Kitimat to Summit Lake Natural Gas Pipeline Looping Project

— Conceptual Compensation Plan for Fish Habitat —

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cover photo: PNG crossing of the Stuart River.

Table of Contents

1 INTRODUCTION

Construction of the Kitimat to Summit Lake Natural Gas Pipeline Looping Project (the KSL Project) will enable delivery of natural gas from the Kitimat Liquefied Natural Gas (KLNG) facility to the Spectra Energy Transmission BC pipeline facilities located east of the Village of Summit Lake. To accommodate the construction and operation of the KSL Project, PNG and KLNG have jointly formed a new company, Pacific Trail Pipelines Inc. (PTP) that will own and operate the proposed pipeline loop as well as the existing PNG pipeline.

The KSL Project involves construction of 462 km of 914 mm (36-inch) diameter pipe between a location immediately north of the City of Kitimat, and a location immediately east of the Village of Summit Lake (Figure 1). The project also includes construction and operation of one new compressor station located at the mid-point of the new pipeline. The project will require construction of temporary camps, stockpile sites and other short-term work yards.

2 PURPOSE

The proposed KSL Project is subject to review under the B.C. Environmental Assessment Act (BCEA Act) 98 as well as the Canadian Environmental Assessment Act (CEA Act) 104. This review and approval process will be conducted under the auspices of the Harmonization Agreement by the B.C. Environmental Assessment Office (BCEAO) and the Canadian Environmental Assessment Agency (CEA Agency). An application has been made to the BCEAO for an Environmental Approval Certificate (EAC) for the purposes of constructing and operating the KSL Project.

During the initial review process Fisheries and Oceans Canada (DFO) requested a conceptual compensation plan for the KSL Project. This document presents conceptual plans for fish habitat compensation to offset impacts from construction and operation of the KSL Project. The document briefly reviews the needs for compensation, the logic proposed to define the amount of compensation required, construction monitoring and post-construction assessment, the types of compensation proposed, and the timelines for compensation. Detailed compensation plans will be developed during the permitting phase of the project.

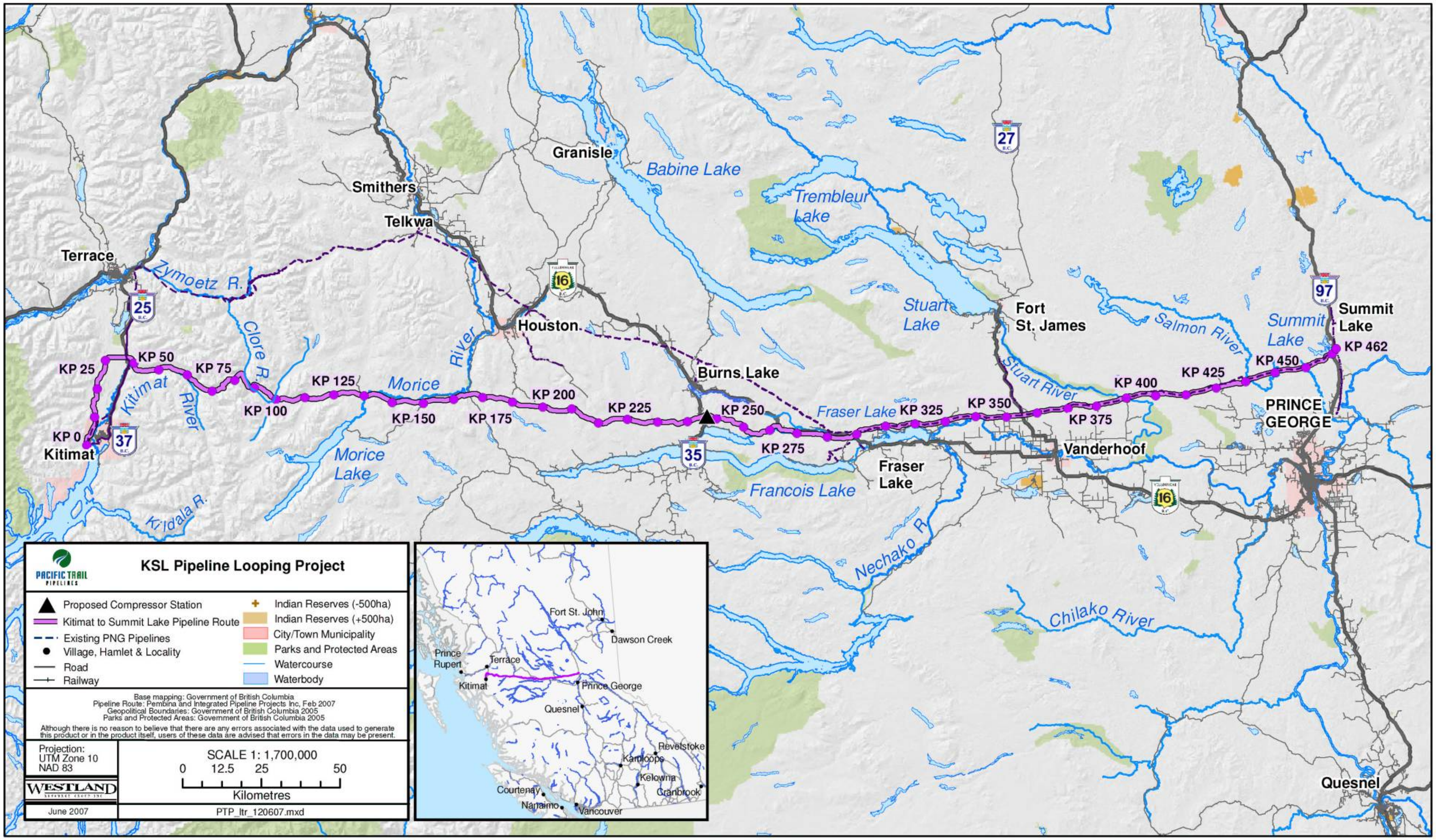

Figure 1. KSL pipeline route and general geographic setting.

3 HABITAT COMPENSATION NEEDS

3.1 Regulations and Legislation

The management of potential impacts to fish and fish habitat is governed by several key pieces of legislation. The dominant legislation is the *Fisheries Act* within which several sections define offences that may occur during a project such as the KSL Project. The key sections of the Act are Section 22, wherein sufficient flow for flooding of spawning grounds and free passage of fish must be maintained during construction, Section 32, which prohibits destruction of fish by any means other than fishing, Section 35, which prohibits the harmful alteration, disruption or destruction of fish habitat (HADD), and Section 36, which prohibits the deposit of deleterious substances.

DFO's long-term policy objective is an overall net gain of the productive capacity of fish habitats. This is to be accomplished through three actions: the conservation of the current productive capacity of habitats, the restoration of damaged fish habitats, and the development of habitats. The conservation of current productive capacity is implemented using the No Net Loss Guiding Principle. Unavoidable habitat losses are balanced with habitat replacement (i.e., habitat compensation) on a project-by-project basis to prevent a net habitat loss. DFO issues authorizations for HADD under Section 35(2) of the *Fisheries Act* when other options are unworkable.

The decision to authorize a HADD is made through a decision framework that identifies the information needed to answer a series of questions that clearly link to a decision on whether a Section 35(2) authorization can be granted. Although the determination of a HADD may be technically complex, the questions are quite simple:

1. Is fish habitat present at the project site or in an area affected by the project?
2. Could the proposed project cause a HADD of fish habitat?
3. Can the impacts to fish habitat be fully mitigated?
4. Should the HADD be authorized?
5. Can the HADD be compensated?

Construction-related impacts are those incurred during the construction phase of a project, and may be associated with activities such as land clearing, grading, and instream construction. Impacts are generally short-term and may include effects such as increases in suspended sediments, or other temporary disturbances to aquatic habitat. Where construction activities may cause HADD, a Fisheries Act authorization from DFO and habitat compensation are required.

Mitigation refers to measures taken to avoid or reduce the likelihood of negative impacts of construction and operation of an intake or diversion. Compensation on the other hand, refers to intentional activities undertaken to offset inevitable impacts once they occur. Compensation offsets negative impacts by providing benefits elsewhere in the system. Thus, the purpose of mitigation is to avoid impacts, whereas the use of compensation implies acceptance of impacts. Mitigation is a superior option to compensation, and proponents are expected to develop mitigation measures to ensure the fish resource is protected during construction and operation of the proposed project.

Where HADD is unavoidable and a Fisheries Act authorization is required, proponents are instructed to develop and submit compensation plans to compensate for habitat impacts and ensure that compensation is effective. This document describes needs for compensation that have been identified through the environmental impact assessment for the KSL Project, and lays out conceptual approaches to fish habitat compensation for project-related impacts.

3.2 Impact Assessment

The EAC application for the KSL Project provides a review of existing information and presents data collected specifically for this project. It describes potential impacts and assesses residual effects in relation to 16 species of fish and the habitats that support these species. Five classes of potential impact are discussed in relation to pipeline construction and vehicle access stream crossings:

1. Direct and indirect mortality of fish,
2. Loss or degradation of instream fish habitat,
3. Loss or degradation of riparian habitat,
4. Loss or degradation of habitat connectivity, and
5. Interbasin transfer of aquatic organisms.

Impact pathways and potential effects of each phase of the KSL Project on the 16 aquatic environment VECs are presented, and mitigation measures to minimize potential effects are discussed. Anticipated residual effects are identified, and assessments of significance are presented.

The assessment identified no significant residual effects from direct and indirect mortality of fish, loss or degradation of habitat connectivity, or interbasin transfer of aquatic organisms. Some residual effects were identified in relation to loss or degradation of instream fish habitat, and loss or degradation of riparian habitat and are discussed briefly below. The EAC application should be consulted for additional detail, such as information sources and assessment methods.

3.2.1 Loss or degradation of instream fish habitat

Potential Impacts.— Temporary disturbance of instream habitat will occur at the majority of pipeline crossings, since trenching of the watercourse will be required to complete most crossings. On crossings requiring a buried pipeline, mitigation, restoration and on-site compensation (i.e., measures to improve habitat within the project footprint area) will offset impacts to instream fish habitat, by controlling suspended sediment releases, restoring or maintaining streambank stability, and restoring or creating instream cover at all fish-bearing crossings. Residual impacts are not expected at crossings completed using isolation methods, provided the crossings are completed within the specified work windows and habitat is restored as indicated in the EAC Application and the KSL Restoration Plan. Off-site compensation (i.e., measures to improve habitat outside the project footprint area) is not anticipated as a requirement for these crossings. Examples of on site compensation and restoration methods and how these will be implemented are presented in Section 3.3.1.

Ten crossings are intended to be completed using HDD or aerial techniques, which require no instream work and therefore have no effect on instream habitat. Residual impacts are not expected at crossings completed using HDD or aerial methods. Riparian habitats will be restored as indicated in the EAC Application and the KSL Restoration Plan. Compensation is not anticipated as a requirement for these crossings.

Residual impacts to instream fish habitat have been identified under two scenarios: crossings constructed outside the instream work window, and crossings where open cut methods are used. Habitat compensation may be required to offset impacts in both cases and each scenario is described in greater detail before conceptual compensation plans are elaborated.

Construction Activities Outside the Instream Work Window.— Three crossings of the Salmon River are planned for winter construction, outside the preferred instream work window, for reasons of flow constraints, access and project management. These crossings will be completed using flow isolation techniques, which will minimize release of suspended sediment to downstream habitat. Impacts to habitat may occur through settling of fines, but these effects are expected to be minimal, short-lived and be mostly offset by flushing flows during spring freshet or storm runoff events. Compensation will be provided to offset these temporary impacts within the zone of influence. The form and amount of compensation is described in Section 3.3.2.1.

PTP has committed sufficient construction resources to complete the great majority of the fish-bearing crossings within the instream work windows, but some crossings may have to be completed at other times if construction progress is slower than expected. This is most likely to occur on construction spreads where the water crossing density is very high and terrain is especially rugged (e.g., upper Kitimat, Morice) and/or where wet weather or unanticipated construction difficulties negatively impact construction progress. Priorities have been set that determine the approximate order of crossings (crossing table in Section 6 of the EAC Application) and it is expected that instream construction outside the windows, if it occurs, will be on relatively small streams with relatively lower fish resource values. Impacts to habitat are expected to be short-lived and be diminished by flushing flows during spring freshet, but if instream construction is required outside the work windows then habitat compensation may be required to offset impacts in these instances. Conceptual plans for compensation are provided in Section 3.3.2.

Open Cut Crossings.— No stream crossings have been planned with open cut as the primary method. Pipeline crossings of the Little Wedeene and Wedeene Rivers are proposed as HDD, with open cut as the contingency crossing method. Flow in these systems is too high year round to make use of isolation methods. Best efforts will be made to complete the crossings using HDD, but open cut remains a possibility if HDD is infeasible or fails. Geotechnical work is underway to evaluate the feasibility of HDD crossings. Compensation will be provided to offset impacts within the zone of influence of all open cut crossings. Conceptual compensation plans are provided in Sections 3.3.3.1 and 3.3.3.1.

3.2.2 *Loss or degradation of riparian habitat*

Riparian zones form a physical transition zone between aquatic and terrestrial ecosystems, and there are often strong physical and biological interactions between the two. For fish, riparian zones offer three important functions: streambank stability (e.g., roots bind streambank soils and prevent erosion or sloughing), instream cover (e.g., large and small woody debris, overhanging vegetation), and food (e.g., contribution to invertebrate drift in streams). Streambank stability and instream cover are important primarily on fish-bearing watercourses; food inputs from riparian areas may be important on both fish-bearing and non-fish bearing watercourses. Losses of riparian habitat occur at both pipeline and temporary vehicle crossings, within the spatial scale of the Project Footprint area.

Potential Impacts.— During the clearing, construction and restoration phases of the KSL project, loss or degradation of riparian habitat will occur at most pipeline crossings, since clearing of riparian trees and shrubs is essential to completing the crossing. Mitigation, restoration and on-site compensation will offset impacts relevant to fish production, by restoring or maintaining streambank stability and providing instream cover at all fish-bearing crossings. Stream crossings will be restored with the intent of replicating or improving existing conditions. General procedures are outlined in Section 3.3.1.

Mitigation, restoration and compensation measures will effectively address changes to streambank stability and instream cover associated with loss or degradation of riparian habitats at pipeline crossings. Riparian contributions of invertebrates to watercourses (a source of food for fish) will be lost or diminished within the project footprint area, but this loss is expected to be negligible and not significant.

Compensation Needs.— Off-site compensation (i.e., measures to improve habitat outside the project footprint area over and above that already prescribed through mitigation, restoration and on-site compensation) is deemed not necessary for KSL Project effects regarding riparian habitat losses.

3.3 Defining Compensation Needs

Compensation involves replacing disturbed or damaged habitat with newly created habitat or improving the productive capacity of some other natural habitat. DFO's hierarchy of preferred compensation options is:

1. create similar habitat at or near the development site within the same ecological unit;
2. create similar habitat in a different ecological unit that supports the same stock or species;
3. increase the productive capacity of existing habitat at or near the development site and within the same ecological unit;
4. increase the productive capacity of a different ecological unit that supports the same stock or species;
5. increase the productive capacity of existing habitat for a different stock or a different species of fish either on or off site.

On-site compensation measures clearly meet the first option. For cases where off-site compensation is necessary, efforts will focus on the first and second compensation option, but will also consider other options.

