Peace Project Water Use Plan

Williston Reservoir Trial Tributaries

Design Final Report

Reference: GMSWORKS-19

GMSWORKS#19 Williston Reservoir Trial Tributaries Design Final Report

Study Period: 2011

Kerr Wood Leidal Associates LTD.

December, 2011

GMSWORKS #19 Williston Reservoir Trial Tributaries Design

Final Report
December 2011

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December 16, 2011

Jason Watson
Water Licensing Requirements - Physical Works
BC Hydro
16th Floor
6911 Southpoint Drive
Burnaby, BC
V3N 4X8

Dear Mr. Watson:

RE: GMSWORKS#19: WILLISTON RESERVOIR – TRIAL TRIBUTARIES
Final Report Submission
Our File 478.114

Please find attached a digital PDF version of the final design report for GMSWORKS#19 Williston Reservoir - Trial Tributaries. This project is the design phase of a study completed in early 2010 that investigated fish passage issues on Williston Reservoir tributary creeks. Based on the terms of reference, KWL has prepared desk-top level designs for fish passage improvements on Six Mile and Ole Creek that are based on utilizing on-site materials insofar as possible, and limited import of construction materials.

Yours truly,

KERR WOOD LEIDAL ASSOCIATES LTD.

David Matsubara, M.Eng., P.Eng.
Project Manager

cc. Karen Skipbo
Bill Poirier
Michael MacArthur

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GMSWORKS #19 Williston Reservoir Trial Tributaries Design

Final Report
December 2011

KWL File No. 478.114

CONTENTS

FIGURES

TABLES

APPENDICES

STATEMENT OF LIMITATIONS

This document has been prepared by Kerr Wood Leidal Associates Ltd. (KWL) for the exclusive use and benefit of BC Hydro & Power Authority for the GMSWORKS #19 Williston Reservoir Trail Tributaries Design. No other party is entitled to rely on any of the conclusions, data, opinions, or any other information contained in this document.

This document represents KWL's best professional judgement based on the information available at the time of its completion and as appropriate for the project scope of work. Services performed in developing the content of this document have been conducted in a manner consistent with that level and skill ordinarily exercised by members of the engineering profession currently practising under similar conditions. No warranty, express or implied, is made.

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REVISION HISTORY

Revision #	Date	Status	Revision	Author
1	March 28, 2011	Draft	Draft	SJL/DTM
2	Nov. 18, 2011	Final Draft	Final Draft	DTM
3	Dec. 16, 2011	Final	Final	DTM

Section 1

Project and Site Description

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1. PROJECT AND SITE DESCRIPTION

1.1 INTRODUCTION

BC Hydro is undertaking GMS WORKS #19, a project defined under the GM Shrum generating station Water Use Plan to address stranding of migrating fish into tributary streams due to changes in channel morphology associated with reservoir operations. The first phase of the project was conducted by Synergy Applied Ecology[1], it involved an overall assessment of all major tributaries to the Williston Reservoir, and included a detailed assessment of two target tributaries. This project is the second phase of the project, which involves detailed design of channel passage improvement works.

The two trial tributaries identified for enhancement were assessed by Synergy Applied Ecology during the Inventory Field Work stage of the project (Synergy 2010). The trial tributaries were chosen to address two different perceived barriers to fish passage from Williston Reservoir into the surrounding tributaries, and included Six Mile Creek and Chichouyenily Creek. These two creeks were assessed as having "drawdown impacts", where fish passage was impaired due to unconfined channel flow in the drawdown zone. Between the initial assessment report, and implementation of the design phase, Chichouyenily Creek was dropped as a test case in favour of Ole Creek, a creek prone to large woody debris (LWD) accumulation at the mouth. General locations of Six Mile Creek and Ole Creek are provided in Section 2 on Figure 2-2.

Six Mile Creek

Six Mile Creek is located on the east side of the Parsnip Reach of Williston Reservoir, a short distance north of Mackenzie. The creek is accessible by a partially overgrown forestry road from the Mackenzie Highway (Hwy 39). This road stops short of the creek channel by a few hundred metres, but is located more than 1 km upstream of the project area in the drawdown zone. There is also an existing boat launch area in Six Mile Bay, but there is no driveable access between the launch area and the site.

Since the operation of the Williston Reservoir, channel morphology in the Six Mile Creek drawdown zone has changed due to the reservoir tailwater conditions and sediment deposition dynamics. Consequently this reach of Six Mile creek has developed into a broad, multi-channel delta land form with generally shallow channels, with poor channel confinement, and potential instability. This process is referred to in the previous phase of the project as having a "perched mouth". During low pool periods, fish access to Six Mile Creek is impaired where the multi-channel "braided" morphology lacks sufficient flow concentration necessary for departing overwintering fish moving into the reservoir

[1] Synergy Applied Ecology. 2010 *Site selection and design recommendations for Williston Reservoir tributary fish access mitigation trial.* Final Report prepared for BC Hydro. January 2010.

and returning spawners moving into the tributary. A site plan of Six Mile Creek is provided in Figure 1-1.

Ole Creek

Ole Creek is located on the west side of Finlay Reach of Williston Reservoir, and about 180 km northwest from Mackenzie. Ole Creek is accessible via a network of logging roads on the west side of Williston Reservoir, but there is no road access to the creek mouth. The mouth of Ole Creek is several kilometres from a forest service road, over generally challenging terrain for any heavy equipment.

Ole Creek is known to be prone accumulation of floating large woody debris during higher pool periods, and also has developed a similar delta feature in the draw down zone. Fish passage at Ole Creek is reported to be impaired based on deposition of large wood debris that can both jam at the creek mouth, as well as abrade and scour physical habitat on the creek fan/delta. Ole Creek was not investigated in detail as part of the Synergy work. A detailed site plan is provided as Figure 1-2.

1.2 FIELD INVESTIGATIONS

Field investigations where conducted on June 21 and 22, 2011 by David Matsubara and Bruce Van Calsteren of KWL. Representative photos of the investigations are provided as Appendix A.

Ole Creek was visited on June 21, and involved a 200 km drive along the radio controlled forest road (direction Tsay Keh Dene), followed by a 30 minute foot traverse from the forest service road to the mouth of the creek. At the time of investigation, the reservoir was flooding, and the reservoir pool level was approximately 665 m elevation. The investigation found that:

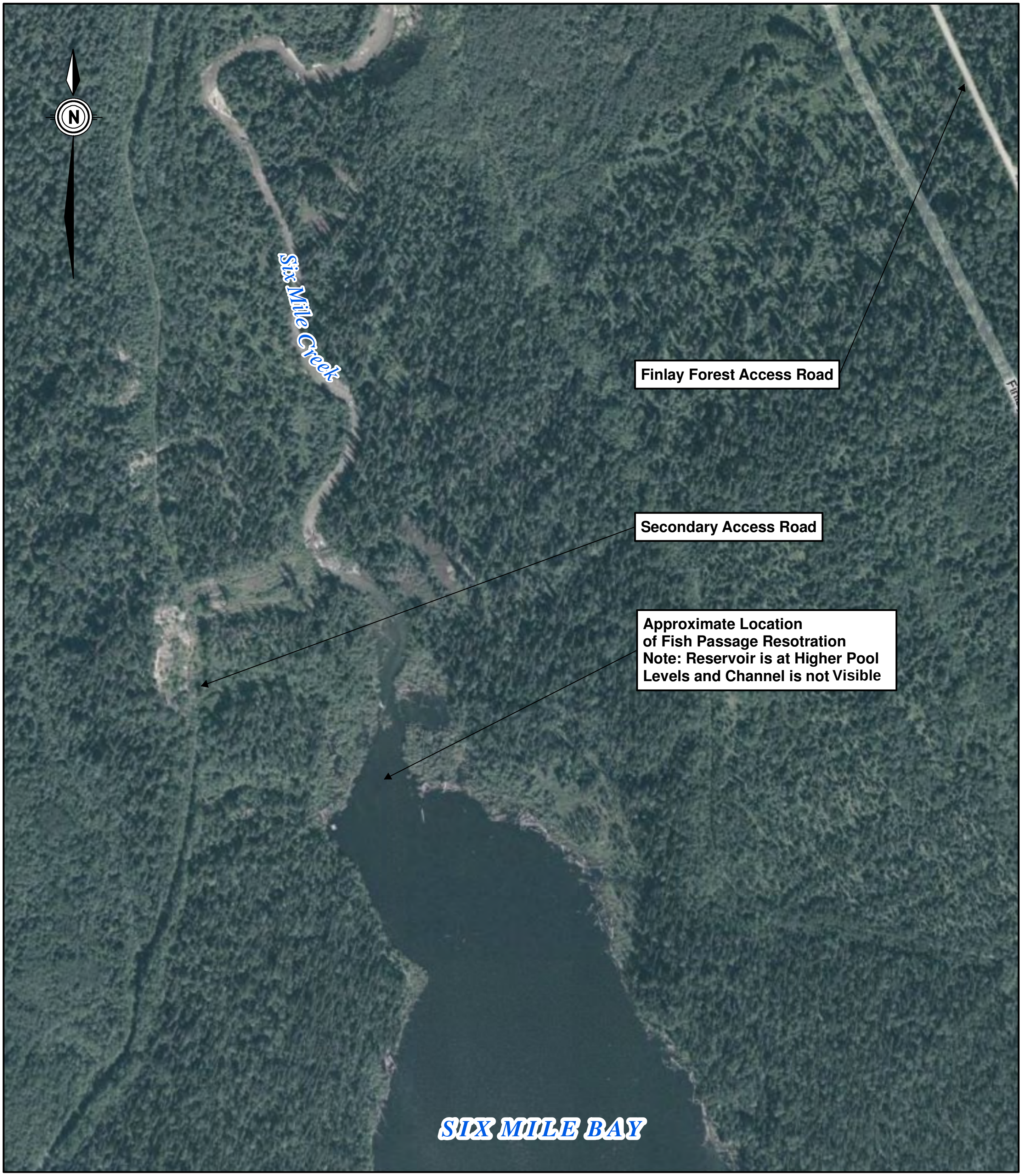
- there are two creek mouths at Ole Creek, the main channel and a side channel (on the north side) that is likely only active in higher discharges;
- there are numerous side channels and evidence of overland flow routes on the contemporary Ole Creek fan downstream of the FSR;
- there is still a substantial volume of LWD across the Ole Creek bay, and the wood is often several units thick;
- older wood and wood lower in the debris pile is less buoyant, and only the top layer is above the pool level;
- the wood jam at the mouth of the main Ole Creek channel is effectively spreading the creek flow laterally across the delta, and limits the formation of an incised channel; and
- sediment near the Ole Creek channel mouth include coarser gravel sediment, but the surface sediment quickly transitions to a uniform sand or sand and silt away from the creek mouth.

GPS observations were made during the field investigation to ascertain whether the channel features shown on the available orthophotos and Lidar mapping are consistent with the current observed features. Based on distinct bank lines near the mouth of Ole Creek, it appears as though the channel has not been actively moving alignment in the past few years.

The general condition and volume of the LWD suggests that the debris has been in the reservoir and likely at Ole Creek for some time. It is possible that the rate of debris generation and accumulation is low and that the aspect and geometry of the Ole Creek bay does not allow for remobilization of the debris in the reservoir.

