Columbia River Project Water Use Plan

Arrow Reservoir Wildlife Management Plan

Arrow Lakes Reservoir Wildlife Enhancement Program (Arrow Lakes Reservoir) - Design

Reference: CLBWORKS-30B

Feasibility Design Final Report

Wildlife Enhancement Program at Burton Flats

Study Period: 2017

Kerr Wood Leidal

August 2017

BC Hydro
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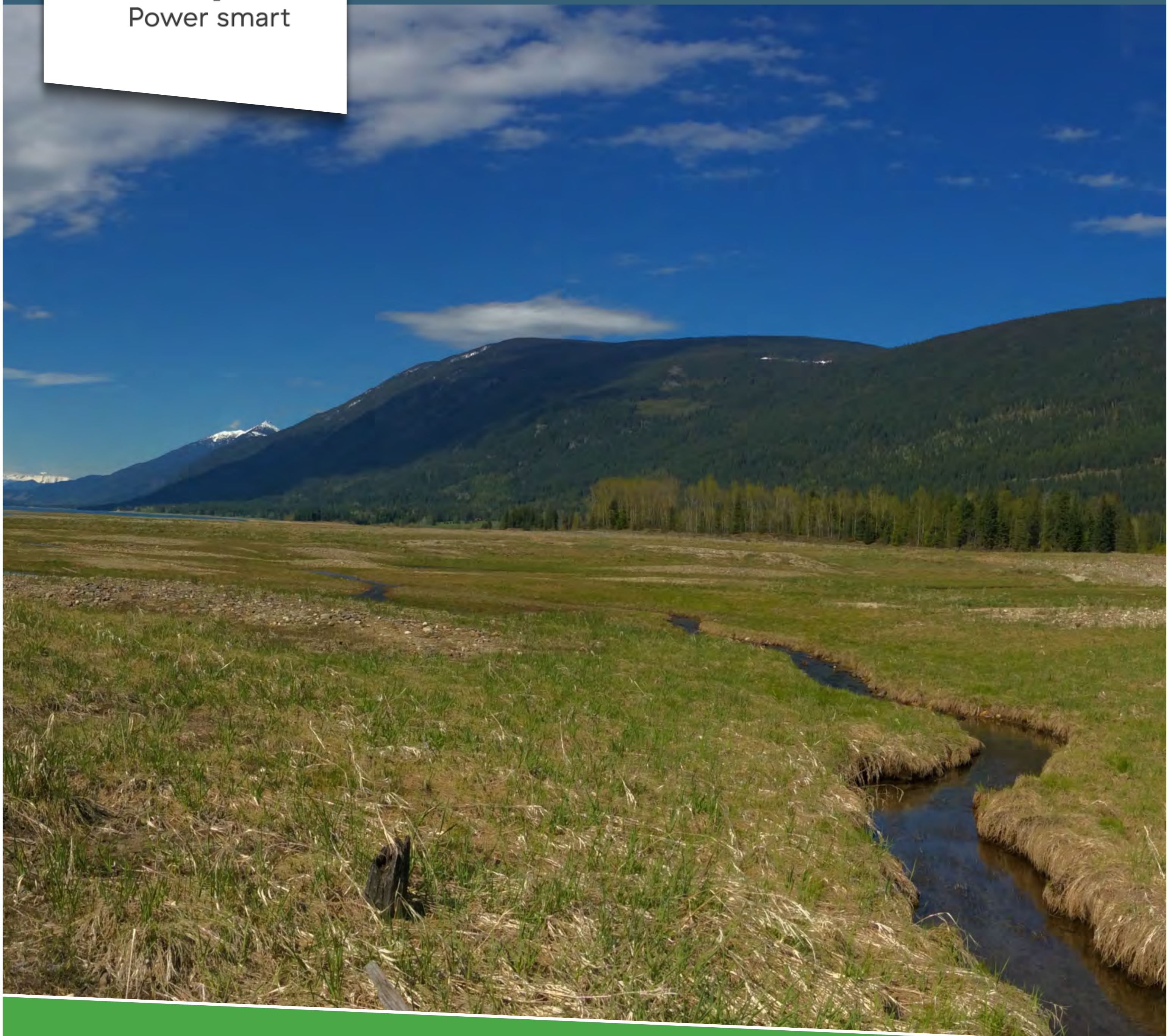

Feasibility Design Final Report

Wildlife Enhancement Program at Burton Flats

August 2017
KWL File No. 0478.203-300

Submitted by:

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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 Burton Flats Wildlife Enhancement Project in collaboration with LGL limited (LGL). The proposed physical works are located south of Burton, BC on Burton flats on the east side of the Arrow Lakes Reservoir. The project is 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 feasibility 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, and hydrogeologic investigation, analysis, and design input was provided by Piteau Associates Ltd.

The proposed design is intended to create a mixture of shallow and deep wetland habitat. The site on Burton flats slopes gently north and northwest towards the reservoir, with some old gravel mining pits that currently serve as habitat at low elevations. An existing slough/watercourse runs along the site parallel to Highway 6, which is fed by shallow subsurface flow from Burton Creek. As the amount of surficial runoff reaching the site is minimal, the design utilizes the high groundwater levels at the site. Three piezometers and one surface water gauge were installed during site investigation to monitor groundwater on site and Burton Creek water levels.

The habitat objectives, design basis, and concepts were developed in collaboration with BC Hydro, LGL, and the design team. The feasibility design proposes the construction of a series of varied habitat features, which can be combined in phases to evaluate the effectiveness of the design prior to completion of the entire proposed works. The design focuses on excavation of wetlands to reach the groundwater surface, rather than berms as was originally proposed in the 2016 Concept Design Report, due to limited surface water availability. Two options were developed which included variations on the main design features shown below:

- Primary shallow tiered wetlands along the existing watercourse
- A secondary shallow disconnected wetland
- Habitat and planting mounds constructed (from excavated material) to full pool elevation
- A deep waterfowl pond at the lower end of the tiered wetlands
- A Reed Canary Grass trial removal area to test suppression techniques
- Drainage channels to connect the above wetlands to the existing gravel pond and the reservoir

The total footprint of the proposed works is 5.7 to 6.1 ha. The full design would retain a total 10,000-12,000 m^3 of water, and create 1.4-1.7 ha of wetland area (wetted surface), with Option 1 creating a greater area of habitat and impounding more water. The deep waterfowl pond may be considered a dam by regulators due to the large volume; however, given the excavated and simple nature of the pond, it could be exempt. Hydrologic and hydrogeologic analyses support that there is sufficient available groundwater for the wetlands from Burton Creek, though further monitoring is recommended.