3.3.1 On-site restoration measures

On S3 to S6 streams, restoration of instream and riparian habitats will be guided by restoration "typicals" and on-site supervision by a restoration specialist. The streambed and banks will be restored, based on preconstruction habitat surveys, and the natural drainage and channel configurations will be maintained or restored. Additional cover will be provided, primarily through the use of boulder and large woody debris placement. Approach slopes will be seeded with a native seed mix and streambanks will be restored with shrubs; some larger tree species will be planted or allowed to recruit to disturbed areas.

3.3.1.1 S3 to S6 Streams – Toolbox Approach

We do not anticipate developing detailed restoration drawings for S3 to S6 streams. Restoration specialists will have at their disposal a "toolbox" of methods that can be used for restoring fish habitat at each crossing. These methods represent a range of options that have been pre-approved by project engineering staff and regulatory agencies as suitable to the terrain and fish habitat conditions. The methods will be deployed with the intent of meeting or exceeding the objective of no net loss of fish habitat at each crossing. Records will be kept that detail the fish habitat conditions prior to construction, the methods used to restore habitat, and conditions at the restored location immediately following restoration.

The rationale and hierarchy for use and application of the various measures is included in Appendix B. The application table and examples are use data collected during site assessments, and are flexible in their application to accommodate channel and stream bank changes associated with the crossing installation.

3.3.1.2 S1 and S2 Streams – Detailed Designs

On S1 and S2 streams, site restoration will require engineering input and will therefore be guided by engineering designs as well as on-site supervision by a restoration specialist. These detailed crossing and restoration plans will be developed post-certification during the detailed design phase. Many of the methods used will be similar to those used on S3 to S6 streams, with the intent of meeting or exceeding the objective of no net loss of fish habitat at each crossing, but the work is larger in scope and scale. Due to the relative stream power and energy of larger streams, a higher level of design, engineering and construction supervision is typically required. Records will be kept detailing the fish habitat conditions prior to construction, the methods used to restore habitat, and conditions at the restored location immediately following restoration.

An example of the level of design for a larger, more complex stream crossing is included in Appendix C. These designs often utilize the same units and measures as earlier described in the toolbox, but they are applied over a larger area and are combined with additional works to provide additional bank protection, or to integrate several different requirements over a larger impacted area.

3.3.2 Crossings Completed Outside the Instream Work Windows

Three crossings of the Salmon River are expected to occur in winter, outside the preferred instream work window. Compensation for these crossings is presented in Section 3.3.2.1.

In addition to the three Salmon River crossings, which are explicitly planned for construction outside the work window, several crossings of fish-bearing streams may have to be completed outside the work windows if the rate of construction progress is slower than anticipated (see Section 3.2.1). Although PTP has committed to sufficient resources to complete all fish-bearing crossings within their respective windows, there is a need to undertake some contingency planning. PTP will provide compensation on these crossings, if they are completed outside the work window, and the compensation needs for these crossings are discussed in Section 3.3.2.2.

3.3.2.1 Salmon River

Three crossings of the Salmon River are expected to occur in winter, outside the preferred instream work window. The crossings will be constructed using flow isolation techniques. Contingency plans are to use the same techniques, but to move the construction timing to summer, within the instream work window.

Type and area of habitat disturbed.— Fish habitat surveys conducted for the KSL Project (AAR 2007) indicate that a variety of high quality rearing, overwintering and spawning habitats occur near the three proposed crossings of the Salmon River. None of the crossing sites are known to be in the immediate vicinity of high use spawning areas for anadromous salmonids, and fish production in the Salmon River is believed to be limited primarily by accessible rearing and overwintering habitats with sufficient depth and cover (Aitken 1993). Spawning habitat is generally abundant and not limiting.

To calculate the area of habitat disturbed by pipeline construction activities, PTP will measure depth and velocity transects across the Salmon River. Three transects will be measured during the summer rearing period, within the vicinity of each crossing where work occurs outside work windows. We propose to calculate weighted useable area using HSI curves for steelhead juveniles (parr) as the target species and life stage. Since they have broad habitat preferences, the HSI curves can be considered conservative for all salmonid species.

To measure the downstream extent of habitat disturbed by pipeline construction activities, PTP will measure total suspended solids at selected points downstream of the crossing. Measurements at these points will be used to calculate fish and fish habitat severity indices using the dose-response model of Newcombe and Jensen (1996). By measuring suspended sediments at two or more distances downstream of the crossing activities it will be possible to interpolate and extrapolate the extent of sediment impacts.

As a preliminary measure (i.e., until transects are measured, weighted habitat areas are calculated, and monitoring of suspended sediments is completed), PTP proposes to use a conservative estimate of half the mean wetted channel width to quantify the useable rearing and overwinter habitat. The downstream extent of disturbance will be determined by monitoring of suspended sediments, and deposition within the channel. In general, finer fractions of suspended materials will remain in suspension without deposition. Coarser silts and sand will travel relatively short distances downstream within the water column before depositing locally in quiescent pools and backwater areas where velocities are low.

During low flows, such as the time of intended construction, the distances that coarser fractions travel will typically be limited to one to three habitat units downstream, based on the successive trapping of pool-riffle units and limited transport capacity. Using bankfull widths (W_{bf}) in small streams, a habitat unit approximates 6 × W_{bf} and therefore the extent of potential impacts can be predicted. In larger streams and rivers, or steeper streams where turbulent flows predominate, these estimates should be used as an initial estimate confirmed with visual assessment and monitoring.

Duration of the disturbance.— The duration of the disturbance from the crossing is expected to be temporary, lasting a maximum of one year from the time of instream construction. Freshet flows are expected to redistribute the streambed and flush fines from the substrate. The disturbance is therefore relatively short-lived.

Type and expected longevity of the compensation habitat.— Compensation habitats are typically engineered to be long-lasting, so the benefits from the compensation habitats accrue over a period that is considerably longer than the duration of physical disturbance from the pipeline construction. Longevity of the habitat compensation therefore allows the total area required to be reduced by some factor. For the purposes of calculating compensation commitments, PTP will use a factor of 20% of the total habitat disturbed.

DFO compensation ratios.— DFO typically requires a compensation ratio of 2:1 for instream habitats, so the total habitat required as compensation is twice the amount disturbed. This ratio is adopted for KSL fish habitat compensation.

Habitat Calculation Summary.— In summary, total habitat compensation requirements for isolated pipeline crossings of the Salmon River when completed outside the work windows will be determined with the following calculation: weighted useable width × extent of downstream impact × 2:1 DFO compensation ratio × 0.20 duration factor. The actual habitat calculations will be possible only when it is determined whether and which streams are crossed outside the work windows, and will be based on monitoring of downstream sediment impacts. Preliminary calculations for the Salmon River crossings, with resulting habitat compensation amounts, are indicated in Table 1, based on channel measurements from AAR 2007.

Monitoring and Post-Construction Assessment.— Monitoring of downstream water quality (NTU and TSS) will occur throughout the construction period to assess risks to downstream habitats. A redd survey will be conducted in August prior to construction to assess whether spawning habitats are potentially affected. The redd survey will be completed for areas within the zone of direct disturbance (i.e., the area proposed for isolation) and downstream for 250 m. If spawning has occurred within this zone of influence additional compensation requirements will be discussed with DFO.

Prior to construction fish will be salvaged and released to appropriate habitat beyond the work area.

Compensation Options.— Proposed compensation habitat will take the form of side channel or off channel rearing and overwintering habitats constructed within the river floodplain on the Salmon River. The identification and development of compensation sites, location and amount of proposed compensation for the project is detailed in Section 5.4.

3.3.2.2 S2 to S6 systems

As noted above, several crossings of fish-bearing streams may have to be completed outside the work windows if the rate of construction progress is slower than anticipated (see Section 3.2.1). Although PTP has committed to sufficient resources to complete all fish-bearing crossings within the window, there is a need to undertake some contingency planning. PTP will provide compensation on these crossings, if they are completed outside the work window, and the compensation needs for these crossings are discussed here.

Type and area of habitat disturbed.— To calculate the area of habitat disturbed by pipeline construction activities, PTP will measure depth and velocity transects across each affected stream. Three transects will be measured during the summer rearing period, within the vicinity of each crossing where work occurs outside work windows. We propose to calculate weighted useable area using HSI curves for steelhead juveniles (parr) as the target species and life stage. Since they have broad habitat preferences, the HSI curves can be considered conservative for all salmonid species.

To measure the downstream extent of habitat disturbed by pipeline construction activities, PTP will measure total suspended solids at selected points downstream of the crossing. Measurements at these points will be used to calculate fish and fish habitat severity indices using the dose-response model of Newcombe and Jensen (1996). By measuring suspended sediments at two or more distances downstream of the crossing activities it will be possible to interpolate and extrapolate the extent of sediment impacts.

As a preliminary measure (i.e., until transects are measured, weighted habitat areas are calculated, and monitoring of suspended sediments is completed), PTP proposes to use a conservative estimate of half the mean wetted channel width to quantify the useable rearing and overwinter habitat. The downstream extent of disturbance will be determined by monitoring of suspended sediments and post-construction habitat surveys, but a preliminary measure of 100 m is used for calculating the extent of the habitat impact.

Duration of the disturbance.— The duration of the disturbance from the crossing is expected to be temporary, lasting a maximum of one year from the time of instream construction. Freshet flows are expected to redistribute the streambed and flush fines from the substrate. The disturbance is therefore relatively short-lived.

Type and expected longevity of the compensation habitat.— Compensation habitats are typically engineered to be long-lasting, so the benefits from the compensation habitats accrue over a period that is considerably longer than the duration of physical disturbance from the pipeline construction. Longevity of the habitat compensation therefore allows the total area required to be reduced by some factor. For the purposes of calculating compensation commitments, PTP will use a factor of 20% of the total habitat disturbed.

DFO compensation ratios.— DFO typically requires a compensation ratio of 2:1 for instream habitats, so the total habitat required as compensation is twice the amount disturbed. This ratio is adopted for KSL fish habitat compensation.

Habitat Calculation Summary.— In summary, total habitat compensation requirements for isolated pipeline crossings completed outside the work windows will be determined with the following calculation: weighted useable width × extent of downstream impact × 2:1 DFO compensation ratio × 0.20 duration factor. The actual habitat calculations will be possible only when it is determined whether and which streams are crossed outside the work windows, and will be based on monitoring of downstream sediment impacts. Preliminary calculations for the Salmon River crossings, with resulting habitat compensation amounts, are indicated in Table 1, based on channel measurements from AAR 2007.

Monitoring and Post-Construction Assessment.— Monitoring of downstream water quality (NTU and TSS) will occur throughout the construction period to assess risks to downstream habitats. A redd survey will be conducted in August prior to construction to assess whether spawning habitats are potentially affected. The redd survey will be completed for areas within the zone of direct disturbance (i.e., the area proposed for isolation) and downstream for 250 m. If spawning has occurred within this zone of influence additional compensation requirements will be discussed with DFO.

Prior to construction fish will be salvaged and released to appropriate habitat beyond the work area.

Compensation Options.— Habitat compensation will take the form of off-channel rearing and overwintering habitats constructed at or near the crossing sites in the floodplain. The identification and development of compensation sites, location and amount of proposed compensation for the project is detailed in Section 5.

3.3.3 Contingency Crossing Methods for Large Rivers

No stream crossings have been planned with open cut as the primary method. Pipeline crossings of the Little Wedeene and Wedeene Rivers are proposed as HDD, with open cut as the contingency crossing method. Flow in these systems is too high year round to make use of full isolation methods as a primary or contingency method. Best efforts will be made to complete the crossings using HDD, but open cut remains a possibility if HDD is infeasible or fails. Geotechnical work is underway to evaluate the feasibility of HDD crossings. Compensation will be provided to offset impacts within the zone of influence of all open cut crossings. Conceptual compensation plans are provided in the following sections.

3.3.3.1 Chist, Morice and Stuart

The pipeline crossing of the Chist, Morice and Stuart Rivers are proposed as HDD, with aerial as the contingency crossing method. Flow in these rivers is too high year round to make use of isolation techniques as a contingency method. Best efforts will be made to complete the crossing using HDD, but aerial crossings may be required if HDD is infeasible or fails. Geotechnical work is underway to evaluate the feasibility of HDD crossings.

Instream work is not expected to be necessary for either HDD or aerial crossings, and riparian impacts are expected to be minimal. Residual impacts are not expected at crossings completed using HDD or aerial methods. Riparian habitats will be restored as indicated in the EAC Application and the KSL Restoration Plan. Compensation is not anticipated as a requirement for these crossings.

3.3.3.2 Little Wedeene and Wedeene

Pipeline crossings of the Little Wedeene and Wedeene are proposed as HDD, with open cut as the contingency crossing method. Flow in these systems is too high to make use of isolation techniques as a contingency method. Best efforts will be made to complete the crossings using HDD, but open cut remains a possibility if HDD is infeasible or fails. Geotechnical work is underway to evaluate the feasibility of HDD crossings. Where open cut techniques are required on fish-bearing watercourses, habitat compensation will be provided in addition to mitigation.

Mitigation of open cut on these systems would include careful selection of work windows and, to the extent feasible, use of specialized techniques to minimize suspended sediment. These techniques may include partial flow bypass, use of a clamshell excavator bucket, and reliance on natural bedload movement to backfill the trench. Timing of any open cut crossings would be selected to minimize potential effects to fish and fish habitat. Instream work windows for all streams are indicated in the EAC Application. For the Little Wedeene and Wedeene Rivers the work window is June 15 to July 15.

Type and area of habitat disturbed.— Fish habitat surveys conducted for the KSL Project (AAR 2007) indicate that a variety of high quality rearing, overwintering and spawning habitats occur near the proposed crossings of the Little Wedeene and Wedeene.

Since the crossings would be completed during the instream work window, we assume that mobile life stages of fish would respond to increased suspended sediment by moving to appropriate habitat elsewhere in the system during construction activities such as trenching, provided that refuge habitats are available. By completing the crossings within the work window, impacts to spawning fish and incubating eggs are minimized.

However, the high number of species occurring in these systems, many of which have different life history timing, means that work windows cannot completely avoid all species' spawning and incubation times. A redd survey will be conducted prior to construction on these systems, if open cut is required. The redd survey will be completed for areas within the zone of direct disturbance and downstream for 500 m. The distance of this survey is greater than that proposed for situations where isolation methods are used outside the work windows, with the rationale that sediment movement will be greater when open cut is the method used in comparison to isolation methods. Compensation will be provided to offset habitat impacts within this zone.

To calculate the area of habitat disturbed by pipeline construction activities, PTP will measure depth and velocity transects across the affected rivers. Three transects will be measured during the summer rearing period, within the vicinity of each crossing where open cut methods are required. We propose to calculate weighted useable area using HSI curves for steelhead juveniles (parr) as the target species and life stage. Since they have broad habitat preferences, the HSI curves can be considered conservative for all salmonid species.

To measure the downstream extent of habitat disturbed by pipeline construction activities, PTP will measure total suspended solids at selected points downstream of the crossing. Measurements at these points will be used to calculate fish and fish habitat severity indices using the dose-response model of Newcombe and Jensen (1996). By measuring suspended sediments at two or more distances downstream of the crossing activities it will be possible to interpolate and extrapolate the extent of sediment impacts.