Six Mile Creek is a short distance from Mackenzie and was accessed via Highway 39. Access to the creek was attempted from several directions. An inactive forestry road located near the Highway 39 crossing of Six Mile Creek was attempted, and the road can be traversed by vehicle to within several hundred metres of the creek. Clearing of this last section would allow access to the creek; however, at this location the proposed work area is more than one kilometre downstream. A second attempt was made from the recreation site boat launch south of the site. The boat launch provides access to Six Mile Bay, but the work area is again more than one kilometre north. This access would be ideal by small boat to reach the site for monitoring or crew access for construction. The site was finally reached by foot overland directly from Highway 39 and required an approximate one kilometre traverse. There is a substantial slope and grade change at the edge of the reservoir that would limit the development of a road to the site. At the time of investigation, the reservoir was flooding, and the reservoir pool level was approximately 665 m elevation. The investigation found that:

- the Six Mile Creek channel is coarse gravel bed channel;
- there is not an abundance of LWD on site, but several isolated wood jams that do not impair fish passage;
- there is lateral erosion of Six Mile Creek at varying elevations leading to abandoned and active channel bifurcations (i.e. this is a perched mouth tributary);
- there are several wood jams located on the medial gravel bars at channel bifurcations;
- there are a few isolated boulder "erratics" on the upper draw down zone; and
- under the available discharge and pool level, fish passage did not appear problematic.



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GMSWORKS#19

Project No.	Date
478-114	November 2010

100 0 300
Scale in Metres 1:10,000

Site Plan
6 Mile Creek Fish Passage Restoration

Figure 1-1

Map Document: O:\0400-0499\478-114\430-GIS\MXD-Rp\478114Fig1-2.mxd
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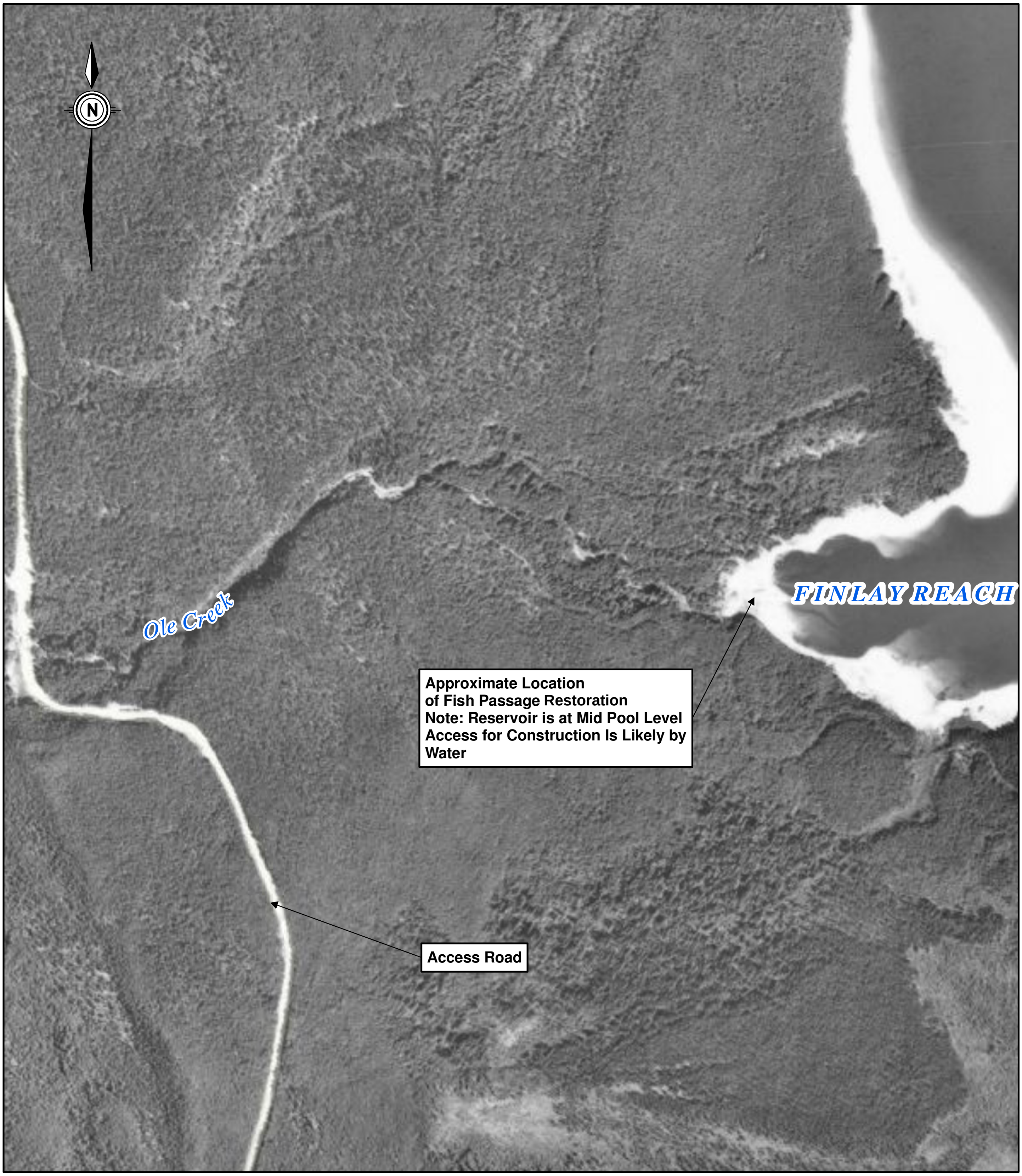

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BC Hydro
GMSWORKS#19

Project No.	Date
478-114	November 2010

100 0 500
Scale in Metres 1:15,000

Site Plan
Ole Creek Fish Passage Restoration

Figure 1-2

Map Document: O:\0400-0499\478-114\430-GIS\MXD-Rp\478114Fig1-2.mxd
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Section 2

Design Parameters

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2. DESIGN PARAMETERS

2.1 WILLISTON RESERVOIR LEVELS

The Williston Reservoir levels for the period from 1972 to 2006 were obtained from BC Hydro for previous work[2]. The average, minimum and maximum daily water levels for Williston Reservoir during this period are summarized in Figure 2-1. The range of average daily reservoir levels for a typical year is:

- minimum: 658.4 m (late-April); to
- maximum: 669.4 m (early-August).

With extreme maximum and minimum values recorded at 672.1 m and 654.4 m, respectively.

The design concepts are based on the range of average reservoir water levels.

2.2 SIX MILE AND OLE CREEK FLOW ESTIMATES

SIX MILE CREEK AND OLE CREEK WATERSHEDS

Six Mile Creek is located on the east side of Parsnip Reach of Williston Reservoir and is approximately 35 km north of Mackenzie. Six Mile Creek discharges to Six Mile Bay in the vicinity of sub-tributary creeks: Lamonti Creek, Patsuk Creek, and Kimta Creek.

Ole Creek is located on the west side of Finlay Reach of Williston Reservoir and is approximately 180 km northwest of Mackenzie. Ole Creek was not assessed in detail during the Inventory Field Work stage of the project; however, based on a desktop reconnaissance, Ole Creek is a smaller, steeper creek that discharges in Finlay Reach at a small bay. Watershed characteristics for Six Mile Creek and Ole Creek are summarized in Table 2-1.

Table 2-1: Six Mile Creek and Ole Creek Watershed Information

Tributary	Watershed Area (km^2)	Median Watershed Elevation (m)
Six Mile Creek	127	1,345
Ole Creek	55.5	1,490

2 Kerr Wood Leidal Associates Ltd. 2008. *Tsay Keh Dene: Extension and Finalization of Erosion Impact Lines.* Final Report prepared for BC Hydro. April 2008.

WATER SURVEY OF CANADA GAUGES

Typically, to estimate the flow conditions on an ungauged watershed, similar, nearby watersheds with Water Survey of Canada (WSC) hydrometric gauges would be used as part of a regional analysis. Gauged watersheds that would be used in the regional analysis would preferably have a period of hydrometric record greater than 10 years, with similar characteristics to the study watershed such as:

- geographic location;
- drainage area;
- elevation (hypsometry);and
- aspect.

This area of British Columbia does not have many WSC gauges and the gauges are often placed on rivers that drain much larger watershed areas. As a result, there are no watersheds nearby with WSC hydrometric gauges that have similar drainage areas to Ole Creek and Six Mile Creek (<=300 km²) and that have a reasonable period of record.

Estimates for the mean annual discharge (MAD), average monthly discharge and 2-year return period discharge in Six Mile and Ole Creeks were made using rivers with larger drainage areas that are nearby (Table 2-2).

Table 2-2: WSC Gauge Information

Gauge Name	Gauge ID	Period of Record	Watershed Area (km²)	Median Watershed Elevation (m)	Mean Annual Discharge (m³/s)
Osilinka River Near End Reservoir	07EC004	1981-2009	1,950	1,340	36.0
Ospika River Above Alley Creek	07EB002	1981-2009	2,190	1,460	40.9

Gauge locations and watersheds are shown on Figure 2-2. The gauges are located near-by on watersheds with similar aspect to the trial tributary watersheds.

Monthly flow estimates for Six Mile and Ole Creeks are summarized in Table 2-3 and illustrated in Figure 2-1. Mean annual discharge (MAD) and the 2-year return period peak flows for each watershed are summarized in Table 2-4.

Table 2-3: Monthly Flow Estimates (m³/s)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Six Mile Creek	0.48	0.40	0.37	0.66	5.01	9.61	4.83	2.17	1.74	1.59	0.91	0.61
Ole Creek	0.21	0.17	0.16	0.29	2.19	4.20	2.11	0.95	0.76	0.70	0.40	0.27

The site visit was conducted in late June, 2011, and regionally, peak stream flows associated with snow melt are experienced in June. Based on observations and comparisons to similarly sized creeks that are gauged, we would estimate that the flows would be representative of a May or July discharge (see table 2-3) rather than capturing the peak of the freshet. We would estimate that the peak of the freshet occurred in early May based on local hydrometric gauges for large rivers. The Osilinka River peaked in the third week of May, while the Omineca River peaked in the last days of May. This would support the observations of discharges similar to a late July or early August regional discharge.

Table 2-4: Mean Annual Discharge and 2-Year Return Period Flow Estimates (m^3/s)

	MAD	2-Year Return Period
Six Mile Creek	2.37	17.0
Ole Creek	1.03	7.44

The larger watershed area at the gauged locations would change the timing of flows in response to rain events, etc., and would likely attenuate peak flows. However, the estimates for Six Mile and Ole Creeks are for average monthly flow conditions, so the larger watershed areas are not expected to affect the monthly flow estimates substantially. The attenuation of peak flows within the larger watersheds may cause the estimated 2-year return period peak flow in Six Mile and Ole Creeks to under predict flow conditions in the tributaries, but could overestimate baseflow conditions.

The percent area-elevation of the gauged watersheds and the trial tributary watersheds were compared in hypsometric curves (Figure 2-3). Based on the hypsometric curves, the elevations of gauged watersheds are similar to the ungauged watersheds. The hypsometric curves indicate that Six Mile Creek would likely have an earlier spring freshet as it is lower elevation than either Osilinka River or Osipika River. However, for the purpose of monthly flows, the gauged stations provide a reasonable approximation of the range of flow conditions on Six Mile Creek and Ole Creek for average conditions throughout the year, but would be expected to peak more quickly in the Spring.

