U.S. Army Corps of Engineers
Seattle District

Wynoochee Dam
Section 1135 Fish Restoration Project

Grays Harbor County, Washington

Final Interim Design Report
August 29, 2003

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1. INTRODUCTION

Wynoochee Dam is located on the Wynoochee River, in Grays Harbor County Washington. Currently, the dam does not provide adequate downstream fish passage. The Seattle District of the U.S. Army Corps of Engineers has initiated the Wynoochee Dam Fish Restoration Project to develop improvements to the dam that will provide adequate downstream fish passage. A previous feasibility study in 1998 (USACE, 1998) included recommendations for a downstream fish bypass facility to enhance anadramous fisheries migration. The study also recommended supplementation ponds and modifications to the existing fish trap facilities to enhance the existing hatchery program. The recommended elements presented in the 1998 feasibility report are the basis of the current design effort as documented in this report.

1.1 Project Location

The project is located in Section 20, Township 22 North, Range 7 West, Grays Harbor County, Washington [USGS Wynoochee Lake quadrangle]. An existing fish trap facility and barrier dam are located at Wynoochee river mile 49.6. The Wynoochee Dam is located further upstream at Wynoochee river mile 51.8, approximately 30 miles due north of the City of Montesano. Plan Sheet 1 in Appendix C includes a vicinity map and a project site map.

1.2 Project Authorization

The Wynoochee Dam Fish Restoration Project is being conducted under Section 1135 of the Water Resources Development Act of 1986, by the U.S. Army Corps of Engineers (USACE), Seattle District.

1.3 Previous Studies

This *"Final Interim Design Report"* represents a continuation of the *Preliminary Draft Interim Design Report* (USACE, 2003a) and the *Draft 35% Design Report* (USACE, 2003b). This report specifically incorporates the comments received during review of both of these reports. The work summarized in this 35% level design also expands upon work previously conducted by others (United States Army Corps of Engineers, Harza Northwest, and Tacoma Public Utilities). Most of this previous work is presented in the

Wynoochee Dam Section 1135 Fish Restoration Project; Project Modification Report and Environmental Assessment (USACE, 1998).

Project objectives as defined in the 1998 Feasibility Report include the improvement of fish migration, outlet mortality, quality of fisheries stock, and reduction in existing residualization problems. Project elements from the feasibility report that address these objectives have been refined in the current design effort. Section 2 and Section 3 of this design report document the 35% level design of these recommended project elements.

The project modification report should be referenced for additional information on the project history, resource problems and opportunities, project conditions, the project selection process, and the initial development of the hydraulic and biological design criteria.

During the development of the *Wynoochee Dam Section 1135 Fish Restoration Project; Project Modification Report and Environmental Assessment*, staff from the Washington Department of Fisheries and the National Marine Fisheries Service provided 25 criteria for hydraulic conditions to be met throughout the bypass system when designing alternatives to address project goals and objectives. These criteria set standards for flow, velocity, and other hydraulic criteria to be used in the design of the bypass system (USACE, 1998).

Prior to development of the *Preliminary Draft Interim Design Report* (USACE, 2003a) and the *Draft 35% Design Report* (USACE, 2003b), a technical committee (Wynoochee Dam Technical Committee), comprised of staff from the United States Army Corps of Engineers (USACE), Tacoma Public Utilities (TPU), Washington Department of Fish and Wildlife (WDFW), United States Forest Service (USFS), and Tetra Tech, Inc. (TT) met to review the previously established hydraulic and biological design criteria. This meeting was conducted on October 18, 2002. The meeting provided an opportunity for a thorough discussion of each of the criterion and an opportunity to recommend changes to the criteria when applicable. The meeting resulted in the production of a revised set of design criteria, which were subsequently used in the development of the project elements presented in this design report. The revised criteria are included in Appendix A of this report.

1.4 Report Overview

This *"Final Interim Design Report"* presents the results of the design phase to date. It identifies project elements at a 35% level of design, and presents the designs in a detailed narrative. The main report is supported by several detailed technical appendices. Specific biological and hydraulic design criteria are presented in Appendix A. Hydrologic/hydraulic analyses are presented in Appendix B. Thirty five percent design plans are presented in Appendix C, however, the 30-sheet design plan set is bound separately due to its size. Preliminary cost estimates are presented in Appendix D. A Preliminary Geotechnical Engineering Report is included as Appendix E. This *"Final Interim Design Report"* will provide the basis for developing each of the project elements to the 65% level of design.

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2. PROJECT ELEMENTS

A downstream fish bypass facility was proposed in USACE (1998). This bypass facility begins at the Wynoochee Dam intake structure. In the current condition, downstream migration of salmon and steelhead smolts does occur at Wynoochee Dam; however, studies by Washington Department of Fish and Wildlife (WDFW) and the University of Washington indicate that there is approximately a 14 percent loss of coho smolts and a 28 percent loss of steelhead and cutthroat smolts as a result of passage through the dam's low level outlets (Dunn 1978). Additionally, a portion of the downstream migrant population does not pass through the outlets, but stays in the reservoir, a problem known as residualization. Large numbers of coho and steelhead have been found during reservoir trapping studies. The residualization, which is dependent on the specific hydraulic and reservoir conditions, is thought to be caused by poor configuration of the downstream passage system at the dam (USACE, 1998).

In the proposed project condition, fish would enter the penstock and would move down gradient to the proposed penstock Eicher screen, which would divert them into a pressurized bypass pipe. This pipe would carry the fish across the U.S. Forest Service (USFS) vehicle bridge to a multi-level discharge system. From this point of discharge, the fish would be transferred into a gravity flume, and would travel down gradient into a transition pond. The transition pond serves to dissipate the energy of the flume discharge, and also functions as a control location from which fish will be collected for monitoring and observation.

In addition to the downstream fish bypass facility, USACE (1998) also included supplementation ponds for hatchery production enhancement, and improvements to the existing downstream fish trap and haul facility.

The project elements are briefly summarized below, in an upstream to downstream sequence. In subsequent sections of the report, each element is described in more detail, along with additional discussion on key assumptions that were made during the 35% level analysis and design. Preliminary level cost estimates, using the Corps of Engineers'

MCACES software, were developed for each project element. Supporting calculations for the preliminary cost estimates are included in Appendix D.

- **Gate Shaft/Wet Well**: There are currently two alternative points for fish to enter the Wynoochee Dam penstock. Prior to 1997, the only path for downstream migrating fish to enter the penstock was to be swept vertically down through the existing wetwell and into the penstock, which has a centerline elevation of 736 feet. In 1997, the City of Tacoma Public Utilities (TPU) cut a temporary 5-foot high by 9-foot wide opening, with a centerline elevation of 777 feet, in the wall between the wetwell and the gate shaft. This higher-level opening was constructed to improve near surface attraction conditions and to reduce residualism rates in the wetwell.

  Results of testing in 1997 by TPU indicated that the higher-level opening was extremely effective in attracting and transporting fish to the penstock entrance. Alterations to the intake structure that are proposed at this level of design include modifications to the higher level opening (gate shaft) to make it the primary entrance to the penstock for the migrating fish. Other improvements include modifications in the gate shaft to smooth obstructions and reduce turbulence in the transition from the entry point to the discharge point in the penstock.

- **Penstock Eicher Screen**: An Eicher screen is a pivoting screen positioned within the cross-sectional area of a penstock that allows water to flow both through and parallel to the screen. Water flowing through the screen is conveyed to the turbines, while the fish bearing water flowing parallel to the screen surface is sent to a bypass pipeline at the crown of the penstock. A primary assumption guiding this aspect of the design is that the Eicher screen is the selected fish screen for this application. No other screen types were considered in the design phase.

  It is proposed that an Eicher screen be installed in the existing penstock, approximately 250 feet downstream of the penstock intake. The existing penstock is located on the west side of the Wynoochee River. Existing flows through the penstock range between 210 and 1,300 cfs. Flows through the penstock, when the Eicher screen is in place, are expected to range between a minimum of 210 cfs and maximum of approximately 800 cfs (Criterion #1). However, the optimum maximum allowable flow rate through the penstock during the fish screening period will be determined based on monitoring of the operation of the bypass facility and post bypass monitoring of the survival and condition of the juvenile fish.

- **Pressure Bypass Pipe**: The pressure bypass pipe is connected to the crown of the penstock, at the downstream end of the Eicher screen. The pipe carries the bypass discharge and the downstream migrating fish to the opposite side of the Wynoochee River. The crossing of the river is accomplished by encasing the HDPE pipeline within a steel pipe, and suspending the steel pipe beneath the existing USFS Road 2294 bridge structure. The pressure bypass pipe discharges into the next downstream component of the bypass system, the proposed multi-level discharge system. High-density polyethylene (HDPE) material is used for the bypass pipeline, due to its smooth interior surface (Criterion #8). Based on the allowable range of velocities in the pressure bypass pipeline (Criterion #5), the magnitude of flows anticipated through the bypass system will range between approximately 19 cfs and 33 cfs.

- **Multi-Level Discharge System**: The need to operate the fish bypass facility with varying reservoir pool elevations (770 ft to 800 ft) and varying penstock flows (210 cfs to 800 cfs) required the development of a project element that would provide operational flexibility during changing hydrologic and hydraulic conditions. At the terminus of the pressure bypass pipe, prior to discharge to the gravity flume, a multi-level discharge system is proposed. This system is comprised of multiple pressure outlet pipes set at different elevations that discharge to the gravity flume. The multi-level discharge system will allow for the single pressure bypass pipeline described above to be connected to one of the five pressure outlet pipes via a rotating selector switch (RSS). The decision as to which outlet pipe to connect to will be dependent on the reservoir pool elevation and the penstock flow rate at the time of operation so as to maintain a relatively constant flow rate.

- **Gravity Flume**: The gravity flume begins at the outlet of the multi-level discharge system and maintains open channel flow conditions for the entire 1,500-foot length. Surfaces and joints will be made smooth to prevent injury to fish. The flume will maintain supercritical flow throughout the alignment (Criterion #11), and will maintain a minimum nominal flow depth of 9 inches (Criterion #12). The gravity flume will convey the bypass flow and the downstream migrating fish from the multi-level discharge system to the transition pond.

- **Discharge Outlet System**: The discharge outlet system is located at the terminus of the gravity flume and consists of a transition pond, connected by an open channel gravity flume to the river. The flume system discharges the bypass flow and the fish directly into the Wynoochee River. The outlet to the Wynoochee River is located just downstream of the existing USGS gauging station.

- **Fish Survival Test Facilities**: The fish survival test facility is required to allow for the examination of fish as they pass through the bypass system, so as to document the survival rate and condition of the juveniles. These facilities are proposed to be incorporated into the construction of the transition pond, which corresponds to the downstream-most portion of the bypass system. When it is desired to observe a population of juveniles, they will be diverted from the transition pond into a holding tank with the use of a manually operated diversion screen. The holding tank is hydraulically connected to a downstream point in the outlet system, which allows for a constant flow of water through the tank during extended observation periods.

- **Supplementation Ponds**: Two small conditioning ponds are proposed for implementation. One pond would host 25,000 winter run steelhead (5-7 fish/lb.) and the other would host 55,700 coho salmon (16-18 fish/lb.). The supplementation ponds are not part of the fish bypass facility, but are proposed as elements to increase the production of the existing hatchery program. These ponds are located in the vicinity of the transition pond, and use the outlet flume to transport released fish to the river.

- **Adult Fish Trap/Haul Facility Modifications**: The existing adult fish trap is located approximately two miles downstream of the Wynoochee Dam, at river mile 49.6. Modifications to the fish trap are required to improve the existing sorting and transportation process of wild fish and hatchery fish. Modifications may include changes in the sorting flume and installation of two additional holding tanks. Other modifications may include the extension of the operator's platform to direct fish into the appropriate tanks, and the installation of new lifting devices to assist in truck loading. The design for this element was not developed beyond the level presented in the *Preliminary Draft Interim Design Report* (USACE, 2003a) due to the lack of specific design objectives.

- **Control Systems**: Due to its remote location, Wynoochee Dam is lightly staffed with typically only one person available for operational procedures at any given time. Therefore, there is a need to automate the control of as many aspects of this fish bypass system from the dam operations office as possible. Automation includes the elements necessary to open and close the gate shaft, to rotate the Eicher screen for backflushing, to open and close the bypass pipe shutoff valves, to rotate the multi-port revolving selector switch, to operate the drain valves, and to initiate emergency shutdown.

2.1 Gate Shaft/Wet Well

The gate shaft/wet well alternative that was initially agreed upon and included in the *Preliminary Draft Interim Design Report* (USACE, 2003a) was to close off the temporary high level gate shaft opening and utilize the penstock entrance as the sole entry point to the bypass system. Subsequent to the 10% design submittal it was determined that utilizing both entry points should instead be the recommended alternative. This decision was based upon two findings. First, upon further review of the *Hydroacoustic Evaluation of Salmonid Smolt Turbine Entrainment at Wynoochee Dam* (Hydroacoustic Technology Inc., 1997), TPU and WDFW agreed that the high level opening should again be considered as the potential primary access to the penstock. The report concluded that "mean downstream out migration rates appeared to be significantly greater in 1997 via the fish bypass opening at elevation 777 ft relative to the rates observed through turbine penstock opening (below elevation 741.5 ft) in 1995" (Hydroacoustic Technology Inc. 1997).

Secondly, during the development of the 35% design, it was determined that the design and operation of the bypass system, specifically the multi-level discharge element, could be made much simpler if there was the ability to flush the system of juvenile fish prior to switching outlets at the multi-level outlet system (refer to Section 2.4). Therefore, it was decided that it would be beneficial for the operation of the multi-level discharge system if the wetwell modifications included two openings, one of which could be closed to prevent fish from entering the bypass for a short period of time between switch overs.

The proposed design modifications for the intake structure include making the necessary modifications to the current, temporary high level opening to make it a permanent access point for downstream migrating fish, and making the necessary modifications to the gate shaft to provide for a larger cross sectional area at the base of the shaft (refer to Plan Sheet 21). Under current conditions, the intake closure gate obstructs a large portion of the gate shaft at approximately elevation 753. In order to provide a cross sectional area below elevation 753 that is equivalent to that which exists above elevation 753, it is proposed to remove a portion of the existing concrete above the penstock between elevation 761 and the top of the penstock (refer to Plan Sheet 21).

Fish will be attracted to the high level gate shaft opening within the well and then will be swept vertically down through the gate shaft directly into the penstock, downstream of the intake closure gate. Monitoring of fish passage through the intake structure, once the bypass system is operational, will be conducted by TPU and WDFW to fine tune operational efficiency.

2.1.1 Assumptions and Background

The following assumptions were made in developing the gateshaft/wetwell design:

- The existing trashrack on the intake structure is sufficient for trapping debris that could become lodged in the gate shaft. The fish bypass system design does not include any modifications to the trashrack, nor does the design include any additional trashracks or other debris handling mechanisms.
- The existing trashrack is capable of screening debris in such a manner that will prevent a sudden and instantaneous obstruction of the Eicher screen surface that could cause overloading of the screen and could result in structural damage and/or failure.
- Once the fish bypass system is constructed and operational, TPU will monitor the bypass system for debris problems. Any modifications to the bypass system that are required to mitigate debris problems will be made once the bypass system is operational. Potential debris problems could include debris loads requiring unacceptably frequent backflushing of the screen, plugging of the gate shaft thus affecting operation of the gate, or debris loads that cannot be effectively flushed from the screen surface.
- Currently, small sticks and debris pass through the existing trashrack, and it is assumed that this passed material is small enough to not significantly damage the Eicher screen or plug the gate shaft. It is also assumed that this material, if conveyed into the bypass system, is small enough to be effectively conveyed through the complete system.
- Construction modifications to the temporary, high-level gate shaft entry portal in the intake structure would occur in the dry (i.e. when the reservoir pool elevation is less than 774 feet).
- Once the fish bypass system is constructed and operational, TPU will continue to monitor fish entry through the gate shaft intake structure. With the additional monitoring results, the Corps, TPU, and interested resource agencies will work together to determine the optimal operational configuration of the gate shaft intake structure for fish passage.

- While the 1997 hydroacoustic evaluation (Hydroacoustic Technology, Inc. 1997) concluded that the high level opening in the wetwell resulted in significantly higher downstream out migration rates as compared to the rates observed in 1995 without the high level opening, it was not possible to evaluate the condition of the migrating fish population. Therefore, no information is currently available that documents fish mortality or descaling due to passage through the gate shaft. Information relative to fish injury and mortality will need to be documented so as to determine the flow rate that can be allowed through the gate shaft relative to that which is allowed through the penstock.

2.1.2 Gate Shaft/Wet Well Design Description

The preferred alternative proposes to modify the high-level gate shaft opening to make it a permanent feature of the intake structure. Implementation of this alternative would provide two permanent water entry points to the penstock. Construction elements associated with this alternative include installation of a permanent gate with hoisting equipment and baffles, modification to the gate shaft to cover the back of the existing closure gate to provide a smooth surface, and removal of concrete on the backside of the gate shaft where the gate shaft intersects with the crown of the penstock. The concrete removal will provide improved hydraulic capacity and will reduce turbulence at the transition with the penstock.

The preliminary contract cost estimate for this element is $195,000, which excludes mobilization/demobilization, contingency, PED costs, S&A costs and escalation costs. For the detailed breakdown of the cost for this element, refer to the 35% MCACES cost estimate (Appendix D). For the plan view and section view of this element, refer to Plan Sheet 21 (Appendix C).

2.2 Penstock/Eicher Screen

An Eicher screen is an elliptical shaped pivoting metal screen that is positioned within the cross-sectional area of a penstock. This screen allows a majority of the flow to pass through the screen to the turbines while at the same time allowing a smaller portion of the main flow, along with the out migrating fish, to be diverted into a bypass pipe. The purpose of an Eicher screen is therefore to provide for continued power generation while safely guiding fish out of the penstock. A previous Eicher screen installation at Elwha Dam, in Clallam County, WA, made use of a variable gradation of porosity so that the velocity component that is parallel to the screen is uniform along the length of the screen (Adam, Pieter et al, 1991). Variable porosity was needed to counter the "tendency for most of the flow to go through the downstream end of the screen, as has been observed in angled and inclined bypass facilities" (Adam, Pieter et al 1991). Another Eicher screen installation at Puntledge River, on Vancouver Island, British Columbia, made use of a constant porosity screen. Model studies conducted for the relatively flat gradient penstock at the Puntledge facility concluded that variable screen porosity "did not significantly adjust the distribution of flow along the screen" (ENSR, 1993).

An additional hydraulic consideration is that the component of the velocity normal to the Eicher screen should not exceed 0.40 times the average penstock velocity (Criterion #9). This should ensure that fish will not be impinged on the screen surface and will be safely guided along the face of the screen and into the bypass pipeline. Maintaining a uniform parallel velocity and a minimal normal velocity are two of the criteria that will minimize the potential for fish impingement on the screen surface.

To incorporate an Eicher screen into the Wynoochee Dam penstock, a section of the penstock will need to be removed and replaced with a section of pipe containing the screen. The existing penstock is a spiral welded steel pipe with a 10-foot nominal diameter. The modified penstock section is located approximately 250 feet downstream of the penstock intake (upstream face of the dam), and immediately upstream of the existing air/vacuum valve assembly structure located adjacent to the Forest Service Road.

The length of the Eicher screen is approximately 40 feet. The angle of the screen was designed at 16.5 degrees, which is consistent with the installations at Elwha Dam and at the Puntledge River Diversion Dam. The screen was designed with a constant porosity of approximately 58 percent, which is comparable with the Puntledge installation. In regards to screen porosity, the conclusions from the hydraulic model study for the Puntledge installation (ENSR, 1993) were considered to be very relevant for the Wynoochee Eicher screen at this preliminary stage of design. The penstock gradient at Wynoochee (–5.5%) corresponds better to the relatively flat gradient of the penstock at Puntledge (approximately 0.5%) than it does the steep gradient penstock at Elwha. The steep penstock gradient at Elwha likely contributed to the need for a variable porosity screen so as to eliminate the tendency for most of the flow to pass through the downstream end of the screen (Adam, Pieter et al 1991). Further analysis and refinement of the inclination angle and screen porosity should be conducted during the 65% design level.

Existing flow rates through the penstock range from 210 to 1,300 cfs. Current design criteria (Criterion #1) specify that the Eicher screen will be used to bypass fish for penstock flows ranging from 210 cfs to a maximum of approximately 800 cfs. However, an unexpected event, such as a turbine runaway, could result in penstock flow rates that exceed 800 cfs while the Eicher screen is in operation. These excessive flows could cause damage to the Eicher screen, and subsequently could damage downstream components of the hydroelectric facility if all or portions of the screen were to become dislodged. Therefore, it is critical that the screen be designed to structurally withstand the fluid forces resulting from a peak flow of 1,300 cfs.

During the fish window, the Eicher screen will operate in one of three different positions. The “fishing” position is when the screen is positioned to bypass fish, and is oriented at 16.5 degrees relative to the flow. The “cleaning”, or “non-fishing” position is when the screen is rotated from the bypass position so as to backflush debris from the screen face. During this position, the screen will be oriented approximately 5 degrees relative to the flow, with the downstream end of the screen positioned below the springline of the penstock. The “neutral” position is when the screen is oriented parallel to the flow and parallel to the springline of the penstock. In the neutral position, flow will not be passing through the screen.

2.2.1 Assumptions and Background

The following assumptions were made in developing the penstock/Eicher screen design:

- The Eicher screen design is the selected screen type and is the only screen type to be considered.
- When the screen is positioned to bypass fish, the angle of inclination of the Eicher screen will be set at 16.5 degrees relative to the penstock invert.
- Field-testing of full scale Eicher screen installations (Elwha Dam), and physical model testing of Eicher screens (Elwha Dam and Puntledge Dam), have been previously conducted by others. Journal articles (Adam, Pieter et al, 1991; Winchel, Fred C. et al, 1991) summarizing the results of the full scale and model studies for the Elwha installation are included in Appendix F. The hydraulic model study for the Puntledge installation was conducted by ENSR (1993) and presents a detailed analysis of the hydraulic performance of alternative screen designs, specifically in regards to the effect of screen porosity on flow distribution. The results of these previous studies were referenced in determining the Eicher screen configuration for the Wynoochee Dam.
- The porosity of the Eicher screen for the Wynoochee installation was designed as constant along the entire length of the screen. As previously stated, this decision was based on the results of physical model studies penstock/Eicher screen at the Puntledge River facility. As the design of the Wynoochee Dam Eicher screen progresses into more detailed levels of design, the benefits and disadvantages of variable versus constant porosity of the screen surface will be analyzed. The level of analysis may depend upon whether or not physical model studies are conducted for the Wynoochee installation.
- Current design criteria (Criterion #1) specify that the Eicher screen will operate with flows ranging between 210 cfs and approximately 800 cfs. However, the structural design of the screen must accommodate flows as high as 1,300 cfs. The determination of the designs loads for the maximum flow condition assumed that the screen is locked in the non fishing position.

- During non-migration periods the screen will not be located within the normal flow stream. The Eicher screen penstock section will be removed. This will prolong the screen life, reduce the risk of screen component failures and subsequent downstream damage, and reduce the risk of damage due to debris within the flow stream.
- The screen will be actuated to rotate approximately 20 degrees to allow stream flow to enter the screen from the underside to backflush collected debris off the surface.
- All structural and foundation elements of the modified penstock section will be designed for seismic zone 3, as defined in the Uniform Building Code.
- Depth to bedrock in the vicinity of the Eicher screen penstock section is 3 feet to 5 feet below existing ground surface. It is further assumed that the underlying bedrock is weathered and can be excavated to an approximately vertical surface with an excavator.
- Lateral earth pressure due to the upper 5 feet of the soil column will exert a uniform pressure of 75 psf, which includes an allowance for equipment surcharge.
- It is assumed that flow through the penstock can be shutdown for several consecutive days to allow for switching between modes of operation (e.g. screened versus non-screened).
- Pressure sensors will be installed upstream and downstream of the Eicher screen to detect increases in pressure differential caused by debris obstruction on the screen. At this time, the pressure differential that will initiate the backflushing of the screen is assumed to be 0.2 feet greater than that associated with an unobstructed screen. This is consistent with National Marine Fisheries Service (NMFS) criteria (NMFS, 1994) and with the operational guidelines that are in place at the Puntlege facility.
- Backflushing of the screen will also occur at regularly scheduled intervals in addition to when the allowable pressure differential is exceeded.
- The penstock has pressure sensors at the intake and at the air/vacuum valve assembly structure that is located just upstream of USFS Road 2294. Additional pressure sensors would be required in the penstock, both upstream and downstream of the Eicher screen, to monitor the pressure differential across the screen.
- Wynoochee Dam operates on a flow (cfs) control system rather than a megawatt control system. Therefore, it is necessary to include in the design the ability to

measure the flow rate in the penstock, upstream of the bypass, and within the bypass pipe itself.

2.2.2 Penstock/Eicher Screen Design Description

The proposed approach involves installing the Eicher screen in a replaceable section of penstock, approximately 100 feet upstream of the existing air/vacuum valve assembly structure (Figure 1). This section would be removed during the non-fish passage window and replaced with an unobstructed penstock section without an Eicher screen.

Figure 1. Proposed Location of Eicher Screen Section.
The existing air/vacuum valve structure is seen in the background, as is USFS Road 2294.

The Eicher screen would be constructed within a 50-foot section of penstock that would be removed and replaced (refer to Plan Sheets 4,16-19, 22, 23, 28, and 29). The modified penstock section containing the Eicher screen would be interchanged with a regular section of penstock. Such an interchange would be expected to occur during times of non-fish screening or during periods of screen maintenance and repair. Prior to switching the sections, the penstock would have to be dewatered. For interchangeable ease, each section would be mounted on a rail system oriented perpendicular to the penstock. This rail system would be bolted to the floor of a concrete vault that is cast between the two ends of the penstock. This rail system would allow the sections to be rolled in and out of alignment with the penstock.

To provide for easy access to all components of the system, a below grade vault approximately 74 feet long and 45 feet wide would be constructed to contain the two penstock sections and the rail system that would be used to move the sections in and out of position. Motor driven "trucks," similar to those used for mobile cranes, will be used to move the two sections of the penstock in and out of position. Bolted flexible connectors will allow for connecting and disconnecting the fixed portions of penstock and the moveable sections of penstock.

Hydraulically actuated or motorized jackscrews will move the Eicher screen from the "fishing" to the "cleaning" positions and back to the "fishing" position. Eicher screen position changes from fishing to cleaning will be automated and coordinated with the fish inlet gate shaft position to minimize the presence of fish in the penstock during the cleaning cycle.

The leading (upstream end) of the Eicher Screen is proposed to be located 140 feet (14 diameters) downstream from an existing 33 degree bend in the penstock. This section of the penstock is constructed at an adverse grade of 5.47 percent.

The preliminary contract cost estimate for this element is $1,654,000, which excludes mobilization/Demobilization, contingency, PED costs, S&A costs, and escalation costs. For the detailed breakdown of the cost for this element, refer to the 35% MCACES cost estimate (Appendix D). For the plan, profile, and section views of this element, refer to Plan Sheets 4, 16-19, 22, 23, 28, and 29 (Appendix C).

2.3 Pressure Bypass Pipe

The pressure bypass pipe would connect to the crown of the penstock, immediately upstream and above the proposed Eicher screen. The bypass pipe would convey fish bearing bypass flows from the west side to the east side of the Wynoochee River. The crossing of the river would be accomplished by encasing the pressure pipe within a steel pipe that is suspended beneath the existing USFS Road 2294 bridge structure. The pressure bypass pipe would discharge into the next downstream component of the bypass system, the proposed multi-level discharge system.

The hydraulics of the bypass system were designed such that the flow velocities are uniform or gradually accelerating along the face of the Eicher screen and gradually accelerate into the pressure bypass pipeline. The bypass system has been designed and will be operated such that the average velocity through the bypass pipe will be equal to or greater than the average velocity through the penstock during the operation of the screen (Criterion #5). Once entry is made into the pressure pipeline, the average flow velocity throughout the remainder of the pressure bypass system will remain moderate and uniform, with magnitudes ranging between 7 feet per second and 12 feet per second (Criterion #5). The magnitude of the actual flow rate through the bypass pipeline, and consequently the magnitude of the velocity, will be dependent on the reservoir pool elevation and the flow rate through the penstock upstream of the Eicher screen. The velocity criteria, and how they apply to the pressurized bypass pipeline, are discussed in more detail in the multi-level flume system section of this report.

Given the velocity criteria (Criterion #5), the flow rate through the bypass pipe will range between 19 cfs and 33 cfs. This range of flow rates will be maintained for varying reservoir pool elevations through the use of a multi-level discharge system, which is described in a later section of this report. The minimum flow rate for power generation is 210 cfs, and the bypass flows represent between 9 percent and 16 percent of this value. Therefore, during periods of minimum flow, the minimum flow rate will have to be increased by an additional 19 cfs to 33 cfs to make up for the diverted flow at the bypass.

2.3.1 Assumptions and Background

The following assumptions were made in developing the pressure bypass pipe design:

- The bypass pipeline is a 24-inch diameter high density polyethylene (HDPE) pipe with a standard dimension ratio (SDR) of 32.5, which has an associated pressure rating of 50 psi. This pipe has a corresponding inside diameter of 22.5 inches.
- Per the biological and hydraulic design criteria (Criterion #8), the minimum allowable bend radius is five times the pipe diameter (e.g. 10 foot radius for a 24-inch diameter pipe).
- The minimum radius that 24-inch 32.5 SDR pipe can be field bent through is 40 times the pipe diameter (e.g. 80 foot radius). Therefore, all bends that are less than 80 feet will be constructed of mitered tangent sections of pipe. Conceptual sketches of three typical mitered bends are included in the Hydrology and Hydraulics Appendix (Appendix B).
- The HDPE pipe segments and mitered bends will be joined using butt fusion welding. The inside weld beads resulting from the butt fusion process will be machine removed.
- The design flow rate through the pressure bypass pipeline will range between 19 and 33 cfs.
- Preliminary structural analysis concluded that the exterior girders of the existing bridge have the reserve capacity to support the additional 45,000 pounds of load resulting from a full 24-inch diameter pipe. The load will be distributed over supports at approximately 25-foot spacing.
- The system must meet all other applicable design criteria as listed in Appendix A.

2.3.2 Pressure Bypass Pipe Design Description

The pipeline alignment is shown on Plan Sheets 5 and 15 in Appendix C. As seen in the drawing approximately 250 linear feet of the bypass pipeline is proposed to be suspended under the existing USFS Road 2294 bridge structure. The HDPE pipe is proposed to be installed within a 26-inch diameter steel casing pipe, which will be attached to the bridge structure with trapeze and bracing. The HDPE pipe will be free to move inside the casing, thereby accommodating thermal expansion and contraction. Lateral movement due to thermal expansion and contraction along the remainder of the alignment will be minimized by directly burying the pipe. Expansion joints will be provided for the above grade sections of the pipe, to allow for expansion and contraction without damaging the pipe material or the joints. The two 10-foot radii that are shown at each end of the USFS Road bridge are required to negotiate around structural features of the bridge superstructure.

Sensors are included in the design of the pressure bypass pipeline to relay the pressure of the bypassed flow to the control center. A set of full port ball valves, or a single full port ball valve, are also included in the design to allow for dewatering of the pressure pipe when it is not being used and when dewatering is required prior to switching outlet pipes at the multi-level discharge system. These valves are motor driven, automated, and will coordinate operation with the fish inlet gate and the rotating selector switch (RSS) downstream of the pressure pipe. Access ports in the pressure pipe would be included at two locations – upstream of the multi-level discharge system and upstream of the bridge crossing.

The preliminary contract cost estimate for this element is $421,000, which excludes mobilization/demobilization, contingency, PED costs, S&A costs, and escalation costs. For the detailed breakdown of the cost for this element, refer to the 35% MCACES cost estimate (Appendix D). For the plan and profile view of this element, refer to Plan Sheet 5 (Appendix C).

2.4 Multi-Level Discharge System

The need to operate the fish bypass facility for varying reservoir pool elevations and varying penstock flow rates requires the development of a project element that provides operational flexibility during these changing conditions. At the terminus of the pressure bypass pipe, prior to discharge to the gravity flume, a multi-level discharge system is proposed. This system is comprised of multiple pressure outlet pipes that discharge into the gravity flume at specific, fixed elevations. The multi-level discharge system will allow for the pressure bypass pipeline to be connected to any one of the multiple outlet pipes. The decision as to which outlet pipe to connect to will depend upon the reservoir pool elevation and the penstock flow rate at the time of operation.

Assuming an initial reservoir pool level of 770 feet, and assuming the reservoir pool level increases during the fish migration window, the multi-level discharge system would operate as follows. Within the fish bypass window, the lowest elevation outlet pipe would be the first outlet pipe to be connected to the gravity flume. Referring to the outlet pipe operating curves presented in Appendix B, the first outlet pipe would be capable of conveying approximately 30 cfs when the penstock is flowing at the maximum anticipated flow rate (700 cfs) and when the reservoir pool elevation is at 770 feet (the minimum reservoir pool elevation).

As the reservoir pool level increases, and assuming the penstock flow remains constant, the resulting flow rate that could be conveyed through the pressurized bypass system would also increase, due to the increase in available upstream head. At some point, when the reservoir pool elevation has increased enough (approximately elevation 773 feet), the flow rate through the bypass pipeline would begin to approach the upper allowable limit of 33 cfs. At this point, it would be necessary to connect the pressure bypass pipeline to the next higher of the outlet pipes in the multi-level discharge system. This would effectively decrease the head differential within the pressure system and allow for a lower magnitude bypass flow to enter the bypass system.

As the reservoir pool level continues to increase, it would at some point become necessary to switch to the next higher of the outlet pipes. This process would continue as the reservoir pool level continued to increase. Once the reservoir pool reaches the maximum elevation for the year, the bypass system would operate with little or no switching of outlet pipes. If, however, the reservoir pool elevation was to decrease, then the procedure would occur in reverse, with subsequent lower elevation outlet pipes being connected as needed. Each outlet pipe would be designed to operate through a specific band of reservoir pool elevations. A more detailed discussion of the operation of the multi-level discharge system and the hydraulic analysis of the system is provided in Appendix B.

2.4.1 Assumptions and Background

The following assumptions were made in developing the multi-level discharge system design:

- During the fish migration window, the reservoir pool elevation will vary between 770 feet (mean sea level) and 800 feet (mean sea level). The 800-foot reservoir pool elevation is associated with full conditions in the reservoir, and the 770-foot elevation is associated with the minimum operating pool elevation for the hydroelectric facility.
- During the fish migration window, it is assumed that the minimum flow rate through the penstock will be 210 cfs, and that TPU will be capable of limiting the maximum flow rate through the penstock to no more than 800 cfs (Criterion #1). The hydraulic analysis of the pressure bypass system was used to provide an estimate of the actual maximum allowable penstock flow rate.
- The configuration of the multi-level discharge system must allow for the conveyance of between 19 and 33 cfs for the range of reservoir pool elevations and penstock flows identified above. This flow rate corresponds to a average velocity of 7 to 12 feet per second within the pressurized pipe.
- The multi-level discharge system must be capable of ensuring that the average velocity in the pressure bypass pipeline is greater than the average velocity in the penstock under all operating conditions (Criterion #5).
- Vehicle access to the area of the proposed multi-level discharge system is limited, and therefore, systems have been designed for maintenance and operation using minimal amounts of mobile equipment.
- The existing paved trail at the site of the proposed multi-level discharge system (refer to Figure 2) can be relocated to the west if necessary.
- The existing water level monitoring wells located at the downstream face of the dam embankment can be abandoned or relocated if required.

- Construction of the multi-level discharge system must not impact previously identified trees of significance.
- In general, the forested area on the east side of the existing paved trail needs to be preserved with minimal to no tree removal.
- The discharge transitions from the pressure pipeline to the gravity flume will need to be designed to prevent injury to fish.
- The multi-level discharge system must meet all other applicable design criteria as listed in Appendix A.

2.4.2 Multi-Level Discharge System Design Description

The multi-level discharge system as proposed and analyzed is described in detail in the following sections, and includes discussion of the five outlets that are required and the invert elevation of each outlet. A detailed discussion of the operation of the multi-level discharge system and the hydraulic analysis of the system is provided in Appendix B.

The multi-level discharge system, which includes a rotating selector switch, includes construction of a below grade pipe selection facility and a bank of five, 24-inch outside diameter, HDPE pressure pipes, each leading to a specific outlet elevation at the gravity flume. Refer to Plan Sheets 20,25, 26, and 30 (Appendix C) for plan views, sections and details of this element. The proposed pipe selection facility vault is located at the downstream end of the pressure bypass pipeline and consists of a specially fabricated twin reverse curve 45-degree gooseneck shaped pipe segment capable of rotating about the inlet pipe centerline and connecting to one of five below grade outlet pipes, each leading to a specific outlet elevation at the gravity flume. The gooseneck pipe would be fabricated from steel or aluminum, depending on cost considerations and constructability. All the piping downstream of the discharge vault that is currently active, including the pipe within the vault, will need to be dewatered each time the discharge pipe is switched.

As seen in Plan Sheets 20, 25, and 26 (Appendix C) each of the five discharge pipes are separately connected to the twin 45-degree, gooseneck pipe section, the outlet of which is aligned and indexed parallel to the gravity flume. The upstream end of the gooseneck section is connected to the pressure bypass pipe using a coupling that is capable of allowing rotation. The downstream end of the gooseneck section is connected to a motor driven circular plate that rotates to index to any of the five discharge pipes, each of which terminate at a different elevation along the discharge flume. Sealing of connection points will be accomplished mechanically. Limit switches will provide verification of indexed positions.

The hydraulic analysis of the pressure bypass system and the configuration of the multi-level discharge system determined that five outlet pipes would be required to allow the bypass system to operate throughout the range of reservoir pool elevations and penstock flow rates expected during the fish passage window. This same analysis was used to determine the required outlet elevations for each outlet pipe and the operating curve for each outlet pipe.

Table 1 summarizes the computed invert elevations of the five outlet pipes, and the range of reservoir pool elevations that each outlet pipe would operate within. These elevations were determined based on a maximum allowable penstock flow rate of 700 cfs. As part of the hydraulic analysis, the required number of outlet pipes for other maximum penstock flow rates was determined, and the results are included in Appendix B. The decision to use five outlet pipes was made by balancing the competing needs of allowing for maximum flexibility in power releases while minimizing operation and maintenance of the bypass system. The design team, including the USACE and TPU, concluded that five outlet pipes was the preferred number. Refer to the Technical Appendix B (Hydrology and Hydraulics) for the basis of design and the complete set of operating curves for the outlet pipes.

Table 1. Multi-Level Outlet Elevations for Rotating Selector Switch

Outlet Pipe #	Invert Elevation of Outlet Pipe (feet)	Lower Limit of Reservoir Pool (feet)	Upper Limit of Reservoir Pool (feet)
1	777.4	791	800
2	771.7	784	792
3	766.0	778	785
4	759.7	772	779
5	753.4	765	773

The existing paved trail would need to be relocated to the west to accommodate the 25-foot by 50-foot below grade vault that would house the pipe selection facility. To accommodate the bank of 24-inch pipelines, some trees located to the west of the existing trail would likely need to be removed, and several existing ground water monitoring wells located on the downstream face of the dam would have to be abandoned.

The preliminary contract cost estimate for this element is $705,000, which excludes mobilization/demobilization, contingency, PED costs, S&A costs, and escalation costs. For the detailed breakdown of the cost for this element, refer to the 35% MCACES cost estimate (Appendix D). For the plan, profile, and section views of this element, refer to Plan Sheets 6, 15, 20, 25, 26, and 30 (Appendix C).

2.5 Gravity Flume

A gravity flume element is required to convey the fish and the bypass flows from the outlet of the pressurized multi-level discharge system to the transition ponds. The alignment of the gravity flume is approximately 1,500 feet in length, as measured from the most upstream multi-level outlet pipe to the transition pond, and drops approximately 120 vertical feet. The proposed alignment of the flume follows the east side of the paved powerhouse access road, at the toe of an existing embankment. As will be described in more detail later in this section, the upper 600 feet of the flume alignment was designed below grade, followed by 500 feet of at grade alignment, and then followed by 400 feet of aerially supported alignment.

The slope of the flume varies between 4 percent and 14 percent. Because of the steep slope at the upstream end of the alignment (approximately 7 percent), the range of flows that will be discharged from the pressurized bypass pipe into the flume will immediately transition to a supercritical flow regime. The design criteria require that no hydraulic jumps be allowed within the flume system, and therefore, supercritical flow will be maintained along the entire length of the alignment. Plan Sheets 6 through 9 show the plan and profile of the proposed gravity flume. Photographs along the gravity flume alignment are included in this report as Figures 2 through 5.

2.5.1 Assumptions and Background

The following assumptions were made in developing the gravity flume design:

- Including the estimated effect of superelevation, a minimum required freeboard height will be provided for throughout the flume alignment. The specific magnitude of the required height of freeboard is computed as a function of the cross sectional velocity and the flow depth and is documented in Section 3.3.1.3 of the Hydrology and Hydraulics Appendix (Appendix B).
- To minimize injury and stress to fish as they are conveyed through the flume, the depth of flow in the flume cannot be less than 9 inches (Criterion #12) and velocities cannot exceed 35 feet per second (Criterion #10).
- Horizontal and vertical curves in the flume alignment must have at least a 60-foot radius (Criterion #13).
- Hydraulic jumps are not allowed within the flume alignment, and hence, supercritical flow must be maintained in the alignment for all operating conditions (Criterion #11).
- If necessary, hydraulic jumps are only allowed at the point where the gravity flume discharges to the transition pond.
- Flume foundations must accommodate the existing subsurface drainage system that is located on the east side of the existing powerhouse access road.
- The flume must not block hillside surface and subsurface drainage.
- The existing powerhouse access road width must remain unchanged.
- Neither roadway nor hillside drainage can be allowed to enter the flume.

- Where the flume is constructed near grade, adjacent to the powerhouse access road, it must also be designed as a retaining structure that allows for the collection and conveyance of the hillside surface water.
- The horizontal and vertical alignment of the substation access road at the downstream end of the flume shall remain as existing.
- The existing trashrack on the intake structure is capable of preventing a sudden and instantaneous obstruction of the Eicher screen. Such an obstruction could result in a flow surge through the bypass system, which would result in overtopping of the flume and undermining of the substation access road.
- The design of the gravity flume must adhere to all other pertinent design criteria as identified in Appendix A.

2.5.2 Gravity Flume Design Description

The gravity flume cross-section remains constant along the entire length. A typical section view of the flume is shown on Plan Sheet 27 in Appendix C. The plan and profile of the gravity flume is shown on Plan Sheets 7 through 9. The entire gravity flume alignment is a precast concrete flume, constructed of 20 to 40-foot long precast concrete segments that are joined in the field. The interior surface of the flume would be lined with a polyurea coating system to provide a smooth surface to minimize injury to fish. The polyurea system consists of a two component elastomeric compound. Each component is heated and applied to the concrete surface at high pressure. A high modulus product with an elongation capability of 650 percent or greater will be used. This material has been tested to be compatible with fish, as determined using the Washington State Department of Ecology Static Acute Toxicity Test. At each joint, a flexible silicon sealant will be applied before the polyurea liner is applied, thus allowing the joint to move without being damaged.

Three interrelated conditions required that the upstream 600 feet of the gravity flume alignment be designed below existing grade. First off, all five fixed elevation outlet pipes were designed to connect into the gravity flume upstream of the USFS road. Since the upper three outlet pipes have invert elevations of 777.4 feet, 771.7 feet, and 766.0 feet, respectively, connecting them into the gravity flume upstream of the USFS road was necessary so as to take advantage of the higher topography upstream of the road. In order to avoid crossing beneath the road with the remaining two outlet pipes, all five pipes were therefore designed to connect into the flume upstream of the road. Secondly, the gravity flume itself had to cross beneath the USFS road, therefore requiring below grade construction of the flume. Last of all, the hydraulics of the open channel flow limited the ability to make use of a flatter gradient that would have otherwise allowed for the ability to quickly transition the flume to a near grade alignment after crossing under the USFS road. As seen on Plan Sheets 6 and 7, the invert elevation of the below grade section of the flume averages approximately five feet below grade and is as deep as ten feet below grade where it crosses beneath the USFS road.

For the sections of the flume that are constructed underneath the existing USFS road, the flume will be constructed with a concrete cover, designed to withstand live traffic loading and vertical earth pressures. The flume sections that are to be constructed near grade will be supported on cast-in-place concrete piers and foundations. All above grade and near grade flume sections will be constructed with a screen cover to prevent limbs and leaves from falling into the flume, to minimize the possibility for vandalism, and to provide for visual inspection of fish.

There is an existing underground drainage system along the alignment of the flume, downstream of the USFS road crossing. Existing underground electrical conduits and a 30” x 77” CMP culvert in the vicinity of Station 63+00 (see Plan Sheet 9) will also limit the allowable depth of excavation in that area. According to Wynoochee Dam Hydroelectric Project Record Drawings (City of Tacoma, 1991), the invert elevation of the CMP culvert is approximately 665 feet in this area. The record drawings also indicate that the electrical conduits are buried with a minimum of 18-inches of cover. At this time, it is unknown whether the conduits are buried above or below the culvert. These near surface utilities have forced the location of the flume to the uphill side of the substation.

Surface and subsurface flows emanating from the adjacent hillside are accommodated by providing a perforated drain line on the uphill side of the flume. The drain will be connected to the existing stormwater conveyance system that parallels much of the access road.

A detailed open channel hydraulic analysis of the flume was conducted to determine the horizontal and vertical alignments. For the range of anticipated flow rates, specific hydraulic parameters, including the depth of flow, the average velocity, and the Froude number, were determined using the HEC-RAS hydraulic model. This model is a numerical model, originally developed by the Corps of Engineers, which analyzes gradually varied open channel flow. The model results were checked to verify that for the anticipated range of flow rates, supercritical flow is maintained throughout the alignment, and that all pertinent hydraulic criteria are met. Additionally, the phenomenon of water surface superelevation was considered in the open channel analysis. For each horizontal bend in the alignment, the minimum allowable radius was determined that would still allow for the required minimum freeboard. A detailed discussion of the hydraulic analysis of the open channel gravity flume is included in Appendix B.

The preliminary contract cost estimate for this element is $987,000, which excludes mobilization/demobilization, contingency, PED costs, S&A costs, and escalation costs. For the detailed breakdown of the cost for this element, refer to the 35% MCACES cost estimate (Appendix D). For plan, profile, and section views of this element, refer to Plan Sheets 6 through 9 and Plan Sheet 27 (Appendix C).

Figure 2. Proposed Gravity Flume Alignment at Upstream End.
Photo looking downstream.

Figure 3. Proposed Gravity Flume Alignment at Station 56+00.
Photo taken looking downstream along the steepest gradient of the alignment.

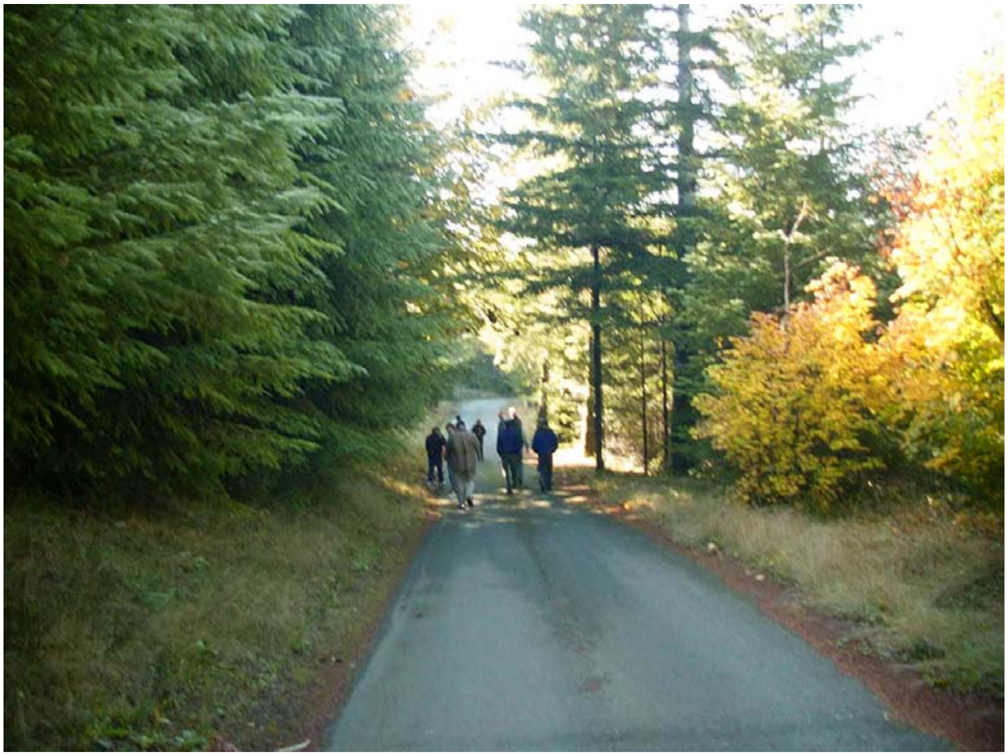

Figure 4. Proposed Gravity Flume Alignment at Station 60+00.
Photo taken looking downstream along the steepest gradient of the alignment.

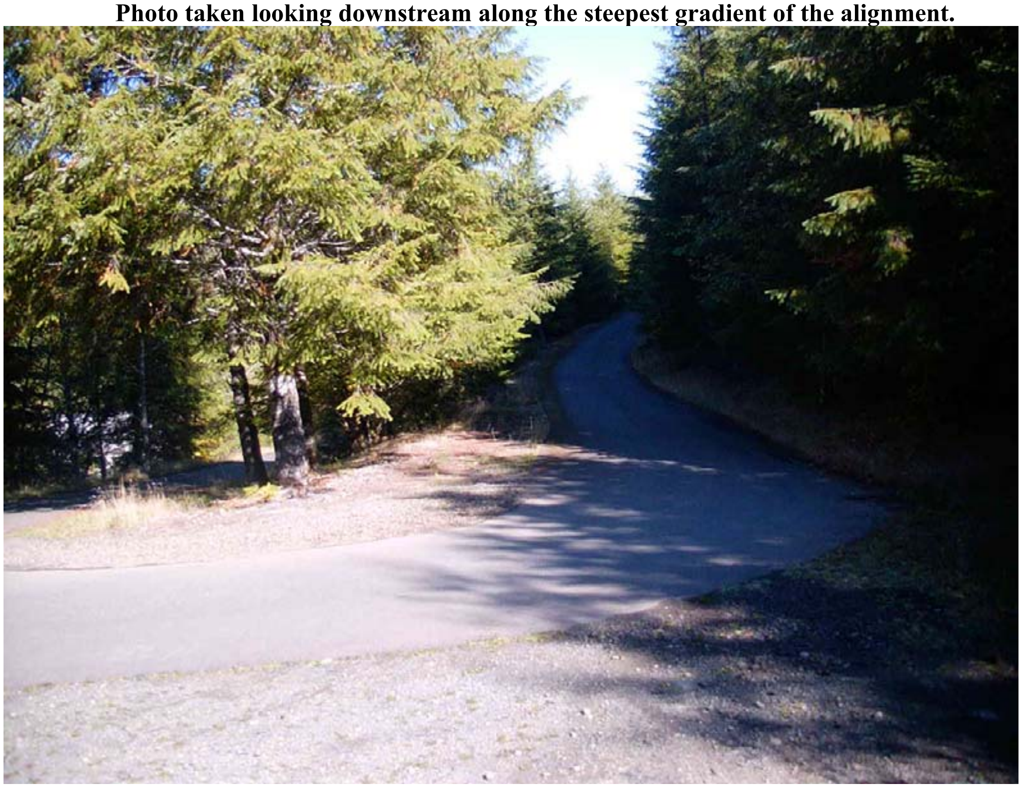

Figure 5. Proposed Gravity Flume Alignment at Station 53+00.
Photo taken from USFS Road 2294 looking upstream.

2.6 Discharge Outlet System

The discharge outlet system is located at the terminus of the open channel gravity flume. This element of the bypass system consists of the necessary improvements to provide a safe and effective transition for fish as they are conveyed from the gravity flume to the Wynoochee River. The discharge outlet system consists of four linearly related components: a multi-cell transition pond, 200 additional feet of below grade open channel gravity flume, 200 additional feet of at grade open channel gravity flume, and a series of four concrete weir drop structures located immediately upstream of the Wynoochee River (refer to Plan Sheets 9 and 10). The outlet of the bypass system to the Wynoochee River is currently proposed to be located just downstream of the existing USGS gauging station #12035400.

2.6.1 Assumptions and Background

The following assumptions were made in developing the discharge outlet system design:

- The system must provide for a safe transition for fish as they move from the bypass system to the Wynoochee River.
- Adult fish must be prevented from migrating upstream through the outlet discharge system.
- All open channels must flow with at least a 9-inch depth.
- No hydraulic jumps are allowed within open channels.
- The discharge outlet is located on the flattest topography of the fish bypass facility, and is a strategic location for collecting and analyzing fish during fish survival testing of the entire bypass facility. Therefore, the discharge outlet system should also be designed to accommodate facilities that can be used to observe the condition of the juvenile fish. The proposed fish testing facility is described in a later section of this report.
- The outlet discharge system is designed to convey 100 percent of the bypass flow rate. There will therefore be no diversion of flows out of the flume or the transition pond.

2.6.2 Transition Pond Design Description

The transition pond is a below grade, concrete lined element with two cells (refer to Plan Sheets 9 and 13). The pond is designed to serve three functions. The first, and primary function of the transition pond is to act as an energy dissipater for the high energy flows that are discharged from the open channel gravity flume into the transition pond. The hydraulics of the transition pond are designed such that the flows from the open channel gravity flume plunge into the transition pond, thereby eliminating the need for a hydraulic jump to dissipate energy. The design depth of the plunge pool is approximately 6 feet and should minimize injury to the juvenile fish as they plunge into the pool. The invert elevation of the flume outlet is set at 672.0 feet and the maximum design water surface elevation in the transition pond is 671.5 feet. Therefore, at least a 6-inch elevation difference is anticipated. The upstream slope of the flume is approximately 4 percent, and the velocity of the flows that will be discharged into the transition pond will range between 17 and 20 feet per second.

The second function of the transition ponds is to provide a control for the collection of juvenile fish. Fish will be diverted from the transition pond into a holding pen to assess and document the health and condition of the fish. While it will be possible to extract fish from various points in the system for incremental assessment, the transition pond provides the control to easily divert small populations of fish into a holding pen. The proposed fish testing and observation facility is described in Section 2.7 of this report.

The third function of the transition pond is to provide relatively tranquil conditions for fish after having been transported through the high velocity pressure pipe and the open channel flume. The second cell of the transition pond is designed for velocities between 1 to 3 feet per second, which will result in tranquil flow conditions for proper acclimation. Up until this point in the bypass system, the fish will have expended tremendous amounts of energy negotiating the high velocities of the bypass system and they will likely be under considerable stress. The fish will have descended up to 120 vertical feet in approximately three to four minutes, and will have endured velocities up to nearly 28 feet per second.

The transition pond is comprised of two connected cells. The first cell functions primarily as the energy dissipation cell, and the point from which flows are diverted into the testing facility. The first cell is approximately 40 feet long and 10 feet wide. The bottom of this cell gently tapers upwards at a 7H:1V slope, thereby slowly decreasing the depth of water and slowly increasing the velocities so that fish will not congregate (refer to Plan Sheet 9). The depth at the upstream end is six feet and the depth at the downstream end is 2.5 feet. To prevent predation in the transition pond, both cells will be covered with ¼ inch delta netting.

A trapezoidal (Cippoletti) weir, located approximately 45 feet downstream of the plunge pool, acts as the downstream control for water surface elevations in the first cell (refer to Plan Sheet 13). The weir has a crest length of 6 feet with 1H:4V side slopes up to a depth of two feet. The trapezoidal weir is designed to pass the maximum design bypass flow rate (Q=33cfs) with a depth of 1.4 feet and the minimum design flow rate (Q=19 cfs) with a depth of 1.0 foot.

A shallow channel, 7 feet wide and 15 feet in length, with a flow depth of approximately 2.5 feet, is located between the first cell of the transition pond and the trapezoidal weir. The purpose of this shallow channel is to allow for the operation of a diversion screen that can be used to shunt fish into the fish testing facility, which is described in more detail in Section 2.7 of this report.

The trapezoidal weir is designed as a free flowing weir for the range of design flows, and therefore will not be submerged. Flows from the weir will plunge into the second cell of the transition pond. The second cell has a constant bottom elevation and a constant depth of approximately 5 feet; however, the width of the second cell tapers from a 10-foot wide section to a 2-foot wide section. The 2 foot width corresponds with the inside width of the outlet gravity flume, which exits this second cell at elevation 664.5 feet.

2.6.3 Below Grade Gravity Flume Design Description

An open channel conveyance system is necessary to convey fish from the transition pond to the Wynoochee River. Due to the need for vehicular access across the open channel to the supplementation ponds, a below grade conveyance system is necessary. In the event that the supplementation ponds are eliminated from the project, the outlet discharge system can be constructed at a shallower depth.

The pre-cast concrete gravity flume sections are proposed for the open channel conveyance from the transition ponds. The below grade gravity flume exits the second cell of the transition pond at elevation 664.5 feet, which allows for approximately 4 feet of cover over the flume. The slope of this flume section is set at 2.0 percent, which is the minimum slope that maintains supercritical flow for the design flow rates (refer to Plan Sheet 9).

During future design phases, a determination will be made as to whether it will be necessary to configure the entrance to the gravity flume to create sufficient backwater in the second cell of the transition pond to approximately elevation 669 feet. The water surface elevation in the second cell should not be allowed higher than the crest of the upstream weir and therefore submerge the weir. An elevation of approximately 669 feet should be maintained in the second cell so as to maintain flow depths of at least 4 feet, thereby providing proper conditions for fishery acclimation.

The length of the below grade gravity flume alignment downstream of the transition pond is approximately 200 linear feet. Average velocities in the below grade flume range between 15 and 17 feet per second The design and construction considerations of this below grade gravity flume are similar to those for the proposed below grade gravity flume located in the vicinity of the USFS Road 2294 (refer to Section 2.5).

2.6.4 At Grade Gravity Flume Design Description

The below grade gravity flume transitions to an at grade gravity flume, which then continues to the bank of the Wynoochee River. The length of the at grade portion of the gravity flume is approximately 200 feet. The gradient of the flume steepens significantly as the alignment approaches the left bank of the Wynoochee River, and ranges from 5 percent to 12.5 percent (refer to Plan Sheets 9 and 10).

A supercritical flow regime will be maintained throughout the alignment for the range of design flow rates. In this reach of the flume, the fish transfer pipe from the supplementation ponds ties into the flume; therefore, fish from the supplementation pond will intermingle with the wild stock from the bypass system. Velocities in the above grade gravity flume range between 18 and 30 feet per second.

The design and construction considerations of this at grade gravity flume are similar to those for the below grade gravity flume located in the vicinity of the USFS Road 2294 (refer to Section 2.5).

2.6.5 Concrete Weir Drop Structures Design Description

At the point in the alignment of the outlet discharge system, where the banks of the Wynoochee River steepen to a gradient in excess of 30 percent, a series of cast-in-place concrete weir drop structures are proposed. A set of four such weirs is proposed to step down through the last 15 vertical feet to the water surface elevation in the river. The weirs are spaced at 10 feet apart, centerline-to-centerline. A 3-foot deep plunge pool will be constructed on the downstream face of each weir and the vertical drop from the weir crest to the plunge pool is a maximum of 2 feet (refer to Plan Sheets 10 and 14).

Adult fish species will be able to negotiate upstream through the concrete weir structures; therefore, these structures will not function to prevent upstream migration. However, the outlet velocities in the open channel gravity flume, combined with the length of the flume that the adults would have to negotiate, would function as an upstream barrier. Adult steelhead species have prolonged fish speeds of 4.6 to 13.7 feet per second and burst speeds of 13.7 to 26.5 feet per second (Powers, et al, 1985). The average velocities in the gravity flume range between 15 and 30 feet per second for the range of design flow rates, and are therefore greater than the prolonged fish speeds. Swimming at burst speeds causes fatigue in 15 seconds or less and would allow adult steelhead to travel between 205 feet and 400 feet, which is less than the length of the gravity flume between the transition pond and the drop structures.

The weir configuration of the drop structures approximates a Cipolleti (trapezoidal) weir, and has a crest length of 8 feet. The design depth of the flow over the weir ranges between 10 inches and 15 inches, with associated velocities in the range of 3 feet per second to 4 feet per second. The weirs will be constructed on continuous spread footings to protect against the effects of localized scour. The Preliminary Geotechnical Engineering Services Report (Appendix E, page 6) documents the soil conditions in the vicinity of the outlet channel, based on field observations of near surface soil conditions. According to the report, the soils in the vicinity of the outlet channel are characterized as loose silty fine sand and soft sandy silt. The report recommended that permanent cut slopes be no steeper than 3H:1V. The cut slopes upstream and downstream of each weir are proposed as 1.5H:1V, and therefore rock armoring of the slopes is recommended. Wingwalls are included to tie the weirs into adjacent high ground and to prevent flows that exceed the magnitude of the design flows from circumventing the weirs.

At the point of discharge, the minimum elevation of the Wynoochee River is estimated to be approximately 631 feet, as determined from USGS gage data. The concrete weir drop structures will tie into the Wynoochee River just downstream of the USGS station shown in Figure 6.

The preliminary contract cost estimate for the discharge outlet system and testing facilities (Section 2.7) is $492,000, which excludes mobilization/demobilization, contingency, PED costs, S&A costs, and escalation. For the detailed breakdown of the cost for these elements, refer to the 35% MCACES cost estimate (Appendix D). For plan, profile, and section views of these elements, refer to Plan Sheets 9, 10, 13, 14 and 27 (Appendix C).

Figure 6. Wynoochee River at USGS Gage Station.
The proposed outlet flume of the fish bypass facility is located just downstream.

2.7 Fish Survival Testing Facility

The fish survival testing facility is required to allow for the examination of fish as they pass through the bypass system and to evaluate the health and condition of the migrating juveniles. This facility is incorporated into the construction of the transition pond element of the outlet discharge system. Juvenile fish will be redirected from the transition pond into a live well holding tank that will have an overflow pipe that is connected back into the outlet discharge system. Once observation of the juvenile fish has been completed, they will be manually removed from the live well with a dip net, and placed into the second cell of the transition pond.

2.7.1 Assumptions

- The testing facility will be used to collect and hold fish for evaluating fish survival and scale loss resulting from the bypass facility. Since it will be a permanent structure, it should also provide a means to conduct other studies that may need to occur in the future.

- Intermittent sampling of juveniles will be necessary, so the design must incorporate the ability to take "grab" samples in addition to larger population samples.
- To minimize further injury to juveniles, the process used to convey fish into the test facility should require minimal to no handling by humans.
- In order to assess mortality rates, it is assumed that extended duration holding periods of at least 24 hours will be desired. Therefore, an element should be incorporated into the design to allow for a continuous circulation of water through the live well.
- The outlet discharge system, including the transition ponds, is designed to convey 100 percent of the bypass flow rate. There will therefore be no permanent flow diversion out of the flume or the transition pond.

2.7.2 Fish Survival Testing Facility Design Description

The fish survival testing facility is designed as a single cell live well that is hydraulically connected to the transition pond. The connection to the transition pond occurs at the shallow concrete channel section located immediately upstream of transition pond control weir. The fish survival testing facility is located below grade, within a 15-foot by 20-foot concrete vault (refer to Plan Sheet 13).

A 2-foot wide by 3-foot high aluminum collection channel intercepts the concrete wall of the transition pond at the shallow concrete channel that is located upstream of the control weir. When sampling of fish is desired, a manually operated diversion screen will be moved into position to divert fish from the main flow into the aluminum collection channel. The aluminum collection channel conveys the diverted flow into a 10-foot long by 5-foot wide by 4-foot deep aluminum live well. Diverted flows plunge from the aluminum collection channel into the live well so as to prevent fish from migrating back into the transition pond. The aluminum live well will be covered with a removable ¼ inch delta mesh netting to prevent fish from jumping out and to protect against predation.

For the 35% design, the diversion screen was assumed to have an orientation of 40 degrees to the main flow, which is the maximum screen angle recommended by National Marine Fisheries Service (NMFS) fish screen criteria. During future design phases, the optimum orientation and porosity of the diversion screen will be finalized. The need for variable porosity or adjustable porosity control may need to be considered if uniform velocity distribution over the screen surface cannot be attained. Input from fisheries agencies will be invaluable as the design of this element progresses.

The depth of flow in the shallow concrete channel, where the diversion screen is located, ranges between 2.0 and 2.5 feet. The cross section averaged velocity through the concrete channel range between 1.5 to 2.0 feet per second for the range of design bypass flow rates. The optimal inflow flow rate into the aluminum live well is 1.0 to 1.5 cfs. During future design phases, if it is found that the diversion is allowing more than the optimal inflow rate, alterations to the diversion screen design should be considered, or partial dewatering of the aluminum collection channel may be considered. If partial dewatering of the aluminum collection channel is considered, a horizontal dewatering screen could be installed along the bottom of the aluminum collection channel.

A screened opening at the bottom of the aluminum holding pen is included in the design to allow for excess flows to pass through the testing facility. A drainage pipe conveys the excess flows from the aluminum holding pen into the gravity flume, thereby allowing for continuous flow through the facility. The overflow system also allows for continuous flow through the facility when juvenile fish are held in the holding pen for longer periods of time to assess mortality rates. During long holding periods, the diversion screen will be moved out of the main flow and will be positioned flush with the wall of the transition pond, thereby terminating the diversion of fish into the testing facility. If the aluminum blocking plate is not inserted to block flow into the aluminum collection channel, a small quantity of water will pass through the portion of the diversion screen that is obstructing the front of the collection channel. When it is desired to completely shut off bypass flows, the aluminum plate is inserted into the aluminum collection channel.

During future design phases, other considerations for the overflow system may be considered, including a small trench drain along the bottom of the aluminum holding pen or a standpipe that would function as a weir in controlling overflows out of the aluminum holding pen.

When observation and testing of the juvenile fish is complete, they will manually be removed from the live well using a dip net, and placed into the second cell of the transition pond.

The preliminary contract cost estimate for the testing facility is included within the contract cost for the entire discharge outlet system. Refer to Section 2.6 for the cost of the discharge outlet system. For the detailed breakdown of the cost for the outlet discharge system and fish testing facility, refer to the 35% MCACES cost estimate (Appendix D). For the plan, profile, and section views of the fish testing facility, refer to Plan Sheets 9 and 13 (Appendix C).

2.8 Supplementation Ponds

Two supplementation ponds are proposed to be constructed, one capable of holding 25,000 winter steelhead, and the other capable of holding 55,700 coho salmon. The pond footprints are programmed to be 30 x 60 feet, with 6-foot maximum depth (refer to Plan Sheets 9 and 12). The ponds are to be designed to allow both volitional release and forced release of the juvenile salmonids. Water temperatures are generally below 12 degrees C during the time the fish are present. The ponds must be impervious to comply with NPDES permit conditions and will be constructed of cast-in place concrete.

2.8.1 Water Supply Design Considerations

The water supply system will be conservatively designed to provide 500 to 700 gallons per minute to each supplementation pond. The primary water supply to the ponds is a 1,200-foot long, 8-inch gravity flow surface water supply line using reservoir water from the existing penstock, delivered to the head end of each pond. A secondary supply utilizing pumps from the river below the dam will be provided in the event that the penstock is dewatered. The river water pump station will have a duplex lead lag type control system, to activate the lag pump if the lead pump stops producing flow.

A 30-inch diameter packed column is provided on the inlet to each pond to ensure adequate oxygenation and dissolved gas pressure levels in the water supply. The flow into each pond is diffused by a supply header, so as to provide uniform flow through the pond and to avoid creating a cascading attraction flow.

2.8.2 Supplementation Pond Design Considerations

As mentioned above, in order to meet current NPDES requirements, the ponds will be constructed of cast-in-place concrete to prevent seepage into groundwater or streams. Other pond construction criteria include:

- An outlet structure, with screens and stop logs, is included in the design for water level and volitional release control.
- The bottom of each pond is sloped towards the outlet structure for positive drainage and dewatering.
- A 2-foot by 2-foot concrete center channel is included along the length of the pond for collecting and crowding fish that do not release volitionally.
- Control valves are required to control the supply flow.
- The perimeter of the supplementation pond footprint is fenced to discourage predation by wading birds and swimming mammals.
- Bird netting canopy is included to discourage predation by flying and swimming birds.
- Optional additions include the use of cobbles and woody debris placed on the pond bottom and shade provided by trees or camouflage netting at pond edges to simulate natural conditions
- Current WDFW practice is to allow volitional release of juvenile fish. This means that fish can leave the ponds at all hours and must be counted electronically. Therefore, an automatic fish counter is included in the outlet pipe.

In recent attempts to improve survival after fish are released, fisheries scientists have explored the use of natural substrates such as cobble rock and woody debris placed on pond bottoms to create a more natural environment. These trials have shown that fish from these types of ponds do adapt and survive better after release. Cobbles will be placed on top of the concrete pond bottom. However, the use of natural materials in the ponds makes cleaning them more difficult.

Disposal of the cleaning waste is another important consideration. Often, cleaning waste is dewatered and hauled off to an approved disposal site or agricultural area. With a 30-foot width, these ponds may be small enough to clean with vacuum equipment from the pool edges.

An automatic fish counter allows tracking of volitionally released fish. The system consists of a pipe mounted scanner and a central processing unit. Scanners cost about $3,500 to $4,500 each, and a CPU capable of tracking up to four scanners is $5,200. More discussion with WDFW is required in order to develop the design of this system. The cost of this system was included in the estimate of the supplementation pond construction.

Mechanical system components for the supplementation ponds include drain valves, flow control elements such as weirs and valves, and associated pumps and automation controls.

The preliminary contract cost estimate for this alternative element is $450,000, which excludes mobilization/demobilization, contingency, PED costs, S&A costs and escalation. For the detailed breakdown of the cost for this element, refer to the 35% MCACES cost estimate (Appendix D). For plan, profile, and section views of this element, refer to Plan Sheets 9 and 12 (Appendix C).

2.9 Fish Trap/Haul Facility Modifications

No change has been made to this element since the *Preliminary Draft Interim Design Report* (USACE, 2003a), and the following discussion is included for reference only. No cost was included for this element at this stage.

The existing Wynoochee Dam adult fish trap has four major components: a fish crowder, a false weir, a flume, and a hopper. In the past, sorting of fish has been done by TPU based on wild stock versus hatchery stock for both steelhead and coho. The existing trap should be modified to allow for more comprehensive sorting of wild fish and hatchery fish stocks. The modifications may include changes in the sorting flume and installation of two additional holding tanks. Other modifications may include the extension of the operator's platform to direct fish into the appropriate tanks and the installation of new lifting devices to assist in truck loading. The hauling truck may need to be modified as well, to match the hopper for the water-to-water transfers.

It has not, however, been currently established which fish will be sorted, nor what the sorting parameters will be. Due to the fact that the sorting protocols have not yet been fully defined, specific design criteria and cost estimates for the facility modifications were not developed at this stage. The assumption was therefore made that sorting will be done for only one parameter at a time (i.e. age, species, or origin), thus requiring a system of two tanks with the requisite facilities to conduct the sorting. Once the sorting criteria are better defined, detailed facility modification recommendations can be analyzed and designed. The following sections of this report provide brief, general descriptions of the function of each component and the modifications that are necessary based on the one parameter assumption, as previously presented in the *Preliminary Draft Interim Design Report* (USACE, 2003a).

2.9.1 Fish Crowder

The fish crowder retains fish until they are moved to the hopper or transportation trucks. Fish enter the crowder through the flow outlet. To operate the crowder, the tank is constricted by moving the screen toward the false weir. Fish exit the crowder as they are forced to swim over the false weir.

2.9.2 False Weir

Fish are attracted to the false weir by upwelling water at the peak of the weir that falls into the fish crowder. Fish jump up and over the weir, and end up sliding down the backside of the weir into the sorting flume and ultimately toward the sorting gate and hopper. Currently, workers are able stand over the weir and rudimentarily sort fish as they jump over the weir, before they enter the fish flume for official sorting. If a worker selects a fish, the fish is captured, handed to another person, and is then carried by hand to either a transport truck or placed in the PVC pipe that directs the fish to the hopper. This fish handling is quite strenuous with little room to work. There is therefore the need for an improved platform or other structure for workers to operate from.

2.9.3 Fish Flume and Sorting Gate

After the fish pass over the false weir, they slide down the flume in less than one inch of water (fish can swim upstream in depths greater than 1 inch) and are either directed to the hopper or to the river with the use of the manually operated sorting gate. An additional fish tank and sorting mechanism are required due to additional fish sorting needs and to reduce worker strain. It is recommended that the existing PVC pipe be removed and that the additional fish tank be constructed below where the pipe was located. An additional sorting gate is recommended for installation in the flume so as to direct fish into the new tank. Alternatively, a multi-directional single sorting gate could be installed that directs fish to each of the three directions (i.e. new fish tank, fish hopper, river).

2.9.4 Hopper

Once the hopper is full of fish, the hopper is raised and moved over a truck where the bottom of the hopper is opened, dumping the fish into the truck. This is only used for transporting adult salmon and steelhead upstream of the dam. Currently, the WDFW truck is unable to handle the load released from the hopper. Therefore, a system will need to be designed that will lift the proposed additional fish tank from the position adjacent to the sorting flume and onto the truck for transport. This system would likely be a mobile crane or other such hoisting mechanism.

2.10 Control Systems

Due to its remote location, Wynoochee Dam is lightly staffed and typically only one person is available for operational procedures at any given time. Therefore, there is a need to automate and control as many aspects of this fish bypass system as is feasibly possible. During the more detailed levels of design, close coordination will need to occur between the design team, the Corps, and TPU to ensure that the design of all elements are compatible with TPU's existing control system.

Mechanical elements included in the control system will need to be closely coordinated with electrical elements such as pressure sensors, limit switches, and flow meters. This coordination will allow for automated control of the movement of the mechanical systems. For example, an elapsed time meter and pressure differential switch can be connected in series to change position of the Eicher Screen for cleaning during periods of migration. At preset time intervals or upon reaching a predetermined pressure differential across the Eicher Screen, the "cleaning mode" will be initiated. An "anticipator" control algorithm could be included that would anticipate when a screen cleaning mode is forthcoming. This algorithm could close the fish inlet gate shaft at the intake structure. After a suitable time interval for fish bearing water to pass the Eicher screen location, then the screen can be moved to the "cleaning" position. After a programmable preset time delay, the screen will move back to the "fishing" position. Once the screen is back in the "fishing" position the fish inlet gate shaft will open to allow fish to enter the penstock. Should a higher than normal pressure differential still exist when the screen moves back to the "fishing" position, (indicating that the screen did not get adequately cleaned), the screen will once again move to the cleaning position. However, if a higher than normal pressure differential across the Eicher screen still exists after two "cleaning" attempts, the screen will move to the "cleaning" position, remain there, and an alarm will be initiated to call for operator attention. During the cleaning attempts the fish inlet gate will remain closed.

With changes in reservoir levels, it will be necessary to change the elevation of the fish bypass pipe discharge port. These changes are accomplished via the Revolving Selector Switch (RSS). Initiation for these changes can be automated but manual initiation may be preferred. Upon initiation, the fish inlet gate shaft located in the Inlet Structure will close keeping the fish out of the system during discharge pipe change. A time delay will allow the downstream bypass system to flush and carry all fish out of the system. A bypass valve will then be closed and the RSS rotation initiated to index to the appropriate downstream pressure pipe. The previously used pressure pipe will be drained. Once the RSS indexing is verified, the bypass pipe valve is opened and flow established. After a brief time delay, the fish inlet gate will open to allow fish to enter the penstock.

The Eicher screen, the RSS, shutoff valves, and the fish inlet gate shaft positions will all be monitored via limit switches and provide a position readout at a central control location for observation by the operator. Manual overrides will allow all functions to be manually initiated or terminated.

3. CONSTRUCTION COST ESTIMATE SUMMARY

Table 2 presents a summary of the 35% level cost estimates for all Wynoochee Dam fish bypass alternatives, exclusive of the supplementation ponds and PED costs. Table 3 presents a summary of the 35% level cost estimates for each design element of the Wynoochee Dam fish bypass facility, including the supplementation ponds and PED costs. Refer to Appendix D of this report for the detailed MCACES cost estimates for each design element. All costs are expressed as 2005 dollars escalated from 2001. As described in the text of this report, cost estimates for the modifications at the adult fish trap facility were not determined, and therefore, costs for this element are not included in Table 2 or 3.

The cost for the fish bypass facilities without the supplementation ponds is estimated at $8,163,000. Cost components in the estimate include contract cost, a 25% contingency, 12.5% escalation costs, 10% PED costs, and 12% S&A costs. Excluding PED costs results in an estimate of $7,5000,000 for the bypass facilities without the supplementation ponds. The preliminary cost estimate for the sum of all of the project elements, including PED, is $8,942,000.

The estimated construction costs shown in Table 2 and 3 include all construction elements and a 25% construction contingency. A 12.5% escalation factor was used to project the project costs from 2001 dollars to the anticipated midpoint of construction in July 2005. The planning, engineering and design (PED) subtotal is based on 10% of the estimated construction cost and includes money that is allocated for the remaining design activities for project implementation (PED is not shown in Table 2.). The supervisory and administration (S&A) subtotal is based on 12% of the estimated construction cost and includes money that is allocated for federal construction management related activities. It is assumed that there are no real estate costs, and permitting costs were not included in the cost estimates. The total preliminary cost estimate for a specific alternative element is therefore a summation of the estimated construction costs, contingency, escalation, PED costs, and S&A costs (Table 3).

Table 2. Preliminary Cost Estimate Summary for the Wynoochee Dam Fish Bypass System (Excluding the Supplementation Pond and PED Costs)

Design Element	Estimated Contract Cost	Contingency (25%)	Escalation (12.5%)	S & A (12%)	Total Cost
Wet Well/Gate Shaft	$194,454	$48,614	$30,319	$36,087	$309,473
Eicher Screen	$1,654,030	$413,508	$257,891	$306,957	$2,632,385
Pressure Bypass Pipeline	$420,651	$105,163	$65,587	$78,065	$669,466
Multi-Level Discharge	$704,695	$176,174	$109,874	$130,778	$1,121,520
Gravity Flume	$986,653	$246,663	$153,836	$183,104	$1,570,257
Transition Pond to Drop Structures	$491,536	$122,884	$76,639	$91,220	$782,278
Mobilization Demobilization	$260,495	$65,124	$40,616	$48,343	$414,578
Totals	$4,712,515	$1,178,129	$870,900	$734,761	$7,499,957

Table 3. Preliminary Cost Estimate Summary for the Wynoochee Dam Fish Bypass System (Including the Supplementation Pond and PED Costs)

Design Element	Estimated Contract Cost	Contingency (25%)	Escalation (12.5%)	PED (10%)	S & A (12%)	Total Cost
Wet Well/Gate Shaft	$194,454	$48,614	$30,319	$27,339	$36,087	$336,812
Eicher Screen	$1,654,030	$413,508	$257,891	$232,543	$306,957	$2,864,928
Pressure Bypass Pipeline	$420,651	$105,163	$65,587	$59,140	$78,065	$728,606
Multi-Level Discharge	$704,695	$176,174	$109,874	$99,074	$130,778	$1,220,594
Gravity Flume	$986,653	$246,663	$153,836	$138,715	$183,104	$1,708,972
Transition Pond to Drop Structures	$491,536	$122,884	$76,639	$69,106	$91,220	$851,384
Supplementation Ponds	$449,545	$112,386	$70,563	$63,249	$83,489	$779,233
Mobilization Demobilization	$260,495	$65,124	$40,616	$36,623	$48,343	$451,201
Totals	$5,162,060	$1,290,515	$805,323	$725,790	$958,043	$8,941,731

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4. POTENTIAL COST SAVINGS

Subsequent to the Draft 35% submittal, the Tetra Tech design team conducted a short value engineering review of the project to identify specific areas of the project where cost savings may be realized as a result of more detailed development of unit costs, more detailed estimation of project quantities, or further refinement of the project design. It is assumed that these refinements would be verified during future design phases and that at this point, they simply represent possible cost savings. None of the design refinement ideas were incorporated into the 35% level design or the 35% level cost estimate, and some of the refinements may result in a violation of one or more of the biological and hydraulic design criteria. Therefore some of the ideas would need to be scrutinized by the Wynoochee Dam Technical Committee prior to recommending them as part of the final design. This list is not exclusive and it is possible that a more intensive value engineering analysis could identify additional cost saving measures.

For each project element, a bulleted list of potential areas of cost savings is presented. All estimated costs savings are expressed in terms of savings to the estimated contract cost line item (column 2 of Table 2 and Table 3). To project this savings to total project cost savings, 1.73, which represents the cumulative add-on multiplier for contingency, escalation, PED, and S&A costs, must multiply the value. All cost savings were originally estimated in terms of 2003 dollars and were reduced by 5% to represent 2001 dollars so as to be consistent with the MCACES cost estimating methodology.

4.1 Gateshaft/Wet Well

The following cost saving items were identified for the gate shaft/wet well:

- Demolition of the existing concrete is the most expensive line item of this project element. There may be some refinement of the unit cost when additional analysis is conducted during the 65% design. Contract cost savings may range from $1,700 to $4,200

The total estimated contract cost savings for this project element might range from $1,700 to $4,200.

4.2 Penstock/Eicher Screen

The following cost saving items were identified for the penstock/Eicher screen:

- Reduce the footprint of the penstock/Eicher screen vault as much as possible. The reduction in the size of the vault footprint would have a significant effect on reducing the cost, due to the fact that the quantities associated with the excavation, off-site hauling of material, cast-in-place concrete, formwork, backfill, and the roof would all be reduced. Contract cost savings may range from $85,000 to $170,000 due to the following refinements of the Eicher screen vault:

    a. Minimize the clear space between the penstock pipe sections. It may be possible to decrease the clear space from six feet clear to three or four feet clear. This would result in an overall reduction in the width of the vault of four to six feet.
    b. As per discussions with the geotechnical subconsultant, it may be possible that the walls below the 18 foot depth can be poured directly against the fractured rock surface, thereby reducing wall thickness and eliminating formwork.
    c. It may be possible to reduce the length of removable pipe section, which would have a subsequent effect of reducing the length of the Eicher screen vault.

- Confirm the loading assumptions for the Eicher screen and determine if they are too conservative and whether they can be reduced. A reduction in the loading assumptions would result in a reduction in the size of the supporting frame. Currently, the screen is designed for the head losses associated with 1,300 cfs of flow and enough obstruction of the screen to cause an additional two feet of head loss. The total head loss for the design condition is thirteen feet. Contract cost savings may range from of $4,200 to $8,500.

- Reconsider an alternative that would include installation of the Eicher screen in a fixed section of the penstock and rotation of the screen into the neutral position when it is not in use. This idea deviates significantly from the recommended alternative, however, there is potential for substantial savings in the cost of the penstock/Eicher screen element provided the concept of leaving the Eicher Screen in-place throughout the year is acceptable to the Corps and Tacoma Public Utilities. The pit width would likely be reduced to one-third of what is required for the removable Eicher screen. The extra section of the penstock and the mechanism required to move it would also be eliminated. Due to the significant deviation from the recommended alternative, no cost savings were estimated.

The total estimated contract cost savings for this project element might range from $85,000 to $178,500.

4.3 Pressure Bypass Pipe

The following cost saving items were identified for the pressure bypass pipe:

- Instead of aerially supporting the pressure bypass pipe between Station 10+50 and Station 11+00 (refer to Plan Sheet 5), using on sight material to bury the pipe would result in a cost savings. This would save money by using on-site material to cover the pipe (thus saving export costs) and would eliminate four aerial supports. Contract cost savings may range from $35,000 to $45,000.

The total estimated contract cost savings for this project element might range from $35,000 to $45,000.

4.4 Multi-Level Discharge System

The following cost saving items were identified for the multi-level discharge system:

- Reduce the number of outlets from five outlets to four outlets. This may have an adverse effect on reducing the maximum allowable penstock flow rate from 700 cfs to approximately 650 cfs and would reduce the operational flexibility that is inherent in having more outlet pipes. Reducing the number of outlets would result in reducing the depth and size of the multi-level discharge vault, reducing the linear footage of bypass pipe, and reducing the number of junction vaults. Contract cost savings may range from $55,000 to $95,000.

Total estimated contract savings for the project element might range from $55,000 to $95,000.

4.5 Gravity Flume

The following cost saving items were identified for the gravity flume:

- Replace between 550 and 800 linear feet of the gravity flume with high-density polyethylene (HDPE) pipe with an inside diameter no larger than 22.5”. Assuming a Manning’s roughness coefficient of 0.010, this pipe would convey the range of design flows at the required minimum 9-inch depth as long as the pipe is not constructed at a gradient steeper than 6 percent. Since the current design shows the upper 800 linear feet of the gravity flume at a gradient between 5.5 percent and 7.3 percent, it is possible that all or a portion of the upper 800 linear feet can be replaced with a conventional HDPE pipe. This modification would likely require a structure to transition from the round pipe to the flume. Contract cost savings may range from $90,000 to $140,000.

The total estimated contract cost savings for this project element might range from $90,000 to $140,000.

4.6 Discharge Outlet System

The following cost saving items were identified for the discharge outlet system:

- Replace up to 300 linear feet of the gravity flume with high-density polyethylene (HDPE) pipe with an inside diameter no larger than 22.5”. Assuming a Manning’s roughness coefficient of 0.010, this pipe would convey the range of design flows at the required minimum 9-inch depth as long as the pipe is not constructed at a gradient steeper than 6 percent. Downstream of the transition ponds, the gradient of the gravity flume is currently designed at a gradient that ranges between 2 percent and 5 percent, so it may be possible that all or a portion of the upper 300 linear feet (between Station 65+78 and 68+80) can be replaced with a conventional HDPE pipe. This modification would likely require a structure to transition from the round pipe to the flume. Contract cost savings may range from $40,000 to $50,000.

The total estimated contract cost savings for this project element might range from $40,000 to $50,000.

4.7 Summary of Potential Cost Savings

The preceding sections described potential cost savings that were identified at the end of the 35% draft design effort. These cost savings are only preliminary and further engineering analysis will be needed to refine the design to determine if these or other cost savings can be realized. It is recommended that a workshop be held at the beginning of the next design phase to determine which, if any, design refinements would yield cost savings. Any design refinements would have to meet the project objectives, while not resulting in an increase in operation and maintenance costs. The outlined contract cost savings as describe above might result in a potential savings ranging from $0 to $513,000. That would translate to a maximum project savings of $887,490. Although, these projected savings only present the savings identified to date and do not include all engineering refinements, they serve to illustrate the potential usefulness of a formal effort to identify and incorporate engineering refinements that may lead to cost savings.

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Appendix A

Biological and Hydraulic Design Criteria

BIOLOGICAL HYDRAULIC DESIGN CRITERIA

Wynoochee Dam Downstream Fish Passage Project

INTRO: Staff from the Washington Department of Fish and Wildlife and the National Marine Service originally provided criteria for hydraulic conditions to be met throughout the bypass system. These criteria were based on the environmental requirements of the fish which are to be passed through the system. On October 18, 2002, the Wynoochee Dam Technical Committee met to discuss and comment on the original list of criteria. The following list is therefore a modified version of the original criteria list, and reflects the comments of those attending the committee meeting:

1) **The flow rate through the Eicher screen section of the penstock during the fish migration window is anticipated to range between 210 and 800 cfs. The maximum allowable flow rate will, however, be determined during the hydraulic analysis of the bypass system and during post project monitoring of the system. It is likely that the maximum flow rate will be between 600 cfs and 800 cfs.**

2) **Penstock minimum diameter = 10.0 ft.**

3) **Eicher screen removable penstock section diameter = 10.0 ft.**

4) **The maximum average allowable penstock velocity within the removable Eicher screen penstock section during screen operation will be determined during the post construction evaluation phase. Based on previously published data, it is anticipated that the optimum maximum velocity will be in the range of 7.6 fps (600 cfs) and 10.2 fps (800 cfs). .**

5) **The minimum average velocity through the bypass pipe shall be 7 fps and the maximum average velocity through the bypass pipe shall be 12 fps. At no time shall there be a deceleration along the screen face and through the entrance of the bypass pipe.**

6) **No light must enter the bypass transition upstream of the 24-inch diameter pressure pipe.**

7) **Pressure bypass pipe minimum diameter = 24 inches.**

8) **Pressure bypass pipe will be material smooth wall HDPE pipe or equivalent. Should have smooth surface, smooth joints, and is bendable. Minimum bend radius within pressure bypass pipe = 5 diameters (i.e. 10 feet) .**

9) Flow velocity normal to Eicher screen at any one point must not exceed 0.40 times the average upstream penstock velocity. Screen should be at a 16-19 degree orientation.

10) Free surface open channel flume or pipe flow velocity must not exceed 35 fps.

11) Hydraulic jumps are not permitted within the bypass system. There may be a jump at the END of the system, but all efforts to avoid this should be made.

12) Nominal Water depth within the open channel flume or free surface pipe flow must exceed 9 inches at all times.

13) Horizontal or vertical bends with radius less than 60 feet are not permitted within the high velocity free surface pipe or flume flow.

14) At no point will full pipe flow conditions be permitted within the free surface flow pipe, either as a result of excessive depth of water or as a result of air entrainment into the flow.

15) Viewing ports must be provided at strategic locations along any enclosed pipe with which free surface flow conditions are to be maintained.

16) In progress. Discharge of the bypassed flow into the river is to be effected through a spreading of flow such that no plunging singular jet is formed.

17) Maximum entrance jet total velocity of bypassed flow into the river must be less than 30 fps.

18) Bypass flow discharge must exit into a pool of water greater than five (5) feet in depth.

Appendix B

Hydrology and Hydraulics
Technical Appendix

U.S. Army Corps
of Engineers
Seattle District

Wynoochee Dam
Section 1135 Fish Restoration Project

Grays Harbor County, Washington

Technical Appendix
Hydrology and Hydraulics
August 29, 2003

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Wynoochee Dam
Section 1135 Fish Restoration Project

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1. INTRODUCTION

Wynoochee Dam is located on the Wynoochee River approximately 30 miles due north of the City of Montesano, in Gray's Harbor County Washington. In 1994, Tacoma Public Utilities (TPU) began commercial operation of hydropower units at Wynoochee Dam, originally constructed as a flood control and water supply facility. Previous to the hydroelectric turbine installation, downstream migrant salmonids were routed past the dam using a series of four multi level outlets specifically designed for fish passage. The hydroelectric turbine installation therefore created an additional outlet for downstream fish passage. Previous studies have shown that fish passing through turbines may incur significant mortality. Therefore, to minimize turbine mortality of outmigrant smolts, FERC licensing requirements have required TPU to annually halt hydroelectric turbine operation for a 77-day period during peak juvenile salmonid outmigration. This shutdown therefore routes juvenile coho salmon and steelhead smolts through the original multi-level outlets, which have presumably lower mortality rates (Hydroacoustic Technology, Inc., 1997)

So that TPU may continue to operate the hydroelectric turbine units during the peak juvenile salmonid outmigration period, the U.S. Army Corps of Engineers (USACE) and TPU have been working together on the design of a juvenile fish bypass facility that would meet target survival rates for outmigrating coho and steelhead. The proposed project includes the following elements:

- Structural and mechanical modifications to the intake structure to improve fish attraction into the penstock and to decrease fish residualism.
- Installation of an Eicher screen within the 10-foot diameter penstock, approximately 200 feet downstream of the dam face. The screen will function to divert fish into the juvenile bypass system.

- Construction of 500 linear feet of a pressurized bypass pipeline to convey fish from the penstock on the west side of the river to approximately the same elevation on the east side of the Wynoochee River.
- Construction of a multi-port switch structure, which will function to discharge the bypassed flows to five different outlet elevations on an open channel gravity flume.
- Construction of 1,500 linear feet of an open channel gravity flume which will convey bypassed flows from elevation 776 feet (NGVD29) to an outlet elevation of 672 feet (NGVD29).
- Construction of a single cell transitional pond to allow the juvenile fish to acclimate prior to discharge to the Wynoochee River.
- Construction of an outlet discharge system, from the transition pond to the Wynoochee River, comprised of 400 linear feet of an open channel gravity flume and a set of concrete weir drop structures at the outlet to the Wynoochee River.

2. HYDROLOGY

Wynoochee Dam is located on the Wynoochee River approximately 30 miles due north of the City of Montesano, in Gray's Harbor County Washington. The dam is located at approximately RM 51.8. The United States Geological Service (USGS) gaging station No. 12035400 (Wynoochee River near Grisdale) is located approximately 0.5 miles downstream of the dam at river mile (RM) 51.3. A USGS water stage recorder (USGS Gage No. 12035380) is located in monolith No. 6, near the centerline axis of Wynoochee Dam.

Hydrologic analysis for the juvenile bypass facility was limited to compiling the previous fifteen years of mean daily flow data and mean daily reservoir data, developing plots of the data, and using the plotted data for the hydraulic analysis and design of the juvenile bypass system.

2.1 Hydrologic Data

Under the current operational plan, dam releases are set to augment natural flows for fish migration and industrial water supply during the dry summer and fall seasons and to reduce flood discharges in the lower valley during the winter flood control period. The operation of the Wynochee Dam provides higher summer flows in the river downstream of the dam site than those under natural pre-project conditions. The project is operated to provide at least the minimum instream flows for the downstream fishery resource. According to the Wynoochee Dam Water Control Manual, project operation currently provides a year round minimum discharge of 120 cfs downstream of the Aberdeen diversion, located at RM 8.1. The minimum discharge from the dam, as measured at the USGS gaging station near Grisdale, is 140 cfs between May 1st and July 1st, and 190 cfs for the remainder of the year (USACE, 1998).

During the winter flood season, the Wynoochee Project reserves the top 24,000 acre feet as vacant storage for flood control. As the potential for floods decreases through the spring, the Wynoochee Dam gradually begins storing runoff so as to reach the full pool elevation (Elevation 800 feet) by early May. Between reservoir elevations 720 feet and

800 feet, nearly 60,000 acre-feet of conservation storage is available to augment natural flows for fish migration and industrial water supply during the late spring, summer and fall seasons (USACE, 1998).

