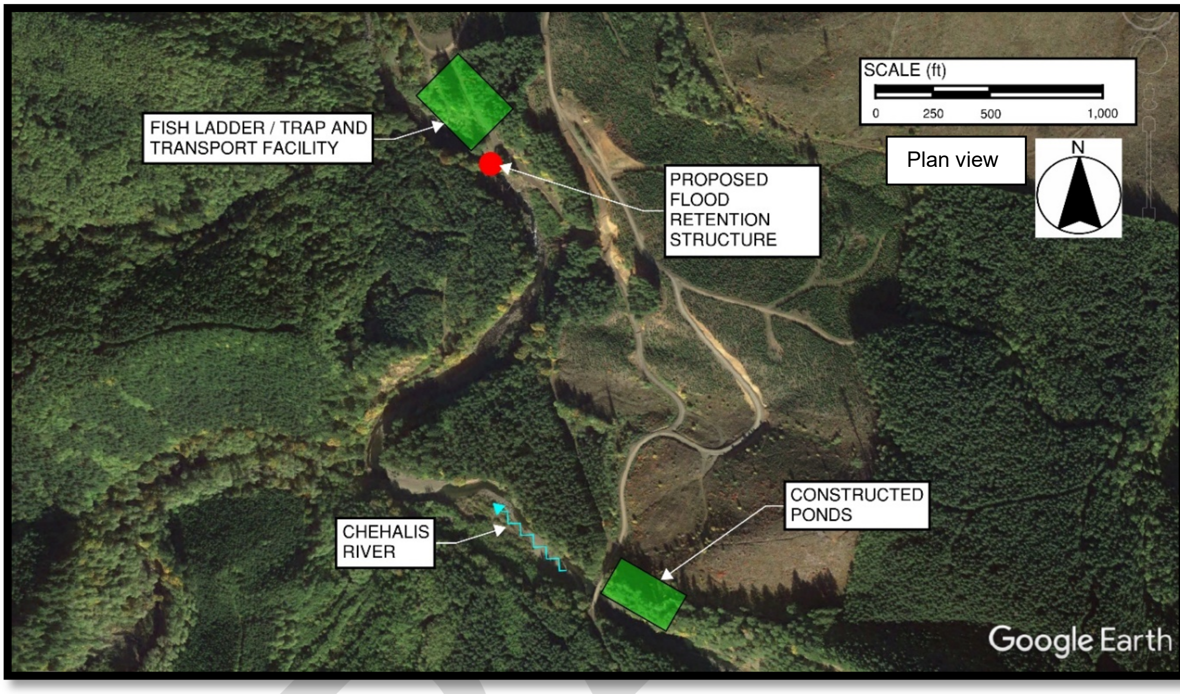
As an experimental technology, the Whooshh system is unable to transport certain species and life stages of fish. The volitional entry into the pneumatic fish transport system requires that fish species are highly motivated to migrate upstream and pass over a false weir into the scanner and sorting module. Pacific Lamprey, juvenile fish, and many of the other target resident fish species are also unable to be transported by the Whooshh system given that tube diameters are not yet compatible with small-bodied fish. Thus, the Whooshh technology was removed from consideration due to its inability to meet the anticipated fish passage performance and survival feasibility requirement of providing passage for all fish and fish life stages believed to be present in the system.

4.2.5 Trap and Transport

As stated in Section 3.1.5, trap and transport technologies are generally composed of five main components that include a barrier or guidance structure; fish entrance; collection, sorting, and holding facility; vehicle with a transport vessel; and designated release location or locations. Similar to fish ladders, documented fish passage rates for resident and juvenile fish using upstream trap and transport technology were not identified in the brief data research conducted for this TM, though there are many qualitative observations of these fish at facilities using this technology. Figure 22 shows the approximate construction footprint that for the construction phase upstream fish passage using an upstream trap and transport facility. The system would collect fish downstream of the flood retention structure and transport all fish to a sorting facility.

A short road would also be constructed to connect the facility to the nearby existing road to the north. Trucks would transport the fish upstream of the construction zone and release them to continue upstream. Specific release points would be identified during the design development phase if this technology was selected for further development.

Figure 22. Trap and Transport Facility Potential Construction Footprint



As displayed in Figure 22, the upstream trap and transport technology exhibits the smallest and most economical construction footprint. Historically, upstream trap and transport facilities in the Pacific Northwest have been designed for adult-sized salmonids. Designing the facility for smaller, resident and juvenile fish would be an experimental undertaking, but is anticipated to be possible through careful consideration of fish swimming behavior and selection of trap and haul components.

Trap and transport technology could be implemented on the right bank of the river, consisting of a short channel connecting to a crowder and hopper. Alternatively, while a fish ladder functioning as the primary technology does not meet feasibility criteria as explained in Section 3.1.2, fish ladders are on occasion used in combination with a trap and transport system. Fish would swim up a short ladder downstream of the flood retention structure before entering the fish hopper and lift system described in this section, similar to the permanent facility design, to be trucked upstream to the release site.

The water supply needs of the fish ladders and lamprey ramp for the permanent CHTR facility (HDR 2018b)_ are listed in Table 8. At this stage of design, it is assumed that the same water supply would be required for a construction phase facility.

Table 8. Permanent Facility Conceptual Design Water Supply

Water Supply Need	Flow Requirement (cfs)
Adult fish ladder	25
Adult fish ladder AWS	0-200
Juvenile fish ladder	18
Juvenile fish ladder AWS	0-50
Lamprey ramp	3.6
Lift, hopper, holding, sorting facility	10
Total required for ladder and trap and transport combination	56.6 – 306.6
Total required for trap and transport on the bank	10 – 260

AWS = auxiliary water supply

Water supplied to the CHTR facility is gravity-fed from the reservoir upstream of the flood retention structure for portions of its operation; however, the construction phase facility does not provide an impoundment of water upstream to pull from. The fish passage design flows, as discussed in Section 2.2.1, range from 16 cfs to approximately 2,200 cfs. As a result, at the low fish passage design flow of 16 cfs, a fish ladder as an upstream passage technology would not be able to operate due to the water supply needs in the adult and juvenile ladders as well as the lamprey ramp. This application of the technology does not meet the water supply criteria because the amount of water required is greater than the lower range of target design flows for fish passage.

However, use of the trap and transport system directly on the bank would meet the water supply criteria as a fish ladder is not necessary. The low fish passage design flow of 16 cfs can accommodate the approximately 10 cfs needed to operate the hopper, lift system, and holding and sorting facilities (HDR 2018b). As flows increase in the river, additional water could be used as the AWS for the collection facility, until approximately 220 cfs is used for the fishway entrance at the high design flow of 2,200 cfs.

This technology meets all the feasibility criteria defined:

- **Anticipated Fish Passage Performance and Survival** – Though actual passage performance for resident and juvenile fish would be an experimental undertaking, all target species and life stages have been observed using this technology in other applications, thereby meeting this criteria.
- **Cost Effectiveness** – The cost of construction of this facility will be substantially less than the permanent flood retention facility as the site footprint is limited, the excavation is comparatively shallow, and the infrastructure is simple in nature and limited in amount.

- **Environmental and Cultural Impact** – The environmental impact of this technology will be substantially less than the permanent flood retention structure facility as the footprint of the required infrastructure is limited and compact.
- **Water Supply** – The low fish passage design river flow (16 cfs) is sufficient to accommodate the water required for function of the technology (10 cfs). River flow is sufficient during the full range of design flows to accommodate operation of the facility.
- **Maintenance and Reliability** – The simplicity of the system and the minimal infrastructure subject to damage from debris and sediment during high river flows reduces the risk of the facility being inoperable for long periods of time. The risk of damage to the facility is low and maintenance required to return the facility to operability is relatively short. As such, the environmental conditions affecting the technology and O&M required for this facility are not anticipated to leave the facility inoperable for appreciable periods of time.