MONTHLY FLOW ESTIMATES COMPARED TO WILLISTON RESERVOIR LEVELS

Compared to average reservoir levels in Williston Reservoir, it appears that the lowest reservoir levels and lowest flow period occurs in April. Monthly flows begin to increase in May and peak in June, with water levels in Williston Reservoir lagging approximately a month behind.

This indicates that the greatest obstacle for fish passage due to lack of water depth in the channels would likely occur during April when reservoir levels and flow levels are at their combined lowest.

2.3 TARGET FISH SPECIES

Synergy Applied Ecology completed fish presence/absence sampling in Six Mile and Ole Creeks during the Inventory Field Work stage of the project (Synergy 2010). From the Synergy report, the following fish presence was confirmed:

- Ole Creek: bull trout, mountain whitefish, kokanee, and sculpin; and
- Six Mile Creek: bull trout, rainbow trout, slimy sculpin, kokanee, and prickly sculpin.

In addition to the Synergy report, Fisheries Information Summary System (FISS) database lists Six Mile Creek as supporting: bull trout, rainbow trout, slimy sculpin, Arctic grayling, Dolly Varden. No FISS records exist for Ole Creek.

2.4 GOALS FOR FISH PASSAGE

A summary of habitat characteristics for each species and life history stage is in Table 2-5 below. However, the goal for the channel designs is to improve fish passage and provide more accessibility rather than provide ideal habitat.

Table 2-5: Fish Habitat Summary

Species	Habitat	Spawning	YOY	Juvenile	Adult
Mountain Whitefish	Depth Range (m)	0.5-9.0	-	Deep	Deep
	Dominant Substrate	Gravel-boulder	Silt-boulder	Gravel-cobble	Gravel-cobble
	Velocity Range (m/s)	-	-	-	-
	Duration	Sept. – Feb.			
Bull Trout	Depth Range (m)	0.3-0.6	<1.0	<1.0	-
	Dominant Substrate	Gravel-rubble	Cobble-boulder	Silt, cobble-boulder	Larger than gravel-boulder
	Velocity Range (m/s)	0.14-0.52	0.1-0.28	0.1-0.28	-
	Duration	Sept. – Dec.			
Prickly Sculpin	Depth Range (m)	-	-	-	>1.0
	Dominant Substrate	Cobble-bedrock			Gravel-boulder
	Velocity Range (m/s)	-	-	-	<0.05
	Duration	**Feb. – Jul**.			
Slimy Sculpin	Depth Range (m)	-	-	-	-
	Dominant Substrate	-	-	-	Sand-boulder
	Velocity Range (m/s)	-	-	-	-
	Duration	-	-	-	-
Rainbow Trout	Depth Range (m)	-	-	-	-
	Dominant Substrate	Gravel	-	-	Gravel-large substrate
	Velocity Range (m/s)	-	-	-	-
	Duration	**Mar. – Jun**.	-	-	-
Kokanee	Depth Range (m)	<1.0	-	-	-
	Dominant Substrate	Gravel-cobble	-	-	-
	Velocity Range (m/s)	-	-	-	-

	Duration	Aug. – Nov.	-	-	-
Dolly Varden	Depth Range (m)	-	-	-	0.3
	Dominant Substrate	Large gravel	-	-	-
	Velocity Range (m/s)	-	-	-	-
	Duration	Sep. – Nov.	-	-	-
Arctic Grayling	Depth Range (m)	-	0-0.6	>0.6	<0.3
	Dominant Substrate	Mud, gravel-rock	Silt-boulder	-	Gravel, boulder-bedrock
	Velocity Range (m/s)	-	-	<0.8	0.21-0.8
	Duration	**Apr. – Jul.**	-	-	-

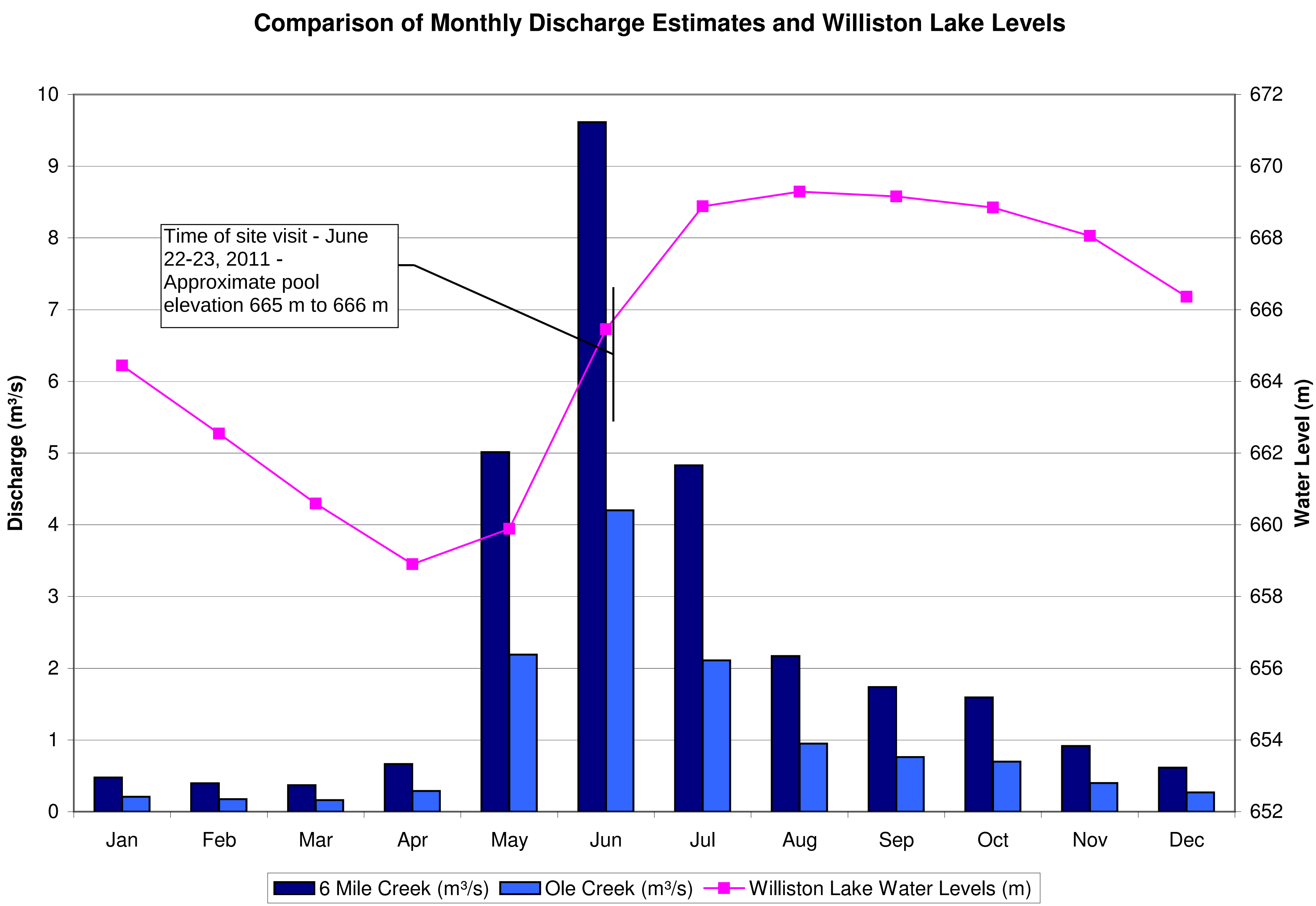
From Table 2-5, the species of interest that will be trying to move into the system during the lowest flow and water level period (March to mid-May) as shown in the shading includes:

- Prickly Sculpin;
- Rainbow Trout; and
- Arctic grayling.

Because fish passage during low pool is the design goal, the depth guideline for fish passage through culverts is used to determine minimum water depths in the channel at low flow. The general requirements for fish passage are:

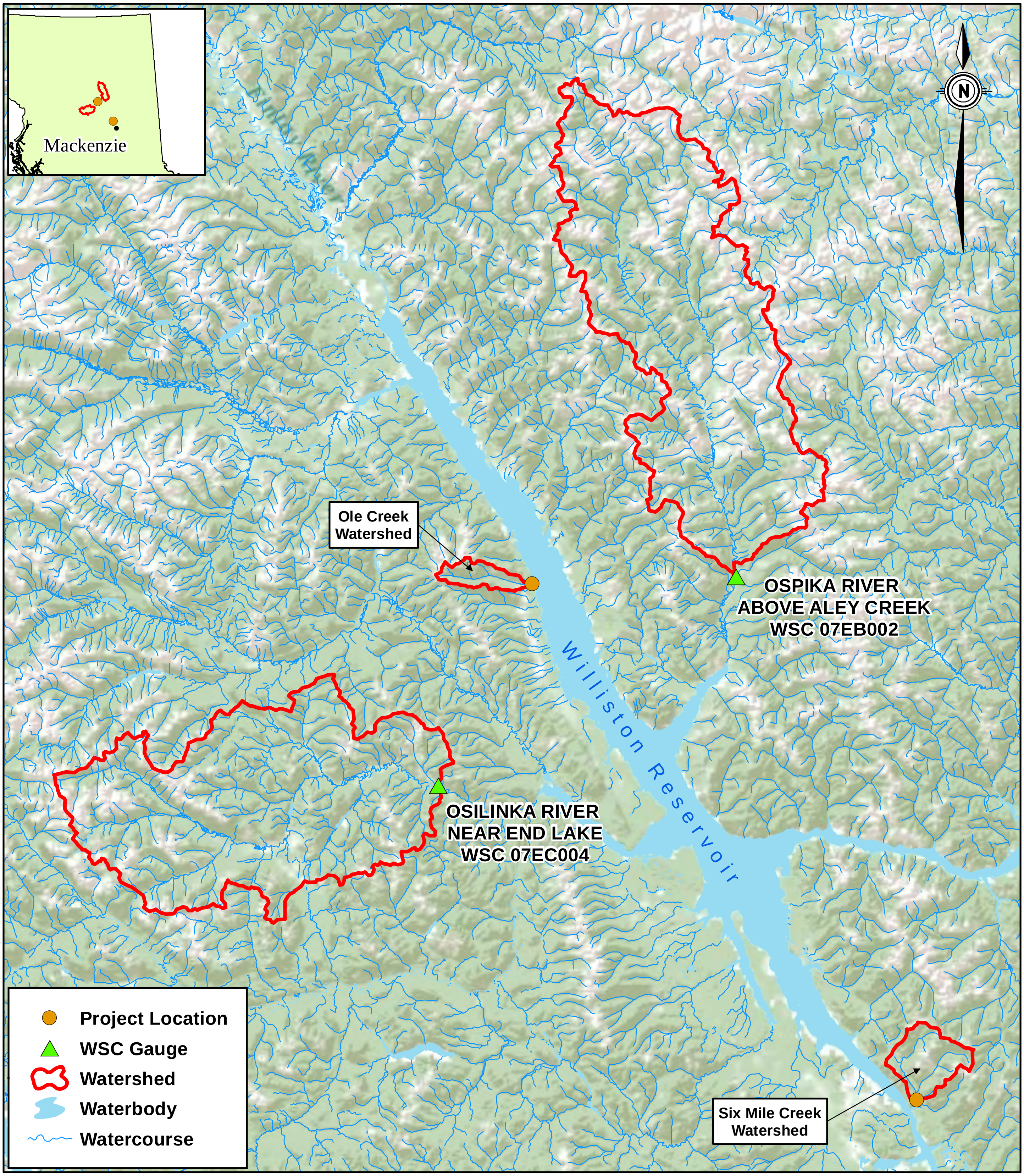
- adult anadromous salmonids minimum depth = 0.3 m (1 ft);
- adult non-anadroumous salmonids minimum depth = 0.2 m (0.67 ft); and
- juvenile salmonids minimum depth = 0.05 m (0.5 ft).