As a preliminary measure (i.e., until transects are measured, weighted habitat areas are calculated, and monitoring of suspended sediments is completed), PTP proposes to use a conservative estimate of half the mean wetted channel width to quantify the useable rearing and overwinter habitat. The downstream extent of disturbance will be determined by monitoring of suspended sediments, but a preliminary measure of 250 m is used for calculating the extent of the habitat impact for open cut crossings. Note that this is considerably greater than the value used for isolated crossings.

Duration of the disturbance.— The duration of the disturbance from the crossing is expected to be a maximum of one year from the time of initiation of instream construction, because freshet flows are expected to redistribute the streambed and flush fines from the substrate. The disturbance is therefore relatively short-lived.

Type and expected longevity of the compensation habitat.— Compensation habitats are typically engineered to be long-lasting, so the benefits from the compensation habitats accrue over a period that is considerably longer than the duration of physical disturbance from the pipeline construction. Longevity of the habitat compensation therefore allows the total area required to be reduced by some factor. For the purposes of calculating compensation commitments, PTP will use a factor of 20% of the total habitat disturbed.

DFO compensation ratios.— DFO typically requires a compensation ratio of 2:1 for instream habitats, so the total habitat required as compensation is twice the amount disturbed. This ratio is adopted for KSL fish habitat compensation.

Habitat Calculation Summary.— In summary, total habitat compensation requirements for open cut pipeline crossings will be determined with the following calculation: weighted useable width × extent of downstream impact × 2:1 DFO compensation ratio × 0.20 duration factor. The actual habitat calculations will be possible only when it is determined whether and which streams are crossed using open cut techniques, and will be based on monitoring of downstream sediment impacts. Preliminary calculations for these crossings, with resulting habitat compensation amounts, are indicated in Table 1, based on channel measurements from AAR 2007.

Monitoring and Post-Construction Assessment.— During construction water samples will be taken at 100 m, 250 m and 500 m downstream of the construction site and be compared to an upstream control site. Water samples will be taken within 0.5 m above the streambed in mid-channel. Controls will be collected upstream of the construction activities. Samples will be taken during construction and for several hours after its completion. Suspended sediments will be measured as both NTU and TSS. TSS will be measured in the lab, and some samples will be fractionated into component size classes. Compensation will be provided to offset impacts to spawning habitats if spawning occurs within the zone of influence, and if the cumulative concentration of suspended coarse sediments exceeds a specified threshold. The threshold will be discussed with DFO during the permitting phase of the project, prior to initiation of construction.

Habitat surveys and a redd survey will be conducted prior to construction for comparison to post-construction conditions. The habitat surveys will be completed for areas within the zone of direct disturbance (i.e., the area proposed for isolation) and downstream for 500 m. If, prior to construction, spawning has occurred within this zone of influence additional compensation requirements will be discussed with DFO.

To assess habitat impacts and determine the amount of compensation required, a detailed habitat survey will be conducted immediately prior to construction and immediately after. The survey will be completed for areas within the zone of direct disturbance (i.e., the area proposed for isolation) and downstream for 500 m. The survey will provide a plan-view map of habitat types, key habitat features and substrate qualities. Compensation will be based on before-after comparisons of habitat areas and habitat quality. Detailed habitat maps will be supplemented with cross-channel transects measuring substrate quality; transects will be spaced 50 m intervals within this zone of influence.

To assess potential impacts to spawning habitats, a redd survey will be conducted immediately prior to construction within the zone of direct disturbance (i.e., the area proposed for isolation) and downstream for 500 m. If spawning has occurred within this zone of influence additional compensation may be required.

Compensation Options.— Conceptually, compensation for the Little Wedeene and Wedeene will take the form of constructed off-channel rearing habitat in the general proximity of the crossings, with the rationale that fish production in these systems is believed to be limited primarily by accessible overwintering habitats with sufficient depth and cover. Examination of air photos (see Appendix A) confirms that there are numerous locations in close proximity to the proposed crossing locations, which have suitable land and drainage features and are accessible for construction equipment. Suitable locations on the Little Wedeene and Wedeene are in the floodplains of those systems.

3.3.4 Monitoring and Post-Construction Assessment

Details of the KSL monitoring program will be developed post-certification, as part of the permitting process. Some information is provided here because it relates to the identification of compensation needs.

HDD Crossings.— HDD crossings will be monitored during construction to ensure immediate detection of drilling mud leakage ("frac out"), and to confirm that impacts do not occur. Impacts to fish habitat are not expected with this crossing method. If monitoring identifies impacts requiring compensation, these needs will be discussed with DFO.

Isolation Methods.— Residual impacts are not expected at crossings completed using isolation methods, where these crossings are completed within the specified work windows and habitat is restored as indicated in the EAC Application. Off-site compensation is therefore not anticipated as a requirement for these crossings.

On all watercourses monitoring will ensure that sediment control is in place and functioning properly. Monitoring will also include continuous measurement and recording of downstream water quality (NTU and TSS) where the crossing is immediately upstream of high value fish habitat. Monitoring will be more intensive on fish-bearing watercourses. Construction activities will be modified as needed, based on input from the environmental monitor. Impacts to fish habitat are not anticipated, but if monitoring identifies impacts requiring compensation, these needs will be discussed with DFO.

Where isolation methods are used outside the least risk work window there is increased risk to fish and fish habitat, and compensation may be required where impacts occur. Additional monitoring will occur in these instances, including fish and fish habitat surveys within the zone of influence prior to construction. In some cases several surveys may be required, and mitigation may be used to prevent spawning within the zone of influence.

Open Cut Crossings.— No stream crossings have been planned with open cut as the primary method, although open cut has been planned as a contingency crossing method for the Little Wedeene and Wedeene Rivers. Should open cut techniques be required they will be used during the instream work window of least risk. Temporary impacts to fish and fish habitat are nevertheless likely and compensation is expected to be required. The amount of compensation will depend on the findings of monitoring studies completed during and immediately following completion of the crossings. Monitoring will include continuous measurement and recording of downstream water quality (NTU and TSS), and visual assessments of habitat when construction activities are complete. Additional monitoring may also be necessary, including fish and fish habitat surveys within the zone of influence prior to construction. Construction activities will be modified as needed, based on input from the environmental monitor. Monitoring is expected to identify the amount of compensation required, by quantifying the impact from construction activities.

Post-construction Monitoring.— A five year monitoring program will be implemented to identify locations where fish habitat maintenance and improvement objectives have not been met. In such cases additional measures will be implemented on site to achieve the objectives. Monitoring activities and reporting requirements will be provided in the KSL Restoration Plan, which will be developed and submitted post-certification. Post-construction monitoring will examine ROW approaches and riparian areas to ensure that exposed soils do not cause significant inputs of sediment to fish-bearing watercourses.

3.3.5 Habitat Calculations for Off-Site Compensation

As noted earlier, two scenarios may require off-site compensation: crossings completed with isolation techniques outside the proposed instream work windows, and crossings completed with open cut techniques, should HDD or other techniques prove infeasible. These scenarios are elaborated on below and the logic is presented for calculating the amount of compensation required in each case. The final determination of compensation will depend in part on monitoring during construction and assessments made immediately following the crossing completion. Preliminary calculations are provided here to help gauge the commitments required by KSL.

The amount of habitat to be provided as compensation for the KSL Project will consider four primary factors:

1. the type and area of habitat disturbed,
2. the duration of the disturbance,
3. the type and expected longevity of the compensation habitat, and
4. DFO compensation ratios.

Type and area of habitat disturbed.— Fish habitat surveys conducted for the KSL Project (AAR 2007) indicate that a variety of habitats occur near the proposed crossings of fish-bearing streams. Rearing, overwintering and spawning habitat in streams is related to flow, which determines depth and velocity conditions across the channel. The amount of habitat available for fish can be quantified using habitat suitability indices (HSI), which weight an area of wetted stream by HSI scores. HSI scores vary from 0 to 1, such that a weighted area is less than or equal to the full wetted area. For example, 1 m^2 of high quality habitat is measured as 1 m^2; 1 m^2 of medium quality habitat is measured as, say 0.5 m^2; together these two would be tallied as 1.5 m^2. In essence, the measure calculates an amount of high quality habitat available at the site.

In small to medium-sized streams suitable habitat is typically distributed across the full width or much of the width of a stream. On larger rivers, rearing and overwintering habitat for most species of management interest is typically associated with pools, stream margins or instream structures such as boulders and large woody debris. The weighted useable rearing and overwintering habitat is therefore usually considerably less than the full width of the river. The actual amount that is useable for a given species and life stage depends on the depth and velocity distributions across the channel, the type of substrate and the distribution of cover, and the HSI scores for that species and life stage. As part of the Water Use Planning process, MOE and DFO signed off on HSI curves for several salmonid species and life stages in BC. HSI scores are available for depth, velocity, substrate and cover for those species. An example is provided in Figure 2.

To calculate the area of habitat disturbed by pipeline construction activities, PTP will measure depth and velocity transects across affected streams. Three transects will be measured during the summer rearing period on all fish-bearing streams requiring compensation (i.e., where work occurs outside work windows, or open cut methods are used). We propose to use HSI curves for steelhead juveniles (parr) as the target species and life stage. Since they have broad habitat preferences, the HSI curves can be considered conservative for all salmonid species.

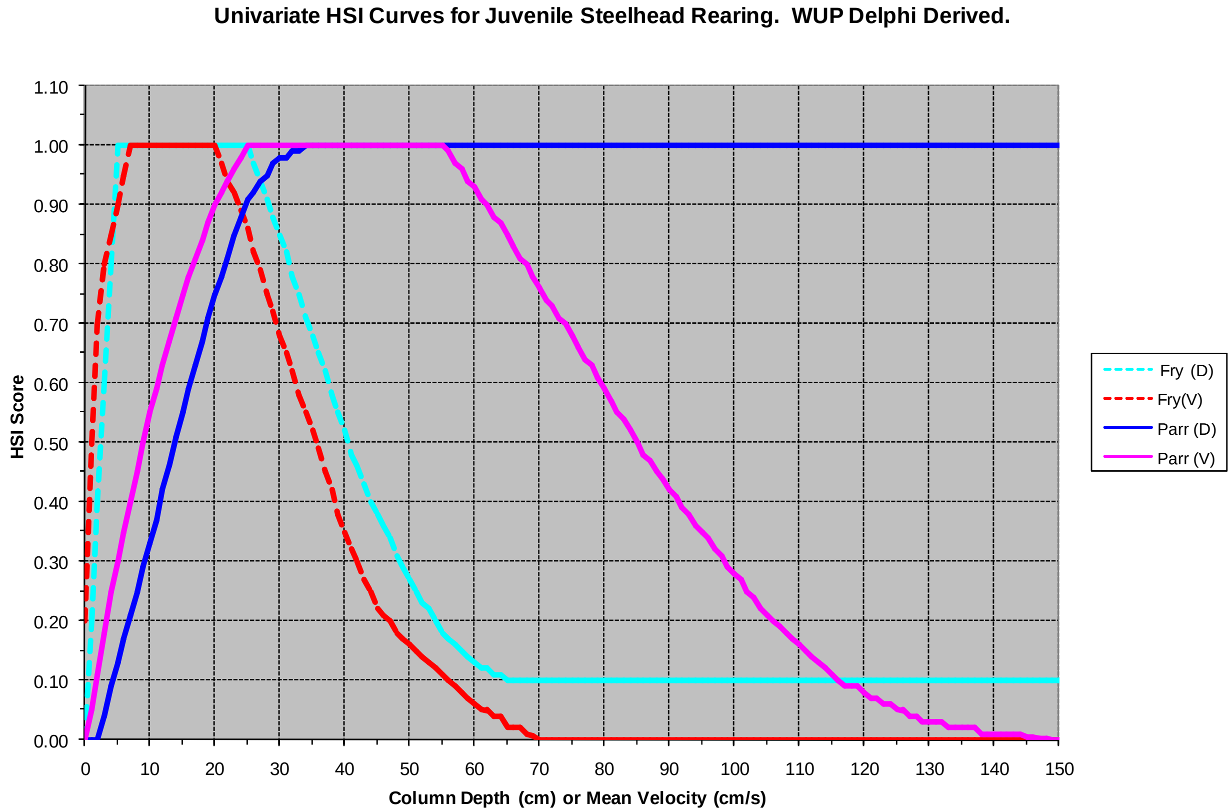

Figure 2. Example of British Columbia HSI scores for steelhead fry and parr.

To measure the downstream extent of habitat disturbed by pipeline construction activities, PTP will measure total suspended solids at selected points downstream of the crossing. Measurements at these points will be used to calculate fish and fish habitat severity indices using the dose-response model of Newcombe and Jensen (1996). By measuring suspended sediments at two or more distances downstream of the crossing activities it will be possible to interpolate and extrapolate the extent of sediment impacts.

As a preliminary measure (i.e., until transects are measured, weighted habitat areas are calculated, and monitoring of suspended sediments is completed), PTP proposes to use a conservative estimate of half the mean wetted channel width to quantify the useable rearing and overwinter habitat. The downstream extent of disturbance will be determined by monitoring of suspended sediments, and deposition within the channel. In general, finer fractions of suspended materials will remain is suspension without deposition. Coarser silts and sand will travel relatively short distances downstream within the water column before depositing locally in quiescent pools and backwater areas where velocities are low. During low flows, the distances these coarser fractions travel will typically be limited to one to three habitat units downstream, based on the successive trapping of pool-riffle units and limited transport capacity. Using bankfull widths (W_{bf}) in small streams, a habitat unit approximates $6 \times W_{bf}$ and therefore the extent of potential impacts can be predicted. In larger streams and rivers, or steeper streams where turbulent flows predominate, these estimates should be used as an initial estimate confirmed with visual assessment and monitoring.

Pre- and post-construction assessments will be conducted, and water quality monitoring will be conducted throughout construction to assess risks to downstream habitats. Prior to construction, fish will be salvaged and released to appropriate habitat beyond the work area.

Duration of the disturbance.— The duration of disturbance from crossing activities is expected to be temporary, lasting a maximum of one year from the time of instream construction. Freshet flows are expected to redistribute the streambed and flush fines from the substrate. The disturbance is therefore relatively short-lived.

Type and expected longevity of the compensation habitat.— Compensation habitats are typically engineered to be long-lasting, so the benefits from the compensation habitats accrue over a period that is considerably longer than the duration of physical disturbance from the pipeline construction. Longevity of the habitat compensation therefore allows the total area required to be reduced by some factor. For the purposes of calculating compensation commitments, PTP will use a factor of 20% of the total habitat disturbed.

DFO compensation ratios.— DFO typically seeks a compensation ratio of 2:1 for instream habitats, to adjust for uncertainty in the assessment of habitat impacts and the efficacy of compensation works. This ratio is adopted for KSL fish habitat compensation.

Habitat Calculation Summary.— In summary, total habitat compensation requirements for isolated pipeline crossings of small streams when completed outside the work windows will be determined with the following calculation: weighted useable width × 2:1 DFO compensation ratio × 0.20 duration factor × extent of downstream impact. The actual habitat calculations will be possible only when it is determined whether and which streams are crossed outside the work windows, and will be based on monitoring of downstream sediment impacts.

Table 1. Preliminary habitat compensation calculations for the KSL Project. Note that these amounts are based on measurements provided in AAR (2007) and will be updated based on measurements at the time of construction. Habitat amounts may be added to based on monitoring during construction and post-construction assessments. Note: disturbance for open cut of Little Wedeene and Wedeene will be based on post-construction assessments. An arbitrary value of 100 m is used here to demonstrate the calculation formula. Final figures may be greater or less than this amount.

