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memorandum

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To:	**Pat Slaney, R.P. Bio.** **PSlaney Aquatic Science Ltd.**	Date:	September 1, 2008
From:	Northwest Hydraulic Consultants **(NHC)**	Project:	3.5039
cc:		Page:	1 of 9

Re: Big Silver Creek
Fish Passage Assessment and Concepts

Assessment of fish passage examines to the ability of individual fish to swim and leap, and migrate against critical hydraulic conditions. Critical hydraulics are localized conditions within the flowing channel that potentially impede, delay or prevent the passage of fish forming a barrier to upstream migration or movement. These flow conditions include:

1. Supercritical flows and water velocities in excess of fish swimming speeds;
2. Swimming distances in excess of critical fish swimming distances;
3. Barrier heights in excess of fish leaping capabilities;
4. Adverse hydraulic conditions that exhaust, disorient, subject the fish to injury;
5. Insufficient depths of flow or aerated flow conditions; and
6. Insufficient pool volumes or for resting or approach.

The timing of migration and swimming capability of fish combined with the natural hydrology ands geomorphology of streams is considered a process that has – through natural selection – brought about distinct characteristics in stocks or races of fish (e.g. summer and winter steelhead on Vancouver Island).

Fish Passage and Fishways

The potential fish passage options and fishways discussed for use on the Big Silver include:

- Vertical Slot fishway
- Denil or Alaska Steep-pass Fishway
- Pool and Weir, and
- Natural Channel, Roughened Channel or Nature-like Fishway.

[1] Burst speeds are sustained for up to 20 s.
[2] Prolonged speeds are sustained for durations of 20 s to 200 m.

Below is short description, typical drawing and example of each fish passage technique for reference to the current study.

Vertical Slot Fishway

Vertical slot fishways utilized a deep vertical slot within a baffle wall to provide the hydraulic control between pools. As flows increase, the pool volumes increase to provide additional dissipation of energy and maintain suitable passage hydraulics. In a typical application, a vertical slot fishway is designed with pool-to-pool drop of approximately 0.3 m - which determines the slot velocity and fishway flows. These fishways commonly use a 3 m x 3. m pool that provides an approximate 10% slope. Fishway slopes up to 15% (0.45 m drop) have been used for in applications for strong swimming salmonids **(**pers. obs.). Vertical slot fishways are typically constructed of cast-in-place reinforced concrete with metal plating. Pre-cast concrete and wood baffles have been used, but are less durable against debris, ice and bedload. Applications of vertical slot fishways include the Stamp River Falls Fishway and Great Central Lake Dam near Port Alberni, several of the Hells Gate Fishways on the Fraser River, and the fishway on Cowichan Lake Dam.

Vertical Slot Fishway – Bonaparte River

Denil or Steep Pass Fishway

Denil and Alaska steep-pass (ASP) fishways use a series of vanes or spoilers that creates turbulent flow conditions that dissipate energy and reduce water velocities to provide fish passage. Unlike other fishway designs, the baffles or spoilers within the section, slopes and dimensions must be designed with low tolerances to ensure hydraulic performance. Slopes up to 25% have been used to pass fish. However, as the fish must use either burst or strongly sustained swimming speeds, the fishways length must be conservatively designed with adequate resting pools between fishway legs.

Because the hydraulics are flow sensitive and the passable section within the fishway relatively small, both Denil and ASP fishways are susceptible to debris damage and blockage. Headwater levels must be kept relatively stable and sufficient flows to ensure the section is watered to full design depths. An ASP fishway was recently installed on Hadden Creek – a tributary to the Capilano River – that provided passage to coho salmon at a slope of 17%.

Alaska Steep-pass Fishway

Pool and Weir Fishway

Pool and weir fishways use vertical baffle walls as broad-crested weirs between pools to provide passage for fish. Often the wall are notched to concentrate low flows, or have submerged orifices to provide passage for bottom-oriented or non-leaping fish. The pool-to-pool elevation is the typical design criteria for fish passage, and is typically 0.3 m or less.

The pool volume is typically designed to dissipate the required energy prior to the next baffle and provide adequate holding area for fish. High flows through a pool and weir fishway result in streaming flows and very little of the pool volume is used to dissipate energy. The supercritical velocities and hydraulics of this state are not ideal for fish passage. Due to the hydraulic stability in the plunging flow condition, pool and weir fishways are ideally suited to applications where fish passage is required at stable or low stream flows.

Regardless of their potential limitations, pool and weir fishways are perhaps the most widely applied type of fishway. Their simple design concept allows for application in a variety of river and stream setting and construction with a range of materials. Wood, concrete, steel, rock and raw logs have all be used to build pool and weir fishways.

Pool-and-Weir Fishway

Natural Channel Fishway

Nature- like fishways have been used for several years, but have considered a separate type of fishways only in the recent years. Biologists and fisheries engineers have understood that fish utilize the roughness and hydraulics created in a natural stream channel to pass considerable obstacles. With proper design and construction, engineered rough, steep channels can provide fish passage for both juvenile and adult fish. In Europe, natural channel fishways have been increasingly used to pass weaker swimming freshwater fish species over a multitude of low head barriers and dams.

