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Lewis River Hydroelectric Projects
Constructed Channel
Concept Design

***Final Draft* Report**

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northwest hydraulic consultants nhc

INLAND AND ALPINE FISHERIES CONSULTING

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1 Introduction

1.1 Purpose

Northwest Hydraulic Consultants (**nhc**) and Mr. Bob Pfeifer of Inland and Alpine Fisheries Consulting (IAFC) have been contracted by PacifiCorp Energy to provide recommendations for habitat improvement options in the Swift River Bypass Channel. The proposed improvements relate to the Lewis River Settlement Agreement for relicensing of the Lewis River hydroelectric projects.

Background and rationale for this study is contained in the **nhc** memo *Lewis River Relicensing – Swift Bypass Habitat Channel Reconnaissance Study* (**nhc** May, 2003). This report included the recommendation that further consideration be given to potential habitat improvements in Site 1 of the Swift Bypass Habitat Channel but that habitat improvements would not be feasible at Site 2. Site 1 is known as the "Constructed Channel" and lies between Lewis River and the Diversion Canal; it is located downstream of the Canal Spillway and is fed by the canal drain.

The purpose of this report is to provide a conceptual level design for habitat improvements to the constructed channel. It goes on to present the anticipated habitat benefits from the proposed improvements so that the relative benefit of the various components can be independently evaluated. These improvements have been designed to maximize benefits to target aquatic species and life stages within the existing physical framework and site constraints of the constructed channel. The conceptual approach has been to create stable, long-term improvements to the existing habitat with as little damage as possible; some of the components will take decades to mature and reach full potential while others will provide immediate benefit. Our presumed species of interest are Bull Trout, spring Chinook and Coho salmon (*Oncorhychus kisutch*). While targeting these species, the plan has been designed, however, to provide significant benefits to other life stages and aquatic organisms. The various features of the conceptual design should be viewed as components that can be independently constructed and that do not necessarily rely on each other for success.

1.2 Available Information

The design of the habitat enhancement treatments in the Constructed Channel are based on fisheries information provided by IAFC and two site visits. Fisheries, existing habitats, target habitats, and background information for the project has been compiled by IAFC in their *Technical Memorandum* included as Appendix B. Site visits were made during the reconnaissance study in October, 2003 and November, 2006. During the 2006 site visit, topographic survey information was collected, including a longitudinal profile, cross sections, channel widths and water depths at the proposed flow rate of 14 cfs.

1.3 Site Overview

Swift Reservoir is located in the Southeast Cascades Ecological Region of Washington State, approximately 10 miles south of Mount Saint Helens (Figure 1 from Pacificorp Website). The site is at an elevation of about 550 feet, which is within the zone of intermittent seasonal snowpack. Swift Dam was completed in 1958 and it is presumed that the Constructed Channel was built around this time.

The Constructed Channel is situated between Lewis River and Swift Canal downstream of Swift Dam and adjacent to the spillway. The channel is fed from the upstream end by a culvert draining water from Swift Canal (Canal Drain Culvert) and from groundwater along its right (north) bank. From the culvert, the channel extends approximately 1000 feet downstream to its confluence with Lewis River. The channel has a relatively low gradient of 1.2% over most of its length with locally steeper sections immediately downstream of the water intake (up to 8%) and at the channel outlet (up to 10%). Wetted channel widths vary from between 15 to 20 feet in the free flowing sections, and from between 40 to 50 feet in the backwatered pond sections.

The existing bed material is composed of coarse gravel and cobbles with some small boulders; most of this substrate is covered by sand and fine sediment except where channel hydraulics are sufficient to transport high sand loads. The right (north) bank is composed of fine sandy material that is perennially wetted by seepage flow from the upslope canal. Seepage flow carries fine sediment from the north bank and floodplain into the channel which represents a continuous impact to the morphology and fish usability of the channel. The south bank is generally drier and composed of coarser Lewis River alluvial materials. The riparian zone is characterized by mature to decadent, early succession-stage species dominated by red alder. Some upslope and south bank areas (drier areas of the site) are covered in a young stand of coniferous trees. Ground conditions, particularly on the right side of the channel, vary from moist to saturated.

1.4 Flow Regime and Channel Hydraulics

Water is delivered to the Constructed Channel by a culvert that carries water from the canal to the channel – the Canal Drain Culvert. Flow in the culvert is set by a manual gate located at the inlet to the culvert in the canal. Over the past four years, flows have varied between 14 cfs and 47 cfs. The 401 Water Quality Certification for the Swift No. 1 and Swift No. 2 hydroelectric projects calls for increased flow to be introduced to Lewis River bypass reach and subsequent decreased flow to the Constructed Channel. As a result, an initial constant flow rate of 14 cfs has been designated for the channel. To aid the site survey, the flow rate was set at 14 cfs for the November 2006 site visit. For the purposes of design, a flow rate of 14 cfs has been assumed for habitat calculations and channel performance.

In addition to water entering at the top of the channel, there is significant seepage flow entering the channel from Swift Canal along the entire right (north) bank. Overland and groundwater/seepage water may account for an additional flow of 4 to 5 cfs at the downstream end of the channel.

Flows in the adjacent Lewis River bypassed reach are controlled by releases from the reservoir at one or both of two sources: the existing canal drain and a new structure called the Upper Release to be constructed at the upper end of the canal; these two sources can provide up to 55,200 acre-feet of water each year (about 76 cfs) into the bypassed reach. Participants in the Lewis River relicensing process agreed in October 2003 to adopt the flow regime for Lewis River outlined in Table 1.

Table 1 Flow regime to be adopted for Lewis River based on tentative relicensing agreement reached in October 2003.

Month	Flow (cfs)
January	100
February	75
March	75
April	75
May	75
June	75
July	60
August	60
September	60
October	60
November	100
December	100

This flow regime was altered by Washington Department of Ecology (WDOE) when that agency issued the 401 Certification for the Swift projects. The Lewis River Aquatics Coordination Committee (ACC) still retains the ability to alter the WDOE flows if needed after they become established with the new FERC license. The new flows are as follows (Table 2):

Table 2 Initial flow regime as required by the Lewis River Water Quality 401 Certifications.

Month	Upper Release Flow (cfs)	Constructed Channel Flow (cfs)	Total Flow (cfs)
January	51	14	65
February	75	14	89
March	76	14	90
April	76	14	90
May	76	14	90
June	54	14	68

July	54	14	68
August	54	14	68
September 1-23	54	14	68
September 24-30	55	14	69
October	61	14	75
November 1-15	76	14	90
November 16-30	56	14	70
December	51	14	65

Periodically, during high runoff events, flows are passed via the Swift Dam spillway into Lewis River. Spillway flows are highly variable and generally occur only during the winter and spring months when inflows to Swift Reservoir are in excess of storage and powerhouse capacity. Appendix A provides a complete listing of these spill events. Typically, spills do not in every year but spills in excess of about 20,000 cfs have occurred several times since Swift Dam was constructed. Spills in excess of 40,000 cfs have occurred at least once in that same period.

These extreme spill flows may represent a hazard to the Constructed Channel and any improvements constructed there. Three main hazards exist: 1) greatest consequence would be upstream overtopping and floods flowing downstream through the site, 2) moderate consequence would be lateral erosion at the downstream end of the channel where it meets Lewis River, and 3) lowest consequence would be back-flooding and ponding in the channel from high downstream Lewis River water levels.

To evaluate the upstream overtopping hazard (highest consequence), a cross section of Lewis River near the upper end of the Constructed Channel was surveyed in November 2006. The water stage (height above the bed) was calculated for this section for a 50,000 cfs flood event using Manning's equation and an assumed water surface slope of 1%. Results of this calculation indicate that the existing berm between the Constructed Channel and Lewis River is sufficiently high to prevent flood flows from entering the Constructed Channel and damaging the proposed habitat improvements. This calculation confirms observations made at the site in November 2006 that noted debris on the floodplain near Lewis River but a lack of flood indicators at the toe of the berm.

No specific investigations have been undertaken to evaluate the lateral erosion and back-flooding hazards because of their assumed low to moderate consequence and hazard rating. Improvements to the outlet will be exposed to the direct attack of spill events and will therefore be exposed to a lateral erosion hazard of Lewis River. Existing riprap and apparent stability of the north bank of Lewis River at the outlet, however, lead us to conclude that this hazard is moderate to low. At risk is the value of the improvements to the outlet.

Back-flooding of the lower portion of the constructed channel by turbid Lewis River water has the potential to transport a substantial volume of fine material into the site. As well, the greater water depths during these conditions may have the ability to float unanchored LWD from the lower portions of the channel. At risk is the value of the LWD and gravel added to the lower portions of the channel (likely below the first beaver dam). There was no apparent increase in fine sediment at the downstream end of the channel, however, that would lead us to conclude that the hazard posed by back-flooding is greater than low.

2 Habitat Assessment

A habitat assessment of the Constructed Channel was completed by Inland and Alpine Fisheries Consulting (IAFC) and **nhc** for the purposes of addressing both the biological and physical limitations of the Constructed Channel and determining a baseline of the existing habitat from which improvements can be calculated. IAFC's complete habitat assessment is included in Appendix B and is summarized below.

2.1 Target Species to Benefit

IAFC has reported that although the Joint Explanatory Statement and Settlement Agreement are clear that anadromous fish (salmon and steelhead) and bull trout are to be enhanced, primarily by reintroduction of adults into spawning and rearing areas above the three dams, there is no explicit language indicating which fish species the habitat enhancement in the Constructed Channel should benefit. Consequently we have adopted these species as the species of interest for the Constructed Channel Improvements.

2.2 Biological Assessment

Although the Constructed Channel is currently functioning at a satisfactory level of productivity, limiting biological habitat conditions were identified. These include: 1) the lack of suitable spawning areas for the target salmonid species, 2) the general lack of deep pools, 3) the paucity of over-wintering and rearing habitat types, and 4) the lack of long-term, stable LWD and cover elements in the channel. As well, the steep, shallow-flow section at the channel outlet has the potential to be a location of difficult passage to upstream fish migration.

2.3 Physical Assessment

The physical components of the Constructed Channel were assessed by **nhc** on the basis of form and process. In making this assessment, the form of the channel was compared to what would be typical of a natural stream in the region, but keeping in mind the processes are necessarily quite different. The Constructed Channel is isolated from coarse sediment inputs and the constant flow regime is set at the canal drain culvert with minor contribution by seepage flows. Fine sediment inputs are limited to suspended fractions that enter the channel from Swift Reservoir (i.e. through the canal drain culvert) and the significant amounts of sediment that enter the channel from the banks and floodplain.

Given the limited range of flows, the channel is in some respects surprisingly unstable. Overland seepage flow and continuous slumping on the north bank contribute significant amounts of fine sediment to the channel. The high water table on the north side of the channel seems to be a limiting factor in the health of the riparian ecosystem, preventing the growth of most coniferous species and resulting in shallow root structure in the existing population of mature alder. Significant wind throw is apparent, however, woody debris inputs from deciduous species do not generally represent stable, long-term habitat elements.

In contrast to deep scour pools in natural river systems, most of the deep pools in the Constructed Channel are dammed pools above channel-spanning beaver dams. There is evidence at the site that these beaver dams (composed of deciduous tree material that quickly rots) do not remain stable over the long-term (of the four dams identified two have failed and one is currently failing). While failure of beaver dams and subsequent dewatering of the upstream beaver ponds is a natural process and part of the evolution of streams and floodplains in many western streams, dam failure in the Constructed Channel has several undesirable consequences for the habitat.

First, the dams and upstream ponds represent the only deep-water habitat in the channel. Loosing these ponds reduces the amount of total habitat available (reduces the overall wetted area) and limits adult holding and refuge habitat. Second, the ponds trap much of the fine sediment transported into the site from the north bank. These sediments, and their amount, represent the greatest limiting condition to the value of the habitat. Beaver dam failure exposes previously trapped sediment to renewed downstream transport. Once remobilized, these sediments degrade downstream channel features such as spawning gravels and pools. Finally, rapid failure of beaver dams may result in fish stranding.

Flow conditions in the Constructed Channel are generally quite tranquil except at the inlet and at the outlet to Lewis River. The overall gradient of the site is about 6% but much of the drop in the gradient is gained in two short areas (near the inlet and at the outlet to Lewis River); flow velocities in these sections of the channel likely approaches 9 ft/s at 14 cfs. Between the inlet and outlet, the slope of the Constructed Channel is typically about 2.2% over a channel length of 1000 ft. This lower gradient section of the channel has three large ponds where the local water surface gradient is nearly flat producing flow conditions that are slow and deep. Between the ponded sections, the stream gradient approaches 3% producing 0.3 to 1.5 ft depths and 1 to 6 ft/s stream velocities as the width of the channel varies at 14 cfs.

3 Recommended Habitat Enhancements

nhc and IAFC have developed a comprehensive Habitat Enhancement Plan to improve key habitat types for the intended target species and life stages in the Constructed Channel. This plan addresses the habitat limitations that have been identified in the context of the physical processes affecting the site. Thus the plan represents our recommendations for habitat improvements given the site limitations and existing conditions.

We have proposed a plan that will entail some short-term disturbance to the site but we feel that these impacts are outweighed by future benefits and we propose that the access routes will be treated to allow conifer growth in the wet, alder-dominated riparian zone (see Section 3.6 below). The plan includes the following main components:

- Outlet channel realignment and construction of a step-pool morphology,
- Channel narrowing using LWD,
- Installation of porous rock weirs to stabilize existing beaver dams,
- Excavation of off-channel ponds and pools,
- Inlet channel realignment,
- Creation of raised planting pads, and
- Coniferous riparian planting.

It should be stressed that the proposed plan is composed of a series of components that do not necessarily rely on other components for their success. As such, individual parts of the plan can be implemented independently of other parts at the ACC's discretion. The plan outlines our recommended improvements.

These habitat components with their design considerations and intended benefits are outlined in the sections below; they are roughly arranged from downstream to upstream. Figure 2 shows the project layout and Figure 3 provides construction details and typical treatments. Table 5 outlines the materials required for construction while Table 6 outlines the anticipated costs.

We have assumed that the Constructed Channel will be dewatered and resident fish temporarily removed from the site for construction. Heavy equipment requirements will include an articulated rock truck(s) and a small excavator to be supported by logging trucks and highway dump trucks that will be used to deliver specified materials to the site. A 'Spyder' excavator or a logging helicopter will be required to construct the LWD structures where access is difficult (i.e. between well defined access points) and a small suction dredge may be required to remove fine sediment from the upper pond if the sediment is too liquid to excavate. A small labour crew using hand tools such as chainsaws and winches will be required to support the heavy machinery.

A key consideration of the plan is the short-term damage that construction will create. To reduce impacts, heavy machinery will be limited to the north bank, defined access points into the north riparian zone (laid out to avoid larger trees where possible), and the existing upstream berm. Improvements between these access points (LWD and gravel additions) will be moved by a 'Spyder' excavator or preferably by logging helicopter. Because of the wetness of the site, access into the north riparian zone will require a solid foundation or tote road to be constructed. This raised platform will create an opportunity to create a drier planting area on the north floodplain suitable for conifer planting. Channel construction at the inlet and outlet will be through upland areas above the floodplain. Machines will be confined to the centreline of these areas to avoid damaging the surrounding riparian vegetation.

3.1 Outlet Channel Realignment

The steep outlet channel has been identified as a difficult passage location for upstream fish migration. Realignment of the outlet channel would allow for an increase in the channel length, thus reducing the overall gradient, and would take advantage of an existing pool in Lewis River where fish could hold prior to entering the Constructed Channel.

