Columbia River Project Water Use Plan

Arrow Lakes Reservoir Wildlife Management Plan

Arrow Lakes Wildlife Physical Works

Implementation Year 2

Reference: CLBWORKS-30B

Lower Inonoaklin Preliminary Design and Feasibility Report

Study Period: 2016-2017

Kerr Wood Leidal Associates Ltd.
Burnaby, BC

February 2018

BC Hydro
Power smart

Feasibility Report - Final

Lower Inonoaklin Wildlife Enhancement Project

February 2018
KWL No. 0478.201-300

Submitted by:

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THURBER ENGINEERING LTD.

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Executive Summary

Kerr Wood Leidal Associates Ltd (KWL) was retained by BC Hydro to provide engineering services to develop preliminary designs for the Lower Inonoaklin Wildlife Enhancement Project in collaboration with LGL Ltd (LGL). The site is an existing wetland located south of Needles, BC on the west side of the Arrow Lakes Reservoir. The project was a part of the CLBWORKS 30B Lower Arrow Lakes Reservoir Wildlife Enhancement program that seeks to create, protect or enhance habitat for nesting and migratory birds and wildlife.

KWL prepared preliminary designs based on the site selection and conceptual design undertaken and documented in the 2016 CLBWORKS 29B report originally prepared by LGL and KWL in 2012 and updated by LGL in 2016. Geotechnical investigation, analysis and design input was provided by Thurber Engineering Ltd.

The proposed design was intended to protect and enhance the existing shallow wetland, with specific habitat objectives developed by LGL. The design was expanded from the original scope to include removal of an area of Reed Canary Grass, an invasive species. The site is currently a narrow wetland that provides high suitability habitat for waterfowl, shore birds and pond-breeding amphibians. The wetland is fed by upland drainage in the fall and spring and is normally flooded in the summer months when the reservoir level is highest.

Following completion of the draft preliminary design, habitat objectives were further refined and assessed in comparison to the design. As a result of this assessment (described further below), BC Hydro elected not to proceed with habitat improvements at the Lower Inonoaklin Site at this time.

The preliminary design proposed the construction of three 1 to 1.5 m high berms with two riprap spillways creating a tiered wetland system with upper and lower wetlands retaining 18,300 m^3 and 10,800 m^3 of water, respectively. The intention of the design was to enhance and preserve the existing wetland habitat by retaining upland drainage in spring and delaying inundation and mixing in late-spring. The proposed berms included two passive riprap spillways designed to pass the estimated 200-year upland design flood and resist wave attack. The spillways included a sheet pile core to limit seepage through the porous riprap revetment. The berm side slopes were shallow to limit the potential for erosion due to wave attack and provide a more natural terrain for habitat.

Berm fill would be comprised of onsite borrow material taken from areas adjacent to the lower wetland elevations to expand the wetland area and avoid imported fill. Riprap would be imported to site. Planting would primarily be from salvaged onsite material (to a level not detrimental to the existing vegetation) with some nursery stock and would use only native and locally present species, to increase the cover of native plants.

The berms would likely be considered a 'Part 2 dam' as defined in the Dam Safety Regulation (DSR). A 'low consequence' classification designation was proposed. A few exceptions were proposed to the minimum guidelines from in the *BC Dam Safety Guidelines*: a reduced freeboard of 0.6 m (rather than 1 m), and no low-level outlet. This would require confirmation of acceptability from the Province.

The hydrologic and hydraulic modelling conducted as a part of this project indicates that the design would meet the intended purpose of enhancing and maintaining the wetland for a longer duration throughout the year by:

- retaining upland drainage and providing a wetland area increase of approximately 50%;
- delaying reservoir inundation and mixing to lengthen the time habitat is available (approximately one to two weeks average delay in the spring and one to two weeks additional inundation free time in the fall); and
- providing increased depth and water retention within with the wetlands to support varied wetland habitat.

A construction cost estimate was prepared for the preliminary design. It is significantly higher than the 2016 Concept Design Report estimate; however, options for cost reduction are provided for BC Hydro's consideration.

Due to high modelled water levels and relatively short delay of inundation in the spring (one to two weeks not viewed as biologically significant), environmental objectives were further refined and evaluated following the draft preliminary design. This included reducing the target water depths to 30 to 50 cm and evaluating the wetland area at target depths. This analysis indicates that though the design increases the total area in the good and target depth ranges (<0.3 m and 0.3 to 0.5 m respectively), it creates a greater area with depths greater than 0.5 m, which is undesirable for the potential to attract Canada Geese. Based on the hydrologic analysis and these refined objectives, BC Hydro decided not to proceed with berms to preserve the existing shallow wetland habitat rather than risk creating deep wetlands and making a large investment for moderate to low improvement in habitat.

The design was proposed to be scaled down considerably, to focus instead on improving and supplementing the existing habitat and removal of invasive Reed Canary Grass. As removal methods for Reed Canary Grass are uncertain, it was noted that this is an area of considerable risk, particularly if site conditions are not altered to prevent regrowth.

Based on these considerations, BC Hydro has elected to not proceed with habitat improvements at the Lower Inonoaklin site. In the future, Reed Canary Grass removal trials at Burton Flats may illustrate successful methods that could be employed at the Lower Inonoaklin Wetland. At that time, BC Hydro could consider minor excavation to increase shallow habitat in the wetland and use that excavation for mounding and planting.

1. Introduction

Kerr Wood Leidal Associates Ltd. (KWL) was retained by BC Hydro to provide engineering services for the Lower Inonoaklin Wildlife Enhancement Project. Thurber Engineering Ltd. (Thurber) sub-consulted to KWL to provide geotechnical site investigation, assessment, and design input. The project is based on the conceptual wetland enhancement designs previously prepared by KWL and LGL Limited (LGL). LGL is the environmental consultant to BC Hydro on this project and have been involved in the development of the preliminary design, including the design basis.

The proposed works are a part of the CLBWORKS30B Lower Arrow Lakes Reservoir Wildlife Enhancement program. The objective of the enhancement program is to create, protect or enhance habitat for nesting and migratory birds and wildlife. The Lower Inonoaklin Wetland Site is located immediately south of Needles, BC on the west side of the Arrow Lakes Reservoir. Site selection and conceptual design for the site was undertaken and documented in the CLBWORKS 29B report, updated in August 2016 and referred to herein as '2016 Concept Design Report' (originally issued March 2012).[1]

At Lower Inonoaklin Road, the proposed design is intended to protect and enhance the existing shallow wetland. The site (also known as Porcupine Island) is currently a narrow linear pond with a soft mud bottom. The existing wetland currently provides high suitability habitat for waterfowl, shore birds and pond-breeding amphibians. The wetland is fed by upland drainage in the fall and spring and is normally flooded in the summer months when the reservoir level rises following freshet. The original design objective was to increase the total wetland area and delay inundation to increase the amount of time wetland habitat would be available.

The conceptual design proposed the construction of three berms adjacent to the existing wetland area to create a larger wetland area. The berms were approximately 60 m, 130 m and 170 m long and approximately 1 to 1.5 m in height. The purpose of this design was to maintain an appropriate water elevation in the wetland for a longer duration throughout the year and postpone reservoir inundation to lengthen the time habitat is available. The conceptual design was refined as a part of this project and modified to a tiered wetland system with three berms. It also was expanded to include the removal of an area of Reed Canary Grass, an invasive species. Analysis was completed to confirm that drainage from the upland catchment was sufficient to provide water to the wetlands for low reservoir years.

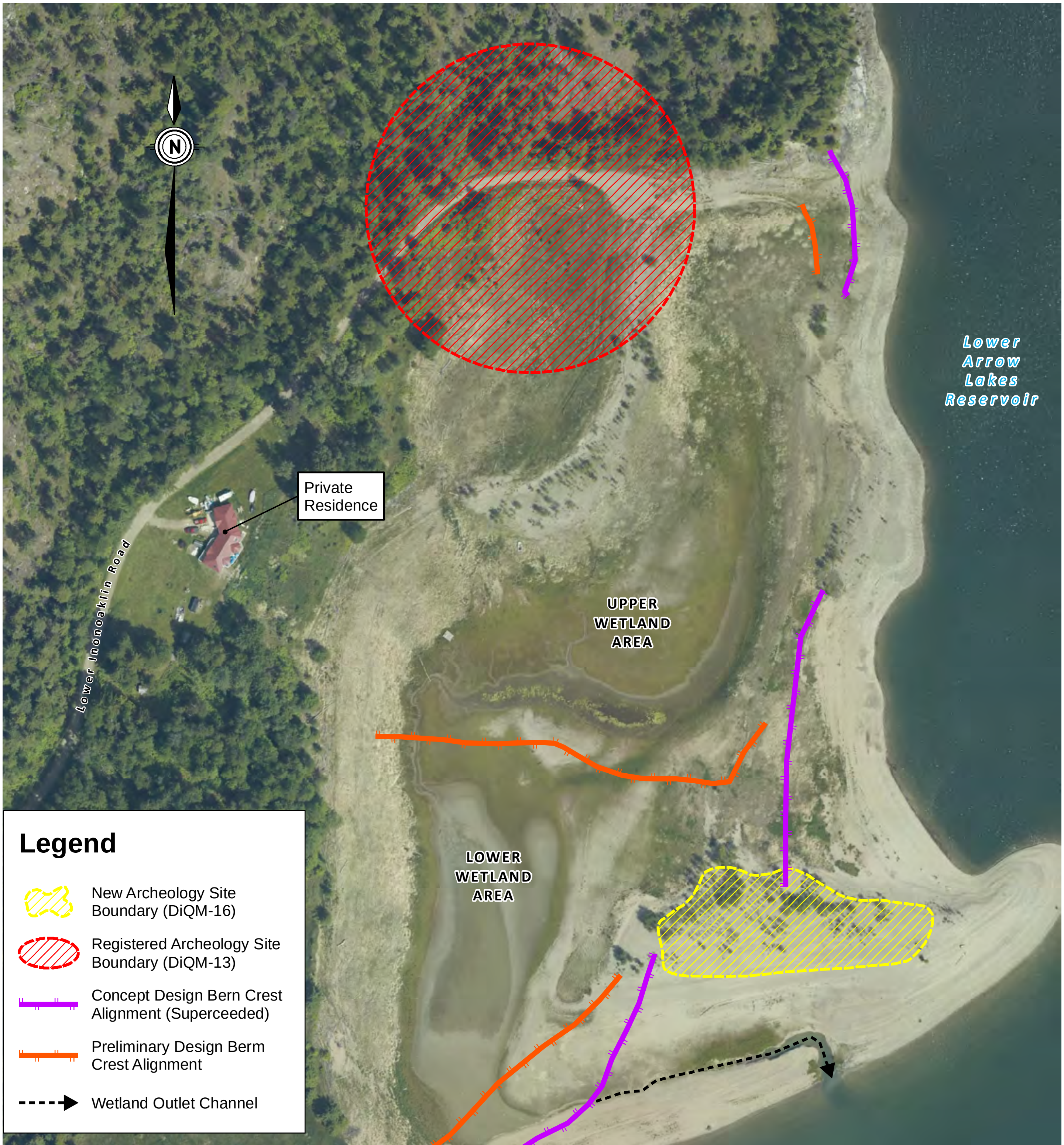
As a part of this project, BC Hydro conducted a topographic survey of the area and commissioned an archaeological impact assessment of the site. The topographic survey provided accurate ground elevations for design. Figure 1-1 provides a site location map with the archaeological areas, as well as the conceptual design (superseded) and the preliminary design crest alignments.

[1] CLBWORKS-29B: Arrow Feasibility Study of High Value Habitat for Wildlife Physical Works. Update in 2016 by LGL; original 2012 Report by LGL and KWL. Prepared for BC Hydro.

The preliminary design phase of this project, which is documented in this report involved:

- background review and development of a design basis;
- field investigation;
- geotechnical investigation (test pitting) and design input by Thurber;
- hydrologic and hydrotechnical analysis of the wetland catchment and reservoir interaction; and
- the development of feasibility level design drawings and cost estimate and preparation of preliminary design report.

Following BC Hydro review of the preliminary design, additional refinement and analysis of habitat objectives resulted in BC Hydro's decision not to proceed at this time with habitat works at the site. Later, BC Hydro may consider an alternative concept, focusing on minor habitat improvements and Reed Canary Grass removal.



Reference: 2016 Orthophoto from BC Hydro.

KERR WOOD LEIDAL
consulting engineers

BC Hydro
Lower Inonoaklin Wildlife Enhancement Project

Project No.	Date
478-201	February 2018

50 0 50 (m)
1:2,500

Site Location

Figure 1-1

Path: O:\0400-0499\478-201\430-GIS\MXD-Rp\478201_Fig1-1_SiteLocation.mxd Date Saved: 2/16/2018 11:38:51 AM
Author: AMatfin

2. Site Visit and Field Work

A field visit to the Lower Inonoaklin Wildlife Enhancement site was conducted on November 24, 2016. Staff from KWL, Thurber, and LGL met on-site to observe, review, and discuss the site conditions. Staff in attendance included:

- Allison Matfin (ARM) – KWL
- Peter Fearon (PF) – KWL
- Melanie Woytiuk (MW) – Thurber
- Virgil Hawkes (VH) – LGL Ltd.
- Richard Watson (RW) – local excavator operator

The weather was overcast and windy with intermittent rain through the day. The reservoir level was 431.1 m above sea level (ASL, from WSC 08NE102) that day. Details of the field visit are described below. Photos of the site from the field visit are provided in Appendix A.

2.1 Geotechnical Test Pits and Observations

Test pits were excavated to enable Thurber to assess the on-site soils, focussing on the footprint locations of the proposed berms. The test pits were based on berm alignments from the 2016 Concept Design Report. Test Pit observations and soil materials are documented in the geotechnical investigation report presented in Appendix B. The test pit locations are also presented in the preliminary design drawings, Drawing C-101, in Appendix C.

2.2 Berm Design Concept and Alignment

The berm concept and alignments from the 2016 Concept Design Report were reviewed on site. They were considered largely reasonable, but the preferred locations for the middle and south berms were both shifted to accommodate the newly located archeological area at the southwest end of the site.

2.3 Drainage Observations

The drainage infrastructure and patterns in and near the wetland area were observed to inform the hydrologic and hydraulic modelling of the watershed:

1. A ditch runs along the Lower Inonoaklin Road. Two 0.6 m corrugated steel pipe (CSP) culverts drain the ditch and discharge to the to the wetland area via overland flow. Past the end of the road, the ditch flows towards the wetland.
2. Shallow pools were located in the northwest corner of the area above the wetland, though the area is generally higher ground and not an active part of the main wetland.
3. The wetland appears to have a sill between south and north pools, which could accommodate a tiered wetland design (incorporated in the preliminary design discussed later in this report).

Water discharges from the south end of the wetland to a channel that flows to the east for a distance and then turns sharply south through a steeply eroded bank towards the reservoir. Based on aerial photographs of the lake shore, site observations, and previous KWL work on the Arrow Lakes, this feature is due to northeast littoral drift from waves generated from the south creating a spit at the southeast end of the site (identified through the preliminary design process).

3. Design Criteria and Preliminary Design Components

The 2016 Concept Design Report provides a comprehensive discussion on project background, environmental rationale, and proposed environmental monitoring and performance measures. This is documented in Section *7.0 Lower Inonoaklin Road Wetland Retention* of that report, which has been excerpted and included in Appendix D of this report.

This section of the report outlines the design criteria and summarizes the preliminary design for the proposed physical works at the Lower Inonoaklin Site.

A draft design basis technical memorandum was developed in collaboration with LGL and with review and input from BC Hydro. It summarized the criteria, constraints, and requirements for the berm design to meet the intended goals of the enhancement project. The design basis has been integrated into this section of the report, with updates to environmental objectives following the draft preliminary design.

Thurber provided an assessment of site soil materials, seepage, and conditions relative to the locations and foundations of the proposed berms and provided input to the design. Details of the assessment and results can be found in Thurber's Draft Report *Lower Inonoaklin Road Wildlife Improvement Project Geotechnical Investigation*, attached as Appendix B.

The preliminary design drawings are provided in Appendix C.

3.1 Habitat Enhancement Objectives and Criteria

The purpose of this project is to preserve and enhance habitat for birds and wildlife by retaining upland drainage and reducing site inundation to promote stability of the wetland habitat. As discussed in the 2016 Concept Design Report, the objectives of the proposed wildlife physical works are to:

- increase the temporal availability of shallow wetland habitat for wildlife in the drawdown zone of Arrow Lakes Reservoir. The construction of berms will enable the shallow wetland habitat to persist longer into the summer, which will improve habitat suitability for pond-breeding amphibians, bats, reptiles, certain species of birds, semi-aquatic mammals, and some terrestrial mammals;
- improve habitat complexity in the drawdown zone of Arrow Lakes Reservoir; and
- vegetate the constructed berms (primarily with native sedges).

To be certain that the berm design satisfies environmental needs, LGL and BC Hydro were consulted prior to preliminary design to provide the environmental requirements and constraints for the design. Objectives were further refined in consultation with BC Hydro and LGL during review of the draft preliminary design, as discussed below:

1. Revised target water depth in the majority of the wetland of between 30 to 50 cm (revised following draft preliminary design from the original target depths of 50 to 100 cm). Following the draft preliminary design, it was noted that higher water levels in the wetland are not desirable as this would increase the suitability for Canada Geese. Environmental monitoring conducted by LGL in 2012 to 2015 noted that the wetland always had water present and did not dry out, though the warmest and sunniest time of year typically coincides with reservoir inundation;
2. Retain water from spring runoff within the wetland;
3. Protect the wetland from inundation and mixing by the reservoir for as long as reasonably possible given the target water depths, typical reservoir operations, and other project constraints;

4. Provide connectivity of any ditches or pools to the main wetland to avoid fish or other species being trapped due to decreasing water levels;
5. Include environmental planting with sedges and possibly willow or other tree species in the design in designated planting areas, while ensuring existing stakeholder views are not obstructed;
6. Salvage existing planting disturbed during construction for replanting;
7. Incorporate naturalized elements in the design for both habitat complexity and aesthetics (local stakeholder buy-in) such as 'softer' solutions on the wetland side slope of the berms, and gentle edges and variations to the berm geometry (height, width, alignment, and cross section). This could allow designated planting areas at higher elevation; and
8. Incorporate trial planting approaches and species to continue to enhance knowledge regarding planting within and adjacent to the drawdown zone of reservoirs and specifically the Arrow Lakes system.

Invasive Reed Canary Grass

In addition to the above, there is an area of Reed Canary Grass identified by LGL at the north end of the site. It is an invasive species that LGL has recommended for removal. This would involve clearing and grubbing 0.3 to 0.5 m deep across the affected area, proper disposal of the grass, and revegetation of the area with native species. The removal area could remain at a slightly lower elevation and potentially increase the wetland area.

The location where the Reed Canary Grass is growing overlaps the archaeological site DIQm13; however, it is understood that there is some uncertainty about this archaeological site. An additional archaeological investigation should be performed to confirm the site boundaries and the extent of Reed Canary Grass removal in order to avoid disturbance to the archaeological site. BC Hydro agreed that removal of this invasive species would be considered as an experimental trial, and as a result it was included in the works. However, in case there is a residual potential to inadvertently affect archaeological items, BC Hydro has recommended that the material stay on site and preferably in the same location. To accomplish this, the removed grass and surface sediments can be buried on site in a trench. To increase the likelihood of the success of the removal, the Reed Canary Grass should preferably be buried 2 to 3 m, but a minimum of 1 m, based on LGL input. Alternatively, a geotextile could be used to cover the Reed Canary Grass and prevent shoot growth, which would limit the burial depth required.

Fisheries Considerations

In the 2016 Concept Design Report LGL notes that at present the site does not provide fisheries values for most of the year. During periods of the year when the site is inundated, there may be some value to fish. The proposed project should reduce the amount of time that fish are able to access the site, which is not considered to be detrimental to fish. Since the 2016 report, LGL has had some preliminary discussions regarding the potential for fish stranding with BC Hydro noting that there is some risk of fish stranding. There is currently limited data regarding fish presence and use of the wetland at Lower Inonoaklin Road. LGL has suggested considering a field program to:

- assess the species of fish that are in the wetland or that occur in the reservoir prior to inundation;
- determine the species of fish that enter the wetland location during inundation; and
- determine which species of fish are left behind following inundation.

Proposed methods may include beach seining, trapping, and electro-fishing. The assessment would be completed pre-and post construction to assess impacts of the design.

3.2 Property and Land Considerations

Based on land ownership information from the 2016 Concept Design Report, the area identified for the proposed physical works is Provincial Crown Land and lies entirely within BC Hydro's Water Licence for the Arrow Lakes Reservoir. Accordingly, KWL understands that BC Hydro has the necessary land rights for investigative activity under the Permission Land Use Policy. Consent for physical infrastructure will need to be obtained and BC Hydro will apply for a Section 16 withdrawal from disposition. Two private properties border the crown property the site is located on; however, these properties will not be directly impacted by the works.

An archaeology investigation has been conducted by Tipi Mountain Eco-Cultural Services Ltd. An archaeological site was identified between the middle and south berms of the conceptual design and the spatial location and extents of the site have been provided by Tipi Mountain. As noted earlier, the alignments of the berms were adjusted from the conceptual design to avoid the archaeology area shown on Plan C-101, and in Figure 1-1.

3.3 Regulations

There are several regulations that have been considered during the preliminary design.

1. Dam Safety Regulation (DSR)
    a. The berms will hold water in two directions: retaining upland drainage water in the wetland when the reservoir is low, and delaying wetland inundation when reservoir levels are high;
    b. The DSR does not apply to a barrier for water storage that is less than 7.5 m in height <u>and</u> capable of impounding at full supply level a maximum total storage volume of water in the reservoir of the dam of less than 10,000 m^3;
    c. The estimated impoundment volumes of the proposed wetland tiers are 18,300 m^3 in the upper tier, and 10,800 m^3 in the lower tier, which would classify the berm structures as a 'Part 2 dams';
    d. Part 3 of the DSR describes the requirements applicable to 'certain dams'. It is not expected that the berms would be considered 'certain dams', since:
        i. the dam height will be between 1 and 1.5 m (may be revised in detailed design), but since the reservoir could only flood the area of the wetland it is assumed that Clause 7 (a) of Part 3 would not apply even though the Arrow Lakes Reservoir volume far exceeds 1M m^3 within 1 m of storage; and
        ii. the berm height will not exceed 2.5 m, so Clause 7 (b) of Part 3 would not apply.
    e. BC Hydro has confirmed with the Province that the wetland berms would be considered 'Part 2 dams', even though they will often be inundated by the reservoir. However, the Province may agree to treat them as 'minor dams' for which DSR requirements are minimal; and
    f. If designation as a 'Part 2 proves problematic for BC Hydro, the berm heights could be reduced to limit each partition to less than 10,000 m^3 of water retained. This however would reduce the environmental benefit, and the Province may consider the total retained water of the two wetland tiers rather than each separately. Alternately, the south berm retaining the lower wetland tier could be excluded, leaving that section in existing condition, and the upper wetland tier berm could be reduced in height to retain less than 10,000 m^3.

2. Navigable Waters Protection Act (NWPA)
    a. When the berms are inundated, they may have a minor impact on navigation within the reservoir. For navigational safety, signage near the berm structures could be considered.
3. Water Sustainability Regulation (WSR)
    a. It is expected that a Water Conservation license will be required for this project. For engineering inputs, the Water Conservation license application is expected to require design drawings, an overview figure, and a detailed description of the proposed works including storage volumes, property information, and dam design.[2]
    b. This project is expected to result in "changes in or about a stream", which will require a license or approval in accordance with Part 3 of the WSR. Application for a Water Conservation license may negate the need for a Part 3 approval. For design and material sourcing, impacts to the existing wetland and habitat will be minimized as much as reasonably practicable.
4. Federal Fisheries Act
    a. The Fisheries Act may apply, but is not expected to impact the project beyond the requirements of the WSR.
5. Dike Maintenance Act (DMA) – *not applicable*
    a. It has been assumed that the DMA would not apply to the berms as they are not dikes under the regulatory definition.

[2] FrontCounter BC Water Licence Application: http://www.frontcounterbc.gov.bc.ca/guides/surface-water/new-water-licence/what-you-need-to-apply/

3.4 Berm Design

The berm design seeks to meet environmental objectives under changing reservoir levels and varying upstream catchment conditions. This requires consideration of inundation, drawdown, seepage, erosion protection, outlet works, biological requirements, and water retention, in the context of available materials and regulatory requirements.

As is discussed, it has been assumed that the berms will be considered a 'Part 2 dam' under the DSR, and as such, the minimum design standards for dams outlined in the *Plan Submission Requirements for the Construction and Rehabilitation of Dams – BC Dam Safety Guidelines* (May 2016), have been considered. Where the design has deviated from the BC Dam Safety Guidelines, this has been noted for confirmation of acceptability with the Province. If the berms were not considered 'Part 2 dams', more alternative designs could be considered. The preliminary berm design is discussed below.

Engineering Design Parameters and Considerations

Proposed Downstream Consequence Classification: Low Consequence

Assuming the berms will be considered 'Minor Dams', then based on the DSR, the dams are considered to be of 'Low' consequence classification since there is no population at risk and the following consequences of failure for a Low Consequence of Failure dam from the Schedule 1 of the DSR apply:

1. there would be *no possibility of loss of life other than through unforeseeable misadventure*;
2. there would be *minimal short-term loss or deterioration and no long-term loss or deterioration of (a) fisheries habitat or wildlife habitat, (b) rare or endangered species, (c) unique landscapes, or (d) sites having significant cultural value*; and
3. there would be *minimal economic losses mostly limited to the dam owner's property, with virtually no pre-existing potential for development within the dam inundation zone*.

Accordingly, a 200-year return period was selected for the design elements.

Normal Reservoir Operating Range: Between approximately 419 and 440 m ASL

Historic reservoir operational range is discussed in the 2016 Concept Design Report and Section 4 of this report. This large operating range means that the berms will be fully submerged at times, so the design needs to consider inundation and drawdown.

Typical Maximum Rate of Reservoir Rise or Fall: Approximately 0.02 m per Hour

This is based on maximum changes in reservoir level using daily data (1969-2015).[3] Note that the corresponding spillway velocity will be much less than that associated with a 200-year discharge. This parameter will not govern when considering erosion mitigation in the design of the works.

[3] Note that hourly data was initially assessed and considered, but false data spikes created unrealistic rates, so the daily dataset was used.

Estimated Design Wave Height: 1.5 m (200-year return period)

KWL estimates the wave height at the Lower Inonoaklin site to be on the order of 1.5 m based on an assessment KWL conducted for BC Hydro at a nearby site to the south at Edgewood in 2014.[4] This wave height is larger than had been expected at the conceptual design stage in 2011/2012.

Wave height acting on the berm structure will depend on the water level and the local topography in the vicinity of the berm in the direction of the wave path. This will be considered further at the detailed design stage of this project.

Peak Discharge from Upland Drainage: 1.1 m^3/s (200-year return period)

For a 4 to 5 m wide spillway, this corresponds to a maximum depth of approximately 0.3 to 0.4 m and velocity of approximately 0.6 to 0.7 m/s. The flow was estimated based on the hydrologic assessment outlined in Section 4 of this report. This flow estimate includes attenuation effects of the wetland storage.

Minimum Spillway Width: 4 m (however 5 m has been selected for preliminary design)

This meets the 4.0 m minimum spillway width presented in the *BC Dam Safety Guidelines*.

Freeboard: A minimum of 0.6 m above the peak discharge water level at the spillway

<u>Note that this varies from the 1.0 m minimum freeboard presented in the *BC Dam Safety Guidelines*.</u> This variation is based on the low consequences associated with a 200-year or other flood event overtopping the berms. If the Province will not accept a lesser freeboard, then the design will be adjusted accordingly, but it will reduce the flexibility in the ability to vary the berm height away from the spillway at the south end of the site.

Upland Sediment and Debris: Fine sediment in small volumes is expected

Based on site observations, upland generated sediment is expected to be limited to fine sediment released in small annual volumes. Sediment accumulation is not considered to be a significant design concern.

Reservoir Sediment and Debris: Fine sediment littoral drift is observed and expected for the future at the south end of the site

Limited large woody debris (LWD) is anticipated to be deposited to the site.

There is significant littoral drift of sediment south to north and locally to the northeast as evidenced by the spit at the south end of the site and the existing east-west wetland outflow channel (See Figure 1-1). The existing wetland outlet channel flows parallel to the lake shore due to this littoral drift, and in the future, this process could result in sediment deposition in the vicinity of the outlet. This was considered in the design and the location of the works.

There is the potential for LWD (logs) from the reservoir to be deposited at the site, however there was no evidence of significant quantities of LWD observed on site and as such it is not considered a significant design consideration.

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[4] 2014, KWL, Edgewood Breakwater Review, Report to BC Hydro, KWL File No. 0478.176

Berm Alignment and Geometry

The original conceptual design included three low-height perimeter berms with shallow side slopes, with one spillway outlet at the existing low point of the wetland. The preliminary design is based on the conceptual design; however, it will create a tiered wetland system with an upper and a lower wetland that enhances an existing narrowing of the wetland that already somewhat compartmentalizes the existing wetland. Also, for the preliminary design, the berms have been set back further from the wetland bank edge of the reservoir.

These changes were made due to two main factors: large estimated potential wave height at the southern end of the wetland and existing sediment transport and deposition patterns at the location of the original outlet concept. A tiered system set back from the reservoir is advantageous for several reasons:

1. It reduces the need for fill and limits erosion protection at the south end of the site where wave heights are expected to be greatest;
2. It allows for varied wetland levels and elevations without a complex outlet control structure; and
3. It reduces the potential for the works to be affected by sedimentation at the south outlet, and the need for associated protective structures (such as groynes).

The berm alignments and tiered wetland areas are presented on Drawing C-101 in Appendix C. The upper wetland area is referred to as ‘Tiered Wetland Area 1’, and the lower wetland area is referred to as ‘Tiered Wetland Area 2’ on Drawing C-101.

The proposed elevation for the berms in the 2016 Concept Design Report was approximately 438.5 m above sea level (ASL). Since the conceptual design, BC Hydro conducted a topographic survey that refined the elevation information in the wetland area. The berm design height (elevation) was further assessed during the hydrologic analysis to evaluate the appropriate height to meet environmental targets and regulatory considerations. The proposed berm spillway elevations and estimated retained water volume for the preliminary design are as follows:

1. Upper berm (Berm 2 on Drawing C-101) spillway elevation of 436.0 m (approximately 1.5 m high), top of berm elevation of 437.0 m, with a stored water volume of approximately 18,300 m^3 (Tiered Wetland Area 1); and
2. Lower berm (Berm 3) spillway elevation of 435.5 m (approximately 1.5 m high), top of berm elevation of 436.5 m, with a stored water volume of approximately 10,800 m^3 (Tiered Wetland Area 2).