To account for some uncertainty in the flow estimate and water level estimates, the minimum depth being used for the conceptual design is 0.3 m.



Comparison of Monthly Discharge Estimates and Williston Lake Levels
Time of site visit - June 22-23, 2011 - Approximate pool elevation 665 m to 666 m
Discharge (m³/s)
Water Level (m)
10
9
8
7
6
5
4
3
2
1
0
672
670
668
666
664
662
660
658
656
654
652
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
6 Mile Creek (m³/s)
Ole Creek (m³/s)
Williston Lake Water Levels (m)

Figure 2-1



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BC Hydro (GMS Works #19)

Project No.	Date
478-114	February, 2011

25 0 25
Kilometers

Project Location and WSC Stations

Figure 2-2

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Author: RTaylor

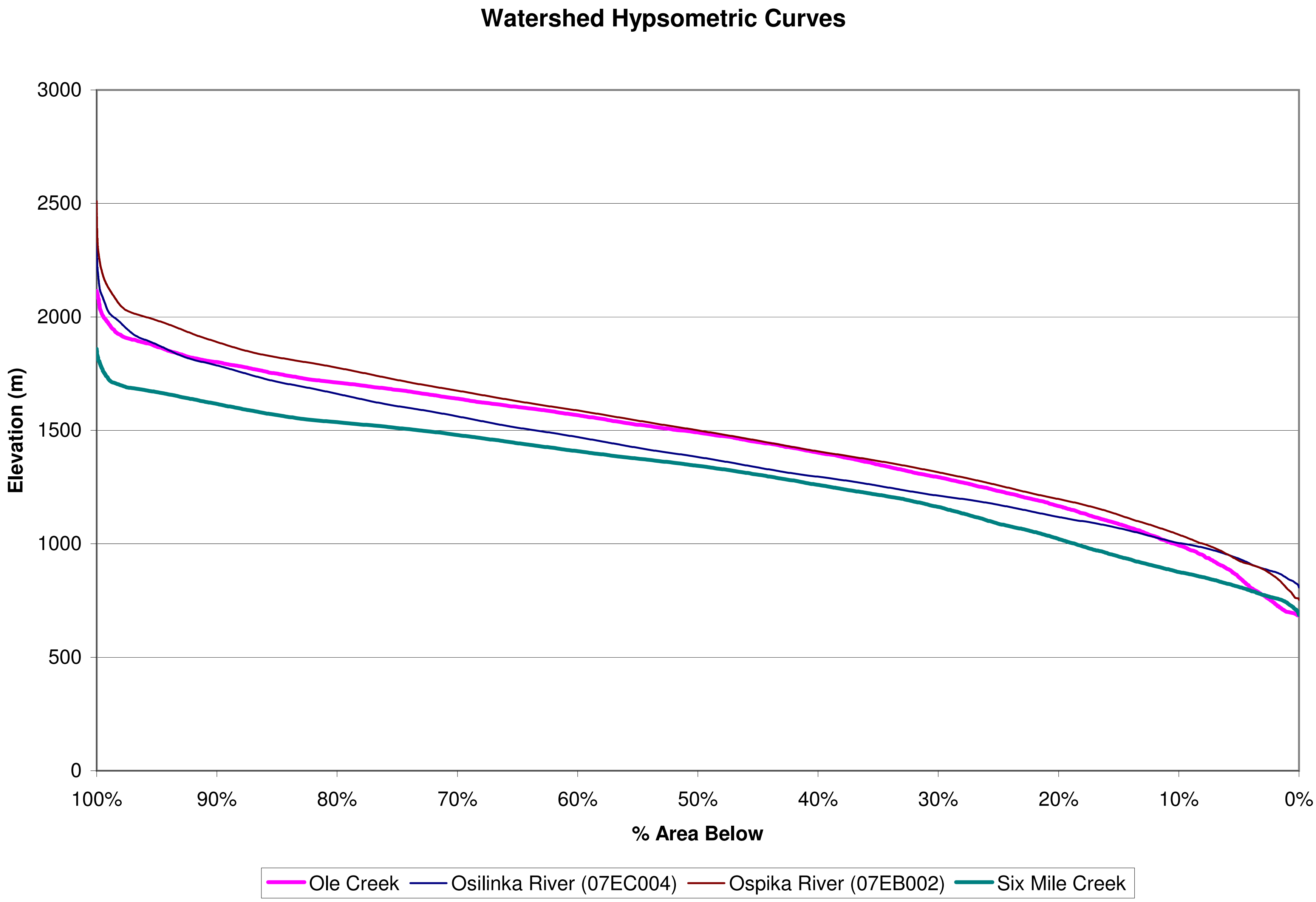
Watershed Hypsometric Curves
3000
2500
2000
1500
1000
500
0
Elevation (m)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
% Area Below
Ole Creek
Osilinka River (07EC004)
Ospika River (07EB002)
Six Mile Creek

Figure 2-3

Section 3

Design

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3. DESIGN APPROACH

A plan and profile for Six Mile Creek and Ole Creek is shown in the design drawings in Appendix B. The basis for design is a combination of Lidar aerial survey data, aerial orthophotos, and site investigations.

At the early stage of this project, a number of concepts were developed to assess feasible options for the project. These concepts were reviewed in the field and with Michael McArthur and Jason Watson of BC Hydro. Based on the site constraints and the review process, a number of goals were developed that include:

- the design should incorporate the implementation of a number of concepts to test the performance, suitability, construction costs, and maintenance requirements for a number of approaches;
- the design should limit the need to import large volumes of costly or other off-site materials;
- the design should try in incorporate the reuse of on-site or regionally available wood debris;
- the works should be able to be constructed by local contractors; and
- the works can include the utilizing earthworks equipment.

The approach for both creeks is to improve fish passage over the fan/delta area during low flow periods. This involves confining the current channel to a single thread channel where possible and beneficial to fish passage. In additional to general excavation and filling of side channels, a number of design treatments were developed to create instream flow training structures that provide instream habitat potential and ongoing channel structure. The design also includes more traditional approaches such as debris booms to test the effectiveness of a simple on-site structure. The design elements are as follows and are detailed in the design drawings in Appendix B.

Floating Debris Boom

A floating debris boom was considered for Ole Creek to prevent additional debris from entering the Ole Creek bay and potentially worsening the problem at the creek mouth. In general BC Hydro experience with debris booms on Williston Reservoir have been poor and problematic. To limit ongoing maintenance issues, debris booms are not being considered for this project.

Low Gravel Berm with Buried Wood Debris

At the mouth of Ole Creek, two low gravel containment berms are proposed. These berms will act to confine the channel and will involve some excavation of the channel bed to source the berm material. The berms will incorporate low buried wood debris that is salvaged from the site, and will be incorporated to create low scour elements and near bank erosion resistance. The wood debris utilized should be of moderate size and could be selectively the older and wetter wood to limit buoyancy. No mechanical connections to limit the cost of imported ballast boulders, but rather an appropriate depth of bury and cover to resist movement.

While lack of mechanical anchoring is not standard practice in fish habitat design typically seen in watershed restoration works, this approach has been selected to test the applicability, and due to the very low risk associated with loss of one or more wood elements. If some wood is lost, the overall berm structure will not be sacrificed.

Mechanical connections can however be used, and have been noted on the design drawings as being optional and based the conditions at the time of construction and ability for the contractor to effectively complete the work. The approach with mechanical anchors is to use “boom chains” or an equivalent product to link wood members together, using the deeper fully buried members as deadman anchors for the partially buried members.

The low gravel berm is proposed to be willow live staked to allow revegetation where possible. In the event that not enough coarse gravel is available to construct the berm, finer sediment should be used and protected with erosion control matting.

Woody Debris Catcher

Situated outside of the gravel berms at Ole Creek, a higher woody debris catcher has been proposed. This structure would be constructed by excavating a trench that would be sequentially filled with wood debris and gravel ballast in a layered approach. The key to this structure is the orientation of a large volume of wood in a vertical orientation to trap debris that may be mobile in the Ole Creek bay. In addition to the vertical members, a high density of lateral debris members are proposed to lock-in and pin down the vertical members, and these members would be entirely buried. This structure will be located near the upper range of the reservoir operation (pool level) and it is proposed that the catcher ballast fill be vegetated with live willow cuttings and grass ground cover.

The structure should be constructed from coarse gravel and cobble sediment which should be occurring in the higher elevations. The side slopes should be left as gentle as possible (e.g. 2 to 3 horizontal to 1 vertical), but could adjust over time given reservoir operations and wave action. The sediment should be bucket compacted and all void areas around the wood effectively filled.

For a higher factor of safety, mechanical connections (e.g. boom chains) could be utilized between the vertical and lateral debris members to improve overall stability and resistance as discussed in the previous section.

Woody Revetment (sand cover)

For the lower reaches of Ole Creek, at key bifurcation points, woody revetments are proposed. These structures would be constructed in the bifurcation channel to confine the main channel, utilize available debris, and create channel structure. These structures would be constructed in sand and silt, and consequently the ballast fill would be fine grained soils that would need to be protected. An erosion control matting is proposed to cover this fill, and would be staked in place with willow live stakes. It is likely that the live stakes would not root, but would act to anchor the erosion control matting and would be locally available and natural material.

The berm should be constructed from competent granular fill, and compacted with light compaction equipment (e.g. heavy plate tamper) where possible. The side slopes should be graded to 3:1 horizontal to vertical and armoured with any available gravel or cobble.

The erosion control matting should be an entirely bio-degradable product, and medium weight coconut matting has been proposed for this application. Like the low gravel berm, low buoyancy wood debris should be selected for this application, and mechanical connections can be used.

Woody Revetment (gravel cover)

The gravel cover woody revetment is proposed for Six Mile Creek, where there is more available sand and gravel; however, either structure could be used in either application depending on the available channel sediment.

The purposed of the woody revetment is similar to the approach on the Ole Creek. The goal is to provide confining structures at key bifurcation points, consequently concentrating the discharge and providing deeper channel depths. The large wood component provides two main purposes: scour elements around the root wads for fish passage, but also to provide lower velocity areas adjacent to the berm (lower potential for fluvial erosion), woody revetments are proposed. The channel confinement will allow sediment transport further into the reservoir rather than the early deposition and channel bifurcation. Parts of the channel should be maintained by the scour provided for by the root wads.