4.3 Feasibility of Barrier Technologies

Barrier technologies are used to minimize attraction and prevent the migration of upstream migrating fish into areas where there is no suitable upstream passage (NMFS 2011). In addition, barrier technologies are also used to guide fish into fish passage facilities. Feasibility of barrier technologies is investigated as part of this TM because the diversion tunnel is unsuitable for upstream fish passage and each of the passage technologies examined in the previous section achieves better passage performance when used in conjunction with an upstream barrier.

4.3.1 Velocity Barrier

Preliminary calculations for two locations at the FRE project site indicate that a velocity barrier can be designed to meet most of the NMFS Anadromous Salmonid Passage Facility Design Guidelines (2011) for the 95 percent and 5 percent exceedance flows. The NMFS criteria for 2 feet of maximum head over the weir crest is surpassed by the 5 percent exceedance flows at the two potential velocity barrier locations and will require NMFS approval on a site-specific basis.

A velocity barrier allows flow and debris to pass freely over a weir, is not likely to impinge fish (NMFS 2011), and is able to serve as an effective barrier for the target fish species and life stages. Inclusion of a bypass in the velocity barrier could allow downstream passage at low river flows. A bypass would likely involve a weir with a notch in the velocity barrier; a bypass pipe in the velocity barrier; or an open channel and fyke combination.

Following storm events debris such as large branches and trees as well as cobbles and larger rock may be deposited on the velocity barrier apron and crest. Removal of large debris and rock from the velocity barrier is anticipated to be achieved by mobile crane or excavator located on the river bank. Removal of smaller debris and sediment is expected to occur by hand by maintenance personnel during low river flow conditions with the use of tie-offs, safety wire, or other safe access methods.

This barrier technology meets all the feasibility criteria. This technology has the best anticipated survival of the barrier technologies examined for all species and life stages as it is less likely to impinge fish and is expected to return to full functionality the most quickly after a high flow event. As with the other barrier technologies, the velocity barrier meets the cost effectiveness and environmental and cultural impact feasibility criteria as it is substantially less cost and environmental footprint than the permanent flood retention facility. The ability to add a low-flow channel to the velocity barrier allows the technology to provide sufficient flow at the low fish passage design river flow, meeting the water supply. Additionally, the velocity barrier is the most reliable of the examined barrier technologies as it allows debris and sediment to pass downstream without impeding passage and with the least need for human intervention and maintenance.

4.3.2 Jump Barrier

A jump barrier (or vertical drop structure) is required to have a minimum 5-foot-deep pool for fish leaping at the jump barrier flow to land in to prevent injury (NMFS 2011). Preliminary calculations for the 95 percent exceedance flow depths for the FRE project site do not meet this required 5-foot minimum tailwater depth. These depths are 0.6 feet at Location 1 near the project site, and 1.3 feet at Location 2 at the low fish passage design flow (Figure 23). Although deeper pools can be constructed at these locations to meet the minimum depth requirement, these constructed pools would require regular maintenance to preserve the minimum depth as they fill with sediment and debris. This maintenance may not be possible during certain times of the year (e.g., when river flow is too high to put machines in the river) and would require additional fish exclusion and removal efforts to achieve.

When the constructed pools fill with sediment but are unable to be maintained, the facility is considered inoperable due to its inability to meet pool depth criteria. The inability of staff to perform required maintenance for extended periods of time, rendering the facility functionally inoperable, classifies this technology as infeasible relative to the Maintenance and Reliability criterion. A jump barrier was removed from consideration as a feasible barrier technology due to its inability to meet the Maintenance and Reliability feasibility criterion.

4.3.3 Picket Barrier

Because the likelihood of impinging downstream moving fish using picket barriers is high, these types of barriers cannot be used in waters containing species listed under the Endangered Species Act (ESA), unless they are continually monitored by personnel on site, and have a sufficient operational plan and facility design in place to provide timely removal of impinged or stranded fish prior to injury (NMFS 2011). While the Chehalis River does not have any salmonids federally listed under the ESA (Ecology 2016), the risk likelihood of impinging downstream moving fish remains for the construction phase fish passage target fish.

In addition, picket barriers must be continually monitored for debris accumulations, and debris must be removed before it concentrates flow and violates the criteria and guidelines established in the NMFS Anadromous Salmonid Passage Facility Design Guidelines (2011). Picket barriers also usually require removal during high flow events to prevent damage to the structure. Winter flows, flood events, and the debris load that come down the Chehalis River are anticipated to be large enough to damage a picket barrier, rendering it non-functional or a detriment to fish health.

Thus, picket barriers were removed from consideration as a viable barrier technology due to their inability to meet the anticipated fish passage performance and survival and reliability criterion.

4.3.4 Barrier Net

Barrier nets are typically only effective in low water velocity and light debris load conditions. The Chehalis River exhibits flashy conditions with high flows and high debris loads. If barrier nets were used in all flow conditions they would frequently be destroyed, washed downstream, and heavily damaged. Replacement and repair following such events would require long delays until river flows reduced enough to safely install replacements and lengthy delays while replacement material was obtained and installed. These conditions would leave the construction phase fish passage facility without an exclusionary barrier for long periods of time, multiple times each year. Thus, barrier nets were removed from consideration due to their inability to meet the Maintenance and Reliability feasibility criterion.

4.4 Recommended Technologies

Table 9 provides a summary of the discussion in Sections 4.2 and 4.3. After comparing all technologies to the feasibility criteria, the only viable technology is the upstream trap and transport facility. Additionally, the only viable barrier technology is the velocity barrier. Each of the other passage and barrier technologies exhibit a fatal flaw that would make them infeasible.

Table 9. Summary of Technology Evaluation Against Feasibility Criteria

Technology	Reason for Removal
Passage Technology	
Nature-like Fishways	Does not meet environmental and cultural impact criteria due to substantive effect on environment and does not meet cost effectiveness criteria due to substantive cost
Fish Ladders	Does not meet environmental and cultural impact criteria due to substantive effect on environment; does not meet cost effectiveness criteria due to substantive cost; does not meet water supply criteria due to amount of water required for facility operation
Fish Passes	Does not meet environmental and cultural impact criteria due to substantive effect on environment and does not meet cost effectiveness criteria due to the range of facilities that would be required for construction phase technology and likely never used again
Pneumatic Fish Transport Tube System	Does not meet anticipated fish passage performance and survival criteria due to inability to pass resident species, juvenile fish, and Pacific Lamprey
Trap and Transport	Not removed from consideration
Barrier Technology	
Velocity Barrier	Not removed from consideration
Jump Barrier	Does not meet Maintenance and Reliability criterion due to the frequency in which this technology is anticipated to be inoperable

Technology	Reason for Removal
Picket Barrier	Does not meet anticipated fish passage performance and survival criteria due to inability to meet agency criteria for use and reliability due to the frequency in which this technology is expected to be inoperable because of high flows
Barrier Net	Does not meet Maintenance and Reliability criterion due to the frequency in which this technology will be inoperable because of ineffectiveness at high flows and debris loads

The recommendation of the velocity barrier technology is consistent with the technical memorandum (HDR 2021) regarding the District's correction of the assumption in the Draft SEPA EIS that a picket barrier would be used as part of the construction phase fish passage facility (Ecology 2020). In this TM as well as HDR 2021, it is noted that a velocity barrier is anticipated to prevent upstream movement of aquatic species with better effectiveness, is not rendered less effective due to damage from debris and sediment, and has less potential for harm to aquatic species compared with a picket barrier. The greater feasibility and performance of the velocity barrier was the basis for the District's request that Ecology revise the survival and performance rates assumed in the SEPA EIS for the construction phase fish passage facility to match that of the permanent CHTR structure (HDR 2021).

5.0 Alternatives Analysis

An alternative analysis was performed using the preferred upstream fish passage technology identified in the previous section.. First, conceptual design alternatives for a trap and transport facility with velocity barrier immediately downstream of the diversion tunnel outlet were developed using the design criteria in Section 2.0. Formulation of the alternatives is described in Section 5.1. Next, a range of potential conceptual design alternatives for upstream trap and transport meeting these design criteria, identified as the preferred technologies in Section 4.0, were developed for comparison using evaluation factors. The identification and development of evaluation factors included removal of those that did not differentiate alternatives. Next, three alternatives were developed to a conceptual level. Alternatives were then scored based on how well they meet the intent of the evaluation factors. Discussion and conclusions resulting from this exercise are summarized in the following sections.