The following were also considered in the berm alignment and geometry for the proposed preliminary design:

1. The berm height is based on developing enhanced wetland pools in accordance with the wetland habitat criteria;
2. The berm spillway heights do not exceed 2.5 m to avoid the ‘certain dam’ designation, see Regulations discussion section above;
3. The berm crest elevation and cross section are varied to naturalize the berms and enable more habitat complexing, as noted in the Habitat Enhancement Objectives and Criteria section above;
4. Berm side slopes are shallow, 4 horizontal to 1 vertical (4H:1V) or shallower (up to 10H:1V);

5. The berm crest is a minimum of 4 m wide along the majority of the alignment. This width could allow vehicle access and also meets minimum crest width standards in the BC Dam Safety Guidelines;
6. The berm alignments avoid disruption of known archaeological sites;
7. It is expected that future access for maintenance could be provided off the berm crest (likely along the beach side of the reservoir) to allow planting of the crest, see Operation and Maintenance section below; and
8. As noted above, the design considers the local long-shore drift and wave attack. Due to this, the proposed berm alignments are set back from the reservoir to reduce impacts to the structures and limit the need for sediment and/or wave mitigation structures.

Seepage and Water Retention

The design will limit seepage through the berms to result in improved wetland function. Seepage is a consideration for two design conditions: water retention in the wetland when reservoir levels are low and seepage into the wetland when reservoir levels are high.

Thurber discussed seepage design considerations in their Draft Report (see Appendix B). They noted that it is anticipated that the establishment of steady-state flow paths through the berm is unlikely. They also note that existing wetland seepage rates are expected to be low since water is currently retained by the existing wetland throughout the year, based on monitoring completed by LGL from 2012 to 2015.

Given the low-height berm configuration, seepage is not a major consideration. Blending any clean sand used within the berms with the fine-grained material on site will aid in reducing the seepage rate through the berm. Assuming the berms will primarily be constructed with the silt and fine to medium grained sand that will be exposed in the borrow ditch inside of the wetland, saturated hydraulic conductivity is expected to range between 0.36 and 3.6 mm/hr for the berms (refer to Geotechnical report attached in Appendix B). Additional seepage analysis can be completed, if required, during detailed design.

Seepage through the riprap spillways would be large without mitigation, so seepage mitigation at the spillways has been included in the design, and is discussed below.

Erosion Mitigation and Protection

Erosion mitigation and protection has been designed for the governing design scenario of reservoir wave-induced erosion. Upland storm-discharge-induced erosion at the spillways will be less aggressive than wave-induced erosion. Surficial erosion of the berms due to reservoir inundation and drawdown is expected to be relatively insignificant. A riprap source has not yet been identified for the project, but BC Hydro has noted that if sourced from a new location, testing will need to be completed to ensure the riprap is not acid generating.

Wave-induced erosion has been mitigated in the design through a combination of using shallow slopes along most of the berm that mimic the existing relatively stable slopes of the shore, and armouring with rock riprap where steeper slopes are desired at the spillways. The shallow slopes of the berm will be re-vegetated after construction with native plants for habitat and to limit surficial erosion. The riprap areas (spillway and spillway transition) will not be planted. Trees and large shrubs will be avoided near the berm core, as they could affect the integrity of the berm if they die or are uprooted.

At the spillways, the riprap erosion protection will have slopes in the range of between 2 and 4 horizontal to 1 vertical (2H:1V to 4H:1V). For this range of slope, a preliminary design riprap thickness of 1 m has been assumed, based on an average riprap nominal size in the range of 0.5 to 0.7 m, to resist wave-induced erosion.

The preliminary design also includes a 0.5 m thick cobble-sized, smaller riprap revetment in the transition from the steeper spillway section to the shallow-sloped berm further from the spillway.

Spillway Outlet Structures

The proposed preliminary design has two outlet spillways, one at the southern berm for the lower wetland, and another at the middle berm for the upper wetland. The southern spillway has been set back from the conceptual design location and aligned with the existing wetland drainage path where it appears more stable and less affected by the littoral drift of sediment.

The outlet control structure spillways were designed to:

- convey the 200-year return period storm event flow with 0.6 m of freeboard; and
- convey the majority of the inflow during reservoir rise and wetland inundation (once the reservoir elevation exceeds the spillway elevation).

It is understood that BC Hydro would prefer a passive outlet rather than one that requires active management. Simple spillways allow for passive management, but they do not allow for flexible operation of the wetland water level (for example during very low water levels or to adjust environmental water levels). Additional flexible design elements are not proposed, but if desired could include a gated culvert (low level outlet/inlet) at the existing wetland outlet elevation; or a flexible outlet spillway elevation (e.g., a structure with stop logs, however this would not meet the requirements of the *BC Dam Safety Guidelines*).

Though including a low-level outlet/inlet in the design has some merits, it would add cost and complexity to the project, and has not been included in the design. Note that this is a deviation from the requirements of the *BC Dam Safety Guidelines*. If the Province doesn't accept the exclusion of a low-level outlet, then the design could be adjusted accordingly.

At present, the outlet spillway is proposed to be a passive riprap channel with a sheet pile core to minimize seepage through the riprap. The spillway is presently designed to be 5 m wide. The spillway will have 2 horizontal to 1 vertical (2H:1V) side slopes, a 2 m long crest (in the flow direction), and a 4H:1V channel base slope on both the reservoir and wetland sides of the spillway crest. A 5 m long toe apron has also been included to limit scour and erosion effects at the toe of the spillway. Spillway details are shown on Drawing C-301 in Appendix C.

The sheet piles are included within the spillway cross section with their tops aligned to the desired wetland elevation. They will not be supporting a cantilevered load since there will be riprap on both sides of the spillway for erosion protection. The riprap will also hide the sheet piles and maintain a more 'natural' appearance. Installation of the sheet piles could limit settlement as well as reduce seepage. The sheet pile burial depth presented on the drawings may be reduced during detailed design, and will be evaluated further based on a seepage analysis including the sheet piles.

The test pits were located based on the conceptual design and not located in the vicinity of the middle berm (Berm 2 on the drawings), nor at the proposed sheet pile locations. Assuming BC Hydro agrees with the sheet piling approach, confirmation drilling could be conducted prior to construction (perhaps by the contractor) to confirm that there are not large boulders at depth that could affect driving sheet piles.

Alternative spillway designs that do not utilize sheet piles could be incorporated into design, such as the use of cedar logs, geomembrane, and reinforced rock. This type of outlet would provide a more natural appearance to the outlet, and be less costly, but may not be as effective in retaining water. Following the preliminary design BC Hydro indicated that they favoured the more natural log outlet approach, particularly if the spillway heights were reduced.

Berm Material and Placement

In order to reduce construction costs, on-site material will be used for berm construction as much as possible. However, the design requires importing some materials to site such as riprap erosion protection, sheet piles, and geotextile.

The borrow material excavated from the topographically high areas on the wetland side of the berm should generally be suitable for use as fill material, while avoiding heavily vegetated areas. The sand and gravel material from reservoir beach can also be used as fill. It is not recommended that the material from the lowest areas of the wetland be used for berm construction, as it will be too wet to be compacted or trafficable. Additional detail is provided in Thurber's report (Appendix B)

At present, wide and shallow borrow areas are proposed along the wetland side of the berms as shown on Drawing C-101, where the material is considered to be appropriate for use as berm fill. Excavation of borrow in close proximity to the berms will require further consideration for the potential for increased seepage due to excavation and may require a minimum set-back from the berms. This will be further assessed in the geotechnical analysis for detailed design.

The borrow material should be placed in lifts no greater than 200 mm and compacted to a minimum of 95% Standard Proctor Maximum Dry Density (SPMDD).

Slope Stability and Settlement

The proposed slope angle for the berm side slopes is 4H:1V or shallower. Thurber noted that given the height of the proposed berm, proposed construction material, and foundation conditions, stability is not considered a concern for slopes at this angle.

Some time-dependent settlement of the foundation is anticipated, but it is not possible to estimate the amount of settlement since we do not know the depth or properties of the underlying soil conditions. It is recommended that the crest be surveyed after two full seasons to check if the crest elevation has been maintained. Alternatively, the berm can be over-built to reduce the impact of the settlement of the crest on the wetland function. The settlement will not occur uniformly, but this may be favourable for the aesthetic preferences for the final berm configuration.

As noted, installation of the proposed sheet piles could limit settlement in the vicinity of the spillway.

Additional detail is provided in Thurber's report (Appendix B).

3.5 Reed Canary Grass Removal Design

The invasive Reed Canary Grass removal location is at north end of the site in the vicinity of the archaeological site DIQm13. The removed material will be buried on site in the in the vicinity of DIQm13. BC Hydro has noted that in order to avoid DIQm13, an additional archaeological investigation will be required to delineate the site boundaries.

The design includes clearing and grubbing a depth of 0.3 to 0.5 m within the Reed Canary Grass Area, estimated to be approximately 4,600 m^2 by LGL, and disposal within an excavated trench. The trench could be covered with a 2 m high berm and revegetated with native species in order to suppress regrowth of the invasive species (depth provided by LGL). The removal area and borrow location will remain at a slightly lower elevation than the existing area. A culvert discharges upland drainage to this location, so a drainage channel will be excavated from the lowered Reed Canary Grass removal and borrow area to prevent ponding and convey drainage to the wetland.

BC Hydro has noted that use of biodegradable geotextile cover to minimize the required burial depth is preferred, and this option can be developed in detailed design. Based on input from LGL, it is expected that a minimum fill over the trench would be 0.5 m if geotextile was used. Detailed design should also focus on refining the site boundaries to avoid impacts to existing native vegetation and encroachment on the adjacent property and DIQm 13 archaeology site.

3.6 Planting Plan

The project includes planting with sedges and possibly willow or other tree species. Wherever possible, existing plants will be salvaged onsite during the construction and used to revegetate excavated areas, the base of berms, and the perimeter of the reed canary grass removal site. Additional cuttings or transplants will be collected on site, to a level not detrimental to the existing vegetation.

Trees and large shrubs will be avoided near the berm core, as they could affect the integrity of the berm if they die or are uprooted. Planting trees and large shrubs in the designated widened planting areas would be acceptable. We understand that the adjacent resident would prefer if the new planting were not to include additional cottonwood trees due to an allergy.

Trial planting approaches and species will be incorporated in the detailed design to continue to enhance knowledge regarding planting within and adjacent to the drawdown zone of reservoirs and specifically the Arrow Lakes system.

A preliminary planting plan schematic has been provided by LGL, and is presented in Figure 3-1. The plan provides a list of species to use in each area, and this plan would be developed further for detailed design. Most of the plants will be planted at elevations below 439 m ASL to allow adequate moisture. The following plants can be used at elevations at or above 439 m ASL, which are all common to the drawdown zone of Arrow Lakes Reservoir:

- Salix Sitchensis (sitka willow);
- Populus Trichocarpa (cottonwood). (Note: This species may be reduced or eliminated in the detailed planting plan due to local resident allergy.);
- Betula Papyrifera (paper birch);
- Alnus Incana (grey alder); and
- Deschampsia Cespitosa (tufted hairgrass).

There is an area in the Tiered Wetland Area 2 that contains about 100 specimens of moss grass at 434.27 m elevation, which is of significance from a reservoir ecology perspective. Arrow Lakes Reservoir has not exceeded 434.27 m ASL in April in any year of operation and this elevation has been exceeded in May in only eight of 48 years. As a result, the moss grass population at Lower Inonoaklin Road would be exposed in April and most of the time in May. The proposed physical works includes the construction of a berm with a spillway elevation of 435.5 m ASL, or 1.23 m higher than the moss grass population. If wetland water level elevations exceed 434.27 m ASL in the April to May period for consecutive years, this could have an impact on the survivorship of moss grass at Lower Inonoaklin Road. Hydrologic and hydraulic modelling (refer to Section 4) indicates that water levels in Tiered Wetland 2 will consistently be above this elevation in April and May, due to the berm retaining drainage and higher water levels. As such, construction of Tiered Wetland 2 would negatively impact the moss grass population and a salvage and transplant program should be considered. Transplant success is unknown as transplanting has not been attempted with this species.

3.7 Construction Access and Timing

Access

Construction access is expected to be from Lower Inonoaklin Road where it ends at the north end of the project site. Barge access is possible, but given the road access, it is not considered likely or required. Access routes would avoid the archaeological site at the south end of the site, which will be flagged and taped off during the construction. Access would avoid the vegetated wetland area wherever possible.

As noted in Thurber's Draft Report (Appendix B), access route trafficability may be an issue on the reservoir beach, natural wetland outlet channel and through the middle of the wetland. Trafficability is somewhat dependent on the water level at the time of construction, however, much of this silt and sand is loosely placed and saturated at lower elevations. Equipment may need to use granular borrow material to create a working surface as they move out over these loose areas.

Timing

Construction timing will need to consider reservoir elevation and site inundation, snow cover, site soil saturation, as well as environmental considerations. LGL recommended that the construction window be scheduled for fall since bird nesting use of the wetland occurs in the spring.

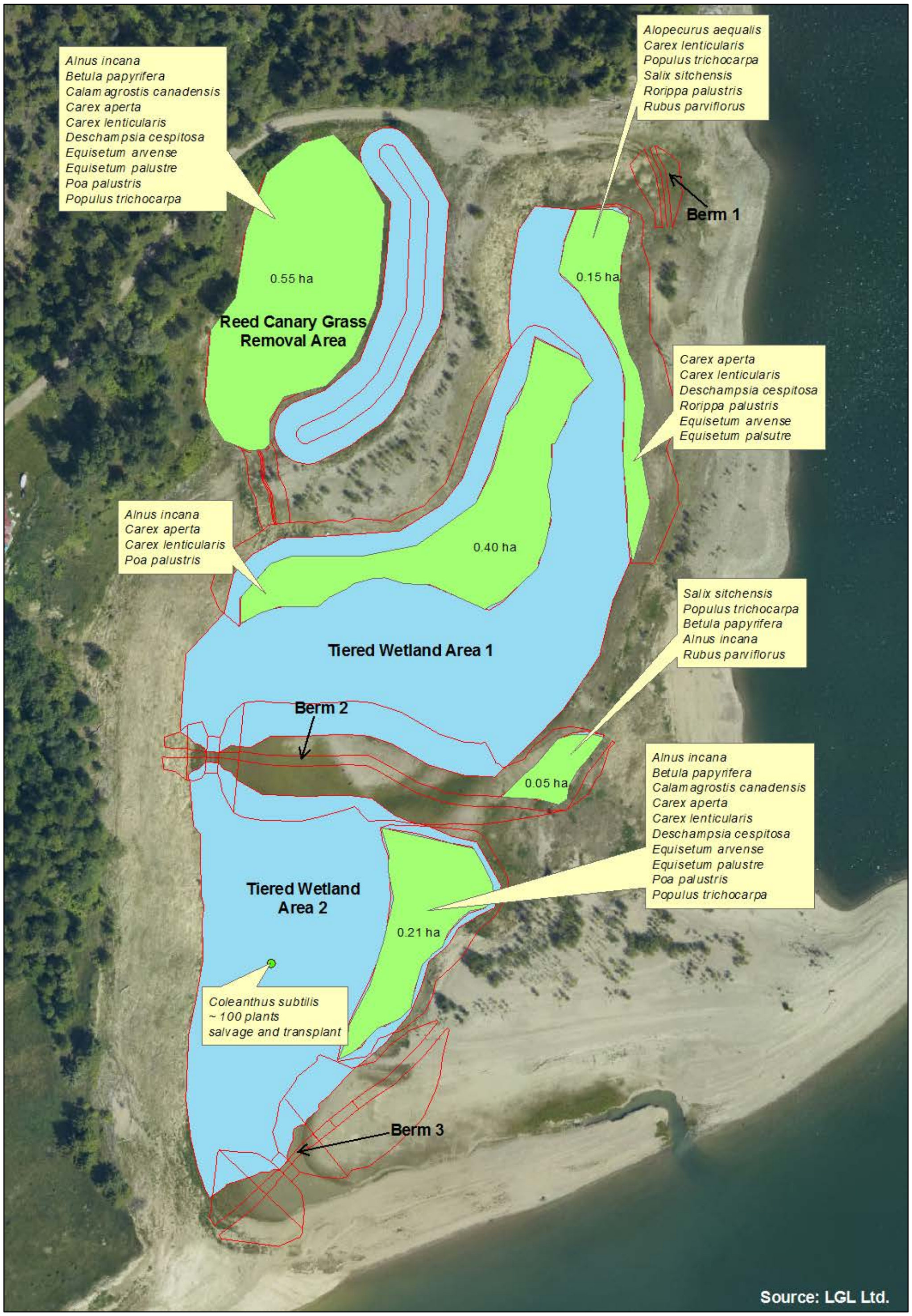

Figure 3-1: Preliminary Planting Plan Schematic

4. Wetland Analysis

4.1 Watershed Overview

The Lower Inonoaklin Wetland has a relatively small catchment of approximately 60 ha. The upper catchment is forested and steep, with slopes ranging from 10 to 35%. The lower catchment is largely grass and shrubs with slopes of 3 to 11%. The wetland itself consists of two storage areas or 'cells' connected by a relatively low sill between them. Above the main wetland area there is a small pool (upper wetland cell), which had 10 to 40 cm of water during the November 24 site visit. The outlet to the lower cell has a small channel that parallels the reservoir before a sharp cut into the reservoir. This outlet geometry is caused by the littoral drift at the site, which results in sediment deposition along the shore in this location.

Survey was conducted by BC Hydro of the area surrounding the wetland, not including the upper forested areas. The wetland itself was not surveyed other than to the waterline at the time of survey. The lowest point in the wetland is estimated based on anecdotal information provided by the surveyors and LGL to be at approximately 433.9 m geodetic, and the existing height of land between the reservoir and the wetland, is at approximately 434.5 m geodetic. When the reservoir level exceeds this elevation, the wetland becomes inundated from the reservoir.

Environmental monitoring conducted by LGL in 2012 to 2015 noted that the wetland always had water present and did not dry out, though the warmest and sunniest time of year typically coincides with reservoir inundation. According to reservoir level records from 1969 to 2015, the wetland is inundated by the reservoir on an almost annual basis, taking into account more recent low water levels.

The preliminary design entails three berms to create two separate wetland cells. The upper wetland cell will have a spillway at 436 m elevation and the lower wetland cell will have a spillway at 435.5 m, resulting in two different wetland typical depths and varying inundation timing and frequency. The final design elevations of the spillway and berms may be revised in the detailed design phase. Hydrologic modelling was completed for the existing site conditions and the proposed preliminary design concept.

4.2 Inundation Frequency

Figure 4-1 and Figure 4-2 below show the average reservoir level as well as the maximum, minimum, seventy-fifth percentile, and twenty-fifth percentile reservoir levels for the entire period of record and for 2000 to 2015 only. The years 2000 to 2015 was selected for subsequent analysis at the request of BC Hydro, as it was noted that more recent years are expected to be more reflective of reservoir operations in the future. In addition, the figures show the proposed lower and upper spillway elevations (435.5 and 436 m respectively) and the existing height of land that controls inundation timing for the existing wetland (approximately 434.5 m).

The main period of interest for habitat is April 1 to October 31, with the spring being the time with highest habitat value noted by LGL and BC Hydro. Wetland improvements in the fall season are expected to have habitat benefits for shorebirds; however, this has not been assessed in detail and so the magnitude of this benefit is not known with certainty.

Figure 4-3 shows the spring reservoir levels for 2000 to 2015, to demonstrate inundation timing expected for the existing condition and the design for the most recent period of reservoir operations. As shown in the Figures below, delay of inundation in the spring on average could be one to two weeks, and a more detailed inundation analysis is presented below.

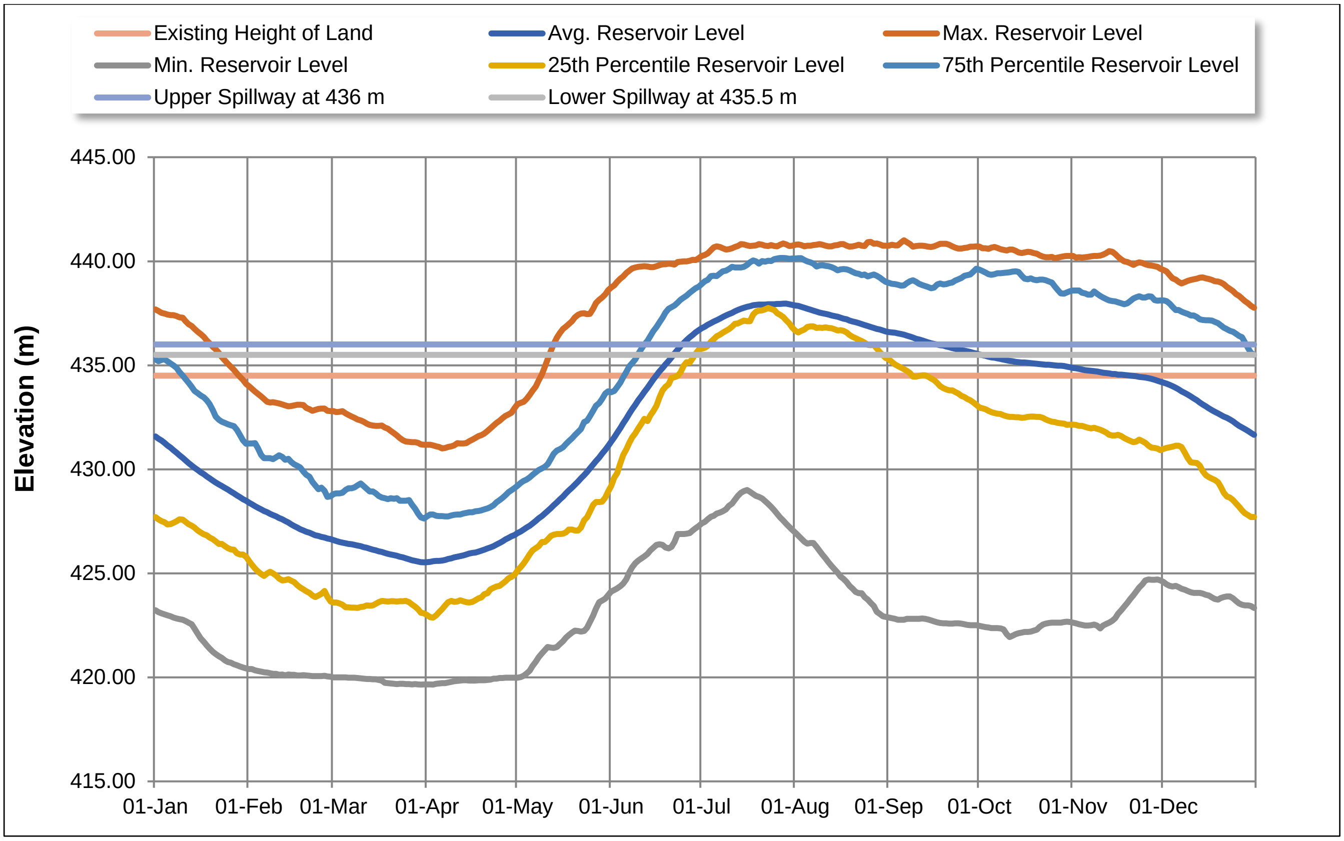

Figure 4-1: Arrow Lakes Daily Reservoir Levels at Fauquier 1969-2015

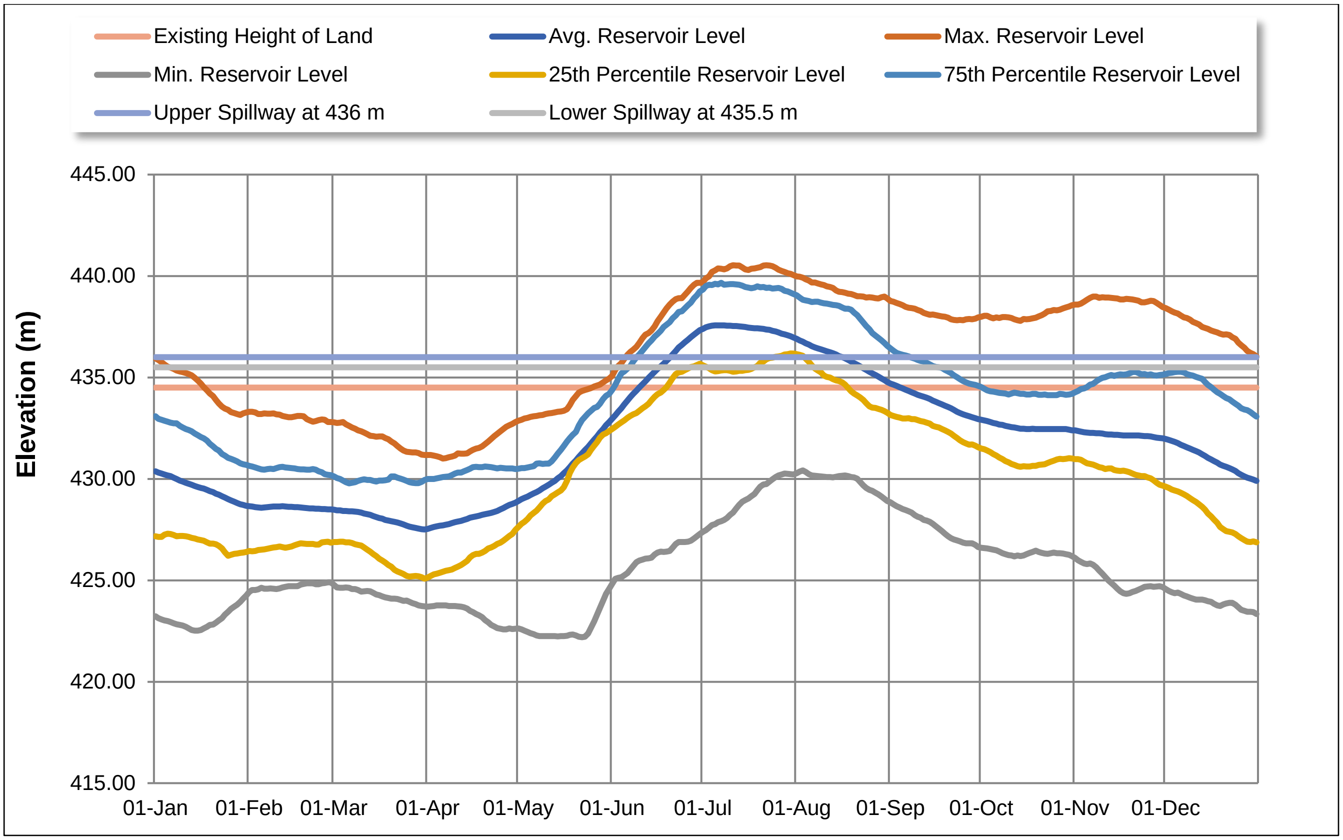

Figure 4-2: Arrow Lakes Daily Reservoir Levels at Fauquier 2000-2015

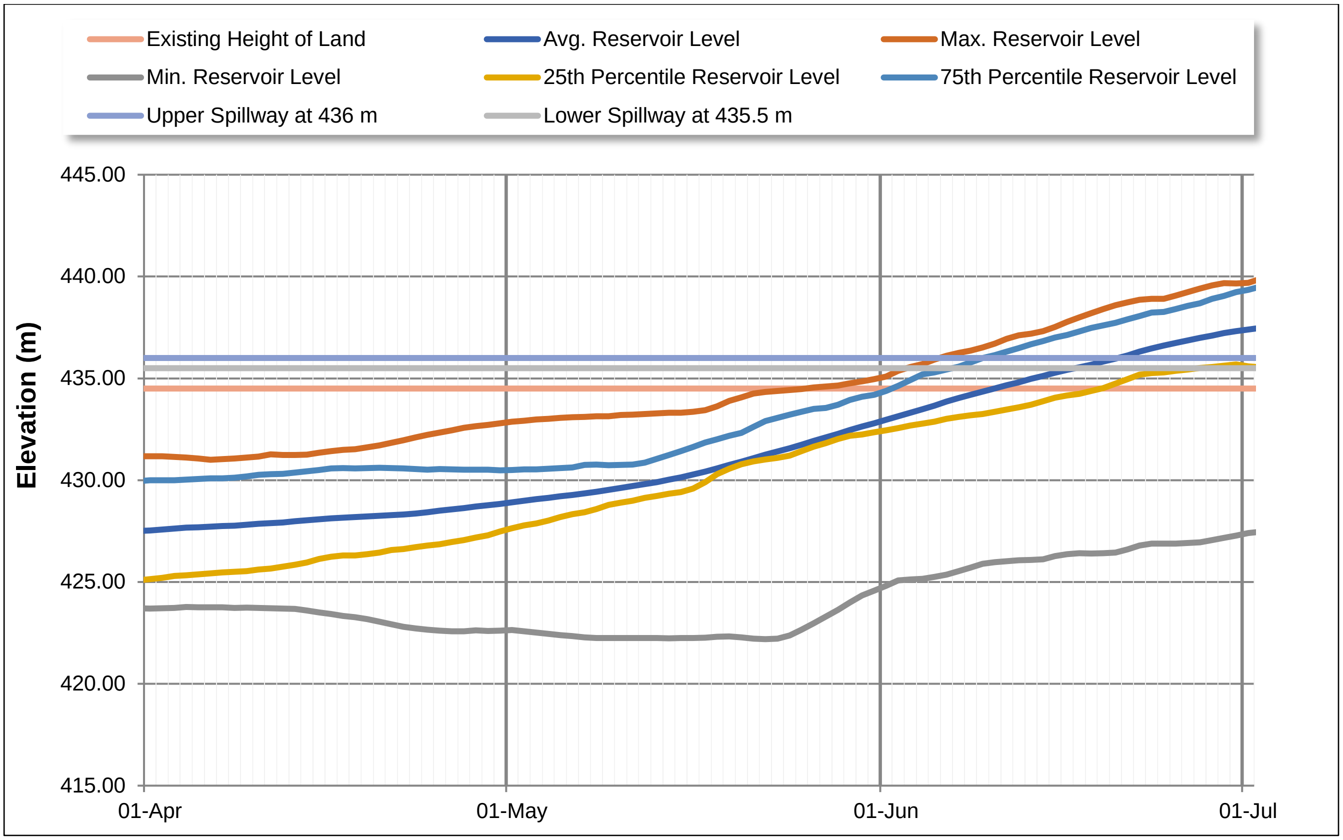

Figure 4-3: Arrow Lakes Daily Spring Reservoir Level 2000-2015

The daily reservoir data for 2000 to 2015 was used to estimate the length of time that the conceptual design could delay inundation in the main period of interest (April 1 to October 31). In addition, a frequency analysis was conducted for four common reservoir operating regimes, previously identified by LGL. The most common operating regime for the reservoir over the last 15 years is the Type 3 (high water level year-round), and the Type 4 regime (low spring, high summer, and fall) is most common overall.