Realignment of the outlet channel would be completed using a small excavator. The work site will be accessed from the adjacent road at the base of the canal and a short trail constructed on the north bank. The new outlet channel would be excavated into the existing materials but may require some imported larger rock to stabilize the channel (D_{50}= 2 feet), particularly along the south edge of the channel when periodic large spill flows would cause more extreme hydraulic conditions. To concentrate outflow from the channel into the new alignment, a small berm will be created to the south at the small alder island.

The channel will be composed of a series of step-pools on an overall gradient of 7%. The overall drop in the grade will be made up on twelve, 1 foot high steps. Between the steps, a series of 1 foot deep, 3 foot long pools will provide temporary resting locations for migrating fish. Water level in the pools will be controlled by the crest of the next downstream step.

3.2 Channel Narrowing Using LWD

The channel between station 02+30 and 04+10 has a relatively consistent channel geometry (width and depth) and slope with very few cover features or hydraulic diversity (depth and velocity). There exists an opportunity to improve this habitat using LWD pieces with rootwads in the bed to slightly narrow the channel, raise water depths upstream, and produce plunging, scouring flows downstream. Figure 3 shows a typical design that would employ two LWD pieces on opposing banks, narrowing the width by up to two thirds. This would tend to increase upstream water levels, and accelerate flow between the LWD which will flush fine sediment from the coarser bed material. Slack water would exist in and around the LWD pieces that will be suitable for juvenile rearing.

In selected areas of higher velocity, such as between LWD pieces or below rock weirs, spawning gravel meeting WDFW gradation criteria would be placed as spawning pads (Table 3). Existing bed materials would be excavated and the appropriate gravel mix placed at a thickness of approximately 1.5 feet.

Table 3 Typical spawning gravel gradation.

Size range (in)	Percent composition
fines	8
0.12 – 0.47	23
0.51 – 1.97	43
2.00 – 3.94	23
3.98 – 5.91	3

Access to this site would be via a continuation of the access created to complete the realignment of the outlet as well as for construction of the upstream porous weir. We have shown a design that does not require rock ballast or cable anchors but relies on the weight of the LWD on bank to provide stability. Rootwads with stem lengths at least 16 feet are required.

3.3 Porous (Leaky) Rock Weirs

Porous rock weirs have been included in the design to reinforce existing beaver dams, creating more permanent backwater features within the channel. At present the existing dams are fragile and may fail in the near future. Failure of the dams will drain the ponds (reducing the available ponded area in the channel) allowing the remobilization of fine sediment that is stored in the ponds. Remobilized sediment will impact downstream channel units and may degrade downstream gravel additions. The habitat enhancement design includes three rock weirs at the three main beaver dams (Figure 2; stations 04+30, 06+30, and 08+20 ft).

Construction of porous rock weirs will require that a stable access point be constructed across the soft, saturated floodplain soils in order to move the necessary volume of rock to the site and to provide machine access for construction. Adjacent to the lower two rock weirs, these access points will also function as lateral berms to prevent overflow channels from eroding across the floodplain surface and create raised planting areas for conifers.

The leaky rock weirs will be constructed using well-graded rock with a median diameter of 12 inches. The gradation will limit flow through the structure, thereby forcing water across the surface of the structure and minimizing the risk of drying. Where possible, the bed and banks should be excavated slightly to key the weir into the existing bed and banks to a distance of one to two feet. Rock should be placed against the downstream side of the existing beaver dam and have a 5 horizontal to1 vertical downstream slope. The weir crest and the center of the downstream face should be lowered slightly to concentrate flow in the middle of the channel giving the structure a concave-up cross profile. Additional rock should be placed as required along the upstream and downstream banks to prevent erosion. The rock weirs will be constructed to an elevation that is slightly lower than the existing dam elevation.

The weirs will be built to the same elevation as the existing dam. As a result the dams will not pond additional water upstream; their sole function will be to create stable features in the channel. The weirs will have a "dished" cross profile so that water spilling over the weir will be concentrated in the center of the structure to provide adequate upstream migration conditions.

LWD would be placed immediately downstream of weir structures to add cover to the anticipated scour pool that is likely to form. Gravel meeting the WDFW gradation criteria will be placed in the downstream channel to provide a fine-sediment free spawning area in these faster flowing sections of the channel.

3.4 Excavation of Ponds and Pools

Ponds and pools will provide high-quality rearing areas for juvenile salmonids, particularly coho. The design lays out three potential sites for pool or pond excavation (Figure 2): a pocket pool at the outlet (station 01+80 ft), a mid-channel pool near the inlet (station 10+80 ft), and a large upper pond (station 11+70 ft).

The lowest excavated pool will be constructed at station 02+10 during the outlet realignment. This small pool will be located at the top of the steep outlet channel and will provide a resting location for fish entering the site. Water level in the pool will be controlled by the most upstream step in the realigned outlet channel. Pool depth will be limited by local site conditions but should be in excess of four feet. Material excavated from the pond may be used to construct an additional raised planting pad on the north floodplain or trucked from the site.

Near the inlet channel an existing pool spans the main channel at station 10+80 ft. The construction of an upstream porous weir will ensure that this pool is maintained by scour and as a result we recommend that the existing pool is enlarged and deepened to increase rearing use. Access to the excavation will be from the north bank and materials removed from the streambed may be suitable for fill at the inlet channel.

The final pond/pool at the site will be a partly excavated, partly ponded pool at station 11+70 ft. The pool depth will be increased by removing much of the fine sediment filling the area then ponding water upstream of a porous weir constructed at station 11+70 ft. Combined these two techniques will give a large (12700 ft^2) pond that has depths greater than 4 ft. The area may contain sediment that is too fine and liquid to be removed by conventional excavator. As a result, a suction dredge may be required to remove this material. Access to the pool will be from the inlet channel and the existing berm. All material will be trucked from the site to a pre-determined spoil site that is located at the upstream end of the south berm for coarse material and off-site for fine material.

All excavated or dredged ponds will be complexed with LWD pieces to provide critical cover for juvenile salmonids. Detail D in Figure 2 shows several options for securing LWD where burial in disturbed banks, weight of the wood above the water, or mass of the non-buoyant roots will provide stability. Salmonid production has been shown to be related to LWD density in ponds and pools and therefore we recommend that LWD be added to pools to a density of about 25% of the pool or pond surface area (Table 5 outlines the wood required by habitat feature).

3.5 Inlet Channel Realignment

The steeper channel immediately downstream of the canal drain culvert presents a good opportunity to enhance the existing riffle habitat of the upper channel by raising the elevation of the bed and extending the channel length to provide a longer, shallower inlet channel (Figures 2 and 3). The longer channel will be composed of a series of steeper and shallower riffles designed for spawning and tumbling flow. The shallow or spawning riffles will be at least 8 feet wide and will contain gravels that meet the WDFW gradation specifications (Table 3). Water depths in these channel sections will be about 12 inches deep and flowing at about 1.7 feet/sec. Water level in the spawning sections will be controlled by a series of steeper riffles where the overall drop in the grade will be achieved. Conditions on the steeper riffles will be more extreme than on the spawning riffles with local velocities as high as 6 feet/sec and depths as low as 8 inches. Boulders on the face of the steep riffles will be positioned to create a deep, sinuous slot across the feature.

The lengthened inlet channel will join the upper pond via a porous weir. The weir crest will be set to provide suitable spawning conditions on the next upstream spawning riffle of the inlet channel. The upstream pond will provide a refuge area for adult fish using the upstream spawning area and a suitable rearing area for fry.

To isolate the new inlet channel from the main channel a rock berm will be constructed along the center of the existing channel, corresponding approximately to the existing island, to divide the flow entering the upstream pond and that draining the pond (Detail D in Figure 2). A porous rock weir made of a well-graded 12 inch boulder mix would be constructed on either side of the berm, at the downstream end of the inlet channel section as well at the pond outlet. Dredging will further deepen the pond and extend its lifespan.

We expect that fine sediment will enter the pond from the adjacent slopes, however the outlet weir will backwater the pond and isolate those sediments from the rest of the channel. Over time, sediment infilling will cause a gradual shift in habitat type from deep pond to shallow marsh, however flow through the pond should maintain a clear channel between the two rock weirs. LWD placed in a line from the end of the rock berm will extend its effective length out into the upstream pond.

Upstream from the inlet channel, large riprap will be placed on the base of the slope at the canal drain culvert to prevent further erosion and slumping of the steep side slopes; this will reduce the sediment transport to downstream areas of the channel. In anticipation of re-introduced anadromous salmon, the conditions at the base of the inlet require alteration to prevent injury in jumping fish. Adult fish may attempt to jump at the flow coming from the intake culvert and be injured on the coarse riprap below the culvert. We recommend constructing a very steep rock barrier from coarse (2 to 3 foot diameter) rock immediately downstream of the culvert. Flow would disperse through the rock and flow out the downstream end across the channel width so that there would be no concentrated jet of water. The configuration would resemble a groundwater source entering at the base of a steep bank. With no water spilling from overhead adult fish will be less likely to jump at the barrier.

3.6 Raised Planting Pads

The normal ground conditions adjacent to the channel appear to be wet to saturated fine-grained soils. These are not optimal growing conditions for most tree species, particularly conifers, and may be the cause of the significant amount of tree blow down within the riparian area and lack of conifer recruitment on the north bank. There exists several opportunities to create locally higher ground above the saturated soils where conifer and other species could be planted (Detail C in Figure 2).

Raised planting pads would be added to those areas adjacent to the raised access points and gravel berms required for porous weir construction. They would create drier growing conditions, allowing conifer species to become established. In addition, the access points and berms themselves would represent improved growing sites. Other sites include those areas adjacent to the excavated pond and pool where excavated material could be spoiled to create an improved growing site.

The pads would be constructed from well-drained coarse gravel material such as pit-run and will be capped with a one-foot thick layer of local fine material or imported topsoil. Upon completion of the project, machine access points should be de-compacted and a one-foot layer of local fine material added prior to planting.

3.7 Riparian Planting

The importance of a healthy riparian habitat is well documented in the scientific literature. Riparian trees and shrubs contribute to the physical habitat by various means including providing shade, imparting bank strength, providing inputs of LWD for instream structure, and providing food through leaf litter and bug drop. Riparian vegetation also plays an important role in terms of nutrient inputs as well as providing physical habitat for non-aquatic species. It is difficult to quantify the benefits of an enhanced riparian vegetation community in terms of area or depth of habitat, however, the long-term benefits should be considered as adding significantly to the aquatic habitat values of the Constructed Channel and are an essential part of the long-term plan.

At present the composition of the riparian vegetation is limited to mature and decadent alders. Adopting a program of riparian planting would accelerate the natural succession to a conifer-dominated ecosystem, particularly by taking advantage of the improved growing sites created during construction. The British Columbia (Canada) Ministry of Environment has circulated guidelines for planting riparian areas titled "Planting Criteria and Recommended Native Tree and Shrub Species for Restoration and Enhancement of Fish and Wildlife Habitat" in July 1998. This information package includes valuable guidelines for riparian projects. We recommend using the tree and shrub species listed in Table 4 from the planting criteria included below:

Table 4 Recommended riparian species composition.

Botanical Name	Common Name	Fruit Bearing	Mature Height (m)	Best Growth Conditions
Deciduous Trees				
Acer circinatum	Vine maple		To 7	Moist to wet
Acer glabrum var. douglasii	Douglas maple		To 10	Dry to moist
Acer macrophyllum	Broadleaf maple		To 35	Dry to moist
Alnus rubra	Red alder		To 25	Moist
Betula papyrifera var. commutata	Western white birch		To 30	Moist to wet
Crataegus douglasii	Black hawthorn	Y	To 10	Moist
Populus balsamifera or P. trichocarpa	Black cottonwood		To 50	Moist to wet
Rhamnus purshiana	Cascara		To 10	Dry to wet
Salix lucida spp. lasiandra	Pacific willow		To 12	Wet
Coniferous Trees				
Picea sitchensis	Sitka spruce		Up to 70	Moist
Pseudotsuga menziesii	Douglas fir		To 70	Dry
Thuja plicata	Western red cedar		To 60	Moist to wet
Tsuga heterophylla	Western hemlock		To 60	Dry to wet
Shrubs				
Alnus crispa ssp. Sinuata	Sitka alder		1-5	Moist
Amelanchier alnifolia	Saskatoon	Y	1-5	Dry to moist
Cornus sericea or C. stolonifera	Red-osier dogwood	Y	1-6	Moist
Holodiscus discolor	Oceanspray		To 4	Dry to moist
Physocarpys capitatus	Pacific ninebark		To 4	Wet
Prunus virginianan	Choke cherry	Y	1-4	Dry
Rosa nutkana	Nootka rose	Y	To 3	Dry to moist
Rosa gymnocarpa	Baldhip or dwarf rose	Y	To 1.5	Dry to moist
Rubus parviflorus	Thimbleberry	Y	0.5 to 3	Moist
Rubus spectabilis	Salmonberry	Y	To 4	Moist to wet
Salix hookeriana	Hooker's willow		To 6	Wet
Salix lucida spp. lasiandra	Pacific willow		To 12	Wet
Salix scouleriana	Scouler's willow		2-12	Moist
Salix sitchensis	Sitka willow		1-8	Moist to wet
Sambucus caerulea or S. glauca	Blue elderberry	Y	-	Dry to moist
Sambucus recemosa var arborescens	Red elderberry	Y	To 6	Moist
Symphoricarpos albus	Snowberry	Y	0.5 to 2	Dry to moist

Planting Criteria:

The guide recommends the following criteria when planting in riparian areas:

- All riparian plantings should be based on 1 tree or shrub per 1 square meter (11 square feet) density.
- Due to the predominance of mature deciduous trees on the site, coniferous trees should comprise the bulk of the tree stock planted.
- All tree/shrub species should be of guaranteed nursery stock.
- The botanical name should be used when ordering stock to ensure that the desired native species is being purchased. Each specimen should be tagged with the botanical name and the tag should be left after planting.

- Tree stock should be a minimum of 1.2 meters (4 feet) in height when purchased and planted 1.5 to 2 meters (5 to 6.5 feet) apart.
- Stock planted during the fall (Sept.-Oct.) and spring (Mar.-Apr.) has the greatest likelihood of surviving. Regular watering may be required until the plants are established. Additional advice on proper planting procedures should be obtained from the nursery supplying the stock.
- Planting on a given area being enhanced must be successful to an 80% take. If more than 20% die over one year replanting is required.
- A minimum of 50% of trees and shrubs planted should be fruit-bearing species.

The right (north) bank and floodplain are moist to saturated and therefore water tolerant tree species such as Western Red Cedar (*Thuja plicata*) should be planted in wet areas.

4 Materials and Costs

Table 5 outlines the construction materials required to complete the proposed habitat enhancement design by treatment. 226 individual LWD pieces (logs, rootwads, and stumps) are required as cover elements, 56,100 ft^3 of excavation is required at four areas, 18,130 ft^3 of coarse rock and riprap is required and 35,270 ft^3 of gravels and fills are required.