At Six Mile Creek, it is proposed that a willow brush layer be included in the revetment, especially in the higher reaches that are infrequently inundated, and for shorter duration. The brush layer has been proposed to encourage revegetation, some root cohesion, and other environmental values, but this would be more experimental approach rather than a core element of the design. Regular fluvial erosion would also be resisted by the coarse gravel sediment.

Vegetated Geogrid Bank

The vegetation geogrid bank is a typical bioengineering treatment to create a reinforced soil bank that can be protected against current erosion. The bioengineering approach includes a high density of willow cuttings that provide long term stability, and may be successful in some elevation bands in Williston Reservoir. The structure can be constructed without the willow cuttings, but then would be reliant only on the erosion control matting for local erosion resistance.

The vegetation geogrid approach is proposed to provide a treatment that can be constructed with finer soils found on-site to provide an erosion (fluvial) resistant channel confinement structure. This structure is best suited at higher locations in the reservoir where the willow would be expected to better grow. The overall purpose of the geogrid berm is to provide bifurcation channel cut-offs and channel confinement.

Enhanced Log Jam

Log jams occur at several locations on Six Mile Creek at channel bifurcation areas. This treatment would enhance the log jam by utilizing the existing wood debris and adding additional debris to effectively cut off the channel bifurcation. This approach is similar to some of the others, but is expected to be a longer, narrower, and structure, that could experience flow over the top surface. As such, the goal is to utilize sand and gravel ballast fill for erosion resistance and natural armouring.

Mechanical connections are not necessary if site conditions permit; however, connectors can be used, and have been noted on the design drawings as being optional and based the conditions at the time of construction and ability for the contractor to effectively complete the work. The approach with mechanical anchors is to use “boom chains” or an equivalent product to link wood members together, using the deeper fully buried members as deadman anchors for the partially buried members.

It is the intention that all of the works could be constructed with one or two excavators and a small crew of labourers, and would ideally be constructed during low pool in the dry. The jams are located at 664 m and higher, so ideally the water levels would be at 662 m or lower unless mechanical connectors are used. In order to construct these works, site would be prepared by excavating a trench across the proposed location. The vertical oriented logs would be placed first followed by horizontal logs to overlay the first logs. This sequence would occur a number of times until the three or four rows of vertical members have been placed, adding soil as the work advances. The finished surface should ensure that there is enough coarse gravel over the structure to resist regular erosion. In the event that only fine grained soil is available, mechanical connectors should be considered.

If mechanical connectors are used, the installation approach could be revised. Ideally one large horizontal member would be connected to three or more vertical members and lowered into the trench. This would allow the horizontal member to be entirely covered and act as a deadman anchor. The connectors could be simple boom chains that are fit through field drilled holes and set in place. A general sequence would occur moving across the trench creating a cohesive jam.

3.1 CONSTRUCTION LAYOUT AND APPROACH

A general construction layout has been presented in the following section, and includes a preliminary layout of features, that would be contingent on available material and access and budget. The layout is depicted in the preliminary design drawings in Appendix B.

Six Mile Creek

The works on Six Mile Creek are focussed in the upper reaches of the stream where the channel bifurcations are most evident and established. During construction addition treatments could be constructed in the lowest reaches, however, this would be a field based decision given the current channel configuration in that area. The works for Six Mile Creek include:

- 100 m long of woody revetment;
- 200 m long of vegetated geogrid slope; and
- 450 m^2 of enhanced log jam.

Ole Creek

The works on Ole Creek are generally focussed around the mouth of Ole Creek, but also include woody revetments in the lower reaches and the debris boom. During construction addition woody revetments could be constructed in the lower reaches, however, this would be a field based decision given the current channel configuration in that area. The works for Ole Creek include:

- 60 m long (approximately 400 m^3) of low gravel berm;
- 50 m long (approximately 1000 m^3) of low gravel berm; and
- 60 m long of woody revetment.

3.2 CONSTRUCTION ACCESS AND LOGISTICS

SIX MILE CREEK

Construction access for Six Mile Creek appears to be fairly straight forward from Mackenzie. Six Mile Bay is approximately 40 km northwest of Mackenzie via Hwy 43 and the Parsnip West Forest Service Road (FSR). Barge access is recommended for the site to reduce the access disturbance and allow more effective importing of construction materials. If beneficial, smaller barges could be used to shuttle equipment from the recreatational boat launch site on Six Mile Bay, rather than a larger barge from Mackenzie.

Work on the Six Mile Creek delta may require the use of timber track pads to prevent excavator stranding issues. Some construction materials may be available from or near the access to the creek.

OLE CREEK

Ole Creek is about 180 km northwest of Mackenzie (along the Finlay Reach of Williston Reservoir). Travel to Ole Creek is more complicated and requires travelling a network of FSRs. In addition, the mouth of Ole Creek is not accessible from the nearest FSR. As a result, barges may be the most effective mode of access for heavy equipment and materials.

One of the local barge operators, Peace Navigation (located in Mackenzie), was contacted and they have available a barge complete with lodging accommodations for the work crews. This type of arrangement may be preferable to reduce travel time and cost.

TIMING OF CONSTRUCTION

The timing of construction is an issue for this work. There should be a short window between ice "break up" on the reservoir and reservoir filling. As can be seen on Figure 2-1, the larger rivers will peak in June, or near the end of May. The smaller tributaries would be expected to have peaked earlier with the local snow melt.

The ideal time to construct would be during the lowest reservoir levels, which may coincide with higher flows on the tributaries. However, it should be possible to effectively divert creek flows in the lowest reaches to construct the first works, the work should move successively upstream where the works will be more confined. While formal cofferdams are not foreseen for this work, construction of gravel berms with temporary erosion resistant lining (e.g. poly sheeting, filter fabric, etc) would be appropriate to control creek flows. Proceeding with works below the reservoir level is not recommended.

Any willow cuttings should be harvested while the plants are dormant, and could be cut in the early spring. Some of these plants will be inundated, partially or fully, in summer, so concerns over dry conditions should not be a concern. It will be very dependent on reservoir operations how the willow cuttings will survive, which can not be predicted.

3.3 SITE MONITORING

The construction of these works are very dependent on the conditions during construction, construction materials available on-site and expertise of the crew. The nature of the work will involve field decisions and direction. During construction, an appropriately qualified individual should ensure that the works are being constructed in accordance with the design, and that works are well documented to support the long term project monitoring. Ideally this individual would represent BC Hydro, and could work cooperatively with the contractor to ensure the works are constructed well.

These sites are not easily accessed. It is proposed that the design include a remote data collection platform, consisting of a digital camera, data collector, solar battery tender, and remote telemetry, and potentially a water level / temperature transducer. This would allow regular photo documentation, and continuous water data to support the pilot project monitoring. KWL has developed and implemented numerous stations across BC to collect various streams of data, and would cost substantially less than just one site visit by a team of professionals. It is expected that the two stations could be fabricated and installed for about $15,000 or $20,000 depending on the instrumentation. Monthly data costs would be about $100/month.

The site telemetry could be satellite or cellular telemetry depending on coverage at the Six Mile Creek site.

Section 4

Construction Costs

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4. CONSTRUCTION COSTS

It is expected that the cost of mobilizing equipment and materials to the sites will be quite high given the access issues. Therefore the design approach utilizes as much on-site material as possible to minimize the cost of transporting material to the sites. Based on this approach there are fixed costs associated with access and materials, and the remainder of the costs related to production. The design proposes a number of techniques to improve fish passage. In order to achieve the project goals and meet overall budgets developed under the water use plan, the works should be scalable to utilize techniques both to maximize extent of construction and employ some innovative techniques where appropriate.

Given the lack of site information at this point, the construction of the works will likely require on-site field direction to address the limitations of the Lidar data (due to spatial uncertainty, and possible channel changes since data capture), and to adapt the work to meet an overall budget. In order to achieve this, a unit rate style contract based on equipment time rather than units of construction may provide the necessary flexibility.

4.1 COST ESTIMATES

To develop the cost estimates and project scope, a guiding budget of $100,000 was used to account for fixed costs (e.g. mobilization) and scalable costs (e.g. materials, labour and equipment). The following Table 4-1 outlines the costs for Six Mile Creek, while Table 4-2 outlines the costs for Ole Creek.

Table 4-1: Six Mile Creek Class D Cost Estimates

Item	Description	Unit	Estimated Quantity	Unit Rate	TOTAL PRICE $	Comment
1	**General Costs**					
1.01	Insurance, Bonding Overhead	L.S.	1	6,000	6,000	Allowance for 5%
1.02	Barge Equipment and Material	hr	14	650	9,100	load/unload
	SUBTOTAL FOR TASK				**15,100**	
2	**Six Mile Creek Materials**					
2.01	Coconut Matting	sq.m	1600	2.25	3,600	Allows for 200 lineal metres to a height of 0.9 m.
2.02	Woody Debris	cu.m	375	25.00	9,375	Allows for 100 m at 1 log per m at 1.5 cu.m
2.03	Live Willow	each	10,000	1.50	15,000	
	SUBTOTAL FOR TASK				**27,975**	
3	**Six Mile Creek Equipment and Labour**					
3.01	Excavator (Ex 200)	days	20	1,600	32,000	Includes 20 days for construction
3.02	Track Pads	days	20	200	4,000	
3.03	Labourer 1	days	20	280	5,600	Includes 20 days for construction
3.04	Labourer 2	days	20	280	5,600	Includes 20 days for construction
	SUBTOTAL FOR TASK				**47,200**	
	Contingencies	11%			9,930	
	TOTAL AMOUNT (excl. HST)				**100,000**	

Table 4-2: Ole Creek Class D Cost Estimate

Item	Description	Unit	Estimated Quantity	Unit Rate	TOTAL PRICE $	Comment
1	**General Costs**					
1.01	Insurance, Bonding Overhead	L.S.	1	5,000	5,000	Allowance for 5%
1.02	Barge Equipment and Material	hours	44	450	19,800	150km from MacKenzie + 4 hrs to load/unload
1.03	Live out Barge Costs	days	12	1,500	18,000	To be confirmed
	SUBTOTAL FOR TASK				**42,800**	
2	**Six Mile Creek Materials**					
2.01	Additional hardware allowance	l.s.	1	2,500	2,500	Allows for about 150 cu.m
2.02	Willow Cuttings	l.s.	1	10,000.00	10,000	Allowance
	SUBTOTAL FOR TASK				**12,500**	
3	**Six Mile Creek Equipment and Labour**					
3.01	Excavator (Ex 200)	days	15	1,600	24,000	Allows for 15 days consturction
3.02	Track Pads	days	15	200	3,000	
3.03	Labourer 1	days	15	280	4,200	
3.04	Labourer 2	days	15	280	4,200	
	SUBTOTAL FOR TASK				**35,400**	
	Contingencies	10%			9,070	
	TOTAL AMOUNT (excl. HST)				**100,000**	

Construction costs will be very dependent on the approach to purchasing and the allocation of risk to the contractor. Given the short period for construction, this work will require ideal conditions, and could be affected by ice on Williston Reservoir, snow on the ground at the sites, or other factors.

The costs outlined above are typical unit rate for equipment and material for this type of work. Given the local economy and availability or lack of availability for equipment and labour unit rate can vary. These rates represent typical rates in a moderately competitive market. It is recommended that the work be issued as a unit rate contract to provide cost control ability for BC Hydro, and a lower level of risk to the contractor. In the event that costs are above the available budget, it is recommended that the scope of work be revised to meet the project constraints.

