Electron Project Downstream Fish Passage Improvement Concepts

Prepared for:
Electron Downstream
Fish Passage Work Group

Prepared by:
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in association with
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EXECUTIVE SUMMARY

This white paper was prepared on behalf of the Electron Downstream Fish Passage Work Group to review potential options and assess the technical feasibility for improving the downstream fish passage conditions at the Electron Hydroelectric Project. The objective of the study was to assess a wide variety of potential options for downstream passage and determine which options appear to have the possibility of functioning given the relatively extreme design and operating conditions at the Electron Project.

A variety of general approaches were considered, including:

- Screen fish at the intake and prevent them from entering the flume.
- Divert all fish from the flume near the intake and bypass them back to the river.
- Divert all fish from the flume near the settling basin and bypass them back to the river.
- Divert all fish from the flume near the forebay and truck fish to the river.
- Allow fish to pass to forebay and improve collection facilities there, and truck fish to the river.

Descriptions are provided for five options the study team felt have enough merit to warrant further investigation, and met the evaluation criteria. Options that were not believed to be feasible are also documented, with discussions describing why the study team felt they would likely not function well in this environment. Key differentiators for the five remaining alternatives include facility location, fish bypass mechanisms, and whether or not to design to fingerling or fry criteria. The key concern with all of the design concepts is sediment management.

The five alternatives considered to be potentially viable include:

- Plate fingerling screen near intake
- Plate fry screen downstream of settling basin
- Inclined fingerling screen near intake
- Inclined fry screen downstream of settling basin
- Improve existing forebay trap and holding

This list of options can be reduced with further definitions of biological needs and practical options for sediment management. A framework on how to proceed with further analysis is provided if the work group chooses to proceed further with fish passage improvement investigations. It should be understood that this was only a brief review with the main goal of eliminating options that clearly had deficiencies given the local conditions in the Puyallup River at Electron. The fact that five options are considered worth some level of further review should not be taken as an implication that upon further feasibility development some of them may prove to be unworkable.

Budget and time constraints for this review limited the level of detail that was possible for these assessments. Therefore, some of the option descriptions provide multiple potential locations and approaches for providing the passage downstream, with little detail and significant questions that will need to be assessed in further feasibility studies. Although rough ranges of potential construction costs are provided, they are based on the overall costs of similar facilities that have been installed at other projects and not on any detailed breakdown of quantities and unit costs for the components that may be required or the site conditions at Electron. Additionally, assessments of long-term operation and maintenance costs, or the potential cost of lost generation during construction, were beyond the scope of this review.

The Electron Project is a challenging site for fish passage facilities, however, there are options worth further consideration. Additional information should be developed to quantify the existing system's performance, and help determine how to resolve some of the trade-offs between approach, screen location, and sediment management issues. This could be developed with the work group based on biological data and goals, along with a thorough sediment investigation. If this recommended information were developed, it would be possible to further reduce the list of potentially viable alternatives, at which time a more detailed engineering feasibility analysis could be conducted. Close coordination of biological goals along with a potentially iterative engineering feasibility analysis and assessment to meet the goals is recommended with any further study.

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1 INTRODUCTION

1.1 GOALS AND SCOPE

The goal of this white paper was to perform a high-level review of potential downstream fish passage alternatives that could improve the downstream passage conditions at the Electron Hydroelectric Project, and identify any potentially feasible alternatives. This work was commissioned to support the Electron Downstream Fish Passage Work Group.

This paper provides engineering and biological professional opinions concerning which alternatives are best to further explore, and provides guidance on how to proceed with future consideration of the alternatives. During the scoping process, it was anticipated that the next steps would likely include a more robust feasibility study to develop the alternatives with the most potential for success.

The Electron Project is a challenging facility with respect to fish passage, and this paper is not intended to provide final recommendations on what facilities would provide the best fish passage performance. The technical analysis performed for this white paper was conducted by senior engineers experienced with the design, performance, and limitations of fish passage facilities with a limited budget and tight schedule constraints. This study was completed to assist the Electron Work Group's report to the Washington State Legislature in December, 2008.

1.2 WHITE PAPER ORGANIZATION AND CONTENTS

Section 2 provides a description of the project's physical features, operational characteristics, and constraints relevant to designing and implementing improved downstream fish passage facilities. Descriptions are provided for: fish passage design flows; project flows and constraints; site topography, access, and power availability; sediment deposition and bedload transport concerns; and biological information for the target fish species and life stages, including target fish sizes and run timing.

Section 3 provides a review of the fish passage evaluation parameters and design criteria, and an analysis of potential fish passage alternatives believed to be feasible. An estimate of capital costs for those alternatives is provided based on comparisons to known facilities. This section also documents the design team's review of all potential alternatives, and those that are not believed to be feasible at this site. A qualitative comparison of the feasible alternatives is provided at the end of Section 3.

Conclusions and recommendations on how the Fish Passage Work Group could proceed in the future are provided in Section 4.

A draft white paper was distributed to the Work Group on November 11, 2008. Comments were received from the Puyallup Tribe of Indians, Puget Sound Energy, and the Washington Department of Fish and Wildlife. Comments received were compiled with the authors' responses and are included in Appendix A.

1.3 AUTHORIZATION

The funding for this study was provided by the Washington State Legislature and the Washington Department of Fish and Wildlife to the Electron Downstream Fish Passage Work Group. As a member of the Work Group, the Puyallup Tribe of Indians contracted with R2 Resource Consultants (R2), in association with Kozmo Ken Bates (Kozmo, Inc.), to prepare this white paper.

1.4 ACKNOWLEDGEMENTS

The study team would like to thank Puget Sound Energy for their assistance during the project kick-off meeting and site visit, and their willingness to share information including project drawings and historic data associated with the project. Additionally, we appreciate the guidance, information, and timely comments received from all parties, including: Russ Ladley and Sam Stiltner from the Puyallup Tribe; Cary Feldmann, Jacob Venard, and Steve Schmidt from PSE; and Curt Leigh, David Mudd, and Al Wald from WDFW.

2 BACKGROUND

2.1 SOURCES OF PROJECT INFORMATION

A primary source of information was a field visit to the site. The study team and members of the Electron Downstream Fish Passage Work Group visited the forebay, headworks, and settling basin on October 14, 2008. The group discussed concerns, expectations, site conditions, and operations of the project among itself and with Puget Sound Energy (PSE) operations staff. Follow-up phone interviews were conducted with PSE biological and Electron operating staff to clarify and answer specific questions. Attendees at the site visit included:

- Curt Leigh (WDFW)
- David Mudd (WDFW)
- Al Wald (WDFW)
- Russ Ladley (Puyallup Tribe)
- Sam Stiltner (Puyallup Tribe)
- Tom Nelson (Pierce County)
- Jacob Venard (PSE)
- Steve Schmidt (PSE)
- Kozmo Ken Bates (Kozmo, Inc.)
- Dana Postlewait (R2)
- Peter Christensen (R2)

PSE provided drawings of the intake, settling basin, and forebay. PSE also made available, through R2 Resource Consultants, a DVD of an Aerial video flight of the river and the flowline. With permission from PSE, the study team also reviewed the following documents for information relative to existing conditions at the project:

- 1996 Montgomery Watson report, *Electron Project Fish Passage Concepts Report*, regarding fish passage options at the project.
- Unpublished draft of the Electron HCP was referenced for project and site descriptions and hydrology information.
- 2006 report by R2 Resource Consultants, *Biological Evaluation Program – Electron Fish Bypass Facility*.

2.2 DESCRIPTION OF EXISTING SYSTEM

Puget Sound Energy (PSE) owns and operates the Electron Hydroelectric Project (Electron) on the Puyallup River in Pierce County, Washington. Electron generates electricity using water diverted from the Puyallup River at River Mile (RM) 41.7. Electron began operation in 1904.

The generating facilities consist of a diversion dam, intake, rock chutes, wooden flume flowline, flowline spillways, settling basin, forebay, and powerhouse. Fish facilities include a fishway and juvenile trap and hauling facilities at the forebay. Figure 1 shows the primary components of the project.

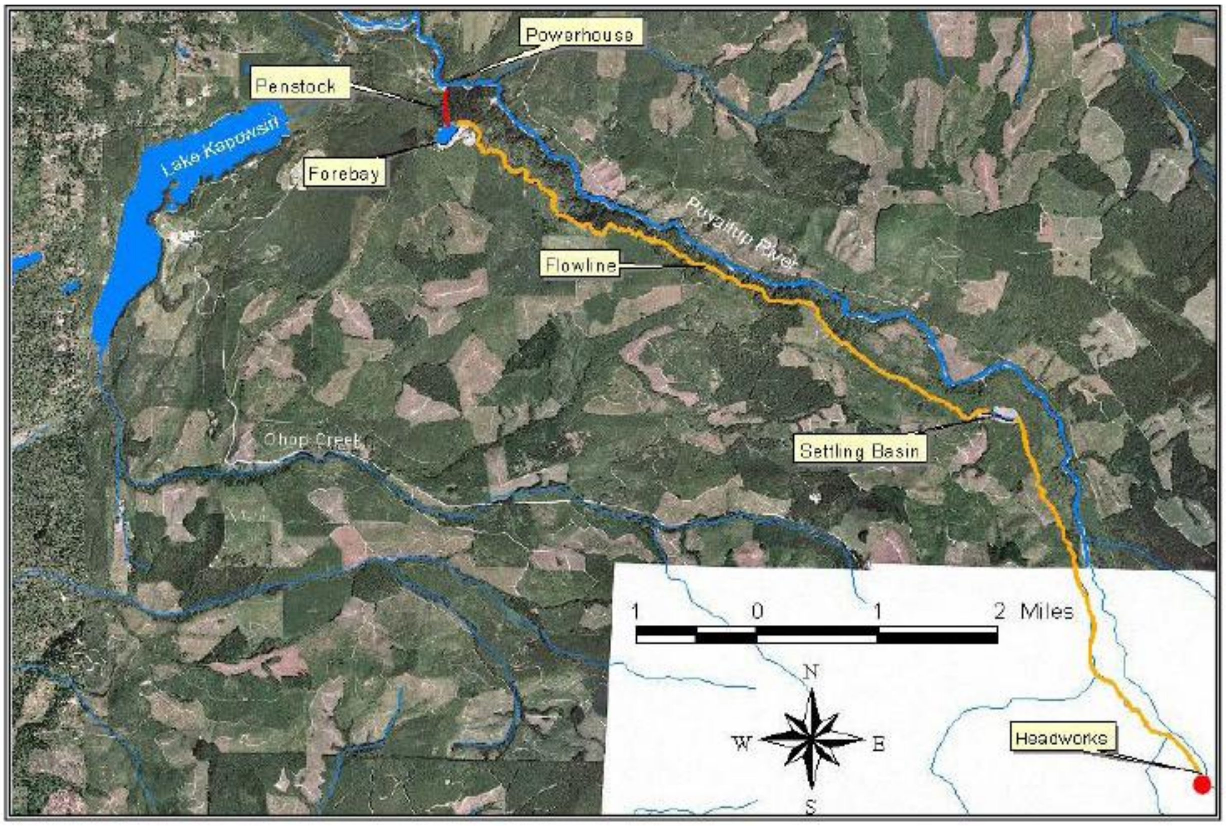

Figure 1. Electron Project (source: 2005 Biological Evaluation Program / Electron Fish Bypass Facility Summary Report)