For these calculations, inundation is defined reservoir level exceeding the spillway elevation or existing height of land at the edge of the wetland and water from the reservoir begins flowing into the wetland. The results of this frequency analysis are summarized in Table 4-1.

These results show that the preliminary design concept will reduce the time the wetland is inundated by 20 to 30 days on average, for the lower and upper wetlands respectively, with most of the improvement taking place in early fall. These estimates are based on average conditions, and the minimum and maximum number of additional days inundation free are expected to be 8 and 50 days respectively. For the spring and early summer, the design is expected to delay inundation by 7 to 11 days on average. For Type 3 and Type 4 operating regimes (the most common), the delay of inundation in the spring is similarly short.

This indicates that the delay of inundation during the most important habitat window (late spring) is not substantial. Though there are benefits associated with delaying inundation by this relatively short amount of time, additional analysis was completed to further evaluate environmental benefits of the design, which is documented in Section 4.4.

Table 4-1: Inundation Frequency based on Four Common Operating Regimes*

Operating Regime		Existing Condition	Wetland 1 (Upper) Design	Wetland 2 (Lower) Design	Notes
Average 2000-2015	Avg. Days Inundation Free (April 1 – October 31)	127	158	147	Maximum additional days: 50 (upper) 35 (lower) Minimum additional days: 11 (upper) 8 (lower)
	Avg. Days Inundation Free Spring (April 1 – July 31)	70	81	77	Maximum additional days: 36 (upper) 24 (lower) Minimum additional days: 11 (upper) 8 (lower)
Type 1: Low Water Level Year-Round	Avg. Days Inundation Free (April 1 – October 31)	214	214	214	Includes: 1968, 1973, 1977, 1992, 2001, 2004, 2015, 2016
	Avg. Days Inundation Free Spring (April 1 – July 31)	122	122	122	
Type 2: Low Maximum Water Level	Avg. Days Inundation Free (April 1 – October 31)	104	178	149	Least common operating regime Includes: 1979, 1987, 1993, and 1994
	Avg. Days Inundation Free Spring (April 1 – July 31)	73	93	82	
Type 3: High Water Level Year-Round	Avg. Days Inundation Free (April 1 – October 31)	60	122	108	Most common operating regime in last 15 years Includes: 1981, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014
	Avg. Days Inundation Free Spring (April 1 – July 31)	60	69	66	
Type 4: Low Spring, High Summer, and Fall	Avg. Days Inundation Free (April 1 – October 31)	76	83	81	Most common operating regime 1969 – 2015 Includes all other years between 1969 and 2015
	Avg. Days Inundation Free Spring (April 1 - July 31)	76	83	81	

*Based on average of water levels for years indicated for each operating condition

4.3 Hydrology and Hydraulics Model

A PCSWMM model was created to assess the existing hydrology of the wetland and the effects of the conceptual design. Two types of models were developed – a 200-year 24-hour storm event and a continuous 6-year simulation using 2001 to 2006 weather and reservoir data.

These models allow for the design to be evaluated for regular and extreme event conditions. The 200-year event was selected to be conservative, as the additional expected design and construction effort would be minimal for the 200-year versus 100-year event. The hydrology model was developed for the initial design concept, which included one wetland cell with a spillway and wetland outlet to maintain set environmental water levels. During the preliminary design, the design concept and model were adjusted to create two wetland cells with separate spillways at different elevations. The data inputs, assumptions, and results are described in the following sections.

Data Inputs and Assumptions

The PCSWMM model performs hydrologic and hydraulic simulations. The hydrologic component calculates surface runoff, evaporation, infiltration, and groundwater flows. The hydraulic component uses Dynamic Wave Routing to simulate channel and pipe flows and water levels, storage and peak flow attenuation, and backwatering from downstream boundary conditions.

Catchment Parameters

For the hydrologic simulations, catchment characteristics, such as area, slope, roughness, and flow path were determined from: survey completed of the wetland by BC Hydro in November 2016, a digital surface model provided by LGL for the entire catchment, and aerial photography provided by LGL.

Wetland Storage

No survey was conducted of the submerged part of the wetland. In order to produce storage relationships for the wetland cells, it was assumed that the base of the lower wetland cells is 433.9 m geodetic and the base of the upper cell is 434.1 m geodetic, based on site information from the BC Hydro surveyors and LGL. Stage-area-storage curves were then developed for the existing topography and the conceptual design. An initial wetland depth of 0.2 m was used for all model runs. The following figure shows the developed stage-storage curves (note total proposed wetland volume is the sum of wetland 1 and 2 shown in Figure 4-4).

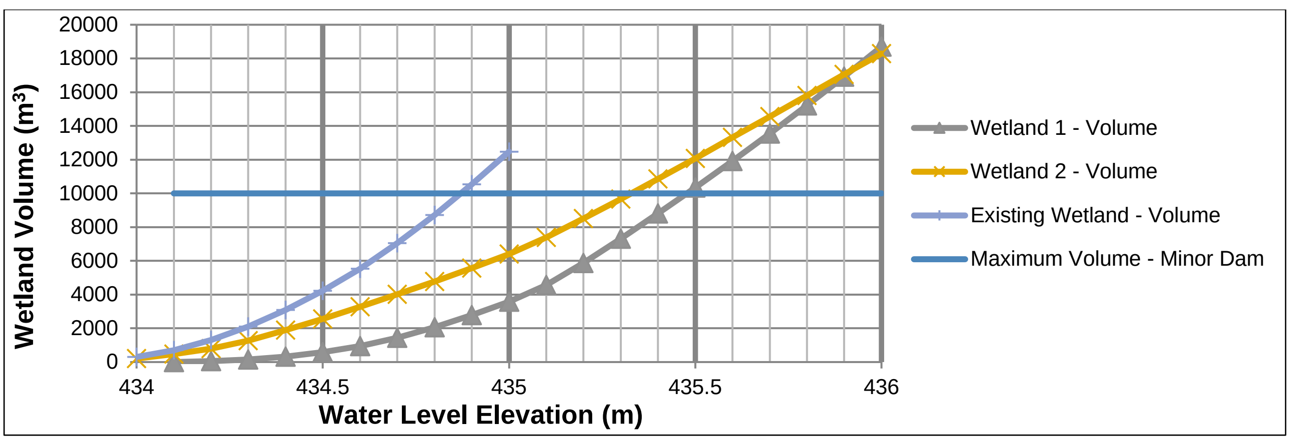

Figure 4-4: Wetland Stage-Storage Curves used in PCSWMM Model

Rain and Snow Data

The 200-year 24-hour event rainfall was developed with IDF curves for the Fauquier weather station (Climate ID: 1142820) and the AES British Columbia Interior distribution for the 24-hour duration storm. Fauquier is located 2 to 3 km northeast of the Lower Inonoaklin site on the east side of the reservoir. Based on weather data from Fauquier, the peak annual storms typically occur in the summer months (June through August) and are not associated with rain-on-snow conditions.

For the continuous simulation, historical weather data from the Fauquier station (Climate ID: 1142820) was used to generate a time series of equivalent rainfall composed of:

- total rainfall from daily station records; and
- total snowmelt calculated when the average temperature was greater than 0 °C[5]

This time series of total daily equivalent rainfall was compared to the total precipitation records on an annual volume basis, and the results agreed to within ± 5%.

Reservoir Water Levels

Daily reservoir level data for the Arrow Reservoir at Fauquier (Water Survey of Canada Station 08NE102) was provided by LGL. For the date of the survey (November 25, 2016), the surveyed reservoir elevation at the Lower Inonoaklin site was compared to the WSC gauge to ensure reservoir levels are not significantly different between the sites and that the WSC gauge elevations match the surveyed geodetic elevations. For the continuous simulation, 2001 to 2006 (inclusive) were selected for modelling due to the quality of weather data, and because these years had summer reservoir levels resulting in inundation and non-inundation conditions. Reservoir levels were used in the model as a time series for the outlet boundary conditions in the continuous model only.

Soils and Infiltration Information

Soils information for the catchment included: coarse BC GSC terrain mapping, nearby well drilling logs, and test pits conducted at the berm locations. Based on the information available, it was assumed that the upper forested catchment consisted of silty loam soil and the lower catchment consisted of silty clay loam soil. This was used to estimate soil moisture parameters, infiltration, and groundwater movement.

The following are the key assumptions related to groundwater and infiltration:

1. The analysis assumes wet initial conditions for the 200-year storm, and dry initial conditions for the continuous model;
2. All groundwater flows to the sub-catchment outlet points; there is no alternate groundwater flow route away from the system; and

[5] Assuming rain-free conditions and 6 to 10 km/h average wind in a forested area, according to the US Army Corps of Engineers Design Manual for Runoff from Snowmelt. Engineer Manual 1110-2-1406: Runoff from Snowmelt. US Army Corps of Engineers, March 1998. http://www.publications.usace.army.mil/Portals/76/Publications/EngineerManuals/EM_1110-2-1406.pdf

3. Saturated hydraulic conductivity:

    a. Silt loam: 21 mm/hr (expected range 15 -50 mm/hr); and [6]
    b. Silty clay loam: 13.2 mm/hr (expected range 5 – 15 mm/hr).[6]
    c. Storage nodes:

        i. Calibrated the existing condition model to 0.1 mm/hr based on LGL observed site conditions 2012-2015 (wetlands don't dry out). 0.1 mm/hr results in typical water levels in the wetland (excluding the period of inundation from the reservoir) of 0.2 to 0.5 m for the existing condition. This seepage results in the upper pool drying out part of the summer.

        ii. Conducted a sensitivity analysis for the design condition based on expected conductivity range of 0.36 to 3.6 mm/hr for the berms and surrounding ground (based on test pits completed by Thurber Engineering) and 0.1 mm/hr for the existing wetland base. The results of this analysis are discussed in the following section.

These assumptions do not account for potential sand and gravel zones in the subsurface, which would increase the rate of subsurface flow and seepage in the local vicinity of higher permeability zones. If excavation exposed course-grained material, placement and compaction of fine-grained material would aid in reducing seepage.

Evaporation

Monthly average daily evaporation input to the model was estimated based on historical evapotranspiration data for Nakusp from FarmWest (see table below). [7] Nakusp is located approximately 50 km northeast of the Lower Inonoaklin site.

Table 4-2: Monthly Evaporation Averages

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Monthly Evaporation (mm/day)	0.3	0.7	1.4	2.4	3.8	4.5	5.1	4.3	2.4	1	0.6	0.3

Wetland Drainage

The preliminary design modelled consisted of:

- a lower berm with spillway elevation of 435.5 m and stored water volume of 10,800 m^3;
- an upper berm with spillway elevation of 436.0 m and stored water volume of 18,300 m^3; and
- three borrow areas for material sources to build the berms within the areas of the wetland pools.

The berms are modelled as vertical walls. The existing outlet of the wetland is between 434 and 434.25 m geodetic.

Simulation Time Step

A hydrologic reporting time step of 60 minutes for the continuous models was used to match the rainfall data. A hydraulic routing time step of 5 seconds was used for the 200-year model runs and 1 second for the continuous model (due to instabilities associated with reservoir inundation).

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[6] US Department of Agriculture. Saturated Hydraulic Conductivity in Relation to Soil Texture. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/office/ssr10/tr/?cid=nrcs144p2_074846

[7] FarmWest Evapotranspiration. http://farmwest.com/climate/et.

Simulation Results

200-year 24-hour Storm

The 200-year 24-hour model was run for two conditions: a low initial wetland level scenario, and a high initial wetland elevation (water level at the spillway at storm initiation) to evaluate spillway sensitivity (See Figures 4-5 and 4-6). The model results predict the maximum depth and flow rate over the spillways during the 200-year return period rainfall event. The more conservative values were used for design.

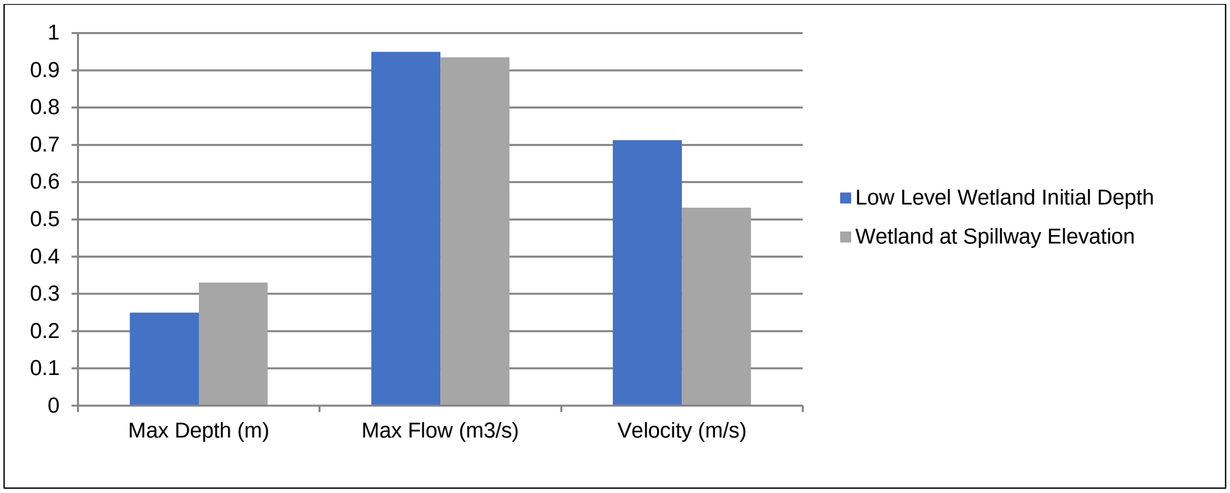

Figure 4-5: Upper Wetland Spillway – 200-year, 24-hour Storm

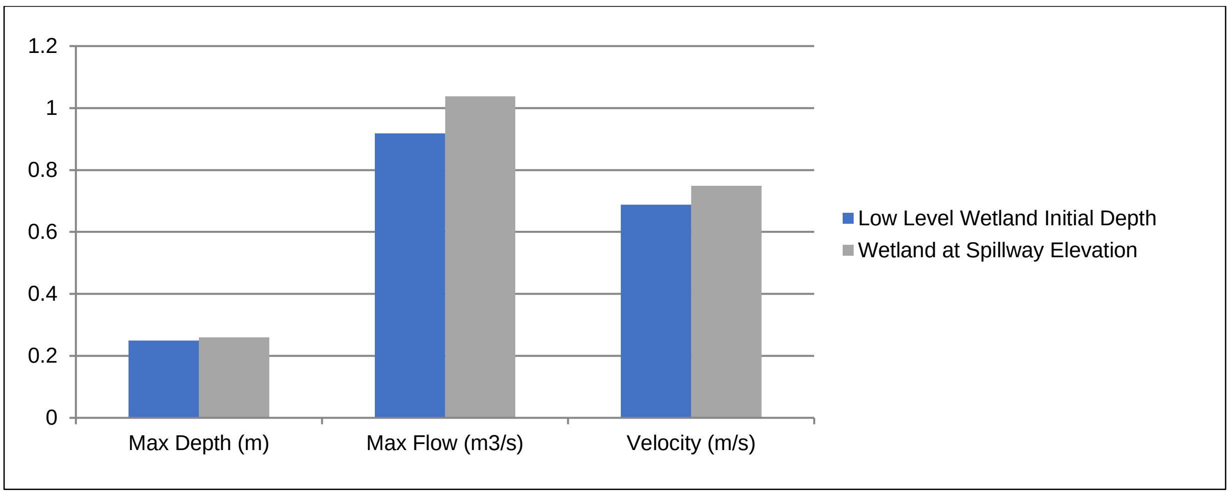

Figure 4-6: Lower Wetland Spillway – 200-year, 24-hour Storm

Continuous Model (2001-2006)

The continuous model was run multiple times and a sensitivity analysis was completed for the rate at which water seeps out of the design wetland via infiltration, to determine the potential range of infiltration volumes and wetland levels. The existing wetland infiltration rate was calibrated to 0.1 mm/hr as previously described. Saturated hydraulic conductivity of the berms and surrounding higher ground is expected fall between 0.36 and 3.6 mm/hr based on Thurber test pit results. Based on these values, the model was run with four conductivity conditions for the initial design concept (one large wetland with a spillway and low-level outlet) with an upper limit of 1.5 mm/hr. Figure 4-7 shows the results of the sensitivity analysis for one year of the continuous model.

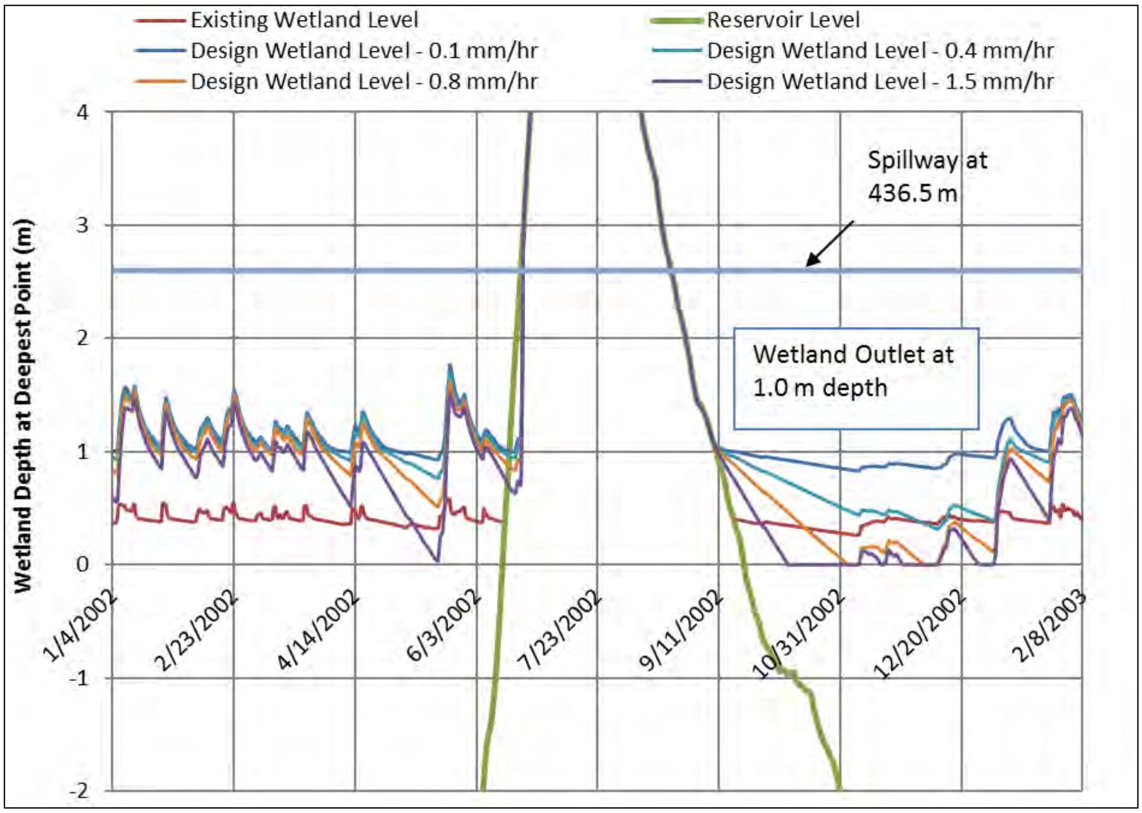

Figure 4-7: Wetland Infiltration Rate Sensitivity Analysis

It is expected that with the raising of the wetland using berms, the overall infiltration rate will increase. This is because the bottom of the existing wetland is bound off with fine and organic material resulting in the very small 0.1 mm/hr rate, but the berms will not have bound off and will seep at a higher rate. An infiltration rate of 0.4 mm/hr saturated hydraulic conductivity results in wetland depths of 0.1 to 0.2 m during non-inundation years, while higher conductivity values result in the wetland frequently reaching fully dry conditions, which is not expected. Over time the berms and the ground below elevation 454.5 m within the wetland may bind off reducing the infiltration rate to 0.1 mm/h. Therefore, over time the wetland depths are expected to be within the range of the two model runs for infiltration rates of 0.1 mm/hr and 0.4 mm/hr.

Figures 4-8 and 4-9 show the results for the entire continuous model run for the existing condition and for the modelled design wetlands with the selected 0.4 mm/hr and 0.1 mm/hr infiltration rates.

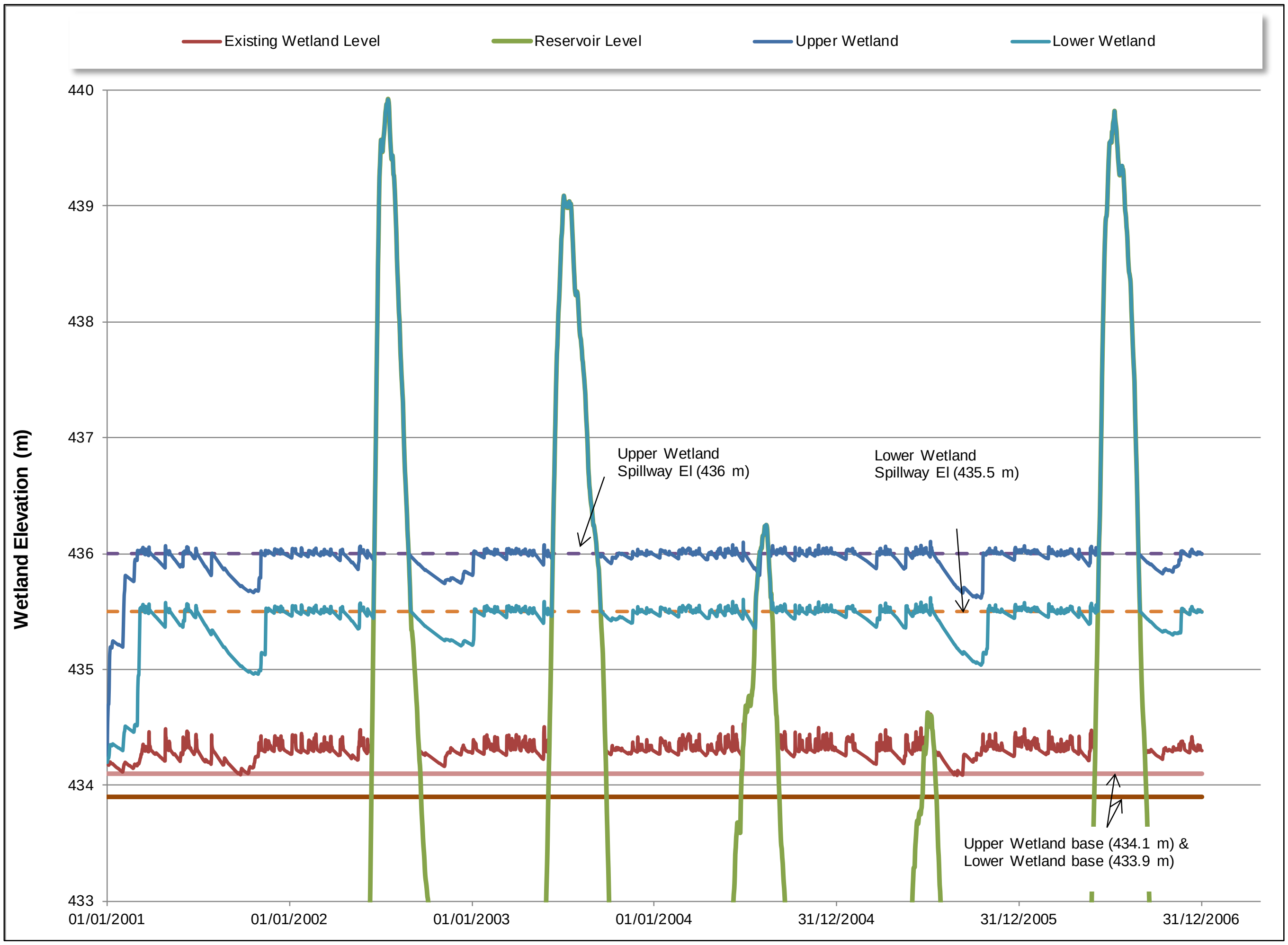

Figure 4-8: Continuous Model Wetland Depth (0.1 mm/hr infiltration) 2001-2006

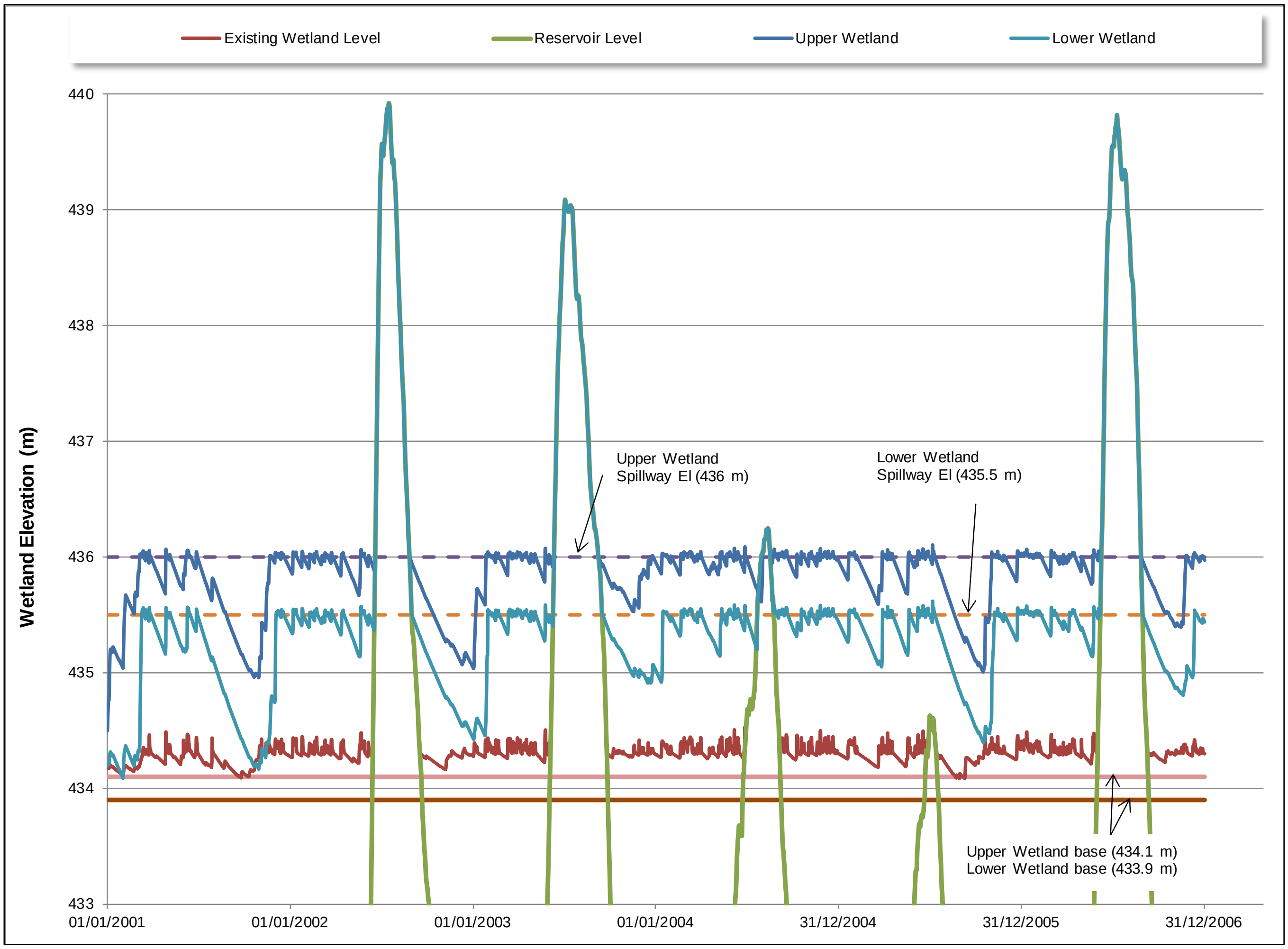

Figure 4-9: Continuous Model Wetland Depth (0.4 mm/hr infiltration) 2001-2006

The continuous model results indicate that the design as modelled retains additional water in the wetland and prevents inundation during lower reservoir water years (2005) and for a greater length of time. Large water level increases in the above figure are due to wetland inundation from the reservoir. Under existing conditions, the wetland water level varies between 0.2 and 0.7 m at the deepest point when the wetland is not inundated (infiltration calibrated to reach this result based on observed site conditions). The water level as modelled varies between 0.9 m and 2.0 m deep (when not inundated) for the upper wetland and between 0.2 m and 1.7 m for the lower wetland, as measured from the lowest point in the wetlands. The original environmental criteria set a target range of 0.5 m to 1 m depth, and the continuous simulation predicts variation above and below (lower wetland only) these levels. However, the revised target depths of 0.3 to 0.5 m are exceeded majority of the time. This design would increase the variability in depth across the areas of the wetlands, which is desirable for diversity of habitat.

These results indicate that there is sufficient drainage from the upland catchments to fill the wetland every year during typical conditions, though infiltration rates are expected to vary. The model demonstrated that the water depths in the wetland are expected to be relatively high year-round, with maximum depths often greater than the target range. A low-level outlet in the lower wetland could reduce water levels. Additional analysis was completed to assess acceptable depth ranges for the whole wetland area and is documented in Section 4.4.

During very low water years, it is possible that the wetlands could run dry, and a drought sensitivity analysis has not been conducted. The majority of the catchment drainage enters the upper wetland, and so if this wetland does not spill water, the lower wetland may experience lower water levels. However, this does not seem to be an issue as there was sufficient spillage from the upper wetland throughout the six years modelled. The lower wetland typically lagged behind the upper wetland when filling but would quickly catch up.

Based on the expected infiltration rate range, infiltration loss ranges from 3 to 20% of the total wetland inflow, while evaporation loss amounts to 3 to 5% of the total wetland inflow.

4.4 Wetland Depth Analysis

Following preliminary design, additional analysis and refinement of wetland depths and areas was conducted, to better quantify the benefit considering reduced target wetland depths of 30 to 50 cm. This analysis focused on answering three questions:

1. Is there a significant benefit from retaining water in the spring?
2. What is the average wetland depth (now and with the proposed design)?
3. What is the distribution and area of various water depths in the wetland?