5.1 Alternative Formulation

To develop alternatives using the trap and transport and velocity barrier technologies, numerous options were considered and previous work regarding fish passage during construction was reviewed. Alternative formulation focused on location, specifically the challenging topography of the project area, as well as complexity and the interplay between construction phase and permanent project elements. Each facility follows the trap and transport design criteria described in the trap and transport technology section above. The following sections describe trap and transport alternatives, evaluation factors, and the alternative comparison.

5.1.1 Trap and Transport Design Criteria

For design of the recommended upstream trap and transport technology, a variety of facilities are required such as trapping and holding facilities, a fishway with an associated fishway entrance, lamprey passage facilities, and a pump station to supply the required water. The criteria associated with these facilities are noted in Section 5.1.1.1 through 5.1.1.4 and were taken from a previous report (HDR 2018b). These design criteria were followed to perform alternative evaluation.

5.1.1.1 Trapping and Holding Criteria

The criteria for fish trapping and holding facilities are provided in Table 10 and Table 11.

Table 10. Trapping and Holding Criteria

Criteria	Value	Reference
Holding duration – holding gallery	24 hours, maximum	NOAA Fisheries (2011)
Holding duration – hopper and transport tank	24 hours, maximum 1/2 hour, maximum during peak run rates	NOAA Fisheries (2011)
Temperature	50°F	NOAA Fisheries (2011)
Dissolved oxygen	6 to 7 parts per million	NOAA Fisheries (2011)
Water supply, holding, fry	0.0075 gallons per minute (gpm) per fish	Piper et al. 1982
Water supply, holding, smolts	0.13 gpm per fish	Piper et al. 1982
Water supply, holding, adults	0.67 gpm per fish	NOAA Fisheries (2011)
Adult jump provisions	Required	NOAA Fisheries (2011)
Segregation of fish	Capability required	Not applicable
General	Decrease poundage of fish held by 5% for every degree over 50ºF	

Table 11. Fish Size, Holding Volume, and Long-Term Holding Flow Criteria

Species	Average Assumed Weight/Fish (pounds)	Long-Term Holding: Flow/fish (gpm)	Holding Volume (cubic feet/pounds)
Spring-Run Chinook Salmon	23	1	0.25
Fall-run Chinook Salmon	23	1	0.25
Coho Salmon	9.5	0.5	0.25
Winter-Run Steelhead Trout	9	2.0	0.25
Summer-Run Steelhead Trout	8	2.0	0.25
Coastal Cutthroat Trout	1	Unknown	0.25

Species	Average Assumed Weight/Fish (pounds)	Long-Term Holding: Flow/fish (gpm)	Holding Volume (cubic feet/pounds)
Lamprey	Unknown		
Resident species	Unknown		

Notes: Holding volume and long-term holding flow requirements per NOAA Fisheries (2011)
Long-term flow requirements are for emergency situations where fish must be held for more than 72 hours Adult fish sizes per Bell (1991).

Fish holding volume requirements do not change based on the amount of time held. However, flow requirements are contingent upon holding time, and fish held longer than 72 hours require more flow than fish held less than 72 hours. The Subcommittee did not address fish holding periods during emergencies (e.g., a situation where washed out roads prevent fish transportation activities). Fish holding during emergency situations where holding may be required for more than 72 hours will be addressed in the next phase of design development. Flow requirements for long-term holding are provided in Table 11 for reference in future design development discussions.

Volume and flow needed for the holding gallery, fish hoppers, and transport tanks were determined using the trapping and holding criteria presented in Table 12 and the peak daily and hourly number of fish as determined in Section 5.1.1. The number of fish used to size these design elements is as follows:

- Holding gallery
  - Flow: Peak daily number of fish
  - Volume: Peak daily number of fish
- Hopper
  - Flow: Half the peak hourly number of fish
  - Volume: Half the peak hourly number of fish
- Transport tank
  - Flow: Not applicable
  - Volume: Half the peak hourly number of fish

The hoppers hold half the peak hourly count of fish to limit the size of the hoppers. Fish hoppers would be emptied frequently during peak short-term runs (e.g., every 20 minutes). However, during most of the trapping period, low numbers of fish will enter the low volume, low velocity entrance each day, so the hopper would be emptied less frequently (e.g., every few hours). While the hopper will hold fish for up to 24 hours, the hopper would be operated such that no more than half the peak hourly count of fish is held at any time. Receptacles for life support systems would be provided on the outside wall of the hopper vessel (e.g., oxygen tanks). Use of such equipment would be evaluated based on need during the commissioning and demonstration period.

Calculations determining the size of these elements are provided in Table 12 and Table 13.

Table 12. Adult Holding Gallery Sizing

Criteria	No. of Fish	Pounds of Fish	Cubic Feet Required	Flow (gpm)
Spring-Run Chinook Salmon	135	3,105	776.25	--
Coho Salmon	1,290	12,255	3,063.75	--
Winter-Run Steelhead	563	5,067	1,266.75	--
Subtotal	--	--	5,107	--
Factor of Safety	--	20%	1,022	--
Total	**1,988**	**20,427**	**6,130**	**1,332**

Notes: Holding gallery sized for 1 day of peak-day run.

Table 13. Hopper and Transport Tank Sizing

Criteria	No. of Fish	Pounds of Fish	Cubic Feet Required	Flow (gpm)
Adult hopper and transport tank	200	2,043	511	134
Juvenile/resident hopper and transport tank	Same as adult hopper and transport tank			

Notes: Juvenile/resident hopper and transport tank sized to match adult hopper and transport tank.

5.1.1.2 Fishway Criteria

Designs of upstream fish passage facilities at dams are developed based on criteria and guidelines developed to successfully pass adult salmonids. The fishway is comprised of two major components: the fishway entrance(s) and the fish ladder. Table 14 lists the primary design criteria for the fishway entrance(s) and fish ladder, respectively.

Table 14. Fishway Entrance Criteria

Criteria	Value	Reference
Location	Easily located by fish	NOAA Fisheries (2011), WDFW (2009)
Width	4 feet, minimum	NOAA Fisheries (2011)
Depth	6 feet, minimum	NOAA Fisheries (2011)
Head differential, adults	1 – 1.5 feet	NOAA Fisheries (2011), WDFW (2009)
Head differential, juveniles	0.13 inches	NOAA Fisheries (2011)
Attraction flow	5% – 10% of the maximum of the 5% exceedance flows for the migration period of each species	NOAA Fisheries (2011)

Criteria	Value	Reference
AWS energy dissipation factor	16 foot-pounds/second/cubic foot	NOAA Fisheries (2011)
AWS diffuser velocity, vertical	1 foot/second, maximum	NOAA Fisheries (2011)
AWS diffuser velocity, horizontal	0.5 foot/second, maximum	NOAA Fisheries (2011)
AWS diffuser bar spacing	1.75 millimeter, maximum (juvenile criteria)	NOAA Fisheries (2011)
Fish darting speed	27 feet per second, maximum	Bell (1991), pg. 6.3 (steelhead)
Fish darting duration	10 seconds, maximum	Bell (1991), pg. 6.2
Depth required for jumping	2 feet, minimum	USFS (2001), Adult Salmonid Migration Blockage Table (adapted)

5.1.1.3 Lamprey Passage Criteria

Throughout the preliminary design of the CHTR, the best available science relating to the lamprey passage at dams and in fishways was discussed, used to inform fish passage facility requirements, and incorporated into the design. This included information contained in the scientific literature, lessons learned from experimental facilities at USACE dams on the Columbia River, and interviews with researchers who specialize in studying lamprey behavior and navigational capabilities. The following resources outline the experimental facilities and best practices used in the CHTR design for adult lamprey:

- Best Management Practices to Minimize Adverse Effects to Pacific Lamprey (USFWS 2010)
- Adult Pacific Lamprey Passage: Data Synthesis and Fishway Improvement Prioritization Tools (Keefer et al. 2012)
- Pacific Lamprey and NRCS: Conservation, Management and Guidelines for Instream and Riparian Activities (USDA 2011)
- Pacific Lamprey Protection Guidelines for USDA Natural Resources Conservation Service Instream and Riparian Activities (USDA 2010)
- Lamprey Passage in the Willamette Basin: Considerations, Challenges, and Examples (USFWS 2011)
- Adult Pacific Lamprey: Known passage challenges and opportunities for improvement (Keefer et al. 2014)
- Evaluation of Adult Pacific Lamprey Fish Passage at Snake River Dams (Stevens et al. 2015)

Based on information contained in these resources, the lamprey passage design criteria listed in Table 15 will be used for the preliminary design of lamprey passage components of the construction phase upstream fish passage facility.