Table 5 Materials Required for Habitat Enhancement

Habitat Enhancement	Chainage	Treatment	LWD			Excavation			Coarse Rock		Gravels and Fills		Comments
			Specified Type	Channel, Pool, or Pond Area (ft^2)	Number Required	Area (ft^2)	Average Depth (ft)	Volume (ft^3)	Material Type	Volume (ft^3)	Material Type	Volume (ft^3)	
Outlet Channel	00+00 to 01+80	Excavation	-	-	-	2400	3	7200	Angular riprap	1600	-	-	Much of excavation in coarse riprap; armour with 8 ft^3 per linear foot coarse riprap
Pocket Pool	01+80 to 02+20	LWD complexing	Log, Rootwad, and Stump	1200	6	-	-	-	-	-	-	-	25% coverage by area, 50 ft^2 per LWD
		Excavation	-	-	-	1200	3	3600	-	-	-	-	Pool at upstream end of new outlet channel
Small Berm	01+90 to 02+10	Gravel berm	-	-	-	-	-	-	-	-	Coarse gravel fill	200	Block flow in secondary opening, 20 ft long, 2 ft high
Lower Channel	02+20 to 04+10	LWD narrowing	Rootwad	7 structures	14	-	-	-	-	-	-	-	Rootwads are essential to the functioning of this structure
		LWD complexing	Log, Rootwad, and Stump	3800	8	-	-	-	-	-	-	-	10% coverage by area, 50 ft^2 per LWD
		Gravel additions	-	-	-	-	-	-	-	-	Spawning gravel	630	7 areas of gravel additions downstream of LWD narrowing structures; 90 ft^3 per structure
Gravel Berms and Planting Pads	04+10 to 04+70	Raised access point	-	-	-	-	-	-	-	-	Coarse gravel fill	4000	80 ft long, 10 ft wide, 5 feet deep
		Planting pads	-	-	-	-	-	-	-	-	Coarse gravel fill	3000	2 pads at 600 ft^2 each, 2.5 ft deep
		Gravel berm	-	-	-	-	-	-	-	-	Coarse gravel fill	600	50 ft long, 4 ft wide, 3 feet deep
Porous Weir	04+30	Rock weir	-	-	-	-	-	-	Rounded weir rRock	900	-	-	2 ft high, 40 ft wide
Beaver Pond	04+30 to 05+50	LWD complexing	Log, Rootwad, and Stump	4300	22	-	-	-	-	-	-	-	25% coverage by area, 50 ft^2 per LWD
Stream Channel	05+50 to 05+90	LWD complexing	Log, Rootwad, and Stump	1500	5	-	-	-	-	-	-	-	15% coverage by area, 50 ft^2 per LWD
		Gravel additions	-	-	-	-	-	-	-	-	Spawning gravel	200	Add gravel to upstream 20 ft of channel
Gravel Berms and Planting Pads	06+05 to 06+65	Raised access point	-	-	-	-	-	-	-	-	Coarse gravel fill	3000	60 ft long, 10 ft wide, 5 feet deep
		Planting pads	-	-	-	-	-	-	-	-	Coarse gravel fill	3000	2 pads at 600 ft^2 each, 2.5 ft deep
		Gravel berm	-	-	-	-	-	-	-	-	Coarse gravel fill	240	20 ft long, 4 ft wide, 3 feet deep
Porous Weir	06+30	Rock weir	-	-	-	-	-	-	Rounded weir rock	790	-	-	2 ft high, 35 ft wide
Beaver Pond	06+30 to 07+50	LWD complexing	Log, Rootwad, and Stump	6500	33	-	-	-	-	-	-	-	25% coverage by area, 50 ft^2 per LWD
Stream Channel	07+50 to 08+10	LWD complexing	Log, Rootwad, and Stump	2000	6	-	-	-	-	-	-	-	15% coverage by area, 50 ft^2 per LWD
		Gravel additions	-	-	-	-	-	-	-	-	Spawning gravel	200	Add gravel to upstream 20 ft of channel
Planting Pad	08+00 to 08+20	Planting pads	-	-	-	-	-	-	-	-	Coarse gravel fill	1500	1 pad at 600 ft^2, 2.5 ft deep
Porous Weir	08+20	Rock weir	-	-	-	-	-	-	Rounded weir rock	900	-	-	2 ft high, 40 ft wide
Beaver Pond	08+20 to 09+20	LWD complexing	Log, Rootwad, and Stump	2900	15	-	-	-	-	-	-	-	25% coverage by area, 50 ft^2 per LWD
Stream Channel	09+20 to 11+60	LWD complexing	Log, Rootwad, and Stump	5700	17	-	-	-	-	-	-	-	15% coverage by area, 50 ft^2 per LWD
		Gravel additions	-	-	-	-	-	-	-	-	Spawning gravel	200	Add gravel to upstream 20 ft of channel
Rock/Gravel Berm	10+70 to 13+00	Gravel Berm	-	-	-	-	-	-	Angular riprap	1750	Coarse gravel fill	4400	175 ft long: riprap - 10 ft^3 per linear foot; fill 25 ft^3 per linear foot
		LWD Extension	Rootwad	-	20	-	-	-	-	-	-	-	Continuous LWD line in centre of pool
Mid-Channel Pool	10+80 to 11+20	Excavation	-	-	-	2400	3	7200	-	-	-	-	Deepen existing pool
		LWD complexing	Log, Rootwad, and Stump	2400	12	-	-	-	-	-	-	-	25% coverage by area, 50 ft^2 per LWD
Porous Weir	11+70	Rock weir	-	-	-	-	-	-	Rounded weir rock	1200	-	-	up to 4 ft high, 26 ft wide
Upper Pond	11+70 to 12+60	Excavation	-	-	-	12700	3	38100	-	-	-	-	Backwatered pond on left bank
		LWD complexing	Log, Rootwad, and Stump	12700	64	-	-	-	-	-	-	-	25% coverage by area, 50 ft^2 per LWD
Porous Weir	12+60	Rock weir	-	-	-	-	-	-	Rounded weir rock	1040	-	-	3 ft high, 46 ft wide
Spawning Channel	12+60 to 13+90	General fill	-	-	-	-	-	-	-	-	Clean fill	12500	Average 2 ft depth of fill to establish general grade for new channel
		Spawning riffles	-	-	-	-	-	-	Rounded weir rock	200	Spawning gravel	1600	1.6 ft depth minimum; line channel edges with weir rock
		LWD complexing	Rootwad and Stump	1200	4	-	-	-	-	-	-	-	15% coverage by area, 50 ft^2 per LWD
		Riffle drops	-	-	-	-	-	-	Rounded weir rock	1350	-	-	
Settling Basin	13+90	Riprap lining	-	-	-	-	-	-	Angular riprap	8400	-	-	2 to 3 ft riprap
TOTAL					226			56100		18130		35270	

To place and excavate these materials we estimate that construction will require two excavators, support machines, trucks, and crews 28 days to construct. We recommend that a budget of $550,000 (including a 25% contingency) be secured (Table 6).

Table 6 Proposed Habitat Enhancement Costs

Item	Rate ($)	Units	Comment	Total ($)	Total units
1. Materials					
- rootwads, logs, and stumps [1]	300	piece	Assumes 1.5 yd^3 per log, $300 per piece delivered	$67,800	226
- rounded weir rock	30	yd^3	Delivered	$7,080	236
- spawning gravel	30	yd^3	Delivered	$3,150	105
- coarse gravel fill	30	yd^3	Delivered	$22,170	739
- clean fill	30	yd^3	Delivered	$13,890	463
- riprap	35	yd^3	Delivered and placed	$15,225	435
			SUBTOTAL - MATERIALS	**$129,315**	
2. Fish Salvage					
- fish removal from site	15000	lump	lump sum	$15,000	-
			SUBTOTAL - FISH SALVAGE	**$15,000**	
3. Supervision					
- environmental monitor	400	day	$40/hour and 10 hour day	$11,054	28
- incidentals	103	day	assumes meals and accomodations	$2,846	28
- junior engineer / technician	900	day	$90/hour and 10 hour day	$24,872	28
- incidentals	103	day	assumes meals and accomodations	$2,846	28
- project engineer	1,250	day	$125/hour and 10 hour day	$34,544	28
- incidentals	103	day	assumes meals and accomodations	$2,846	28
			SUBTOTAL - SUPERVISION	**$79,010**	
3. Heavy Machinery					
- excavator (excavations)	7	yd^3	on-site trucking included	$43,633	6233
- excavator (log placements)	145	hour	assumes 3/4 of LWD placed by excavator	$7,250	50
- excavator (weir and planting pad construction)	125	hour	2 days per weir/pad combination (3 areas)	$7,500	60
- excavator (inlet and upper channel construction)	125	hour		$6,250	50
- 40' trash hauler dump truck or self-loading logging truck	100	hour	inc. in materials estimate	$0	0
- tracked Komatsu dump or articulated dump truck (2)	125	hour	inc. in excavations estimate	$0	0
- logging helicopter	10,400	hour	assumed 4 min. turn per log (1/4 of logs placed by helicopter); 2 hours ferry time included	$59,973	5.8
- "Spyder" excavator	170	hour	possible alternative to logging helicopter (not inc.)	$0	0
- mobilization costs	15000	lump		$15,000	1
			SUBTOTAL - HEAVY MACHINERY	**$139,607**	
4. Labour Crews (2 persons)					
- wages	900	day	$30/hour, 10 hour day, 3 persons	$24,872	28
- incidentals	300	day	assumes meals and accomodations	$8,291	28
			SUBTOTAL - LABOUR	**$33,163**	
5. Other Costs					
- vehicle rentals (2)	3600	month	2 supervisor vehicles	$3,600	1.0
- consumables [2]	2000	month	see notes for inclusions	$2,000	1.0
- equipment rentals [3]	5000	month	see notes for inclusions	$5,000	1.0
			SUBTOTAL - OTHER	**$10,600**	
6. Planting					
- seedlings	10.00	stem	mixed species; 1 stem per square yard	$10,000	1000
- grass seed, fertilizer included	15.00	bag	10 lb bag; mix to be specified by monitor	$450	30
			SUBTOTAL - PLANTING	**$10,450**	
7. Reporting					
- as-built reporting	20000	lump	lump sum	$20,000	
			SUBTOTAL - REPORTING	**$20,000**	
8. Contingency					
- Assumed 25% contingency				**$109,286**	
Construction Estimate			**TOTAL ALL TASKS**	**$546,430**	

5 Summary and Recommendations

We recommend that the habitat enhancement of the Constructed Channel include the following:

* The greatest impact to aquatic habitat in the Constructed Channel is the on-going fine sediment input from the right (north) bank. Habitat improvements should be planned that limit the effect of this on-going impact;

* The compensation works should target rearing habitats with strategic spawning gravel placement;

* Pool habitats should enhanced by increasing residual depth to more than 3 feet and wood cover should be added to provide adult holding habitat;

* Existing beaver dams should be reinforced to prevent the transport of fine sediment from the upstream pond to downstream stream habitats. Reinforced dams will maintain pond-rearing habitat;

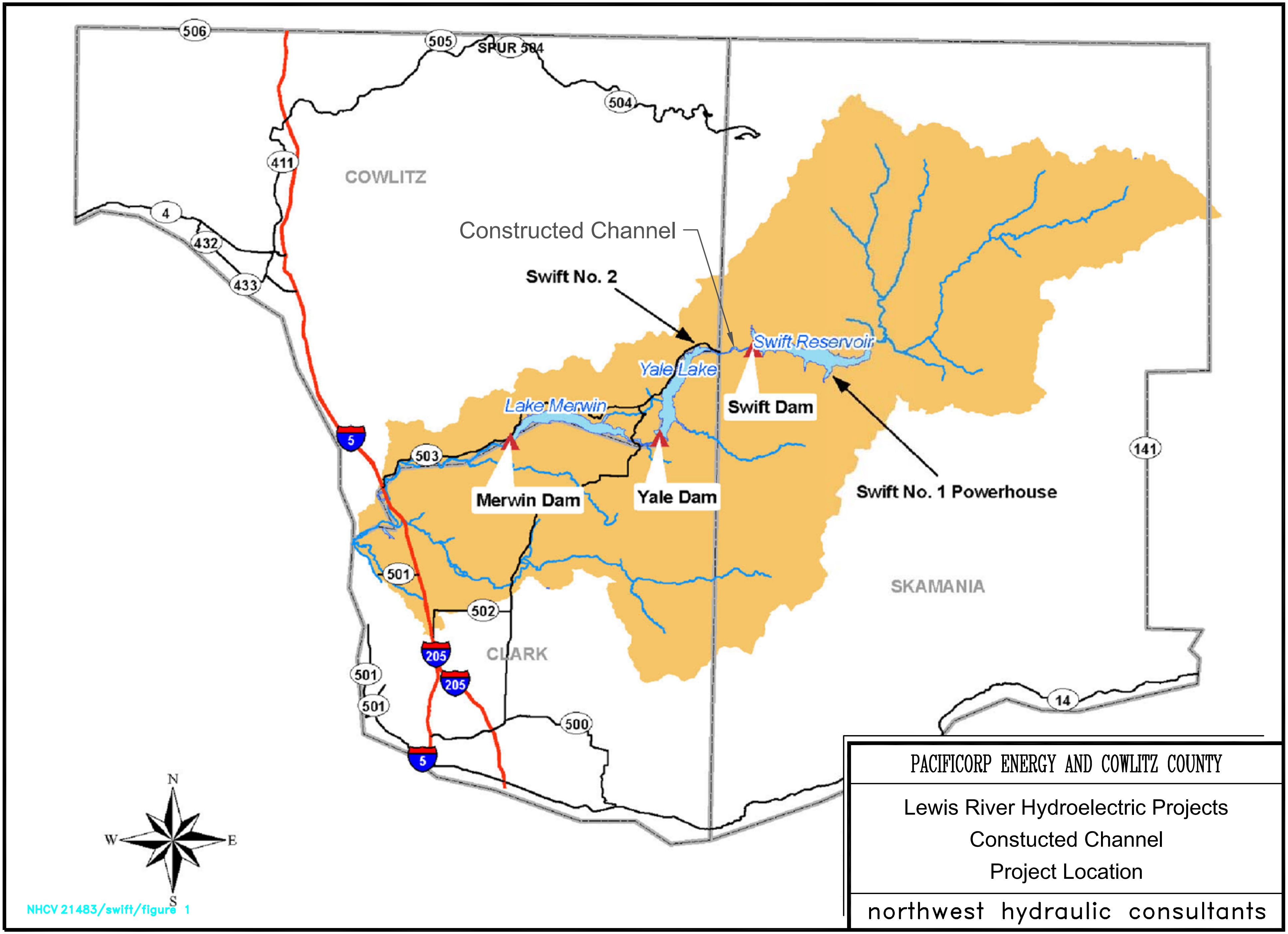
* Coniferous LWD should be added at strategic locations throughout the site for stable, long-term cover and creation of pocket-spawning habitat. Existing alder LWD has a short life-span in water;

* Compensation works should minimize damage to existing riparian habitat, instream LWD, and the stream channel. Heavy machinery should be confined to set access points that will be planted after construction;

* Secondary compensation benefits are available by realigning the inlet and outlet channels; and

* The Constructed Channel should be dewatered and fish salvaged during construction. Construction should be planned for the month of July when fish use and egg/alevin incubation in the gravels is lowest.