2.2.1 Dam and Diversion

The dam is timber crib dam that spans the Puyallup River. The dam is about 10 feet high and has a crest length of 200 feet. The channel upstream of the dam commonly fills with bedload causing the low flow channel to shift frequently. A pool and weir fishway with vee-shaped weirs is located on the right bank with the exit about 200 feet upstream of the dam crest.

The dam diverts up to about 400 cfs from the Puyallup River through the headworks and into a 10.1 mile-long wooden flume to the forebay.

A 32-foot wide spillway is located at the west end of the dam. The spillway has three 10-foot air bladder gates that operate over about four feet of vertical range. The spillway is used to sluice bedload from the vicinity of the intake just upstream. Operators report that the sluice is somewhat effective but can be quickly overwhelmed by bedload as flows and sediment loads change quickly.

The intake is just upstream of the spillway. It is parallel to the channel and is 62.5 feet wide. It includes a coarse trash rack in front of it and guides where large steel plates can be installed to help control flow and sediment into and past the intake. The diverted flow is controlled by a radial gate within the intake.

Apparently no hydraulic analysis of the dam and intake is available. Without an accurate analysis of the hydraulic profile through the intake and flume, we cannot confirm the capacity of the intake and flume or the effects of the screening options located near the intake. Effects of the screening operations include additional headloss, associated impacts on flow capacity, and sediment deposition characteristics of a fish bypass conduit.

The intake area is about ten miles from the end of paved public roads and is accessed by two-lane gravel roads in good condition. Facilities at the site include control and communications equipment, storage buildings, and a 15 kW propane generator.

2.2.2 Flowline

The flowline is a 10.1-mile long, 10-ft high by 8-ft wide wooden flume. Within the flowline there are rock chutes, flood gates, spillways, and a settling basin. Rails are located on the top of the flume to facilitate maintenance and inspection cars for accessing remote sections. Figure 2 shows a section of the existing flume.

Figure 2. Electron Project Flowline Flume Section

Capacity of the flume in new condition is greater than the powerhouse capacity, which was last experienced when the flume was rebuilt in the mid-1980's. Depth in the flume was 65 inches and could have gone to 76 inches. Capacity is currently reduced by leakage that occurs when the depth is greater than about 54 inches and by moss growth in the flume that increases roughness and depth.

Velocity in the flume is typically greater than eight fps. Water depth is controlled by the normal hydraulics of the flume and varies by as much as three feet from low to high flow.

Two rock chutes are located in a concrete section of flume just downstream of the intake to remove large bedload material from the flume. Each rock chute is controlled by a three-foot square sluice gate set at an elevation slightly below the floor of the flume. A 12-inch high steel beam is mounted on the floor of the flume at the sluice gate to divert large sediment into the sluice gate. The sluice gates lead to channels and back to the river channel. The rock chute gates are normally operated about a foot open, with each passing about 20 cfs. The rock chutes are equipped with Accusonic velocity/water level meters. Figure 3 shows the features of the timber crib dam and the flume intake.

Figure 3. Features of the Diversion Dam and Flume Intake

A large deposit of 3-inch to 15-in cobbles was observed at the outlet of the rock chutes and was described as being typical of the material passed there. The rock chutes get overwhelmed with bedload at times. They fill up and rocks are passed on in the flume downstream of the rock chutes. Some gravel and cobble is transported all the way to the settling basin. Other material deposits at various locations on the inside of bends of the flume. There are four flood release gates about ¼ mile below the headworks. They are operated remotely from the powerhouse when water level sensors indicate there is excess water in the flume. They are used about once per year when canal flow is uncontrolled during a flood.

There are also three overflow sections on the flume between the settling basin and the forebay. Their purpose is to spill water out of the flume in case there is a blockage in the flowline. They are currently also used to spill ice out of the flume. Ice is entrained from the river and anchor ice builds up in the flume when the temperature is consistently below 18 degrees for a week.

2.2.3 Settling Basin

A settling basin is located on the flowline about four miles from the headworks. It is about 250 feet higher than the river and about 1,500 feet from it laterally.

The settling basin is located about ten miles from the end of paved public road and is accessed by two- and one-lane gravel roads. There is no power or other facilities at the settling basin site.

2.2.4 Forebay and Powerhouse

The forebay is a 120 ac-ft reservoir, which is generally kept full but has a water level that varies slightly. Four penstocks convey water from the forebay (elevation 1,538 ft msl) to the powerhouse (elevation 667 ft msl), which has horizontal-type Pelton impulse turbines. The powerhouse returns flow to the Puyallup River at RM 31.2.

The forebay is drained annually and settled material is excavated and hauled to a storage site nearby. Until recently, material was hydraulically dredged.

2.2.5 Fish Trap

The downstream fish trap at the forebay is designed to capture and transport fish that have been diverted from the Puyallup River into the forebay during power generation. A fish exclusion and guide net is placed in the forebay annually between April 1 to November 1 to prevent fish from entering the penstocks and to guide fish toward the fish collection facility. The net is made up of two 450-ft net sections (total length = 900 ft) and is removable for cleaning by spooling it onto a take-up reel while a new section is pulled into the forebay from a similar spool on the opposite shore of the forebay, which allows the guide net to be operational at all times during the season.

Water entering the forebay is directed toward the fish collection facility by a line of 6 x 4-ft. steel plates attached to a string of buoys near the flowline entrance. An additional group of flow deflectors helps control circulation patterns near the entrance to the trap.

The fish trap consists of an intake structure, weir gate, holding area, screens and baffles, fish hopper, electric hoist, fish sampling tank, and pumping system. Up to 28 cfs of water is pumped through the trap to create a current to draw fish to the trap. Water is drawn into the trap over an adjustable weir gate, which is adjusted to maintain a preset water level in the holding area. The purpose of the weir gate is to trap fish within the trap after they have entered. An undesirable effect of the weir gate is that it creates turbulence within the holding area.

The fish holding area of the trap is 6 ft. wide by 40 ft. long, and water is maintained at a depth of approximately 4 ft. Fish are excluded from the pumps by wedgewire screens extending along the one side of the holding area. An electrically operated crowder screen is used to concentrate fish to the downstream end of the holding pool where the fish hopper is located. An electric hoist lifts the hopper, containing fish and holding water, out of the trap and discharges them into a sample tank or transport truck tank trailer.

Fish captured in the fish trap are identified, enumerated, measured to the nearest mm fork length, and transported by tank trailer to downstream of the powerhouse where they are released back into the Puyallup River. The fish collection facility is operated continuously throughout the year when the project is operating. Fish are transported from the trap from one to three times per week depending on the number of fish in the trap.

It is the judgment of the study team that excess turbulence and poor opportunity for debris management in the trap holding area jeopardize fish health. There some observations that some fish are injured in the holding area and some smaller fish are impinged, especially when there is debris present and/or the water is turbid. There is no refuge for fish to escape the turbulence and exposure to the screens during the period they are held.

2.2.6 Fish Species and Timing

Up to eight anadromous salmonid fish species currently inhabit the Puyallup River. Chinook, coho, chum, pink and sockeye salmon, steelhead and sea-run cutthroat trout are found at various times of the year in the Puyallup River. Native resident salmonids include rainbow and cutthroat trout, and mountain whitefish. Other native fish species are also present including lamprey, minnows, sculpin, and sucker. Chinook, steelhead, and bull trout are federally listed as threatened. Dolly Varden is listed as potentially threatened, and lamprey is listed as a species of concern. Figure 4 provides seasonal timing information for the various life stage activities of the significant species present in the Puyallup River. (R2 2006)