Table 15. Lamprey Passage Design Criteria

Criteria	Value	Reference
Flow velocity	6 feet per second, maximum	USDA (2010)
Ramp width	1.0 feet minimum	USACE (2015)
Distance between resting pools	20 feet maximum	USACE (2015)
Water depth in ramp	3 inches, minimum	USACE (2015)
Wetted surface finish	Smooth	USACE (2015)

5.1.1.4 Pump Station Intake Criteria

Construction phase upstream fish passage facility alternatives include the use of pumped flow to supply flows to multiple facility components. The intake for pump stations is designed in accordance with the Hydraulic Institute's (2012) pump intake design guidelines and NMFS 2011 salmonid passage facility design guidelines. The pump station intake will be screened according to NMFS 2011 guidelines, which include the values shown in Table 16.

Table 16. Intake Screen Design Criteria

Criteria	Value
Screen bar spacing	1.75 millimeter
Approach velocity	0.40 fps, maximum
Screen cleaning	Active

5.1.2 Description of Alternatives

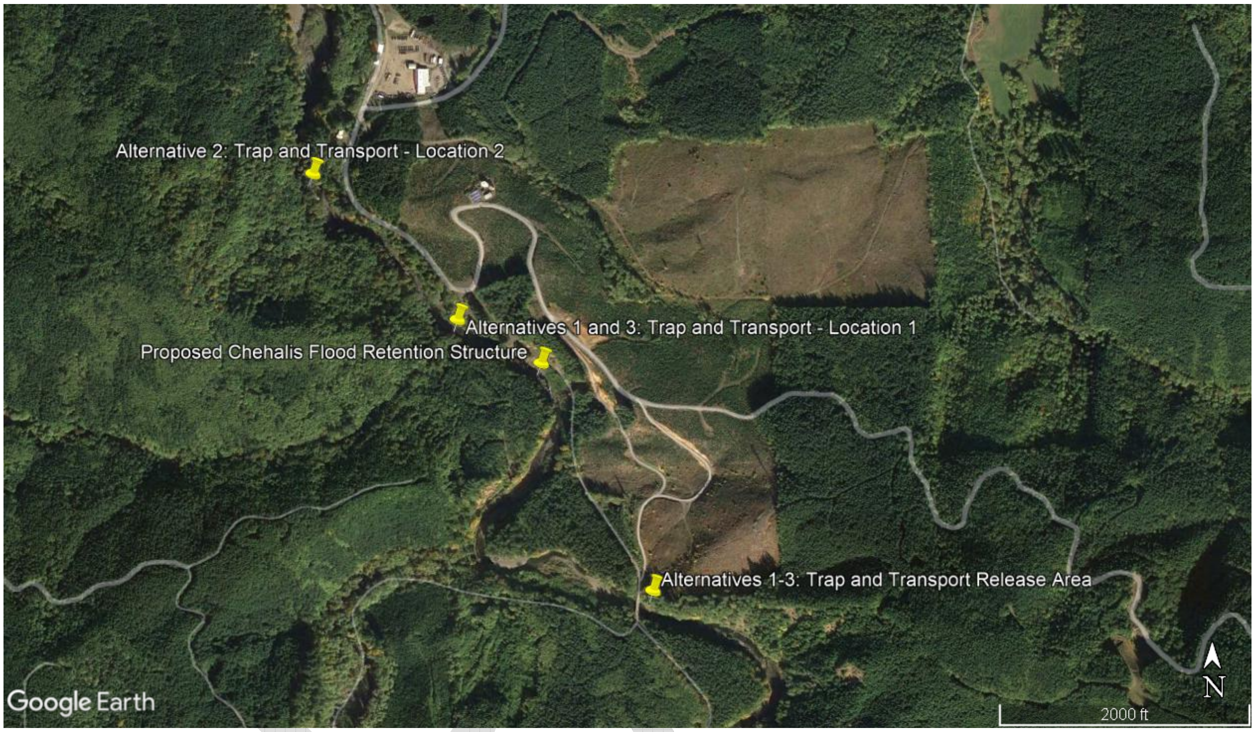
Previous analysis conducted during preliminary design of the permanent fish passage facility identified two possible locations for a construction phase trap and transport facility. Both locations were on the right bank of the river and chosen based on the presence of small floodplains that could accommodate potential construction phase facilities and construction laydown. Further, consideration was given to minimizing complexity of the project by comparing construction phase and permanent facility elements to determine where project challenges could be mitigated. Three alternatives for a construction phase upstream trap and transport system using a velocity barrier were evaluated:

- Alternative 1: Trap and Transport Facility at Location 1
- Alternative 2: Trap and Transport Facility at Location 2
- Alternative 3: Trap and Transport Facility at Location 1 using Permanent Facility Elements

These alternatives encompass two different locations at the FRE project site (Figure 23). Location 1 is approximately 1,200 feet downstream of the proposed Chehalis flood retention structure. Location 2 is approximately 1,300 feet downstream of Location 1 (approximately

2,500 downstream of the proposed flood retention structure). The upstream release area for all of the alternatives is yet to be determined, but is shown for conceptual purposes as approximately 950 feet upstream from the proposed flood retention structure. Specific release locations will be determined during future design development phases.

Figure 23. Potential Locations for Construction Phase Upstream Trap and Transport Systems using a Velocity Barrier at the FRE Project Site



The construction phase trap and transport facility for each alternative will include six main components:

- Velocity barrier
- Water supply
- Fish entrance
- Collection, holding, and sorting facilities
- Vehicle with a transport vessel (tank of water)
- Designated release location

Components that are the same or similar among the three alternatives are described in this section. Components that vary among alternatives and additional detail for each of the three alternatives are described in Section 5.3.

Velocity Barrier

A velocity barrier meeting design criteria and guidance listed in NMFS 2011 will be utilized as an exclusion barrier. The velocity barrier for each alternative will consist of a weir and concrete apron as described in Section 3.2.1. There will be a bypass to allow downstream passage. This bypass will involve a weir with a notch in the velocity barrier; a bypass pipe in the velocity barrier; or an open channel and fyke combination. The bypass design will meet criteria in Sections 11.9.3 and 11.9.4 of the NMFS (2011) Anadromous Salmonid Passage Facility Design.

At higher flows where fish can pass downstream directly over the velocity barrier, it is expected that it will be necessary to close off this bypass to avoid effects of higher flows with sediment and debris loads. Details will be provided during future design development phases.

Water Supply

Water supply for each alternative will consist of a set of tee screens located upstream the each velocity barrier. The screens will be submerged as water is backwatered behind the velocity barrier. There will be a pump system providing water to the collection, holding, and sorting facilities, prior to flowing out the fishway entrance. When necessary, water will also be provided to the AWS system through the screened intake and pump system.

Under the low fish passage design flow of 16 cfs upstream of the velocity barrier, the river will be a backwater pool. Approximately 10 cfs will be used by the pumps to operate the trap and transport facility. As stated under the velocity barrier component description, a bypass for the velocity barrier will be reduced to approximately 6 cfs as stream flow for a short distance of less than 20 feet. Downstream of the bypass, flow will be returned from the trap and transport facility to the river, returning the river flow to 16 cfs.

There is no regulatory minimum flow in the Chehalis Headwaters (where the project site is located), as stated in Supplement IV to the Chehalis Watershed Management Plan (Chehalis Basin Partnership 2004). As a result, the bypass for the velocity barrier will be designed such that criteria will be met under the low flow of 6 cfs through the bypass.

