ELECTRON PROJECT DOWNSTREAM FISH PASSAGE

FINAL REPORT

Report to the State Legislature
Pursuant to ESHB 2687, Section 307 (39)

December 2008

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Prepared for:

Washington State Legislature
Pursuant to ESHB 2687, Section 307 (39)
Electron Fish Passage Legislative Work Group

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INTRODUCTION

The 2008 Washington State Legislature approved Engrossed Substitute House Bill 2687 that included direction to conduct the Electron Dam Fish Passage Study. The bill established a work group comprised of two members of the state Senate (Senator Dan Swecker and Senator Ken Jacobsen), two members of the state House of Representatives (Representative Brian Blake and Representative Jim McCune), and representatives of the Puyallup Tribe of Indians (Russ Ladley), Puget Sound Energy (Cary Feldmann), and the Washington Department of Fish and Wildlife (Curt Leigh). The work group was established to "study possible enhancements for improving outbound juvenile salmon passage at Electron dam on the Puyallup River." The group met for three work sessions on August 27, 2008; November 14, 2008; and, December 12, 2008. In addition to the above members, participants in the work group meetings included Curt Gavigan (Senate staff); Jaclyn Ford, Jason Callahan, John Charba, Amy Cruver (House of Representatives staff); Bill Sullivan, Sam Stiltner, Dawn Vyvyan, Ehren Flygare, Blake Smith (Puyallup Tribe of Indians); Cary Feldmann, Jacob Venard (Puget Sound Energy); Ken Bates (Kozmo, Inc.); Peter Christensen (R2 Resource Consultants, Inc.); and, Greg Hueckel, Tom Davis, Alan Wald, Travis Nelson, and David Mudd (Washington Department of Fish and Wildlife).

An engineering team consisting of R2 Resource Consultants, Inc., and Kozmo, Inc., was retained to perform a review of potential downstream fish passage alternatives that could improve the downstream passage conditions at the Electron project. They completed their report on December 5, 2008. (Bates, et al., 2008)

The National Marine Fisheries Service (NOAA Fisheries), U.S. Fish and Wildlife Service (USFWS), and Puget Sound Energy (PSE) are involved in additional work related to downstream fish passage at the Electron project. These entities are working on an Endangered Species Act Habitat Conservation Plan (HCP). The purpose of the HCP is to prepare an incidental take permit because the project takes some number of bull trout, steelhead, and Chinook salmon, all of which are listed species in the Puyallup River. As of August, 2008, the HCP is on hold (Steve Fransen, NOAA Fisheries, personal communication).

PROJECT DESCRIPTION

Construction began on the Electron Project in 1902 and the project went on-line on April 12, 1904. The project diverts water from the Puyallup River at River Mile 41.7 into a wooden flowline (flume) where it travels about 10 miles to a forebay and down through penstocks into a powerhouse and back into the Puyallup River at River Mile 31.2 (Figure 1). The Puyallup River originates in glaciers on Mt. Rainier and its gradient is relatively steep in the project area resulting in substantial bedload and sediment transport. The project is located near the town of Kapowsin in Pierce County, Washington, and is owned and operated by Puget Sound Energy (PSE).

The project features include a timber crib diversion dam approximately 10-feet high with a crest length of 200 feet; a 32-foot wide spillway containing three 10-foot air bladder gates to sluice bedload from the vicinity of the intake; a 62.5 foot wide intake with a coarse trash rack in front of it; a radial gate within the intake to control flow; a wooden flowline (flume) approximately 10 miles long with a maximum capacity of 400 cfs; two rock chutes near the beginning of the flume to divert large gravel and cobble back into the river; a settling basin approximately halfway along the flume to allow additional sediment to settle out; a forebay at elevation 1,500 ft msl with a maximum capacity of 124 acre-feet; four penstocks; and, a powerhouse at elevation 667 ft msl containing four generating units, each consisting of two horizontal-type Pelton turbines. (Bates et al., 2008) Total generating capacity is 25 megawatts. (Jeanes, 2006) Figure 2 shows the features of the Electron dam, intake, and beginning of the flowline.