Prior to moving forward with construction, the next foreseeable steps will include;

- obtain necessary environmental approvals;
- determine method of procurement and confirm final construction budget;
- identify construction schedule windows and time for procurement.

4.2 REPORT SUBMISSION

Prepared by:

KERR WOOD LEIDAL ASSOCIATES LTD.

David Matsubara, M.Eng., P.Eng..
Senior Hydrotechnical Engineer

Reviewed by:

Dave Murray, P.Eng.
Senior Technical Review

Appendix A

Photographs

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Appendix A - Photographs

Photo A.1: Six Mile Creek looking downstream from forestry road

Photo A.2: Six Mile Bay from Recreational Boat Launch

Appendix A - Photographs

Photo A.3: Six Mile Creek looking upstream in the upper reaches – note fine floodplain sediment over gravel / cobble

Photo A.4: Six Mile Creek looking downstream about mid reach

Appendix A - Photographs

Photo A.5: Six Mile Cree at upper woody revetment proposed location

Photo A.6: Example of bar surface – tape measure set to 1 m

Appendix A - Photographs

Photo A.7: Ole Creek from FSR Bridge

Photo A.8: Ole Creek looking upstream and across to main mouth of Ole Creek

Appendix A - Photographs

Photo A.9: Looking south across Ole Creek delta

Photo A.10: Finer gravel gradation on the north banks of the Ole Creek delta

Appendix A - Photographs

Photo A.11: Coarser gravel on the south bank of the Ole Creek delta near the main mouth – note this coarser gravel is spotty.

Photo A.12: Looking downstream from the mouth of Ole Creek, proposed low gravel berm area for right bank in foreground.

Appendix A - Photographs

Photo A.13: Looking north across the Ole Creek delta, note the creek flow through the debris, and proposed location of the low gravel berm and debris catcher in the foreground.

Photo A.14: Looking downstream in Ole Creek from the mouth, standing at the edge of the debris.

Appendix B

Design Drawings

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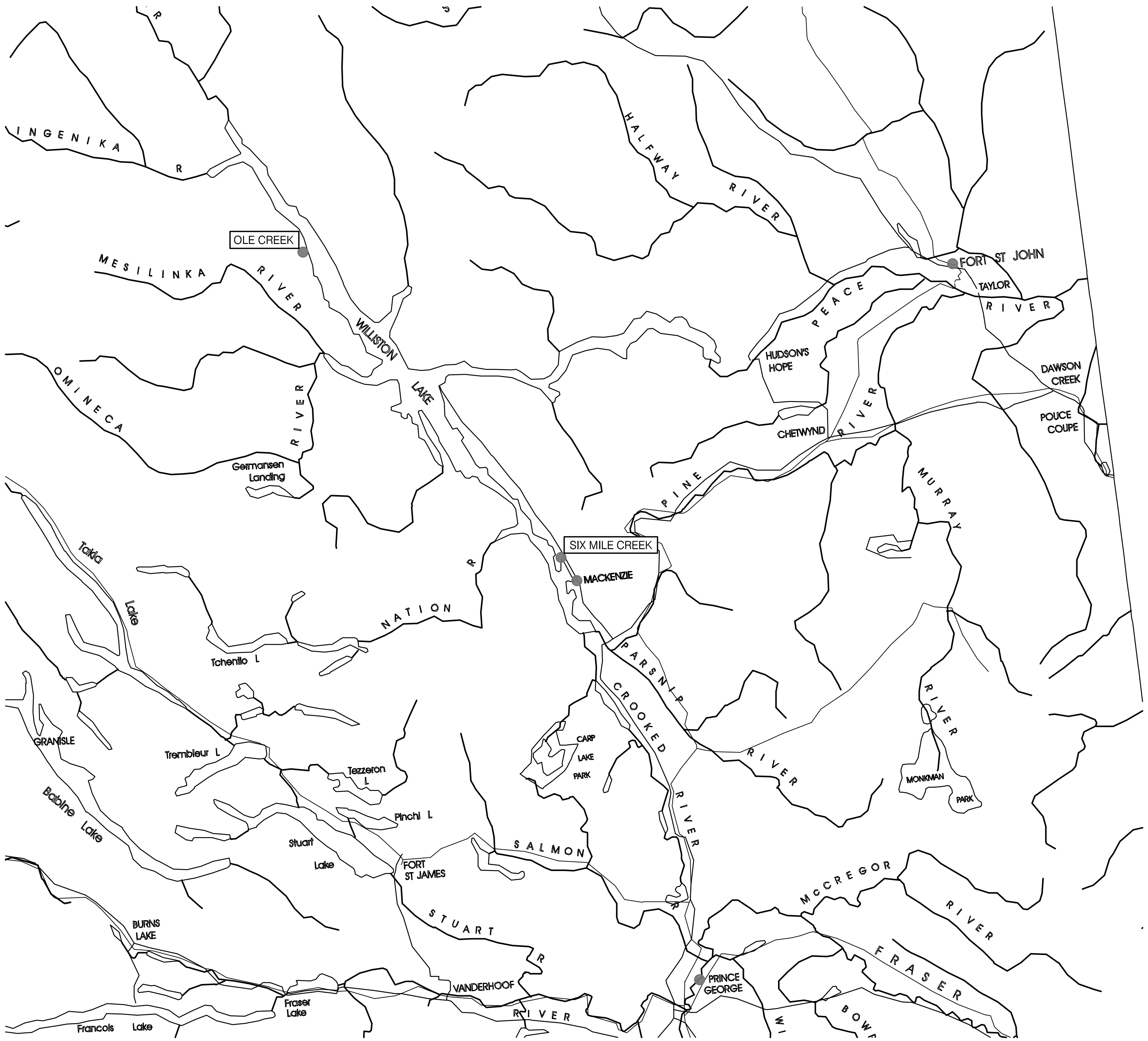

LOCATION PLAN
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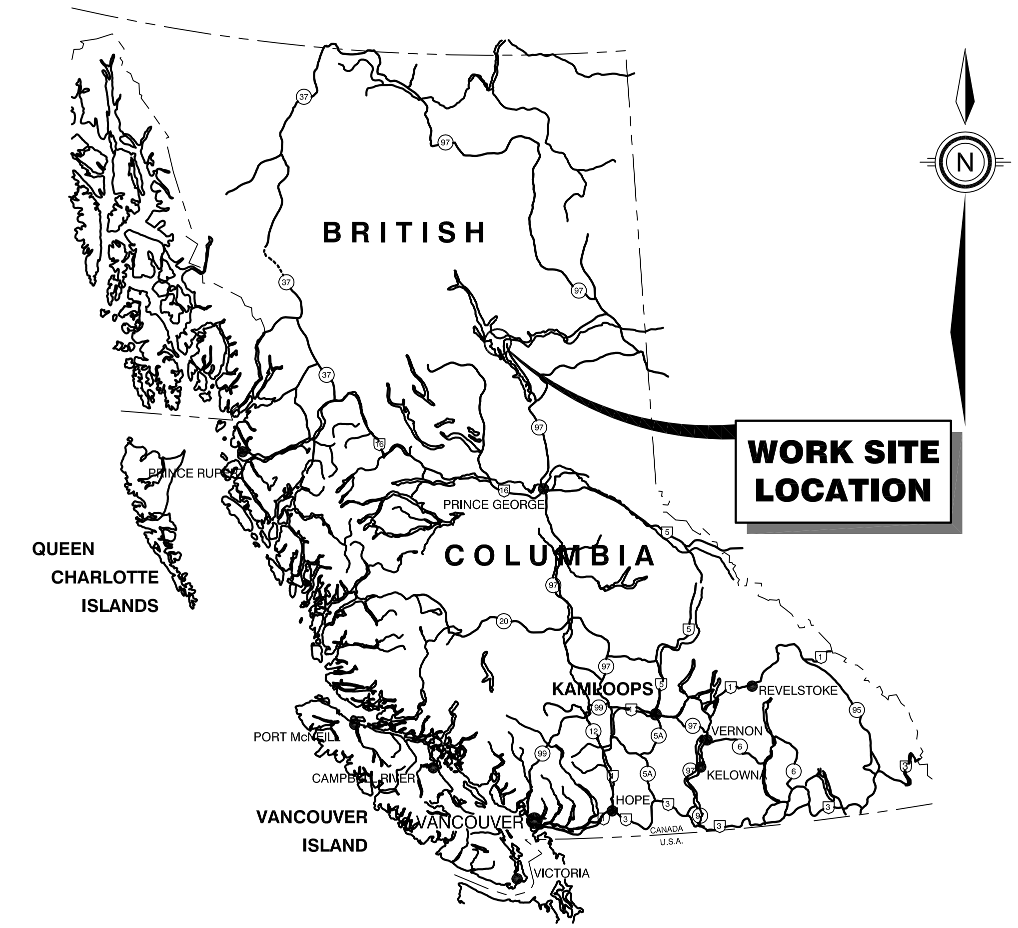

KEY PLAN
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DRAWING LIST

SHEET NO.	DRAWING NO.	DESCRIPTION
1	G1	LOCATION PLAN, KEY PLAN, AND DRAWING LIST
2	SW1	OLE CREEK PLAN AND PROFILE
3	SW2	OLE CREEK DETAILS
4	SW3	SIX MILE CREEK PLAN AND PROFILE
5	SW4	SIX MILE CREEK PLAN AND PROFILE
6	SW5	SIX MILE CREEK DETAILS

GMS WORKS #19
WILLISTON RESERVOIR TRIAL TRIBUTARIES
OLE CREEK AND SIX MILE CREEK

AT FULL SIZE THIS BAR MEASURES 100mm. ALL SCALES REFERENCED TO FULL SIZE.