Watercourse	Mean Wetted Width (m)	Disturbance[1] (m)	Rearing Habitat Factor	DFO Compensation Ratio	Duration Factor	Total Area (m^2)
winter flow isolation						
Salmon 1	33.3	20	0.5	2:1	0.2	133.2
Salmon 2	36.3	20	0.5	2:1	0.2	145.2
Salmon 3	30.5	20	0.5	2:1	0.2	122
						400.4
open cut contingency						
Little Wedeene	29	100	1	2:1	0.2	1160
Wedeene	33	100	1	2:1	0.2	1320
						2480

4 ADDITIONAL OFF-SITE COMPENSATION AND HABITAT BANKING

Portions of the compensation proposed for the KSL project are contingent on timing and method of construction. On-site compensation (i.e., measures to improve habitat within the project footprint area) will be provided for all crossings and consist of restoration of instream and riparian habitats, stabilization of streambed and banks, restoration of the natural drainage and channel configurations, addition of fish cover elements using boulder and large woody debris placement. Off-site compensation (i.e., measures to improve habitat outside the project footprint area) will occur where residual impacts are expected. Off-site compensation will be provided where work occurs outside the instream work windows, and at crossings completed using open cut methods.

Regulators and First Nations have expressed a strong desire for fish habitat compensation to offset cumulative or diffuse impacts associated with the KSL Project. In addition to compensation for well-defined local impacts, such as those associated with open cut crossing techniques, PTP has committed to providing substantial "baseline" off-site compensation and to distribute this effort among the major watersheds along the route. PTP has also committed to pre-building or "banking" some portions of fish habitat compensation prior to completion of the project. By undertaking compensation prior to completing pipeline construction PTP will in effect offset temporal losses of fish production, and demonstrate good faith in meeting fish habitat protection objectives. The final determination of compensation needs will depend to a large extent on results from monitoring during project construction, but it is understood that "banked" compensation will be applied against the total required for the KSL project. The following sections provide conceptual plans for components of compensation that will be built in advance of project completion. Detailed design of compensation will be undertaken through the permitting and authorization stage of the project approval process.

5 HABITAT COMPENSATION PROJECTS

5.1 Identification of Compensation Options

After certification of the KSL project, PTP will meet with DFO, MOE, and First Nations to identify compensation options and priorities within each of the major watersheds. Site visits will be organized as necessary to help develop detailed plans for the location of compensation efforts, and the types of compensation that are appropriate.

5.1.1 Off-channel Rearing Habitat

Fish production in many of the larger rivers within the KSL project area is believed to be limited primarily by accessible rearing and overwintering habitats with sufficient depth and cover. Spawning habitat in these systems is often abundant and not limiting. PTP will construct a minimum of six off-channel rearing habitat projects along the route. These projects will be distributed within the Kitimat, Morice/Gosnell, Salmon, and possibly other watersheds. Each project will create 1,000 – 2,500 m^2 of high-quality rearing and overwintering habitat, for a minimum total of 6,000 – 15,000 m^2 of compensatory habitat. The location of these habitat complexes and distribution among watersheds will be determined in conjunction with DFO, MOE and First Nations. Design of the compensatory works will be undertaken post-certification. At a current cost estimate of $75-$100 per m^2, this represents a minimum commitment by PTP of $450,000 to $1.5 M for this form of habitat compensation. Some of the planning details for developing this form of habitat compensatory works is discussed in Sections 5.3 and 5.4.

5.1.2 *Spawning Habitat*

Fish production is believed to be limited by rearing and overwintering habitats in many of the larger rivers, but several systems in the KSL project area may benefit from additional spawning habitat. Typically these habitats would be of benefit on small to moderate sized systems that may be gravel poor. PTP proposes to initiate a program to identify systems that would benefit from construction of additional spawning habitat. Construction techniques to establish such habitat may vary from establishment of small check dams to allow recruitment of spawning gravels, to techniques in which spawning gravels are added to engineered spawning platforms. Essentially, the techniques are the same as those used to construct riffle habitats. DFO Area staff have identified the utility of such projects within the Kitimat watershed, but the location and number of possible sites requires additional study. Further work is also required to identify whether such compensatory works would be of benefit in other watersheds. PTP commits to identifying such sites through discussions and site visits with DFO, MOE and First Nations. The amount of habitat provided by such compensatory works tends to be on the order of 25 to 50 m^2 per project, with costs starting at about $100 per m^2. With the understanding that spawning habitat is generally not limiting on most systems, PTP commits to building 250 m^2 of spawning habitat in the KSL project area at a projected minimum cost of $50,000 including engineering and study support.

5.1.3 *Culvert Removal and Replacement*

A program of culvert replacement will be initiated within the KSL study area, which has been developed extensively by the forestry sector, and to a lesser extent by other industries, Ministry of Transportation and Highways, and agriculture. Numerous culverts exist on creeks supporting populations of resident and anadromous fish species. Improper culvert placement during previous road construction, beaver colonization, and changes in stream morphology have led to inadequate fish passage conditions over time at some locations. In some areas these stream systems have lost their historical complement of fishes (and probably other fauna).

PTP will complete an inventory of fish passage conditions at existing culverts within the project study area. Potential habitat gains will be calculated at each culvert for which poor fish passage conditions are found to exist. This inventory will permit identification of those crossings most readily replaced and those whose removal would provide the greatest net benefit for fish habitat. PTP is prepared to commit $150,000 to this effort including study support.

5.1.4 *Riparian Planting and Restoration*

Broad areas of the KSL project area have been affected by forest harvest, much of which was conducted prior to restrictions on harvest in riparian areas. As result, many riparian areas have been impacted and recovery is ongoing. PTP proposes to initiate a program to identify areas that would benefit from riparian restoration. Restoration techniques employed in these areas would include planting of conifers and bank and soil stabilization, with the objective of increasing the speed of recovery. PTP expects that there is considerable opportunity to pursue this form of compensation and to help recover considerable areas of riparian habitat that has been affected by other industrial activities. PTP is willing to commit $100,000 to this effort including study support.

5.1.5 Beaver Habitat Modifications

Extensive forest harvest throughout the project area has facilitated colonization of many smaller tributaries by beaver. Typically, colonization has been facilitated by presence of culverts (which beavers can block to help establish ponded areas) and the widespread presence of deciduous trees (which beavers use as food and as debris for dams and lodges). Beaver control is often difficult and at times controversial, but can improve fish production by improving access for migrating and rearing fish. PTP proposes to undertake an inventory of fish passage and rearing conditions in relation to beaver presence and activities within the project study area. Potential habitat gains may be possible through replacement of existing culverts with larger crossing structures, to improve poor fish passage conditions. This inventory will permit identification of those areas where modifications of certain terrain or habitat features may be used strategically to obtain net benefit for fish habitat. PTP will commit a minimum of $50,000 to this effort including study support.

5.2 Baseline Compensation Summary

Table 2 provides a summary of proposed fish habitat compensation for the KSL Project.

5.3 Proposed Development Approach to Physical Habitat Construction

5.3.1 Siting

Generally, physical habitat compensation areas are sited based on river geomorphology, flooding and floodplain issues, and site access. Ideal sites are those within the contemporary floodplain subject to rare flooding and outside of the active river meander belt. Airphoto, LiDAR and surveys can be used at a desktop level to identify potential sites, followed by field inspections to confirm site suitability. Poor water quality – low dissolved oxygen or high water temperatures – can limit fish utilization, therefore good water supplies are often crucial. Ideal sites are fed by groundwater, access small side valley tributaries or utilize small surface water intakes to provide inflows.

With respect to the compensation requirements for the KSL project, we would identify candidate sites using site and airphotos and knowledge of the project watercourses. Based on our current knowledge, it is likely that viable compensation sites can be located at or near the crossing locations to develop 1000 – 2000 m^2 of rearing habitat. Appendix A has samples of the airphotos data available at the existing major crossings. Conceptual designs are developed prior to site surveys and detailed design for regulatory review and approvals. Detailed design of the channel and habitat complexing will be undertaken post-certification, when final costing and engineering design will be completed.

Table 2. Summary of baseline and other compensation needs for KSL Project. Baseline compensation will be distributed among the major watersheds in the project area and represents a minimum commitment for fish habitat compensation efforts. Additional compensation will be provided, as determined by crossing method selection at specific crossings, timing of construction works, and results from construction monitoring and post-construction assessments.

KP	System	Reason for Compensation	Proposed Compensation	Habitat Banking Commitment	Cost of Baseline Compensation
0 to 78.7	Kitimat River system	potential work outside window, direct effects from trenching, possible downstream effects	construct off-channel rearing habitat in Kitimat floodplain, increase access on Cecil Ck	1. 2,000 to 5,000 m2 of off-channel rearing habitat 2. spawning riffle construction 3. riparian restoration 4. culvert replacement 5. beaver habitat modifications	$270,000 to $620,000
12.9	Little Wedeene River	open cut if HDD not possible, direct effects from trenching, possible effects to downstream habitats	construct off-channel rearing habitat in floodplain of Little Wedeene River, if open cut technique is used. Amount of compensation will be based on construction monitoring results.	see Kitimat River system	
17	Wedeene River	open cut if HDD not possible, direct effects from trenching, possible effects to downstream habitats	construct off-channel rearing habitat in floodplain of Wedeene River, if open cut technique is used. Amount of compensation will be based on construction monitoring results.	see Kitimat River system	
38.8	Chist Creek	direct effects from trenching, possible effects to downstream habitats	construct off-channel rearing habitat in Kitimat River floodplain	see Kitimat River system	
104.6 to 173.7	Morice River system	potential work outside window, direct effects from trenching, possible downstream effects	construct off-channel rearing habitat in Morice or Gosnell floodplain	1. 2,000 to 5,000 m2 of off-channel rearing habitat 2. spawning riffle construction 3. riparian restoration 4. culvert replacement 5. beaver habitat modifications	$270,000 to $620,000
430.3 441.2 449.2	Salmon River	winter construction (outside the window) on three crossings, likely effects to rearing and overwintering habitats	construct off-channel rearing and overwintering habitat in Salmon River floodplain	1. 2,000 to 5,000 m2 of off-channel rearing habitat 2. spawning riffle construction 3. riparian restoration 4. culvert replacement 5. beaver habitat modifications	$270,000 to $620,000
					total = $800,000 to $1,850,000

5.3.2 *Bioengineering Design*

Off channel habitat design criteria include a minimum residual low water pool depth of 1.5 m, sufficient inflow or groundwater to maintain suitable water quality to support salmonids, and sufficient complexing with large wood to provide cover and overwintering habitat. Limited juvenile access as a result of reduced flood flows, low freshet flows or channel changes can result in lower recruitment to these refugia and overwintering habitats. An assured water supply ensures flows from the off channel area to mainstem.

As these compensatory habitat works are planned for main floodplain areas, floodproofing and erosion protection may be required on some aspects of the design. Typically, these areas inundate with major floods greater than a 1-in-10 to 1-in-25 year flood. Inundation may result in sediment deposition within the side or off channel area, but these minor events can be designed for by adding additional storage within the channel. Channel avulsion or lateral migration resulting in erosion and loss of the channel is typically a greater risk. Berming and limited dyking can provide some flood protection, but extensive bank protection to protect these compensatory channels are typically not considered.

5.3.3 *Quantities and Costing*

To minimize costs, relic dry or intermittent floodplain channels can be used to limit excavation requirements. Often small groundwater monitoring stations or flow monitoring is conducted prior to design in order to determine potential water depths over the site or excavation depths required to access groundwater. Sites close to existing access roads or FSRs, and areas that allow side casting of excavation materials without negatively impacting floodplain hydraulics are ideal.

These sites are typically constructed during the work window, with materials sourced at the site or locally. Complexing wood and rock boulders can be developed or salvaged on the site from existing sources or brought in and installed as required. Quantities and unit costs along with estimates for monitoring and engineering supervision, and contingencies (e.g., dewatering, erosion and sediment control, intakes) can be used to develop notional budgets. Costs can vary considerably, but a value of \$75-\$100 per m^2 is suggested for initial costing purposes, based on recent contractor pricing on similar works under similar conditions.

5.3.4 *Physical and Biological Monitoring*

Compensation habitats will be engineered to remain stable and functional over the long-term. All fish habitat features will be monitored over a period of five years to confirm that they are effective and continue to functional properly.

5.4 Overview of Potential Sites

Due to the low gradient, meandering morphology of most of the river systems, initial air photo overview analysis indicates there are several opportunities at each location to develop compensatory habitat works to offset potential residual impacts associated with the pipeline construction. Air photos of the main project areas that are proposed for compensation works are provided in Appendix A.

5.4.1 Salmon River

The proposed crossing at KP449.2 crosses the Salmon River within a meandering reach and has two potential sites within a 1 km radius. Road access is close to the upstream site, but further airphoto interpretation and analysis is required. An off-channel section near KP 456 is a potential site, and is currently wetted only at high water.

5.4.2 Morice River / Gosnell Creek

A large portion of floodplain is adjacent to the pipeline from KP 144 to 147, and has sufficient area to develop a significant off channel complex through a combination of rewatering side channels and excavation. Potential exists for intake for both river and groundwater flows.

5.4.3 Kitimat River

Airphoto review identified large wetland areas upstream of the Cecil Creek confluence as well as potential Cecil Creek off channel opportunities.

5.4.4 Wedeene

Initial airphoto review identified several potential compensation sites with good road access within a 3 km radius of the proposed pipeline crossing.

5.4.5 Little Wedeene

Air photo review indicates the pipeline route may cross relic flood channel on the left bank. Opportunity exists to enhance or extend the channel upstream and connect to mainstem river via intake. Other opportunities exist in close proximity to the proposed crossing location.

5.4.6 Chist

Potential opportunities for side channel works exist along the pipeline ROW and access road immediately downstream of the proposed crossing on the left bank of Chist Creek. Further reconnaissance is warranted.

5.5 Timelines

PTP has committed to building some portions of fish habitat compensation prior to completion of the project. By undertaking compensation prior to completing pipeline construction PTP will in effect offset temporal losses of fish production, and demonstrate good faith in meeting fish habitat protection objectives.

Many of the compensation requirements are contingent on which crossing methods are used, on which watercourses, and when the crossings are completed relative to fish life histories in that system. A full tally of compensation requirements will therefore only be possible when it is known which methods will be used to cross each stream (e.g., on which streams HDD is infeasible and where construction delays cause work outside windows), and the measurement impacts that occur "on the ground."

PTP commits to completing all compensation activities within two years following final cleanup. This timeline will allow habitat assessments to be completed, which will in turn finalize the determination of compensation requirements for the KSL Project. Compensation habitats will be monitored for integrity and effectiveness for a period of five years after compensation is implemented.

6 REFERENCES

Aitken, D. 1993. Salmon River Biophysical Assessment - Preliminary Results. 63 pp. Report for: BC Ministry of Environment.

Applied Aquatic Research. 2007. Fish and Fish Habitat Investigations for the Proposed Kitimat – Summit Lake Natural Gas Pipeline Looping Project. Prepare for Pacific Trail Pipelines LP

Newcombe, C. P., and J. O. T. Jensen. 1996. Channel suspended sediment and fisheries: a synthesis for quantitative assessment of risk and impact. North American Journal of Fisheries Management 16:693-727.