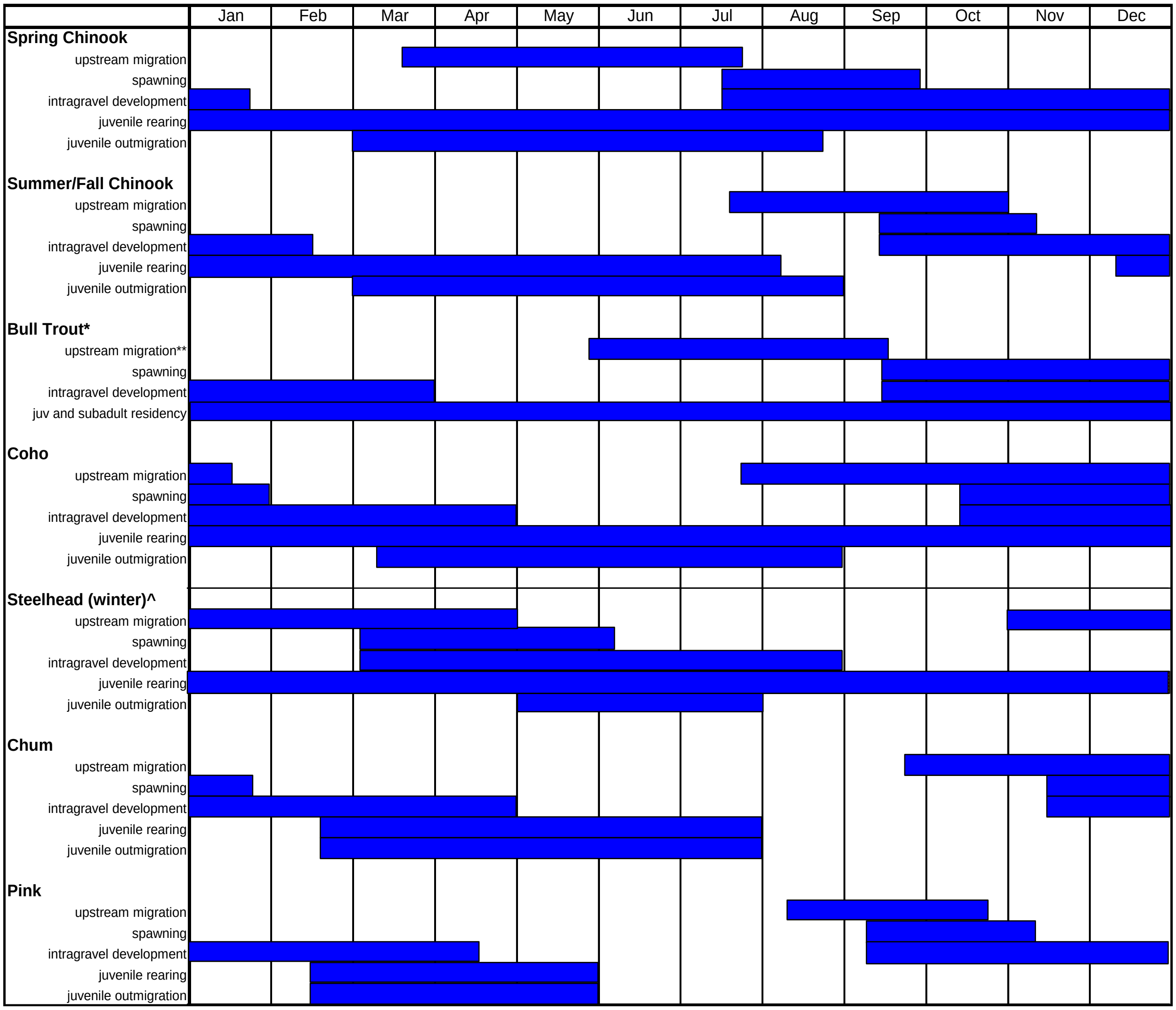

Figure 4. Life History of Puyallup River Salmonid Species

2.2.7 Hydrology and Sediment

As a glacier-fed system, the Puyallup River typically experiences two seasonal peaks in runoff, a large, long-duration peak in the summer in response to snowmelt and smaller peaks in the winter in response to rainfall. Figure 5 shows mean monthly flows at the USGS gage upstream of Electron Dam.

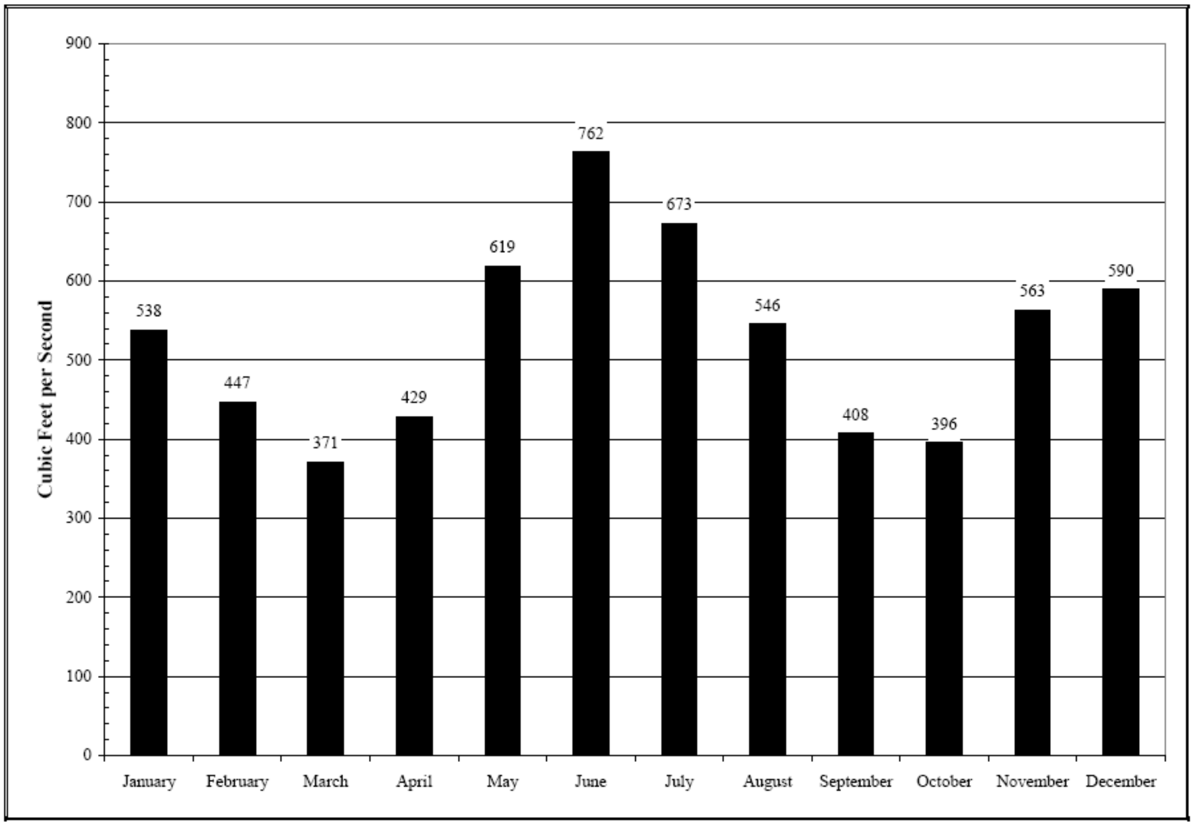

Figure 5. Mean monthly flows, Puyallup River upstream of Electron Dam.; 1909-2002. (source; USGS gage 20192000)

Bedload and suspended sediment loads in the Puyallup River are extreme and are a major consideration for any fish protection facilities at the project. The challenge is to separate water destined for power production from fish and a wide variety of sizes of sediment. Bedload and suspended sediment concentrations are naturally high in the river, particularly in late spring through early fall when snow and glacier melt are at their highest. High suspended sediment concentrations can occur at any flows during the summer and may last for several months. The large sediment load adds to the dynamic nature of the channel, causing extensive braiding, bedload movement, and channel shifting.

2.2.8 Project Operations

2.2.8.1 Diversion

Electron operates year-round except for a shut-down during the entire month of June and emergency shut-downs. It operates on a run-of-the-river basis. The June shut-down is scheduled to coincide with the peak of the downstream juvenile salmonid migration. The shut-down also coincides with a high concentration of sediment load in the Puyallup River.

Deposition of sediment upstream of the dam often causes the low flow channel to move away from the intake and precludes water diversion. Flashboards are added to the dam crest at low flows to get water to the intake.

2.2.8.2 Instream Flow

A minimum instream flow of 80 cfs is passed downstream of the diversion dam during salmon and steelhead upstream migration periods (July 15 through November 15) and 60 cfs otherwise (per 1997 Resource Enhancement Agreement). Low flow is managed by monitoring the combination of flows in the fishway, rock chutes, and over the diversion dam. The instream flow requirement is based on fish passage through the canyon below the intake. Introducing some of the instream flow somewhere downstream of the intake might be acceptable.

Maintaining instream flow and where the instream flow is measured have an affect on screening options and/or power production. If a bypass is required to return fish to the river from a location far downstream of the intake, that flow is not part of the instream flow or the powerhouse flow.

2.2.8.3 Sediment Management

The first sediment management within the diversion is the pair of rock chutes located in the flume just downstream of the intake. At least one of the rock chutes is continuously operated, using about 20 cfs. They have a capacity of 60 cfs. The rock chutes are capable of moving most gravel and larger material from the flume. Smaller material is carried to the settling basin. The rock chutes get overwhelmed with bedload at times, fill up, and bedload is passed down the flume.

Sediment is removed from the settling basin on an as needed basis throughout the year by excavation with a track hoe during annual outages. Removed material is stored adjacent to the settling basin. Operators report they have estimated that about 400,000 cubic yards of material is excavated per year, which might include material excavated from the forebay. There is also a sluice at the settling basin that can be used to move material from the basin onto the slope between the basin and the river. Sluicing of material from the settling basin occurs during emergency conditions when high river flows and suspended sediment cause rapid filling of the settling basin. Sediment excavated from the settling basin was inspected during the site visit and sizes were estimated visually. The material varies in size through the length of the basin with it being very coarse sand (1.0 - 2.0 mm) and finer near the upstream end and very fine sand (.062 - .125 mm) and finer near the downstream end. The sediment at the downstream end is characteristic of what is also deposited at the forebay. Samples of sediment from each end of the settling basin were collected for sieving but have not yet been analyzed. Figure 6 shows the settling basin before and after the June 2008 shutdown and cleaning. The large pile of sediment next to the basin represents a portion of the sediment removed in a single cleaning.

Figure 6. Settling Basin April 25, 2008 (left) and October 14, 2008 (right)

PSE shuts the diversion and powerhouse down during the month of June for regular maintenance. The forebay is drained and sediment is excavated during the annual outage.

3 FISH PASSAGE AT ELECTRON PROJECT

Ideas for fish passage options were collected from participants during the field trip, the 1996 MW report, and a brainstorm session among the study team.