Natural channels can be comprised of boulders embedded in cobbles and gravels on stream slopes to approximately 5%. Steeper slopes to 10% require larger founding substrates or anchoring with concrete. The channels can also be blasted out of bedrock. Generally, there are no empirical methods to support the hydraulic and fish passage design of these structures, but all forms tend to behave hydraulically similar to a pool-and-weir fishway. There are smaller examples of natural channel fishways in the many fish habitat restoration projects throughout BC, but the designs of these structures are not well documented. Examples of larger modified natural fishways include those constructed in blasted bedrock on Nib and Stotan Falls on the Puntledge River for steelhead, coho and chinook salmon, Saddle Rock on the Fraser River and the newly constructed Millstone River Channel in Nanaimo.

In-channel Rock Fishway – Stotan Falls, Puntledge River

Site Assessment

An inherent difficulty in the assessment of fish passage at natural barriers is the lack of structured classification and system of analysis (Osborne, 1985). Significant fish passage barriers or locations of difficult passage were identified from the mouth to the upper Big Silver Creek. The following paragraphs describe each of the sites progressing upstream. The barriers identified in Table 1 were investigated in the field at flows of approximately 15 m^3/s on August 26th, 2008. Detailed hydrology is not available, but watershed size and river widths suggest a watershed comparable to Capilano or Seymour River.

7 Km Falls

Km 7 Falls are logically located approximately 6.2 km upstream of the mouth of Big Silver Creek. At this location, the river is confined and controlled vertically by bedrock. The barrier consist of two hydraulic features. The lowermost hydraulic is a rock-fall within the channel that has confined the river to the left bank creating a significant cascade (4 m vertical by 20 m horizontal). The rock fall occupies over 50% of the channel confining the flow into a high velocity cascade that impinges bedrock halfway along the section, rolling the flow over into the lower pool. As the lowest barrier in the system, the condition factor of the upstream migrating fish would be high and could account for passage upstream.

Approximately 75 m upstream the river falls over a 3.8± m high bedrock structure with two distinct overflows. The right bank[3] flow drops over a single drop with flow separation from the bedrock face and non-aerated flow down a third of the drop. The pool at the base of fall is deep and would provide adequate depth for leaping at the barrier. The fish would have to hit the non-aerated chute and burst through the falls crest to the upstream pool. The vertical height of the falls is likely within the limits of summer steelhead or winter steelhead, and chinook. Passage efficiency would be flow dependant and likely require multiple attempts to hit the non-aerated water, therefore considered low.

The left bank channel splits around a bedrock outcrop in the middle of the river and falls vertically into a shallow pool with some secondary cascading onto on exposed rock at the base of the falls. Unlike the right fall, the left fall does not provide either adequate depth or suitable orientation to allow the possibility of leaping and ascending the hydraulic.

Aside from these two possible opportunities, there are no other overflow or alternative flow paths at the falls at lower or higher flows. The section does constitute a total barrier for resident fish species. We concur with other assessments that this is the likely current extent of anadromous access from Harrison Lake, but coho, sockeye and chinook salmon and steelhead would likely make repeated attempts prior to dropping downstream.

Fish Passage Concepts

Each barrier was reviewed in terms of the type of barrier, types of critical hydraulics at the design flow, bed material and constraints like constructability and access. Depending on the objectives and the species requiring passage, the range of options include incremental improvements to improve passage efficiency for existing stocks (minor) to providing fish passage to all fish resident below the obstruction (major). At many natural barriers with partial or difficult passage conditions, in-channel works (i.e., rock removal, blasting, adding roughness, etc.) can be undertaken to improve the critical hydraulics and provide improved passage. Where

[3] As viewed looking downstream.

wholly impassable hydraulics exist or a high degree of reliability is required (e.g. high passage efficiency), a fishway can be constructed to provide access around or over the barrier.

For this report, a potential option to provide consistent, safe fish passage for all anadromous stocks was developed at each site. Where there several potential options, both or all were provided. Costs developed are conceptual to provide order-of-magnitude comparisons between various options and barrier locations.

7 km Falls is a significant falls with multiple hydraulic barriers. It is likely a partial barrier for steelhead stocks, being very limited due to adverse hydraulics and vertical drops greater that the leaping ability of adult fish. The options to improve fish passage at these falls could include:

a. Major removal of rock at the lower barrier to construct a naturalized channel through the rock fall with a 0.4-0.6 m drop per section proving passage for all species along the right bank; and
b. Construction of a 20% grade Denil/ASP fishway at the left bank of the upper falls with resting pools and a constructed intake providing passage for all salmon and larger resident trout; or
c. Construction of a reinforced concrete vertical slot fishway through the left bank at the falls consisting of 10 pools with 0.4 m drop per 3 m x 3 m pool.