An initial assessment was conducted to estimate the number of days at various average wetland depths in the spring (for model period of 2001 to 2006), to evaluate whether there is a significant benefit from retaining runoff in the spring. This analysis estimates the average wetland depth as the total volume of water stored divided by the wetland area at the respective water level, but it does not account for variability of depth in the wetland. The results of this assessment are shown in the following figure.

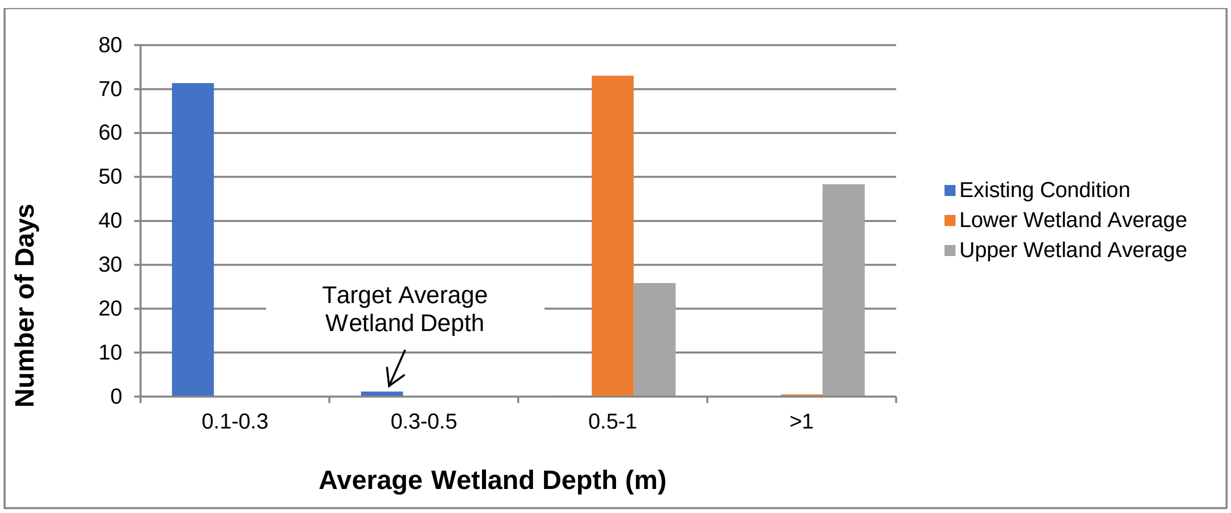

Figure 4-10: Frequency of Average Wetland Depth April 1 – June 15 (2001-2006)

Figure 4-10 indicates that the existing condition has average water levels below the target depth, while the design results in water levels above the target depths. This indicates that there is benefit in the spring from retaining water, but it results in deeper wetland habitat than desired (less than 0.5 m depth).

The preliminary design tiered wetland depths are known to be too deep based on Figure 4-10. Following this initial assessment, additional analysis was conducted to determine whether the existing and potential wetland depths are within the desirable ranges, to what extent, and whether a lower spillway could improve the wetland distribution and duration of depths relative to the existing wetland.

The wetland depths considered include:

- <0.3 m as good for project objectives;
- 0.3 to 0.5 m as a target or ideal; and
- >0.5 m as undesirable for project objectives since it could attract geese.

At any given wetland elevation, there is a range of depths throughout the wetland. This analysis aimed to capture the frequency of a given elevation range and its associated wetland depths and areas. The following tables present the area of the wetland within each range of wetland depths (<0.3 m, 0.3 to 0.5 m, 0.5 to 1 m and >1m) at a given range of wetland elevations (0.1 m increments). Weighted average areas are also presented to provide an overall impression of the typical depths and areas for the various wetland scenarios.

The following scenarios were considered:

1. The existing wetland;
2. Two potential low spillway scenarios (0.2 m and 0.3 m - very roughly estimated. Note that this used the existing wetland geometry (i.e., no excavation or fill, for simplicity); and
3. The preliminary design – a tiered wetland with approximately 1.5 m high spillways (information broken down by upper, lower and total wetland).

Table 4-3: Depth Area Analysis – Existing Wetland

Existing Wetland	Area (m^2) within Elevation Range (% of total area)					Time Weighted Avg.	
	434.1-434.2 m	434.2-434.3 m	434.3-434.4 m	434.4-434.5 m	>434.5 m	Average Areas (m^2)	% of Total Area
0 to 0.3 m depth	4,620 (100%)	4,562 (65%)	5,430 (61%)	6,028 (57%)	5,166 (42%)	5,020	62%
0.3 to 0.5 m depth	0 (0%)	2,454 (35%)	3,502 (39%)	2,167 (20%)	3,513 (29%)	2,864	36%
0.5 to 1 m depth	0 (0%)	0 (0%)	0 (0%)	2,454 (23%)	3,502 (29%)	182	2%
>1 m depth	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0	0%
Total Wetland Area (m^2)	4,620	7,015	8,932	10,648	12,182	**8,066**	
Inundation Free Days	1	36	31	4	1	**Total Days**	**73**
% of time	1%	49%	42%	5%	1%		

Note: This analysis was conducted for the inundation free period (April 1 – June 15) based on 2001 to 2006 modelled results.

Table 4-4: Depth Area Analysis – Reduced Design Estimate – 0.2 m high spillway

Rough Estimate 0.2 m high Spillway	Area (m^2) within Elevation Range (% of total area)					Time Weighted Avg.	
	434.3-434.4 m	434.4-434.5 m	434.5-434.6 m	434.6-434.7 m	>434.7 m	Average Areas (m^2)	% of Total Area
0 to 0.3 m depth	5,430 (61%)	6,028 (57%)	5,166 (42%)	5,131 (36%)	5,381 (34%)	5,596	49%
0.3 to 0.5 m depth	3,502 (39%)	2167 (20%)	3,513 (29%)	4,311 (31%)	3,633 (23%)	2,894	25%
0.5 to 1 m depth	0 (0%)	2454 (23%)	3,502 (29%)	4,620 (33%)	7,015 (44%)	3,047	26%
>1 m depth	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0	0%
Total Wetland Area (m^2)	8,932	10,648	12,182	14,062	16,030	**11,537**	
Inundation Free Days	1	36	31	4	1	**Total Days**	**73**
% of time	1%	49%	42%	5%	1%		

Note: This analysis was conducted for the inundation free period (April 1 – June 15) based on 2001 to 2006 modelled results.

Table 4-5: Depth Area Analysis – Reduced Design Estimate – 0.3 m high spillway

Rough Estimate 0.3 m high Spillway	Area (m^2) within Elevation Range (% of total area)					Time Weighted Avg.	
	434.4-434.5 m	434.5-434.6 m	434.6-434.7 m	434.7-434.8 m	>434.8 m	Average Areas (m^2)	% of Total Area
0 to 0.3 m depth	6,028 (57%)	5,166 (42%)	5,131 (36%)	5,381 (34%)	5,293 (30%)	5,176	45%
0.3 to 0.5 m depth	2,167 (20%)	3,513 (29%)	4,311 (31%)	3,633 (23%)	3,250 (19%)	3,837	33%
0.5 to 1 m depth	2,454 (23%)	3,502 (29%)	4,620 (33%)	7,015 (44%)	8,932 (51%)	4,230	37%
>1 m depth	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0	0%
Total Wetland Area (m^2)	10,648	12,182	14,062	16,030	17,475	**13,243**	
Inundation Free Days	1	36	31	4	1	**Total Days**	**73**
% of time	1%	49%	42%	5%	1%		

Note: This analysis was conducted for the inundation free period (April 1 – June 15) based on 2001 to 2006 modelled results.

Table 4-6: Depth Area Analysis – Lower Wetland (Design)

Lower Wetland (Design)	Area m^2 within Elevation Range (% of total area)			Time Weighted Avg.	
	435.3-435.4 m	435.4-435.5 m	435.5-435.6 m	Average Areas (m^2)	% of Total Area
0 to 0.3 m depth	9,672 (37%)	4,628 (17%)	2,284 (8%)	4,313	16%
0.3 to 0.5 m depth	2,216 (8%)	6,908 (25%)	8,913 (32%)	7,141	26%
0.5 to 1 m depth	7,507 (28%)	6,979 (26%)	6,863 (25%)	6,990	25%
>1 m depth	7,073 (27%)	8,709 (32%)	9,932 (35%)	8,968	33%
Total Wetland Area (m^2)	**26,467**	**27,223**	**27,992**	**27,411**	
Inundation Free Days	**7**	**42**	**25**	**Total Days**	**74**
% of time	**9%**	**57%**	**34%**		

Note: This analysis was conducted for the inundation free period (April 1 – June 15) based on 2001 to 2006 modelled results.

Table 4-7: Depth Area Analysis – Upper Wetland (Design)

Upper Wetland (Design)	Area m^2 within Elevation Range (% of total area)			Time Weighted Avg.	
	435.8 to 435.9 m	435.9 to 436.0 m	436.0 to 436.1 m	Average Areas (m^2)	% of Total Area
0 to 0.3 m depth	13,09 (4%)	1,337 (4%)	1,877 (6%)	1,530	5%
0.3 to 0.5 m depth	1,525 (5%)	1,189 (4%)	867 (3%)	1,095	4%
0.5 to 1 m depth	11,887 (41%)	11,536 (39%)	11,197 (36%)	11,437	38%
>1 m depth	14,579 (50%)	15,688 (53%)	16,795 (55%)	16,013	53%
Total Wetland Area (m^2)	**29,301**	**29,750**	**30,735**	**30,075**	
Inundation Free Days	**5**	**43**	**27**	**Total Days**	**75**
% of time	**7%**	**57%**	**36%**		

Note: This analysis was conducted for the inundation free period (April 1 – June 15) based on 2001 to 2006 modelled results.

Table 4-8: Depth Area Analysis – Total Wetland (Design)

Total Wetland (Design)	Area m^2 (% of total area)			Weighted Average Areas (m^2)	% of Total Area
0 to 0.3 m depth	10981 (20%)	5965 (10%)	4160 (7%)	5738	10%
0.3 to 0.5 m depth	3740 (7%)	8097 (14%)	9780 (17%)	8335	14%
0.5 to 1 m depth	19394 (35%)	18514 (32%)	18060 (31%)	18426	32%
>1 m depth	21652 (39%)	24397 (43%)	26727 (46%)	24993	43%
Total Wetland Area (m^2)	**55768**	**56973**	**58727**	**57492**	
Inundation Free Days	**6**	**42**	**26**	**Total Days**	**74**
% of time	**8%**	**57%**	**35%**		

Note: This analysis was conducted for the inundation free period (April 1 – June 15) based on 2001 to 2006 modelled results.

Based on Tables 4-3 to 4-8, the following are general observations:

- The existing wetland has most of its depths in the good range (approximately 62%) and many in the target depths (approximately 35%) for most of the April 1 to June 15 period.
- The preliminary design spillway heights are too high since most of the wetland area (75%) has depths above the good or target depths (i.e., >0.5 m) for most of the April 1 – June 15 period, however:
  - The preliminary design wetland has over seven times the wetland area of the existing wetland; and
  - The preliminary design has almost three times the area within the target depth range relative to the existing wetland and slightly more wetland area in the less than 0.3 m depth range.
- A design with a lower spillway, perhaps about 0.3 m in height, could increase the area of the target wetland depth (0.3 to 0.5 m) compared to the existing wetland, however it would add area of wetland within the 0.5 to 1 m range.

Based on the above assessment, it was determined that though the design increases the area in the target and good depth ranges, it creates a significant area with depths greater than 0.5 m, which are higher than revised project objectives. A significantly reduced spillway height could increase the wetland area compared to the existing condition; however, the main increase in wetland area would be for areas with depths greater than 0.5 m, with only minor increases in the target and good ranges. As the existing shallow wetland is functioning relatively well, BC Hydro decided not to proceed with any berm design, to avoid risking the existing habitat and making a large investment for a moderate to low improvement in habitat.

The existing water level in the wetlands is maintained by the high ground created at the south end of the site by sediment deposition as a result of littoral drift. Due to the ongoing deposition in this area, the high ground at the outlet is not anticipated to be at risk of erosion. Monitoring of the site and outlet could be conducted annually or semi-annually to assess changes in outlet geometry that would negatively impact the wetland function. If erosion or other significant negative changes at the outlet are identified, mitigation work (such as an armoured berm) could be completed to restore the outlet condition.

4.5 Summary of Results and Environmental Benefits of Design

The results of the modelling and wetland depth analysis indicate several key points about the wetland hydrology, and thus the expected environmental benefits of the tiered wetland design:

1. Wetland water loss from evaporation is relatively small, and water loss from infiltration is expected to be moderate;
2. The upper catchment provides sufficient flows to maintain water in the wetland through the summer prior to inundation in most years, though during very low-water years depths may be lower than preferred for environmental habitat. The additional pool depth of the proposed preliminary design allows more of the runoff from the upland area to be captured and held in the wetland to support wetland habitat during dry conditions;
3. The berms delay inundation and mixing of the wetland by the reservoir in the spring-autumn season for a relatively short time, which is of benefit to the wetland function, providing for:
   a. 20 days longer inundation free on average for 2000 to 2015 in the lower wetland area (seven days in spring); and
   b. 31 days longer inundation free on average for 2000 to 2015 in the upper wetland area (11 days in spring).
4. The preliminary design provides for increased wetland area on the site, from the existing condition of approximately 20,100 m^2 to the design condition providing approximately 30,700 m^2 (12,400 m^2 in the lower wetland and 18,300 m^2 in the upper wetland area). This represents an increase of 53% in wetland area over the existing condition on the site;
5. In addition to the increased wetland area, holding water behind the berms to the height of the spillways will result in increase in the depth within with the wetlands. The water level as modelled varies between 0.9 m and 2.0 m deep (when not inundated) for the upper wetland and between 0.2 m and 1.7 m for the lower wetland, as measured from the lowest point in the wetlands; and
6. A detailed wetland depth analysis indicates that though the design increases the total area in the target and good depth ranges (<0.3 m and 0.3-0.5 m respectively), it creates a greater area with undesirable depths (>0.5 m). A reduced spillway height could provide a moderate increase in wetland area in the target depths; however, the main effect would be to create more deep wetland area, which is undesirable.

Based on environmental benefit analysis, BC Hydro decided not to proceed with the design, in order to preserve the existing shallow habitat and avoid the creation of deep wetlands which may attract undesirable Canada Geese.

4.6 Potential Future Habitat Improvements

Though berm construction was excluded following the preliminary design, other wetland improvement works were considered to focus instead on improving and supplementing the existing habitat and removal of invasive Reed Canary Grass. As removal methods for Reed Canary Grass are uncertain, it was noted that this is an area of considerable risk, particularly if the site conditions are not altered to prevent regrowth.

Based on these considerations, BC Hydro elected to not proceed with any habitat improvements at the Lower Inonoaklin site at this time. In the future, Reed Canary Grass removal trials at Burton Flats may illustrate successful methods that could be employed at the Lower Inonoakin Wetland. At that time, BC Hydro could consider completing the following works to improve the wetland habitat at Lower Inonoaklin:

1. Minor excavation along the upper part of the wetland to increase shallow wetland area;
2. Habitat mounding and burial of large woody debris (LWD) to increase habitat complexity;
3. Excavation and burial of invasive Reed Canary Grass above the main wetland, considering methods to reduce or prevent regrowth; and
4. Planting in designated areas around the wetland.

5. Class C Construction Cost Opinion

Based on the preliminary design, a Class C construction cost opinion (estimate) has been prepared for the proposed works as represented by the preliminary design. Class C construction cost opinions, as defined by the Association of Professional Engineers and Geoscientists of BC (APEGBC) and the Consulting Engineers of BC (CEBC) are expected to have 25 to 40% accuracy, though this level of accuracy is not guaranteed.

This Class C construction cost opinion has been prepared with a topographic survey, limited site soils and vegetation information and is based on probable conditions affecting the project. This cost opinion represents KWL's best judgement based on the available site information, previous projects in the area and BC, or with similar components, cost estimates provided by local riprap suppliers, *The Blue Book 2016-2017 Equipment Rental Rate Guide,* and the preliminary design details and volumes. It represents the summation of all reasonably identifiable project elemental construction costs (less taxes, professional fees, and BC Hydro internal costs).

Due to the uncertainty and potential for the adjustments to the design between preliminary and detailed design, BC Hydro requires a construction cost estimate of +50%/-15%. Therefore a 50% contingency on the construction cost is included in the estimate. This has been assumed to be a 35% contingency to completion of detailed design, and a 15% bid and construction contingency following detailed design. The cost opinions exclude professional fees and taxes and operation and maintenance costs. Two Class C construction cost opinions have been prepared, one including the Reed Canary Grass Removal presented in Table 5-1, and one excluding it, presented in Table 5-2.

Excluding the Reed Canary Grass Removal, the estimated costs are considerably higher than the conceptual level construction costs presented in the 2016 Concept Design Report. This is primarily due to the estimated berm fill being approximately 40% more than estimated in the conceptual design, and the inclusion of sheet piles to mitigate seepage through the riprap spillways.

Estimated construction costs could be reduced in the detailed design stage by a number of means that could be considered in consultation with BC Hydro and LGL:

1. Reduce the berm height, or reduce both the berm crest and the spillway crest elevations. A reduction in the berm crest elevation would reduce the planting area at a higher elevation, and a reduction in the spillway crest elevation would reduce the environmental benefit of the wetland enhancement project (area, volume and inundation free days);
2. Evaluate the depth of pile burial required for seepage control (expected to be less than assumed in the preliminary design), or select an alternate outlet design such as a log outlet structure (may be more permeable). An alternate outlet design such as a log outlet is more feasible with a reduced spillway crest height (item above);
3. Employ a cheaper seepage mitigation method such as constructing a grouted riprap plug at the spillway crests to limit seepage. This would be susceptible to cracking, settlement and would not be as effective against seepage as sheet piles;
4. Removal of the lower wetland area from the design. This would reduce cut and fill volumes and eliminate one spillway; however, it would reduce the environmental benefit of the wetland enhancement project; and
5. Consider a reduced depth of burial for the Reed Canary Grass removal, perhaps with the addition of a geotextile fabric to reduce the likelihood of regrowth. As an initial estimate, it is expected that reducing burial depth by use of geotextile could result in approximately $47,000 savings.

Table 5-1: Class C Cost Estimate Including Reed Canary Grass Removal

Item	Description	Unit	Estimated Quantity	Unit Rate	TOTAL PRICE	Comment
1	**General**					
1.01	Mobilization and demobilization	LS	1	1.5%	$8,000	1.5% of total construction cost.
1.02	Sediment and water control allowance	LS	1	$10,000.00	$10,000	Allowance - depends on duration, water level, staging, etc.
1.03	Quality control (testing and construction survey)	LS	1	$15,000.00	$15,000	Allowance for construction survey, testing equipment, labour and expenses.
1.04	Bonding and insurance	LS	1	1.5%	$8,000	1.5% of total construction cost.
	Subtotal for Task 1				**$41,000**	**(Rounded to the Nearest $1,000)**
2	**Berms Areas**					
2.01	Excavation, clearing, grubbing, and stockpiling	m^3	6,500	$10.00	$65,000	Assumes no offsite disposal.
2.02	Placement and compaction of berm material.	m^3	6,500	$20.00	$130,000	Onsite disposal of cleared & grubbed material (berm use)
2.03	Riprap supply and place	m^3	540	$90.00	$48,582	Based on supplier estimate and typical placement costs
2.04	Sheet Pile Provision/Installation (Steel)	m^2	110	$800.00	$88,000	Approximately 110 m^2 needed according to drawings based on recent contractor quotes in BC.
2.05	Planting Allowance	LS	1	$10,000.00	$10,000	Allowance based on discussion with LGL
2.06	Geotextile under Riprap	m^2	600	$7.00	$4,200	Placed under Riprap
2.07	Cobble / small riprap supply and place	m^3	450	$80.00	$36,000	
2.08	Geotextile under cobble / small riprap supply and place	m^2	900	$7.00	$6,300	depends on site material and cobble/small riprap gradation. A granular filter may be preferred.
	Subtotal for Task 2				**$388,000**	**(Rounded to the Nearest $1,000)**
3	**Reed Canary Area**					
3.01	Clearing, grubbing Canary Grass volume	m^3	1,850	$10.00	$18,500	assumed depth 0.4 m depth over area of 4,600 m^2
3.02	Excavation of Trench, berm material, and drainage channel.	m^3	3,800	$10.00	$38,000	Includes sloping and shaping to drainage channel
3.03	Trench Filling (with Reed Canary Grass material)	m^3	1,850	$15.00	$27,750	
3.04	Placement and compaction of Berm cover over canary grass trench	m^3	3,800	$20.00	$76,000	Assumes a minimum of 2 m cover over canary grass trench.
3.05	Planting Allowance	LS	1	$4,000.00	$4,000	Allowance
3.06	Water, sediment and invasive species control	LS	1	$5,000.00	$5,000	Allowance
	Subtotal for Task 3				**$169,000**	**(Rounded to the Nearest $1,000)**
Construction Cost Subtotal					**$598,000**	**(Rounded to the Nearest $1,000)**
	Design Contingency	35%			$209,000	Contingency for design phase only. Percentage of construction cost.
	Bid Contingency and Construction Contingency	15%			$90,000	Contingency for bid and for construction phase only. Percentage of construction cost.
Total Construction Amount (excl. GST)					**$897,000**	**(Rounded to the Nearest $1,000)**

Note: This Class C estimate has been prepared with limited site information and is based on probable conditions affecting the project. This cost opinion represents KWL's best judgment based on the available site information, previous projects in the area or with similar components, cost opinions provided by others (contractor), the Blue Book 2016-2017 Equipment Rental Rate Guide, and the preliminary design details and volumes. It represents the summation of all reasonably identified project element costs from the preliminary design. This estimate does not include professional fees or operation and maintenance costs. Costs are in 2017 dollars.

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Table 5-2: Class C Cost Estimate Excluding Reed Canary Grass Removal

Item	Description	Unit	Estimated Quantity	Unit Rate	TOTAL PRICE	Comment
1	**General**					
1.01	Mobilization and demobilization	LS	1	1.5%	$6,000	1.5% of total construction cost.
1.02	Sediment and water control allowance	LS	1	$10,000.00	$10,000	Allowance - depends on duration, water level, staging, etc.
1.03	Quality control (testing and construction survey)	LS	1	$15,000.00	$15,000	Allowance for construction survey, testing equipment, labour and expenses.
1.04	Bonding and insurance	LS	1	1.5%	$6,000	1.5% of total construction cost.
	Subtotal for Task 1				**$37,000**	**(Rounded to the Nearest $1,000)**
2	**Berms Areas**					
2.01	Excavation, clearing, grubbing, and stockpiling	m^3	6,500	$10.00	$65,000	Assumes no offsite disposal.
2.02	Placement and compaction of berm material.	m^3	6,500	$20.00	$130,000	Onsite disposal of cleared & grubbed material (berm use)
2.03	Riprap supply and place	m^3	175	$90.00	$15,750	Based on supplier estimate and typical placement costs
2.04	Sheet Pile Provision/Installation (Steel)	m^2	110	$800.00	$88,000	Approximately 110 m^2 needed according to drawings based on recent contractor quotes in BC.
2.05	Planting Allowance	LS	1	$10,000.00	$10,000	Allowance based on discussion with LGL
2.06	Geotextile under Riprap	m^2	600	$7.00	$4,200	Placed under Riprap
2.07	Cobble / small riprap supply and place	m^3	450	$80.00	$36,000	
2.08	Geotextile under cobble / small riprap supply and place	m^2	900	$7.00	$6,300	depends on site material and cobble/small riprap gradation. A granular filter may be preferred.
	Subtotal for Task 2				**$355,000**	**(Rounded to the Nearest $1,000)**
Construction Cost Subtotal					**$392,000**	**(Rounded to the Nearest $1,000)**
	Design Contingency	35%			$137,000	Contingency for design phase only. Percentage of construction cost.
	Bid Contingency and Construction Contingency	15%			$59,000	Contingency for bid and for construction phase only. Percentage of construction cost.
Total Construction Amount (excl. GST)					**$588,000**	**(Rounded to the Nearest $1,000)**

Note: This Class C estimate has been prepared with limited site information and is based on probable conditions affecting the project. This cost opinion represents KWL's best judgment based on the available site information, previous projects in the area or with similar components, cost opinions provided by others (contractor), the Blue Book 2016-2017 Equipment Rental Rate Guide, and the preliminary design details and volumes. It represents the summation of all reasonably identified project element costs from the preliminary design. This estimate does not include professional fees or operation and maintenance costs. Costs are in 2017 dollars.

\\bbyfs1.kwl.ca\0000-0999\0400-0499\478-201\300-Report\FeasibilityReport\Tables\[2018-02-16_ClassC_Tables_5-1_and_5-2.xlsx]Table 5-2 no RCG removal

6. Operation, Maintenance, and Monitoring

As noted above in the Section 3, it is understood that BC Hydro would prefer minimal operations and maintenance requirements, and that a passive outlet rather than one that requires active management is preferred. This would minimize the need for any additional safeguards to protect the system from unauthorized uses (e.g., locks on a gate mechanism).

Future monitoring and maintenance access could be from the end of Lower Inonoaklin Road and along the unvegetated area of the wetland shoreline on the reservoir side avoiding the southwest archaeological site. It may be possible to utilise the berm crests, but preferably not, to avoid damaging the planting. The route will not be formalized or include any gravel running surface, in order to keep the area in as natural a state as possible.

Monitoring for the engineering structures is outlined in Schedule 2 of the DSR for low consequence dams, which includes: quarterly site surveillance, and annual formal inspection. Inspections should follow the DSR requirements (assuming it is considered a 'minor dam'). The berms and spillways will require inspection to assess if there is any deterioration or damage to:

- berm crest and slopes (e.g., ruts, loss of surfacing material, erosion, slumping, cracking, seepage and evidence of piping, problem vegetation);
- erosion protection (e.g., loss of rock, settlement, slumping, wave damage); and
- outlet control spillway structures (e.g., damage to or loss of riprap, sediment and debris build-up).

Maintenance for the structures is expected to be minimal for the berms and outlet spillway structures. To support inspection and maintenance, these items will be developed further during the detailed design.

A more comprehensive outline of the operation and maintenance items as well as recommended monitoring of the physical works will be included in the detailed design report.

Performance monitoring of the environmental and wetland habitat performance has been proposed in the 2016 Concept Design Report.

BC Hydro could also consider installing a webcam for long-term monitoring of the wetland habitat.

7. Conclusions and Future Design Considerations

KWL prepared preliminary designs for the Lower Inonoaklin Wildlife Enhancement Project based on the site selection and conceptual design undertaken and documented in the CLBWORKS 29B 2016 Concept Design Report.

The proposed design is intended to protect and enhance the existing shallow wetland. The site is currently a narrow wetland that provides high-suitability habitat for waterfowl, shorebirds and pond-breeding amphibians. The wetland is fed by upland drainage in the fall and spring and is normally flooded in the summer months when the reservoir level is highest following freshet.

The preliminary design proposed the construction of three 1 to 1.5 m high berms with two riprap spillways creating a tiered wetland system with an upper and a lower wetland to enhance and preserve the existing wetland habitat. The design was expanded to include removal of an area of Reed Canary Grass, an invasive species.

The berms will retain approximately 30,000 m^3 of water in total and will likely be considered a 'Part 2 dam' as defined in the DSR. A low consequence classification designation is proposed. A few exceptions are proposed to the minimum requirements from the *BC Dam Safety Guidelines*: a reduced freeboard of 0.6 m (rather than 1 m), and no low-level outlet. This would require confirmation of acceptability from the Province.

A construction cost opinion was prepared for the preliminary design. It is significantly higher than the 2016 Concept Design Report estimate, however some options for cost reduction are provided for BC Hydro's consideration.

Modelling indicates that the design will meet the intended purpose of retaining runoff, increasing and maintaining the wetland area for a longer duration throughout the year (approximately 50% greater area), and delaying reservoir inundation and mixing to lengthen the time habitat is available (approximately one to two weeks average delay in the spring and one to two weeks of additional inundation free time in the fall). However, the design will result in increased depth within with the wetlands, from 0.2 m to up to 2 m.

Due to the high modelled water levels and a relatively short delay of inundation during the most important habitat window (spring), depth objectives were refined (reduced from 0.5 to 1 m to 0.3 to 0.5 m) and a more detailed analysis of target water depths and wetland area was completed, following the preliminary design. This analysis indicates that though the design increases the total area in the good and target depth ranges (<0.3 m and 0.3-0.5 m respectively), it creates a greater area with undesirable depths (>0.5 m). BC Hydro decided not to proceed with berm design, in order to preserve the existing shallow habitat and avoid the creation of deep wetlands that may attract undesirable Canada Geese.

In addition, removal methods for Reed Canary Grass are not certain, which indicates a risk of success, particularly if the site conditions are not altered to prevent regrowth. Based on these considerations, BC Hydro elected not to proceed with any habitat improvements at the Lower Inonoaklin site at this time.

Wetland improvement works could be considered in the future to focus on improving and supplementing the existing habitat by minor excavation, mounding, LWD, and planting, as well as removal or shading of invasive Reed Canary Grass following trials to be conducted at other sites such as Burton Flats.

8. Report Submission

KERR WOOD LEIDAL ASSOCIATES LTD.

Prepared by:

This document is a copy of the sealed and signed hard copy original retained on file. The content of the electronically transmitted document can be confirmed by referring to the filed original.