One other option would be to place the screens and pump system downstream of the trap and transport facility. Under this scenario, at the low fish passage design flow of 16 cfs, all instream water would flow through the velocity barrier bypass. Downstream of the trap and transport facility, screens would take 10 cfs from the river, pump it through the trap and transport facility, and release it upstream in the fishway entrance to rejoin the instream flow. This recirculation system provides a minimum 16 cfs in the river upstream of the fishway and downstream of the pumps, with 26 cfs in the river between the fishway and the pumps. This option is less attractive because it would likely require channel grading or a grade structure downstream to impound the water to gain the required submergence of the screens. Under the first option, the velocity barrier would be used to impound the water and therefore cause less impact to the stream and would be less expensive.

Once permanent construction of the flood retention structure is completed, the tee screens will be removed and reused for water supply for the permanent facility. The structural support system for the construction phase tee screens will be removed and the site restored to pre-project conditions.

Fish Entrance

The fish entrance will be located on the right bank of the Chehalis River for each alternative. It will meet the criteria specified by accepted fisheries design guidelines (NMFS 2011; WDFW 2000a). Water for this entrance will be provided by water emanating from the fish collection facility, as well as water used for downstream fish passage. As flows in the river increase, an AWS will also be provided at the fish entrance for attraction.

Collection, Holding, and Sorting Facilities

All alternatives will have collection, holding, and sorting facilities. The collection facility in each alternative will be located on the right bank of the Chehalis River adjacent to the velocity barrier and utilize a fish hopper and lift system. The fish hopper and lift system will use flumes to transport fish to the holding facility, which will also be connected via a gravity flume to the sorting facility. The sorting facility will be located at a height far enough above ground that a truck could drive underneath to collect the fish.

Vehicle with a Transport Vessel

A vehicle (or vehicles as required in peak times) will be needed to transport fish from the sorting facility to the upstream release site. The truck will drive under the sorting facility, which will open and transfer fish below to the truck. The truck will then immediately drive upstream to the release site. Existing roads will be used, but it is anticipated some additional roads will need to be constructed.

Designated Release Locations

The upstream release locations are the same for all alternatives. Trucks will arrive at the release point, release fish in the designated location, and return to the sorting facility as necessary.

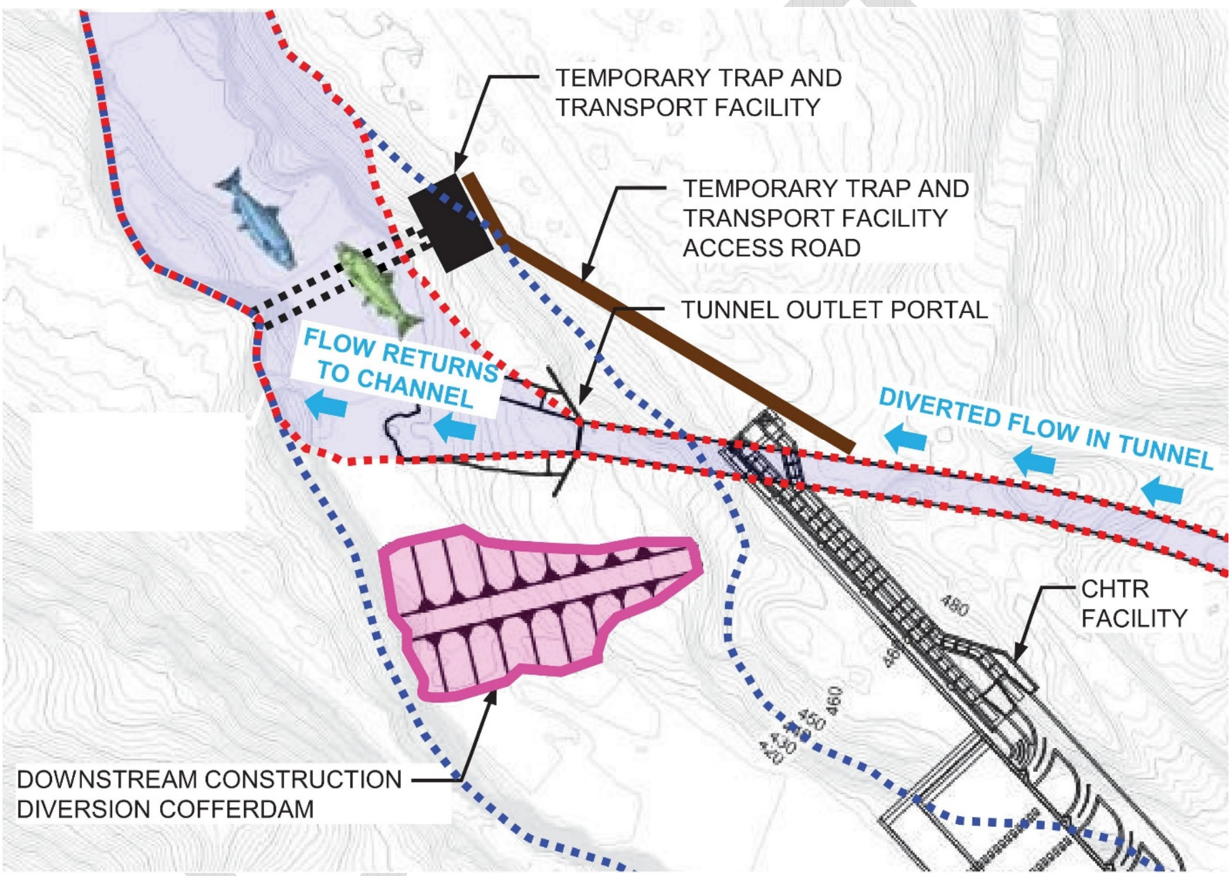
The release area is yet to be determined. As design progresses, the release locations will be determined in collaboration with stakeholders such as WDFW, NMFS, and other agencies. There will be multiple locations for fish release due to different species, life stage migration, or other considerations. Release points will utilize existing roads or add extensions of these existing roads to access the river or stream identified for release; hardened infrastructure is not anticipated to be constructed.

5.1.2.1 Alternative 1

Alternative 1 consists of a construction phase trap and transport facility at Location 1 with a velocity barrier (Figure 24). The facilities built as part of Alternative 1, such as the collection, holding, and sorting facilities, will all be temporary and require associated temporary grading of the site during their construction. Implementation of Alternative 1 would also require a new temporary access road in and out of the construction phase trap and transport facility. After construction of the flood retention structure is completed, the construction phase fish passage facility will be removed completely.

Preliminary velocity barrier calculations at Location 1 indicate there is 0.1 feet of head over the weir for the 95 percent exceedance flow and 3.8 feet of head for the 5 percent exceedance flow. The head over the weir crest for the 5 percent exceedance flow is greater than the 2-foot maximum specified by NMFS guidelines and will thus need to be approved by NMFS on a site-specific basis. The velocity barrier creates an upstream impoundment that backwaters to the downstream construction diversion cofferdam at all fish passage flows. This also causes backwatering of the diversion tunnel outlet, with an extent of about 200-550 feet into the tunnel. Refinements to this design at Location 1 will need to be made to limit backwatering effects and addressed during future design development phases[3].