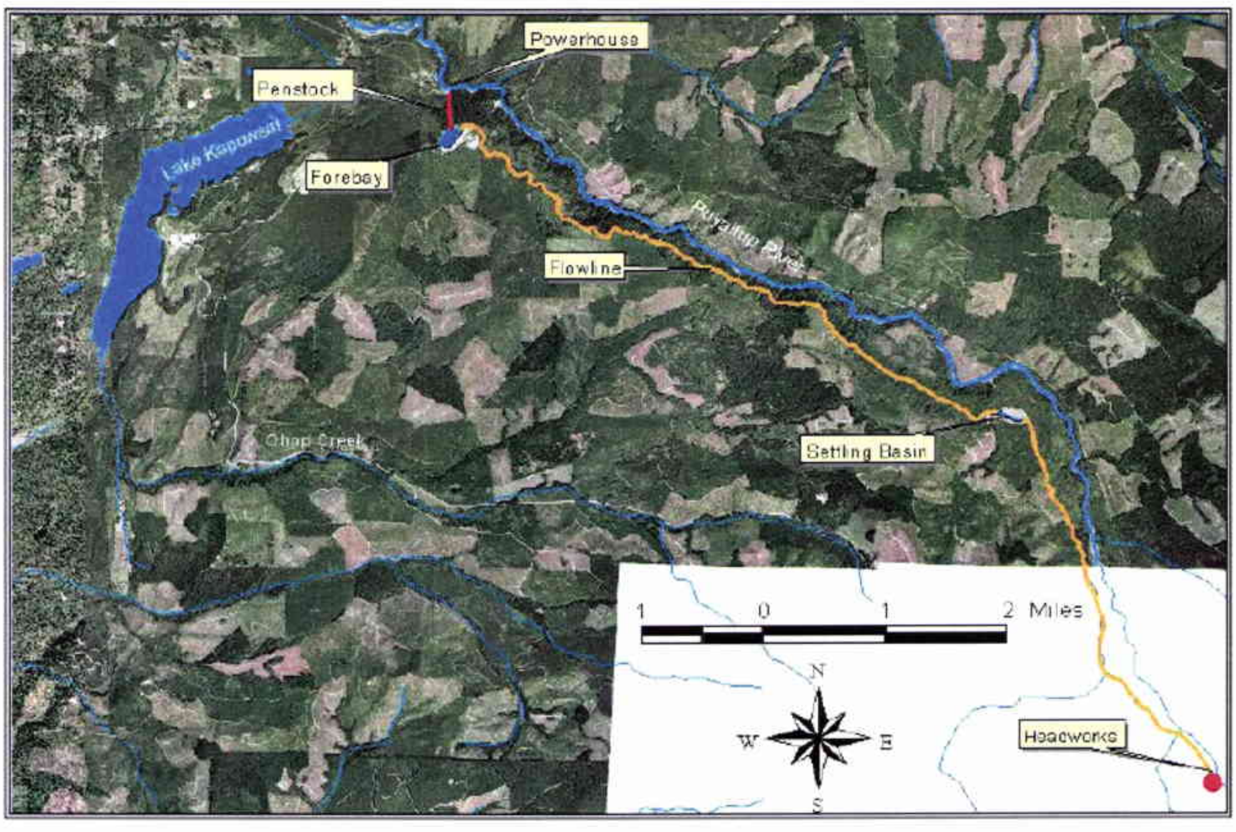

Figure 1. Map of Electron Project, showing headworks, settling basin, flowline, forebay, and powerhouse locations. (Bates et al., 2008)

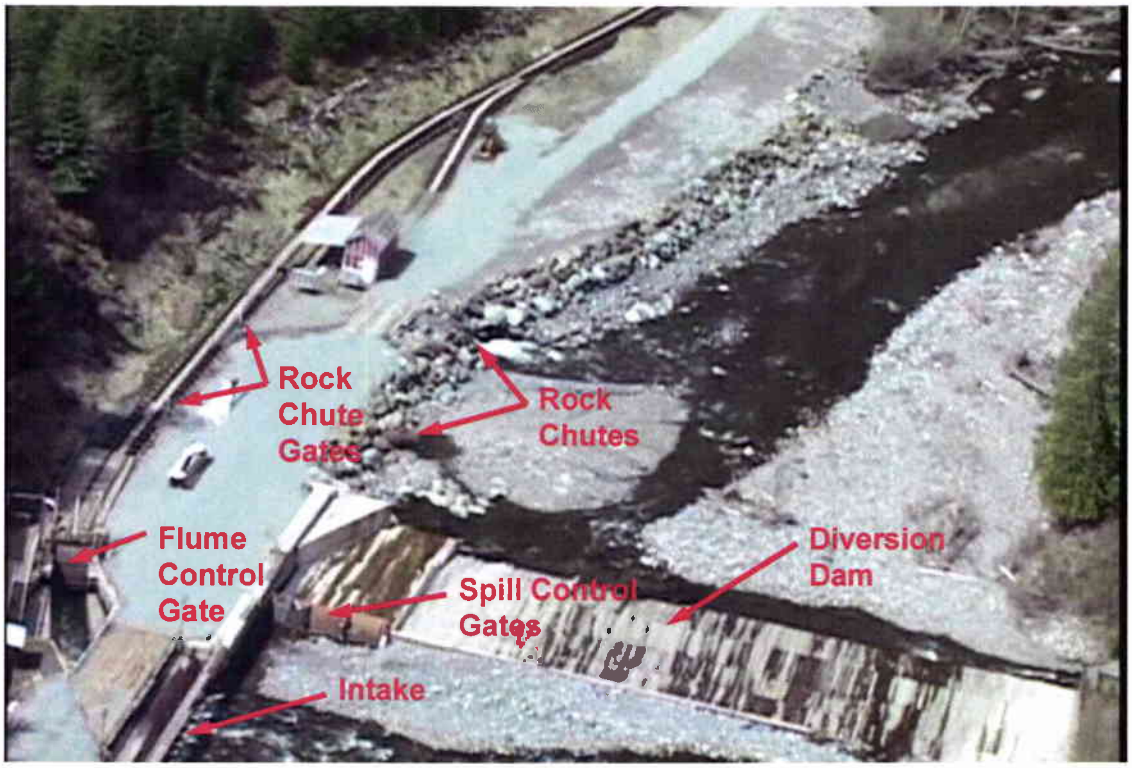

Figure 2. Features of the Electron diversion dam, intake, and beginning of flowline (Bates et al., 2008)

As originally constructed, there were no fish screens to keep fish out of the flow-line or out of the penstocks.

PSE and the Puyallup Tribe of Indians (PTI) entered into a Resource Enhancement Agreement in 1997. This 30-year agreement includes minimum instream flows in the river between the diversion dam and the powerhouse (bypass reach); three acclimation ponds upstream of the diversion; a pool and weir fishway at the diversion dam; and measures to enhance downstream fish passage through or around the project. (PSE and PTI, 1997) As constructed in 1998, those measures included a guide net, net cleaning system, floating dredge, flow deflectors, and a smolt collection facility (trap), all in the forebay. Fish that are collected at the trap are trucked back to the Puyallup River to a release site downstream from the powerhouse. R2 Resource Consultants, Inc. was hired to assist with daily operations, conduct biological monitoring, and recommend improvements.

Improvements and changes have been made to the original design. (Jeanes, 2006) Some of these changes have not been specifically tested to determine if they improved passage.

- 2001, flow deflectors and an additional guide net were installed to direct flow toward the trap.
- 2001, the forebay bed was smoothed to allow a new guide net to fit the contours of the bed and decrease fish loss over or under the net.
- 2003, a portable pump was installed to increase the attraction flow through the trap from 12.5 cfs to 20.5 cfs. Additional flow deflectors were installed in an attempt to direct the flow and migrating fish toward the trap.
- 2003, PSE moved the timing of its project shutdown to the middle of the smolt migration season.
- 2004, an experimental trap transition structure was fabricated and installed to increase trap efficiency.
- 2005, a new weir gate and actuator controls were installed, widening the opening to the trap from 36 inches to 48.5 inches.
- 2007, installation of screen baffles to balance the flow distribution through the screens in the fish trap.