Appendix A

Air Photos of KSL Project Areas

Appendix B

Site habitat restoration guide, example typical drawings and applications

1 SCOPE

The site restoration application guide and tool box was developed to assist in the proper identification and application of site-specific restoration measures at pipeline crossing sites on S3 toS4 fish bearing streams, and non-fish bearing S5 and S6 streams that support fish habitat. As identified earlier, the temporary impacts associated with excavation of the stream channel, burial of the pipeline and restoration of the channel would be fully mitigated through:

- control of suspended sediment release during construction through isolation of the work area,
- utilization of proper materials and construction techniques to reconstruct the stream channel and banks, and
- enhancement and restoration of stream bank cover, bank and channel structure and fish habitat, through utilization of restoration measures during reconstruction.

This section deals specifically with the issue of the application and implementation of appropriate measures to fully mitigate aquatic fish habitats impacted or lost during construction such that no residual losses – or HADD – remain. The rationale and design of compensatory habitats for residual losses related to the project are dealt with in Appendix C.

For these streams, restoration of instream and riparian habitats will be field designed using an application guide, restoration "typicals" and on-site direction by a restoration specialist, who will be a qualified registered professional with experience in aquatic habitat and stream restoration.

1.1 Goals and Limitations

The process and measures identified in this section address replacement or restoration of the function and value of both aquatic and riparian habitats lost within the right-of-way during construction. Bank stability and instream cover provided by large wood – either along the bank or within the channel – are primary riparian values that are impacted. Stream substrates and channel structure – or morphology – are in-channel values impacted during construction of the crossing.

While full mitigation of the fish habitat impacts are expected with implementation of these measures, they secondarily provide important channel stability, and erosion, scour and flood hazards protection to the pipeline. Typically, engineering design of the crossing location, burial depth and/or rock protection provide fundamental pipeline protection. Additional bank protection, grade control and channel works are occasionally used. The restoration measures utilized are intended to support increased bank and channel stability compatible with the overall design philosophy.

These site crossing fish habitat mitigation measures do not replace complex habitats that are formed through channel change, morphology or disturbance processes. They are designed to be compatible with these processes so that in the long-term, channel processes are unaffected at the pipeline crossings and the potential for undue change and instability is avoided. Correspondingly, site specific treatments will not correct reach-scale issues affected by flood history, sediment supply or other morphological factors that have led to channel instability and excess sediment, and potentially fish habitat conditions.

These measures cannot replace sound biological and engineering judgement, experience and training, and considerable deviation in size and application of the measures is expected over the wide range of stream crossings and settings along the KSL route. Field-fitting and innovation are expected to be used by the restoration specialist overseeing the work. Further refinement of the application guide is possible following the hydrotechnical investigations and pipeline crossing design process.

2 Site Assessment and Data Collection

Overview information can be collected from TRIM and airphoto information of the crossings – especially on the larger S1 and S2 systems with large floodplains like the Wedeene and the Kitimat Rivers. Smaller S3 and S4 systems that have extensive forest cover or are relatively small and stable are difficult to assess using desktop methods. As such, basic field site habitat and channel surveys have been undertaken prior to the construction of the pipeline crossing and installation of the pipeline through the stream segment.

These data would likely include measures of grade and channel properties, channel substrate and bank materials, riparian and aquatic habitat inventories. Important stream segment or reach-level characteristics should be assessed prior to the crossing construction, including the channel classification, bank and channel stability. Photo-inventory, geo-referencing and field surveying of the channel and classification of habitats are also important in developing the assessment of mitigation requirements at the site.

3 Design Process and Rationale

This section presents an abbreviated design process that highlights the key steps and issues involved with the crossing mitigation design using the “toolbox” approach. Key documents have been highlighted in the References that provide examples of an approach that is similar to that used for the KSL project.

In an effort to simplify and work with the crossing construction techniques and equipment, the habitat mitigation measures utilize essentially all natural materials available at or near the sites. No cabling or excess ballast rock is proposed for wood placements, and utilization of in-bank placement and embedding with rock or as pinned jams is the suggested approach. Methods and typicals were selected that support the overall goal of stabilizing stream banks and channel sections, mitigating impacted habitats and ensuring normal channel processes.

3.1 Application Matrix

To assist in the design of fully-mitigated stream crossings at each site, an application matrix has been developed that suggests appropriate habitat mitigation measures and typicals relative to channel attributes and required values. This matrix approach is suggested as a guide to associating suitable and robust options. The matrix is presented in Table 1, following the text. Typicals can be combined to provide multiple attributes or reinforce characteristics lacking with a single typical method alone.

4 HABITAT MITIGATION TYPICALS

The habitat mitigation typicals represent a range of structural measures that can be implemented at the crossing site. These typicals are broken into several classes related to bank, instream and riparian habitats. Additional mitigation typicals are being prepared from a collection of over 100 typicals on file, and examples have been included with the document.

4.1 Stream Bank Habitats

Stream bank typicals are intended to stabilize constructed banks, providing channel definition, edge habitat and cover for fish, and stabilize riparian floodplains allowing revegetation.

4.1.1 Multi-piece Wood Structures (MWS)

These consist of 3 to 5 pieces of stem, bole and rootwad, with key pieces embedded into granular fill within the stream bank and /or massed with boulders to provide addition stability. Placed adjacent or up to 3 projection widths apart, these structures protect banks from direct attack and provide instream cover and holding habitat. Designs can be stacked, braced, tripod-style or pinned depending on bank height and materials.

Example: *LWD and Rock Spur Bank Protection*
Whole Tree Bank Protection

4.1.2 *LWD Crib Wall (LCW)*

Log crib walls form a wood-based wall feature that prevents direct attack on the bank – especially suitable for low banks, composed of fine sediment. Cribbing can be loosely placed providing cover habitat and integration with single pieces of complexing wood. Embedment of log ends or use of rock ballast is required, especially if rootwads are not attached to the boles. Log crib walls can be stacked to protect relatively high stream banks.

Example: *Embedded LWD Bank Protection*
Rootwad Bank Complexing and Stabilization

4.1.3 *Rootwad Bank (RWB)*

Boles with rootwads are placed with the rootwads projecting into the channel, and the stems embedded into the stream bank. The rootwads form a bank edge – effective for low height banks and stems can be ballasted with rock or granular materials forming the reconstructed bank.

Example: *Rootwad Bank Complexing and Protection*
Embedded LWD Bank Protection

4.1.4 *Natural Rock Bank (NRB)*

Rounded to semi-angular native boulder and cobble – oversized relative to the dominant streambed material – is placed in a thick wedge along the toe of bank forming an erosion-resistant bank. The rock can be keyed into the channel and extend to either the top of bank or elevation to which a new natural boundary will develop.

Example: *Natural Rock Bank Protection*
Bioengineered Bank Protection

4.1.5 *Riprap Bank (RRB)*

Produced, angular blast rock is used in lieu of rounded natural boulder and stones which has higher interlocking strength and resistance to erosion, but is not natural and may not be available at the site. Hydraulic design and sizing can be completed using a number of design guides, typical drawings have not been included.

4.1.6 *Bioengineered Bank (BEB)*

This bank reconstruction technique utilizes a biodegradable erosion control matting (coir) and fill, in conjunction with active revegetation (e.g. staking, wattling or brush mat placement).

Often constructed in layers, bank heights may be limiting, but it can be used as a top-of-bank treatment in conjunction with rock placement (NRB, RRB) at the toe of bank. This may be useful in situations where certain materials are limited or multiple attributes are required. For example, rounded boulder and multiple wood structures may be used at the toe of bank to stabilize and provide cover habitat at low flows, while a vegetated bioengineered high bank stabilized fine bank sediments, providing shade and food sources.

Example: *Bioengineered Bank Protection and Stabilization*
Bioengineered Bank Protection
Embedded LWD Bank Protection

4.1.7 Rock Spurs or Groynes (RSG)

Using natural rock or produced riprap, spurs or groynes constructed from the base of the bank projecting perpendicular into the flow are used to deflect high velocities away from the bank. Typically installed at a relatively low height and spaced 3-5 times the projection distance into the channel, these features can be integrated with wood elements to form complexed, stable banks.

Example: *LWD Structures and Rock Spur Bank Protection*
Rock Spur and LWD Channel Restoration

4.2 Instream Habitat

Instream habitat structures provide elements that – in combination with flow – provide instream aquatic habitat for fish, stabilize channels or provide complexity, cover and rearing habitats.

4.2.1 LWD Wood Structure (LWD)

Individual boles and rootwads, embedded in the channel and bank that stabilize the channel grade and banks. Suitable for small channels where a large log can easily span the channel and be embedded in both stream banks. Elements can be oriented at an angle to the stream flow and used in groups or 1 -3 boles – preferably with root wads attached.

Example: *Rootwad Bank Complexing and Protection*
Embedded LWD Bank Protection
Bioengineered Bank Protection

4.2.2 *Boulder Rock Placements (BRP)*

These consist of 1 to 6 large rocks that are sized such that when embedded approximately one half their diameter into the stream bed, they project into the flow creating turbulence and/or aerated flow. These placements can provide cover and rearing habitat for larger fish, and hydraulic control through sections of stream channel. Sizing relative to stream grade, bed materials size and sediment transport is critical, and analogs within nearby sections of stream should be reviewed.

Example: *Boulder and Rock Channel Complexing*

4.2.3 *Full Riffle Structures (RS)*

Large boulder or angular rock is placed across the stream channel width extending downstream a minimum of a channel width and with overall thickness of at least the largest rock diameter. The rocks are arranged to concentrate low flows in the center and can be integrated into bank habitat elements. They control stream grades and provide channel structure and opportunities for pool development. Notional riffle rock sizing can be based on LOR[1] or hydraulic design guides.

Example: *Rock Riffle Channel Stabilization*

4.2.4 *Engineered Log Jams (ELJ)*

Engineered log jams or ELJs are structured placements of many boles, boles with rootwads and wood pieces to replicate natural log jams. Typically used to provide channel and bank stabilization at a reach level, ELJs utilize embedded key members, piles and ballast rock to ensure stability during flood flows.

Example: *Engineered Log Jan (ELJ) Channel Complexing and Bank Protection*

4.3 Riparian Floodplain Habitat

4.3.1 *Wood Debris Placement (WDP)*

In this element, large wood debris, broken logs, smaller diameter boles and deciduous tree species are placed on the floodplain. This provides habitat for wildlife, sources of carbon and nutrients for revegetation, and overbank roughness at high flows that can potentially prevent erosion and channel destabilization. Materials can be scattered and placed by hydraulic excavator in a manner similar to that used in road deactivation.

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[1] Largest Observed Rock

4.3.2 Reseeding and Replanting (RAR)

Native seed stock and fertilizer is applied to bare soils to promote revegetation, soil moisture retention and erosion protection for replanted riparian tree and shrub species.

5 FIELD LAY-OUT AND CONSTRUCTION

Using the procedures outlined above, sketches and a field lay-out of the proposed elements and their location, size relative to the stream channel would be undertaken. As stated earlier in the document, detailed preconstruction habitat and channel surveys will be undertaken within and 500 m above and below the site.

These data will provide the amount and types of habitat lost during construction and required mitigation to be reconstructed to ensure no residual losses occur. Field sketches, georeferenced photography and monitoring reports will form the basis of as-built reporting for the mitigation work.

On smaller, low gradient systems with lower stream energy, there is inherently less risk to both the pipeline crossing and the habitat mitigation works. The direction and experience of the restoration specialist is key to successful implementation of the mitigation strategy for these crossings, and where required, additional qualified specialists should be available to provide assistance where required or to develop designs for difficult sections or high-energy stream sections.

6 REFERENCES

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Schiectl. 1980. Bioengineering for Land Reclamation and Conservation. University of Alberta Press, Edmonton, Alberta.

Slaney, P.A. and D. Zaldokas [eds.]. 1997. Fish Habitat Rehabilitation Procedures. British Columbia Ministry of Environment, Lands and Parks, and British Columbia Ministry of Forests, Watershed Restoration Program, Technical Circular No. 9.

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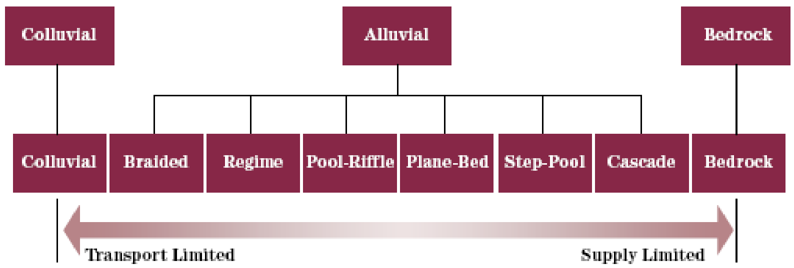
Table 1 Stream Habitat Mitigation Application Matrix

		Stream Bank Habitats							Instream Habitat				Flood plain	
	Relative Condition and Attribute Assessment: **G – Good, ideal** **F- Fair, effective** **P – Poor, ineffective** **'-' – not applicable**	Multi-piece Wood Structure (MWS)	LWD Crib Wall (LCW)	Rootwad Bank (RWB)	Natural Rock Bank (NRB)	Riprap Bank (RRB)	Bioengineered Bank (BEB)	Rock Spurs / Groynes (RSG)	Single Wood Structure (SWS)	Boulder Rock Placement (BRP)	Full Riffle Structure (FRS)	Engineered Log Jam (ELJ)	Wood Debris Placement (WDP)	Reseed and Replant) (RAR)
Channel Condition	Reach Aggrading	F	F	F	G	G	F	G	G/F	F/P	G/F	G	-	-
	Reach Degrading	G	P	F	F	F	F	F	F	G	G/F	F	-	-
	Unstable Laterally	G	P	P	F	F	F	G	F/P	P	P	F	P	P
	Over-widened	G	F	F	G	G	G	G	F	P	P	G	G/F	G/F
	Incised	G	P	P	F	F	F	F	-	-	-	-	G	G
Channel Characteristics	Low Bank	F	G	G	G	G	G	G/F	G	F	G	G	-	-
	High Bank	G	F	F	F	G	F	G/F	G	G	G	G	-	-
	High Gradient (5-20%)	F	P	P	P	G	F	F	F	G	F	-	F/P	-
	Low Gradient (< 5%)	G	G/F	G	G	G	G	G	G	F	G	G	G	-
	Small Streams (< 3 m)	P	F	G	G	P	G	P	G	F	G	-	-	-
	Large Streams (> 3 m)	G	G	F	F	G	F	G	F/P	G	G	G	-	-
Fish Habitat Attributes	Cover	G	F	G	G	F	G	F	P	G	P	G	-	-
	High-water Refugia	G	F	P	F	F	G	F	P	P	P	G	-	-
	Juvenile Rearing	G	F	F	P	P	G	F	P	F	F	G	-	-
	Holding	G	P	P	P	P	F	G	F	F	F	G	-	-
	Spawning	P	P	P	P	P	P	F	F	P	G	F	-	-
	Overwintering	G	F	F	G	G	G	F	P	P	G	G	-	-
Stream Channel Attributes	Stabilize Bank	F	F	F	G	G	G	F	F	P	P	F	G	G
	Increase Lateral Stability	F	G	G	G	G	G	G	F	P	F	F	F	G
	Increase Vertical Stability	F	P	P	P	P	P	F	G	F	G	F	-	-
	Maintain Channel Capacity	F	G	G	F	G	F	G	F	F	G	F	-	F
	Promote Bedload Retention	P	P	P	P	P	P	F	G	F	G	F	-	-
	Stabilize Floodplain	G	P	P	G	F	G	G	P	P	F	G	G	G
	Retain Wood Debris	G	F	F	P	P	F	F	F	P	P	G	F	-

Figure 1 Stream Channel Classification

The Montgomery and Buffington (1993a) system classifies channel reach morphology based on field observations made in Washington, Oregon, and Alaska. The significance and acknowledgement of the role of large woody debris (LWD) in the forested channel systems makes this classification system applicable. The classification system is a geomorphic process-based system that does an excellent job of identifying the morphologic differences in the streams, and aids in identifying source, transport and response (erosional, transport, and depositional) reaches.