A variety of general approaches were considered, including:

- Screen fish at the intake and prevent them from entering the flume.
- Divert all fish from the flume near the intake and bypass them back to the river.
- Divert all fish from the flume near the settling basin and bypass them back to the river.
- Divert all fish from the flume near the forebay and truck fish to the river.
- Allow fish to pass to forebay and improve collection facilities there, and truck fish to the river.

We also considered sediment management improvements that would improve some of the potential fish passage options.

Based on the scope for this work, the goals of this paper are to perform an initial cursory review to suggest fish protection alternatives that may warrant further study. These include the full range of alternatives that would meet state and federal resource agency criteria, along with alternatives that may typically be considered experimental or interim measures, but could provide real benefits over the existing system. This latter group was included not only because they may represent less expensive alternatives but more importantly because the study team believes that the hydraulic and bedload conditions near the intake, where fish could be returned most expediently to the river, are not conducive to a facility that totally satisfies agency screening criteria. To be feasible, alternatives must accommodate site conditions. We considered alternatives with mixes of high and low capital cost and operations & maintenance (O&M) costs.

The options were refined to a point that they could be briefly described and evaluated. Of those, five were selected as most feasible and were further developed to ensure their feasibility and to estimate their relative costs and benefits. Feasibility was based on a very cursory review of site conditions for construction and operation, level of fish protection, and an estimated opinion of probable construction cost.

3.1 EVALUATION PARAMETERS

The following parameters were considered when selecting options for further consideration.

- Fish protection effectiveness and certainty
  - Goal is to protect all life stages and species present.
  - Tested technologies are more certain than experimental.
  - Locations near intake result in less exposure of fish to the flume, less handling of fish at a collection site, and less exposure to bypass systems, and therefore less risk to fish. This is based on the assumption that there does not need to be a permanent evaluation facility. We conferred with the Puyallup Tribe on this and they agreed. The added handling therefore refers to holding, trucking, hauling, and release operations at a facility at the forebay, for example, compared to a bypass directly to the river.
  - Locations near the intake result in less stranding of fish within the flowline when it is shut down.
  - Screen facilities in low velocity environments (less than about 3.0 fps) are easier to design and operate.
  - Opportunity for trapping and monitoring fish is <u>not</u> an evaluation parameter.
  - A good gravity bypass is more benign and less costly to operate, and reduces delay and exposure inherent in a holding and hauling operation.

- Operational certainty
  - A screen that does not operate continuously because of sediment or other issues is less protective than one that does.
  - Screening in a high sediment concentration is more effective with small-grained material than larger.

- Risk to flowline and facilities
  - Facilities that do not accumulate ice and/or sediment are less risky
  - Screens near the headworks might have less risk than screens located further down the flowline because any blockage that might cause the flume to be backwatered generally has less consequence when there is less length of flume affected and the elevation above the river is less.

- Cost
  - Capital and O&M costs
  - Operational demand
  - Access and power availability

- Several screening options are feasible only if the existing dam, fishway, and intake are rebuilt. Costs of a new dam were not considered and those options were not ranked high.
- Consider a mix of high-capital/low-O&M versus low-capital/high-O&M costs.

- Constructability
  - Common construction materials and practices.
  - Consider likely slope stability, foundation suitability, construction access, etc.

- Fish passage criteria (criteria are summarized and discussed in the next section).

3.2 FISH PASSAGE DESIGN CRITERIA

Washington Department of Fish & Wildlife and NOAA Fisheries (NMFS) publish criteria and guidelines for the design and operation of fish protection screens. Facilities that comply with existing agency design criteria are more acceptable and certain of success. Table 1 summarizes the state and federal criteria that are most relevant to this project and that might affect the location or scale of the project. The following documents were referenced to provide the information provided in Table 1.

- *Anadromous Salmonid Passage Facility Design*, National Marine Fisheries Service, Northwest Region, February 2008.
- *Fish Protection Screen Guidelines for Washington State*, Washington Department of Fish & Wildlife, April 25, 2000.

Table 1. Summary of WDFW and NMFS fish screen criteria.

Criteria/Guideline	Design Value	Notes
Screen		
Screen Location	In river if possible. If in canal, as close to the intake as possible.	Management of extreme sediment load may control location.
Approach Velocity	0.4 fps	This is intended to protect fry. It controls screen area and size of structure. Several options exceed this criterion.
Uniform Approach Velocity	Nearly Uniform Distribution	This is usually achieved with baffling behind the screens to distribute flow.

Criteria/Guideline	Design Value	Notes
Sweeping Velocity	0.8 fps min 3.0 fps max	Sweeping velocity must not decrease along face of screen, which will control geometry of screen bay. Sweeping velocity may exceed maximum so sediment remains suspended.
Inclined Screen Face	Less than 45 degrees from horizontal. Minimum 1.0 foot bypass depth.	Screen area is calculated using the vertical projection of the screen height, which adds screen area in a screen that is not vertical. An exception is allowed if bypass is efficient.
Screen Mesh Opening Size	1.75 mm	Assumes slotted screen material. This greatly affects passage of sediment. Several options exceed this criterion.
Screen Material	Corrosion Resistant	Screen material must also be sufficiently durable to maintain a smooth uniform surface with long term use.
Screen Cleaning	Automatic Screen Cleaning	Screens shall be automatically cleaned as frequently as necessary to prevent accumulation of debris. Must clean when screen headloss exceeds 0.1 ft.
Bypass		
Bypass location	Bypass required at downstream end of screen.	
Bypass Entrance Geometry	Full depth. 18” wide min	This assumes a slot bypass. Does not relate to inclined screen geometry.
Bypass Entrance Velocity	110% of canal velocity approaching	This, with bypass entrance geometry and number of bypasses, controls bypass flow requirement. Bypass flow can be screened with secondary screening to reduce final bypass flow. Secondary screened water would be pumped back to flowline.
Screen Exposure Time	60 seconds max	Assumes fish travel past the screen face at the speed of the sweeping velocity. Otherwise multiple bypasses required.

Criteria/Guideline	**Design Value**	**Notes**
Bypass Conduit		
Material	Smooth and durable Wide bends	Typically HDPE pipe. Bend R/D > 5.0.
Bypass flow	12.5 cfs min	Flow also governed by bypass entrance described above.
Bypass Water depth	9.5”	
Bypass Water velocity	6.0 – 12 fps	Other ranges allowed with special design of bypass pipe
Bypass Hydraulics	Open channel flow	If open channel flow is not feasible, a closed conduit must not have negative pressure.
Bypass outfall	Outfall into pool with velocity to distribute fish	This is difficult in a river channel that changes frequently.

Of these criteria, the approach velocity and mesh opening size are most critical to this project. These criteria are intended for protection of fry-sized (30 to 60 mm) fish. These criteria, however, will be difficult to achieve where they may cause accumulation or blockage of sediment movement in the canal. The screen mesh size opening can physically block passage of large sand. A low approach velocity can cause sediment to settle and accumulate rather than stay in suspension and moving.

The approach velocity is especially critical in this case because of a wide variation in diversion flow with a high concentration of suspended sediment. The approach velocity is not the actual water velocity; it is just one component of the actual water velocity and therefore does not control deposition on its own. However, the lower the approach velocity, the more care must be given to not allowing deposition. Also, this criterion is based on smallest fish (28 mm) and lowest probable water temperature (34 deg) and might be increased for other conditions and high sweep velocity.

3.3 FISH PASSAGE OPTIONS

This section provides descriptions of the five highest-ranking options based on the parameters listed above. These five options were considered most feasible and are developed with further detail than the others. The next phase of feasibility design should include at least several of these options. Each option is described as an entire system. Some systems necessarily include additional sediment control or modification to the flume or other existing facilities. A conceptual-level range of probable construction cost and additional information needs are included for each. A comparison of the five options including pros and cons is included at the end of this section. Section 3.4 provides brief descriptions of all other options that were considered.

There are five preferred options recommended for further feasibility design. These are the preferred options listed in order to generally group types of screens together.

- Plate fingerling screen near intake
- Plate fry screen downstream of settling basin
- Inclined fingerling screen near intake
- Inclined fry screen downstream of settling basin
- Improve existing forebay trap and holding

Sub-options are also described. For example, Option 2, the plate screen downstream of the settling basin, might be located within the settling basin, just downstream of it, or at the end of the flume near the forebay. If it is at or near the settling basin, it might include a bypass to the river or fish might be hauled. There are therefore as many as three sub-options for that design.

Two of these options do not target fry-sized fish less than 60 mm in length. Those options would be eliminated if the decision were made to specifically target fry-sized fish. The Puyallup Tribe has stated as a comment to a draft of this document, “The Tribe feels strongly that whichever screen design(s) is ultimately selected that it must effectively protect fish of all sizes.” We have kept those options in the list for further consideration because we don’t have enough information to be certain that sediment issues can be resolved adequately for a fry screen.

Additionally, sediment management improvements are recommended. Various sediment management improvements would improve the effectiveness and operation of any of the screening options. Several sediment management options are listed here but not developed since PSE may be investigating that issue independently.

3.3.1 Option 1 - Plate Fingerling Screen Near Intake

3.3.1.1 Description

Option 1 is a traditional flat plate screen facility in a long bank of screen panels, or a vee screen configuration similar to White River screen owned by PSE. It would be located in the flowline downstream of improved and/or expanded rock chutes.

- Design as fingerling screen (1/4" screen opening, 0.8 fps approach velocity) designed to pass all sediment that is not diverted at rock chutes. The trade-off of the fingerling screen is that the screen can be located near the intake to minimize exposure of fish to the flume and to provide a gravity bypass to the river.
  - Further study would be required in the next phase of concept development to assess the feasibility of this approach given the sediment loading conditions and/or the likelihood that the screen could become overwhelmed during high flow events.
  - Fry screen near intake has the risk of being plugged with sediment. Very course sand, which is larger than the allowable opening in a fry screen, currently passes through this section of the flume and is deposited at the settling basin and forebay downstream.
  - The higher velocity would control deposition at the screen.
  - Multiple parallel screens might be needed to maintain sweeping velocities even at low diversion flows.
  - Fingerling screen is likely to safely divert a high percentage of fry, even though theoretically the smaller fry could fit through the screen. Those that are not diverted would be passed downstream to the settling basin and forebay, or, more likely, impinged on the screen.