A construction cost opinion was prepared based on the feasibility design for each design option, including a potential three-phase approach to construction. The cost estimate is minimally higher than the 2016 Concept Design Report estimate; however, the project includes additional components not originally considered and cost saving and scaling options have been included for BC Hydro's consideration.

Following feasibility design, BC Hydro plans to undertake stakeholder consultation. Detailed design will consider the inputs from public consultation, BC Hydro review and option selection, and operation and maintenance requirements to further refine the preferred design option based on ongoing groundwater and surface water monitoring and project objectives.

1. Introduction

1.1 Scope

This report outlines the feasibility design for proposed wildlife enhancement physical works at the Burton Flats Site. The feasibility design report summarizes the design basis, hydrologic and hydrogeologic analysis, design components, operation and maintenance considerations, and considerations for detailed design, and provides a Class C construction cost opinion for the physical works to meet the intended goals of the enhancement project.

Kerr Wood Leidal Associates Ltd. (KWL) was retained by BC Hydro to provide engineering services for the Burton Flats Wildlife Enhancement Project. The project is based on the conceptual wetland enhancement designs prepared by KWL and LGL Limited (LGL). LGL is the environmental consultant on the project and are involved in the development of the design, including the design basis.

The feasibility 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 Engineering Ltd.;
- Installation and monitoring of groundwater on Burton Flats and Burton Creek water levels;
- Hydrologic, hydrogeological, and hydrotechnical analysis of the upland drainage to the wetland, Burton Creek, and reservoir interaction, with input by Piteau Associates Ltd.; and
- The development of feasibility design drawings and cost estimate and preparation of feasibility design report.

Following BC Hydro review of the preliminary design, KWL and Thurber will work with BC Hydro and LGL to develop detailed design drawings, cost estimate, technical specifications, and report.

1.2 Background

The proposed works are a part of the CLBWORKS 30B Lower Arrow Lakes Reservoir Wildlife Enhancement program. According to the Columbia Order, Conditional Section, Clause 7.a., the objective of the enhancement program is “to improve conditions for nesting and migratory birds, and wildlife within the drawdown zone of Arrow Lakes Reservoir”. The Burton Flats Site is located south of Burton, BC on the east side of the Arrow Lakes Reservoir, just northwest of Highway 6. Site selection and conceptual design for the Burton Flats Site was undertaken and documented in the CLBWORKS 29B report (“2016 Feasibility Study”), updated in August 2016 (originally prepared in March 2012)[1].

The Burton Flats area currently contains several excavated ponds (from aggregate mining) below 434 m elevation that are seasonally inundated. Since the existing ponds are at a lower elevation and inundated early in spring, it is unclear whether Western Toad breeding (survivorship of tadpoles and larvae) is affected by early reservoir inundation. The proposed site is located closer to the treeline than the existing depressions, and it is currently characterized by dry soils and grass cover (including non-native Reed Canary Grass) with a small watercourse running parallel to Highway 6.

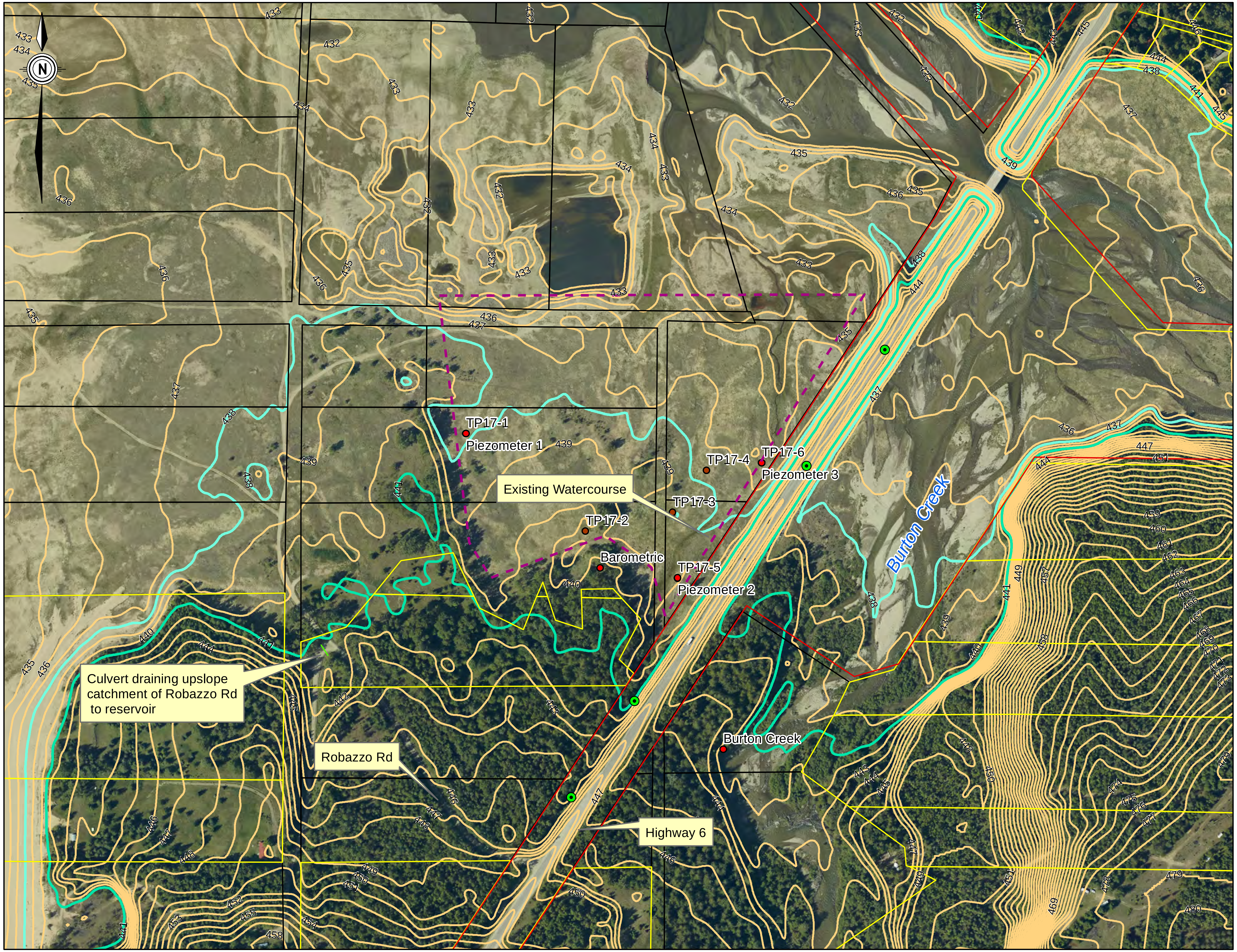
[1] CLBWORKS-29B: Arrow Feasibility Study of High Value Habitat for Wildlife Physical Works. Update in 2016 by LGL; original 2012 Report by LGL and KWL. Prepared for BC Hydro.