	Braided	Regime	Pool-Riffle	Plane-Bed	Step-Pool	Cascade	Bedrock	Colluvial
Typical Bed Material	Variable	Sand	Gravel	Gravel, cobble	Cobble, boulder	Boulder	N/A	Variable
Bedform Pattern	Laterally oscillary	Multi-layered	Laterally oscillary	None	Vertically oscillary	None	•	Variable
Reach Type	Response	Response	Response	Response	Transport	Transport	Transport	Source
Dominant Roughness Elements	Bedforms (bars, pools)	Sinuosity, bedforms (dunes, ripples, bars) banks	Bedforms (bars, pools), grains, LWD, sinuosity, banks	Grains, banks	Bedforms (steps, pools), grains, LWD, banks	Grains, banks	Boundaries (bed & banks)	Grains, LWD
Dominant Sediment Sources	Fluvial, bank failure, debris flow	Fluvial, bank failure, inactive channel	Fluvial, bank failure, inactive channel, debris flows	Fluvial, bank failure, debris flow	Fluvial, hillslope, debris flow	Fluvial, hillslope, debris flow	Fluvial, hillslope, debris flow	Hillslope, debris flow
Sediment Storage Elements	Overbank, bedforms	Overbank, bedforms, inactive channel	Overbank, bedforms, inactive channel	Overbank, inactive channel	Bedforms	Lee & stoss sides of flow obstructions	•	Bed
Typical Slope (m/m)	S < 0.03	S < 0.001	0.001 < S and S < 0.02	0.01 < S and S < 0.03	0.03 < S and S < 0.08	0.08 < S and S < 0.30	Variable	S > 0.20
Typical Confinement	Unconfined	Unconfined	Unconfined	Variable	Confined	Confined	Confined	Confined
Pool Spacing (Channel Widths)	Variable	5 to 7	5 to 7	none	1 to 4	< 1	Variable	Variable

Example typicals

Appendix C

Example of detailed design for on-site restoration and compensation

Design Brief Example: K Creek

1 RATIONALE

The construction and operation of the proposed Project will impact fish habitat in K Creek and therefore the project requires compensation or the creation of new or improved fish habitat to offset these losses. The impacts of the Project were estimated to be 1230 m^2 footprint, 1002 m^2 rearing area, and no spawning area losses. The project-specific habitat compensation has been set at 2:1 for the K Creek project giving a total compensation requirement of 4400 m^2. The initial compensation concept detailed a 150 m long rearing and spawning channel that paralleled the main channel. Flow would be introduced into the channel by a stream bank intake located near the abandoned FSR Bridge.

This concept was investigated by a joint site inspection by the Engineer and Biologist. This site visit revealed the potential for a larger project than initially proposed. The delta contains numerous swales that could be developed into new channels. The most extensive of these swales continues from the proposed channel alignment to the north side of the delta providing an additional 350 m of usable channel length before joining the Lake. This new alignment was surveyed and is the focus of this design report.

The rationale for the channel design is to: 1) meet the fish habitat compensation requirements of the Project, 2) maximize the amount of spawning and rearing habitat given the site area, grades and intake design flows, and 3) potentially exceed the project-specific compensation requirements to provide habitat gains that can be used to offset losses associated with other nearby Projects.

2 CONCEPT

The proposed channel consists of a water intake and supply pipeline that feeds a long spawning and rearing channel that includes a series of large complexed rearing and overwintering ponds that are isolated from the Creek by an elevated berm and higher ground. Co-location of spawning, rearing and holding habitats within the channel complex provides suitable habitat for all lifestages and should allow the habitat to become self-sustaining for anadromous and resident fish species.

The compensation works would be constructed along a series of existing swales that contain isolated sections of water at their downstream end. Excavating a channel in pre-existing swales will reduce the excavation volume and therefore reduce the footprint of the channel on the delta. The site is roughly 520 m long and the proposed channel, ponds, and berms will cover an area of about one hectare of the delta.

The design of the channel is intended to intercept existing groundwater to supply the channel.

The existing outlet of the proposed channel had a groundwater flow of 150-250 L sec^{-1} during the time of the site inspection. Located at the base of the fan, the channel would develop sufficient length at design grades to capture groundwater moving down towards the Lake. To ensure supplementary water, a small intake has been included in the design. Supplementary flows would include flows to operate the channel to meet ecohydraulic conditions (e.g. additional spawning flows). The requirement for the intake will be assessed in the field during construction.

A stream channel intake that operates independently of the Project will be located on the right bank immediately downstream of the existing FSR bridge on lower Creek at the abandoned forestry bridge. Flows from the supply pipeline would discharge into a large pond complex at the upstream end of the channel complex. This pond would provide an area where fine sediment entrained into the intake can settle out before it impacts the downstream spawning areas. Periodic maintenance of the settling pond may be required to prevent the downstream migration of sand.

Downstream flows out of the settling pond complex are carried through a series of ponds and channels that includes numerous logs and boulders that add cover elements. Large wood complexes, logs, rootwads, and small jams will be installed along the perimeter of the ponds, pools, and available channel banks. Rock riffles will be constructed at the downstream end of each pond to provide a water-level control for the upstream pond and provide aeration while dropping the elevation of the water surface. Downstream of these water-level controls, flow will pass over a moderately-deep, slow moving spawning riffle. Grading and riparian revegetation along the banks of the ponds and channels would be completed after construction.

Based on the draft plans and specifications, the proposed compensation works provide the following estimated quantities of fish habitat. These totals are subject to changes pending final design. Although the design criteria target coho salmon, it is expected that the channel will be utilized by most Creek stocks including chum, sockeye and pink salmon.

Table 1 Compensatory Fish Habitat Estimates

Species/Lifestage	Area
Coho juvenile rearing pond habitat	3080 m^2
Coho juvenile rearing stream habitat	185 m^2
Coho adult spawning habitat	730 m^2

3 DESIGN AND MATERIALS

3.1 Channel Intake

We proposed that a 400 mm (16”) diameter steel and PVC pipeline be installed from the creek bank near the abutment of the abandoned forestry bridge to the upper pond complex. The bank is stable but low. A riprap protected berm will be required to protect the channel from floods. The creek at the proposed intake location is shallow on the right bank and some minor re-working of the streambed and bank will be required to provide good intake hydraulics. The stream bed will be excavated about 1 m and the stream channel narrowed by a riprap spur. About 1 m depth over the intake is required to provide the proposed maximum 350 L/s spawning flow and 200 L sec^{-1} incubation/rearing flow and prevent dewatering of the intake and downstream channel.

The bank intake is a steel design that lays parallel to the river bed, and is typically installed in a natural or constructed pool in the stream channel. These intakes – initially designed by DFO SEP engineers – have been used for over 10 years on Cheakamus, Englishman and Chilliwack rivers with good success. The intake will not be screened because juvenile fish entrainment is unlikely given the low inlet velocities and juveniles entrained would be at low risk of injury. An unscreened intake will also avoid screen impingement.

The intake would be flanged and bolted on to the flanged steel pipe. The pipe would have a butterfly or slide gate valve downstream of the intake within a pre-cast vault or embedded in engineered fill to control flows. The pre-cast concrete outlet would have a sluice gate to regulate flow on the downstream end. The outlet would be designed to dissipate hydraulic energy and provide a sump for minor amounts of bed load entrained by the intake.

Disturbed areas on the pipeline alignment should be back filled and protected with Class III riprap. This rock will be used to rebuild the natural bank where disturbed; approximately 50 m^3 of this riprap will be required.

Table 2 Riprap Gradation

Gradation	Material Size (mm)
D_{20}	500
D_{50}	750
D_{80}	900

3.2 Rearing and Overwintering Pond Habitats

A preliminary plan was prepared based on existing topographical data and field survey data (attached). Once design grades and water surface elevations were established, channel lay-out and pond extents were determined. A minimum 1.5 m pond depth was selected to ensure sufficient depth for overwintering of coho juveniles. The water supply will ensure excellent water quality and dissolved oxygen concentration though the winter months and a reduce flow rate is recommended to reduce sediment entrainment during fall and winter storm events.

Minimum large wood coverage of 25% of the open wetted pond area is required to ensure maximum overwintering carrying capacity and smolt production. No ballast or cable will be added to the logs. Instead, logs will be anchored by burial in disturbed slopes, placed so that more than 50% of the log length lies on the bank, or logs with rootwads attached will be stable in the ponds without anchoring.

3.3 Channel Riffles

The available grade between the settling pond water-surface varies as the lake level fluctuates. The upper pond water-surface is at 14.25 m while the lake varies between 8 m and 12 m; a difference of 2.25 m to 6.25 m. The 1% overall grade of the site will be made up is a series of riffle / spawning run platforms. Riffles will be built to have a 15% downstream slope and will vary in height from 0.1 m to 0.15 m (total length will vary from 0.6 m to 1.0 m).

The low drop structures will provide hydraulic control over the spawning areas and will be adjusted to produce a 30 cm depth over the spawning areas at the design discharge. The riffles will be constructed from a uniformly graded 300 mm D_{50} rounded-boulder mix. Grades and riffle length are also designed to ensure juvenile access during the rearing flows.

Table 3 Typical Riffle Details

Design Width	2 m
Design Height (water-to-water)	Varies to 0.3 m
Average Wetted Width	2.5 m
Average Wetted Depth	0.15 m
Length	Varies to 1 m
Maximum Velocity	3 m/s

Note: average conditions at 350 L/s design flow

Table 4 Bank Protection / Riffle Material Gradation

Gradation	Material Size (mm)
D_{15}	200
D_{50}	300
D_{85}	400

3.4 Channel Habitat

The channel section dimensions were selected based on flow rates and ecohydraulic design criteria confirmed by the Biologist. The 2 m wide (bottom width) platforms will have a water depth of 0.3 m and a mean velocity of 0.5 m/s at 350 L/s for maximum coho spawning utilization. The spawning areas will be constructed of screened, graded alluvial gravels, placed 0.5 m deep and 2.0 m wide at 0.2% slope. The gravel gradation uses a recommended proportion of fines and sands that are thought to improve egg-fry survivals (Mel Sheng, DFO Nanaimo, *pers. comm.*).

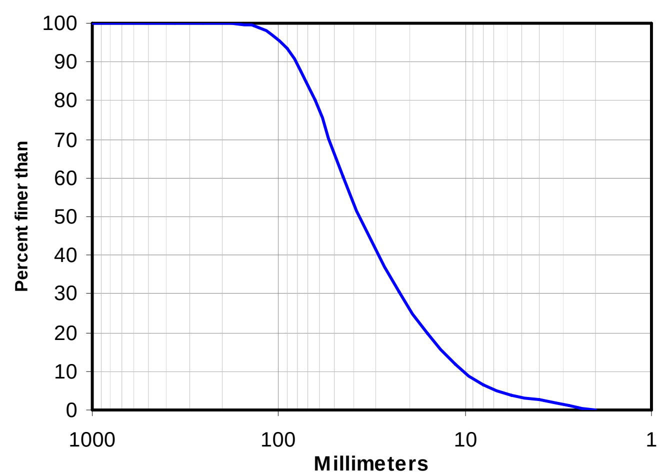
Table 5 Typical Channel Section Details

Bottom Width	2 m
Bankfull Depth	0.75 m
Average Wetted Width	3.1 m
Wetted Depth	0.3 m
Average Velocity	0.5 m/s

Note: average conditions at 350 L/s design flow

Table 6 Coho Spawning Gravel Gradation

Size finer than (mm)	Percent Finer	Size finer than (mm)	Percent Finer
2	0.0	22.6	30.5
2.8	1.3	32	43.7
4	2.6	45.3	60.3
5.6	4.0	64	80.1
8	6.6	90.5	93.4
11.3	11.9	128	98.7
16	19.9	181	100.0



Outside the salmon spawning window we recommend that flow in the channel be reduced to 200 L sec^{-1} during incubation during winter through to emergence. Flows for the 0+ rearing period should remain near 200 L sec^{-1} to maximize rearing coho juvenile hydraulic suitability in the channel (e.g. suitability is maximized at velocities $\leq$ 0.2 m sec^{-1} and depths greater than 0.25 m). Hydraulic conditions in the channel will be 0.18 m depth and 0.48 m sec^{-1} velocity.

Suitability and cover habitat for rearing salmonids would be increased through placement of large instream wood at a minimum target of 4 pieces per bankfull channel width – or 1 per meter of channel length and placement of boulder bank protection materials along channel margins. Engineered ballasting of the wood is not required, and bank embedment with static placement is recommended through the channel sections. These design flows will provide adequate downstream migration flows for coho smolts. As discussed earlier, the reduced flows through the freshet period will moderate sediment entrainment before increasing flows for the fall period to 350 L sec^{-1} for migration and spawning.

4 QUANTITIES

The construction of the compensatory fish habitat at the K Creek Hydro Project is estimated to require the following quantities of materials and work. These figures do not include level of effort related to construction and installation.

Table 7 Construction Quantity Estimates

Item	Description	Quantity
Excavation	Channel and pond rough-out to grade	5,500 m^3
Large Woody Debris	Pond and channel complexing	330 pieces
Boulder Gradation	Riffle and bank lining	325 m^3
Spawning Gravel	Lining channel sections	700 m^3

5 DESIGN AND CONSTRUCTION REVIEW

An environmental monitor and a qualified registered professional familiar with the design of the compensation will be on site during construction to ensure the works are constructed as designed while meeting the requirements of all authorizations and permits. Modifications of these preliminary design drawings and dimensions may be required during construction to suit site conditions, available equipment and materials.

Any required site modifications should be made pending field review and verification of the biological and hydrotechnical engineering consultants. The rationale and description of any modification(s) will be submitted to the construction contractor, owners representative and environmental monitor as required during construction. Modifications to the design will be fully documented in an as-built construction report undertaken by the responsible party.

Equipment and material access to the site will be from existing roads on the delta. Tenure and access requirements should be confirmed prior to final design. A provincial water licence is required for construction, operation and maintenance of the intake on the Creek.

5.1 Drawings and Specifications

The following documents are attached for construction:

- typical drawings were prepared with special notations and specific site requirements as noted;
- *General LWD Construction Specifications* for general information on installation of large woody debris for habitat complexing;
- *General Rock Placement Specifications* for information on the placement of boulders, drop structures, riffles and general bank protection.