The selective withdrawal system is currently used during the April 15th through June 30th period each year while the hydroelectric facility is shut down. Currently, during this time period, reservoir flows are released through the high level outlets. To allow for safe downstream fish passage through these outlets, the high level outlets are operated in either a fully open or a fully closed position (USACE, 1998). With the implementation of the proposed Wynochee Dam fish bypass facility, survival rates of outmigrant smolts will increase, and TPU will be provided a greater operational flexibility. Flow releases will again be allowed through the penstock during the April 15th through June 30th time period, and the bypass system will be designed such that downstream fish passage will be safe and effective for the range of reservoir pool elevations and penstock release rates that can be expected during this time period.

Instantaneous daily reservoir data and mean daily flow data was obtained from the USGS for the time period 1/1/90 through 12/31/02. Mean daily flow data for the Wynoochee River near Grisdale, WA (Gage #12035400) is official, published data through WY 2001. At the time the data was obtained from the USGS, the WY 2002 data had not received director's approval and was therefore considered provisional. The entire data set of daily reservoir elevations (Gage #12035380) was obtained directly from the USGS. For this gage, the USGS only publishes month end data, and therefore, the entire daily data set is considered as "unpublished" data.

Since the Wynoochee Dam has only been in operation as a hydropower facility since 1994, only the years 1994 through 2002 were compiled and plotted. Figure 1 shows the reservoir fill trend during the spring refill period for each year since 1994. Figure 2 shows the mean daily flow rate in the Wynoochee River for the years 1994 through 2002, for the time period of April 1 through July 31. Since there are no major tributaries between the

Wynoochee Dam and the USGS gaging station, the flow rates shown in Figure 2 approximate the release rates from the Wynoochee Dam.

The fish-screening window during which the Eicher screen and the juvenile bypass facility will operate is assumed as April 15th through June 30th. As seen in Figure 1, the reservoir pool elevations range between 770 feet and 800 feet during this time window. During normal years, full pool is typically attained by early to mid-May and is held constant through the remainder of the assumed fish-screening window. Flows are then regulated through the dam to maintain the reservoir pool elevation.

The minimum flow rate through the penstock is assumed to be 210 cfs (personal communication, Steve Fisher), and this is verified by the graph in Figure 2. This flow rates is based on a minimum allowable turbine operating flow rate of 190 cfs plus an additional allowance of 10% for factor of safety. According to TPU operations staff, the maximum allowable flow rate through the penstock during operation of the hydroelectric facility is 1,300 cfs. Flows in excess of 1,300 cfs are spilled through other outlets in the dam.

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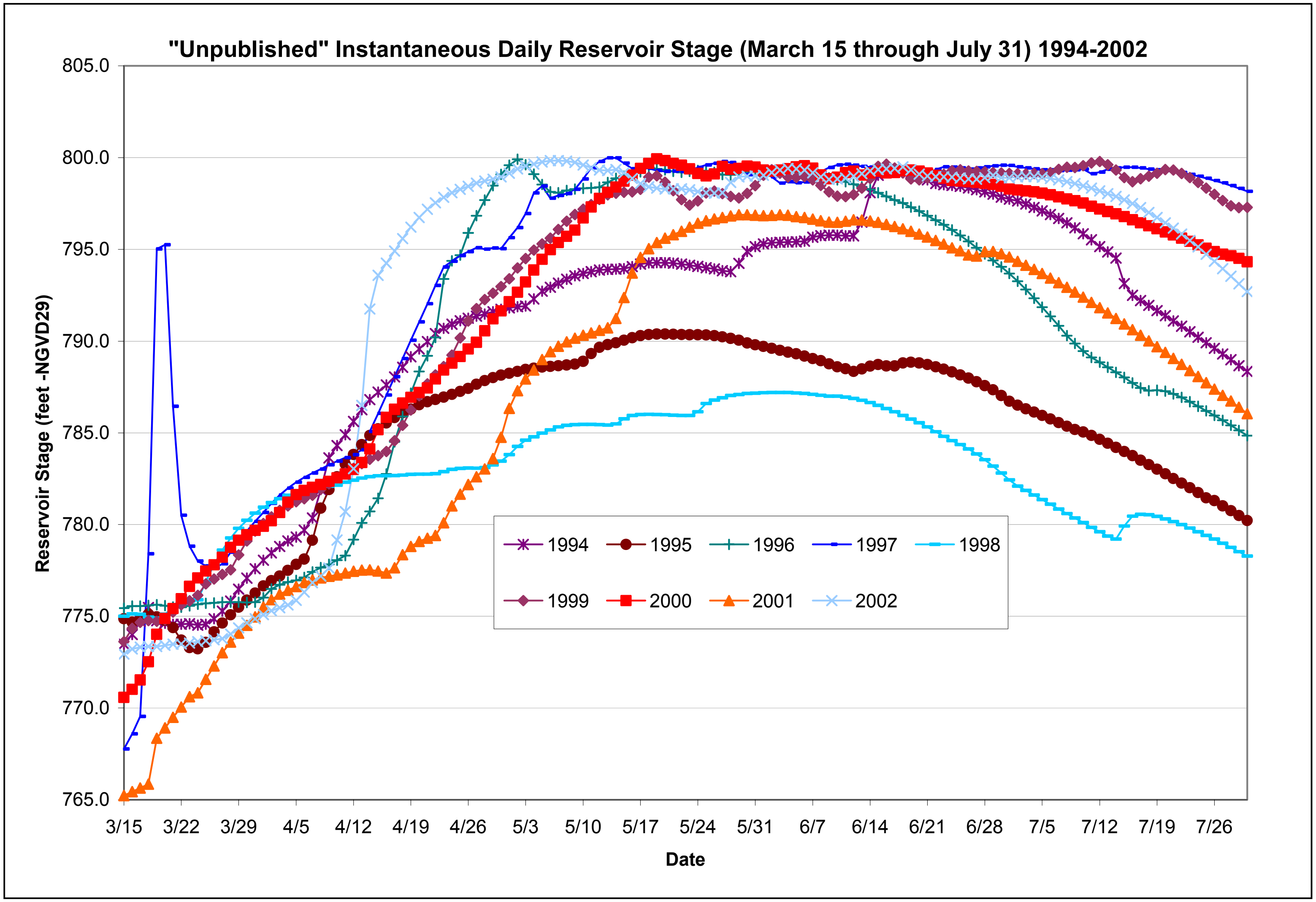


Figure 1. 1994-2002 Wynoochee Lake Reservoir Stage (March 15 through July 31)

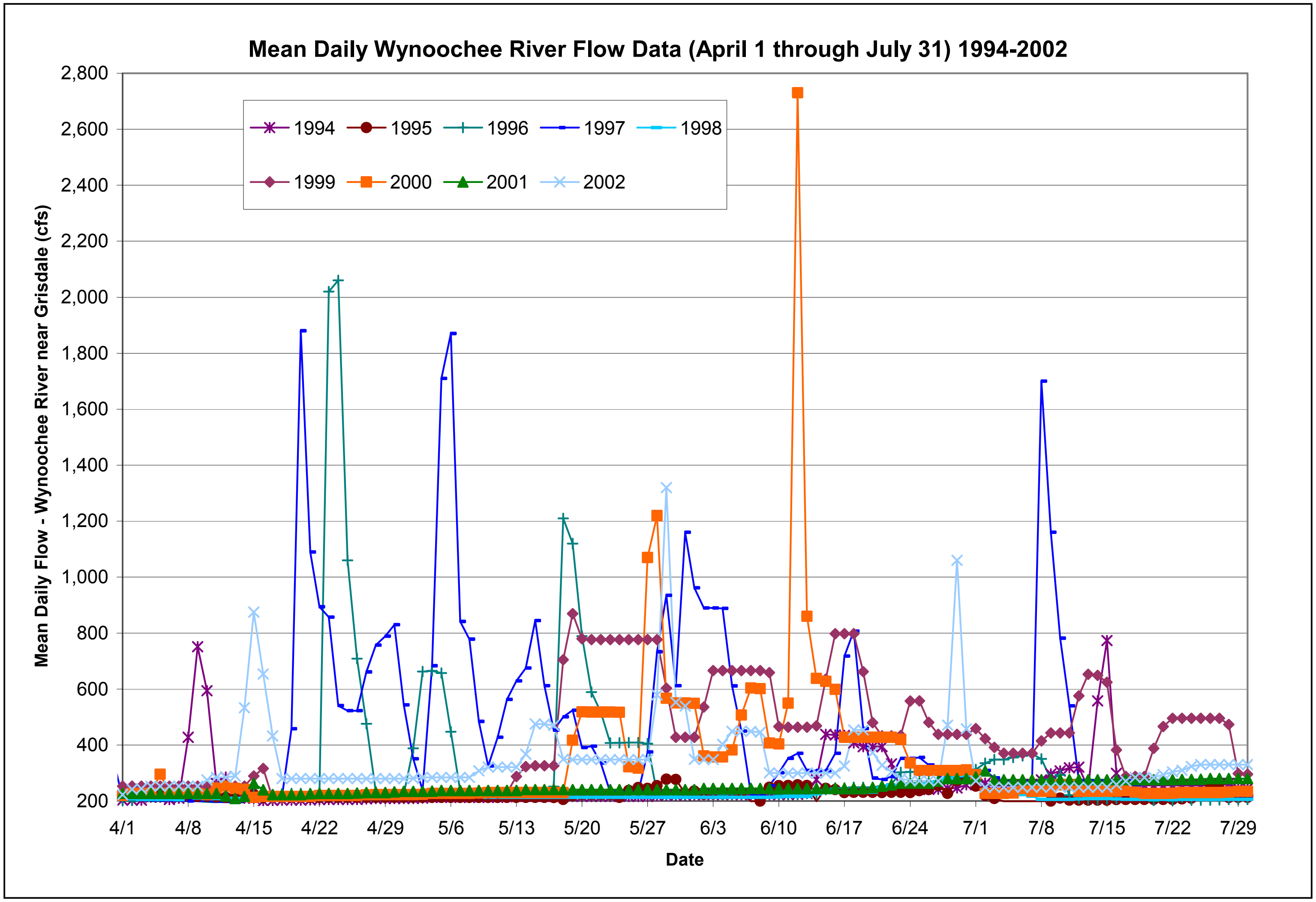


Figure 2.1994-2002 Wynoochee River Mean Daily Flow Rate (April 1 through July 31)

3. HYDRAULICS

The proposed Wynoochee Dam fish bypass facility is composed of numerous interrelated features. Some level of hydraulic analysis, in support of the 35% level design effort, was required for each feature to ensure that it would function properly throughout the range of operating conditions that can be expected during the fish bypass window. The following features were included in the hydraulic analysis:

- Penstock/Eicher Screen
- Pressure Bypass Pipeline
- Multi-Port Selector Switch and the Multi-Level Discharge System
- Open Channel Gravity Flume
- Transitional Pond and Outlet Channel

3.1 Penstock/Eicher Screen

The concept of installing a fish screen inside of a penstock at a shallow angle to the flow was first applied by George Eicher at the T.W. Sullivan hydroelectric plant in Oregon. The Eicher screen functions under different principles than other types of screens, in that it is designed to sweep fish rapidly towards a bypass pipe at high velocities. Other types of screen systems are designed to maintain velocities lower than the sustained swimming speed of the target fish species (Winchell, Fred C. and Charles Sullivan, 1991).

Due to the fact that the Eicher screen is a relatively new concept for fish screening applications, there is a limited amount of physical model hydraulic data and field collected hydraulic data available for the evaluation of the screen performance. There are three known previous installations of the Eicher screen on the West Coast, two of which are still in operation. In 1980, a prototype installation was installed and tested at the T.W. Sullivan Plant at Willamette Falls, Oregon. In 1990, an Eicher screen was installed at the Elwha River Hydroelectric Project, near Port Angeles, Washington. Finally, in 1993, BC Hydro installed Eicher screens within twin 12-foot diameter penstocks at their Puntledge River Diversion Dam facility in the province of British Columbia. Physical models of the intake, the penstock, the Eicher screen, and the bypass pipe were constructed for both the Elwha River facility and the Puntledge River facility. The physical models were used to develop detailed hydraulic information on the flow field upstream of the Eicher screen, the flow distribution over the screen surface, and the flow distribution at the entrance of the bypass pipe. Table 1 summarizes key parameters and conditions at each of the three previous installations and compares them to those at the Wynoochee Dam Hydroelectric Project.

Table 1. Eicher Screen Installations

Site	Nominal Penstock Diameter (feet)	Maximum Penstock Flow with Screen in Place (cfs)	Maximum Penstock Velocity with Screen in Place (fps)	Head Above Centerline of Screen (feet)	Angle of Inclination (degrees)	Porosity of Screen
T.W. Sullivan	11.0	470	5.0	unknown	19.3	unknown
Elwah	9.0	496	7.8	unknown	16	Variable - 32% to 63%
Puntledge	12.0[1]	678	6.0	3	16.5	Constant – 58.5%
Wynoochee	10.0	tbd[2]	tbd[2]	54	16.5	Constant – 57.3%
Notes: (1) Twin 12-foot diameter penstocks at Puntledge facility (2) tbd = to be determined						

3.1.1 Eicher Screen Hydraulics

Throughout the last twenty-three years, Eicher screen hydraulics have been modeled and analyzed by others. Much of this analysis has been physical model studies in support of the design of specific Eicher screen installations. The most widely published data is that of Winchell, et al (1991) and Adam, et al (1991), which was conducted in support of the Eicher screen installation at the Elwha Hydroelectric Dam, and that of ENSR (1994), which was conducted in support of the Eicher screen installation at the Puntledge River Dam. The results of these two studies were partially used in the development of the hydraulic and biological design criteria for the Wynoochee Dam project and were also used as guidance in the hydraulic analysis of the proposed Wynoochee Dam Eicher screen and fish bypass system.

For the 35% level hydraulic analysis of the proposed Wynoochee Dam Eicher screen, the analysis was limited to estimating the head losses through the screen structure for a range of penstock flow rates, and computing the fluid forces acting on the screen under different operational flow rates and magnitudes of screen obstruction. The primary resource for this data was the previous hydraulic evaluation of an Eicher screen installed at the Elwha Hydroelectric Project in Washington State (Adam, et al, 1991). This installation consisted of a screen installed in a 9-foot diameter penstock at an approximately 16-degree angle, relative to the centerline of the penstock. The design porosity configuration for the screen was 63% for the upstream 2/3 of the screen and 32% and 8% for the remaining 1/3 of the screen.

Among other parameters, the studies of the Elwha Dam Eicher screen installation evaluated the head loss through the Eicher screen through a range of penstock flow rates. Head loss was measured under both in-field conditions and in a physical model study. The measurements in the field indicated a maximum of 1.9 feet of head loss, and the maximum head loss that was measured in the physical model was 1.3 feet (Adam, et al, 1991). The average penstock velocities associated with these two magnitudes of maximum head loss were 7.5 fps and 8 fps for the field measurement and the physical model measurement, respectively. The study concluded that the difference in head loss between the full scale and the physical model measurements was likely attributed to the lack of seals and clamping bars in the physical model, and the required removal of wedge wire support u-clips in the physical model (Adam, et al, 1991). Figure 3 was reproduced from Adam, et al. (1991) and graphically shows the results.

For the proposed Wynochee Dam Eicher screen analysis, screen head losses for velocities that exceeded those presented in Figure 3 were extrapolated, and hence should be considered approximate. The measured head losses, and the extrapolated head losses, were then used to estimate the fluid forces that would act on the screen installation at Wynoochee Dam. Forces acting on the screen surface were computed for both the clear screen (unobstructed flow) and a partially obstructed screen condition. The partially obstructed condition is defined as that which would result in two feet of additional head loss due to the partial obstruction of the screen face during a given penstock flow rate. The resulting forces are presented in Table 2. The head losses and fluid forces that are summarized in Table 2 are for the steady state equilibrium condition. For this condition, the fluid forces that are acting on the screen are a function of the pressure differential across the screen surface, and are oriented normal to the upstream face of the screen. The structural design of the screen was based on the fluid forces acting on the screen as a result of a penstock flow rate of 1,300 cfs (maximum possible penstock flow rate) and sufficient obstruction of the screen face that would cause an additional two feet of head loss.

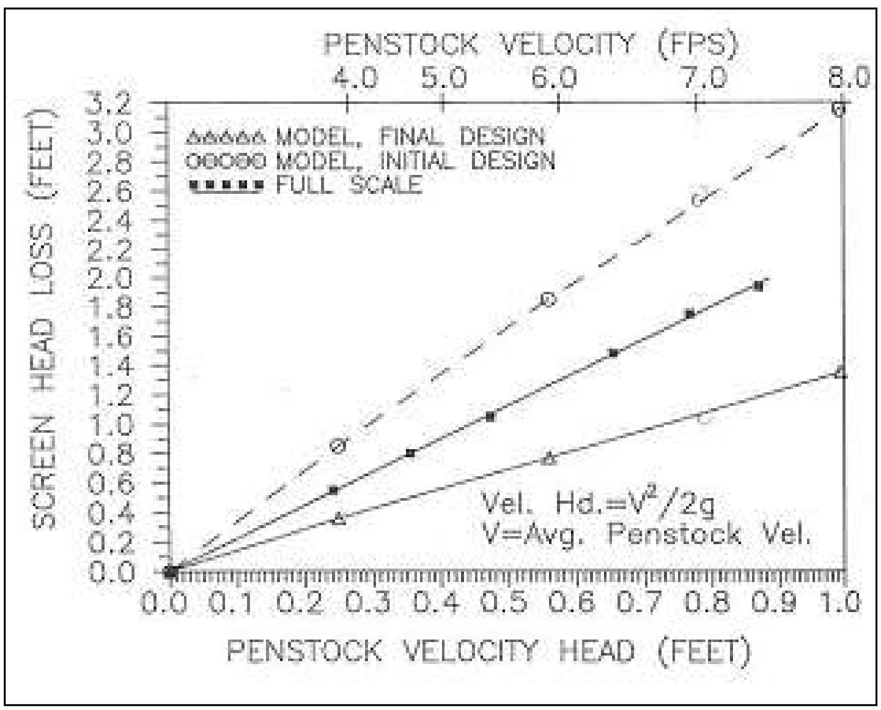


Figure 3. Full-Scale and Model Screen Head Loss Results for Elwha Dam Eicher Screen Installation (Adam, et al, 1991).

Table 2. Computed Fluid Forces Acting on Proposed Eicher Screen

		Clear Screen			Partially Obstructed Screen		
Penstock Flow (cfs)	Penstock Velocity (fps)	Head Loss (ft)	Pressure Differential (psf)	Resultant Force (kips)	Head Loss (ft)	Pressure Differential (psf)	Resultant Force (kips)
600	7.6	2.2	138	38.2	4.2	262	72.5
650	8.3	2.7	168	46.5	4.7	293	81.2
800	10.2	4.0	250	69.3	6.0	370	103.6
1,300	**16.6**	**10.7**	**670**	**185.0**	**12.7**	**790**	**219.4**

Head loss through the Eicher screen can be subdivided into the losses associated with the screen itself, and the losses associated with the structural supporting frame that is located behind the screen. In discussions with staff at the Puntledge facility, it was reported that physical models of their Eicher screen installation indicated that 60% of the measured head loss through the screen structure was attributed to the supporting frame, while the other 40% was attributed to the screen itself.

In-field measurement of the headloss through the Eicher screen at the Puntledge facility found that approximately 1.3 feet of head loss was reported for an average penstock velocity of 6 ft/s (J. Graeme Matthews, personal communication 2003). Additionally, the physical model studies for the Puntledge Eicher screen (ENSR 1993) concluded that the head loss through the screen for an average penstock flow rate of 6 fps ranged between 1.29 feet (constant screen porosity) and 1.54 feet (variable screen porosity). These in-field and physical model measurements correspond well with the reported head losses at the Elwha facility.

3.1.2 Hydraulic Transient Analysis

During normal operation of the Eicher screen, a scenario could develop whereby the screen could become partially or entirely plugged in a fairly rapid timeframe, before the upstream and downstream pressure sensors trigger the screen to rotate into the backflushing position. The clear opening of the existing trashrack is 4-inches, so it seems unlikely that sheets of material (i.e. tarps and other plastic sheeting) would be capable of passing through the existing trashrack. However, it doesn't seem unlikely that a large quantity of organic debris such as leaves or needles could pass through the existing trashrack and quickly load the Eicher screen. This loading condition was analyzed by assuming that the transient hydraulic conditions resulting from a gradual or sudden obstruction of the Eicher screen would mimic those associated with the gradual or sudden closure of a valve. Therefore, the water hammer equations were applied for the analysis.

When a flowing fluid is abruptly stopped due to the sudden closure of a valve, dynamic energy is converted to elastic energy, and a series of positive and negative pressure waves travel back and forth in the pipe until they are damped out by friction (Linsley and Franzini, 1979). At the moment when the valve is closed, the element of water just upstream of the valve, x_1, will be compressed by the element of water flowing against it, x_2. This results in an increase in pressure immediately upstream of the valve. In the next moment, the forward motion element x_2 is stopped, and it too is compressed by the remaining water behind it. This compression also results in a pressure rise and causes a portion of the pipe to expand. This process proceeds rapidly upstream until the pressure wave has traveled back to the reservoir and all water in the pipe is at rest. At this moment, the pressure in the pipeline at the junction with the reservoir is quickly reduced to hydrostatic pressure. This reduction in pressure results in a normal pressure wave that travels back downstream towards the closed valve, resulting in contraction of the pipe and a return to the conditions that initiated that water hammer in the first place. This process repeats itself until it is damped out by friction.

The applicable equations for this analysis are shown below.

$$C = (E / \rho)^{\frac{1}{2}} \qquad \text{(Equation 1)}$$

where,

C = wave celerity (ft/s)

E = modulus of elasticity of water at 50^{O} Fahrenheit (3.05×10^3 psi)

ρ = density of water at 50^{O} Fahrenheit (1.94 slugs/ft^3)

$$C_p = (E / \rho)^{\frac{1}{2}} \times \left[\left(\frac{1}{1 + \left(\frac{E * D}{E_p * t} \right)} \right) \right]^{\frac{1}{2}} \qquad \text{(Equation 2)}$$

where,

C_p = velocity of the pressure wave (ft/s)

E = modulus of elasticity of water at 50^{O} Fahrenheit (3.05×10^3 psi)

ρ = density of water at 50^{O} Fahrenheit (1.94 slugs/ft^3)

D = diameter of pipe (ft)

E_p = modulus of elasticity of pipe material (28.5×10^6 psi)

t = wall thickness of pipe (0.35 inches)

Using Equation 1 and Equation 2, the wave celerity (C) and the pressure wave celerity (C_p) were computed as 4,760 ft/s and 2,200 ft/s respectively. The time for the pressure wave to travel from the obstructed screen surface to the reservoir and back to the screen surface is a function of the pressure wave celerity and the length of travel (500 feet) and was computed as 0.23 seconds, or ¼ second. This is the length of time a positive pressure will be maintained at the screen (valve). The water hammer equations (which are derived by applying Newton's second law of physics) can be applied to this problem to quantify the increase in pressure that would occur if the complete obstruction of the screen occurred in less than the time it took for the pressure wave to travel from the screen to the reservoir and back to the screen. The pressure increase associated with this rapid obstruction can be determined from the following basic water hammer equation:

$$p_h = \rho \times C_p \times \Delta V \qquad \text{(Equation 3)}$$

where,

p_h = maximum water hammer pressure (psi)

ρ = density of water at 50^{O} Fahrenheit (1.94 slugs/ft^3)

C_p = velocity of the pressure wave (ft/s)

ΔV = differential velocity resulting from rapid valve closure (ft/s)

The water hammer pressure resulting from an obstruction of the screen surface that occurs in less time than it takes for the pressure wave to travel from the screen surface to the reservoir and back to the screen surface (i.e. less than ¼ of a second) is tremendous and is calculated as 227 psi, which is equivalent to 522 feet of head. This is obviously an unrealistic design consideration. However, the results of this calculation are useful in another way. Knowing the maximum water hammer pressure that can be developed upstream of the screen, the water hammer pressure that would develop as a result of a longer "closure" or obstruction time can be calculated using the following equation:

$$p'_h = \left(\frac{t}{t_c \times p_h} \right) \qquad \text{(Equation 4)}$$

where,

p'_h = water hammer pressure developed as a result of gradual closure (psi)

t = travel time for pressure wave (1/4 second)

t_c = closure or obstruction time (seconds)

p_h = maximum water hammer pressure (227 psi)

By inputting a range of assumed closure/obstruction times in Equation 4, a relationship can be developed which plots the increase in head upstream of the screen as a function of the time it takes for complete obstruction of the screen. This relationship is shown in Figure 4. As seen in Figure 4, the computed rise in upstream head is quite high for obstruction time less than one or two seconds, but quickly decreases in magnitude for obstruction times that exceed five seconds. The close proximity of the screen to the open reservoir, and thus atmospheric pressure, allows for rapid damping of the pressure wave for obstruction times greater than about five seconds.

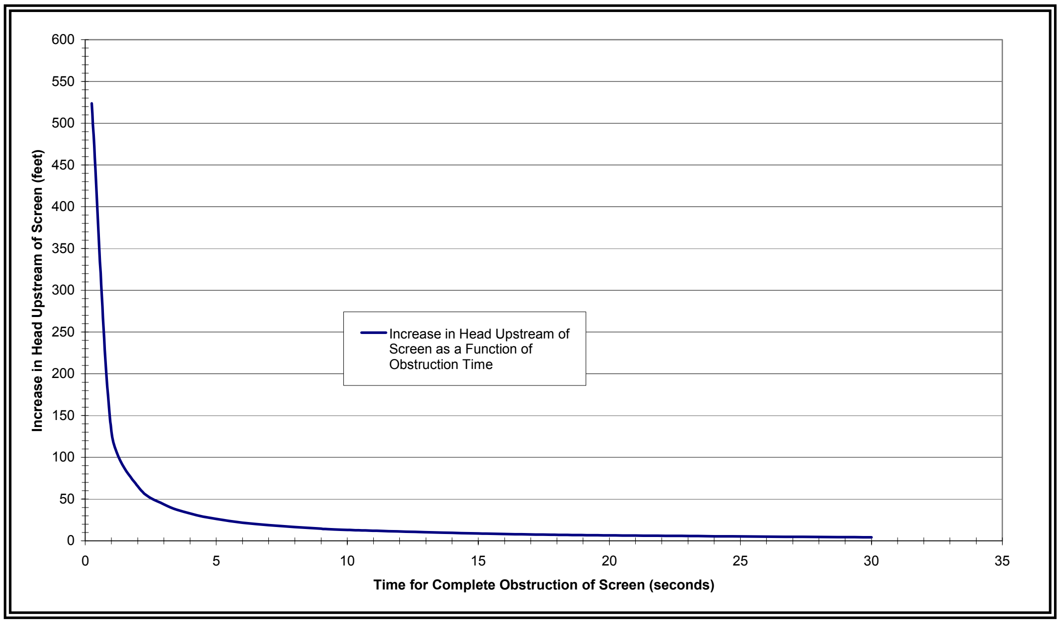


Figure 4. Increase in Head Upstream of Eicher Screen as a Function of Obstruction Time

As part of the design of the original penstock, a similar, although more detailed, transient analysis was conducted that iteratively determined the allowable closure time for the wicket gates at the turbine and the structural capacity of the penstock material. The results of this analysis were not reviewed as part of this analysis; however, the transient hydraulic grade line (HGL) that is included on the record drawings of the penstock (TPU, 1991) was referenced. The elevation of the transient HGL in the vicinity of the proposed Eicher screen is approximately 813 feet. For the current analysis, the assumption was made that whatever the causes of transient conditions in the penstock, the resulting increased pressure will be less than or equal to that associated with the 813 foot HGL indicated on the record drawings. Assuming a full pool elevation of 800 feet in the reservoir, the resulting allowable increase in head upstream of the Eicher screen is approximately 13 feet. Referring to Figure 4 this equates to a minimum allowable obstruction time of approximately 10 seconds.

3.2 Pressure Bypass Pipeline and Multi-Level Discharge System

High-density polyethylene (HDPE) pipe, with a standard dimension ratio (SDR) of 32.5 is proposed for the pressurized bypass pipe, to be constructed from the Eicher screen vault to the multi-level discharge system. This pipe has a nominal outside diameter of 24-inches with a minimum wall thickness of ¾”. The approximate inside diameter of the pipe is therefore 22 ½”. This pipe is pressure rated for 50 psi. HDPE pipe was the only pipe material considered for this application, due to the smooth interior surface that the material provides and due to the stipulations of the design criteria.

The smallest bend radius that SDR32.5 HDPE pipe can be field bent through is 40 times the outside diameter of the pipe, which in this case would be 80 feet. All radii in the pressure pipe alignment that are less than 80 feet will therefore require that mitered pipe segments be welded together to make the bend. In discussions with FNW, Inc (a local HDPE pipe representative), it was stated that the inside weld bead at each mitered section can be removed to provide a smooth interior surface, and that the removal of the bead doesn’t compromise the structural integrity of the pipe. Figure 5 shows conceptual drawings of three typical mitered bends that would be used in the pressure bypass pipe alignment. An alternative that may be considered to minimize the use of mitered bends is to use a higher pressure rated pipe through some of the bends. For instance, SDR21 pipe, which has a wall thickness of 1.14”, can be field bent through radii as small as 28 times the outside diameter, which corresponds to 56 feet. During future design phases of the project, alternatives such as this can be considered so as to minimize the need for mitered bends.

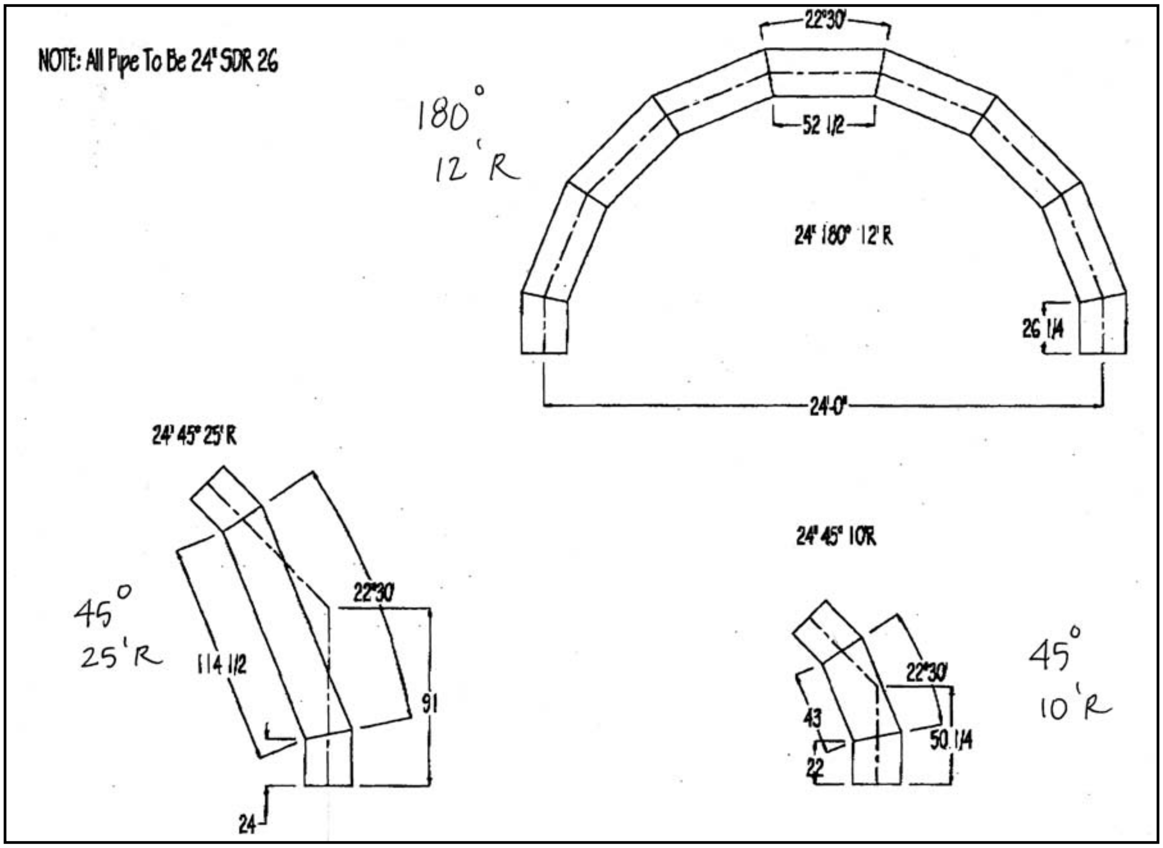


Figure 5. Typical Mitered Bend Configurations for 24-inch HDPE Pipe

The length of the bypass pipe alignment is approximately 500 linear feet. The pressure bypass pipe is proposed to convey the fish bearing bypass flows from the Eicher screen, across the United States Forest Service (USFS) Road 2294 Bridge to the multi-level discharge system. The hydraulic design of pressure bypass system will be such that flow accelerates across the screen face and through the entrance of the pressure bypass pipeline. The range of the average velocity through the bypass pipe will depend on the flow rate, but will remain moderate (7 - 12 fps) and uniform. Smooth walls and moderate velocities will prevent abrasion injury to the fish. The bypass will be designed to prevent debris jams, facilitate operation and maintenance, and to protect fish from injury. The uniform velocity throughout the bypass would also encourage fish to follow, rather than fight, the water particle velocity.

Due to the fact that the hydraulics of the pressure bypass pipeline are integrally related to and dependent on the hydraulics of the multi-level discharge system, the hydraulic analyses of these two features were combined. The portion of the bypass system (including the penstock) that will be flowing under pressure extends from the penstock intake structure to the point where the pressure bypass pipe discharges into the gravity flume. The details of this hydraulic analysis are described in the following section.

The following design criteria are the primary basis for the hydraulic design and analysis of the pressure bypass system:

- All horizontal and vertical bends in the pipe alignment that are less than 80-feet would need to be constructed with compound mitered pipe sections.
- The minimum allowable operating velocity in the bypass system is 7 fps, which corresponds to a minimum allowable operating bypass flow rate of 19 cfs.
- The maximum allowable operating velocity in the bypass system is 12 fps, which corresponds to a maximum operating bypass flow rate of 33 cfs.
- The maximum pool elevation during the operation of the bypass system is 800 feet
- The minimum pool elevation during the operation of the bypass system is 770 feet.
- The average velocity in the pressure bypass pipeline must be equal to or greater than the average velocity in the penstock during bypass operation.

As a result of the above design criteria, a single pressure bypass pipe with a fixed elevation cannot be used for this application. The fixed elevation pipe could be designed to pass the minimum allowable operating flow rate of 19 cfs at the 770-foot minimum pool elevation. However, as the pool elevation rises during the spring refill, the flow rate through the bypass pipe would increase, and would quickly exceed the maximum allowable flow rate of 33 cfs.

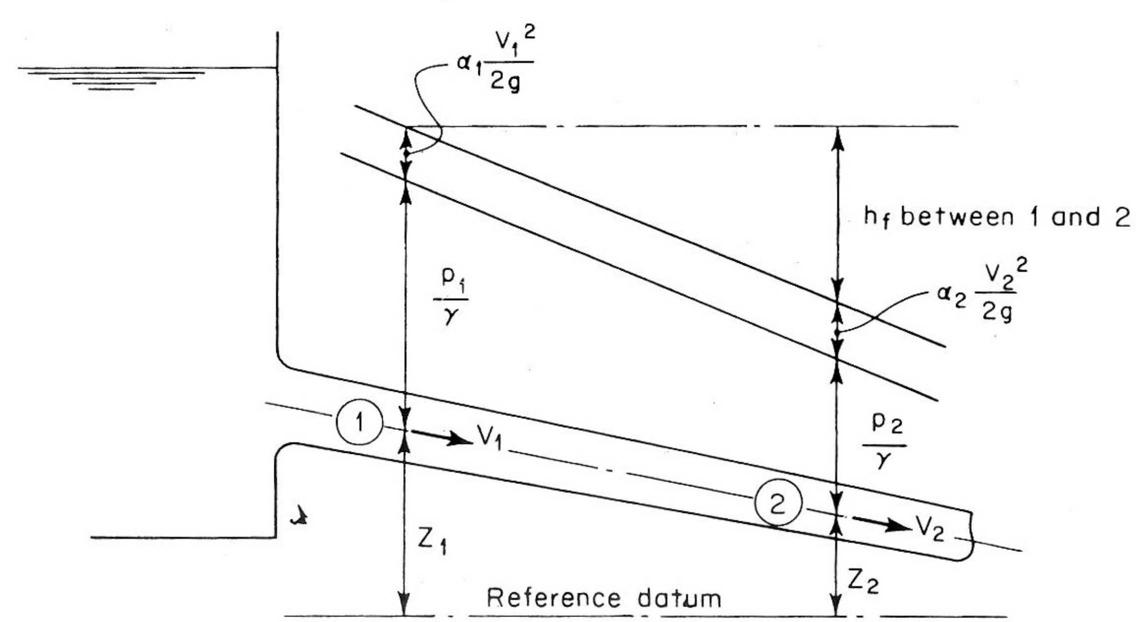
The criteria that the fish bypass facility is operable through a range of reservoir pool elevations and a range of penstock flow rates required the development of a project feature that would allow for this operational flexibility. At the terminus of the pressure bypass pipe, prior to discharge to the gravity flume, a multi-port switch device is proposed. This device is based on similar devices that are used to divert dry bulk granular materials from a single pipe to one of a series of bins or hoppers.

The proposed Wynochee Dam multi-port switch device is comprised of a single, gooseneck shaped pipe segment that can be rotated to one of multiple fixed elevation pressure pipes. Each of these fixed elevation pressure pipes will then outlet to the gravity flume at specific fixed elevations. The elevation of each outlet pipe is set such that it is capable of conveying between 19 cfs and 33 cfs for a specific band width of reservoir elevations. Multiple outlet pipes would therefore ensure that no less than 19 cfs and no more than 33 cfs would be conveyed through the bypass system through the entire 30 foot range of reservoir pool elevations.

3.2.1 Pressure Bypass/Multi Level Outlet Hydraulic Analysis – Background

A one-dimensional, steady state hydraulic analysis was used for the analysis of the pressure pipe/multi-level discharge system. The Bernoulli equation, which is a special form of the law of energy conservation, was used as the basis for the analysis. The Bernoulli equation states that for a constant discharge in a closed conduit, the energy head at any point in the system must be equal to that at any other downstream point plus the intervening hydraulic losses. Figure 6 shows these relationships for a typical closed conduit system.

The purpose of the hydraulic analysis was to determine the number of required outlet pipes, the required outlet elevation of each outlet pipe, and the range of hydrologic operating conditions that each outlet pipe would be functional. The analysis was conducted for the pressure bypass system, extending from the penstock intake structure to the point where the pressure bypass pipes discharge into the gravity flume. The reservoir pool elevation was used as the upstream boundary condition and the outlet pipes were assumed to discharge at atmospheric pressure. A Microsoft Excel spreadsheet was the platform for this analysis.



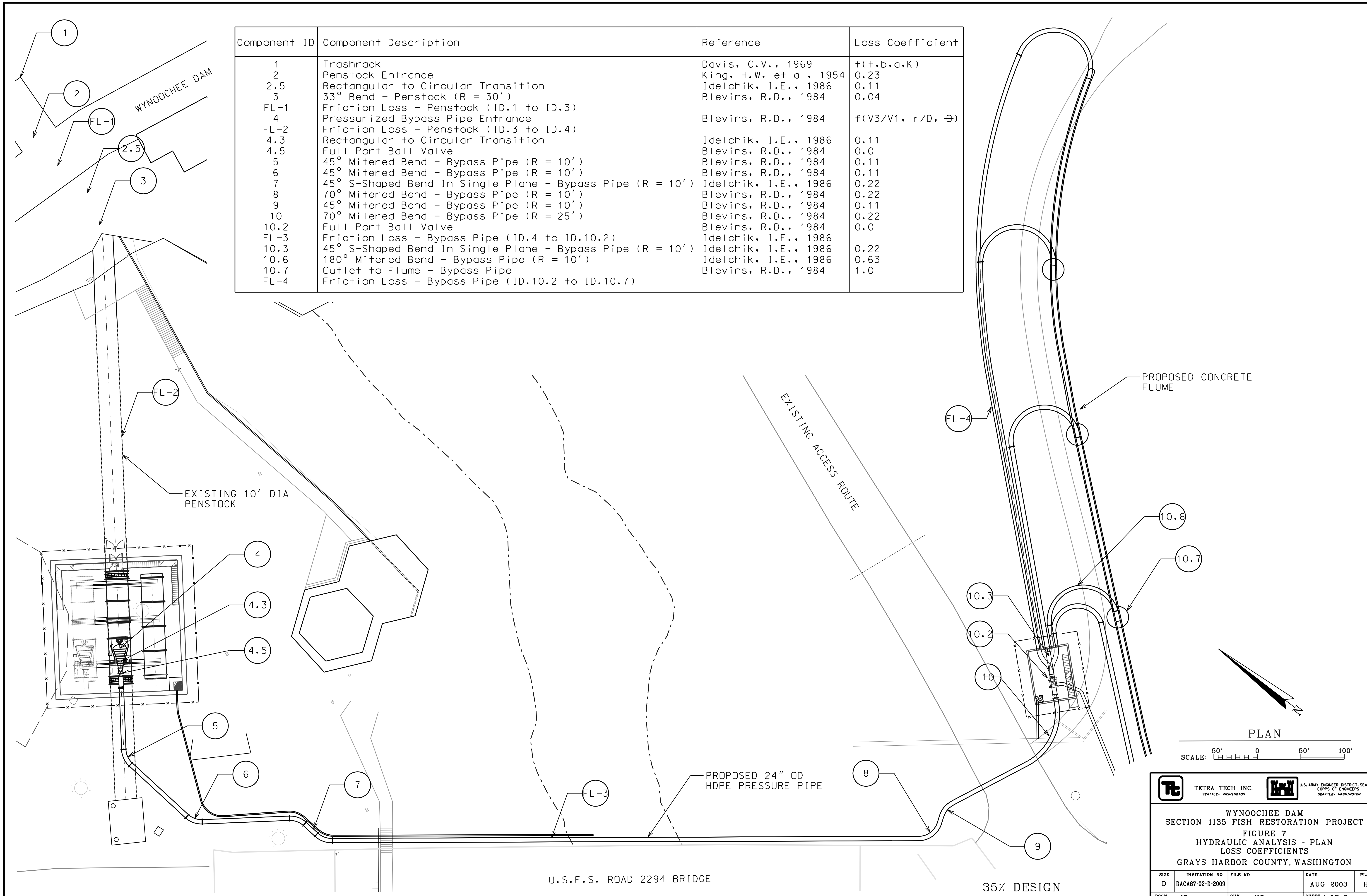
$$\frac{p_1}{\gamma} + Z_1 + \alpha_1 \frac{V_1^2}{2g} = \frac{p_2}{\gamma} + Z_2 + \alpha_2 \frac{V_2^2}{2g} + h_f \text{ (between 1 and 2)}$$

where p = average pressure
Z = distance above reference datum
V = velocity
α = kinetic - energy factor
γ = specific weight

Figure 6. Relationships in the Bernoulli Equation

The spreadsheet model accounted for entrance and exit losses, transitional losses, frictional losses, and minor losses due to bends and fittings. Figures 7 and 8 show the system elements that were accounted for in the hydraulic analysis. The figures include tables that summarize each component in the system, the description of the component, the references that were cited in the determination of the loss coefficients, and the loss coefficients. Figure 9 is an example printout of the Excel spreadsheet used for the analysis.

Component ID	Component Description	Reference	Loss Coefficient
1	Trashrack	Davis, C.V., 1969	f(t,b,a,K)
2	Penstock Entrance	King, H.W. et al, 1954	0.23
2.5	Rectangular to Circular Transition	Idelchik, I.E., 1986	0.11
3	33° Bend - Penstock (R = 30')	Blevins, R.D., 1984	0.04
FL-1	Friction Loss - Penstock (ID.1 to ID.3)		
4	Pressurized Bypass Pipe Entrance	Blevins, R.D., 1984	f(V3/V1, r/D, θ)
FL-2	Friction Loss - Penstock (ID.3 to ID.4)		
4.3	Rectangular to Circular Transition	Idelchik, I.E., 1986	0.11
4.5	Full Port Ball Valve	Blevins, R.D., 1984	0.0
5	45° Mitered Bend - Bypass Pipe (R = 10')	Blevins, R.D., 1984	0.11
6	45° Mitered Bend - Bypass Pipe (R = 10')	Blevins, R.D., 1984	0.11
7	45° S-Shaped Bend In Single Plane - Bypass Pipe (R = 10')	Idelchik, I.E., 1986	0.22
8	70° Mitered Bend - Bypass Pipe (R = 10')	Blevins, R.D., 1984	0.22
9	45° Mitered Bend - Bypass Pipe (R = 10')	Blevins, R.D., 1984	0.11
10	70° Mitered Bend - Bypass Pipe (R = 25')	Blevins, R.D., 1984	0.22
10.2	Full Port Ball Valve	Blevins, R.D., 1984	0.0
FL-3	Friction Loss - Bypass Pipe (ID.4 to ID.10.2)	Idelchik, I.E., 1986	
10.3	45° S-Shaped Bend In Single Plane - Bypass Pipe (R = 10')	Idelchik, I.E., 1986	0.22
10.6	180° Mitered Bend - Bypass Pipe (R = 10')	Idelchik, I.E., 1986	0.63
10.7	Outlet to Flume - Bypass Pipe	Blevins, R.D., 1984	1.0
FL-4	Friction Loss - Bypass Pipe (ID.10.2 to ID.10.7)		



35% DESIGN

TETRA TECH INC. SEATTLE, WASHINGTON

U.S. ARMY ENGINEER DISTRICT, SEATTLE CORPS OF ENGINEERS SEATTLE, WASHINGTON

WYNOOCHEE DAM
SECTION 1135 FISH RESTORATION PROJECT
FIGURE 7
HYDRAULIC ANALYSIS - PLAN
LOSS COEFFICIENTS
GRAYS HARBOR COUNTY, WASHINGTON

SIZE	INVITATION NO.	FILE NO.	DATE:	PLATE
D	DACA67-02-D-2009		AUG 2003	H1
DSGN. JS		CHK. YC	SHEET 1 OF 2	

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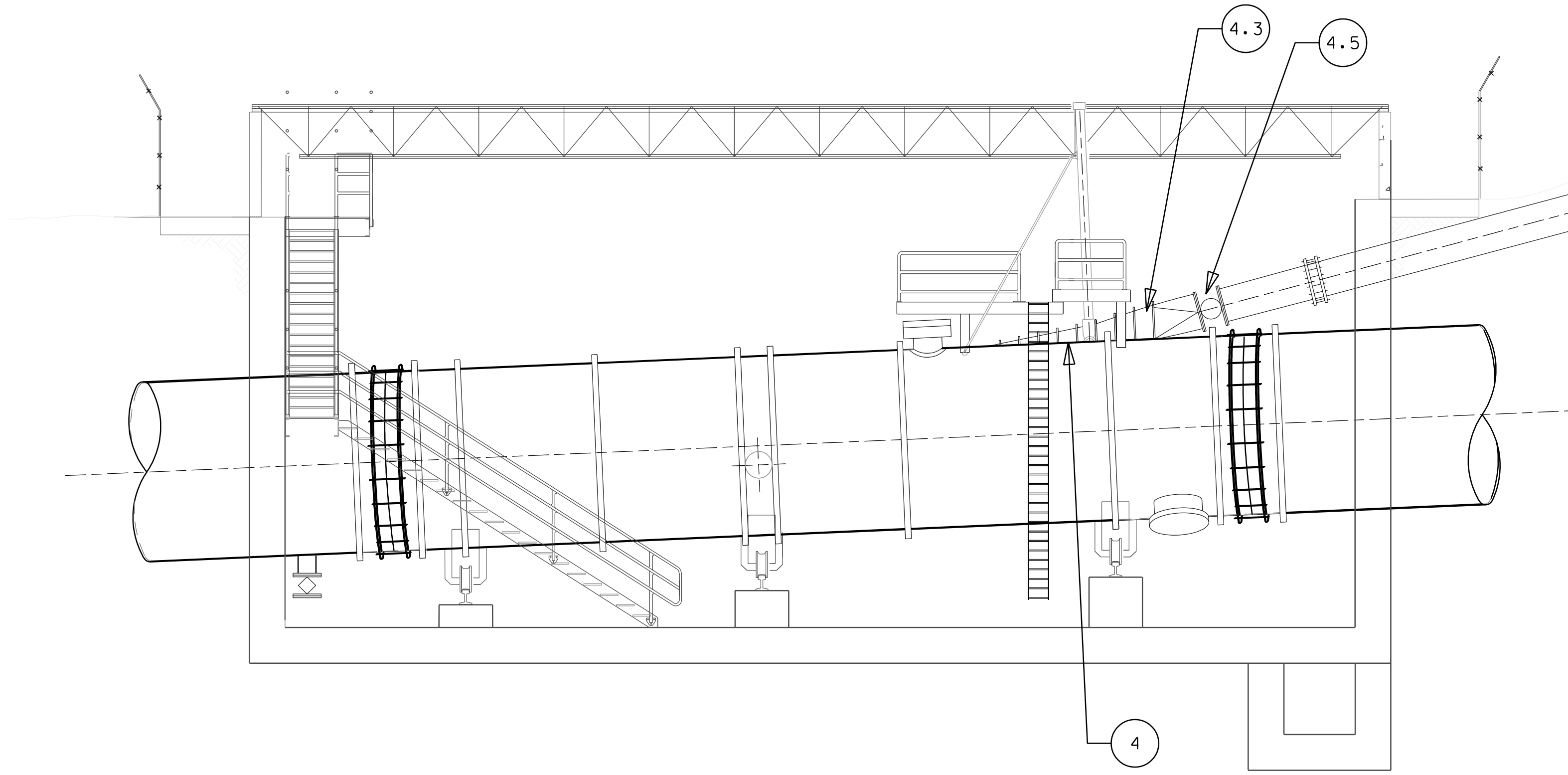
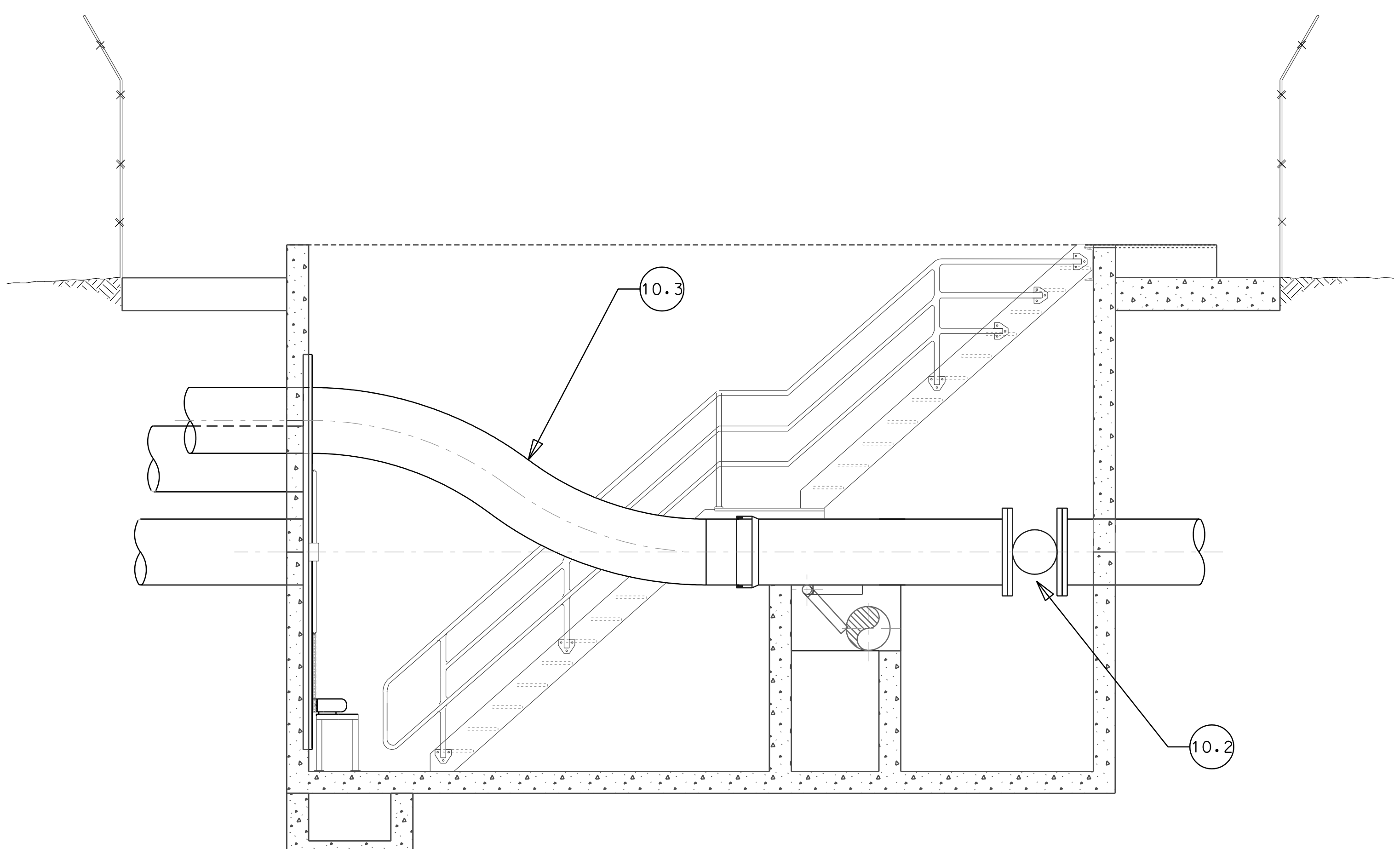


PENSTOCK - SECTION

Component ID	Component Description	Reference	Loss Coefficient
1	Trashrack	Davis, C.V., 1969	f(t,b,a,K)
2	Penstock Entrance	King, H.W, et al, 1954	0.23
2.5	Rectangular to Circular Transition	Idelchik, I.E., 1986	0.11
3	33° Bend - Penstock (R = 30')	Blevins, R.D., 1984	0.04
FL-1	Friction Loss - Penstock (ID.1 to ID.3)		
4	Pressurized Bypass Pipe Entrance	Blevins, R.D., 1984	f(V3/V1, r/D, θ)
FL-2	Friction Loss - Penstock (ID.3 to ID.4)		
4.3	Rectangular to Circular Transition	Idelchik, I.E., 1986	0.11
4.5	Full Port Ball Valve	Blevins, R.D., 1984	0.0
5	45° Mitered Bend - Bypass Pipe (R = 10')	Blevins, R.D., 1984	0.11
6	45° Mitered Bend - Bypass Pipe (R = 10')	Blevins, R.D., 1984	0.11
7	45° S-Shaped Bend In Single Plane - Bypass Pipe (R = 10')	Idelchik, I.E., 1986	0.22
8	70° Mitered Bend - Bypass Pipe (R = 10')	Blevins, R.D., 1984	0.22
9	45° Mitered Bend - Bypass Pipe (R = 10')	Blevins, R.D., 1984	0.11
10	70° Mitered Bend - Bypass Pipe (R = 25')	Blevins, R.D., 1984	0.22
10.2	Full Port Ball Valve	Blevins, R.D., 1984	0.0
FL-3	Friction Loss - Bypass Pipe (ID.4 to ID.10.2)	Idelchik, I.E., 1986	
10.3	45° S-Shaped Bend In Single Plane - Bypass Pipe (R = 10')	Idelchik, I.E., 1986	0.22
10.6	180° Mitered Bend - Bypass Pipe (R = 10')	Idelchik, I.E., 1986	0.63
10.7	Outlet to Flume - Bypass Pipe	Blevins, R.D., 1984	1.0
FL-4	Friction Loss - Bypass Pipe (ID.10.2 to ID.10.7)		



ROTATING SELECTOR SWITCH - SECTION

35% DESIGN

TETRA TECH INC.
SEATTLE, WASHINGTON

U.S. ARMY ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

WYNOOCHEE DAM
SECTION 1135 FISH RESTORATION PROJECT
FIGURE 8
HYDRAULIC ANALYSIS - SECTIONS
LOSS COEFFICIENTS
GRAYS HARBOR COUNTY, WASHINGTON

SIZE	INVITATION NO.	FILE NO.	DATE:	PLATE
D	DACA67-02-D-2009		AUG 2003	H2
DSGN. JS		CHK. YC	SHEET 2 OF 2	

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Figure 9. Pressure Pipe Hydraulic Analysis Spreadsheet Model

These parameters are variables that will be changed by the USER throughout the course of the analysis
These parameters are USER INPUT parameters that do not change.
These parameters are variables that will automatically be changed by the spreadsheet during the analysis

Alternative 1A - Multi Level Discharge Using 45^{0} Gooseneck Shaped Mulit-Port Switch to Control Flows into Flume

INPUT PARAMETERS

Z1	Upstream Head (Reservoir Pool Elev.) - Variable	**800.0**	feet	Assumed
Q1	Flow in Penstock	**700**	cfs	Q1 is controlled by wickett gates and isn't a function of reservoir pool elevation
Q3	Flow in Bypass Pipe	**33.0**	cfs	Flow in bypass is a function of u/s head or head loss up to the bypass
L4	Length of Individual Multi-Level Discharge Pipe (Variable)	**325**	feet	Length of HDPE Bypass From Centerline of Existing Access Road to the end of specific multi-level outlet pipe (ID.10.7). The length of this pipe segment depends on the outlet elevation, and be iteratively determined (see chart to right for outlet elev vs. length of multi-level pipe)
D1	Diameter of Penstock	**10**	feet	Diameter of Existing Penstock
D2	Outside Diameter of HDPE Bypass Pipe	**24**	inches	Diameter of Proposed HDPE Bypass Pipeline
D2	Inside Diameter of HDPE Bypass Pipe	**22.5**	inches	Diameter of Proposed HDPE Bypass Pipeline
D2	Inside Diameter of HDPE Bypass Pipe	**1.875**	feet	Diameter of Proposed HDPE Bypass Pipeline
L1	Length of Penstock (intake to bend no.1)	**50**	feet	Length of Penstock from U/S Face of Dam (ID.1) to Centerline of Bend No.1 (ID.3)
L2	Length of Penstock (Bend No. 1 to Bypass Entrance)	**220**	feet	Length of Penstock from Centerline of Bend No. 1 (ID.3) to Bypass Entrance (ID.4)
L3	Length of HDPE (Entrance to Full Port Ball Valve)	**485**	feet	Length of HDPE Bypass From Entrance (ID.4) to Centerline of Existing Access Road
V1	Average Velocity in Penstock	**8.91**	fps	V1=Q_penstock / Area_penstock; assumed constant
V3	Average Velocity in HDPE Pipe	**11.96**	fps	V3=Q_pipe / Area_pipe; assumed constant (V3 must be >= to V1)
V3/V1	Ratio of Bypass Velocity to Penstock Velocity (V3/V1)	**1.34**	--	Ratio of Average Velocity in Bypass to Average Velocity in Penstock (Used for Computing Losses Due to Dividing Pipe Flow)

NOTE: Bend losses DO NOT include the friction losses associated with the upstream and downstream tangent pipe sections. The friction losses for these segments are accounted for in the separate friction loss computation

ID	Component Description	Loss Coefficient (K or f)	Head Loss (ft)	Invert* (ft)	Total Energy Grade Line Elev (ft)	Hydraulic Grade Line (ft)		Notes
Penstock System Losses								
1	Trashrack	0.15	0.19		800.00			(Davis, Calvin. 1969. Page 24-14)
2	Penstock Entrance	0.23	0.28	730.57				Slightly Rounded Entrance within Wall. (King, Horace. 1954. Page 6-51)
2.5	Transition from Rectangular to Circular Cross Section	0.11	0.14					Rectangular to Circular Transition (Idelchik, I.E. 1986. Pgs. 187-258)
F-L1	Friction loss from ID.1 to ID.3	0.0155	0.10					Using Darcy-Weisbach Equation
3	33° Bend (R=5D) in Penstock	0.04	0.05					Existing Bend in Penstock. (Blevins, Robert D. 1984. Page 56)
F-L2	Friction loss from ID.3 to ID.4	0.0155	0.42	735.00	798.83	797.60		Using Darcy-Weisbach Equation
Bypass Pipe System Losses								
4	Entrance to Bypass Pipe (Dividing Flow)	0.60	0.74	745.00	798.83	796.61		Loss Coefficient Based on Polynomial Eq'n in "Divided Pipe Flow" Worksheet
4.3	Transition from Rectangle to Circular Cross Section	0.11	0.24					Rectangular to Circular Transition (Idelchik, I.E. 1986. Pgs. 187-258)
4.5	Full Port Ball Valve	0.00	0.00					Resistance Through Fully Open Valve Assumed (Blevins, Robert D. 1984. Pg. 88)
5	45° Mitered Bend (R=5D)	0.11	0.24					Compound Mitered Bend. (Blevins, Robert D. 1984. Page 60)
6	45° Mitered Bend (R=5D)	0.11	0.24					Compound Mitered Bend. (Blevins, Robert D. 1984. Page 60)
7	S Shaped Bend (Gooseneck w/two 45° Mitered Bends)	0.22	0.49					S Shaped Bend - Gooseneck w/two 45O Mitered Bends (Idelchik, I.E. 1986. Page 310)
8	70° Mitered Bend (R=5D ft)	0.22	0.49					Compound Mitered Bend. (Blevins, Robert D. 1984. Page 60)
9	45° Mitered Bend (R=5D)	0.11	0.24					Compound Mitered Bend. (Blevins, Robert D. 1984. Page 60)
10	70° Mitered Bend (R=12.5D ft)	0.22	0.49					Compound Mitered Bend. (Blevins, Robert D. 1984. Page 60)
F-L3	Friction loss from ID.4 to ID.10.2	0.0114	6.55					Using Darcy-Weisbach Equation
Multi-Level Distribution System Losses (Alternative 1A)								
10.2	Full Port Ball Valve	0.00	0.00		789.10	786.88		Resistance Through Fully Open Valve Assumed (Blevins, Robert D. 1984. Pg. 88)
10.3	S Shaped Bend (Gooseneck w/two 45° Mitered Bends)	0.22	0.49					S Shaped Bend - Gooseneck w/two 45O Mitered Bends (Idelchik, I.E. 1986. Page 310)
10.6	180° Mitered Bend (R=5D)	0.63	1.40					Use Loss Coefficient for Smooth 180 Degree Bend. (Idelchik, I.E. 1986. Pg. 291)
10.7	Exit Loss From Pressure Pipe to Open Channel	1.00	2.22					Exit Loss
F-L4	Friction loss from ID.10.2 to ID.10.7	0.0114	4.39	777.38	780.60	778.38		Using Darcy-Weisbach Equation
	total losses (friction and minor losses) =		**19.40**					
			D/S EGL Elev =		**780.60**			Downstream Total Energy Grade Line
	Computed Invert Elevation of Outlet Pipe			**777.4**				Invert Elevation = (Reservoir Elev) - (total head losses) - (velocity head) - (one-half pipe diameter)
	Input Computed Invert Elevation			777.4		0.02	**800.0**	**Lower Reservoir Elevation Limit for a Given Outlet Pipe (Input to D5)**

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At the intake structure, the analysis assumed 100 percent of the incoming flows would enter via the penstock entrance and that the temporary high level opening would be closed, as per the original recommended alternative for the intake structure. During the development of the 35% design, the intake structure recommended alternative was changed to include the necessary modifications required to make the high level opening a permanent feature (refer to Section 2.1 of the main body of the report). However, due to the fact that this modification has not yet been reviewed by the Wynoochee Dam Technical Committee, the hydraulic analysis was not changed to include the twin flow paths that would result from making the high level opening permanent. Specific decisions as to the optimal allocation of the flow through the two openings for the safe passage of juveniles, keeping in mind the biological and hydraulic design criteria, have not yet been made.

Friction losses were calculated using the Darcy-Weisbach equation. A value of 1.41×10^{-6} ft^2/s was assumed for the kinematic viscosity of water (assuming a water temperature of 50^O Fahrenheit). The specific roughness of the 10-foot diameter penstock was assumed to be 0.04 inches (0.0033 feet), which is representative for welded steel pipe with general rust and deposits (Blevins, R.D., 1984). The specific roughness of the 22.5-inch inside diameter HDPE bypass pipe was assumed to be 0.000005 feet, which is representative of smooth PVC pipe. Relative roughness is a dimensionless parameter that is a ratio of the specific roughness to the inside pipe diameter, and was computed to be 0.00033 and 0.0000027 for the penstock and the bypass pipe, respectively. The friction factor for each pipe material was then obtained from the Moody chart and was computed as 0.0155 and 0.0114 for the penstock and the bypass pipe, respectively.

For the most part, loss coefficients for each component were selected from previously published charts, graphs, or were determined through the use of simple equations (Blevins, 1984 and Idelchick, 1986). However, the computation of head loss through two of the system components relied on somewhat more involved equations. The head losses through the trashrack at the entrance to the intake structure were computed with the following equation, which was taken from Davis (1969):

$$h_r = K \times \left(\frac{t}{b}\right)^{4/3} \times \left(\frac{V_o^2}{2g}\right) \times \sin\alpha \qquad \text{(Equation 5)}$$

where,

h_r = head loss (feet)

t = thickness of bars (0.5 inches)

b = clear spacing between bars (4 inches)

V_o = velocity of approach (fps)

g = acceleration due to gravity (32.2 ft^2/s)

α = angle of bar inclination to horizontal (90 degrees)

The head losses associated with the flow divergence at the entrance to the bypass pipe were computed using equations presented in Blevins (1984). Losses associated with dividing pipe flow are a function of junction geometry, surface roughness, ratio of incoming to outgoing velocities, and Reynolds number.

The vast majority of physical model tests on dividing pipe flow have been carried out on smooth circular pipes at Reynolds numbers in excess of $1x10^4$ (Blevins, 1984), and the equations have therefore been developed based on these conditions. In the case of the Wynoochee bypass system, the Reynolds numbers are certainly in excess of 10^4, and the pipes are smooth circular pipes. The bypass pipe however is proposed to branch off of the penstock with a rectangular cross section. According to Blevins (1984), the effect of noncircular cross sections on losses in dividing pipe flow is not known in detail, however, it is reasonable to assume that hydraulic diameter or equivalent diameter could be used in place of pipe diameter for instances of noncircular cross section. For the hydraulic analysis, it was assumed that the noncircular branching pipe would be sized with a hydraulic diameter that is equivalent to that of the circular bypass pipe.

Secondly, the equations presented in Blevins (1984) were taken from physical model tests on junctions composed of equal pipe area, where the incoming and outgoing pipes were all of equal area. However, Blevins (1984) references the conclusions of Williamson, J.V and T.J. Rhone ("Dividing Flow in Branches and Wyes", ASCE, 1973) which state that in simple dividing flow scenarios, such as lateral dividing branches, total pressure losses are nearly independent of the area of the branching pipe as long as (a) the total loss coefficient is expressed as a function of the ratio of the branch flow velocity (V_3) to the flow velocity in the main pipe (V_1), and (b) the branch flow area is less than the main pipe area.

Therefore, the empirical equation presented in Blevins (1984) for computing pressure loss in dividing pipe flow was used to compute head loss due to the flow split at the bypass pipe. The friction loss components of the original equation were eliminated and the original equation, which was written in terms of pressure loss, was rewritten in terms of head loss. The simplified equation is expressed below:

$$\Delta h = K_{13}\left(\frac{V_1^2}{2g}\right) \quad \text{(Equation 6)}$$

where,

Δh = head loss (feet)

K_{13} = dimensionless loss coefficient

V_1 = cross section averaged flow velocity in main pipe (fps)

g = acceleration due to gravity (32.2 ft^2/s)

The value of the dimensionless loss coefficient, K_{13}, is a function of the velocity ratio (V_3/V_1), the branch angle, and the ratio of the radius of rounding to the pipe diameter (r/D). Although the branch angle of the bypass pipe is currently designed at approximately a 15-degree angle, due to limited available test data, the branch angle was conservatively assumed to be 45 degrees for the hydraulic analysis. Therefore, the computed head losses due to the dividing flow are conservatively high. Using published values of K_{13} from Blevins (1984), the value of K_{13} is expressed as a third order polynomial equation as shown in Figure 10. A value of r/D of 0.1 was assumed.

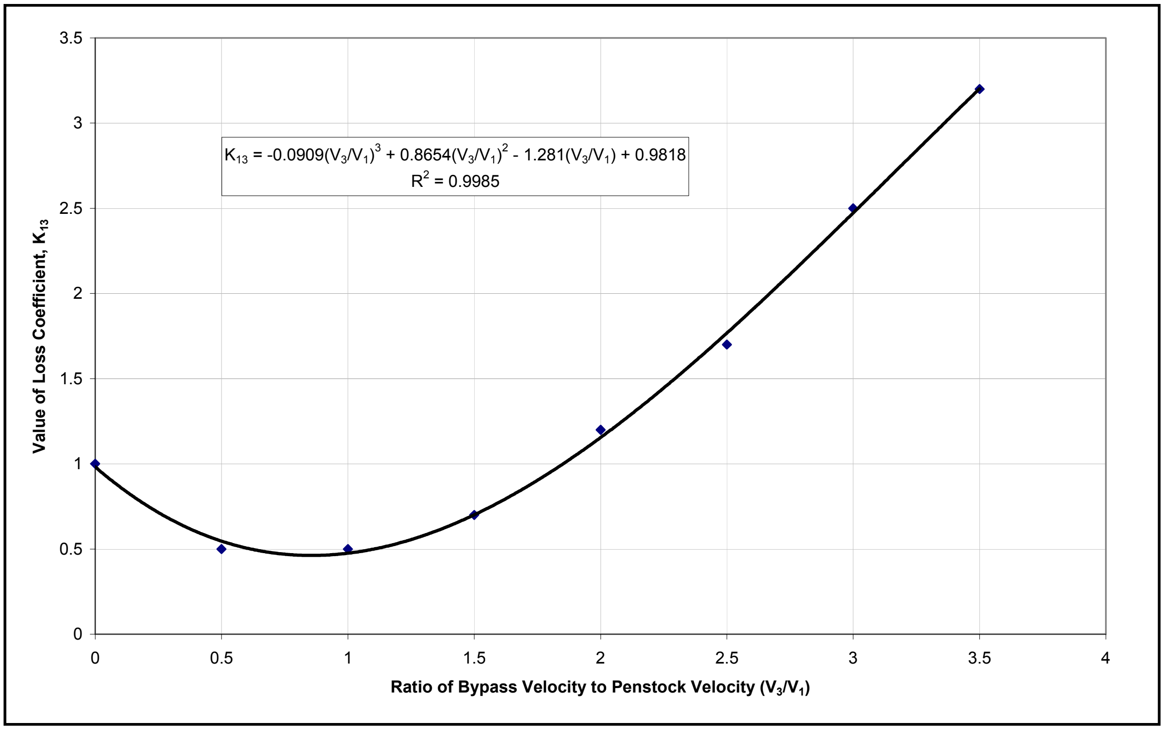

Figure 10. Loss Coefficient (K_{13}) for Divided Pipe Flow

3.2.2 Hydraulic Analysis

One of the critical biological design criteria was the range of velocities that are allowed through the pressure bypass pipe during the fish migration window. The criterion states that the bypass pipe will have average velocities within the range of 7 fps to 12 fps. Given that the inside diameter of the pressure pipe is 22.5-inches, these velocities correspond with a flow rate range of 19 cfs to 33 cfs. Another of the critical biological design criteria was that the magnitude of average velocity in the HDPE bypass should be equal to or greater than that in the penstock. This criterion was necessary so as to assure that fish do not resist entering the bypass system, and to minimize injury to fish through the opening.

The above two biological design criteria are interrelated and dictate the required number of fixed elevation outlet pipes. The number of required fixed elevation outlet pipes is a function of the maximum anticipated penstock flow rate during the fish passage window. For example if the maximum penstock flow rate was expected to be 550 cfs ($V_{penstock}$ = 7 fps), then each of the fixed elevation outlet pipes would be capable of operating through the entire range of allowable bypass flow rates, and a fewer number of outlet pipes would be required. However, if the maximum penstock flow rate was expected to be 800 cfs ($V_{penstock}$ = 10.2 fps), then each of the fixed elevation outlet pipes would only be capable of operating between 28 cfs (V_{bypass} = 10.2 fps) and 33 cfs (V_{bypass} = 12 fps), and more outlet pipes would be required.

Therefore, the first step was to determine the number of fixed elevation outlet pipes for specific maximum allowable penstock flow rates. The following criteria were used in the determination of the number of required outlet pipes, and Table 3 summarizes the results.

- The invert elevation of the highest elevation outlet pipe was determined using a maximum reservoir pool elevation of 800 feet and a bypass discharge of 33 cfs.
- The minimum allowable flow rate in each outlet pipe was based on a minimum allowable velocity equal to the velocity in the penstock.
- A one-foot overlap was assumed in the range of reservoir levels that adjacent outlet pipes would operate within.
- The minimum reservoir pool elevation during operation of the bypass system is 770 feet.

Table 3. Required Number of Fixed Elevation Outlet Pipes for Various Maximum Penstock Flow Rates

Maximum Penstock Flow Rate (cfs)	Penstock Velocity (fps)	Allowable Range of Velocities in Bypass Pipe (fps)		Allowable Range of Flows in Bypass Pipe (cfs)		Required Number of Fixed Elevation Outlet Pipes
600	7.6	7.6	12.0	21.1	33.0	3
650	8.3	8.3	12.0	22.9	33.0	4
700	8.9	8.9	12.0	24.6	33.0	5
750	9.6	9.6	12.0	26.4	33.0	6
800	10.2	10.2	12.0	28.1	33.0	8

As shown in the above table, as the assumed maximum operating flow rate through the penstock is increased, the range of flows that the bypass pipe is allowed to operate within (given the constraints of the two aforementioned biological design criteria) decreases, thus requiring more fixed elevation outlet pipes. Based on previous analyses conducted by others (Harza, 1997), and discussions with the client (USACE) and the local sponsor (TPU), it was decided that five fixed elevation outlets was the preferred number of outlets for the project. With the five-outlet configuration, the optimum maximum allowable flow rate through the penstock during the fish window will therefore be 700 cfs.

The decision to use 700 cfs as the optimum maximum flow rate has sound basis from an operational perspective as well. Test results from the Eicher screen installation at the Elwha facility in 1990 found that little or no fish injury was observed during tests conducted at penstock velocities of 4 to 6 fps. Slightly more injury occurred at higher velocities, but even at the highest velocity condition tested (7.8 fps), only 3.6 percent of the test fish had over 16% scale loss on either side (Winchell, et al, 1991). Based on these test results, it seems likely that the maximum allowable flow rate through the Wynoochee Dam penstock may be in the range of 600 to 650 cfs. However, configuring the multi-outlet system to operate with an optimum maximum flow rate of 700 cfs will provide TPU greater operational flexibility in the event that post-bypass monitoring of the juvenile fish shows that scale loss is not significant at velocities greater than 7.8 fps.

Graphical illustration of the operating curves for the five outlet pipes are shown in Figure 11, and a tabular presentation of the rating curves are presented in Table 4. The upper and lower allowable bypass flow rates, based on a maximum penstock flow rate of 700 cfs, are shown in Figure 11 and are indicated in bold in Table 4. These upper and lower bounds are based on the previously described biological design criteria. For illustrative purposes, the operating curves were extended beyond the upper and lower bypass flow rate limits.

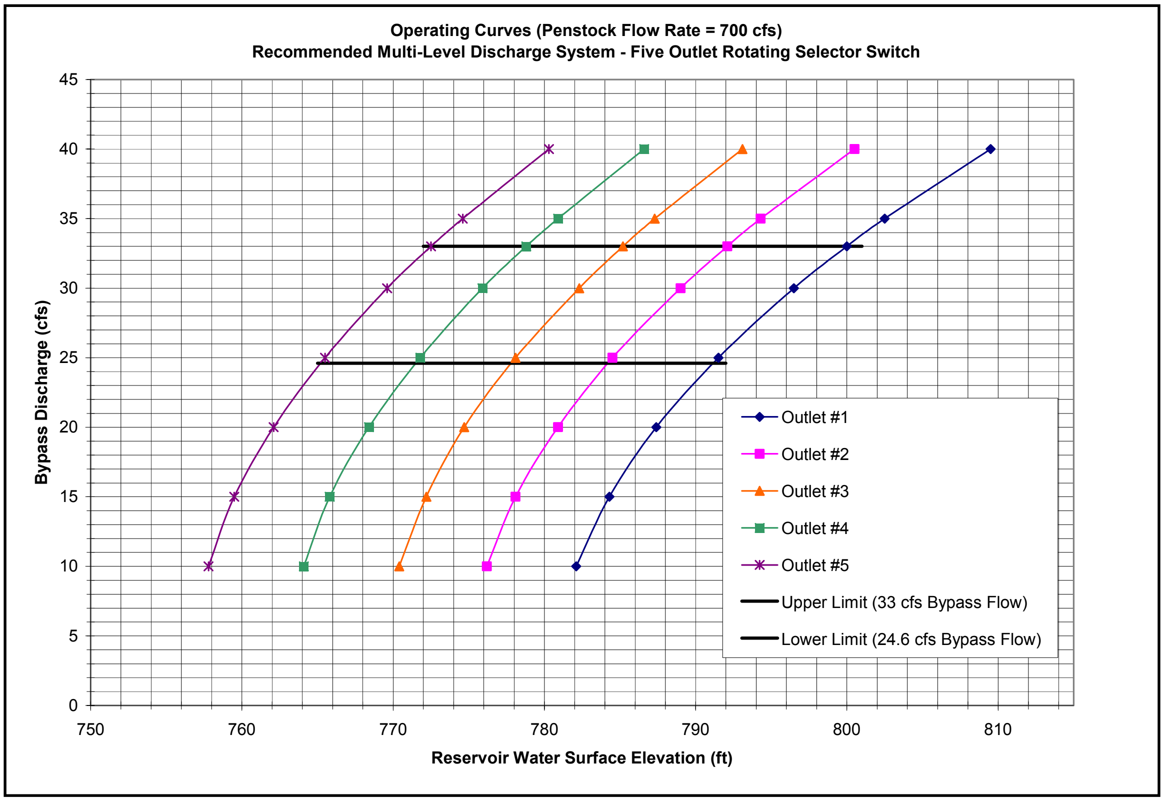

Figure 11. Operational Curves for the Five-Outlet Pipe Configuration with a 700 cfs Penstock Flow Rate.

As seen in column 10 of Table 4, during the operation of the bypass system, with a 700 cfs penstock flow rate, the ratio of the average bypass velocity to the average penstock velocity ranges between 1.34 and 1.02. Head losses through the bypass opening range from 0.59 to 0.74 feet. Both of these results are due to the fact that the bypass system is operating within the constraints of the biological and hydraulic criteria, specifically Criterion #5.

Table 4. Operational Curve Coordinates for the Five Outlet Pipe Configuration with a Penstock Flow Rate of 700 cfs.

Operating Curve Coordinates for Recommended Outlet Configuration
Operating Penstock Flow Rate of: 700 cfs

Reservoir Water Surface Elevation (feet)					Bypass	Bypass	Penstock	Penstock	Velocity Ratio	Pressure Bypass	Pressure Bypass
Outlet #1	Outlet #2	Outlet #3	Outlet #4	Outlet #5	Discharge	Velocity	Discharge	Velocity	Bypass/Penstock	Ent. Loss Coefficient	Entrance Headloss
809.5	800.5	793.1	786.6	780.3	40	14.49	700	8.92	1.63	0.80	0.98
802.5	794.3	787.3	780.9	774.6	35	12.68	700	8.92	1.42	0.65	0.80
800.0	**792.1**	**785.2**	**778.8**	**772.5**	**33**	**11.96**	**700**	**8.92**	**1.34**	**0.60**	0.74
796.5	789.0	782.3	775.9	769.6	30	10.87	700	8.92	1.22	0.54	0.67
791.5	**784.5**	**778.1**	**771.8**	**765.5**	**25**	**9.06**	**700**	**8.92**	**1.02**	**0.48**	0.59
787.4	780.9	774.7	768.4	762.1	20	7.25	700	8.92	0.81	0.46	0.57
784.3	778.1	772.2	765.8	759.5	15	5.44	700	8.92	0.61	0.50	0.62
782.1	776.2	770.4	764.1	757.8	10	3.62	700	8.92	0.41	0.60	0.74

TPU has the capability to control the flows through the penstock during the fish passage window, by allowing excess flows to pass through the lower outlets of the dam, thereby bypassing the penstock. Therefore, TPU has the flexibility to limit the flow through the penstock during the fish migration window to a predetermined maximum specified flow rate. However during the operation of the bypass system, most of the time, the releases through the dam will be significantly less than 700 cfs, and may frequently be reduced to the 210 cfs minimum flow. Additionally, post bypass monitoring of the juvenile fish will determine the optimal maximum allowable penstock flow rate that will ensure safe passage of fish along the screen face and into the bypass system.

The operating curves shown in Figure 11 reference the reservoir pool elevation on the independent axis, and therefore, the curves theoretically cannot be used for penstock flow rates other than 700 cfs. However, due to the fact that the computed head losses in the penstock, between the trashrack and the bypass pipe entrance, are relatively low and do not vary significantly with penstock flow rate (0.11 feet for Q = 210 cfs versus 1.18 feet for Q=700 cfs), the operating curves shown in Figure 11 can be approximately used for penstock flow rates less than 700 cfs. In actuality, separate operating curves should be developed for the different penstock flow rates, or the curves should be developed using the energy grade line at the Eicher screen as the independent axis. At this level of analysis, it was felt that using the reservoir pool elevation as the independent axis was sufficient.

The effect of operating the bypass system during penstock flow rates less than 700 cfs would simply shift the lower limit of the bypass flow downward from the 24.6 cfs shown in Figure 11. Each fixed elevation outlet pipe would therefore operate through a wider range of flow rates. For example, Table 5 presents the operating curve coordinates for the minimum operating penstock flow rate of 210 cfs. The operating range for each outlet pipe is maximized during this penstock flow condition, because the outlet pipes are allowed to convey flow rates as low as 19.3 cfs, which corresponds with the minimum allowable bypass velocity of 7 fps. One of the possibly negative side effects of operating the bypass system during penstock flows lower than 700 cfs is seen in the columns on the far right of this table. Due to the low penstock velocity, the bypass to penstock velocity ratio is consistently higher than 2.4 (at Q_{bypass} = 20 cfs), and attains a high value of 4.08 (at Q_{bypass} = 33 cfs). Exposing juvenile fish to this high rate of acceleration may be a concern for fisheries agencies. If this is the case, then the allowable upper limit of the flow rate in the bypass pipe may need to be reduced during lower penstock flow rates.

Table 5. Operational Curve Coordinates for the Five Outlet Pipe Configuration with a Penstock Flow Rate of 210 cfs.

Operating Curve Coordinates for Recommended Outlet Configuration
Operating Penstock Flow Rate of: 210 cfs

Reservoir Water Surface Elevation (feet)					Bypass	Bypass	Penstock	Penstock	Velocity Ratio	Pressure Bypass	Pressure Bypass
Pipe #1	Pipe #2	Pipe #3	Pipe #4	Pipe #5	Discharge	Velocity	Discharge	Velocity	Bypass/Penstock	Ent. Loss Coefficient	Entrance Headloss
808.1	799.1	791.8	785.3	779.0	40	14.49	210	2.68	5.42	4.99	0.55
801.3	793.1	786.1	779.6	773.3	35	12.68	210	2.68	4.74	4.67	0.52
798.8	**790.8**	**784.0**	**777.6**	**771.3**	**33**	**11.96**	**210**	**2.68**	**4.47**	**4.43**	0.49
795.3	787.7	781.1	774.7	768.4	30	10.87	210	2.68	4.06	3.97	0.44
790.2	783.2	776.8	770.5	764.2	25	9.06	210	2.68	3.39	3.04	0.34
786.0	**779.5**	**773.4**	**767.0**	**760.7**	**20**	**7.25**	**210**	**2.68**	**2.71**	**2.06**	0.23
782.7	776.6	770.6	764.3	758.0	15	5.44	210	2.68	2.03	1.19	0.13
780.4	774.5	768.7	762.4	756.1	10	3.62	210	2.68	1.35	0.61	0.07

3.2.3 Surge Flows into Bypass

During the backflushing cycle of the Eicher screen, or in the event of a fairly rapid partial obstruction of the screen that occurs faster than the backflushing cycle can accommodate, a temporary positive pressure rise will result upstream of the screen face. Assuming that the closure valve at the entrance to the bypass pipe remains open, this temporary increase in the pressure will result in a temporary increase in the flow rate, or surge flow, through the pressure bypass pipe.

The same spreadsheet model that was used to analyze the pressure bypass pipe and the multi-level discharge system was used to determine the maximum surge flow that can be expected in the system. The Eicher screen transient analysis, described earlier in this appendix, referenced the design transient hydraulic grade line (HGL) from the Wynoochee Dam Hydroelectric Project record drawings (TPU, 1991). Sheet WA301 of the record drawings showed a maximum transient HGL of 813 feet (NGVD29) at the point in the penstock where the proposed bypass pipe originates. Inputting this value into the hydraulic analysis spreadsheet, and assuming that the lowest outlet pipe would be in operation at the time, a surge flow of approximately 60 cfs was computed.

The hydraulic effects of the 60 cfs surge flow passing through the pressure bypass pipe system was not considered, however, the surge flow was used as a design flow rate in the open channel analysis, which is described in the next section of this appendix. The 60 cfs surge flow was assumed as the maximum expected flow through the open channel system and was used to determine whether the open channel system would overtop.

3.3 Gravity Flume

An open channel gravity flume is proposed for conveyance of bypass flows from upstream of USFS Road 2294 road to the hydroelectric project substation. Figure 12 shows a typical cross section of the flume. The cross-section of the flume consists of a semi-circular invert with a 6-inch radius, approximately 3V:1H side slopes extending vertically to approximately 2 feet above the invert, and vertical walls extending another 1 foot, thereby resulting in a cross section with 3 feet of total cross-sectional depth. The flume will be constructed of precast concrete sections and will be lined with a synthetic liner to provide for a smooth surface.

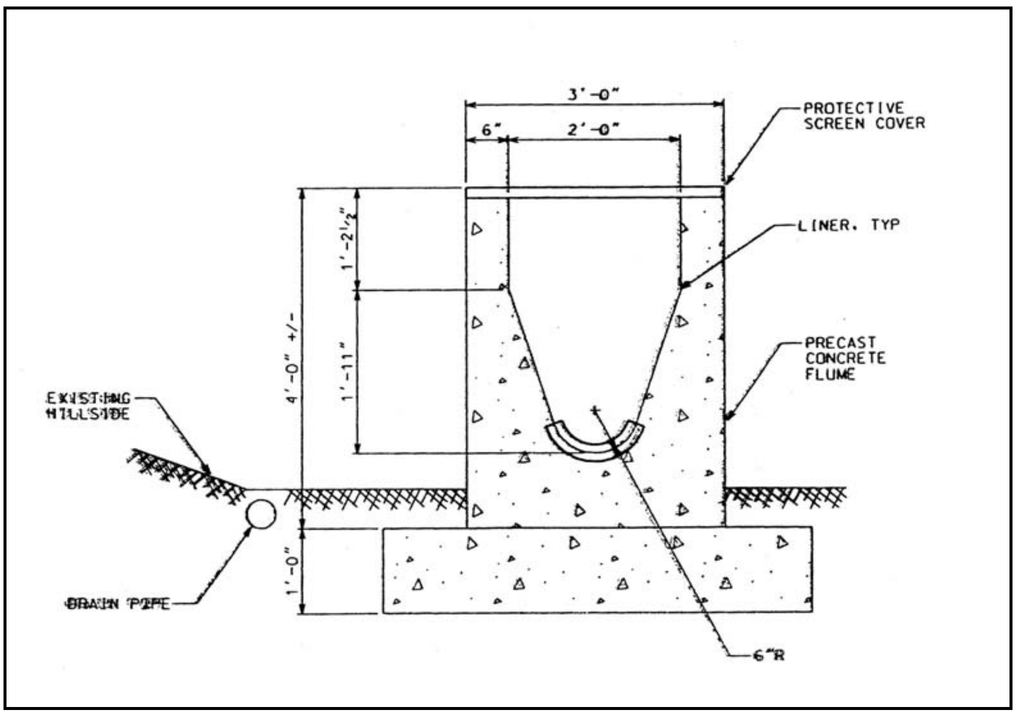

Figure 12. Typical Open Channel Gravity Flume Cross Section

A majority of the flume alignment will follow along the east side of the existing substation access road, and will descend from a high point of 776 feet (NGVD29) to a outlet elevation of 672 feet (NGVD29). The length of the flume alignment between these two points is approximately 1,500 linear feet, thereby resulting in an average gradient of 6.9%. The actual gradient of the flume ranges between 3.7% and 14.2%.

For nearly half of the flume alignment, the invert elevation of the flume will be set at approximately existing grade, and therefore, the gradient of the flume will correspond with the gradient along the substation access road. There are two locations along the alignment where the flume invert will not follow existing grade. The upstream 500 linear feet of the alignment will be constructed below grade so as to accommodate the outlet elevations of the five pressurized bypass pipelines and to make the below grade crossing of USFS Road 2294. Secondly, approximately 300 feet of the alignment near the downstream end will be constructed above grade on elevated foundations. The above grade flume alignment is partly due to the need to maintain supercritical flow where the topography flattens out at the base of the substation access road.

3.3.1 Hydraulic Analysis

As per the hydraulic/biologic design criteria, a supercritical flow regime is to be maintained throughout the open channel alignment. The minimum required depth of flow for the low flow condition is 9-inches, and the maximum allowable velocity is 35 feet per second. A numerical hydraulic model of the 1,500 foot flume alignment was used to determine specific hydraulic parameters along the length of the flume. The open channel hydraulic analysis assumed a steady state, gradually varied water surface profile and analyzed three flow rates: the design low flow rate (19 cfs), the design high flow rate (33 cfs), and the design surge flow rate (60 cfs).

The hydraulic analysis of the gravity flume included the following steps:

1. Determination of the steady state gradually varied water surface profile for a range of possible flow rates

2. Analysis and quantification of superelevated conditions at the horizontal bends
3. Determination of the likelihood for the formation of an unstable pulsating flow regime known as slug flow or roll waves
4. Computation of the required freeboard and comparison of the required freeboard to the provided freeboard. Freeboard calculations included the effects of superelevation and standing waves.

Version 3.0 of the U.S. Army Corps of Engineers HEC-RAS computer program (USACE, 2001) was used to analyze the open channel hydraulics of the gravity flume. The HEC-RAS program is a one-dimensional analytical tool that has the capability of calculating water surface profiles for both gradually varied steady and unsteady flow. The hydraulics of the proposed Wynoochee Dam gravity flume was analyzed assuming gradually varied steady flow conditions. Three steady condition flow rates were included in the analysis:

- Design Low Flow – This represents the minimum design flow rate that can be expected through the bypass system. This is the flow rate associated with the minimum allowable velocity in the pressure bypass pipeline (7 feet per second) and is quantified as 19 cfs.
- Design High Flow – This represents the maximum design flow rate that can be expected through the bypass system. This is the flow rate associated with the maximum allowable velocity in the pressure bypass pipeline (12 feet per second) and is quantified as 33 cfs.
- Surge Flow – This represents the flow rate that would be generated through the bypass system during transient hydraulic conditions in the penstock associated with the sudden obstruction of the Eicher Screen or the sudden closure of the gates that control flow through the turbines. The derivation of this flow rate was described in Section 3.2.3 of this appendix, and was quantified as 60 cfs.

The flume will be constructed with 40-foot pre-cast concrete sections that will then be lined with a smooth synthetic material. Henderson (1966) published a table of typical

Manning's roughness coefficients for a variety of open channel materials and conditions. For glass, plastic, and machined metal, the typical Manning's roughness coefficient is estimated as 0.010. As stated in Henderson (1966), this value represents the mean value for the given material and has a range of ± 0.001. For the hydraulic analysis, the Manning's roughness coefficient for the synthetically lined concrete flume was therefore assumed to be 0.009 and 0.011. Given that the synthetic liner will be installed over a precast concrete surface, which has an associated Manning's roughness coefficient of 0.012, a sensitivity analysis was conducted using this higher roughness coefficient to determine if a more conservative estimate of the roughness coefficient results in any violations of the biological and hydraulic design criteria.

The horizontal and vertical alignment of the gravity flume was designed such that supercritical flow (Froude No. > 1.1) is maintained throughout the open channel flume for the range of flows described above. Therefore, within the range of flow rates listed above, the design assured and the open channel hydraulic analysis confirmed that formation of hydraulic jumps in the system would not occur.

For flow regimes that are in proximity of critical depth, a relatively large change of depth may occur as a result of a small variation of specific energy. A flow regime that is very close to critical flow is therefore unstable and excessive wave action or undulations of the water surface may occur. Experiments by the US Army Engineer District, Los Angeles (1949), on a rectangular channel established criteria to avoid such instability, as follows (USACE, 1994):

Tranquil Flow (Subcritical Flow): $d > 1.1d_c$ or $F < 0.86$

Rapid Flow (Supercritical Flow): $d < 0.9d_c$ or $F > 1.13$

The results of the open channel analysis were reviewed to ensure that the Froude number was greater than 1.13 at all points along the flume. Adjustments to the horizontal alignment were made in cases where the computed Froude number was close to 1.13.

Refer to the set of design drawings for the final proposed horizontal alignment of the flume.

The HEC-RAS model was set up and run for the three design flow rates and the two values of the Manning's roughness coefficient that represent the surface conditions of the synthetic liner (0.009 and 0.011). The results of the model runs using the two values of the roughness coefficient were used for different portions of the open channel analysis. The smoother value (0.009) was used to verify that the minimum depth criterion (Criterion #12) is consistently met and that the maximum velocity criterion (Criterion #10) is consistently met. The rougher value (0.011) was used to verify that supercritical flow is maintained throughout the alignment (Criterion #11) and to compute the required freeboard.