PROFESSIONAL
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Statement of Limitations

This document has been prepared by Kerr Wood Leidal Associates Ltd. (KWL) for the exclusive use and benefit of BC Hydro for the Lower Inonoaklin Wildlife Enhancement Project. 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
0	February 20, 2018	Final	Final report incorporating BCH comments	ARM/SFJ
B	August 3, 2017	Updated Draft	Incorporate BCH comments, additional detailed analysis, and decision process	ARM/SFJ
A	February 7, 2017	Draft	Draft for BCH Review	ARM/LM/SFJ

OQM CERTIFIED

KERR WOOD LEIDAL
consulting engineers

Appendix A

Site Visit Photo Log

Appendix A – Field Visit Photos (November 24, 2016)

Photo 1: Culvert 3 on Lower Inonoaklin Road (south of residence)

Photo 2: Test Pit 1 at North Berm

Photo 3: Test Pit 1 at North Berm

Photo 4: Test Pit 3 at North End of Middle Berm

Appendix A – Field Visit Photos (November 24, 2016)

Photo 5: Test Pit 3 at North End of Middle Berm

Photo 6: Looking from Proposed Middle Berm Alignment to Height of Land (PF and VH location)

Photo 7: Test Pit 3 Near South end of Middle Berm

Photo 8: Test Pit 3 Near South End of Middle Berm

Photo 9: Test Pit 5 Near Proposed North End of South Berm

Photo 10: Test Pit 5 Near North End of South Berm

Appendix A – Field Visit Photos (November 24, 2016)

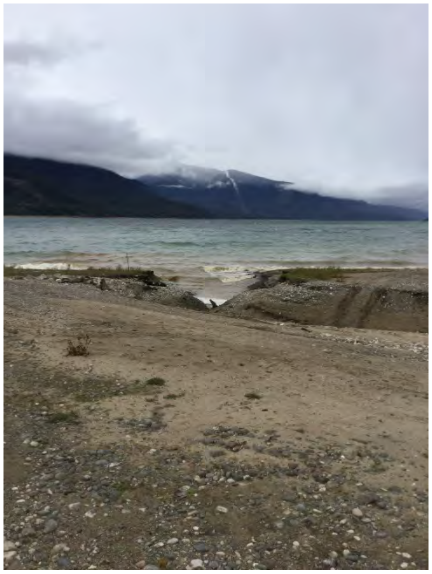

Photo 11: Outlet of Wetland with Waterfall/drop at Lake

Photo 12: Historic High Water Mark

Photo 13: Looking South from Upper Pools

Photo 14: Culvert 4 on Lower Inonoaklin Road (channelized flow upstream)

Appendix A – Field Visit Photos (November 24, 2016)

Photo 15: Panorama of Wetland from Northwest

KERR WOOD LEIDAL
consulting engineers

Appendix B

Lower Inonoaklin Road Wildlife Improvement Project Geotechnical Investigation

Thurber Engineering Ltd.
Draft Report

THURBER ENGINEERING LTD.

celebrating 60 YEARS

LOWER INONOAKLIN ROAD WILDLIFE HABITAT IMPROVEMENT PROJECT GEOTECHNICAL INVESTIGATION - REVISED

Report

to

Kerr Wood Leidal

PROFESSIONAL ENGINEER
PROVINCE OF BRITISH COLUMBIA
S. M. BEAN

June 20/17

Stephen M. Bean, M.Eng., P. Eng.
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Project Engineer

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THURBER

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1. INTRODUCTION

1.1 General

This report presents the results of a geotechnical investigation carried out by Thurber Engineering Ltd. (Thurber) for Kerr Wood Leidal (KWL) at the BC Hydro Lower Inonoaklin wildlife enhancement project near Fauquier, BC.

The scope of work was outlined in our proposal letter dated November 3, 2016, and the project was initiated on November 22, 2016.

It is a condition of this report that Thurber's performance of its professional services is subject to the attached Statement of Limitations and Conditions.

1.2 Project Description

BC Hydro is working to enhance habitat for nesting and migratory birds and wildlife as part of the CLBWORKS 30B Lower Arrow Lakes Reservoir Wildlife Enhancement Program. Site selection and conceptual design for the Lower Inonoaklin Site, the focus of this project, was undertaken in the CLBWORKS 29B report, updated in August 2016.

The project design criteria are outlined in the Design Basis Document (Draft) prepared by KWL and dated December 5, 2016.The project is intended to protect a shallow wetland in an area known as Porcupine Island, located immediately south of Needles on the west side of the Arrow Lakes Reservoir. The wetland is a narrow mud bottom pond adjacent to the Reservoir and is currently fed by upland drainage in fall and spring, and is flooded in the summer when the Reservoir level is the highest. The conceptual design included the construction of a series of berms meant to maintain optimal water level for a longer duration during the year by retaining water during parts of the year and postponing inundation in the summer months.

The conceptual design included three berms approximately 63 m, 128 m and 171 m long, 1 m to 1.5 m high with a maximum elevation of 438.8 m above sea level, located in low areas between the existing wetland and the reservoir. The current design still consists of three berms, but the berms are approximately 23 m (Berm 1), 140 m (Berm 2), and 123 m (Berm 3) in length and Berm 2 now crosses the wetland area, creating a tiered wetland with two wetland areas. There are two spillways, one between the wetland areas and one that spills into the reservoir. KWL's site plan drawing No. 478201-C101 shows the wetland layout.

We understand that the work will be completed in three phases; feasibility design, detailed design and construction and completion. Award for each phase is contingent on receiving the necessary regulatory and internal approvals. We anticipate that our work will primarily be completed as part of the feasibility design (Phase 1).

1.3 Scope

The scope of work was outlined in a letter dated November 3, 2016. Thurber anticipated completing the following tasks:

- Attending a project kick-off meeting.
- Conducting a site reconnaissance to confirm excavator access prior to the field investigation.
- Obtaining any approvals required for the investigation.
- Completing a geotechnical investigation in November consisting of a test pitting program at the conceptual design berm locations (access permitting). We anticipated completing 4 or 5 test pits. Soil samples were to be collected for moisture content determination, visual identification and grain size analysis/Atterberg Limits testing (as required).
- The soils and substrate were to be assessed for geotechnical stability and loading considerations.
- Preparation of a Geotechnical Report summarizing the investigation and geotechnical analysis.

An allowance was made to complete additional seepage analysis for the proposed berms (if required). Any additional design input required in later phases of the project would be provided on an as-needed basis.

2. METHODOLOGY

Given the short project timeline, a site inspection was not completed prior to the geotechnical investigation. The geotechnical investigation was completed under a Safety Management Plan prepared by Kerr Wood Leidal and an existing BC Hydro Permission Land Use Policy. Precautions were made to avoid areas of archeological significance. Prior to the investigation, the BC One Call service was contacted to identify potential underground or overhead utilities that might be impacted by the proposed investigation.

A total of five test pits were excavated on November 24, 2016, using a rubber tired backhoe operated by Crescent Bay Construction Ltd. of Nakusp, BC. The test pits were terminated at depths between 1.3 m and 3.1 m. Test pits were backfilled with bucket packed excavated material. A shallow test pit (TP16-6) was hand-excavated in an area that wasn't easily accessible by the backhoe.

The test pits were completed while Peter Fearon (KWL), Allison Matfin (KWL) and Virgil Hawkes (LGL Limited) were on site. The test pits were logged by Melanie Woytiuk, P.Eng. of Thurber, and disturbed samples were collected at selected depths for routine visual identification and moisture content determination at our Kamloops laboratory. Thurber also conducted wash sieves and Atterberg Limits on selected samples. Approximate locations of the tests pits were determined using a handheld GPS and are shown on the site plan included in Appendix A. Test pit logs are included in Appendix B, laboratory testing results in Appendix C and photos from the investigation are included in Appendix D.

3. SITE CONDITIONS

3.1 Surface Conditions

The existing wetland is located on the west bank of the Upper Arrow Lake reservoir. The wetland is bounded by a terrace of lacustrine deposits to the west, a portion of which has been developed as seasonal recreational properties. Beyond the terrace and to the north, the area is bounded by steep rock controlled slopes. The reservoir bounds the wetland to the south and east, with a relatively narrow topographical high separating the two waterbodies. The wetland is inundated during periods where the reservoir elevation is high.

A larger area of this topographical high, closer to the south end of the wetland, has undergone a successful BC Hydro tree planting program and contains some artifacts of archeological significance. The remainder of the area is either bare or covered in grasses and shrubs.

3.2 Subsurface Conditions

The following description is meant to provide a brief summary of the conditions encountered during the geotechnical investigation. The reader is directed to the test pit location plan, test pit logs, and laboratory testing results in Appendices A through C for a detailed description of subsurface and groundwater conditions.

Surficial mapping of the project area describes it as a lacustrine terrace (Kootenay Lake, Open File 1084, Geological Survey of Canada, 1984). This is consistent with the conditions encountered at the test pit locations.

3.2.1 Topographical High

Three test pits (TP16-01 to TP16-03) are located on the narrow topographical high that separates the wetland from the reservoir. These test pits encountered a thin topsoil layer underlain by silt or silt/sand. This soft silt or silt/sand layer extended to depths between 0.8 m and 1.3 m. Moisture contents range from 23.6% to 31.3% and the material is described as moist to wet.

The silt layer is underlain by compact fine to medium grained sand at TP16-2 and TP16-3. This layer is 1.1 m to 1.3 m thick and has moisture contents ranging from 7.2% to 12.3%. A washed sieve completed on a sample showed 7.3% fines. This material is underlain by stiff high plasticity clay at TP16-2 and gravel at TP16-3.

At TP16-1, the silt layer is underlain by sand and gravel containing cobbles. TP16-1 was terminated at the relatively shallow depth of 1.5 m due to free water causing the pit walls to collapse.

3.2.2 Reservoir Beach

TP16-4 and TP16-5 are both located on the reservoir beach, near the natural channel that connects the wetland to the reservoir. Loose gravelly sand or sand and gravel were encountered at both locations. Testing indicates a fines content of 10% at a depth of 1.3 m at TP16-5.

3.2.3 Terrace

The terrace to the west of the site was not accessible with the backhoe without crossing the private recreational properties. A hand excavated sample (TP16-6) taken from the exposure (photos are included in Appendix D) was characterized as high plasticity clay. The sample has a liquid limit of 50%, a plastic limit of 27% and a moisture content of 43.3%.

3.3 Groundwater Conditions

According to the real-time water levels collected and published by BC Hydro for the Arrow Reservoir at Fauquier the water level at the time of the investigation was 431.1 m. Free water was encountered at TP16-1, TP16-4, and TP16-5. The water level at TP16-4 and TP16-5 appears to be closely tied to the reservoir level, as free water was encountered at elevations consistent with the reservoir. Free water was encountered at what appears to be a higher elevation at TP16-1. This location is closest to the rock slope to the north of the wetland, and the presence of the slope or a bedrock high may be influencing the water level at this location.

4. GEOTECHNICAL DISCUSSION

4.1 General

The Draft Design Basis Report (dated December 5, 2016) discusses in detail the design constraints, including environmental, aesthetic and regulatory that will influence the berm and outlet structure design. The following design constraints and assumptions were considered when completing the geotechnical assessment.

Berm Construction

- Berms must be designed to withstand inundation, overtopping and reservoir drawdown.
- Berms crest elevation will be no higher than 438.5 m, minimum 4 m wide and have a side slope of 4 horizontal to 1 vertical (4H:1V) or shallower.
- Borrow for the berms will be taken from shallow ditches inside the wetland, with any shortfall made up from the terrace to the west of the wetland.
- Berms should limit seepage in and out of the wetland, depending on the time of year.

Outlet Control Structure

Two outlet controls have been included in the design, one on Berm 2, which allows water to flow between Wetland Area 1 and Wetland Area 2, and one on Berm 3, that connects Wetland 2 and the reservoir. The structure itself will consist of a high-level passive riprap channel. These structures will likely be founded on a sheet pile wall.

4.2 Berm Construction

4.2.1 Stripping and Foundation Preparation

All topsoil, organic material or debris encountered within the berm footprints should be removed and stockpiled. The sub-grade surface should then be re-compacted prior to placement of fill. Trafficability may be an issue on the reservoir beach, natural wetland outlet channel and through the middle of the wetland. Trafficability is somewhat dependent on the water level at the time of construction, however, much of this silt and sand is loosely placed and saturated at lower elevations. Equipment will need to use granular borrow material to create a working surface as they move out over these loose areas.

4.2.2 Borrow Suitability and Placement

The borrow from the topographically high areas on the wetland side of the berms should generally be suitable for use as backfill material provided any oversized material (i.e. cobbles and boulders greater than 150 mm), surficial organic or other deleterious material is removed. It is anticipated that the borrow will consist primarily of silt and fine to medium grained sand, and to a lesser amount high plastic clay.

The sand and gravel material from reservoir beach can also be used as fill, but the borrow ditch side slopes will have to be shallow in these areas to prevent caving. The proposed slopes of 6H:1V should be sufficient for this purpose. We do not recommend that the material from the lowest areas of the wetland be used for berm construction, as it will be too wet to be compacted or trafficable. Again, this is somewhat dependent on the season and water level in the wetland at the time of construction.

Based on the samples collected at the test pit locations, it is anticipated that the silt material will be wet of optimum, and some moisture conditioning will be required to achieve sufficient compaction. In addition, as the excavation moves closer to the wetland, it is anticipated that moisture content will increase along with the thickness of the surficial organic material. It may be possible to blend the silt material with the sand encountered below it by digging portions of the borrow ditch to full depth and then spreading (feathering) that material out over a longer section of the berm. The borrow material should be placed in lifts no greater than 200 mm and compacted to a minimum of 95% Standard Proctor Maximum Dry Density (SPMDD).

High plastic clay can be used for berm construction, however, placement will be difficult due to its relatively high moisture content and the materials blocky nature. A non-vibrating sheep foot roller is recommended for compaction of high plastic clay.

4.2.3 Slope Stability Considerations

The proposed slope angle for the berm side slopes is 4H:1V or shallower. Given the height of the berms, proposed construction material, and foundation conditions, stability is not considered a concern for slopes at this angle and no additional analysis is required at this time.

4.2.4 Settlement Considerations

Some time-dependent settlement of the foundation is anticipated, especially in areas of thick loose sand (i.e. the channel connecting the wetland to the reservoir) or thick silt deposits directly below the berms (i.e. within the wetland). In addition, compaction of the fill may not be optimal, given the variability of the borrow combined with the high moisture content, and the berm fill may settle over time as well.

It is not possible to estimate the amount of settlement since we do not know the depth or properties of the underlying soil conditions. We recommend that the crest is surveyed after two full seasons to check if the crest elevation has been maintained. Alternatively, the berms can be over-built to reduce the impact of the settlement of the crest on the wetland function. The settlement will not occur uniformly, but this may be favourable given the aesthetic preferences for the final berm configuration.

4.2.5 Seepage Considerations

Given the anticipated berm configuration seepage through the berms is not a major consideration. We anticipate that annually inundation of the berms will have the following pattern:

- Complete inundation will not occur every year, but can occur and could last up to a few months, based on the maximum water levels measured by BC Hydro at the Fauquier location. Depending on the length of the inundation period, the berms could be completely saturated.

- When the reservoir level drops below spillway elevation, the reservoir level will drop more quickly than the water level within the wetland. If the berms were completely saturated during inundation, a drying front will move from the outside crest of Berm 1 and 3, and seepage will occur on the reservoir side of these berms. If the berms were not complete saturated, steady state seepage across the berm may never be established.

- As the reservoir levels rise again, a wetting front will form on the reservoir side of Berm 1 and 3, while the wetland side of theses berms dries out.

Given this pattern, the establishment of steady-state flow paths through the Berm 1 and 3 is unlikely. Steady state seepage will establish across Berm 2, provided the wetland retains water all the time, however, based on the spillway elevations, the head difference on either side of Berm 2 is never expected to be more than 0.5 m, so even if steady state seepage is to establish across this berm, seepage volume will be minimal.

Continuous layers of sand within the berm and those found naturally within the foundation materials are more permeable than silt and clay. Blending any clean sand used within the berms with the fine-grained material will aid in reducing the seepage rate through the berms.

The rate of seepage out of the wetland will also be influenced by the excavation of borrow from the inside of the wetland. The rate of seepage is influenced by the length of the seepage path, the hydraulic conductivity of the material the water must pass through, and the difference in water elevation at either end of that seepage path. It follows that seepage rates out of the wetland will increase in areas where borrow is being excavated from within the wetland, as this automatically reduces the length of the seepage path. This increase is anticipated to be small and possibly insignificant. The increase will be more pronounced if interconnected or continuous bands of higher hydraulic conductivity material are exposed within the borrow excavations. This risk can be managed during construction by limiting the excavation to relatively low hydraulic conductivity material (i.e. fine-grained) and re-covering any high hydraulic conductivity material (i.e. “bony” gravel) that is exposed during excavation. This approach will require field fitting the borrow locations and boundaries to the conditions encountered during construction.

Published saturated hydraulic conductivity ranges are given below. If the berms are primarily constructed with the silt and fine to medium grained sand that will be exposed in the borrow ditch inside of the wetland, hydraulic conductivity values should fall between the lower bound of the ‘silty sand, fine sand’ and upper bound of ‘silt, sandy silts, clayey sands’, or 1.0(10^{-5}) cm/sec and 1.0(10^{-4}) cm/sec. A hydraulic conductivity value between 1.0(10^{-6}) cm/sec and 1.0(10^{-5}) cm/sec is appropriate for the base of the wetland (as it exists now).

Table 1: Saturated Hydraulic Conductivity Values

Soil Description	Range of Saturated Hydraulic Conductivity	
	cm/sec	
Well sorted sands	1.E-03	1.0
Silty Sands, Fine Sands	1.E-05	1.E-03
Silt, Sandy Silts, Clayey Sands	1.E-06	1.E-04
Clay	1.E-09	1.E-06

From “Fetter, C.W.; Applied Hydrogeology, Pearson Prentice Hall, 2001.”

Additional seepage analysis can be completed if required.

4.2.6 Erosion Control

As noted earlier in the report, the berm must be able to withstand overtopping, inundation, and drawdown conditions, as well as significant wave action. Both the silt and fine to medium grained sand that will predominantly be used in berm construction and exposed in the slopes of the borrow ditch are considered highly erodible. However, given the aesthetic requirements of this project, limited erosion is welcomed in the interest of establishing a natural wetland. The preferred erosion control measure is to mimic the slopes that currently exist around the wetland, resulting in relatively shallow vegetated slopes ranging between 6H:1V to 10H:1V.

4.3 Outlet Control Structure

We understand that the two outlet structures will consist of riprap channel spillways with a sheet pile wall installed to limit seepage through the riprap.

Settlement of the spillways is a concern given that loose and saturated sand was encountered between wetland and main reservoir. If possible, excavating the spillways into the constructed berms will result in better compaction around the spillways, and allow for some foundation settlement to occur prior to riprap installation.

We understand that installation of a sheet pile wall below the structure is being considered to limit seepage through the riprap. A preliminary embedment depth of 3 m is recommended for the preliminary cost estimate. It is anticipated that the sheet pile embedment depth can be reduced, however, a seepage assessment is required to determine a suitable embedment depth. An allowance was made for this type of assessment in the detailed design phase of work.

5. CLOSURE

We trust this meets your requirements at this time. Please contact the undersigned if you have any questions.

THURBER

STATEMENT OF LIMITATIONS AND CONDITIONS

1. STANDARD OF CARE

This Report has been prepared in accordance with generally accepted engineering or environmental consulting practices in the applicable jurisdiction. No other warranty, expressed or implied, is intended or made.

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All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment are a part of the Report, which is of a summary nature and is not intended to stand alone without reference to the instructions given to Thurber by the Client, communications between Thurber and the Client, and any other reports, proposals or documents prepared by Thurber for the Client relative to the specific site described herein, all of which together constitute the Report.

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The Report has been prepared for the specific site, development, design objectives and purposes that were described to Thurber by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the Report, subject to the limitations provided herein, are only valid to the extent that the Report expressly addresses proposed development, design objectives and purposes, and then only to the extent that there has been no material alteration to or variation from any of the said descriptions provided to Thurber, unless Thurber is specifically requested by the Client to review and revise the Report in light of such alteration or variation.

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5. INTERPRETATION OF THE REPORT

a) Nature and Exactness of Soil and Contaminant Description: Classification and identification of soils, rocks, geological units, contaminant materials and quantities have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature. Comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel may fail to locate some conditions. All investigations utilizing the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarizing such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and the Client and all other persons making use of such documents or records with our express written consent should be aware of this risk and the Report is delivered subject to the express condition that such risk is accepted by the Client and such other persons. Some conditions are subject to change over time and those making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. If special concerns exist, or the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.

b) Reliance on Provided Information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to Thurber. Thurber has relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, Thurber does not accept responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of misstatements, omissions, misrepresentations, or fraudulent acts of the Client or other persons providing information relied on by Thurber. Thurber is entitled to rely on such representations, information and instructions and is not required to carry out investigations to determine the truth or accuracy of such representations, information and instructions.

c) Design Services: The Report may form part of design and construction documents for information purposes even though it may have been issued prior to final design being completed. Thurber should be retained to review final design, project plans and related documents prior to construction to confirm that they are consistent with the intent of the Report. Any differences that may exist between the Report's recommendations and the final design detailed in the contract documents should be reported to Thurber immediately so that Thurber can address potential conflicts.

d) Construction Services: During construction Thurber should be retained to provide field reviews. Field reviews consist of performing sufficient and timely observations of encountered conditions in order to confirm and document that the site conditions do not materially differ from those interpreted conditions considered in the preparation of the report. Adequate field reviews are necessary for Thurber to provide letters of assurance, in accordance with the requirements of many regulatory authorities.

6. RELEASE OF POLLUTANTS OR HAZARDOUS SUBSTANCES

Geotechnical engineering and environmental consulting projects often have the potential to encounter pollutants or hazardous substances and the potential to cause the escape, release or dispersal of those substances. Thurber shall have no liability to the Client under any circumstances, for the escape, release or dispersal of pollutants or hazardous substances, unless such pollutants or hazardous substances have been specifically and accurately identified to Thurber by the Client prior to the commencement of Thurber's professional services.

7. INDEPENDENT JUDGEMENTS OF CLIENT

The information, interpretations and conclusions in the Report are based on Thurber's interpretation of conditions revealed through limited investigation conducted within a defined scope of services. Thurber does not accept responsibility for independent conclusions, interpretations, interpolations and/or decisions of the Client, or others who may come into possession of the Report, or any part thereof, which may be based on information contained in the Report. This restriction of liability includes but is not limited to decisions made to develop, purchase or sell land.

APPENDIX A

Drawing No. 16076-1

Plotted: January 10, 2017

This copyrighted drawing forms part of a Thurber report and its use is subject to Thurber's Statement of Limitations and Conditions

NOTES:

1. Test Pit locations are approximate only.
2. Aerial image from Google Earth.

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TEST PIT LOCATION PLAN

LOWER INONOAKLIN WILDLIFE ENHANCEMENT PROJECT
GEOTECHNICAL INVESTIGATION

NEEDLES, B.C.

DESIGNED	DRAWN	APPROVED	DATE	SCALE	PROJECT No.	DWG. NO.	REV.
MEW	RRS		JANUARY 10, 2017	1:3000 Approx.	16076	- 1	-

TED04669.dwg

APPENDIX B

Unified Classification System for Soils (ASTM D2487)

Symbols and Terms used on the Test Pit Logs

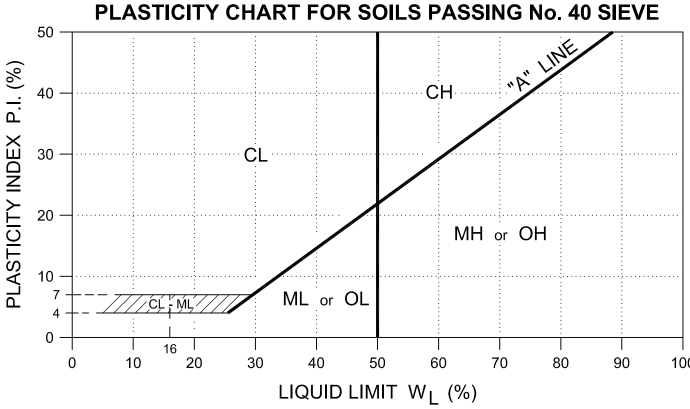
Test Pit Logs

UNIFIED CLASSIFICATION SYSTEM FOR SOILS (ASTM D2487)

THURBER

MAJOR DIVISION			SYMBOLS GROUP	SYMBOLS GRAPH	TYPICAL DESCRIPTION	LABORATORY CLASSIFICATION CRITERIA
COARSE-GRAINED SOILS (MORE THAN 50% BY WEIGHT RETAINED ON No. 200 SIEVE)	GRAVELS MORE THAN 50% COARSE FRACTION RETAINED ON No. 4 SIEVE	CLEAN GRAVELS (< 5% FINES)	GW		WELL GRADED GRAVEL and WELL GRADED GRAVEL with SAND.	$C_U = \frac{D_{60}}{D_{10}} \geq 4$ $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}} = 1$ to 3
			GP		POORLY GRADED GRAVEL and POORLY GRADED GRAVEL with SAND.	NOT MEETING ABOVE REQUIREMENTS
		GRAVELS WITH FINES (> 12% FINES)	GM		SILTY GRAVEL, GRAVEL - SAND - SILT MIXTURES.	FINES CLASSIFY AS ML or MH (3)
			GC		CLAYEY GRAVEL, GRAVEL - SAND - CLAY MIXTURES.	FINES CLASSIFY AS CL or CH (3)
	SANDS MORE THAN 50% COARSE FRACTION PASSES No. 4 SIEVE	CLEAN SANDS (< 5% FINES)	SW		WELL GRADED SAND and WELL GRADED SAND with GRAVEL	$C_U = \frac{D_{60}}{D_{10}} \geq 6$ $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}} = 1$ to 3
			SP		POORLY GRADED SAND and POORLY GRADED SAND with GRAVEL.	NOT MEETING ABOVE REQUIREMENTS
		SANDS WITH FINES (> 12% FINES)	SM		SILTY SAND, SAND - SILT MIXTURES.	FINES CLASSIFY AS ML or MH (3)
			SC		CLAYEY SAND, SAND - CLAY MIXTURES.	FINES CLASSIFY AS CL or CH (3)
FINE-GRAINED SOILS (MORE THAN 50% BY WEIGHT PASSES No. 200 SIEVE)	SILTS BELOW "A" LINE NEGLIGIBLE ORGANIC CONTENT	W_L < 50%	ML		INORGANIC SILTS, SILTS with SAND and SILTS with GRAVEL and SANDY or GRAVELLY SILTS.	P.I. < 4 or PLOTS BELOW THE "A" LINE
		W_L > 50%	MH		INORGANIC SILTS, SILTS with SAND & SILTS with GRAVEL & SANDY or GRAVELLY SILTS, FINE SANDY or SILTY SOILS.	P.I. PLOTS BELOW THE "A" LINE
	CLAYS ABOVE "A" LINE ON PLASTICITY CHART NEGLIGIBLE ORGANIC CONTENT	W_L < 50%	CL		INORGANIC CLAYS of LOW PLASTICITY, GRAVELLY, SANDY, or SILTY CLAYS, LEAN CLAYS.	P.I. > 7 and PLOTS ON OR ABOVE THE "A" LINE
		W_L near 50%	CL-CH		BORDERLINE INORGANIC CLAYS and SILTY CLAYS with LIQUID LIMITS NEAR 50%.	(only used for visual identification)
		W_L > 50%	CH		INORGANIC CLAYS of HIGH PLASTICITY, FAT CLAYS.	P.I. PLOTS ON OR ABOVE THE "A" LINE
	ORGANIC SILTS and CLAYS	W_L < 50%	OL		ORGANIC SILTS and ORGANIC SILTY CLAYS of LOW PLASTICITY.	$\frac{W_L \text{ (oven dried)}}{W_L \text{ (not dried)}} < 0.75$
		W_L > 50%	OH		ORGANIC CLAYS OF HIGH PLASTICITY.	$\frac{W_L \text{ (oven dried)}}{W_L \text{ (not dried)}} < 0.75$
HIGHLY ORGANIC SOILS			PT		PEAT and other HIGHLY ORGANIC SOILS.	STRONG COLOR OR ODOR, AND OFTEN FIBROUS TEXTURE.

PLASTICITY CHART FOR SOILS PASSING No. 40 SIEVE



NOTES:

1. ALL SIEVE SIZES ARE U.S. STANDARD, A.S.T.M. E11-04.
2. COARSE GRAINED SOILS WITH 5 TO 12% FINES REQUIRE DUAL SYMBOLS (GW-GM, GW-GC, GP-GM, GP-GC, SW-SM, SW-SC, SP-SM, SP-SC).
3. IF FINES CLASSIFY CL-ML USE DUAL SYMBOL (GC-GM or SC-SM).
4. WHERE TESTING IS NOT CARRIED OUT, THE IDENTIFICATIONS ARE DETERMINED BY VISUAL-MANUAL PROCEDURES DESCRIBED IN ASTM D2488-06.

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SYMBOLS AND TERMS USED ON TEST LOGS

1. PARTICLE SIZE CLASSIFICATION OF MINERAL SOILS

DESCRIPTION		APPARENT PARTICLE SIZE
BOULDERS		> 200 mm
COBBLES		75 mm to 200 mm
GRAVEL	coarse	19 mm to 75 mm
	fine	4.75 mm to 19 mm
SAND	coarse	2 mm to 4.75 mm
	medium	0.475 mm to 2 mm
	fine	0.075 mm to 0.475 mm
SILT		Non-plastic particles, not visible to the naked eye
CLAY		Plastic particles, not visible to the naked eye

NOTE: Metric Conversion is approximate only

2. TERMS DESCRIBING CONSISTENCY (Cohesive Soils Only)

DESCRIPTION	APPROXIMATE UNDRAINED SHEAR STRENGTH
Very Soft	Less than 10 kPa (250 psf)
Soft	10 to 25 kPa (250 - 500 psf)
Firm	25 to 50 kPa (500 - 1000 psf)
Stiff	50 to 100 kPa (1000 - 2000 psf)
Very Stiff	100 to 200 kPa (2000 - 4000 psf)
Hard	Greater than 200 kPa (4000 psf)

NOTE: Metric Conversion is approximate only

3. TERMS DESCRIBING DENSITY (Cohesionless Soils Only)

DESCRIPTION	STANDARD PENETRATION TEST Number of blows per foot (300 mm) *
Very Loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	over 50

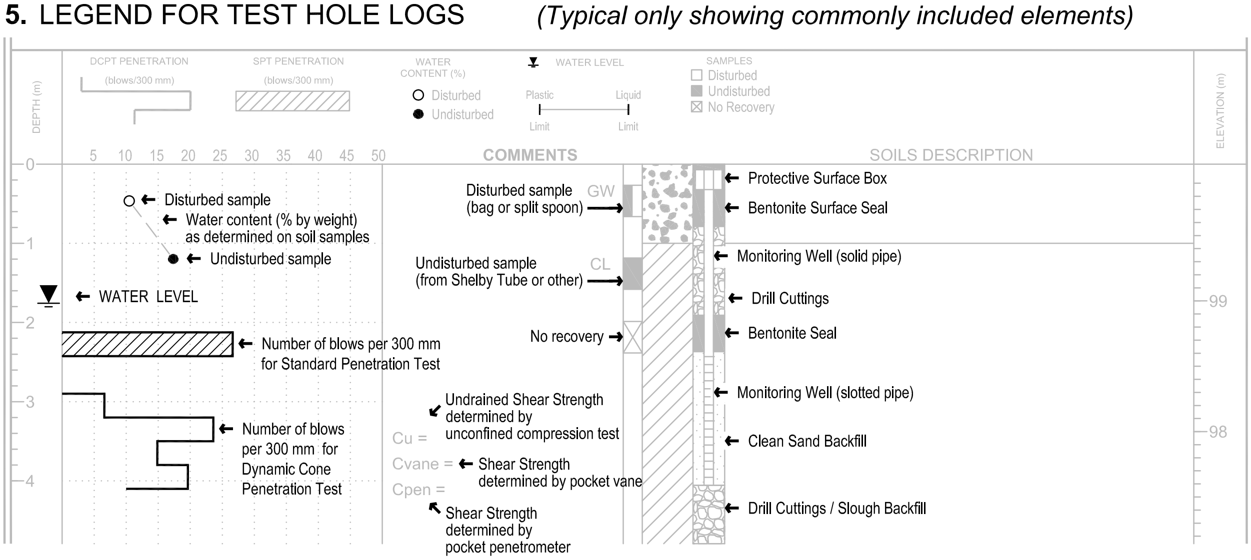
** Directly applicable to sands and, with interpretation, to gravels*

4. PROPORTION OF MINOR COMPONENTS BY WEIGHT

DESCRIPTION	PERCENT BY WEIGHT
and	35 to 50 %
y / ey	20 to 35 %
some	10 to 20 %
trace	less than 10 %

EXAMPLE: Silty SAND, trace of gravel = Sand with 20 to 35% silt and up to 10% gravel, by dry weight. (Percentages of secondary materials are estimates based on visual and tactile assessment of samples).