6 Figures

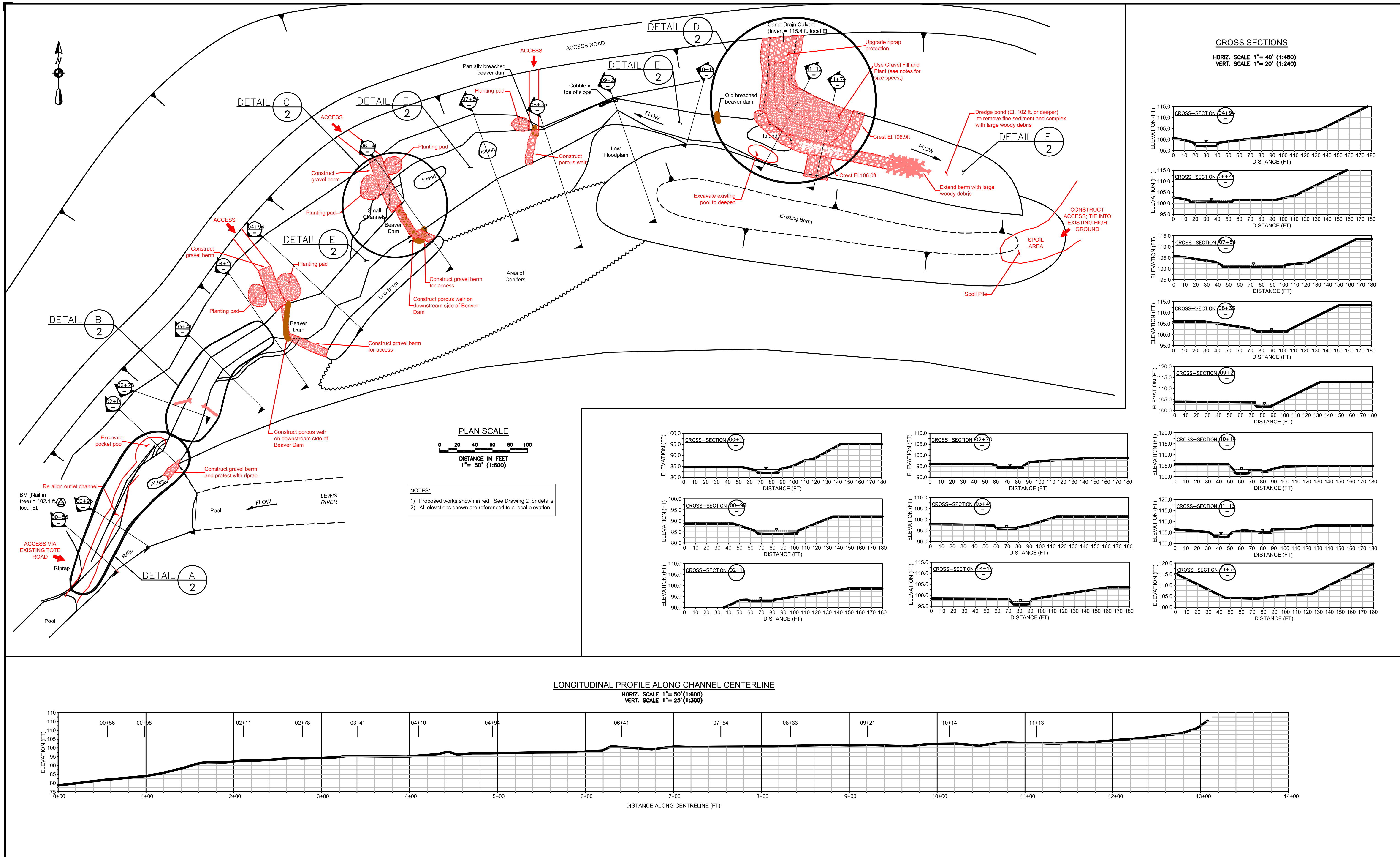


PACIFICORP ENERGY AND COWLITZ COUNTY

Lewis River Hydroelectric Projects
Constucted Channel
Project Location

northwest hydraulic consultants

Figure 1

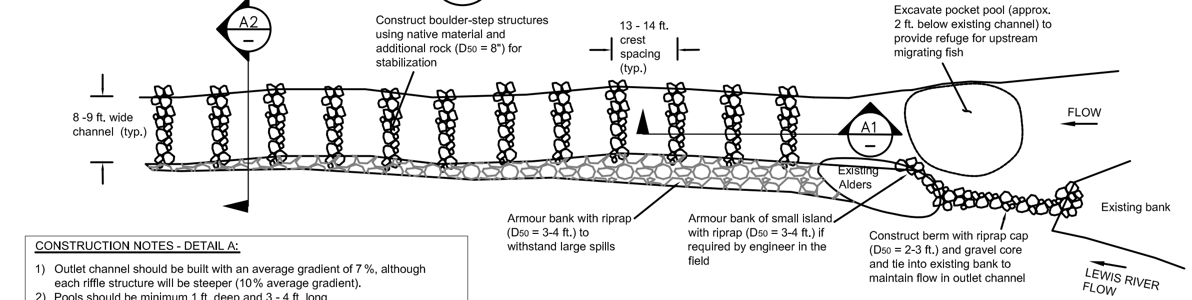


Sheet Reference Number 1 1 OF 2	LEWIS RIVER HYDROELECTRIC PROJECTS CONSTRUCTED CHANNEL CONCEPT DESIGN PLAN - PROFILE - SECTIONS	PACIFICORP 105 Merwin Village Court Ariel, Wa., U.S.A. 98603 Office: (360) 225-4411 Fax: (360) 225-4420	nhc	Northwest Hydraulic Consultants Ltd 30 Gostick Place North Vancouver, B.C., Canada V7M 3G3 Office: (604) 980-6011 Fax: (604) 980-9264	Designer: DER/DAR Drafter: DAR/WPH Reviewer: BWW	Project Number: 2-1483 Drawing Date: 02/19/2007 Drawing File Name: Swift Habitat Channel v3.dwg	Drawing Scale: (As Specified) Original Drawing Scale: 0—1 inch

REVISIONS

No.	Description	By	Date
0	PACIFICORP REVIEW	WPH	01/08/2007
1	PACIFICORP COMMENTS	DER	02/19/2007

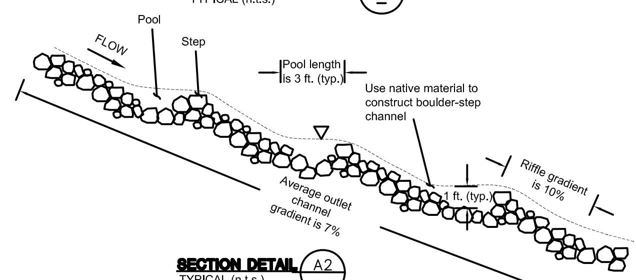
PLAN DETAIL A/1 OUTLET CHANNEL
TYPICAL (n.t.s.)



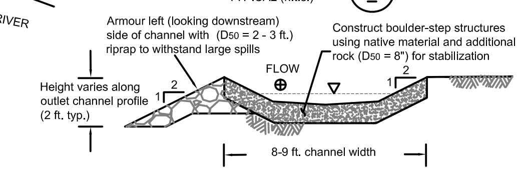
CONSTRUCTION NOTES - DETAIL A:

1) Outlet channel should be built with an average gradient of 7 %, although each riffle structure will be steeper (10% average gradient).
2) Pools should be minimum 1 ft. deep and 3 - 4 ft. long.
3) Typical outlet channel width is 8 - 9 ft.
4) Outlet channel to be constructed with native material although additional rock (D50 = 8") may be imported to stabilize the riffle structures.
5) Gravel core berm to be constructed to connect small alder island to existing bank. Berm to be armoured with rock (D50 = 8") and tied into existing banks.
6) Armour bank of small alder island with rock (D50 = 8") if required by engineer in the field.
7) Excavate pocket pool at head of outlet channel to 2 ft. below existing channel elevation (3 ft. min. depth).

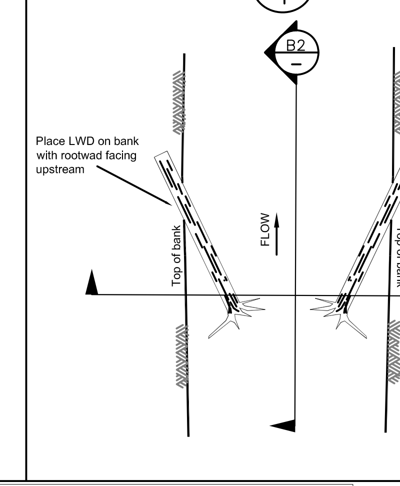
LONGITUDINAL PROFILE A1
TYPICAL (n.t.s.)



SECTION DETAIL A2
TYPICAL (n.t.s.)



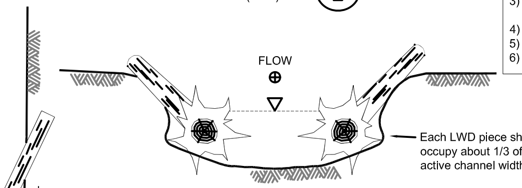
PLAN DETAIL B/1 LOWER CHANNEL
TYPICAL (n.t.s.)



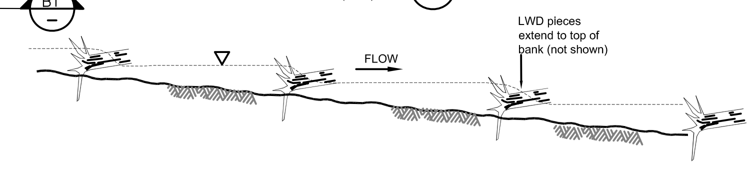
CONSTRUCTION NOTES - DETAIL B:

1) Wood species shall be Douglas Fir, Red Cedar, Yellow Cedar, Sitka Spruce or Western Hemlock unless otherwise specified. No dimensional beams, timbers, or Red Alder species shall be used for large woody debris complexing.
2) No ballast rock required.
3) Adequate coverage will be determined by the engineer or environmental consultant in the field (Nominal spacing is 25
4) Min. diameter of logs is 2 ft. (at breast height).
5) Min. diameter of rootwads and stumps is 8 ft.
6) Min. log length of 16 ft. required.

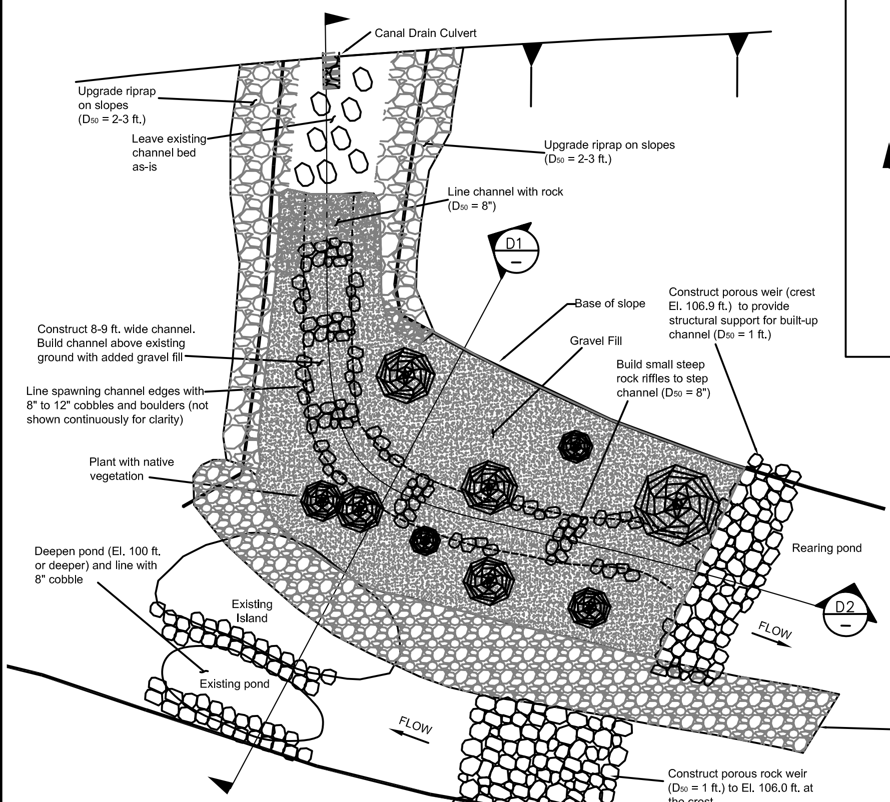
SECTION DETAIL B1
TYPICAL (n.t.s.)



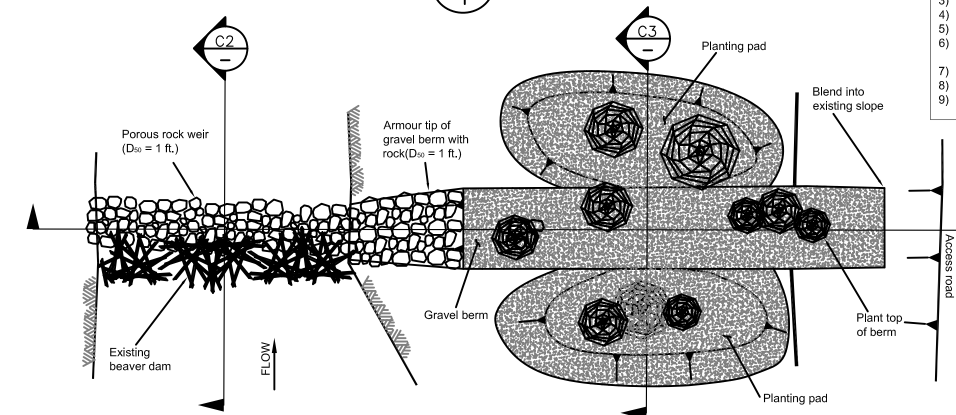
SECTION DETAIL B2
TYPICAL (n.t.s.)



PLAN DETAIL D/1 INLET AND UPPER CHANNEL
TYPICAL (n.t.s.)



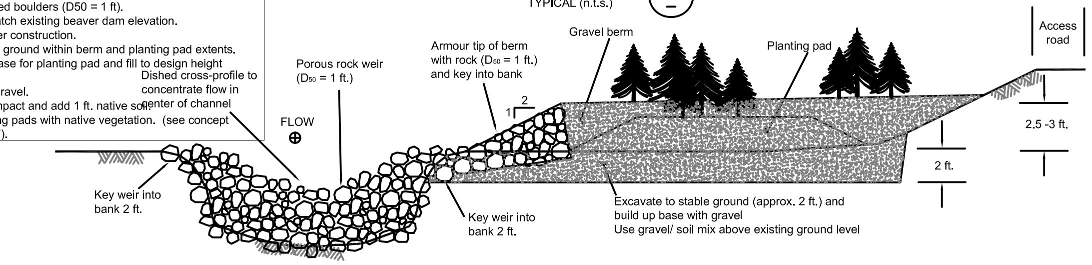
PLAN DETAIL C/1 GRAVEL BERM AND POROUS WEIR
TYPICAL (n.t.s.)



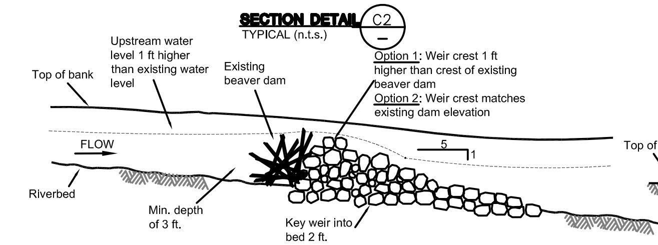
CONSTRUCTION NOTES - DETAIL C

1) Construct porous weir directly against existing beaver dam.
2) Construct weir with rounded boulders (D50 = 1 ft).
3) Weir crest elevation to match existing beaver dam elevation.
4) Beaver dam to remain after construction.
5) Excavate up to 2 ft. of wet ground within berm and planting pad extents.
6) Build 2 ft. coarse gravel base for planting pad and fill to design height using a gravel/soil mix.
7) Build berm using coarse gravel.
8) After construction, de-compact and add 1 ft. native soil
9) Plant berm top and planting pads with native vegetation. (see concept design report - section 3.7).