Since the "Project Stationing" shown on the set of design drawings increases numerically in the downstream direction, and the HEC-RAS software requires stationing to increase in the upstream direction, the "River Stationing" used in the hydraulic model does not correspond with the Project Stationing". The hydraulic model stationing starts at River Station 9.93 at the downstream end of the alignment and ends at River Station 25 at the upstream end of the alignment. The "Project Stationing" at the downstream end of the flume alignment is 65+07 and 50+00 at the upstream end of the alignment. The relationship between the two stationing schemes is expressed in Equation 7:

"Project Station" = 75 – "River Station" (Equation 7)

Where,

"River Stationing" is expressed in decimal format (i.e. 65+07 = 65.07)

Cross sections were located at each grade break in the alignment, and at the 50-foot "Project Station" marks along the alignment. Therefore, the maximum spacing of cross sections was 50 feet, and in the vicinity of breaks in the profile, cross section spacing ranged between 10 feet and 50 feet.

The results of the HEC-RAS analysis are shown in Tables 6 through 11. Tables 6 through 8 include the model output for the three design flow rates assuming the 0.009 roughness coefficient, while Tables 9 through 11 include the model output for the three design flow rates assuming the 0.011 roughness coefficient. HEC-RAS output profiles for the 1,500 foot flume alignment are included as Figures 13 through 15, and show the water surface elevation, critical depth profile, and the energy grade line for the design low flow rate, the design high flow rate, and the surge flow rate, respectively. The profiles in Figures 13 through 15 reflect the conditions associated with the 0.011 roughness coefficient. The following results and conclusions were made relative to the open channel hydraulic analysis of the gravity flume:

- For the design low flow condition (with n=0.009), the average cross-sectional velocity ranged from a low of 17.6 fps at River Station 10.5 to a high of 28.2 fps at River Station 14.1. Therefore, the range of velocities for this flow condition is less than the allowable 35 fps velocity stipulated in the design criteria.
- For the design high flow condition (with n=0.009), the average cross-sectional velocity ranged from a low of 19.9 fps at River Station 10.5 to a high of 31.4 fps at River Station 14.1. Therefore, the range of velocities for this flow condition is less than the allowable 35 fps velocity stipulated in the design criteria.
- A supercritical flow regime is maintained throughout the alignment for the range of anticipated operational design flow rates and roughness coefficients. The Froude number is greater than 2.9 for all sections in the model, and therefore hydraulic jumps are not expected to develop.
- For the design low flow (with n=0.009), the minimum flow depth is 0.74 feet (9-inches), which corresponds to the minimum required flow depth stipulated by the design criteria.
- For the surge flow rate (with n=0.011), the flow is predicted to be contained within the flume and will not overtop the flume.
- The cross section averaged velocities at the outfall of the open channel flume to the transitional pond were determined to be 17.6 fps for the design low flow condition and 19.9 fps for the design high flow condition (with n=0.009).

- The maximum total cross sectional shear stress was computed to be 3.5 lbs per square foot along the steepest portion of the alignment. Due to the shear forces that will be acting on the liner, shear stresses may be a design consideration in the selection and design of both the synthetic liner and the adhesive.

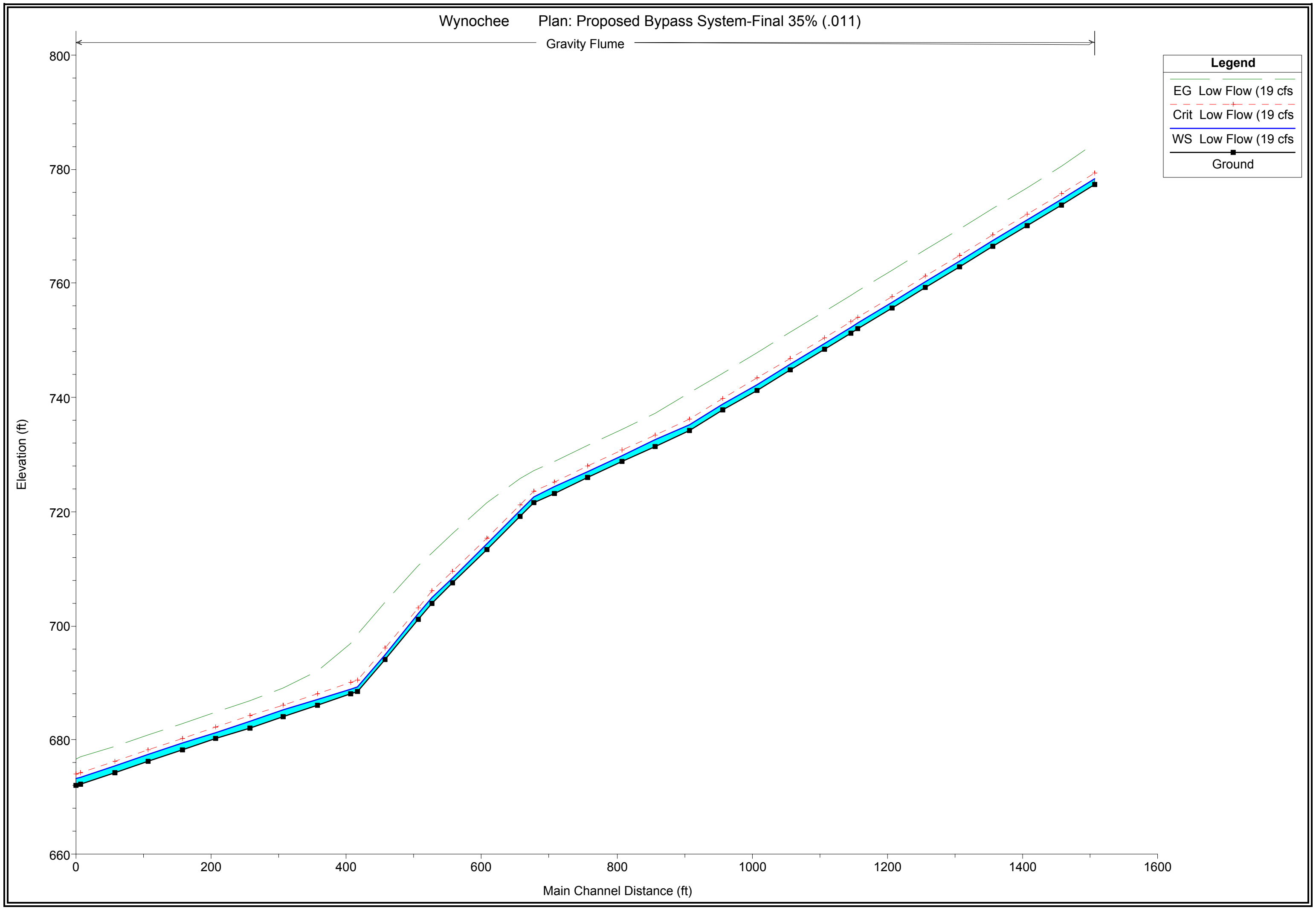

Figure 13. HEC-RAS Results – Gravity Flume Profile for Design Low Flow (n=0.011)

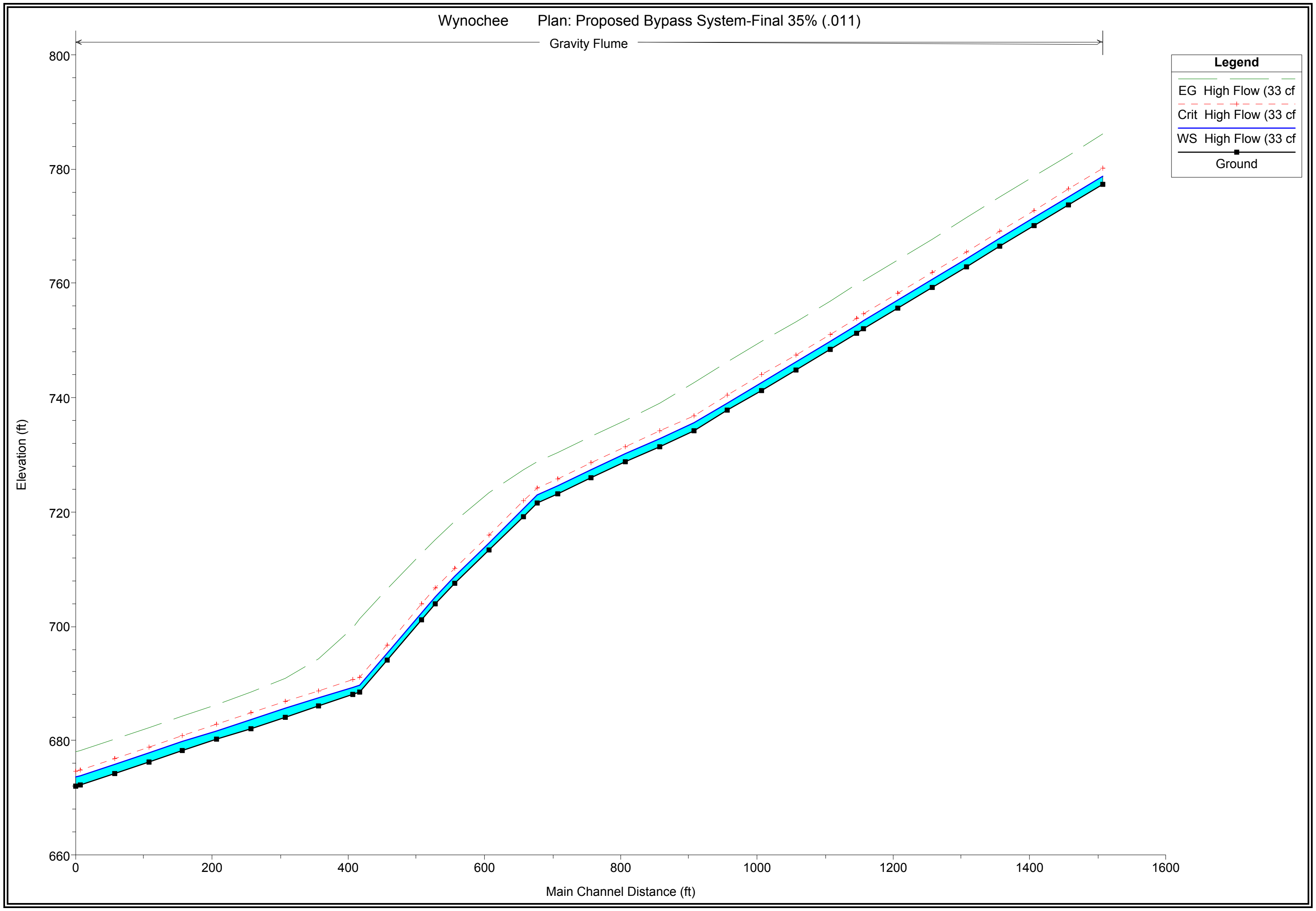

Figure 14. HEC-RAS Results - Gravity Flume Profile for Design High Flow (n=0.011)

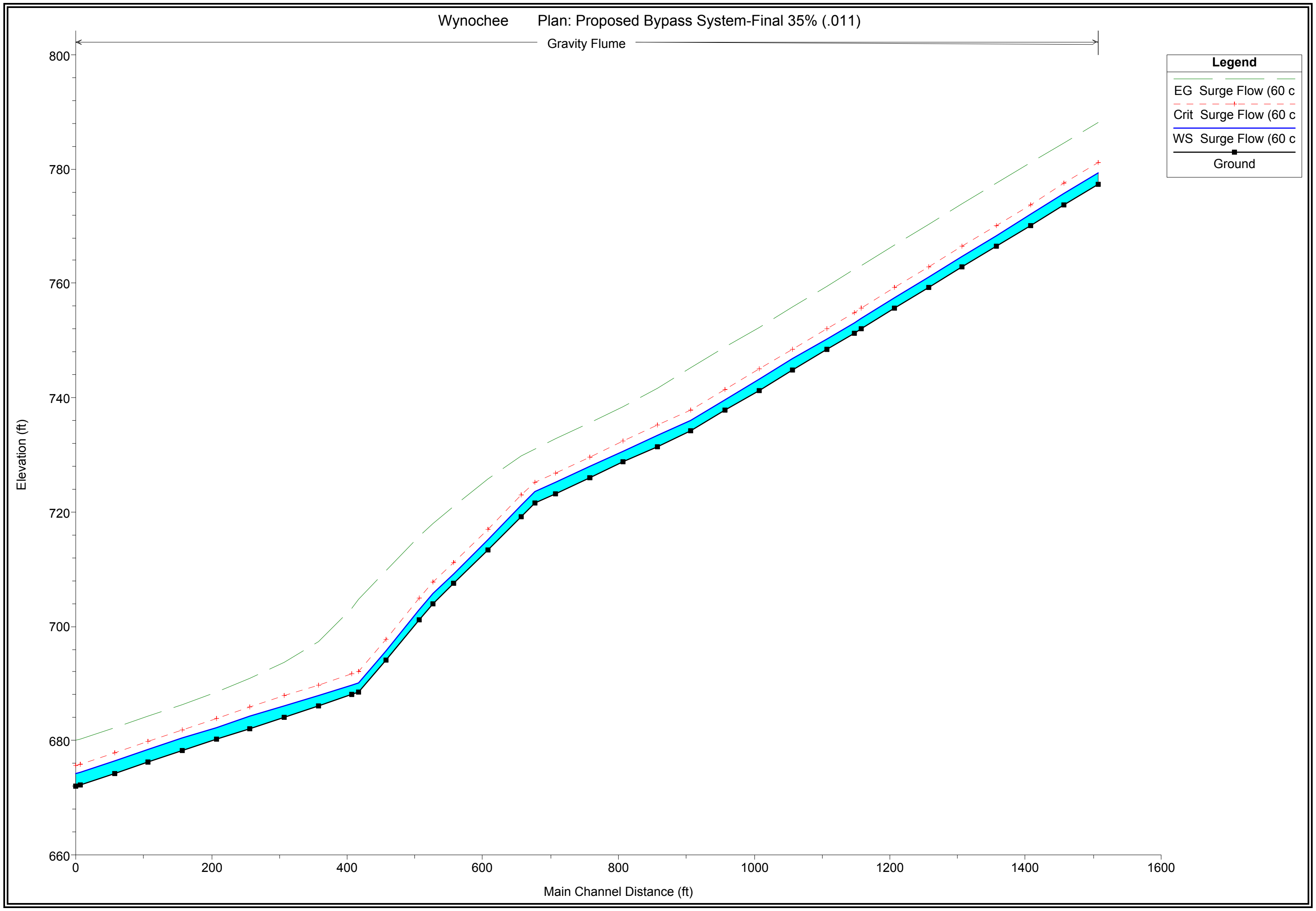

Figure 15. HEC-RAS Results - Gravity Flume Profile for Surge Flow (n=0.011)

Table 6. HEC-RAS Tabular Results – Design Low Flow (with n=0.009)

HEC-RAS Plan: Final .009 River: Fish Bypass Reach: Gravity Flume Profile: Low Flow (19 cfs																
Reach	River Sta	Mann Wtd Total	Q Total	Cum Ch Len	Min Ch El	Max Chl Dpth	Hydr Depth	Crit W.S.	E.G. Elev	E.G. Slope	Vel Total	Shear Total	Flow Area	Top Width	W.P. Total	Froude # XS
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(lb/sq ft)	(sq ft)	(ft)	(ft)	
Gravity Flume	25	0.009	19	1507	777.4	0.85	0.63	779.44	786.75	0.08202	23.39	1.78	0.81	1.29	2.34	5.19
Gravity Flume	24.5	0.009	19	1457	773.78	0.87	0.64	775.81	782.65	0.075928	22.71	1.67	0.84	1.3	2.37	4.99
Gravity Flume	24	0.009	19	1407	770.15	0.88	0.65	772.19	778.86	0.073844	22.45	1.63	0.85	1.31	2.39	4.92
Gravity Flume	23.5	0.009	19	1357	766.53	0.88	0.65	768.56	775.17	0.072994	22.36	1.62	0.85	1.31	2.39	4.89
Gravity Flume	23	0.009	19	1307	762.9	0.88	0.65	764.94	771.52	0.07278	22.33	1.61	0.85	1.31	2.4	4.88
Gravity Flume	22.5	0.009	19	1257	759.28	0.88	0.65	761.31	767.88	0.072502	22.3	1.61	0.85	1.31	2.4	4.88
Gravity Flume	22	0.009	19	1207	755.65	0.88	0.65	757.69	764.26	0.072639	22.31	1.61	0.85	1.31	2.4	4.88
Gravity Flume	21.5	0.009	19	1157	752.03	0.88	0.65	754.06	760.63	0.072397	22.29	1.61	0.85	1.31	2.4	4.87
Gravity Flume	21.4	0.009	19	1147	751.3	0.88	0.65	753.34	759.91	0.072544	22.3	1.61	0.85	1.31	2.4	4.87
Gravity Flume	21	0.009	19	1107	748.45	0.89	0.65	750.49	757	0.071846	22.21	1.6	0.86	1.31	2.4	4.85
Gravity Flume	20.5	0.009	19	1057	744.88	0.89	0.65	746.92	753.41	0.071656	22.19	1.59	0.86	1.31	2.41	4.84
Gravity Flume	20	0.009	19	1007	741.32	0.89	0.65	743.36	749.84	0.071467	22.17	1.59	0.86	1.31	2.41	4.83
Gravity Flume	19.5	0.009	19	957	737.75	0.89	0.65	739.79	746.27	0.071469	22.17	1.59	0.86	1.31	2.41	4.83
Gravity Flume	19	0.009	19	907	734.22	0.89	0.65	736.26	742.7	0.070979	22.11	1.58	0.86	1.31	2.41	4.82
Gravity Flume	18.5	0.009	19	857	731.47	0.93	0.68	733.51	739.17	0.061236	20.87	1.4	0.91	1.34	2.49	4.46
Gravity Flume	18	0.009	19	807	728.72	0.95	0.69	730.76	736.1	0.05744	20.36	1.32	0.93	1.35	2.53	4.32
Gravity Flume	17.5	0.009	19	757	725.97	0.95	0.7	728.01	733.23	0.055955	20.15	1.29	0.94	1.36	2.54	4.26
Gravity Flume	17	0.009	19	707	723.22	0.96	0.7	725.26	730.44	0.055442	20.08	1.29	0.95	1.36	2.55	4.24
Gravity Flume	16.7	0.009	19	677	721.57	0.96	0.7	723.61	728.78	0.055324	20.06	1.28	0.95	1.36	2.55	4.23
Gravity Flume	16.5	0.009	19	657	719.23	0.9	0.66	721.27	727.45	0.067704	21.71	1.52	0.88	1.32	2.44	4.7
Gravity Flume	16	0.009	19	607	713.37	0.83	0.61	715.41	723.37	0.090512	24.3	1.93	0.78	1.27	2.29	5.47
Gravity Flume	15.5	0.009	19	557	707.52	0.8	0.59	709.56	718.45	0.102954	25.54	2.15	0.74	1.25	2.22	5.84
Gravity Flume	15.2	0.009	19	527	704	0.79	0.59	706.04	715.26	0.107435	25.97	2.23	0.73	1.25	2.2	5.97
Gravity Flume	15	0.009	19	507	701.18	0.78	0.58	703.22	712.98	0.114883	26.65	2.36	0.71	1.24	2.17	6.19
Gravity Flume	14.5	0.009	19	457	694.12	0.75	0.56	696.16	706.84	0.127757	27.77	2.57	0.68	1.22	2.12	6.54
Gravity Flume	14.1	0.009	19	417	688.47	0.74	0.55	690.51	701.58	0.133292	28.22	2.67	0.67	1.22	2.1	6.68
Gravity Flume	14	0.009	19	407	688.07	0.78	0.57	690.11	699.96	0.116151	26.76	2.38	0.71	1.24	2.17	6.22
Gravity Flume	13.5	0.009	19	357	686.1	0.9	0.66	688.14	694.45	0.06935	21.91	1.55	0.87	1.32	2.42	4.76
Gravity Flume	13	0.009	19	307	684.12	0.99	0.71	686.17	691.02	0.051557	19.51	1.21	0.97	1.37	2.59	4.08
Gravity Flume	12.5	0.009	19	257	682.15	1.02	0.74	684.19	688.43	0.04442	18.42	1.07	1.03	1.4	2.68	3.78
Gravity Flume	12	0.009	19	207	680.17	1.05	0.75	682.22	686.21	0.041562	17.93	1.01	1.06	1.41	2.73	3.65
Gravity Flume	11.5	0.009	19	157	678.2	1.05	0.76	680.25	684.14	0.040425	17.75	0.99	1.07	1.42	2.74	3.6
Gravity Flume	11	0.009	19	107	676.22	1.05	0.76	678.27	682.12	0.03987	17.66	0.98	1.08	1.42	2.74	3.57
Gravity Flume	10.5	0.009	19	57	674.25	1.05	0.76	676.29	680.12	0.039675	17.62	0.97	1.08	1.42	2.75	3.56
Gravity Flume	10	0.009	19	7	672.27	1.05	0.76	674.31	678.14	0.039642	17.62	0.97	1.08	1.42	2.75	3.56
Gravity Flume	9.93	0.009	19		672	1.05	0.76	674.04	677.87	0.039618	17.61	0.97	1.08	1.42	2.75	3.56

Table 7. HEC-RAS Tabular Results – Design High Flow (with n = 0.009)

HEC-RAS Plan: Final .009 River: Fish Bypass Reach: Gravity Flume Profile: High Flow (33 cf																
Reach	River Sta	Mann Wtd Total	Q Total	Cum Ch Len	Min Ch El	Max Chl Dpth	Hydr Depth	Crit W.S.	E.G. Elev	E.G. Slope	Vel Total	Shear Total	Flow Area	Top Width	W.P. Total	Froude # XS
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(lb/sq ft)	(sq ft)	(ft)	(ft)	
Gravity Flume	25	0.009	33	1507	777.4	1.2	0.85	780.06	788.69	0.075057	25.49	1.98	1.29	1.52	3.06	4.87
Gravity Flume	24.5	0.009	33	1457	773.78	1.2	0.86	776.44	784.94	0.073752	25.33	1.96	1.3	1.52	3.07	4.82
Gravity Flume	24	0.009	33	1407	770.15	1.21	0.86	772.81	781.25	0.073156	25.24	1.94	1.31	1.52	3.08	4.8
Gravity Flume	23.5	0.009	33	1357	766.53	1.2	0.86	769.19	777.6	0.072808	25.2	1.93	1.31	1.52	3.08	4.79
Gravity Flume	23	0.009	33	1307	762.9	1.21	0.86	765.57	773.96	0.072798	25.19	1.93	1.31	1.53	3.08	4.79
Gravity Flume	22.5	0.009	33	1257	759.28	1.2	0.86	761.94	770.33	0.072676	25.18	1.93	1.31	1.53	3.08	4.79
Gravity Flume	22	0.009	33	1207	755.65	1.21	0.86	758.32	766.7	0.072706	25.18	1.93	1.31	1.53	3.08	4.79
Gravity Flume	21.5	0.009	33	1157	752.03	1.2	0.86	754.69	763.07	0.072518	25.16	1.93	1.31	1.53	3.08	4.78
Gravity Flume	21.4	0.009	33	1147	751.3	1.21	0.86	753.96	762.34	0.072622	25.17	1.93	1.31	1.53	3.08	4.78
Gravity Flume	21	0.009	33	1107	748.45	1.21	0.86	751.11	759.43	0.072006	25.08	1.91	1.32	1.53	3.09	4.76
Gravity Flume	20.5	0.009	33	1057	744.88	1.21	0.86	747.54	755.83	0.07172	25.04	1.91	1.32	1.53	3.09	4.75
Gravity Flume	20	0.009	33	1007	741.32	1.21	0.86	743.98	752.25	0.071539	25.02	1.9	1.32	1.53	3.09	4.75
Gravity Flume	19.5	0.009	33	957	737.75	1.21	0.86	740.41	748.68	0.07154	25.02	1.9	1.32	1.53	3.09	4.75
Gravity Flume	19	0.009	33	907	734.22	1.22	0.86	736.88	745.11	0.071095	24.96	1.89	1.32	1.53	3.1	4.73
Gravity Flume	18.5	0.009	33	857	731.47	1.26	0.89	734.13	741.51	0.062827	23.78	1.71	1.39	1.56	3.19	4.44
Gravity Flume	18	0.009	33	807	728.72	1.28	0.9	731.38	738.34	0.058823	23.17	1.62	1.42	1.57	3.24	4.29
Gravity Flume	17.5	0.009	33	757	725.97	1.29	0.91	728.63	735.38	0.056863	22.86	1.57	1.44	1.58	3.26	4.22
Gravity Flume	17	0.009	33	707	723.22	1.3	0.92	725.88	732.53	0.055904	22.71	1.55	1.45	1.59	3.27	4.18
Gravity Flume	16.7	0.009	33	677	721.57	1.3	0.92	724.23	730.86	0.055701	22.68	1.54	1.46	1.59	3.28	4.17
Gravity Flume	16.5	0.009	33	657	719.23	1.24	0.88	721.89	729.54	0.065483	24.16	1.77	1.37	1.55	3.16	4.54
Gravity Flume	16	0.009	33	607	713.37	1.16	0.83	716.03	725.63	0.084725	26.73	2.19	1.23	1.49	2.98	5.18
Gravity Flume	15.5	0.009	33	557	707.52	1.11	0.8	710.18	720.97	0.096997	28.19	2.46	1.17	1.46	2.88	5.55
Gravity Flume	15.2	0.009	33	527	704	1.1	0.79	706.66	717.94	0.102059	28.76	2.56	1.15	1.45	2.85	5.7
Gravity Flume	15	0.009	33	507	701.18	1.08	0.78	703.84	715.76	0.10879	29.48	2.71	1.12	1.44	2.81	5.89
Gravity Flume	14.5	0.009	33	457	694.12	1.05	0.76	696.78	709.89	0.121574	30.79	2.97	1.07	1.42	2.74	6.24
Gravity Flume	14.1	0.009	33	417	688.47	1.03	0.75	691.13	704.84	0.128067	31.43	3.1	1.05	1.41	2.71	6.41
Gravity Flume	14	0.009	33	407	688.07	1.06	0.77	690.74	703.27	0.1154	30.17	2.84	1.09	1.43	2.77	6.08
Gravity Flume	13.5	0.009	33	357	686.1	1.2	0.85	688.76	697.45	0.07562	25.57	2	1.29	1.52	3.05	4.88
Gravity Flume	13	0.009	33	307	684.12	1.3	0.91	686.8	693.57	0.057235	22.91	1.58	1.44	1.58	3.26	4.23
Gravity Flume	12.5	0.009	33	257	682.15	1.35	0.95	684.83	690.65	0.048346	21.45	1.37	1.54	1.62	3.39	3.88
Gravity Flume	12	0.009	33	207	680.17	1.4	0.97	682.84	688.2	0.04403	20.66	1.27	1.6	1.64	3.47	3.7
Gravity Flume	11.5	0.009	33	157	678.2	1.41	0.98	680.86	685.97	0.041735	20.25	1.21	1.63	1.66	3.5	3.6
Gravity Flume	11	0.009	33	107	676.22	1.42	0.99	678.89	683.88	0.04061	20.03	1.18	1.65	1.66	3.53	3.55
Gravity Flume	10.5	0.009	33	57	674.25	1.42	0.99	676.91	681.84	0.040113	19.93	1.17	1.66	1.67	3.54	3.53
Gravity Flume	10	0.009	33	7	672.27	1.43	0.99	674.94	679.84	0.039864	19.89	1.17	1.66	1.67	3.54	3.52
Gravity Flume	9.93	0.009	33		672	1.43	0.99	674.66	679.56	0.039825	19.88	1.17	1.66	1.67	3.54	3.51

Table 8. HEC-RAS Tabular Results - Surge Flow (with n = 0.009)

HEC-RAS Plan: Final .009 River: Fish Bypass Reach: Gravity Flume Profile: Surge Flow (60 c																
Reach	River Sta	Mann Wtd Total	Q Total (cfs)	Cum Ch Len (ft)	Min Ch El (ft)	Max Chl Dpth (ft)	Hydr Depth (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Total (ft/s)	Shear Total (lb/sq ft)	Flow Area (sq ft)	Top Width (ft)	W.P. Total (ft)	Froude # XS
Gravity Flume	25	0.009	60	1507	777.4	1.71	1.16	781.06	791.18	0.068023	27.88	2.21	2.15	1.86	4.13	4.56
Gravity Flume	24.5	0.009	60	1457	773.78	1.69	1.16	777.44	787.73	0.069281	28.09	2.25	2.14	1.85	4.11	4.61
Gravity Flume	24	0.009	60	1407	770.15	1.69	1.15	773.81	784.22	0.070237	28.23	2.27	2.13	1.85	4.1	4.64
Gravity Flume	23.5	0.009	60	1357	766.53	1.68	1.15	770.19	780.68	0.070848	28.34	2.29	2.12	1.84	4.09	4.66
Gravity Flume	23	0.009	60	1307	762.9	1.68	1.15	766.56	777.12	0.071396	28.42	2.3	2.11	1.84	4.08	4.68
Gravity Flume	22.5	0.009	60	1257	759.28	1.68	1.15	762.94	773.54	0.071668	28.47	2.31	2.11	1.84	4.08	4.69
Gravity Flume	22	0.009	60	1207	755.65	1.68	1.14	759.31	769.95	0.071999	28.51	2.32	2.1	1.84	4.08	4.7
Gravity Flume	21.5	0.009	60	1157	752.03	1.67	1.14	755.69	766.35	0.072096	28.54	2.32	2.1	1.84	4.07	4.7
Gravity Flume	21.4	0.009	60	1147	751.3	1.68	1.14	754.96	765.63	0.07219	28.54	2.33	2.1	1.84	4.07	4.7
Gravity Flume	21	0.009	60	1107	748.45	1.68	1.14	752.11	762.72	0.071789	28.48	2.31	2.11	1.84	4.08	4.69
Gravity Flume	20.5	0.009	60	1057	744.88	1.68	1.14	748.54	759.14	0.071672	28.46	2.31	2.11	1.84	4.08	4.69
Gravity Flume	20	0.009	60	1007	741.32	1.68	1.15	744.98	755.56	0.071536	28.44	2.31	2.11	1.84	4.08	4.68
Gravity Flume	19.5	0.009	60	957	737.75	1.68	1.15	741.41	751.99	0.071537	28.44	2.31	2.11	1.84	4.08	4.68
Gravity Flume	19	0.009	60	907	734.22	1.69	1.15	737.88	748.41	0.071173	28.38	2.3	2.11	1.84	4.09	4.67
Gravity Flume	18.5	0.009	60	857	731.47	1.73	1.17	735.13	744.75	0.064263	27.27	2.11	2.2	1.87	4.19	4.43
Gravity Flume	18	0.009	60	807	728.72	1.76	1.19	732.38	741.47	0.060344	26.6	2	2.26	1.89	4.25	4.3
Gravity Flume	17.5	0.009	60	757	725.97	1.78	1.2	729.63	738.41	0.058083	26.2	1.94	2.29	1.91	4.28	4.21
Gravity Flume	17	0.009	60	707	723.22	1.79	1.21	726.88	735.48	0.056779	25.97	1.9	2.31	1.91	4.31	4.16
Gravity Flume	16.7	0.009	60	677	721.57	1.79	1.21	725.23	733.78	0.056354	25.89	1.89	2.32	1.92	4.31	4.15
Gravity Flume	16.5	0.009	60	657	719.23	1.73	1.18	722.89	732.47	0.063974	27.22	2.1	2.2	1.88	4.19	4.42
Gravity Flume	16	0.009	60	607	713.37	1.63	1.12	717.03	728.69	0.079788	29.69	2.53	2.02	1.81	3.98	4.95
Gravity Flume	15.5	0.009	60	557	707.52	1.58	1.08	711.18	724.28	0.091067	31.27	2.83	1.92	1.77	3.86	5.29
Gravity Flume	15.2	0.009	60	527	704	1.55	1.07	707.66	721.4	0.096193	31.95	2.96	1.88	1.76	3.81	5.44
Gravity Flume	15	0.009	60	507	701.18	1.53	1.05	704.84	719.34	0.102258	32.73	3.12	1.83	1.74	3.76	5.62
Gravity Flume	14.5	0.009	60	457	694.12	1.48	1.03	697.78	713.79	0.114561	34.22	3.43	1.75	1.71	3.66	5.95
Gravity Flume	14.1	0.009	60	417	688.47	1.46	1.01	692.13	708.98	0.121526	35.02	3.6	1.71	1.69	3.61	6.13
Gravity Flume	14	0.009	60	407	688.07	1.49	1.03	691.73	707.47	0.112319	33.96	3.37	1.77	1.71	3.67	5.9
Gravity Flume	13.5	0.009	60	357	686.1	1.63	1.11	689.76	701.51	0.080461	29.78	2.55	2.01	1.81	3.97	4.97
Gravity Flume	13	0.009	60	307	684.12	1.75	1.18	687.79	697.24	0.06307	27.06	2.08	2.22	1.88	4.21	4.39
Gravity Flume	12.5	0.009	60	257	682.15	1.82	1.23	685.81	693.93	0.05324	25.32	1.8	2.37	1.93	4.37	4.03
Gravity Flume	12	0.009	60	207	680.17	1.88	1.26	683.84	691.16	0.047608	24.22	1.64	2.48	1.97	4.49	3.81
Gravity Flume	11.5	0.009	60	157	678.2	1.91	1.28	681.86	688.72	0.044233	23.54	1.54	2.55	1.99	4.56	3.67
Gravity Flume	11	0.009	60	107	676.22	1.94	1.3	679.89	686.47	0.04227	23.13	1.48	2.59	2	4.61	3.58
Gravity Flume	10.5	0.009	60	57	674.25	1.95	1.31	677.91	684.33	0.041122	22.89	1.45	2.62	2	4.64	3.52
Gravity Flume	10	0.009	60	7	672.27	1.96	1.32	675.94	682.26	0.040453	22.74	1.43	2.64	2	4.66	3.49
Gravity Flume	9.93	0.009	60		672	1.96	1.32	675.66	681.98	0.040371	22.72	1.43	2.64	2	4.66	3.49

Table 9. HEC-RAS Tabular Results – Design Low Flow (with n = 0.011)

HEC-RAS Plan: Final .011 River: Fish Bypass Reach: Gravity Flume Profile: Low Flow (19 cfs																
Reach	River Sta	Mann Wtd Total	Q Total	Cum Ch Len	Min Ch El	Max Chl Dpth	Hydr Depth	Crit W.S.	E.G. Elev	E.G. Slope	Vel Total	Shear Total	Flow Area	Top Width	W.P. Total	Froude # XS
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(lb/sq ft)	(sq ft)	(ft)	(ft)	
Gravity Flume	25	0.011	19	1507	777.4	0.96	0.7	779.44	784.57	0.082009	20	1.9	0.95	1.36	2.55	4.22
Gravity Flume	24.5	0.011	19	1457	773.78	0.98	0.72	775.81	780.53	0.074468	19.27	1.76	0.99	1.38	2.61	4.01
Gravity Flume	24	0.011	19	1407	770.15	0.99	0.72	772.19	776.81	0.072982	19.11	1.73	0.99	1.38	2.62	3.97
Gravity Flume	23.5	0.011	19	1357	766.53	0.99	0.72	768.56	773.17	0.072627	19.09	1.72	1	1.38	2.62	3.96
Gravity Flume	23	0.011	19	1307	762.9	0.99	0.72	764.94	769.54	0.07265	19.08	1.72	1	1.38	2.62	3.96
Gravity Flume	22.5	0.011	19	1257	759.28	0.99	0.72	761.31	765.92	0.072596	19.08	1.72	1	1.38	2.62	3.96
Gravity Flume	22	0.011	19	1207	755.65	0.99	0.72	757.69	762.29	0.072635	19.08	1.72	1	1.38	2.63	3.96
Gravity Flume	21.5	0.011	19	1157	752.03	0.99	0.72	754.06	758.67	0.072596	19.08	1.72	1	1.38	2.62	3.96
Gravity Flume	21.4	0.011	19	1147	751.3	0.99	0.72	753.34	757.95	0.072675	19.08	1.72	1	1.38	2.62	3.96
Gravity Flume	21	0.011	19	1107	748.45	1	0.72	750.49	755.04	0.071705	18.98	1.7	1	1.38	2.63	3.93
Gravity Flume	20.5	0.011	19	1057	744.88	1	0.72	746.92	751.46	0.071534	18.97	1.7	1	1.38	2.63	3.93
Gravity Flume	20	0.011	19	1007	741.32	1	0.72	743.36	747.89	0.071349	18.95	1.69	1	1.38	2.64	3.92
Gravity Flume	19.5	0.011	19	957	737.75	1	0.72	739.79	744.32	0.071351	18.95	1.69	1	1.38	2.64	3.92
Gravity Flume	19	0.011	19	907	734.22	1	0.73	736.26	740.76	0.07082	18.89	1.68	1.01	1.39	2.64	3.91
Gravity Flume	18.5	0.011	19	857	731.47	1.05	0.76	733.51	737.32	0.058823	17.57	1.44	1.08	1.42	2.75	3.55
Gravity Flume	18	0.011	19	807	728.72	1.07	0.77	730.76	734.39	0.055889	17.22	1.38	1.1	1.43	2.79	3.46
Gravity Flume	17.5	0.011	19	757	725.97	1.07	0.77	728.01	731.61	0.055271	17.15	1.37	1.11	1.43	2.79	3.44
Gravity Flume	17	0.011	19	707	723.22	1.07	0.77	725.26	728.85	0.055126	17.13	1.37	1.11	1.43	2.79	3.43
Gravity Flume	16.7	0.011	19	677	721.57	1.07	0.77	723.61	727.2	0.055121	17.13	1.37	1.11	1.43	2.79	3.43
Gravity Flume	16.5	0.011	19	657	719.23	0.99	0.72	721.27	725.84	0.07202	19.02	1.71	1	1.38	2.63	3.94
Gravity Flume	16	0.011	19	607	713.37	0.91	0.67	715.41	721.48	0.099125	21.54	2.23	0.88	1.33	2.45	4.65
Gravity Flume	15.5	0.011	19	557	707.52	0.88	0.65	709.56	716.21	0.109887	22.42	2.43	0.85	1.31	2.39	4.91
Gravity Flume	15.2	0.011	19	527	704	0.87	0.64	706.04	712.85	0.112904	22.66	2.49	0.84	1.3	2.38	4.98
Gravity Flume	15	0.011	19	507	701.18	0.86	0.63	703.22	710.46	0.121206	23.29	2.64	0.82	1.29	2.34	5.16
Gravity Flume	14.5	0.011	19	457	694.12	0.83	0.62	696.16	704.04	0.133559	24.18	2.86	0.79	1.28	2.29	5.43
Gravity Flume	14.1	0.011	19	417	688.47	0.83	0.61	690.51	698.59	0.137569	24.46	2.93	0.78	1.27	2.28	5.51
Gravity Flume	14	0.011	19	407	688.07	0.88	0.64	690.11	696.96	0.113698	22.72	2.5	0.84	1.3	2.37	5
Gravity Flume	13.5	0.011	19	357	686.1	1.05	0.76	688.14	691.99	0.05965	17.67	1.46	1.08	1.42	2.75	3.58
Gravity Flume	13	0.011	19	307	684.12	1.15	0.81	686.17	689.14	0.0448	15.79	1.15	1.2	1.48	2.93	3.08
Gravity Flume	12.5	0.011	19	257	682.15	1.17	0.83	684.19	686.92	0.040848	15.23	1.06	1.25	1.5	2.99	2.94
Gravity Flume	12	0.011	19	207	680.17	1.18	0.84	682.22	684.88	0.03983	15.07	1.04	1.26	1.5	3.02	2.9
Gravity Flume	11.5	0.011	19	157	678.2	1.18	0.84	680.25	682.89	0.039616	15.05	1.04	1.26	1.5	3.01	2.9
Gravity Flume	11	0.011	19	107	676.22	1.18	0.84	678.27	680.92	0.039591	15.05	1.04	1.26	1.5	3.01	2.89
Gravity Flume	10.5	0.011	19	57	674.25	1.18	0.84	676.29	678.94	0.03955	15.04	1.03	1.26	1.5	3.02	2.89
Gravity Flume	10	0.011	19	7	672.27	1.18	0.84	674.31	676.96	0.039543	15.04	1.03	1.26	1.5	3.01	2.89
Gravity Flume	9.93	0.011	19		672	1.18	0.84	674.04	676.69	0.039499	15.03	1.03	1.26	1.51	3.02	2.89

Table 10. HEC-RAS Tabular Results – Design High Flow (with n = 0.011)

HEC-RAS Plan: Final .011 River: Fish Bypass Reach: Gravity Flume Profile: High Flow (33 cf																
Reach	River Sta	Mann Wtd Total	Q Total	Cum Ch Len	Min Ch El	Max Chl Dpth	Hydr Depth	Crit W.S.	E.G. Elev	E.G. Slope	Vel Total	Shear Total	Flow Area	Top Width	W.P. Total	Froude # XS
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(lb/sq ft)	(sq ft)	(ft)	(ft)	
Gravity Flume	25	0.011	33	1507	777.4	1.34	0.94	780.06	786.1	0.074996	21.77	2.11	1.52	1.61	3.36	3.96
Gravity Flume	24.5	0.011	33	1457	773.78	1.34	0.95	776.44	782.36	0.073303	21.59	2.08	1.53	1.62	3.37	3.91
Gravity Flume	24	0.011	33	1407	770.15	1.35	0.95	772.81	778.69	0.072816	21.52	2.06	1.53	1.62	3.38	3.9
Gravity Flume	23.5	0.011	33	1357	766.53	1.35	0.95	769.19	775.06	0.072596	21.5	2.06	1.53	1.62	3.38	3.89
Gravity Flume	23	0.011	33	1307	762.9	1.35	0.95	765.57	771.43	0.072625	21.5	2.06	1.53	1.62	3.38	3.89
Gravity Flume	22.5	0.011	33	1257	759.28	1.35	0.95	761.94	767.8	0.072549	21.5	2.06	1.53	1.62	3.38	3.89
Gravity Flume	22	0.011	33	1207	755.65	1.35	0.95	758.32	764.18	0.072589	21.49	2.06	1.54	1.62	3.38	3.89
Gravity Flume	21.5	0.011	33	1157	752.03	1.35	0.95	754.69	760.55	0.072549	21.5	2.06	1.53	1.62	3.38	3.89
Gravity Flume	21.4	0.011	33	1147	751.3	1.35	0.95	753.96	759.83	0.072703	21.51	2.06	1.53	1.62	3.38	3.9
Gravity Flume	21	0.011	33	1107	748.45	1.35	0.95	751.11	756.93	0.071991	21.42	2.04	1.54	1.62	3.39	3.88
Gravity Flume	20.5	0.011	33	1057	744.88	1.36	0.95	747.54	753.34	0.07172	21.39	2.04	1.54	1.62	3.39	3.87
Gravity Flume	20	0.011	33	1007	741.32	1.36	0.95	743.98	749.76	0.071474	21.36	2.03	1.54	1.62	3.39	3.86
Gravity Flume	19.5	0.011	33	957	737.75	1.36	0.95	740.41	746.19	0.071475	21.36	2.03	1.54	1.62	3.39	3.86
Gravity Flume	19	0.011	33	907	734.22	1.36	0.95	736.88	742.63	0.070945	21.3	2.02	1.55	1.63	3.4	3.85
Gravity Flume	18.5	0.011	33	857	731.47	1.42	0.99	734.13	739.11	0.06052	20.01	1.77	1.65	1.67	3.53	3.55
Gravity Flume	18	0.011	33	807	728.72	1.44	1	731.38	736.09	0.056888	19.53	1.68	1.69	1.68	3.58	3.44
Gravity Flume	17.5	0.011	33	757	725.97	1.45	1.01	728.63	733.24	0.055638	19.36	1.65	1.7	1.69	3.6	3.4
Gravity Flume	17	0.011	33	707	723.22	1.46	1.01	725.88	730.47	0.055263	19.31	1.64	1.71	1.69	3.6	3.38
Gravity Flume	16.7	0.011	33	677	721.57	1.46	1.01	724.23	728.82	0.055259	19.31	1.64	1.71	1.69	3.6	3.38
Gravity Flume	16.5	0.011	33	657	719.23	1.37	0.96	721.89	727.48	0.068752	21.04	1.97	1.57	1.63	3.43	3.79
Gravity Flume	16	0.011	33	607	713.37	1.26	0.89	716.03	723.32	0.092676	23.66	2.52	1.39	1.56	3.2	4.41
Gravity Flume	15.5	0.011	33	557	707.52	1.22	0.87	710.18	718.31	0.104765	24.82	2.8	1.33	1.53	3.11	4.7
Gravity Flume	15.2	0.011	33	527	704	1.21	0.86	706.66	715.08	0.108957	25.21	2.89	1.31	1.52	3.08	4.79
Gravity Flume	15	0.011	33	507	701.18	1.18	0.84	703.84	712.77	0.116539	25.88	3.06	1.27	1.51	3.03	4.96
Gravity Flume	14.5	0.011	33	457	694.12	1.15	0.82	696.78	706.55	0.12917	26.95	3.33	1.22	1.49	2.96	5.23
Gravity Flume	14.1	0.011	33	417	688.47	1.14	0.82	691.13	701.24	0.134441	27.37	3.45	1.21	1.48	2.93	5.34
Gravity Flume	14	0.011	33	407	688.07	1.19	0.84	690.74	699.62	0.115974	25.83	3.05	1.28	1.51	3.04	4.95
Gravity Flume	13.5	0.011	33	357	686.1	1.38	0.97	688.76	694.21	0.066871	20.81	1.92	1.59	1.64	3.45	3.73
Gravity Flume	13	0.011	33	307	684.12	1.51	1.04	686.8	690.93	0.049354	18.47	1.49	1.79	1.72	3.7	3.19
Gravity Flume	12.5	0.011	33	257	682.15	1.56	1.07	684.83	688.47	0.04305	17.51	1.33	1.89	1.76	3.82	2.98
Gravity Flume	12	0.011	33	207	680.17	1.59	1.09	682.84	686.31	0.040747	17.12	1.27	1.93	1.77	3.87	2.89
Gravity Flume	11.5	0.011	33	157	678.2	1.59	1.09	680.86	684.27	0.039915	16.99	1.25	1.94	1.78	3.89	2.87
Gravity Flume	11	0.011	33	107	676.22	1.6	1.09	678.89	682.29	0.039765	16.97	1.24	1.94	1.78	3.89	2.86
Gravity Flume	10.5	0.011	33	57	674.25	1.59	1.09	676.91	680.3	0.039604	16.94	1.24	1.95	1.78	3.89	2.86
Gravity Flume	10	0.011	33	7	672.27	1.6	1.09	674.94	678.32	0.039573	16.94	1.24	1.95	1.78	3.89	2.85
Gravity Flume	9.93	0.011	33		672	1.59	1.09	674.66	678.04	0.039537	16.93	1.24	1.95	1.78	3.9	2.85

Table 11. HEC-RAS Tabular Results – Surge Flow (with n = 0.011)

HEC-RAS Plan: Final .011 River: Fish Bypass Reach: Gravity Flume Profile: Surge Flow (60 c																
Reach	River Sta	Mann Wtd Total	Q Total	Cum Ch Len	Min Ch El	Max Chl Dpth	Hydr Depth	Crit W.S.	E.G. Elev	E.G. Slope	Vel Total	Shear Total	Flow Area	Top Width	W.P. Total	Froude # XS
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(lb/sq ft)	(sq ft)	(ft)	(ft)	
Gravity Flume	25	0.011	60	1507	777.4	1.9	1.27	781.06	788.11	0.068062	23.82	2.36	2.52	1.98	4.53	3.73
Gravity Flume	24.5	0.011	60	1457	773.78	1.88	1.26	777.44	784.64	0.069737	24.05	2.41	2.49	1.97	4.5	3.77
Gravity Flume	24	0.011	60	1407	770.15	1.88	1.26	773.81	781.11	0.070776	24.19	2.44	2.48	1.97	4.49	3.8
Gravity Flume	23.5	0.011	60	1357	766.53	1.87	1.26	770.19	777.55	0.071407	24.28	2.46	2.47	1.97	4.48	3.82
Gravity Flume	23	0.011	60	1307	762.9	1.87	1.25	766.56	773.97	0.071879	24.34	2.47	2.47	1.97	4.48	3.83
Gravity Flume	22.5	0.011	60	1257	759.28	1.86	1.25	762.94	770.36	0.072081	24.37	2.48	2.46	1.96	4.47	3.83
Gravity Flume	22	0.011	60	1207	755.65	1.87	1.25	759.31	766.76	0.072308	24.39	2.48	2.46	1.96	4.47	3.84
Gravity Flume	21.5	0.011	60	1157	752.03	1.86	1.25	755.69	763.14	0.072305	24.4	2.49	2.46	1.96	4.47	3.84
Gravity Flume	21.4	0.011	60	1147	751.3	1.87	1.25	754.96	762.42	0.072412	24.41	2.49	2.46	1.96	4.47	3.84
Gravity Flume	21	0.011	60	1107	748.45	1.87	1.25	752.11	759.51	0.071812	24.33	2.47	2.47	1.97	4.48	3.83
Gravity Flume	20.5	0.011	60	1057	744.88	1.87	1.25	748.54	755.92	0.071652	24.31	2.47	2.47	1.97	4.48	3.82
Gravity Flume	20	0.011	60	1007	741.32	1.87	1.26	744.98	752.35	0.071484	24.28	2.46	2.47	1.97	4.48	3.82
Gravity Flume	19.5	0.011	60	957	737.75	1.87	1.26	741.41	748.78	0.071484	24.28	2.46	2.47	1.97	4.48	3.82
Gravity Flume	19	0.011	60	907	734.22	1.88	1.26	737.88	745.21	0.071038	24.22	2.45	2.48	1.97	4.49	3.81
Gravity Flume	18.5	0.011	60	857	731.47	1.94	1.31	735.13	741.62	0.062124	22.99	2.19	2.61	2	4.63	3.55
Gravity Flume	18	0.011	60	807	728.72	1.98	1.34	732.38	738.49	0.058155	22.41	2.07	2.68	2	4.69	3.41
Gravity Flume	17.5	0.011	60	757	725.97	1.99	1.36	729.63	735.57	0.056393	22.14	2.02	2.71	2	4.73	3.35
Gravity Flume	17	0.011	60	707	723.22	2	1.36	726.88	732.76	0.055708	22.03	2	2.72	2	4.74	3.33
Gravity Flume	16.7	0.011	60	677	721.57	2	1.36	725.23	731.09	0.055538	22.01	1.99	2.73	2	4.74	3.32
Gravity Flume	16.5	0.011	60	657	719.23	1.91	1.28	722.89	729.78	0.066354	23.58	2.31	2.54	1.99	4.56	3.68
Gravity Flume	16	0.011	60	607	713.37	1.78	1.2	717.03	725.8	0.086638	26.19	2.89	2.29	1.91	4.29	4.21
Gravity Flume	15.5	0.011	60	557	707.52	1.72	1.17	711.18	721.06	0.098936	27.59	3.23	2.17	1.87	4.16	4.5
Gravity Flume	15.2	0.011	60	527	704	1.7	1.15	707.66	717.98	0.103873	28.12	3.37	2.13	1.85	4.11	4.62
Gravity Flume	15	0.011	60	507	701.18	1.67	1.14	704.84	715.77	0.110805	28.85	3.55	2.08	1.83	4.05	4.77
Gravity Flume	14.5	0.011	60	457	694.12	1.62	1.11	697.78	709.8	0.123423	30.1	3.89	1.99	1.8	3.95	5.04
Gravity Flume	14.1	0.011	60	417	688.47	1.6	1.1	692.13	704.69	0.129673	30.69	4.06	1.96	1.79	3.9	5.17
Gravity Flume	14	0.011	60	407	688.07	1.65	1.12	691.73	703.1	0.115773	29.35	3.69	2.04	1.82	4.01	4.88
Gravity Flume	13.5	0.011	60	357	686.1	1.86	1.25	689.76	697.33	0.073605	24.56	2.52	2.44	1.96	4.45	3.88
Gravity Flume	13	0.011	60	307	684.12	2.02	1.37	687.79	693.6	0.055008	21.92	1.98	2.74	2	4.76	3.3
Gravity Flume	12.5	0.011	60	257	682.15	2.1	1.46	685.81	690.8	0.046544	20.54	1.72	2.92	2	4.94	2.99
Gravity Flume	12	0.011	60	207	680.17	2.16	1.51	683.84	688.44	0.042724	19.85	1.6	3.02	2	5.05	2.84
Gravity Flume	11.5	0.011	60	157	678.2	2.17	1.54	681.86	686.29	0.040936	19.52	1.54	3.07	2	5.09	2.78
Gravity Flume	11	0.011	60	107	676.22	2.19	1.55	679.89	684.24	0.040138	19.37	1.52	3.1	2	5.11	2.74
Gravity Flume	10.5	0.011	60	57	674.25	2.19	1.55	677.91	682.23	0.039777	19.3	1.51	3.11	2	5.13	2.73
Gravity Flume	10	0.011	60	7	672.27	2.2	1.56	675.94	680.24	0.039699	19.29	1.5	3.11	2	5.13	2.73
Gravity Flume	9.93	0.011	60		672	2.19	1.56	675.66	679.97	0.039651	19.28	1.5	3.11	2	5.13	2.72

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3.3.1.1 Superelevation

In open channel flow, centrifugal forces caused by water flowing through horizontal bends can result in an increase in the water surface elevation on the outside of the bend and an accompanying depression of the water surface elevation on the inside of the bend. This phenomenon is called superelevation. In addition to superelevation, horizontal bends in open channels that are flowing under a supercritical flow regime can also create cross waves, which can propagate downstream of the bend (Clark County, 1999). The proposed alignment of the open channel gravity flume includes five horizontal bends. Table 12 summarizes the locations and the geometric parameters of each of the bends.

Table 12. Horizontal Bends in the Proposed Gravity Flume Alignment

Bend No.	Upstream "Project Station:	Downstream "Project Station"	Upstream "River Station"	Downstream "River Station"	Angle of Deflection (degrees)	Radius of Bend (ft)
1	50+00	51+00	25	23	40	235
2	54+20	55+20	22	19.4	30	270
3	57+40	58+00	17.6	17	20	220
4	61+00	62+00	14	13	25	220
5	64+00	65+07	11	9.93	65	100

The magnitude of superelevation is a function of the geometry of the cross section, the average cross sectional velocity, the top width of the flow, and the radius of curvature of the channel centerline. Quantification of super-elevated flow through each of the horizontal bends was based on the methodology presented in (USACE, 1994). Equation 8 presents the relationship between the specific hydraulic parameters and superelevation.

$$\Delta y = C \times \left(\frac{V^2 \times W}{g \times R} \right) \qquad \text{(Equation 8)}$$

Where,

$\Delta y =$ rise in water surface elevation between a theoretical level water surface at the centerline and outside water surface elevation (superelevation)

$C =$ coefficient, ranging between 0.5 and 1.0

$V =$ mean channel velocity (fps)

W = channel width at elevation of centerline water surface (ft)

g = acceleration of gravity (ft/s2)

R = radius of channel centerline curvature (ft)

The coefficient in Equation 8 is a function of the flow regime (tranquil versus rapid), the channel cross sectional shape, and the type of horizontal curve. According to Table 2-4 in USACE (1994), the value of the coefficient under rapid flow conditions with a trapezoidal cross section and a simple circular curve is 1.0. Using the HEC-RAS output (with n=0.011) from the cross sections within each of the five horizontal bends, the height of the superelevated flow was computed for each of the three flow conditions. Table 13 summarizes the results.

Table 13. Maximum Computed Height of Superelevation through Horizontal Bends

Bend No.	Design Low Flow (Q=19 cfs)	Design High Flow (Q = 33 cfs)	Surge Flow (Q = 60 cfs)
1	0.07 feet	0.10 feet	0.15 feet
2	0.06 feet	0.09 feet	0.13 feet
3	0.06 feet	0.09 feet	0.14 feet
4	0.10 feet	0.15 feet	0.23 feet
5	0.11 feet	0.16 feet	0.23 feet

3.3.1.2 Wave Formation

Unstable pulsating flow, which is subdivided into two categories: slug flow and roll waves, may develop in long steep open channels. These two types of waves typically form in open channels that are sufficiently long (>200 feet) and that have bottom slopes that are flatter than 20 degrees (s = 36.0%). Transverse flow, or cross waves, may also develop in an open channel where there are abrupt transitions in cross sectional shape or unsymmetrical structures (BOR, 1978).

Slug flows are characterized by surges of turbulent ridges with wave crests separated by highly agitated regions. For slug flow to form, the surface velocity must be greater than the wave speed. Roll waves are characterized by transverse ridges of high velocity with quiescent conditions between the crests of the waves (Clark County, 1999). Waves in open channels are objectionable since they result in a reduction of channel capacity and may result in overtopping. In the case of juvenile fish bypass facilities, the presence of large waves in very rapid flow regimes may result in injury or mortality to fish. Some open channel sections are more likely to sustain waves than others. Shallow, dished sections are particularly susceptible to transverse flow, while deep, narrow sections with small bottom width to wetted perimeter ratios, are less likely to develop transverse flow or pulsating flow (BOR, 1978).

The methodology outlined in BOR (1978) was used to determine the possibility for the formation of unstable flow conditions. The Vedernikov number is used to identify if the uniform flow conditions in an open channel are stable. Stable flow conditions will exist when the Vedernikov number is less than or equal to unity. The Vedernikov number is a function of the ratio of the bottom width to the wetted perimeter and the Froude number, and is expressed in the following equation:

$$\underline{V} = \frac{2}{3} \times \frac{b}{wp} \times \left(\frac{V}{\sqrt{g \times d \times \cos\theta}} \right) \qquad \text{(Equation 9)}$$

Where,

$\underline{V}$ = Vedernikov number (dimensionless)

b = bottom width of channel section (feet)

wp = wetted perimeter of the channel section (feet)

V = cross section averaged velocity (feet/second)

g = acceleration of gravity (ft/s2)

d = hydraulic depth (feet)

The dimensionless Montuori number is used in conjunction with the Vedernikov number to determine if flow conditions in an open channel will result in unstable pulsating flow.

The Montuori number is defined by the following equation:

$$M = \sqrt{\frac{V^2}{g \times sL \times \cos\theta}} \qquad \text{(Equation 10)}$$

Where,

M = Montuori number (dimensionless)

V = cross section averaged velocity (feet/second)

g = acceleration of gravity (ft/s2)

s = average slope of energy gradient (ft/ft)

L = length of reach under consideration (feet)

θ = angle of inclination of the energy gradient (degrees)

The computed values of the Vedernikov number and the Montuori number are then used to enter the following chart (Figure 16 reprinted from BOR 1978) to determine if the geometric and hydraulic conditions are likely to result in unstable pulsating flow. As mentioned earlier, and as seen in Figure 16, the flow will remain stable when the Vedernikov number is less than unity. For both design flow conditions (19 cfs and 33 cfs), which cover the range of operating flow rates in the bypass system, the Vedernikov number at each cross section in the hydraulic model was computed to be less than 0.29 indicating that the formation of unstable flow patterns is unlikely. Even though the Froude number of the flow approaches 7 at some cross sections (see Tables 6 through 11), the cross-sectional geometry of the proposed channel flume, with it's small to bottom width (for the analysis, the bottom width of the proposed flume cross section was set equal to 0.18 feet or 2 inches), results in the prediction of stable flow conditions. Therefore, it is concluded that the developed free surface in the open channel will remain stable, and that neither slug flow nor roll waves are a design consideration. Tables 14 and 15 summarize the computed Vedernikov and Montuori numbers for each cross section in the hydraulic model (with n = 0.011).

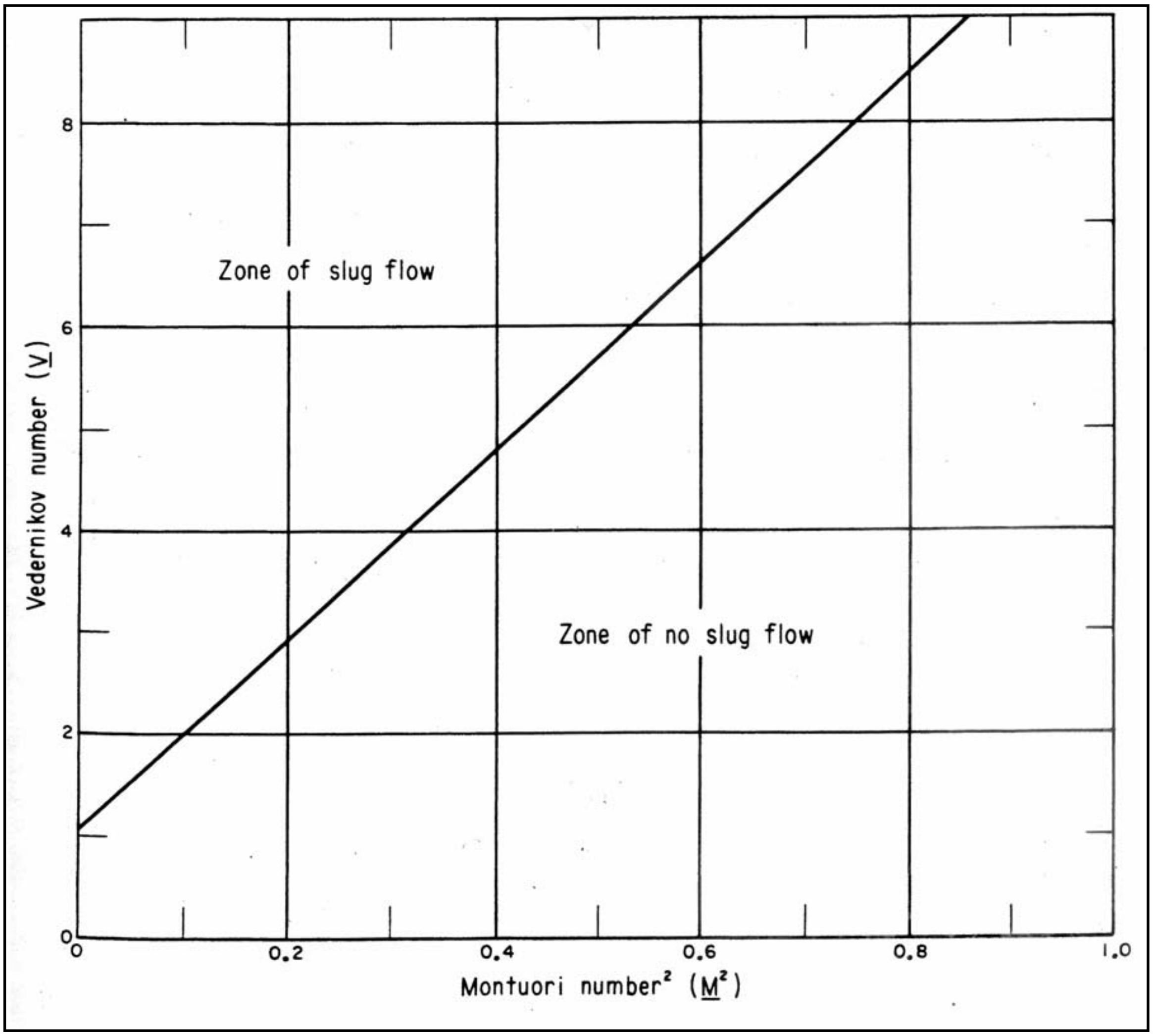

Figure 16. Criteria for Slug Flow

Table 14. Calculations for Slug Flow and Roll Waves for Design Low Flow

Flow Rate (cfs): **19**
Mannings Roughness Coefficient **0.011**

Horiz. Bend No.	River Station	Centerline Radius (ft)
1	25 to 23	235
2	22 to 19.4	270
3	17.6 to 17	220
4	14 to 13	220
5	11 to 9.93	100

Bottom Width of Section is Approx. 0.18

SPECIFIC HEC-RAS OUTPUT PARAMETERS

HEC-RAS River Station	Cum Ch Len (ft)	Max Chl Dpth (ft)	Hydr Depth (ft)	Vel Total (ft/s)	W.P. Total (ft)	Cumm. EGL Slope from U/S End to Current (ft/ft)	Angle of EGL (radians)	Vedernikov Number	Montuori Number	d/wp	Height of Wave* (ft)
25	1507	0.96	0.7	20	2.55						
24.5	1457	0.98	0.72	19.27	2.61	0.080800	0.080625	0.18	2.86	0.28	0
24	1407	0.99	0.72	19.11	2.62	0.077600	0.077445	0.18	1.47	0.27	0
23.5	1357	0.99	0.72	19.09	2.62	0.076000	0.075854	0.18	1.00	0.27	0
23	1307	0.99	0.72	19.08	2.62	0.075150	0.075009	0.18	0.75	0.27	0
22.5	1257	0.99	0.72	19.08	2.62	0.074600	0.074462	0.18	0.61	0.27	0
22	1207	0.99	0.72	19.08	2.63	0.074267	0.074131	0.18	0.51	0.27	0
21.5	1157	0.99	0.72	19.08	2.62	0.074000	0.073865	0.18	0.44	0.27	0
21.4	1147	0.99	0.72	19.08	2.62	0.073944	0.073810	0.18	0.43	0.27	0
21	1107	1	0.72	18.98	2.63	0.073825	0.073691	0.18	0.38	0.27	0
20.5	1057	1	0.72	18.97	2.63	0.073578	0.073445	0.18	0.34	0.27	0
20	1007	1	0.72	18.95	2.64	0.073360	0.073229	0.18	0.30	0.27	0
19.5	957	1	0.72	18.95	2.64	0.073182	0.073052	0.18	0.28	0.27	0
19	907	1	0.73	18.89	2.64	0.073017	0.072887	0.18	0.25	0.28	0
18.5	857	1.05	0.76	17.57	2.75	0.072692	0.072565	0.16	0.20	0.28	0
18	807	1.07	0.77	17.22	2.79	0.071686	0.071563	0.15	0.18	0.28	0
17.5	757	1.07	0.77	17.15	2.79	0.070613	0.070496	0.15	0.17	0.28	0
17	707	1.07	0.77	17.13	2.79	0.069650	0.069538	0.15	0.16	0.28	0
16.7	677	1.07	0.77	17.13	2.79	0.069120	0.069011	0.15	0.16	0.28	0
16.5	657	0.99	0.72	19.02	2.63	0.069094	0.068984	0.18	0.19	0.27	0
16	607	0.91	0.67	21.54	2.45	0.070100	0.069986	0.23	0.23	0.27	0
15.5	557	0.88	0.65	22.42	2.39	0.071958	0.071834	0.25	0.23	0.27	0
15.2	527	0.87	0.64	22.66	2.38	0.073184	0.073053	0.25	0.22	0.27	0
15	507	0.86	0.63	23.29	2.34	0.074110	0.073975	0.27	0.23	0.27	0
14.5	457	0.83	0.62	24.18	2.29	0.076695	0.076545	0.28	0.23	0.27	0
14.1	417	0.83	0.61	24.46	2.28	0.078881	0.078718	0.29	0.22	0.27	0
14	407	0.88	0.64	22.72	2.37	0.079645	0.079478	0.25	0.18	0.27	0
13.5	357	1.05	0.76	17.67	2.75	0.080504	0.080331	0.16	0.11	0.28	0
13	307	1.15	0.81	15.79	2.93	0.079525	0.079358	0.13	0.08	0.28	0
12.5	257	1.17	0.83	15.23	2.99	0.078120	0.077962	0.12	0.07	0.28	0
12	207	1.18	0.84	15.07	3.02	0.076685	0.076535	0.12	0.07	0.28	0
11.5	157	1.18	0.84	15.05	3.01	0.075319	0.075177	0.12	0.07	0.28	0
11	107	1.18	0.84	15.05	3.01	0.074036	0.073901	0.12	0.07	0.28	0
10.5	57	1.18	0.84	15.04	3.02	0.072848	0.072720	0.12	0.07	0.28	0
10	7	1.18	0.84	15.04	3.01	0.071740	0.071617	0.12	0.07	0.28	0
9.93	0	1.18	0.84	15.03	3.02	0.071586	0.071464	0.11	0.07	0.28	0

* Following BOR metholodology, it was found that there is no potential for the formation of slug flow or roll waves.

(Reference: Design of Small Canal Structures. Bureau of Reclamation. 1978. pgs. 108-115)

Table 15. Calculations for Slug Flow and Roll Waves for Design High Flow

Flow Rate (cfs): **33**

Mannings Roughness Coefficient **0.011**

Horiz. Bend No.	River Station	Centerline Radius (ft)
1	25 to 23	235
2	22 to 19.4	270
3	17.6 to 17	220
4	14 to 13	220
5	11 to 9.93	100

Bottom Width of Section is Approx. 0.18

SPECIFIC HEC-RAS OUTPUT PARAMETERS

HEC-RAS River Station	Cum Ch Len (ft)	Max Chl Dpth (ft)	Hydr Depth (ft)	Vel Total (ft/s)	W.P. Total (ft)	Cumm. EGL Slope from U/S End to Current (ft/ft)	Angle of EGL (radians)	Vedernikov Number	Montuori Number	d/wp	Height of Wave* (ft)
25	1507	1.34	0.94	21.77	3.36						
24.5	1457	1.34	0.95	21.59	3.37	0.074800	0.074661	0.14	3.88	0.28	0
24	1407	1.35	0.95	21.52	3.38	0.074100	0.073965	0.14	1.95	0.28	0
23.5	1357	1.35	0.95	21.5	3.38	0.073600	0.073468	0.14	1.30	0.28	0
23	1307	1.35	0.95	21.5	3.38	0.073350	0.073219	0.14	0.98	0.28	0
22.5	1257	1.35	0.95	21.5	3.38	0.073200	0.073070	0.14	0.79	0.28	0
22	1207	1.35	0.95	21.49	3.38	0.073067	0.072937	0.14	0.66	0.28	0
21.5	1157	1.35	0.95	21.5	3.38	0.073000	0.072871	0.14	0.56	0.28	0
21.4	1147	1.35	0.95	21.51	3.38	0.072972	0.072843	0.14	0.55	0.28	0
21	1107	1.35	0.95	21.42	3.39	0.072925	0.072796	0.14	0.49	0.28	0
20.5	1057	1.36	0.95	21.39	3.39	0.072800	0.072672	0.14	0.43	0.28	0
20	1007	1.36	0.95	21.36	3.39	0.072680	0.072552	0.14	0.39	0.28	0
19.5	957	1.36	0.95	21.36	3.39	0.072564	0.072437	0.14	0.36	0.28	0
19	907	1.36	0.95	21.3	3.4	0.072450	0.072324	0.14	0.32	0.28	0
18.5	857	1.42	0.99	20.01	3.53	0.072292	0.072167	0.12	0.27	0.28	0
18	807	1.44	1	19.53	3.58	0.071443	0.071322	0.12	0.24	0.28	0
17.5	757	1.45	1.01	19.36	3.6	0.070480	0.070364	0.11	0.22	0.28	0
17	707	1.46	1.01	19.31	3.6	0.069538	0.069426	0.11	0.21	0.28	0
16.7	677	1.46	1.01	19.31	3.6	0.069012	0.068903	0.11	0.20	0.28	0
16.5	657	1.37	0.96	21.04	3.43	0.068965	0.068856	0.13	0.24	0.28	0
16	607	1.26	0.89	23.66	3.2	0.069756	0.069643	0.17	0.28	0.28	0
15.5	557	1.22	0.87	24.82	3.11	0.071358	0.071237	0.18	0.28	0.28	0
15.2	527	1.21	0.86	25.21	3.08	0.072469	0.072343	0.19	0.28	0.28	0
15	507	1.18	0.84	25.88	3.03	0.073330	0.073199	0.20	0.28	0.28	0
14.5	457	1.15	0.82	26.95	2.96	0.075762	0.075617	0.21	0.28	0.28	0
14.1	417	1.14	0.82	27.37	2.93	0.077853	0.077696	0.22	0.27	0.28	0
14	407	1.19	0.84	25.83	3.04	0.078618	0.078457	0.20	0.24	0.28	0
13.5	357	1.38	0.97	20.81	3.45	0.079904	0.079735	0.13	0.15	0.28	0
13	307	1.51	1.04	18.47	3.7	0.079308	0.079143	0.10	0.11	0.28	0
12.5	257	1.56	1.07	17.51	3.82	0.078104	0.077946	0.09	0.10	0.28	0
12	207	1.59	1.09	17.12	3.87	0.076762	0.076611	0.09	0.09	0.28	0
11.5	157	1.59	1.09	16.99	3.89	0.075430	0.075287	0.09	0.09	0.28	0
11	107	1.6	1.09	16.97	3.89	0.074150	0.074015	0.09	0.09	0.28	0
10.5	57	1.59	1.09	16.94	3.89	0.072966	0.072836	0.09	0.08	0.28	0
10	7	1.6	1.09	16.94	3.89	0.071853	0.071730	0.09	0.08	0.28	0
9.93	0	1.59	1.09	16.93	3.9	0.071705	0.071583	0.09	0.08	0.28	0

* Following BOR metholodology, it was found that there is no potential for the formation of slug flow or roll waves.

(Reference: Design of Small Canal Structures. Bureau of Reclamation. 1978. pgs. 108-115)

3.3.1.3 Freeboard

Once the phenomenon of super-elevation was quantified, and once the possibility of the occurrence of unstable pulsating flow determined, the freeboard along the entire length of the channel alignment was computed. Freeboard provides for a water surface elevation that is higher than the design elevation, which can be caused by sedimentation, deviations from the design operational conditions, excess flows entering the system, increased roughness of the boundary surface, and accumulation of debris. Freeboard is always computed in addition to superelevation, standing waves, and translatory waves.

Required freeboard for canals and flood control channels has been expressed as a function of average velocity and flow depth (Clark County, 1999) or as a function of flow rate (BOR, 1978). Both references use a base of 1 foot of required freeboard and add additional freeboard as the hydraulic conditions (average velocity/flow rate) in the channel increase in magnitude. USACE (1994) states that freeboard cannot be fixed by a single, widely applicable formula, and recommends approximate freeboard allowances of 2 feet for rectangular cross sections and 2.5 feet for concrete-lined trapezoidal cross sections.

For the 33 cfs maximum design bypass flow rate, the required freeboard dictated by Clark County (1999) and BOR (1978) is very similar (approximately 1.5 feet). For the analysis of the Wynoochee Dam bypass facility, the following equation, adopted by the Clark County Regional Flood Control District, was used to determine minimum required freeboard:

$$F_b = 1.0 + 0.025 \times V \times \sqrt[3]{d} \qquad \text{(Equation 11)}$$

Where,

$F_b =$ required depth of freeboard (feet)

$V =$ cross section averaged velocity (feet/second)

$d =$ depth of flow (feet)

At each cross section in the hydraulic model, the required freeboard depth was computed using Equation 11 and the HEC-RAS output. The actual depth of freeboard, which is computed as the total depth of the flume minus the sum of the flow depth (including superelevation) and the wave height, was also computed at each cross section. The two values were compared with one another to verify that the actual freeboard was equal to or greater than the required freeboard throughout the alignment.

For the design low flow condition, the actual freeboard values, including the effects of superelevation and wave formation, ranged between 1.7 feet and 2.2 feet, and were consistently greater than the required freeboard values. For the design high flow condition, the actual freeboard values ranged between 1.2 feet and 1.9 feet, and with one exception, were consistently greater than the required freeboard values (refer to Table 14). The reach where the freeboard criteria was violated occurred at the horizontal bend located just upstream of the transitional ponds, where the gradient of the flume flattens from a 14.1% slope to a 4.0% slope. The cause of the freeboard violation is primarily due to the flat flume gradient, but is exacerbated by the presence of the 100-foot radius horizontal bend.

The freeboard violation could be corrected in one of four ways: by increasing the radius of the horizontal bend, by increasing the slope of the flume upstream of the transitional pond, by a combination of the two, or by locally increasing the height of the flume section by four inches. Due to the flat gradient, the horizontal bend radius would have to be increased to nearly 1,000-feet to satisfy the freeboard criteria, which is not a feasible option. The current gradient of the downstream portion of the flume currently results in an above grade alignment with the invert elevation nearly seven feet above existing grade. Increasing the gradient of the flume would increase the height of the above grade alignment, which is also not a very feasible option. The likely solution would be to increase the height of the flume section by four inches to provide for the required freeboard. All options should, however, be considered during final design.

The results of the freeboard analysis of the surge flow condition (Q= 60 cfs) concluded that the freeboard criteria would be violated along the entire length of the flume alignment, however, the surge flow condition would not result in overtopping of the flume.

Tables 16 through 18 summarize the results of the freeboard analysis for the three flow conditions. The model output using the 0.011 roughness coefficient was used throughout the freeboard calculations.

Table 16. Freeboard Calculations for Design Low Flow (with n = 0.011)

Flow Rate: **19**

Mannings Roughness Coefficient **0.011**

Horiz. Bend No.	River Station	Centerline Radius (ft)
1	25 to 23	235
2	22 to 19.4	270
3	17.6 to 17	220
4	14 to 13	220
5	11 to 9.93	100

Bottom Width of Section is Approx. 0.18

SPECIFIC HEC-RAS OUTPUT PARAMETERS

HEC-RAS River Station	Cum Ch Len (ft)	Max Chl Dpth (ft)	Hydr Depth (ft)	Vel Total (ft/s)	Top Width (ft)	Super-Elevation (ft)	Computed Freeboard[1] (ft)	Required Freeboard[2] (ft)	Freeboard Violation?
25	1507	0.96	0.7	20	1.36	0.07			
24.5	1457	0.98	0.72	19.27	1.38	0.07	2.0	1.5	
24	1407	0.99	0.72	19.11	1.38	0.07	1.9	1.5	
23.5	1357	0.99	0.72	19.09	1.38	0.07	1.9	1.5	
23	1307	0.99	0.72	19.08	1.38	0.07	1.9	1.5	
22.5	1257	0.99	0.72	19.08	1.38		2.0	1.5	
22	1207	0.99	0.72	19.08	1.38	0.06	2.0	1.5	
21.5	1157	0.99	0.72	19.08	1.38	0.06	2.0	1.5	
21.4	1147	0.99	0.72	19.08	1.38	0.06	2.0	1.5	
21	1107	1	0.72	18.98	1.38	0.06	1.9	1.5	
20.5	1057	1	0.72	18.97	1.38	0.06	1.9	1.5	
20	1007	1	0.72	18.95	1.38	0.06	1.9	1.5	
19.5	957	1	0.72	18.95	1.38	0.06	1.9	1.5	
19	907	1	0.73	18.89	1.39		2.0	1.5	
18.5	857	1.05	0.76	17.57	1.42		2.0	1.4	
18	807	1.07	0.77	17.22	1.43		1.9	1.4	
17.5	757	1.07	0.77	17.15	1.43	0.06	1.9	1.4	
17	707	1.07	0.77	17.13	1.43	0.06	1.9	1.4	
16.7	677	1.07	0.77	17.13	1.43		1.9	1.4	
16.5	657	0.99	0.72	19.02	1.38		2.0	1.5	
16	607	0.91	0.67	21.54	1.33		2.1	1.5	
15.5	557	0.88	0.65	22.42	1.31		2.1	1.5	
15.2	527	0.87	0.64	22.66	1.3		2.1	1.5	
15	507	0.86	0.63	23.29	1.29		2.1	1.6	
14.5	457	0.83	0.62	24.18	1.28		2.2	1.6	
14.1	417	0.83	0.61	24.46	1.27		2.2	1.6	
14	407	0.88	0.64	22.72	1.3	0.09	2.0	1.5	
13.5	357	1.05	0.76	17.67	1.42	0.06	1.9	1.4	
13	307	1.15	0.81	15.79	1.48	0.05	1.8	1.4	
12.5	257	1.17	0.83	15.23	1.5		1.8	1.4	
12	207	1.18	0.84	15.07	1.5		1.8	1.4	
11.5	157	1.18	0.84	15.05	1.5		1.8	1.4	
11	107	1.18	0.84	15.05	1.5	0.11	1.7	1.4	
10.5	57	1.18	0.84	15.04	1.5	0.11	1.7	1.4	
10	7	1.18	0.84	15.04	1.5	0.11	1.7	1.4	
9.93	0	1.18	0.84	15.03	1.51	0.11	1.7	1.4	

1 Computed freeboard includes superelevation, standing waves, and other surface disturbances.

2 Required Freeboard is a function of velocity and depth of flow (ref: Clark County Flood Control District and Bureau of Reclamation

(Reference: USACE. EM 1110-2-1601. Hydraulic Design of Flood Control Channels. 1991. pg 2-12)

Table 17. Freeboard Calculations for Design High Flow (with n = 0.011)

Flow Rate: **33**

Mannings Roughness Coefficient **0.011**

Horiz. Bend No.	River Station	Centerline Radius (ft)
1	25 to 23	235
2	22 to 19.4	270
3	17.6 to 17	220
4	14 to 13	220
5	11 to 9.93	100

Bottom Width of Section is Approx. 0.18

SPECIFIC HEC-RAS OUTPUT PARAMETERS

HEC-RAS River Station	Cum Ch Len (ft)	Max Chl Dpth (ft)	Hydr Depth (ft)	Vel Total (ft/s)	Top Width (ft)	Super-Elevation (ft)		Computed Freeboard[1] (ft)	Required Freeboard[2] (ft)	Freeboard Violation?
25	1507	1.34	0.94	21.77	1.61	0.10				
24.5	1457	1.34	0.95	21.59	1.62	0.10		1.6	1.6	
24	1407	1.35	0.95	21.52	1.62	0.10		1.6	1.6	
23.5	1357	1.35	0.95	21.5	1.62	0.10		1.6	1.6	
23	1307	1.35	0.95	21.5	1.62	0.10		1.6	1.6	
22.5	1257	1.35	0.95	21.5	1.62			1.7	1.6	
22	1207	1.35	0.95	21.49	1.62	0.09		1.6	1.6	
21.5	1157	1.35	0.95	21.5	1.62	0.09		1.6	1.6	
21.4	1147	1.35	0.95	21.51	1.62	0.09		1.6	1.6	
21	1107	1.35	0.95	21.42	1.62	0.09		1.6	1.6	
20.5	1057	1.36	0.95	21.39	1.62	0.09		1.6	1.6	
20	1007	1.36	0.95	21.36	1.62	0.09		1.6	1.6	
19.5	957	1.36	0.95	21.36	1.62	0.09		1.6	1.6	
19	907	1.36	0.95	21.3	1.63			1.6	1.6	
18.5	857	1.42	0.99	20.01	1.67			1.6	1.6	
18	807	1.44	1	19.53	1.68			1.6	1.6	
17.5	757	1.45	1.01	19.36	1.69	0.09		1.5	1.5	
17	707	1.46	1.01	19.31	1.69	0.09		1.5	1.5	
16.7	677	1.46	1.01	19.31	1.69			1.5	1.5	
16.5	657	1.37	0.96	21.04	1.63			1.6	1.6	
16	607	1.26	0.89	23.66	1.56			1.7	1.6	
15.5	557	1.22	0.87	24.82	1.53			1.8	1.7	
15.2	527	1.21	0.86	25.21	1.52			1.8	1.7	
15	507	1.18	0.84	25.88	1.51			1.8	1.7	
14.5	457	1.15	0.82	26.95	1.49			1.9	1.7	
14.1	417	1.14	0.82	27.37	1.48			1.9	1.7	
14	407	1.19	0.84	25.83	1.51	0.14		1.7	1.7	
13.5	357	1.38	0.97	20.81	1.64	0.10		1.5	1.6	Y
13	307	1.51	1.04	18.47	1.72	0.08		1.4	1.5	Y
12.5	257	1.56	1.07	17.51	1.76			1.4	1.5	Y
12	207	1.59	1.09	17.12	1.77			1.4	1.5	Y
11.5	157	1.59	1.09	16.99	1.78			1.4	1.5	Y
11	107	1.6	1.09	16.97	1.78	0.16		1.2	1.5	Y
10.5	57	1.59	1.09	16.94	1.78	0.16		1.3	1.5	Y
10	7	1.6	1.09	16.94	1.78	0.16		1.2	1.5	Y
9.93	0	1.59	1.09	16.93	1.78	0.16		1.3	1.5	Y

1 Computed freeboard includes superelevation, standing waves, and other surface disturbances.

2 Required Freeboard is a function of velocity and depth of flow (ref: Clark County Flood Control District and Bureau of Reclamation

(Reference: USACE. EM 1110-2-1601. Hydraulic Design of Flood Control Channels. 1991. pg 2-12)

Table 18. Freeboard Calculations for Design Surge Flow (with n = 0.011)

Flow Rate: 60

Mannings Roughness Coefficient 0.011

Horiz. Bend No.	River Station	Centerline Radius (ft)
1	25 to 23	235
2	22 to 19.4	270
3	17.6 to 17	220
4	14 to 13	220
5	11 to 9.93	100

Bottom Width of Section is Approx. 0.18

SPECIFIC HEC-RAS OUTPUT PARAMETERS

HEC-RAS River Station	Cum Ch Len (ft)	Max Chl Dpth (ft)	Hydr Depth (ft)	Vel Total (ft/s)	Top Width (ft)	Super-Elevation (ft)		Computed Freeboard[1] (ft)	Required Freeboard[2] (ft)	Freeboard Violation?
25	1507	1.9	1.27	23.82	1.98	0.15				
24.5	1457	1.88	1.26	24.05	1.97	0.15		1.0	1.7	Y
24	1407	1.88	1.26	24.19	1.97	0.15		1.0	1.7	Y
23.5	1357	1.87	1.26	24.28	1.97	0.15		1.0	1.7	Y
23	1307	1.87	1.25	24.34	1.97	0.15		1.0	1.7	Y
22.5	1257	1.86	1.25	24.37	1.96			1.1	1.7	Y
22	1207	1.87	1.25	24.39	1.96	0.13		1.0	1.8	Y
21.5	1157	1.86	1.25	24.4	1.96	0.13		1.0	1.8	Y
21.4	1147	1.87	1.25	24.41	1.96	0.13		1.0	1.8	Y
21	1107	1.87	1.25	24.33	1.97	0.13		1.0	1.7	Y
20.5	1057	1.87	1.25	24.31	1.97	0.13		1.0	1.7	Y
20	1007	1.87	1.26	24.28	1.97	0.13		1.0	1.7	Y
19.5	957	1.87	1.26	24.28	1.97	0.13		1.0	1.7	Y
19	907	1.88	1.26	24.22	1.97			1.1	1.7	Y
18.5	857	1.94	1.31	22.99	2			1.1	1.7	Y
18	807	1.98	1.34	22.41	2			1.0	1.7	Y
17.5	757	1.99	1.36	22.14	2	0.14		0.9	1.7	Y
17	707	2	1.36	22.03	2	0.14		0.9	1.7	Y
16.7	677	2	1.36	22.01	2			1.0	1.7	Y
16.5	657	1.91	1.28	23.58	1.99			1.1	1.7	Y
16	607	1.78	1.2	26.19	1.91			1.2	1.8	Y
15.5	557	1.72	1.17	27.59	1.87			1.3	1.8	Y
15.2	527	1.7	1.15	28.12	1.85			1.3	1.8	Y
15	507	1.67	1.14	28.85	1.83			1.3	1.9	Y
14.5	457	1.62	1.11	30.1	1.8			1.4	1.9	Y
14.1	417	1.6	1.1	30.69	1.79			1.4	1.9	Y
14	407	1.65	1.12	29.35	1.82	0.22		1.1	1.9	Y
13.5	357	1.86	1.25	24.56	1.96	0.17		1.0	1.8	Y
13	307	2.02	1.37	21.92	2	0.14		0.8	1.7	Y
12.5	257	2.1	1.46	20.54	2			0.9	1.7	Y
12	207	2.16	1.51	19.85	2			0.8	1.6	Y
11.5	157	2.17	1.54	19.52	2			0.8	1.6	Y
11	107	2.19	1.55	19.37	2	0.23		0.6	1.6	Y
10.5	57	2.19	1.55	19.3	2	0.23		0.6	1.6	Y
10	7	2.2	1.56	19.29	2	0.23		0.6	1.6	Y
9.93	0	2.19	1.56	19.28	2	0.23		0.6	1.6	Y

1 Computed freeboard includes superelevation, standing waves, and other surface disturbances.

2 Required Freeboard is a function of velocity and depth of flow (ref: Clark County Flood Control District and Bureau of Reclamation

(Reference: USACE. EM 1110-2-1601. Hydraulic Design of Flood Control Channels. 1991. pg 2-12)

3.3.2 Sensitivity Analysis

The sensitivity of the open channel hydraulic analysis to variation in Manning's roughness coefficient was assessed by increasing the Manning's roughness coefficient to 0.012, which is a typical value for "concrete, steel troweled" (Henderson 1966). The roughness coefficients in the HEC-RAS model were increased to 0.012, and the three design flow rates were run through the model. The following conclusions were made:

- For all flow rates, the increased roughness coefficient resulted in a decrease in the dimensionless Vedernikov and Montuori numbers, which are used as indicators in determining whether the flow regime is stable or unstable and if pulsating flow can be expected. As expected, the increased roughness coefficient therefore did not result in an unstable, pulsating flow regime.
- For the design low flow condition, the actual freeboard is less than the required freeboard along the entire length of the alignment. The difference is approximately 4 inches.
- For the design high flow condition, the actual freeboard is less than the required freeboard at all five of the horizontal bends. Typically, the actual freeboard is 1" to 2" less than that determined with Equation 11. However, there remains at least 1.2 feet of freeboard at all cross section locations.
- The flume is not predicted to overtop under any of the design flow conditions, including the surge flow condition.

The results of the sensitivity analysis indicate that the open channel hydraulic analysis and the currently proposed flume design is sensitive to the value of the Manning's roughness coefficient. There are many factors that can make selection of either of the modeled Manning's roughness coefficients appropriate. It may not be a significant issue if the depth of the required freeboard is not met due to the selection of a rougher Manning's coefficient, due mainly to the fact that the selection of a rougher, more conservative Manning's coefficient takes into account what the freeboard allowance is intended to account for.

4. REFERENCES

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Appendix C

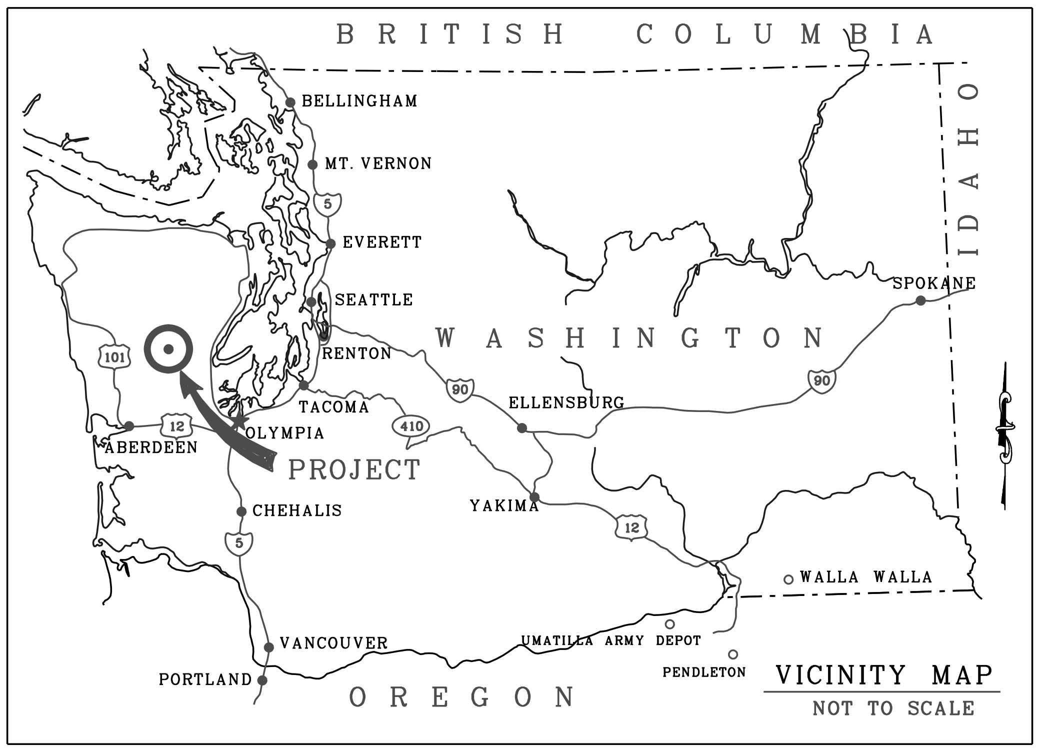
35% Plan Sheets (Bound Separately)

U.S. ARMY CORPS
OF ENGINEERS
SEATTLE DISTRICT

WYNOOCHEE DAM

SECTION 1135 FISH RESTORATION PROJECT

GRAYS HARBOR COUNTY, WASHINGTON



VICINITY MAP
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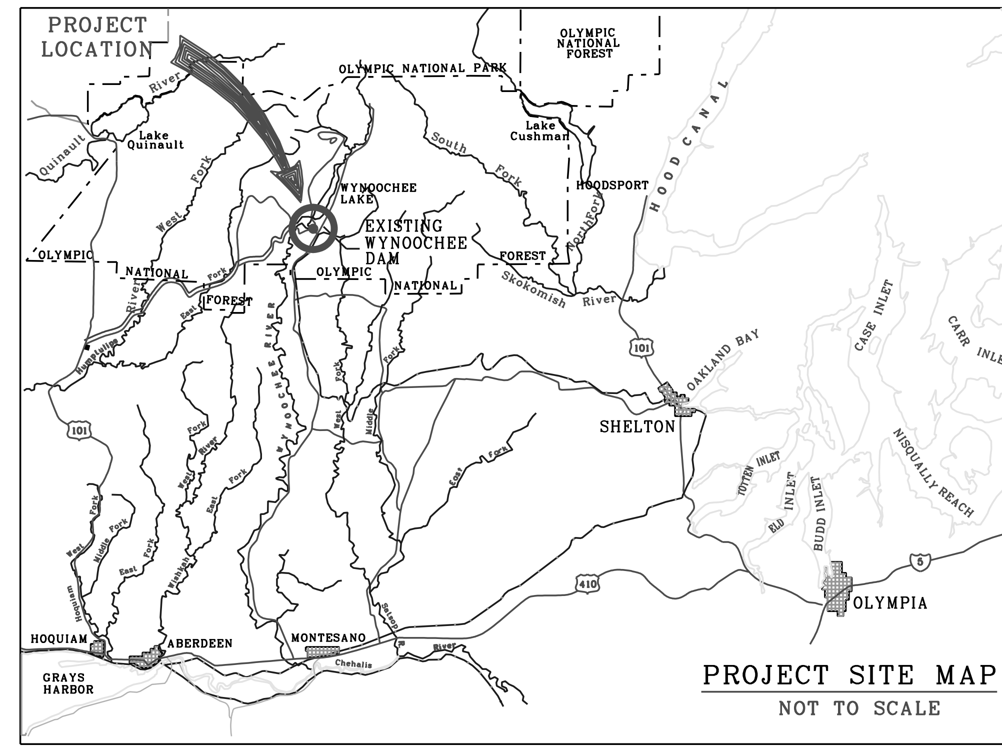

PROJECT SITE MAP
NOT TO SCALE

THIS PROJECT WAS DESIGNED BY:
TETRA TECH, INC.
FOR THE U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT

TETRA TECH, INC.
1925 POST ALLEY, STE. 4
SEATTLE, WA 98101
(206) 728-9655

COMPUTER AIDED DESIGN & DRAFTING

CONTRACT NO. DACA67-02-D-2009
DELIVERY ORDER NO. 0002

SAFETY PAYS

VALUE ENGINEERING PAYS

35% DESIGN

TETRA TECH INC.
SEATTLE, WASHINGTON

U.S. ARMY ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

WYNOOCHEE DAM
SECTION 1135 FISH RESTORATION PROJECT

TITLE PAGE

GRAYS HARBOR COUNTY, WASHINGTON

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D	DACA67-02-D-2009		AUG 2003	G1
DSGN. JS		CHK. YC	SHEET 1	

REVISIONS				
SYMBOL	ZONE	DESCRIPTION	DATE	BY

SHEET INDEX

GENERAL NOTES

GENERAL CONSTRUCTION NOTES

1. CONSTRUCTOR SHALL FURNISH ALL MATERIALS, EQUIPMENT, AND LABOR NECESSARY TO COMPLETE ALL WORK AS INDICATED ON THE CONSTRUCTION DOCUMENTS.