The site is located entirely within the drawdown zone of Arrow Lakes Reservoir, and is normally flooded in the late spring and early to late summer when the reservoir level is highest following freshet. Burton and Caribou Creeks, which flow into the reservoir to the southeast of Highway 6 and Burton Flats, will not be impacted by the works. It was noted that there may be a nearby spring which could influence the site hydrology. During a site visit in May 2017 this potential spring was identified as a small watercourse that originates from a culvert that conveys groundwater, primarily originating from Burton Creek, under Highway 6 and flows north along the site. A general site map is shown in Figure 1-1.

The early concept design presented in the 2016 Feasibility Study intended to create approximately 2.8 ha of shallow wetland habitat through a combination of site excavation and berm construction. This design proposed excavation of an upper pond and two lower ponds, with the lower and upper ponds separated by a berm, with the goal of protecting the upper pond from inundation. The proposed berm was approximately 390 m long, 0.5 to 1.5 m high, and had a spillway outlet.

Following the 2016 Feasibility Study, an alternative design concept was suggested for consideration based on smaller-scale bio-technical windrow-type water control structures. In the original scoping of this project, BC Hydro wished to explore alternative design options based on these two design concepts.

During the field investigation for the project in 2017, BC Hydro, LGL, and KWL discussed the benefits of excavation versus berm construction, as excavation reduces the need for compaction, armouring, and maintenance (though it produces larger volumes of material). In addition, excavation allows for more reliable access to groundwater, which is expected to be the main water source. All parties were in general agreement on reducing the use of berms, using simple natural structures, phasing of the construction, and an alternative alignment to more closely follow the existing watercourse.



WILDLIFE ENHANCEMENT PROGRAM AT BURTON, FLATS BC

Legend

- Test Pits
- Culverts (MOTI records)
- Water Level Sensors
- Site Area
- Railways, Highways, and Roads
- Other Ownership
- Private Property
- Contour 1m
- 438 m Average High Water Level
- 441 m Maximum High Water Level

Service Layer Credits:
Surveyed Railways, Highways, and Roads - DataBC, ParcelMap BC Parcel Fabric - DataBC, ESRI, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN and the GIS User Community 2009/05/24

KERR WOOD LEIDAL
consulting engineers

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(m)

Project No.	Date
478-203	August 2017

Burton Flats Site Map
1:4,000

Figure 1-1

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Author: AMatfin

2. Site Visit and Field Work

A total of three site visits were completed for field investigations and design discussion as follows:

- May 4:
  - *Attendees*: KWL, LGL, and BC Hydro biologists
  - *Goal*: to review site drainage and discuss design concepts
- May 5:
  - *Attendees*: KWL, Thurber, and Piteau
  - *Goal*: to complete test pits and install piezometers and Burton creek water level sensor
- May 16-17:
  - *Attendees*: KWL
  - *Goal*: to complete topographic survey of site and collect instrument data

Key observations and discussion items are described below.

Vegetation

- Reed Canary Grass (RCG) covers a large portion of the site above damp and marshy areas, and BC Hydro and LGL agreed that trials of various suppression techniques should be conducted.
- Prior to construction, all sedge and cottonwood must be flagged and salvaged (may require fall flagging if construction takes place early spring/late winter).
- The planting plan needs to consider elevations at which native species have been successfully established in the Arrow lakes reservoir (described in later sections of report).

Site Hydrology and Hydrogeology

- All runoff reaching Robazzo Rd. runs to a culvert located at the northwest corner of the road, which results in only local drainage from Highway 6 and a small forested area reaching the Burton Flats site. Based on this, overland drainage is considered to be a negligible contribution to the proposed wetland area.
- A 900 mm CSP culvert runs under Highway 6, approximately 200 m north of Robazzo Rd, which had a small volume of water flowing through it. The inlet of the culvert had ponded water with sediment and debris filling 50% of the culvert capacity. There is no direct surface connection to Burton Creek.
- From the 900 mm CSP, a small watercourse/slough flows north parallel to Highway 6, with intermittent shallow ponds. At approximately 436 m elevation, the slough is a more defined channel.
- Seepage was observed along the toe of Highway 6 adjacent to the channel.
- Three water level sensors were installed in piezometers in test pits, one water level sensor was installed on Burton Creek, and one barometric sensor was installed in the trees near the site.

Design Concepts & Construction

- BC Hydro, LGL, and KWL agreed to focus on excavation rather than berms based on limited site drainage and the expected dependence on groundwater.
- Similarly, the group agreed to shift the alignment to follow the existing watercourse, with additional features branching off the main alignment.
- A phased construction approach is preferable to all, starting with the areas with highest chances of success.
- The design should incorporate shallow and deep wetland features with higher mounds for nesting habitat.
- Construction window of late February to early March potentially to avoid impacting the most important habitat window.

Geotechnical

- Six test pits were excavated on May 5, 2017, three of which had piezometers installed in them. Topsoil depths ranged from 0.2 to 0.6 m typically. Below the topsoil, several of the test pits noted a layer of loose to compact moist sand with some silty sand 0.3 to 0.8 m thick. These layers, if present, were underlain by loose to compact poorly graded sand, gravel and sand, or gravel with cobbles often present.
- Refer to geotechnical report by Thurber in Appendix A for further details, discussion, and analysis.

Public Use and Consultation

- The site is well used by the public with nearby picnic tables and paths for walking, dirt-biking, etc. around the site.
- There has been public opposition to environmental projects here in the past (based on BC Hydro's experience with Cottonwood planting according to project biologists).
- There is a local stewardship group that is quite active as well as other residents who are interested in being involved (several stopped at the site to ask questions).
- Based on the above, public consultation is viewed as a key component for the success of the project. The design could incorporate features for public use such as information signage, trails, etc.

3. Design Basis

The design basis summarizes the design concepts and the criteria, constraints, and requirements for the physical works to meet the intended goals of the enhancement project. The design basis was developed in consultation with BC Hydro and LGL and agreed upon prior to feasibility design.