5. LEGEND FOR TEST HOLE LOGS *(Typical only showing commonly included elements)*



Client: TEL Standard Detail
File No.: n/a
E-File: UCSFS-20140807.dwg

Revised: August 07, 2014

TEST PIT LOGS

TP16-1

DEPTH (m)	DESCRIPTION	SAMPLE DEPTH (m)	USCS	M.C. (%)
0.0 – 0.1	Moist to wet, brown, SILT. Organics and rootlets encountered.			
0.1 – 1.2	Firm, moist, mottled brown and grey SILT; trace to some clay, some fine gravel, oxide staining and trace organics.	0.6	ML	23.6
1.2 – 1.5	Loose to compact, wet, brown SAND and GRAVEL; trace fines, rounded to 500 mm diameter. Contains cobbles.	1.5	GP/SP	
1.5	End of Pit -Pit terminated due to caving below 1.3 m. -Free water at 1.3 m. -Backfilled with excavated material			

TP16-2

DEPTH (m)	DESCRIPTION	SAMPLE DEPTH (m)	USCS	M.C. (%)
0.0 – 0.1	Moist to wet, grey-brown, SILT. Organics and rootlets encountered.	-	-	-
0.1 – 0.8	Firm, moist, grey, SILT; some sand, trace organics, oxide staining.	0.5	ML	29.0
0.8 – 1.9	Compact, moist, brown, SAND; trace fines, trace gravel, fine to medium grained sand. Cobbles encountered, oxide staining.	1.3	SP	12.3
1.9 – 2.9	Stiff, moist, grey, silty CLAY; high plasticity, slickenside surfaces noted. At 2.0 m: Liquid Limit = 59%, Plastic Limit = 26%, Pocket Pen = 2.0 At 2.8 m: Pocket Pen = 1.75	2.0 2.8	CH	40.2 44.6
2.9	End of Pit -Walls vertical at completion, moderate caving between 0.8 m to 1.9 m -No free water upon completion -Backfilled with excavated material			

Client: Kerr Wood Leidal
File No.: 16076

Date: December 11, 2016

TP16-3

DEPTH (m)	DESCRIPTION	SAMPLE DEPTH (m)	USCS	M.C. (%)
0.0 – 0.1	Moist to wet, grey-brown, SILT. Organics and rootlets encountered.	-	-	-
0.1 – 1.3	Soft, moist to wet, grey, SILT and SAND, some clay, no to low plasticity, trace organics.	0.5	ML/SM	31.1
1.3 – 2.6	Loose to compact, moist, brown, SAND; trace fines, trace gravel, fine to medium grained sand, gravel rounded to 30 mm diameter. Cobbles encountered, oxide staining. At 1.5 m: 7.3% Fines	1.5	SP	7.2
2.6 – 3.1	Loose to compact, moist, brown, GRAVEL; trace fines, trace gravel, medium to coarse grained sand, gravel rounded to 30 mm diameter. Cobbles encountered, oxide staining. At 3.1 m: increased sand content.	2.0 2.8	GP	3.2 5.2
3.1	End of Pit -Slight caving. -No free water upon completion -Backfilled with excavated material			

TP16-4

DEPTH (m)	DESCRIPTION	SAMPLE DEPTH (m)	USCS	M.C. (%)
0.0 – 0.03	Organics and rootlets encountered.	-	-	-
0.03 – 1.3	Loose, moist, brown SAND and GRAVEL; trace to no fines, fine to medium grained, rounded to 30 mm diameter. At 1.0 m: some gravel, medium to coarse grained sand.	1.3	SP/GP	
1.3	End of Pit -Pit terminated due to caving at 1.3 m. -Free water upon completion. -Backfilled with excavated material.			

THURBER

60 YEARS

TP16-5

DEPTH (m)	DESCRIPTION	SAMPLE DEPTH (m)	USCS	M.C. (%)
0.0 – 2.4	Loose, moist, brown, gravelly SAND; trace to no fines, medium grained. Cobbles encountered. At 0.0 to 0.1 m: lenses of silt and organics. At 1.3 m: 10% Fines	1.3 1.8	SP	6.6 5.7
2.4	End of Pit -Pit terminated due to caving at 2.4 m. -Free water at 2.3 m upon completion. -Backfilled with excavated material.			

TP16-6 (Hand Excavated)

DEPTH (m)	DESCRIPTION	SAMPLE DEPTH (m)	USCS	M.C. (%)
0.0 – 0.2	Firm, moist, grey, silty CLAY; low to high plasticity. At 2.0 m: Liquid Limit = 50%, Plastic Limit = 27%	0.15	CL-CH	43.3
0.2	End of Hand Excavated Hole -No free water at upon completion. -Backfilled with excavated material.			

APPENDIX C

Laboratory Testing Results

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ATTERBERG LIMITS SUMMARY

INONOAKIN RD WILDLIFE HABITAT IMPROVEMENT
Project No: 16076

Test Hole	Depth (m)	Liquid Limit	Plastic Limit	Plastic Index	Classification
TP16-1	0.6	-	-	Non plastic	ML
TP16-1	0.5	-	-	Non plastic	ML
TP16-2	2.0	59	26	33	CH
TP16-6	0.15	50	27	23	CL-CH

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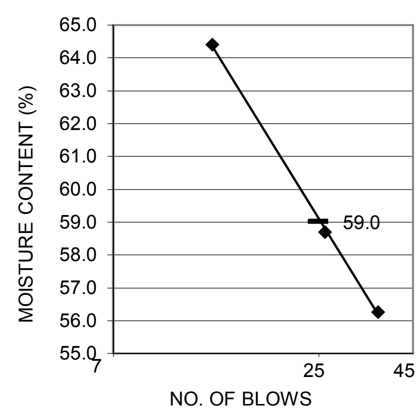
ATTERBERG LIMITS
ASTM D4318

Client:
Project: Inonoaklin Rd Wildlife Habitat Improvement
Project No: 16076
Date Tested: November 28, 2016
Test Hole: TP16-2 Depth: 2.0m
Tested By: TJB
Sample No: Sa3
Checked By:

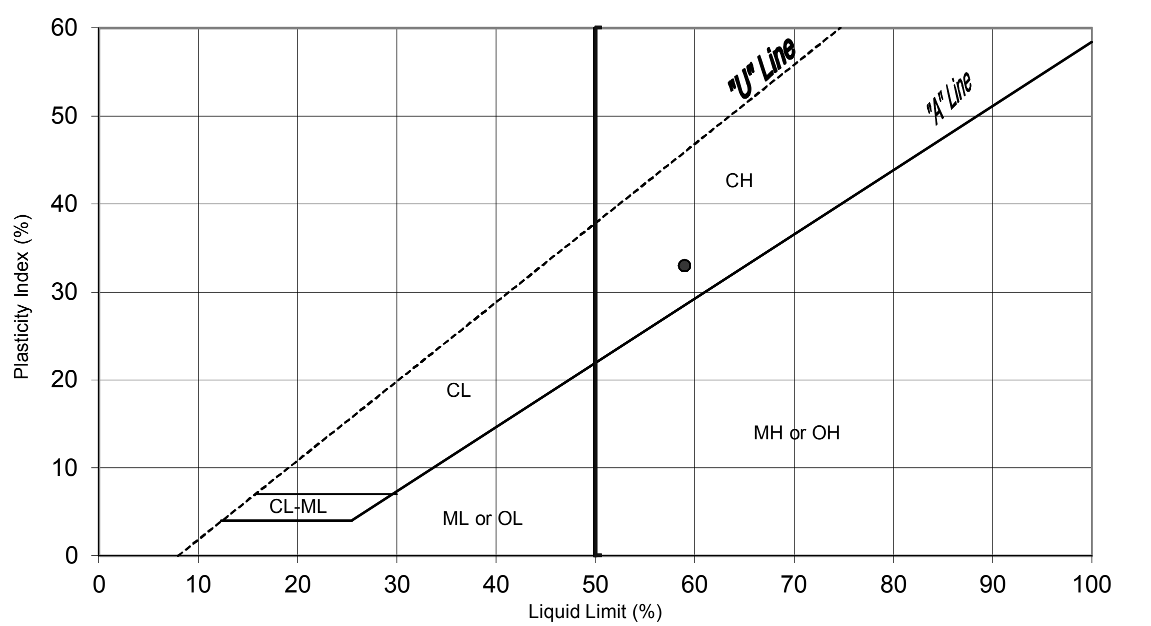
LIQUID LIMIT

Trial No:	1	2	3	4
No of Blows:	36	26	13	
Container No.	E4	E6	E12	
Wet Soil + Container	21.05	24.22	26.40	
Dry Soil + Container	13.82	15.62	16.43	
Wt. Of Container	0.97	0.97	0.95	
Moisture Content	56.3	58.7	64.4	



PLASTIC LIMIT

	1	2		AVERAGE
Container No.	A3	A5		
Wet Soil + Container	11.14	10.99		
Dry Soil + Container	9.03	8.92		
Wt. Of Container	0.97	1.05		
Moisture Content	26.2	26.3		**26.2**



REMARKS

Liquid Limit:	**59**
Plastic Limit:	**26**
Plasticity Index:	**33**
USC Classification:	**CH**

THURBER ENGINEERING LTD.

Project: **INONOAKLIN RD WILDLIFE HABITAT I** File No: **16076**

WASH TEST SUMMARY

Test Hole	Sample No.	Sample Depth Meters	As Received Moisture Content	Wash Test % Passing 0.075mm
TP16-3	Sa2	1.5	7.2	7.3
TP16-5	Sa1	1.3	6.6	10

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60 YEARS

APPENDIX D

Selected Photographs

THURBER

60 YEARS

PHOTO 1: TP16-1.

PHOTO 2: TP16-1 excavated material.

PHOTO 3: TP16-2.

PHOTO 4: TP16-2 excavated material.

PHOTO 5: TP16-3.

PHOTO 6: TP16-3 excavated material.

THURBER

60 YEARS

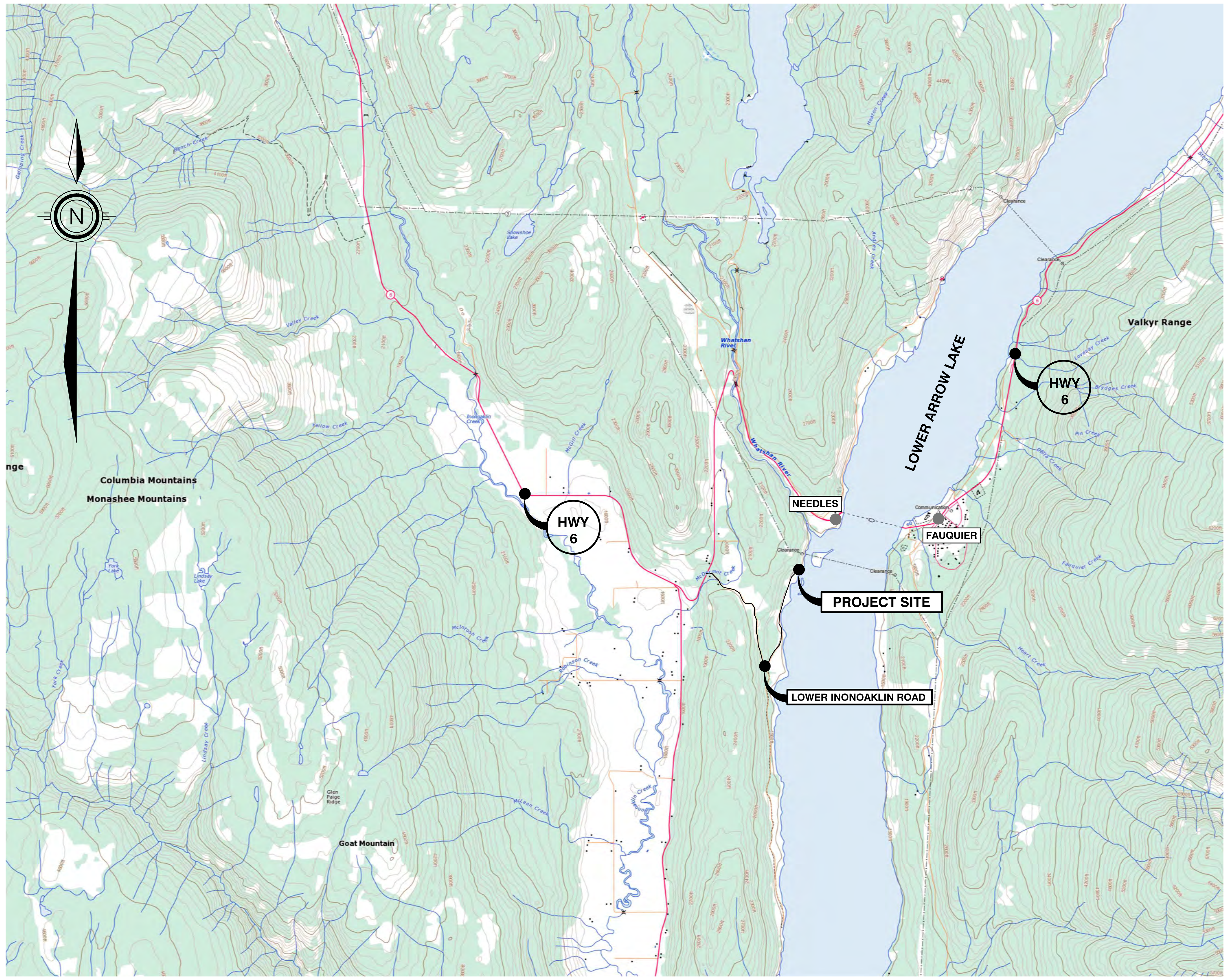
PHOTO 7: TP16-5.

PHOTO 8: TP16-5 excavated material.

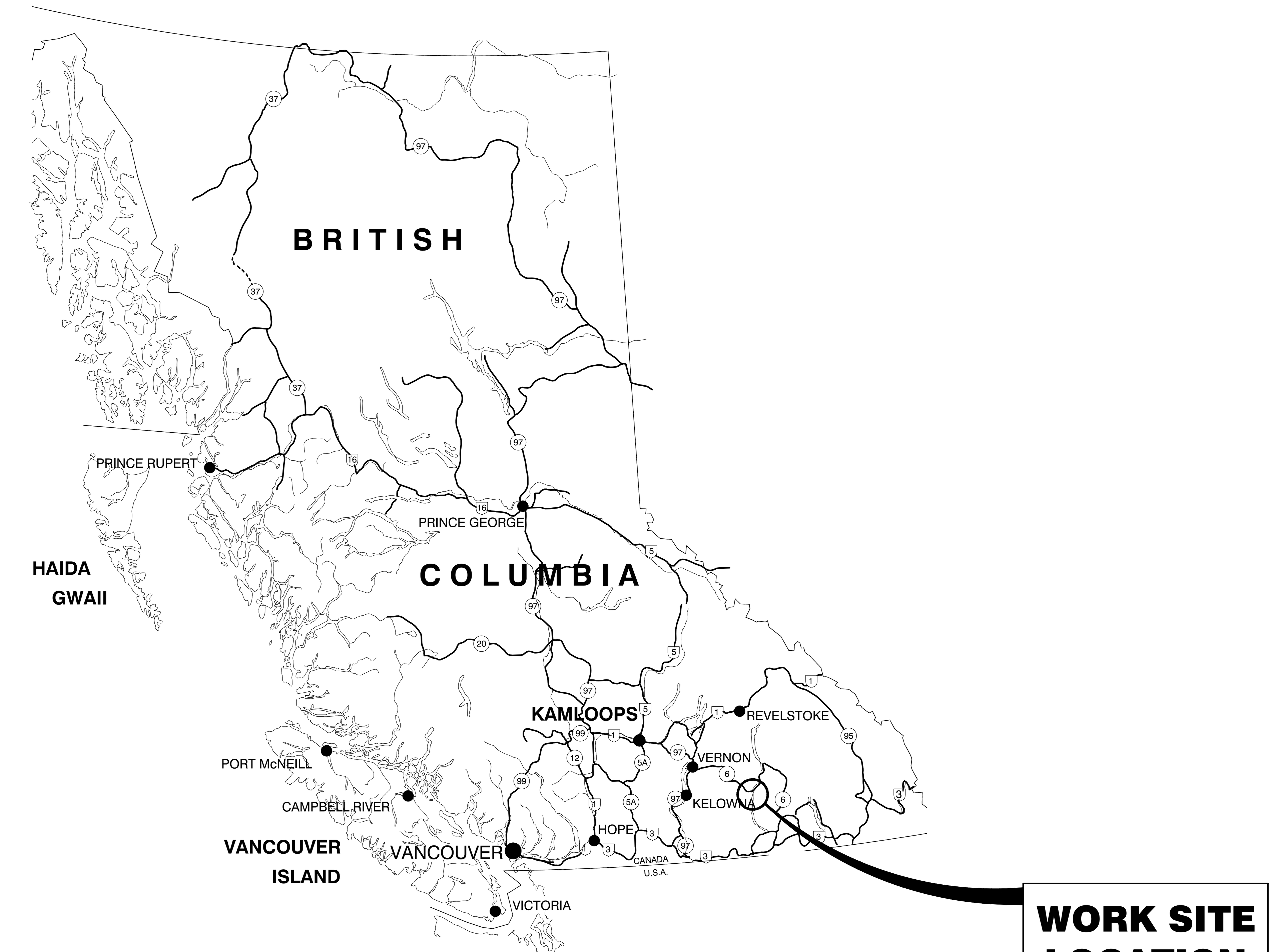
PHOTO 9: Fine grained terrace. TP16-6 was collected from the base.

Appendix C

Preliminary Design Drawings



LOCATION PLAN
N.T.S.



KEY PLAN
Scale N.T.S.

CLWORKS-30B
LOWER INONOAKLIN WILDLIFE ENHANCEMENT PROJECT

DRAWING LIST

SHEET NO.	DRAWING NO.	DESCRIPTION
1	G-101	LOCATION PLAN, KEY PLAN, AND DRAWING LIST
2	C-101	PLAN
3	C-102	PROFILE AND SECTIONS
4	C-301	DETAILS

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NO	REMARKS	DATE	DESIGNED	INDEP CHK	DFTG	DFTG CHK	INSP	REV	ACPT
C	PRELIMINARY DESIGN – FINAL	2018/FEB/19	SFJ	PF	GCP	ACL	–	SFJ	–
B	PRELIMINARY DESIGN – DRAFT	2017/AUG/03	SFJ	PF	GCP	ACL	–	SFJ	–
A	PRELIMINARY DESIGN – DRAFT	2017/JAN/27	SFJ	PF	GCP	ACL	–	SFJ	–

REVISIONS

REF#	DRAWING NUMBER	TITLE

REFERENCE DRAWINGS

REF#	DRAWING NUMBER	TITLE

REFERENCE DRAWINGS

DSGN	SJF
INDEP CHK	PF
DFTG	GCP
DFTG CHK	ACL
INSP	–
REV	SFJ
ACPT	–

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BChydro

LOWER INONOAKLIN WILDLIFE ENHANCEMENT PROJECT (CLWORKS-30B)

WETLAND HABITAT ENHANCEMENT WORKS

LOCATION PLAN, KEY PLAN, AND DRAWING LIST

DATE	DIST	DWG NO	SIZE	R
2018-FEB	-	G-101	D	C

LEGEND

- EXCAVATED AREAS
- BERM SLOPE DIRECTION
- TRANSVERSE HUB SET

SURVEY NOTES:

1. CONTOURS SHOWN ARE FROM BC HYDRO SURVEY PERFORMED IN NOVEMBER 2016
2. DATE SURVEYED 2016-11-25 TO 2016-11-26. COORDINATE SYSTEM: UTM ZONE 11, NAD83 ELEVATION DATUM: CGVD28 (HTv2.0)
3. HORIZONTAL AND VERTICAL POSITIONS ARE DERIVED FROM GPS OBSERVATIONS ON BCH SURVEY CONTROL POINTS #5168 PROCESSED WITH CSRS-PPP ONLINE SOFTWARE. DATE 2016-11-25
4. IB 5168 (5.5 hrs)
   N 5524107.888m ±0.003m
   E 420305.028m ±0.05m
   Z 440.288m ±0.010m

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NO	REMARKS	DATE	DESIGNED	INDEP CHK	DFTG	DFTG CHK	INSP	REV	ACPT
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A	PRELIMINARY DESIGN – DRAFT	2017/FEB/06	SFJ	PF	GCP	ACL	–	SFJ	–

REVISIONS

REF#	DRAWING NUMBER	TITLE	REF#	DRAWING NUMBER	TITLE

REFERENCE DRAWINGS

DSGN	SJF
INDEP CHK	PF
DFTG	GCP
DFTG CHK	ACL
INSP	–
REV	SFJ
ACPT	–

Signed and Sealed Original

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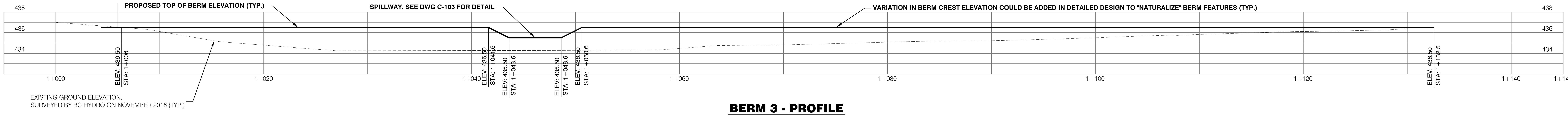
LOWER INONOAKLIN WILDLIFE ENHANCEMENT PROJECT (CLWORKS-30B)

WETLAND HABITAT ENHANCEMENT WORKS

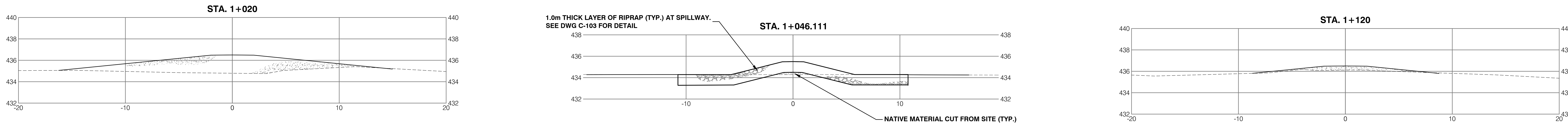
PLAN

DATE	DIST	DWG NO	SIZE	R
2018-FEB	-	C-101	D	C



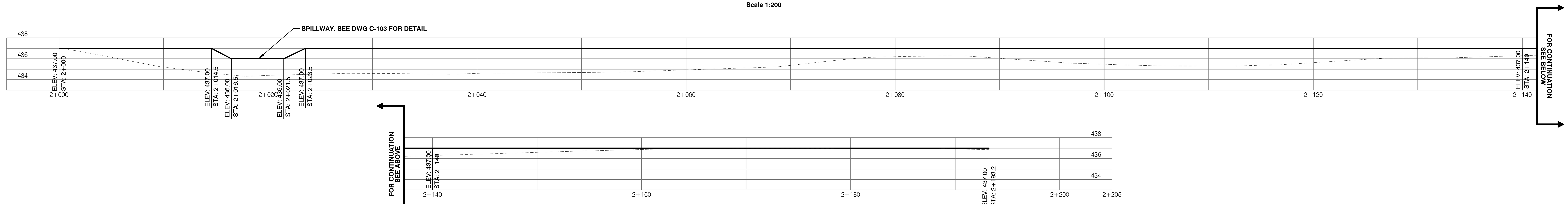
BERM 3 - PROFILE

Scale 1:200



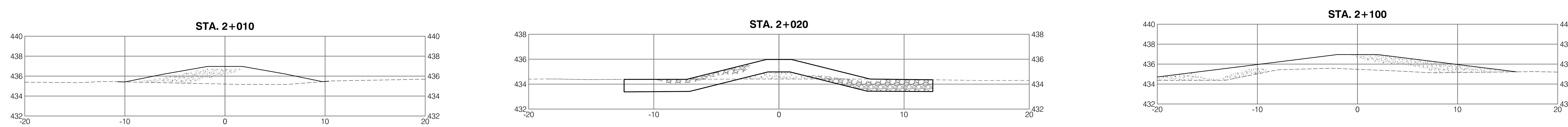
BERM 3 - SECTIONS

Scale 1:200



BERM 2 - PROFILE

Scale 1:200



BERM 2 - SECTIONS

Scale 1:200

BERM 1 - PROFILE & SECTION

Scale 1:200

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NO	REMARKS	DATE	DESIGNED	INDEP CHK	DFTG	DFTG CHK	INSP	REV	ACPT
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REVISIONS

REF#	DRAWING NUMBER	TITLE	REF#	DRAWING NUMBER	TITLE

REFERENCE DRAWINGS | REFERENCE DRAWINGS

DSGN	SFJ
INDEP CHK	PF
DFTG	GCP
DFTG CHK	ACL
INSP	–
REV	SFJ
ACPT	–

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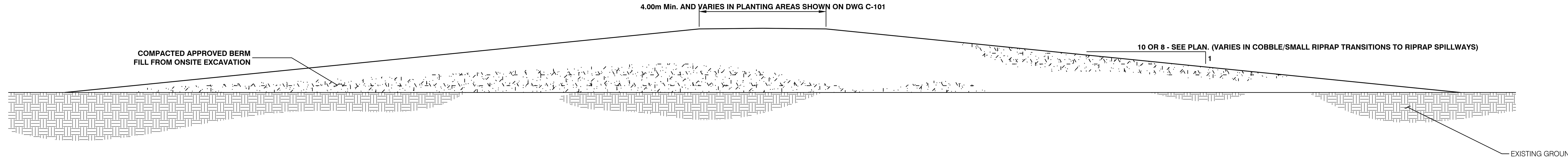
BC hydro

LOWER INONOAKLIN WILDLIFE ENHANCEMENT PROJECT (CLWORKS-30B)

WETLAND HABITAT ENHANCEMENT WORKS

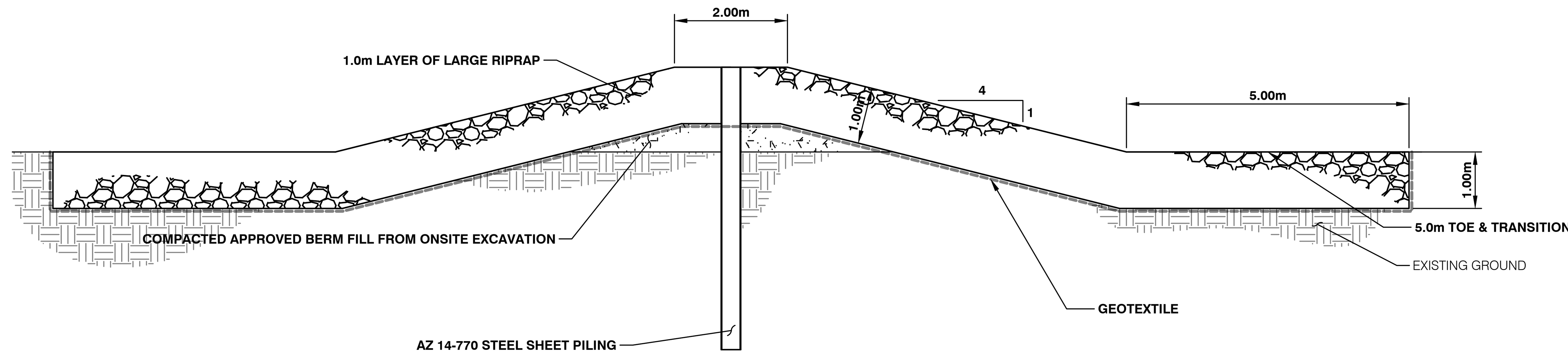
PROFILE AND SECTIONS

DATE	DIST	DWG NO	SIZE	R
2018-FEB	-	C-102	D	C



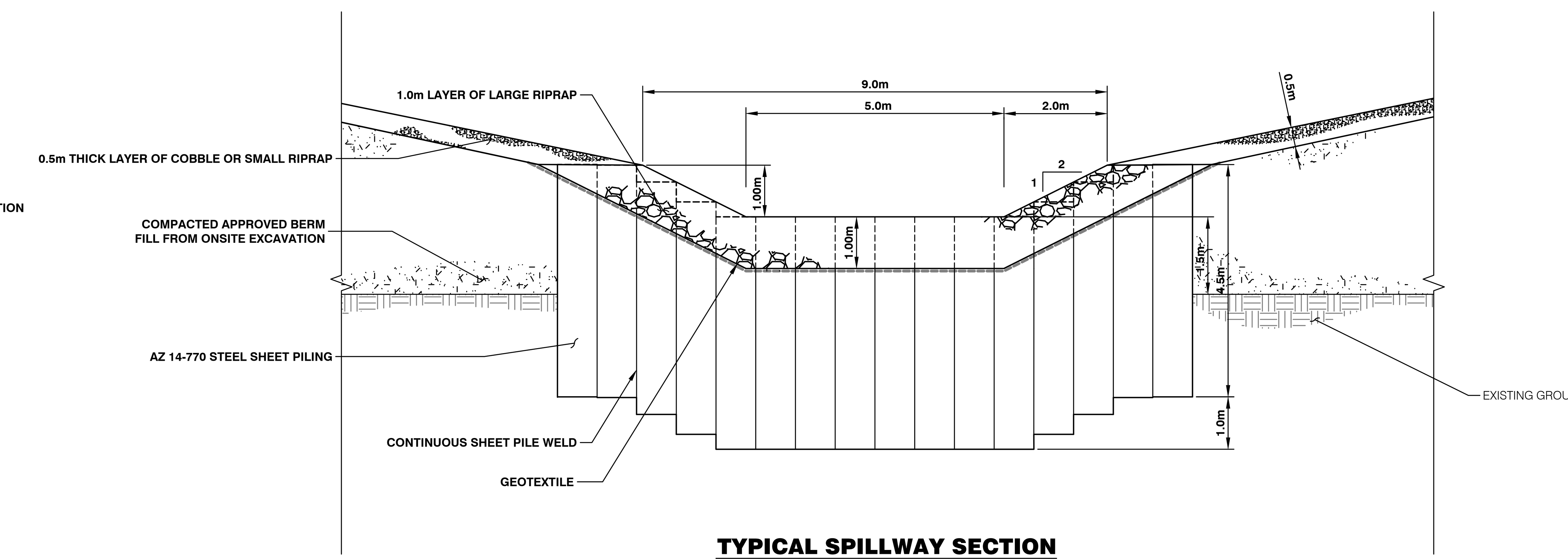
TYPICAL BERM PROFILE

Scale N.T.S.