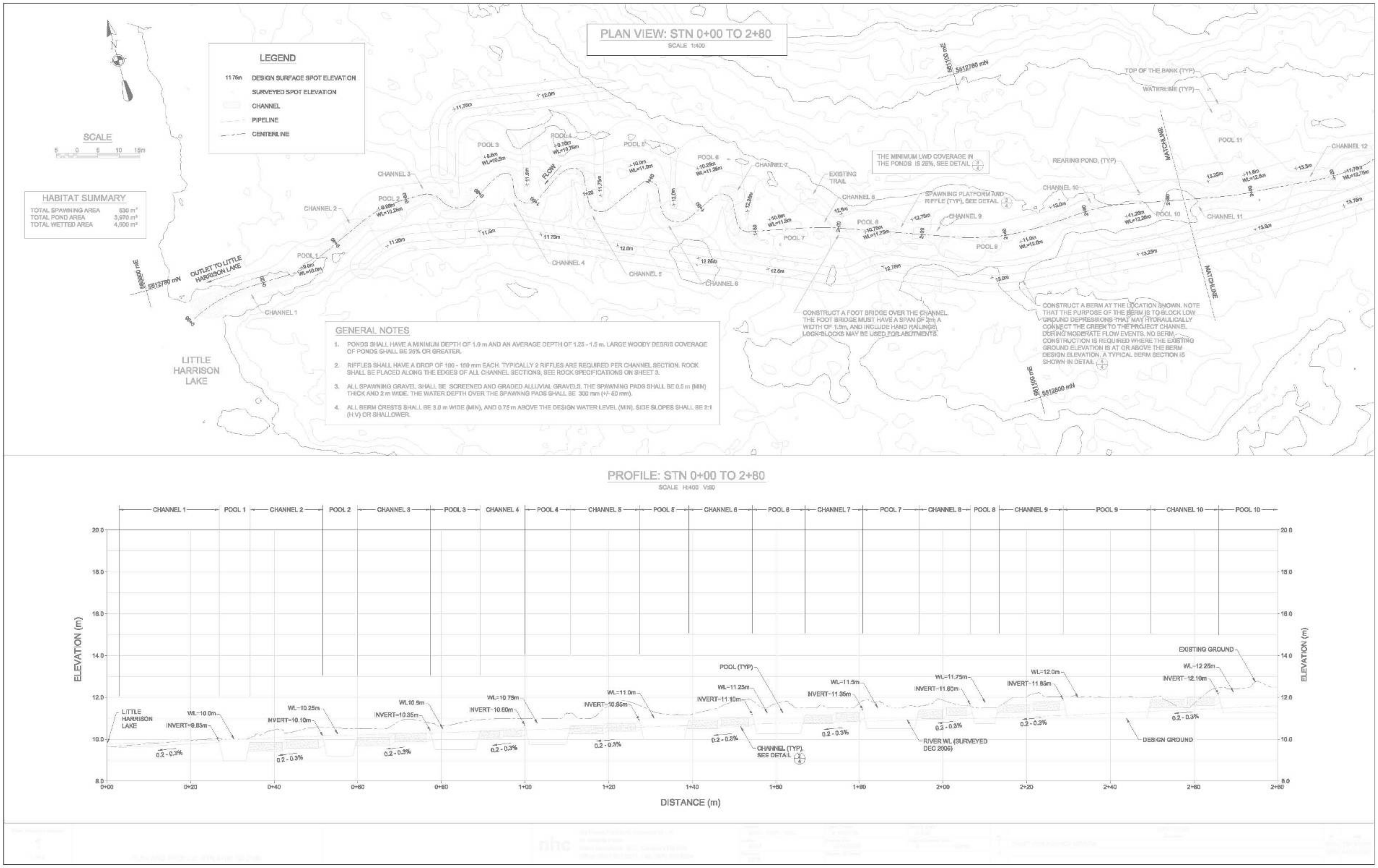
5.1.1 General Large Wood Complexing Construction Specifications

- Wood species shall be Douglas Fir, Red Cedar, Yellow Cedar, Sitka Spruce or Western Hemlock unless otherwise specified. No dimensional beams or timbers, Red Alder, or other deciduous tree species shall be used for large wood complexing (LWC) or engineered log jams (ELJ).
- The actual number and volume of ballast rock required per site is dependant on the volume of LWD placed and anchoring system employed in the field.
- Root wads: minimum diameter of 0.6 meters dbh, minimum wad diameter of 2.5 meters and 1.5 meter minimum stem length to a maximum of 5.0 meters
- LWD pieces: minimum diameter of 0.6 meters dbh, minimum wad diameter of 2.5 meters and length to suit but no less than 5.0 meters.
- Framing LWD or additional wood used to brace LWD should be aligned and anchored as required to create structural frame (see WRTC No 9).
- Static water habitat complexing assumes mixture of root wads and LWD pieces covering 3.0 m^2 per piece. Design coverage off channel habitat is 25 % by area.
- Embedding LWD requires a minimum of 66% coverage of stem length by a minimum cover of 1.0 meters of machine-compacted granular material or shot rock.

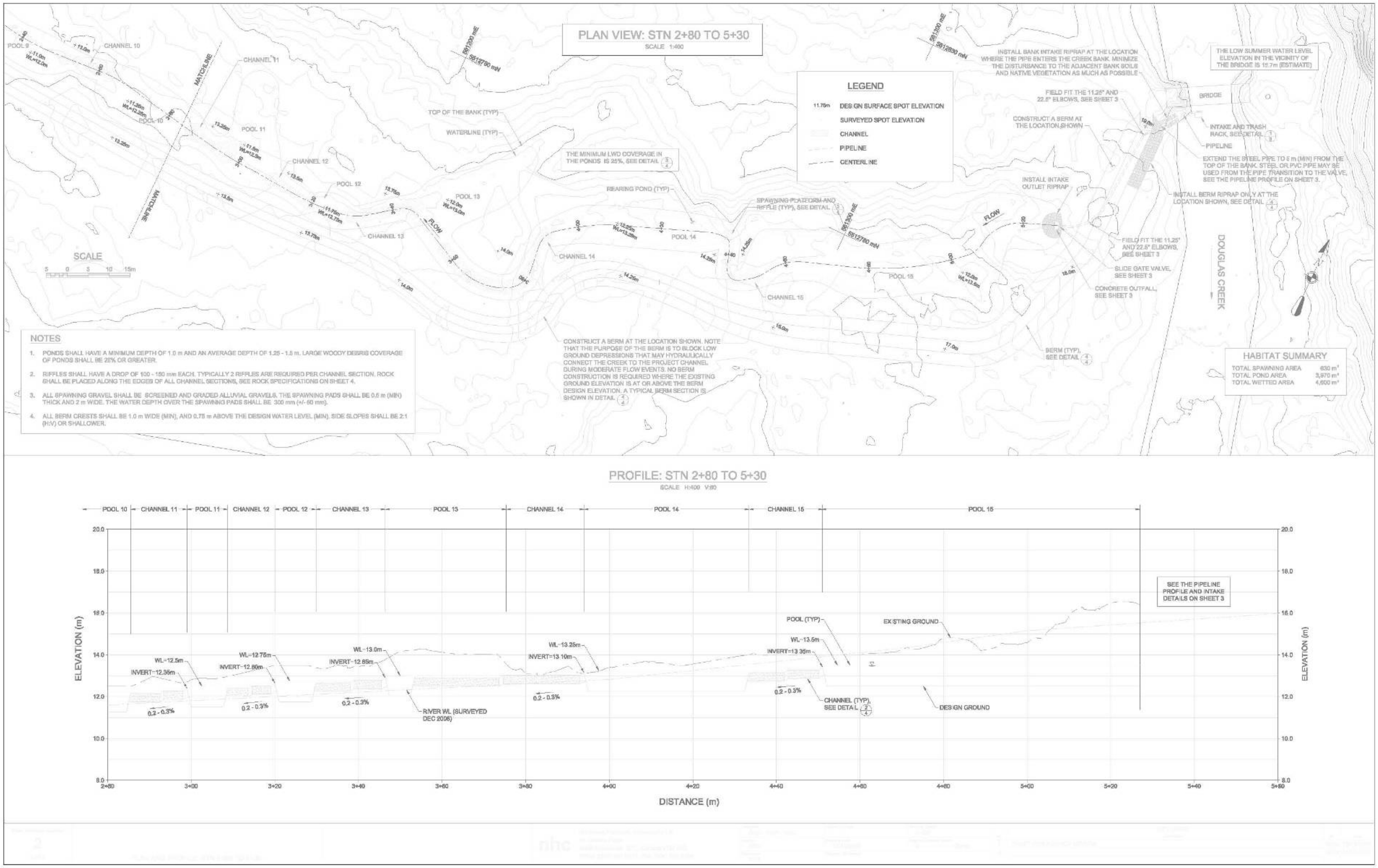
5.1.2 General Rock Placement Specifications

- Minimum specified rock rip rap shall used for general bank erosion prevention unless otherwise specified.
- Boulders used singly or in groupings less than 3 shall be sized to minimum of those in comparable hydraulic conditions, and shall not be less than 0.6 meters diameter.
- Channel drop structures or weirs shall be made with rocks not following the gradation specified by location. Upstream face slopes at a maximum 2:1 H:V and downstream face slopes at a minimum 5:1 H:V to a maximum of 20:1 H:V.
- Rip rap or rock is used to protect outlet, inlets or curved banks of channels from erosion, ensure rock extends 0.5 meters above expected water surface and to a suitable depth to mitigate expected scour and erosion. Areas of application shall be determined by the QRP.

Example Drawings and Specifications

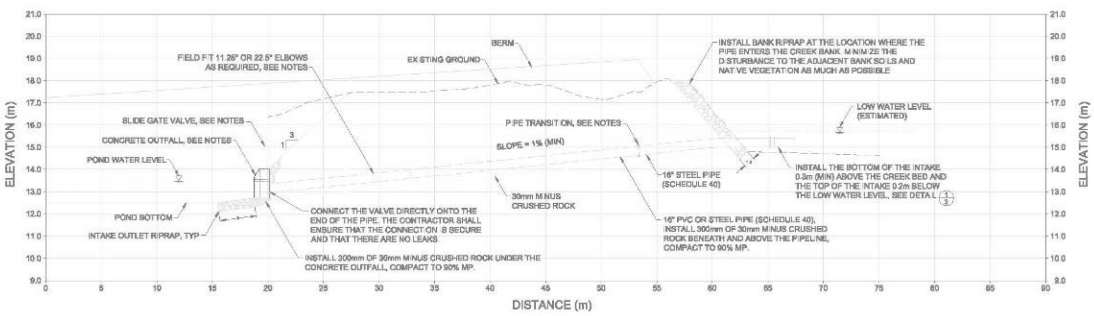


PLAN VIEW: STN 0+00 TO 2+80
SCALE 1:400
LEGEND
11.76m DESIGN SURFACE SPOT ELEVATION
SURVEYED SPOT ELEVATION
CHANNEL
PIPELINE
CENTERLINE
SCALE
5 0 5 10 15m
HABITAT SUMMARY
TOTAL SPAWNING AREA 630 m²
TOTAL POND AREA 3,970 m²
TOTAL WETTED AREA 4,600 m²
OUTLET TO LITTLE HARRISON LAKE
LITTLE HARRISON LAKE
5612780 mN
5612800 mN
561100 mE
GENERAL NOTES
1. PONDS SHALL HAVE A MINIMUM DEPTH OF 1.0 m AND AN AVERAGE DEPTH OF 1.25 - 1.5 m. LARGE WOODY DEBRIS COVERAGE OF PONDS SHALL BE 25% OR GREATER.
2. RIFFLES SHALL HAVE A DROP OF 100 - 150 mm EACH. TYPICALLY 2 RIFFLES ARE REQUIRED PER CHANNEL SECTION. ROCK SHALL BE PLACED ALONG THE EDGES OF ALL CHANNEL SECTIONS, SEE ROCK SPECIFICATIONS ON SHEET 3.
3. ALL SPAWNING GRAVEL SHALL BE SCREENED AND GRADED ALLUVIAL GRAVELS. THE SPAWNING PADS SHALL BE 0.5 m (MIN) THICK AND 2 m WIDE. THE WATER DEPTH OVER THE SPAWNING PADS SHALL BE 300 mm (+/- 50 mm).
4. ALL BERM CRESTS SHALL BE 3.0 m WIDE (MIN), AND 0.75 m ABOVE THE DESIGN WATER LEVEL (MIN). SIDE SLOPES SHALL BE 2:1 (H:V) OR SHALLOWER.
THE MINIMUM LWD COVERAGE IN THE PONDS IS 25%, SEE DETAIL 3/4
SPAWNING PLATFORM AND RIFFLE (TYP), SEE DETAIL 2/4
EXISTING TRAIL
REARING POND, (TYP)
TOP OF THE BANK (TYP)
WATERLINE (TYP)
MATCHLINE
FLOW
CONSTRUCT A FOOT BRIDGE OVER THE CHANNEL. THE FOOT BRIDGE MUST HAVE A SPAN OF 2m, A WIDTH OF 1.5m, AND INCLUDE HAND RAILINGS. LOCK-BLOCKS MAY BE USED FOR ABUTMENTS.
CONSTRUCT A BERM AT THE LOCATION SHOWN. NOTE THAT THE PURPOSE OF THE BERM IS TO BLOCK LOW GROUND DEPRESSIONS THAT MAY HYDRAULICALLY CONNECT THE CREEK TO THE PROJECT CHANNEL DURING MODERATE FLOW EVENTS. NO BERM CONSTRUCTION IS REQUIRED WHERE THE EXISTING GROUND ELEVATION IS AT OR ABOVE THE BERM DESIGN ELEVATION. A TYPICAL BERM SECTION IS SHOWN IN DETAIL 4/4
PROFILE: STN 0+00 TO 2+80
SCALE H:400 V:50
CHANNEL 1 POOL 1 CHANNEL 2 POOL 2 CHANNEL 3 POOL 3 CHANNEL 4 POOL 4 CHANNEL 5 POOL 5 CHANNEL 6 POOL 6 CHANNEL 7 POOL 7 CHANNEL 8 POOL 8 CHANNEL 9 POOL 9 CHANNEL 10 POOL 10
ELEVATION (m)
DISTANCE (m)
LITTLE HARRISON LAKE
WL=10.0m
INVERT=9.85m
WL=10.25m
INVERT=10.10m
WL10.5m
INVERT=10.35m
WL=10.75m
INVERT=10.60m
WL=11.0m
INVERT=10.85m
WL=11.25m
INVERT=11.10m
POOL (TYP)
WL=11.5m
INVERT=11.35m
WL=11.75m
INVERT=11.60m
WL=12.0m
INVERT=11.85m
WL=12.25m
INVERT=12.10m
EXISTING GROUND
DESIGN GROUND
0.2 - 0.3%
CHANNEL (TYP), SEE DETAIL 1/4
RIVER WL (SURVEYED DEC 2006)