3.1 Environmental Objectives

The purpose of this project is to create shallow wetland habitat for Western Toad (assessed as a species of Special Concern by the Committee on the Status of Endangered Species in Canada; COSEWIC 2012), nesting and migratory birds, and other wildlife by excavation of pools and construction of water retention berms or similar to meet the terms of the Columbia Order. The goal is to retain site drainage and groundwater to promote stability of the wetland habitat. As discussed in the 2016 Feasibility Study, the objectives of the proposed wildlife physical works are to:

- Increase the spatial and temporal availability of shallow wetland habitat for wildlife in the drawdown zone of Arrow Lakes Reservoir within the habitat window of interest of April 1 to October 31.
- Improve habitat complexity in the drawdown zone of Arrow Lakes Reservoir.
- Improve wildlife habitat suitability by creating habitat that will benefit several groups of wildlife including migratory birds, nesting birds, pond-breeding amphibians, reptiles, bats, insects, and mammals.
- Reduce the cover of Reed Canary Grass (RCG) in the drawdown zone to promote the growth of native plants through terrestrial revegetation program that will follow the completion of the physical works.
- Revegetate the new wetland habitat with native aquatic macrophytes and riparian vegetation.

To ensure that the design satisfies environmental needs, LGL and BC Hydro were consulted to provide the environmental requirements and constraints for the design, as listed below:

- Create successful wetland habitat incorporating shallow and deep configurations with submerged and floating macrophytes, considering a phased approach with various add-on features. The 2016 Feasibility Study proposed approximately 2.8 ha of shallow wetland habitat, with a minimum area of 2.0 ha. However, the project team agreed that there is no specific minimum area target, and that the main goal is to ensure the creation of successful habitat. As such, the feasible wetland area will be determined considering the hydrology/hydrogeology assessment, and phasing will be incorporated to initially test success at a smaller scale.
- Target water depth in the majority of the wetlands with an average depth of between 0.3 and 0.5 m for shallow wetland habitat, with some limited areas that could be slightly deeper. The feasibility study proposed depths of 0 to 1.5 m; however, target depths have been decreased to limit the suitability and attractiveness for Canada Geese in the shallow pond habitat. Deeper wetland features for waterfowl are under consideration (potentially as a later phase) with depths in the range of 1 to 1.2 m, with shallow fringes.
- Retain water from runoff and shallow groundwater from Burton Creek along the eastern side of the proposed site.

- Create wetlands with and without connectivity to each other to allow comparative study on the effectiveness of these types of configurations and connectivity. It is expected that outlet structures and disconnected wetlands will pose a barrier to fish or other species returning to the reservoir, which may result in stranding due to decreasing water levels. Disconnected wetlands could be connected if monitoring results indicate connected wetlands perform better; however, it is expected that fish stranding will be an ongoing risk (an assessment has not been conducted to confirm that). The existing gravel pits at the north end of Burton Flats currently pose a risk for fish stranding, and the design concepts could incorporate reconnecting these ponds to the reservoir. It was noted that fish stranding would benefit some target wildlife.
- Include planting with native sedges and possibly cottonwood, willow or other tree species in the design. Where possible, the plants should align to culturally important native species.
- Create habitat mounds with the top of the mounds at a minimum elevation of 439 m, planted with inundation-tolerant shrubs. Planting of nesting shrubs should have a minimum elevation of 439 m.
- Incorporate naturalized elements and bio-technical approaches in the design for both habitat complexity and aesthetics (to promote local stakeholder support), such as 'soft engineering' solutions on the wetland side of the berms, large woody debris with root wads in select locations, riffle and pool sequences, and gentle edges or other variations to berm geometry (height, width, alignment and cross section). Consider variation from pond to pond for diverse habitats.
- Incorporate trial RCG suppression techniques with varied planting approaches and species to enhance continued learning regarding planting within and adjacent to the drawdown zone of reservoirs, and specifically the Arrow Lakes system (See Vegetation sub-section of Section 2.3 - Wetland Design).

The design and habitat objectives have not considered mitigation of potential impacts of contaminants from Highway 6 (primarily salt) running off into the wetlands. Scientific literature on this topic has shown that the input of road salts into nearby wetlands and ponds is known to alter the physicochemical parameters of wetlands, in particular conductivity. The Burton Flats site currently receives runoff from Highway 6, and negative effects from salt and other potential contaminants from vehicle traffic have not been observed for the existing habitat, though there has not been targeted monitoring for conductivity and associated impacts. There is the possibility that road salts could enter the wetland during the winter and spring, and expose pond-breeding amphibian adults, eggs, and tadpoles to higher conductivity levels. With reservoir inundation expected on a near annual basis, there will be flushing of materials from Highway 6 runoff each summer.

During detailed design, impacts and potential mitigation of road salts could be considered. Following construction of the wetlands, it is recommended that environmental monitoring include conductivity data logging to assess whether road salts associated with highway maintenance impact the conductivity of wetlands and the species that inhabit them. If monitoring indicated that road salts have a detrimental impact on the wetlands, mitigation measures could be considered at that time.

3.2 Hydrologic and Hydrogeologic Analysis

The hydrologic analysis was conducted to support the design, and this included:

1. a hydrogeology review of the spring and groundwater at the site;
2. a hydrologic assessment of Burton Creek (source of existing watercourse through the site) based on a regional hydrology review (since Burton Creek is ungauged);
3. concept level estimate of wave height; and
4. assessment of erosion potential during reservoir inundation.

A hydrologic model was initially planned for the hydrologic analysis; however, the site investigation revealed that Robazzo Rd cuts off overland drainage to the site, indicating that surficial runoff to the site is very limited and does not warrant modelling. Effort planned for the hydrologic modelling has been redirected to hydrologic analysis of Burton Creek and more assessment and evaluation of the local groundwater.

The hydrogeology review included water level monitoring of Burton Creek and groundwater at the site, using pressure transducer water level sensors and analysis of the site groundwater conditions, based on the site field investigation, geotechnical investigation, and on-going water level data collection. Five water level sensors were installed on the site as part of the site investigations on May 5, 2017, three sensors in PVC piezometers installed in test pits, one sensor in a surface water station on Burton Creek, and one barometric control sensor. Data has been collected from the sensors in the spring of 2017 by KWL and LGL, and data may continue to be collected at BC Hydro's discretion. Initial results indicated that the groundwater table is highest near Burton Creek along the highway embankment and then drops in elevation to the northwest away from the highway embankment towards the reservoir. The level sensors locations and results are described further in Section 4 of this report.

The hydrologic and hydrogeologic analysis estimates the average and annual variation of the proposed wetland groundwater supply levels and consider reservoir levels and seepage to meet the habitat objectives. The analysis is based on:

1. reservoir water level information provided by BC Hydro;
2. available hydrologic and site data for the area;
3. data from nearby Water Survey of Canada (WSC) Stations to conduct a regional hydrology assessment of Burton Creek;
4. test pit results for soil stratigraphy and groundwater conditions;
5. water level sensor data and manual measurements collected at three piezometers and on Burton Creek; and
6. field and survey data collected at the site.