2. THE CONSTRUCTOR SHALL VISIT THE JOB SITE AND BE RESPONSIBLE FOR ALL CONTRACT DOCUMENTS, FIELD CONDITIONS AND DIMENSIONS, AND CONFIRMING THAT THE WORK MAY BE ACCOMPLISHED AS SHOWN PRIOR TO PROCEEDING WITH CONSTRUCTION.

3. ANY DISCREPANCIES ARE TO BE BROUGHT TO THE ATTENTION OF THE COE AND ARCHITECT/ENGINEER PRIOR TO PROCEEDING WITH THE WORK.

4. THE CONSTRUCTOR SHALL RECEIVE, IN WRITING, AUTHORIZATION TO PROCEED BEFORE STARTING WORK ON ANY ITEM NOT CLEARLY DEFINED OR IDENTIFIED BY THE CONTRACT DOCUMENTS.

5. THE CONSTRUCTOR SHALL INSTALL ALL EQUIPMENT AND MATERIALS IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS UNLESS SPECIFICALLY INDICATED OTHERWISE OR WHERE LOCAL CODES OR REGULATIONS TAKE PRECEDENCE.

6. ALL WORK PERFORMED AND MATERIALS INSTALLED SHALL BE IN STRICT ACCORDANCE WITH ALL APPLICABLE CODES, REGULATIONS AND ORDINANCES.

7. CONSTRUCTOR SHALL ASSUME SOLE AND COMPLETE RESPONSIBILITY FOR JOB SITE CONDITIONS DURING THE COURSE OF CONSTRUCTION OF THIS PROJECT INCLUDING SAFETY OF ALL PERSONS AND PROPERTY. THIS REQUIREMENT SHALL APPLY CONTINUOUSLY AND NOT BE LIMITED TO NORMAL WORKING HOURS.

8. THE CONSTRUCTOR SHALL DEFEND, INDEMNIFY AND HOLD THE COE AND THE ARCHITECT/ENGINEER HARMLESS FROM ANY AND ALL LIABILITY, REAL OR ALLEGED, IN CONNECTION WITH THE PERFORMANCE OF WORK ON THIS PROJECT, EXCEPTING FOR LIABILITY ARISING FROM THE SOLE NEGLIGENCE OF THE COE OR THE ARCHITECT/ENGINEER.

9. THE CONSTRUCTOR SHALL SUPERVISE AND DIRECT THE WORK, USING THE BEST SKILLS AND ATTENTION. THE CONSTRUCTOR SHALL BE SOLELY RESPONSIBLE FOR ALL CONSTRUCTION MEANS, METHODS, TECHNIQUES, SEQUENCES AND PROCEDURES AND FOR COORDINATING ALL PORTIONS OF THE WORK UNDER THIS CONTRACT.

10. DETAILS ARE INTENDED TO SHOW FINAL RESULT OF DESIGN. MINOR MODIFICATIONS MAY BE REQUIRED TO SUIT JOB SITE DIMENSIONS OR CONDITIONS, AND SUCH MODIFICATIONS SHALL BE INCLUDED AS PART OF THE WORK.

11. THE CONSTRUCTOR SHALL MAKE ALL NECESSARY PROVISIONS TO PROTECT EXISTING IMPROVEMENTS, ROADWAY, DRAINAGE WAYS, CULVERTS, AND VEGETATION UNTIL SUCH ITEMS ARE TO BE DISTURBED OR REMOVED AS INDICATED ON THE CONSTRUCTION DOCUMENTS.

12. CONSTRUCTOR SHALL KEEP JOB SITE AREA CLEAN, HAZARD FREE, AND DISPOSE OF ALL DIRT, DEBRIS, RUBBISH AND AT COMPLETION OF PROJECT REMOVE ALL MATERIAL AND EQUIPMENT NOT SPECIFIED AS REMAINING ON THE PROPERTY.

13. REPRESENTATIONS OF TRUE NORTH SHALL NOT BE USED TO IDENTIFY OR ESTABLISH THE BEARING OF TRUE NORTH AT THIS JOB SITE.

14. IT SHALL BE THE RESPONSIBILITY OF THE CONSTRUCTOR TO LOCATE ALL EXISTING UTILITIES WHETHER SHOWN HEREON OR NOT AND TO PROTECT THEM FROM DAMAGE. CONSTRUCTOR SHALL CALL LOCAL DIGGER HOTLINE FOR UTILITY LOCATIONS 48 HOURS PRIOR TO START OF CONSTRUCTION.

15. SIZE, LOCATION AND TYPE OF ANY UNDERGROUND UTILITIES OR IMPROVEMENTS SHALL BE ACCURATELY NOTED AND PLACED ON AS-BUILT DRAWINGS BY THE CONSTRUCTOR AND ISSUED TO THE ARCHITECT/ENGINEER AT COMPLETION OF THE PROJECT.

STANDARD CIVIL NOTES

1. ALL SITE WORK SHALL BE AS INDICATED ON THE CONSTRUCTION DOCUMENTS, WHICH INCLUDE THE DESIGN REPORT.

2. DO NOT EXCAVATE OR DISTURB BEYOND THE JOB SITE AREA, UNLESS NOTED OTHERWISE.

3. RUBBISH, DEBRIS, AND OTHER REFUSE SHALL BE REMOVED FROM THE JOB SITE AND DISPOSED OF LEGALLY.

4. NO TOP SOIL, ORGANIC SPOILS, FILL, EXCAVATED MATERIAL, RIPRAP, FOUNDATION MATERIAL, EQUIPMENT OR ANY OTHER SUCH ITEMS SHALL BE PLACED, STOCKPILED OR PARKED IN THE EXISTING ROADWAY.

5. ALL EXISTING ACTIVE UTILITIES WHERE ENCOUNTERED IN THE WORK, SHALL BE PROTECTED AT ALL TIMES, AND WHERE REQUIRED FOR THE PROPER EXECUTION OF WORK, SHALL BE RELOCATED AS DIRECTED BY THE ARCHITECT/ENGINEER.

6. EXTREME CAUTION SHOULD BE USED BY THE CONSTRUCTOR WHEN EXCAVATING AROUND OR NEAR UTILITIES. CONSTRUCTOR SHALL PROVIDE SAFETY TRAINING FOR THE WORK CREW.

7. ALL INACTIVE UTILITIES WHICH INTERFERE WITH THE EXECUTION OF WORK, SHALL BE REMOVED AND SHALL BE CAPPED, PLUGGED OR OTHERWISE DISCONTINUED AT POINTS WHICH WILL NOT INTERFERE WITH THE EXECUTION OF THE WORK, SUBJECT TO THE APPROVAL OF THE ARCHITECT/ENGINEER.

8. THE AREAS OF THE JOB SITE DISTURBED BY THE WORK AND NOT PART OF THE NEW IMPROVEMENT, SHALL BE GRADED TO A UNIFORM SLOPE AND REVEGETATED AS SPECIFIED HEREON.

GENERAL STRUCTURAL NOTES

1. WHERE A CONSTRUCTION DETAIL IS NOT SHOWN OR NOTED, THE DETAIL SHALL BE THE SAME AS FOR OTHER SIMILAR WORK.

2. NOTES AND DETAILS ON THE CONSTRUCTION DOCUMENTS SHALL TAKE PRECEDENCE OVER GENERAL NOTES.

3. DIMENSIONS SHALL TAKE PRECEDENCE OVER SCALES SHOWN ON THE CONSTRUCTION DOCUMENTS.

4. THE CONSTRUCTION DOCUMENTS REPRESENT THE FINISHED STRUCTURE. THEY DO NOT INDICATE THE METHOD OF CONSTRUCTION. THE CONSTRUCTOR SHALL PROVIDE ALL MEASURES NECESSARY TO PROTECT THE STRUCTURES, WORKERS, PEDESTRIANS, AND MOTORIST DURING CONSTRUCTION. SUCH MEASURES SHALL INCLUDE, BUT NOT LIMITED TO BRACING, SHORING FOR LOADS DUE TO CONSTRUCTION EQUIPMENT, TEMPORARY STRUCTURES, PARTIALLY COMPLETED WORK, AND ETC. OBSERVATION VISITS TO THE JOB SITE BY THE ARCHITECT/ENGINEER SHALL NOT INCLUDE INSPECTION OF SUCH ITEMS.

5. ASTM SPECIFICATIONS NOTED ON THE CONSTRUCTION DOCUMENTS SHALL BE OF THE LATEST REVISION.

LEGEND

- EXISTING GROUND
- EXISTING TREELINE
- EXISTING FENCE LINE
- EXISTING 2' CONTOUR (RECENT SURVEY)
- EXISTING 2' CONTOUR (PREVIOUS SURVEY)
- EXISTING STRUCTURE
- EDGE OF WATER
- ENERGY GRADE LINE
- PROPOSED GRADE LINES
- PROPOSED TREELINE
- PROPOSED STRUCTURE
- PROPOSED CONTROL LINE
- PROPOSED FLOWLINE
- PROPOSED FENCE LINE
- PROPOSED RIPRAP
- PROPOSED CONCRETE
- COMPACTED SOIL
- WATER SURFACE
- ℄ CENTERLINE
- SLOPE

ABBREVIATIONS

AC	ASPHALTIC CONCRETE
A/E	ARCHITECT/ENGINEER
ALT	ALTERNATE
ASTM	AMERICAN SOCIETY FOR TESTING AND MATERIALS
CF	CUBIC FEET
CFS	CUBIC FEET PER SECOND
℄	CENTERLINE
CMP	CORRUGATED METAL PIPE
COE	CORPS OF ENGINEERS
CONC.	CONCRETE
CP	CONTROL POINT
CY	CUBIC YARD
DIA	DIAMETER
DI	DUCTILE IRON
D/S	DOWNSTREAM
EA	EACH
EL	ELEVATION
EXST	EXISTING
(E)	EAST
FT	FEET
GA	GAUGE
GAL	GALLON
GB	GRADE BREAK
GRN	GREEN
HDPE	HIGH DENSITY POLYETHYLENE PIPE
HHW	HIGHER HIGH WATER
HOR	HORIZONTAL
HW	HIGH WATER
IE	INVERT ELEVATION
LBS	POUNDS
LF	LINEAR FEET
LRFD	LOAD RESISTANCE FACTOR DESIGN
LS	LUMP SUM
MAX	MAXIMUM
MIN	MINIMUM
NTS	NOT TO SCALE
OC	ON CENTER
OD	OUTSIDE DIAMETER
OHW	ORDINARY HIGH WATER
PHSE	POWER HOUSE
PL	PLATE
PVC	POLYVINYL CHLORIDE
R	RADIUS
RD	ROAD
S	SLOPE
SD	STORM DRAIN
SS	SANITARY SEWER
SF	SQUARE FEET
STA	STATION
SY	SQUARE YARD
TBD	TO BE DETERMINED
(TYP)	TYPICAL
U/S	UPSTREAM
UG	UNDERGROUND
USFS	UNITED STATES FOREST SERVICE
UTL	UTILITY
VERT	VERTICAL
VLF	VERTICAL LINEAR FEET
W	WEST
WS	WATER SURFACE

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WYNOOCHEE DAM
SECTION 1135 FISH RESTORATION PROJECT

SHEET INDEX, GENERAL NOTES, LEGEND AND ABBREVIATIONS

GRAYS HARBOR COUNTY, WASHINGTON

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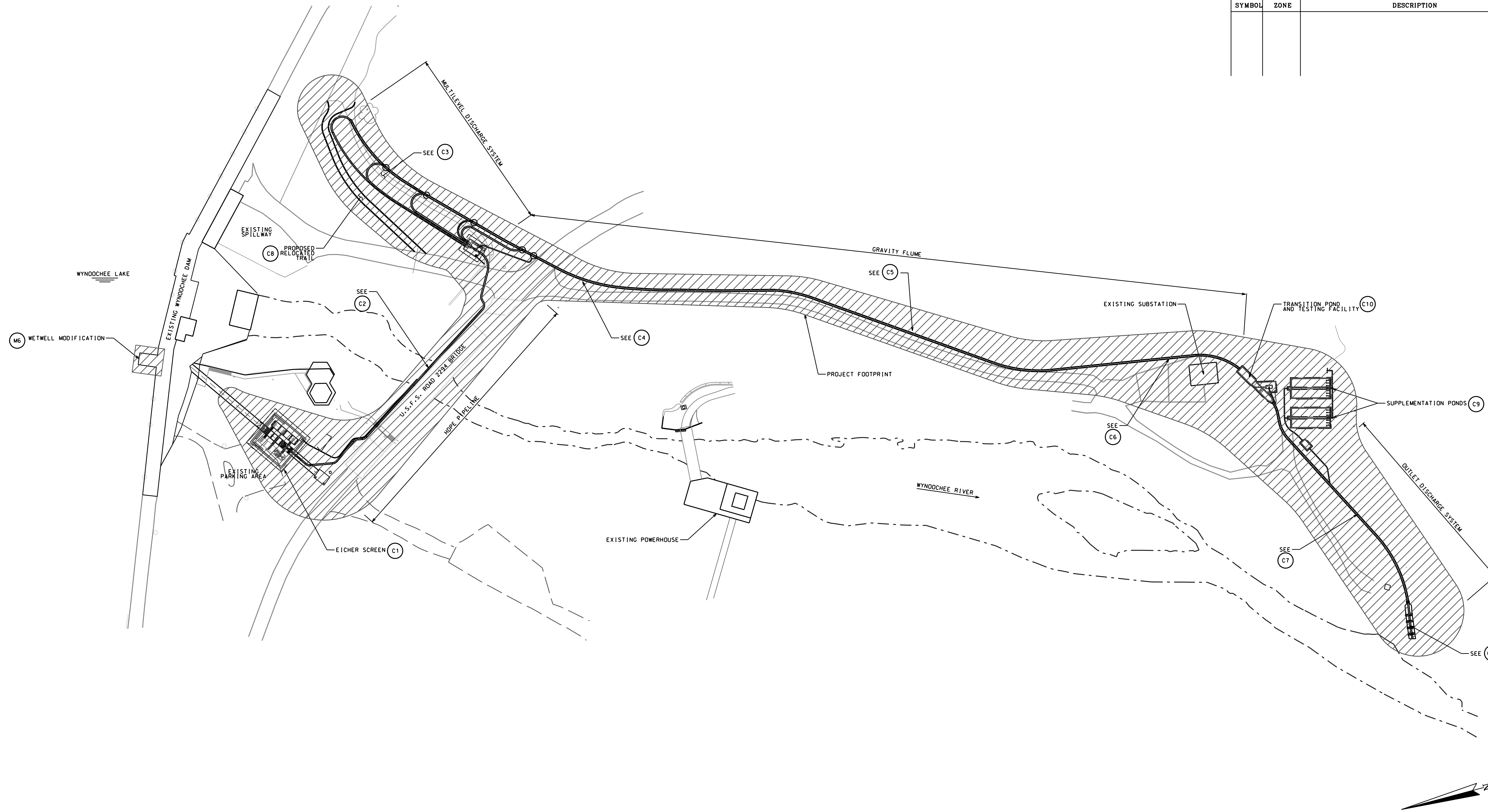

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WYNOOCHEE DAM
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LOCATION MAP

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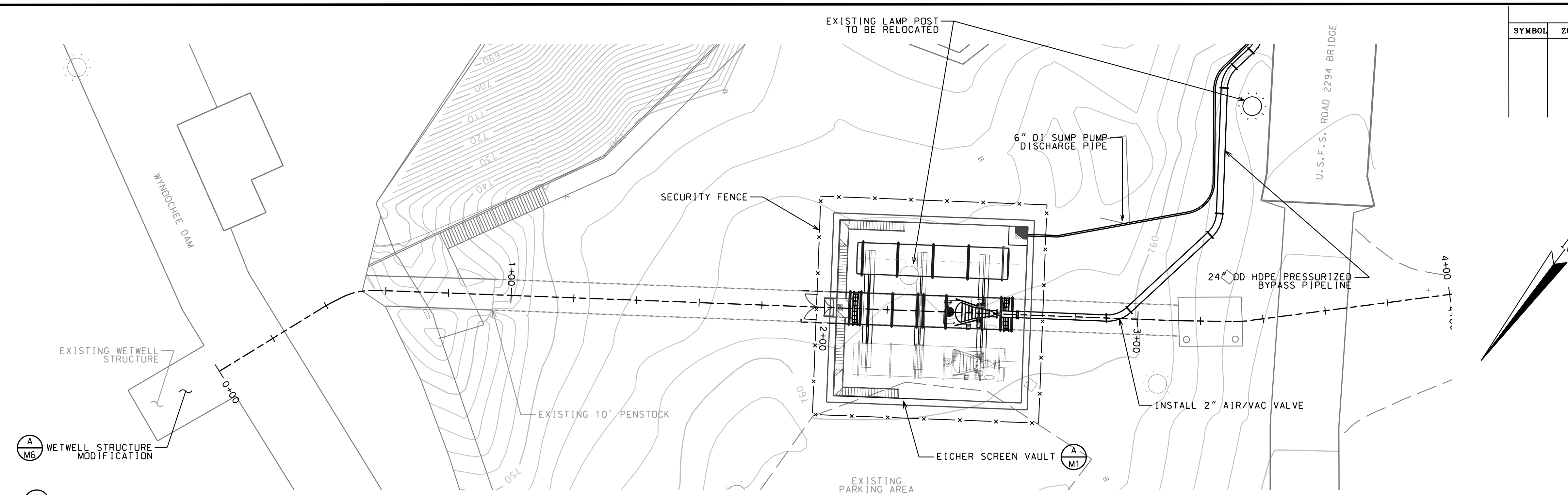

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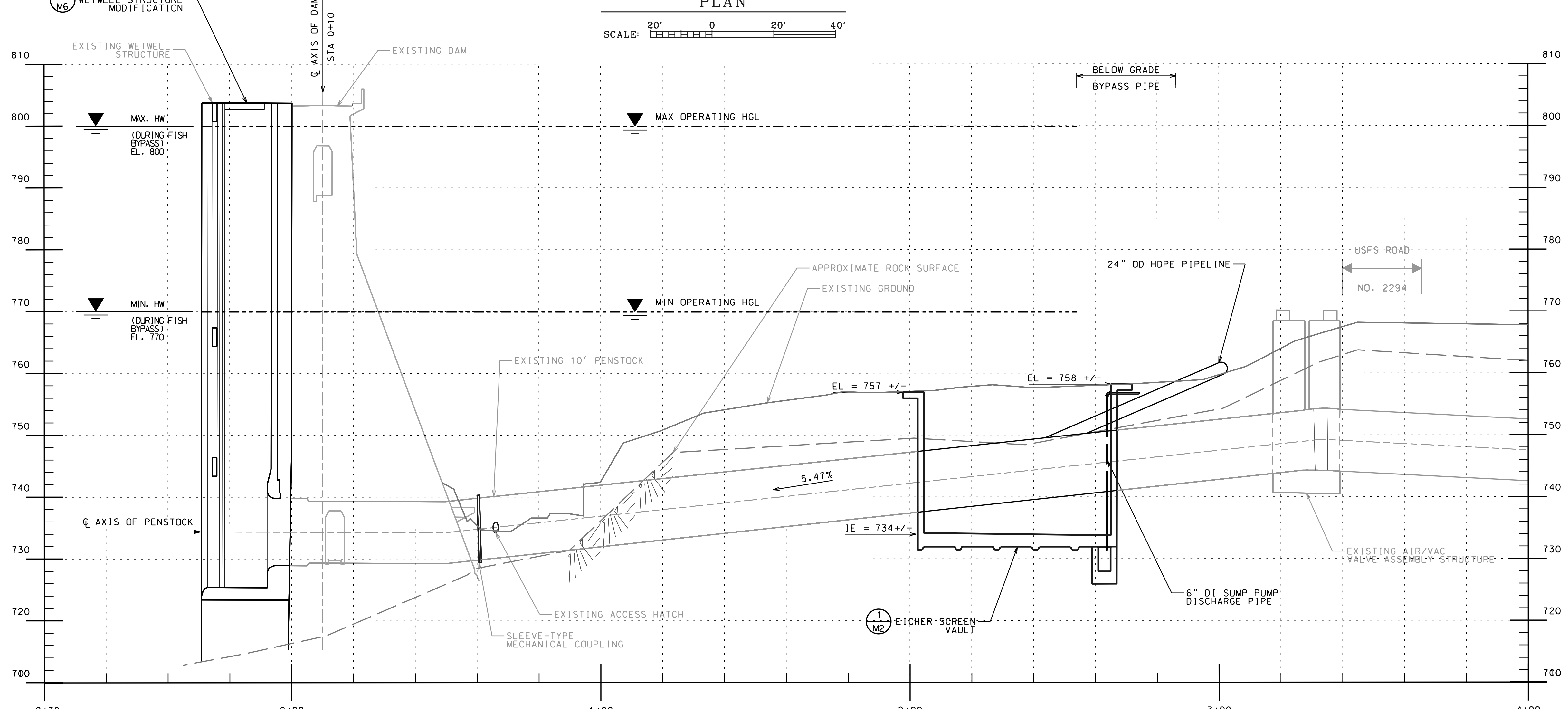

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SECTION 1135 FISH RESTORATION PROJECT

PENSTOCK EICHER SCREEN SLIDING PIPE
SITE PLAN AND PROFILE

GRAYS HARBOR COUNTY, WASHINGTON

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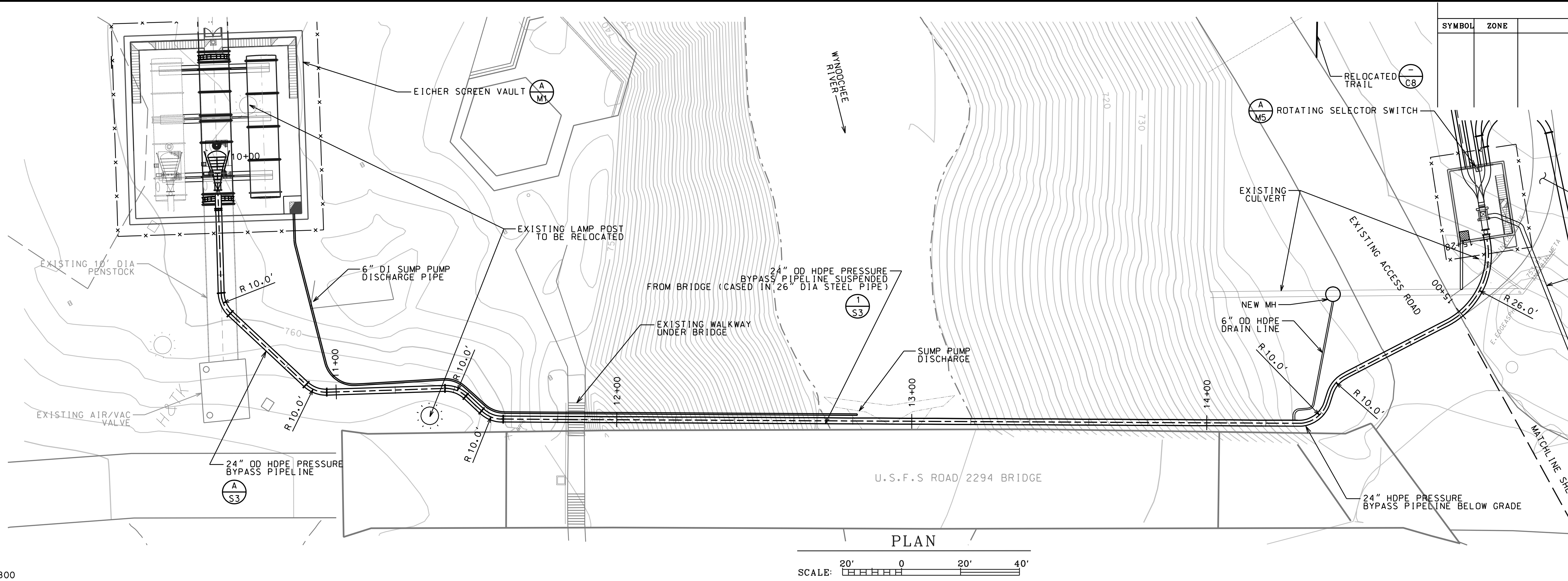

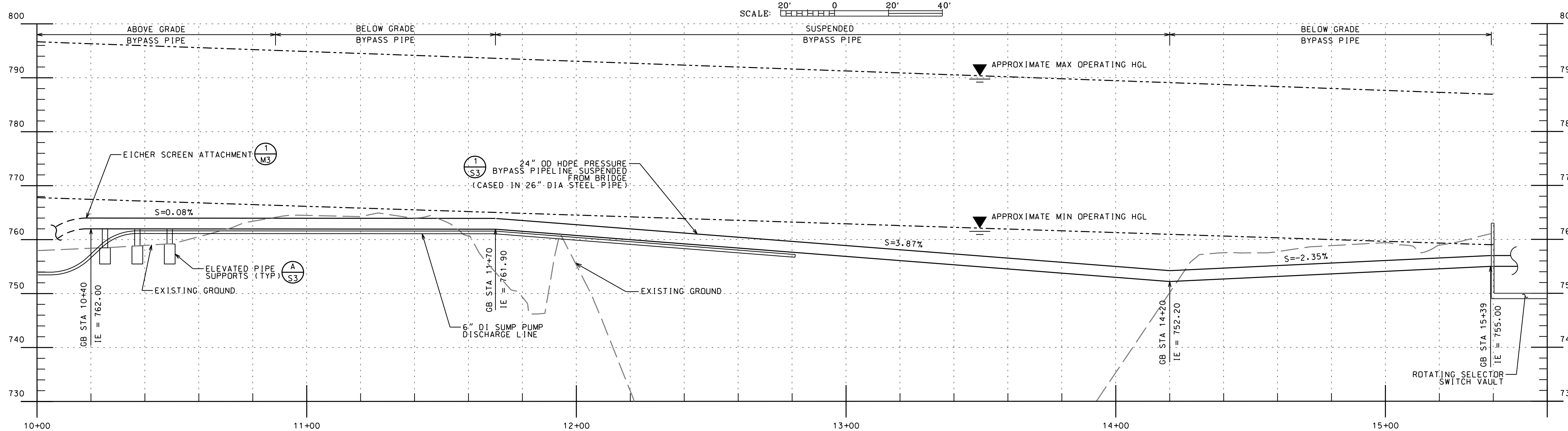

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PRESSURIZED HDPE BYPASS PIPELINE
PLAN AND PROFILE

GRAYS HARBOR COUNTY, WASHINGTON

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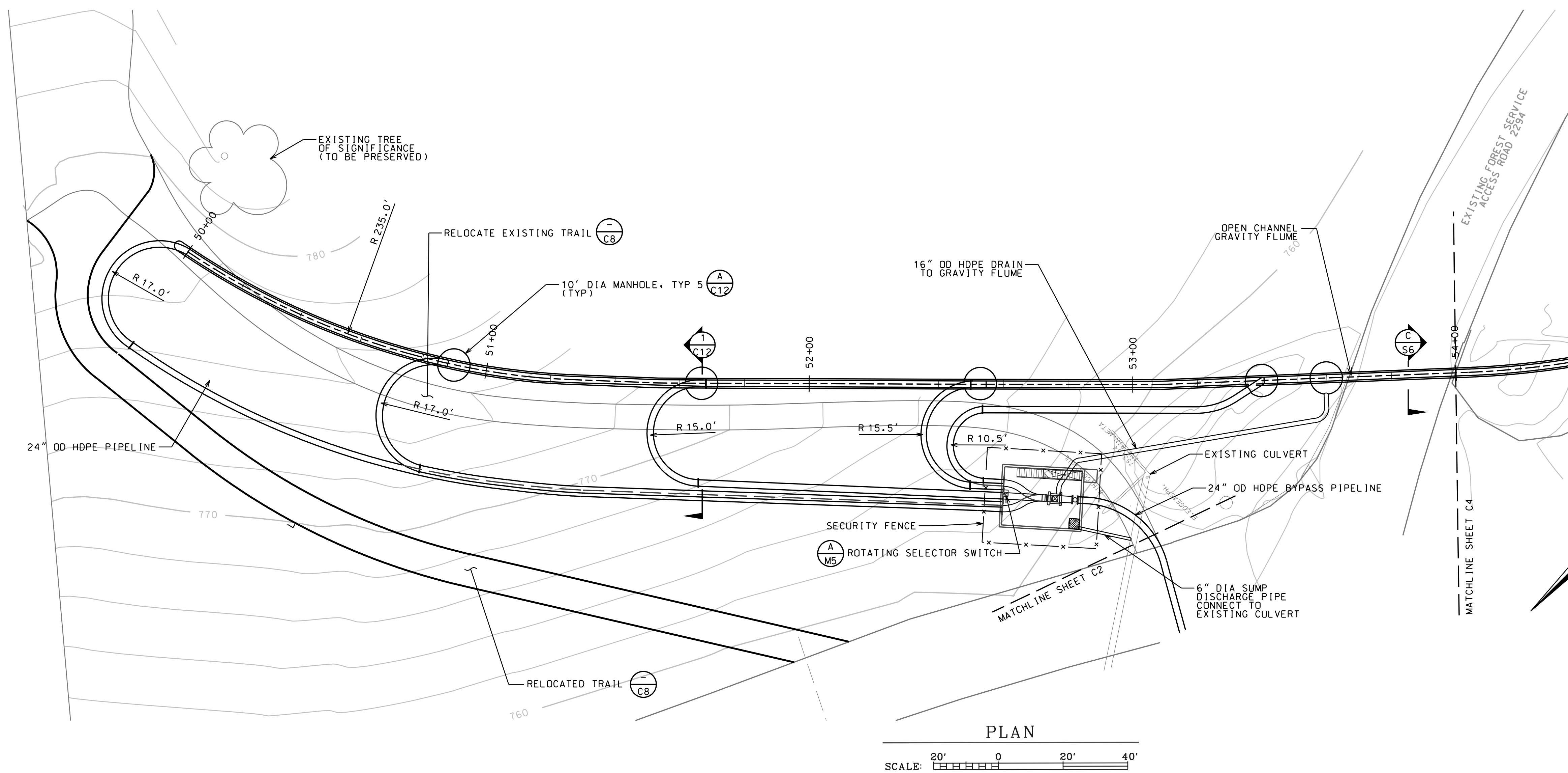

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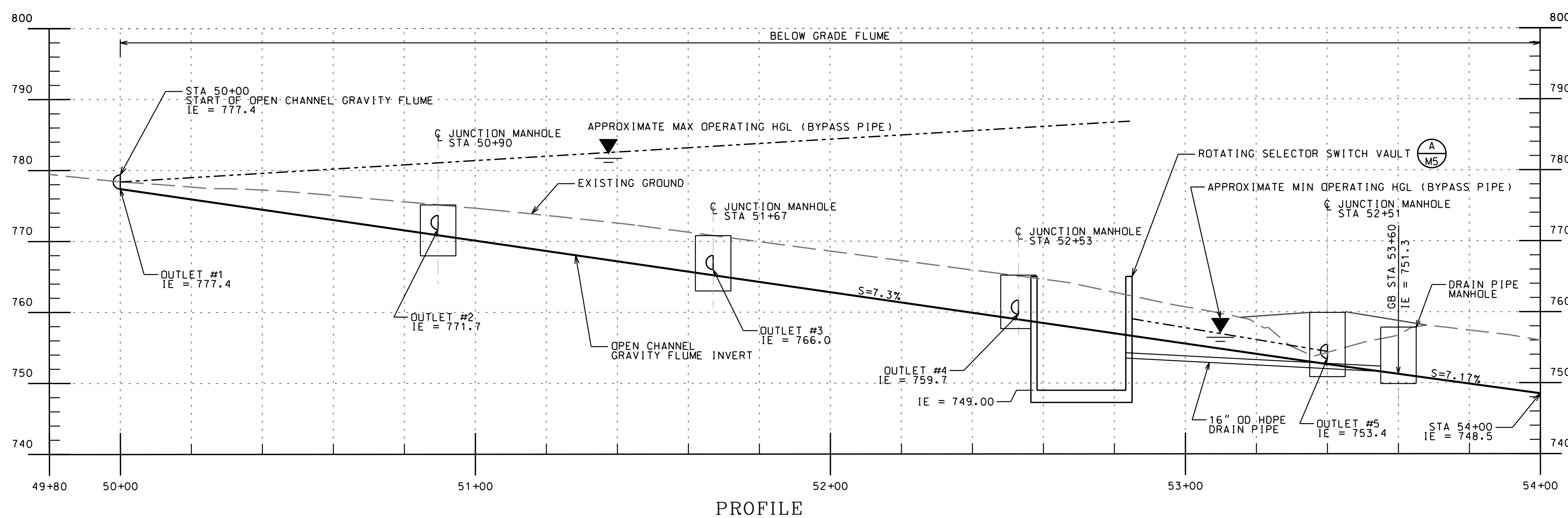

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SECTION 1135 FISH RESTORATION PROJECT

GRAVITY FLUME
PLAN AND PROFILE

GRAYS HARBOR COUNTY, WASHINGTON

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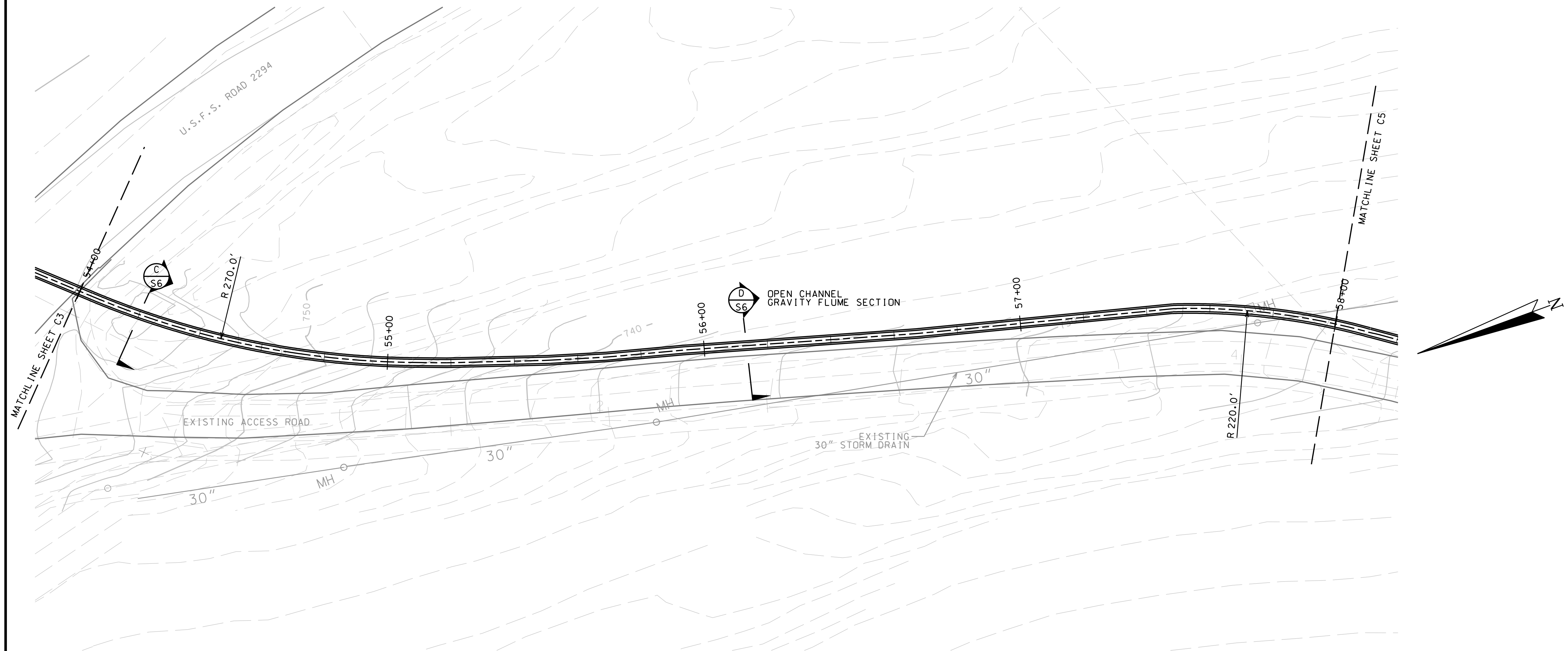

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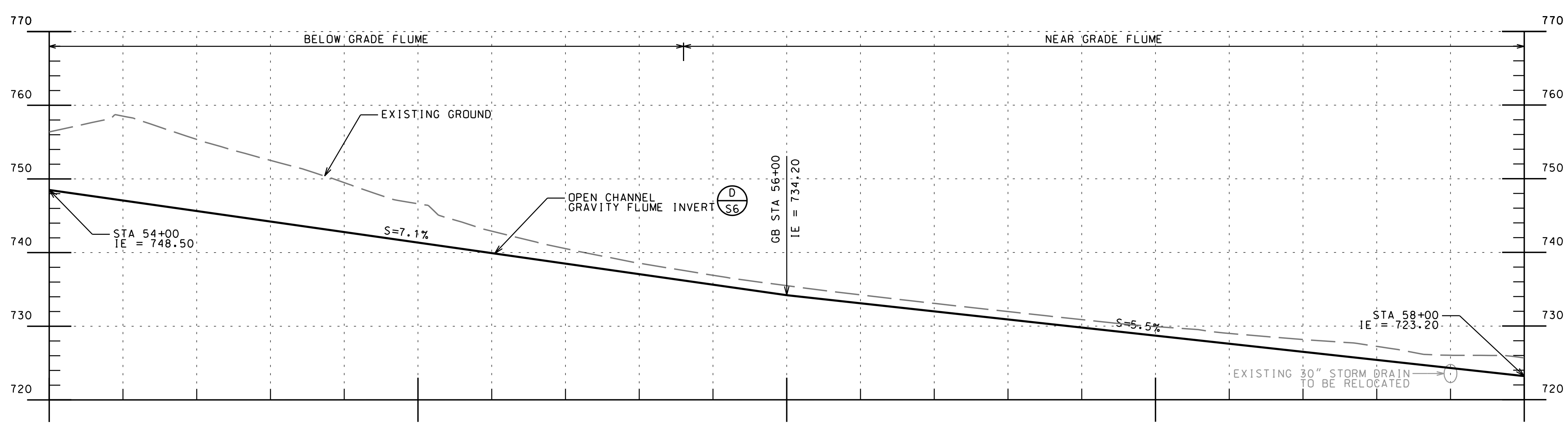

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SECTION 1135 FISH RESTORATION PROJECT

GRAVITY FLUME
PLAN AND PROFILE

GRAYS HARBOR COUNTY, WASHINGTON

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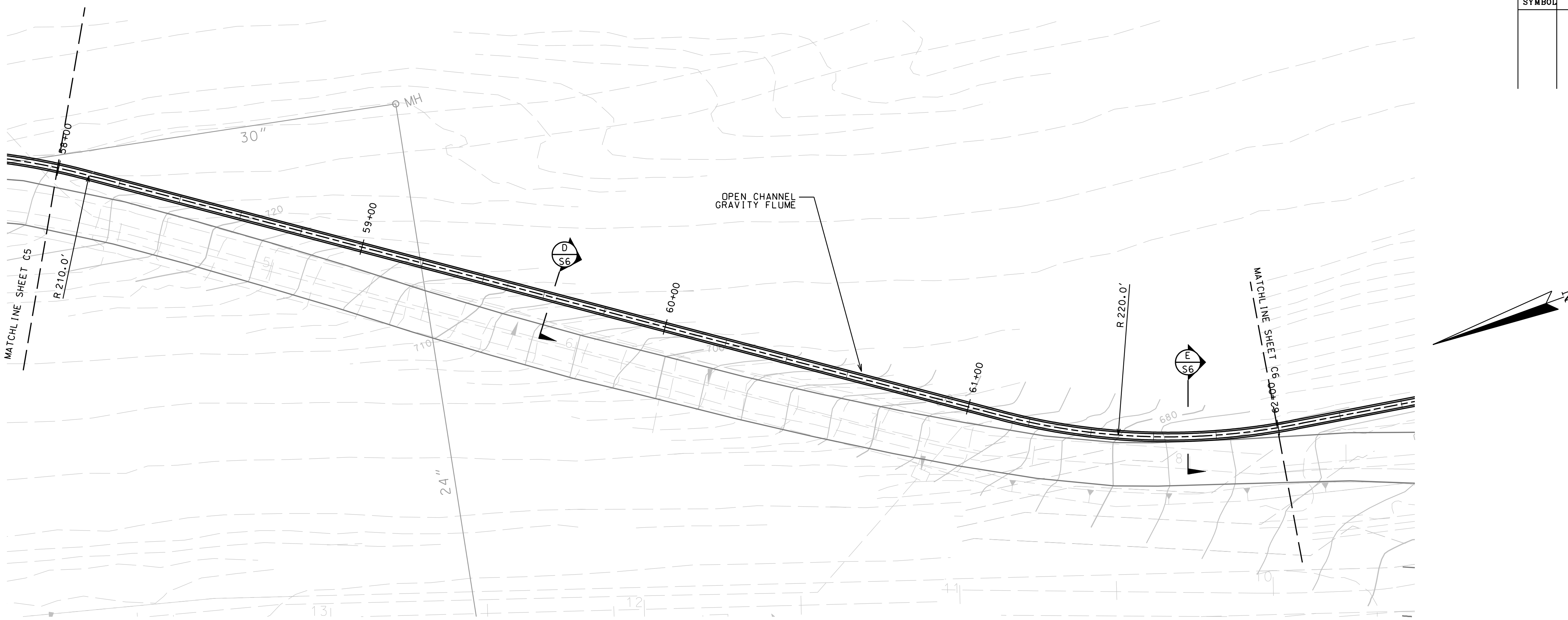

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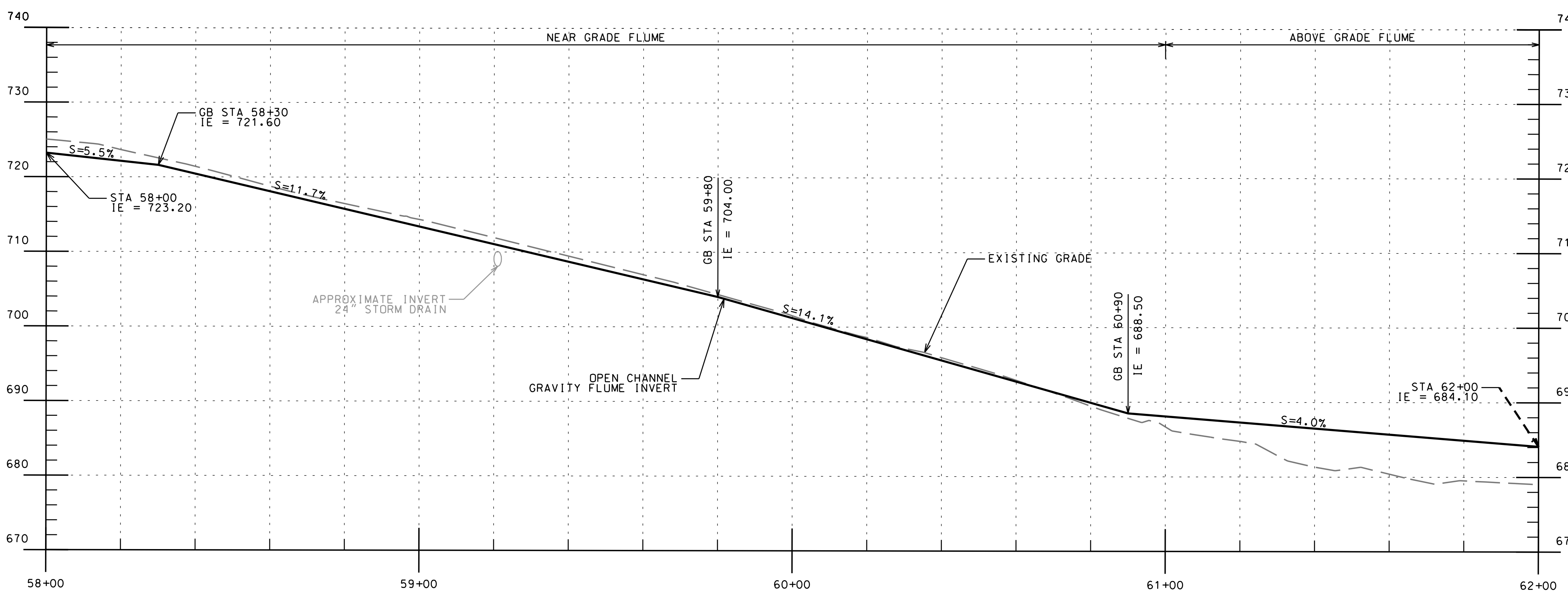

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SECTION 1135 FISH RESTORATION PROJECT

GRAVITY FLUME
PLAN AND PROFILE

GRAYS HARBOR COUNTY, WASHINGTON

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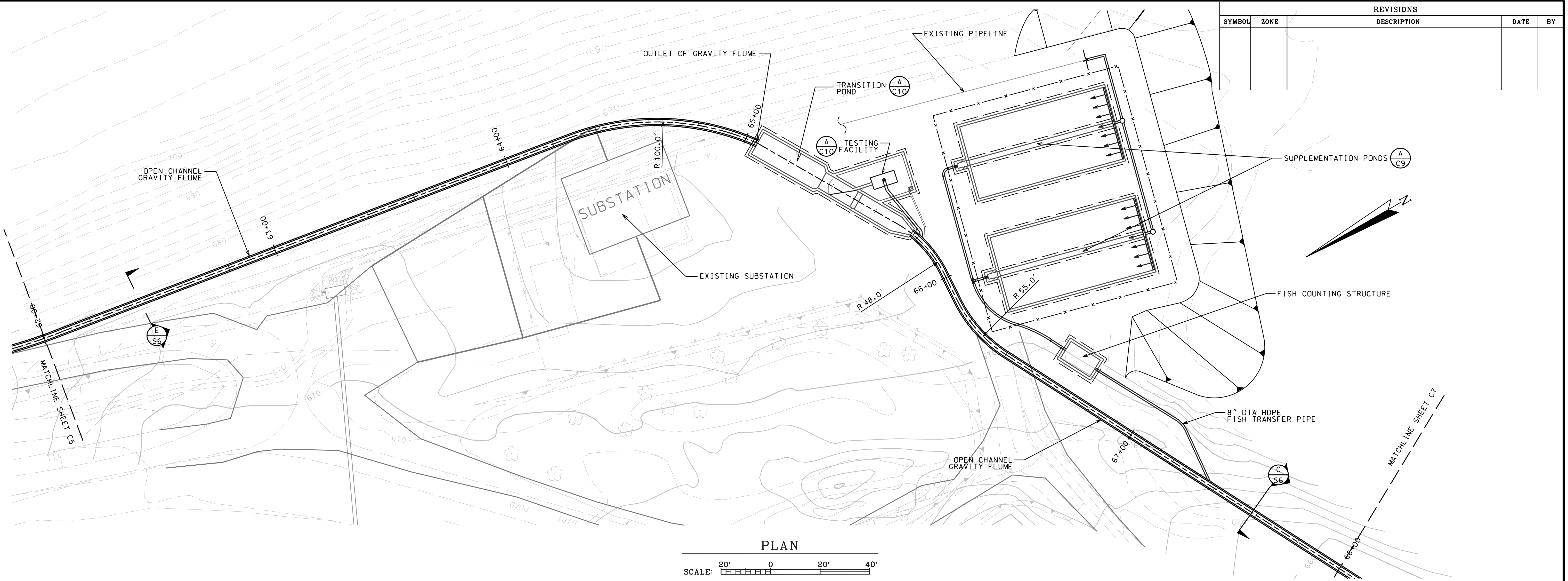

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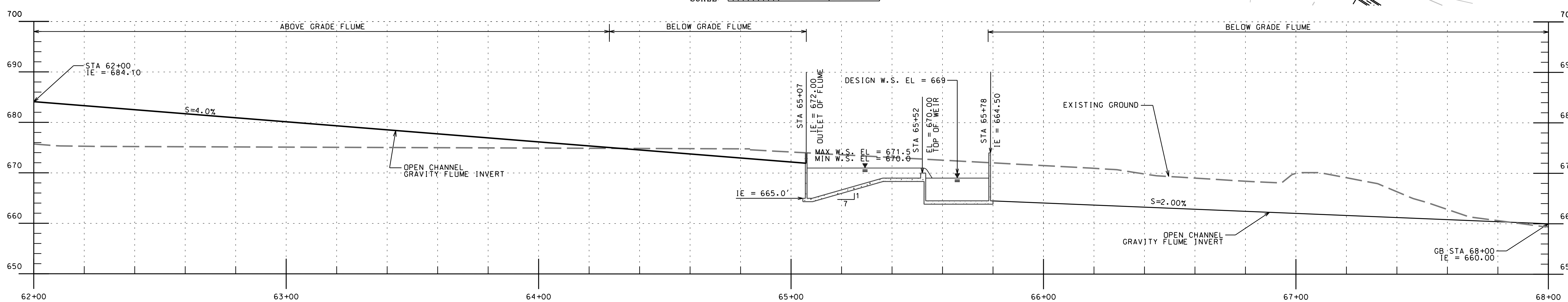

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WYNOOCHEE DAM
SECTION 1135 FISH RESTORATION PROJECT

GRAVITY FLUME AND TRANSITION POND
PLAN AND PROFILE

GRAYS HARBOR COUNTY, WASHINGTON

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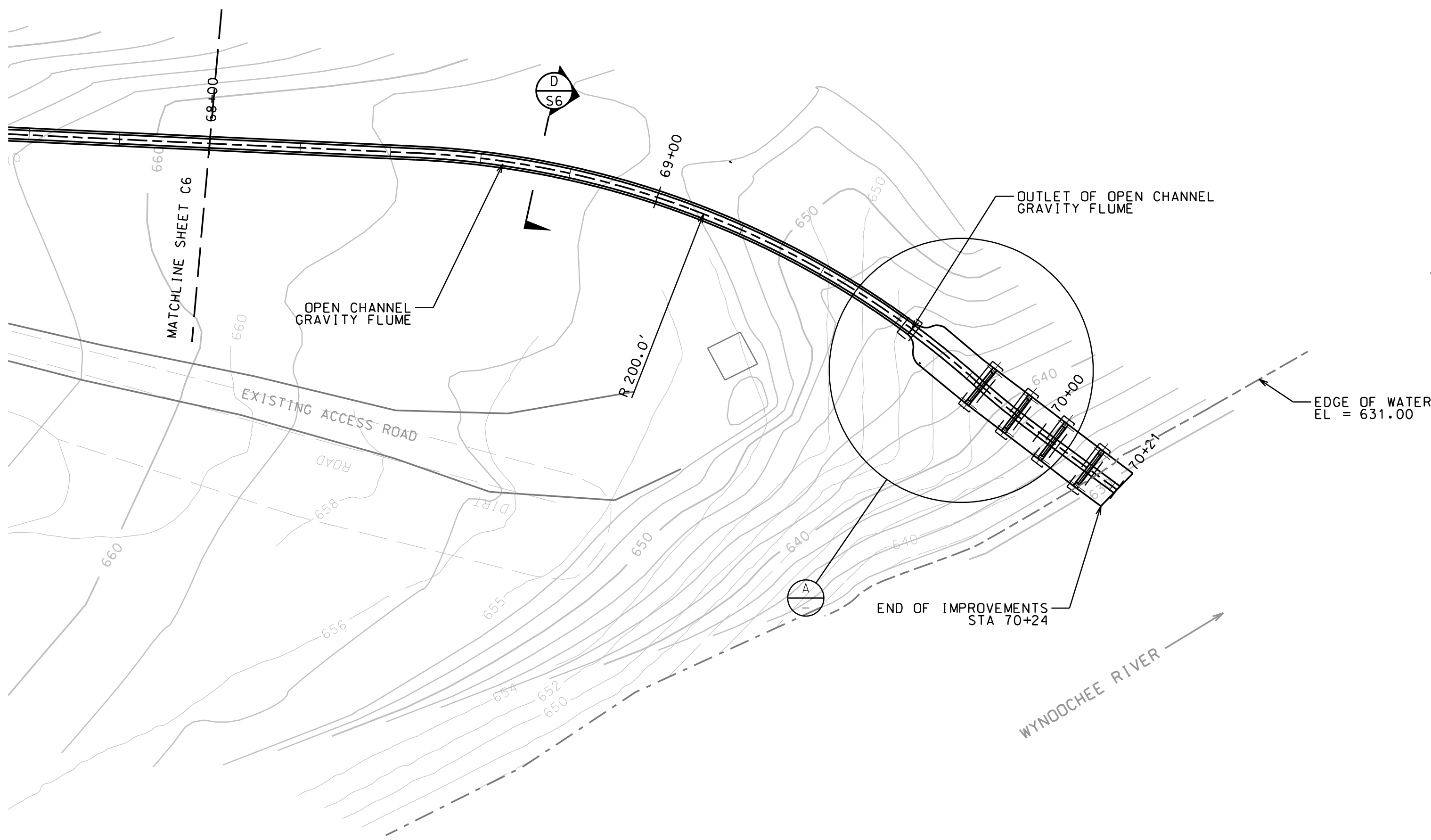

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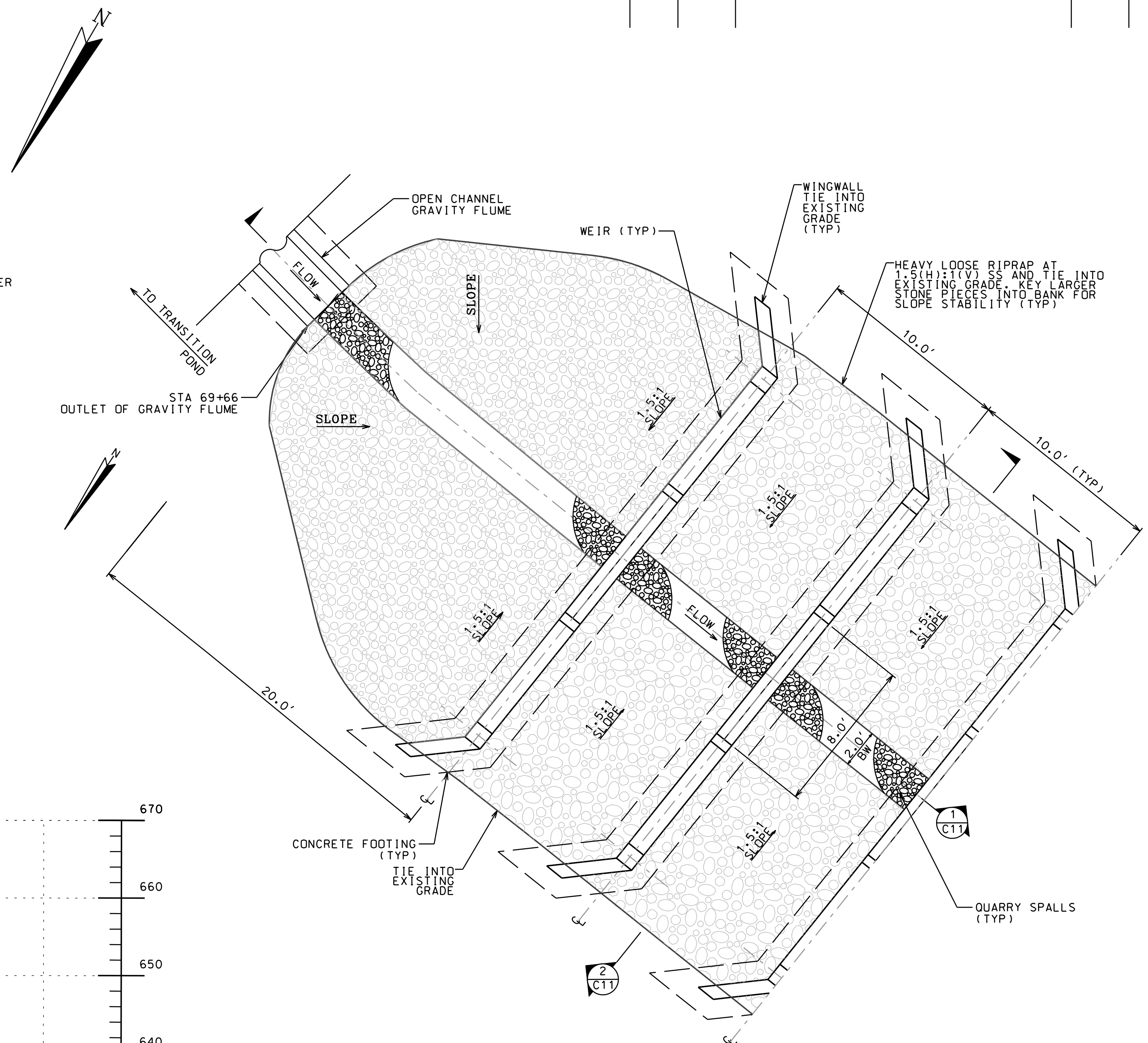

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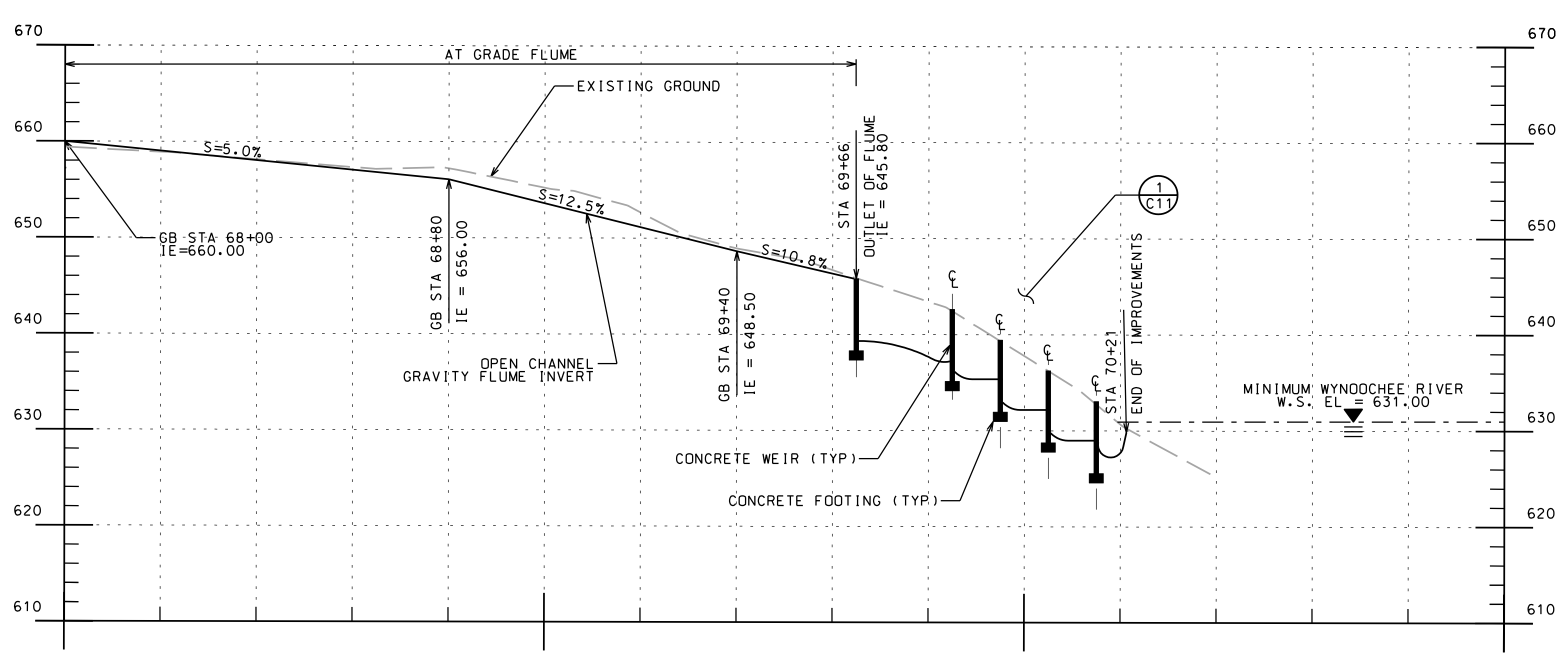

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WYNOOCHEE DAM
SECTION 1135 FISH RESTORATION PROJECT

GRAVITY FLUME AND DROP STRUCTURES
PLAN AND PROFILE

GRAYS HARBOR COUNTY, WASHINGTON

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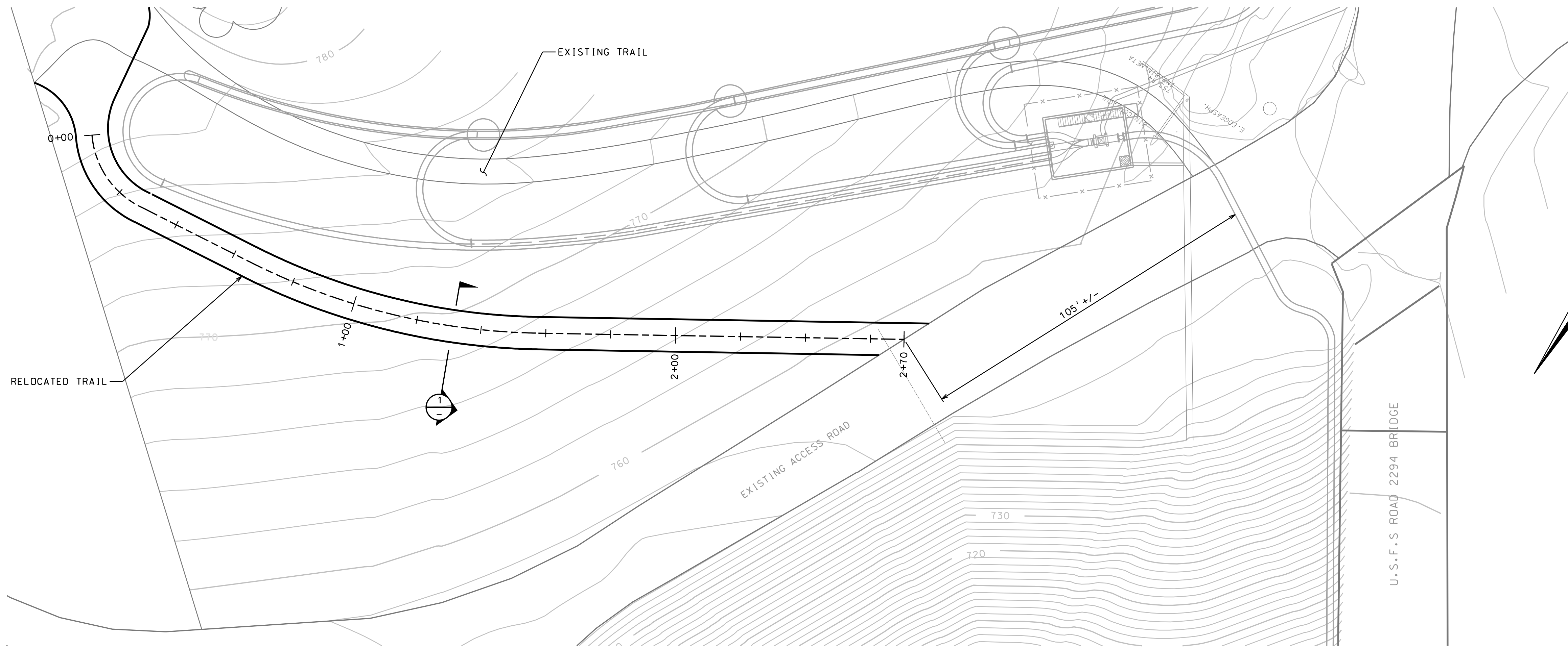

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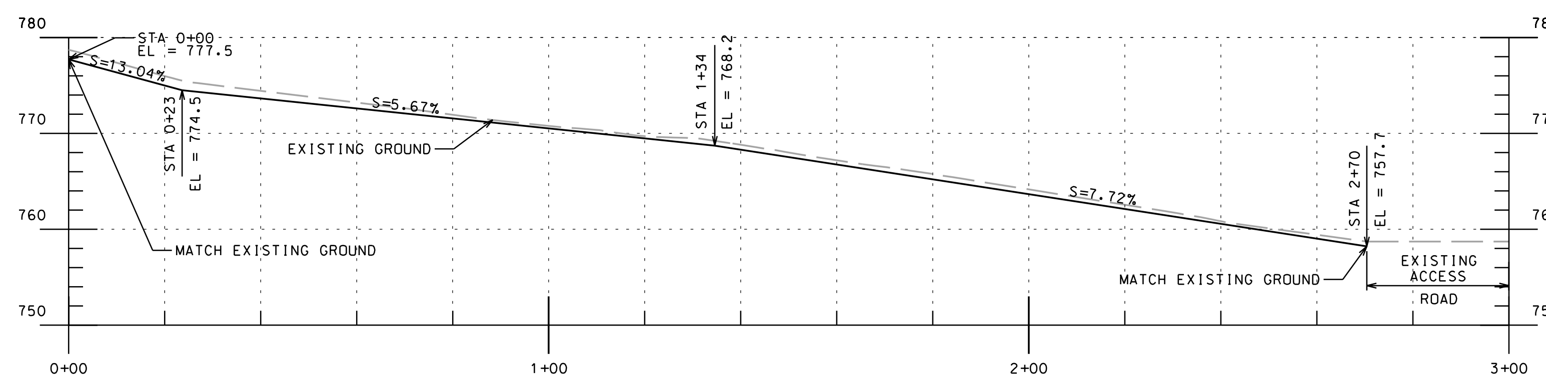

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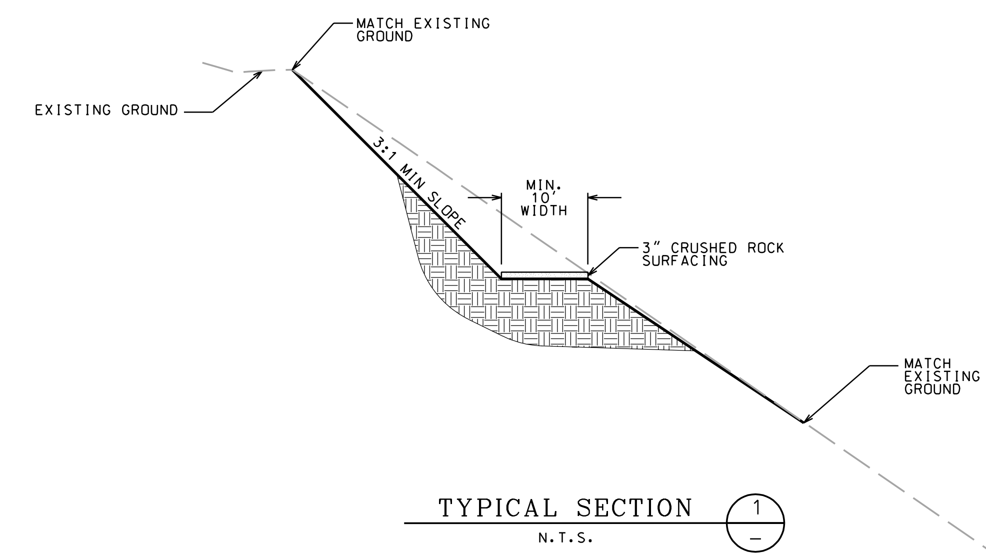

TYPICAL SECTION (1/–)

N.T.S.

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SECTION 1135 FISH RESTORATION PROJECT

TRAIL RELOCATION
PLAN AND PROFILE

GRAYS HARBOR COUNTY, WASHINGTON

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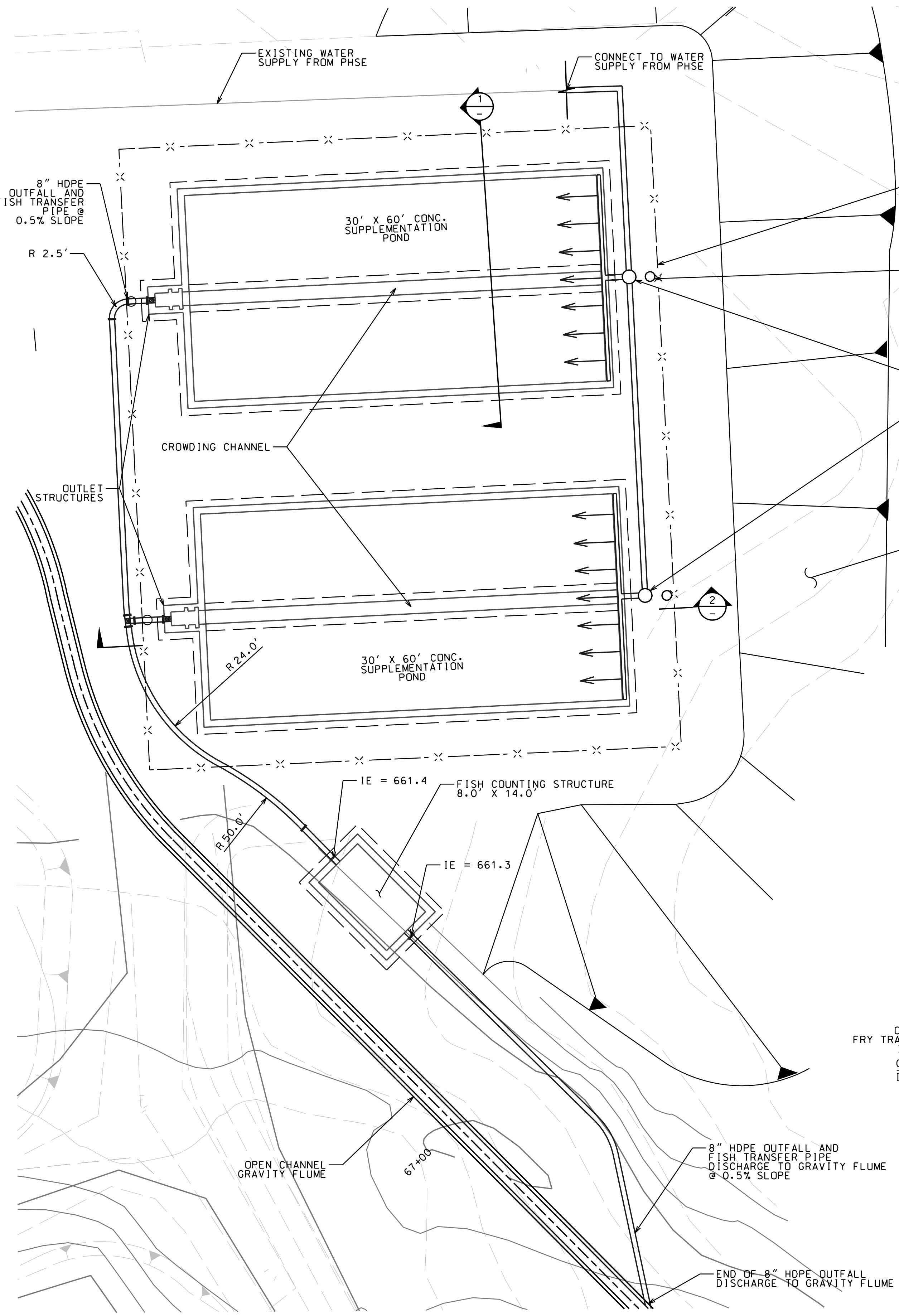
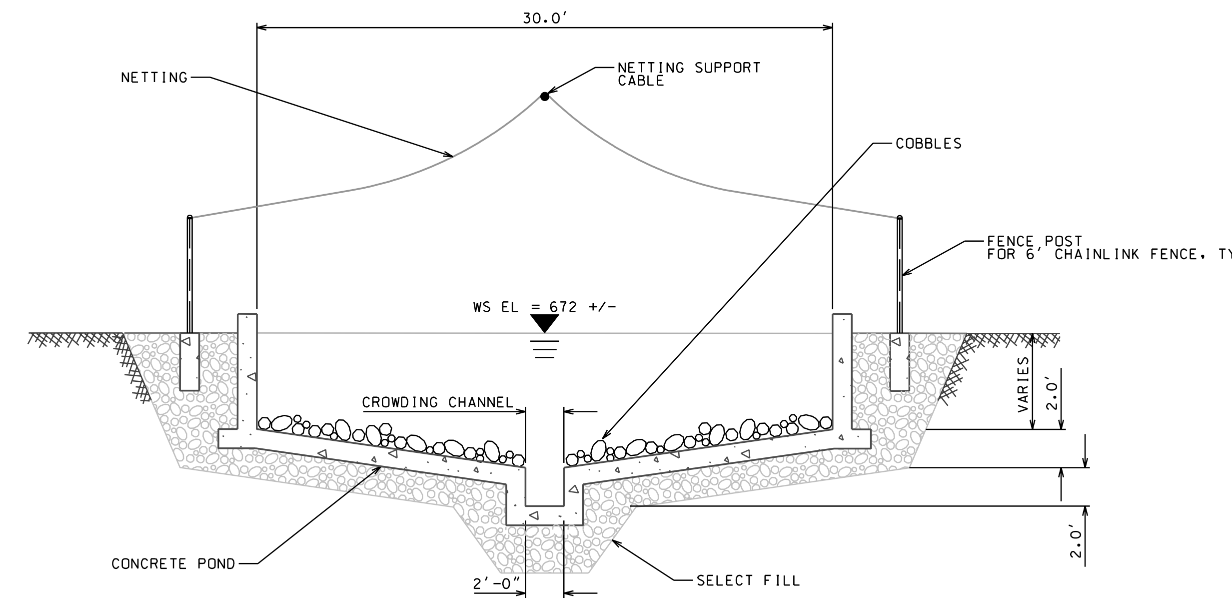


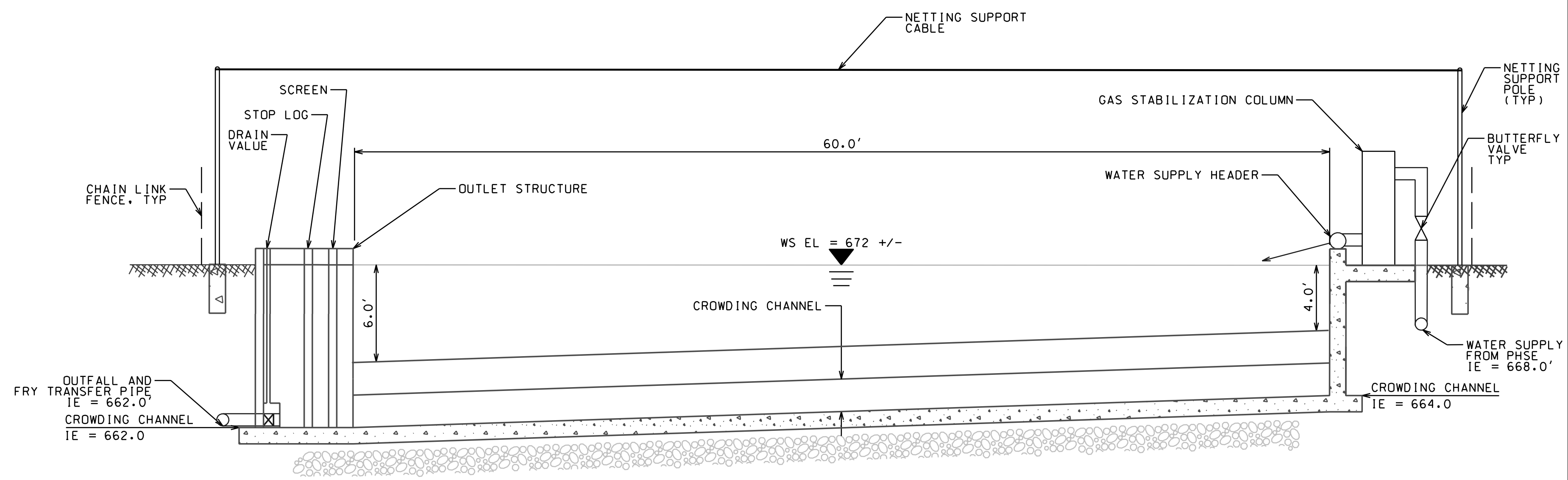
PLAN A C6

SCALE: 10' 0 10' 20'



TYPICAL SECTION 1 -

SCALE: 5' 0 5' 10'



LONGITUDINAL SECTION 2 -

SCALE: 5' 0 5' 10'

35% DESIGN

TETRA TECH INC. SEATTLE, WASHINGTON

U.S. ARMY ENGINEER DISTRICT, SEATTLE CORPS OF ENGINEERS SEATTLE, WASHINGTON

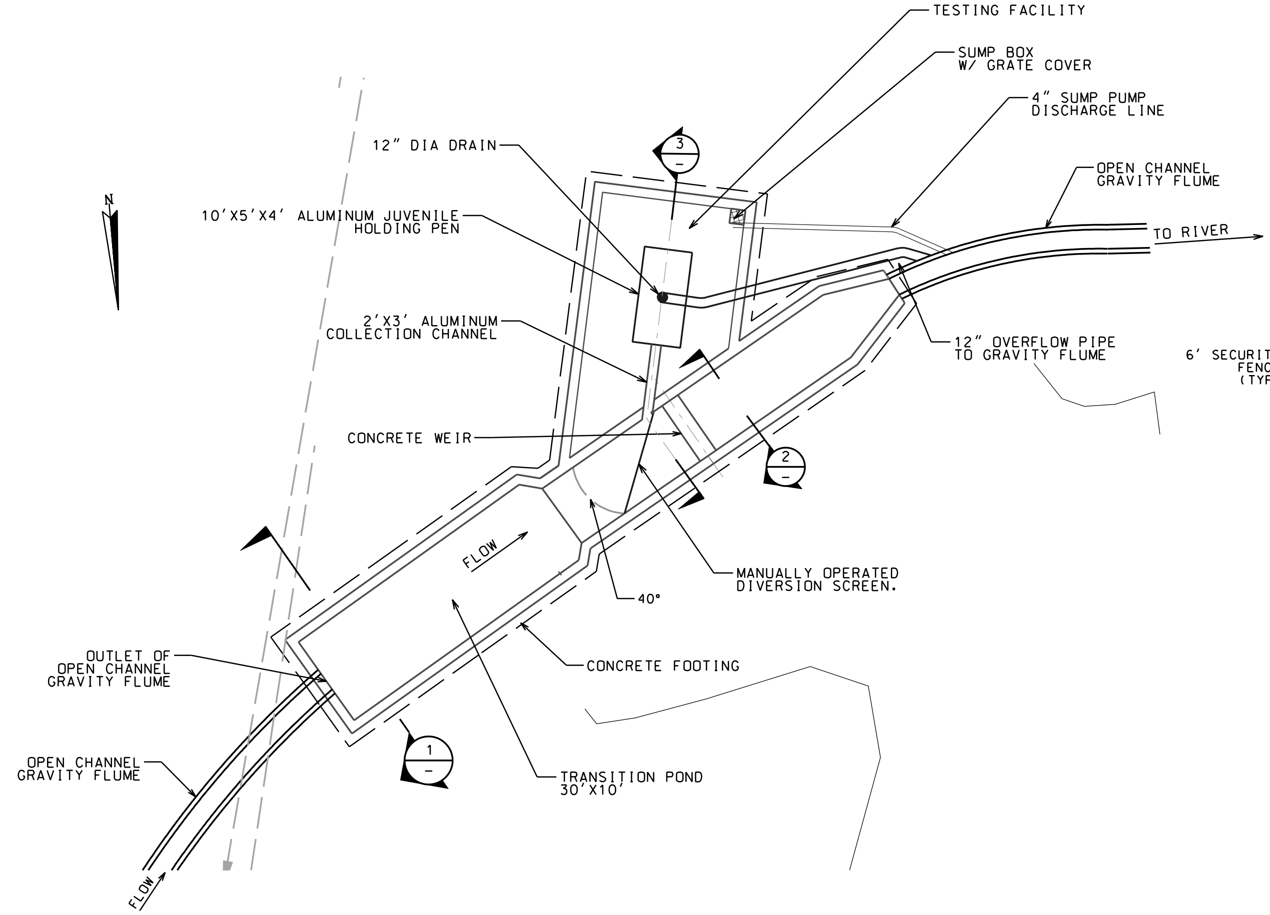
WYNOOCHEE DAM
SECTION 1135 FISH RESTORATION PROJECT

SUPPLEMENTATION PONDS
PLAN AND SECTIONS

GRAYS HARBOR COUNTY, WASHINGTON

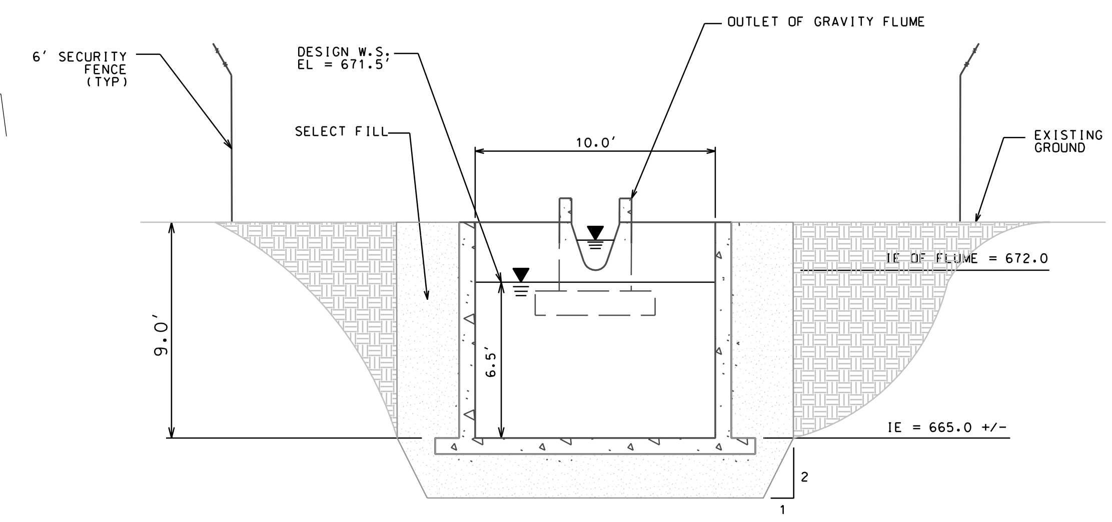
SIZE	INVITATION NO.	FILE NO.	DATE:	PLATE
D	DACA67-02-D-2009		AUG 2003	C9
DSGN. MR		CHK. YC	SHEET 12	

REVISIONS				
SYMBOL	ZONE	DESCRIPTION	DATE	BY



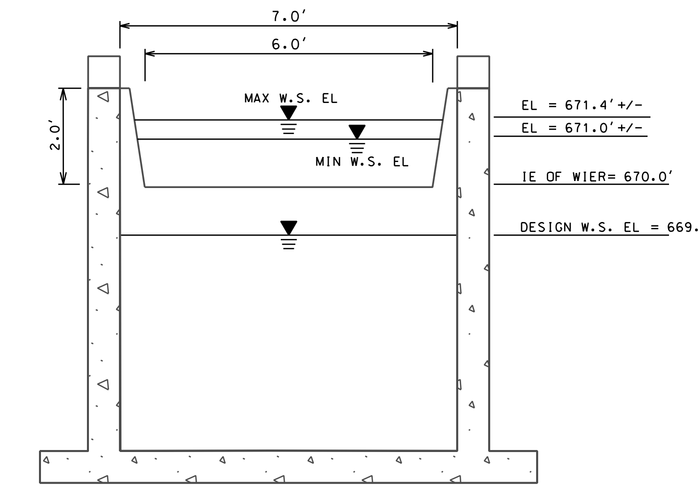
PLAN A C6

SCALE: 10' 0 10' 20'



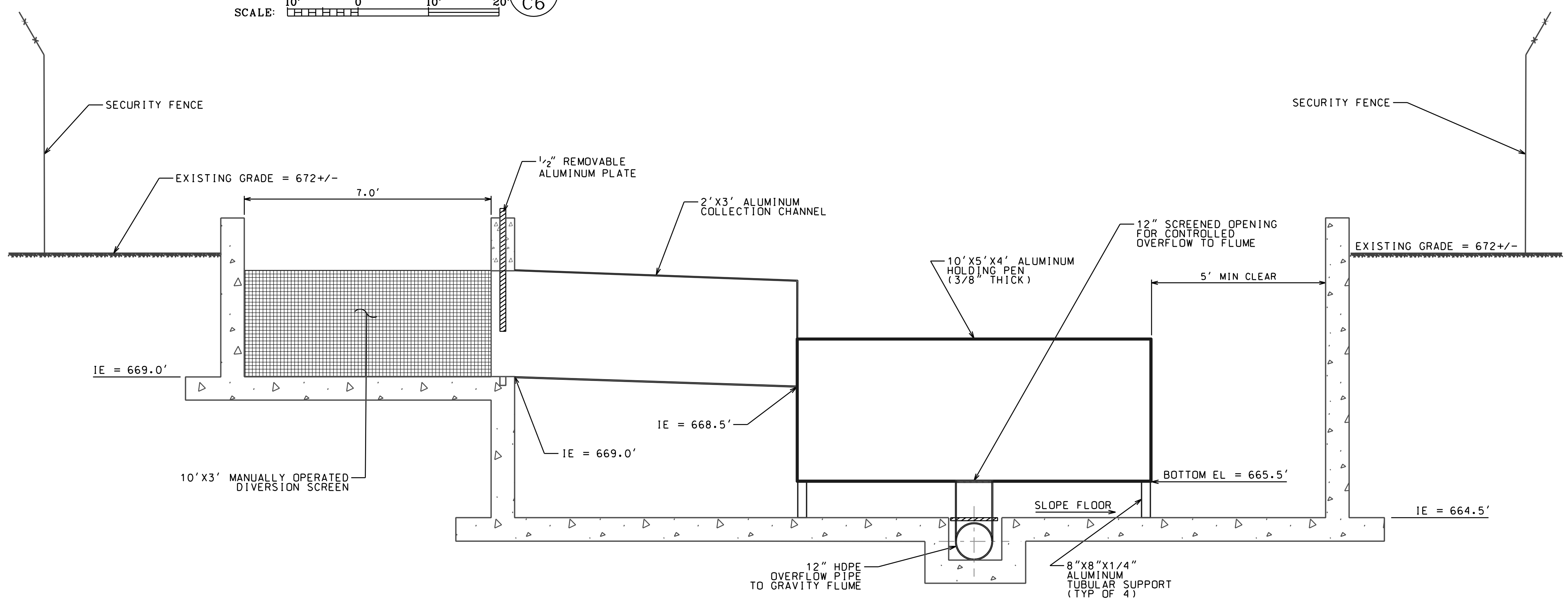
SECTION 1 -

SCALE: 4' 0 4' 8'



SECTION 2 -

SCALE: 2' 0 2' 4'



SECTION 3 -

SCALE: 2' 0 2' 4'

35% DESIGN

TETRA TECH INC. SEATTLE, WASHINGTON

U.S. ARMY ENGINEER DISTRICT, SEATTLE CORPS OF ENGINEERS SEATTLE, WASHINGTON

WYNOOCHEE DAM
SECTION 1135 FISH RESTORATION PROJECT

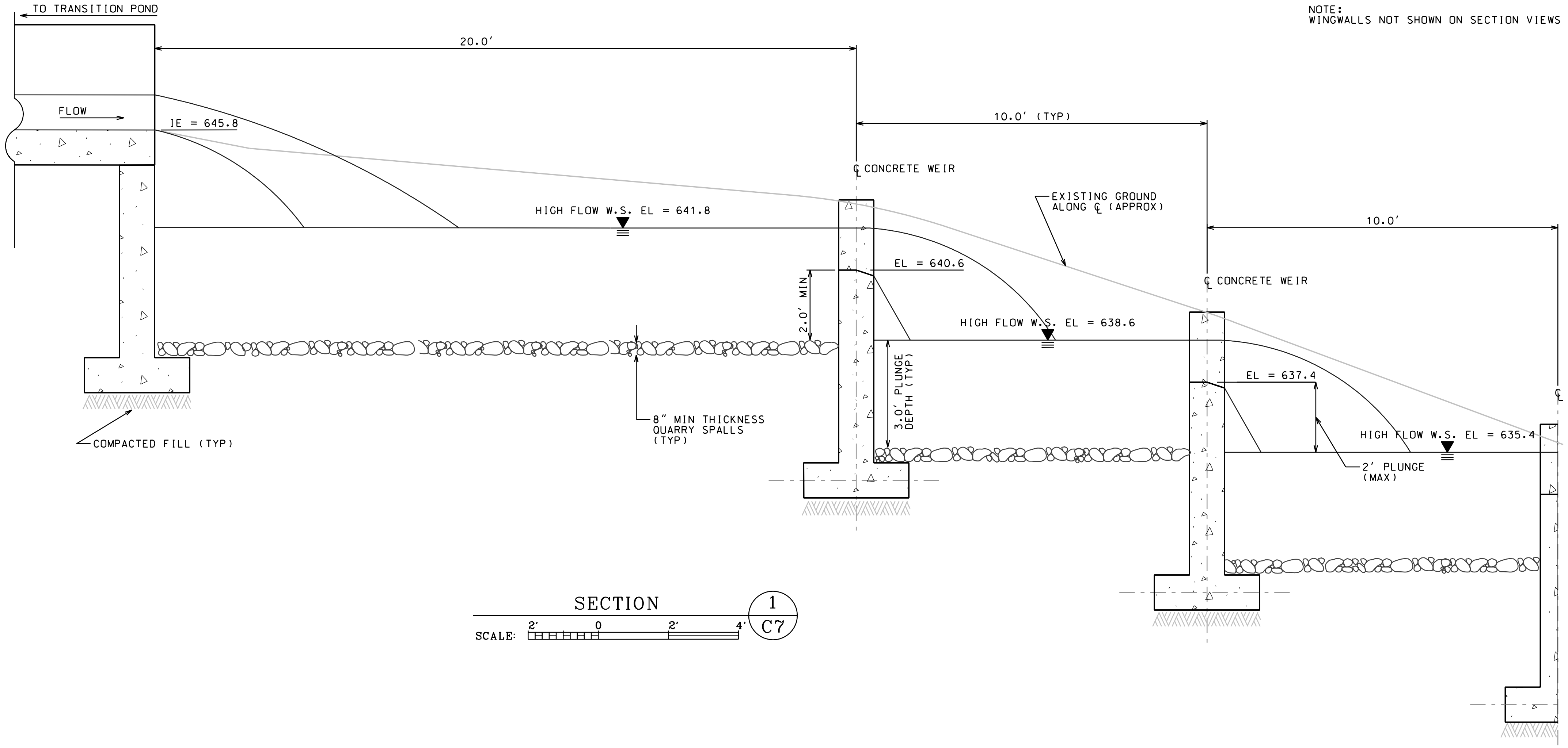
TRANSITION POND AND TESTING FACILITY
PLAN AND SECTIONS

GRAYS HARBOR COUNTY, WASHINGTON

SIZE	INVITATION NO.	FILE NO.	DATE:	PLATE
D	DACA67-02-D-2009		AUG 2003	C10
DSGN. JS		CHK. YC	SHEET 13	

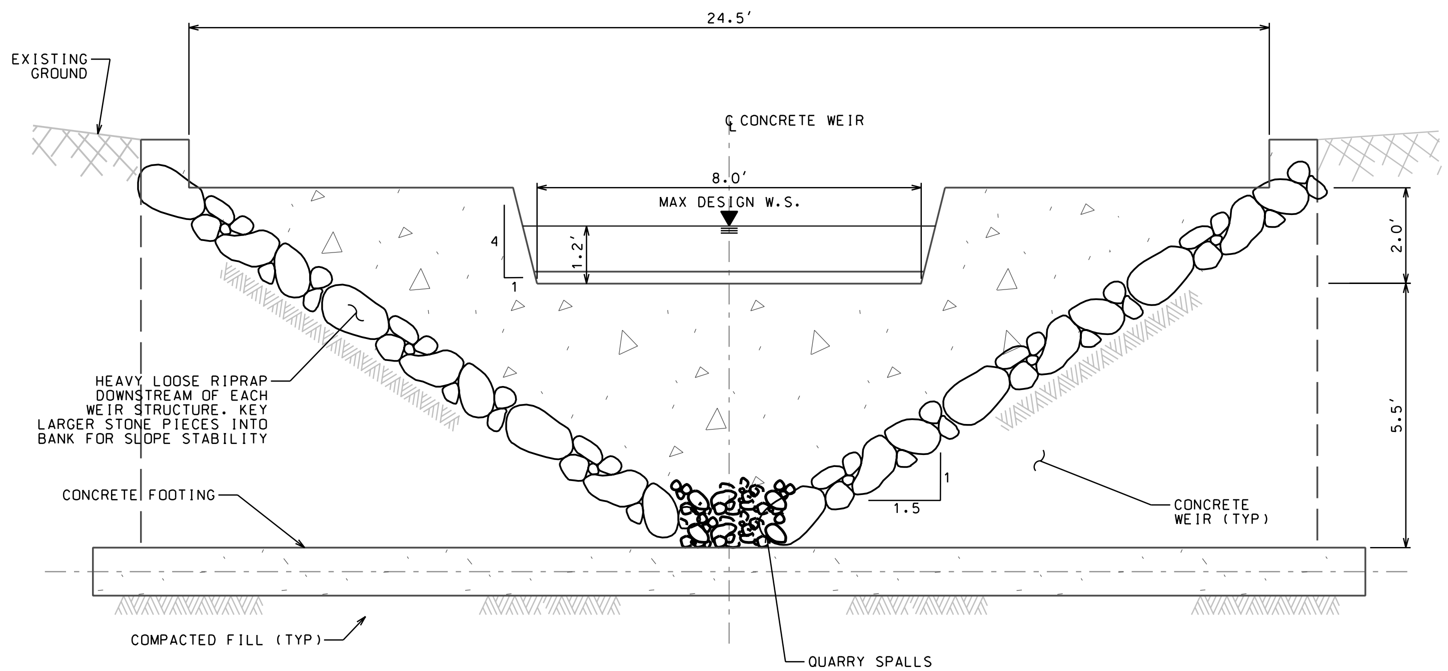
REVISIONS				
SYMBOL	ZONE	DESCRIPTION	DATE	BY

NOTE:
WINGWALLS NOT SHOWN ON SECTION VIEWS



SECTION (1 / C7)

SCALE: 2' 0 2' 4'



CONCRETE WEIR
SECTION (2 / C7)

SCALE: 2' 0 2' 4'

35% DESIGN

TETRA TECH INC.
SEATTLE, WASHINGTON

U.S. ARMY ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

WYNOOCHEE DAM
SECTION 1135 FISH RESTORATION PROJECT

DROP STRUCTURES
PARTIAL PLAN AND SECTIONS

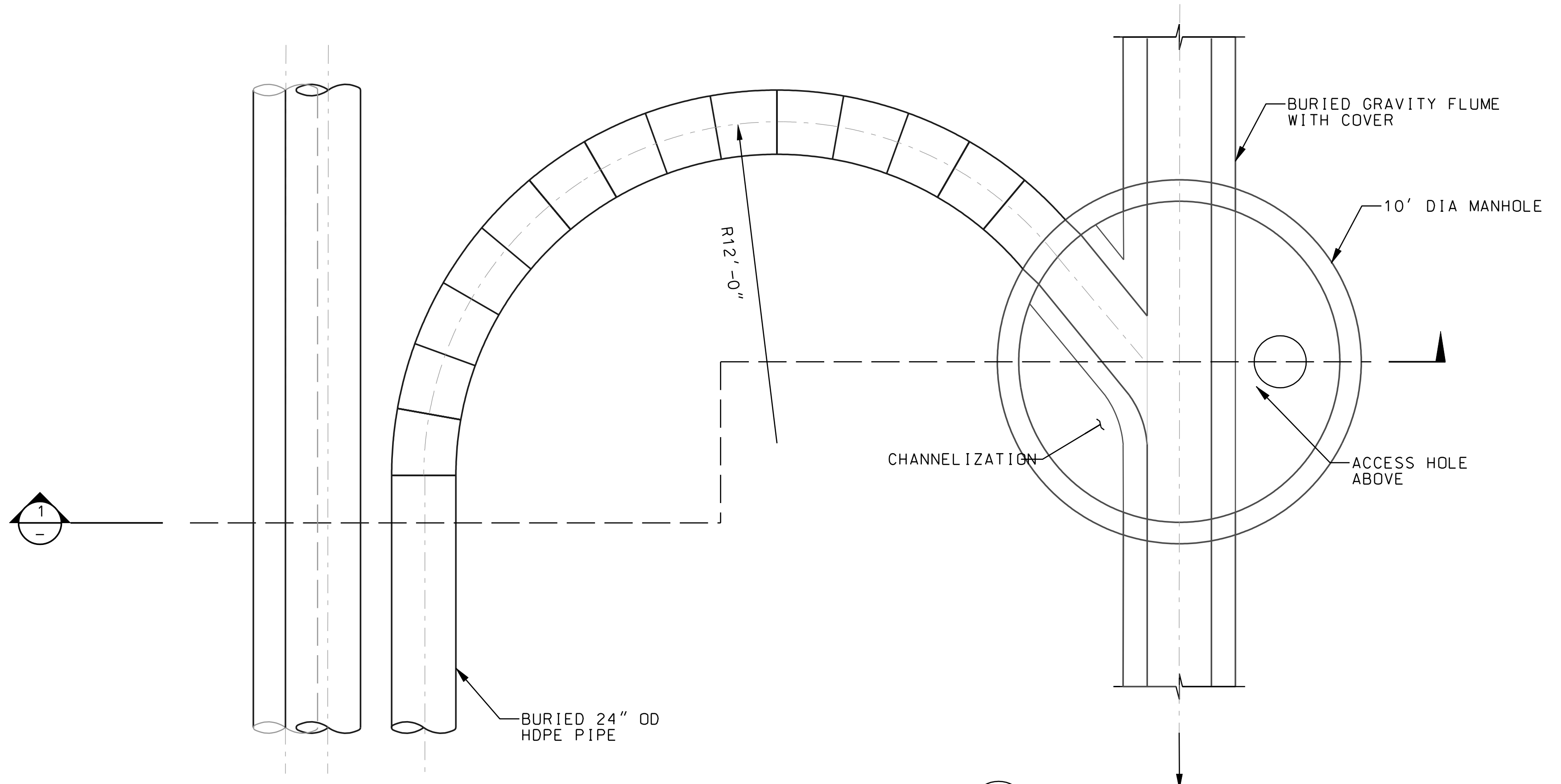
GRAYS HARBOR COUNTY, WASHINGTON

SIZE	INVITATION NO.	FILE NO.	DATE:	PLATE
D	DACA67-02-D-2009		AUG 2003	C11
DSGN. JS		CHK. YC	SHEET 14	

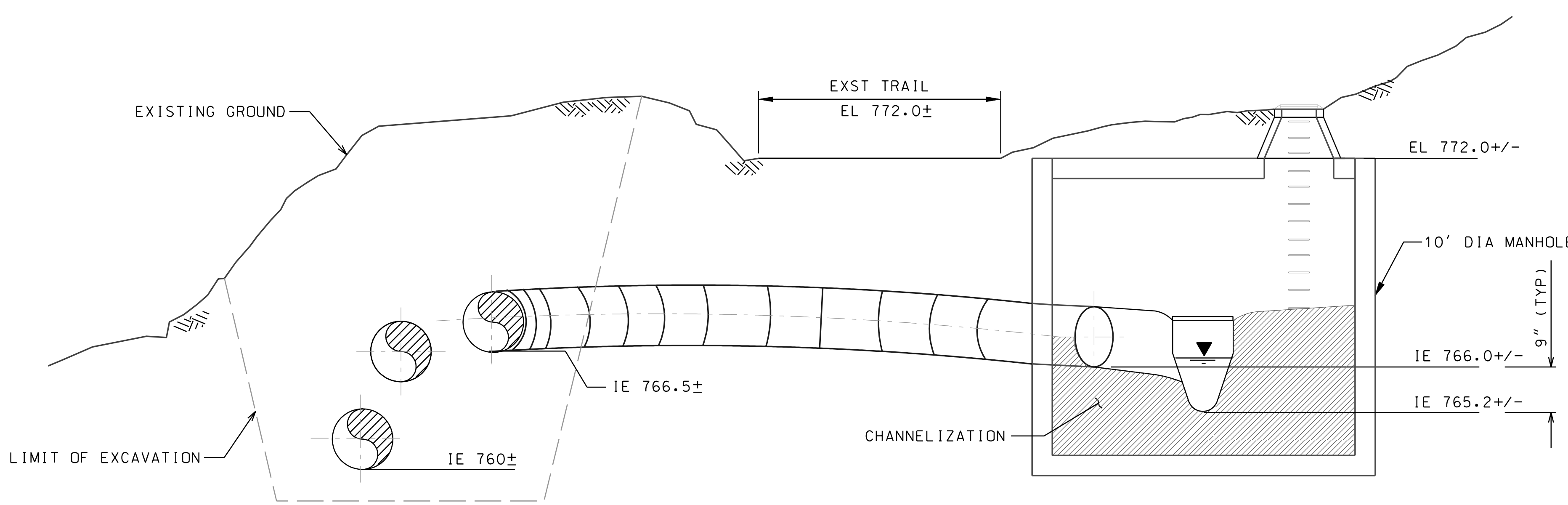
REVISIONS				
SYMBOL	ZONE	DESCRIPTION	DATE	BY

NOTES:

1. ALL UNDERGROUND PIPING IS SHOWN AS SOLID LINE FOR CLARITY.
2. SEE DRAWING C3 FOR GRAVITY FLUME SITE PLAN.



PLAN (A/-)
SCALE: 3/8" = 1'-0"



SECTION (1/C3)
SCALE: N.T.S.