Figure 24. Alternative 1—Construction Phase Trap and Transport Facility with Velocity Barrier at Location 1



5.1.2.2 Alternative 2

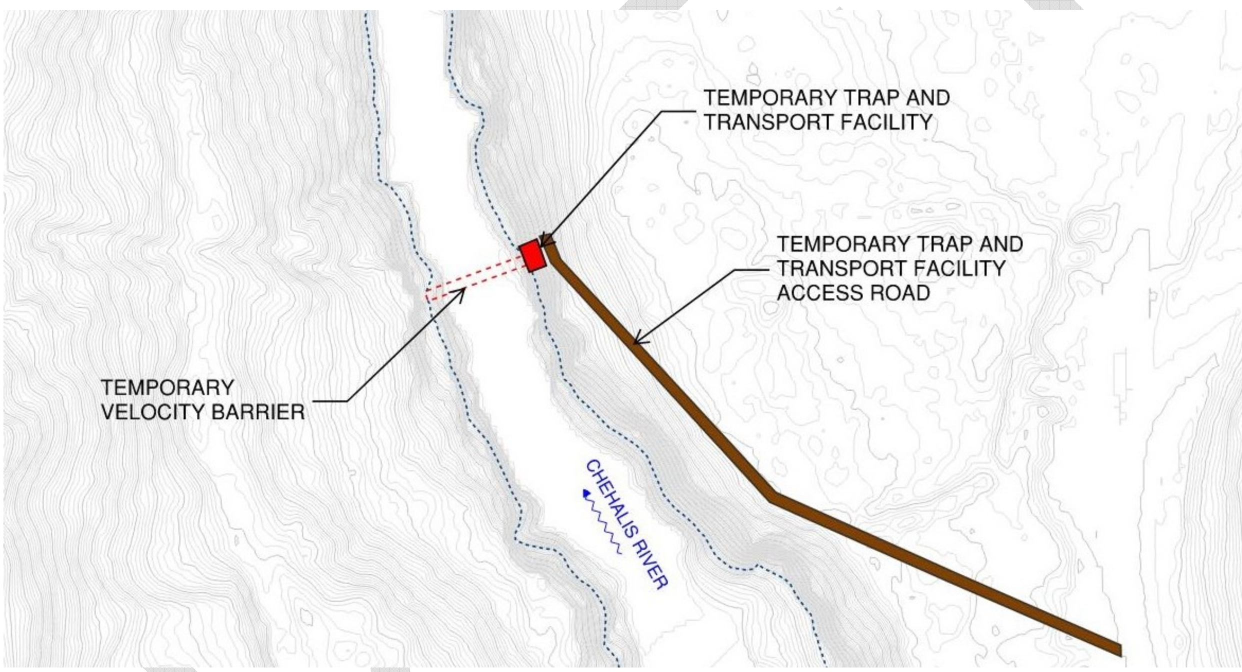
Alternative 2 consists of a construction phase trap and transport facility approximately ¼ mile downstream of the diversion tunnel outlet at Location 2 with a velocity barrier (Figure 25). Similar to Alternative 1, the facilities built as part of Alternative 2, such as the collection, holding, and sorting facilities, will all be temporary and require associated temporary grading of the site during their construction. Implementation of Alternative 2 would also require a new temporary access road in and out of the construction phase trap and transport facility. After construction of

[3] Hydraulic modeling of the backwater effects of the velocity barrier on the tunnel outlet are being performed on the recommended alternative for the 10% design. The location of the velocity barrier will be refined during the 10% design and future design development based on hydraulic modeling. A discussion of the hydraulic modeling and the refined velocity barrier location will be included in the final version of this technical memorandum.

the flood retention structure is completed, the construction phase fish passage facility will be removed completely.

Preliminary calculations for the velocity barrier at Location 2 indicate there is 0.2 feet of head over the weir for the 95 percent exceedance flow and 5.7 feet of head for the 5 percent exceedance flow. The head over the weir crest for the 5 percent exceedance flow at this location is greater than at Location 1 and the 2-foot maximum specified by NMFS guidelines. Thus, this design will need to be approved by NMFS on a site-specific basis. The velocity barrier at Location 2 creates an upstream impoundment that backwaters approximately 750 feet upstream of the velocity barrier at the 95 percent exceedance flow and approximately 1,250 feet upstream at the 5 percent exceedance flow. This 5 percent exceedance flow backwater pool extends to approximately 180 feet downstream of the diversion tunnel outlet and does not inundate the tunnel outlet.

Figure 25. Alternative 2—Construction Phase Trap and Transport Facility with Velocity Barrier at Location 2



5.1.2.3 Alternative 3

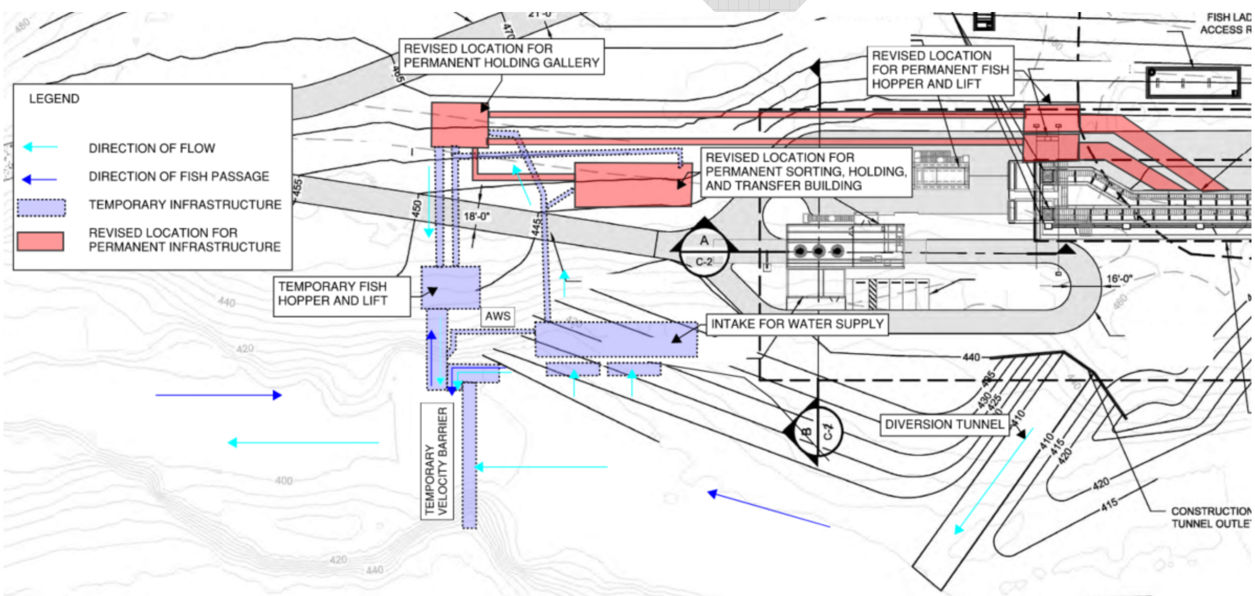
Similar to Alternative 1, Alternative 3 utilizes a trap and transport facility at Location 1 with a velocity barrier. The construction phase fish hopper and lift, velocity barrier, and water supply intake are consistent with Alternative 1, using the same design and location. The primary difference between Alternative 1 and Alternative 3 is that several elements of the construction phase fish passage facility would remain and be incorporated into the permanent CHTR facility as part of Alternative 3.

Elements such as access roads, the holding gallery, and the sorting facility will be constructed to provide construction phase upstream fish passage and later integrated into the permanent CHTR facility. As shown in Figure 26, several elements of the CHTR design, will be reconfigured and shifted west to be used for both construction phase and permanent fish passage. Access roads and parking will be reconfigured to accommodate these shifted facilities.

Alternative 3 shares a significant footprint with the proposed CHTR facility, at the toe of an identified landslide (Shannon & Wilson 2016). Shannon & Wilson (2016) note that more substantial retrogressive-type failures for this landslide are unlikely. Nonetheless, Shannon & Wilson (2016) recommend implementing mitigation measures such as monitoring the landslide for movement and installing deep drains, structural reinforcements, and stability berms. Alternative 3 would include implementation of these mitigation measures.

Not all of the CHTR fish passage facilities would be constructed for construction phase fish passage Alternative 3. The stilling basin, adult and juvenile fish ladders, as well as permanent fish hoppers and lifts would remain on their original construction schedule. After construction of the flood retention structure is completed, the permanent elements of the facility would remain in place for use as part of the permanent fish passage facility. The construction phase fish lift and hopper facility would be removed.

Figure 26. Alternative 3 Detail Figure



5.2 Alternative Evaluation

5.2.1 Evaluation Factors Not Providing Differentiation Between Alternatives

Multiple alternative evaluation factors were considered for use in comparing upstream passage. Many were not included as evaluation factors because all the alternatives presented met the evaluation criteria to the same level and therefore were not differentiated by these factors. The removed factors and reason for removal are specified in Table 17.