As currently operated, water enters the forebay from the flowline and is directed toward the smolt collection facility by a series of 6-foot x 4-foot steel plate flow deflectors hanging from a string of buoys. An additional set of flow deflectors helps control circulation patterns near the entrance to the fish trap. A 450-foot long guide net behind the flow deflectors is designed to restrict the fish from moving farther into the forebay and entering the penstocks. The guide net is periodically cleaned to remove algae, leaves, and silt. During cleaning a new section of net is pulled into place from a spool on the opposite bank of the forebay. The guide net is in place from April 1 to November 1 each year. (Bates et al., 2008)

During the 4-6 week project shutdown, no water and no fish are diverted into the flowline. Fish recovery operations are conducted at the start of the shutdown to remove fish from the flowline and forebay and return them to the river. This fish recovery returns some adult fish and hundreds to a few thousand juvenile fish to the river. However, it is likely that thousands of juvenile fish are lost through a combination of those that move into the penstocks and those that are lost in the sediment and are not salvageable. (Russ Ladley, Puyallup Tribe of Indians, personal communication)

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. The migrating fish are attracted to the fish collection facility by a flow of 20.5 cfs produced by two electric pumps. The attraction water flows through an adjustable weir gate into the 6-foot wide and 40-foot long fish trap. To remove the fish from the trap, an electric crowder screen concentrates the fish in the portion of the trap where the fish hopper is located. The fish hopper is lifted out of the trap by an electric hoist and fish and water are discharged into a sample tank for study, or the tank trailer for transport back to the Puyallup River. Fish are removed from the trap and transported at least once a week throughout the year with increasing frequency as fish numbers increase during the migration period. (Jeanes, 2006)

Bates, et al. (2008) report that excess turbulence and poor opportunity for debris management in the trap holding area may jeopardize fish health. They concluded that some fish may be injured in the holding area and some smaller fish could be impinged, especially when there is debris present and/or the water is turbid. They also reported that there is no refuge for fish to escape the turbulence and exposure to the screens during the period they are held in the trap.

A minimum instream flow of 80 cubic feet per second (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). The instream 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 downstream of the intake could be considered as an amendment to the 1997 Resource Enhancement Agreement.

Maintaining instream flow and where the instream flow is measured have an effect 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. (Bates, et al., 2008)

EXISTING FISH PASSAGE INFORMATION

Up to eight anadromous salmonid fish species currently inhabit the Puyallup River. Chinook, coho, chum, pink and sockeye salmon, steelhead, bull trout, 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. (Bates et al., 2008) The Puyallup River has 26 to 30 miles of stream habitat suitable for rearing juvenile fish upstream of the diversion and seasonal downstream fish passage is particularly important to fish production in the river. (Marks et al., 2007)

The Puyallup Tribe of Indians conducted fish passage studies at the Electron forebay in 1999, 2000, 2001, and 2006. R2 Resource Consultants, Inc., conducted fish passage studies in coordination with the Puyallup Tribe of Indians and Puget Sound Energy at the Electron forebay in 2002, 2003, 2004, and 2005. Due to a variety of factors, there has been considerable variability in the study methods, study timing, origin of test fish, and release sites. A summary is provided in Table 1. All of the studies were done with fingerling-sized fish, none of the studies used smaller migrant fry.

The fish passage information was analyzed to determine if there were identifiable differences between coho and Chinook; between hatchery and natural fish; and, between months that the studies were conducted.

It was difficult to analyze differences between hatchery and natural fish because the only natural fish that were studied were a combination of coho and Chinook that totaled 200 fish. These fish were captured from the forebay fish trap and released on 18 July 2003. Eighty two percent of them were recaptured in the forebay fish trap but since these fish were already experienced with finding their way into the trap this is not directly comparable to fish that had no experience with the forebay fish trap.

Comparing coho and Chinook test results was difficult, also. Coho results range from 1999 to 2003 and Chinook results range from 1999 to 2006. A number of changes and improvements have been made to the fish passage structures in the forebay during 2004 and 2005 and these structural changes may have improved the ability of migrating fish to access the fish trap. Since only the 1999 to 2003 results were comparable for both species and the fish passage structures used today are updated, no valid comparison was derivable.

Analyzing the fish passage information by the month in which the fish were released for the study indicated a steady progression upward of improved fish passage as the summer months went along. For both coho and Chinook studies combined, the results were 23 percent for May, 30 percent for June, 45 percent for July, and 89 percent for August. A number of factors may combine to cause this upward progression. One factor may be that the fish may be beginning to smolt and their urge to move downstream may be enhanced as the summer progresses. This monthly comparison does not include the fish passage achieved during the project shutdown in June, however, nor does it reflect the testing limitations that have prevented early season evaluation of fish passage enhancements that are included in the late summer months.

To help decide on fish screening options, it is useful information to know the percentage of migrating juvenile fish that are fry and the number that are fingerlings or smolts. The number of different age class Chinook and coho captured at the Electron forebay fish bypass facility for the years 1999 through 2007 is reported in Marks, et al., 2008. The totals are: Chinook fry – 62,399; coho fry – 31,130; Chinook fingerlings – 20; coho fingerlings – 73,082. The total of Chinook and coho fry was 93,529 (56 percent of the total) and the total of Chinook and coho fingerlings was 73,102 (44 percent of the total).

The attempted comparisons above highlight the need for standardized fish passage study protocols for this project. Recommendations for standardized protocols appear later in this report.

Table 1. Fish Passage Summary

Year	Study Done By	Origin of Test Fish	Type of Mark	Release Site	Release Date	Number Released	Species	Percent Recapture	Comments
1999	PTI	Puyallup Hatchery	Vis Imp	F-line @ f-bay	29-Jun	237	Chinook	30	
2000	PTI	R-water Acc Pond	PIT	F-bay near f-line	23-May	148	Coho	1	Many fish escaped by guide net
					23-May	153	Chinook	4	Many fish escaped by guide net
					18-Jul	152	Coho	15	Guide net improved
					18-Jul	90	Chinook	19	Guide net improved
2001	PTI	Below Acc Pond	PIT	F-line @ f-bay	3-Jun	257	Coho	35	
					15-Jun	254	Chinook	25	
2002	R2				16-Jul		Ch/Coho	37	
					16-Jul		Chinook	52	
2003	R2	Below Acc Pond	PIT	F-line @ f-bay	16-May	100	Coho	29	
					19-May	100	Coho	33	
					23-May	100	Coho	35	
					27-May	100	Coho	37	
					2-Jul	100	Chinook	33	
					7-Jul	100	Chinook	36	
					10-Jul	100	Chinook	39	
					15-Jul	100	Chinook	43	
		Forebay fish trap	PIT		18-Jul	200	Ch/Coho	82	Experienced with trap
2004	R2	Clark's Cr Acc Pond	PIT		19-Jul	100	Chinook	89	Later releases
					21-Jul	100	Chinook	85	Later releases
					2-Aug	100	Chinook	81	Later releases
					4-Aug	100	Chinook	83	Later releases
2005	R2	Forebay fish trap	PIT	F-bay near f-line	27-Jul	50	Chinook	94	Later releases
					3-Aug	50	Chinook	92	Later releases
					10-Aug	50	Chinook	96	Later releases
					17-Aug	50	Chinook	92	Later releases
2006	PTI	Clark's Cr Hatchery	PIT	F-line @ rock chute	12-May	427	Chinook	5	Had to travel entire flowline, 2-wk study

SUMMARY OF SEDIMENT FINDINGS AND MANAGEMENT

The Puyallup River carries a heavy load of cobble, gravel, sand, and silt at the site of the Electron diversion dam, in part because the river drains glaciers on Mt. Rainier and also due to the elevation gradient of the river. Operation of the diversion is currently affected by sediment deposition at the diversion dam and entrainment and deposition of sediment in the flume and forebay above the power plant. 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. 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. Puget Sound Energy has incorporated rock chutes, a settling basin, and dredging of the settling basin and forebay as a means to manage this sediment load.