- The existing forebay trap and screen could be preserved as a backup or for evaluation of fry protection at a fingerling screen.

- Cleaning
  - Locate screen downstream of improved rock chutes
  - Screen cleaning would be with an air burst cleaning system
    - Brush cleaning will be problematic in high velocity flow and with large caliber sediment potentially depositing at base of panels.
    - A sloping face screen could be used to optimize the air burst cleaning. A vertical flat plate could also be used.

  - Sediment deposited can be re-suspended with an air-burst cleaning system. The ability to re-suspension fine silt particles that have deposited is uncertain and should be tested.
- Sediment sumps and sluices could be provided in the floor of an expanding section of flume upstream of the screen bay to deposit and sluice material as the flume expands and velocity decreases.

- Bypass would route fish back to near the base of the dam. There does not appear to be good bypass outfall sites beyond several hundred feet below the dam.
  - The operational range of a bypass in this area may be limited by backwater from the river, which can reduce the capacity of the bypass and can cause deposition within it.

- Existing rock chutes would be optimized or replaced to try to remove all sediment greater than ¼ inch.
  - A series of rock chutes might be constructed in the floor of an expanding screen section of the flume. Smaller material would deposit and be sluiced as the velocity decreases.
  - Hydraulic profile through rock chutes, potential sluicing, and effects of river backwater are not clear with the information available.

- There is a risk of screen plugging, backing up the flow line, and causing an uncontrolled spill from the flume. Raised walls and an overflow section would divert flow back to the river in a controlled location.
  - Alternatively, a section of the screen could collapse to pass the flow.

- There is only generator power at the site.

Figure 7 shows the general vicinity within the flume where Option 1 would be located. Inset within Figure 7 is a view of the existing White River screen facility for reference. The White River screen is sized for up to 2,000 cfs at the fry approach velocity criterion of 0.4 fps. A 400-cfs screen designed to fingerling criteria at Electron would be approximately 10-15% the size of the White River Screen.

Figure 7. Location of Option 1 (with White River fish screen for reference)

3.3.1.2 Range of Probable Construction Cost

An estimated range of probable construction cost for Option 1 was developed based on the general description above and the cost of fish screen facilities at other sites. Given the very preliminary nature of the concept, and the limited information available at this point in the study, a wide range of probable construction cost is considered. Further development of the concept in future phases of this study will help refine the cost estimate; however, the range is useful in the context of this preliminary assessment in that it can be compared to the estimated ranges of cost for the other options to help focus the goals of future study phases. The range of probable construction cost for Option 1 is estimated to be $3,000,000 to $9,000,000.

This range does not include lost generating revenue during construction. A construction flume bypass could be constructed to minimize plant down-time though would be expensive for this option considering the need to reconfigure the section of the flume with the rock chutes as well. An assessment of these costs, or the costs of operation and maintenance are beyond the scope of this preliminary assessment of options.

3.3.1.3 Additional Information Needs

- Rating curve of flume
  - Actual screen area and bypass feasibility are not known until a rating curve shows the relationship of diversion rate to water level in the flume.

- Rating curve of dam tailrace
  - Tailrace rating curve is needed to calculate hydraulics of fish bypass, rock chutes, and sediment sluices. It's not clear whether there is adequate head to operate a screen bypass in the range of conditions from high flume flow to low flume flow with high river flow.

- Hydraulic profile through intake and flume to flood gates.
  - The hydraulic profile will reveal how much headloss can be expended through the screen system.

- Efficacy of sediment management
  - Screen options near the intake depend on improved sediment management either at the dam and/or within the flume. The ability to extract small gravel could be tested.

- Power requirements

3.3.2 Option 2 - Plate Fry Screen just Downstream of Settling Basin

3.3.2.1 Description

Option 2 is a traditional flat plate screen facility in a long bank of screen panels, or a vee screen, similar to Option 1 - Plate Fingerling Screen Near Intake except it is designed to fry criteria (3/32" screen opening, 0.4 fps approach velocity) and located at the downstream end of the flume near the forebay or at the downstream end of the settling basin. A fry screen can be successful here because sediment that passes the settling basin can pass through the screen.

- If located at forebay, collect and truck fish to river release point.
  - Secondary dewatering screen, pump extra water to forebay.
  - Holding, crowding, truck loading facilities could be by gravity.

- If located at settling basin, bypass to river.
  - Bypass pipe: 18-inch diameter, 2500 feet long, 20-30 cfs bypass flow, 250 feet of elevation drop at 8% slope, maximum velocity of 25 fps.
    - Length is greater but slope is less than White River bypass.
    - Velocity exceeds the bypass velocity criterion.
    - Bypass route, topography, slope stability, and outfall feasibility have not been investigated other than on a USGS topographic map.
    - Bypass flow would be subtracted from instream flow or power flow. Bypass enters Puyallup River about 3.2 miles below intake.
    - If taken from the instream flow, the flume from the headworks to the settling basin would need a capacity for the additional bypass flow.

- There is some risk of screen plugging, backing up the flow line, and causing spill from the flume. There is an existing spillway upstream of the forebay. There is no spillway from the flume upstream of the settling basin. An additional spillway could be designed into the flume or settling basin or a section of the screen could collapse to pass the flow.

- There is no power, communication equipment, or other facilities at the settling basin site.

Figure 8 shows the downstream end of the flume where it enters the forebay, looking downstream into the forebay and upstream along the flume. This is the area that would be modified to accept the screen and trapping facility associated with Option 2 at the forebay. Figure 9 shows the downstream end of the settling basin, where the flow reenters the flume. This is the alternate location for Option 2 that might possibly include a piped bypass back to the river.

Figure 8. Downstream End of Flume at Forebay (looking downstream left and upstream right)

Figure 9. Downstream End Settling Basin

The settling basin site is much less feasible than the forebay site but is described here to provide an option with fry protection but that minimizes the exposure of fish to the flume. Trade-offs between the two sites involve long-term fisheries and cost concerns, and will require consideration beyond the scope of this assessment. The tradeoff for fisheries is the effect of fish being exposed to four additional miles of the flume and the holding and handling involved in trucking versus the potential effects of 2,500 feet of steep high velocity bypass pipe and discharge into a potentially unstable river condition. The cost consideration involves the cost of trucking fish from the forebay site versus lost revenue due to bypass flow at the settling basin site. Not only is the bypass flow lost to generation, but since the bypass is far downstream of the diversion, it could not contribute to the in-stream flow which would have to be passed at the dam. Based just on mean monthly flows as shown in Figure 5, the bypass flow would reduce power generating flow for as much as five months of the year. Since these are mean monthly flows, the actual reduction may vary from that. The flume would have to have capacity for the bypass flow in addition to power flow. The diversion water right would also be affected.

3.3.2.2 Range of Probable Construction Cost

Option 2 will be more expensive than Option 1 for two significant reasons. A screen designed to meet the fry criteria for fish screening will be twice the size of a screen designed to meet fingerling criteria, and there will be cost associated with transporting the fish, either trapping, holding, and truck loading facilities or a long fish bypass pipe to be installed on steep terrain from the settling basin down to the river. Therefore, a range of probable construction costs for Option two is estimated to from $6,000,000 to $18,000,000.

This range does not include lost generating revenue during construction. A construction flume bypass could be constructed to minimize plant down-time. This might be a reasonable approach if the facility were located at the end of the flume near the forebay, but could be the very expensive if located at the settling basin considering the uncertainties of the topography at the screen location.

3.3.2.3 Additional Information Needs

- Efficacy of sediment management.
  - The ability to re-suspend settled fines should be tested.

- Forebay site.
  - Suitability of spillway operation upstream of the forebay.

  - Feasibility of flume bypass during construction.

- Settling basin site.
  - Constructability of screen site.
  - Constructability of bypass pipe.
  - River conditions (stability, rating curve, etc.) in vicinity of potential bypass outfall.
  - Feasibility of flume bypass during construction.
  - Locations, capacities, effects of flume spillways upstream of settling basin.
  - Rating curve of flume below settling basin.
  - Power requirements.

3.3.3 Option 3 - Inclined Fingerling Screen Near Intake

3.3.3.1 Description

Option 3 is an inclined plate screen at same general location as Option 1 - Plate Fingerling Screen Near Intake. An inclined screen would span across the flume and slopes upward in the downstream direction so the leading edge is near the floor and the downstream end is just below the water surface. The fish and debris bypass is the water flowing over the downstream end of the screen.

- Design as fingerling screen (1/4” screen opening, 0.8 fps approach velocity) designed to pass all sediment that is not diverted at rock chutes. Further study would be required in the next phase of concept development to assess the feasibility of this approach given the sediment loading conditions and/or the likelihood that the screen could become overwhelmed during high flow events.

- Screen is inclined and hinged at the leading edge or in segments. Automatic controls would operate screen to maintain depth into bypass at all flume water levels.
  - Screen configuration requires seals between the edges of the screen and the flume walls and a complex mechanism to control the elevation of the screen.
  - Consider a pair of parallel screens in separate bays to operate at better efficiency through wide flow range and better management of bypass flow.

- Locate downstream of improved rock chutes.

- Screen could have operable sediment sluice at base. In that case, only the upper column would be screened. Sluice would return to river.

- Fish bypass would be routed back to as close to the base of the dam as possible. There does not appear to be good bypass outfall sites further than several hundred feet below the dam. The operational range of a bypass in this area may be limited by backwater from the river, which will reduce the capacity of the bypass and can cause deposition within it.

- Existing rock chutes would be optimized and or enlarged to try to remove all sediment greater than ¼ inch.

- There is a risk of screen plugging, backing up the flow line, and causing a spill from the flume. Screen could automatically lower to the floor to facilitate flushing debris from the screen, and/or include a collapsible section in case of screen failure or plugging.

- There is only generator power at the site.