The groundwater fed stream is not expected to have 'peaky' high flows due to the dampening effects of the groundwater seepage; accordingly, a typical return period type discharge event is not considered appropriate for the outlet design. The outlets consider the relatively gentle groundwater fed stream/wetland outflow when the reservoir is low and the similarly gentle inflows as the reservoir inundates the area. In detailed design, limited additional analysis may be completed to confirm the outlet capacity is sufficient for the design intent.

A concept level estimate of potential wave heights will be completed based on readily available data, such as past projects near the site and wind or wave data.

3.3 Wetland Design

The proposed wetland project site is located adjacent to Highway 6 (coordinates: 11 U 435757 E and 5536952 N) and is accessed by Robazzo Rd.

In the original scoping of this project, BC Hydro noted that they would like to explore alternative designs at the Burton Flats, including:

1. A single berm of approximately 390 m in length at and height of 0.5 to 1.8 m (retaining an estimated 10,000 m^3 of water) per the conceptual design in CLBWORKS 29B reports;
2. A series of smaller scale, bio-technical windrow-type water control structures along the east side of the site, taking advantage of a natural groundwater fed watercourse to ensure the area is wetted even in years of low reservoir levels; and
3. A hybrid of the above two concepts, if technically possible.

In early May 2017, KWL, LGL, and BC Hydro met on site to discuss design concepts. The group agreed upon shifting the alignment of the wetlands to follow the existing drainage path that parallels Highway 6, to increase the likelihood of water availability and reduce excavation. As groundwater is expected to be the main source of water for the wetlands, excavation is advantageous compared to berms, which pose a greater risk for water supply and require more construction effort and maintenance. An excavation approach would still require construction of habitat mounds, and perhaps some localized berms at pond outlets for water retention, but they would be significantly smaller than originally envisioned in the 2016 Feasibility Study. These considerations were discussed on site, and consensus amongst the group was that berms were not preferred, instead favouring excavation, logs for outlet water control, and windrow/mound-type habitat berm fill areas (not for water retention). In addition, a phased approach was preferred by all.

Based on the 2017 work, design alternative 1 noted above, was rejected since a groundwater fed water supply would not enable a flooded wetland (above the water table) to be created by constructed berms.

It was agreed that KWL would develop alternative designs that would be based on this site visit and subsequent design concept discussions, considering various configurations with excavation, natural features, and windrows/mounds/small berms for water retention. It was agreed that two design options with flexible design components and phasing would be developed, generally in accordance with design alternative 2, due to the shift in alignment and the preference for excavation over large berms.

The following sections outline the design basis and considerations for the proposed physical works, considering phasing and two general potential wetland design concepts to be developed, each of which have multiple components that can be excluded, swapped between options, or phased as desired.

Inundation and Drawdown

The normal maximum reservoir level is 440.13 m above sea level (ASL); however, surcharge to 440.75 m may be requested (and granted) by the Comptroller under the Columbia River Treaty flood control agreement. It was agreed that inundation prevention is not a driving factor or consideration for the design.

Based on the proposed elevation and recent historical reservoir levels, some of the wetland ponds, outlet structures, and portions of the habitat mounds will typically be inundated annually, depending on climate and reservoir operations. As such, physical works must be designed to withstand inundation, overtopping, and reservoir drawdown. This includes the following:

- Scour and erosion considerations when overtopped (not anticipated to be significant) and due to waves (discussed further below);
- Buoyancy of materials (such as logs) while inundated; and
- Geotechnical stability of the mounds/windrows during reservoir inundation and drawdown, and during full submergence (not expected to be an issue given the low berm height and shallow proposed side slopes).

Since the top elevation of the habitat mounds are proposed to be approximately 439 m, parts of the habitat mounds will be regularly inundated. The habitat mounds design heights (elevation) will be further assessed during the hydrologic analysis and design development to determine the appropriate height to meet environmental targets, considering excavation volumes, regulations, and existing topography.

Alignment and Geometry

As discussed during the May 2017 site visit, the alignment of the wetland habitat is proposed to follow the existing watercourse to increase the likelihood of water availability and reduce excavation (refer to Figure 1-1).

The existing watercourse begins at a CMP culvert underneath Highway 6, which is adjacent to the private property south of the site and within the Ministry of Transportation and Infrastructure (MoTI) highway right-of-way (ROW). This culvert is shown on drawing C-101 attached, directly west of the water level sensor on Burton Creek. The watercourse then flows north-northeast towards the reservoir. In addition, a local resident suggested the concept of having the watercourse flow through the two large excavated gravel ponds, which he stated was the original creek path. This area is noted to already have habitat value, as well as recreational use.

As described previously, initial results indicate that the groundwater table is highest near Burton Creek along the highway embankment and then drops in elevation to the northwest away from the highway embankment towards the reservoir. These results support the alignment of wetlands in higher groundwater areas parallel to the highway.

Based on discussion and input with project biologists, it was agreed that concepts would include several different features that could be incorporated at different phases and scales, starting in areas that are expected to have the greatest success and incorporating additional features over time.

The following describes the proposed general alignment and habitat features, as developed on-site and in follow-up discussions with BC Hydro and LGL as part of the design basis. These habitat features can be combined, altered, and completed in phases to test success, create a diversity of habitat, and incorporate features amenable to the project team and local stakeholders. From these components, two general options for the feasibility design were proposed (see Section 5), which incorporate variations of these features:

- **Primary Shallow Wetlands:**
  - Tiered shallow wetlands approximately 0.3 to 0.5 m deep starting at approximately 438 m elevation, downstream from the existing high-quality habitat, progressing downstream along the watercourse ending at the height of land at approximately 434 m elevation.