Existing Sediment Management

Rock Chutes. Two rock chutes are located near the beginning of the flowline to remove cobble and gravel from the diverted water. The rock chutes consist of a 12-inch high steel beam mounted on the floor of the flowline at an angle toward a 3-foot square sluice gate that returns the rock to the river channel. Flow through each chute is regulated by a sluice gate and is usually operated to pass approximately 20 cfs. They have a capacity of 60 cfs. During the site visit in October 2008, a large deposit of 3-inch to 15-inch cobbles was observed in the river channel 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 and bedload is passed down the flume. (Bates, et al., 2008)

Settling Basin. The flowline opens up into a settling basin four miles down from the diversion dam. As sediment settles out in the basin it is removed on an as-needed basis throughout the year by dredging and the use of a track hoe during annual outages. Removed material is piled next to the basin. Up to 400,000 cubic yards of material is excavated per year from the settling basin and forebay. During the October 2008 site visit, sediment stored next to the basin was inspected and sizes estimated visually. Very coarse sand (1 – 2 mm) settles out at the upstream end of the basin and finer sand (.06 - .12 mm) settles out near the downstream end of the basin. (Bates, et al., 2008) Figure 3 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 3. Settling Basin April 25, 2008 (left) and October 14, 2008 (right). (Bates, et al., 2008)

Forebay. At the end of the 10-mile long flowline is the forebay with a capacity of 120 ac-ft. Fine silt and sand settle out there and are removed during the annual outage.

Hydrology and Hydraulics

The Puyallup River near Electron, WA drains an area of 93 square miles above USGS streamflow gage #12092000 (http://waterdata.usgs.gov). The gage is 0.3 miles downstream of the Mowich River, a major tributary to the Puyallup River. 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 4 shows mean monthly flows at the USGS gage upstream of Electron Dam. Daily discharge at the gage typically varies from less than 200 cubic feet per second (cfs) to more than 2,000 cfs in a year. The average discharge for 75 years of record (between 1909 and 2002) is 528 cfs and flows ranged from a low of 75 cfs on October 19, 1994, to a high of 21,500 cfs in November 2006. The 2-year and 10-year frequency peak flows are 5280 cfs and 9600 cfs, respectively (http://streamstats.usgs.gov). (Wald, 2008)

Mean annual discharge is exceeded only 25 to 30 percent of the time on most streams (i.e., 70-75 percent of the time flow is less than the mean annual discharge). The mean annual discharge can typically transport silt and fine sand sizes and organic matter as suspended sediment and is considered a "flushing flow" at which a river "colors up" with colloidal and suspended sediment. The mean annual discharge of 528 cfs on the upper

Puyallup River occurs several times a year in most years (as shown in Figure 5). (Wald, 2008)

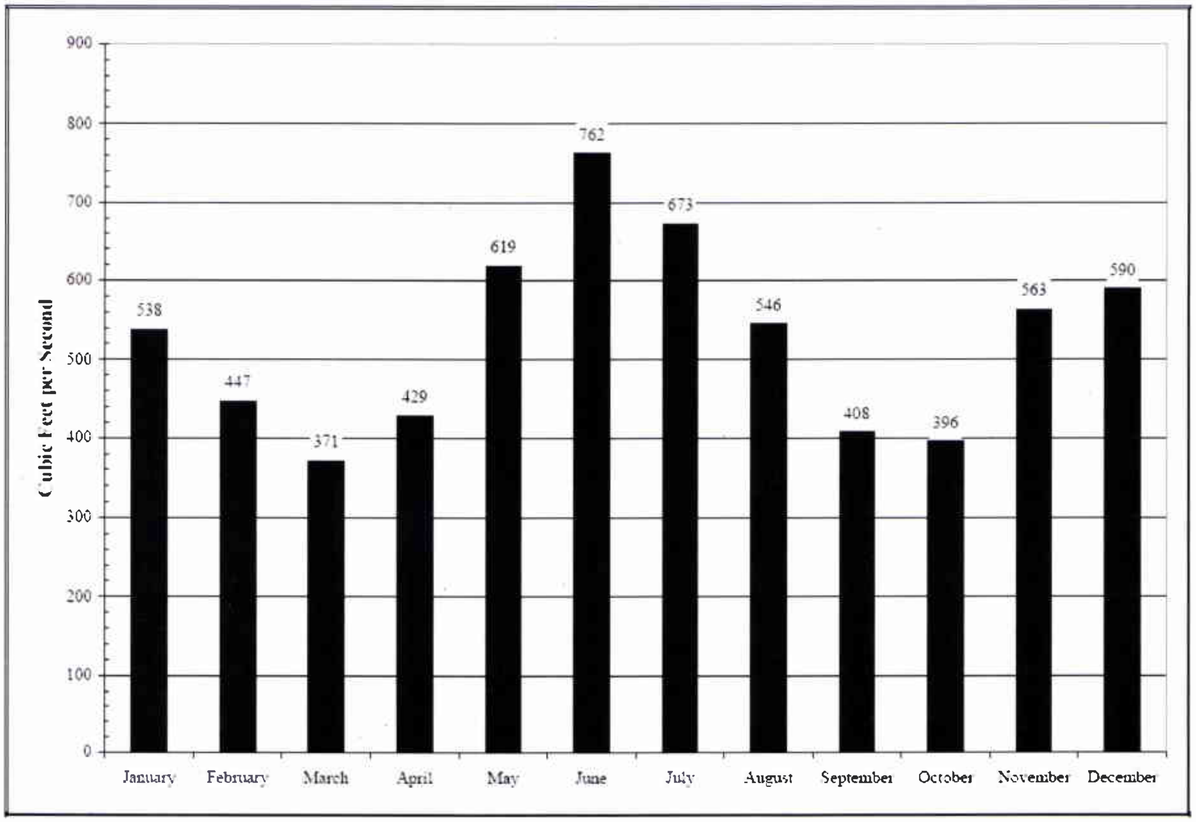

Figure 4. Mean monthly flows, Puyallup River upstream of Electron Dam.; 1909-2002. (source; USGS gage 20192000)

The 2-year frequency high flow can typically transport coarse gravel and cobble and is considered the "channel maintenance flow" for many rivers. A 2-year frequency peak flow of 5280 cfs or greater on the upper Puyallup River occurred 29 times in the 75 year period of record between 1916 to 2005 (Figure 6).