Figure 10 provides a conceptual sketch of an inclined screen that could be located in a modified section of the flume.

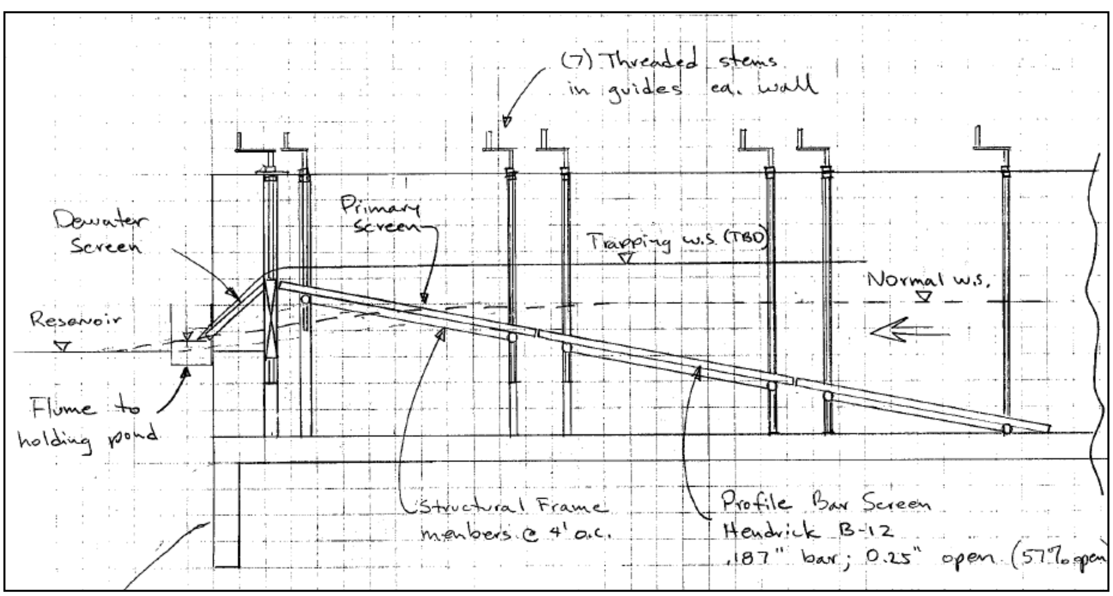

Figure 10. Inclined Screen Concept Sketch

3.3.3.2 Range of Probable Construction Cost

Although the inclined fingerling screen in Option 3 would be similar in size to the screen in Option 1, since they are both designed to fingerling criteria for the same flow rate, Option 3 would be expected to be somewhat more expensive. This is because Option 3 is a movable screen requiring seals between the edges of the screen and the flume walls, a durable hinge mechanism at the upstream end, a means of collecting the fish flow from the downstream end of the screen and bypassing it to the river, and a complex mechanism to control the elevation of the screen. An estimated range of probable construction costs for Option 3 is $4,000,000 to $12,000,000.

This range does not include lost generating revenue during construction. A flume bypass during construction could be built to minimize plant down-time though would be expensive for this option considering the need to reconfigure the section of the flume with the rock chutes as well and complications of the site.

3.3.3.3 Additional Information Needs

Same as for Option 1 - Plate Fingerling Screen Near Intake

3.3.4 Option 4 - Inclined Fry Screen Downstream of Settling Basin

3.3.4.1 Description

Option 4 is similar to Option 3 - Inclined Fingerling Screen Near Intake except would be designed to fry criteria and be located similar to Option 2, either at the forebay or at the settling basin. A fry screen can be successful here because sediment that passes the settling basin will pass through the screen.

- Trucking fish or bypass same as Option 2 - Plate Fry Screen just Downstream of Settling Basin

3.3.4.2 Range of Probable Construction Cost

As was the case for Option 3 versus Option1, Option 4 would be expected to cost somewhat more than Option 2 at the same location. An estimated range of probable construction cost for Option 4 is $7,000,000 to $21,000,000.

This range does not include lost generating revenue during construction. A flume bypass during construction could be built to minimize plant down-time though issues would be the same as those discussed for Option 2.

3.3.4.3 Additional Information Needs

Same as for Option 2 – Plate Fry Screen Downstream of Settling Basin

3.3.5 Option 5 - Improve Existing Forebay Trap and Holding

3.3.5.1 Description

Option 5 would improve the existing collection and trap facilities at the forebay. Changes would be made to the guidance net, the trap, and holding facilities.

- Improve the net by attaching to permanent float system or frame. A track on the float or frame would deploy and recover net. Net would not sink when loaded with debris and sediment.
  - Alternatively, replace net with a vertical plate screen and solid guide walls. Cleaning would be done with a mechanical rake.

- Optimize hauling operations. Daily operations would reduce injury to fish in trap.

- Reconfigure trap.
  - Narrow the screen channel towards the downstream end of the bay, add a conventional bypass and a holding area downstream of the screen bay.
  - Replace trap weir with sloping high-velocity screen or finger weir and reduce head differential at trap entrance. The sloping screen would trap fish and the reduced head differential would reduce turbulence and fish injury in the trap.

3.3.5.2 Range of Probable Construction Cost

Given the spectrum of possible approaches and components associated with this concept for fish passage improvement no construction cost estimate has been developed. However, it is reasonable to assume that some level of improvement to the existing facilities could be realized for significantly less cost than is associated with the other four options. Making all of the improvements listed above could bring the cost up to something similar to those for Option 1 or Option 3.

This range does not include lost generating revenue during construction. If a rigid screen is constructed in the forebay, no bypass is possible. If an improved net were constructed and attached to permanent floats, no power down-time would be needed though the fish collection facilities would be shut down for several months.

3.3.5.3 Additional Information Needs

- Suitability of forebay for rigid screen and guidewalls.
- Downtime required for construction.

3.3.6 Comparison of Options 1 – 5.

Table 2. Comparison Considerations for Options 1 - 5

	1 – Plate Fingerling Screen Near Intake		**2 – Plate Fry Screen Downstream of Settling Basin (assume at forebay)**		**3 – Inclined Fingerling Screen Near Intake**		**4 – Inclined Fry Screen Downstream of Settling Basin (assume at forebay)**		**5 – Improve Existing Forebay Trap and Holing**	
Consideration	**Pros**	**Cons**	**Pros**	**Cons**	**Pros**	**Cons**	**Pros**	**Cons**	**Pros**	**Cons**
Fish protection effectiveness and certainty	Minimizes fish exposure to canal and delay Few fish lost during diversion shut-down Bypass flow used as part of in-stream flow below dam	Does not protect all fry	Protects all life stages	Screen bypass flow must be subtracted from either in-stream flow or power flow Minor delay of fish through settling basin Fish passing through settling basin exposed to dredging operation Fish in flume and settling basin when flume shut down may be lost. Fish must pass down a long, high-velocity bypass pipe.	Minimizes fish exposure to canal and delay Few fish lost during diversion shut-down Bypass flow used as part of in-stream flow below dam	Does not protect all fry	Protects all life stages	Screen bypass flow must be subtracted from either in-stream flow or power flow. Bypass flow might be higher than for plate screen. Minor delay of fish through settling basin Fish passing through settling basin exposed to dredging operation Fish in flume and settling basin when flume shut down may be lost. Fish exposed to long, high-velocity bypass pipe.	Existing trap is a known entity and improvements to it are therefore likely to at least improve protection over existing conditions with a fair level of certainty	Some delay and potential loss of fish through settling basin and forebay Fish passing through settling basin are exposed to dredging operation
Operational certainty		Exposed to greatest sediment load	Largest sediment at the location is silt, which should pass through screen. No additional sediment management needed.		Long seals and mechanical screen operator are complex and subject to wear and failure.	Exposed to greatest sediment load Articulating screen panel has mechanical complexity	Largest sediment at the location is silt, which should pass through screen. No additional sediment management needed. Screen seals and mechanical screen operator are complex and subject to wear and failure.		Existing trap is a known entity operationally	

	1 – Plate Fingerling Screen Near Intake		**2 – Plate Fry Screen Downstream of Settling Basin (assume at forebay)**		**3 – Inclined Fingerling Screen Near Intake**		**4 – Inclined Fry Screen Downstream of Settling Basin (assume at forebay)**		**5 – Improve Existing Forebay Trap and Holing**	
Consideration	**Pros**	**Cons**	**Pros**	**Cons**	**Pros**	**Cons**	**Pros**	**Cons**	**Pros**	**Cons**
Risk to flowline and facilities	Little risk because of location near intake.			Some risk of screen plugging causing spill from flume	Little risk because of location near intake.			Some risk of screen plugging causing spill from flume	No risk to flowline or facilities	
Cost	Lower capital cost than fry criteria screens with trucking or long bypass facilities Lowest likely operating cost		If located at settling basin, operating cost relatively low though higher than fingerling screen because larger facility	High operating cost includes hauling from forebay site. If located at settling basin, affected by long bypass and larger fry criteria screen	Lower capital cost than fry-criteria screen with long bypass (but likely higher than a plate screen in the same location)	Operating cost higher than plate screens because of mechanical and seal complexities	If located at settling basin, operating cost relatively low though higher than fingerling screen because larger facility	High operating cost includes hauling from forebay site. If located at settling basin, affected by long bypass and larger fry criteria screen		Highest operating cost due to holding and hauling fish and pump operation.
Constructability	Good location and access for construction. Flume bypass during construction likely feasible. Local generator power and communication equipment at site.			If located at settling basin marginal and uncertain constructability. If located at settling basin long bypass route across unknown slope conditions with no current access. If located at settling basin it is more isolated than others. No power or facilities currently at site If located at settling basin flume bypass during construction may not be feasible	Good location and access for construction Flume bypass during construction is likely feasible Local generator power and communication equipment at site			If located at settling basin marginal and uncertain constructability. If located at settling basin long bypass route across unknown slope conditions with no current access. If located at settling basin site it is more isolated than others. No power or facilities currently at site If located at settling basin flume bypass during construction may not be feasible		Flume bypass during construction is likely feasible. Power operations would have to be shut down for some construction

3.4 SCREEN ALTERNATIVES CONSIDERED BUT NOT RANKED HIGH

The following additional options were introduced during the site visit or in the brainstorm session and later dropped because of fatal flaws, or because they are less feasible or less protective of fish than the selected options. Each option is briefly described along with significant disqualifying faults. All of these screens are assumed to have a capacity for the full 400 cfs diversion flow. Several of these are judged infeasible because of the headloss they create. If the dam and intake were reconstructed to maintain a higher hydraulic profile within the upper end of flume, these might become more feasible.