35% DESIGN

TETRA TECH INC. SEATTLE, WASHINGTON
U.S. ARMY ENGINEER DISTRICT, SEATTLE CORPS OF ENGINEERS SEATTLE, WASHINGTON

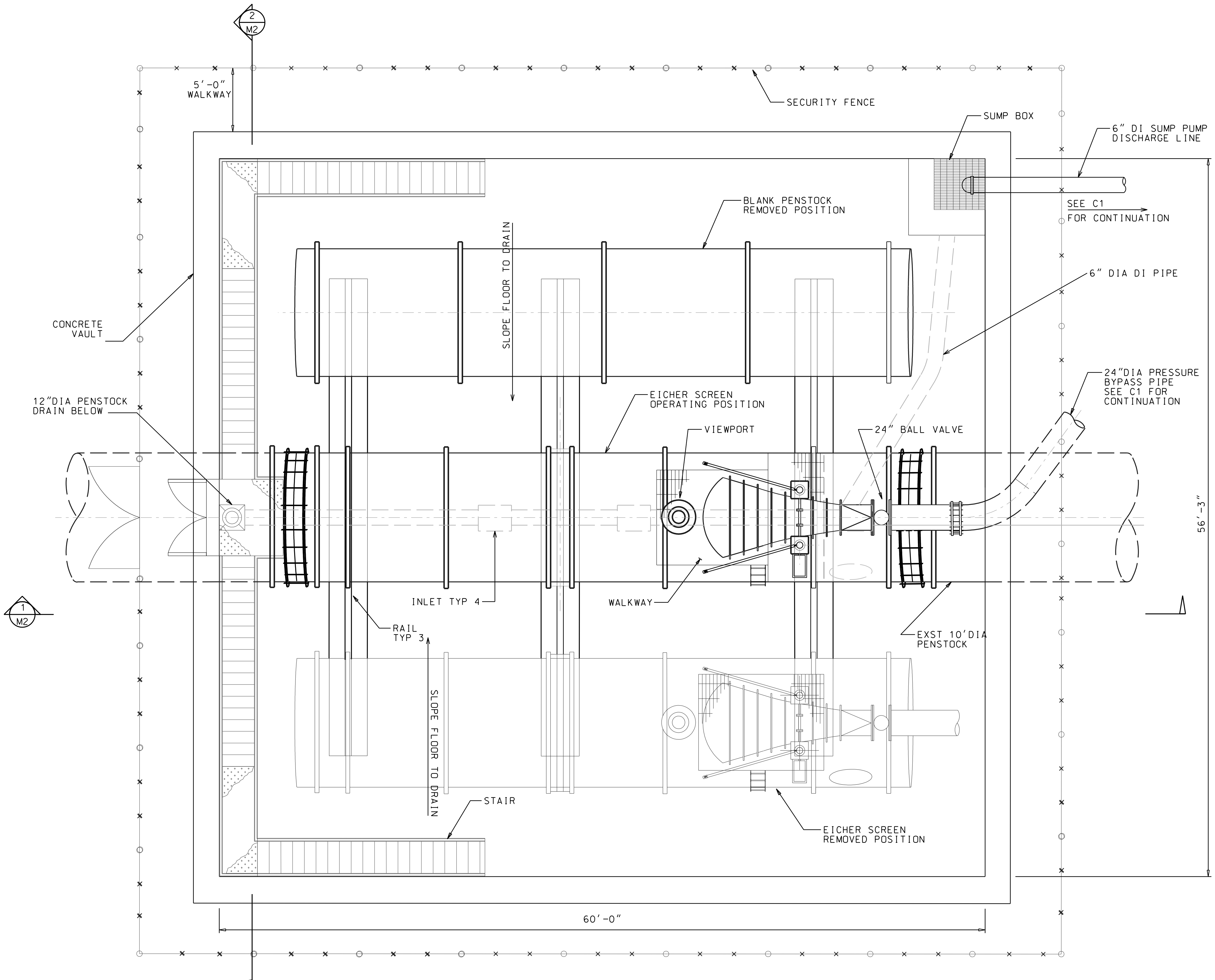
WYNOOCHEE DAM
SECTION 1135 FISH RESTORATION PROJECT
PRESSURE PIPE CONNECTION
W/ GRAVITY FLUME
PLAN AND SECTION
GRAYS HARBOR COUNTY, WASHINGTON

SIZE	INVITATION NO.	FILE NO.	DATE:	PLATE
D	DACA67-02-D-2009		AUG 2003	C12
DSGN. CJ		CHK. DW	SHEET 15	

REVISIONS				
SYMBOL	ZONE	DESCRIPTION	DATE	BY

NOTES:

1. EICHER SCREEN VAULT ROOF IS NOT SHOWN ON THIS DRAWING
SEE S7, S8 FOR ROOF PLAN AND SECTIONS.



PLAN (A / C1)
SCALE: 1/4"=1'-0"

35% DESIGN

TETRA TECH INC.
SEATTLE, WASHINGTON

U.S. ARMY ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

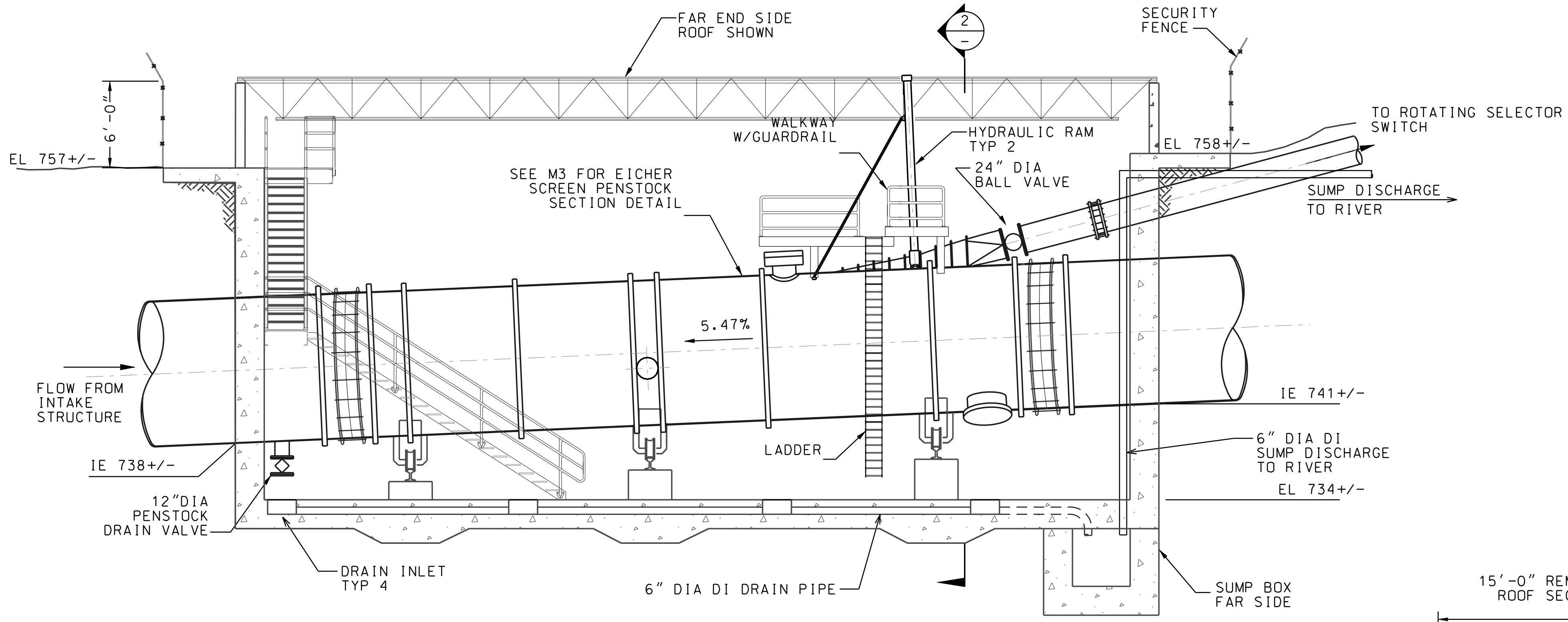
WYNOOCHEE DAM
SECTION 1135 FISH RESTORATION PROJECT

EICHER SCREEN LAYOUT
PLAN

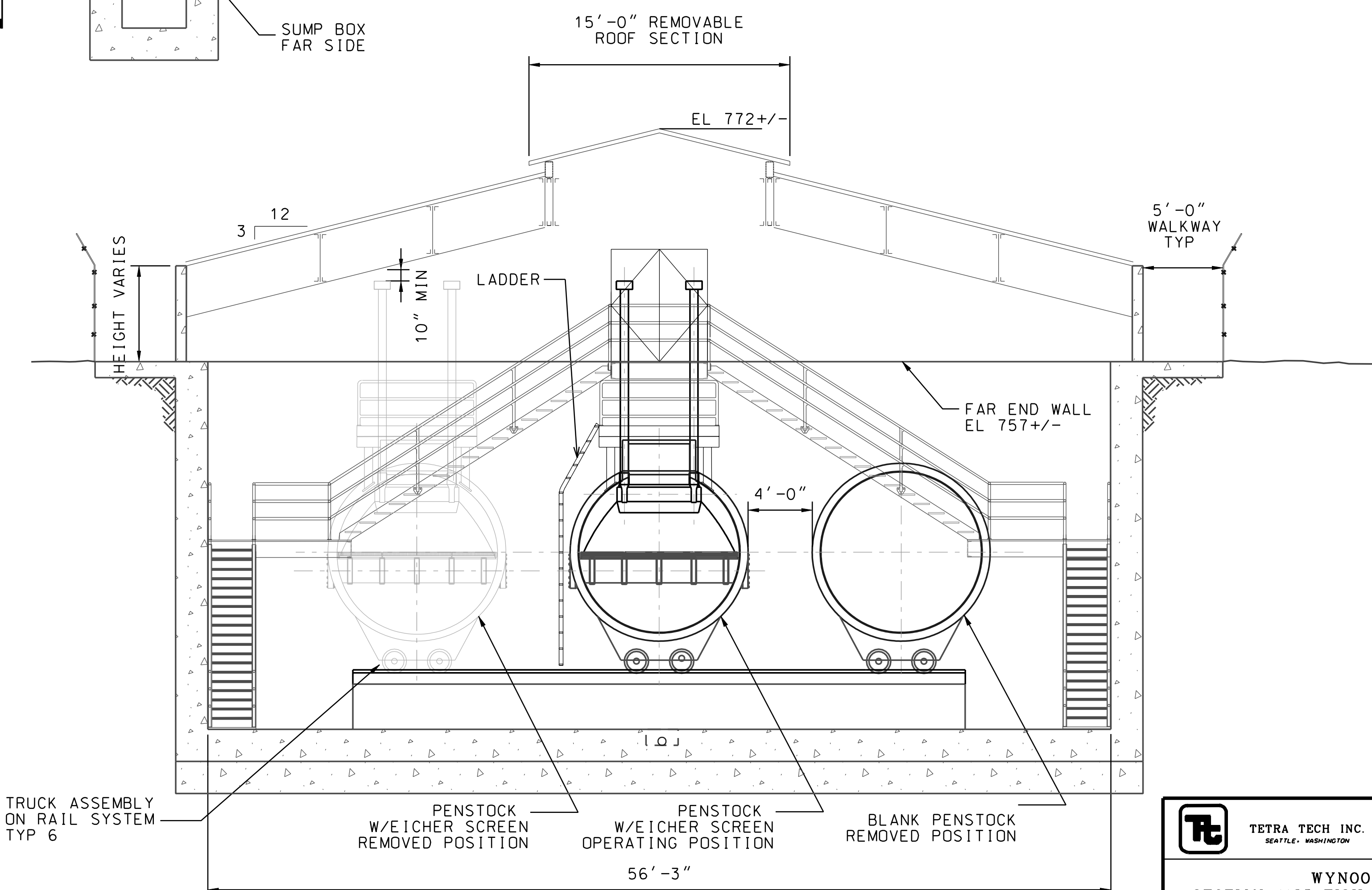
GRAYS HARBOR COUNTY, WASHINGTON

SIZE	INVITATION NO.	FILE NO.	DATE:	PLATE
D	DACA67-02-D-2009		AUG 2003	M1
DSGN. CJ		CHK. DW	SHEET 16	

REVISIONS				
SYMBOL	ZONE	DESCRIPTION	DATE	BY



SECTION 1/M1
SCALE: 3/16"=1'-0"



SECTION 2/M1
SCALE: 3/16"=1'-0"

35% DESIGN

TETRA TECH INC.
SEATTLE, WASHINGTON

U.S. ARMY ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

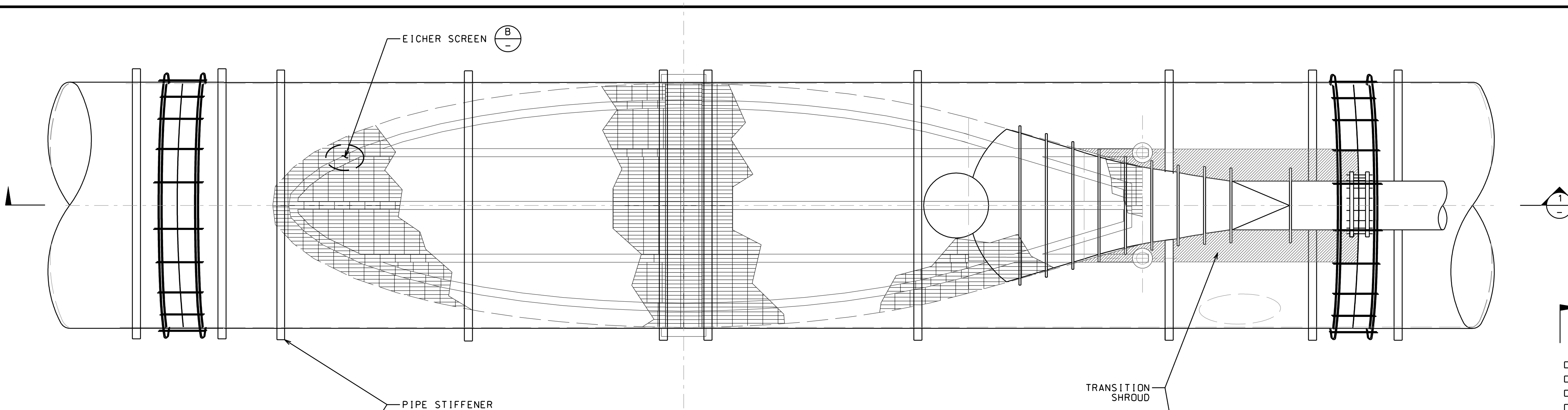
WYNOOCHEE DAM
SECTION 1135 FISH RESTORATION PROJECT

EICHER SCREEN LAYOUT
SECTIONS

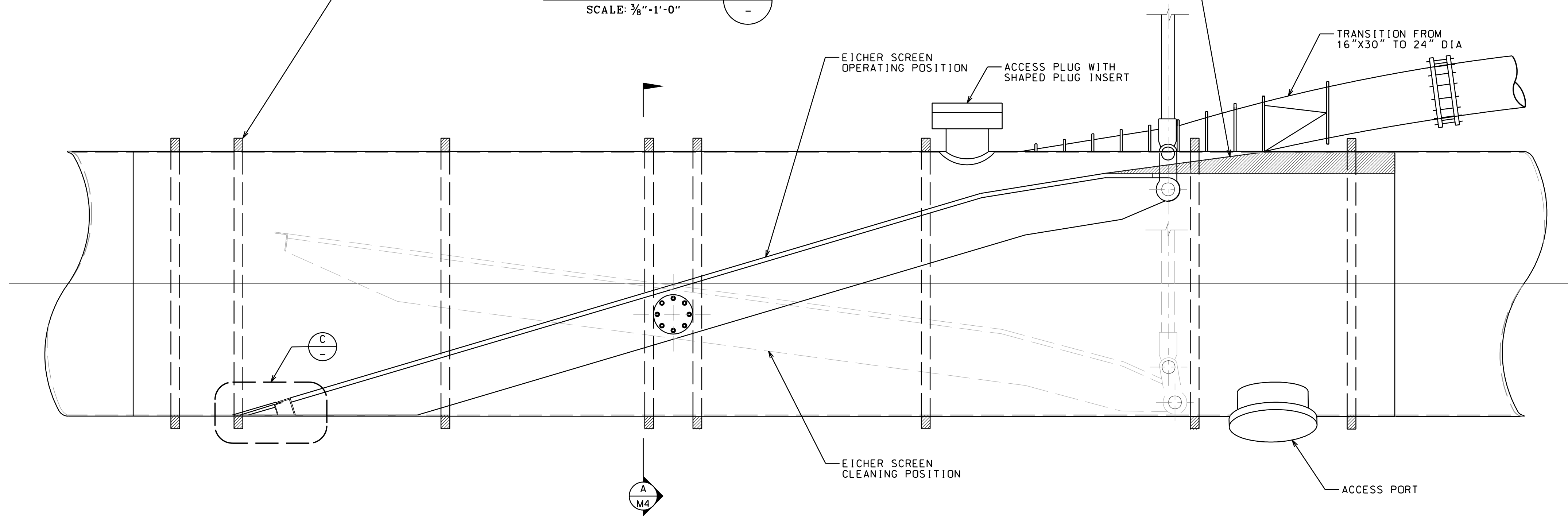
GRAYS HARBOR COUNTY, WASHINGTON

SIZE	INVITATION NO.	FILE NO.	DATE:	PLATE
D	DACA67-02-D-2009		AUG 2003	M2
DSGN. CJ		CHK. DW	SHEET 17	

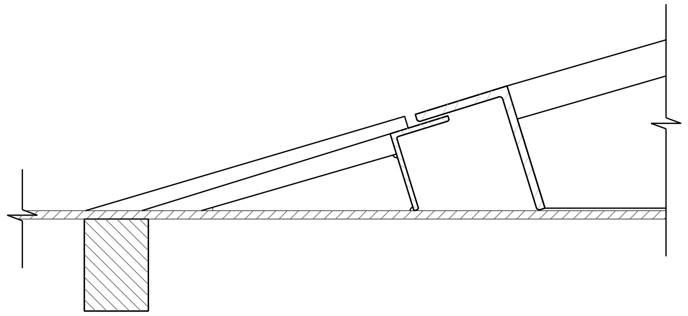
REVISIONS				
SYMBOL	ZONE	DESCRIPTION	DATE	BY



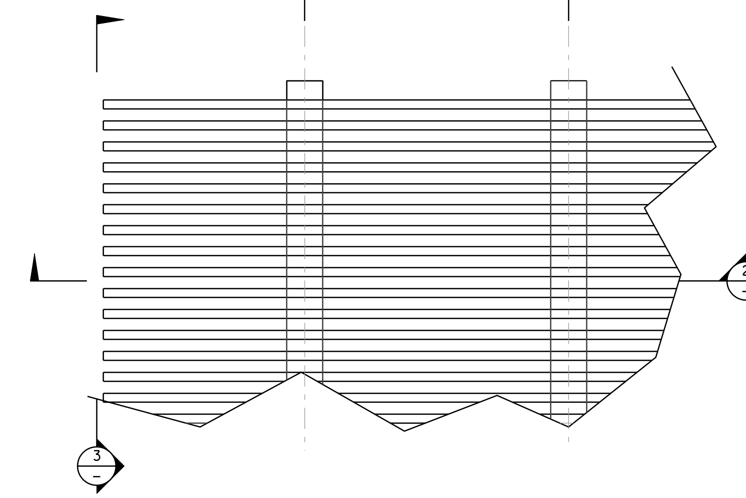
PLAN A/–
SCALE: 3/8"=1'-0"



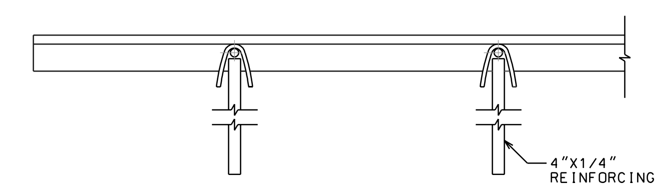
SECTION 1/–
SCALE: 3/8"=1'-0"



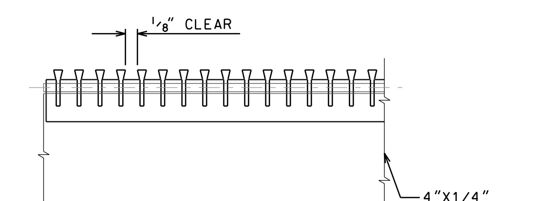
EICHER SCREEN LEADING EDGE
DETAIL C/–
SCALE: N.T.S.



SCREEN PLAN B/–
SCALE: N.T.S.



SCREEN SECTION 2/–
SCALE: N.T.S.



SCREEN SECTION 3/–
SCALE: N.T.S.

35% DESIGN

TETRA TECH INC.
SEATTLE, WASHINGTON

U.S. ARMY ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

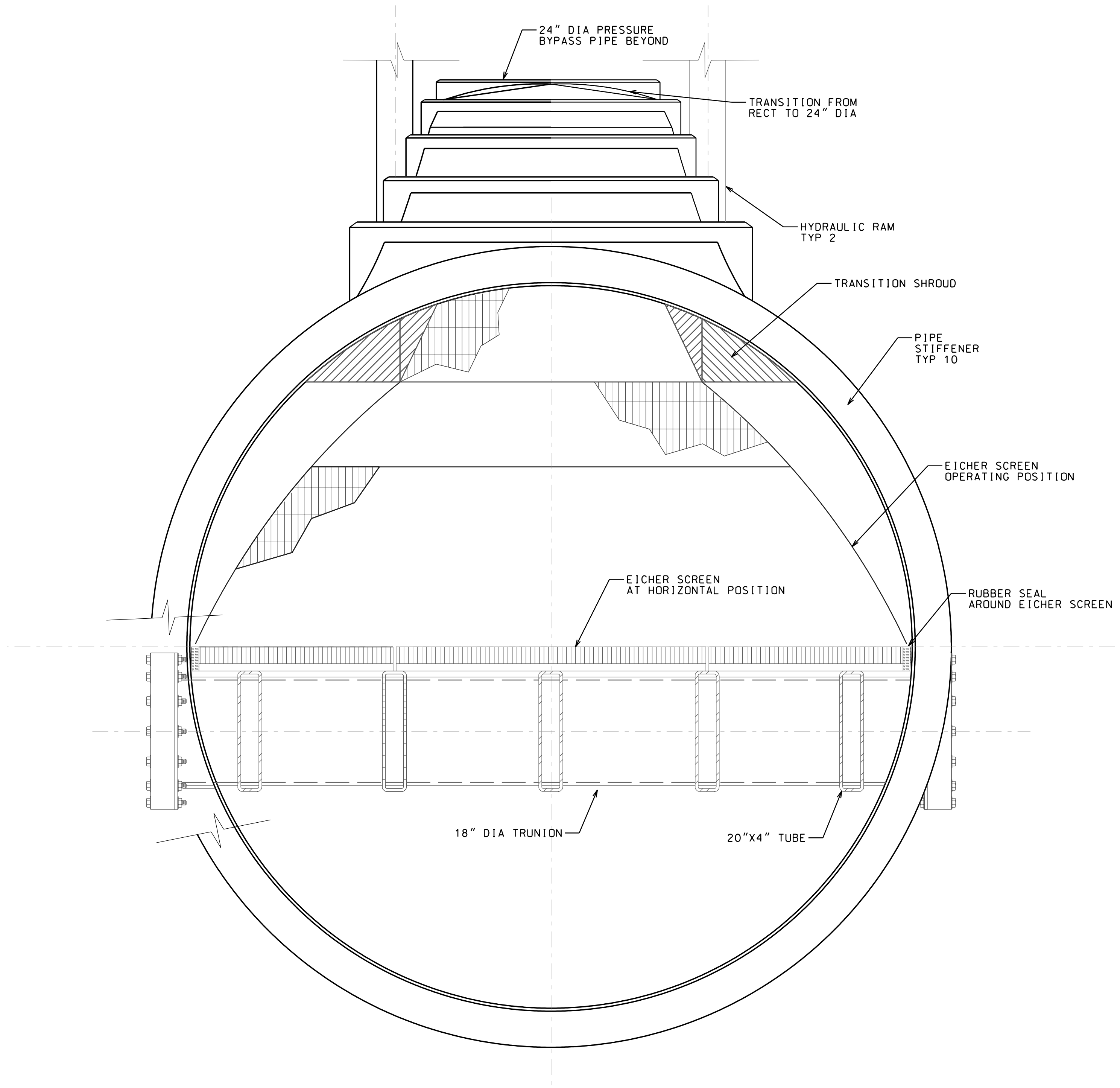
WYNOOCHEE DAM
SECTION 1135 FISH RESTORATION PROJECT

PENSTOCK W/ EICHER SCREEN
PLAN AND SECTION

GRAYS HARBOR COUNTY, WASHINGTON

SIZE	INVITATION NO.	FILE NO.	DATE:	PLATE
D	DACA67-02-D-2009		AUG 2003	M3
DSGN. CJ		CHK. DW	SHEET 18	

REVISIONS				
SYMBOL	ZONE	DESCRIPTION	DATE	BY



SECTION (A / M3)

SCALE: 1" = 1'-0"

35% DESIGN

TETRA TECH INC.
SEATTLE, WASHINGTON

U.S. ARMY ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

WYNOOCHEE DAM
SECTION 1135 FISH RESTORATION PROJECT

PENSTOCK W/ EICHER SCREEN
SECTION

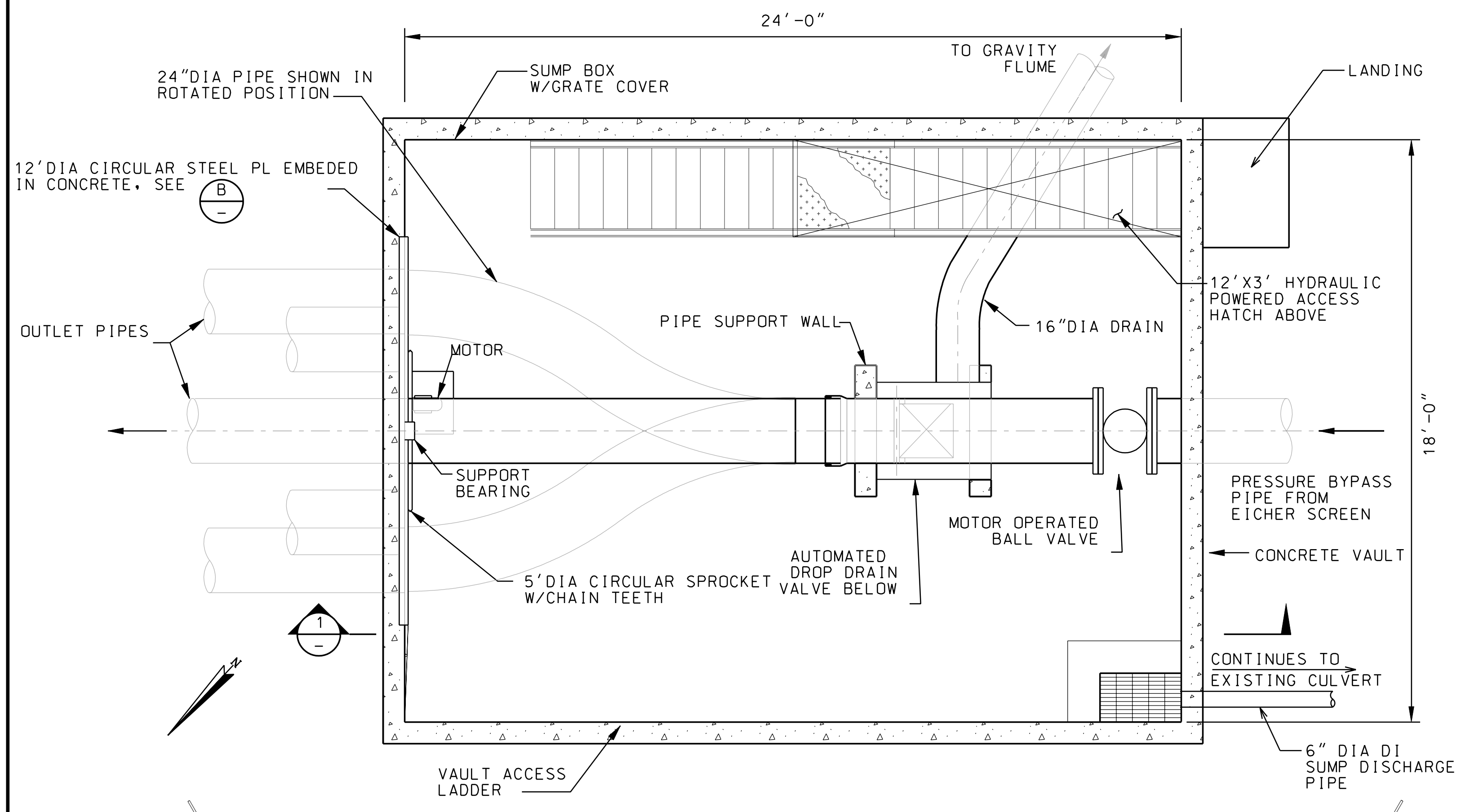
GRAYS HARBOR COUNTY, WASHINGTON

SIZE	INVITATION NO.	FILE NO.	DATE:	PLATE
D	DACA67-02-D-2009		AUG 2003	M4
DSGN. CJ		CHK. DW	SHEET 19	

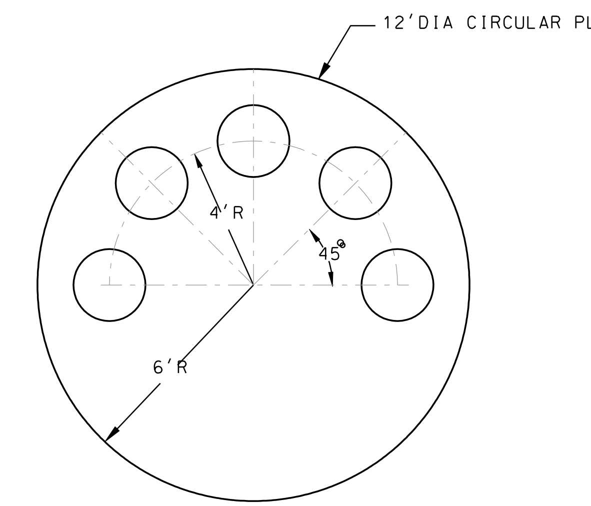
NOTES:

1. ROTATING SELECTOR SWITCH VAULT ROOF IS NOT SHOWN ON THIS DRAWING. SEE S9 FOR ROOF PLAN AND SECTIONS.

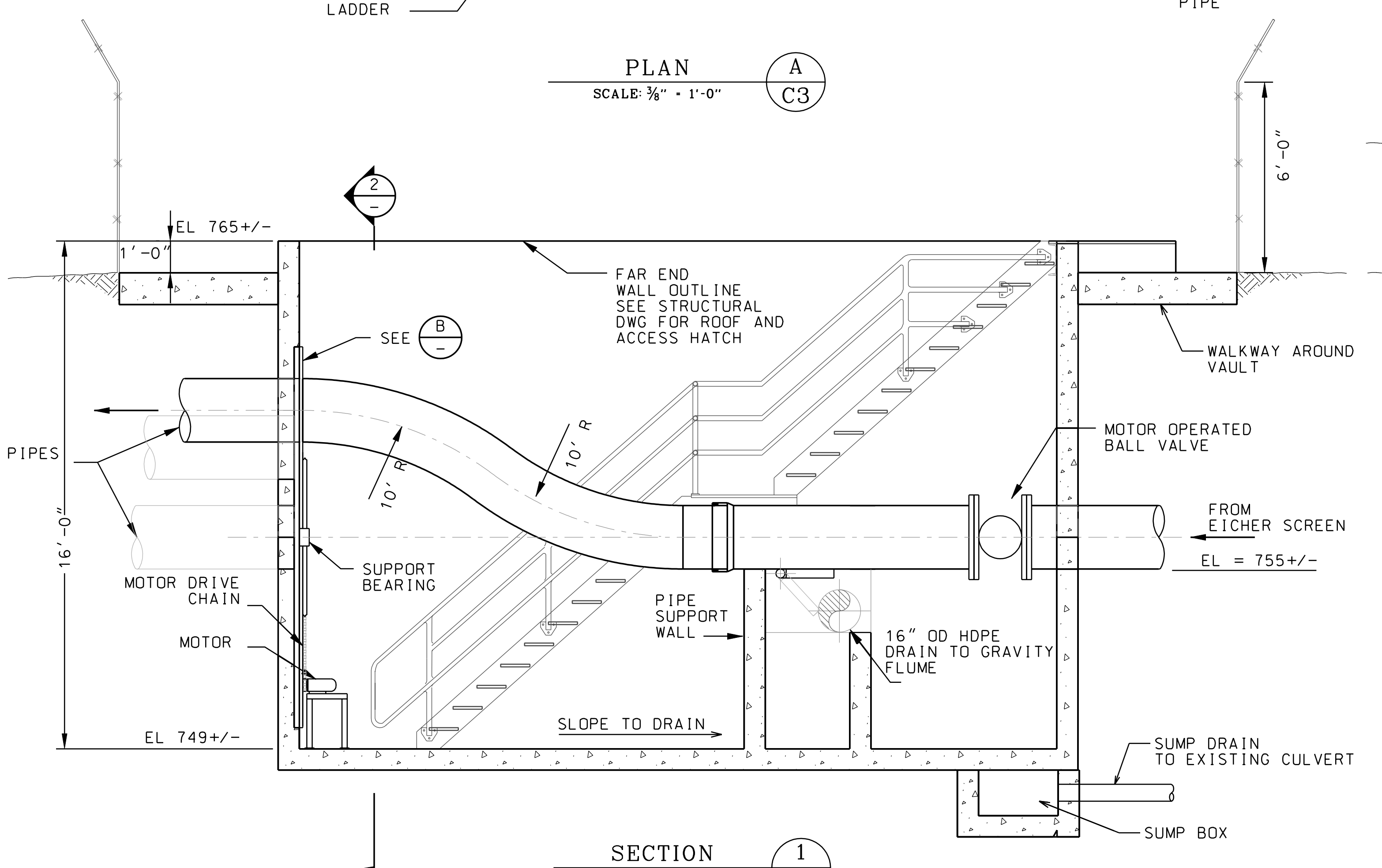
REVISIONS				
SYMBOL	ZONE	DESCRIPTION	DATE	BY



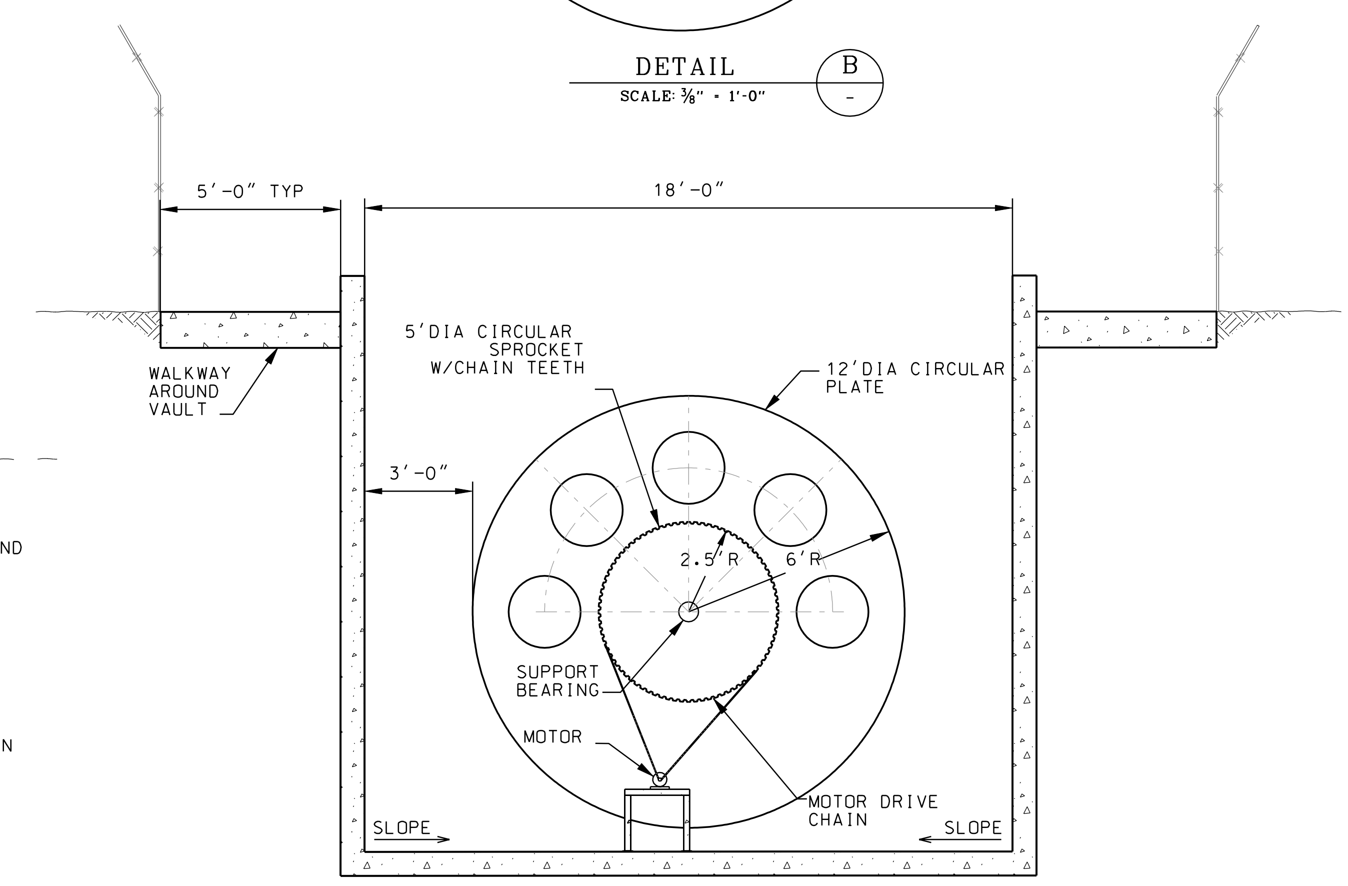
PLAN A / C3
SCALE: 3/8" = 1'-0"



DETAIL B
SCALE: 3/8" = 1'-0"



SECTION 1
SCALE: 3/8" = 1'-0"



SECTION 2
SCALE: 3/8" = 1'-0"

35% DESIGN

TETRA TECH INC. SEATTLE, WASHINGTON
U.S. ARMY ENGINEER DISTRICT, SEATTLE CORPS OF ENGINEERS SEATTLE, WASHINGTON

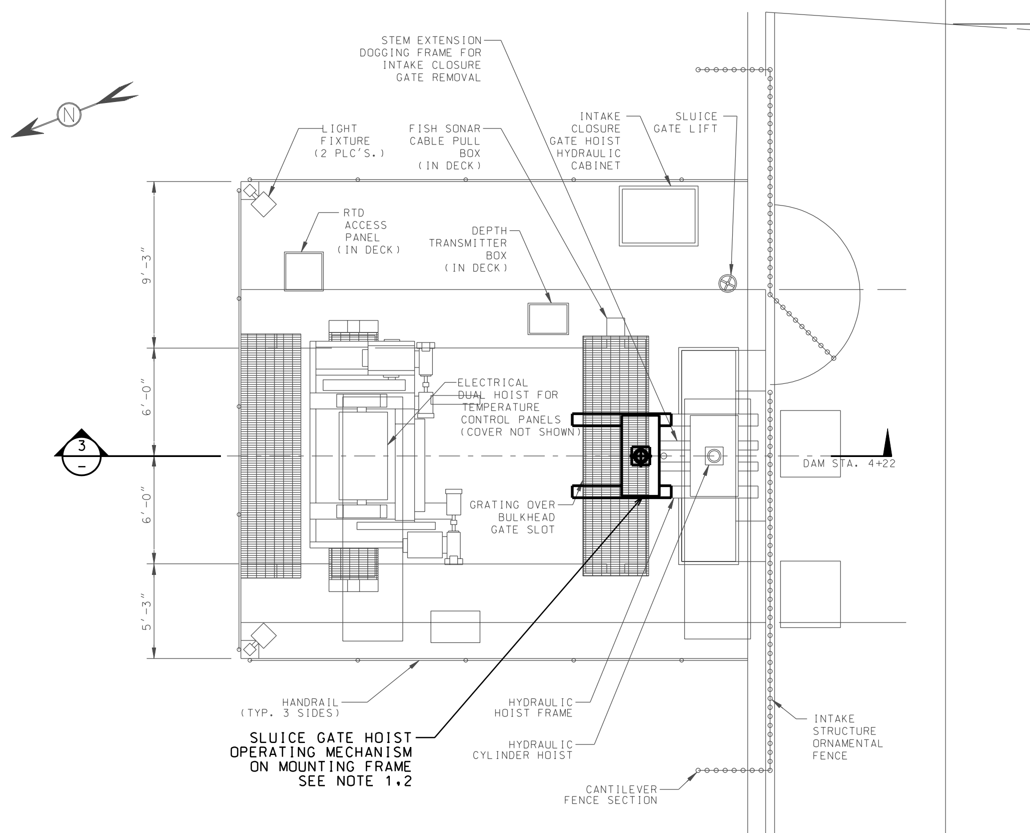
WYNOOCHEE DAM
SECTION 1135 FISH RESTORATION PROJECT

ROTATING SELECTOR SWITCH LAYOUT
PLAN, SECTIONS, AND DETAIL

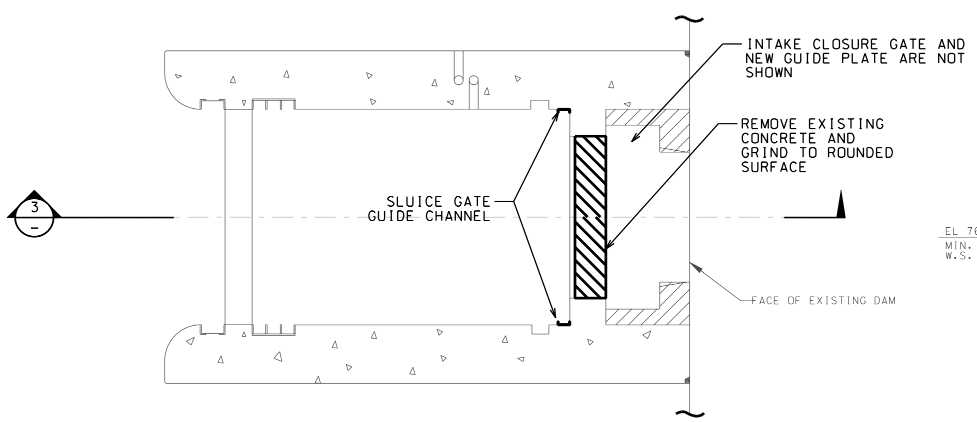
GRAYS HARBOR COUNTY, WASHINGTON

SIZE	INVITATION NO.	FILE NO.	DATE:	PLATE
D	DACA67-02-D-2009		AUG 2003	M5
DSGN. CJ		CHK. DW	SHEET 20	

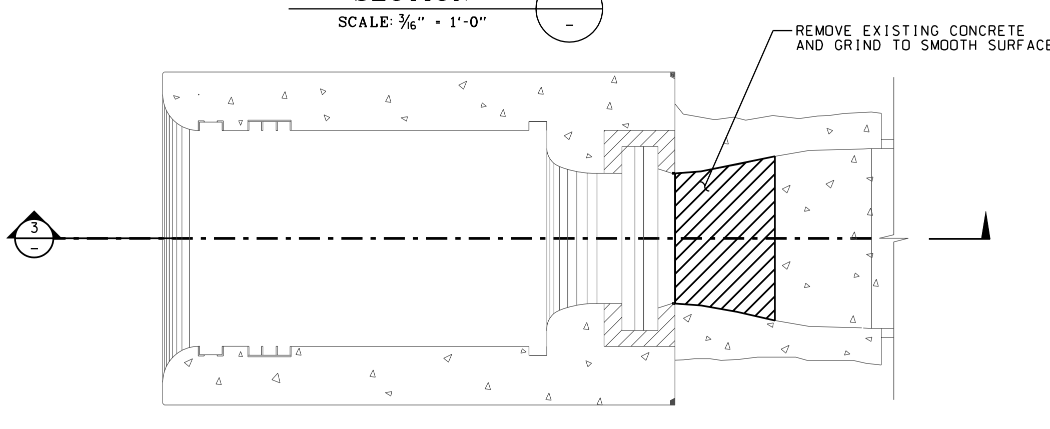
REVISIONS				
SYMBOL	ZONE	DESCRIPTION	DATE	BY



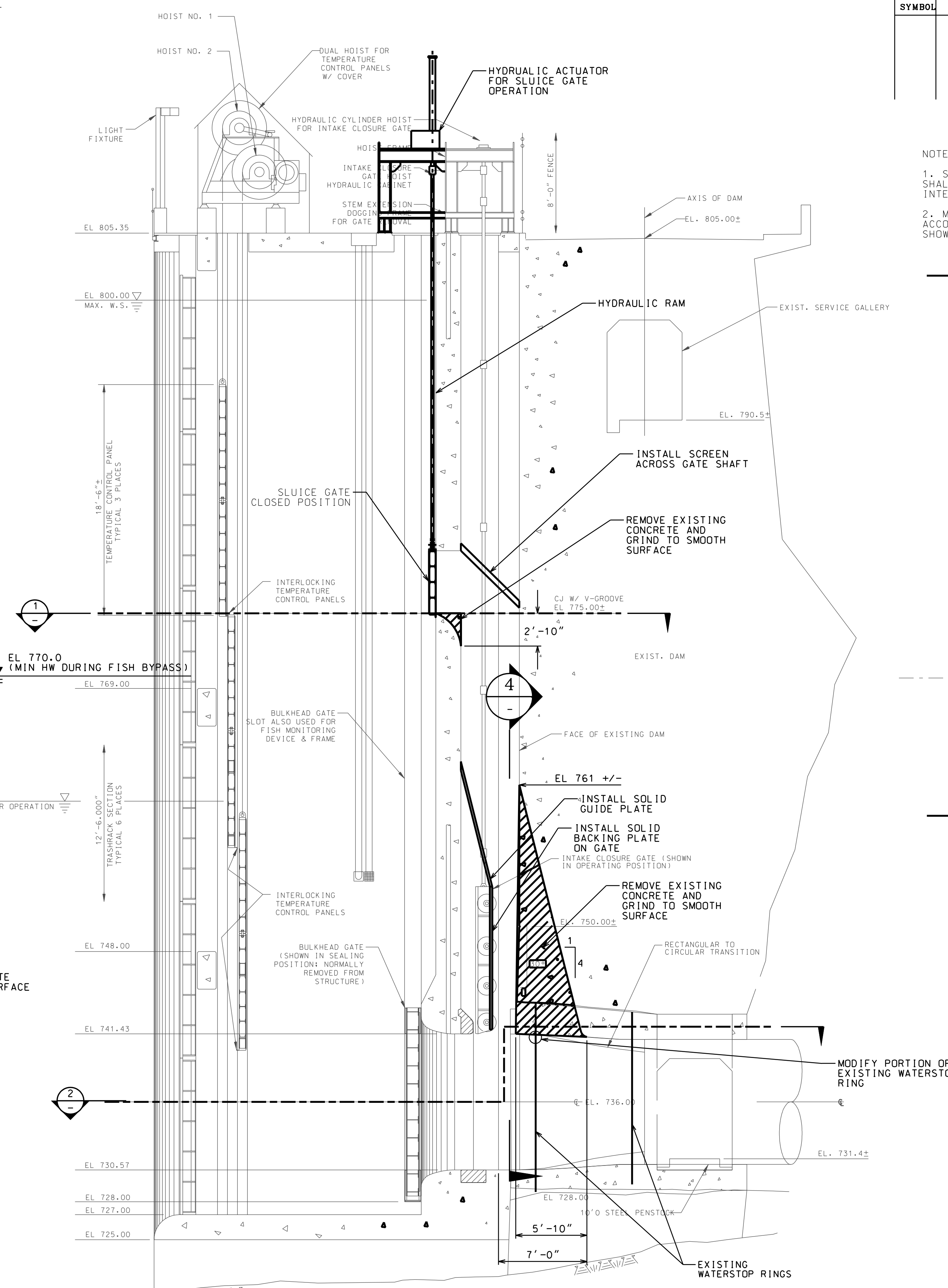
PLAN VIEW @ EL 805.35 A/C1
SCALE: 3/16" = 1'-0"



SECTION 1
SCALE: 3/16" = 1'-0"



SECTION 2
SCALE: 3/16" = 1'-0"

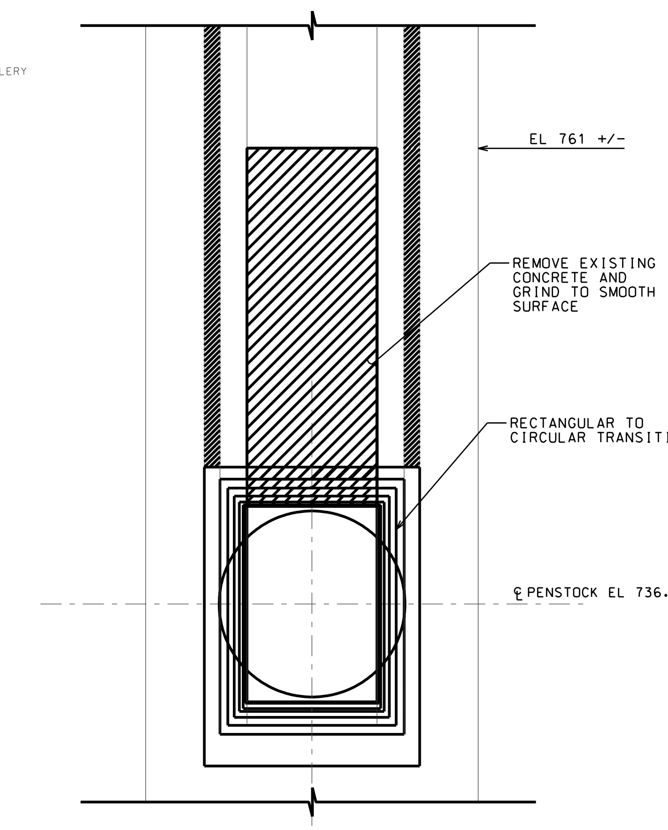


SECTION 3
SCALE: 3/16" = 1'-0"

NOTES:

1. SLUICE GATE OPERATING MECHANISM MOUNTING FRAME SHALL BE MOUNTED AS SHOWN ON DRAWING WITHOUT INTERFERING OPENING OF GRATE COVER

2. MODIFY EXISTING HYDRAULIC HOIST FRAME TO ACCOMODATE SLUICE GATE MOUNTING FRAME CONNECTION AS SHOWN ON DRAWING



SECTION 4
SCALE: 3/16" = 1'-0"

35% DESIGN

TETRA TECH INC. SEATTLE, WASHINGTON

U.S. ARMY ENGINEER DISTRICT, SEATTLE CORPS OF ENGINEERS SEATTLE, WASHINGTON

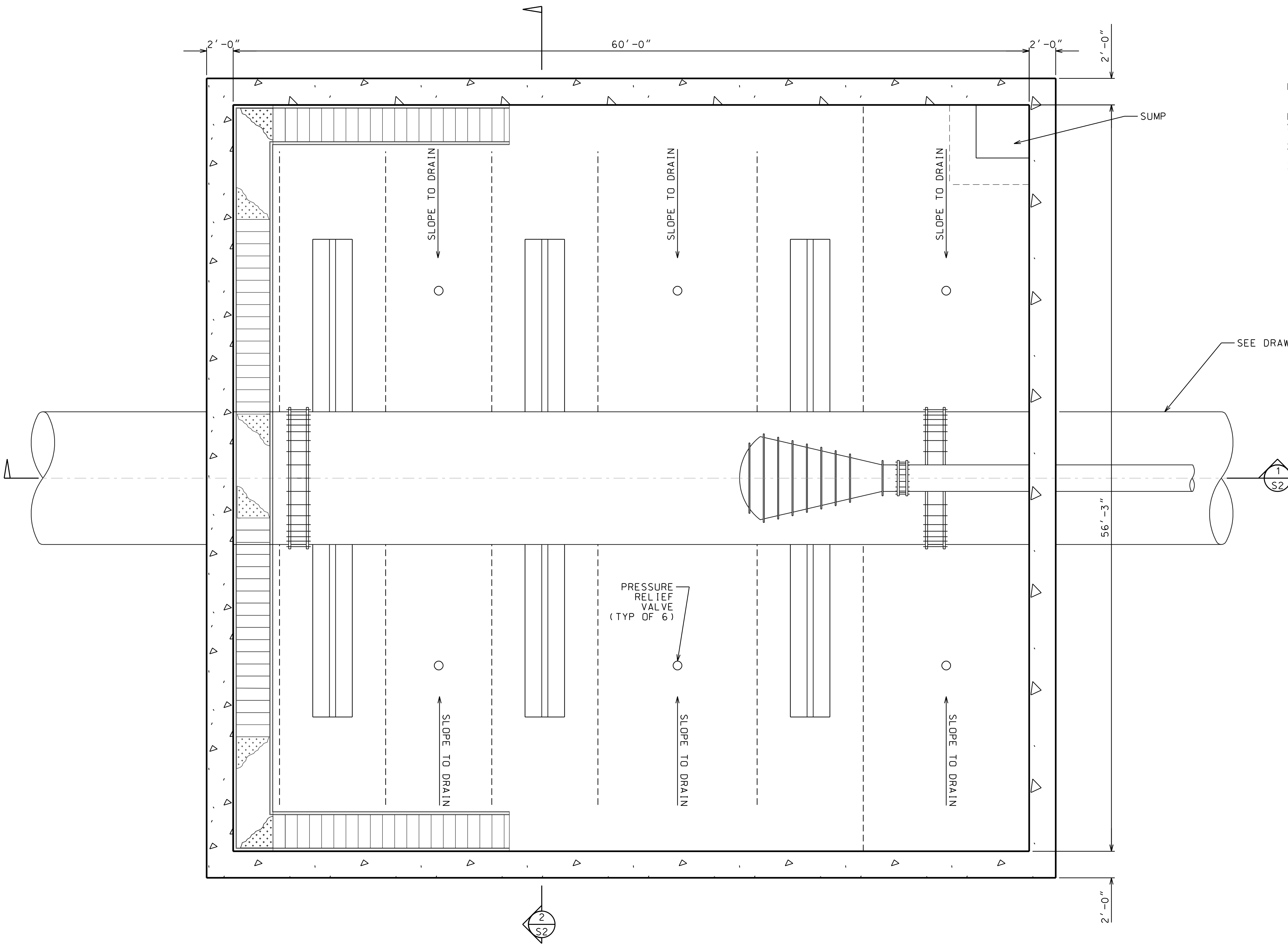
WYNOOCHEE DAM
SECTION 1135 FISH RESTORATION PROJECT

WET WELL STRUCTURE
PLAN AND SECTIONS

GRAYS HARBOR COUNTY, WASHINGTON

SIZE	INVITATION NO.	FILE NO.	DATE:	PLATE
D	DACA67-02-D-2009		AUG 2003	M6
DSGN. CJ		CHK. DW	SHEET 21	

REVISIONS				
SYMBOL	ZONE	DESCRIPTION	DATE	BY



NOTE:

1. EICHER SCREEN VAULT ROOF IS NOT SHOWN ON THIS DRAWING. SEE DRAWINGS S7 AND S8 FOR ROOF PLAN AND SECTION
2. SEE CIVIL DRAWINGS FOR LOCATION OF THIS VAULT
3. SEE MECHANICAL DRAWINGS FOR EQUIPMENT ARRANGEMENT IN VAULT

PLAN (A / -)
SCALE: ¼"=1'-0"

35% DESIGN

TETRA TECH INC.
SEATTLE, WASHINGTON

U.S. ARMY ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

WYNOOCHEE DAM
SECTION 1135 FISH RESTORATION PROJECT

EICHER SCREEN VAULT
PLAN

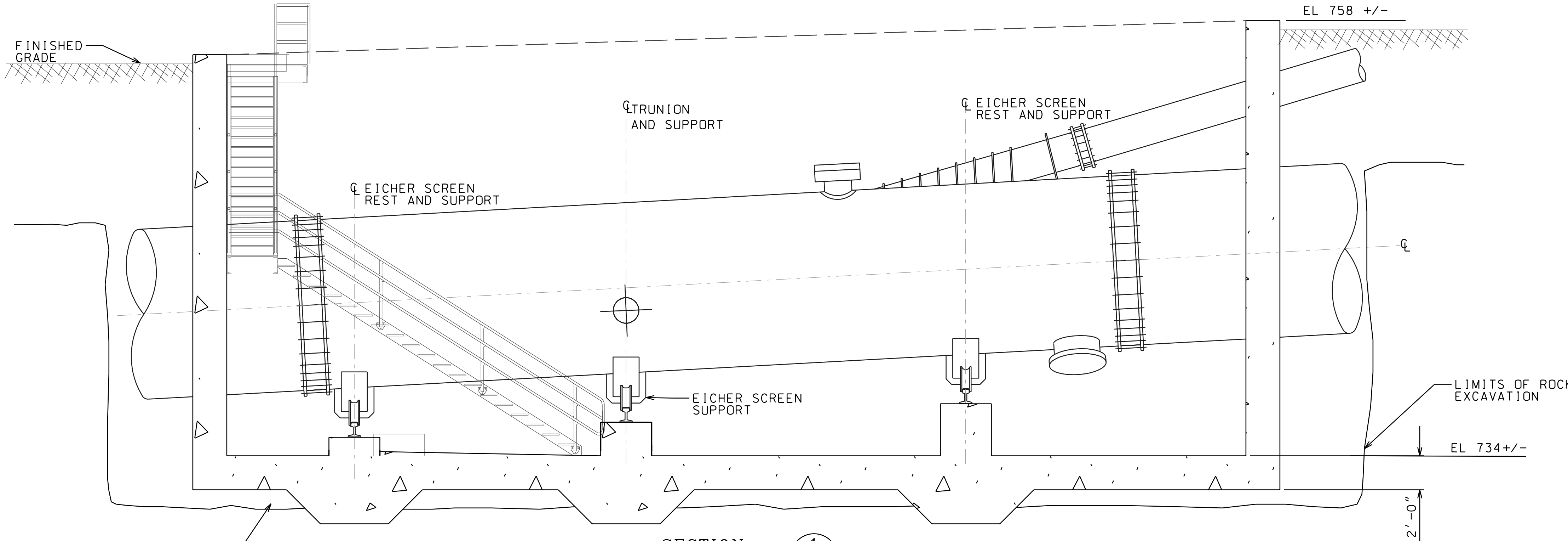
GRAYS HARBOR COUNTY, WASHINGTON

SIZE	INVITATION NO.	FILE NO.	DATE:	PLATE
D	DACA67-02-D-2009		AUG 2003	S1
DSGN. SJ		CHK. DW	SHEET 22	

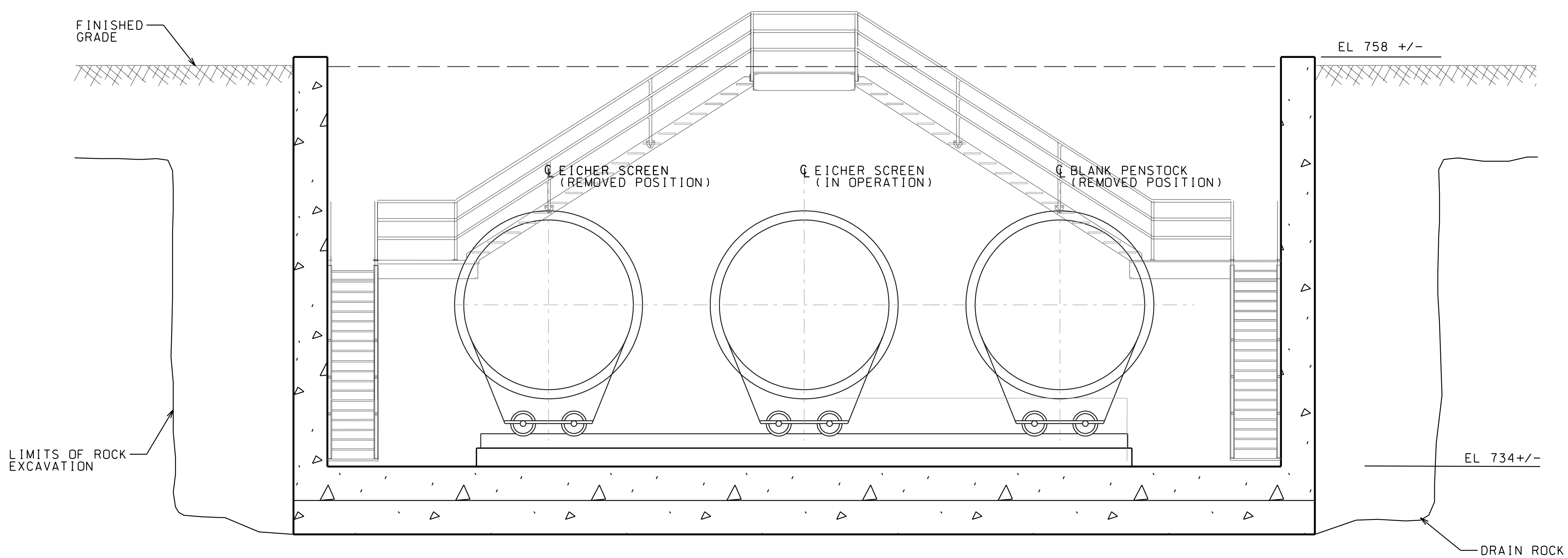
REVISIONS				
SYMBOL	ZONE	DESCRIPTION	DATE	BY

NOTE:

EICHER SCREEN VAULT ROOF IS NOT SHOWN ON THIS DRAWING. SEE DRAWINGS S7 AND S8 FOR ROOF PLAN AND SECTIONS



SECTION 1/S1
SCALE: 1/4" = 1'-0"



SECTION 2/S1
SCALE: 1/4" = 1'-0"

35% DESIGN

TETRA TECH INC. SEATTLE, WASHINGTON

U.S. ARMY ENGINEER DISTRICT, SEATTLE CORPS OF ENGINEERS SEATTLE, WASHINGTON

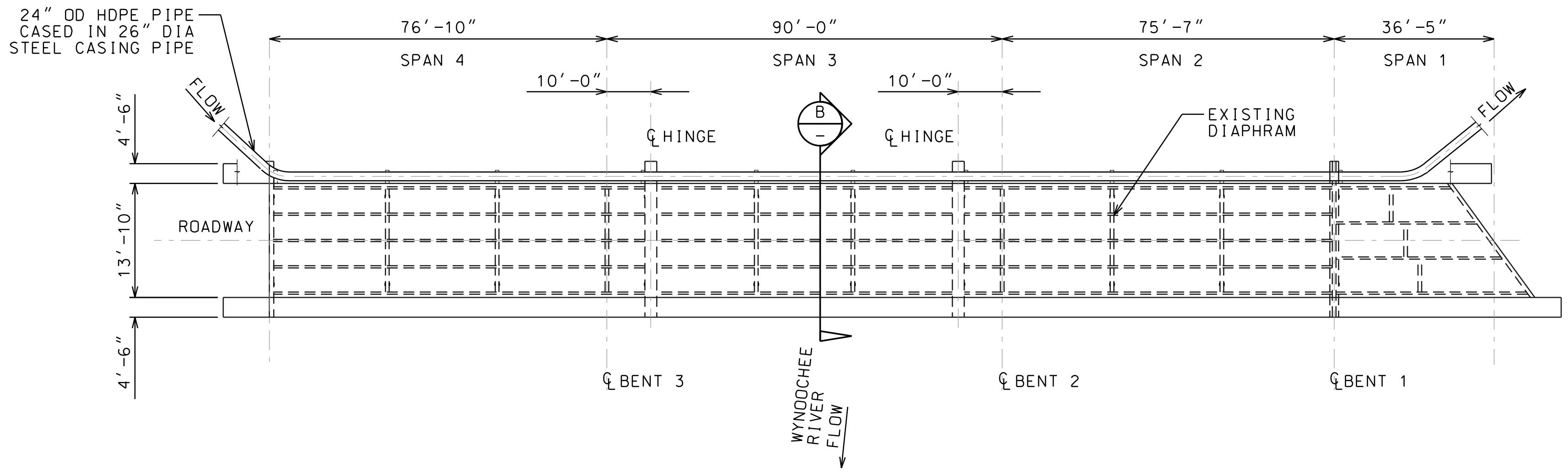
WYNOOCHEE DAM
SECTION 1135 FISH RESTORATION PROJECT

EICHER SCREEN VAULT
SECTIONS AND DETAILS

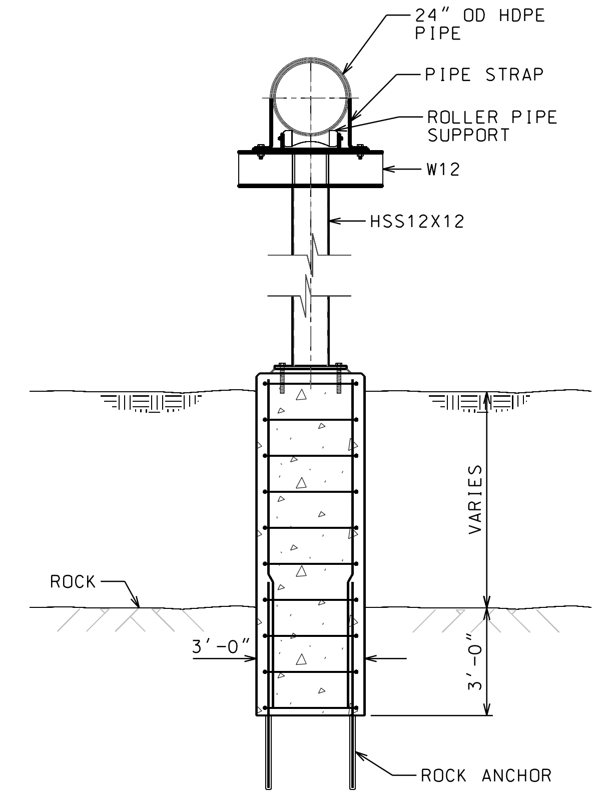
GRAYS HARBOR COUNTY, WASHINGTON

SIZE	INVITATION NO.	FILE NO.	DATE:	PLATE
D	DACA67-02-D-2009		AUG 2003	S2
DSGN. SJ		CHK. DW	SHEET 23	

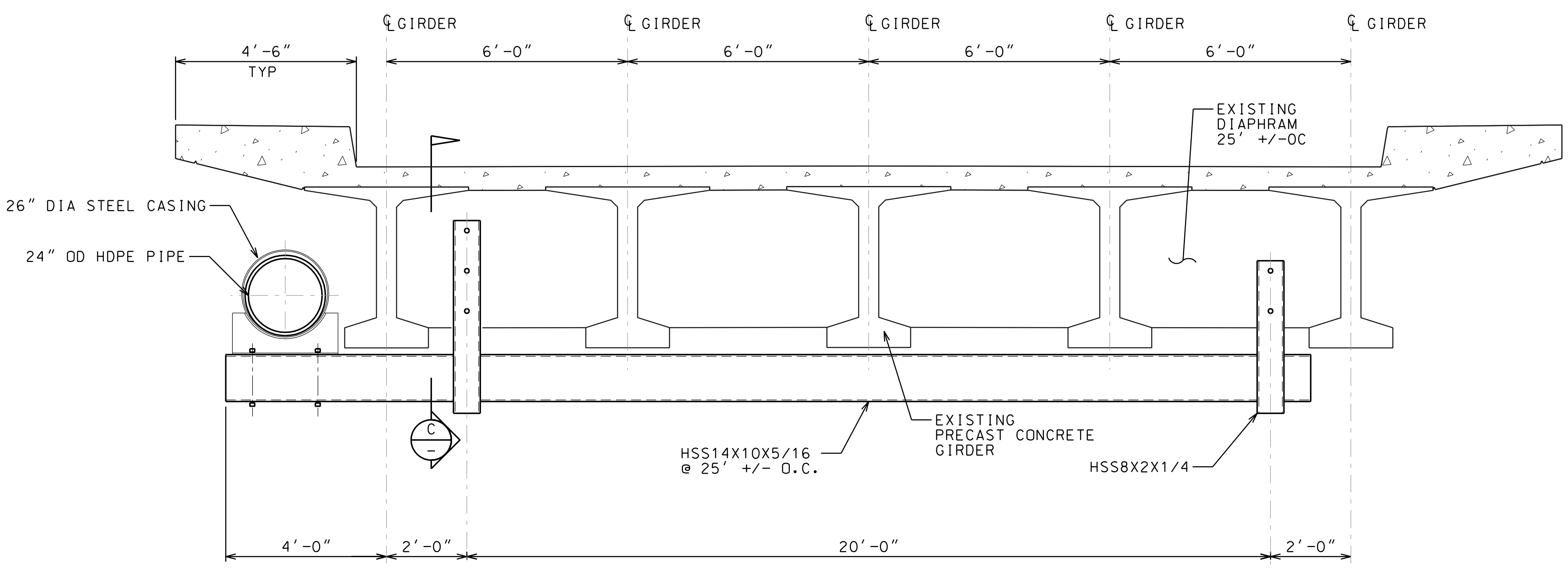
REVISIONS				
SYMBOL	ZONE	DESCRIPTION	DATE	BY



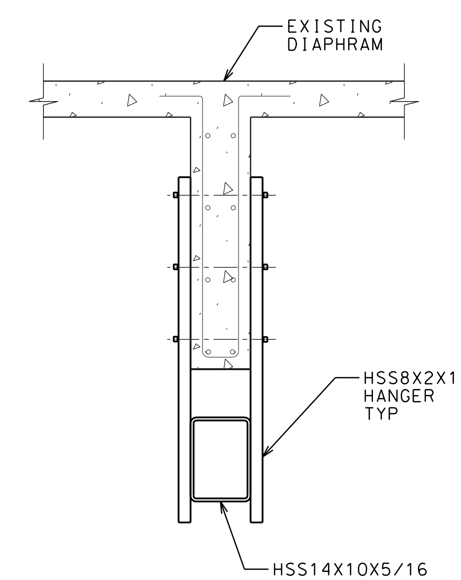
WYNOOCHEE RIVER BRIDGE
USFS ROAD 2294
PLAN (1/C2)
SCALE: AS SHOWN



TYPICAL
ELEVATED PIPE SUPPORT
DETAIL (A/C2)
SCALE: 3/8" = 1'-0"



SPAN 3
SECTION (B/-)
SCALE: 1/2" = 1'-0"



HANGER SUPPORT
SECTION (C/-)
SCALE: 3/4" = 1'-0"

35% DESIGN

TETRA TECH INC. SEATTLE, WASHINGTON
U.S. ARMY ENGINEER DISTRICT, SEATTLE CORPS OF ENGINEERS SEATTLE, WASHINGTON

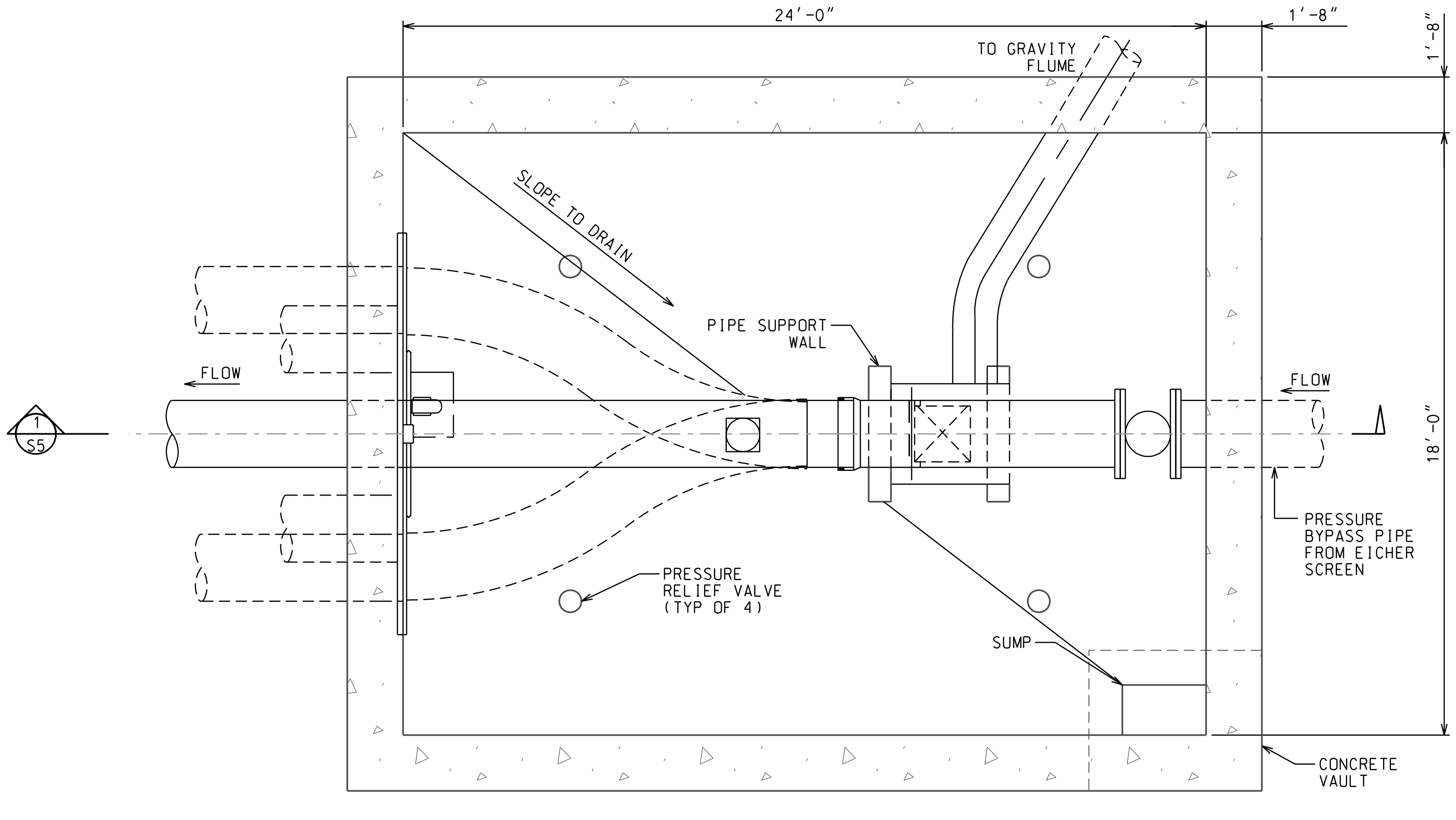
WYNOOCHEE DAM
SECTION 1135 FISH RESTORATION PROJECT
USFS ROAD 2294 BRIDGE
PLAN AND SECTIONS
GRAYS HARBOR COUNTY, WASHINGTON

SIZE	INVITATION NO.	FILE NO.	DATE:	PLATE
D	DACA67-02-D-2009		AUG 2003	S3
DSGN. SJ		CHK. DW	SHEET 24	

REVISIONS				
SYMBOL	ZONE	DESCRIPTION	DATE	BY

NOTE:

1. ROTATING SELECTOR VALVE VAULT ROOF IS NOT SHOWN ON THIS DRAWING. SEE DRAWING S9 FOR ROOF PLAN AND ROOF SECTIONS.
2. SEE CIVIL DRAWINGS FOR LOCATION OF THIS VAULT
3. SEE MECHANICAL DRAWINGS FOR EQUIPMENT ARRANGEMENT IN THIS VAULT



PLAN
SCALE: 3/8" = 1'-0"
A
-

35% DESIGN

TETRA TECH INC.
SEATTLE, WASHINGTON

U.S. ARMY ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

WYNOOCHEE DAM
SECTION 1135 FISH RESTORATION PROJECT

ROTATING SELECTOR SWITCH VAULT
PLAN

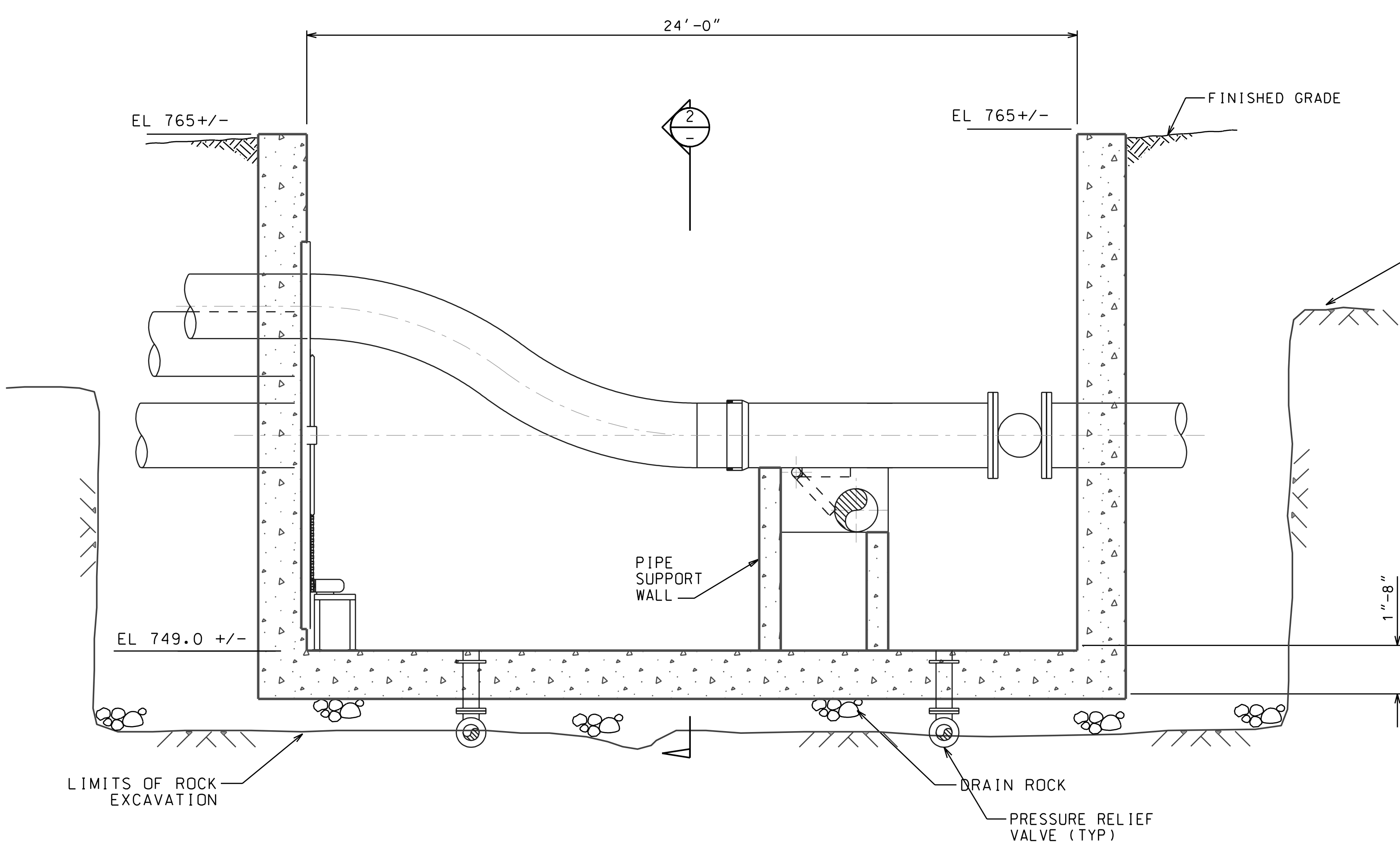
GRAYS HARBOR COUNTY, WASHINGTON

SIZE	INVITATION NO.	FILE NO.	DATE:	PLATE
D	DACA67-02-D-2009		AUG 2003	S4
DSGN. SJ		CHK. DW	SHEET 25	

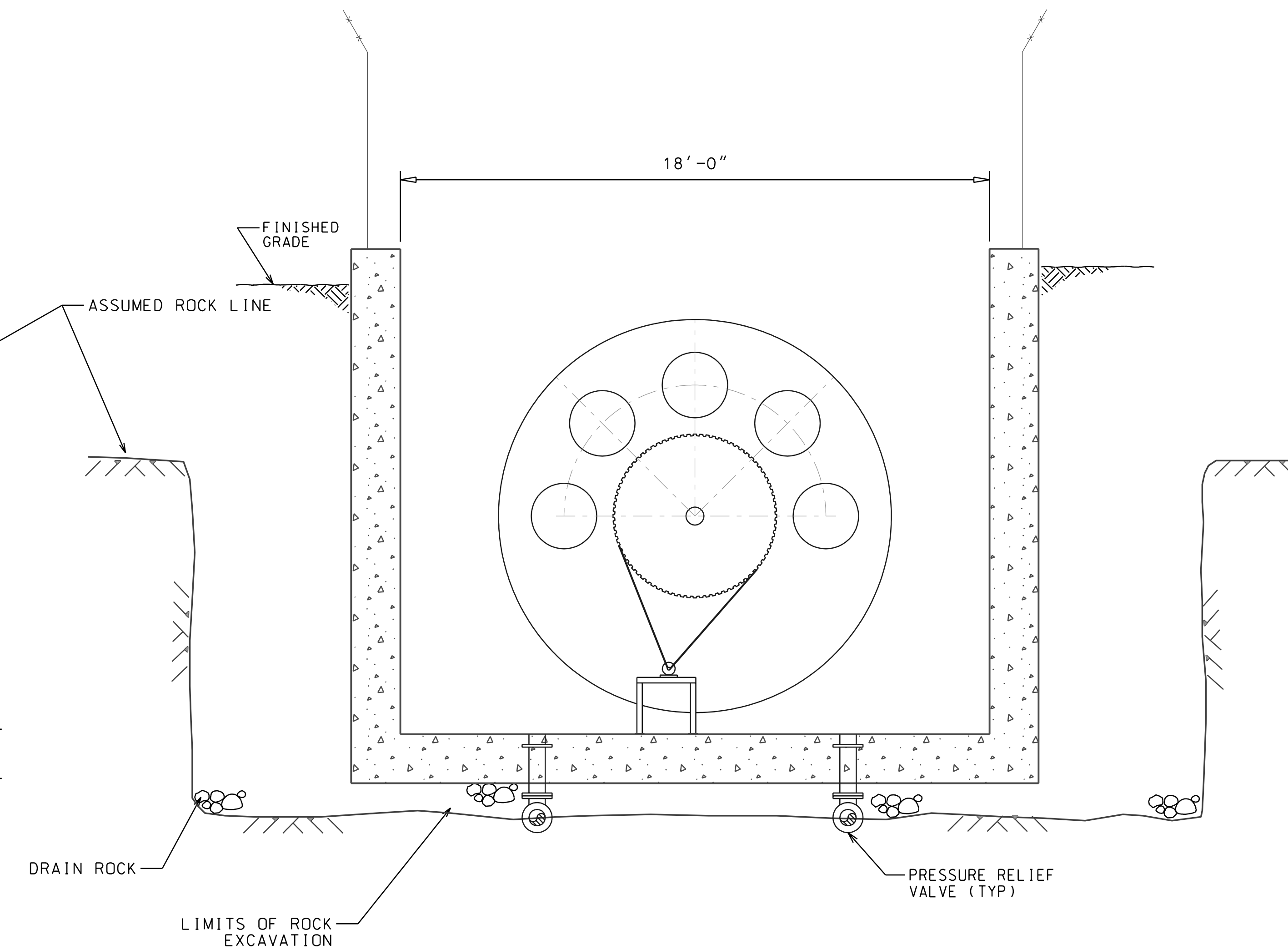
REVISIONS				
SYMBOL	ZONE	DESCRIPTION	DATE	BY

NOTE:

1. ROTATING SELECTOR SWITCH VAULT ROOF IS NOT SHOWN ON THIS SHEET. SEE DRAWING S9 FOR ROOF PLAN AND ROOF SECTION



SECTION 1 / S4
SCALE: 3/8" = 1'-0"



SECTION 2 / -
SCALE: 3/8" = 1'-0"