Peak flows on the order of a 10-year frequency event (.10 probability of occurrence) are "channel forming flows" associated with rapid bank erosion, side-channel development, and channel avulsions. A peak flow of 9600 cfs or greater on the upper Puyallup River occurred 7 times in the 75 year period of record between 1916 and 2005. (Wald, 2008)

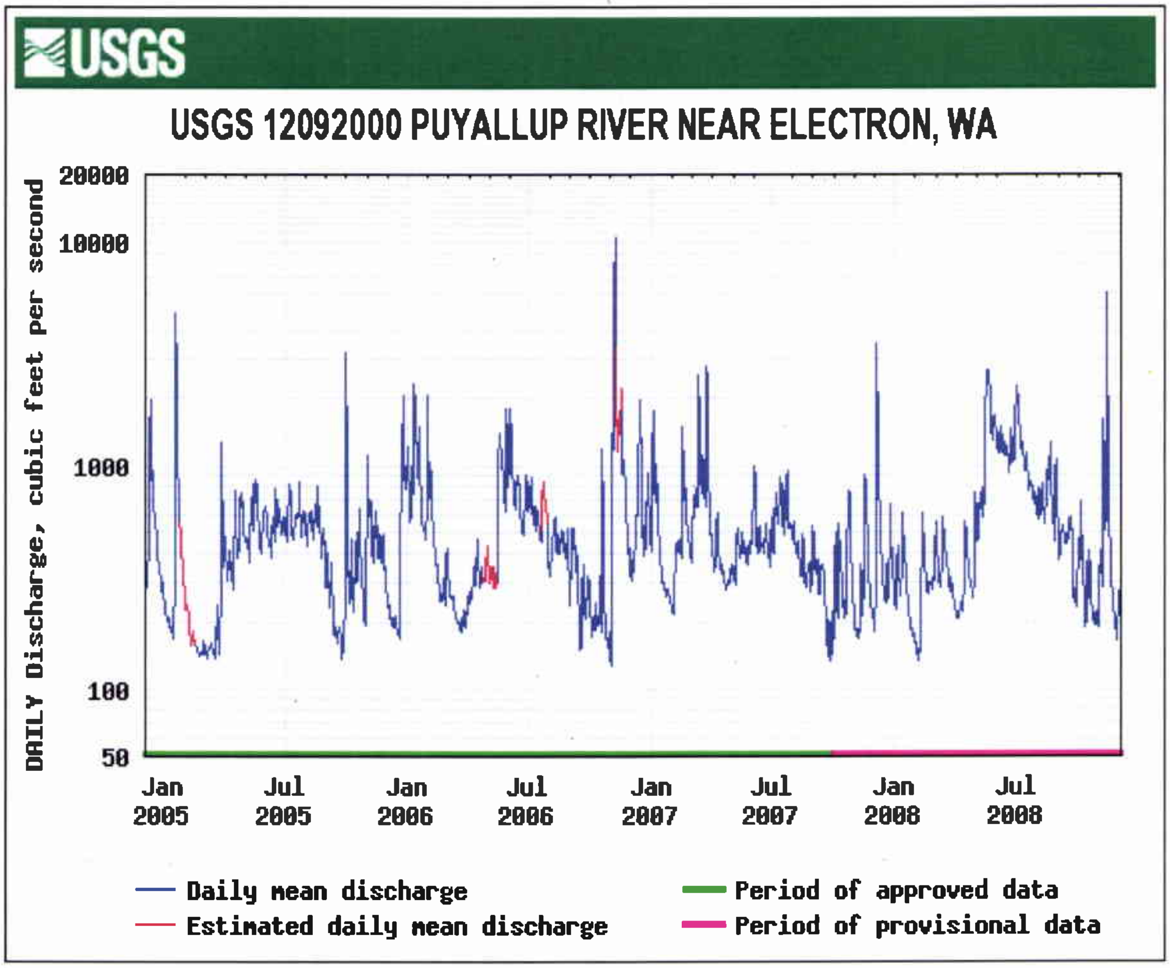

Figure 5. Hydrograph, Puyallup River near Electron, WA.

The effective discharge is the discharge at which the greatest amount of sediment transport occurs and is in the range of a 2-year peak flow.

Field measurements of Puyallup River discharge in 2003 and 2005 documented the relatively high velocities that occur during peak flows. Mean velocity for a cross-section of the channel varies according to velocity distribution across the channel. A flow of 2170 cfs had a mean velocity of 7.41 feet per second (fps). A flow of 5330 cfs had a mean velocity of 10.3 fps. These flows are more than adequate to entrain and transport bedload sediments varying in size from coarse sand and gravel to large cobble. Field observations during the flow of 5330 cfs noted "turbulent, unsteady flow, brown with boulders moving and some debris". (Wald, 2008)