- **Secondary Wetland:**
  - Additional shallow wetlands along the existing depressions to the west of the primary shallow wetlands. Initially, this wetland may be disconnected to test success of a disconnected system. Note that the estimated water levels (and hence base elevation) would likely be higher for a disconnected wetland than a connected wetland.
- **Habitat and Planting Mounds:**
  - Incorporate nesting and planting mounds (from excavated material) around the proposed wetlands with top elevations of approximately 439 to 440 m, that would be staked and planted to promote nesting and shade for RCG suppression/removal. Some parts of the top of habitat mounds could be higher than 440 m if sufficient material is available, and a higher elevation is desired for habitat purposes. Initial designs show that there may be an excess of excavated material that could be used to raise the nesting mounds, or to have them at variable heights for diversity.
- **Deep Waterfowl Pond:**
  - A large deep wetland (up to 1.2 m deep with shallow fringes) at the existing depression at the north end of the watercourse.
  - Due to the size and depth of this pond and regulatory interpretation, it may result in enough retained volume that it could be classified as a Part 2 dam under the *Dam Safety Regulation (DSR).*
- **Variable Depth Pond:**
  - A habitat pond with features of the shallow ponds and deep pond (part of Option 2).
- **Connectivity to Existing Ponds and Reservoir:**
  - Tie-in to the existing gravel mining pits (as mentioned by local stakeholder) from the secondary wetlands or the deep waterfowl pond and connection of these pits/ponds to the reservoir. This component could be added at a later phase of the constructed works.
- **Reed Canary Grass Trial Area:**
  - Higher elevation area on the existing upper bench west of the secondary wetlands for trial reed canary grass suppression work, which could include a stakeholder engagement/training workshop (see vegetation section for further description).

The two concepts are further described in Section 5.

Tiered wetlands are beneficial as they allow for simple passive outlet structures that can maintain target shallow water depths over the varying terrain along the watercourse, while creating varied habitat with riffles and pools. Tiered wetlands also reduce the risk associated with potential water shortages if they are situated below the expected low groundwater levels. Compared with the earlier (2016) concept, the current design concept uses smaller tiered wetlands close to the highway and Burton Creek that has higher potential to provide shallow habitat with limited excavation to reach reliable groundwater.

Habitat mounds will be incorporated into the design to utilize excavated material and create nesting habitat. BC Hydro has indicated that the minimum elevation of the mid-point of nesting mounds should be approximately 439 m. In addition, excess excavated material and mound locations will be considered for use as a “breakwater” to limit erosion from wind and waves (discussed further below).

The geometry and alignment of excavations, water retention structures, and nesting mounds will consider the following:

- Naturalized appearance with variation in elevation and cross-section dimensions to improve aesthetics and enable more habitat complexing;
- Construction and monitoring access;
- Existing topography and depressions which may be suitable for habitat;
- Habitat features for complexity, such as buried large woody debris;
- Water availability based on the hydrology and hydrogeology assessment; and
- Recreational use, pending public consultation.

Seepage and Water Retention

Seepage is a consideration for two scenarios: water retention in the wetlands between tiered wetlands when reservoir levels are low, and seepage into the wetland when reservoir levels are high. The primary concern is loss of water from the tiered wetlands when reservoir levels are low. The design will seek to limit seepage between the tiers through spacing of the ponds and/or the water retention design. Seepage through the tiered wetlands will be assessed as part of the geotechnical and hydrogeological evaluation.

Seepage rates of the upper soils near the existing watercourse are expected to be low given that water is currently retained. However, Burton Flats is located on the old fan of Burton Creek, and so coarse alluvial material may result in higher seepage rates in some areas. The design could incorporate an impermeable fill or liner (such as clay or geomembrane) to reduce seepage losses, but based on geotechnical and hydrogeological investigations, this is not required.

Outlet Control Structures

It is understood that BC Hydro would prefer passive outlets rather than ones that require active management. Spillway or sill type outlet structures allow for passive management, but they do not allow for flexible operation of the wetland (for example during very low water levels or to adjust environmental water levels).

The design intent is to create tiered wetlands with passive spillways or sills separating each cell. The outlet control structure spillways/sills will be designed to:

- Convey the relatively gentle flows of the groundwater fed stream / wetland outflow when the reservoir is low and the similarly gentle inflows as the reservoir inundates the area. As mentioned previously, extreme event analysis is not warranted given that groundwater is the main water source for the site.
- Convey the majority of the inflow during reservoir rise and wetland inundation (once the reservoir elevation exceeds the outlet elevations). The reservoir inundation inflows over the wetland outlets are expected to be low, which will allow gradual equalization of the wetland and reservoir levels, so this is not a significant design consideration.
- Limit seepage through the structure using logs, low permeability materials, or an impervious core.

- Have low velocities to reduce the potential for scour and negative impacts to wetland habitat. This is not expected to be a significant design factor due to the expected relatively gentle groundwater flows.

Erosion Protection

Erosion and scour protection will be considered for outlet control structures and in some areas on both the wetland and reservoir sides of constructed water retention structures. The erosion protection will be designed for the following design events:

- Reservoir-side:
    - o Due to the potential Part 2 dam designation (*if larger deeper ponds are included*) of some of the larger ponds, erosion protection may need to be designed for a 200-year wave event based on local observations and design practice (if available), and available wind or wave data for the reservoir.
    - o Excess excavated material will be considered for use as habitat mounds and an informal breakwater, which would offer some protection for the physical works from waves and reduce the need for erosion protection.
- Wetland-side:
    - o Erosion protection will be consider overtopping the water retention structures due to rising reservoir water levels. This will be based on the maximum rate of reservoir level rise.

Erosion protection of the works will primarily be achieved by limiting cut and fill slopes, and potentially incorporate bioengineering solutions that considers vegetation success limitations due to annual inundation. David Polster, a subject matter expert (SME) on vegetation and bioengineering will be consulted on this matter. Erosion protection along the main drainage path could consist of riprap or cobble/boulder drainage channels at inlets / outlets where slopes would be steeper.

Materials

Material requirements for the project (excluding vegetation) are expected to include the following, which are discussed further below:

- Fill for berms or water retaining windrows and habitat mounds;
- Riprap or cobbles and boulders for erosion protection and habitat features;
- Buried logs or other impermeable material for outlet control structures, which may require anchoring; and
- Impermeable material to line aspects of the excavated wetlands, which may be required depending on the results of the geotechnical and hydrogeological analyses.

To reduce costs, on-site material will be used for construction as much as reasonably possible, contingent on the results of the geotechnical analysis. However, the design may require import of some materials to site; at a minimum, this is expected to include riprap or cobbles for erosion protection and logs for outlet control structures.

For design, a significant amount of excavation is expected to be required to create wetlands, and it is expected that the volume of material excavated will be in excess of the amount required to create water retention structures (pending results of the geotechnical analysis for material suitability). Thus, it is expected that there will be additional material for uses on site, such as habitat mounds that could also function as breakwaters, RCG burial, or site grading.

As the majority of the ponds are not expected to be regulated dams (see Section 3.4 below), the outlet structures can be less formally engineered and be constructed of natural materials (such as logs), rather than more standard dam construction materials, to give the design a more natural appearance. Some of the larger ponds discussed on site may qualify as regulated Part 2 dams, and in this instance the water retaining structures and outlets may likely require a more robust design to meet provincial requirements.