35% DESIGN

TETRA TECH INC. SEATTLE, WASHINGTON

U.S. ARMY ENGINEER DISTRICT, SEATTLE CORPS OF ENGINEERS SEATTLE, WASHINGTON

WYNOOCHEE DAM
SECTION 1135 FISH RESTORATION PROJECT

ROTATING SELECTOR SWITCH VAULT
SECTIONS

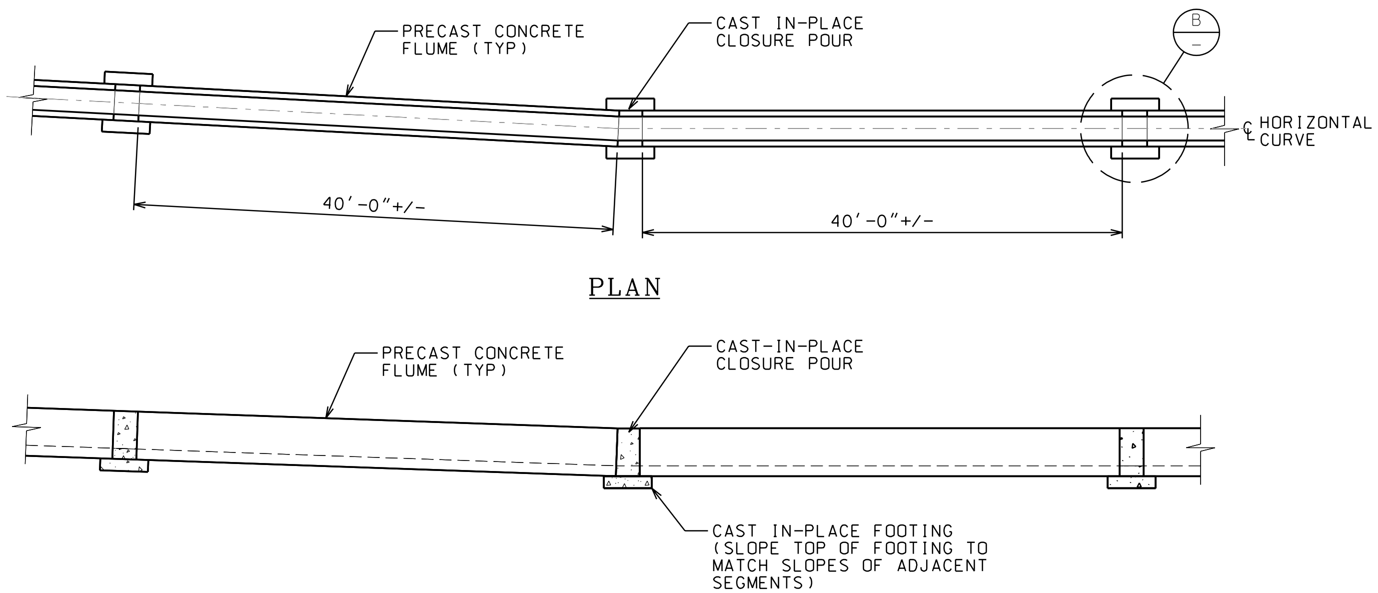
GRAYS HARBOR COUNTY, WASHINGTON

SIZE	INVITATION NO.	FILE NO.	DATE:	PLATE
D	DACA67-02-D-2009		AUG 2003	S5
DSGN. SJ		CHK. DW	SHEET 26	

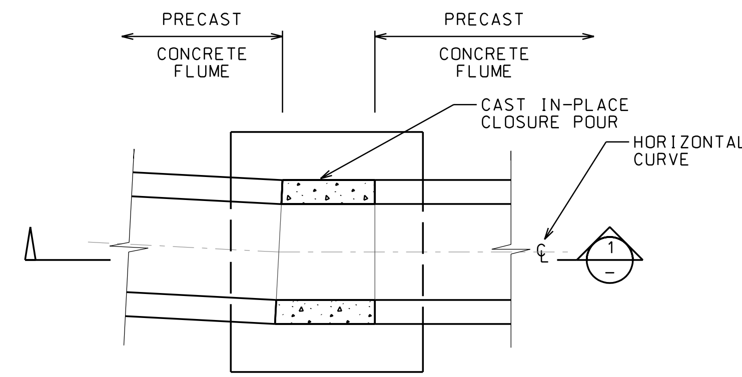
REVISIONS				
SYMBOL	ZONE	DESCRIPTION	DATE	BY

NOTE:

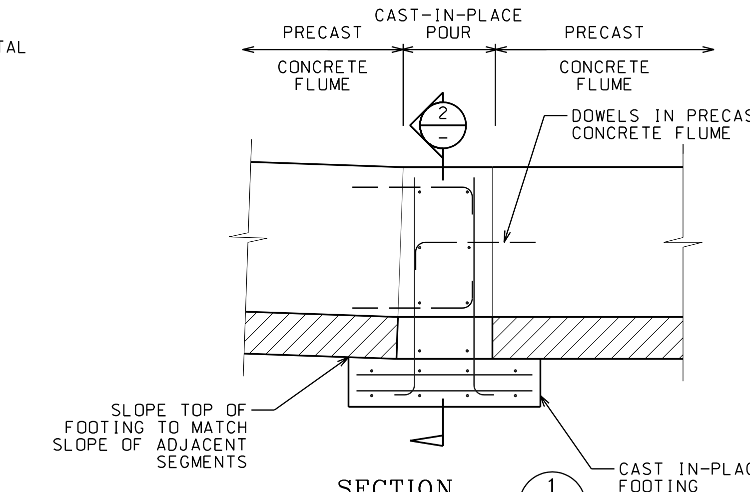
1. SEE CIVIL DRAWINGS FOR LOCATION OF THE FLUME



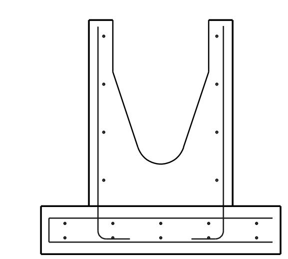
FLUME DETAIL (A)
SCALE: 1/8" = 1'-0"



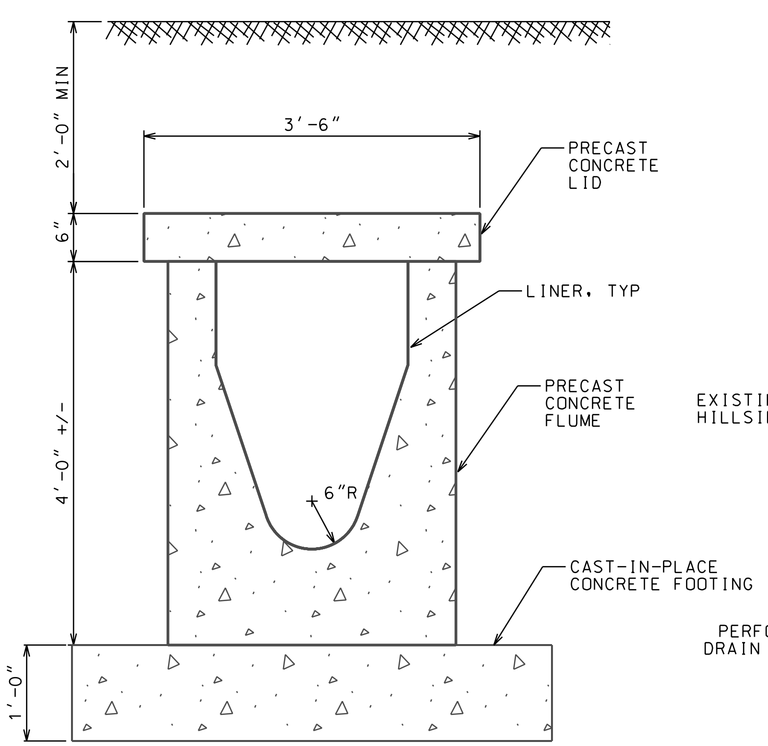
DETAIL (B)
SCALE: 1/2" = 1'-0"



SECTION (1)
SCALE: 1/2" = 1'-0"

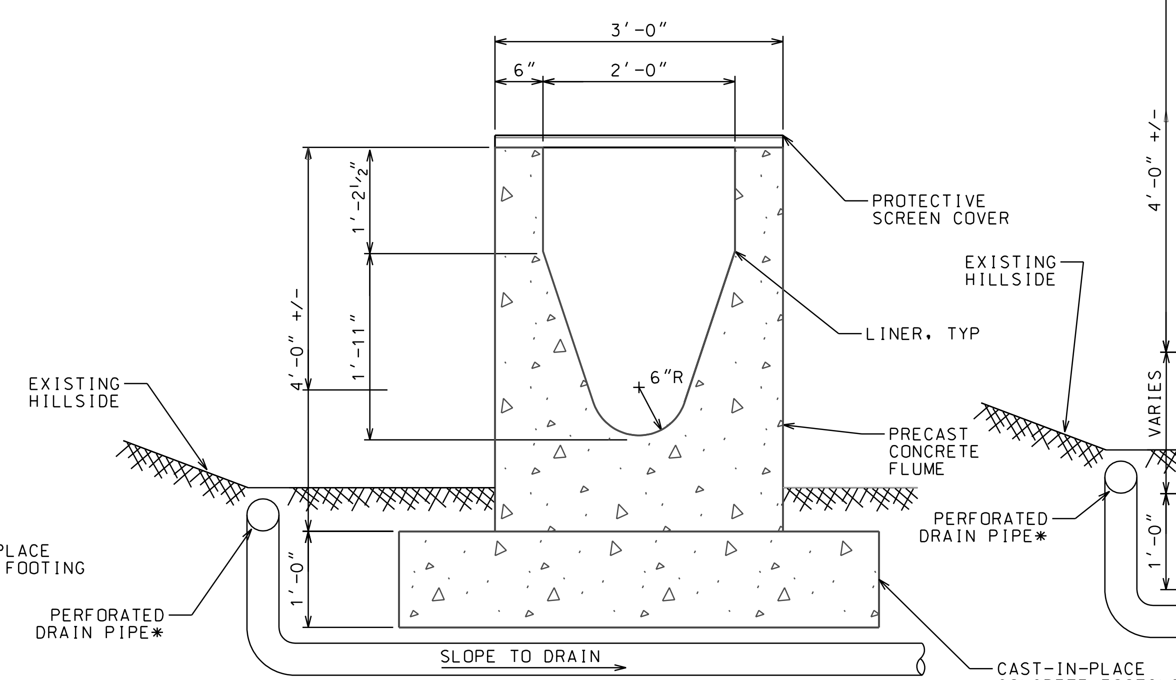


SECTION (2)
SCALE: 1/2" = 1'-0"



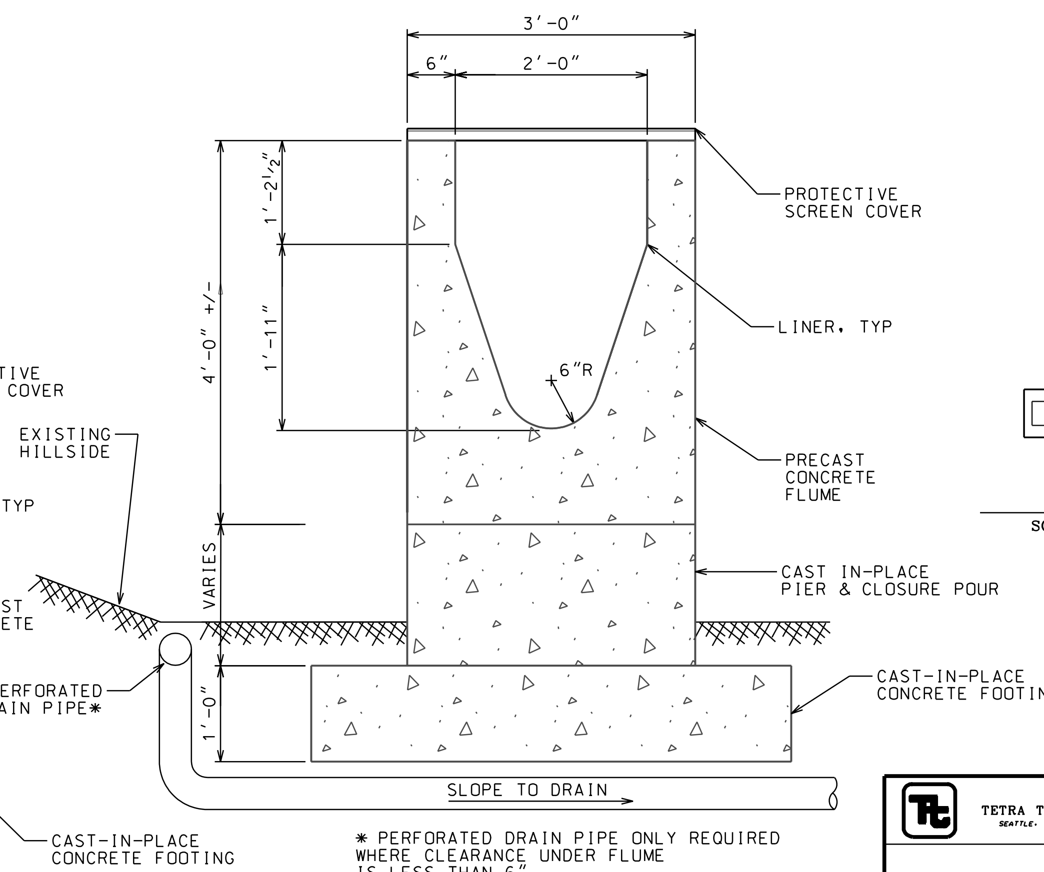
BELOW GRADE GRAVITY FLUME

SECTION (C)
SCALE: 1" = 1'-0"



AT GRADE GRAVITY FLUME

SECTION (D)
SCALE: 1" = 1'-0"



* PERFORATED DRAIN PIPE ONLY REQUIRED WHERE CLEARANCE UNDER FLUME IS LESS THAN 6"

ABOVE GRADE GRAVITY FLUME

SECTION (E)
SCALE: 1" = 1'-0"

35% DESIGN

TETRA TECH INC.
SEATTLE, WASHINGTON

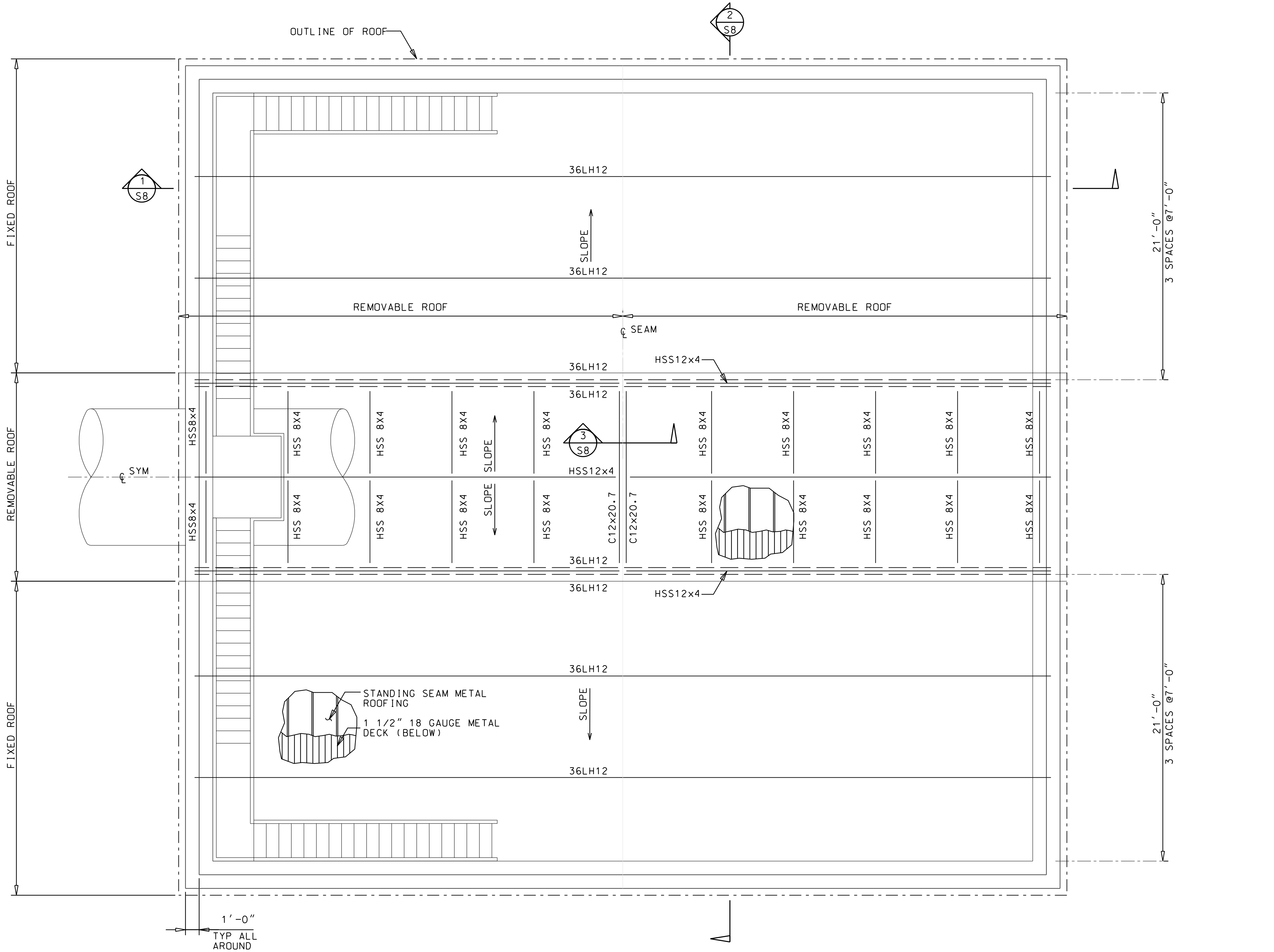
U.S. ARMY ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

WYNOOCHEE DAM
SECTION 1135 FISH RESTORATION PROJECT

GRAVITY FLUME
PLAN, SECTIONS AND DETAILS

GRAYS HARBOR COUNTY, WASHINGTON

SIZE	INVITATION NO.	FILE NO.	DATE:	PLATE
D	DACA67-02-D-2009		AUG 2003	S6
DSGN. SJ		CHK. DW	SHEET 27	



ROOF FRAMING - PLAN (A/-)
SCALE: 1/4" = 1'-0"

REVISIONS				
SYMBOL	ZONE	DESCRIPTION	DATE	BY

35% DESIGN

TETRA TECH INC.
SEATTLE, WASHINGTON

U.S. ARMY ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

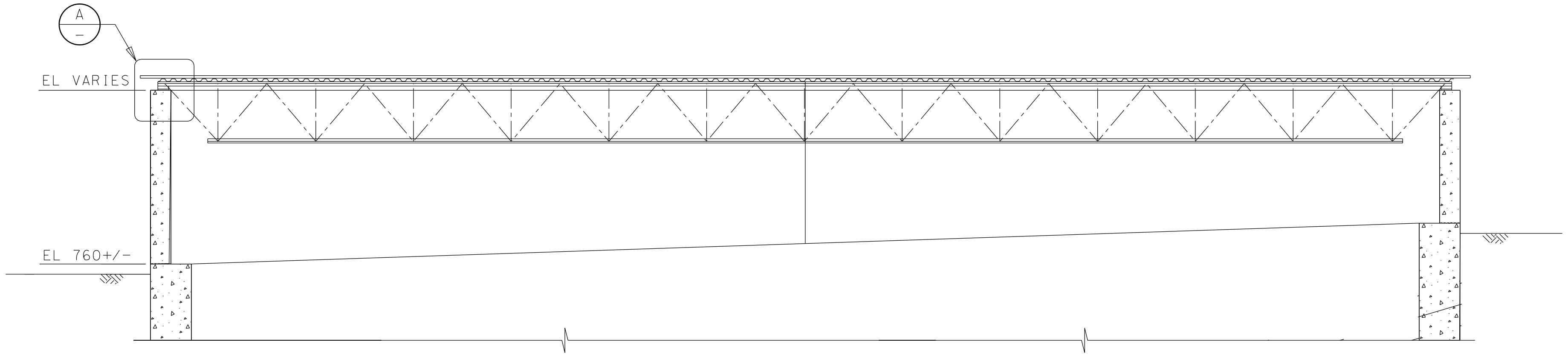
WYNOOCHEE DAM
SECTION 1135 FISH RESTORATION PROJECT

EICHER SCREEN VAULT
ROOF PLAN

GRAYS HARBOR COUNTY, WASHINGTON

SIZE	INVITATION NO.	FILE NO.	DATE:	PLATE
D	DACA67-02-D-2009		AUG 2003	S7
DSGN. SJ		CHK. DW	SHEET 28	

REVISIONS				
SYMBOL	ZONE	DESCRIPTION	DATE	BY



SECTION 1 / S7
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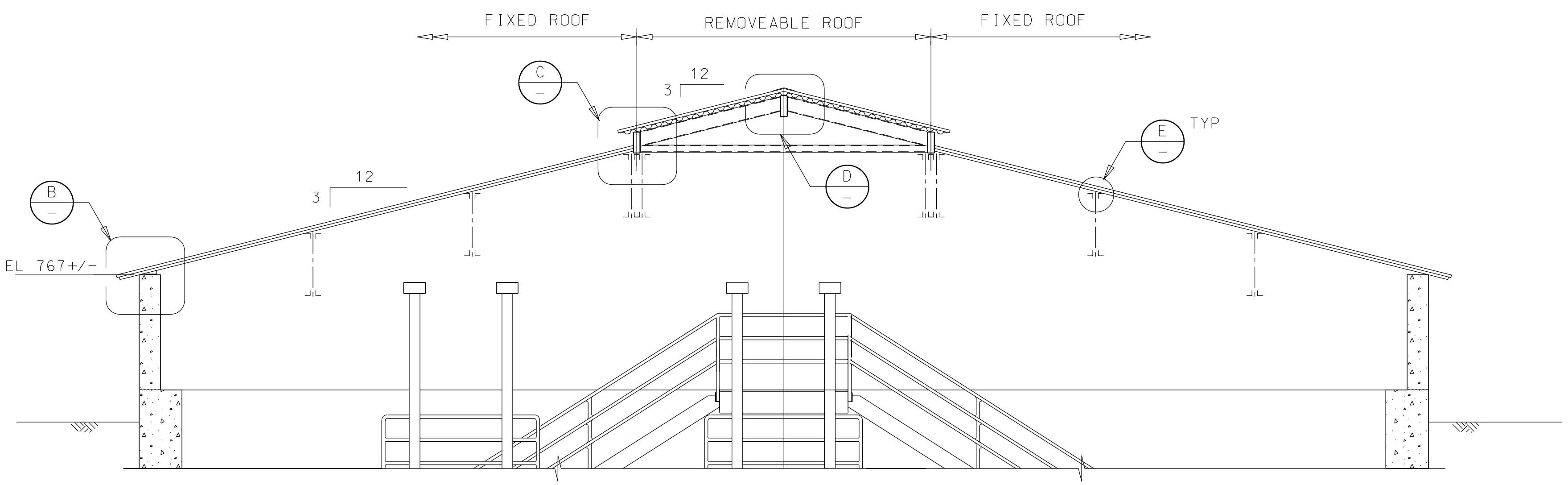

SECTION 2 / S7
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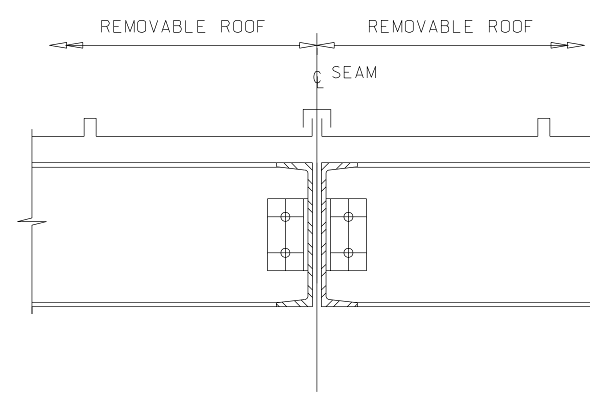
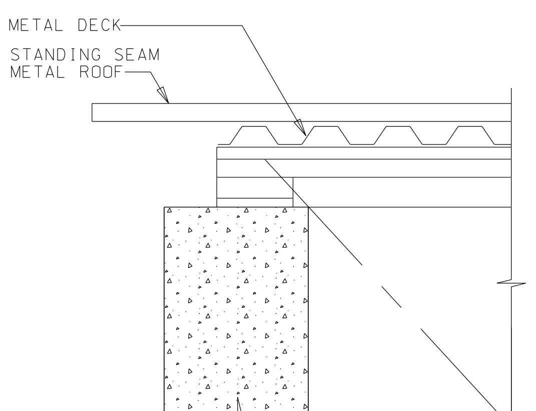
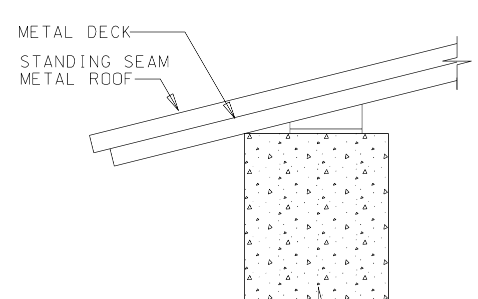


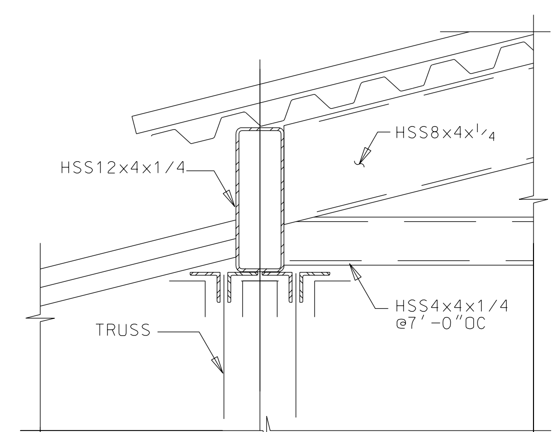
DETAIL 3 / S7
SCALE: 1 1/2"=1'-0"



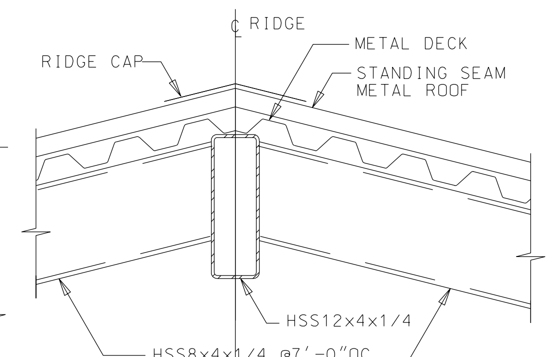
DETAIL A / -
SCALE: 1 1/2"=1'-0"



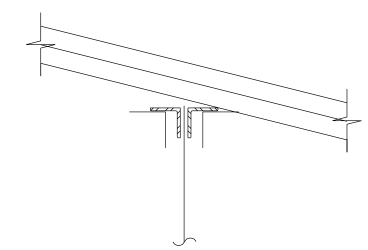
DETAIL B / -
SCALE: 1 1/2"=1'-0"



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



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



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

35% DESIGN

TETRA TECH INC.
SEATTLE, WASHINGTON

U.S. ARMY ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

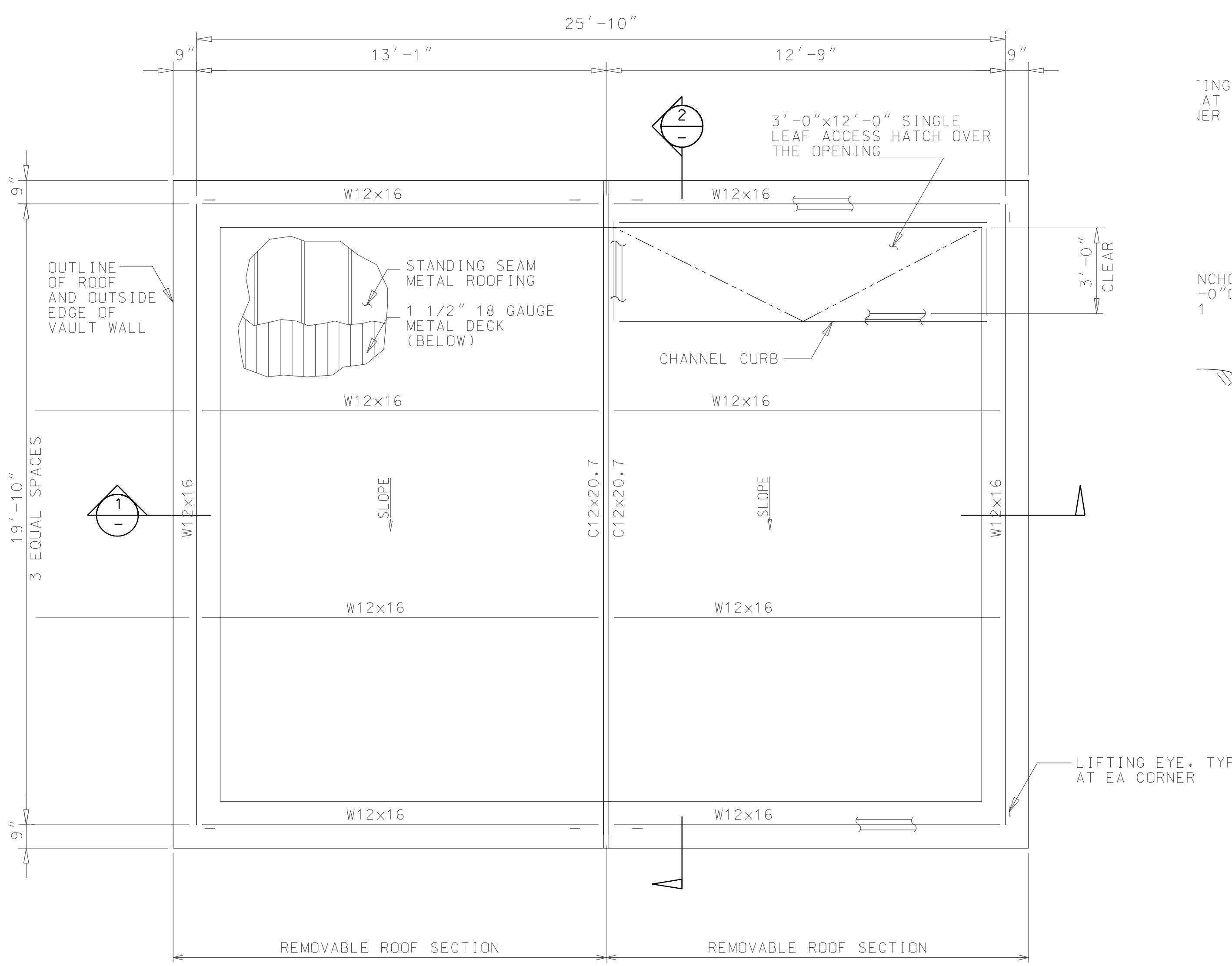
WYNOOCHEE DAM
SECTION 1135 FISH RESTORATION PROJECT

EICHER SCREEN VAULT
ROOF PLAN AND SECTIONS

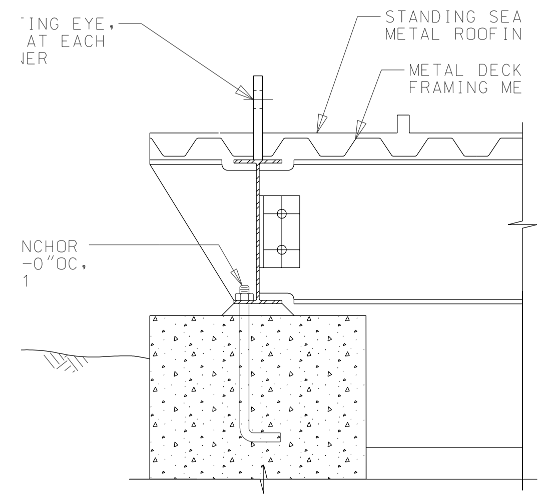
GRAYS HARBOR COUNTY, WASHINGTON

SIZE	INVITATION NO.	FILE NO.	DATE:	PLATE
D	DACA67-02-D-2009		AUG 2003	S8
DSGN. SJ		CHK. DW	SHEET 29	

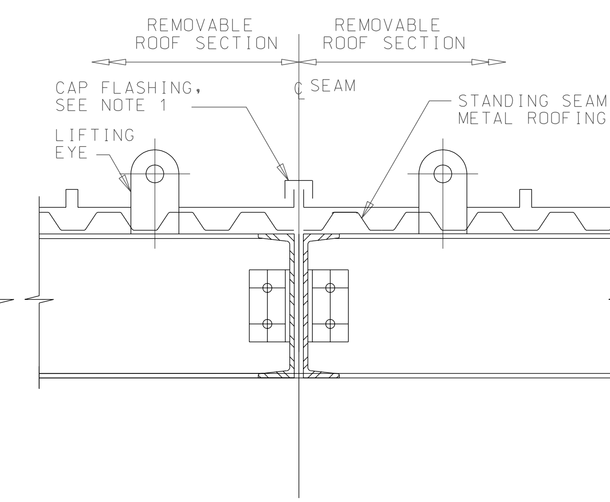
NOTES:
1. REMOVE FLASHING AND UNSCREW ANCHOR BOLTS FOR LIFTING THE ROOF PANEL.



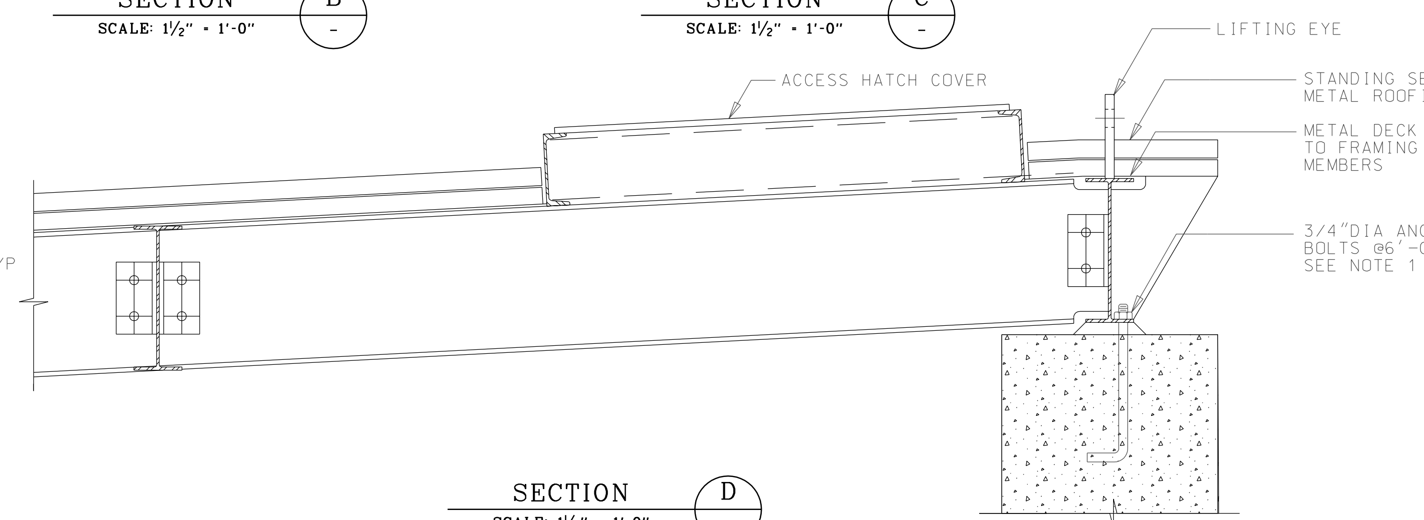
PLAN (A)
SCALE: 3/8" = 1'-0"



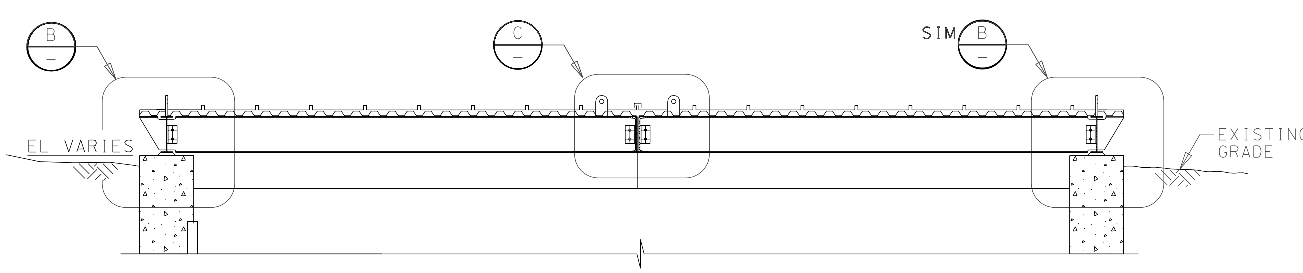
SECTION (B)
SCALE: 1½" = 1'-0"



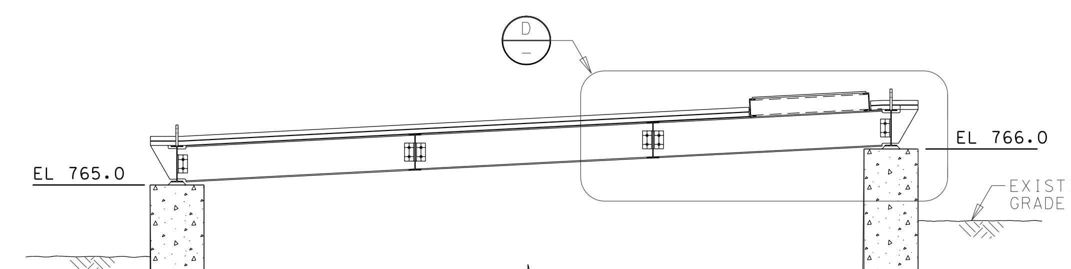
SECTION (C)
SCALE: 1½" = 1'-0"



SECTION (D)
SCALE: 1½" = 1'-0"



SECTION (1)
SCALE: 3/8" = 1'-0"



SECTION (2)
SCALE: 3/8" = 1'-0"

35% DESIGN

TETRA TECH INC.
SEATTLE, WASHINGTON

U.S. ARMY ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

WYNOOCHEE DAM
SECTION 1135 FISH RESTORATION PROJECT

ROTATING SELECTOR SWITCH VAULT
ROOF PLAN AND SECTIONS

GRAYS HARBOR COUNTY, WASHINGTON

SIZE	INVITATION NO.	FILE NO.	DATE:	PLATE
D	DACA67-02-D-2009		AUG 2003	S9
DSGN. SJ		CHK. DW	SHEET 30	

Appendix D

35% Cost Estimate

WYNOOCHEE DAM, SECTION 1135
Fish Restoration Project

Designed By: Tetra Tech, Inc.
Estimated By: Tetra Tech, Inc.

Prepared By: Ike Pace

Preparation Date: 08/27/03
Effective Date of Pricing: 01/01/01
Est Construction Time: 180 Days

Sales Tax: 8.5%

The following methodology was used in the preparation of the Cost Estimate for the Wynoochee Dam, Section 1135 Fish Restoartion Project:

a. The estimate was developed in accordance with guidance contained in ER 1110-2-1302, Civil Works Cost Engineering, and ER 5-7-1, Total Project Cost Summary.

b. The estimate is presented in the Standard Work Breakdown Structure.

c. The effective pricing data is Jan 2001 (Date of UPB). Use 2Q01 data from EM 1110-2-1304, tables Revised 30 September, 2002.

d. Price levels are escalated to the anticipated midpoint of construction in July 2005. Escalation cost factor for 4Q05 of Dams and Fish and Wildlife Facilities were taken from Civil Works Construction Cost Index System (EM 1110-2-1304, tables Revised 30 September, 2002).

e. Construction cost developed by Tetra Tech. This cost was entered using the Army Corps of Engineers M-CACES for Windows estimating software. A copy of the M-CACES cost estimate is included.

f. Labor costs are based the national database (NAT01ALL) provided by the Seattle District.

g. Equipment costs are taken from EP 1110-1-8 Construction Equipment Ownership and Operating Expense Schedule as contained in the NAT99A database provided by the Seattle District.

h. Crews were based on the national crews database (NAT01ACC) provided by the Seattle District.

i. Item costs were based on the M-CACES database and historical data as contained in NAT'l UPB English -A- eff Jan 01, Provided by the Seattle District.

j. Costs for Lands and Damages, Relocations, and Cultural Activities are not included in the estimate.

k. Costs for Construction Supervison and Administration (S&A) and Engineering & Design (E&D) are included as an owner cost and are calculated by percentages (12% and 10% respectively).

l. Bond Costs are based on Class B Bond Rate as showwn in ER1110-2-1302, Appendix D.

Contingency - Per ER 1110-2-1302 "Cost Engineering for Civil Works", the contingeny for feasibility design of a project expected to cost less $10 million is 25%.

Profit:
Prime Contractor Profit Factor:

Factor	Rate	Weight	Value

1. Degree of Risk	20	0.090	1.80%
2. Relative Difficulty of Work	15	0.090	1.35%
3. Size of Job	15	0.040	0.60%
4. Period of Performance	15	0.071	1.07%
5. Contractors Investment	5	0.070	0.35%
6. Assistance by Government	5	0.070	0.35%
7. Subcontracting	25	0.118	2.95%
	Profit Factor		8.47%

Reasons for Weight Assigned
1. Moderate to high Risk - Dam Facilities.
2. Moderate to high difficulty, short schedule, work within fish window
3. Cost to Prime including Field Office, Home Office, and OH Assume 8M
4. Preliminary schedule = Assume 12 months
5. Average
6. Average - Work is on public property. Government provides lands for access and staging. No government provided equipment or facilities.
7. Subcontracting = 20+%

Landscape Contractor Profit Factor

Factor	Rate	Weight	Value
1. Degree of Risk	20	0.060	1.20%
2. Relative Difficulty of Work	15	0.060	0.90%
3. Size of Job	15	0.120	1.80%
4. Period of Performance	15	0.034	0.51%
5. Contractors Investment	5	0.070	0.35%
6. Assistance by Government	5	0.070	0.35%
7. Subcontracting	25	0.120	3.00%
	Profit Factor		8.11%

Reasons for Weight Assigned
1. Moderate to high Risk - Dam facilities
2. Average difficulty, short schedule
3. Cost to LS = Assume $26K
4. 1-2 months for planting
5. Low - Labor intensive work
6. Average - Work is on public property. Government provides lands for access and staging. No government provided equipment or facilities.
7. Subcontracting = 0%

SUMMARY REPORTS SUMMARY PAGE

DETAILED ESTIMATE DETAIL PAGE

DETAILED ESTIMATE DETAIL PAGE

DETAILED ESTIMATE DETAIL PAGE

No Backup Reports...

* * * END TABLE OF CONTENTS * * *

	QUANTITY	UOM	CONTRACT COST	CONTINGN	ESCALATN	E & D	S & A	TOTAL COST	UNIT COST
01 FISH RESTORATION PROJECT									
01 04 DAMS									
01 04 03 Outlet Works									
01 04 03 01 Mobilization/Demobilization	1.00	JOB	260,495	65,124	40,616	36,623	48,343	451,201	451201.45
01 04 03 02 Wetwell Modification	1.00	JOB	194,454	48,614	30,319	27,339	36,087	336,812	336812.14
01 04 03 03 Eicher Screen / Penstock Section	1.00	JOB	1,654,030	413,508	257,891	232,543	306,957	2,864,928	2864928
01 04 03 04 Pressure Bypass Pipeline	1.00	JOB	420,651	105,163	65,587	59,140	78,065	728,606	728606.07
01 04 03 05 Multi-Level Discharge	1.00	JOB	704,695	176,174	109,874	99,074	130,778	1,220,594	1220594
01 04 03 06 Gravity Flume	1.00	JOB	986,653	246,663	153,836	138,715	183,104	1,708,972	1708972
01 04 03 07 Transitional Pond to Drop Struct	1.00	JOB	491,536	122,884	76,639	69,106	91,220	851,384	851383.78
TOTAL Outlet Works	1.00	JOB	4,712,515	1,178,129	734,761	662,540	874,553	8,162,498	8162498
TOTAL DAMS	1.00	JOB	4,712,515	1,178,129	734,761	662,540	874,553	8,162,498	8162498
01 06 FISH AND WILDLIFE FACILITIES									
01 06 03 Wildlife Facilities & Sanctuary									
01 06 03 01 Supplementation Ponds	1.00	JOB	449,545	112,386	70,563	63,249	83,489	779,233	779232.74
TOTAL Wildlife Facilities & Sanctuary	1.00	JOB	449,545	112,386	70,563	63,249	83,489	779,233	779232.74
TOTAL FISH AND WILDLIFE FACILITIES	1.00	JOB	449,545	112,386	70,563	63,249	83,489	779,233	779232.74
TOTAL FISH RESTORATION PROJECT	1.00	JOB	5,162,060	1,290,515	805,323	725,790	958,043	8,941,731	8941731

		QUANTITY	UOM	CONTRACT COST	CONTINGN	ESCALATN	E & D	S & A	TOTAL COST	UNIT COST
01	FISH RESTORATION PROJECT									
01 04	DAMS									
01 04 03	Outlet Works									
01 04 03 01	Mobilization/Demobilization									
01 04 03 01- 01	Mobilization/Demobilization	1.00	JOB	260,495	65,124	40,616	36,623	48,343	451,201	451201.45
	TOTAL Mobilization/Demobilization	1.00	JOB	260,495	65,124	40,616	36,623	48,343	451,201	451201.45
01 04 03 02	Wetwell Modification									
01 04 03 02-020	Demolition	1.00	JOB	69,732	17,433	10,872	9,804	12,941	120,783	120782.85
01 04 03 02-045	Concrete - Structural	1.00	JOB	839	210	131	118	156	1,453	1453.46
01 04 03 02-070	Structural Modifications	1.00	JOB	38,299	9,575	5,971	5,385	7,108	66,337	66337.36
01 04 03 02-093	Automated Hoisting Gate Valve	1.00	JOB	44,338	11,085	6,913	6,234	8,228	76,798	76798.25
01 04 03 02-200	Controls and Instrumentation	1.00	JOB	23,569	5,892	3,675	3,314	4,374	40,823	40822.99
01 04 03 02-210	Power and Telemetry	1.00	JOB	17,676	4,419	2,756	2,485	3,280	30,617	30617.24
	TOTAL Wetwell Modification	1.00	JOB	194,454	48,614	30,319	27,339	36,087	336,812	336812.14
01 04 03 03	Eicher Screen / Penstock Section									
01 04 03 03-005	Clearing and Grubbing	1.00	JOB	6,381	1,595	995	897	1,184	11,052	11052.44
01 04 03 03-010	Dewatering	1.00	JOB	11,195	2,799	1,746	1,574	2,078	19,391	19390.92
01 04 03 03-015	Erosion Control	1.00	JOB	2,634	658	411	370	489	4,562	4562.12
01 04 03 03-020	Demolition	1.00	JOB	32,053	8,013	4,998	4,506	5,948	55,519	55519.26
01 04 03 03-025	Excavation - Soil	1.00	JOB	86,024	21,506	13,413	12,094	15,964	149,002	149001.87
01 04 03 03-026	Excavation - Rock	1.00	JOB	183,239	45,810	28,570	25,762	34,006	317,387	317386.55
01 04 03 03-030	Fill - Select Granular	1.00	JOB	43,595	10,899	6,797	6,129	8,090	75,510	75510.07
01 04 03 03-032	Fill - On-Site Material	1.00	JOB	2,909	727	454	409	540	5,039	5038.85
01 04 03 03-035	Road Improvements	1.00	JOB	5,665	1,416	883	796	1,051	9,812	9812.10
01 04 03 03-040	Utility Relocations	1.00	JOB	1,178	295	184	166	219	2,041	2041.15
01 04 03 03-045	Concrete - Structural Foundation	1.00	JOB	86,131	21,533	13,429	12,109	15,984	149,186	149185.94
01 04 03 03-046	Concrete - Structural Walls	1.00	JOB	256,625	64,156	40,012	36,079	47,625	444,497	444497.24
01 04 03 03-049	Roof System	1.00	JOB	154,033	38,508	24,016	21,656	28,586	266,800	266799.72
01 04 03 03-050	Fencing	1.00	JOB	23,515	5,879	3,666	3,306	4,364	40,730	40729.90
01 04 03 03-055	Facility Access	1.00	JOB	61,709	15,427	9,621	8,676	11,452	106,885	106884.82
01 04 03 03-060	Drainage System	1.00	JOB	17,055	4,264	2,659	2,398	3,165	29,541	29541.25
01 04 03 03-080	10-foot Dia Penstock Section	1.00	JOB	55,221	13,805	8,610	7,764	10,248	95,648	95647.51
01 04 03 03-090	Eicher Screen Valve	1.00	JOB	284,266	71,067	44,322	39,965	52,754	492,374	492374.50
01 04 03 03-091	24-inch Valves	1.00	JOB	53,029	13,257	8,268	7,455	9,841	91,852	91851.72
01 04 03 03-100	Track System	1.00	JOB	240,530	60,132	37,503	33,816	44,638	416,619	416619.01
01 04 03 03-150	Revegetation	1.00	JOB	5,797	1,449	904	815	1,076	10,041	10041.04
01 04 03 03-200	Controls and Instrumentation	1.00	JOB	17,676	4,419	2,756	2,485	3,280	30,617	30617.24

		QUANTITY	UOM	CONTRACT COST	CONTINGN	ESCALATN	E & D	S & A	TOTAL COST	UNIT COST
01 04 03 03-210	Power and Telemetry	1.00	JOB	23,569	5,892	3,675	3,314	4,374	40,823	40822.99
	TOTAL Eicher Screen / Penstock Section	1.00	JOB	1,654,030	413,508	257,891	232,543	306,957	2,864,928	2864928
01 04 03 04	Pressure Bypass Pipeline									
01 04 03 04-005	Clearing and Grubbing	1.00	JOB	6,719	1,680	1,048	945	1,247	11,638	11638.46
01 04 03 04-015	Erosion Control	1.00	JOB	1,718	429	268	242	319	2,976	2975.58
01 04 03 04-020	Demolition	1.00	JOB	2,135	534	333	300	396	3,698	3698.05
01 04 03 04-025	Excavation - Soil	1.00	JOB	4,533	1,133	707	637	841	7,852	7852.11
01 04 03 04-031	Fill - Sand	1.00	JOB	1,428	357	223	201	265	2,473	2473.24
01 04 03 04-032	Fill - On-Site Material	1.00	JOB	168	42	26	24	31	292	291.73
01 04 03 04-035	Road Improvements	1.00	JOB	1,406	351	219	198	261	2,435	2435.11
01 04 03 04-040	Utility Relocations	1.00	JOB	1,178	295	184	166	219	2,041	2041.15
01 04 03 04-081	Steel Casing	1.00	JOB	262,812	65,703	40,977	36,949	48,773	455,213	455213.38
01 04 03 04-082	24-inch HDPE Pipe	1.00	JOB	57,273	14,318	8,930	8,052	10,629	99,202	99202.33
01 04 03 04-091	24-inch Valves	1.00	JOB	54,561	13,640	8,507	7,671	10,126	94,505	94505.22
01 04 03 04-150	Revegetation	1.00	JOB	3,150	788	491	443	585	5,457	5456.72
01 04 03 04-200	Controls and Instrumentation	1.00	JOB	11,784	2,946	1,837	1,657	2,187	20,411	20411.49
01 04 03 04-210	Power and Telemetry	1.00	JOB	11,784	2,946	1,837	1,657	2,187	20,411	20411.49
	TOTAL Pressure Bypass Pipeline	1.00	JOB	420,651	105,163	65,587	59,140	78,065	728,606	728606.07
01 04 03 05	Multi-Level Discharge									
01 04 03 05-005	Clearing and Grubbing	1.00	JOB	8,719	2,180	1,359	1,226	1,618	15,102	15102.38
01 04 03 05-010	Dewatering	1.00	JOB	11,195	2,799	1,746	1,574	2,078	19,391	19390.92
01 04 03 05-015	Erosion Control	1.00	JOB	2,972	743	463	418	552	5,148	5147.69
01 04 03 05-020	Demolition	1.00	JOB	8,006	2,002	1,248	1,126	1,486	13,868	13867.68
01 04 03 05-025	Excavation - Soil	1.00	JOB	66,185	16,546	10,319	9,305	12,283	114,638	114637.58
01 04 03 05-026	Excavation - Rock	1.00	JOB	20,155	5,039	3,143	2,834	3,740	34,911	34911.00
01 04 03 05-030	Fill - Select Granular	1.00	JOB	1,686	421	263	237	313	2,920	2919.92
01 04 03 05-031	Fill - Sand	1.00	JOB	1,536	384	239	216	285	2,660	2659.73
01 04 03 05-032	Fill - On-Site Material	1.00	JOB	295	74	46	41	55	511	510.53
01 04 03 05-033	Grading	1.00	JOB	1,894	473	295	266	351	3,280	3280.34
01 04 03 05-035	Road Improvements	1.00	JOB	12,749	3,187	1,988	1,792	2,366	22,082	22082.00
01 04 03 05-040	Utility Relocations	1.00	JOB	1,178	295	184	166	219	2,041	2041.15
01 04 03 05-045	Concrete - Structural Foundation	1.00	JOB	13,152	3,288	2,051	1,849	2,441	22,781	22780.95
01 04 03 05-046	Concrete - Structural Walls	1.00	JOB	65,482	16,370	10,210	9,206	12,152	113,421	113420.59
01 04 03 05-048	Concrete - Vault	1.00	JOB	30,359	7,590	4,733	4,268	5,634	52,584	52583.77
01 04 03 05-049	Roof System	1.00	JOB	33,939	8,485	5,292	4,772	6,298	58,785	58785.10
01 04 03 05-050	Fencing	1.00	JOB	11,373	2,843	1,773	1,599	2,111	19,700	19699.50
01 04 03 05-055	Facility Access	1.00	JOB	22,652	5,663	3,532	3,185	4,204	39,236	39235.52
01 04 03 05-060	Drainage System	1.00	JOB	14,450	3,613	2,253	2,032	2,682	25,029	25028.94
01 04 03 05-083	24-inch Rotating Pipe Section	1.00	JOB	164,571	41,143	25,659	23,137	30,541	285,052	285051.89
01 04 03 05-084	24-inch Outlet Pipes	1.00	JOB	167,780	41,945	26,160	23,588	31,137	290,610	290609.72
01 04 03 05-150	Revegetation	1.00	JOB	3,122	780	487	439	579	5,407	5407.06
01 04 03 05-200	Controls and Instrumentation	1.00	JOB	17,676	4,419	2,756	2,485	3,280	30,617	30617.24

		QUANTITY	UOM	CONTRACT COST	CONTINGN	ESCALATN	E & D	S & A	TOTAL COST	UNIT COST
01 04 03 05-210	Power and Telemetry	1.00	JOB	23,569	5,892	3,675	3,314	4,374	40,823	40822.99
	TOTAL Multi-Level Discharge	1.00	JOB	704,695	176,174	109,874	99,074	130,778	1,220,594	1220594
01 04 03 06	Gravity Flume									
01 04 03 06-005	Clearing and Grubbing	1.00	JOB	6,411	1,603	1,000	901	1,190	11,105	11104.69
01 04 03 06-015	Erosion Control	1.00	JOB	18,649	4,662	2,908	2,622	3,461	32,302	32302.24
01 04 03 06-020	Demolition	1.00	JOB	14,411	3,603	2,247	2,026	2,674	24,962	24961.82
01 04 03 06-025	Excavation - Soil	1.00	JOB	48,291	12,073	7,529	6,789	8,962	83,644	83644.03
01 04 03 06-030	Fill - Select Granular	1.00	JOB	2,160	540	337	304	401	3,741	3740.80
01 04 03 06-031	Fill - Sand	1.00	JOB	21,418	5,355	3,339	3,011	3,975	37,099	37098.56
01 04 03 06-033	Grading	1.00	JOB	4,545	1,136	709	639	844	7,873	7872.82
01 04 03 06-035	Road Improvements	1.00	JOB	1,178	294	184	166	219	2,040	2040.20
01 04 03 06-040	Utility Relocations	1.00	JOB	1,178	295	184	166	219	2,041	2041.15
01 04 03 06-044	Concrete - Structural Flume Join	1.00	JOB	52,991	13,248	8,262	7,450	9,834	91,785	91785.25
01 04 03 06-047	Concrete - Pre-Cast	1.00	JOB	607,637	151,909	94,741	85,429	112,766	1,052,482	1052482
01 04 03 06-056	Flume Accessories	1.00	JOB	129,154	32,288	20,137	18,158	23,968	223,706	223705.68
01 04 03 06-060	Drainage System	1.00	JOB	45,175	11,294	7,044	6,351	8,384	78,248	78247.63
01 04 03 06-150	Revegetation	1.00	JOB	9,885	2,471	1,541	1,390	1,834	17,122	17121.95
01 04 03 06-200	Controls and Instrumentation	1.00	JOB	11,784	2,946	1,837	1,657	2,187	20,411	20411.49
01 04 03 06-210	Power and Telemetry	1.00	JOB	11,784	2,946	1,837	1,657	2,187	20,411	20411.49
	TOTAL Gravity Flume	1.00	JOB	986,653	246,663	153,836	138,715	183,104	1,708,972	1708972
01 04 03 07	Transitional Pond to Drop Struct									
01 04 03 07-005	Clearing and Grubbing	1.00	JOB	5,144	1,286	802	723	955	8,909	8909.13
01 04 03 07-010	Dewatering	1.00	JOB	11,195	2,799	1,746	1,574	2,078	19,391	19390.92
01 04 03 07-015	Erosion Control	1.00	JOB	6,408	1,602	999	901	1,189	11,099	11099.13
01 04 03 07-025	Excavation - Soil	1.00	JOB	57,210	14,302	8,920	8,043	10,617	99,092	99092.05
01 04 03 07-028	Fill - RipRap	1.00	JOB	2,158	540	337	303	401	3,739	3738.70
01 04 03 07-029	Fill - Quarry Spall	1.00	JOB	378	94	59	53	70	654	654.00
01 04 03 07-030	Fill - Select Granular	1.00	JOB	5,183	1,296	808	729	962	8,978	8977.93
01 04 03 07-032	Fill - On-Site Material	1.00	JOB	2,442	611	381	343	453	4,230	4230.14
01 04 03 07-033	Grading	1.00	JOB	8,485	2,121	1,323	1,193	1,575	14,696	14695.93
01 04 03 07-035	Road Improvements	1.00	JOB	1,331	333	208	187	247	2,306	2306.00
01 04 03 07-040	Utility Relocations	1.00	JOB	1,178	295	184	166	219	2,041	2041.15
01 04 03 07-044	Concrete - Structural Flume Join	1.00	JOB	13,186	3,297	2,056	1,854	2,447	22,839	22839.36
01 04 03 07-045	Concrete - Structural Foundation	1.00	JOB	15,268	3,817	2,381	2,147	2,833	26,446	26445.73
01 04 03 07-046	Concrete - Structural Weirs	1.00	JOB	74,907	18,727	11,679	10,531	13,901	129,745	129745.41
01 04 03 07-047	Concrete - Pre-Cast	1.00	JOB	167,329	41,832	26,089	23,525	31,053	289,829	289829.26
01 04 03 07-050	Fencing	1.00	JOB	46,005	11,501	7,173	6,468	8,538	79,685	79684.93
01 04 03 07-054	Structural Aluminum	1.00	JOB	7,398	1,850	1,153	1,040	1,373	12,814	12814.12
01 04 03 07-055	Facility Access	1.00	JOB	2,228	557	347	313	413	3,858	3858.36
01 04 03 07-056	Flume Topper	1.00	JOB	16,241	4,060	2,532	2,283	3,014	28,132	28131.68
01 04 03 07-060	Drainage System	1.00	JOB	8,647	2,162	1,348	1,216	1,605	14,978	14977.60
01 04 03 07-105	Testing Facilities	1.00	JOB	2,593	648	404	364	481	4,491	4490.53
01 04 03 07-150	Revegetation	1.00	JOB	13,053	3,263	2,035	1,835	2,422	22,609	22608.71

		QUANTITY	UOM	CONTRACT COST	CONTINGN	ESCALATN	E & D	S & A	TOTAL COST	UNIT COST
01 04 03 07-200	Controls and Instrumentation	1.00	JOB	11,784	2,946	1,837	1,657	2,187	20,411	20411.49
01 04 03 07-210	Power and Telemetry	1.00	JOB	11,784	2,946	1,837	1,657	2,187	20,411	20411.49
	TOTAL Transitional Pond to Drop Struct	1.00	JOB	491,536	122,884	76,639	69,106	91,220	851,384	851383.78
	TOTAL Outlet Works	1.00	JOB	4,712,515	1,178,129	734,761	662,540	874,553	8,162,498	8162498
	TOTAL DAMS	1.00	JOB	4,712,515	1,178,129	734,761	662,540	874,553	8,162,498	8162498
01 06	FISH AND WILDLIFE FACILITIES									
01 06 03	Wildlife Facilities & Sanctuary									
01 06 03 01	Supplementation Ponds									
01 06 03 01-005	Clearing and Grubbing	1.00	JOB	2,345	586	368	330	435	4,064	4064.08
01 06 03 01-010	Dewatering	1.00	JOB	11,195	2,799	1,757	1,575	2,079	19,405	19405.37
01 06 03 01-015	Erosion Control	1.00	JOB	2,563	641	402	361	476	4,443	4442.96
01 06 03 01-025	Excavation - Soil	1.00	JOB	44,928	11,232	7,052	6,321	8,344	77,877	77876.80
01 06 03 01-026	Excavation - Rock	1.00	JOB	22,395	5,599	3,515	3,151	4,159	38,819	38818.91
01 06 03 01-030	Fill - Select Granular	1.00	JOB	6,479	1,620	1,017	912	1,203	11,231	11230.78
01 06 03 01-033	Grading	1.00	JOB	7,575	1,894	1,189	1,066	1,407	13,131	13131.15
01 06 03 01-035	Road Improvements	1.00	JOB	7,752	1,938	1,217	1,091	1,440	13,438	13437.80
01 06 03 01-040	Utility Relocations	1.00	JOB	1,178	295	185	166	219	2,043	2042.67
01 06 03 01-046	Concrete - Structural Walls	1.00	JOB	146,509	36,627	22,997	20,613	27,210	253,957	253956.52
01 06 03 01-050	Fencing	1.00	JOB	47,025	11,756	7,381	6,616	8,733	81,512	81511.99
01 06 03 01-055	Facility Access	1.00	JOB	2,228	557	350	313	414	3,861	3861.23
01 06 03 01-060	Drainage System	1.00	JOB	8,092	2,023	1,270	1,139	1,503	14,027	14027.15
01 06 03 01-085	8-inch Pipe	1.00	JOB	89,834	22,459	14,101	12,639	16,684	155,717	155716.87
01 06 03 01-092	8-inch Valves	1.00	JOB	5,150	1,287	808	725	956	8,926	8926.47
01 06 03 01-115	Outlet Structure	1.00	JOB	5,821	1,455	914	819	1,081	10,091	10090.79
01 06 03 01-150	Revegetation	1.00	JOB	3,122	780	490	439	580	5,411	5411.09
01 06 03 01-200	Controls and Instrumentation	1.00	JOB	29,461	7,365	4,624	4,145	5,471	51,067	51066.77
01 06 03 01-210	Power and Telemetry	1.00	JOB	5,892	1,473	925	829	1,094	10,213	10213.35
	TOTAL Supplementation Ponds	1.00	JOB	449,545	112,386	70,563	63,249	83,489	779,233	779232.74
	TOTAL Wildlife Facilities & Sanctuary	1.00	JOB	449,545	112,386	70,563	63,249	83,489	779,233	779232.74
	TOTAL FISH AND WILDLIFE FACILITIES	1.00	JOB	449,545	112,386	70,563	63,249	83,489	779,233	779232.74
	TOTAL FISH RESTORATION PROJECT	1.00	JOB	5,162,060	1,290,515	805,323	725,790	958,043	8,941,731	8941731

	QUANTITY	UOM	TOTAL DIRECT	FOOH	OVERHEAD	PROF	BOND	TOTAL COST	UNIT COST
01 FISH RESTORATION PROJECT									
01 04 DAMS									
01 04 03 Outlet Works									
01 04 03 01 Mobilization/Demobilization	1.00	JOB	210,000	21,000	6,930	20,141	2,425	260,495	260495.45
01 04 03 02 Wetwell Modification	1.00	JOB	156,760	15,676	5,173	15,035	1,810	194,454	194454.23
01 04 03 03 Eicher Screen / Penstock Section	1.00	JOB	1,333,406	133,341	44,002	127,885	15,396	1,654,030	1654030
01 04 03 04 Pressure Bypass Pipeline	1.00	JOB	339,111	33,911	11,191	32,524	3,915	420,651	420651.50
01 04 03 05 Multi-Level Discharge	1.00	JOB	568,094	56,809	18,747	54,485	6,559	704,695	704694.61
01 04 03 06 Gravity Flume	1.00	JOB	795,397	79,540	26,248	76,285	9,184	986,653	986653.32
01 04 03 07 Transitional Pond to Drop Struct	1.00	JOB	396,254	39,625	13,076	38,004	4,575	491,536	491535.65
TOTAL Outlet Works	1.00	JOB	3,799,023	379,902	125,368	364,358	43,864	4,712,515	4712515
TOTAL DAMS	1.00	JOB	3,799,023	379,902	125,368	364,358	43,864	4,712,515	4712515
01 06 FISH AND WILDLIFE FACILITIES									
01 06 03 Wildlife Facilities & Sanctuary									
01 06 03 01 Supplementation Ponds	1.00	JOB	362,404	36,240	11,959	34,758	4,184	449,545	449545.12
TOTAL Wildlife Facilities & Sanctuary	1.00	JOB	362,404	36,240	11,959	34,758	4,184	449,545	449545.12
TOTAL FISH AND WILDLIFE FACILITIES	1.00	JOB	362,404	36,240	11,959	34,758	4,184	449,545	449545.12
TOTAL FISH RESTORATION PROJECT	1.00	JOB	4,161,426	416,143	137,327	399,116	48,048	5,162,060	5162060
CONTINGENCY	25.00	%						1,290,515	
SUBTOTAL								6,452,575	
ESCALATION	12.48	%						805,323	
SUBTOTAL								7,257,898	
	10.00	%						725,790	
SUBTOTAL								7,983,688	
	12.00	%						958,043	
TOTAL INCL OWNER COSTS								8,941,731	

		QUANTITY	UOM	TOTAL DIRECT	FOOH	OVERHEAD	PROF	BOND	TOTAL COST	UNIT COST
01	FISH RESTORATION PROJECT									
01 04	DAMS									
01 04 03	Outlet Works									
01 04 03 01	Mobilization/Demobilization									
01 04 03 01- 01	Mobilization/Demobilization	1.00	JOB	210,000	21,000	6,930	20,141	2,425	260,495	260495.45
	TOTAL Mobilization/Demobilization	1.00	JOB	210,000	21,000	6,930	20,141	2,425	260,495	260495.45
01 04 03 02	Wetwell Modification									
01 04 03 02-020	Demolition	1.00	JOB	56,215	5,622	1,855	5,392	649	69,732	69732.45
01 04 03 02-045	Concrete - Structural	1.00	JOB	676	68	22	65	8	839	839.13
01 04 03 02-070	Structural Modifications	1.00	JOB	30,875	3,088	1,019	2,961	356	38,299	38299.03
01 04 03 02-093	Automated Hoisting Gate Valve	1.00	JOB	35,744	3,574	1,180	3,428	413	44,338	44338.50
01 04 03 02-200	Controls and Instrumentation	1.00	JOB	19,000	1,900	627	1,822	219	23,569	23568.64
01 04 03 02-210	Power and Telemetry	1.00	JOB	14,250	1,425	470	1,367	165	17,676	17676.48
	TOTAL Wetwell Modification	1.00	JOB	156,760	15,676	5,173	15,035	1,810	194,454	194454.23
01 04 03 03	Eicher Screen / Penstock Section									
01 04 03 03-005	Clearing and Grubbing	1.00	JOB	5,144	514	170	493	59	6,381	6380.98
01 04 03 03-010	Dewatering	1.00	JOB	9,025	903	298	866	104	11,195	11195.10
01 04 03 03-015	Erosion Control	1.00	JOB	2,123	212	70	204	25	2,634	2633.88
01 04 03 03-020	Demolition	1.00	JOB	25,840	2,584	853	2,478	298	32,053	32053.34
01 04 03 03-025	Excavation - Soil	1.00	JOB	69,349	6,935	2,289	6,651	801	86,024	86024.34
01 04 03 03-026	Excavation - Rock	1.00	JOB	147,719	14,772	4,875	14,168	1,706	183,239	183239.11
01 04 03 03-030	Fill - Select Granular	1.00	JOB	35,144	3,514	1,160	3,371	406	43,595	43594.78
01 04 03 03-032	Fill - On-Site Material	1.00	JOB	2,345	235	77	225	27	2,909	2909.11
01 04 03 03-035	Road Improvements	1.00	JOB	4,567	457	151	438	53	5,665	5664.89
01 04 03 03-040	Utility Relocations	1.00	JOB	950	95	31	91	11	1,178	1178.43
01 04 03 03-045	Concrete - Structural Foundation	1.00	JOB	69,435	6,943	2,291	6,659	802	86,131	86130.61
01 04 03 03-046	Concrete - Structural Walls	1.00	JOB	206,880	20,688	6,827	19,842	2,389	256,625	256624.85
01 04 03 03-049	Roof System	1.00	JOB	124,175	12,418	4,098	11,909	1,434	154,033	154033.44
01 04 03 03-050	Fencing	1.00	JOB	18,957	1,896	626	1,818	219	23,515	23514.89
01 04 03 03-055	Facility Access	1.00	JOB	49,747	4,975	1,642	4,771	574	61,709	61708.60
01 04 03 03-060	Drainage System	1.00	JOB	13,749	1,375	454	1,319	159	17,055	17055.26
01 04 03 03-080	10-foot Dia Penstock Section	1.00	JOB	44,517	4,452	1,469	4,270	514	55,221	55220.88
01 04 03 03-090	Eicher Screen Valve	1.00	JOB	229,163	22,916	7,562	21,979	2,646	284,266	284266.18
01 04 03 03-091	24-inch Valves	1.00	JOB	42,750	4,275	1,411	4,100	494	53,029	53029.43
01 04 03 03-100	Track System	1.00	JOB	193,905	19,390	6,399	18,597	2,239	240,530	240529.71
01 04 03 03-150	Revegetation	1.00	JOB	4,673	467	154	448	54	5,797	5797.07
01 04 03 03-200	Controls and Instrumentation	1.00	JOB	14,250	1,425	470	1,367	165	17,676	17676.48

		QUANTITY	UOM	TOTAL DIRECT	FOOH	OVERHEAD	PROF	BOND	TOTAL COST	UNIT COST
01 04 03 03-210	Power and Telemetry	1.00	JOB	19,000	1,900	627	1,822	219	23,569	23568.64
	TOTAL Eicher Screen / Penstock Section	1.00	JOB	1,333,406	133,341	44,002	127,885	15,396	1,654,030	1654030
01 04 03 04	Pressure Bypass Pipeline									
01 04 03 04-005	Clearing and Grubbing	1.00	JOB	5,417	542	179	520	63	6,719	6719.32
01 04 03 04-015	Erosion Control	1.00	JOB	1,385	138	46	133	16	1,718	1717.92
01 04 03 04-020	Demolition	1.00	JOB	1,721	172	57	165	20	2,135	2135.02
01 04 03 04-025	Excavation - Soil	1.00	JOB	3,655	365	121	351	42	4,533	4533.32
01 04 03 04-031	Fill - Sand	1.00	JOB	1,151	115	38	110	13	1,428	1427.89
01 04 03 04-032	Fill - On-Site Material	1.00	JOB	136	14	4	13	2	168	168.43
01 04 03 04-035	Road Improvements	1.00	JOB	1,133	113	37	109	13	1,406	1405.88
01 04 03 04-040	Utility Relocations	1.00	JOB	950	95	31	91	11	1,178	1178.43
01 04 03 04-081	Steel Casing	1.00	JOB	211,867	21,187	6,992	20,320	2,446	262,812	262811.69
01 04 03 04-082	24-inch HDPE Pipe	1.00	JOB	46,171	4,617	1,524	4,428	533	57,273	57273.21
01 04 03 04-091	24-inch Valves	1.00	JOB	43,985	4,399	1,452	4,219	508	54,561	54561.39
01 04 03 04-150	Revegetation	1.00	JOB	2,540	254	84	244	29	3,150	3150.37
01 04 03 04-200	Controls and Instrumentation	1.00	JOB	9,500	950	314	911	110	11,784	11784.32
01 04 03 04-210	Power and Telemetry	1.00	JOB	9,500	950	314	911	110	11,784	11784.32
	TOTAL Pressure Bypass Pipeline	1.00	JOB	339,111	33,911	11,191	32,524	3,915	420,651	420651.50
01 04 03 05	Multi-Level Discharge									
01 04 03 05-005	Clearing and Grubbing	1.00	JOB	7,029	703	232	674	81	8,719	8719.17
01 04 03 05-010	Dewatering	1.00	JOB	9,025	903	298	866	104	11,195	11195.10
01 04 03 05-015	Erosion Control	1.00	JOB	2,396	240	79	230	28	2,972	2971.96
01 04 03 05-020	Demolition	1.00	JOB	6,454	645	213	619	75	8,006	8006.33
01 04 03 05-025	Excavation - Soil	1.00	JOB	53,355	5,336	1,761	5,117	616	66,185	66184.55
01 04 03 05-026	Excavation - Rock	1.00	JOB	16,248	1,625	536	1,558	188	20,155	20155.43
01 04 03 05-030	Fill - Select Granular	1.00	JOB	1,359	136	45	130	16	1,686	1685.78
01 04 03 05-031	Fill - Sand	1.00	JOB	1,238	124	41	119	14	1,536	1535.56
01 04 03 05-032	Fill - On-Site Material	1.00	JOB	238	24	8	23	3	295	294.75
01 04 03 05-033	Grading	1.00	JOB	1,527	153	50	146	18	1,894	1893.86
01 04 03 05-035	Road Improvements	1.00	JOB	10,277	1,028	339	986	119	12,749	12748.76
01 04 03 05-040	Utility Relocations	1.00	JOB	950	95	31	91	11	1,178	1178.43
01 04 03 05-045	Concrete - Structural Foundation	1.00	JOB	10,603	1,060	350	1,017	122	13,152	13152.29
01 04 03 05-046	Concrete - Structural Walls	1.00	JOB	52,789	5,279	1,742	5,063	610	65,482	65481.94
01 04 03 05-048	Concrete - Vault	1.00	JOB	24,474	2,447	808	2,347	283	30,359	30358.57
01 04 03 05-049	Roof System	1.00	JOB	27,360	2,736	903	2,624	316	33,939	33938.84
01 04 03 05-050	Fencing	1.00	JOB	9,169	917	303	879	106	11,373	11373.26
01 04 03 05-055	Facility Access	1.00	JOB	18,261	1,826	603	1,751	211	22,652	22652.13
01 04 03 05-060	Drainage System	1.00	JOB	11,649	1,165	384	1,117	135	14,450	14450.14
01 04 03 05-083	24-inch Rotating Pipe Section	1.00	JOB	132,670	13,267	4,378	12,724	1,532	164,571	164571.10
01 04 03 05-084	24-inch Outlet Pipes	1.00	JOB	135,257	13,526	4,463	12,972	1,562	167,780	167779.85
01 04 03 05-150	Revegetation	1.00	JOB	2,517	252	83	241	29	3,122	3121.70
01 04 03 05-200	Controls and Instrumentation	1.00	JOB	14,250	1,425	470	1,367	165	17,676	17676.48

		QUANTITY UOM	TOTAL DIRECT	FOOH	OVERHEAD	PROF	BOND	TOTAL COST	UNIT COST
01 04 03 05-210	Power and Telemetry	1.00 JOB	19,000	1,900	627	1,822	219	23,569	23568.64
	TOTAL Multi-Level Discharge	1.00 JOB	568,094	56,809	18,747	54,485	6,559	704,695	704694.61
01 04 03 06	Gravity Flume								
01 04 03 06-005	Clearing and Grubbing	1.00 JOB	5,168	517	171	496	60	6,411	6411.15
01 04 03 06-015	Erosion Control	1.00 JOB	15,034	1,503	496	1,442	174	18,649	18649.29
01 04 03 06-020	Demolition	1.00 JOB	11,618	1,162	383	1,114	134	14,411	14411.39
01 04 03 06-025	Excavation - Soil	1.00 JOB	38,930	3,893	1,285	3,734	449	48,291	48290.82
01 04 03 06-030	Fill - Select Granular	1.00 JOB	1,741	174	57	167	20	2,160	2159.71
01 04 03 06-031	Fill - Sand	1.00 JOB	17,267	1,727	570	1,656	199	21,418	21418.38
01 04 03 06-033	Grading	1.00 JOB	3,664	366	121	351	42	4,545	4545.27
01 04 03 06-035	Road Improvements	1.00 JOB	950	95	31	91	11	1,178	1177.89
01 04 03 06-040	Utility Relocations	1.00 JOB	950	95	31	91	11	1,178	1178.43
01 04 03 06-044	Concrete - Structural Flume Join	1.00 JOB	42,719	4,272	1,410	4,097	493	52,991	52991.05
01 04 03 06-047	Concrete - Pre-Cast	1.00 JOB	489,850	48,985	16,165	46,981	5,656	607,637	607637.24
01 04 03 06-056	Flume Accessories	1.00 JOB	104,118	10,412	3,436	9,986	1,202	129,154	129153.64
01 04 03 06-060	Drainage System	1.00 JOB	36,418	3,642	1,202	3,493	420	45,175	45175.28
01 04 03 06-150	Revegetation	1.00 JOB	7,969	797	263	764	92	9,885	9885.14
01 04 03 06-200	Controls and Instrumentation	1.00 JOB	9,500	950	314	911	110	11,784	11784.32
01 04 03 06-210	Power and Telemetry	1.00 JOB	9,500	950	314	911	110	11,784	11784.32
	TOTAL Gravity Flume	1.00 JOB	795,397	79,540	26,248	76,285	9,184	986,653	986653.32
01 04 03 07	Transitional Pond to Drop Struct								
01 04 03 07-005	Clearing and Grubbing	1.00 JOB	4,147	415	137	398	48	5,144	5143.58
01 04 03 07-010	Dewatering	1.00 JOB	9,025	903	298	866	104	11,195	11195.10
01 04 03 07-015	Erosion Control	1.00 JOB	5,166	517	170	495	60	6,408	6407.94
01 04 03 07-025	Excavation - Soil	1.00 JOB	46,120	4,612	1,522	4,423	533	57,210	57209.54
01 04 03 07-028	Fill - RipRap	1.00 JOB	1,740	174	57	167	20	2,158	2158.49
01 04 03 07-029	Fill - Quarry Spall	1.00 JOB	304	30	10	29	4	378	377.58
01 04 03 07-030	Fill - Select Granular	1.00 JOB	4,179	418	138	401	48	5,183	5183.29
01 04 03 07-032	Fill - On-Site Material	1.00 JOB	1,969	197	65	189	23	2,442	2442.22
01 04 03 07-033	Grading	1.00 JOB	6,840	684	226	656	79	8,485	8484.51
01 04 03 07-035	Road Improvements	1.00 JOB	1,073	107	35	103	12	1,331	1331.34
01 04 03 07-040	Utility Relocations	1.00 JOB	950	95	31	91	11	1,178	1178.43
01 04 03 07-044	Concrete - Structural Flume Join	1.00 JOB	10,630	1,063	351	1,020	123	13,186	13186.02
01 04 03 07-045	Concrete - Structural Foundation	1.00 JOB	12,308	1,231	406	1,180	142	15,268	15268.11
01 04 03 07-046	Concrete - Structural Weirs	1.00 JOB	60,387	6,039	1,993	5,792	697	74,907	74906.87
01 04 03 07-047	Concrete - Pre-Cast	1.00 JOB	134,894	13,489	4,451	12,937	1,557	167,329	167329.26
01 04 03 07-050	Fencing	1.00 JOB	37,087	3,709	1,224	3,557	428	46,005	46005.09
01 04 03 07-054	Structural Aluminum	1.00 JOB	5,964	596	197	572	69	7,398	7398.07
01 04 03 07-055	Facility Access	1.00 JOB	1,796	180	59	172	21	2,228	2227.57
01 04 03 07-056	Flume Topper	1.00 JOB	13,093	1,309	432	1,256	151	16,241	16241.47
01 04 03 07-060	Drainage System	1.00 JOB	6,971	697	230	669	80	8,647	8647.13
01 04 03 07-105	Testing Facilities	1.00 JOB	2,090	209	69	200	24	2,593	2592.55
01 04 03 07-150	Revegetation	1.00 JOB	10,523	1,052	347	1,009	121	13,053	13052.86

		QUANTITY	UOM	TOTAL DIRECT	FOOH	OVERHEAD	PROF	BOND	TOTAL COST	UNIT COST
01 04 03 07-200	Controls and Instrumentation	1.00	JOB	9,500	950	314	911	110	11,784	11784.32
01 04 03 07-210	Power and Telemetry	1.00	JOB	9,500	950	314	911	110	11,784	11784.32
	TOTAL Transitional Pond to Drop Struct	1.00	JOB	396,254	39,625	13,076	38,004	4,575	491,536	491535.65
	TOTAL Outlet Works	1.00	JOB	3,799,023	379,902	125,368	364,358	43,864	4,712,515	4712515
	TOTAL DAMS	1.00	JOB	3,799,023	379,902	125,368	364,358	43,864	4,712,515	4712515
01 06	FISH AND WILDLIFE FACILITIES									
01 06 03	Wildlife Facilities & Sanctuary									
01 06 03 01	Supplementation Ponds									
01 06 03 01-005	Clearing and Grubbing	1.00	JOB	1,890	189	62	181	22	2,345	2344.60
01 06 03 01-010	Dewatering	1.00	JOB	9,025	903	298	866	104	11,195	11195.10
01 06 03 01-015	Erosion Control	1.00	JOB	2,066	207	68	198	24	2,563	2563.18
01 06 03 01-025	Excavation - Soil	1.00	JOB	36,219	3,622	1,195	3,474	418	44,928	44927.70
01 06 03 01-026	Excavation - Rock	1.00	JOB	18,054	1,805	596	1,732	208	22,395	22394.92
01 06 03 01-030	Fill - Select Granular	1.00	JOB	5,223	522	172	501	60	6,479	6479.12
01 06 03 01-033	Grading	1.00	JOB	6,107	611	202	586	71	7,575	7575.46
01 06 03 01-035	Road Improvements	1.00	JOB	6,250	625	206	599	72	7,752	7752.36
01 06 03 01-040	Utility Relocations	1.00	JOB	950	95	31	91	11	1,178	1178.43
01 06 03 01-046	Concrete - Structural Walls	1.00	JOB	118,109	11,811	3,898	11,328	1,364	146,509	146509.39
01 06 03 01-050	Fencing	1.00	JOB	37,909	3,791	1,251	3,636	438	47,025	47024.87
01 06 03 01-055	Facility Access	1.00	JOB	1,796	180	59	172	21	2,228	2227.57
01 06 03 01-060	Drainage System	1.00	JOB	6,524	652	215	626	75	8,092	8092.37
01 06 03 01-085	8-inch Pipe	1.00	JOB	72,420	7,242	2,390	6,946	836	89,834	89834.21
01 06 03 01-092	8-inch Valves	1.00	JOB	4,152	415	137	398	48	5,150	5149.75
01 06 03 01-115	Outlet Structure	1.00	JOB	4,693	469	155	450	54	5,821	5821.45
01 06 03 01-150	Revegetation	1.00	JOB	2,517	252	83	241	29	3,122	3121.70
01 06 03 01-200	Controls and Instrumentation	1.00	JOB	23,750	2,375	784	2,278	274	29,461	29460.79
01 06 03 01-210	Power and Telemetry	1.00	JOB	4,750	475	157	456	55	5,892	5892.16
	TOTAL Supplementation Ponds	1.00	JOB	362,404	36,240	11,959	34,758	4,184	449,545	449545.12
	TOTAL Wildlife Facilities & Sanctuary	1.00	JOB	362,404	36,240	11,959	34,758	4,184	449,545	449545.12
	TOTAL FISH AND WILDLIFE FACILITIES	1.00	JOB	362,404	36,240	11,959	34,758	4,184	449,545	449545.12
	TOTAL FISH RESTORATION PROJECT	1.00	JOB	4,161,426	416,143	137,327	399,116	48,048	5,162,060	5162060
CONTINGENCY		25.00	%						1,290,515	
SUBTOTAL									6,452,575	
ESCALATION		12.48	%						805,323	
SUBTOTAL									7,257,898	
		10.00	%						725,790	

** PROJECT INDIRECT SUMMARY - BID ITEM **

	QUANTITY UOM	TOTAL DIRECT	FOOH	OVERHEAD	PROF	BOND	TOTAL COST	UNIT COST
SUBTOTAL							7,983,688	
	12.00 %						958,043	
TOTAL INCL OWNER COSTS							8,941,731	

** PROJECT DIRECT SUMMARY - ELEMENT **

	QUANTITY	UOM	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 FISH RESTORATION PROJECT									
01 04 DAMS									
01 04 03 Outlet Works									
01 04 03 01 Mobilization/Demobilization	1.00	JOB	0	0	0	0	210,000	210,000	210000.00
01 04 03 02 Wetwell Modification	1.00	JOB	1,393	47,928	9,028	26,115	73,690	156,760	156760.46
01 04 03 03 Eicher Screen / Penstock Section	1.00	JOB	8,307	360,113	121,098	342,729	509,467	1,333,406	1333406
01 04 03 04 Pressure Bypass Pipeline	1.00	JOB	215	105,919	43,775	114,227	75,189	339,111	339110.78
01 04 03 05 Multi-Level Discharge	1.00	JOB	2,097	85,058	41,321	99,180	342,536	568,094	568093.88
01 04 03 06 Gravity Flume	1.00	JOB	3,436	304,388	135,739	320,879	34,390	795,397	795396.62
01 04 03 07 Transitional Pond to Drop Struct	1.00	JOB	2,834	152,023	56,895	123,126	64,210	396,254	396254.47
TOTAL Outlet Works	1.00	JOB	18,282	1,055,429	407,856	1,026,256	1,309,481	3,799,023	3799023
TOTAL DAMS	1.00	JOB	18,282	1,055,429	407,856	1,026,256	1,309,481	3,799,023	3799023
01 06 FISH AND WILDLIFE FACILITIES									
01 06 03 Wildlife Facilities & Sanctuary									
01 06 03 01 Supplementation Ponds	1.00	JOB	3,136	152,116	48,830	94,542	66,915	362,404	362403.55
TOTAL Wildlife Facilities & Sanctuary	1.00	JOB	3,136	152,116	48,830	94,542	66,915	362,404	362403.55
TOTAL FISH AND WILDLIFE FACILITIES	1.00	JOB	3,136	152,116	48,830	94,542	66,915	362,404	362403.55
TOTAL FISH RESTORATION PROJECT	1.00	JOB	21,418	1,207,545	456,686	1,120,798	1,376,396	4,161,426	4161426
FIELD OFFICE OVERHEAD	10.00	%						416,143	
SUBTOTAL								4,577,569	
HOME OFFICE OVERHEAD	3.00	%						137,327	
SUBTOTAL								4,714,896	
PROFIT	8.46	%						399,116	
SUBTOTAL								5,114,012	
MISC. TAXES	0.94	%						48,048	
TOTAL INCL INDIRECTS								5,162,060	
CONTINGENCY	25.00	%						1,290,515	
SUBTOTAL								6,452,575	
ESCALATION	12.48	%						805,323	
SUBTOTAL								7,257,898	
	10.00	%						725,790	

	QUANTITY	UOM	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
SUBTOTAL								7,983,688	
	12.00	%						958,043	
TOTAL INCL OWNER COSTS								8,941,731	

		QUANTITY	UOM	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01	FISH RESTORATION PROJECT									
01 04	DAMS									
01 04 03	Outlet Works									
01 04 03 01	Mobilization/Demobilization									
01 04 03 01- 01	Mobilization/Demobilization	1.00	JOB	0	0	0	0	210,000	210,000	210000.00
	TOTAL Mobilization/Demobilization	1.00	JOB	0	0	0	0	210,000	210,000	210000.00
01 04 03 02	Wetwell Modification									
01 04 03 02-020	Demolition	1.00	JOB	1,384	40,479	6,171	0	9,565	56,215	56215.24
01 04 03 02-045	Concrete - Structural	1.00	JOB	9	324	7	346	0	676	676.47
01 04 03 02-070	Structural Modifications	1.00	JOB	0	0	0	0	30,875	30,875	30875.00
01 04 03 02-093	Automated Hoisting Gate Valve	1.00	JOB	0	7,125	2,850	25,769	0	35,744	35743.75
01 04 03 02-200	Controls and Instrumentation	1.00	JOB	0	0	0	0	19,000	19,000	19000.00
01 04 03 02-210	Power and Telemetry	1.00	JOB	0	0	0	0	14,250	14,250	14250.00
	TOTAL Wetwell Modification	1.00	JOB	1,393	47,928	9,028	26,115	73,690	156,760	156760.46
01 04 03 03	Eicher Screen / Penstock Section									
01 04 03 03-005	Clearing and Grubbing	1.00	JOB	66	1,988	2,396	0	760	5,144	5144.07
01 04 03 03-010	Dewatering	1.00	JOB	0	0	0	0	9,025	9,025	9025.00
01 04 03 03-015	Erosion Control	1.00	JOB	53	1,442	0	434	247	2,123	2123.32
01 04 03 03-020	Demolition	1.00	JOB	0	0	0	0	25,840	25,840	25840.00
01 04 03 03-025	Excavation - Soil	1.00	JOB	847	27,652	28,076	6,022	7,600	69,349	69349.05
01 04 03 03-026	Excavation - Rock	1.00	JOB	2,236	72,318	64,381	0	11,020	147,719	147719.33
01 04 03 03-030	Fill - Select Granular	1.00	JOB	393	11,135	13,159	10,850	0	35,144	35144.20
01 04 03 03-032	Fill - On-Site Material	1.00	JOB	56	1,633	538	174	0	2,345	2345.20
01 04 03 03-035	Road Improvements	1.00	JOB	32	900	1,128	2,539	0	4,567	4566.79
01 04 03 03-040	Utility Relocations	1.00	JOB	0	0	0	0	950	950	950.00
01 04 03 03-045	Concrete - Structural Foundation	1.00	JOB	649	25,087	1,252	43,095	0	69,435	69434.72
01 04 03 03-046	Concrete - Structural Walls	1.00	JOB	3,530	124,831	1,980	80,069	0	206,880	206879.70
01 04 03 03-049	Roof System	1.00	JOB	0	0	0	0	124,175	124,175	124175.00
01 04 03 03-050	Fencing	1.00	JOB	67	4,546	575	3,755	10,080	18,957	18956.67
01 04 03 03-055	Facility Access	1.00	JOB	266	12,488	335	36,925	0	49,747	49746.76
01 04 03 03-060	Drainage System	1.00	JOB	63	2,414	6	3,730	7,600	13,749	13749.21
01 04 03 03-080	10-foot Dia Penstock Section	1.00	JOB	0	6,365	2,900	35,252	0	44,517	44516.65
01 04 03 03-090	Eicher Screen Valve	1.00	JOB	0	32,300	3,945	111,218	81,700	229,163	229162.93
01 04 03 03-091	24-inch Valves	1.00	JOB	0	4,750	0	0	38,000	42,750	42750.00
01 04 03 03-100	Track System	1.00	JOB	0	28,500	0	6,185	159,220	193,905	193904.50
01 04 03 03-150	Revegetation	1.00	JOB	50	1,763	426	2,484	0	4,673	4673.34
01 04 03 03-200	Controls and Instrumentation	1.00	JOB	0	0	0	0	14,250	14,250	14250.00

		QUANTITY	UOM	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 03-210	Power and Telemetry	1.00	JOB	0	0	0	0	19,000	19,000	19000.00
	TOTAL Eicher Screen / Penstock Section	1.00	JOB	8,307	360,113	121,098	342,729	509,467	1,333,406	1333406
01 04 03 04	Pressure Bypass Pipeline									
01 04 03 04-005	Clearing and Grubbing	1.00	JOB	72	2,162	2,495	0	760	5,417	5416.82
01 04 03 04-015	Erosion Control	1.00	JOB	35	938	0	282	165	1,385	1384.91
01 04 03 04-020	Demolition	1.00	JOB	15	417	544	0	760	1,721	1721.16
01 04 03 04-025	Excavation - Soil	1.00	JOB	38	1,187	1,164	0	1,304	3,655	3654.56
01 04 03 04-031	Fill - Sand	1.00	JOB	15	427	542	182	0	1,151	1151.10
01 04 03 04-032	Fill - On-Site Material	1.00	JOB	2	77	50	9	0	136	135.78
01 04 03 04-035	Road Improvements	1.00	JOB	8	220	274	639	0	1,133	1133.36
01 04 03 04-040	Utility Relocations	1.00	JOB	0	0	0	0	950	950	950.00
01 04 03 04-081	Steel Casing	1.00	JOB	0	88,730	33,896	89,241	0	211,867	211867.25
01 04 03 04-082	24-inch HDPE Pipe	1.00	JOB	0	5,670	4,644	22,557	13,300	46,171	46171.15
01 04 03 04-091	24-inch Valves	1.00	JOB	0	5,035	0	0	38,950	43,985	43985.00
01 04 03 04-150	Revegetation	1.00	JOB	30	1,056	167	1,317	0	2,540	2539.69
01 04 03 04-200	Controls and Instrumentation	1.00	JOB	0	0	0	0	9,500	9,500	9500.00
01 04 03 04-210	Power and Telemetry	1.00	JOB	0	0	0	0	9,500	9,500	9500.00
	TOTAL Pressure Bypass Pipeline	1.00	JOB	215	105,919	43,775	114,227	75,189	339,111	339110.78
01 04 03 05	Multi-Level Discharge									
01 04 03 05-005	Clearing and Grubbing	1.00	JOB	91	2,674	3,215	0	1,140	7,029	7029.01
01 04 03 05-010	Dewatering	1.00	JOB	0	0	0	0	9,025	9,025	9025.00
01 04 03 05-015	Erosion Control	1.00	JOB	60	1,623	0	488	285	2,396	2395.86
01 04 03 05-020	Demolition	1.00	JOB	55	1,564	2,040	0	2,850	6,454	6454.35
01 04 03 05-025	Excavation - Soil	1.00	JOB	257	12,890	13,908	24,087	2,470	53,355	53355.08
01 04 03 05-026	Excavation - Rock	1.00	JOB	242	7,788	7,092	0	1,368	16,248	16248.42
01 04 03 05-030	Fill - Select Granular	1.00	JOB	14	402	523	434	0	1,359	1359.00
01 04 03 05-031	Fill - Sand	1.00	JOB	15	427	542	269	0	1,238	1237.90
01 04 03 05-032	Fill - On-Site Material	1.00	JOB	4	135	87	15	0	238	237.62
01 04 03 05-033	Grading	1.00	JOB	33	1,027	500	0	0	1,527	1526.75
01 04 03 05-035	Road Improvements	1.00	JOB	71	2,015	2,518	5,744	0	10,277	10277.49
01 04 03 05-040	Utility Relocations	1.00	JOB	0	0	0	0	950	950	950.00
01 04 03 05-045	Concrete - Structural Foundation	1.00	JOB	123	4,573	161	5,869	0	10,603	10602.80
01 04 03 05-046	Concrete - Structural Walls	1.00	JOB	894	31,670	515	20,604	0	52,789	52788.67
01 04 03 05-048	Concrete - Vault	1.00	JOB	0	4,875	1,425	18,174	0	24,474	24473.75
01 04 03 05-049	Roof System	1.00	JOB	0	0	0	0	27,360	27,360	27360.00
01 04 03 05-050	Fencing	1.00	JOB	34	2,210	284	1,949	4,725	9,169	9168.62
01 04 03 05-055	Facility Access	1.00	JOB	115	5,372	144	12,745	0	18,261	18261.15
01 04 03 05-060	Drainage System	1.00	JOB	55	2,129	6	3,339	6,175	11,649	11649.07
01 04 03 05-083	24-inch Rotating Pipe Section	1.00	JOB	0	1,520	2,900	0	128,250	132,670	132670.00
01 04 03 05-084	24-inch Outlet Pipes	1.00	JOB	0	950	5,225	4,394	124,688	135,257	135256.75
01 04 03 05-150	Revegetation	1.00	JOB	34	1,212	237	1,068	0	2,517	2516.57
01 04 03 05-200	Controls and Instrumentation	1.00	JOB	0	0	0	0	14,250	14,250	14250.00