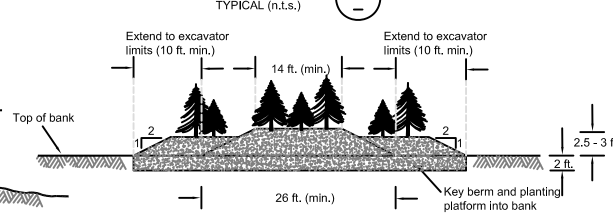
SECTION DETAIL C1
TYPICAL (n.t.s.)



SECTION DETAIL C2
TYPICAL (n.t.s.)



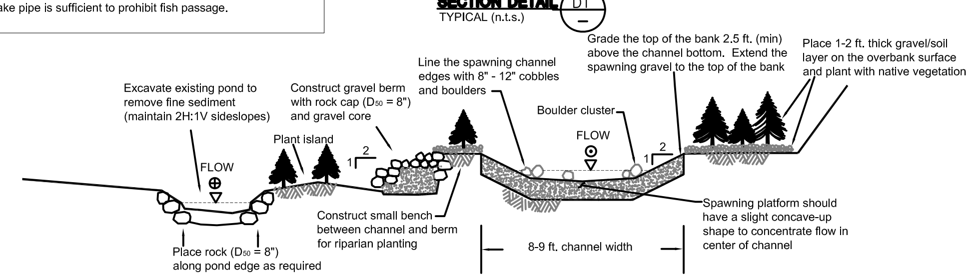
SECTION DETAIL C3
TYPICAL (n.t.s.)



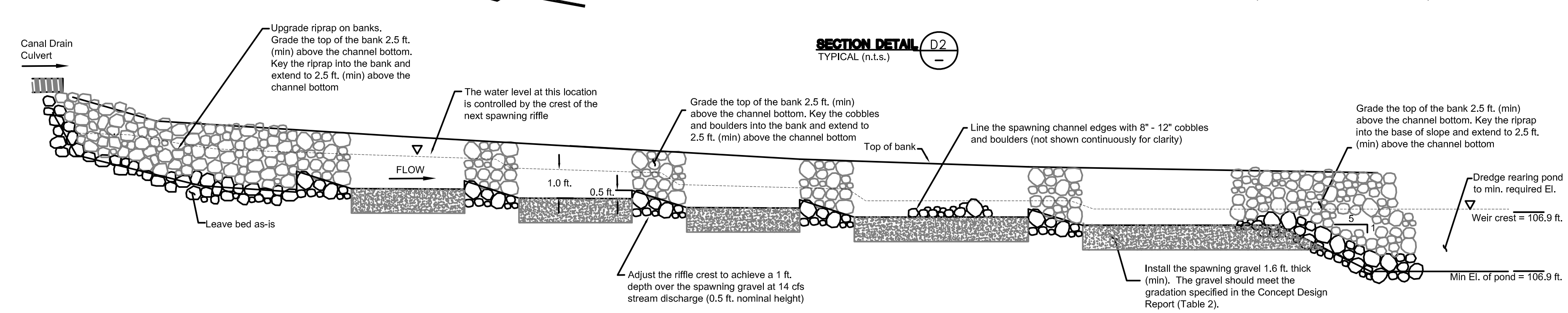
CONSTRUCTION NOTES - DETAIL D

1) Construct porous rock weirs (D50 = 1 ft.) and berm prior to dredging pond.
2) Dredge pond to remove fine sediments and complex as specified in Detail E notes.
3) Construct coarse gravel platform extending from constructed berm to base of slope.
4) Build rock riffles (D50 = 8") to achieve stepped channel and line the channel edges with 8" - 12" cobbles and boulders.
5) Line channel with 1.6 ft thick layer of spawning gravel (see table 2 of concept design report).
6) Above the upstream most rock riffle, line channel with 8" cobbles to blend into riprap upgrade.
7) Fill in overbank with coarse gravel/soil mix and plant with native vegetation, (see concept design report - section 3.7).
8) Ensure height of intake pipe is sufficient to prohibit fish passage.

SECTION DETAIL D1
TYPICAL (n.t.s.)

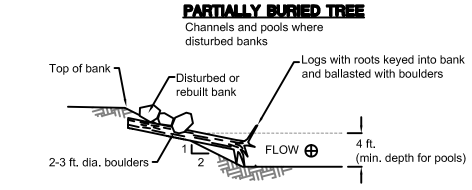


SECTION DETAIL D2
TYPICAL (n.t.s.)

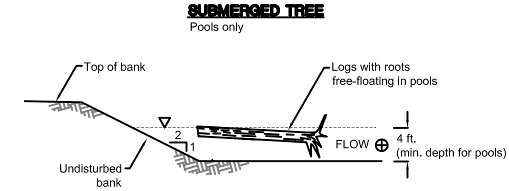


DETAIL E/1 LWD PLACEMENT OPTIONS
TYPICAL (n.t.s.)

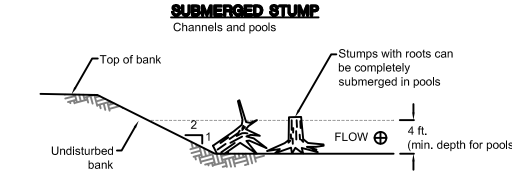
PARTIALLY BURIED TREE
Channels and pools where disturbed banks



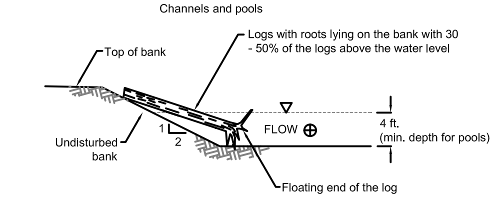
SUBMERGED TREE
Pools only



SUBMERGED STUMP
Channels and pools



PARTIALLY SUBMERGED TREE
Channels and pools



CONSTRUCTION NOTES - DETAIL E:

1) Wood species shall be Douglas Fir, Red Cedar, Yellow Cedar, Sitka Spruce or Western Hemlock unless otherwise specified. No dimensional beams or timbers, or Red Alder species shall be used for large woody debris complexing.
2) No ballast rock required.
3) Use coniferous logs and stumps with roots attached whenever possible.
4) Group smaller logs to provide more complete pond and channel coverage.
5) Adequate coverage will be determined by the engineer or environmental consultant in the field.
6) Min. diameter of logs is 2 ft. (at breast height).
7) Min. diameter of rootwads and stumps is 8 ft.
8) Min. log length of 16 ft. required.

Sheet Reference Number: 2 (2 OF 2)

LEWIS RIVER HYDROELECTRIC PROJECTS

CONSTRUCTED CHANNEL CONCEPT DESIGN
DETAIL DRAWINGS AND CONSTRUCTION NOTES

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Northwest Hydraulic Consultants Ltd
30 Gostick Place
North Vancouver, B.C., Canada V7M 3G3
Office: (604) 980-6011 Fax: (604) 980-9264

Designer: DER/DAR	Project Number: 2-1483	Drawing Scale: (As Specified)
Drafter: WPH	Drawing Date: 02/19/2007	Original Drawing Scale: 0 — 1 inch
Reviewer: BWW	Drawing File Name: Swift Habitat Design v3.dwg	

REVISIONS

No.	Description	By	Date
0	PACIFICORP REVIEW	WPH	01/08/2007
1	PACIFICORP COMMENTS	DER	02/19/2007

7 Photographs

Photograph 1: View upstream of station 01+70 near the point of channel re-alignment

Photograph 2: View downstream of station 03+94 toward channel reach to be prescribed LWD as specified in Detail A

Photograph 3: View upstream toward existing beaver dam at station 06+41. Porous weir to be constructed here.

Photograph 4: View toward left bank (looking downstream) at station 08+20 at location of prescribed backwatered off-channel pool.

Photograph 5: View downstream of station 10+50 toward old breached beaver dam. Pond in to be deepened to the left of the island.

Photograph 6: Looking toward intake culvert. Riprap to be upgraded and spawning channel to be built at the right.

Appendix A: Frequency and Magnitude of Spills at the Lewis River Projects

Table A1: Frequency and magnitude of spills (average cfs/day) at the Lewis River projects from 1994 through 2006.

DATE	MERWIN (cfs)	YALE (cfs)	SWIFT (cfs)
12/26/94		444	0
12/27/94		10466	0
12/28/94		10038	0
12/29/94		3355	0
1/31/95		1047	1383
2/1/95		5740	4978
2/2/95		4533	2651
2/5/95		515	
2/6/95		2053	
2/7/95		2050	
2/8/95		897	
2/18/95		685	
2/19/95		8904	
2/20/95		7475	
2/21/95		3276	
2/22/95		1048	
2/23/95		1050	
2/24/95		394	
1/11/95	5214	6827	
11/12/95	5285	7754	
11/13/95		4423	
11/14/95		3589	
11/15/95		4294	
11/16/95		638	
11/17/95			
11/18/95			
11/19/95			
11/20/95			
11/21/95			
11/22/95			
11/23/95			
11/24/95	890		
11/25/95			
11/27/95	5565	9672	
11/28/95	20727	19254	
11/29/95	28015	21909	14270
11/30/95	31270	24988	23225
12/1/95	30063	24531	14695
12/2/95	13124	10822	7995
12/3/95	4668	8280	1624
12/4/95	1888	3103	
12/12/95	4884	7712	4865
12/13/95	5090	18841	9695

DATE	MERWIN (cfs)	YALE (cfs)	SWIFT (cfs)
12/14/95	14348	13736	4611
12/15/95	5858	7642	
12/16/95		5128	
12/17/95		4859	
12/18/95		4949	
12/19/95		4240	
12/20/95		2022	
1/7/96	1013	964	
1/8/96	3401	3041	
1/19/96		932	
1/20/96		3019	
1/21/96		3185	
1/22/96		3153	
1/23/96		1203	
2/7/96	3574	3033	
2/8/96	44114	34418	28989
2/9/96	**51084**	**39747**	**44711**
2/10/96	24482	20600	16088
2/11/96	10707	10466	4467
2/12/96	5863	8751	844
2/13/96	1368	2298	
2/14/96			
2/15/96			
2/16/96			
2/17/96			
2/28/96		27	
12/29/96	389		
12/30/96	3874	857	
12/31/96	7771	5268	
1/1/97	13281	12509	12193
1/2/97	14425	14549	15941
1/3/97	6889	8052	5395
2/13/97		1945	
2/14/97		1239	
7/15/98	22		
11/25/98	1833		
11/26/98	8719	667	
11/27/98	2000	1833	
12/28/98	8779	3066	
12/29/98	14774	5527	
12/30/98	20245	4567	2358
12/31/98	8606	5000	4049
1/1/99	5075	4356	337
1/2/99		2200	
1/3/99		1700	
1/7/99		650	
1/8/99		1010	

DATE	MERWIN (cfs)	YALE (cfs)	SWIFT (cfs)
1/9/99		1010	
1/10/99		800	
5/4/99	292		
6/6/99	175		
10/20/99	500		
11/25/99	2573	1795	
11/26/99	8087	4151	
11/27/99	154		
11/28/99	1085		
12/3/99	779		
12/14/99	5306	1707	
12/15/99	15185	7135	
12/16/99	13002	6858	
12/17/99	6883	1282	
12/18/99	11269	3600	
12/19/99	5074	2475	
12/20/99	2075		
12/31/99	73		
1/1/00	36		
5/17/00			140
5/18/00			247
5/19/00			188
6/12/00	487	367	
6/13/00	429	275	
12/16/01	445		
12/17/01	1669		
3/27/02			490
3/28/02			500
4/4/02			604
4/5/02			500
5/1/02	867		
11/6/02	288		
1/26/03	191		
1/27/03	1781		
1/28/03	2117		
1/29/03	4000		
1/30/03	4000	2550	
1/31/03	26345	15481	4095
2/1/03	33785	28736	12689
2/2/03	8708	6313	1374
2/3/03	2423	2920	
2/4/03	16		
3/12/03	214		
3/18/03	919		
1/9/06	5040	3488	
1/10/06	13745	7700	

DATE	MERWIN (cfs)	YALE (cfs)	SWIFT (cfs)
1/11/06	17427	7700	
1/12/06	18021	7700	
1/13/06	18250	7700	170
1/14/06	11865	6033	864
1/15/06	3792	2700	
1/16/06	6521	2700	
1/17/06	3229	2700	
1/18/06	4100	2700	
1/19/06	3343	2025	
1/30/06	3855		
1/31/06	1298		
2/1/06	488		
2/2/06	0		
2/3/06	2295		
2/4/06	3918		
2/5/06	625		
2/21/06	50		
11/5/06	2771	2708	
11/6/06	22383	6237	
11/7/06	24189	8145	
11/8/06	10902	5829	
11/9/06	5116	2850	
11/10/06	4292	2604	
11/11/06	3354	2938	
11/12/06	2640	3200	
11/13/06	5746	3200	
11/14/06	4663	2750	
11/15/06	1208	417	
12/12/06	850		
12/13/06	575		
12/14/06	3727		
12/15/06	3429		

Appendix B: IAFC Technical Memorandum

Technical Memorandum

TO: NHC Staff
FROM: Bob Pfeifer; Inland and Alpine Fisheries Consulting
SUBJECT: Swift Constructed Channel Habitat Improvements
DATE: December, 2006

My recommendations for habitat improvements in the Constructed Channel follow. They are preceded by a brief mention of my understanding of the background and purpose of the channel improvement project. I describe assumptions I have made where relevant local data or explicit resource enhancement goals were lacking.

1.0 Background, Purpose and Assumptions

I was unable to locate or review documents that describe or review the background leading to the proposed improvements of the Constructed Channel. However, the proposed work is mentioned in two references: the pending "Settlement Agreement" for the relicensing of the Lewis River hydroelectric projects, and the "Joint Explanatory Statement" that supports it. Language specific to the Constructed Channel generally refers to providing "connectivity" in both of these documents, especially with respect to bull trout. The most explicit language, from the Joint Explanatory Statement, is extracted below:

> *"In addition, a "constructed channel" associated with the canal drain discharge location will be built to increase habitat benefits from flow releases and to improve connectivity. Additional, higher quality habitat for over-wintering and rearing (*Pfeifer underlining*) will be provided by the constructed channel for several species of resident fish (bull trout, kokanee, lamprey, mountain whitefish, cutthroat and rainbow trout) and anadromous salmonids once reintroduction into Yale Lake takes place. Also, construction of the channel in the bypass reach will maximize the biological benefits of canal drain flows. Construction of the channel also will help to reduce the overall negative impacts of large spill events into the bypass reach by providing a protected area that will not be as subject to large-scale scouring."*

Note that there is no explicit mention of improvement or enlargement of spawning area in this statement, unless they would be covered under "biological benefits".

Assumptions

I have assumed that water temperatures provided by the power canal up to the end of the first week in November are equivalent to that provided by Pacificorp for 1994. I further assumed that Swift Reservoir deep water temperature from early November through

December is similar to that observed in Spada Lake (reservoir) east of Everett, Washington.

I assumed that should bull trout choose to spawn in the Constructed Channel, eastern brook trout could spawn there also, and that hybridization between the two species could occur.

I assumed that anadromous salmon and steelhead will be passed above Merwin and Yale Dams in the relatively short term future, as described in the Settlement Agreement. I recognize the staged nature of this fish passage, with incremental evaluation of its success. Therefore, it will likely be 10 years or more before adult salmon or steelhead use the Bypass Channel, and their progeny may seek to use the Constructed Channel.

2.0 Aquatic Species to Benefit

Although the Joint Explanatory Statement and Settlement Agreement are clear that anadromous fish (salmon and steelhead) and bull trout are to be enhanced, primarily by reintroduction of adults into spawning and rearing areas above the three dams, there is no explicit language indicating which fish species habitat enhancement in the Constructed Channel should benefit.