Based on the results of the geotechnical and hydrogeological analyses, fine-grained material located on site may be used to reduce seepage from the outlets of the wetlands and to line more permeable areas that may be exposed during excavation, as the site is located on the previous Burton Creek fan. Import of impermeable materials is not considered necessary at this stage of design.

Vegetation

Lower elevation wetted areas of the site are currently vegetated with native sedges, while higher elevation areas are dominated by invasive Reed Canary Grass (RCG) with previous cottonwood planting completed by BC Hydro. The design concept includes establishment of native species in and along the wetlands and trial techniques to suppress RCG. In addition to BC Hydro's biologists, Dave Polster (vegetation SME) and LGL will be consulted during the design.

The design will include planting with sedges and tree and/or shrub species (willows, cottonwood). Where possible, the plants should align to culturally important native species. Species common to the site or local area will also be considered in the planting program. The following general elevations will be considered for successful vegetation establishment based on other locations on the Arrow Lakes Reservoir and trial planting:

- 433 to 434 m: sedges (lenticular, Columbia, and water) and bluejoint reedgrass,
- >436 m: cottonwood trees
- >439 m: white pine trees, willow, red osier dogwood, and hardhack.

The existing sedges and cottonwoods in the construction area should be salvaged prior to construction, which may require flagging in the fall depending on the construction season. Some nursery stock may be required to complete vegetation of the design. A comprehensive planting plan will be developed with LGL during detailed design.

Based on discussions with LGL, BC Hydro, and Dave Polster, RCG suppression needs to consider removal, as well as altering the environmental conditions (either shading or flooding) to reduce the likelihood of recolonization. Based on this approach, RCG removal will focus on the areas in the design wetland footprint, with some small additional areas at higher elevations for trial techniques. An additional consideration for RCG removal is preservation of the existing topsoil for planting, and SME input has indicated that RCG sod can be used for planting, as long as the material is turned over first. The following techniques could be tested for suppression of reed canary grass, which will require ongoing monitoring to evaluate the success:

- **In wetlands:** scrape RCG and root mass for use in mounds along wetlands. It is expected that the water levels in the wetland will suppress all RCG in the constructed wetlands.

- **Along wetlands**: scrape RCG and root mass and incorporate the RCG sod (approximately 0.4 m below surface) from the wetland excavation, flip the material upside down, and construct mounds with the sod and material from excavations (loosely compacted). The top elevations of mounds will be near full pool (439 to 440.1 m elevation) and densely staked to promote shading out of any RCG that may try to recolonize the site. The lower elevations of mounds can be planted with nesting shrubs and other native aquatic species.
- **Above wetlands in trial areas**: At full pool elevation or near, scrape/cut the RCG to the ground surface, cover with cardboard or similar, and densely stake to promote shading out of any RCG that may try to recolonize the site.

3.4 Regulations and Guidelines

There are several regulations and guidelines that will be considered during the preliminary design.

Dam Safety Regulation (DSR)

- Any berm that would be constructed on the site 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.
- The DSR does not apply to a barrier for water storage that is less than 7.5 m in height and 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 m3. Structures that are below these thresholds are classified as "Minor Dams".
- At present none of the shallow wetland cells discussed are expected to impound more than 10,000 m^3; however the deep waterfowl pond at the north end of the site could exceed that volume. This would exempt most the structures from the requirements of the DSR.
- If the design storage volume is above 10,000 m^3, the structure would be classified as a "Part 2 Dam", provided that the total storage does not exceed 30,000 m^3 and the dam height does not exceed 2.5 m (Clause 7 of Part 3). The structure would be required to meet the requirements of the DSR. The design could consider alternatives to construct works that would not be classified as dams or exemption from the DSR given the low consequence of the structure.

Navigable Waters Protection Act (NWPA)

When the physical works are inundated, they may have a minor impact on navigation within the reservoir. For navigational safety, signage near the structures could be considered.

Water Sustainability Regulation (WSR)

- It is expected that a Water Conservation license for storage purposes 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 diversion/storage structures.[2]
- This project is expected to result in "changes in or about a stream", which will require a permit or approval in accordance with Part 3 of the WSR. This is due to the existing watercourse noted in the approximate project site. Application for a Water Conservation license may negate the need for a Part 3 approval. For design and material sourcing, impacts to existing habitat will be minimized as much as reasonably practicable.

Federal Fisheries Act

The Fisheries Act may apply. This will be confirmed by BC Hydro as the project progresses.

Species at Risk Act

The goal of the *Species at Risk Act* (SARA) to prevent wildlife species in Canada from disappearing, to provide for the recovery of wildlife species that are extirpated (no longer exist in the wild in Canada), endangered, or threatened as a result of human activity, and to manage species of special concern to prevent them from becoming endangered or threatened. The project will need to determine if any species under Schedule 1 (Parts 1, 2, and 3) of SARA are located on the site, which would require a permit if project activities may affect these species.

Heritage Conservation Act

The *Heritage Conservation Act* facilitates the protection and conservation of heritage property in British Columbia. An Archaeological Impact Assessment (AIA) of the site has been completed and no archaeological sites were identified in the proposed project area. The project area has increased with the concepts proposed, and BC Hydro has confirmed that an additional AIA is not required as part of the additional area was surveyed in 2013 and the northern area is considered to have a low potential for pre-contact archaeology. As a result, the *Heritage Conservation Act* is only expected to impact the work if heritage objects are uncovered during construction.

Dike Maintenance Act

The DMA will not apply to the habitat mounds and fill as they are not dikes under the regulatory definition.

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

3.5 Property and Land Considerations

The proposed site near Burton Creek is Provincial Crown Land and lies entirely within BC Hydro's Water License area for Arrow Lakes Reservoir. Adjacent land parcels are either held by BC Hydro, privately owned, or highway ROW. The highway ROW parallels the site, and in some locations, the existing watercourse runs through the ROW. The design will be confined to the crown land and will not include any works on private property, and will maintain a 5 m buffer from the highway ROW. This may require the wetlands to shift to the northwest of the existing drainage alignment.

Figure 1-1 shows the site topography, property lines and piezometer locations.

3.6 Public Use

The Burton Flats site has considerable public use, which has been noted to include dirt-biking, recreational ATV and vehicle access, dog-walking, with a picnic area located west of the proposed physical works. In addition, it has been noted by BC Hydro and LGL (and observed while on site) that there is considerable public interest in the site and work that may be completed there. It is expected that public consultation will take place with the community to better understand site uses and ideas the community may have, in order to increase the success of the design and avoid future damage to the works.