Option a. would entail modification of the existing right bank though existing rock fall and bedrock – creating roughness within the channel to reduce flow velocities and increase depth of flow. This would entail a large rock removal at 15% grades to provide a step-pool through the chute into the reach downstream of the upper falls. Further inspection and surveys are required to confirm grades and total drop.

Option b. would entail construction of a 20% slope standard section steel or aluminum Denil or ASP fishway, installed along the left bank in a rock cut. Access would be constructed from the existing FSR down to a ledge area above the falls. A steep tote road would be required down the bank. The intake would have a small concrete headwall and trash rack, free spanning sections where if would outlet to the pool below the falls. This fishway would provide access for all steelhead, coho and chinook salmon and larger resident trout. Maximum run length would be 15-20 m with 1 pool section. The rock cut would only be 500 mm wide.

Option c. would require significant rock excavation and reinforced concrete construction. The right bank bedrock excavation is favours a sloped benched channel approximately 30 m long at 15% grade. Reinforced concrete weir and common side walls would be installed to form a 3 m wide vertical slot fishway with 3.0 by 3.0 m pools and 0.4 m drop. This would provide access for all species downstream of the falls. Heavy grating and debris protection would likely be required over the fishway as the section would be inundated during floods.

Conceptual Costs

Conceptual costs for rock removal at the lower cascade and construction of a denil/ASP over the falls, or rock removal and construction of a vertical slot fishway at the falls range from $430k to $1,350k. Costs do not include approvals, permitting, design and engineering costs or expanded environmental costs.

Future Work

The presence of target species downstream of either the upper falls or lower cascade need to verified during the expected timing of adult migration for winter steelhead, chinook, coho and sockeye. A temporary gauge should be installed at or near the falls or lower bridge site to develop preliminary hydrology.

Cloudworks Energy Inc. has several IPP (independent power projects) hydro sites upstream of Km 7 on the mainstem (15 km) and in higher elevation tributaries. They should be approached for support in-kind, such as hydrological information, and potentially as a financial supporter of a potentially larger fish passage project. Further workplans should be developed if funding is available for development and construction of the project.

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Prepared by:

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Km 7 Big Silver Fish Passage

Item	Description	Unit	Rate	Amount		Cost
a. Rock-based Pool and Weir Fishway along left bank of lower cascade						
Mobilization/Access	road access to site	km	$250,000	0.25	$	62,500
Rock Excavation	drilling, blasting and rock removal	m^3	$500	100	$	50,000
Reinforced Concrete Construction	weirs, side walls and base slabs	m^3	$1,500	-	$	-
Metalwork	gratings, trash racks, baffles	kg	$10	-	$	-
Site preparation	dewatering, site isolation	LS	$20,000	1	$	20,000
Construction Labour	site labour (person-day)	d	$500	20	$	10,000
Construction Equipment	20T Hydraulic Excavator, 20T Off-road Truck	d	$2,500	10	$	25,000
Environmental	fish salvage stop netting, WQ monitoring	d	$1,000	10	$	10,000
Contingency	25% - Class C				$	44,375
Total Costs - Option a					$	221,875
b. Steel/Aluminum Denil or Steep-pass Fishway along left bank of upper falls						
Mobilization/Access	road access to site	km	$250,000	0.25	$	62,500
Rock Excavation	drilling, blasting and rock removal	m^3	$500	35	$	17,500
Reinforced Concrete Construction	weirs, side walls and base slabs	m^3	$2,000	4	$	8,000
Fishway Fabrication	aluminum or steel with grating	m	$1,200	20	$	24,000
Metalwork	gratings, trash racks, baffles	kg	$10	2,000	$	20,000
Site preparation	dewatering, site isolation	LS	$5,000	1	$	5,000
Construction Labour	site labour (person-day)	d	$500	20	$	10,000
Construction Equipment	20T Hydraulic Excavator, 20T Off-road Truck	d	$2,500	5	$	12,500
Environmental	fish salvage stop netting, WQ monitoring	d	$1,000	10	$	10,000
Contingency	25% - Class C				$	42,375
Total Costs - Option a					$	211,875
b. Vertical Slot Fishway though left bank of upper falls						
Mobilization/Access	road access to site	km	$250,000	0.25	$	62,500
Rock Excavation	drilling, blasting and rock removal	m^3	$500	500	$	250,000
Reinforced Concrete Construction	weirs, side walls and base slabs	m^3	$2,000	200	$	400,000
Metalwork	gratings, trash racks, baffles	kg	$10	3,000	$	30,000
Site preparation	dewatering, site isolation	LS	$20,000	1	$	20,000
Construction Labour	site labour (person-day)	d	$500	40	$	20,000
Construction Equipment	20T Hydraulic Excavator, 20T Off-road Truck	d	$2,500	40	$	100,000
Environmental	fish salvage stop netting, WQ monitoring	d	$1,000	20	$	20,000
Contingency	25% - Class C				$	225,625
Total Costs - Option b					$	1,128,125
Total Costs	**Options a. + b. / rock removal and Denil/ASP**				**$**	**433,750**
	Options a. + c. / rock removal and Vertical slot				**$**	**1,350,000**