Table 17. Summary of Evaluation Factors Not Providing Differentiation

Evaluation Factor	Reason for Removal
Meet federal and state fish passage criteria	Each proposed alternative must meet federal and state fish protection and screening criteria to be acceptable and qualify for potential environmental permitting during implementation. None of the alternatives will be able to better meet the criteria and therefore this was not selected as a potential differentiator among alternatives.
Reliability	Each alternative implements the same upstream passage technology and barrier technology; as a result, none provides more reliable passage than another.
Public safety	Each alternative will comply with all state and federal safety requirements. As a result, safety will not be a differentiating factor between the alternatives.
Permitting	Each alternative implements the same upstream passage technology and barrier technology; as a result, none provides a more permittable alternative than another.

5.2.2 Alternative Evaluation Factors

All alternatives presented in Section 5.1 meet the feasibility criteria summarized in Section 4.1. Evaluation factors used to compare the alternatives for an upstream trap and transport system with a velocity barrier include:

- **Fish Passage Performance** – Provide safe fish passage for all target species and life stages throughout the range of anticipated flows where fish require upstream passage through the project site.
- **Compatibility with Construction Activity** – Minimize the potential for impacts to construction of the permanent infrastructure associated with the flood retention structure.
- **Minimization of Relative Capital Costs** – Minimize total construction cost of the construction phase and permanent facilities.
- **Simplicity of Operation and Maintenance** – Minimize O&M level of effort and complexity.

5.2.2.1 Fish Passage Performance

The intent of this evaluation factor is to measure how well each alternative is expected to provide safe and effective upstream fish passage for all target species and life stages throughout their anticipated migration periods. It considers the ability of fish passage pathways to remain free of failure, occlusion, or disruption and meet agency criteria. For example, an alternative that meets all agency criteria, and is therefore safer for fish passage, will have higher suitability than one that requires a variance from recommended criteria.

5.2.2.2 Compatibility with Construction Activity

The intent of this evaluation factor is to consider the impact of each alternative on construction activities associated with the flood retention structure. Construction of the flood retention structure is anticipated to last approximately 3 to 5 years; throughout this time, construction phase upstream fish passage must remain viable while mitigating impacts to the facility construction footprint. For example, an alternative that avoids all impacts to the facility construction will have higher suitability than one that conflicts with, causes delays to, or otherwise affects construction of the flood retention structure.

5.2.2.3 Simplicity of Operation and Maintenance

The intent of this evaluation factor is to estimate the level of effort and complexity required for O&M of a proposed facility. This is based on the skill level and level of effort required for facility operation, as well as the anticipated frequency of maintenance required. For example, an alternative that must be maintained once per month on a regular basis will have higher suitability than one that must be maintained once per week.

5.2.2.4 Minimization of Relative Capital Costs

Capital cost is the fixed, one-time expense, of construction of the entire fish passage facility – including both construction phase and permanent elements. Costs are qualitative and comparative; no detailed cost estimating has been performed at this stage of design. A lower capital cost is preferred, and therefore, an alternative with a lower anticipated capital cost will have higher suitability than a more expensive alternative. For example, an alternative that reuses construction phase upstream fish passage infrastructure in permanent fish passage facilities will incur an overall lesser capital cost and rate higher than one that requires construction of an entirely separate construction phase upstream fish passage facility from the permanent fish passage facility.

5.3 Comparison of Alternatives

A qualitative rating scale was used to evaluate each alternative for the criteria listed above. A qualitative comparison is commensurate with the conceptual level of design. More quantitative analysis would require further design development which is planned for be undertaken prior to project permitting. Each alternative was ranked as low, medium, or high suitability using the evaluation factors in the following sections. In the evaluation all criteria were assumed to be of relatively equal importance. Results are summarized in Table 18.

5.3.1 Fish Passage Performance

As discussed in Sections 5.1.2.1 and 5.1.2.2, preliminary calculations for the velocity barrier at Locations 1 and 2 indicate there is 3.8 feet and 5.7 feet of head over the weir for the 5 percent exceedance flow respectively. Both of these values exceed the 2-foot maximum specified by NMFS guidelines and will require site-specific approval. Because Location 1 requires a smaller variance from NMFS criteria, Alternatives 1 and 3 were assigned a higher suitability ranking for fish passage performance.

Also discussed in Sections 5.1.2.1 and 5.1.2.2, the velocity barrier creates backwater effects at both Locations 1 and 2. At Location 1, the velocity barrier creates an upstream impoundment that backwaters to the downstream construction diversion cofferdam at all fish passage flows. This also causes backwatering of the diversion tunnel outlet, with an extent of about 200-550 feet into the tunnel. Refinements at Location 1 will need to be made during future design development phases to limit backwater effects. At Location 2, the velocity barrier creates an upstream impoundment that backwaters approximately 750 feet upstream of the velocity barrier at the 95 percent exceedance flow and approximately 1,250 feet upstream at the 5 percent exceedance flow. This 5 percent exceedance flow backwater pool extends to approximately 180 feet downstream of the diversion tunnel outlet and does not inundate the tunnel outlet. Because refinements to the alternatives design at Location 1 will be made to limit backwater effects for Alternatives 1 and 3, the current backwater implications were not used to assign suitability rankings for fish passage performance for the alternatives.

5.3.2 Compatibility with Construction Activity

Alternative 2 is located furthest away from the permanent facility construction site (approximately 2,500 feet downstream). Its remote location makes it unlikely to affect construction activities. Thus, Alternative 2 was ranked as high suitability in terms of compatibility with construction activity.

Alternatives 1 and 3 are located in close proximity to the permanent facility construction site. Therefore, the potential for these alternatives to interfere with construction activity is higher and both Alternatives 1 and 3 were ranked as medium suitability.

Alternative 3 requires the use of constructed permanent elements that could make coordination of construction and phasing between the construction phase and permanent upstream fish passage elements challenging. At this stage of design, the compatibility of Alternative 3 construction with the phasing of the permanent facility has not been evaluated. To determine the true construction suitability of Alternative 3 further investigation during future design would be required. At this time, Alternative 3 remains ranked as medium suitability until further investigation has been performed.

5.3.3 Simplicity of Operation and Maintenance

All three alternatives have facilities located at the base of a steep bank on the river, which would be difficult to access for O&M purposes. Alternative 2 is located on a steeper bank than the other alternatives and further away from the permanent facility construction site, making it less suitable for O&M access. For this reason, Alternative 2 was given a low suitability ranking. Alternatives 1 and 3 are in close proximity to the construction site, which would have both readily available equipment and access points to the river, making these alternatives more suitable for O&M. In addition, Alternative 3 consists of permanent facilities rather than construction phase facilities. The permanent facilities within this alternative would require less maintenance than a construction phase counterpart, giving it a higher suitability than the other alternatives in terms of O&M. Alternative 2 was ranked as medium suitability and Alternative 3 as high suitability.

5.3.4 Minimization of Relative Capital Costs

Capital costs for each alternative are assessed on a total basis, inclusive of the construction phase upstream fish passage facilities and all permanent facilities constructed with the flood retention structure. The remote location in Alternative 2 directly affects its total costs, as the steep bank would make construction more challenging by requiring more hillside stabilization and grading than in the other alternatives. Additionally, the collection point in Alternative 2 is further from the release site than the other alternatives by about 0.4 mile, which could increase the number of trucks and associated expenses needed for transport at peak fish passage times. O&M at the remote Alternative 2 site would also be more time consuming and costly due to access (further described in 5.3.3). Alternative 2 was ranked as low suitability compared to the other alternatives.

Alternatives 1 and 3 are both in the same approximate location, so it is not a differentiator between alternatives. However, under Alternative 1, separate construction phase and permanent fish holding and sorting facilities would be constructed, while for Alternative 3 fish holding and sorting facilities constructed for the construction phase fish passage facility would also be used for the permanent facility. Alternative 3 would have lower capital costs as fewer facilities would be constructed overall. Alternative 1 was ranked as medium suitability, and Alternative 3 as high suitability compared to the other alternatives.