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WILLISTON RESERVOIR TRIAL TRIBUTARIES
OLE CREEK AND SIX MILE CREEK
LOCATION PLAN, KEY PLAN, AND DRAWING LIST

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Sheet 1 of 6 | Rev. No. 0

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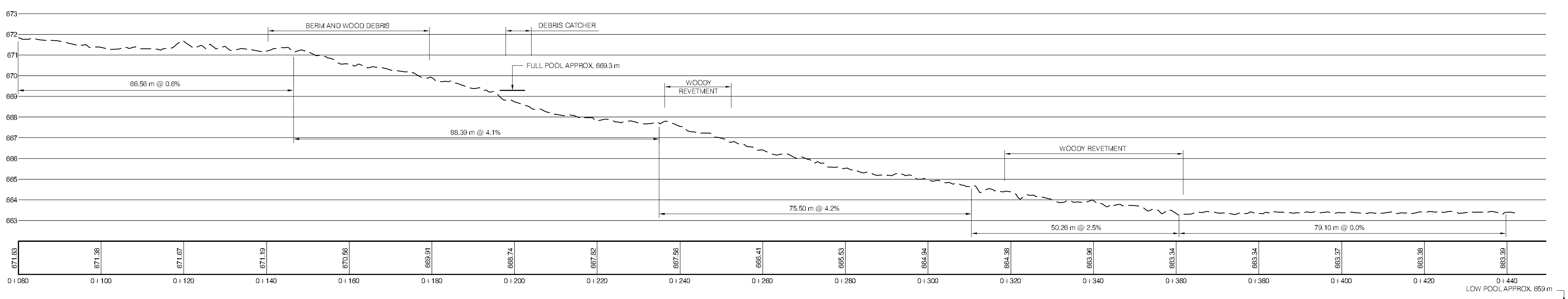

CREEK PROFILE

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OLE CREEK - PLAN AND PROFILE

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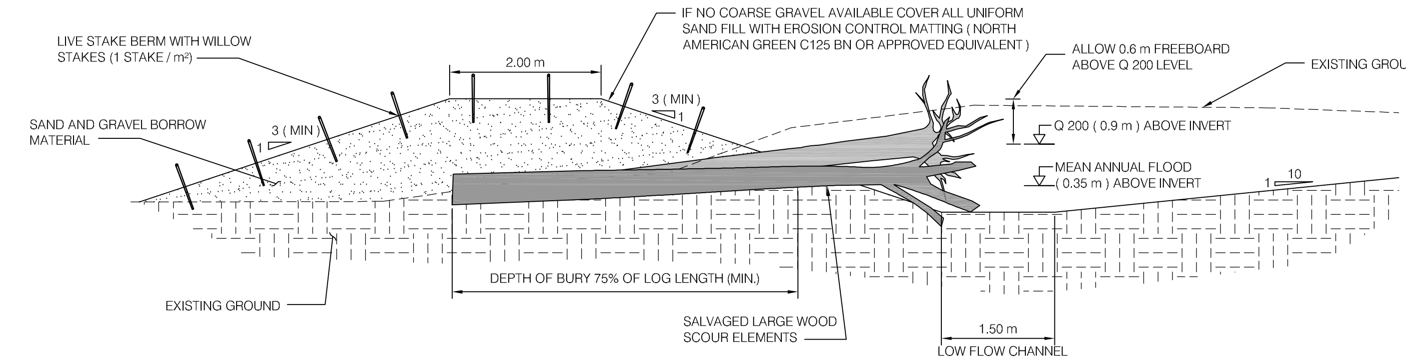

LOW GRAVEL BERM WITH BURIED WOOD DEBRIS DETAIL A / SW1

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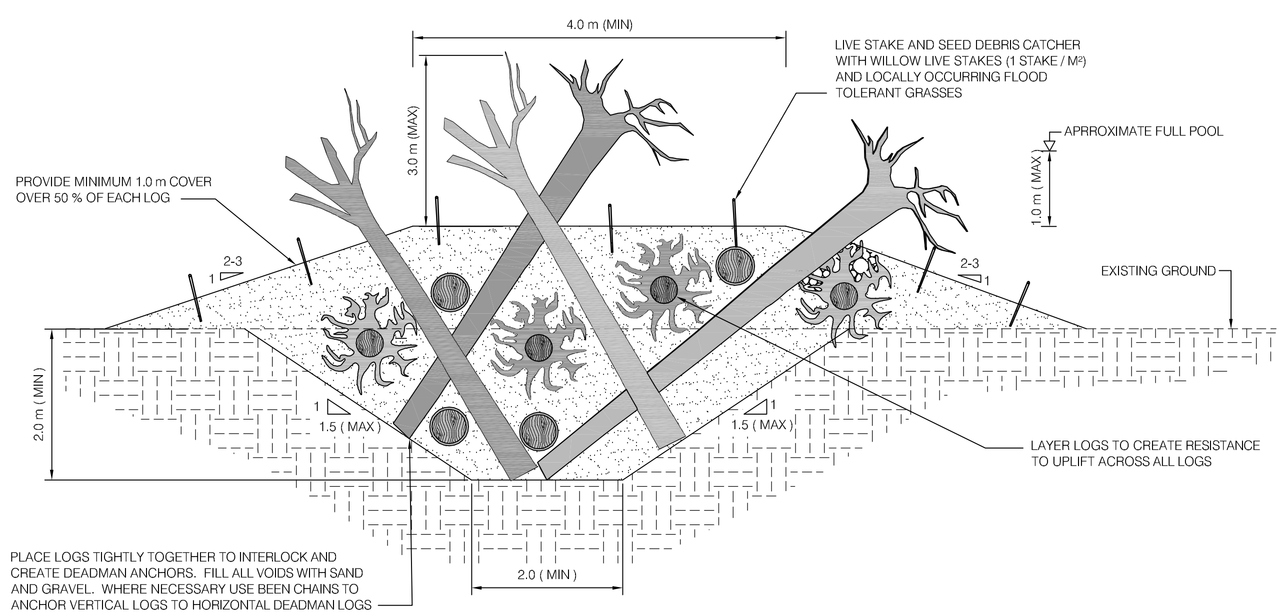

WOODY DEBRIS CATCHER DETAIL B / SW1

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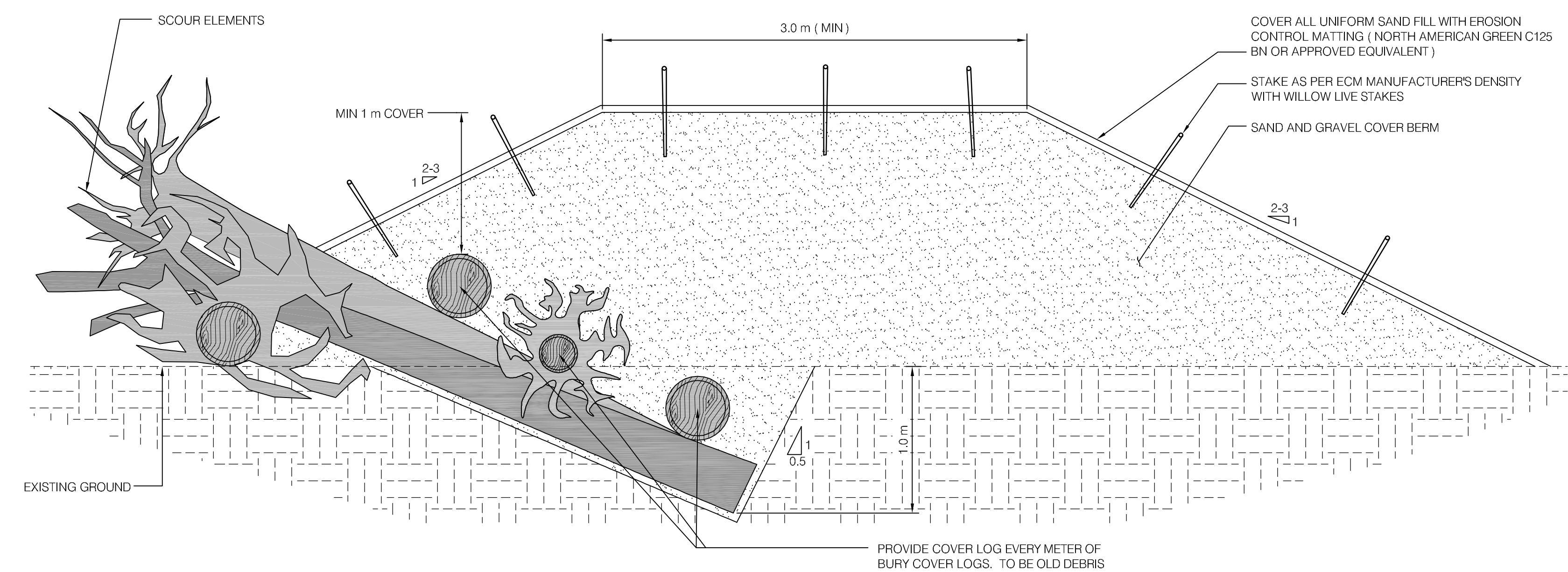

WOODY REVETMENT DETAIL C / SW1

SCALE 1:25

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OLE CREEK - DETAILS

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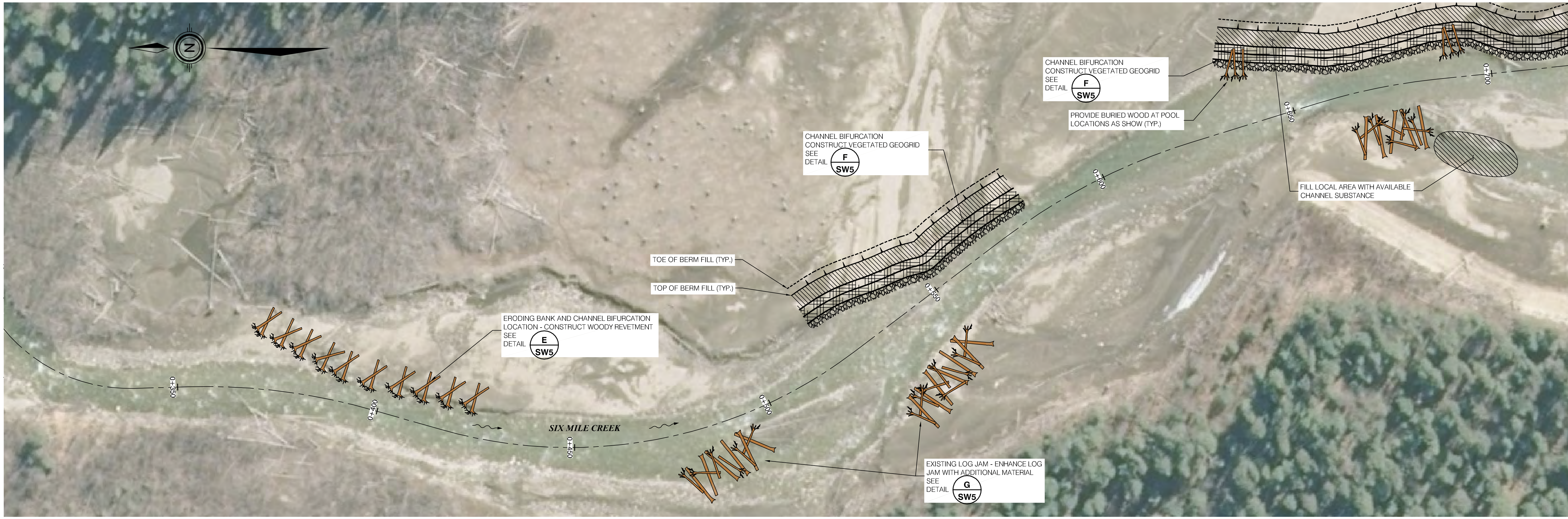

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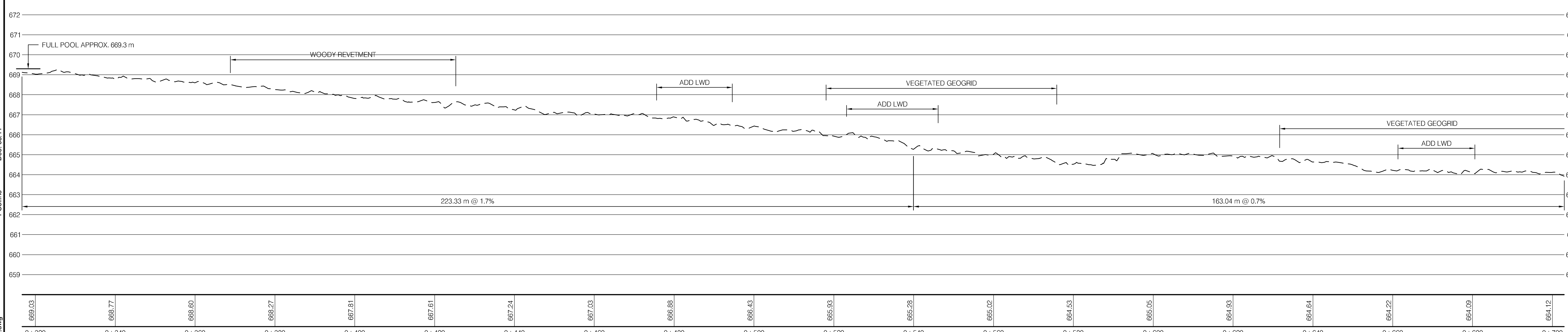