3.4.1 Group 1 – Screen at Diversion Dam

- **Infiltration Gallery**
  An infiltration gallery is a series of perforated galleries buried in the channel upstream of the diversion dam. They draw water from beneath the river bed and deliver it through a manifold system to the flume.
  - High uncertainty and risk of failure especially in high sediment environment and high proportion of river flow being diverted.
  - Diverted flow capacity would be much higher than common infiltration galleries.
  - Percentage of overall flow being diverted is much higher than common infiltration galleries.

- **Coanda Screen at Dam**
  A coanda is a down-sloping screen shaped like an ogee. Water flows over the top and down the sloping face. The diverted flow passes through the screen and the bypass drops into a channel at the bottom of the screen and is diverted back to the river. This option would be built into the downstream crest of the diversion dam and span the entire dam crest length. Its greatest benefit is that large sediment is not diverted from the river channel.
  - Hydraulics of existing system not clear. Coanda screen requires several feet of head loss as water drops through the screen.
    - This option would likely require an entire new dam with higher crest elevation. The fishway would have to be extended.
    - Coanda benefits are not possible with a wide range of river flows unless the dam crest is divided into bays with control gates.
  - Requires maintaining an even distribution of flow over the crest of the dam, which commonly doesn’t occur due to sediment deposition upstream of the dam.

- **Coanda Screen in the Canal**.
  This coanda screen would be built into the downstream face of a long weir within a wall of the canal near the intake. Overflow, including fine sediment and fish, would drop into a chute and back to the river.
  - Requires several feet of head loss as water drops through the screen.
  - Requires substantial bypass flow.
  - Coanda benefits are not possible with a wide range of canal flows. A series of screen bays would be used and selected bays would operate depending on flow.
  - Requires a nearly constant water level within the canal regardless of flow, which may not be possible without raising the dam.
  - Constant water level in the flume would likely result in excess deposition upstream of the screen weir.

- **Sloping Flat Plate Screen in Front of Intake**
  A screen with trash racks, a deep sluice channel, and control gate would be added to intake. Sediment would be managed by sluicing from a channel at the face of the screen. The screen would be sloping primarily so an air burst cleaning system could be used. This would require a major or entire rebuild of the diversion dam.
  - Low probability of successful sediment management and constant dredging to keep intake area clean. Assuming 0.4 fps approach criteria and six feet deep, screen and sluice channel are about 100 feet long. Large sediment cannot be sluiced from such a long sluice channel.

- **High Velocity Wall Screen**

A wall screen would be constructed in the left wall of the flume just inside intake. It might be about six feet high and 85 feet long. The high velocity flow would constantly sluice sediment past the screen, through a fish bypass slot, and back to river. Flow control devices would be needed downstream of screen to backwater the screen and also downstream of bypass slot to control flow.

  - An advantage of a wall screen is that any deposition occurs in the flume or sediment sump at the base of the screen rather than on the face of the screen.
  - Vertical screen requires brush screen but is not practical in high velocity flow.
  - Hydraulics of sluicing flow is problematic with changing diversion flows and water level.
  - Screen should be located downstream of a headgate so screen can be dewatered and maintained.

– If located near headgate, turbulence at screen face can negatively affect fish protection.

3.4.2 Group 2 – Screen within Flume

This includes any criteria exclusion screen located from downstream from head gate to downstream end of the settling basin.

- **Plate Fingerling Screen near Intake.**
  Preferred Option 1; see description above in Section 3.3.1.

- **Plate Fry Screen just Downstream of Settling Basin**
  Preferred Option 2; see description above in Section 3.3.2.

- **Inclined Fingerling Screen Near Intake**
  Preferred Options 3; see description above in Section 3.3.3.

- **Inclined Fry Screen Downstream of Settling Basin**
  Preferred Options 4; see description above in Section 3.3.4.

- **Farmers' Screen near the Intake**
  A Farmers' screen is a flat horizontal screen; the water flows over the screen at a high velocity and the diversion flow drops down through it. For this situation, the screen might be in the floor of two adjacent flumes, each varying in width from four to two feet and 100 feet long. The bypass and sediment flow over the downstream end of the screen and is flumed back to the river channel. It is different than the inclined screen described as Options3 and 4 in that it is at a fixed elevation and horizontal.
  – Requires consistent water level with varying canal flow, which may not be possible without raising the dam crest.
  – Sediment deposition on the screen will be problematic at lower flows since there are commonly high sediment loads even with low diversion rates, when the canal velocity will be low. Splitting the screen into adjacent flumes is an effort to keep velocities high; additional parallel screens could be added though each one also adds additional bypass flow requirement.

- **Tee Screens in Canal**

Prefabricated cylinders with profile bar screen faces could be mounted in a widened section of flume. They would deliver diverted water to an adjacent flume and the flowline. The screens would be cleaned with an air burst system.

- Located in high velocity flume so sediment continuously moves past screen, to bypass or rock chute, and back to river.
- Size of screen cylinders would require widened flume, which would result in excess sediment deposition. By the time the last of the diverted flow is taken through the tee screens there won't be enough flow or velocity remaining in the flume to continue suspension and transport of sediment.
- Size of screen cylinders would also require greater depth than currently available at low flows.

3.4.3 Group 3 –Screen in Forebay

- **Improve Existing Trap and Holding**
  Preferred Option 5; see description above in Section 3.3.5.

- **Plate Screen at Canal Exit**
  This is the same as <u>Option 2 - Plate Fry Screen Downstream of Settling Basin</u> except it is located near the end of the flume at the forebay. Fish would be bypassed to a holding area and hauled by truck. This is as feasible as that Option 2 though fish would be exposed to the entire flume and fish would be trucked from the bypass instead of through a gravity bypass. This could be considered as an alternative to Option 2 if a bypass pipe from the settling basin down to the river is found to be not feasible.
  An emergency flume bypass to the forebay would alleviate risk of screen plugging. There is also an emergency spillway just upstream.

- **Inclined Screen at Canal Exit**
  This is the same as <u>Option 4 - Inclined Fry Screen Downstream of Settling Basin</u> except it is located near the end of the flume at the forebay. Fish would be bypassed to a holding area and hauled by truck. This is as feasible as that Option 4 though fish would be exposed to the entire flume and fish would be trucked from the bypass instead of through a gravity bypass. This could be considered as an alternative to Option 4 if a bypass pipe from the settling basin down to the river is found to be not feasible.
  - An emergency flume bypass to the forebay would alleviate risk of screen plugging. There is also an emergency spillway just upstream.

- **Screen at Powerhouse Intake**
  - Flat plate screen in the forebay at the face of powerhouse intake. To control flow patterns at screen, an additional guide wall would be needed.
  - Fish bypass to a trap and bypass flow would be screened into the intake similar to the existing trap.
  - Fish would be hauled.
  - Structure would be costly.

3.5 SEDIMENT MANAGEMENT OPTIONS

Sediment management options are considered as a group because they might be combined with any of the screening options. They are most advantageous if used with the options located near the headworks. The value of optimizing sediment management in the context of fish passage is efficient sediment removal will greatly enhance those screening options and minimizing the flow needed for sediment management will increase the flow available for fish bypasses. The options are listed here in order of feasibility.

- Improve existing rock chutes for fish passage.
  - Slope the floor of the flume down to an abrupt rise back to the normal floor elevation at the location of the rock chute, rather than having a beam across the flume floor.
    - Should result in better hydraulics and less headloss in the flume.
    - With a series of chutes like this through a widening flume section, with decreasing flume velocity, smaller rocks and sediment can be removed upstream of the screen.

- Optimize rock and sediment sluices for sediment removal.
  - Objective would be to improve removal of cobbles and gravel with a minimum flow velocity to move sizes of rock.

- Sediment sluice in front of intake.

- Sediment sluices in screen bay.
  - Combine with as velocity decreases.

- Cyclone separator for entire diversion flow with screen downstream.
  - No known cyclone separators exist of this size.

- "Coal car" sediment sump beneath flume. Car would be filled, removed for disposal, and replaced with empty car.
  - Beneficial to minimize flow used in rock chutes.
  - Cars would have to seal against underside of flume and be removable when flume is in operation. This would be a difficult design.
  - Likely several separators so they are optimized through range of diversion flows
  - This does not appear to be feasible due to the quantity of sediment.

4 CONCLUSIONS AND RECOMMENDATIONS

The primary purpose of this investigation was to answer the question "whether or not improvements to the downstream fish passage system at Electron are feasible." We believe that improvements could be made. However, the extent of the resulting biological value associated with the improvements is not currently definable. The Electron Project is a very challenging site with respect to fish passage due to the extreme variations in the flows defined by the basin's hydrology, and the extreme sediment load that must be addressed with any solution. Because of these two key concerns, we were not able to define a clear path or linear work plan to define the "best" fish passage system based on our limited investigation.

We believe this complex site will be best served with an iterative approach where the stakeholders work together to define clear biological objectives within the context of the best possible technical solution based on further engineering feasibility analysis, with possible practical limitations on biological performance clearly understood. For example, locating any type of screen at the forebay would be technically more feasible due to bedload concerns; however, this requires fish to pass through the 10-mile long canal, and requires a trucking operation to return the fish to the river. Alternately, a fish screen located at the point of diversion might be better biologically, as downstream migrating fish would be kept in the natural river to the maximum extent possible. However, if this approach is not technically feasible due to the sediment loads and extreme flow fluctuations, a better understanding of the relative merits of these approaches would be in order. Alternatives defined at the settling basin or located elsewhere in the system could return fish to the river with a bypass pipe or with trucking, and each of these approaches has technical and operational tradeoffs. For example, a bypass pipe would require approximately 30 cfs, which would impact generating capacity or require an additional 30 cfs to be diverted. Trucking from an intermediate location may require road improvements and would be subject to the normal trucking risks.