I obtained some clarification on which species to emphasize in this project by interviewing the local Washington Department of Fish and Wildlife Area Fishery Biologist (John Weinheimer), and the local fish biologist assisting John with field surveys in the Lewis River basin (Jim Byrne). The general conclusion from my meeting with WDFW was that anything that could be done to benefit bull trout in the Constructed Channel would be good, but that it may not be a suitable area to seek additional spawning habitat for that species. Their secondary goal would be to see the channel enhanced for general over-wintering habitat and year-round rearing for spring Chinook and coho. These anadromous species should receive more emphasis than resident trout or kokanee. Notes from my meeting with these two men have been provided separately.

It is my understanding that the Yakama Indian Nation intended that enhancement of the Constructed Channel benefit spring Chinook, but this information is anecdotal. Nevertheless, this guidance is consistent with the secondary preferred species noted by WDFW.

I take it as a given that any enhancements in the Constructed Channel should be designed and built so as to not significantly impair habitat for State Sensitive Species that likely already use the habitat. See Construction and Permitting Considerations, below.

3.0 Assessment of Existing Habitat

3.1 Methods

At about 0900 hours on 20 November Pacificorp staff reduced the power canal drain valve that supplies water to the Constructed Channel. Inflow was reduced from about 47 cubic feet per second (cfs) to the expected constant future flow of 14 cfs. This flow was not altered during the two days of field survey.

Typical methods used to conduct a physical assessment of existing habitat conditions in the Constructed Channel are described by Platts et al. (1983), and in an on-line guidance document provided by WDFW (2004). Habitat units were identified using the definitions from Bisson et al. (1987), and were measured for length using a hip chain. Thalweg and pool depths were measured with an extendable measuring rod. Wetted channel width, bankfull width, and unit gradient were mapped using a TopCon Total Station optical instrument and standard field surveying equipment.

We were not able to visually assess or measure the area of the substrate on the field survey dates (20-21 November 2006) since the power canal water supply was extremely turbid, and the stream bottom could not be seen except for a very few higher sediment accumulations. What sediment could be seen (primarily on 21 November) was photographed, and qualitative notes were taken on the probable sediment grain size distribution.

All wood debris pieces larger than 4 inches, and larger than 12 inches in diameter were counted within each habitat unit. The number of pieces that were in the water at 14 cfs and were judged to be able to affect habitat structure were enumerated for each habitat unit as well. Root wads of stems lying in or across the flowing stream were also enumerated, and were distinguished as being in or out of the water.

Digital photographs were taken of typical habitat at numerous stations along the Constructed Channel. The locations where images were taken were later assigned to individual habitat units.

All habitat unit measurement data were summarized in an Excel spreadsheet to support this Technical Memorandum.

3.1.1 Water Temperature

Historic data on water temperature of the power canal, or in the Constructed Channel are generally not available. Data from the Swift No. 1 powerhouse tailrace for a few months in 1994 were provided by Pacificorp. Inflow temperature just below the culvert at about noon on 21 November 2006 was 46^{o} F (7.8^{o} C).

3.1.2 Flow

Flow (Q) in the Constructed Channel is gauged by Pacificorp using a staff gage located at the head of the low gradient channel just below the supply culvert. No historic flow data were provided by Pacificorp, although anecdotal information is that the flow has been 47 cfs for quite some time since the repair of the power canal was completed following its failure and shutdown in 2002.

3.1.3 Riparian Habitat

Digital images (n=130) and qualitative field notes were taken on the characteristics of the riparian zone plant community. Notes and images were taken on signs of beaver (*Castor canadensis*) activity.

3.1.4 Fish Use

Fish were generally not sampled. Information on fish use of the Constructed Channel was provided orally, as well as through documents and technical reports provided by Pacificorp staff. However, the flow reduction from 47 cfs to 14 cfs created a few side channel pools that stranded a few salmonids. One each of rainbow trout (*Oncorhynchus mykiss*), cutthroat trout (*O. clarki*), and brook trout (*Salvelinus fontinalis*) were collected by dip net in a left bank side channel near the head of the Constructed Channel on 21 November by Pacificorp staff. This species list of resident salmonids is consistent with that reported orally and by earlier technical reports.

Pacificorp and WDFW staff indicated that occasional Chinook (*O. tshawytscha*) and bull trout (*S. confluentus*) adults have been seen in the Constructed Channel. Kokanee (*O. nerka*) spawners are regularly seen in the upper end of this channel in the Fall, although none were present on the survey dates.

3.1.5 Habitat Conditions Limiting Spawning, Rearing, and Migration

Spawning habitat was assessed by noting the relative distribution and area of spawnable riffles or patch gravel, as well as by qualitatively noting (and photographing) the general character of the spawnable material. This task was severely hindered by very poor water quality. Notes and photographs were taken of significant springs, very wet soils, and soft sediments in and adjacent to the channel.

Rearing area was assessed by measuring the area, distribution, and depth of pools and low velocity habitats. Rearing habitat complexity provided by boulders and woody debris was also noted and photographed. Shading and vegetative cover was noted through photographs and qualitative comments in the field notes.

Migration barriers were assessed by measuring slope gradients, water depths, and widths in selected fast water habitat units. These areas were also photographed, but velocity was not measured. The inlet culvert is an obvious velocity barrier to upstream fish passage.

3.2 Findings

3.2.1 Water Temperature

The lack of data that spans more than a few months, or for data from the Constructed Channel itself is a major shortcoming of this habitat assessment. Available information from Pratt (2003) and data provided by Pacificorp staff all indicate that it is likely that water temperature in the Constructed Channel exceeds the optimum values needed by bull trout for successful reproduction. However, thermal conditions are expected to be suitable for juvenile rearing, particularly over-wintering or off-channel refuge during major spills into the old Lewis River channel.

Temperature data from the Swift No. 1 tailrace in 1994 provided by Pacificorp are confusing. Daily differences between minimum and maximum temperature commonly were 4 to 8 degrees Celsius between early June and early November 1994. I have no idea what would cause such swings in temperature on a daily basis if water is being withdrawn consistently from a deep location in Swift Reservoir. In any case, daily maximum water temperature was commonly above 50 degrees Fahrenheit in late October and early November in 1994. These temperatures would result in very high egg mortality early in the bull trout incubation period (McPhail and Murray 1979; Willamette National Forest 1989; Pratt 2003).

A much better thermal profile data set from multiple years is available from Spada Lake (reservoir) in Snohomish County, Washington (Pfeifer et al. 1998). In that 1870-acre reservoir (spillway elevation 1465 ft mean sea level; Swift spillway 1008 ft msl) thermal stratification generally is not completely eliminated with homothermic conditions at 48^{o} F until early December, and deep water temperature does not drop to 44.6^{o} F until mid to late December. (Spada Lake also exhibits very depressed dissolved oxygen conditions at depth near the dam during the stratification period.)

A brief vertical water temperature series from Swift Reservoir in 1999-2000 is provided in Pratt (2003). Although bull trout spawning is likely to occur in the Lewis River bypass channel as early as late September (Pratt 2003), the 1999-2000 data set suggest the deep intake water temperature may not drop below 48^{o} F even by early December. Water temperatures in the 48-50^{o} F range would be expected to result in very high egg mortality (McPhail and Murray 1979).

The information on power canal (or Constructed Channel) water temperature is wholly incomplete and inadequate to assess the probable suitability of the Constructed Channel for bull trout spawning and fry production. Available information strongly suggests water temperature is often too warm in the channels fed by Swift Reservoir to be suitable for bull trout reproduction. This is supported by the fact that the vast majority of bull trout from Yale Lake spawn in Cougar Creek, a much colder system (Pratt 2003). Lacking information to the contrary, based on probable water temperature (as well as sediment, below) I consider the Constructed Channel unsuitable for enhancement of bull trout spawning.

Water temperature in the power canal and Constructed Channel is expected to be suitable for extended rearing or refuge from large spill events in the old Lewis River channel for all salmonid species, including bull trout. Summer temperatures are not expected to be adverse since the water is withdrawn from deep in Swift Reservoir. The 1994 maximum and minimum temperature data provided by Pacificorp suggest that daily maximum temperatures between 2 June and 15 October will not exceed 62.2^{o} F, and are usually less than 57.9^{o} F. These fall within the acceptable maxima for most salmonids, including bull trout (Buchanan and Gregory 1997; Dunham and Chandler 2001; Rich et al. 2003).

3.2.2 Channel and Flow

The majority of the Constructed Channel is of the "B" stream type as defined by Rosgen (1994). The Channel is fully wooded from the inflow culvert to its outlet(s). Gradient of individual habitat units ranged from flat to 11.8% and averaged 3.6%; most were in the range of flat (backwatered beaver pools) to 4%. The stream reach is moderately confined, and of the "transport" type (Overton et al. 1995). Under natural conditions in Idaho, a stream of this nature would generally have 22-25 pools/mile, and 95-100 pieces of LWD/mile (pieces at least 0.33 ft wide, 9.8 ft long). We observed 4 discrete pools, and about 560 pieces of LWD/mile, but perhaps a third of these would not qualify as they were <9.8 ft in length. (Also see Section 3.2.5.4.) In un-dammed habitat units, the mean width to depth ratio for the predominant, lower gradient portion of the Constructed Channel was about 25.7, and ranged from 9.7 to 48.0. This is almost exactly the mean seen in natural streams in Idaho reported by Overton et al. (1995).

The drop from 47 cfs to 14 cfs appeared to result in about a 3-4 inch elevation drop in some areas of the free-flowing channel. The degree to which inundated woody debris was rendered ineffective as habitat, or its role in forming habitat complexity was not determined. Since none of the pools or slots in the channel were close to the general criterion of 2.5-3.0 feet of residual depth or more, this elevation reduction probably did not diminish pool rearing habitat appreciably.

A constant flow of 14 cfs is planned for the Constructed Channel. While this essentially eliminates the risk of flooding and scour, it also poses the potential for inadequate recruitment and sorting of sediment suitable for salmonid spawning. The presence of turbid (high suspended fine sediment loads) conditions in the power canal for weeks or months at a time (Jim Byrne and John Weinheimer, pers. comm.) may also contribute slightly to fine sediment deposition in and on the Constructed Channel spawning gravels (Cooper 1965), particularly without periodic "flushing" flows (Kondolf 2000). However, most of the fine sediment is likely coming from the very wet alluvial soils along the channel.

3.2.3 Riparian Habitat

The Constructed Channel is covered by a complete canopy of mature red alder (*Alnus rubra*) with only a few scattered conifers (Plate 1). Although there was substantial windthrow evident, its cause(s) was not readily apparent. One possibility is poor root strength due to saturated or slumping soils. There is very little opening in the canopy as seen in a 1994 aerial photograph (Plate 2). The banks were almost wholly intact and covered with vegetation, with little or no instability or erosion evident (Plate 3). This is not surprising since flow in the Constructed Channel is constant.

The quality of the riparian zone is currently good, therefore construction impacts from habitat enhancement activities could easily be significant. Soils on either side of the channel were highly saturated, and standing water was evident in numerous areas. Groundwater springs were frequent on the right bank, some having significant volume. The overall riparian zone appeared to be excellent amphibian habitat, along with offering the usual values for wetland-dependant species. Overall, the riparian habitat is currently good for all aquatic species using the Constructed Channel. It is not, of course, a climax community; I would expect wet soil-tolerant conifers to replace the alders in the long term, assuming the riparian forest is not subject to flooding. The mature alder stand is experiencing substantial windthrow, therefore some succession may occur soon anyway. I note below that the alder community is not contributing stable and functional LWD to the stream channel itself, so in this regard it is less than an ideal riparian habitat, however the existing forest does fully shade the stream and in general the banks are stable.

Beaver activity was noted along the Constructed Channel, although it was infrequent. Some felled trees were old (Plate 4), but one was seen with relatively fresh gnawing (Plate 5). However, dams across the stream were not being maintained, and at least one had breached (Plate 6). In general, there was no evidence of active beavers maintaining the dams in the Channel at the time of the field survey. One beaver runway was seen at the head end of the Channel; willows were abundant in the Lewis River channel and showed evidence of beaver cropping (Plate 7).

3.2.4 Fish Use

It is very important to note that in general, the Constructed Channel as it currently exists is certainly not completely dysfunctional as salmonid habitat. It is known to support resident trout and char populations, and spawning kokanee and a few Chinook have been observed within it. Its riparian zone is intact and healthy. It will continue to function as habitat for fish even if nothing is done to it.

As noted in the Methods (3.1.4), fish use in terms of standing stock was not assessed on the sampling dates. Current habitat in the Constructed Channel is clearly adequate to support some resident trout and char as evidenced by the collection of rainbow, cutthroat, and eastern brook fingerlings in a dewatered small side channel. Diverse lateral habitat (Moore and Gregory 1988) and shallow pool habitat is present in abundance, and very likely supports a significant number of individuals of these resident species. Pacificorp and WDFW staff also report seeing substantial numbers of small fish in snorkel surveys conducted in recent years.

Judgments about use by other fish species, now or after enhancement, are made in the following section.

3.2.5 Limiting Habitat Conditions

3.2.5.1 Spawning – all salmonids

In general, there was a dearth of gravel of the appropriate size and quality for good salmonid spawning and egg-to-fry survival. Gravel area (grains >0.08-0.16 in; Platts et al. 1983) only represented about 4.5% of the total wetted area (Table 1). The percentage is even lower if the coarse gravel definition of 0.63-2.5 in of Beechie and Sibley (1997) is used. Fine sediments were very predominant virtually throughout the channel in areas of lower velocity (Plate 8). Where gravel pockets of 0.98 in or larger grains had accumulated or been exposed, disturbance with a boot toe liberated clouds of fines from just beneath the surface layer. Although bulk sediment sample analyses and grain size distributions from the spawnable riffles or bars would be ideal, my experience (Pfeifer 1978; Pfeifer et al. 2001; Pfeifer et al. 2002) indicates that fines (<0.04 in grain size) in these areas of the Constructed Channel are present at well above the general criterion of a maximum of 12-14% (Kondolf 2000) for suitable egg-to-fry-survival.

Kokanee have been observed spawning in sandy, fine silt-dominated bars in the upper end of the Constructed Channel, however it is my experience from detailed fry trapping studies on Issaquah Creek and tributaries to Lake Stevens, near Everett, Washington that substrates of this nature yield very low egg-to-fry survival for kokanee (Pfeifer 1978).

The **rainbow**, **cutthroat**, and **eastern brook** fingerlings observed in the side channel could have been produced elsewhere in the system and simply took up residence in the Constructed Channel. However, there is probably adequate sandy or pebbly gravel sufficient to allow a few small redds by these fish species that seed the habitat, even though contaminated with fines that would yield low fry production. Spring surveys when the water is running clear could yield evidence of newly emerged fry that would confirm successful local reproduction.

Although larger gravel could probably be placed and maintained in areas where stream velocity is increased, such as by placement of channel constricting structures, there is still the very high risk that extended periods of high suspended fine sediment in the power canal would entrain fines into redds that had been constructed (Cooper 1965; Kondolf 2000). Further study of power canal water quality and Constructed Channel hydraulics would be required to refine a risk probability, or an estimate of likely average egg-to-fry survival, but my preliminary impression is that gravel contamination with fines and relatively low egg-to-fry survival is likely to be a predominant condition in this side channel.