		QUANTITY	UOM	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 05-210	Power and Telemetry	1.00	JOB	0	0	0	0	19,000	19,000	19000.00
	TOTAL Multi-Level Discharge	1.00	JOB	2,097	85,058	41,321	99,180	342,536	568,094	568093.88
01 04 03 06	Gravity Flume									
01 04 03 06-005	Clearing and Grubbing	1.00	JOB	85	2,523	2,265	0	380	5,168	5168.39
01 04 03 06-015	Erosion Control	1.00	JOB	374	10,096	0	3,038	1,900	15,034	15034.24
01 04 03 06-020	Demolition	1.00	JOB	98	2,816	3,672	0	5,130	11,618	11617.83
01 04 03 06-025	Excavation - Soil	1.00	JOB	494	19,820	14,660	2,170	2,280	38,930	38929.94
01 04 03 06-030	Fill - Select Granular	1.00	JOB	18	520	668	553	0	1,741	1741.06
01 04 03 06-031	Fill - Sand	1.00	JOB	223	6,409	8,123	2,734	0	17,267	17266.56
01 04 03 06-033	Grading	1.00	JOB	79	2,464	1,200	0	0	3,664	3664.20
01 04 03 06-035	Road Improvements	1.00	JOB	7	193	243	513	0	950	949.56
01 04 03 06-040	Utility Relocations	1.00	JOB	0	0	0	0	950	950	950.00
01 04 03 06-044	Concrete - Structural Flume Join	1.00	JOB	801	28,036	248	14,435	0	42,719	42719.06
01 04 03 06-047	Concrete - Pre-Cast	1.00	JOB	0	164,065	98,083	227,703	0	489,850	489850.48
01 04 03 06-056	Flume Accessories	1.00	JOB	853	49,500	2,972	51,646	0	104,118	104118.00
01 04 03 06-060	Drainage System	1.00	JOB	310	14,640	2,920	14,108	4,750	36,418	36418.33
01 04 03 06-150	Revegetation	1.00	JOB	94	3,305	686	3,978	0	7,969	7968.97
01 04 03 06-200	Controls and Instrumentation	1.00	JOB	0	0	0	0	9,500	9,500	9500.00
01 04 03 06-210	Power and Telemetry	1.00	JOB	0	0	0	0	9,500	9,500	9500.00
	TOTAL Gravity Flume	1.00	JOB	3,436	304,388	135,739	320,879	34,390	795,397	795396.62
01 04 03 07	Transitional Pond to Drop Struct									
01 04 03 07-005	Clearing and Grubbing	1.00	JOB	49	1,406	1,867	0	874	4,147	4146.53
01 04 03 07-010	Dewatering	1.00	JOB	0	0	0	0	9,025	9,025	9025.00
01 04 03 07-015	Erosion Control	1.00	JOB	133	3,606	0	1,085	475	5,166	5165.80
01 04 03 07-025	Excavation - Soil	1.00	JOB	363	18,363	17,789	7,421	2,546	46,120	46119.82
01 04 03 07-028	Fill - RipRap	1.00	JOB	32	1,081	561	98	0	1,740	1740.08
01 04 03 07-029	Fill - Quarry Spall	1.00	JOB	3	95	86	123	0	304	304.39
01 04 03 07-030	Fill - Select Granular	1.00	JOB	44	1,248	1,602	1,328	0	4,179	4178.54
01 04 03 07-032	Fill - On-Site Material	1.00	JOB	35	1,122	721	126	0	1,969	1968.81
01 04 03 07-033	Grading	1.00	JOB	148	4,600	2,240	0	0	6,840	6839.84
01 04 03 07-035	Road Improvements	1.00	JOB	10	286	394	394	0	1,073	1073.27
01 04 03 07-040	Utility Relocations	1.00	JOB	0	0	0	0	950	950	950.00
01 04 03 07-044	Concrete - Structural Flume Join	1.00	JOB	200	7,001	59	3,569	0	10,630	10629.99
01 04 03 07-045	Concrete - Structural Foundation	1.00	JOB	179	6,545	128	5,635	0	12,308	12308.48
01 04 03 07-046	Concrete - Structural Weirs	1.00	JOB	1,177	41,046	248	19,093	0	60,387	60386.63
01 04 03 07-047	Concrete - Pre-Cast	1.00	JOB	0	44,650	26,605	63,639	0	134,894	134893.51
01 04 03 07-050	Fencing	1.00	JOB	155	6,325	1,097	5,166	24,500	37,087	37087.28
01 04 03 07-054	Structural Aluminum	1.00	JOB	0	2,040	1,320	2,604	0	5,964	5964.00
01 04 03 07-055	Facility Access	1.00	JOB	13	600	16	1,179	0	1,796	1795.77
01 04 03 07-056	Flume Topper	1.00	JOB	132	6,200	166	6,727	0	13,093	13093.16
01 04 03 07-060	Drainage System	1.00	JOB	18	679	6	1,536	4,750	6,971	6970.94
01 04 03 07-105	Testing Facilities	1.00	JOB	0	0	0	0	2,090	2,090	2090.00
01 04 03 07-150	Revegetation	1.00	JOB	142	5,129	1,990	3,403	0	10,523	10522.64

		QUANTITY	UOM	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 07-200	Controls and Instrumentation	1.00	JOB	0	0	0	0	9,500	9,500	9500.00
01 04 03 07-210	Power and Telemetry	1.00	JOB	0	0	0	0	9,500	9,500	9500.00
	TOTAL Transitional Pond to Drop Struct	1.00	JOB	2,834	152,023	56,895	123,126	64,210	396,254	396254.47
	TOTAL Outlet Works	1.00	JOB	18,282	1,055,429	407,856	1,026,256	1,309,481	3,799,023	3799023
	TOTAL DAMS	1.00	JOB	18,282	1,055,429	407,856	1,026,256	1,309,481	3,799,023	3799023
01 06	FISH AND WILDLIFE FACILITIES									
01 06 03	Wildlife Facilities & Sanctuary									
01 06 03 01	Supplementation Ponds									
01 06 03 01-005	Clearing and Grubbing	1.00	JOB	17	519	611	0	760	1,890	1890.11
01 06 03 01-010	Dewatering	1.00	JOB	0	0	0	0	9,025	9,025	9025.00
01 06 03 01-015	Erosion Control	1.00	JOB	53	1,442	0	434	190	2,066	2066.32
01 06 03 01-025	Excavation - Soil	1.00	JOB	487	14,939	15,960	0	5,320	36,219	36218.74
01 06 03 01-026	Excavation - Rock	1.00	JOB	269	8,654	7,880	0	1,520	18,054	18053.80
01 06 03 01-030	Fill - Select Granular	1.00	JOB	55	1,561	2,003	1,660	0	5,223	5223.18
01 06 03 01-033	Grading	1.00	JOB	132	4,107	2,000	0	0	6,107	6107.00
01 06 03 01-035	Road Improvements	1.00	JOB	51	1,436	1,983	2,831	0	6,250	6249.62
01 06 03 01-040	Utility Relocations	1.00	JOB	0	0	0	0	950	950	950.00
01 06 03 01-046	Concrete - Structural Walls	1.00	JOB	1,898	67,650	1,386	49,073	0	118,109	118109.44
01 06 03 01-050	Fencing	1.00	JOB	91	10,057	3,828	10,025	14,000	37,909	37909.38
01 06 03 01-055	Facility Access	1.00	JOB	13	600	16	1,179	0	1,796	1795.77
01 06 03 01-060	Drainage System	1.00	JOB	36	1,370	6	2,297	2,850	6,524	6523.71
01 06 03 01-085	8-inch Pipe	1.00	JOB	0	36,290	12,540	19,790	3,800	72,420	72420.40
01 06 03 01-092	8-inch Valves	1.00	JOB	0	1,900	190	2,062	0	4,152	4151.50
01 06 03 01-115	Outlet Structure	1.00	JOB	0	380	190	4,123	0	4,693	4693.00
01 06 03 01-150	Revegetation	1.00	JOB	34	1,212	237	1,068	0	2,517	2516.57
01 06 03 01-200	Controls and Instrumentation	1.00	JOB	0	0	0	0	23,750	23,750	23750.00
01 06 03 01-210	Power and Telemetry	1.00	JOB	0	0	0	0	4,750	4,750	4750.00
	TOTAL Supplementation Ponds	1.00	JOB	3,136	152,116	48,830	94,542	66,915	362,404	362403.55
	TOTAL Wildlife Facilities & Sanctuary	1.00	JOB	3,136	152,116	48,830	94,542	66,915	362,404	362403.55
	TOTAL FISH AND WILDLIFE FACILITIES	1.00	JOB	3,136	152,116	48,830	94,542	66,915	362,404	362403.55
	TOTAL FISH RESTORATION PROJECT	1.00	JOB	21,418	1,207,545	456,686	1,120,798	1,376,396	4,161,426	4161426
	FIELD OFFICE OVERHEAD	10.00	%						416,143	
	SUBTOTAL								4,577,569	
	HOME OFFICE OVERHEAD	3.00	%						137,327	
	SUBTOTAL								4,714,896	
	PROFIT	8.46	%						399,116	

	QUANTITY UOM	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
SUBTOTAL							5,114,012	
MISC. TAXES	0.94 %						48,048	
TOTAL INCL INDIRECTS							5,162,060	
CONTINGENCY	25.00 %						1,290,515	
SUBTOTAL							6,452,575	
ESCALATION	12.48 %						805,323	
SUBTOTAL							7,257,898	
	10.00 %						725,790	
SUBTOTAL							7,983,688	
	12.00 %						958,043	
TOTAL INCL OWNER COSTS							8,941,731	

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01. FISH RESTORATION PROJECT											
01 04. DAMS											
Includes mobe/demobe, earthwork, dewatering, erosion control, demolition and construction costs for the following work: Wetwell Modifications; Eicher Screen with Replaceable Penstock Section; Pressure Bypass Pipeline; Multilevel Dishcharge; Gravity Flume; and Transitional Pond to Drop Structure System.											
01 04 03. Outlet Works											
01 04 03 01. Mobilization/Demobilization											
Mobilization/Demobilization, assume 4% of construction costs											
01 04 03 01- 01. Mobilization/Demobilization											
USR AA < > Mobilization/Demobilization					0.00	0.00	0.00	0.00	210000.00	210000.00	
	1.00	JOB		0.00	0	0	0	0	210,000	210,000	210000.00
TOTAL Mobilization/Demobilization	1.00	JOB			0	0	0	0	210,000	210,000	210000.00

01 04. DAMS		QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
	01 04 03 02. Wetwell Modification Intake structure automated hoisting gate 01 04 03 02-020 . Demolition Demolition, Assume demolish and dispose of concrete											
L MIL AA <02046 2115 >	Site dml, culvert - conc, 7" to 24" thick, reinf, Cost modified based on engineering judgement considering difficulty of work					81.08	2371.56	350.18	0.00	0.00	2721.74	
		17.00	CY	CODLB6	0.04	1,378	40,317	5,953	0	0	46,270	2721.74
MIL AA <02232 0310 >	Load, track loader, 1-1/2 CY, wet rock					0.03	0.82	0.55	0.00	0.00	1.37	
		17.00	CY	CODFB10N	59.38	0	14	9	0	0	23	1.37
L AF AA <02234 0570 >	Dispose, hwy haulers, 12 CY, 20 mile round trip @ base wide rate					0.31	8.75	12.30	0.00	0.00	21.04	
		17.00	CY	COEIB34B	3.20	5	149	209	0	0	358	21.04
USR AA < >	Disposal Fee of $3.80/CY used based on RS Means plus escalated cost factor due to remote site					0.00	0.00	0.00	0.00	3.80	3.80	
		17.00	CY		0.00	0	0	0	0	65	65	3.80
USR AA < >	Grinding of cut surface, Cost based on engineering judgement on similar project experience					0.00	0.00	0.00	0.00	9500.00	9500.00	
		1.00	LS		0.00	0	0	0	0	9,500	9,500	9500.00
	TOTAL Demolition	1.00	JOB			1,384	40,479	6,171	0	9,565	56,215	56215.24

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 02-045 . Concrete - Structural Structure Concrete includes, intake structure modifications											
CIV AA <03150 1050 > Forms in place, elev slab, flat					0.09	3.19	0.00	1.91	0.00	5.10	
plate plywd to 15' high, 2 use	70.00	SF	ACARC2	65.00	6	223	0	134	0	357	5.10
L MIL AA <03217 0550 > Reinforcing in place, footings,					18.18	800.74	0.00	540.33	0.00	1341.07	
#8 to #18	0.10	TON	SIWRRODM4	0.22	2	80	0	54	0	134	1341.07
RSM AA <03326 0400 > Concrete ready mix, regular					0.00	0.00	0.00	79.22	0.00	79.22	
weight, 5000 psi	2.00	CY	N/A	0.00	0	0	0	158	0	158	79.22
AF AA <03372 1600 > Placing conc, elev slabs, over					0.36	10.26	3.30	0.00	0.00	13.56	
10" thick, pumped	2.00	CY	CLABC20	22.50	1	21	7	0	0	27	13.56
TOTAL Concrete - Structural	1.00	JOB			9	324	7	346	0	676	676.47

01 04. DAMS		QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
	01 04 03 02-070 . Structural Modifications Structural Modifications includes: replacing waterstop ring, closure gate backing plate and wedge, screen across gate shaft, and epoxy coating											
USR AA <	> Replacing Waterstop ring, Cost based on engineering judgement on cost break down of required work	1.00	EA		0.00	0.00 0	0.00 0	0.00 0	0.00 0	2375.00 2,375	2375.00 2,375	2375.00
USR AA <	> Intake Closure Gate Backing Plate and Wedge, Cost based on engineering judgement on cost break down of required work	1.00	LS		0.00	0.00 0	0.00 0	0.00 0	0.00 0	9500.00 9,500	9500.00 9,500	9500.00
USR AA <	> Screen Across Gate Shaft, Cost based on engineering judgement on cost break down of required work	1.00	EA		0.00	0.00 0	0.00 0	0.00 0	0.00 0	2850.00 2,850	2850.00 2,850	2850.00
USR AA <	> Remove Epoxy Coating on Conc Surface, Cost based on engineering judgement on similar project experience	170.00	SF		0.00	0.00 0	0.00 0	0.00 0	0.00 0	95.00 16,150	95.00 16,150	95.00
	TOTAL Structural Modifications	1.00	JOB			0	0	0	0	30,875	30,875	30875.00

01 04. DAMS		QUANTY UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
	01 04 03 02-093 . Automated Hoisting Gate Valve Automated Hoisting Gate Valve										
USR AA <	> Hoisting Gate Valve, Cost based on quote from Vendor and RS Means cost data for labor & equipment	1.00 EA		0.00	0.00 0	4750.00 4,750	2850.00 2,850	20615.00 20,615	0.00 0	28215.00 28,215	28215.00
USR AA <	> Gate Operator, Cost based on quote from Vendor and RS Means cost data for labor & equipment	1.00 EA		0.00	0.00 0	2375.00 2,375	0.00 0	5153.75 5,154	0.00 0	7528.75 7,529	7528.75
	TOTAL Automated Hoisting Gate Valve	1.00 JOB			0	7,125	2,850	25,769	0	35,744	35743.75

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 02-200 . Controls and Instrumentation Controls and Instrumentation											
USR AA < > Controls and Instrumentation,					0.00	0.00	0.00	0.00	19000.00	19000.00	
Represents electrical allowance	1.00	LS		0.00	0	0	0	0	19,000	19,000	19000.00
TOTAL Controls and Instrumentation	1.00	JOB			0	0	0	0	19,000	19,000	19000.00

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 02-210 . Power and Telemetry Power and Telemetry											
USR AA < > Power and Telemetry, Represents electrical allowance	1.00	LS		0.00	0.00 0	0.00 0	0.00 0	0.00 0	14250.00 14,250	14250.00 14,250	14250.00
TOTAL Power and Telemetry	1.00	JOB			0	0	0	0	14,250	14,250	14250.00

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 03. Eicher Screen / Penstock Section Eicher screen with replaceable penstock section 01 04 03 03-005 . Clearing and Grubbing Assume clearing vault area of all vegetation and organics											
CIV AA <02109 7310 > Clear & grub, tree rmv, cutting					3.00	85.73	46.42	0.00	0.00	132.16	
& chipping, 6" - 12" dia	3.00	EA	CODFB7	2.00	9	257	139	0	0	396	132.16
AF AA <02109 9110 > Clear & grub, grub stumps, w/335					0.05	1.56	2.66	0.00	0.00	4.22	
HP dozer, to 12" dia	3.00	EA	CODTB10M	31.25	0	5	8	0	0	13	4.22
L AF AA <02234 0570 > Hauling, hwy haulers, 12 CY, 10					0.18	5.12	7.20	0.00	0.00	12.32	
mile round trip @ base wide rate	200.00	CY	COEIB34B	5.46	37	1,024	1,440	0	0	2,464	12.32
USR AA < > Disposal Fee of $3.80/CY used					0.00	0.00	0.00	0.00	3.80	3.80	
based on RS Means plus escalated cost factor due to remote site	200.00	CY		0.00	0	0	0	0	760	760	3.80
AF AA <02110 1050 > Clearing, wet, heavy brush &					20.59	701.45	809.11	0.00	0.00	1510.56	
trees	1.00	ACR	COMCB88	0.34	21	701	809	0	0	1,511	1510.56
TOTAL Clearing and Grubbing	1.00	JOB			66	1,988	2,396	0	760	5,144	5144.07

01 04. DAMS	QUANTY UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 03-010 . Dewatering Quoted from Baker Tanks, Assume 1 month rental										
USR AA < > (1) Dewatering Boxes				0.00	0.00	0.00	0.00	1425.00	1425.00	
	1.00 MO		0.00	0	0	0	0	1,425	1,425	1425.00
USR AA < > (2) 6" Thompson Pump Stations				0.00	0.00	0.00	0.00	3800.00	3800.00	
	1.00 MO		0.00	0	0	0	0	3,800	3,800	3800.00
USR AA < > Operation, Fuel and Oil				0.00	0.00	0.00	0.00	3800.00	3800.00	
	1.00 LS		0.00	0	0	0	0	3,800	3,800	3800.00
TOTAL Dewatering	1.00 JOB			0	0	0	0	9,025	9,025	9025.00

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 03-015 . Erosion Control Erosion Control, Assume silt fencing and sand bags for construction site											
B MIL AA <02266 1120 > Erosion control, w/7.5' posts, silt fence, 3' high, polypropylene					0.07	1.80	0.00	1.09	0.00	2.89	
	400.00	LF	ALABCLAB2	30.00	27	721	0	434	0	1,155	2.89
B MIL AA <02266 1120 > Remove silt fence polypropylene					0.07	1.80	0.00	0.00	0.00	1.80	
	400.00	LF	ALABCLAB2	30.00	27	721	0	0	0	721	1.80
USR AA < > Sand Bags - RS Means Cost Data					0.00	0.00	0.00	0.00	1.90	1.90	
	130.00	EA		0.00	0	0	0	0	247	247	1.90
TOTAL Erosion Control	1.00	JOB			53	1,442	0	434	247	2,123	2123.32

01 04. DAMS		QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
	01 04 03 03-020 . Demolition Demolition, Assume demolish and dispose of 10-foot diameter penstock section, and lamp post											
USR AA <	> 10-foot Diameter Pipe Section - RS Means Cost Data for similar work	1.00	LS		0.00	0.00 0	0.00 0	0.00 0	0.00 0	21850.00 21,850	21850.00 21,850	21850.00
USR AA <	> Lamp Post Relocation, Cost considers relocation of lamp post and rewiring the power	1.00	EA		0.00	0.00 0	0.00 0	0.00 0	0.00 0	950.00 950	950.00 950	950.00
USR AA <	> Haul and Dispose - Applied Means Cost Data for Basis of Estimate	1.00	LS		0.00	0.00 0	0.00 0	0.00 0	0.00 0	3040.00 3,040	3040.00 3,040	3040.00
	TOTAL Demolition	1.00	JOB			0	0	0	0	25,840	25,840	25840.00

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 03-025 . Excavation - Soil Excavate soil and dispose of excess											
L MIL AA <02232 0125 > Excavate & load, hydr excavator, 1.5 CY, wet matl	2500.00	CY	CODEB12B	10.41	0.19 481	6.47 16,183	4.90 12,251	0.00 0	0.00 0	11.37 28,434	11.37
USR AA < > Shoring of Vault Excavation, Sheet Piling 38psf, Cost based on RS Means plus escalated cost factor due to remote site	500.00	SF		0.00	0.00 0	2.45 1,225	2.85 1,425	12.04 6,022	0.00 0	17.34 8,672	17.34
L AF AA <02234 0570 > Hauling, hwy haulers, 12 CY, 10 mile round trip @ base wide rate	2000.00	CY	COEIB34B	5.46	0.18 366	5.12 10,244	7.20 14,400	0.00 0	0.00 0	12.32 24,644	12.32
USR AA < > Disposal Fee of $3.80/CY, Cost based on RS Means plus escalated cost factor due to remote site	2000.00	CY		0.00	0.00 0	0.00 0	0.00 0	0.00 0	3.80 7,600	3.80 7,600	3.80
TOTAL Excavation - Soil	1.00	JOB			847	27,652	28,076	6,022	7,600	69,349	69349.05

01 04. DAMS		QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 03-026 .	Excavation - Rock Excavate rock and dispose of excess											
B MIL AA <02232 0130 >	Excavate & load, hydr excavator,					0.59	19.82	15.00	0.00	0.00	34.82	
	1.5 CY, modified for rock excavation	2900.00	CY	CODEB12B	3.40	1,706	57,465	43,501	0	0	100,966	34.82
L AF AA <02234 0570 >	Hauling, hwy haulers, 12 CY, 10					0.18	5.12	7.20	0.00	0.00	12.32	
	mile round trip @ base wide rate	2900.00	CY	COEIB34B	5.46	531	14,854	20,880	0	0	35,734	12.32
USR AA < >	Disposal Fee of $3.80/CY, Cost					0.00	0.00	0.00	0.00	3.80	3.80	
	based on RS Means plus	2900.00	CY		0.00	0	0	0	0	11,020	11,020	3.80
TOTAL	Excavation - Rock	1.00	JOB			2,236	72,318	64,381	0	11,020	147,719	147719.33

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 03-030 . Fill - Select Granular Assume imported engineered fill for foundation and drainage											
M MIL AA <02232 0225 > Load Borrow, wheeled loader, 1.5					0.02	0.61	0.31	10.85	0.00	11.77	
CY, select granular	1000.00	CY	CODFB10S	80.00	19	610	307	10,850	0	11,766	11.77
L AF AA <02234 0570 > Base Course Hauling, 20 mile					0.31	8.75	12.30	0.00	0.00	21.04	
round trip @ base wide rate	1000.00	CY	COEIB34B	3.20	313	8,747	12,296	0	0	21,043	21.04
MIL AA <02216 5530 > Backfill, strl, 6" lifts,					0.02	0.70	0.47	0.00	0.00	1.17	
w/loader, no compaction, around foundation	1000.00	CY	CODFB10N	70.00	21	697	469	0	0	1,166	1.17
MIL AA <02220 7000 > Compaction, struct/trench, 6"					0.04	1.08	0.09	0.00	0.00	1.17	
lifts, 2 passes18" wide, vib plate	1000.00	CY	ULABA1	25.00	40	1,082	87	0	0	1,169	1.17
TOTAL Fill - Select Granular	1.00	JOB			393	11,135	13,159	10,850	0	35,144	35144.20

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 03-032 . Fill - On-Site Material Assume acceptable excess excavation from vault will be used as backfill											
M MIL AA <02232 0225 > Spread/Stockpile, wheeled					0.02	0.61	0.31	0.00	0.00	0.92	
loader, 1.5 CY, on-site matl	800.00	CY	CODFB10S	80.00	15	488	245	0	0	733	0.92
MIL AA <02220 7000 > Compaction, struct/trench, 6"					0.04	1.08	0.09	0.00	0.00	1.17	
lifts, 2 passes18" wide, vib plate	800.00	CY	ULABA1	25.00	32	865	70	0	0	935	1.17
MIL AA <02220 9010 > Compaction, water, truck, 3000					0.01	0.35	0.28	0.22	0.00	0.85	
gal, 6 mile haul	800.00	CY	COKBB45	180.50	9	280	223	174	0	677	0.85
TOTAL Fill - On-Site Material	1.00	JOB			56	1,633	538	174	0	2,345	2345.20

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 03-035 . Road Improvements Roadway impovements, base course and asphalt pavement											
M MIL AA <02244 0100 > Base course, crushed 3/4" stone,					0.01	0.26	0.28	8.68	0.00	9.22	
compacted, 12"D, large areas	200.00	SY	COFGB36C	625.00	2	52	56	1,736	0	1,844	9.22
L AF AA <02234 0570 > Base Course Hauling, 20 mile					0.31	8.75	12.30	0.00	0.00	21.04	
round trip @ base wide rate	68.00	CY	COEIB34B	3.20	21	595	836	0	0	1,431	21.04
RSM AA <02505 0810 > Asphaltic conc pavement,					0.14	4.10	1.58	28.03	0.00	33.71	
highway, binder course, 1.5" thick	16.50	TON	COKCB25	78.75	2	68	26	462	0	556	33.71
RSM AA <02505 0850 > Asphaltic conc pavement,					0.17	4.99	2.30	30.92	0.00	38.21	
highway, wearing course, 1" thick	11.00	TON	COKCB25B	71.88	2	55	25	340	0	420	38.21
L AF AA <02234 0570 > Asphalt Hauling, 20 mile round					0.31	8.75	12.30	0.00	0.00	21.04	
trip @ base wide rate	15.00	CY	COEIB34B	3.20	5	131	184	0	0	316	21.04
TOTAL Road Improvements	1.00	JOB			32	900	1,128	2,539	0	4,567	4566.79

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 03-040 . Utility Relocations Relocate underground utilities within vault area											
USR AA < > Relocate Utilities, Allowance					0.00	0.00	0.00	0.00	950.00	950.00	
for any utilities in the area	1.00	LS		0.00	0	0	0	0	950	950	950.00
TOTAL Utility Relocations	1.00	JOB			0	0	0	0	950	950	950.00

01 04. DAMS		QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 03-045 . Concrete - Structural Foundation	Concrete - Structure Foundation includes, vault foundation											
MIL AA <03154 0010 >	Forms in place, eqpt					0.30	10.36	0.00	2.79	0.00	13.15	
	foundations, 1 use	500.00	SF	ACARC2	20.00	150	5,180	0	1,394	0	6,574	13.15
L MIL AA <03217 0550 >	Reinforcing in place, footings,					18.18	800.74	0.00	540.33	0.00	1341.07	
	#8 to #18	20.00	TON	SIWRRODM4	0.22	364	16,015	0	10,807	0	26,821	1341.07
RSM AA <03326 0400 >	Concrete ready mix, regular					0.00	0.00	0.00	79.22	0.00	79.22	
	weight, 5000 psi	390.00	CY	N/A	0.00	0	0	0	30,894	0	30,894	79.22
MIL AA <03372 4650 >	Placing conc, slab on grade,					0.35	9.98	3.21	0.00	0.00	13.19	
	over 6" thick, pumped	390.00	CY	CLABC20	23.13	135	3,892	1,252	0	0	5,145	13.19
	TOTAL Concrete - Structural Foundation	1.00	JOB			649	25,087	1,252	43,095	0	69,435	69434.72

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 03-046 . Concrete - Structural Walls Concrete - Structure Walls includes, vault walls											
MIL AA <03182 5100 > Forms in place, retaining wall,					0.24	8.29	0.00	2.95	0.00	11.24	
smooth curve, plywood, 2 use	12000	SF	ACARC2	25.00	2,880	99,458	0	35,414	0	134,873	11.24
L MIL AA <03217 0550 > Reinforcing in place, #8 to #18					18.18	800.74	0.00	540.33	0.00	1341.07	
	24.00	TON	SIWRRODM4	0.22	436	19,218	0	12,968	0	32,186	1341.07
RSM AA <03326 0400 > Concrete ready mix, regular					0.00	0.00	0.00	79.22	0.00	79.22	
weight, 5000 psi	400.00	CY	N/A	0.00	0	0	0	31,686	0	31,686	79.22
MIL AA <03372 5350 > Placing conc, walls, 24" thick,					0.53	15.39	4.95	0.00	0.00	20.34	
pumped	400.00	CY	CLABC20	15.00	213	6,155	1,980	0	0	8,135	20.34
TOTAL Concrete - Structural Walls	1.00	JOB			3,530	124,831	1,980	80,069	0	206,880	206879.70

01 04. DAMS		QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
	01 04 03 03-049 . Roof System Roof System includes: Concrete walls, Removeable roof system and Fixed roof system											
USR AA <	> Removable Roof Section, Cost based on engineering judgement on similar project experience	1000.00	SF		0.00	0.00 0	0.00 0	0.00 0	0.00 0	45.60 45,600	45.60 45,600	45.60
USR AA <	> Fixed Roof, Cost based on engineering judgement on	3100.00	SF		0.00	0.00 0	0.00 0	0.00 0	0.00 0	14.25 44,175	14.25 44,175	14.25
USR AA <	> Concrete Wall, including forms, finish, and steel, Cost based on similar project experience	80.00	CY		0.00	0.00 0	0.00 0	0.00 0	0.00 0	430.00 34,400	430.00 34,400	430.00
	TOTAL Roof System	1.00	JOB			0	0	0	0	124,175	124,175	124175.00

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 03-050 . Fencing Security fencing around vault, includes gate											
AF AA <01534 0100 > Fencing, 11 ga, chain link, 6'					0.21	5.77	0.00	3.56	35.00	44.33	
high, includes foundation	288.00	LF	ALABCLAB2	9.38	61	1,662	0	1,025	10,080	12,767	44.33
USR AA < > Barbwire Strands, Costs based on					0.00	9.50	1.90	8.25	0.00	19.65	
similar project experience	288.00	LF		0.00	0	2,736	547	2,375	0	5,658	19.65
MIL AA <02832 1310 > Fence, CL, 4' x 6', transom					2.75	74.43	13.98	177.64	0.00	266.05	
gate, single, galv	2.00	EA	CLABB80A	1.09	6	149	28	355	0	532	266.05
TOTAL Fencing	1.00	JOB			67	4,546	575	3,755	10,080	18,957	18956.67

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 03-055 . Facility Access Facility Access includes: stairs, handrails, grating, and ladders within the vault											
MIL AA <05518 0010 > Ladder, steel, 20" wide, bolted					0.64	30.02	0.80	58.96	0.00	89.79	
penstock, w/cage	20.00	VLF	SIWSE4	6.25	13	600	16	1,179	0	1,796	89.79
B MIL AA <05542 0622 > Floor grating,stl,1.25" x 3/16",					0.21	10.00	0.27	10.85	0.00	21.12	
ptd brg bars @ 15/16" OC, 300 SF	50.00	SF	SIWSE4	18.77	11	500	13	543	0	1,056	21.12
M MIL AA <05523 0940 > Railing, pipe, steel, 3 rail,					0.18	8.53	0.23	32.55	0.00	41.31	
primed, 1.5" dia, on brackets	350.00	LF	SIWSE4	22.00	64	2,985	80	11,393	0	14,458	41.31
MIL AA <05511 0020 > Stair, stl,grating trd & pipe r,					0.91	42.89	1.15	113.93	0.00	157.97	
3'-6" W, saf nosing, stl strg	104.00	EA	SIWSE4	4.38	95	4,461	120	11,848	0	16,429	157.97
MIL AA <05511 0120 > Stair, grating trd, landing,					0.20	9.38	0.25	28.48	0.00	38.12	
steel, grating, framing	420.00	SF	SIWSE4	20.00	84	3,941	106	11,962	0	16,009	38.12
TOTAL Facility Access	1.00	JOB			266	12,488	335	36,925	0	49,747	49746.76

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 03-060 . Drainage System Drainage system includes: vault drainage and structure subdrainage											
USR AA < > Catch Basins, RS Means cost data					0.00	0.00	0.00	0.00	475.00	475.00	
	4.00	EA		0.00	0	0	0	0	1,900	1,900	475.00
M MIL AA <15155 2570 > Drain Pipe PVC					0.24	9.48	0.00	13.02	0.00	22.50	
	230.00	LF	MPLUQ2	12.25	56	2,181	0	2,995	0	5,176	22.50
M MIL AA <15157 2210 > PVC, 90 deg elbow					2.58	99.94	0.00	325.50	0.00	425.44	
	2.00	EA	MPLUQ2	1.16	5	200	0	651	0	851	425.44
CIV AA <02250 2140 > Geotextile fabric, 120 mil					0.02	0.54	0.10	1.40	0.00	2.04	
thick, non-woven polypropylene	60.00	SY	ULABA2	150.00	1	32	6	84	0	122	2.04
USR AA < > Sump Pump, Complete system, RS					0.00	0.00	0.00	0.00	5700.00	5700.00	
Means cost data plus contingency factor	1.00	EA		0.00	0	0	0	0	5,700	5,700	5700.00
TOTAL Drainage System	1.00	JOB			63	2,414	6	3,730	7,600	13,749	13749.21

01 04. DAMS	QUANTY UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 03-080 . 10-foot Dia Penstock Section 10-foot Dia Penstock Section, Quote from Mfgr (NW Pipe Co.)										
USR AA < > Salvaged and Retrofitted 10-foot				0.00	3135.00	0.00	25768.75	0.00	28903.75	
Dia Penstock Section,	1.00 EA		0.00	0	3,135	0	25,769	0	28,904	28903.75
Engineering judgement										
USR AA < > Flexible Couplings, Quote from				0.00	855.00	0.00	4741.45	0.00	5596.45	
Mfgr (Vicaulic Coupling) & RS	2.00 EA		0.00	0	1,710	0	9,483	0	11,193	5596.45
Means for labor										
USR AA < > (2) 80 Ton Hydraulic Crane				0.00	1520.00	2900.00	0.00	0.00	4420.00	
rental per day - RS Means	1.00 DAY		0.00	0	1,520	2,900	0	0	4,420	4420.00
TOTAL 10-foot Dia Penstock Section	1.00 JOB			0	6,365	2,900	35,252	0	44,517	44516.65

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 03-090 . Eicher Screen Valve Eicher Screen Valve											
USR AA < > 10-foot Dia Penstock Section,					0.00	3135.00	95.00	51537.50	0.00	54767.50	
Quote from Mfgr (NW Pipe Co.) & RS Means for labor	1.00	EA		0.00	0	3,135	95	51,538	0	54,768	54767.50
USR AA < > Flexible Couplings, Quote from					0.00	855.00	0.00	4741.45	0.00	5596.45	
Mfgr (Vicaulic Coupling) & RS Means for labor	2.00	EA		0.00	0	1,710	0	9,483	0	11,193	5596.45
USR AA < > Screen, Quote from vendor					0.00	0.00	0.00	0.00	57000.00	57000.00	
(Hendricks Screen) & RS Means for labor	1.00	LS		0.00	0	0	0	0	57,000	57,000	57000.00
USR AA < > Screen Pivot Mechanism,					0.00	0.00	0.00	0.00	19000.00	19000.00	
Engineering judgement	1.00	LS		0.00	0	0	0	0	19,000	19,000	19000.00
USR AA < > Drain Valve, RS Means cost data					0.00	950.00	0.00	721.53	0.00	1671.53	
	1.00	EA		0.00	0	950	0	722	0	1,672	1671.53
USR AA < > Access Portals, Engineering					0.00	0.00	0.00	0.00	5700.00	5700.00	
judgement	1.00	LS		0.00	0	0	0	0	5,700	5,700	5700.00
USR AA < > Transistion to 24-inch Section,					0.00	3135.00	0.00	3092.25	0.00	6227.25	
Engineering judgement	1.00	LS		0.00	0	3,135	0	3,092	0	6,227	6227.25
USR AA < > Hydraulic Power Unit &					0.00	2850.00	0.00	30922.50	0.00	33772.50	
Cylinders, Engineering judgement	1.00	LS		0.00	0	2,850	0	30,923	0	33,773	33772.50
USR AA < > Screen Support Frame, Cost based					0.00	1900.00	95.00	1546.13	0.00	3541.13	
on $/ton of Steel	10.00	TON		0.00	0	19,000	950	15,461	0	35,411	3541.13
USR AA < > (2) 80 Ton Hydraulic Crane					0.00	1520.00	2900.00	0.00	0.00	4420.00	
rental per day - RS Means	1.00	DAY		0.00	0	1,520	2,900	0	0	4,420	4420.00
TOTAL Eicher Screen Valve	1.00	JOB			0	32,300	3,945	111,218	81,700	229,163	229162.93

01 04. DAMS	QUANTY UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 03-091 . 24-inch Valves 24-inch Valves										
USR AA < > 24" Ball Valve, Quote from vendor (Apco) & RS Means for labor				0.00	4750.00	0.00	0.00	38000.00	42750.00	
	1.00 EA		0.00	0	4,750	0	0	38,000	42,750	42750.00
TOTAL 24-inch Valves	1.00 JOB			0	4,750	0	0	38,000	42,750	42750.00

01 04. DAMS		QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
	01 04 03 03-100 . Track System Track System includes: rails, motorized gears, and attachments to move the penstock section and Eicher screen sections in and out of position											
USR AA <	> Rails, RS Means cost data					0.00	0.00	0.00	0.00	152.00	152.00	
		110.00	LF		0.00	0	0	0	0	16,720	16,720	152.00
USR AA <	> Attachments to Penstock/Eicher,					0.00	4750.00	0.00	1030.75	0.00	5780.75	
	Engineering judgement	6.00	EA		0.00	0	28,500	0	6,185	0	34,685	5780.75
USR AA <	> Motorized Gear Tracks, Quote					0.00	0.00	0.00	0.00	142500.00	142500.00	
	from Mfgr (Ederer Crane Co.)	1.00	LS		0.00	0	0	0	0	142,500	142,500	142500.00
	TOTAL Track System	1.00	JOB			0	28,500	0	6,185	159,220	193,905	193904.50

01 04. DAMS		QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 03-150	. Revegetation Assume revegetation of vault area with trees, shrubs and hydro-seeding											
USR LC < >	Hydroseeding 5#/ac - RSM					0.60	17.15	1.86	37.98	0.00	56.98	
	0292051000 (costworks 2002)	10.00	MSF	XLABE	10.00	6	215	23	477	0	715	71.54
USR LC < >	Rototill, 20Hp tractor 12" deep					0.30	8.77	0.69	0.00	0.00	9.46	
	RSM 029203406100 (costworks 2002	10.00	MSF	CLABB62	10.00	3	110	9	0	0	119	11.88
L MIL LC <02951 0760 >	Mulch, straw, 2" deep, hand					0.01	0.22	0.00	0.09	0.00	0.31	
	spread arnd planted trees/shrubs	2000.00	SF	ALABCLAB1	122.00	16	557	0	218	0	775	0.39
M MIL LC <02947 0400 >	General planting, local					0.57	16.53	7.40	5.43	0.00	29.36	
	varieties, 2' - 3', shrubs	30.00	EA	COEIB17	7.00	17	623	279	204	0	1,106	36.86
MIL LC <02947 0200 >	General planting, local					0.71	20.58	9.21	126.22	0.00	156.00	
	varieties, trees, 2' - 3'	10.00	EA	COEIB17	5.63	7	258	116	1,585	0	1,959	195.86
	TOTAL Revegetation	1.00	JOB			50	1,763	426	2,484	0	4,673	4673.34

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 03-200 . Controls and Instrumentation Controls and Instrumentation											
USR AA < > Controls and Instrumentation,					0.00	0.00	0.00	0.00	14250.00	14250.00	
Represents electrical allowance	1.00	LS		0.00	0	0	0	0	14,250	14,250	14250.00
TOTAL Controls and Instrumentation	1.00	JOB			0	0	0	0	14,250	14,250	14250.00

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 03-210 . Power and Telemetry Power and Telemetry											
USR AA < > Power and Telemetry, Represents					0.00	0.00	0.00	0.00	19000.00	19000.00	
electrical allowance	1.00	LS		0.00	0	0	0	0	19,000	19,000	19000.00
TOTAL Power and Telemetry	1.00	JOB			0	0	0	0	19,000	19,000	19000.00

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 04. Pressure Bypass Pipeline											
Pressure Bypass Pipeline											
01 04 03 04-005 . Clearing and Grubbing											
Assume clearing of all vegetation and organics necessary to place the Pressure Bypass Pipeline											
CIV AA <02109 7310 > Clear & grub, tree rmv, cutting					3.00	85.73	46.42	0.00	0.00	132.16	
& chipping, 6" - 12" dia	5.00	EA	CODFB7	2.00	15	429	232	0	0	661	132.16
AF AA <02109 9110 > Clear & grub, grub stumps, w/335					0.05	1.56	2.66	0.00	0.00	4.22	
HP dozer, to 12" dia	5.00	EA	CODTB10M	31.25	0	8	13	0	0	21	4.22
L AF AA <02234 0570 > Hauling, hwy haulers, 12 CY, 10					0.18	5.12	7.20	0.00	0.00	12.32	
mile round trip @ base wide rate	200.00	CY	COEIB34B	5.46	37	1,024	1,440	0	0	2,464	12.32
USR AA < > Disposal Fee of $3.80/CY used					0.00	0.00	0.00	0.00	3.80	3.80	
based on RS Means plus	200.00	CY		0.00	0	0	0	0	760	760	3.80
AF AA <02110 1050 > Clearing, wet, heavy brush &					20.59	701.45	809.11	0.00	0.00	1510.56	
trees	1.00	ACR	COMCB88	0.34	21	701	809	0	0	1,511	1510.56
TOTAL Clearing and Grubbing	1.00	JOB			72	2,162	2,495	0	760	5,417	5416.82

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 04-015 . Erosion Control											
Erosion Control, Assume silt fencing and sand bags for construction site											
B MIL AA <02266 1120 > Erosion control, w/7.5' posts,					0.07	1.80	0.00	1.09	0.00	2.89	
silt fence, 3' high,	260.00	LF	ALABCLAB2	30.00	17	469	0	282	0	751	2.89
polypropylene											
B MIL AA <02266 1120 > Remove silt fence					0.07	1.80	0.00	0.00	0.00	1.80	
polypropylene	260.00	LF	ALABCLAB2	30.00	17	469	0	0	0	469	1.80
USR AA < > Sand Bags - RS Means Cost Data					0.00	0.00	0.00	0.00	1.90	1.90	
	87.00	EA		0.00	0	0	0	0	165	165	1.90
TOTAL Erosion Control	1.00	JOB			35	938	0	282	165	1,385	1384.91

01 04. DAMS		QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 04-020 . Demolition	Demolition, Assume demolish and dispose of asphalt											
AF AA <02046 1780 >	Site dml, bituminous, pavement					0.03	0.86	0.75	0.00	0.00	1.61	
	removal, pulverize	40.00	CY	COKCB73	300.00	1	34	30	0	0	64	1.61
MIL AA <02232 0310 >	Excavate & load, track loader,					0.03	0.82	0.55	0.00	0.00	1.37	
	1-1/2 CY, wet rock	40.00	CY	CODFB10N	59.38	1	33	22	0	0	55	1.37
L AF AA <02234 0570 >	Dispose, hwy haulers, 12 CY, 20					0.31	8.75	12.30	0.00	0.00	21.04	
	mile round trip @ base wide rate	40.00	CY	COEIB34B	3.20	13	350	492	0	0	842	21.04
USR AA < >	Disposal Fee of $19/CY used					0.00	0.00	0.00	0.00	19.00	19.00	
	based on RS Means plus	40.00	CY		0.00	0	0	0	0	760	760	19.00
	TOTAL Demolition	1.00	JOB			15	417	544	0	760	1,721	1721.16

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 04-025 . Excavation - Soil Excavate soil and dispose of excess											
L MIL AA <02232 0125 > Excavate & load, hydr excavator, 1.5 CY, wet matl	120.00	CY	CODEB12B	10.41	0.19 23	6.47 777	4.90 588	0.00 0	0.00 0	11.37 1,365	11.37
USR AA < > Shoring of Trench, Cost based on RS Means plus escalated cost factor due to remote site	1000.00	SF		0.00	0.00 0	0.00 0	0.00 0	0.00 0	1.00 1,000	1.00 1,000	1.00
L AF AA <02234 0570 > Hauling, hwy haulers, 12 CY, 10 mile round trip @ base wide rate	80.00	CY	COEIB34B	5.46	0.18 15	5.12 410	7.20 576	0.00 0	0.00 0	12.32 986	12.32
USR AA < > Disposal Fee of $3.8/CY used based on RS Means plus	80.00	CY		0.00	0.00 0	0.00 0	0.00 0	0.00 0	3.80 304	3.80 304	3.80
TOTAL Excavation - Soil	1.00	JOB			38	1,187	1,164	0	1,304	3,655	3654.56

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 04-031 . Fill - Sand Fill - Sand includes trench backfill											
M MIL AA <02232 0225 > Load Borrow, wheeled loader, 1.5					0.02	0.61	0.31	4.34	0.00	5.26	
CY, sand	40.00	CY	CODFB10S	80.00	1	24	12	174	0	210	5.26
L AF AA <02234 0570 > Hauling, hwy haulers, 12 CY, 20					0.31	8.75	12.30	0.00	0.00	21.04	
mile round trip @ base wide rate	40.00	CY	COEIB34B	3.20	13	350	492	0	0	842	21.04
MIL AA <02215 1220 > Backfill, trench, front-end					0.03	0.98	0.66	0.00	0.00	1.63	
loader, 40 - 60 HP, no compaction	40.00	CY	CODFB10N	50.00	1	39	26	0	0	65	1.63
MIL AA <02220 9010 > Compaction, water, truck, 3000					0.01	0.35	0.28	0.22	0.00	0.85	
gal, 6 mile haul	40.00	CY	COKBB45	180.50	0	14	11	9	0	34	0.85
TOTAL Fill - Sand	1.00	JOB			15	427	542	182	0	1,151	1151.10

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 04-032 . Fill - On-Site Material Assume acceptable excess excavation from trench will be used as backfill											
M MIL AA <02232 0225 > Spread/Stockpile, wheeled					0.02	0.61	0.31	0.00	0.00	0.92	
loader, 1.5 CY, on-site matl	40.00	CY	CODFB10S	80.00	1	24	12	0	0	37	0.92
MIL AA <02215 1220 > Backfill, trench, front-end					0.03	0.98	0.66	0.00	0.00	1.63	
loader, 40 - 60 HP, no compaction	40.00	CY	CODFB10N	50.00	1	39	26	0	0	65	1.63
MIL AA <02220 9010 > Compaction, water, truck, 3000					0.01	0.35	0.28	0.22	0.00	0.85	
gal, 6 mile haul	40.00	CY	COKBB45	180.50	0	14	11	9	0	34	0.85
TOTAL Fill - On-Site Material	1.00	JOB			2	77	50	9	0	136	135.78

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 04-035 . Road Improvements Roadway impovements, base course and asphalt pavement											
M MIL AA <02244 0100 > Base course, crushed 3/4" stone, compacted, 12"D, large areas	50.00	SY	COFGB36C	625.00	0.01 0	0.26 13	0.28 14	8.68 434	0.00 0	9.22 461	9.22
L AF AA <02234 0570 > Base Course Hauling, 20 mile round trip @ base wide rate	16.50	CY	COEIB34B	3.20	0.31 5	8.75 144	12.30 203	0.00 0	0.00 0	21.04 347	21.04
RSM AA <02505 0810 > Asphaltic conc pavement, highway, binder course, 1.5" thick	4.00	TON	COKCB25	78.75	0.14 1	4.10 16	1.58 6	28.03 112	0.00 0	33.71 135	33.71
RSM AA <02505 0850 > Asphaltic conc pavement, highway, wearing course, 1" thick	3.00	TON	COKCB25B	71.88	0.17 1	4.99 15	2.30 7	30.92 93	0.00 0	38.21 115	38.21
L AF AA <02234 0570 > Asphalt Hauling, 20 mile round trip @ base wide rate	3.60	CY	COEIB34B	3.20	0.31 1	8.75 31	12.30 44	0.00 0	0.00 0	21.04 76	21.04
TOTAL Road Improvements	1.00	JOB			8	220	274	639	0	1,133	1133.36

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 04-040 . Utility Relocations Relocate underground utilities within trench area											
USR AA < > Relocate Utilities, Allowance					0.00	0.00	0.00	0.00	950.00	950.00	
for any utilities in the area	1.00	LS		0.00	0	0	0	0	950	950	950.00
TOTAL Utility Relocations	1.00	JOB			0	0	0	0	950	950	950.00

01 04. DAMS		QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 04-081 . Steel Casing Steel Casing, Costs based on RS Means												
USR AA <	> 26-inch Steel Casing					0.00	95.00	47.50	87.88	0.00	230.39	
		300.00	LF		0.00	0	28,500	14,250	26,366	0	69,116	230.39
USR AA <	> End Caps					0.00	475.00	48.00	515.38	0.00	1038.38	
		2.00	EA		0.00	0	950	96	1,031	0	2,077	1038.38
USR AA <	> Aerial Supports					0.00	4750.00	950.00	5153.75	0.00	10853.75	
		6.00	EA		0.00	0	28,500	5,700	30,923	0	65,123	10853.75
USR AA <	> Bridge Supports					0.00	2850.00	950.00	3092.25	0.00	6892.25	
		10.00	EA		0.00	0	28,500	9,500	30,923	0	68,923	6892.25
USR AA <	> 80 Ton Hydraulic Crane rental					0.00	760.00	1450.00	0.00	0.00	2210.00	
	per day - RS Means	3.00	DAY		0.00	0	2,280	4,350	0	0	6,630	2210.00
	TOTAL Steel Casing	1.00	JOB			0	88,730	33,896	89,241	0	211,867	211867.25

01 04. DAMS	QUANTY UOM CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 04-082 . 24-inch HDPE Pipe 24-inch HDPE Pipe, RS Means cost data									
USR AA < > 24-inch HDPE Pipe			0.00	10.50	8.60	41.77	0.00	60.87	
	540.00 LF	0.00	0	5,670	4,644	22,557	0	32,871	60.87
USR AA < > 24-inch HDPE Elbows			0.00	0.00	0.00	0.00	1900.00	1900.00	
	3.00 EA	0.00	0	0	0	0	5,700	5,700	1900.00
USR AA < > Access Portals			0.00	0.00	0.00	0.00	2375.00	2375.00	
	2.00 EA	0.00	0	0	0	0	4,750	4,750	2375.00
USR AA < > Thrust Block, Engineering			0.00	0.00	0.00	0.00	950.00	950.00	
judgement based on similar project experience	3.00 EA	0.00	0	0	0	0	2,850	2,850	950.00
TOTAL 24-inch HDPE Pipe	1.00 JOB		0	5,670	4,644	22,557	13,300	46,171	46171.15

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 04-091 . 24-inch Valves 24-inch Valves											
USR AA < > 24" Ball Valve					0.00	4750.00	0.00	0.00	38000.00	42750.00	
	1.00	EA		0.00	0	4,750	0	0	38,000	42,750	42750.00
USR AA < > Air Release Valve					0.00	285.00	0.00	0.00	950.00	1235.00	
	1.00	EA		0.00	0	285	0	0	950	1,235	1235.00
TOTAL 24-inch Valves	1.00	JOB			0	5,035	0	0	38,950	43,985	43985.00

01 04. DAMS		QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 04-150	. Revegetation Assume revegetation of the trench area with trees, shrubs and hydro-seeding											
USR LC < >	Hydroseeding 5#/ac - RSM					0.60	17.15	1.86	37.98	0.00	56.98	
	0292051000 (costworks 2002)	5.00	MSF	XLABE	10.00	3	108	12	238	0	358	71.54
USR LC < >	Rototill, 20Hp tractor 12" deep					0.30	8.77	0.69	0.00	0.00	9.46	
	RSM 029203406100 (costworks 2002	5.00	MSF	CLABB62	10.00	2	55	4	0	0	59	11.88
L MIL LC <02951 0760 >	Mulch, straw, 2" deep, hand					0.01	0.22	0.00	0.09	0.00	0.31	
	spread arnd planted trees/shrubs	2000.00	SF	ALABCLAB1	122.00	16	557	0	218	0	775	0.39
M MIL LC <02947 0400 >	General planting, local					0.57	16.53	7.40	5.43	0.00	29.36	
	varieties, 2' - 3', shrubs	10.00	EA	COEIB17	7.00	6	208	93	68	0	369	36.86
MIL LC <02947 0200 >	General planting, local					0.71	20.58	9.21	126.22	0.00	156.00	
	varieties, trees, 2' - 3'	5.00	EA	COEIB17	5.63	4	129	58	792	0	979	195.86
	TOTAL Revegetation	1.00	JOB			30	1,056	167	1,317	0	2,540	2539.69

01 04. DAMS	QUANTY UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 04-200 . Controls and Instrumentation Controls and Instrumentation										
USR AA < > Controls and Instrumentation,				0.00	0.00	0.00	0.00	9500.00	9500.00	
Represents electrical allowance	1.00 LS		0.00	0	0	0	0	9,500	9,500	9500.00
TOTAL Controls and Instrumentation	1.00 JOB			0	0	0	0	9,500	9,500	9500.00

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 04-210 . Power and Telemetry Power and Telemetry											
USR AA < > Power and Telemetry, Represents electrical allowance	1.00	LS		0.00	0.00 0	0.00 0	0.00 0	0.00 0	9500.00 9,500	9500.00 9,500	9500.00
TOTAL Power and Telemetry	1.00	JOB			0	0	0	0	9,500	9,500	9500.00

01 04. DAMS		QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 05. Multi-Level Discharge Multi-Level Discharge 01 04 03 05-005 . Clearing and Grubbing	Assume clearing vault and piping area of all vegetation and organics											
CIV AA <02109 7310 >	Clear & grub, tree rmv, cutting & chipping, 6" - 12" dia	5.00	EA	CODFB7	2.00	3.00 15	85.73 429	46.42 232	0.00 0	0.00 0	132.16 661	132.16
AF AA <02109 9110 >	Clear & grub, grub stumps, w/335 HP dozer, to 12" dia	5.00	EA	CODTB10M	31.25	0.05 0	1.56 8	2.66 13	0.00 0	0.00 0	4.22 21	4.22
L AF AA <02234 0570 >	Hauling, hwy haulers, 12 CY, 10 mile round trip @ base wide rate	300.00	CY	COEIB34B	5.46	0.18 55	5.12 1,537	7.20 2,160	0.00 0	0.00 0	12.32 3,697	12.32
USR AA < >	Disposal Fee of $3.8/CY used based on RS Means plus	300.00	CY		0.00	0.00 0	0.00 0	0.00 0	0.00 0	3.80 1,140	3.80 1,140	3.80
AF AA <02110 1050 >	Clearing, wet, heavy brush & trees	1.00	ACR	COMCB88	0.34	20.59 21	701.45 701	809.11 809	0.00 0	0.00 0	1510.56 1,511	1510.56
TOTAL	Clearing and Grubbing	1.00	JOB			91	2,674	3,215	0	1,140	7,029	7029.01

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 05-010 . Dewatering Quoted from Baker Tanks, Assume 1 month rental											
USR AA < > (1) Dewatering Boxes					0.00	0.00	0.00	0.00	1425.00	1425.00	
	1.00	MO		0.00	0	0	0	0	1,425	1,425	1425.00
USR AA < > (2) 6" Thompson Pump Stations					0.00	0.00	0.00	0.00	3800.00	3800.00	
	1.00	MO		0.00	0	0	0	0	3,800	3,800	3800.00
USR AA < > Operation, Fuel and Oil					0.00	0.00	0.00	0.00	3800.00	3800.00	
	1.00	LS		0.00	0	0	0	0	3,800	3,800	3800.00
TOTAL Dewatering	1.00	JOB			0	0	0	0	9,025	9,025	9025.00

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 05-015 . Erosion Control Erosion Control, Assume silt fencing and sand bags for construction site											
B MIL AA <02266 1120 > Erosion control, w/7.5' posts, silt fence, 3' high, polypropylene					0.07	1.80	0.00	1.09	0.00	2.89	
	450.00	LF	ALABCLAB2	30.00	30	811	0	488	0	1,300	2.89
B MIL AA <02266 1120 > Remove silt fence polypropylene					0.07	1.80	0.00	0.00	0.00	1.80	
	450.00	LF	ALABCLAB2	30.00	30	811	0	0	0	811	1.80
USR AA < > Sand Bags - RS Means Cost Data					0.00	0.00	0.00	0.00	1.90	1.90	
	150.00	EA		0.00	0	0	0	0	285	285	1.90
TOTAL Erosion Control	1.00	JOB			60	1,623	0	488	285	2,396	2395.86

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 05-020 . Demolition Demolition, Assume demolish and dispose of asphalt											
AF AA <02046 1780 > Site dml, bituminous, pavement					0.03	0.86	0.75	0.00	0.00	1.61	
removal, pulverize	150.00	CY	COKCB73	300.00	4	129	113	0	0	242	1.61
MIL AA <02232 0310 > Excavate & load, track loader,					0.03	0.82	0.55	0.00	0.00	1.37	
1-1/2 CY, wet rock	150.00	CY	CODFB10N	59.38	4	123	83	0	0	206	1.37
L AF AA <02234 0570 > Dispose, hwy haulers, 12 CY, 20					0.31	8.75	12.30	0.00	0.00	21.04	
mile round trip @ base wide rate	150.00	CY	COEIB34B	3.20	47	1,312	1,844	0	0	3,156	21.04
USR AA < > Disposal Fee of $19/CY used					0.00	0.00	0.00	0.00	19.00	19.00	
based on RS Means plus	150.00	CY		0.00	0	0	0	0	2,850	2,850	19.00
TOTAL Demolition	1.00	JOB			55	1,564	2,040	0	2,850	6,454	6454.35

01 04. DAMS		QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 05-025 .	Excavation - Soil Excavate soil and dispose of excess											
L MIL AA <02232 0125 >	Excavate & load, hydr excavator,					0.19	6.47	4.90	0.00	0.00	11.37	
	1.5 CY, wet matl	720.00	CY	CODEB12B	10.41	138	4,661	3,528	0	0	8,189	11.37
USR AA < >	Shoring of Vault Excavation,					0.00	2.45	2.85	12.04	0.00	17.34	
	Sheet Piling 38psf, Cost based on RS Means plus escalated cost factor due to remote site	2000.00	SF		0.00	0	4,900	5,700	24,087	0	34,687	17.34
L AF AA <02234 0570 >	Hauling, hwy haulers, 12 CY, 10					0.18	5.12	7.20	0.00	0.00	12.32	
	mile round trip @ base wide rate	650.00	CY	COEIB34B	5.46	119	3,329	4,680	0	0	8,009	12.32
USR AA < >	Disposal Fee of $3.8/CY used					0.00	0.00	0.00	0.00	3.80	3.80	
	based on RS Means plus	650.00	CY		0.00	0	0	0	0	2,470	2,470	3.80
TOTAL	Excavation - Soil	1.00	JOB			257	12,890	13,908	24,087	2,470	53,355	53355.08

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 05-026 . Excavation - Rock Excavate rock and dispose of excess											
B MIL AA <02232 0130 > Excavate & load, hydr excavator,					0.49	16.51	12.50	0.00	0.00	29.01	
1.5 CY, blasted rock	360.00	CY	CODEB12B	4.08	176	5,945	4,500	0	0	10,445	29.01
L AF AA <02234 0570 > Hauling, hwy haulers, 12 CY, 10					0.18	5.12	7.20	0.00	0.00	12.32	
mile round trip @ base wide rate	360.00	CY	COEIB34B	5.46	66	1,844	2,592	0	0	4,436	12.32
USR AA < > Disposal Fee of $3.8/CY is used					0.00	0.00	0.00	0.00	3.80	3.80	
for this estimate.	360.00	CY		0.00	0	0	0	0	1,368	1,368	3.80
TOTAL Excavation - Rock	1.00	JOB			242	7,788	7,092	0	1,368	16,248	16248.42

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 05-030 . Fill - Select Granular Assume imported engineered fill for foundation and drainage											
M MIL AA <02232 0225 > Load Borrow, wheeled loader, 1.5					0.02	0.61	0.31	10.85	0.00	11.77	
CY, select granular	40.00	CY	CODFB10S	80.00	1	24	12	434	0	471	11.77
L AF AA <02234 0570 > Base Course Hauling, 20 mile					0.31	8.75	12.30	0.00	0.00	21.04	
round trip @ base wide rate	40.00	CY	COEIB34B	3.20	13	350	492	0	0	842	21.04
MIL AA <02216 5530 > Backfill, strl, 6" lifts,					0.02	0.70	0.47	0.00	0.00	1.17	
w/loader, no compaction, around foundation	40.00	CY	CODFB10N	70.00	1	28	19	0	0	47	1.17
TOTAL Fill - Select Granular	1.00	JOB			14	402	523	434	0	1,359	1359.00

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 05-031 . Fill - Sand Fill - Sand includes trench backfill											
M MIL AA <02232 0225 > Load Borrow, wheeled loader, 1.5 CY, sand	40.00	CY	CODFB10S	80.00	0.02 1	0.61 24	0.31 12	6.51 260	0.00 0	7.43 297	7.43
L AF AA <02234 0570 > Hauling, hwy haulers, 12 CY, 20 mile round trip @ base wide rate	40.00	CY	COEIB34B	3.20	0.31 13	8.75 350	12.30 492	0.00 0	0.00 0	21.04 842	21.04
MIL AA <02215 1220 > Backfill, trench, front-end loader, 40 - 60 HP, no compaction	40.00	CY	CODFB10N	50.00	0.03 1	0.98 39	0.66 26	0.00 0	0.00 0	1.63 65	1.63
MIL AA <02220 9010 > Compaction, water, truck, 3000 gal, 6 mile haul	40.00	CY	COKBB45	180.50	0.01 0	0.35 14	0.28 11	0.22 9	0.00 0	0.85 34	0.85
TOTAL Fill - Sand	1.00	JOB			15	427	542	269	0	1,238	1237.90

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 05-032 . Fill - On-Site Material Assume acceptable excess excavation from vault will be used as backfill											
M MIL AA <02232 0225 > Spread/Stockpile, wheeled					0.02	0.61	0.31	0.00	0.00	0.92	
loader, 1.5 CY, on-site matl	70.00	CY	CODFB10S	80.00	1	43	21	0	0	64	0.92
MIL AA <02215 1220 > Backfill, trench, front-end					0.03	0.98	0.66	0.00	0.00	1.63	
loader, 40 - 60 HP, no compaction	70.00	CY	CODFB10N	50.00	2	68	46	0	0	114	1.63
MIL AA <02220 9010 > Compaction, water, truck, 3000					0.01	0.35	0.28	0.22	0.00	0.85	
gal, 6 mile haul	70.00	CY	COKBB45	180.50	1	25	20	15	0	59	0.85
TOTAL Fill - On-Site Material	1.00	JOB			4	135	87	15	0	238	237.62

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 05-033 . Grading Grading of area for placement of project features											
L MIL AA <02226 4100 > Grading, fine grade, 3 passes					0.13	4.11	2.00	0.00	0.00	6.11	
w/grader	250.00	SY	COFGB11L	15.17	33	1,027	500	0	0	1,527	6.11
TOTAL Grading	1.00	JOB			33	1,027	500	0	0	1,527	1526.75

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 05-035 . Road Improvements Roadway impovements, base course and asphalt pavement											
M MIL AA <02244 0100 > Base course, crushed 3/4" stone, compacted, 12"D, large areas	450.00	SY	COFGB36C	625.00	0.01 4	0.26 116	0.28 126	8.68 3,906	0.00 0	9.22 4,148	9.22
L AF AA <02234 0570 > Base Course Hauling, 20 mile round trip @ base wide rate	150.00	CY	COEIB34B	3.20	0.31 47	8.75 1,312	12.30 1,844	0.00 0	0.00 0	21.04 3,156	21.04
RSM AA <02505 0810 > Asphaltic conc pavement, highway, binder course, 1.5" thick	38.00	TON	COKCB25	78.75	0.14 5	4.10 156	1.58 60	28.03 1,065	0.00 0	33.71 1,281	33.71
RSM AA <02505 0850 > Asphaltic conc pavement, highway, wearing course, 1" thick	25.00	TON	COKCB25B	71.88	0.17 4	4.99 125	2.30 58	30.92 773	0.00 0	38.21 955	38.21
L AF AA <02234 0570 > Asphalt Hauling, 20 mile round trip @ base wide rate	35.00	CY	COEIB34B	3.20	0.31 11	8.75 306	12.30 430	0.00 0	0.00 0	21.04 737	21.04
TOTAL Road Improvements	1.00	JOB			71	2,015	2,518	5,744	0	10,277	10277.49

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 05-040 . Utility Relocations Relocate underground utilities within vault area											
USR AA < > Relocate Utilities					0.00	0.00	0.00	0.00	950.00	950.00	
	1.00	LS		0.00	0	0	0	0	950	950	950.00
TOTAL Utility Relocations	1.00	JOB			0	0	0	0	950	950	950.00

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 05-045 . Concrete - Structural Foundation Concrete - Structure Foundation includes, vault foundation											
MIL AA <03154 0010 > Forms in place, eqpt					0.30	10.36	0.00	2.79	0.00	13.15	
foundations, 2 use	200.00	SF	ACARC2	20.00	60	2,072	0	558	0	2,630	13.15
L MIL AA <03217 0550 > Reinforcing in place, footings,					18.18	800.74	0.00	540.33	0.00	1341.07	
#8 to #18	2.50	TON	SIWRRODM4	0.22	45	2,002	0	1,351	0	3,353	1341.07
RSM AA <03326 0400 > Concrete ready mix, regular					0.00	0.00	0.00	79.22	0.00	79.22	
weight, 5000 psi	50.00	CY	N/A	0.00	0	0	0	3,961	0	3,961	79.22
MIL AA <03372 4650 > Placing conc, slab on grade,					0.35	9.98	3.21	0.00	0.00	13.19	
over 6" thick, pumped	50.00	CY	CLABC20	23.13	17	499	161	0	0	660	13.19
TOTAL Concrete - Structural Foundation	1.00	JOB			123	4,573	161	5,869	0	10,603	10602.80

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 05-046 . Concrete - Structural Walls											
Concrete - Structure Foundation includes, vault walls											
MIL AA <03182 5100 > Forms in place, retaining wall,					0.24	8.29	0.00	2.95	0.00	11.24	
smooth curve, plywood, 2 use	3000.00	SF	ACARC2	25.00	720	24,865	0	8,854	0	33,718	11.24
L MIL AA <03217 0550 > Reinforcing in place, #8 to #18					18.18	800.74	0.00	540.33	0.00	1341.07	
	6.50	TON	SIWRRODM4	0.22	118	5,205	0	3,512	0	8,717	1341.07
RSM AA <03326 0400 > Concrete ready mix, regular					0.00	0.00	0.00	79.22	0.00	79.22	
weight, 5000 psi	104.00	CY	N/A	0.00	0	0	0	8,238	0	8,238	79.22
MIL AA <03372 5350 > Placing conc, walls, 15" thick,					0.53	15.39	4.95	0.00	0.00	20.34	
pumped	104.00	CY	CLABC20	15.00	55	1,600	515	0	0	2,115	20.34
TOTAL Concrete - Structural Walls	1.00	JOB			894	31,670	515	20,604	0	52,789	52788.67

01 04. DAMS	QUANTY UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 05-048 . Concrete - Vault Concrete - Vault										
USR AA < > Manhole Vault, RS Means cost data	5.00 EA		0.00	0.00 0	975.00 4,875	285.00 1,425	3634.75 18,174	0.00 0	4894.75 24,474	4894.75
TOTAL Concrete - Vault	1.00 JOB			0	4,875	1,425	18,174	0	24,474	24473.75

01 04. DAMS	QUANTY UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 05-049 . Roof System Relocate underground utilities within vault area										
USR AA < > Removable Roof Section w/ hatch				0.00	0.00	0.00	0.00	45.60	45.60	
and anchor bolts, Cost based on engineering judgement on similar project experience	600.00 SF		0.00	0	0	0	0	27,360	27,360	45.60
TOTAL Roof System	1.00 JOB			0	0	0	0	27,360	27,360	27360.00

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 05-050 . Fencing Security fencing around vault, includes gate											
AF AA <01534 0100 > Fencing, 11 ga, chain link, 6'					0.21	5.77	0.00	3.56	35.00	44.33	
high, includes foundations	135.00	LF	ALABCLAB2	9.38	29	779	0	480	4,725	5,984	44.33
USR AA < > Barbwire Strands, Costs based on					0.00	9.50	1.90	8.25	0.00	19.65	
similar project experience	135.00	LF		0.00	0	1,283	257	1,113	0	2,652	19.65
MIL AA <02832 1310 > Fence, CL, 4' x 6', transom					2.75	74.43	13.98	177.64	0.00	266.05	
gate, single, galv	2.00	EA	CLABB80A	1.09	6	149	28	355	0	532	266.05
TOTAL Fencing	1.00	JOB			34	2,210	284	1,949	4,725	9,169	9168.62

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 05-055 . Facility Access Facility Access includes: stairs, handrails, grating, and ladders within the vault											
MIL AA <05518 0010 > Ladder, steel, 20" wide, bolted					0.64	30.02	0.80	58.96	0.00	89.79	
to conc, w/cage	30.00	VLF	SIWSE4	6.25	19	901	24	1,769	0	2,694	89.79
B MIL AA <05542 0622 > Floor grating,stl,1.25" x 3/16",					0.21	10.00	0.27	10.85	0.00	21.12	
ptd brg bars @ 15/16" OC, 300 SF	100.00	SF	SIWSE4	18.77	21	1,000	27	1,085	0	2,112	21.12
M MIL AA <05523 0940 > Railing, pipe, steel, 3 rail,					0.18	8.53	0.23	32.55	0.00	41.31	
primed, 1.5" dia, on brackets	30.00	LF	SIWSE4	22.00	5	256	7	976	0	1,239	41.31
MIL AA <05511 0020 > Stair, stl,grating trd & pipe r,					0.91	42.89	1.15	113.93	0.00	157.97	
3'-6" W, saf nosing, stl strg	52.00	EA	SIWSE4	4.38	48	2,230	60	5,924	0	8,214	157.97
MIL AA <05511 0120 > Stair, grating trd, landing,					0.20	9.38	0.25	28.48	0.00	38.12	
steel, grating, framing	105.00	SF	SIWSE4	20.00	21	985	26	2,991	0	4,002	38.12
TOTAL Facility Access	1.00	JOB			115	5,372	144	12,745	0	18,261	18261.15

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 05-060 . Drainage System Drainage system includes: vault drainage and structure subdrainage											
USR AA < > Catch Basins, RS Means cost data					0.00	0.00	0.00	0.00	475.00	475.00	
	1.00	EA		0.00	0	0	0	0	475	475	475.00
M MIL AA <15155 2570 > Drain Pipe PVC					0.24	9.48	0.00	13.02	0.00	22.50	
	200.00	LF	MPLUQ2	12.25	49	1,897	0	2,604	0	4,501	22.50
M MIL AA <15157 2210 > PVC, 90 deg elbow					2.58	99.94	0.00	325.50	0.00	425.44	
	2.00	EA	MPLUQ2	1.16	5	200	0	651	0	851	425.44
USR AA < > Sump Pump, Complete system, RS					0.00	0.00	0.00	0.00	5700.00	5700.00	
Means cost data plus	1.00	EA		0.00	0	0	0	0	5,700	5,700	5700.00
contingency factor											
CIV AA <02250 2140 > Geotextile fabric, 120 mil					0.02	0.54	0.10	1.40	0.00	2.04	
thick, non-woven polypropylene	60.00	SY	ULABA2	150.00	1	32	6	84	0	122	2.04
TOTAL Drainage System	1.00	JOB			55	2,129	6	3,339	6,175	11,649	11649.07

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 05-083 . 24-inch Rotating Pipe Section 24-inch Rotating Pipe Section - 5 shooter multi-level discharge system											
USR AA < > 24-inch Rotating 5 Shooter,					0.00	0.00	0.00	0.00	128250.00	128250.00	
Quote from Mfgr (Dynamic Air)	1.00	LS		0.00	0	0	0	0	128,250	128,250	128250.00
USR AA < > 80 Ton Hydraulic Crane rental					0.00	760.00	1450.00	0.00	0.00	2210.00	
per day - RS Means	2.00	DAY		0.00	0	1,520	2,900	0	0	4,420	2210.00
TOTAL 24-inch Rotating Pipe Section	1.00	JOB			0	1,520	2,900	0	128,250	132,670	132670.00

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 05-084 . 24-inch Outlet Pipes 24-inch outlet pipes to gravity flume											
USR AA < > 24-inch Straight Sections, Costs					0.00	0.00	0.00	0.00	118.75	118.75	
based on RS Means data	650.00	LF		0.00	0	0	0	0	77,188	77,188	118.75
USR AA < > 24-inch Curved Sections, Costs					0.00	0.00	0.00	0.00	9500.00	9500.00	
based on engineering judgement on breakdown of components of work	5.00	EA		0.00	0	0	0	0	47,500	47,500	9500.00
USR AA < > Depend-O-Lok Couplings, Quote					0.00	190.00	1045.00	878.85	0.00	2113.85	
from vendor (Victaulic)	5.00	EA		0.00	0	950	5,225	4,394	0	10,569	2113.85
TOTAL 24-inch Outlet Pipes	1.00	JOB			0	950	5,225	4,394	124,688	135,257	135256.75

01 04. DAMS		QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
	01 04 03 05-150 . Revegetation Assume revegetation of vault/trench area with trees, shrubs and hydro-seeding											
USR LC <	> Hydroseeding 5#/ac - RSM 0292051000 (costworks 2002)	5.00	MSF	XLABE	10.00	0.60 3	17.15 108	1.86 12	37.98 238	0.00 0	56.98 358	71.54
USR LC <	> Rototill, 20Hp tractor 12" deep RSM 029203406100 (costworks 2002	5.00	MSF	CLABB62	10.00	0.30 2	8.77 55	0.69 4	0.00 0	0.00 0	9.46 59	11.88
L MIL LC <02951 0760	> Mulch, straw, 2" deep, hand spread arnd planted trees/shrubs	2000.00	SF	ALABCLAB1	122.00	0.01 16	0.22 557	0.00 0	0.09 218	0.00 0	0.31 775	0.39
M MIL LC <02947 0400	> General planting, local varieties, 2' - 3', shrubs	20.00	EA	COEIB17	7.00	0.57 11	16.53 415	7.40 186	5.43 136	0.00 0	29.36 737	36.86
MIL LC <02947 0200	> General planting, local varieties, trees, 2' - 3'	3.00	EA	COEIB17	5.63	0.71 2	20.58 77	9.21 35	126.22 475	0.00 0	156.00 588	195.86
	TOTAL Revegetation	1.00	JOB			34	1,212	237	1,068	0	2,517	2516.57

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 05-200 . Controls and Instrumentation Controls and Instrumentation											
USR AA < > Controls and Instrumentation,					0.00	0.00	0.00	0.00	14250.00	14250.00	
Represents electrical allowance	1.00	LS		0.00	0	0	0	0	14,250	14,250	14250.00
TOTAL Controls and Instrumentation	1.00	JOB			0	0	0	0	14,250	14,250	14250.00

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 05-210 . Power and Telemetry Power and Telemetry											
USR AA < > Power and Telemetry, Represents					0.00	0.00	0.00	0.00	19000.00	19000.00	
electrical allowance	1.00	LS		0.00	0	0	0	0	19,000	19,000	19000.00
TOTAL Power and Telemetry	1.00	JOB			0	0	0	0	19,000	19,000	19000.00

01 04. DAMS		QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 06. Gravity Flume												
Gravity Flume												
01 04 03 06-005 . Clearing and Grubbing												
	Assume clearing gravity flume area of all vegetation and organics											
CIV AA <02109 7310 >	Clear & grub, tree rmv, cutting					3.00	85.73	46.42	0.00	0.00	132.16	
	& chipping, 6" - 12" dia	15.00	EA	CODFB7	2.00	45	1,286	696	0	0	1,982	132.16
AF AA <02109 9110 >	Clear & grub, grub stumps, w/335					0.05	1.56	2.66	0.00	0.00	4.22	
	HP dozer, to 12" dia	15.00	EA	CODTB10M	31.25	1	23	40	0	0	63	4.22
L AF AA <02234 0570 >	Hauling, hwy haulers, 12 CY, 10					0.18	5.12	7.20	0.00	0.00	12.32	
	mile round trip @ base wide rate	100.00	CY	COEIB34B	5.46	18	512	720	0	0	1,232	12.32
USR AA < >	Disposal Fee of $3.8/CY used					0.00	0.00	0.00	0.00	3.80	3.80	
	based on RS Means plus	100.00	CY		0.00	0	0	0	0	380	380	3.80
AF AA <02110 1050 >	Clearing, wet, heavy brush &					20.59	701.45	809.11	0.00	0.00	1510.56	
	trees	1.00	ACR	COMCB88	0.34	21	701	809	0	0	1,511	1510.56
TOTAL	Clearing and Grubbing	1.00	JOB			85	2,523	2,265	0	380	5,168	5168.39

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 06-015 . Erosion Control											
Erosion Control, Assume silt fencing and sand bags for construction site											
B MIL AA <02266 1120 > Erosion control, w/7.5' posts,					0.07	1.80	0.00	1.09	0.00	2.89	
silt fence, 3' high,	2800.00	LF	ALABCLAB2	30.00	187	5,048	0	3,038	0	8,086	2.89
polypropylene											
B MIL AA <02266 1120 > Remove silt fence					0.07	1.80	0.00	0.00	0.00	1.80	
polypropylene	2800.00	LF	ALABCLAB2	30.00	187	5,048	0	0	0	5,048	1.80
USR AA < > Sand Bags - RS Means Cost Data					0.00	0.00	0.00	0.00	1.90	1.90	
	1000.00	EA		0.00	0	0	0	0	1,900	1,900	1.90
TOTAL Erosion Control	1.00	JOB			374	10,096	0	3,038	1,900	15,034	15034.24

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 06-020 . Demolition Demolition, Assume demolish and dispose of asphalt											
AF AA <02046 1780 > Site dml, bituminous, pavement					0.03	0.86	0.75	0.00	0.00	1.61	
removal, pulverize	270.00	CY	COKCB73	300.00	7	232	203	0	0	435	1.61
MIL AA <02232 0310 > Excavate & load, track loader,					0.03	0.82	0.55	0.00	0.00	1.37	
1-1/2 CY, wet rock	270.00	CY	CODFB10N	59.38	7	222	149	0	0	371	1.37
L AF AA <02234 0570 > Dispose, hwy haulers, 12 CY, 20					0.31	8.75	12.30	0.00	0.00	21.04	
mile round trip @ base wide rate	270.00	CY	COEIB34B	3.20	84	2,362	3,320	0	0	5,682	21.04
USR AA < > Disposal Fee of $19/CY used					0.00	0.00	0.00	0.00	19.00	19.00	
based on RS Means plus	270.00	CY		0.00	0	0	0	0	5,130	5,130	19.00
TOTAL Demolition	1.00	JOB			98	2,816	3,672	0	5,130	11,618	11617.83

01 04. DAMS		QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 06-025 . Excavation - Soil	Excavate soil and dispose of excess											
L MIL AA <02232 0125 >	Excavate & load, hydr excavator,					0.19	6.47	4.90	0.00	0.00	11.37	
	1.5 CY, wet matl	2000.00	CY	CODEB12B	10.41	384	12,946	9,800	0	0	22,747	11.37
USR AA < >	Shoring, Cost based on RS Means					0.00	3.80	0.54	2.17	0.00	6.51	
	plus escalated cost factor due to remote site	1000.00	SF		0.00	0	3,800	540	2,170	0	6,510	6.51
L AF AA <02234 0570 >	Hauling, hwy haulers, 12 CY, 10					0.18	5.12	7.20	0.00	0.00	12.32	
	mile round trip @ base wide rate	600.00	CY	COEIB34B	5.46	110	3,073	4,320	0	0	7,393	12.32
USR AA < >	Disposal Fee of $3.8/CY used					0.00	0.00	0.00	0.00	3.80	3.80	
	based on RS Means plus	600.00	CY		0.00	0	0	0	0	2,280	2,280	3.80
	TOTAL Excavation - Soil	1.00	JOB			494	19,820	14,660	2,170	2,280	38,930	38929.94

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 06-030 . Fill - Select Granular Assume imported engineered fill for foundation and drainage											
M MIL AA <02232 0225 > Load Borrow, wheeled loader, 1.5 CY, select granular	50.00	CY	CODFB10S	80.00	0.02 1	0.61 30	0.31 15	10.85 543	0.00 0	11.77 588	11.77
L AF AA <02234 0570 > Base Course Hauling, 40 mile round trip @ base wide rate	50.00	CY	COEIB34B	3.20	0.31 16	8.75 437	12.30 615	0.00 0	0.00 0	21.04 1,052	21.04
MIL AA <02216 5530 > Backfill, strl, 6" lifts, w/loader, no compaction, around foundation	50.00	CY	CODFB10N	70.00	0.02 1	0.70 35	0.47 23	0.00 0	0.00 0	1.17 58	1.17
MIL AA <02220 9010 > Compaction, water, truck, 3000 gal, 6 mile haul	50.00	CY	COKBB45	180.50	0.01 1	0.35 18	0.28 14	0.22 11	0.00 0	0.85 42	0.85
TOTAL Fill - Select Granular	1.00	JOB			18	520	668	553	0	1,741	1741.06

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 06-031 . Fill - Sand Fill - Sand includes trench backfill											
M MIL AA <02232 0225 > Load Borrow, wheeled loader, 1.5 CY, sand	600.00	CY	CODFB10S	80.00	0.02 11	0.61 366	0.31 184	4.34 2,604	0.00 0	5.26 3,154	5.26
L AF AA <02234 0570 > Hauling, hwy haulers, 12 CY, 20 mile round trip @ base wide rate	600.00	CY	COEIB34B	3.20	0.31 188	8.75 5,248	12.30 7,378	0.00 0	0.00 0	21.04 12,626	21.04
MIL AA <02215 1220 > Backfill, trench, front-end loader, 40 - 60 HP, no compaction	600.00	CY	CODFB10N	50.00	0.03 18	0.98 585	0.66 394	0.00 0	0.00 0	1.63 979	1.63
MIL AA <02220 9010 > Compaction, water, truck, 3000 gal, 6 mile haul	600.00	CY	COKBB45	180.50	0.01 7	0.35 210	0.28 167	0.22 130	0.00 0	0.85 508	0.85
TOTAL Fill - Sand	1.00	JOB			223	6,409	8,123	2,734	0	17,267	17266.56

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 06-033 . Grading Grading for gravity flume placement											
L MIL AA <02226 4100 > Grading, fine grade, 3 passes					0.13	4.11	2.00	0.00	0.00	6.11	
w/grader	600.00	SY	COFGB11L	15.17	79	2,464	1,200	0	0	3,664	6.11
TOTAL Grading	1.00	JOB			79	2,464	1,200	0	0	3,664	3664.20

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 06-035 . Road Improvements Roadway impovements, base course and asphalt pavement											
M MIL AA <02244 0100 > Base course, crushed 3/4" stone,					0.01	0.26	0.28	8.68	0.00	9.22	
compacted, 12"D, large areas	40.00	SY	COFGB36C	625.00	0	10	11	347	0	369	9.22
L AF AA <02234 0570 > Base Course Hauling, 20 mile					0.31	8.75	12.30	0.00	0.00	21.04	
round trip @ base wide rate	15.00	CY	COEIB34B	3.20	5	131	184	0	0	316	21.04
RSM AA <02505 0810 > Asphaltic conc pavement,					0.14	4.10	1.58	28.03	0.00	33.71	
highway, binder course, 1.5" thick	3.50	TON	COKCB25	78.75	0	14	6	98	0	118	33.71
RSM AA <02505 0850 > Asphaltic conc pavement,					0.17	4.99	2.30	30.92	0.00	38.21	
highway, wearing course, 1" thick	2.20	TON	COKCB25B	71.88	0	11	5	68	0	84	38.21
L AF AA <02234 0570 > Asphalt Hauling, 20 mile round					0.31	8.75	12.30	0.00	0.00	21.04	
trip @ base wide rate	3.00	CY	COEIB34B	3.20	1	26	37	0	0	63	21.04
TOTAL Road Improvements	1.00	JOB			7	193	243	513	0	950	949.56

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 06-040 . Utility Relocations Relocate underground utilities along gravity flume path											
USR AA < > Relocate Utilities					0.00	0.00	0.00	0.00	950.00	950.00	
	1.00	LS		0.00	0	0	0	0	950	950	950.00
TOTAL Utility Relocations	1.00	JOB			0	0	0	0	950	950	950.00

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 06-044 . Concrete - Structural Flume Join Concrete - Structure Flume Joints											
MIL AA <03182 5100 > Forms in place, retaining wall,					0.24	8.29	0.00	2.95	0.00	11.24	
smooth curve, plywood, 1 use	3000.00	SF	ACARC2	25.00	720	24,865	0	8,854	0	33,718	11.24
L MIL AA <03217 0550 > Reinforcing in place, footings,					18.18	800.74	0.00	540.33	0.00	1341.07	
#8 to #18	3.00	TON	SIWRRODM4	0.22	55	2,402	0	1,621	0	4,023	1341.07
RSM AA <03326 0400 > Concrete ready mix, regular					0.00	0.00	0.00	79.22	0.00	79.22	
weight, 5000 psi	50.00	CY	N/A	0.00	0	0	0	3,961	0	3,961	79.22
MIL AA <03372 5350 > Placing conc, walls, 15" thick,					0.53	15.39	4.95	0.00	0.00	20.34	
pumped	50.00	CY	CLABC20	15.00	27	769	248	0	0	1,017	20.34
TOTAL Concrete - Structural Flume Join	1.00	JOB			801	28,036	248	14,435	0	42,719	42719.06

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 06-047 . Concrete - Pre-Cast Concrete - Quote from Concrete Technology Corporation. Pre-Cast includes gravity flume sections											
USR AA < > Sections					0.00	95.00	47.50	134.00	0.00	276.50	
	1507.00	LF		0.00	0	143,165	71,583	201,934	0	416,682	276.50
USR AA < > Topper					0.00	19.00	9.50	51.54	0.00	80.04	
	500.00	LF		0.00	0	9,500	4,750	25,769	0	40,019	80.04
USR AA < > 80 Ton Hydraulic Crane rental					0.00	760.00	1450.00	0.00	0.00	2210.00	
per day - RS Means	15.00	DAY		0.00	0	11,400	21,750	0	0	33,150	2210.00
TOTAL Concrete - Pre-Cast	1.00	JOB			0	164,065	98,083	227,703	0	489,850	489850.48

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 06-056 . Flume Accessories											
Flume Topper includes: grating topper for gravity flume											
B MIL AA <05542 0622 > Floor grating,stl,1.25" x 3/16",					0.21	10.00	0.27	10.85	0.00	21.12	
ptd brg bars @ 15/16" OC, 300 SF	4000.00	SF	SIWSE4	18.77	853	40,000	1,072	43,400	0	84,472	21.12
USR AA < > Flume Coating/Liner					0.00	0.95	0.19	0.82	0.00	1.96	
	10000	SF		0.00	0	9,500	1,900	8,246	0	19,646	1.96
TOTAL Flume Accessories	1.00	JOB			853	49,500	2,972	51,646	0	104,118	104118.00

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 06-060 . Drainage System Drainage system includes: gravity flume and road drainage, Costs based on engineering judgement on similar project experience											
M MIL AA <15107 2480 > Drains/Screen					1.78	66.95	0.00	54.25	0.00	121.20	
	25.00	EA	MPLUQ1	1.13	44	1,674	0	1,356	0	3,030	121.20
M MIL AA <15155 2570 > Drainage Pipe PVC					0.24	9.48	0.00	13.02	0.00	22.50	
	500.00	LF	MPLUQ2	12.25	122	4,742	0	6,510	0	11,252	22.50
M MIL AA <15157 2210 > PVC, 90 deg elbow					2.58	99.94	0.00	43.40	0.00	143.34	
	50.00	EA	MPLUQ2	1.16	129	4,997	0	2,170	0	7,167	143.34
USR AA < > Perforated Pipe					0.00	1.90	1.90	2.06	0.00	5.86	
	1500.00	LF		0.00	0	2,850	2,850	3,092	0	8,792	5.86
CIV AA <02250 2140 > Geotextile fabric, 120 mil					0.02	0.54	0.10	1.40	0.00	2.04	
thick, non-woven polypropylene	700.00	SY	ULABA2	150.00	14	377	70	980	0	1,427	2.04
USR AA < > Outfall w/ Erosion Protection					0.00	0.00	0.00	0.00	4750.00	4750.00	
	1.00	EA		0.00	0	0	0	0	4,750	4,750	4750.00
TOTAL Drainage System	1.00	JOB			310	14,640	2,920	14,108	4,750	36,418	36418.33

01 04. DAMS		QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
	01 04 03 06-150 . Revegetation Assume revegetation of vault/trench area with trees, shrubs and hydro-seeding											
USR LC <	> Hydroseeding 5#/ac - RSM					0.60	17.15	1.86	37.98	0.00	56.98	
	0292051000 (costworks 2002)	15.00	MSF	XLABE	10.00	9	323	35	715	0	1,073	71.54
USR LC <	> Rototill, 20Hp tractor 12" deep					0.30	8.77	0.69	0.00	0.00	9.46	
	RSM 029203406100 (costworks 2002	15.00	MSF	CLABB62	10.00	5	165	13	0	0	178	11.88
L MIL LC <02951 0760	> Mulch, straw, 2" deep, hand					0.01	0.22	0.00	0.09	0.00	0.31	
	spread arnd planted trees/shrubs	5000.00	SF	ALABCLAB1	122.00	41	1,392	0	545	0	1,937	0.39
M MIL LC <02947 0400	> General planting, local					0.57	16.53	7.40	5.43	0.00	29.36	
	varieties, 2' - 3', shrubs	50.00	EA	COEIB17	7.00	29	1,038	465	341	0	1,843	36.86
MIL LC <02947 0200	> General planting, local					0.71	20.58	9.21	126.22	0.00	156.00	
	varieties, trees, 2' - 3'	15.00	EA	COEIB17	5.63	11	387	173	2,377	0	2,938	195.86
	TOTAL Revegetation	1.00	JOB			94	3,305	686	3,978	0	7,969	7968.97

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 06-200 . Controls and Instrumentation Controls and Instrumentation											
USR AA < > Controls and Instrumentation,					0.00	0.00	0.00	0.00	9500.00	9500.00	
Represents electrical allowance	1.00	LS		0.00	0	0	0	0	9,500	9,500	9500.00
TOTAL Controls and Instrumentation	1.00	JOB			0	0	0	0	9,500	9,500	9500.00

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 06-210 . Power and Telemetry Power and Telemetry											
USR AA < > Power and Telemetry, Represents electrical allowance	1.00	LS		0.00	0.00 0	0.00 0	0.00 0	0.00 0	9500.00 9,500	9500.00 9,500	9500.00
TOTAL Power and Telemetry	1.00	JOB			0	0	0	0	9,500	9,500	9500.00

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 07. Transitional Pond to Drop Struct Supplementation Ponds 01 04 03 07-005 . Clearing and Grubbing Assume clearing pond area of all vegetation and organics											
CIV AA <02109 7310 > Clear & grub, tree rmv, cutting					3.00	85.73	46.42	0.00	0.00	132.16	
& chipping, 6" - 12" dia	1.00	EA	CODFB7	2.00	3	86	46	0	0	132	132.16
AF AA <02109 9110 > Clear & grub, grub stumps, w/335					0.05	1.56	2.66	0.00	0.00	4.22	
HP dozer, to 12" dia	1.00	EA	CODTB10M	31.25	0	2	3	0	0	4	4.22
L AF AA <02234 0570 > Hauling, hwy haulers, 12 CY, 10					0.18	5.12	7.20	0.00	0.00	12.32	
mile round trip @ base wide rate	230.00	CY	COEIB34B	5.46	42	1,178	1,656	0	0	2,834	12.32
USR AA < > Disposal Fee of $3.8/CY used					0.00	0.00	0.00	0.00	3.80	3.80	
based on RS Means plus	230.00	CY		0.00	0	0	0	0	874	874	3.80
AF AA <02110 1050 > Clearing, wet, heavy brush &					20.59	701.45	809.11	0.00	0.00	1510.56	
trees	0.20	ACR	COMCB88	0.34	4	140	162	0	0	302	1510.56
TOTAL Clearing and Grubbing	1.00	JOB			49	1,406	1,867	0	874	4,147	4146.53

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 07-010 . Dewatering Quoted from Baker Tanks, Assume 1 month rental											
USR AA < > (1) Dewatering Boxes					0.00	0.00	0.00	0.00	1425.00	1425.00	
	1.00	MO		0.00	0	0	0	0	1,425	1,425	1425.00
USR AA < > (2) 6" Thompson Pump Stations					0.00	0.00	0.00	0.00	3800.00	3800.00	
	1.00	MO		0.00	0	0	0	0	3,800	3,800	3800.00
USR AA < > Operation, Fuel and Oil					0.00	0.00	0.00	0.00	3800.00	3800.00	
	1.00	LS		0.00	0	0	0	0	3,800	3,800	3800.00
TOTAL Dewatering	1.00	JOB			0	0	0	0	9,025	9,025	9025.00