With this understanding in mind, we offer the following suggestions on how best to proceed with any further investigations to improving downstream fish passage at the Electron project.

1. Resolve trade-offs of fry screen, screening location, and sediment.
   - Resolve varying interpretations of fish survival through the flume and forebay, and reach consensus on the biological efficiency and effect of the existing trap, including any reasons why performance may be less than desirable. A better understanding of the

effects of the flume will help to address whether a screen located at the settling basin or the forebay are able to meet biological fish passage goals.

- Evaluate the number of fry subjected to the project, and their biological value to the fish runs. If the fry currently entrained in the system end up being minimal, or their contributions to returning fish runs questionable, it would seem reasonable to consider compromising on the screening criteria to allow a coarser screen and higher approach velocities in order to better address the sediment loads on a fish screen located closer to the point of diversion. This approach would be more likely to result in a feasible screen and fish bypass system that could return fingerlings to the river without trucking.
- Perform a more thorough analysis to quantify the sediment loads and sediment characteristics, and the potential means suggested to address the sediment at the various screen locations. For example, one could study the following sediment management options:
  - Investigate option to optimize effect of rock chutes or other means
  - Investigate effects of water jets on settled and suspended sediment
- Determine whether or not screening at the existing intake should be included in the suite of fish passage alternatives. A total reconstruction of the dam and/or intake may make fish screening alternatives at the point of diversion more feasible; however, this would depend on the style of design of a new dam and is currently not known. We have assumed that additional costs necessary to reconfigure the dam and/or intake for fish passage would represent costs in addition to the alternatives addressed in this study, and were outside the scope of our analysis.

2. Choose options to further develop based on results from Item 1.
   - We recommend limiting the number of options in order to focus the analysis on alternatives that could most likely meet the biological and feasibility objectives.
   - Select preferred location for options downstream of settling basin (i.e., immediately following the settling basin, or at the forebay).

3. Perform a more thorough feasibility study of a refined list of alternatives. Once the above issues are better understood, additional engineering analysis will be required. This analysis would:
   - Address information needs for options chosen.

- Layout designs to scale, based on better site data (i.e., reconnaissance level surveying, hydraulic flow lines, etc.), and perform hydraulics analysis with an emphasis on sediment management.
- Define operational parameters and constraints for each option.
- Prepare detailed feasibility-level capital and operating cost estimates, including an estimate of lost power during construction and impacts to the project's generating capacity.
- Define biological risks and potential benefits for each alternative.

Based on the results of a more detailed engineering analysis and an opinion of biological performance, the stakeholders would be better able to recommend the most beneficial alternative for improved fish passage. An engineering feasibility analysis and report would likely take from six months to over one year, and could cost from about $75,000 to over $300,000 depending on the specific goals, information available at the beginning of the study, and on the number of alternatives to be evaluated.

APPENDIX A – COMMENT RESPONSES

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In Association with Kozmo, Inc.

Memorandum

Date December 2, 2008 *Project Number:* 1729.01/MM101

To: Electron Downstream Fish Passage Work Group

From: Dana Postlewait

Subject: Response to comments received on November 11, 2008 Draft White Paper titled: *Electron Project Downstream Fish Passage Improvement Concepts*

cc: Sam Stiltner, Puyallup Tribe

This memorandum documents pertinent technical comments received from the Electron Downstream Fish Passage Work Group regarding the subject draft white paper, the presentation by Kozmo and R2 on November 14, 2008, and the design team's recommended resolutions. Comments were received from:

PSE - Cary Feldmann, Puget Sound Energy. Via email with redlined white paper dated November 21, 2008.

PT - Russ Ladley, Puyallup Tribe. Via email dated November 26, 2008.

WDFW - Curt Leigh and David Mudd, Washington Department of Fish and Wildlife. Via phone call to Dana Postlewait on December 1, 2008.

Kozmo Bates and R2 are currently revising the draft white paper and will incorporate these comments and responses into the final version. This memorandum will be provided as an appendix to the white paper.

The technical responses listed below were developed by Kozmo Bates, Peter Christensen, and myself. We have numbered them in the order presented by each entity for reference ("PSE01" designates PSE comment 01).

PSE01: Need clear description of the limited scope and time for the study

> Agree. This will be provided with the final white paper.

PSE02: While these are products produced by R2 they were provided by PSE

> Agree. We will clarify with the final white paper.

PSE03: (Referring to ranked options) Rankings will be removed based on discussion during presentation.

> Agree.

PSE04: (Referring to the bullet "Location near intake result…" I don't see how the collection site comment is valid. The fish will have just as much handling at capture and evaluation, however, the bypass system will have more handling the further downstream the facility is built.

> We assumed that there does not need to be a permanent evaluation facility. We conferred with the Tribe on this and they agreed. The added handling therefore refers to holding, trucking, hauling, and release operations compared to a bypass directly to the river.

PSE05: With rankings removed I would recommend reordering intake, sediment basin, forebay.

> This is a logical order from upstream to downstream but we feel the explanation is easier to understand by grouping the plate screens together and the inclined screens together.

PSE06: If fry screening criteria were important, then two options disappear.

> Agree. We will leave the options in the list for further consideration however because we don't have enough information to be certain that sediment issues can be resolved adequately for a fry screen. We will include this comment.

PSE07: (Regarding Option 1 description/cleaning/"Sediment deposited can be re-suspended…") Given the adhesive nature of smaller sediment fractions this may be optimistic.

> Agree. This will be added as an information need.

PSE08: (Regarding Option 1 description/"Existing rock chutes…") Wouldn't this require a large reconfiguration of the flume in this location to permit ¼ materials to drop out? Moreover it the velocities and associated turbulence necessary to remove the 3-15 inch cobble previously noted in the description might be difficult to retain ¼ inch fraction.

> Agree. The flume would be re-configured for the screen and sediment management. There is currently only a small amount of material in the ¼-inch size range that currently gets to the settling basin. This implies that a large settling effort near the intake would not be necessary. We will describe potential options for sediment management in conjunction with modifications needed for the screen.

PSE09: (Regarding *Range of Probable Costs*) Note this does not include lost generation from construction. May want to estimate how much time it might take to do the work i.e., how much time the project would be out of service.

> Agree. This range does not include lost generating revenue during construction. This cost could be substantial, and this issue will be mentioned in the final white paper as information that should be developed as one of the next steps of further analysis. It is beyond the scope of work for this document to estimate down-times for each alternative, other than qualitative statements.

PSE10: (Regarding "Estimated percentage of zero-age…" in *Additional Information Needs* for Option 1.) Is this to determine if fry make up a significant portion of the population and therefore should be protected?

> The Tribe has stated a strong desire to screen for fry. This information need will be modified to reflect that it is needed only if there is uncertainty among the parties regarding the contribution and importance of protecting fry.

PSE11: (Regarding *Table 1*) Headers should have short descriptor title (i.e. smolt screen at intake)

> Agree.

PSE12: (Regarding *Slope Flat Plate Screen in Front of Intake)* Also no good way to trap fish.

> We assumed that there does not need to be a permanent evaluation facility and the Tribe agrees. No trapping is therefore required.

PSE13: (Regarding *Sediment Management Options*) It is fair to say that not very much is known about the timing, volume, and size distribution of the sediment in the River that would markedly influence selection of a preferred option and the design parameters, yet it doesn't show up as a study need.

> It is true that more should be learned about sediment load; it will be added to the information needs. Given that sediment loads are extreme, are often concurrent with peak out-migration, and can occur at a wide range of flows, it is clear that sediment management is a primary design consideration for any design option. We believe that the uncertainty of sediment management is a greater unknown than actual characteristics of the sediment load. Additional information needs will reflect this.

PSE14: (Added to cons of Options 1 and 3 regarding operational certainty) Dynamic channel – Outfall may not be to river channel.

> Agreed. Additional control on the dam might enhance the ability to maintain a low flow channel near the left bank.

PSE15: (Moved from pros to cons of Option 3) "Long seals and mechanical screen operator are complex and subject to wear and failure."

> Agree.

PSE16: (Added to cost cons of Options 1 through 4) "remote site".

> Agree. Costs in Table 1 had not included operational costs. A qualitative comparison will be included.

PSE17: We think there are uncertainties about the options that are understated particularly as they relate to sediment volume, fraction, and timing.

> We will review and clarify if needed.

PSE18: The document should reflect on the volume of work yet to do to arrive at a potentially viable solution.

> Agree.

PT01: Of the five preferred options recommended, we would like to suggest that a combination of these may in fact provide the most effective means of reducing fish mortality. Specifically, a head works located screen in conjunction with a flume or forebay located IPT or wall screen may be necessary to provide acceptable survival rates.

Agree. Any screen could be evaluated to see if fry are entrained through it and additional fry screening could be provided downstream of it either as an initial or following phase.

PT02: While a sampling facility is helpful in terms of data collection, it is a luxury the Tribe is willing to forego if survival rates can be enhanced via a bypass system that prevents fish from ever entering the forebay.

We will clarify.

PT03: whichever screen design(s) is ultimately selected, it must effectively protect fish of all sizes.

Tribe preference will be noted by quoting comment.

WDFW01 – Put “Electron Downstream Fish Passage Work Group” on the cover to address Cary’s “Washington State Legislature” comment.

Change made.

WDFW02 – WDFW would like some input on what to do next; i.e., how long would a feasibility study take, schedule, etc. We understand the design team won’t be making any recommendations on what to do, other than to study it further. More recommendations on where to go from here would help.

We will include a series of “next steps.”

WDFW03 – Can we make any statements on how many fry/small juveniles would likely be diverted successfully if we select a smolt (fingerling) screen over a fry screen.

We know of no data. Results will likely be highly dependent on screen mesh material, sweeping velocity, and turbidity.