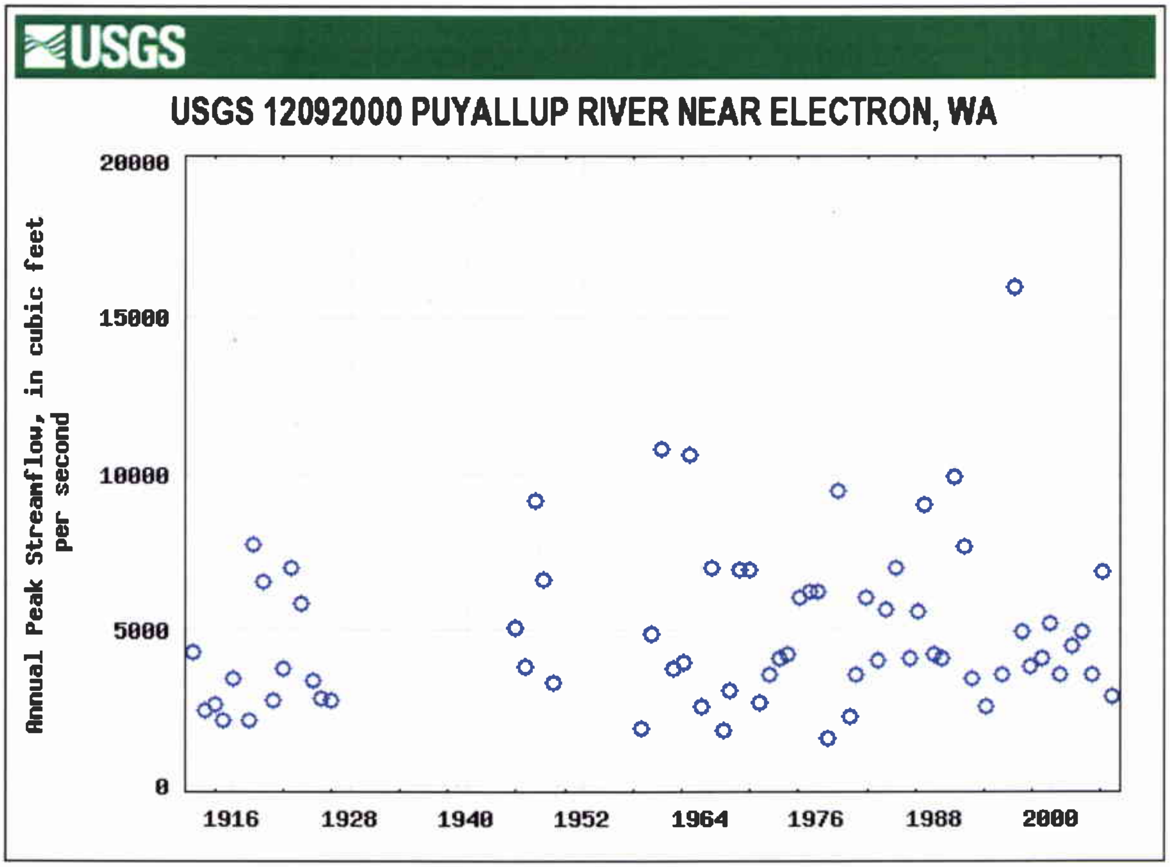

Figure 6. Peak flows, Puyallup River near Electron, WA.

Sediment Transport, Timing, Volume. Stream sediment is classified by size based on particle dimensions. The USCS classification system is commonly used for sediment descriptions, as follows:

Sediment Classification based on Grain Size:

Unified Soil Classification System (USCS)

Sediment Name	Diameter (inches)
Cobble	3 - 10 inches
Gravel	0.18 – 3 inches
Sand	.003 – 0.18 inches
Fines (silt and clay)	less than .003 inches

As shown in photograph #1 (below) sediment in the Puyallup River channel at the diversion is a mix of sand, gravel, and cobble sizes. As shown in photograph #2, most (greater than 50%) of the material at the surface is sand.

Photograph #1. Upstream of the Electron diversion dam.

Photograph #2. Surface deposits, Puyallup River near Electron diversion dam.

Stream discharge, sediment size, and stream power are effective controls on the rate and volume of sediment transport. Small particles of clay, silt, and find sand (up to .02 inches in diameter) move as suspended sediment in the water column. Medium to coarse sand (up to .08 inches in diameter) typically moves as wash load or suspended sediment near the bed surface. Bedload composed of larger sand, gravel, and cobbles (up to 10 inches in diameter) move by entrainment and saltation (skipping or bouncing). Wash load and bedload are difficult to mobilize and typically move in an episodic fashion when high velocity and tractive forces exceed boundary conditions for a mix of substrate sizes. (Wald, 2008)

Depth-velocity criteria and submergence may determine the size of entrained sediment but flow magnitude generally determines the volume of sediment in transport. The duration of high flows with sustained tractive forces determine the distance coarse sediment travels. Rainfall dominated hydrologic regimes with numerous high flow events of fairly short duration (typically a few days at a time) may move suspended sediments a considerable distance downstream but are less likely to move coarse bedload past the next meander. The frequency of occurrence of high flow of sufficient magnitude and duration to mobilize coarse sediment determines the total load or annual sediment yield.

A study of sediment transport on the Puyallup River (Sikonia, 1990) found that a flow of 2,000 cfs at the Puyallup River in Orting had a suspended sediment discharge of more than 1,000 tons per day and bedload discharge of less than 50 tons per day. Suspended sediment and bedload discharge at the Puyallup River near Electron gage would likely be higher because of the greater channel slope at upper elevations.

Sediment Management Options

Efficient sediment removal, particularly near the headworks, may enhance those screening options located there, although the feasibility of any screening option has not been determined. Sediment removal options that minimize the flow needed for sediment management will increase the flow available for fish bypasses but may also diminish flow available for hydropower production. Some options to enhance sediment management are listed in order of a preliminary determination of their feasibility. Detailed costs analyses and engineering would be required to demonstrate feasibility of any of these options (Bates, et al., 2008)

- Improve existing rock chutes to improve sediment removal for the benefit of fish passage facilities.
  - ✓ 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.
  - ✓ Provide water velocities suitable to move rock that is 3 – 15 inches in diameter.

- Sediment sluice in front of intake.

- Sediment sluices in screen bay.
  - ✓ Combine additional sediment sluices with fish screen bays; recommend putting the sluices upstream of the screens to slow the water velocity for the screens.

- 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.

- Temporary screening of the intake for several months may be effective in excluding juvenile fish during peak migration periods. (Wald, 2008)
  - ✓ Normally, peak migration occurs during flows of 400 to 800 cfs, so the main sediment issues at the intake are going to be channel flushing functions and smaller particle sizes.

- Upstream Sediment Traps and Flow Structures. (Wald, 2008)
  - ✓ Flow velocity, channel slope, and channel roughness are hydraulic controls on channel form. The fundamental relationships of velocity, slope, depth of flow, and roughness account for the longitudinal change in sediment accumulations and resulting alluvial channel form.
  - ✓ Each of these hydraulic influences can be modified to some degree by engineering practices.
  - ✓ Construction of sediment traps upstream of the diversion dam or building hard points (vanes, groins, or engineered log structures) can define zones of gravel transport and deposition above the diversion dam to maintain desired flow conditions at the intake structure.

Other Considerations. This discussion of sediment transport does not address the entrainment and transport of coarse woody debris during high flows. Wood movement includes buoyant forces and other transport influences that would need to be considered for estimating wood delivery and deposition at the diversion works. (Wald, 2008)

IDENTIFY ALTERNATIVES TO IMPROVE DOWNSTREAM FISH PASSAGE

Downstream Passage Concepts

Ideas for fish passage options were collected from the legislative work group, participants in the October 2008 site visit, the 1996 Montgomery Watson report, and a brainstorm session among the engineering team (Bates, et al., 2008). General approaches that were considered were to keep fish out of the intake, remove fish near the beginning of the flowline and bypass them back to the river, remove fish at the settling basin and bypass or truck them back to the river, or remove fish at the forebay.