PLAN VIEW: STN 2+80 TO 5+30
SCALE 1:400
LEGEND
11.75m DESIGN SURFACE SPOT ELEVATION
SURVEYED SPOT ELEVATION
CHANNEL
PIPELINE
CENTERLINE
SCALE
5 0 5 10 15m
POOL 9
CHANNEL 10
POOL 10
CHANNEL 11
POOL 11
CHANNEL 12
POOL 12
CHANNEL 13
POOL 13
CHANNEL 14
POOL 14
CHANNEL 15
POOL 15
MATCHLINE
FLOW
TOP OF THE BANK (TYP)
WATERLINE (TYP)
THE MINIMUM LWD COVERAGE IN THE PONDS IS 25%, SEE DETAIL 3/4
REARING POND (TYP)
SPAWNING PLATFORM AND RIFFLE (TYP), SEE DETAIL 2/4
5812780 mN
581300 mE
5812830 mN
INSTALL BANK INTAKE RIPRAP AT THE LOCATION WHERE THE PIPE ENTERS THE CREEK BANK. MINIMIZE THE DISTURBANCE TO THE ADJACENT BANK SOILS AND NATIVE VEGETATION AS MUCH AS POSSIBLE
THE LOW SUMMER WATER LEVEL ELEVATION IN THE VICINITY OF THE BRIDGE IS 15.7m (ESTIMATE)
FIELD FIT THE 11.25° AND 22.5° ELBOWS, SEE SHEET 3
BRIDGE
CONSTRUCT A BERM AT THE LOCATION SHOWN
INTAKE AND TRASH RACK, SEE DETAIL 1/3
PIPELINE
EXTEND THE STEEL PIPE TO 5 m (MIN) FROM THE TOP OF THE BANK. STEEL OR PVC PIPE MAY BE USED FROM THE PIPE TRANSITION TO THE VALVE, SEE THE PIPELINE PROFILE ON SHEET 3.
INSTALL INTAKE OUTLET RIPRAP
INSTALL BERM RIPRAP ONLY AT THE LOCATION SHOWN, SEE DETAIL 4/4
FIELD FIT THE 11.25° AND 22.5° ELBOWS, SEE SHEET 3
SLIDE GATE VALVE, SEE SHEET 3
CONCRETE OUTFALL, SEE SHEET 3
DOUGLAS CREEK
BERM (TYP), SEE DETAIL 4/4
CONSTRUCT A BERM AT THE LOCATION SHOWN. NOTE THAT THE PURPOSE OF THE BERM IS TO BLOCK LOW GROUND DEPRESSIONS THAT MAY HYDRAULICALLY CONNECT THE CREEK TO THE PROJECT CHANNEL DURING MODERATE FLOW EVENTS. NO BERM CONSTRUCTION IS REQUIRED WHERE THE EXISTING GROUND ELEVATION IS AT OR ABOVE THE BERM DESIGN ELEVATION. A TYPICAL BERM SECTION IS SHOWN IN DETAIL 4/4
HABITAT SUMMARY
TOTAL SPAWNING AREA 630 m²
TOTAL POND AREA 3,970 m²
TOTAL WETTED AREA 4,600 m²
NOTES
1. PONDS SHALL HAVE A MINIMUM DEPTH OF 1.0 m AND AN AVERAGE DEPTH OF 1.25 - 1.5 m. LARGE WOODY DEBRIS COVERAGE OF PONDS SHALL BE 25% OR GREATER.
2. RIFFLES SHALL HAVE A DROP OF 100 - 150 mm EACH. TYPICALLY 2 RIFFLES ARE REQUIRED PER CHANNEL SECTION. ROCK SHALL BE PLACED ALONG THE EDGES OF ALL CHANNEL SECTIONS, SEE ROCK SPECIFICATIONS ON SHEET 4.
3. ALL SPAWNING GRAVEL SHALL BE SCREENED AND GRADED ALLUVIAL GRAVELS. THE SPAWNING PADS SHALL BE 0.5 m (MIN) THICK AND 2 m WIDE. THE WATER DEPTH OVER THE SPAWNING PADS SHALL BE 300 mm (+/- 50 mm).
4. ALL BERM CRESTS SHALL BE 1.0 m WIDE (MIN), AND 0.75 m ABOVE THE DESIGN WATER LEVEL (MIN). SIDE SLOPES SHALL BE 2:1 (H:V) OR SHALLOWER.
PROFILE: STN 2+80 TO 5+30
SCALE H:400 V:80
POOL 10
CHANNEL 11
POOL 11
CHANNEL 12
POOL 12
CHANNEL 13
POOL 13
CHANNEL 14
POOL 14
CHANNEL 15
POOL 15
ELEVATION (m)
DISTANCE (m)
WL=12.5m
INVERT=12.35m
WL=12.75m
INVERT=12.60m
WL=13.0m
INVERT=12.85m
WL=13.25m
INVERT=13.10m
WL=13.5m
INVERT=13.35m
0.2 - 0.3%
RIVER WL (SURVEYED DEC 2006)
POOL (TYP)
EXISTING GROUND
CHANNEL (TYP), SEE DETAIL 2/4
DESIGN GROUND
SEE THE PIPELINE PROFILE AND INTAKE DETAILS ON SHEET 3
2+80
3+00
3+20
3+40
3+60
3+80
4+00
4+20
4+40
4+60
4+80
5+00
5+20
5+40
5+60
8.0
10.0
12.0
14.0
16.0
18.0
20.0

PIPELINE PROFILE

SCALE H:200 V:100

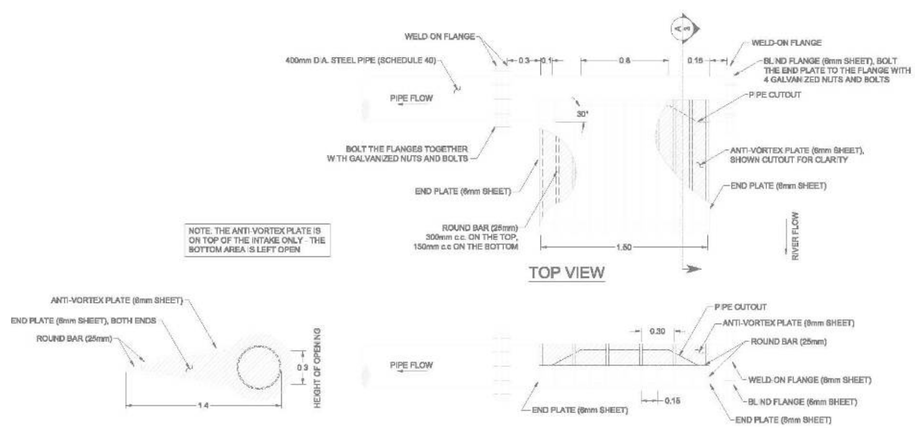


PIPELINE NOTES

1. THE OUTFALL SHALL BE A "11 13 OUTFALL" AS SUPPLIED BY A.E. CONCRETE PRECAST PRODUCTS LTD, 19050 - 54TH AVENUE, SURREY, B.C. V3S 8E5 / TEL: (604) 576 1808), OR EQUIVALENT. INSTALL THE OUTFALL ON A LEVEL, COMPACTED GRAVEL PLATFORM. INSTALL A 3m LONG BY 0.5m THICK APRON OF 300mm DIA RIPRAP AROUND THE OUTFALL. NOTE THAT THE VALVE IS TO BE ATTACHED DIRECTLY ONTO THE END OF THE PIPELINE, NOT ONTO THE OUTFALL.
2. THE VALVE SHALL BE A "410mm X 410m (16") FABRICATED SLIDE GATE VALVE TYPE 20-20" AS SUPPLIED BY ARMTEC (SUITE 100 - 10185 199B STREET LANGLEY, B.C. V1M 3W9 / TEL. 604-881-4430), OR EQUIVALENT. THE GATE VALVE MUST BE RATED TO 6m STATIC HEAD (MINIMUM). THE VALVE SHALL BE ATTACHED DIRECTLY ONTO THE END OF THE PIPELINE AS PER THE MANUFACTURER SPECIFICATIONS.
3. THE PIPELINE BETWEEN THE "PIPE TRANSITION" AND THE RIVER SHALL BE CONSTRUCTED OF 400mm (16") DIA MILD STEEL SCHEDULE 40 PIPE. ALL JOINS MUST BE CONTINUOUSLY WELDED OR FLANGED AND BOLTED TOGETHER. THE CONTRACTOR SHALL SUPPLY 11.25° AND 22.5° ELBOWS TO FACILITATE FIELD FITTING THE PIPE. ALL ELBOWS SHALL HAVE A 1m (MINIMUM) STRAIGHT PIPE SEGMENT SEPARATING THEM. NO 45° OR 90° ELBOWS ARE ACCEPTABLE DUE TO POSSIBLE BLOCKAGE FROM RIVER DEBRIS. THE PIPE SLOPE MUST BE 1.0% OR GREATER EXCEPT AT THE INTAKE - THE INTAKE MAY BE LEVEL.
4. THE PIPELINE BETWEEN THE OUTFALL AND THE "PIPE TRANSITION" SHALL BE CONSTRUCTED OF 400mm (16") DIA MILD STEEL OR 400mm (16") DIA PVC SCHEDULE 40 PIPE. ALL JOINS MUST BE WATER TIGHT, PRESSURE GASKET PIPE IS ACCEPTABLE. THE PIPE SLOPE MUST BE 1.0% OR GREATER.

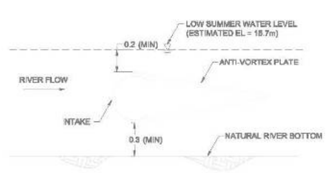
INTAKE FABRICATION DETAIL (1/3)

SCALE 1:20



SECTION (A/3)

SCALE 1:20



VIEW LOOKING TOWARDS THE RIVER CENTERLINE FROM THE LEFT BANK

DO NOT EXCAVATE A "HOLE" TO ACHIEVE THE SPECIFIED DEPTH ABOVE AND BELOW THE INTAKE - REFER TO THE ENGINEER IN THE FIELD

ROCK SPECIFICATIONS

CHANNEL LINING AND RIFFLE GRADATION (ROUND)

GRADATION	MATERIAL SIZE (mm)
D[illegible]	50 - 150
D[illegible]	100 - 300
D[illegible]	200 - 400

SPAWNING GRAVEL GRADATION (ROUND)

GRADATION	MATERIAL SIZE (mm)
D[illegible]	15
D[illegible]	40
D[illegible]	70

INTAKE OUTLET & BERM RIPRAP GRADATION (ANGULAR)

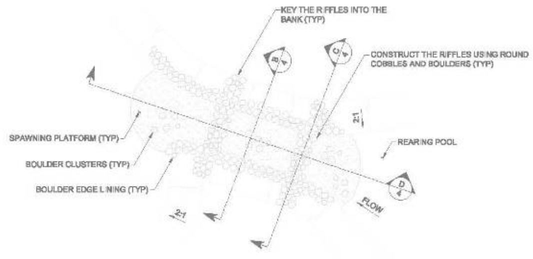
GRADATION	MATERIAL SIZE (mm)
D[illegible]	50 - 150
D[illegible]	100 - 300
D[illegible]	200 - 400

INTAKE BANK RIPRAP GRADATION (ANGULAR)

GRADATION	MATERIAL SIZE (mm)
D[illegible]	200 - 300
D[illegible]	500 - 700
D[illegible]	900 - 1100

NOTE: DETAILED GRADATION SPECIFICATIONS FOR ALL MATERIALS ARE PROVIDED IN THE SPECIFICATIONS DOCUMENT

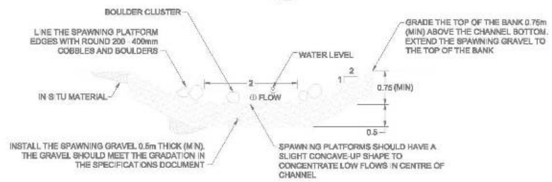
CHANNEL DETAIL 2/1
SCALE 1:100



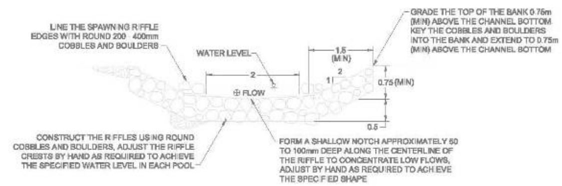
CONSTRUCTION NOTES

1. CONSTRUCT THE RIFFLES USING ROUND COBBLES AND BOULDERS
2. KEY THE RIFFLES 0.5m INTO THE CHANNEL BED AND 1.5m INTO EACH BANK.
3. CONSTRUCT THE SPAWNING PLATFORM USING THE SPAWNING GRAVEL GRADATION IN THE SPECIFICATIONS DOCUMENT.
4. LINE THE EDGES OF THE SPAWNING PLATFORM WITH ROUND COBBLES AND BOULDERS
5. RANDOMLY PLACE CLUSTERS OF 3 TO 5 BOULDERS (D_{50} = 250 TO 400mm) ON THE SPAWNING PLATFORM. INSTALL 4 TO 6 BOULDER CLUSTERS PER PLATFORM.
6. GENERAL EXCAVATION TOLERANCE ± 15cm.
7. RIFFLE CREST / CONTROL STRUCTURES TOLERANCE ± 5cm.
8. LWD / ROCK PLACEMENT TOLERANCE ± 30cm.

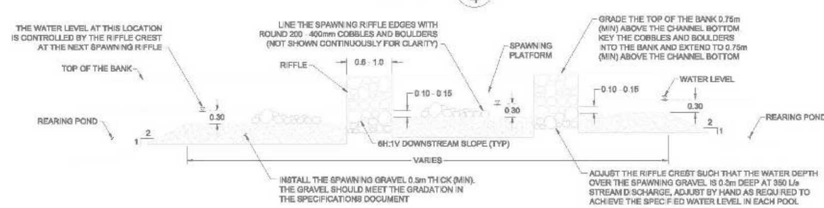
SECTION B/4
SCALE 1:50



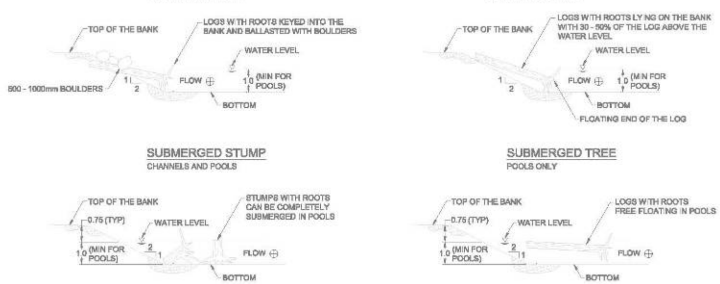
SECTION C/4
SCALE 1:50



SECTION D/4
SCALE 1:50



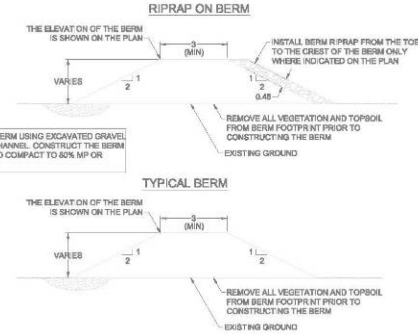
LARGE WOODY DEBRIS (LWD) PLACEMENT DETAIL 3/1
SCALE 1:100



NOTES

USE CONIFEROUS LOGS AND STUMPS (LWD) WITH ROOTS ATTACHED WHENEVER POSSIBLE. THE LWD SHALL HAVE A STEM DIAMETER GREATER THAN 600mm DBH. GROUP SMALLER LOGS TO PROVIDE MORE COMPLETE POND AND CHANNEL COVERAGE. ADEQUATE LWD COVERAGE WILL BE DETERMINED BY THE ENGINEER OR ENVIRONMENTAL CONSULTANT IN THE FIELD.

BERM DETAIL 4/1
SCALE 1:100



CONSTRUCT THE BERM USING EXCAVATED GRAVEL MATERIAL FROM CHANNEL. CONSTRUCT THE BERM IN 400mm LIFTS AND COMPACT TO 80% MP OR GREATER.