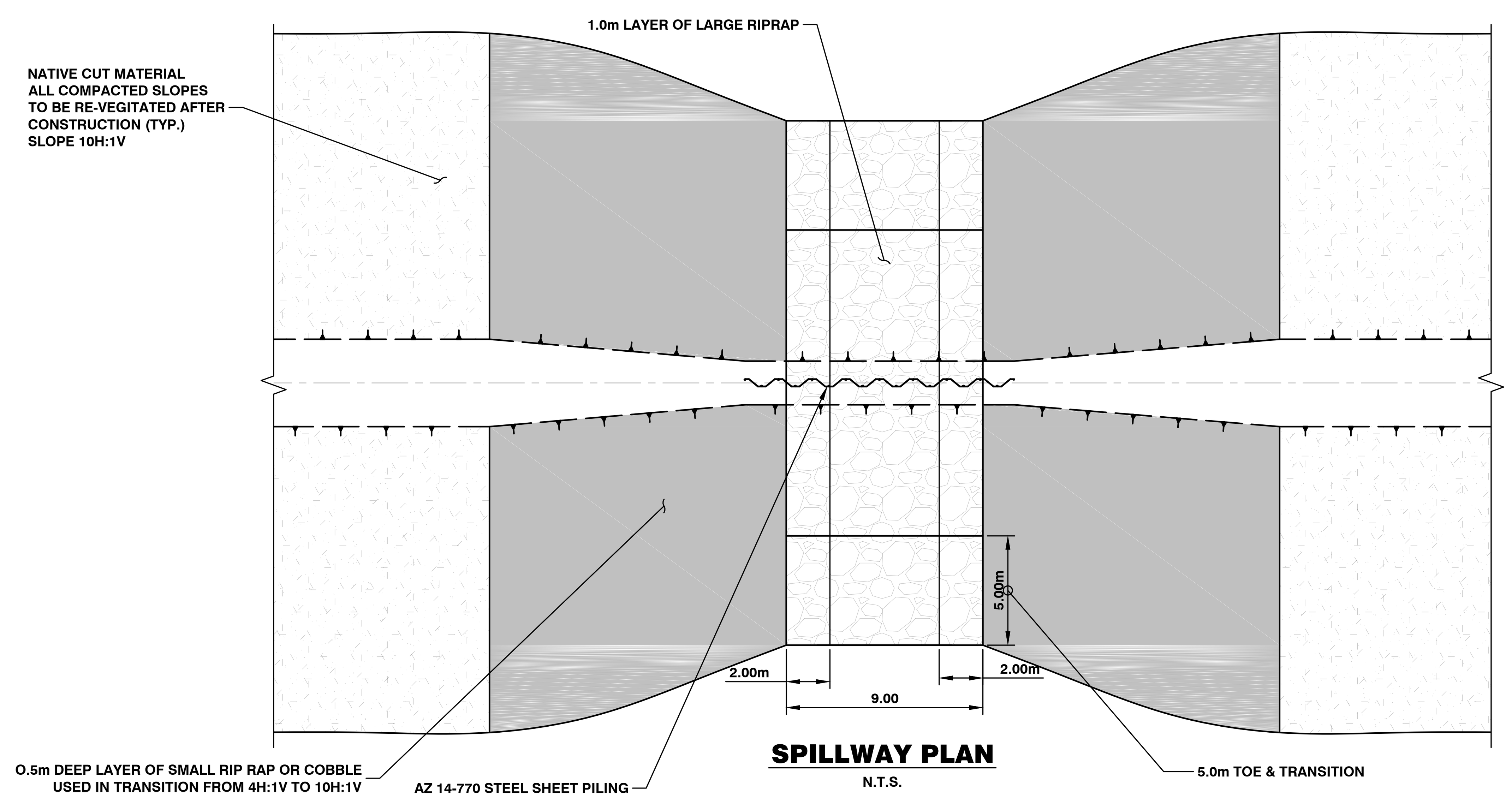
TYPICAL SPILLWAY PROFILE

Scale N.T.S.



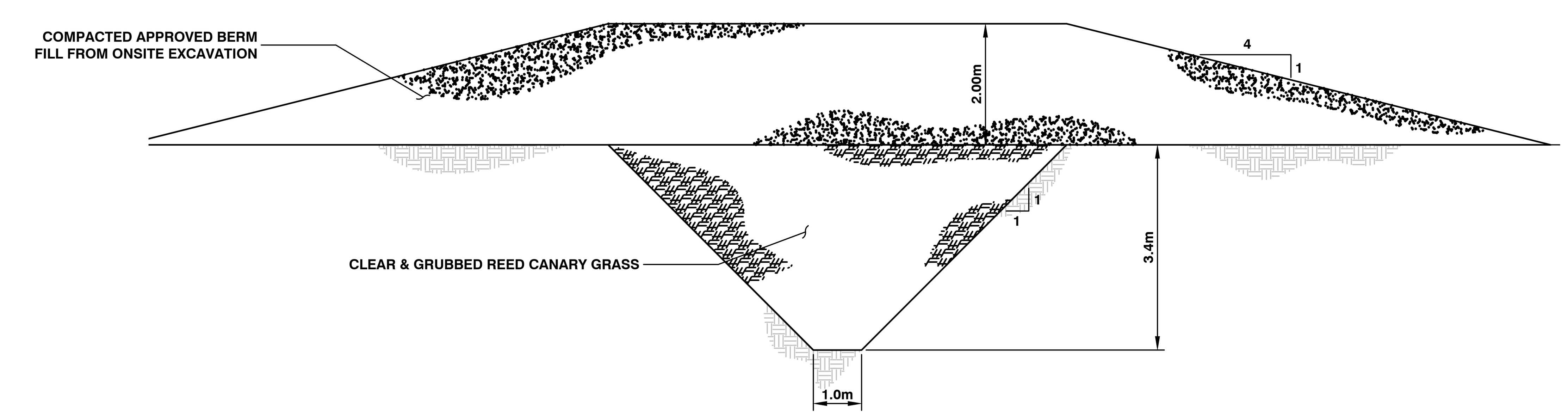
TYPICAL SPILLWAY SECTION

Scale N.T.S.



SPILLWAY PLAN

N.T.S.



TRENCH & COVER CROSS SECTION IN REED CANARY GRASS REMOVAL LOCATION

Scale N.T.S.

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NO	REMARKS	DATE	DESIGNED	INDEP CHK	DFTG	DFTG CHK	INSP	REV	ACPT
C	PRELIMINARY DESIGN – FINAL	2018/FEB/19	SFJ	PF	GCP	ACL	–	SFJ	–
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REVISIONS

REF#	DRAWING NUMBER	TITLE	REF#	DRAWING NUMBER	TITLE

REFERENCE DRAWINGS

DSGN	SFJ
INDEP CHK	PF
DFTG	GCP
DFTG CHK	ACL
INSP	–
REV	SFJ
ACPT	–

Signed and Sealed Original

BChydro

LOWER INONOAKLIN WILDLIFE ENHANCEMENT PROJECT (CLWORKS-30B)

WETLAND HABITAT ENHANCEMENT WORKS

DETAILS

DATE	DIST	DWG NO	SIZE	R
2018-FEB	-	C-301	D	C

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Appendix D

Excerpt of CLBWORKS-29B

Section 7.0 Lower Inonoaklin Road Wetland Retention, Arrow Feasibility Study of High Value Habitat for Wildlife Physical Works

LGL Report to BC Hydro, 2016

7.0 LOWER INONOAKLIN ROAD WETLAND RETENTION

7.1 Overview

The proposed site is comprised of an existing narrow, linear pond with a soft mud bottom. To the west the wetland is bordered by upland habitat dominated by grasses and weedy species and some woody debris. To the east, a partially vegetated gravel bar protects the wetland from inundation for some of the year. The south end of the site is an area referred to as Porcupine Island because of the recent cottonwood planting that occurred there. Immediately upland of the site is a private residence. Site access is possible via Lower Inonoaklin Road, but visibility (with respect to the public) is limited as the site is not adjacent to a main road and there appears to be limited use of the area by the public at present.

The elevation of the proposed physical works occurs between 434 and 440 m ASL. Over the past nine years, Arrow Lakes Reservoir has exceeded 434 m ASL between April 1 and October 31 for 42 (2015) to 157 days (2008). To reduce the potential for site inundation (and to promote the stability of the wetland habitat), the proposed physical works will include the construction of three dikes (63 m, 128 m, and 171 m long, respectively). Each dike will be built to an elevation of ~438.5 m ASL with spillways at ~438 m ASL. The existing wetland area is approximately 6.2 ha. The proposed physical works project will protect existing wetland habitat from reservoir inundation and make it available for a longer period of time each year (between 40 and 55 days per year, depending on reservoir operations). The construction of the dikes is expected to protect the existing wetland from inundation for ~174 days per year (max: 214 days; min: 112 days based on a review of reservoir elevations recorded over the last nine years) assuming that wildlife will be most likely to use the constructed wetland between April 1 and October 31.

The project will improve wildlife habitat suitability through the increased availability of a currently limited habitat type (shallow wetland habitat) that is affected by reservoir operations. Anticipated benefits will be for wildlife including birds, amphibians, reptiles, mammals (bats), insects (dragonflies) and fish. Species with provincial or federal conservation designation that will benefit from this project include the provincially blue-listed and COSEWIC species of Special Concern Western Toad (*Anaxyrus boreas*), the provincially blue-listed Townsend's Big-eared Bat (*Corynorhinus townsendii*) and Fringed Myotis (*Myotis thysanodes*), and the federally (Species at Risk Act) listed Endangered little brown myotis (*Myotis lucifugus*) (listed December 17, 2014).). The existing wetland at Lower Inonoaklin Road is unlikely to be affected by the proposed physical works; however, if the wetland is recharged via inundation, there is a risk a reduction in water supply could impact the wetland over time. For example, in 2015, maximum reservoir elevations were only 435.48 m ASL and the total wetted area of the wetland at Lower Inonoaklin was visibly reduced in 2016. Although more work is required to properly assess the hydrology of the wetland at this location, it appears that reservoir inundation contributes (at least in part) to the volume of water retained in the wetland.

As depicted in Figure 7-7 (see Section 7.10.3), three minor excavations and construction of three mounds are planned. The excavations may not be necessary if existing materials near the location of the proposed mounds can be used to fill the gaps between high points to an elevation of 438 m ASL. Alternatively, material will be brought to the site to avoid the need for any excavations. The total volume of water retained in the excavations (should they be necessary) will occur entirely within existing depressions/wetlands that occur in the drawdown zone. There is potential for the excavations to retain between 2,651.8 m^3 and 17,499.7 m^3 of water. However, none of these excavations constitute impoundments as the water is not retained behind a dike. The mounds should be built between existing points of high land with the goal of precluding inundation of the wetland at Lower Inonoaklin until later in the year. The volumes of water retained in each excavation were calculated using the 2010 Digital Elevation model for Lower Inonoaklin Road, a proposed mound elevation of 438 m ASL, and the delineation of the proposed excavations in a GIS. The excavations will occur across an elevation gradient of 433.6 m to 437 m.

7.2 Rationale

Certain areas of the drawdown zone, through a combination of topography, location, and elevation, provide high quality shallow wetland habitat for part of the year prior to reservoir inundation. One of these areas is situated at the base of Lower Inonoaklin Road and is one of the more productive sites in mid- and lower Arrow Lakes Reservoir (based on an assessment of the diversity and abundance of wildlife and vegetation species using the area). Lower Inonoaklin Road has been treated under CLBWORKS-2, Arrow Lakes Revegetation Program and the planting of cottonwood stakes and various sedges at this site has been successful. The proposed project at Lower Inonoaklin Road would protect the existing shallow wetland habitat from reservoir inundation for a greater duration of each year (40 to 55 days per year relative to current conditions) through the construction of several low-lying mounds. The project will increase the suitability of the site for wildlife by extending its temporal availability on an annual basis.

7.3 Site Description

The Lower Inonoaklin Road site is located immediately south of Needles, B.C. on the west side of the Arrow Lakes Reservoir. The proposed physical works location is centered at 11 U 420302 E 5523907 N. The approximate location of the physical works project at Lower Inonoaklin Road is shown in Figure 7-1. The location of Lower Inonoaklin Road relative to Arrow Lakes Reservoir is shown in Figure 3-1.

Figure 7-1: Existing shallow wetland habitat at Lower Inonoaklin Road, south of Needles, B.C. on the west side of the Arrow Lakes Reservoir. Photo © Virgil C. Hawkes

The site is generally flat and slopes gently to the west with a west to southwest aspect. The elevation of the Lower Inonoaklin Road site ranges from ~ 434 m ASL to > 440 m ASL. As reservoir elevations increase, the site gets inundated from the south (Figure 7-2).

Figure 7-2: Overview of Lower Inonoaklin Road on May 7, 2016 (left; res. elev. 432.62 m ASL) and June 5, 2016 (right; res. elev. 436.2 m ASL) showing the advancement of the reservoir and increased vegetation growth.

7.4 Land Ownership

The area identified for the proposed physical works at Lower Inonoaklin Road is identified as Provincial Crown Land and it lies entirely within BC Hydro's Water License area for Arrow Lakes Reservoir (Figure 7-3).

Figure 7-3 Land ownership on and adjacent to the proposed physical works location at Lower Inonoaklin Road. The proposed project would occur n PID 012-826-014

7.5 Current Site Conditions

7.5.1 Vegetation

Areas situated lower in the drawdown zone at Lower Inonoaklin Road support a diverse assemblage of annual and early seral plant species, which is typical of much of the drawdown zone of the Arrow Lakes Reservoir. Much of the substrate of the site is relatively coarse (e.g., sands, gravels), and the vegetation is reflective of this. Species found commonly throughout these lower elevation habitats include *Carex lenticularis*, *Equisetum arvense*, *Veronica peregrina*, *Collomia linearis*, *Potentilla norvegica, Rorippa palustris, Carex aperta*, *Juncus bufonius*, *J. filiformis*, *Alopecurus aequalis* and *Cerastium* *nutans*, while at slightly higher elevations, weedy species such as *Phalaris arundinacea, Crepis tectorum, Elymus repens*, *Trifolium aureum*, *T. arvense*, *Scleranthus annuus* and *Poa compressa* become more abundant. This area is dominated by *Calamagrostis canadensis* and *Phalaris arundinacea* and supports a small assemblage of species that are typical of finer soils and moister conditions (e.g., *Galium palustre*).

Lower Inonoaklin Road was recently treated under CLBWORKS-2 with cottonwood stakes and sedge plugs planted in the higher elevations around the shallow wetland habitat. The preservation of the shallow wetland habitat will not affect the trees or sedges planted under CLBWORKS-2.

Aquatic macrophytes observed at Lower Inonoaklin Road include Stonewort (*Chara sp.)* and Small Pondweed (*Potamogeton pusilus*; Miller and Hawkes 2014).

7.5.2 Wildlife

Wildlife use of the site is extensive, with songbirds, raptors, water birds, amphibians, reptiles, insects, spiders, bats, and ungulates (deer and moose) having been documented. Thirteen species of mammals have been documented at Lower Inonoaklin Road during spring and summer surveys (based on incidental observations made during field work for CLBMON-11B1 (see Hawkes et al. 2011). A single White-tailed Deer was documented in the drawdown zone near Lower Inonoaklin Road in 2011, but no mammals were observed in 2012. In general, use of the drawdown zone at Lower Inonoaklin Road by ungulates and other large mammals is limited, which is likely related to the proximity of the site to human private residences which border the reservoir. In 2011, 77 species of birds, 13 species of mammals (including 11 species of bats[3] including the endangered little brown myotis [*Myotis lucifugus*]), three species of amphibians (including the blue-listed Western Toad [*Anaxyrus boreas*], a COSEWIC species of Special Concern), and three species of reptiles (Western Terrestrial Garter Snake [*Thamnophia elegans*], Common Garter Snake [*Thamnophis sirtalis*], and Northern Alligator Lizard [*Elgaria coerulea*]) were documented. In 2015 a Northern Rubber Boa (*Charina* bottae) was documented at the site and in June 2016, a Western Skink (*Plestiodon skiltonianus*) was observed. Both the latter species observed are listed as species of Special Concern under the Species at Risk Act.

Multiple species of waterfowl and shorebirds have been documented using the wetland at Lower Inonoaklin Road (during surveys associated with CLBMON-11B1). Since 2011, 19 species of grebe, loon, shorebirds, and waterfowl have been observed in the wetland and adjacent shoreline habitats (Table 7-1). It is not known if waterfowl are nesting at the site, but young of the year have been observed and both killdeer and Spotted Sandpiper nests have been documented on the gravel bars surrounding the wetland.

[3] One of the most frequently documented bats at the Lower Inonoaklin Road site is the little brown myotis (*Myotis lucifugus*), which was emergency listed under Species at Risk Act as Endangered (Dec. 17, 2014) due to the potential threat of White Nose Syndrome (a fungus caused by *Geomyces destructans*).

Table 7-1. Species of grebe, loon, shorebirds, and waterfowl documented from the wetland at Lower Inonoaklin Road between 2011 and 2015. These species were documented during songbird point count surveys conducted for CLBMON-11B1.

Group	Common Name	Scientific Name	2011	2013	2015
Grebes	Red-necked Grebe	*Podiceps grisegena*	1		
Loons	Common Loon	*Gavia immer*	2	3	1
Shorebirds, Gulls, Auks and Allies	Killdeer	*Charadrius vociferus*	29	21	10
	Spotted Sandpiper	*Actitis macularius*	13	8	16
	Wilson's Phalarope	*Phalaropus tricolor*		3	
Waterfowl	American Wigeon	*Anas americana*	10	4	2
	Blue-winged Teal	*Anas discors*	11		2
	Bufflehead	*Bucephala albeola*	16	3	
	Canada Goose	*Branta canadensis*	40	26	28
	Common Goldeneye	*Bucephala clangula*		2	
	Common Merganser	*Mergus merganser*			2
	Gadwall	*Anas strepera*		2	
	Green-winged Teal	*Anas crecca*	2		
	Hooded Merganser	*Lophodytes cucullatus*		1	
	Lesser Scaup	*Aythya affinis*		1	
	Mallard	*Anas platyrhynchos*	11	24	11
	Northern Shoveler	*Anas clypeata*	3	1	
	Redhead	*Aythya americana*		1	
	Ring-necked Duck	*Aythya collaris*		1	
		Total Species (per year)	**11**	**15**	**8**

7.5.3 Soil/Geology

Soils of the Arrow Lakes Reservoir are variable and range in nutrient content and physical characteristics from extremely nutrient- and moisture-poor silt remnants occurring between boulders, to moist sandy-silty soils of the undulating alluvial fans, to rich upland loam soils that are residual from pre-development of the reservoir. Soils are nutrient poor except at high elevation (Gibeau and Enns 2008). Gibeau and Enns (2008) provide a general description of the soils of Arrow Lakes Reservoir but not specifically for Lower Inonoaklin Road. It is recommended that a detailed analysis of the soils at this site be conducted prior to implementing the proposed physical works.

Keefer et al (2009) revegetated a portion of Lower Inonoaklin Road in 2009 and noted that the soils in the cottonwood treatment area were comprised of large cobbles. There are no site-specific data for the habitat immediately adjacent to the shallow wetland habitat, but the substrate in the existing wetland could be described as silt/clay mud with some sand.

7.5.4 Hydrology

The main hydrological feature at the Lower Inonoaklin Road site is a large shallow wetland habitat that is situated at ~437 m ASL. A small drainage ditch is situated alongside the Lower Inonoaklin Road and water flow through this ditch appears to be intermittent, although there may be subsurface flow during the spring. There may also be a spring in the area and a more detailed hydrological assessment is required.

7.6 Goals and Objectives

The primary goal of this proposed physical works is to preserve ~6.2 ha of existing shallow wetland habitat in the drawdown zone of Arrow Lakes Reservoir by constructing three dikes of varying length (63 m, 128 m, and 171 m) to an elevation of ~438.5 m ASL. This will create shallow wetland habitat that is available to wildlife for a minimum of ~174 days per year (max: 214 days; min: 140 days based on a review of reservoir elevations recorded over the last nine years) assuming that wildlife will be most likely to use the constructed wetland between April 1 and October 31. A secondary goal is to meet the direction provided under the Water Use Plan to identify enhancement opportunities in the mid- and lower Arrow Lakes Reservoir under CLBWORKS-29B.

Preserving shallow wetland habitat in the drawdown zone will improve the ecology of the drawdown zone by improving habitat suitability for wildlife and vegetation. The specific objectives of the proposed wildlife physical works are to:

1. Increase the temporal availability of shallow wetland habitat for wildlife in the drawdown zone of Arrow Lakes Reservoir. The construction of mounds will enable the shallow wetland habitat to persist longer into the summer, which will improve habitat suitability for pond-breeding amphibians, bats, reptiles, certain species of birds, semi-aquatic mammals, and some terrestrial mammals;
2. Improve habitat complexity in the drawdown zone of Arrow Lakes Reservoir; and
3. Vegetate the constructed dikes with native sedges (not shrubs and/or trees because they could affect the integrity of the dikes).

7.7 Target Site Conditions

The existing site conditions associated with the shallow wetland habitat at Lower Inonoaklin Road provide high-suitability wildlife habitat, particularly for waterfowl, shorebirds, and pond-breeding amphibians. Increasing the duration of availability of this habitat on an annual basis will further enhance the suitability of the site for wildlife. The proposed physical works will have little effect on the current site conditions (which is the desired effect) and we do not anticipate increases in the cover of native plants (with the exception of planting the dikes) nor do we foresee the introduction of non-native aquatic macrophytes into the shallow wetland habitat. The resulting habitat would appear very much like it does on an annual basis between April and October in Figure 7-1. Additional hydrological work is required to determine whether the hydrology of the site will be altered by increasing the height of the mounds around the wetland.

7.8 Seasonality of Expected Improvements

Seasonality of expected improvements was considered for the period April 1 to October 31 as this is the time of year when wildlife are active and the areas is likely to be snow and ice-free. The typical hydrograph of Arrow Lakes Reservoir includes rapid filling in the spring with high-water achieved between June and August followed by a decline in late August or early September (Figure 7-4). The proposed physical works at Lower Inonoaklin Road are intended to retain existing habitat features at the site and prolong the timing on inundation of the existing wetland. With a dike height of 438 m ASL, inundation will commence in mid- to late June and the wetland could be inundated until mid-July or as late as early September depending on reservoir operations.

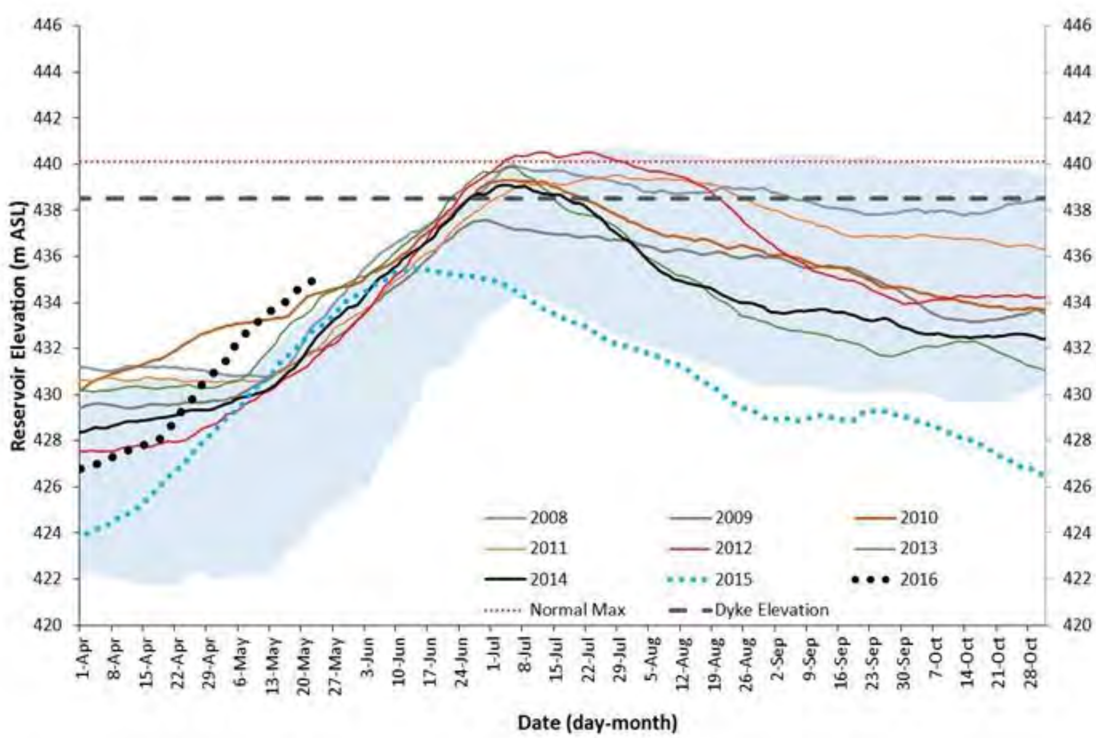

Figure 7-4: Annual hydrographs for Arrow Lakes Reservoir for the period April 1 to Oct 31 and years 2008 through 2015 (through May 21, 2016). The dashed horizontal line represents the top elevation of the proposed dikes (438 m ASL).

7.8.1 Anticipated effects of physical works on Wildlife

7.8.1.1 Amphibians

Reservoir operations in Arrow Lakes Reservoir do not appear to negatively affect amphibians. For example, Western Toad and Columbia Spotted Frog typically lay eggs in late April or Early May. Eggs hatch in 3 to 12 days and free swimming tadpoles develop rapidly allowing them to move within ponds, even when inundated. Recent observations of Western Toad tadpoles and metamorphs at Lower Inonoaklin Road in early June 2016 (when reservoir elevations were 435 to 436 m ASL and inundating the wetland at Lower Inonoaklin Road) suggest that inundation does not affect the development of tadpoles. Because of their mobility and the timing of breeding and development and the limited impact to existing wetland habitat at Lower Inonoaklin Road, it is unlikely that habitat enhancement/creation at the Lower Inonoaklin Road site will negatively affect pond-breeding amphibians. It is more likely that the suitability of the wetland will remain unchanged for amphibians or suitability could be somewhat improved because of the longer period of availability and increased stability of wetland habitat, an assumption that will require testing following the implementation of the proposed works.

7.8.1.2 Birds

Certain species of bird are known to nest in the drawdown zone of Arrow lakes Reservoir including Killdeer (*Charadrius vociferus*) and several species of sparrow (e.g., Savannah Sparrow, *Passerculus sandwichensis*). Very few data are available for bird nests in the drawdown zone at Lower Inonoaklin Road. However, data collected in 2015 indicate that five species of birds (Spotted Sandpiper, Red-eyed Vireo, Chipping Sparrow, American Robin, and Willow Flycatcher) were nesting and adjacent to the wetland in existing vegetation or the revegetated area. Of these, Spotted Sandpiper, and American Robin nested at elevations <440 m ASL (Spotted Sandpiper @ 436 m to 436.5 m ASL; American Robin @ 436 m ASL; Figure 7-5).

A Killdeer nest was observed at near the proposed physical works site at Lower Inonoaklin Road in May 2016 in the area revegetated under CLBWORKS 2 (in the southeast portion of Figure 7-5; M. Sadler, S. Pinkus, BC Hydro, pers. obs.). The elevation of the proposed physical works at Lower Inonoaklin Road overlaps with the median elevation of Savannah Sparrow and Killdeer nests reported for Revelstoke Reach (see Section 6.8.1.2). Depending on reservoir elevations and the location of nests, some nest mortality associated with reservoir operations may occur. However, if nests are within the confines of the existing wetland following the implementation of the physical works, the probability of nest mortality resulting from reservoir elevations is greatly reduced. Additional data collected for CLBMON-11B1 in 2016 should be reviewed to determine whether birds continue to nest in and adjacent to the proposed physical works locations.

Figure 7-5: Distribution of bird nests in and adjacent to the drawdown zone at Lower Inonoaklin Road (2015). Only contours ≤ 440 m ASL are shown. REVI = Red-eyed Vireo; WIFL = Willow Flycatcher; AMRO = American Robin, SPSA = Spotted Sandpiper; CHSP = Chipping Sparrow.

The implementation of physical works may benefit waterfowl by contributing the more stable habitat that is available longer. At a minimum, the use of the wetland and adjacent habitats by shorebirds and waterfowl will not change as the physical works are intended to increase the availability of the wetland to wildlife, including shorebirds and waterfowl.

7.8.1.3 Mammals

Mammals observed at the Lower Inonoaklin Road site include ungulates (deer), small mammals (e.g., Meadow Vole), and several species of bat [based on analysis of data collected by Autonomous Recording Units]. Of the mammal species present at Lower Inonoaklin Road, bats are the most likely to benefit from the increased temporal availability of wetland habitat. Our current understanding of the use of Lower Inonoaklin by bats indicates that as many as eleven species of bat could be using the site between June and September. Relative to both Edgewood South and Burton Creek, bat activity (based on the number of recordings per hour) at Lower Inonoaklin was greater than Edgewood but less than Burton Creek. The same number of species were documented at Edgewood with nine reported for Burton Creek. The maintenance of wetland habitat at Lower Inonoaklin Road will improve the overall suitability of the site for bats for the majority of the active season (e.g., April 1 to October 31), particularly as it relates to foraging opportunities. Data collection on the use of the proposed physical works site by bats is ongoing (as part of CLBMON-11B4) with data collection proposed for the period May through September 2016. Two Autonomous Recording Units are currently deployed – one at the north end of the site and one at the south end. Data from the Autonomous Recording Units will be collected in September and analysed during fall 2016.