Table 18. Evaluation Matrix

Evaluation Factor	Alternative 1: Trap and Transport Facility at Location 1	Alternative 2: Trap and Transport Facility at Location 2	Alternative 3: Trap and Transport Facility at Location 1 using Permanent Facility Elements
Fish Passage Performance	• Requires a smaller variance on velocity barrier head differential	• Requires a larger variance on velocity barrier head differential	• Requires a smaller variance on velocity barrier head differential
Compatibility with Construction Activity	• Located within close proximity to permanent construction footprint • Backwater from velocity barrier inundates diversion tunnel outlet	• Located away from permanent construction footprint • Backwater from velocity barrier does not impact construction footprint	• Requires use of constructed permanent elements; further investigation into construction phasing is required to determine the compatibility of continuous construction phase facility use with the permanent facility construction phasing
Simplicity of O&M	• Facility is nearer to construction site, allowing easier and simpler access for O&M	• Facility is further away from construction site, making access for O&M more difficult	• Facility is nearer to construction site, allowing easier and simpler access for O&M • Required O&M of permanent upstream fish passage elements will be simpler and less frequent than O&M of construction phase project elements
Minimization of Relative Capital Costs	• Requires construction of temporary facilities and access roads in an area with steep topography near the project construction site	• Requires construction of temporary facilities and access roads in an area with very steep topography further from project the construction site	• Requires use of constructed permanent elements, thereby eliminating need and cost for some temporary upstream fish passage elements

= Low Suitability; = Medium Suitability; = High Suitability

5.4 Recommended Alternative

Each of the three alternatives presented in Section 5.0 are viable options for providing construction phase upstream fish passage. **Alternative 3 –Trap and Transport Facility at Location 1 Using Permanent Facility Elements** is the recommended to be the construction phase fish passage design included as part of the flood retention structure project. Alternative 3 meets the suitability criteria better than the other alternatives. Compared to Alternatives 1 and 2, fish passage performance would be more reliable, with improved overall cost effectiveness because fewer temporary project elements would be built and then removed under Alternative 3. O&M would also be simpler and require less effort due to its location nearer to the construction site and more reliable given that operations are dependent on permeant features and equipment rather than on temporary project elements. However, this alternative would need to be vetted further against the construction needs and footprint of the permanent facility to ensure that the permanent infrastructure is not displaced by the space required by various potential phases of the project.

6.0 Next Steps

Following January 28, 2022, submittal of this draft TM to Ecology, the recommended alternative will be developed to a 10 percent design level using readily available data. The 10% design will be added to this TM following Section 5 and submitted to Ecology at the end of February 2022. Additional data collection, review of literature and data published since the CHTR Report was issued, and collaboration with project stakeholders will occur during future design development phases, following 10 percent design.

7.0 References

Bell, M.

1991 Fisheries Handbook of Engineering Requirements and Biological Criteria. U.S. Army Corps of Engineers, North Pacific Division, Portland, Oregon.

Chehalis River Basin Flood Control Zone District (District)

2019 Proposed Flood Retention Dam Construction Schedule Supplemental Information. Submitted to Washington Department of Ecology and United States Army Corps of Engineers.

Chehalis Basin Partnership

2004 Watershed Management Plan for the Chehalis Basin, WRIA 22/23: Supplement Section IV – Issues / Recommendations.

Clay, C.H.

1961 Design of Fishways and Other Fish Facilities. Dept of Fisheries of Canada, Ottawa, 301 p.

HDR Engineering, Inc. (HDR)

2014a Fish Passage Design Technical Memorandum. Prepared for the State of Washington.

2014b Combined Dam and Fish Passage Alternatives Technical Memorandum. Prepared for the State of Washington.

2016 Combined Dam and Fish Passage Conceptual Design Report. Draft. Prepared for the State of Washington.

2017 Combined Dam and Fish Passage Conceptual Design Report. Appendix G – Fish Passage Alternative Concept Design. Prepared for the State of Washington.

2018a Combined Dam and Fish Passage Conceptual Design Report. Supplemental Design Report – FRE Dam Alternative. Prepared for the State of Washington.

2018b Chehalis Basin Strategy - Fish Passage: CHTR Preliminary Design Report. Prepared for the Washington State Recreation and Conservation Office and Chehalis Basin Work Group. Feb 2018

2020 SEPA DEIS Review: FRE Facility Temporary Reservoir Inundation and Vegetation Analysis Clarification Technical Memorandum. Prepared for Chehalis Basin Flood Control Zone District. May 2020.

2021 Description of Construction – Phase Fish Passage Facility Technical Memorandum. Prepared for Chehalis Basin Flood Control Zone District. August 20, 2020.

Hydraulic Institute

2012 Rotodynamic Pumps for Pump Intake Design. Prepared for the American National Standards Institute.

Katopodis, C.

1992 Introduction to Fishway Design. Freshwater Institute, Winnipeg, Manitoba.

Keefer, M., T. Clayburgh, M. Jepson, E. Johnson, C. Boggs, and C. Caudill

2012 Adult Pacific Lamprey Passage: Data Synthesis and Fishway Improvement Prioritization Tools. Prepared for the U.S. Army Corps of Engineers by the Department of Fish and Wildlife Sciences, College of Resources, University of Idaho. Technical Report 2012-8.

Keefer, M., C. Caudill, and M. Moser

2014 Adult Pacific Lamprey: Known passage challenges and opportunities for improvement. Prepared for the U.S. Army Corps of Engineers.

National Marine Fisheries Service (NMFS)

2011 Anadromous Salmonid Passage Facility Design.

Shannon & Wilson

2016 Phase 2 Chehalis Dam Landslide Evaluation Technical Memorandum. Prepared for the State of Washington.

Stevens, P., I. Courter, C.C. Caudill, and C. Peery

2015 Evaluation of Adult Pacific Lamprey Passage at Lower Snake River Dams. Prepared for the U.S. Army Corps of Engineers.

U.S. Army Corps of Engineers (USACE)

2015 Design Guidelines for Pacific Lamprey Passage Structures.

U.S. Department of the Interior Bureau of Reclamation

2007 Rock Ramp Design Guidelines.

*U.S. Department of Agriculture (USDA)

2010 Pacific Lamprey Protection Guidelines for USDA Natural Resources Conservation Service Instream and Riparian Activities.

2011 Pacific Lamprey and NRCS: Conservation, Management, and Guidelines for Instream and Riparian Activities. Biological Technical Note No. 51. March.

U.S. Forest Service (USFS)

2001 FSH 2090.21 – Aquatic Management Handbook.

U.S. Fish and Wildlife Service (USFWS)

2010 Best Management Practices to Minimize Adverse Effects to Pacific Lamprey.

2011 Lamprey Passage in the Willamette Basin: Considerations, Challenges, and Examples.

Washington Administrative Code (WAC)

2015 220-660-200(8)(c). Fish Passage Improvement Structures.

Washington State Department of Ecology (Ecology)

2016 Chehalis Basin Strategy – Draft Programmatic EIS.

2020 State Environmental Policy Act Draft Environmental Impact Statement. Proposed Chehalis River Basin Flood Reduction Project. February 27, 2020.

Washington State Department of Fish and Wildlife (WDFW)

1992 Fishway Design Guidelines for Pacific Salmon.

2000a Draft Fishway Guidelines for Washington State.

2000b Draft Fish Protection Screen Guidelines for Washington State.

2009 Fish Passage Barrier and Surface Water Diversion Screening Assessment and Prioritization Manual.

2013 Water Crossings Design Guidelines.

2016a Juvenile SALMON and steelhead Projected for the Upper Chehalis River FRFA Dam Alternative. Memo from Mara Zimmerman to Justin Allegro and Erik Neatherlin. June 27, 2016.

2016b Design of Downstream Passage System on the Chehalis River under the FRFA Dam Alternative. Memo to Fish Passage Subcommittee by Mara Zimmerman. August 19, 2016.

Watershed Science & Engineering

2016 Upper Chehalis Basin HEC-HMS Development Memorandum. Prepared for the State of Washington.