Based on the scope for this work, the engineering team performed a cursory review of fish protection alternatives that 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 at a minimum accommodate site conditions. (Bates, et al., 2008)

Evaluation Parameters

The following evaluation parameters were considered when selecting options for further study (Bates, et al., 2008):

- 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.
  - ✓ 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 was not 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 existing facilities
    - ✓ Facilities that do not accumulate ice and/or sediment are less risky.
    - ✓ Screens near the headworks might have less risk than farther 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 costs, and operation and maintenance costs, were both considered.
    - ✓ Access and power availability was taken into account.
    - ✓ 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.
    - ✓ Considered a mix of high and low capital and operation and maintenance costs.

- Constructability
    - ✓ Only common construction materials and practices were considered.
    - ✓ Considered likely slope stability, foundation suitability, construction access, etc.

- Fish passage criteria (see next section)

Fish Passage Criteria

Fish passage criteria developed by the Washington Department of Fish and Wildlife (WDFW) and NOAA Fisheries (NMFS) were reviewed in the development of the fish passage options (Table 2). Passage facilities that conform to these criteria are more acceptable and likely to succeed.

Table 2. Summary of WDFW and NMFS fish screen criteria. (WDFW, 2000; and NMFS, 2008)

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.
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	Perf. plate 3/32"; Profile bar 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 head loss exceeds 0.1 ft.
Bypass		
Bypass location	Bypass required at downstream end of screen.	N/A
Bypass Entrance Geometry	Full depth. 18" wide min	This assumes a slot bypass. Does not relate to inclined screen geometry.

Criteria/Guideline	Design Value	Notes
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.
Bypass Conduit		
Material	Smooth and durable Wide bends	Typically HDPE pipe. Radius of Bend/Diameter of Pipe > 5.0.
Bypass flow	12.5 cfs min	Flow also governed by bypass entrance described above.
Bypass Water depth	9.5”	N/A
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, may not be able to be achieved 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. (Bates, et al., 2008)

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 degrees) and might be increased for other conditions and high sweep velocity. (Bates, et al., 2008)

Options for Further Study

Based on the parameters above, five options were recommended for further feasibility design (Bates, et al., 2008). It is recommended that the next phase of feasibility design include at least several of these options. The five options are:

1. Plate fingerling screen near intake;
2. Plate fry screen just downstream of settling basin;
3. Inclined fingerling screen near intake;
4. Inclined fry screen downstream of settling basin; and,
5. Improve existing forebay trap and holding facilities.

In the discussions below, screen size is sometimes described in English units (¼ inch or 3/32 inch) although the screening criteria are in English units (3/32 inch) or metric units (1.75 mm). This difference arises because the screen material is available from the manufacturers in those sizes. (Ken Bates, personal communication)

Plate Fingerling Screen Near Intake

This option would be a traditional flat plate screen facility as a single long bank of screen panels or a vee screen configuration located in the flowline downstream of improved or expanded rock chutes. Screen size would be ¼ inch screen opening with 0.8 fps approach velocity (smolt or fingerling screen). A fry screen near the intake has the risk of being plugged with sediment. The fingerling screen is likely to divert a high percentage of fry. The existing forebay trap and screen could be preserved as a means of evaluating fry protection of the fingerling screen. The fish would be diverted back to the river near the base of the diversion dam through a pipe bypass.

The range of estimated construction costs for this option is $3M to $9M, and does not include lost electrical 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. Additional information needs include the rating curve of the flume; rating curve of the dam tailrace; hydraulic profile through the intake and flume to flood gates; efficacy of sediment management; and, power requirements. (Bates, et al., 2008).

Plate Fry Screen Downstream of Settling Basin

This option would be a traditional flat plate screen facility as a single long bank of screen panels or a vee screen configuration that is designed to fry criteria (3/32 inch screen opening and 0.4 fps approach velocity). It would be located just downstream of the settling basin or at the downstream end of the flowline near the forebay. A fry screen would be feasible at this location because all but the fine sediments would have been removed in the settling basin. Fish would be routed back to the river in a pipe bypass (18 inch diameter, 2500 feet long, 20 – 30 cfs bypass flow, 250 feet of elevation drop at 8% slope, maximum velocity of 25 fps). Alternatively, fish could be gravity loaded to trucks and hauled to the river if the facility is located at the forebay.

The settling basin site is much less feasible than the forebay site but is included here to provide an option with fry protection 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 4, 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. (Bates, et al., 2008)

The range of estimated construction costs for this option is $6M to $18M and does not include lost generating revenue during construction. A construction flume bypass could be constructed to minimize plant down-time. Additional information needs include efficacy of sediment management; feasibility of flume bypass during construction; constructability of the site and the bypass; and, power requirements. (Bates, et al., 2008)

Inclined Fingerling Screen Near Intake

This option would be an inclined plate screen located in the flowline just downstream of improved or expanded rock chutes. Screen size would be ¼ inch screen opening with 0.8 fps approach velocity. Fish and debris pass over the downstream end of the screen and are bypassed back to the river. A pair of parallel screens in separate bays may be required to operate at better efficiency through a wide range of flows and to better manage bypass flows. The screen would be hinged and could lay flat if it became overwhelmed with sediment during high flow events. Automatic controls would operate the screen to maintain the proper depth into bypass at all flowline water levels. Screen configuration would require seals between the edges of the screen and the flume and a complex mechanism to control the elevation of the screen. Fish would be routed back to the river near the base of the diversion dam through a pipe bypass.

The range of estimated construction costs for this option is $4M to $12M, not including 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. Additional information needs are the same as the Plate Fingerling Screen Near Intake option. (Bates, et al., 2008)

Inclined Fry Screen Downstream of Settling Basin

This option would be an inclined plate screen located just downstream of the settling basin or at the downstream end of the flowline at the forebay and would be designed to fry criteria (3/32 inch screen opening and 0.4 fps approach velocity). Fish would be routed back to the river through a pipe bypass or gravity loaded to trucks and hauled.

The range of estimated construction costs for this option is $7M to $21M not including lost generating revenue during construction. A construction flume bypass could be constructed to minimize plant down-time. Additional information needs are the same as the Plate Fry Screen Downstream of Settling Basin option. (Bates, et al., 2008).