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 07-015 . Erosion Control Erosion Control, Assume silt fencing and sand bags for construction site											
B MIL AA <02266 1120 > Erosion control, w/7.5' posts, silt fence, 3' high, polypropylene	1000.00	LF	ALABCLAB2	30.00	0.07 67	1.80 1,803	0.00 0	1.09 1,085	0.00 0	2.89 2,888	2.89
B MIL AA <02266 1120 > Remove silt fence polypropylene	1000.00	LF	ALABCLAB2	30.00	0.07 67	1.80 1,803	0.00 0	0.00 0	0.00 0	1.80 1,803	1.80
USR AA < > Sand Bags - RS Means Cost Data	250.00	EA		0.00	0.00 0	0.00 0	0.00 0	0.00 0	1.90 475	1.90 475	1.90
TOTAL Erosion Control	1.00	JOB			133	3,606	0	1,085	475	5,166	5165.80

01 04. DAMS		QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 07-025 . Excavation - Soil	Excavate soil and dispose of excess											
L MIL AA <02232 0125 >	Excavate & load, hydr excavator,					0.19	6.47	4.90	0.00	0.00	11.37	
	1.5 CY, wet matl	1250.00	CY	CODEB12B	10.41	240	8,092	6,125	0	0	14,217	11.37
USR AA < >	Shoring of Vault Excavation,					0.00	2.85	2.85	3.09	0.00	8.79	
	Cost based on RS Means drive,	2400.00	SF		0.00	0	6,840	6,840	7,421	0	21,101	8.79
	extract and salvage for Sheet											
	Piling 15' deep											
L AF AA <02234 0570 >	Hauling, hwy haulers, 12 CY, 10					0.18	5.12	7.20	0.00	0.00	12.32	
	mile round trip @ base wide rate	670.00	CY	COEIB34B	5.46	123	3,432	4,824	0	0	8,256	12.32
USR AA < >	Disposal Fee of $3.8/CY used					0.00	0.00	0.00	0.00	3.80	3.80	
	based on RS Means plus	670.00	CY		0.00	0	0	0	0	2,546	2,546	3.80
TOTAL	Excavation - Soil	1.00	JOB			363	18,363	17,789	7,421	2,546	46,120	46119.82

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 07-028 . Fill - RipRap Assume imported riprap for outlet weir											
CIV AA <02250 2140 > Geotextile fabric, 120 mil					0.02	0.54	0.10	1.40	0.00	2.04	
thick, non-woven polypropylene	70.00	SY	ULABA2	150.00	1	38	7	98	0	143	2.04
M RSM AA <02270 0100 > Salvaged Rip-rap from vault					0.26	8.69	4.62	0.00	0.00	13.31	
excavation, random, machine placed for slope protection	120.00	CY	UOEHB12G	7.75	31	1,043	554	0	0	1,597	13.31
TOTAL Fill - RipRap	1.00	JOB			32	1,081	561	98	0	1,740	1740.08

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 07-029 . Fill - Quarry Spall Assume imported quarry spall for outlet weir											
L AF AA <02234 0570 > Hauling, hwy , 12 CY, 20 mile					0.31	8.75	12.30	0.00	0.00	21.04	
round trip @ base wide rate	5.00	CY	COEIB34B	3.20	2	44	61	0	0	105	21.04
CIV AA <02250 2140 > Geotextile fabric, 120 mil					0.02	0.54	0.10	1.40	0.00	2.04	
thick, non-woven polypropylene	15.00	SY	ULABA2	150.00	0	8	1	21	0	31	2.04
RSM AA <02270 0100 > Quarry Spall, machine placed on					0.26	8.69	4.62	20.41	0.00	33.72	
bottom of channel	5.00	CY	UOEHB12G	7.75	1	43	23	102	0	169	33.72
TOTAL Fill - Quarry Spall	1.00	JOB			3	95	86	123	0	304	304.39

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 07-030 . Fill - Select Granular Assume imported engineered fill for foundation and drainage											
M MIL AA <02232 0225 > Load Borrow, wheeled loader, 1.5 CY, select granular	120.00	CY	CODFB10S	80.00	0.02 2	0.61 73	0.31 37	10.85 1,302	0.00 0	11.77 1,412	11.77
L AF AA <02234 0570 > Base Course Hauling, 40 mile round trip @ base wide rate	120.00	CY	COEIB34B	3.20	0.31 38	8.75 1,050	12.30 1,476	0.00 0	0.00 0	21.04 2,525	21.04
MIL AA <02216 5530 > Backfill, strl, 6" lifts, w/loader, no compaction, around foundation	120.00	CY	CODFB10N	70.00	0.02 3	0.70 84	0.47 56	0.00 0	0.00 0	1.17 140	1.17
MIL AA <02220 9010 > Compaction, water, truck, 3000 gal, 6 mile haul	120.00	CY	COKBB45	180.50	0.01 1	0.35 42	0.28 33	0.22 26	0.00 0	0.85 102	0.85
TOTAL Fill - Select Granular	1.00	JOB			44	1,248	1,602	1,328	0	4,179	4178.54

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 07-032 . Fill - On-Site Material											
Assume acceptable excess excavation from vault will be used as backfill											
M MIL AA <02232 0225 > Spread/Stockpile, wheeled					0.02	0.61	0.31	0.00	0.00	0.92	
loader, 1.5 CY, on-site matl	580.00	CY	CODFB10S	80.00	11	354	178	0	0	531	0.92
MIL AA <02215 1220 > Backfill, trench, front-end					0.03	0.98	0.66	0.00	0.00	1.63	
loader, 40 - 60 HP, no compaction	580.00	CY	CODFB10N	50.00	17	566	381	0	0	947	1.63
MIL AA <02220 9010 > Compaction, water, truck, 3000					0.01	0.35	0.28	0.22	0.00	0.85	
gal, 6 mile haul	580.00	CY	COKBB45	180.50	6	203	162	126	0	491	0.85
TOTAL Fill - On-Site Material	1.00	JOB			35	1,122	721	126	0	1,969	1968.81

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 07-033 . Grading Grading of pond area											
L MIL AA <02226 4100 > Grading, fine grade, 3 passes					0.13	4.11	2.00	0.00	0.00	6.11	
w/grader	1120.00	SY	COFGB11L	15.17	148	4,600	2,240	0	0	6,840	6.11
TOTAL Grading	1.00	JOB			148	4,600	2,240	0	0	6,840	6839.84

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 07-035 . Road Improvements Roadway impovements, base course											
MIL AA <02244 0100 > Base course, crushed 3/4" stone,					0.01	0.26	0.28	4.37	0.00	4.91	
compacted, 12"D, large areas	90.00	SY	COFGB36C	625.00	1	23	25	394	0	442	4.91
L AF AA <02234 0570 > Base Course Hauling, 20 mile					0.31	8.75	12.30	0.00	0.00	21.04	
round trip @ base wide rate	30.00	CY	COEIB34B	3.20	9	262	369	0	0	631	21.04
TOTAL Road Improvements	1.00	JOB			10	286	394	394	0	1,073	1073.27

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 07-040 . Utility Relocations Relocate underground utilities within pond area											
USR AA < > Relocate Utilities, Allowance					0.00	0.00	0.00	0.00	950.00	950.00	
for any utilities in the area	1.00	LS		0.00	0	0	0	0	950	950	950.00
TOTAL Utility Relocations	1.00	JOB			0	0	0	0	950	950	950.00

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 07-044 . Concrete - Structural Flume Join Concrete - Structure Flume Joints											
MIL AA <03182 5100 > Forms in place, retaining wall,					0.24	8.29	0.00	2.95	0.00	11.24	
smooth curve, plywood, 1 use	750.00	SF	ACARC2	25.00	180	6,216	0	2,213	0	8,430	11.24
L MIL AA <03217 0550 > Reinforcing in place, footings,					18.18	800.74	0.00	540.33	0.00	1341.07	
#8 to #18	0.75	TON	SIWRRODM4	0.22	14	601	0	405	0	1,006	1341.07
RSM AA <03326 0400 > Concrete ready mix, regular					0.00	0.00	0.00	79.22	0.00	79.22	
weight, 5000 psi	12.00	CY	N/A	0.00	0	0	0	951	0	951	79.22
MIL AA <03372 5350 > Placing conc, walls, 15" thick,					0.53	15.39	4.95	0.00	0.00	20.34	
pumped	12.00	CY	CLABC20	15.00	6	185	59	0	0	244	20.34
TOTAL Concrete - Structural Flume Join	1.00	JOB			200	7,001	59	3,569	0	10,630	10629.99

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 07-045 . Concrete - Structural Foundation Concrete - Structure Foundation includes, Weir foundation											
MIL AA <03154 0010 > Forms in place, eqpt					0.30	10.36	0.00	2.79	0.00	13.15	
foundations, 1 use	400.00	SF	ACARC2	20.00	120	4,144	0	1,115	0	5,260	13.15
L MIL AA <03217 0550 > Reinforcing in place, footings,					18.18	800.74	0.00	540.33	0.00	1341.07	
#8 to #18	2.50	TON	SIWRRODM4	0.22	45	2,002	0	1,351	0	3,353	1341.07
RSM AA <03326 0400 > Concrete ready mix, regular					0.00	0.00	0.00	79.22	0.00	79.22	
weight, 5000 psi	40.00	CY	N/A	0.00	0	0	0	3,169	0	3,169	79.22
MIL AA <03372 4650 > Placing conc, slab on grade,					0.35	9.98	3.21	0.00	0.00	13.19	
over 6" thick, pumped	40.00	CY	CLABC20	23.13	14	399	128	0	0	528	13.19
TOTAL Concrete - Structural Foundation	1.00	JOB			179	6,545	128	5,635	0	12,308	12308.48

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 07-046 . Concrete - Structural Weirs Concrete - Structure Weirs											
MIL AA <03182 5100 > Forms in place, retaining wall,					0.24	8.29	0.00	2.95	0.00	11.24	
smooth curve, plywood, 1 use	4560.00	SF	ACARC2	25.00	1,094	37,794	0	13,457	0	51,252	11.24
L MIL AA <03217 0550 > Reinforcing in place, #8 to #18					18.18	800.74	0.00	540.33	0.00	1341.07	
	3.10	TON	SIWRRODM4	0.22	56	2,482	0	1,675	0	4,157	1341.07
RSM AA <03326 0400 > Concrete ready mix, regular					0.00	0.00	0.00	79.22	0.00	79.22	
weight, 5000 psi	50.00	CY	N/A	0.00	0	0	0	3,961	0	3,961	79.22
MIL AA <03372 5350 > Placing conc, walls, 15" thick,					0.53	15.39	4.95	0.00	0.00	20.34	
pumped	50.00	CY	CLABC20	15.00	27	769	248	0	0	1,017	20.34
TOTAL Concrete - Structural Weirs	1.00	JOB			1,177	41,046	248	19,093	0	60,387	60386.63

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 07-047 . Concrete - Pre-Cast Concrete - Quote from Concrete Technology Corporation. Pre-Cast includes gravity flume sections											
USR AA < > Sections					0.00	95.00	47.50	134.00	0.00	276.50	
	398.00	LF		0.00	0	37,810	18,905	53,331	0	110,046	276.50
USR AA < > Topper					0.00	19.00	9.50	51.54	0.00	80.04	
	200.00	LF		0.00	0	3,800	1,900	10,308	0	16,008	80.04
USR AA < > 80 Ton Hydraulic Crane rental					0.00	760.00	1450.00	0.00	0.00	2210.00	
per day - RS Means	4.00	DAY		0.00	0	3,040	5,800	0	0	8,840	2210.00
TOTAL Concrete - Pre-Cast	1.00	JOB			0	44,650	26,605	63,639	0	134,894	134893.51

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 07-050 . Fencing Security fencing around ponds includes 2 gates and overhead netting											
AF AA <01534 0100 > Fencing, 11 ga, chain link, 6'					0.21	5.77	0.00	3.56	35.00	44.33	
high, includes foundations	700.00	LF	ALABCLAB2	9.38	149	4,039	0	2,491	24,500	31,030	44.33
MIL AA <02832 1310 > Fence, CL, 4' x 6', transom					2.75	74.43	13.98	177.64	0.00	266.05	
gate, single, galv	2.00	EA	CLABB80A	1.09	6	149	28	355	0	532	266.05
USR AA < > Overhead Netting, Over					0.00	1.90	0.95	2.06	0.00	4.91	
transitional pond and test facility only	1125.00	SF		0.00	0	2,138	1,069	2,319	0	5,525	4.91
TOTAL Fencing	1.00	JOB			155	6,325	1,097	5,166	24,500	37,087	37087.28

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 07-054 . Structural Aluminum Shoring and False Work includes, sheetpile shoring of roadway and barriers to divde traffic											
USR AA < > Aluminum structural shapes for					0.00	1.70	1.10	2.17	0.00	4.97	
test facility, Cost based on RS	1200.00	LBS		0.00	0	2,040	1,320	2,604	0	5,964	4.97
Means "Structural aluminum under 1 ton"											
TOTAL Structural Aluminum	1.00	JOB			0	2,040	1,320	2,604	0	5,964	5964.00

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 07-055 . Facility Access Facility Access includes: ladders within the pond											
MIL AA <05518 0010 > Ladder, steel, 20" wide, bolted					0.64	30.02	0.80	58.96	0.00	89.79	
to conc, w/cage	20.00	VLF	SIWSE4	6.25	13	600	16	1,179	0	1,796	89.79
TOTAL Facility Access	1.00	JOB			13	600	16	1,179	0	1,796	1795.77

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 07-056 . Flume Topper											
Flume Topper includes: grating topper for gravity flume											
B MIL AA <05542 0622 > Floor grating,stl,1.25" x 3/16",					0.21	10.00	0.27	10.85	0.00	21.12	
ptd brg bars @ 15/16" OC, 300 SF	620.00	SF	SIWSE4	18.77	132	6,200	166	6,727	0	13,093	21.12
TOTAL Flume Topper	1.00	JOB			132	6,200	166	6,727	0	13,093	13093.16

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 07-060 . Drainage System											
Drainage system includes: vault drainage and structure subdrainage											
MIL AA <15107 2480 > Drains/Screen					1.78	66.95	0.00	280.64	0.00	347.58	
	1.00	EA	MPLUQ1	1.13	2	67	0	281	0	348	347.58
M MIL AA <15155 2570 > Drain Pipe PVC					0.24	9.48	0.00	13.02	0.00	22.50	
	40.00	LF	MPLUQ2	12.25	10	379	0	521	0	900	22.50
M MIL AA <15157 2210 > PVC, 90 deg elbow,					2.58	99.94	0.00	325.50	0.00	425.44	
	2.00	EA	MPLUQ2	1.16	5	200	0	651	0	851	425.44
CIV AA <02250 2140 > Geotextile fabric, 120 mil					0.02	0.54	0.10	1.40	0.00	2.04	
thick, non-woven polypropylene	60.00	SY	ULABA2	150.00	1	32	6	84	0	122	2.04
USR AA < > Sump Pump					0.00	0.00	0.00	0.00	4750.00	4750.00	
	1.00	EA		0.00	0	0	0	0	4,750	4,750	4750.00
TOTAL Drainage System	1.00	JOB			18	679	6	1,536	4,750	6,971	6970.94

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 07-105 . Testing Facilities Shoring and False Work includes, sheetpile shoring of roadway and barriers to divde traffic											
USR AA < > Netting, Quote from Vendor					0.00	0.00	0.00	0.00	2090.00	2090.00	
	1.00	LS		0.00	0	0	0	0	2,090	2,090	2090.00
TOTAL Testing Facilities	1.00	JOB			0	0	0	0	2,090	2,090	2090.00

01 04. DAMS		QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 07-150 . Revegetation	Assume revegetation of pond area with trees, shrubs and hydro-seeding											
USR LC < >	Hydroseeding 5#/ac - RSM					0.60	17.15	1.86	37.98	0.00	56.98	
	0292051000 (costworks 2002)	5.00	MSF	XLABE	10.00	3	108	12	238	0	358	71.54
USR LC < >	Rototill, 20Hp tractor 12" deep					0.30	8.77	0.69	0.00	0.00	9.46	
	RSM 029203406100 (costworks 2002	5.00	MSF	CLABB62	10.00	2	55	4	0	0	59	11.88
L MIL LC <02951 0760 >	Mulch, straw, 2" deep, hand					0.01	0.22	0.00	0.09	0.00	0.31	
	spread arnd planted trees/shrubs	2000.00	SF	ALABCLAB1	122.00	16	557	0	218	0	775	0.39
M MIL LC <02947 0400 >	General planting, local					0.57	16.53	7.40	5.43	0.00	29.36	
	varieties, 2' - 3', shrubs	200.00	EA	COEIB17	7.00	114	4,152	1,858	1,362	0	7,372	36.86
MIL LC <02947 0200 >	General planting, local					0.71	20.58	9.21	126.22	0.00	156.00	
	varieties, trees, 2' - 3'	10.00	EA	COEIB17	5.63	7	258	116	1,585	0	1,959	195.86
TOTAL	Revegetation	1.00	JOB			142	5,129	1,990	3,403	0	10,523	10522.64

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 07-200 . Controls and Instrumentation Controls and Instrumentation											
USR AA < > Controls and Instrumentation, Represents electrical allowance	1.00	LS		0.00	0.00 0	0.00 0	0.00 0	0.00 0	9500.00 9,500	9500.00 9,500	9500.00
TOTAL Controls and Instrumentation	1.00	JOB			0	0	0	0	9,500	9,500	9500.00

01 04. DAMS	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 04 03 07-210 . Power and Telemetry Power and Telemetry											
USR AA < > Power and Telemetry, Represents					0.00	0.00	0.00	0.00	9500.00	9500.00	
electrical allowance	1.00	LS		0.00	0	0	0	0	9,500	9,500	9500.00
TOTAL Power and Telemetry	1.00	JOB			0	0	0	0	9,500	9,500	9500.00

01 06. FISH AND WILDLIFE FACILITIES	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 06. FISH AND WILDLIFE FACILITIES Includes earthwork, dewatering, erosion control, demolition and construction costs for the following work: Supplementation Ponds. 01 06 03. Wildlife Facilities & Sanctuary 01 06 03 01. Supplementation Ponds Supplementation Ponds 01 06 03 01-005 . Clearing and Grubbing Assume clearing pond area of all vegetation and organics											
CIV AA <02109 7310 > Clear & grub, tree rmv, cutting					3.00	85.73	46.42	0.00	0.00	132.16	
& chipping, 6" - 12" dia	1.00	EA	CODFB7	2.00	3	86	46	0	0	132	132.16
AF AA <02109 9110 > Clear & grub, grub stumps, w/335					0.05	1.56	2.66	0.00	0.00	4.22	
HP dozer, to 12" dia	1.00	EA	CODTB10M	31.25	0	2	3	0	0	4	4.22
L AF AA <02234 0570 > Hauling, hwy haulers, 12 CY, 10					0.18	5.12	7.20	0.00	0.00	12.32	
mile round trip @ base wide rate	50.00	CY	COEIB34B	5.46	9	256	360	0	0	616	12.32
USR AA < > Disposal Fee of $3.80/CY used					0.00	0.00	0.00	0.00	3.80	3.80	
based on RS Means plus escalated cost factor due to remote site	200.00	CY		0.00	0	0	0	0	760	760	3.80
AF AA <02110 1050 > Clearing, wet, heavy brush &					20.59	701.45	809.11	0.00	0.00	1510.56	
trees	0.25	ACR	COMCB88	0.34	5	175	202	0	0	378	1510.56
TOTAL Clearing and Grubbing	1.00	JOB			17	519	611	0	760	1,890	1890.11

01 06. FISH AND WILDLIFE FACILITIES	QUANTY UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 06 03 01-010 . Dewatering Quoted from Baker Tanks, Assume 1 month rental										
USR AA < > (1) Dewatering Boxes				0.00	0.00	0.00	0.00	1425.00	1425.00	
	1.00 MO		0.00	0	0	0	0	1,425	1,425	1425.00
USR AA < > (2) 6" Thompson Pump Stations				0.00	0.00	0.00	0.00	3800.00	3800.00	
	1.00 MO		0.00	0	0	0	0	3,800	3,800	3800.00
USR AA < > Operation, Fuel and Oil				0.00	0.00	0.00	0.00	3800.00	3800.00	
	1.00 LS		0.00	0	0	0	0	3,800	3,800	3800.00
TOTAL Dewatering	1.00 JOB			0	0	0	0	9,025	9,025	9025.00

01 06. FISH AND WILDLIFE FACILITIES	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 06 03 01-015 . Erosion Control Erosion Control, Assume silt fencing and sand bags for construction site											
B MIL AA <02266 1120 > Erosion control, w/7.5' posts, silt fence, 3' high, polypropylene					0.07	1.80	0.00	1.09	0.00	2.89	
	400.00	LF	ALABCLAB2	30.00	27	721	0	434	0	1,155	2.89
B MIL AA <02266 1120 > Remove silt fence polypropylene					0.07	1.80	0.00	0.00	0.00	1.80	
	400.00	LF	ALABCLAB2	30.00	27	721	0	0	0	721	1.80
USR AA < > Sand Bags - RS Means Cost Data					0.00	0.00	0.00	0.00	1.90	1.90	
	100.00	EA		0.00	0	0	0	0	190	190	1.90
TOTAL Erosion Control	1.00	JOB			53	1,442	0	434	190	2,066	2066.32

01 06. FISH AND WILDLIFE FACILITIES	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 06 03 01-025 . Excavation - Soil Excavate soil and dispose of excess											
L MIL AA <02232 0125 > Excavate & load, hydr excavator,					0.19	6.47	4.90	0.00	0.00	11.37	
1.5 CY, wet matl	1200.00	CY	CODEB12B	10.41	231	7,768	5,880	0	0	13,648	11.37
L AF AA <02234 0570 > Hauling, hwy haulers, 12 CY, 10					0.18	5.12	7.20	0.00	0.00	12.32	
mile round trip @ base wide rate	1400.00	CY	COEIB34B	5.46	256	7,171	10,080	0	0	17,251	12.32
USR AA < > Disposal Fee of $3.8/CY used					0.00	0.00	0.00	0.00	3.80	3.80	
based on RS Means plus	1400.00	CY		0.00	0	0	0	0	5,320	5,320	3.80
TOTAL Excavation - Soil	1.00	JOB			487	14,939	15,960	0	5,320	36,219	36218.74

01 06. FISH AND WILDLIFE FACILITIES	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 06 03 01-026 . Excavation - Rock Excavate rock and dispose of excess											
B MIL AA <02232 0130 > Excavate & load, hydr excavator,					0.49	16.51	12.50	0.00	0.00	29.01	
1.5 CY, blasted rock	400.00	CY	CODEB12B	4.08	196	6,605	5,000	0	0	11,605	29.01
L AF AA <02234 0570 > Hauling, hwy haulers, 12 CY, 10					0.18	5.12	7.20	0.00	0.00	12.32	
mile round trip @ base wide rate	400.00	CY	COEIB34B	5.46	73	2,049	2,880	0	0	4,929	12.32
USR AA < > Disposal Fee of $3.80/CY used					0.00	0.00	0.00	0.00	3.80	3.80	
based on RS Means plus	400.00	CY		0.00	0	0	0	0	1,520	1,520	3.80
TOTAL Excavation - Rock	1.00	JOB			269	8,654	7,880	0	1,520	18,054	18053.80

01 06. FISH AND WILDLIFE FACILITIES	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 06 03 01-030 . Fill - Select Granular Assume imported engineered fill for foundation and drainage											
M MIL AA <02232 0225 > Load Borrow, wheeled loader, 1.5 CY, select granular	150.00	CY	CODFB10S	80.00	0.02 3	0.61 91	0.31 46	10.85 1,628	0.00 0	11.77 1,765	11.77
L AF AA <02234 0570 > Base Course Hauling, 40 mile round trip @ base wide rate	150.00	CY	COEIB34B	3.20	0.31 47	8.75 1,312	12.30 1,844	0.00 0	0.00 0	21.04 3,156	21.04
MIL AA <02216 5530 > Backfill, strl, 6" lifts, w/loader, no compaction, around foundation	150.00	CY	CODFB10N	70.00	0.02 3	0.70 104	0.47 70	0.00 0	0.00 0	1.17 175	1.17
MIL AA <02220 9010 > Compaction, water, truck, 3000 gal, 6 mile haul	150.00	CY	COKBB45	180.50	0.01 2	0.35 53	0.28 42	0.22 33	0.00 0	0.85 127	0.85
TOTAL Fill - Select Granular	1.00	JOB			55	1,561	2,003	1,660	0	5,223	5223.18

01 06. FISH AND WILDLIFE FACILITIES	QUANTY UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 06 03 01-033 . Grading Grading of pond area										
L MIL AA <02226 4100 > Grading, fine grade, 3 passes				0.13	4.11	2.00	0.00	0.00	6.11	
w/grader	1000.00 SY	COFGB11L	15.17	132	4,107	2,000	0	0	6,107	6.11
TOTAL Grading	1.00 JOB			132	4,107	2,000	0	0	6,107	6107.00

01 06. FISH AND WILDLIFE FACILITIES	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 06 03 01-035 . Road Improvements Roadway impovements, base course											
MIL AA <02244 0100 > Base course, crushed 3/4" stone,					0.01	0.26	0.28	4.37	0.00	4.91	
compacted, 12"D, large areas	300.00	SY	COFGB36C	625.00	2	78	84	1,312	0	1,473	4.91
MIL AA <02244 1620 > Base course, crushed stone,					0.03	0.92	1.09	30.38	0.00	32.40	
bitum stabilized,macadam base, large areas	50.00	CY	COFGB36E	175.00	1	46	55	1,519	0	1,620	32.40
L AF AA <02234 0570 > Base Course Hauling, 20 mile					0.31	8.75	12.30	0.00	0.00	21.04	
round trip @ base wide rate	150.00	CY	COEIB34B	3.20	47	1,312	1,844	0	0	3,156	21.04
TOTAL Road Improvements	1.00	JOB			51	1,436	1,983	2,831	0	6,250	6249.62

01 06. FISH AND WILDLIFE FACILITIES	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 06 03 01-040 . Utility Relocations Relocate underground utilities within pond area											
USR AA < > Relocate Utilities					0.00	0.00	0.00	0.00	950.00	950.00	
	1.00	LS		0.00	0	0	0	0	950	950	950.00
TOTAL Utility Relocations	1.00	JOB			0	0	0	0	950	950	950.00

01 06. FISH AND WILDLIFE FACILITIES	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 06 03 01-046 . Concrete - Structural Walls Concrete - Structure Foundation includes, ponds											
MIL AA <03182 5100 > Forms in place, retaining wall,					0.24	8.29	0.00	2.95	0.00	11.24	
smooth curve, plywood, 1 use	6000.00	SF	ACARC2	25.00	1,440	49,729	0	17,707	0	67,436	11.24
L MIL AA <03217 0550 > Reinforcing in place, #8 to #18					18.18	800.74	0.00	540.33	0.00	1341.07	
	17.00	TON	SIWRRODM4	0.22	309	13,613	0	9,186	0	22,798	1341.07
RSM AA <03326 0400 > Concrete ready mix, regular					0.00	0.00	0.00	79.22	0.00	79.22	
weight, 5000 psi	280.00	CY	N/A	0.00	0	0	0	22,180	0	22,180	79.22
MIL AA <03372 5350 > Placing conc, walls, 15" thick,					0.53	15.39	4.95	0.00	0.00	20.34	
pumped	280.00	CY	CLABC20	15.00	149	4,308	1,386	0	0	5,694	20.34
TOTAL Concrete - Structural Walls	1.00	JOB			1,898	67,650	1,386	49,073	0	118,109	118109.44

01 06. FISH AND WILDLIFE FACILITIES		QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 06 03 01-050 . Fencing												
	Security fencing around ponds includes 2 gates and overhead netting											
AF AA <01534 0100 >	Fencing, 11 ga, chain link, 6'					0.21	5.77	0.00	3.56	35.00	44.33	
	high, includes foundations	400.00	LF	ALABCLAB2	9.38	85	2,308	0	1,424	14,000	17,731	44.33
MIL AA <02832 1310 >	Fence, CL, 4' x 6', transom					2.75	74.43	13.98	177.64	0.00	266.05	
	gate, single, galv	2.00	EA	CLABB80A	1.09	6	149	28	355	0	532	266.05
USR AA < >	Overhead Netting					0.00	1.90	0.95	2.06	0.00	4.91	
		4000.00	SF		0.00	0	7,600	3,800	8,246	0	19,646	4.91
TOTAL Fencing		1.00	JOB			91	10,057	3,828	10,025	14,000	37,909	37909.38

01 06. FISH AND WILDLIFE FACILITIES	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 06 03 01-055 . Facility Access Facility Access includes: ladders within the pond											
MIL AA <05518 0010 > Ladder, steel, 20" wide, bolted					0.64	30.02	0.80	58.96	0.00	89.79	
to conc, w/cage	20.00	VLF	SIWSE4	6.25	13	600	16	1,179	0	1,796	89.79
TOTAL Facility Access	1.00	JOB			13	600	16	1,179	0	1,796	1795.77

01 06. FISH AND WILDLIFE FACILITIES	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 06 03 01-060 . Drainage System Drainage system includes: pond drainage and structure subdrainage											
M MIL AA <15155 2570 > Drain Pipe PVC					0.24	9.48	0.00	13.02	0.00	22.50	
	120.00	LF	MPLUQ2	12.25	29	1,138	0	1,562	0	2,701	22.50
M MIL AA <15157 2210 > PVC, 90 deg elbow					2.58	99.94	0.00	325.50	0.00	425.44	
	2.00	EA	MPLUQ2	1.16	5	200	0	651	0	851	425.44
CIV AA <02250 2140 > Geotextile fabric, 120 mil					0.02	0.54	0.10	1.40	0.00	2.04	
thick, non-woven polypropylene	60.00	SY	ULABA2	150.00	1	32	6	84	0	122	2.04
USR AA < > Outfall w/ Erosion Protection					0.00	0.00	0.00	0.00	2850.00	2850.00	
	1.00	EA		0.00	0	0	0	0	2,850	2,850	2850.00
TOTAL Drainage System	1.00	JOB			36	1,370	6	2,297	2,850	6,524	6523.71

01 06. FISH AND WILDLIFE FACILITIES	QUANTY UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 06 03 01-085 . 8-inch Pipe 8-inch Pipe										
USR AA < > 8-inch HDPE Pipe				0.00	28.50	9.50	10.31	0.00	48.31	
	1200.00 LF		0.00	0	34,200	11,400	12,369	0	57,969	48.31
USR AA < > 8-inch HDPE Elbows				0.00	285.00	47.50	309.23	0.00	641.72	
	4.00 EA		0.00	0	1,140	190	1,237	0	2,567	641.72
USR AA < > Gas Stabilization Column,				0.00	475.00	475.00	3092.25	0.00	4042.25	
Aluminum	2.00 EA		0.00	0	950	950	6,185	0	8,085	4042.25
USR AA < > Supply Header, PVC				0.00	0.00	0.00	0.00	1900.00	1900.00	
	2.00 EA		0.00	0	0	0	0	3,800	3,800	1900.00
TOTAL 8-inch Pipe	1.00 JOB			0	36,290	12,540	19,790	3,800	72,420	72420.40

01 06. FISH AND WILDLIFE FACILITIES	QUANTY UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 06 03 01-092 . 8-inch Valves 8-inch Valves										
USR AA < > 8" Butterfly Valve				0.00	475.00	47.50	515.38	0.00	1037.88	
	2.00 EA		0.00	0	950	95	1,031	0	2,076	1037.88
USR AA < > 8" Drainage Valve				0.00	475.00	47.50	515.38	0.00	1037.88	
	2.00 EA		0.00	0	950	95	1,031	0	2,076	1037.88
TOTAL 8-inch Valves	1.00 JOB			0	1,900	190	2,062	0	4,152	4151.50

01 06. FISH AND WILDLIFE FACILITIES	QUANTY UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 06 03 01-115 . Outlet Structure Outlet Structure										
USR AA < > Screen				0.00	95.00	47.50	1030.75	0.00	1173.25	
	2.00 EA		0.00	0	190	95	2,062	0	2,347	1173.25
USR AA < > Stop Log				0.00	95.00	47.50	1030.75	0.00	1173.25	
	2.00 EA		0.00	0	190	95	2,062	0	2,347	1173.25
TOTAL Outlet Structure	1.00 JOB			0	380	190	4,123	0	4,693	4693.00

01 06. FISH AND WILDLIFE FACILITIES		QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 06 03 01-150 . Revegetation	Assume revegetation of pond area with trees, shrubs and hydro-seeding											
USR LC < >	Hydroseeding 5#/ac - RSM					0.60	17.15	1.86	37.98	0.00	56.98	
	0292051000 (costworks 2002)	5.00	MSF	XLABE	10.00	3	108	12	238	0	358	71.54
USR LC < >	Rototill, 20Hp tractor 12" deep					0.30	8.77	0.69	0.00	0.00	9.46	
	RSM 029203406100 (costworks 2002	5.00	MSF	CLABB62	10.00	2	55	4	0	0	59	11.88
L MIL LC <02951 0760 >	Mulch, straw, 2" deep, hand					0.01	0.22	0.00	0.09	0.00	0.31	
	spread arnd planted trees/shrubs	2000.00	SF	ALABCLAB1	122.00	16	557	0	218	0	775	0.39
M MIL LC <02947 0400 >	General planting, local					0.57	16.53	7.40	5.43	0.00	29.36	
	varieties, 2' - 3', shrubs	20.00	EA	COEIB17	7.00	11	415	186	136	0	737	36.86
MIL LC <02947 0200 >	General planting, local					0.71	20.58	9.21	126.22	0.00	156.00	
	varieties, trees, 2' - 3'	3.00	EA	COEIB17	5.63	2	77	35	475	0	588	195.86
TOTAL	Revegetation	1.00	JOB			34	1,212	237	1,068	0	2,517	2516.57

01 06. FISH AND WILDLIFE FACILITIES	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 06 03 01-200 . Controls and Instrumentation Controls and Instrumentation											
USR AA < > Controls and Instrumentation,					0.00	0.00	0.00	0.00	23750.00	23750.00	
Represents electrical allowance	1.00	LS		0.00	0	0	0	0	23,750	23,750	23750.00
TOTAL Controls and Instrumentation	1.00	JOB			0	0	0	0	23,750	23,750	23750.00

01 06. FISH AND WILDLIFE FACILITIES	QUANTY	UOM	CREW ID	OUTPUT	MHRS	LAB	EQUIP	MAT	OTHER	TOTAL COST	UNIT COST
01 06 03 01-210 . Power and Telemetry Power and Telemetry											
USR AA < > Power and Telemetry, Represents					0.00	0.00	0.00	0.00	4750.00	4750.00	
electrical allowance	1.00	LS		0.00	0	0	0	0	4,750	4,750	4750.00
TOTAL Power and Telemetry	1.00	JOB			0	0	0	0	4,750	4,750	4750.00
TOTAL FISH RESTORATION PROJECT	1.00	JOB			21,418	1,207,545	456,686	1,120,798	1,376,396	4,161,426	4161426
TOTAL WYNOOCHEE DAM, SECTION 1135	1.00	JOB			21,418	1,207,545	456,686	1,120,798	1,376,396	4,161,426	4161426

Appendix E

Preliminary Geotechnical Engineering Report

Report

Preliminary Geotechnical Engineering Services

Wynoochee Dam Fish Passage

Grays Harbor Country, Washington

December 26, 2002

For

Tetra Tech Inc.

GeoEngineers

December 26, 2002

Consulting Engineers
and Geoscientists

Tetra Tech Inc.
1925 Post Alley
Seattle, Washington 98101

Attention: Harry Gibbons, Ph.D.

Report
Preliminary Geotechnical Engineering Services
Wynoochee Dam Fish Passage
Grays Harbor County, Washington
File No. 0371-090-00

INTRODUCTION

This report presents the results of our preliminary geotechnical engineering services for the proposed fish passage project at the Wynoochee Dam located on the Wynoochee River in Grays Harbor County, Washington. Our services have been completed in general accordance with the Tetra Tech Subconsultant Professional Services Agreement dated November 25, 2002.

The fish passage project will require installation of a fish screen and bypass pipeline/flume to reduce the smolt mortality rate and avoid periods of downtime for the generation facility. The project will include modifications to the intake at the penstock, installation of an Eicher screen in the penstock pipeline, and construction of a bypass pipeline, distribution vault, gravity flume, and open channel to transport the smolt to the Wynoochee River below the dam and powerhouse.

SCOPE

The purpose of our services is to review existing geologic studies and design reports for the Wynoochee Dam project, complete a site visit, and provide an opinion regarding the level of additional geotechnical studies that may be necessary for final design. Our specific scope of services therefore includes the following tasks:

1. Review existing geologic studies and design reports provided by the Corps of Engineers and Tetra Tech, Inc. This includes review of geologic mapping available in our files for the project area.
2. Complete a site visit and perform a preliminary geologic reconnaissance along the alignment proposed for the improvements.
3. Attend one design team meeting to present the results of our review and site visit, and discuss design issues.
4. Prepare a letter summarizing the results of our review and preliminary evaluation of the site conditions, along with general conclusions of geotechnical design issues.

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Our scope of services does not include developing final design recommendations for foundations, pipeline support or other improvements. The level of study requested at this time is to be sufficient to determine if adequate geotechnical information is available to support final design development.

SITE DESCRIPTION

REGIONAL GEOLOGY

We reviewed information in our files and available geologic mapping for the project area including the following:

- “Geologic Map of the Olympic Peninsula, Washington”, United States Geologic Survey (USGS) Map I-994 dated 1988
- ”Geology of the Pacific Northwest” by W.N. Orr and E.L. Orr, 2002

Our review of the available geologic information indicates subsurface conditions in the Lake Wynoochee area include basalt bedrock and overlying deposits that resulted from episodes of alpine glaciation. The glacial processes included scour by the glaciers, deposition of glacial and non-glacial sediments, and post-glacial deposition and erosion. The soils in the project area within the Wynoochee Valley are mapped by the USGS as deposits of the Olympic alpine glaciers that include unsorted glacial deposits (till) and stratified deposits of sand, gravel silt and clay. The mapped deposits include moraines and high river terraces along the major rivers that may not be directly related to the glaciation. The mapped surface soils also include river alluvium from the Wynoochee River that consists of sand, gravel, and silt. The surface soils at the project location are underlain by basalt bedrock.

We also reviewed the following maps and studies that were provided by the Corps of Engineers and Tetra Tech, Inc.:

- “Reservoir Geology, Wynoochee Lake, Washington” by U.S. Army Corps or Engineers dated October 18, 1972.
- "Design Geotechnical Report, Wynoochee Hydroelectric Project, Grays Harbor County, Washington" by Converse Consultants NW dated February 11, 1991.
- “Wynoochee Dam Exploratory Drilling Program Summary” by Carr Associates dated November 8, 1991.
- “Penstock Profile” by City of Tacoma Department of Public Utilities dated October 28, 1991.

The reservoir geology map presents no mapping of the conditions in the project area, but indicates that numerous explorations have been completed along portions of the planned fish passage alignment.

The Design Geotechnical Report dated February 1991 includes a geologic map (Figure 3) showing the north portion of the project area. The geologic map indicates bedrock in the river gorge below the dam, and non-differentiated deposits of colluvium, glacial till, and glacial outwash along the project alignment. The map also indicates glacial lacustrine clay deposits located along both sides of the river that appears to be interlayered in the non-differentiated deposits. The report includes only one boring (DH-101) that is located along the project alignment (approximately at screen location). The boring log indicates about 3.5 feet of fill overlying basalt bedrock. The fill consists of sand and gravel with silt.

SITE RECONNAISSANCE

General

A geotechnical engineer/engineering geologist from GeoEngineers, Inc. visited the site on December 13, 2002 to observe general site and near surface soil conditions. The reconnaissance included shallow hand holes to evaluated surface soils along the planned alignment. Our observations are described in the following paragraphs starting at the planned Eicher screen location and proceeding downstream along the bypass pipeline/flume alignment. The soil descriptions presented below are generally consistent with the descriptions presented on the geologic map included in the Converse Consultants NW 1991 report.

Eicher Screen

The Converse Consultants NW 1991 report included one boring at the approximate Eicher screen location. The subsurface conditions included about 3.5 feet of fill overlying basalt bedrock. The fill thickness likely increases toward the dam, because the penstock pipeline is exposed at a lower elevation than the existing parking lot. However, the Penstock Profile we reviewed shows bedrock through the screen area and adjacent roadway embankment at depths less than about 5 feet.

Bridge Crossing

The proposed bypass pipeline will be supported on the United States Forest Service (USFS) bridge. We expect that the pipeline will be supported on the bridge at about the elevation of the bottom of the deck support girders. The proposed bypass pipeline extends along the toe of the roadway fill embankment, from the Eicher screen location to the bridge support columns on the west side of the bridge. The depth to bedrock is not known in the area of the roadway embankment fill. However basalt bedrock is exposed about 20 feet below the bottom of the bridge in the river gorge. The roadway embankment fill in this area includes brown, moist medium dense, silty sand with gravel and occasional cobbles.

The surface soil conditions on the east side of the bridge include reddish-brown, moist, medium dense, silty sand with gravel and cobbles. These soil deposits are exposed in the slope below the east bridge abutment. Basalt bedrock is exposed in the river gorge about 20 feet below the east end of the bridge.

Distribution Vault

The bypass pipeline alignment crosses the east dam abutment access road and follows the Wynoochee Lake Shore Trail. The distribution vault will be located on the east side of the access road at the beginning of the trail. The ground surface in the planned distribution vault area is generally level but slopes up to the east along the east side of the trial. A drainage swale is located along the south side of the vault loctation. We observed brown, moist, medium dense silty sand with gravel in the area of the planned vault.

Wynoochee Lake Shore Trail

The lake shore trail appears to have been cut into the relatively gentle west facing slope that rises to the east of the east dam abutment access road. Cut slopes on both sides of the trail are inclined upward at about 1½H:1V (horizontal to vertical) or flatter. No apparent indications of slope instability were observed. The toe of the cut slope is located at about the edge of the east side of the trail along the first approximately 180 feet of the trail. The cut slopes flatten after the first approximately 180 feet on both sides of the trail, providing more room for the planned bypass pipeline/flume. We observed brown, moist, medium dense silty sand with gravel along the trail and at the toe of the dam fill embankment.

Powerhouse Access Road

We understand that the bypass pipeline/flume to be located down-slope of USFS Road 2312 will likely be an open box flume. The powerhouse access road heads down-slope to the south from USFS Road 2312. The flume will be located on the up-slope (east) edge of the road. The road also provides access to a substation that is located at the bottom of the slope where the road makes a hard right turn to the north to the powerhouse. The road is cut into the west facing slope and some fill appears to have been placed along portions of the west edge of the roadway. The cut slope is inclined upward to the east at about 1½H:1V to 1¾ H:1V. No apparent indications of slope instability were observed. We observed brown, moist, medium dense silty sand with gravel in the cut slope from USFS Road 2312 to the substation.

Substation to Outlet Channel

The proposed flume alignment extends from the access road across relatively level ground along the west side of the substation, through a small detention pond that remains from previous construction activities, to the area planned for the outlet channel. This portion of the alignment crosses what appears to be an alluvial bench located 20 to 30 feet above the current river elevation. The ground surface slopes down very gently to the south and west from the powerhouse access road to the small detention pond and outlet channel area. We observed brown, moist, medium dense silty sand with gravel along this portion of the alignment.

Outlet Channel

The outlet channel section begins about 50 feet south of the existing detention pond. An existing small forest road extends from near the southeast corner of the existing detention pond to the river gauging station (cable car crossing). Soil in the area of the outlet channel include dark brown, wet, loose silty fine sand and soft sandy silt along the road. These soils are also exposed in the river bank at the cable car crossing and farther south. A small creek flows from the east and into the river just south of the cable car crossing. It appears that the creek comes from a small ravine east of the site and is likely the source of the fine-grained soil in the outlet channel area.

A low narrow bench exists along the edge of the river. The bench generally extends about two to three feet above the river elevation and is about ten to fifteen feet wide where the channel will enter the river. The river deposits evident in the bench include sand, gravel, cobbles and boulders.

CONCLUSIONS AND RECOMMENDATIONS

GENERAL

Based on our review of existing information and the results of the field reconnaissance, it appears that the soils in much of the alignment will provide good support for the structures and pipeline/flume. However, we completed only widely spaced shallow hand dug holes to observe surface soil conditions and have not reviewed exploration logs from previous studies besides the one log mentioned above. No additional studies were available during the course of our review.

We recommend that additional explorations (test pits) be completed in the outlet channel area. This area is underlain by wet, loose/soft soil that may be problematic for channel construction. Furthermore, it may be desirable to complete explorations at the Eicher screen and distribution vault locations to reduce the risk of "changed condition" claims during construction.

The following paragraphs present our conclusions regarding subsurface conditions along the various portions of the project alignment and recommendations for additional review and explorations, as appropriate.

EICHER SCREEN

We expect that bedrock in the area of the Eicher screen will be 3 to 5 feet below the existing ground surface. Rock excavation may be a significant impact on the contractor's bid. We therefore recommend that additional explorations be completed once the screen location and elevations have been determined. As an alternate, it may possible to structure the bid documents to anticipate the potential extra cost of excavation with a line item for rock excavation.

BRIDGE CROSSING

Based on our observations, it appears that the bypass pipeline will be excavated in roadway embankment fill and native glacial deposits on both sides of the bridge. These soils should provide good support for a properly bedded pipe.

DISTRIBUTION VAULT

The distribution vault will be located on the east side of the access road at the beginning of the Wynoochee Lake Shore Trail. The native soil evident in this area should provide good support for the vault, provided loose roadway fill is not present below the vault. We therefore recommend that explorations be completed to determine the support conditions at the planned bottom elevation of the vault.

WYNOOCHEE LAKE SHORE TRAIL

The trail appears to have been cut into the slope along a portion of the alignment. The cut slopes appear stable. We expect that temporary cuts as steep as 1¼H:1V can be excavated along the toe of the adjacent slopes without creating instability. However, it appears that there is adequate space to locate the bypass pipeline/flume away from the slope located along the east side of the trail. If excavations in excess of about 4 feet are planned then it would be prudent to complete explorations to verify soil conditions at depth. The native soil evident in this area should provide good support for the pipeline/flume.

POWERHOUSE ACCESS ROAD

The east side of the access road appears to have been cut into the west facing slope and the slope appears stable. We expect that temporary cuts as steep as 1¼H:1V can be excavated along the toe of the adjacent slopes without creating instability. However, if excavations in excess of about 4 feet are planned then it would be prudent to complete explorations to verify soil conditions at depth. The native soil evident in this area should provide good support for the flume.

SUBSTATION TO OUTLET CHANNEL

The proposed flume alignment crosses what appears to be an alluvial bench located 20 to 30 feet above the current river elevation. The surface soils observed should provide good support for the flume. However, the firm silty sand with gravel changes to loose silty fine sand and soft silt near the beginning of the outlet channel. We recommend that explorations be completed to evaluate the extent of loose/soft soil and the depth to firm bearing. It may be necessary to remove and replace some of the loose/soft soil to provided proper support for the flume near the outlet channel.

OUTLET CHANNEL

The outlet channel begins about 50 feet south of the existing detention pond. The firm silty sand with gravel that is characteristic along much of the project alignment changes to wet, loose silty fine sand and soft silt near the beginning of the outlet channel. The loose/soft soil is also present in the river bank that will be excavated for the proposed channel. It is likely that permanent cut slopes must be inclined no steeper than 3H:1V to reduce the risk of instability. If significant amounts of groundwater seepage are present then flatter cut slopes or retaining structures may be necessary. We recommend that explorations be completed along the outlet channel alignment to evaluate the extent of loose/soft soil and the depth to firm bearing.

LIMITATIONS

We have prepared this report for the exclusive use of the U.S. Army Corps of Engineers-Seattle District, Tetra Tech, Inc. and their authorized agents for preliminary assessment of the proposed fish passage project at the Wynoochee Dam in Grays Harbor County, Washington.

Within the limitations of scope, schedule and budget, our services have been executed in accordance with generally accepted practices in the field of geotechnical engineering in this area at the time this report was prepared. No warranty or other conditions, express or implied, should be understood.

Any electronic form, facsimile or hard copy of the original document (email, text, table, and/or figure), if provided, and any attachments are only a copy of the original document. The original document is stored by GeoEngineers, Inc. and will serve as the official document of record.

Please refer to the attachment titled Report Limitations and Guidelines for Use for additional information pertaining to use of this report.

We appreciate the opportunity to provide geotechnical services on this project. Should you have any questions or comments, or if we may be of further service, please do not hesitate to call.

Respectfully submitted,

GeoEngineers, Inc.

JEROME J. McFADDEN, JR. STATE OF WASHINGTON 26693 REGISTERED PROFESSIONAL ENGINEER
12/26/02
EXPIRES 3/4/03

Bo McFadden, P.E.
Associate

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Two copies submitted (plus one unbound and one pdf by e-mail)

Attachment

ATTACHMENT A

REPORT LIMITATIONS AND GUIDELINES FOR USE

ATTACHMENT A
REPORT LIMITATIONS AND GUIDELINES FOR USE[1]

This appendix provides information to help you manage your risks with respect to the use of this report.

GEOTECHNICAL SERVICES ARE PERFORMED FOR SPECIFIC PURPOSES, PERSONS AND PROJECTS

This report has been prepared for the exclusive use of the U.S. Army Corps of Engineers-Seattle District, Tetra Tech, Inc. and their authorized agents for preliminary assessment of the proposed fish passage project at the Wynoochee Dam in Grays Harbor County, Washington. This report is not intended for use by others, and the information contained herein is not applicable to other sites.

GeoEngineers structures our services to meet the specific needs of our clients. For example, a geotechnical or geologic study conducted for a civil engineer or architect may not fulfill the needs of a construction contractor or even another civil engineer or architect that are involved in the same project. Because each geotechnical or geologic study is unique, each geotechnical engineering or geologic report is unique, prepared solely for the specific client and project site. Our report is prepared for the exclusive use of our Client. No other party may rely on the product of our services unless we agree in advance to such reliance in writing. This is to provide our firm with reasonable protection against open-ended liability claims by third parties with whom there would otherwise be no contractual limits to their actions. Within the limitations of scope, schedule and budget, our services have been executed in accordance with our Agreement with the Client and generally accepted geotechnical practices in this area at the time this report was prepared.. This report should not be applied for any purpose or project except the one originally contemplated.

A GEOTECHNICAL ENGINEERING OR GEOLOGIC REPORT IS BASED ON A UNIQUE SET OF PROJECT-SPECIFIC FACTORS

This report has been prepared for the proposed fish passage project at Wynoochee Dam in Grays Harbor County, Washington. GeoEngineers considered a number of unique, project-specific factors when establishing the scope of services for this project and report. Unless GeoEngineers specifically indicates otherwise, do not rely on this report if it was:

- not prepared for you,
- not prepared for your project,
- not prepared for the specific site explored, or
- completed before important project changes were made.

For example, changes that can affect the applicability of this report include those that affect:

- the function of the proposed structure;
- elevation, configuration, location, orientation or weight of the proposed structure;

[1] Developed based on material provided by ASFE, Professional Firms Practicing in the Geosciences; www.asfe.org .

- composition of the design team; or
- project ownership.

If important changes are made after the date of this report, GeoEngineers should be given the opportunity to review our interpretations and recommendations and provide written modifications or confirmation, as appropriate.

SUBSURFACE CONDITIONS CAN CHANGE

This geotechnical or geologic report is based on conditions that existed at the time the study was performed. The findings and conclusions of this report may be affected by the passage of time, by manmade events such as construction on or adjacent to the site, or by natural events such as floods, earthquakes, slope instability or ground water fluctuations. Always contact GeoEngineers before applying a report to determine if it remains applicable.

MOST GEOTECHNICAL AND GEOLOGIC FINDINGS ARE PROFESSIONAL OPINIONS

Our interpretations of subsurface conditions are based on field observations from widely spaced sampling locations at the site. Site exploration identifies subsurface conditions only at those points where subsurface tests are conducted or samples are taken. GeoEngineers reviewed field and laboratory data and then applied our professional judgment to render an opinion about subsurface conditions throughout the site. Actual subsurface conditions may differ, sometimes significantly, from those indicated in this report. Our report, conclusions and interpretations should not be construed as a warranty of the subsurface conditions.

GEOTECHNICAL ENGINEERING REPORT RECOMMENDATIONS ARE NOT FINAL

Do not over-rely on the preliminary construction recommendations included in this report. These recommendations are not final, because they were developed principally from GeoEngineers' professional judgment and opinion. GeoEngineers' recommendations can be finalized only by observing actual subsurface conditions revealed during construction. GeoEngineers cannot assume responsibility or liability for this report's recommendations if we do not perform construction observation.

Sufficient monitoring, testing and consultation by GeoEngineers should be provided during construction to confirm that the conditions encountered are consistent with those indicated by the explorations, to provide recommendations for design changes should the conditions revealed during the work differ from those anticipated, and to evaluate whether or not earthwork activities are completed in accordance with our recommendations. Retaining GeoEngineers for construction observation for this project is the most effective method of managing the risks associated with unanticipated conditions.

A GEOTECHNICAL ENGINEERING OR GEOLOGIC REPORT COULD BE SUBJECT TO MISINTERPRETATION

Misinterpretation of this report by other design team members can result in costly problems. You could lower that risk by having GeoEngineers confer with appropriate members of the design team after submitting the report. Also retain GeoEngineers to review pertinent elements of the design team's plans and specifications. Contractors can also misinterpret a geotechnical engineering or geologic report. Reduce that risk by having GeoEngineers participate in pre-bid and preconstruction conferences, and by providing construction observation.

DO NOT REDRAW THE EXPLORATION LOGS

Geotechnical engineers and geologists prepare final boring and testing logs based upon their interpretation of field logs and laboratory data. To prevent errors or omissions, the logs included in a geotechnical engineering or geologic report should never be redrawn for inclusion in architectural or other design drawings. Only photographic or electronic reproduction is acceptable, but recognize that separating logs from the report can elevate risk.

GIVE CONTRACTORS A COMPLETE REPORT AND GUIDANCE

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Appendix F

Eicher Screen Reference Articles

Development of an Eicher Screen
at the Elwha Dam Hydroelectric Project

Pieter Adam, P.E.[1]
Donald P. Jarrett, P.E.[2]
Allan C. Solonsky[3]
Larry Swenson, P.E.[4]

Abstract

The Eicher Screen is a relatively new concept for screening juvenile fish out of hydroelectric turbine penstocks. The concept was developed by Mr. George Eicher and one was recently installed and evaluated at the Elwha Hydroelectric Project in Washington State. The Eicher Screen was installed inside a 9-foot diameter penstock in March 1990. The screen assembly consists of wedgewire panels of varying porosities mounted on a support frame. A pivot shaft inside the penstock allows the screen to be rotated and backflushed for cleaning. Hydraulic analyses, operational testing and initial biological evaluation were conducted from April through June 1990. Maximum headloss measured through the screen never exceeded two feet (0.61 m) and debris has not created any problems at the site to date. Biological evaluations consisted of passing 5,000 coho salmon smolts through the screened penstock. Over 99 percent of the fish were recovered from the penstock and survived a three day holding period. Additional biological evaluations will be performed in 1991.

Introduction

The Elwha Hydroelectric Project is currently undergoing FERC licensing. The Project was constructed in 1911 without upstream or downstream fish passage facilities and restoration of anadromous fish runs above the Project is a central licensing issue. Restoration is a goal shared by the Project's owner, James River II, Inc. (JRII), federal and state resource agencies and the Lower Elwha Indian Tribe.

To provide effective protection for future downstream migrants (juvenile fish), several alternatives were reviewed representing a range of complexity, cost and potential for success. These included conventional

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systems acceptable to regulatory agencies, such as traveling belt or angled drum screens or shutdown and spill options. An alternative, the Eicher Screen, is a relatively new concept of screening that holds promise for good performance. An economic evaluation indicated that, assuming reasonable Eicher Screen bypass flow requirements, its life cycle costs would be lower than a forebay screening facility or the shut down and spill alternative. The Eicher Screen alternative was attractive to JRII as a cost effective method to provide passage survival rates necessary to achieve restoration of anadromous fish. James River is presently engaged with the Electric Power Research Institute (EPRI) in the evaluation of the effectiveness of the Eicher Screen technology.

The basic concept of the Eicher Screen is a smooth, elliptical screen positioned at a shallow angle inside a penstock. Bypass flows exit the penstock through a pipe at the downstream end of the screen. According to George Eicher, successful fish passage is provided as long as the ratio of Vx (velocity component in the plane of the screen, parallel to the screen centerline) to Vz (velocity component perpendicular to the plane of the screen) is maintained at three to one (Figure 1).

In 1980, a prototype installation was tested at the T.W. Sullivan Plant at Willamette Falls, Oregon. Although poor hydraulic conditions were present at the site, studies indicated that the screen had a diversion efficiency near 100 percent. An accurate assessment of injuries to fish was precluded by injuries caused in the fish collection facilities. The collection facilities are currently being rebuilt and further testing will occur in 1991. With promising passage results, EPRI funded model tests at the University of Washington in 1984. During these tests, various species of fish were passed through an inclined plane screen in a rectangular cross-sectional model. Screen angles of 10.5, 16.5 and 30 degrees were tested over a range of varying bypass and approach flows. Results from the model tests indicated that fish touched the screen more frequently when screen angle was increased. These initial test results provided a starting point for the Elwha design.

U of W TESTING

Fisheries Considerations

Federal and Washington State design criteria (Vx and Vz) for conventional screening technology are based upon the site specific size and swimming capabilities of the juvenile fish present. At Elwha Dam, primary anadromous species targeted for restoration are chinook salmon, coho salmon and steelhead trout. Chinook salmon migrate downstream as sub-yearlings at approximately four inches (10 cm) in length. Coho salmon and steelhead trout migrate downstream as yearlings reaching lengths of five to eight inches (13 to 21 cm), respectively.

Using conventional forebay screening facilities, fish at Elwha Dam would limit the maximum Vz velocity component to 0.8 fps (0.24 m/s). A Vx velocity component at least twice the Vz velocity component would also be required according to federal and Washington State screening criteria. Because the Eicher Screen does not adhere to conventional screening methodology, only general guidelines were available to engineers and biologists during development of the Eicher Screen technology. Resource agencies and the Tribe required that careful evaluation of the Eicher Screen be performed to demonstrate that it can achieve equal or better passage rates than conventional screens.

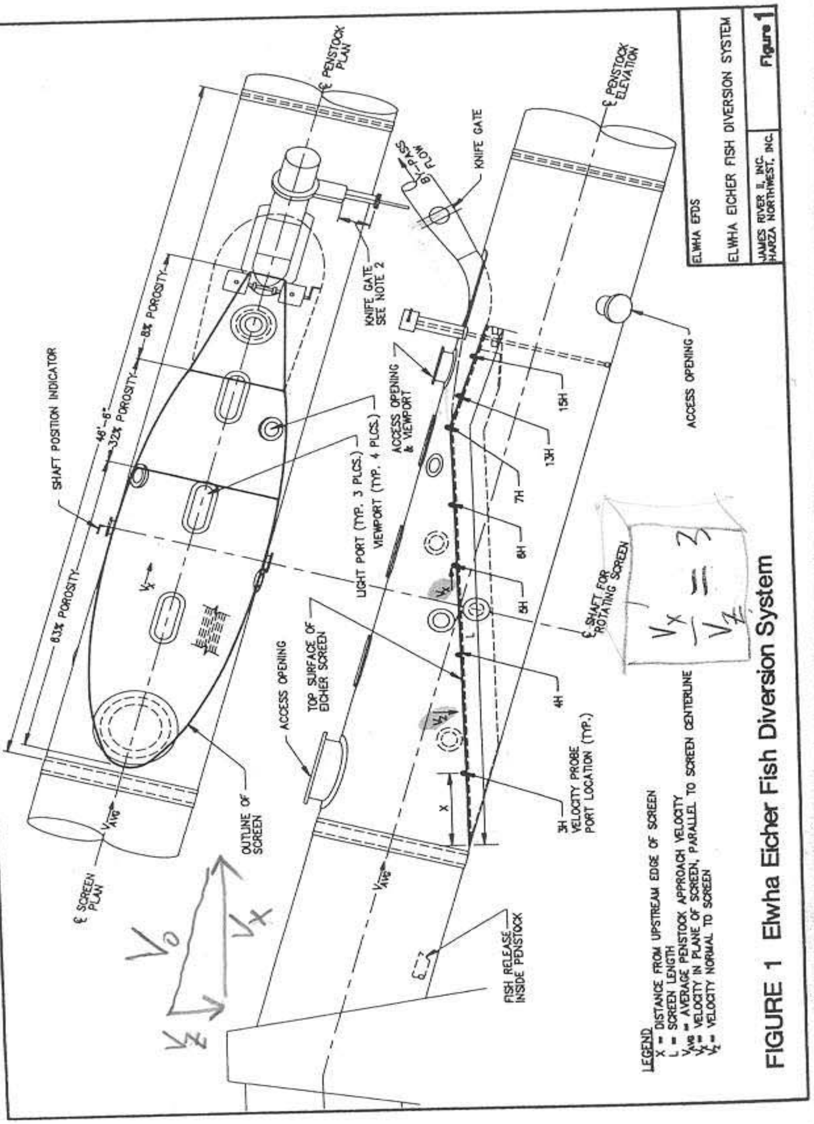

FIGURE 1 Elwha Eicher Fish Diversion System

Design Objectives

In the absence of established design criteria, development of screen parameters was a product of a consensus among the resource agencies, tribal representatives, JRII, JRII's consultant (Harza NW staff), George Eicher, EPRI, and EPRI's consultant (Stone & Webster). The process of design and evaluation was guided by a study plan which was jointly developed. The overall goal for the system was to provide 95 percent passage survival for all downstream migrating fingerlings and yearlings.

Because there was general belief that velocity components should have absolute limits, specific hydraulic objectives to provide effective fish protection were to develop a uniform Vx component (not to exceed about 10 fps (3 m/s) at full-gate) and limit the Vz component as much as practical. Additional design objectives were to minimize economic costs, such as initial capital cost and lost power generation due to fish bypass flows, minimize operational constraints, minimize headloss and provide effective debris management.

The Elwha Eicher Screen required several sub-assemblies and fabrications (Figure 1). Provisions were made for pivoting the screen, viewing ports, lighting ports, velocity measurement ports and mandoors for access into the penstock.

Hydraulic Model

A model study was conducted by Engineering Hydraulics, Inc. to help achieve the desired velocity patterns near the screen and minimize headloss. A 1:4.7 scale hydraulic model of the intake, penstock, screen and bypass was constructed. The penstock was modeled using 24-inch clear acrylic tubing. Maintaining the same screen headloss coefficients in the model and the full-scale penstock screen required using penstock screen material in the model and operating at penstock velocities, thereby producing full-scale Reynolds Numbers in the model. Since the scale of the screen material was 1:1 and the support beams were scaled 1:4.7, the model did not have strict geometric similarity. The screen bars and openings of the model were large relative to the size of the support beams and to the model penstock diameter. Nevertheless, it was believed that the overall flow patterns in the model would be similar to the full-scale screen because of the high model Reynolds Number (in the range of 0.7×10^6 to 1.4×10^6).

Three flow combinations were tested in the model: 4 fps (1.2 m/s) average velocity in the penstock and bypass pipe, 6 fps (1.8 m/s) in each and 8 fps (2.4 m/s) in each (referred to as 4-4, 6-6 and 8-8 respectively). Velocity measurements were made using a United Sensor five-hole prism probe. The probe was inserted through ports in the wall of the penstock at various locations (Figure 1). The probe axes were parallel to and about 3/8-inch (0.01 m) above the screen surface. The piezometric head measured at each of the five prism sensor ports was resolved to determine the three orthogonal velocity components for each velocity reading. Velocities are presented in a normalized format, where the actual velocity component (either Vx or Vz) is divided by the average penstock velocity. Normalized velocities allowed easy comparison of the velocity profiles under different flow conditions (Figure 2).

An initial model test using 63% porosity screen was performed. This test indicated a peak normalized Vx component in excess of 1.5 and a peak

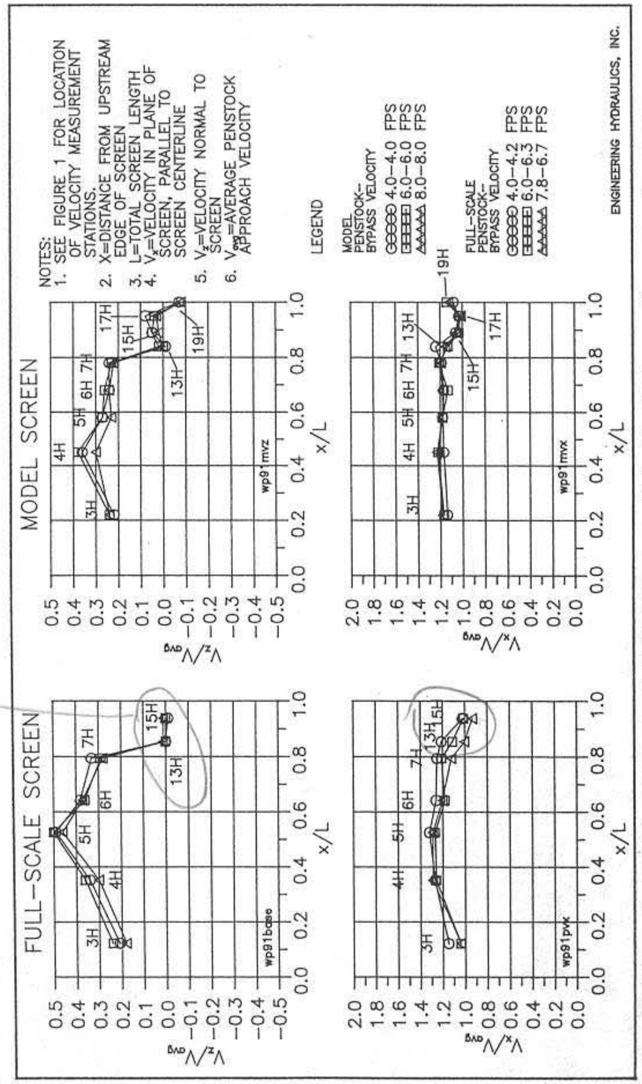

Figure 2 Full-Scale and Model Screen Velocity Data - Traverse Averages

normalized Vz component of 0.4. Subsequently, a series of tests were performed with various combinations of baffles to simulate different screen surface materials. The objective of these tests was to develop a screen design with a uniform normalized Vx component along the length of the screen and to limit the normalized Vz component to as uniformly low a value as practical. The variation of the normalized Vx and Vz components along the length of the screen are illustrated in Figure 2. A final model test was performed with actual wedgewire porosity to confirm the results with baffles.

In order to handle the hydraulic load caused by accumulated debris under emergency conditions, the design criterion for the screen (and frame) was set at 7 psi (48 kPa). This criterion required relatively deep backing bars for support. During model testing it was determined that the deep backing bars created excessive head loss (greater than 3 feet (.9 m)) and consequently, the backing bars were rotated to be more in line with the direction of the flow. It was also determined that spacing between the support bars should be kept as large as practical (8.25-inches (0.2 m) for the Hendrick material selected) in order to minimize head loss. Screen induced head losses were determined by measuring the difference in average piezometric head upstream and downstream of the screen. Figure 3 illustrates the head loss measured in the model study for the initial and final screen support bar arrangement.

Screen Configuration

A major design issue was the selection of the screen surface material. All parties believed that a screen built from stainless steel profile bars (referred to as wedgewire screen) was the best material to minimize debris accumulation and injury to fish. Several types of wedgewire screen were reviewed. Ultimately, material from Hendrick Screen Co. was selected.

Screen porosity was an additional design issue. Screen porosity affects head loss, debris management, velocity distribution and fish injury. Relatively large openings between screen bars could increase injury to fish and increase debris retention. A 63% porosity was considered to be a reasonable compromise between the need to minimize head loss, provide fish protection and maintain the ability to pass debris. The 63% porosity was achieved by using the manufacturer's standard bar width and the maximum allowed Washington State Department of Fisheries' opening between bars of 0.125-inch (0.3 cm).

Most participants agreed that some type of variation in porosity would be required in order to maintain uniform velocities along the length of the screen. This variation in porosity would eliminate the tendency for most of the flow to go through the downstream end of the screen, as has been observed in angled and inclined bypass facilities. Based on model studies, the final porosity configuration selected for the Elwha penstock screen was 63% for the upstream 2/3 of the screen and 32% and 8% for the remainder. This combination of porosity, based on the model results, was found to yield a relatively uniform Vx component along the length of the screen with reasonable limits to both Vx and Vz components.

Fish Bypass

Design of the bypass entrance area (transition from penstock to bypass) was considered critical for successful fish passage. Most participants felt that velocities through the transition section should not exceed about 10 fps in order for fish to maintain orientation into the flow.

Original concepts had a small pipe (2-foot (0.6 m) or less) intersecting at a shallow angle to the penstock section. The pipe would intersect a small area on the top of the penstock. This would require fish to travel to the extreme downstream end of the screen to be swept into the elliptical shaped bypass entrance. This geometry concerned fisheries biologists who felt that fish following the peripheral areas of the penstock could sustain high injury rates at the abrupt transition into the bypass. There also was a concern about a potential drop in velocity at the bypass entrance. Subsequently, George Eicher suggested a modified bypass entrance geometry which would solve these problems and the new geometry was selected for the screen (Figure 1). The modification provides a more gentle transition from penstock to bypass.

Bypass Velocity

The dimension of the bypass entrance was also an economic issue because it established the required bypass flow. The bigger the entrance the larger the bypass flow and the greater the economic cost of operating the Eicher Screen. A small entrance opening would run the risk of becoming clogged with debris. Ultimately the parties agreed to a final entrance height of 16-inches (0.4 m).

The bypass design includes a truncation of the screen at the downstream end, a transition to a rectangular shape and a second transition from a rectangular shape into the 24-inch (0.6 m) diameter bypass pipe. The bypass portion of the penstock section was consequently complex and considerable reinforcement was required to maintain the penstock's structural integrity. The model study indicated a more favorable Vx distribution along the length of the screen if 8% porosity wedgewire screen was used in the floor of the transition section. According to the model, porosity higher than 8% created excessively high velocities in the fish bypass entrance (1.5-1.6 normalized Vx).

Screen Support Frame & Pivot System

The wedgewire screen was mounted on a structural frame for support. The frame was required to be strong enough to support a fully clogged condition. Based on the model studies performed at the University of Washington, an angle of 16.5 degrees was selected as a reasonable compromise between effective debris management, fish passage and cost of construction.

The support frame was designed to pivot in order to enable backflushing the screen for cleaning. Two options were evaluated during the design phase to pivot the screen: hydraulic cylinders and a lead screw arrangement. Operator loads were expected to become quite large if debris loading was non-uniform. Because of the size of the support frame, it was decided to use two operators, one at each corner of the downstream end of the frame. Hydraulic cylinders were not used because the long rods would be subject to buckling. Furthermore, the frame could be subjected to distortion if debris prevented one side of the screen from returning to the "fishing" position. Twin lead screws were selected as being relatively inexpensive and not subject to imposing a torsional load on the frame, since the lead screws would be driven by a single gearbox.

Installation

Site specific installation issues that were unusual at this site included an old penstock with an irregular diameter and limited access. The condition of the penstock material was assessed by a metallurgical analysis. The penstock shell material was found to be readily weldable, but only .19-inch (0.5 cm) thick. The interior of the penstock was physically inspected and found to be in reasonably good condition for its age. Due to the difficulty of field fabricating the bypass transition section and numerous penetrations, it was decided to fabricate a new penstock section and install the screen assembly into place on site.

Due to schedule constraints, the replacement penstock section and the screen were not assembled in the fabrication shop together. This resulted in field modifications which were required to align the 8% screen surface to the bypass transition section within allowed tolerances (0.125-inch). Because the existing penstock was out-of-round and could not be brought into a round condition, a short transition section was field fabricated and installed between the penstock and the replacement penstock section.

Biological Evaluation Results

An injury classification system developed by the National Marine Fisheries Service for studies on the Columbia River was used to evaluate fish passage success through the Eicher Screen. Categories of injuries were:

- "partially descaled" (scattered or patchy scale loss 3 to 16% per side);
- "descaled" (over 16% scale loss on one side); and
- "other injuries" (bruises, cuts, eye injuries, etc.).

All fish were held from three to ten days following tests. Results from over 5,000 fish passed through the screened penstock in groups of 100 fish indicated that the recovery rate averaged over 99 percent. Little or no injury was observed during tests conducted at low penstock velocities and at highest penstock velocity (full gate) only 3.6 percent of the test fish showed substantial injury (descaled). At full gate, an average of approximately 24% of the fish also exhibited partial descaling. Actual mortality (fish killed) during spring tests was 0.21 percent; all these fish died during fresh water holding. Studies to determine the effectiveness of diverting larger and smaller fish (steelhead yearlings and chinook sub-yearlings) will be conducted in 1991.

Hydraulic Evaluation

Velocity measurements at the Elwha screen were made in locations close to those in the model, but were shifted slightly due to interference with penstock stiffener rings. Measurements indicated reasonably good agreement with the model for the normalized Vx velocity component, but a higher peak normalized Vz velocity component (Figure 2). Observations made during the biological tests indicated that there were short term fish contacts with the screen in the area where the peak Vz velocity was measured (only at 8-8 condition).

The higher peak Vz components measured at the Elwha screen may be due to the fact that the model was not fitted for the screen seal and clamping bars. These two items increase the Vz component by blocking about 15% of the surface of the main screen. The higher velocities may also be due to different locations used for velocity measurements. The measurement location for 5H, for example, was situated over higher porosity screen and an area of unexpected high velocities.

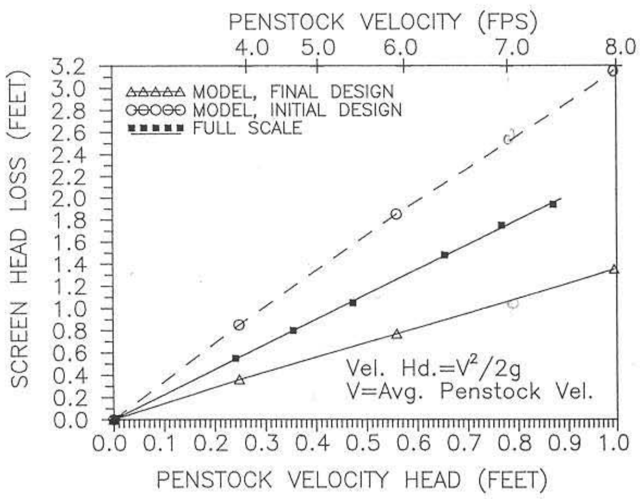

Figure 3 Full-Scale and Model Screen Head Loss

Head loss measurements at the Elwha Screen were made in the same manner as the model study. The head losses measured in the field indicated a maximum of 1.9-feet (0.6 m) and the maximum measured in the model was 1.3-feet (0.4 m), see Figure 3. The difference in head loss between the full scale and model measurements could be due to the lack of seals and clamping bars in the model. Additionally, some of the wedge wire support u-clips were removed during the model runs, which probably resulted in lower head loss.

Operational Impacts and Costs

No operational impacts have been noted to date. The screen cleaning system has been successful in removing any accumulated debris. Screen head loss at the site represents a negligible reduction in generation.

The construction cost for the installation of the Eicher Screen was about $400,000 (1989 dollars). This construction cost included about $60,000 for the installation of a crane to service this installation as well as other nearby construction. Additionally, there was another $400,000 incurred for professional services, the hydraulic model and lost generation (during installation and evaluation). A cost estimate to install Eicher Screens in all four penstocks at the Elwha Project, including bypass facilities is $3 million. A series of forebay drum screens is estimated to cost approximately $7 million.

Recommendations for Refinement

Based on the results of the biological evaluation and the prototype hydraulic tests performed to date, minor refinements may be made to improve performance. If refinements are made, it will be important to make hydraulic measurements following any modifications to the existing design. These measurements will provide a better understanding of observations made during biological tests.

Conclusion

Initial results from the Elwha Dam Eicher Screen are very encouraging. It is expected that with some minor modifications, fish contacts with the screen can be reduced. Future testing will determine the effectiveness of the screen to handle debris loading and the ability of the screen to successfully pass other species of fish. Gaining information at new sites with different fish species will also provide valuable information with which to understand required velocity conditions for the Eicher Screen technology. If tests continue to be successful, it is expected that the Eicher Screen will be a viable solution to downstream passage at other sites.

Acknowledgements

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Evaluation of an Eicher Fish Diversion Screen at Elwha Dam

Fred C. Winchell[1] and Charles W. Sullivan[2]

Abstract

In the spring of 1990, the Electric Power Research Institute (EPRI) initiated testing of an inclined fish screen installed in a 9-foot diameter penstock at the Elwha Hydroelectric Project in Washington State. In tests performed with coho salmon smolts, over 99 percent of the fish were diverted without mortality. At penstock velocities from 4 to 6 fps, less than 0.1 percent of the fish had scale loss exceeding 16 percent on either side (considered "descaled" in criteria used on the Columbia River), and less than 5 percent showed any type of injury. Slightly more descaling was observed at higher penstock velocities. At the maximum velocity tested (7.8 fps), 3.6 percent of the fish had scale loss of over 16 percent, and 18.1 percent of the fish had scale loss between 3 percent and 16 percent. Mortality after a 3 to 10-day holding period averaged 0.21 percent for test fish and 0.14 percent for controls.

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Introduction

The concept of installing a fish screen inside of a penstock at a shallow angle to the flow was first applied by George Eicher at the T.W. Sullivan hydro plant in Oregon. This type of screen is now commonly referred to as an "Eicher Screen." Its basic principle is to sweep fish rapidly towards a bypass at high velocities, as opposed to other types of screens which are designed to maintain velocities lower than the swimming speed of the target fish species.

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Advantages of Eicher's design include low capital and maintenance costs, minimal space requirements, minimal icing potential and insensitivity to forebay level fluctuations. However, a demonstration of the screen's ability to safely pass fish is necessary before it can gain widespread acceptance.

This paper describes the evolution of the Eicher Screen design from its initial installation at the Sullivan hydro plant to the refined prototype recently installed at the Elwha Hydroelectric Project in Washington state. The results of passage tests performed in 1990 with coho salmon smolts are presented. Passage tests for coho salmon and other species will be continued in 1991 and in following years.

Background

The original "Eicher Screen" was installed in 1980 at Portland General Electric's T.W. Sullivan hydro plant at Willamette Falls, and is still in operation. It consists of a 21-foot long stainless steel wedgewire screen with 0.08-inch (2 mm) bars and 0.08-inch openings between bars. The screen is located inside an 11-foot diameter penstock, and is inclined at a slope of 19 degrees to the flow, leading to a surface bypass. The average water velocity through the penstock is approximately 5 fps.

The screen at the Sullivan plant has been relatively free of operational problems. Despite non-uniform flow conditions caused by the layout of the intake and penstock, testing has shown that the screen can divert several species of smolts at high rates. However, an accurate evaluation of fish injury has been precluded by the lack of adequate fish collection facilities. New test facilities planned by Portland General Electric should provide more information on the effectiveness of this screen in the near future.

Without conclusive data on fish injury rates, the Eicher screen has been slow to gain agency acceptance. In order to test and demonstrate the concept's potential, the Electric Power Research Institute (EPRI) initiated a research and development effort in 1984. This program started with laboratory studies conducted at the University of Washington and has culminated in the current test program of the Elwha prototype.

The University of Washington laboratory studies were conducted in a plexiglass flume, with a screen mounted in a test section 8-feet in length and 6-inches in width. The effects of bypass and flume velocities, screen angle, lighting, and various screen materials on the passage of several species of salmonid juveniles and smolts were examined. Fish were effectively diverted under a wide range of velocity conditions. Impingement did not occur at conditions where a high sweeping velocity was maintained along the full length of the screen. At most conditions where impingement did occur, it was limited to the area approaching the bypass entrance. Impingement was reduced or eliminated when the spacing between bars was reduced from 2 mm to 1 mm in the 18-inches of screen closest to the bypass entrance.

Soon after beginning the laboratory tests, EPRI started a search for a suitable site to test a prototype installation. The Elwha Hydroelectric Project, located on the Elwha River near Port Angeles, Washington was selected. With four 3.2 MW units and a total project flow capacity of 2,000 cfs, the site offers a high degree of operational flexibility for testing. The exposed section of the Elwha penstocks provided good access to several possible installation sites. Unlike the Sullivan plant, good alignment of the intakes and penstocks indicated that relatively uniform flow fields could be expected.

In 1989, EPRI entered into an agreement with the project's owners, James River II Inc., to evaluate the Eicher screen in one of the 9-foot diameter penstocks at the Elwha plant. James River II Inc. funded design and installation of the Eicher screen, including a hydraulic model study which was used to refine the initial design. EPRI funded design and installation of evaluation facilities and is also funding the ongoing biological and hydraulic evaluation of the screen.

Prototype Design

James River II Inc. contracted with Hosey and Associates Engineering Company to design the prototype screen and oversee hydraulic model testing. Hosey, in turn, contracted with Engineering Hydraulics, Inc., to build the model and conduct the laboratory tests.

A model of the intake, penstock and screen was constructed on a scale of 1 to 4.7 to develop detailed information on the flow field immediately upstream of the Eicher Screen and in the fish bypass. The initial design used profile bar screen with uniform bar spacing. The screen angle was set at 16 degrees to the penstock for all tests, except for a short section of screen in the bypass transition which was roughly parallel with the penstock.

Two major refinements were made to the screen design during the hydraulic model studies. The design of the support structure was streamlined in order to reduce headloss, and the porosity (percent open area) of the screen was reduced in the downstream end of the screen to provide a more uniform flow field over its entire length.

The prototype using the refined design was installed in the spring of 1990 as part of a 46.5-ft long, prefabricated penstock section. Plan and section views of the screen are shown in Figure 1. The inclined portion of the screen is comprised of two sections with uniform bar width (0.073-inch or 1.9 mm) but different bar spacing. The upstream section is 20-feet in length, has a porosity of 63 percent with an opening between bars of 0.125-inches (3.2 mm). The downstream section is 7.5-feet in length and has a screen porosity of 32 percent with an opening between bars of 0.035-inches (0.9 mm). The section of screen in the bypass transition is 7 feet in length and has a porosity of 8 percent, with an 0.093-inch (2.4 mm) bar width and an 0.008-inch (0.2 mm) opening between bars. The entire screen including the transition section is designed to pivot so that it can be cleaned by backflushing or put into a position parallel to the penstock when not in use.

The Elwha Testing Program

EPRI initiated its testing program at Elwha in the spring of 1990 with

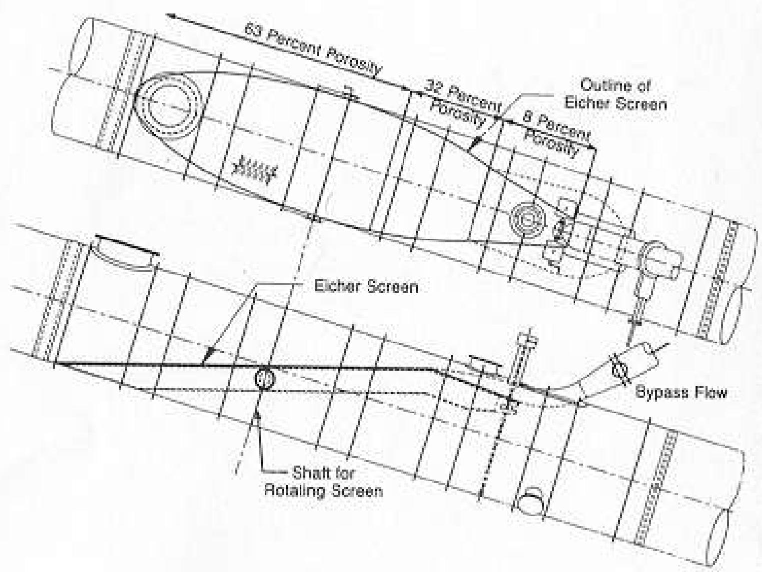

Figure 1. Plan and Section Views of the Elwha Eicher Screen (courtesy Harza Northwest and Hydro Review).

construction of evaluation facilities and completion of the first series of tests with coho salmon smolts. Stone & Webster Environmental Services was retained by EPRI to review hydraulic modelling efforts and design the evaluation facilities. The testing program was developed in a cooperative effort by Stone & Webster and Hosey & Associates with extensive input from state and federal fishery agencies and the Lower Elwha Tribe. A detailed report on the tests performed in the spring of 1990 is presented in EPRI Report No. GS-7036, "Evaluation of an Inclined Penstock Screen at Elwha Dam, Spring 1990 Test Results" (in press). Testing will be continued in 1991 with smolts of steelhead trout, chinook salmon and additional coho salmon.

Evaluation Facility Design

The evaluation facilities installed at Elwha are shown in Figure 2. A pressurized system is used to release test fish into the penstock upstream of the screen. this system is composed of a 60-gallon fish release tank connected to an 8-inch diameter release pipe. The fish are released into the penstock by gradually displacing the water from the release tank and pipe with compressed air. The system releases the fish into the base of the

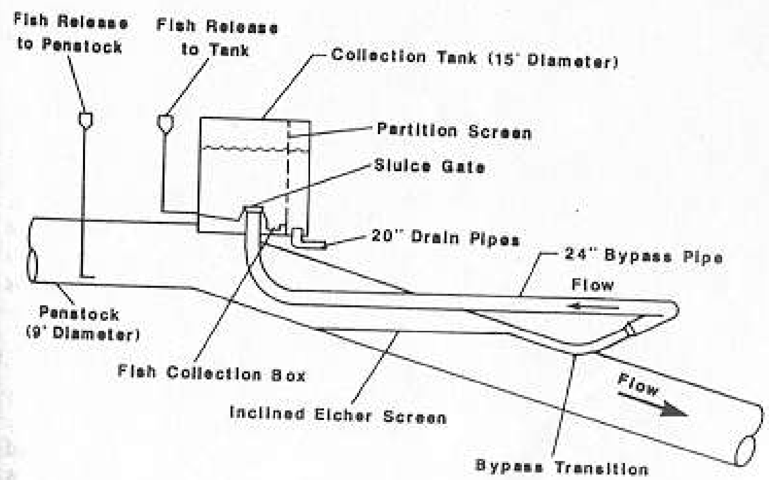

Figure 2. Section View of the Elwha Evaluation Facilities.

penstock approximately 15 feet upstream of the leading edge of the screen. An identical system releases the control fish into the collection tank.

Bypassed fish are delivered into the collection tank through a 24-inch pipe, which discharges the bypass flow and fish upward vertically through an open sluice gate at the floor of the tank. Bypass flows are regulated by adjusting the elevation of the water in the tank, with depths ranging from 7 to 10 ft for the range of bypass flows evaluated (4 to 7.8 fps). The water level in the tank is controlled by adjusting two 20-inch valves which drain flow from the tank behind a screen partition designed to retain collected fish in the tank.

When a test is completed, the tank is drained and the fish are guided by the sloped floor into a 60-gallon collection box. The box is lifted to the uppermost of three work decks surrounding the collection tank. Tanks are provided on the middle and upper decks to hold groups of fish prior to release and following recovery.

Test Parameters

Six combinations of penstock and bypass velocities were evaluated, as shown in Table 1. Penstock velocities were selected to cover the normal operating range of the turbine. Based on results of the University of Washington laboratory studies, the velocity at the bypass entrance was set equal to or greater than the average velocity in the penstock to minimize the potential for fish impingement. The condition with 7 fps in the penstock and bypass was added after a slight increase in injury rate was noted between the 6 fps and 7.8 fps (full gate) penstock conditions.

A study schedule was developed which replicated each test condition twelve times over a fifteen day period. Since the 7 fps condition was added later in the tests, it was only replicated five times. In order to examine time of day as a variable that could affect passage success, each of the five primary conditions were replicated six times during daylight hours and six times during hours of darkness.

Test Methods

The coho smolts used in the spring 1990 testing program were obtained from the Lower Elwha Tribal Hatchery. They were reared for five months to an average size of 135 mm in a net pen located in the forebay of the Elwha project. The fish were monitored to assure that they were in peak migratory (smolted) condition at the time of the tests. At this time, they are

Table 1. Test Conditions Evaluated in the Spring of 1990.

Penstock Velocity (fps)	Bypass Velocity[1] (fps)	Turbine Flow (cfs)	Bypass Flow (cfs)	Wicket Gate Position (%)	Test Replicates	
					Day	Night
4	4	240	11.8	48	6	6
4	6	240	17.7	48	6	6
6	6	360	17.7	70	6	6
6	7.8	360	23.0	70	6	6
7[2]	7	425	20.6	88	2	3
7.8	7.8[3]	475	23.0	100	6	6

[1] Average velocity at the downstream terminus of the bypass transition.

[2] The 7/7 condition was added after a slight increase in injury was noted at the 7.8 fps penstock condition.

[3] 7.8 fps was the highest bypass velocity that could be maintained for extended periods due to wave action in the collection tank.

most prone to scale loss injury. The 15-day test program was initiated on May 19, 1990, and covered the period of peak smoltification.

Before testing, fish were marked with one of four colors of dye pneumatically injected at one of seven locations, producing a total of 28 distinct marks. Marked groups of 100 fish each were held in square, 100-gallon fiberglass tanks situated on the middle deck of the evaluation facility. Each fish was later examined to assure that its mark was visible, to cull out any fish with significant scale loss or other injuries, and to obtain an accurate count of the fish remaining in each mark group.

At the initiation of testing each day, the Eicher Screen was moved from the neutral position (with the screen parallel to the penstock flow) to the fishing position (with the screen at a 16 degree angle to the penstock). Penstock and bypass flows were then set to the first scheduled test condition. A final count was then made as the fish were transferred into buckets. Next, the fish were poured into the appropriate release tanks and the covers were closed and sealed. The fish were then gradually purged from the release systems.

The bypass flow specified for the test condition was maintained for five to ten minutes after fish were released. When the bypass velocity was 7 fps or less, a run time of 10 minutes was used. At a 7.8 fps bypass velocity, the run time was reduced to 5 minutes. These durations were found to be sufficient to allow the fish to pass through the system into the collection tank.

After a test was completed, the inlet sluice gate was closed and the collection tank was gradually drained. Most of the fish moved readily into the collection box as the water depth dropped. The collection box was then hoisted to the upper deck of the evaluation facility.

Fish were evaluated immediately after recovery, directly from the collection box. Each fish was anesthetized and its dye mark, fork length and condition was recorded. A classification system developed by the National Marine Fisheries Service for studies on the Columbia River was used to categorize injuries. The major categories used were:

- o "partial descaling" (scattered or patchy loss 3 to 16% per side);
- o "descaled" (over 16% scale loss on one side); and
- o "other injuries" (bruises and eye injuries).

Fish recovered during the first half of the study were held for three days following recovery to assess delayed mortality. In the last half of the study, the loading density in each tank was increased to enable fish to be held for six to ten days.

Test Results

Results from over 5,000 fish passed through the Eicher Screen prototype indicate that the screen safely diverts coho salmon smolts under a wide range of operating conditions (Table 2). The recapture rate for test and control fish averaged over 98% for each of the test conditions evaluated. Recapture rates increased with time as release and recovery techniques were improved upon. During the last ten days of testing, only 5 fish out of the 3,365 fish released into the penstock were unaccounted for. Four of these fish were lost at test conditions with a penstock velocity of 4 fps, which appears to be too low a velocity to prevent some coho smolts from escaping upstream.

Little or no injury was observed during tests conducted at penstock velocities of 4 or 6 fps. Slightly more injury occurred at higher velocities, but even at the highest velocity condition tested (7.8 fps) only 3.6 percent of the test fish had over 16% scale loss on either side.

Table 2. Summary of Evaluation Results with Coho Salmon.

Penstock/Bypass Velocities (fps)	Replicates		Fish Recovered	Injury Class >16% Descaled	3-16% Descaled	Other Injuries	Delayed Mortality
4/4	Test	12	99.6%	0.0%	0.8%	1.0%	0.3%
	Control	12	100.0%	0.0%	1.2%	0.7%	0.0%
4/6	Test	12	99.2%	0.0%	1.4%	0.7%	0.2%
	Control	12	100.1%	0.1%	0.5%	0.9%	0.2%
6/6	Test	12	99.7%	0.1%	3.3%	0.5%	0.0%
	Control	12	99.9%	0.0%	0.5%	0.9%	0.1%
6/7.8	Test	12	99.9%	0.0%	4.1%	1.1%	0.3%
	Control	12	100.0%	0.0%	1.0%	0.8%	0.2%
7/7	Test	5	99.8%	1.3%	10.4%	1.4%	0.0%
	Control	5	99.7%	0.0%	0.8%	1.0%	0.3%
7.8/7.8	Test	12	98.8%	3.6%	10.1%	0.9%	0.3%
	Control	12	100.4%	0.0%	1.4%	0.7%	0.2%
All Conditions	Test	65	99.5%	0.8%	6.3%	1.0%	0.2%
	Control	65	100.0%	0.0%	0.9%	0.8%	0.2%

Of over 10,000 fish recovered during testing (5,000 test fish and 5,000 controls), only 12 test fish and 8 controls died during the three- to ten-day holding period. The mortality rate was quite low even for the few fish that showed substantial levels of descaling (Table 3).

The salmon smolts used in the tests ranged from 101 to 165 mm in length. No relationship was found between fish length and injury rates. Small numbers of hatchery steelhead (188-282 mm in length), resident rainbow trout (53-122 mm) and sticklebacks (32-60 mm) were also recovered in good condition.

No operational problems were evident during the testing period. Headloss measured across the screen ranged from 0.5 ft at a penstock velocity of 4 fps to 2.0 ft at 7.8 fps. The screen appears to be largely self-cleaning, and backflushing has effectively removed any debris pinned on the screen.

EPRI studies at Elwha are continuing, and are planned to include chinook salmon and steelhead smolts in 1991.

Table 3. Mortality by Injury Class After 6-10 Days Holding.

Injury Class	Total Observed	No. of Mortalities	Mortality Rate
Descaled (>16% loss on one side)	46	4	8.7%
Scattered Scale Loss (3-16% per side)	202	0	0.0%
Patchy Scale Loss (3-16% per side)	184	2	1.1%
Other Injury	93	4	4.3%
OK (<3% scale loss)	10,611	10	0.1%
Total	11,136	20	0.2%

Conclusions

Results of the May-June 1990 tests at Elwha indicate that the Eicher Screen prototype has excellent potential for protecting downstream migrating fish. If the Eicher Screen can safely bypass other species and sizes of fish, the device may see widespread application at hydroelectric projects with penstocks. The screen's modest space requirements, low initial cost and low O&M costs constitute significant advantages over other screening systems.