If discharge into the Channel will be constant at 14 cfs, it is my expectation that the lack of a normal process of gravel sorting from storms will result in gravels that are chronically contaminated with fines. Some fines can be liberated by salmonids in their normal redd digging, but the general fines-dominated nature of the entire Constructed Channel floodway raises a very serious doubt that productive spawning can ever be a dominant use of the habitat. Annual increases in discharge to 47 cfs for a few days may help to loosen and mobilize some fine sediment, and this treatment option should be evaluated.

The low-fines, high quality gravel generally preferred by **bull trout** was totally absent from the Constructed Channel. It's highly questionable whether the Channel could be modified in such a way that clean gravels could be maintained, given the constant low flow and frequent periods of high suspended fine sediment in the power canal. Pratt (2003) also opined that egg-to-fry survival for bull trout would likely be low (10-20%) in the Bypass channel (mainly due to warm water), but she did not address the Constructed Channel explicitly.

The potential for hybridization of brook trout with bull trout is a major issue in most bull trout recovery plans. Pratt (2003) cites Susan Graves, Pacificorp biological staff, and others as having seen bull trout x brook trout hybrids in the Swift Reservoir system above Swift Dam. Since Yale Reservoir and the Constructed Channel are known to currently support eastern brook trout, enhancement of spawning gravel such that bull trout spawning was enticed to occur there may increase the likelihood of hybridization between these two char species.

I have commonly seen **coho salmon** use substrates of relatively low quality such as seen in the Constructed Channel under current conditions. However, it may be possible to create larger areas of gravel patches or riffles that contain a lower fraction of fines.

3.2.5.2 Rearing – Resident Trout

WDFW staff indicated their preference for enhancement of the Constructed Channel would be to provide over-wintering and general rearing habitat for salmonids, with an emphasis on bull trout and juvenile salmon. They agreed that spawning habitat should not be a primary objective.

Existing conditions for salmonid rearing habitat in the Constructed Channel appeared to be fairly good, although water transparency conditions made full assessment difficult. Also, invertebrates were not sampled. Banks next to the flowing stream were stable and not eroding, and supported mature alder and an herbaceous understory that shaded the habitat fully, and undoubtedly contributes terrestrial insects to the drift, and organic matter to the pools and substrate. Beaver dams have created backwater pools in some areas which, when coupled with boulders and some in-water wood, provide a good deal of rearing area. However, singular scour pools were scarce, and relatively shallow (Table 1). While there is some low velocity lateral habitat or dammed pool habitat for resident cutthroat or rainbow (Moore and Gregory 1988) rearing to a relatively small size, deeper pools are generally absent for production of larger, older fish. I presume that any resident trout actually produced in the Channel could emigrate to Yale Reservoir for additional rearing and maturation.

3.2.5.3 Rearing – Eastern brook

Brook trout clearly use the Constructed Channel now, although their source is unclear. They could immigrate from the old Lewis River channel, wash in from the power canal, or spawn successfully to some degree within the Channel itself. Brook trout tend to prefer cool to cold headwater ponds and streams fed by springs (Wydoski and Whitney 2003), very much the conditions found in the man-made Constructed Channel.

I mentioned above that the potential for hybridization of brook trout with bull trout is a major issue in most bull trout recovery plans. While discouraging bull trout from spawning in the Constructed Channel may be a goal with some potential for success given its warmer water supply, creation of allopatry between these two species based on rearing area is much more unlikely. Multiple authors have noted brook and bull trout rearing in sympatry (Peters 1985; Rode 1988; Sexauer and James 1997). If bull trout from Yale Reservoir spawn primarily, if not exclusively in Cougar Creek (Pratt 2003), the probability and extent of char hybridization in the Constructed Channel will likely be minimal.

It is unlikely that anything could be done in a practicable way to alter the habitat in the Constructed Channel so as to preclude its use by brook trout, while at the same time enhancing it for other salmonids. Eastern brook need to be eliminated at their source(s). If that is accomplished, a local application of a piscicide to remove any relict brook trout populations may be feasible (Gresswell 1991).

3.2.5.4 Rearing – Chinook, Coho, and Winter Steelhead

My initial impression when seeing the Constructed Channel was that it appeared to primarily offer good over-winter and general rearing habitat for coho salmon. That is still my belief, although it may be “tweaked” to offer some enhanced benefits to spring Chinook and steelhead as well. My general understanding is that the Yakama Nation and WDFW view spring Chinook as the primary anadromous species to enhance above Merwin Dam.

Another general observation was that wood debris seemed to be having almost no effect on development of pools, especially ones with at least 3.3 ft of residual depth. For moderate gradient streams (2-5%) with about 23 ft of bankfull width, Andrus et al. (1988) suggest pools created by wood debris should occur at about the rate of 2.63-14.1 pools/100ft. That would be about 4 to 21 pools in the Constructed Channel, while currently there are no pools even close to having 3.3 ft of residual depth. Those authors also suggest individual pool volumes should range from 102 to 187 ft^3. The wood (mostly lying across) the Constructed Channel is also relatively small. Kennard et al.

(1997) suggest a minimal functional piece size (dbh) of 17.4 in for streams with a bankfull channel width of 23.6 ft. No pieces this thick were seen in or over the Channel.

Montgomery et al. (1995) provide data plots from old growth and logged forested streams that give some guidance on how much downed wood we should expect to see in this Channel with its 23.3-ft mean width (understanding that it is unnatural with a constant discharge) where wetted stream area below the head end marsh is about 35,453 ft^2 (Table 1). Their plots suggest about 0.32 pieces/ft^2 for clear cut areas, and 1.08 pieces/ft^2 for old growth. I tallied 141 pieces of a similar size criterion as those authors' (> 3.9 in and 3.3 ft in length) for a density in the Channel of 0.43 pieces/ft^2. Thus, the observed loading of fallen alder and smaller woody debris appears to be "about right" for a stand of this age following assumed clear cutting at the time the power canal and Constructed Channel were built. However, what we see in the Channel now is less than half of what would be expected (322 pieces) in an old growth forest. Fox et al. (2001) had a different perspective; although Washington Forest Practices considers wood loading adequate at 2 "qualifying pieces" per unit channel width (that works out to 114 pieces here below the head end marsh), they noted natural conditions in Washington range up to over 100 pieces per channel width. With this extreme variability, we should be focusing on whether the existing wood in the Constructed Channel is creating optimal habitat, with an eye towards adding some pieces or repositioning some while minimizing instream and riparian impacts.

In summer, **steelhead** are commonly observed occupying faster water habitat than coho (Bisson et al. 1988). Winter habitat is either interstices of large substrate in main stem channels, or side channel pools and ponds (Cederholm and Scarlett 1982). When winter steelhead are re-introduced above the dams, some spawning in the old Lewis River Bypass would be expected, with summer rearing at that location. The Constructed Channel might offer a few gravel patches with suitable spawning conditions for steelhead. Juvenile non-winter rearing would be expected to occur in the Bypass Channel or in Yale Reservoir, rather than in the quieter Constructed Channel. However, some co-habitation of the Constructed Channel with coho and Chinook would be expected in the winter.

Rearing habitat in the Constructed Channel is already good for **coho**, but it could be improved by creation of more and deeper standing water or low velocity areas. These could be scour pools created by placed instream structure, but it may make more sense to abet inevitable periodic beaver damming by attempting to create more or less permanent backwatered pools, or at least a combination of these two approaches. The head end spring-fed "bog" (Plate 9) could also be deepened by suction dredging, or through the judicious use of explosives (Cederholm et al. 1988). In general, under the existing conditions faster water habitat is far more prevalent than slow water habitat (Table 2). None of the "pools" measured were more than 2.2 feet deep (mean 1.44 ft), and most were less than 1.6 feet deep. This was also not residual pool depth, but included the height of the running water over the slower pocket of water. Estimated total pool surface area (1,751 ft^2) was less than 5% of the total wetted area surveyed (35,453 ft^2). The "pool" habitat unit was only 15.4% of all of the discrete habitat units identified. "Fast water" comprised 75.3% of all of the wetted surface area.

Chinook salmon generally prefer channel habitat with abundant cover for juvenile rearing, although they will use pond and lake habitats. Richards et al. (1992) found that juvenile Chinook used all habitat types created or made available by re-connecting ponds to the adjacent Yankee Fork River in Idaho, however channel habitat with cover that occurred between the ponds was strongly preferred. My personal experience with a lengthy series of ponds in a spring-fed side channel of the Skykomish River (Haskell Slough) near Monroe, Washington also showed substantial use by juvenile Chinook, even though channel habitat was dwarfed by pool or pond habitat. However, in that system coho far outnumbered Chinook. Current conditions in the Constructed Channel are not ideal for Chinook rearing, but would almost certainly be used to some degree. The current lack of deeper slow-water channel habitat units with internal structural cover suggests it is relatively poor Chinook rearing habitat.

3.2.5.5 Migration Barriers

There is only one location where access to most of the Constructed Channel is problematic, and that is at its mouth (Plate 10). My impression is that it is probably not a barrier to juvenile salmonids, and almost certainly not for adult resident trout, char, salmon, or steelhead. Relatively small kokanee were observed spawning in the Channel this past Fall when the discharge was 47 cfs. Juvenile trout and char occupy the Channel now, but may have immigrated by way of the power canal drain, or were produced in the Constructed Channel by natural reproduction.

Velocities in the outlet cascades can be measured with a suitable instrument, or estimated by hydraulic modeling, based on the flow width, bed roughness, and slope.

Literature I reviewed supports the supposition that this natural bed is passable by juvenile salmonids. Kahler and Quinn (1998) stated their literature review indicates "that under certain conditions, fish are capable of swimming through higher velocities than those indicated by current culvert design guidelines. The ability of fish to exploit zones of lower velocity…is the most likely explanation for differences between predicted and actual swimming performance." They also noted a useful reference (Katopodis 1992) who "has produced fish endurance and swimming distance versus water velocity curves for nine species of salmonids" that may be a useful adjunct to Bell's (1973) older curves and tables.

Reiser and Peacock (1985) present a table of adult salmonid cruising, sustained, and darting speeds, as well as maximum jumping heights. Darting speeds (fps) range from 6.4 fps (cutthroat) to 26 fps (steelhead) for the species likely to use the Constructed Channel. Juvenile salmonid swimming criteria are more difficult to locate. Peake and McKinley (1998) report that atlantic salmon (*Salmo salar*) "maintained velocities as high as 5.38 ft/sec for 2-10 minutes", and short bursts at speeds up to 6.4 ft/sec. It's noteworthy that this burst speed figure is the same as that reported for adult cutthroat by Reiser and Peacock (1985).

Most recently, Kondratieff and Myrick (2006), citing 10 other published works, provide summary tables of sustained and burst swimming speeds for rainbow, cutthroat, and brook trout ranging in size from 2.4 to 15 in. These are particularly useful as they bracket the total length range expected for the resident trout and char seen in the Channel, as well as juvenile Chinook that may be produced in the Bypass Channel in future years (1.6-3.9 in; Galbreath et al. 2006). Reported burst swimming speeds from these various studies ranged from 3.1 ft/s for 4.3 in (TL) brook trout, to 9.1 ft/s for 12.4 in rainbow, and a maximum of 13.2 ft/s for "adult" cutthroat.

The slope of the outlet cascade is about 8% with one short 4-foot segment at the crest being 11.8%. It is not uncommon to find juvenile trout and salmon, or resident cutthroat in forested stream systems of Western Washington that have stream gradients of this general magnitude. It is important to note that fish were found in the Constructed Channel in our survey, and prior to the survey the flow had been 47 cfs, not 14 cfs.

Despite the fact that salmonids can probably negotiate these cascades at the Channel mouth, current WDFW guidelines for constructed side channels recommend smoother transitions at their mouths where the side channel meets the main river channel (WDFW 2004). They cite Peterson (1982a) as stating "that the point where the egress channel joins the stream is the most critical aspect of project design." They go on to state that "If flow from a channel exits into a low-velocity area or eddy with cover, the water is not rapidly diluted and fish have a better opportunity to find it than if it is rapidly dispersed and diluted in rapid turbulent flow. Channel outlets have been designed as a wide alcove in the bank of the mainstem." Since the discharge of the old Lewis River Bypass channel is not expected to be much greater than 100 cfs or so, this consideration may not be as urgent, however an alcove and/or deep pool at the mouth would certainly aid in allowing fish to find or use the Constructed Channel.

4.0 Habitat Improvement Options

4.1 General Remarks

Since the Constructed Channel is currently functioning as viable habitat for salmonids and other aquatic species, my recommendation is to do no lasting harm in an attempt to increase its utility as rearing habitat for resident trout, char, and salmon. My belief is that the probable short term impacts associated with access and construction pose the principal threat to degradation of the present habitat. The large amount of very wet and deep fine sediments on both sides of the Channel are very worrisome. The density of the mature alder forest and scattering of alder stems across the channel (Plate 1) will make access a challenge without having to cut live mature trees. In general WDFW recommends against removing mature trees unless absolutely necessary. This may be a permitting issue for Pacificorp. However, the potential impacts can be largely mitigated or avoided by careful planning, and very conscientious follow-up on riparian plantings.

Since access to the Constructed Channel is probably not a barrier to salmonids, I did not see any habitat features that were obvious and completely limiting for any species. The only potential exception is water temperature for the early portion of the bull trout spawning period. I am not aware of any practicable mechanism whereby Swift Reservoir discharge water temperature can be controlled downward for use in this Channel for the benefit of bull trout. In fact, its use by bull trout for spawning should be discouraged, not encouraged, due to the presence of eastern brook trout in the Channel.

As noted earlier, WDFW staff believe enhancement of the Constructed Channel should focus on rearing, not spawning. Development of a limited spawning channel type of arrangement at the culvert inlet can be a side benefit of a diversion of the flow into an enlarged pool area at the head of the Constructed Channel. The primary benefit of this realignment would be to keep an enlarged and deepened rearing area clear of sediments for a longer time period. Localized increases in higher quality gravel (size, lack of fines) associated with placement of instream structures will provide increased opportunity for more productive spawning. Since Chinook would be expected to use the Bypass Channel or its planned improvement near Swift No. 1 powerhouse, the target species for any enhanced spawning in the Constructed Channel should be coho and winter steelhead primarily, and resident trout secondarily.

Depth, velocity, substrate, and redd size criteria for coho and steelhead (Table 3) should be used in the design process in an attempt to produce spawning areas in association with placed instream cover (see also WDFW 2004, Technique 8, Tables 1 and 2, pp. 9-10).

Steelhead rearing habitat may end up being optimum in the Lewis River Bypass Channel or its planned improvements near Swift Dam. However, overwinter habitat for steelhead will undoubtedly occur in the Constructed Channel, even without any improvements to it.

Coho rearing habitat clearly can be improved by creating deeper areas of quiet water, and greater surface area of this type of habitat. I recommend that this be the primary focus of the enhancement of the Constructed Channel.

4.2 Recommended Improvements

4.2.1 Spring-fed marsh excavation

Portions of the marsh at the head end of the Constructed Channel should be excavated to provide greater depth. The scope of the excavation will presumably be dictated by the hydrologic constraints of the adjacent soils, both in terms of side slope stability, and risk of slumping into the excavated area(s). Explosives (Cederholm et al. 1988), mechanical excavation, or suction dredging should be evaluated for cost-effectiveness and risk to the adjacent riparian areas. Created holes or deeper areas should be at least 10 ft deep after settling. The more open and deep water that can be created in this marsh the better, within the soils and access and materials disposal constraints likely to occur.