PROFILE

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WILLISTON RESERVOIR TRIAL TRIBUTARIES
6 MILE CREEK - PLAN AND PROFILE

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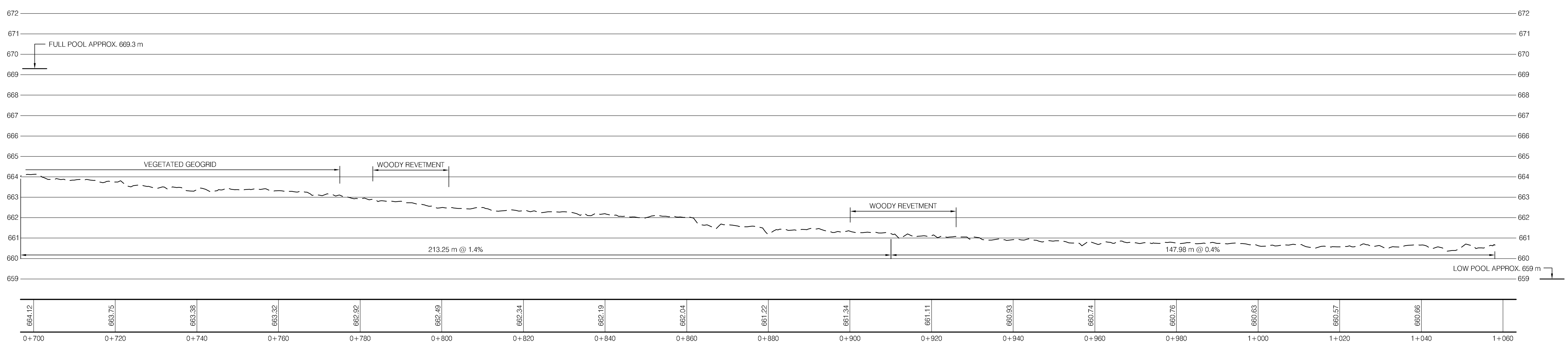

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WILLISTON RESERVOIR TRIAL TRIBUTARIES
6 MILE CREEK - PLAN AND PROFILE

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SW4
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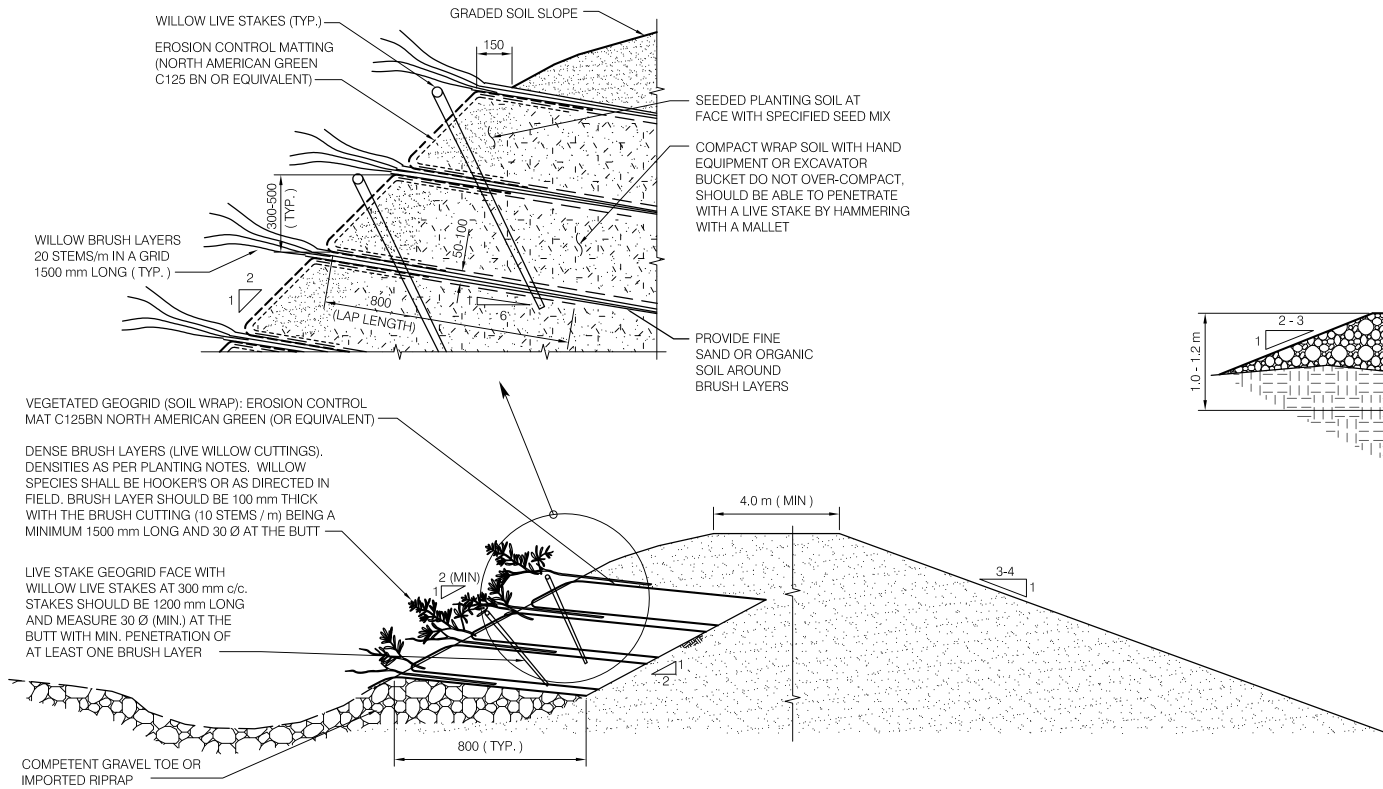

VEGETATED GEOGRID - SOIL WRAP (SECTION) DETAIL F / SW3

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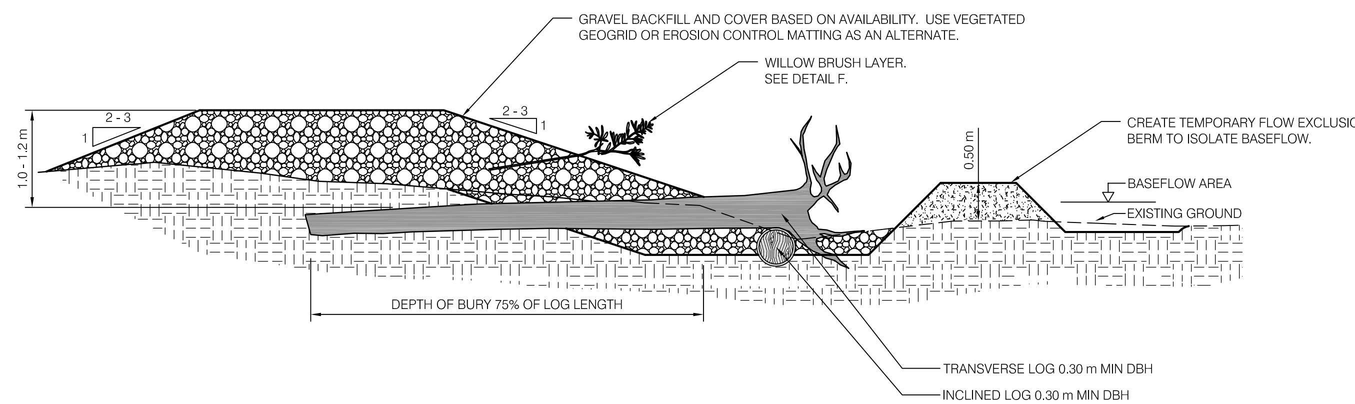

WOODY REVETMENT DETAIL - TYPICAL SECTION 0+400 E / SW3

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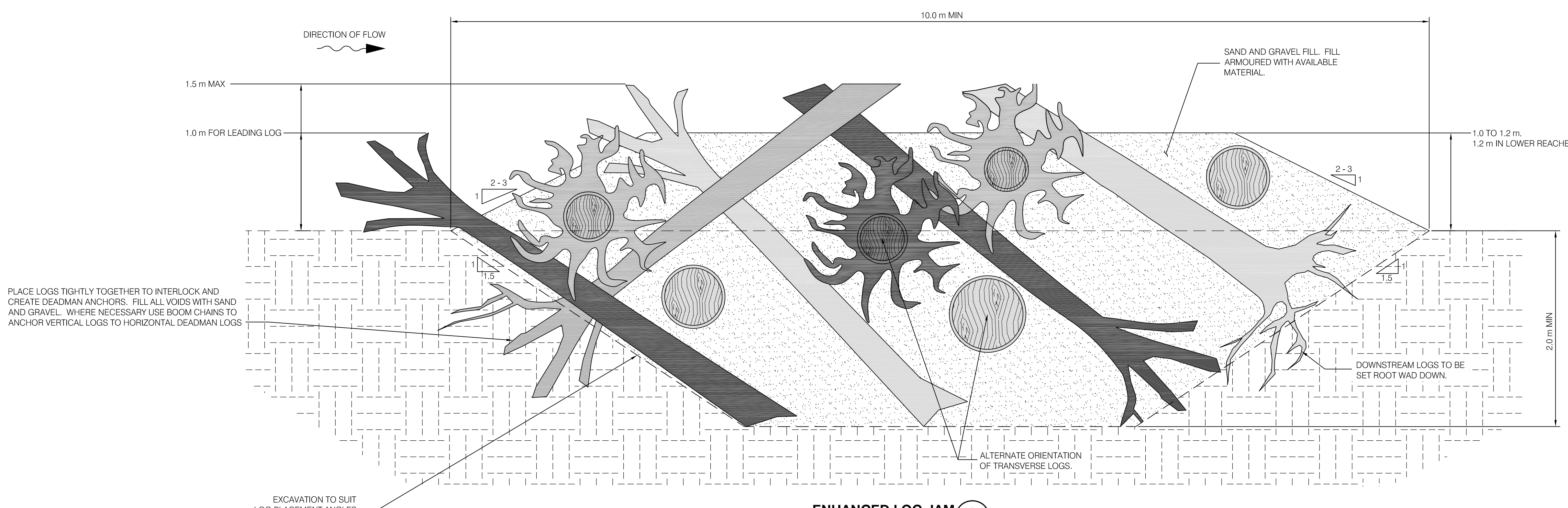

ENHANCED LOG JAM G / SW3

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OLE CREEK AND SIX MILE CREEK
SIX MILE CREEK DETAILS

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