7.9 Performance Measures

The effectiveness of the proposed physical works at Lower Inonoaklin Road should be assessed using an index of habitat function that is based on post-construction monitoring data to describe the use of the wetland by waterfowl, shorebirds, songbirds, amphibians, and bats and on the species composition and cover of aquatic macrophytes. Macroinvertebrate species composition should also be considered in the development of an index that describes wetland productivity and function. Some of these data could be compared to pre-construction data (e.g., bats, macrophytes, amphibians and reptiles), while other data (e.g., hydroperiod, water depth) will be based solely on post-construction data (unless this information is collected prior to project implementation).

The following performance measures are suggested to guide the collection of data with which to assess the success of the proposed wildlife physical works project at Lower Inonoaklin Road:

2. Spatio-temporal availability
   a. Maintenance of current spatial extent of the wetland at Lower Inonoaklin Road.

b. Maintenance of the temporal availability of wetland that overlaps with the migratory bird (particularly wetland-associated species) and amphibian breeding seasons (May-August). The permanence of the wetland should be assessed (i.e., is the wetland available each year and for how long?)

c. Hyrdoperiod and depth of wetland does not change more that 25% from pre-construction condition (there is likely to be natural annual variation related to precipitation and reservoir elevations).

3. Wetland productivity:

a. Maintenance of native macrophytes. Additional data are required to ensure the current species list in Miller and Hawkes (2014) is complete.

b. Continued use of the wetland by breeding by amphibians (specifically Western Toad). The number of egg strings or masses should be counted on an annual basis following the implementation of the physical works.

c. Continued use of the wetland by waterfowl and shorebirds and no reduction in species composition (assuming some level of inter-annual variation as suggested by Table 7-1).

d. Evidence of use of habitat enhancements (e.g., nest boxes, floating islands) by target waterfowl species (which will need to be determined) following completion of construction.

e. Continued use of the wetland by bats (as determined by autonomous recording units) and use of any enhancements such as bat boxes, snags, or other enhancements) by bats.

f. No reduction in the species composition of bats at Lower Inonoaklin Road, which currently includes up to 11 species (Table 7-2).

Table 7-2. Bat species documented[1] using bat detectors at the Lower Inonoaklin Road area in 2015. The bat detectors were situated near the area proposed for physical works. The species in this table should be considered a good representation of the use of the Lower Inonoaklin Road area by bats, but see footnote.

Scientific Name	Common Name	BC CDC	COSEWIC	SARA
Corynorhinus townsendii	Townsend's Big-eared Bat	Blue	--	--
Eptesicus fuscus	Big Brown Bat	Yellow	--	--
Lasiurus cinereus	Hoary Bat	Yellow	--	--
Lasionycteris noctivagans	Silver-haired Bat	Yellow	--	--
Myotis californicus	California Myotis	Yellow	--	--
Myotis ciliolabrum	Western small-footed Myotis	Blue	--	--
Myotis evotis	Long-eared Myotis	Yellow	--	--
Myotis lucifugus	Little Brown Bat	Yellow	Endangered	1-E (2014)
Myotis thysanodes	Fringed Myotis	Blue	Data Deficient	3 (2005)
Myotis volans	Long-legged Myotis	Yellow	--	--
Myotis yumanensi	Yuma Myotis	Yellow	--	--

[1]bat species presence is based on a probability of presence via the analysis of acoustic signature recordings. Because of the difficulty associated with assigning species identification based solely on the use of acoustic signatures, this

species list may not be accurate (e.g., Myotis species are often grouped due to the overlap in the frequency of their acoustic signatures).

4. No measureable change in wetland productivity. Wetland productivity will need to be determined prior to the implementation of the proposed physical works and will be require calculating productivity using dissolved oxygen, conductivity, temperature and local meteorological data. No measureable change means that there will be no measureable decrease in either primary productivity within five years of the implementation of the physical works that can be directly attributed to the physical works. A measureable change will be assumed to be a change of 25 per cent or greater.
5. No measurable increases greater than 25 per cent from baseline conditions in cover and diversity (species richness and evenness) of key undesirable macrophyte species over 10 years. Key undesirable species include Eurasian Water-milfoil (*Myriophyllum spicatum*) and Reed Canarygrass (*Phalaris arundinacea*).
6. Little to no erosion of the mounds as determined by immediate post-construction monitoring and subsequent integrity checks by a qualified engineer.

7.10 Description of Work

7.10.1 Approach

The proposed physical works will protect ~6.2 ha existing wetland habitat from reservoir inundation for a greater proportion of each year relative to current conditions. This will be achieved by constructing three dikes 63 m, 128 m, and 171 m long, respectively and ~1 to 1.5 m in height in low-lying areas adjacent to the existing wetland. To create this habitat at the lowest cost, local materials will be used to the extent possible.

7.10.2 Construction Methods

The method of construction will generally consist of excavation using hydraulic excavators and transport of the materials using dump trucks. This material will then be dumped in lifts and compacted to a suitable density. Following compaction a hydraulic excavator will form the final shape of the features and place the erosion protection or other material on the mounds. The final step in construction will involve planting, which will be performed primarily by individuals using shovels.

Most of the project will be constructed using materials imported to the site. Ideally this material would be located in a nearby borrow pit. It is expected that the following materials will be brought to the site:

- Fine materials for the base of each mound;
- Plants and seeds for vegetating the site;
- Rock for providing erosion protection on the reservoir side of the mound and spillways; and
- Fine-grained soils may be required to improve the soil retention capabilities of the ponds/wetlands.

The construction will be inspected periodically by a representative of the engineer. This inspection will be to confirm that the works are constructed in accordance with the design.

Riprap materials will be hard, durable, angular quarry rock of a quality that will not disintegrate upon exposure to water or the atmosphere. Riprap will be 300 mm diameter minus (subject to current and wave erosion analysis). The fill and pond-bottom material would ideally be a pit run gravel containing a minimum of 10 per cent fine material (fine material have particle sizes less than 0.075 mm). Slightly more permeable material may also be acceptable depending on local site conditions.

Mounds will be constructed of fine materials that will either be retrieved from the site or transported to the site from a nearby borrow pit. Numerous layers of this material will be laid down to construct the mounds, with each layer being thoroughly compacted by a compactor; repeated driving over the material by rock trucks and excavators will further contribute to its compaction. Once the dikes are built, the outer face will be armoured with coarse rip-rap and the inner face will be coated with a layer of organic material that will act as a substrate for the establishment of vegetation.

The mound at the lower elevation (south end of the wetland) should be equipped with an armoured spillway that will allow water to move in a downhill direction towards the reservoir. The spillways will be situated 30 to 40 cm lower than the top elevation of the dikes. The final engineering specifications will dictate whether this is required.

Structural loads on the proposed dike structure will consist primarily of maintenance equipment loads, hydrostatic forces, and wave and erosive forces. To resist these loads the mounds will be constructed of well-graded material. This material will be compacted to a suitable level to minimize future settlement and seepage through the dikes. Additionally, to distribute vehicle loads, reduce seepage, and prevent erosion the dikes will be constructed at relatively gentle side slopes of 6 (horizontal) to 1 (vertical) or flatter. To resist erosive wave forces the reservoir side of the dikes may need to be faced with riprap rock armouring.

Environmental loads on the proposed physical works will depend on annual fluctuations in weather conditions and the reservoir operating regime. The impact of wave wash will be the primary environmental force acting on the dike. Once reservoir levels exceed the height of the dikes, wave erosion should decrease, but as reservoir levels recede, wave wash will again impact the dikes until water levels are below the base of the dikes. Compaction of the materials used in the mounds and armouring the mounds with riprap will reduce the erosive force of waves.

This project design will take into consideration the following criteria:

- The seepage rates of the material used to construct the dikes and the soils that will form the bottom of the pond will be checked to determine if the feature will adequately retain water;
- The dikes and pond features (including plantings) will be designed so that the removal of sediment will be possible with conventional excavation equipment. This will include providing adequate running surface widths on the top of the dikes;

- The compaction of the dike fill materials will be specified so that detrimental settlement will not occur;
- Erosion protection will be provided to prevent erosion as a result of current and wave forces; and
- The spillways through the dikes will be designed for the 100-year return period storms event flow without overtopping the dikes in other locations.

7.10.3 Construction Schematics

The proposed physical works project for Lower Inonoaklin Road is illustrated in Figure 7-7 and a cross-section of the proposed dikes is provided in Figure 7-7. The distance between dikes (~130 m and 69 m) and the installation of spillways will ensure that the velocity of water flowing into the wetlands will not impact the existing conditions of the wetland (i.e., the creation of a dendritic channel is not anticipated).

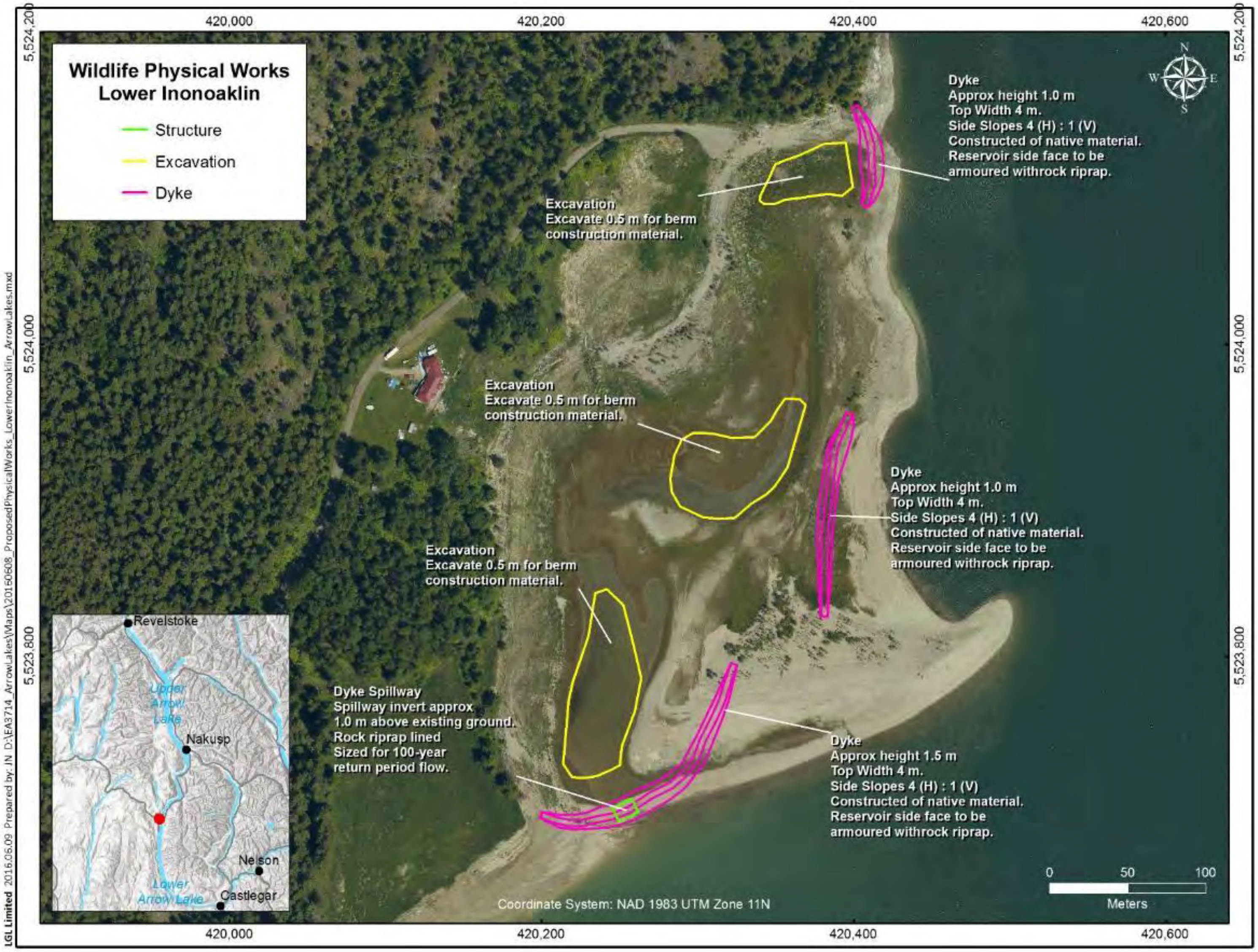

Figure 7-6: Schematic of proposed physical works project in the drawdown zone of Arrow Lakes Reservoir at Lower Inonoaklin Road. The location of each dike and excavation areas is approximate

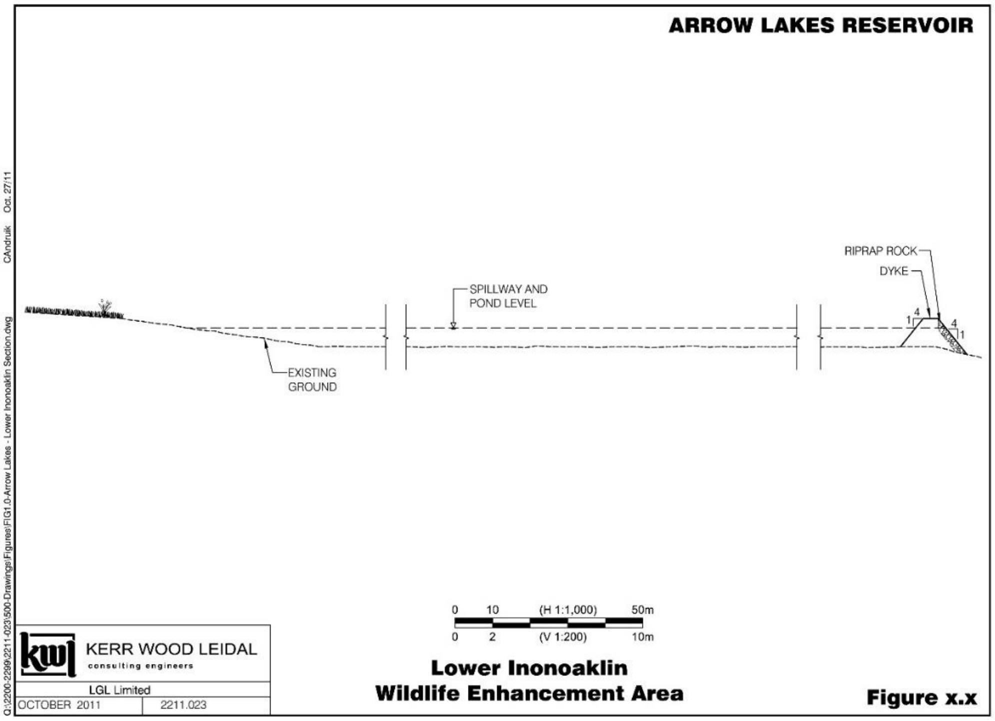

Figure 7-7: **Cross-section of the proposed physical works project in the drawdown zone of Arrow Lakes Reservoir at Lower Inonoaklin Road**

7.10.4 Construction Schedule

The proposed schedule for the Lower Inonoaklin Road wildlife physical works depends on when funds are made available to do the work. A generic schedule is provided as a guide and will be adjusted as needed. Activities and timeframes associated with an Archaeological Impact Assessment and acquisition of permits has not been factored into the generic schedule. The generic schedule is based on having completed pre-work activities and having obtained necessary permits and approvals.

Quarter 1: January to March. Contract development and tendering.

Quarter 2: April to June. Mobilization, construction, environmental monitoring, demobilization. Some revegetation with sedges and aquatic macrophytes could occur.

Quarter 3: July to September. Revegetation. Immediate post-construction monitoring.

Quarter 4: October to December. Revegetation (live staking) if required. Reporting and development of a long-term monitoring program that is either developed specifically for the wildlife physical works sites or that builds on programs currently being implemented in the drawdown of Arrow Lakes Reservoir (e.g., CLBMON-11B1, CLBMON-11B4, CLBMON-37).

7.10.5 Cost Estimate

A Class C site estimate has been prepared for the Lower Inonoaklin Road shallow wetland habitat preservation project and was estimated using information from a comparable-sized project. A Class C budget is an estimate prepared with limited site information and is based on probable conditions affecting the project. It represents the summation of all identifiable project component costs. It is used for program planning, establishing a more specific definition of needs, and obtaining approval in principle. The estimate has been derived from unit costs for similar projects. Actual project costs may be higher or lower and will vary depending on numerous factors including material availability, contractor competition, and site conditions during the construction period. The Class C cost estimate for the Lower Inonoaklin Road project is provided in Table 7-3.

There are project-related activities that have not been included in the costs estimate including an Archaeological Impact Assessment, acquisition of permits and approvals, final engineering design, First Nation and stakeholder engagement, and post-construction inspects etc. The costs below were developed to demonstrate the costs associated with constructing the physical works only. A more detailed cost estimate and timeline should be prepared for this project if it proceeds.

Table 7-3: Class C cost estimate for the proposed physical works project in the drawdown zone of Arrow Lakes Reservoir at Lower Inonoaklin Road. L.S.: lump sum; c.m.: cubic metre; l.m.: linear metre; s.m.: square metre

Item	Description	Unit	Estimated Quantity	Unit Rate ($)	Total Estimate	Comment
1	**General**					
1.01	Mobilization and Demobilization	L.S.	1	12,000	$ 12,000.00	
1.02	Bonding and Insurance (1.5% of Other Tasks)	L.S.	1	3,445.50	$ 3,445.50	
1.03	Diversion, Erosion and Sediment Control	L.S.	1	10,000	$ 10,000.00	
1.04	Survey Layout of Works	L.S.	1	2,000	$ 2,000.00	
	SUBTOTAL FOR TASK				**$ 27,445.50**	
			Units	**Cost / Unit ($)**	**Estimate**	
2	**Earthworks**					
2.01	Subgrade Preparation	c.m.	4,100	2.0	$ 8,200.00	*Assume 20 min round*
2.02	Import Fill Material	c.m.	4,700	25.0	$117,500.00	*trip + $5/m³*
	SUBTOTAL FOR TASK				**$ 125,700.00**	
3	**Drainage Works and Structures**					
3.01	Riprap Armouring	c.m.	960	100	$ 96,000.00	
3.02	Planting	L.S.	1	8,000.0	$ 8,000.00	
	SUBTOTAL FOR TASK				**$ 104,000.00**	
	SUBTOTALS - All Tasks				**$ 257,145.50**	
	Environmental Monitoring				$ 18,000.00	
	Engineering & Construction Management	10%			$ 25,714.55	
	Contingencies	20%			$ 51,429.10	
				Total Estimate (excl. tax) +50%/-15%	**$ 352,289.15**	

7.11 Considerations

7.11.1 Reservoir Operating Regime

Reservoir operations are predictable yet variable. Assessing the hydrograph of the reservoir for the years 2008 to 2016 (partial; Figure 7-4) provides an indication of the potential construction window, which could extend from April 1 to 10 June or June 24. Based on the project planning provided in Section 7.13, this should provide enough time to plan and execute the work. There are years (e.g., 2015) when the construction could have occurred at any time between April 1 and Oct 31 due to low reservoir levels. The project reservoir elevations for Arrow Lakes should be reviewed prior to construction to determine the best window in which to operate.

7.11.2 Public Safety

Appropriate signage will be erected prior to and during construction. Given that the area identified for the proposed physical works is not commonly used by people, there is little to no risk associated with public safety. An environmental monitor will be on site during construction and will ensure that the public remains a safe distance from the site during construction activities. The construction of the dikes should not pose a risk to the public.

7.11.3 Wildlife

The proposed project will ultimately benefit wildlife because wildlife habitat retention/preservation is the main consideration of this project. The proposed project area was evaluated for nesting birds in 2015 (Figure 7-5). Additional work is occurring in 2016 and the results of those surveys should be reviewed prior to establishing the construction window. Data on the use of the site by bats was collected in 2015 with additional data collection occurring in 2016. The occurrence of shorebirds and waterfowl has been documented during songbird point count surveys for CLBMON-11B1. Neither bats, shorebirds, nor waterfowl should be negatively affected by the proposed physical works and ultimately all will benefit from the increased availability and stability of shallow wetland habitat in the drawdown zone. To ensure birds are not impacted during construction nest searching should occur prior to work starting at the site.

7.11.4 Fisheries

At present the site does not provide fisheries values for most of the year. During periods of the year when the site is inundated, there may be some value to fish. The proposed project should reduce the amount of time that fish are able to access the site, which is not considered to be a detriment to fish.

7.11.5 Archaeology

The proposed project will not likely include ground-disturbing activities. However, because of the level terrain and proximity of the site to other known archaeological sites, an Archaeological Impact Assessment will be required at this site prior to the implementation of the proposed physical works.

7.11.6 Recreation

The Lower Inonoaklin Road area receives limited recreational use. The proposed physical works may temporarily affect that use. There are no recreational concerns post construction.

7.11.7 Summary of Agency, First Nations, and Stakeholder Consultation

In fall 2010 a meeting with BC Hydro, the Ministry of Environment, and the Fish & Wildlife Compensation Program–Columbia Region was held in Nelson B.C. to disuses the proposed wildlife physical works and to prioritize the projects. Additional consultation with agencies, First Nations, and local stakeholders will be required prior to the implementation of the proposed physical works.

There is private property near the proposed project area, but the proposed physical works will not affect the property.

7.11.8 Codes and Standards

The Lower Inonoaklin Road shallow wetland habitat preservation project will be constructed in accordance with the following codes and standards:

- Good engineering practice;
- Engineering components will be designed by professional engineers and/or professional geoscientists registered with the Association of Professional Engineers and Geoscientists of BC; and
- Growing soil medium and plant specifications will be designed by professional ecologists registered with the Association of Professional Biology of BC.

7.11.9 Maintenance

The expected maintenance for this project will include the following:

- Removal of invasive vegetation; and
- Inspection of constructed features for signs of instability and erosion.

The frequency of this maintenance will be determined based on monitoring of the field conditions. We estimate that this maintenance will initially occur on an annual basis but will occur less frequently as the site stabilizes.

7.11.10 Monitoring Requirements

7.11.10.1 During construction

In addition to the inspection described in Section 7.11.9, monitoring during construction will consist of environmental monitoring and archaeological monitoring. The purpose of this monitoring will be to ensure that the appropriate environmental protection measures including flow diversions and sediment control are in place. Additionally, prior to construction fish and wildlife within the construction zone will be relocated. Removal and relocation of fish and wildlife will be done according to the stipulations of a wildlife sundry permit.

7.11.10.2 Post construction

Post-construction monitoring will involve monitoring the integrity of the physical works and the effectiveness of the physical works in meeting the ecological objectives of the project. An annual site inspection will be conducted to document the following:

- Dike integrity;
- Sedimentation rates; and
- Erosion and slope stability.

Effectiveness monitoring will occur as part of CLBMON-11B1/CLBWORKS-29B using methods developed for CLBMON-11B4 and will include the monitoring of pond-breeding amphibians, bats, riparian and terrestrial vegetation, and aquatic macrophytes (see Hawkes et al. 2010 for the monitoring protocol).

7.12 Permitting and regulatory Requirements

Numerous laws and rules govern water use, protection, conservation and sustainability in British Columbia. Currently, the Ministry of Environment, the Ministry of Forests, Lands, and Natural Resources Operations, the Ministry of Health, and pother provincial agencies manage and protect water in BC.

The *Water Sustainability Act* (WSA) was brought into force on February 29, 2016 to ensure a sustainable supply of fresh, clean water that meets the needs of B.C. residents today and in the future.

The *Water Protection Act* (WPA) protects B.C.'s water by reconfirming the Province's ownership of surface and groundwater, clearly defining limits for bulk water removal, and prohibiting the large-scale diversion of water between major provincial watersheds and/or to locations outside of the province.

The *Environmental Management Act* (EMA) regulates industrial and municipal waste discharge, pollution, hazardous waste and contaminated site remediation. EMA provides the authority for introducing wastes into the environment, while protecting public health and the environment. The Act enables the use of permits, regulations and codes of practice to authorize discharges to the environment and enforcement options, such as administrative penalties, orders and fines to encourage compliance. Guidelines and objectives for water quality are developed under EMA.

Other relevant provincial legislation includes:

The *Dike Maintenance Act*; and

Dam Safety Regulation of the *Water Sustainability Act.*

Based on an assessment of the current Dam Safety regulations, the proposed physical works at Lower Inonoaklin Road does not prescribe the retention of water in addition to what occurs there naturally. As such, this project should be exempt from the Dam Safety Regulation. Similarly if the project includes the establishment of a minor dam that is less than 7.5 m in height and impounds less than 10,000 $m^3$and as such, it will likely be exempt from regulation. Lastly, if excavations are required and the total volume of water retained behind the low-level mounds exceeds 10,000 m^3, an application under the Water Sustainability Act may be required. Refer to Dam Safety Regulation 40/2016, Part 1, Section 2. The Comptroller of Water Rights could determine that the structure is not exempt from regulation. In this case, the dikes proposed for construction are not designed to impound water. They are designed to prevent water from inundating the wetland at Lower Inonoaklin Road until they are over-topped by the reservoir (if elevations exceed 438 m ASL). If excavations occur at the site, the total volume of impounded water will need to be recalculated based on the final design of the proposed physical works at Lower Inonoaklin Road. Any required post-construction dike maintenance will also need to be detailed in the final site plans

Conservation Water Licence

The current water licence for Arrow Lakes allows BC Hydro to store water for purposes related to power production. The proposed physical works is not intended to retain water in addition to what occurs there naturally. However, if additional water is stored, it will be used for an alternate purpose from that currently covered by the water licence. Because the physical works may retain water for a conservation purpose, a Conservation Water Licence may be required.

Other regulatory requirements to consider include the Navigation Protection Act (it is likely that the proposed project would be defined as a minor works and be exempted from the Navigation Protection Act) and the Wildlife Act (a wildlife sundry permit is required to capture, handle, or salvage wildlife including amphibians and fish). See Appendix A for a summary of applicable acts and regulations.

7.13 Project Planning

A project planning flowchart is provided in Figure 7-8 that illustrates the need to complete the project before late June, when the elevation of Arrow Lakes Reservoir is generally at its highest level of the year (Figure 7-4). The exact timing of the steps in Figure 7-8 will likely be modified based on the timing of project approval, but for the purposes of the illustration, timing is associated with the beginning of the fiscal year (i.e., April 1) and considers the average elevation of the reservoir over the last five years (2007 through 2015).

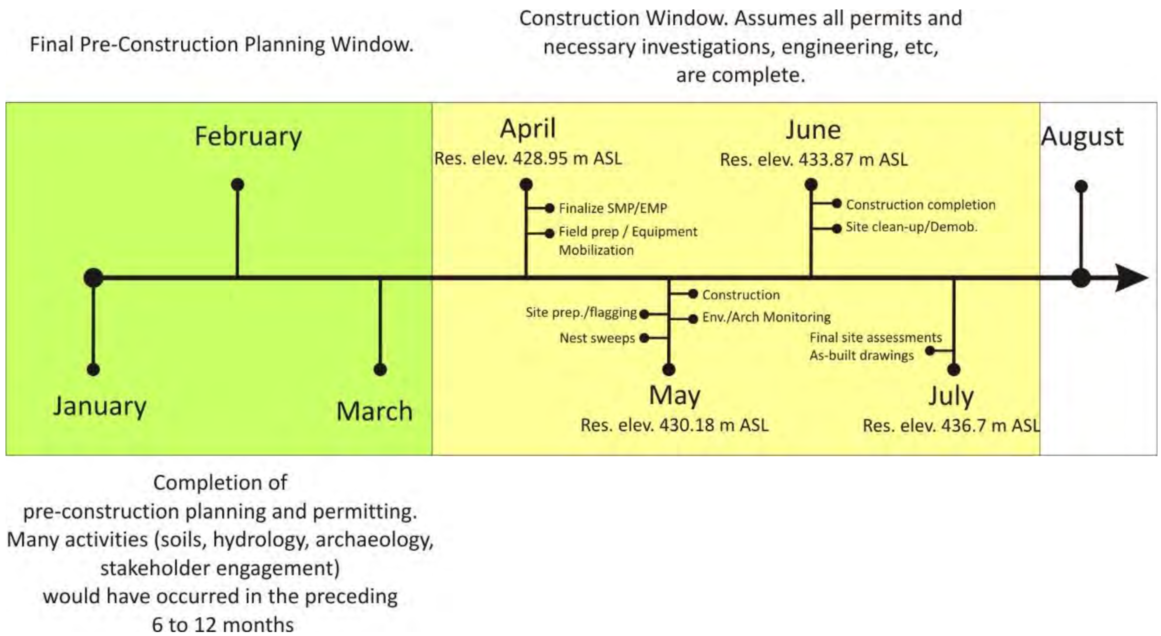

Figure 7-8: Project planning flowchart illustrating timing (months) for pre-construction and construction windows. Most of the pre-construction work will have occurred in the 6 to 12 months preceding January of the year of construction. Activities post-August will include the development and implementation of a post-construction monitoring program to test the effectiveness of the physical works to enhance wildlife habitat suitability in the drawdown zone of Arrow Lakes Reservoir. Reservoir elevations are month-end averages over the past nine years and used as a guide only.

7.14 Construction Plan

A detailed construction plan will be developed once all approvals and funding are in place. In general, the project should be constructed when the reservoir is low enough that the site is accessible with light and heavy equipment for the duration of construction, which is estimated at approximately five weeks (based on a similar project completed by LGL Limited and KWL in the drawdown zone of Diversion Reservoir on Vancouver Island (see Hawkes and Fenneman 2010). Suitable reservoir elevations typically occur between mid-February and mid-May (Figure 7-4). If construction occurs in April and/or May, some consideration of wildlife, particularly ground-nesting birds and pond-breeding amphibians will be required.

Prior to construction the project will be designed and assembled in a complete tender-ready package for public tender. Bids from contractors will be reviewed and analyzed and the project will be awarded to the contractor deemed to provide the best overall value for the project.

The construction plan will consider the following:

- Site access
- Permits and Regulations
- Archaeology
- Safety

- Schedules
- Material (types and sources)
- Costs (including an archaeological assessment, if required)
- Monitoring (environmental)
- Post-construction clean-up

As part of the tender package the contractor will be required to install the appropriate erosion protection works prior to earth works construction. This will include silt fencing and the installation of bypass pumping works.

An environmental management plan (EMP) that addresses site safety and environment concerns will be developed for the proposed physical works. The EMP will also contain information related to environmental monitoring, incident reporting, construction schedules, and mitigation strategies for incidents.