As noted in WDFW (2004), predation on rearing juveniles is a significant concern. Thus, the sides of the created deep areas should be steep that quickly drop to more than 2.0 feet deep to thwart herons, and at least 75% of the area should be 4-8 feet deep or more. A 5-foot wide "beach" is optional around the edge that slopes to up to a foot of depth. If this is incorporated into the design, the disturbed edges must be planted with an appropriate mix of aquatic plants common to floodplain ponds (see WDFW 2004, Technique 3, page 28 for a plant species list). Most important, gnarly, very complex woody debris must be sunk and anchored in the deeper areas to provide refuge from diving birds (e.g. mergansers) and otters. If available, water-logged wood would pose the least risk of flotation and anchoring problems.

4.2.2 Created Pools and Patch Spawning Gravel – Modifications for Coho

I am suggesting as a general guideline or target that pools (scour or backwater) at least 3.3 ft deep (residual depth) be created at one or two strategic locations along the channel such that "slow water" rearing habitat is increased to at least 70% of the total wetted area (cf. Tables 1 and 2). This would roughly be a reversal of the existing conditions (Table 2). Deepened area in the head end marsh would be included in the calculation of the total slow water area. The balance of the wetted area would be composed of riffles, rapids, or cascades.

Porous weirs in conjunction with well-anchored large wood with root wads could be used to narrow the channel at one or two points to maintain appropriately-sized spawning gravel (Table 3) in the faster water areas. The gravel should be inset into excavated areas downstream of the structure during the initial construction to assure that properly-sized material remains after any adjustments when flow is returned. The coho spawning mix and spawnable area (Table 3) should be the design criteria. However, as time passes I would expect smaller grain sizes to shift at least portions of the mixture towards distributions suitable for kokanee and resident trout as well.

Backwatering from weir and/or LWD placement will likely inundate areas where structure (boulders, woody debris) is currently inadequate to provide optimum, or even good refuge cover within the pool rearing areas. Wood and/or rock should be placed and anchored well in the areas that will be inundated by the backwater. Existing alder may be simply rearranged and anchored to achieve this objective, although I recognize that this species will not last as long as sound conifer. A mix of imported conifer and local alder would also be fine.

ALL of the weir and wood placement work should be designed to be done where heavy equipment access can be accomplished from a single point on the right bank. See Section 4.3, below.

To the greatest extent possible, the placement of structures (weirs, LWD) should incorporate existing beaver dams, regardless of their condition. The idea is to simply increase the elevation (depth) of the existing backwater pools from the old dams, rather than inundating new riparian area. Structure placement should also try to take advantage of existing higher gradient segments for placement of spawnable materials.

4.2.3 Channel Modifications for Chinook

Channel segments that are not deepened or otherwise modified for deep/slow water rearing habitat should be enhanced with placed or repositioned wood or boulders to provide more refuge habitat for juvenile Chinook and steelhead. However, Chinook prefer relatively deep, low-velocity water, so wood or boulder placements should occur in channel reaches where deeper slots currently exist, or can be encouraged to develop. A target finished depth for these rearing areas is 0.66 ft or more, preferably closer to 2.3 ft, and with velocities less than 0.6 ft/s. The following quote from Cramer et al. (1999) is helpful:

"Habitat preferences for juvenile Chinook within a given stream will depend on what habitats a fish has to choose from. Hillman et al. (1987) found that Age 0+ spring Chinook (non-migrants) in a heavily-sedimented Idaho stream used habitats during the summer with water velocities less than 0.6 fps, depths of 0.6-2.4 ft, and close associations with cover (undercut banks). As the fish became larger they selected faster, deeper water."

The site studied by Hillman et al. (1987) is an excellent analog to the Constructed Channel. Therefore, based on that work, one possible objective for this project would be to use hand tools and hand labor to arrange available cobble with a mean diameter of 7.5 in (range 3.5-14.6 in) in slower velocity areas of runs, glides, or backwatered pools having at least 2.3 ft of depth. The assumed expectation is that Chinook fry rearing area would be increased in direct proportion to the areas enhanced (Table 6), although

Chinook would undoubtedly use the Channel to some degree, even under its current relatively shallow condition.

4.2.4 Moderated Channel Mouth Slope and Alcove

I am not certain that the existing mouth of the Constructed Channel is a migratory barrier for juvenile salmonids, therefore I do not know what benefits would accrue from moderating the slope from the current 8-11%. Whatever design is chosen (e.g. rock weirs), obviously great care must be taken to assure that the grade control structures do not fail, undermine, etc. The benefits (if any) of a moderated entrance slope must be balanced against the short or long terms damage done to the riparian plant community where the heavy equipment access is provided.

If heavy equipment is brought to the Channel mouth area, an alcove and pool with at least 6.0 feet of residual depth should be created to allow fish to hold where the Channel outflow meets the Lewis River Bypass Channel. The placement and shape of the heavy rock alcove should be such that there is little risk of collapse or undermining from high flows in the Bypass Channel. If possible, the entrance pool should be self-cleaning, and not likely to quickly fill with bedload sediment from the Bypass Channel.

4.3 Construction and Permitting Considerations

Pacificorp would be very well-advised to avail itself of the FREE consultations provided by wildlife and habitat biologists and habitat engineers within WDFW's Wildlife and Habitat Programs. Locally, the Area Wildlife Biologist at the Vancouver Office who can advise regarding the occurrence of State Sensitive Species and other wildlife concerns is Eric Holman (360 906 6755). The local Area Habitat Biologist at Vancouver is Ann Friesz (360 906 6764). Ann can advise as to the details of the JARPA (HPA) process, and what issues or pitfalls may be involved with this project. Perhaps most important of all, the technical assistance habitat engineer for this area who works out of the Olympia office is Pat Klavis (360 902 2606). Pat and Ann in particular should be brought into the review of this project as soon as possible, even during the design phase if possible. Again, their consultation is at no charge.

Work in the water will likely be limited to the month of July, only. There may be an exception (a wider work window) granted if the Constructed Channel is dewatered, and all fish are salvaged. Since there is a great deal of spring activity along the Constructed Channel, substantial measures will still be required to contain the work areas, and control fine sediment at the Channel mouth before the dirty water re-enters the Lewis River.

Access to the Channel from the parallel road should be at a single point if at all possible, or one at the top (marsh dredging) and one at the bottom (mouth re-grade and alcove). Avoiding spring areas and very wet, unstable soils will likely be a challenge.

Bisson et al. (1987) present two useful regressions of channel width and LWD length and diameter. The Constructed Channel is not comparable to their natural study streams since its flow is constant, but for a channel of about 23 ft bankfull width, wood pieces should be at least 23 feet long, and 16 inches in diameter. At least a few of the fallen alders seen in the Channel were this size (Table 4). Plots of hardwood loading against years since logging in both Bisson et al. (1987) and Andrus et al. (1988) suggest that wood loading from aging alder along the Channel will continue for up to 10 more years, assuming the channel riparian area was logged in the mid-1950s. The problem I observed in this case is that most of the wood spans the stream, and with its constant flow, it is unlikely to move and encounter fallen wood and thereby create more diverse habitat, especially scour pools. Design and construction should seek to reposition fallen wood so more of the stem volume or root wad is in the flowing stream where this is convenient, and where bank and riparian areas will not be unduly impacted.

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Digital Image Plates

Plate 1. Mature alder and grass understory along the Constructed Channel.

Plate 2. GPS waypoints along the Constructed Channel, 30 July 1994.

Plate 3. Fully vegetated, stable banks along the Constructed Channel.

Plate 4. Older beaver activity along the Constructed Channel.


Plate 5. Relatively recent beaver activity along the Constructed Channel.


Plate 6. Failed beaver dam in the Constructed Channel.


Plate 7. Beaver-cropped willows and alders in the Lewis River channel (UR).


Plate 8. Fines, sand, and small pebble substrate in the Constructed Channel.

Plate 9. Spring-fed marsh habitat at the head of the Constructed Channel.

Plate 10. West outlet of the Constructed Channel at the Lewis R. Bypass Channel.

Table 1. Habitat Unit Areas and Dimensions (all in feet or square feet).

Habitat Unit	Stationing		Length	Width	Unit Area	Pool Depth	Pool Area	Gravel Area
Cascade	0	100	100	22	2200			
Cascade	156	160	4	20	80			
Rapid	160	270	110	22	2420	1.6		
Cascade	270	288	18	25	450			
Rapid	288	336	48	18	864			86
Run	336	363	27	20	540	1.1		
Riffle	363	389	26	17	442			
Run	389	408	19	18	342			
Pool	408	410	2	18	36		36	
Rapid	410	464	54	32	1728			
Pool	464	506	42	22	924	1.6	924	
Run	506	595	89	23	2047	1.4		
Rapid	595	628	33	32	1056			
Run	628	673	45	39	1755	2.2		
Riffle	673	792	119	58	6902			
Riffle	792	801	9	42	378			
Riffle	801	880	79	29	2291			
Pool	880	892	12	18	216		216	
Riffle	892	1055	163	23	3749			1500
Rapid	1055	1085	30	24	720			
Run	1085	1134	49	14	686			
Riffle			35	2	70			
Pool	1134	1157	23	25	575		575	
Run	1157	1196	39	22	858	1.3		
Cascade	1196	1297	101	21	2121			
Run	0	257	257	3	771	1.8		
Totals:			1,589		35,453		1,751	1,586

NOTES: Gravel area in Unit 00+288 to 00+336 estimated to be 10% of the unit area (highly turbid).
Gravel area in Unit 00+892 to 00+1055 estimated to be 40% of the unit area.
"Gravel" is grain sizes >3-5 mm.
Some deeper pockets that occurred within larger units were measured as pools by NHC staff.
Final Cascade Unit ascends to the canal drain culvert.
Final Run Unit runs east through the spring-fed marsh at the channel head.
The right bank side channel below the culvert occurs between Stations 00+1085 and 00+1134.

Table 2. Relative areas of Constructed Channel fast and slow water habitat units.

	Faster Water Units			Slower Water Units	
	Cascade	**Rapid**	**Riffle**	**Run**	**Pool**
Number of Units	4	5	6	7	4
Total Surface Area (sf)	6,083	6,788	13,832	6,999	1,751
"Faster Water" Area		26,703 (75.3 %)			
"Slower Water" Area				8,750 (24.7%)	

Table 3. Design criteria for created spawning areas in the Constructed Channel

Species	Minimum Depth (ft)	Velocity (ft/sec)	Substrate Mix Size Range (in)	Mean Redd Area (ft^2)	Required Area per Spawning Pair (ft^2)
Spring Chinook	0.79	1 – 3	0.5 – 4	35.5	144
Coho	0.59	1 – 3	0.5 – 4*	30.1	126
Steelhead	0.79	1.3 – 3	0.25 – 4	52.7	
Kokanee	0.20	0.5 – 3	0.5 – 4	3.2	
Rainbow	0.59	1.6 – 3	0.25 – 52	2.2	
Cutthroat	0.20	0.4 – 2.4	0.25 – 4	5.4	

*NOTE: For coho, gravel size breakout should be:

Fines	– 8%
0.12-0.47 in	– 23%
0.51-1.97 in	– 43%
2.00-3.94 in	– 23%
3.98-5.91 in	– 3%

Table 4. Distribution of larger woody debris in the Constructed Channel.

Habitat Unit	Stationing		No. of Pieces > 4”	Size Range (in.)	No. of Pieces in the Water	No. of Pieces > 12”	No. of Root Wads	No. of Wads in the Water
Cascade	0	100	0				0	
Cascade	156	160	0				0	
Rapid	160	270	6	5 - 12	0		2	0
Cascade	270	288	0		0		0	
Rapid	288	336	4	6 – 11	1		2	0
Run	336	363	1	10	0		0	
Riffle	363	389	1	9	10		0	
Run	389	408	0		0		0	
Pool	408	410	0		0		0	
Rapid	410	464	7	5 – 13	2		3	3
Pool	464	506	5	6 – 11	2		4	4
Run	506	595	12	4 – 12	2		3	2
Rapid	595	628	11	4 – 7	5		1	1
Run	628	673	6	4 – 6	4	0	0	
Riffle	673	792	26	4 – 10	2	0	7	7
Riffle	792	801	0		0	0	1	1
Riffle	801	880	27	4 – 11	3	0	1	1
Pool	880	892	4	5 – 10	3	0	1	1
Riffle	892	1055	17	4 – 16	5	1	2	1
Rapid	1055	1085	2	5 – 5.5	0	0	0	
Run	1085	1134	2		2	0	0	
Riffle			3		1	0	0	
Pool	1134	1157	2	4.5	2	0	0	
Run	1157	1196	0		0	0	0	
Cascade	1196	1297	5	4	3	0	1	1
Run	0	257	0		0	0	0	
Totals:			141		47		28	22

NOTES: All dimensions are for average stem diameter.
“In the water” means wood is affecting habitat unit value or shape by hydraulic effects.
Although plentiful, wood pieces < 4” in diameter were not tallied or mapped.
Pieces > 12” were not noted until Station 00+628.
Initial root wad tally includes all within the “floodway” of the constant-flow stream.

Table 5. Summary of Enhancements and Potential Coho Production Benefits of Constructed Channel Work.

Chainage		Length of Channel Enhanced (ft)	New Coho Rearing Area			New Coho Spawning Area			
Start	End		Backwatered Pool / Run (ft^2)	Scour Pool (ft^2)	# Fry or Smolt*	Area (ft^2)	Potential # of Redds	Adult Fish Holding Area (ft^2)	Comments
180	220	40		1200	6852 f			1200	Excavated new pool.
220	410	190				630	69		Seven new 90 square foot patches. Assumes 9.2 ft^2/redd.
430	580	150	859		4905 f				Increases existing pooled area about 20% if raise water elevation by 1 ft.
630	750	120	1306		7457 f				Increases existing pooled area about 20% if raise water elevation by 1 ft.
810	870	60	296		1690 f				Increases existing pooled area about 20% if raise water elevation by 1 ft.
1080	1120	40		420	2398 f			420	Excavated new pool.
1170	1427	257	6760		466 s				Enlarged from 6000 square feet.
1260	1390					1305	142		Assumes 9.2 ft^2/redd from WDFW criteria.

* Used conservative value of 5.71 fry/ft^2 from Sedell et al. (1984) for scour or backwatered pools. Could possibly be as much as 50% higher.
Used 0.069 smolts/ft^2 for side channel ponds from Cederholm et al. (1988).

Table 6. Summary of Enhancements and Potential Chinook Production Benefits of Constructed Channel Work.

Chainage Start	Chainage End	Length of Channel Enhanced (ft)	New Chinook Rearing Area: Scour or Backwater Pool (ft^2)*	Rapid or Riffle (ft^2)**	Number of Juveniles	Comments
180	220	40	1200		5040	Excavated new pool.
415	430	15		240	594	Exposed coarser gravel and cobble below weir.
430	580	150	859		3608	Increases existing pooled area about 20% if raise water elevation by 1 ft.
615	630	15		240	594	Exposed coarser gravel and cobble below weir.
630	750	1306	1306		5485	Increases existing pooled area about 20% if raise water elevation by 1 ft.
795	810	15		315	780	Exposed coarser gravel and cobble below weir.
810	870	60	296		1243	Increases existing pooled area about 20% if raise water elevation by 1 ft.
1080	1120	40	420		1764	Excavated new pool.
1155	1170	15		165	409	Exposed coarser gravel and cobble below weir.
1170	1427	257	6760		28,392	Enlarged from 6000 square feet.

* Used 4.2/ft^2 from Hillman et al. (1987) for fall densities in glide habitat. Skagit River backwater values (Hayman et al. 1996) were much higher.
** Used 2.476/ft^2 from Hillman et al. (1987) for fall densities in riffle habitat.