Improve Existing Forebay Trap and Holding Facilities

This option would improve the existing fish guidance, collection, and holding facilities at the forebay. It would include improving the guidance net by attaching a permanent float system or frame, or replacement of the net with a vertical plate screen. Daily hauling to reduce injury to fish in the trap would optimize hauling operations. The trap would be reconfigured to narrow the screen channel towards the downstream end, add a conventional bypass, and add a holding area downstream of the screen bay. The trap weir would be replaced with a sloping high-velocity screen or finger weir. The sloping screen would trap fish and the reduced head differential would reduce turbulence and fish injury in the trap.

The range of estimated construction costs for this option is currently hard to define given the spectrum of possible improvements. However, it is reasonable to assume that some level of improvements to the existing facilities could be realized for significantly less than the four previous options. Making all of the improvements listed above could bring the cost up to something similar to those for the first and third options. 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. Additional information needs include the suitability of the forebay for rigid screen and guidewalls, and the downtime required for construction. (Bates, et al., 2008)

IDENTIFY PROS AND CONS OF EACH OPTION

Table 3 describes the pros and cons of each chosen option, subject to further analysis.

Table 3. Comparison Considerations for Each Fish Passage Alternative. (from Bates, et al., 2008)

	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

Consideration	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	
	Pros	**Cons**	**Pros**	**Cons**	**Pros**	**Cons**	**Pros**	**Cons**	**Pros**	**Cons**
Operational certainty		Exposed to greatest sediment load	Largest sediment at the location is silt, which should pass through screen. No additional sediment management needed.			Exposed to greatest sediment load. Articulating screen panel has mechanical complexity. Long seals and mechanical screen operator are complex and subject to wear and failure.	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	
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.

Consideration	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	
	Pros	Cons	Pros	Cons	Pros	Cons	Pros	Cons	Pros	Cons
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

RECOMMENDATION

Long-Term

Puget Sound Energy should continue working with the Puyallup Tribe of Indians and the Washington Department of Fish and Wildlife to evaluate and improve, if studies warrant, downstream fish passage at the project. Consideration of the full range of fish passage enhancements will become possible once Puget Sound Energy resolves the question of their long term commitment to the Electron Hydroelectric Project. Further information is needed about sediment management, hydrology and hydraulics, the efficiency of the current fish passage system, and the constructability of some of the fish passage improvement options. Studies into these issues should go forward as joint funding from Puget Sound Energy, Puyallup Tribe of Indians, and the State Legislature allow.

Short-Term

In the current economic climate it is recognized that large sums of capital funding needed for a long-term solution to the fish passage issue may be difficult to procure. Incremental progress is still obtainable through the following short-term recommendations agreed to by all members of the work group:

- ✓ Additional fish passage studies should be done by WDFW, or a third party, following the protocols contained in this report. In order for passage studies to monitor the primary passage period, preparations for monitoring must be complete by April;
- ✓ Fish passage studies should be initiated in 2009 with 3-way funding from the Puyallup Tribe, Puget Sound Energy, and the Legislature;
- ✓ Hydrology studies and sediment information are needed to lay the groundwork for any of the fish screening alternatives, and it is recommended that an appropriate engineering firm or WDFW's hydrogeologist be funded to perform these;
- ✓ Detailed hydraulics information relating to the configuration of the intake area will be needed to support any passage option that involves the diversion dam and project intake;
- ✓ Further research into the fish passage issue should be jointly funded by the Legislature, Puget Sound Energy, and the Puyallup Tribe;
- ✓ A work session/hearing should be held to discuss downstream fish passage at the Electron project in the 2009 legislative session;
- ✓ The operators of the project and the fish passage system should consider the improvements suggested by the engineering team or others that may emerge from more detailed evaluations of the system or from the studies recommended above; and,
- ✓ The final report to the legislature and the final report of the engineering team shall be placed on WDFW's website.

All work group members did not agree to the following two recommendations. We suggest that these proposed recommendations be discussed further for possible resolution at the work session/hearing to be held during the 2009 legislative session:

- ✓ A public meeting/hearing, chaired by interested legislators (possibly some combination of Representative Blake and Senator Jacobsen or Representative McCune and Senator Swecker), should be held in Pierce County to inform the public and receive public input about the Electron Project;

- ✓ Expand the horizon of interest groups studying this issue by involving the state Utilities and Transportation Commission staff in discussions concerning the value of carbon-free electricity generation and the possibility of additional funding sources related to carbon-free generation.

FISH PASSAGE MONITORING PROTOCOL

The recommended fish passage monitoring protocol for future studies depends on the type of fish passage structure or operation that is in place. If the type of fish passage changes to a screening system, then the fish passage studies would need to be modified. The recommended course of action would be for representatives of PSE, PTI, and WDFW to meet and agree upon the study protocol based on the type and location of the screen.

If the fish passage system continues to be a forebay fish trap, then the following protocol is recommended to standardize the studies.

1. Test fish shall be Chinook and coho fingerlings/smolts collected as volitional outmigrants moving downstream from the acclimation ponds and Chinook and coho migrant fry.

2. Fingerling/smolt test fish shall be PIT tagged; the PIT tag detection system shall consist of three portable FS-2001F Destron Receiver/Coils (or equivalent) mounted in series on a release pipe or flow return structure. Migrant fry test fish shall be marked with a temporary marker such as fluorescent dye or other appropriate marker.

3. PIT tags used shall be Biomark TX1400ST, or equivalent. PIT tag procedures shall follow those recommended by the Columbia Basin Fish and Wildlife Authority PIT Tag Steering Committee (Prentice et al. 1990).

4. The PIT tag detection system shall be calibrated once per week during the test schedule by passing ten marked fish through the detection system.

5. Test fish shall be released into the upper end of the flowline downstream from the rock chutes.

6. Each monthly test shall consist of 250 chinook fingerlings/smolts, 250 Chinook migrant fry, 250 coho fingerlings/smolts, and 250 coho migrant fry for a total of 1000 test fish.

7. Two tests shall be conducted, one prior to the June outage and one following the outage. Test fish shall be released on or about May 1 and July 1 and each test conducted for the entire month.

8. Recapture rates shall be reported in total and as a daily tally to determine passage delay.

9. Four hundred (400) experimental control fish (100 of each type of test fish) shall be held in a floating net pen within the forebay. Control fish shall be examined weekly for mortalities, shed tags, tag malfunctions, and fish trap retention throughout the study. Control fish shall be hand-fed hatchery rations on a daily basis.

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Cover photo provided courtesy of Ken Bates, Kozmo, Inc. Photographs 1 and 2 provided courtesy of Alan Wald, Washington Department of Fish and Wildlife.

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