Additional features could be included in the design to increase the public's enjoyment of the site, such as:

- information signage;
- designated walking trail around or through the constructed wetlands; and
- designated ATV/off-road areas.

For the preliminary design, these additional features are not included, pending input from the community and BC Hydro.

There may be opportunities to incorporate public engagement with the project through workshops, on-going monitoring, or future maintenance works. This could include minor adjustments to outlet structures, workshops for reed canary grass removal and suppression, and habitat monitoring to inform later stages of the project.

4. Hydrologic and Hydrogeologic Analysis

4.1 Overview of Site Hydrology and Hydrogeology

The proposed wetlands are located on Burton flats, which consist of shallow undulating terrain sloping gently north. Burton flats was part of the Burton Creek alluvial fan prior to construction of Highway 6, which now cuts across the fan and separates the flats from Burton Creek. Burton flats ranges in elevation from 440 m near the treeline to approximately 432 m near the reservoir, and as such it is located within the drawdown zone of the reservoir (full pool 440.1 m elevation). Minimal overland drainage reaches the site due to Robazzo Rd, which intercepts drainage, thereby limiting overland flow to the region north of Robazzo Rd.

A small watercourse/slough with small pools runs north from a 900 mm CSP culvert under Highway 6 to the reservoir, paralleling Highway 6. Additional seepage was noted along the toe of Highway 6, and MOTI records indicate that several other culverts are located along the site under Highway 6. The source of water is near surface groundwater that is influenced by Burton Creek, which is discussed further in later sections. Based on the expected importance of groundwater to the design, three piezometers and one surface water gauge on Burton Creek were installed during site investigations.

Due to the expected influence of Burton Creek (ungauged) on shallow site groundwater, a regional hydrology analysis has been completed using nearby stations and water level data collected in Spring 2017. Burton Creek near the site is a braided gravel channel, and the creek has a mountainous catchment of approximately 289 km^2 with a mean basin elevation of 1640 m. Hydrology of Burton Creek is discussed further in the regional hydrology section.

4.2 Water Level Data Collection

As discussed previously, water level sensors were installed on site to monitor groundwater and Burton Creek. Table 4-1 contains the location and details of the water level sensors, which are shown in Figure 4-1 with the preliminary groundwater contours from the date of survey (May 16, 2017).

Table 4-1: Water Level Sensors

Hobo Name (set during launch)	Sensor	Approx. Ground Elevation (m)	Installation & Logging[1]	Location (UTM)
Piezometer 1	BC Hydro SIN: 896051 U20-001-01	438	Logging started 12:00 p.m. PST Installed at 1:30 p.m. PDT	11U 435689 E 5536661 N
Piezometer 2	KWL SIN: 20081906 U20-001-04	439	Logging started 1:00 p.m. PST Installed at 3:30 p.m. PDT	11U 435917 E 5536507 N
Piezometer 3	KWL SIN: 20081906 U20-001-04	436.5	Logging started 3:30 p.m. PST Installed at 4:30 p.m. PDT	11U 436006 E 5536629 N
Barometric	BC Hydro SIN: 896046 U20-001-01	440	Logging started 1:00 p.m. PST Installed at 4:30 p.m. PDT	On tree branch: 11U 435834 E 5536518 N
Burton Creek	BC Hydro SIN: 896047 U20-001-01	442	Logging started 1:00 p.m. PST Installed at 3 p.m. PDT	Burton Creek: 11U 435965 E 5536325 N

1. Logging frequency is every 30 minutes. Laptop time set to PST. All sensors initially installed on May 5, 2017.

Initial results indicate that the groundwater table is highest near to Burton Creek along the highway embankment and then drops in elevation to the northwest away from the highway embankment towards the reservoir. The elevations appear to be correlated to Burton Creek levels, but with considerable dampening. See Figures 4-1, 4-2, and 4-3 for results from May 5 to June 21, 2017.

Water levels and in turn the rate of groundwater flow in the Burton Creek Fan are controlled by the difference in elevation between the Arrow Lakes Reservoir and Burton Creek. The results indicate that wetland features should be aligned along the present groundwater drainage course that roughly parallels the highway embankment in order to access groundwater at shallower depths. Further from the highway and Burton Creek, excavation would need to be deeper to access groundwater.

The magnitude of water level fluctuation is less in close proximity to Burton Creek, increasing to the west approaching the reservoir. Excavation for construction of the primary wetlands and deep waterfowl pond, which are relatively close to Burton Creek, will penetrate the water table and the base of the excavations will be recharged with groundwater. Due to the relatively permeable sediments in the Burton Fan, groundwater flow will be primarily through the sediments. Some evaporative and transpirative losses will occur within the wetlands, however these are expected to be minor in relation to the volume of groundwater flow. Monitoring results, wetland water balance, and seepage are discussed further in Piteau's memorandum *Burton Flats Wildlife Enhanced Project – Hydrogeology* (Appendix B).

4.3 Reservoir Inundation

Prevention of inundation is not a design criterion for the wetlands at Burton Flats; however, the reservoir levels influence the site hydrogeology and seasonal usefulness of the proposed works. Burton Flats is located between two WSC gauges on the reservoir, one at Nakusp (08NE104) and one at Fauquier (08NE102). Based on site survey and WSC data for these two stations, the historical reservoir level for Burton flats was interpolated, and Figure 4-4 shows the average, maximum, minimum, and 75th and 25th percentile water levels for the site. The impact of reservoir levels on the site hydrogeology is discussed in Piteau's memorandum *Burton Flats Wildlife Enhanced Project – Hydrogeology* (Appendix B).

The lowest proposed pond is at elevation 432.5 m, while the other wetlands range in elevation from 434 to 438.5 m. Based on these elevations, the lowest wetlands will typically be inundated at the beginning of June and the remaining wetlands will be inundated mid-June to mid-July (depending on reservoir operation). During low water years, the upper wetlands may not be inundated at all. Figure 4-5 shows the average reservoir levels for four reservoir operating regimes, as provided by LGL, and Table 4-2 summarizes the inundation timing for the habitat window of interest (April 1 to October 31). This analysis shows that some of the proposed wetlands located at lower elevations will be inundated a significant amount of the time; in particular, wetlands D1, A5, A6, AD1, and B1 (connected) are expected to be inundated for more than 50% of the habitat window (average). These results indicate that the lower wetlands are less valuable habitat due to the shortened window of use.

Table 4-2: Wetland Inundation Timing

Design Option	Wetland	Outlet Elevation (m)	Average Inundation Window and Percent of Time Inundated between April 1 and October 31 [1, 2]									
			Average 1970-2015		Operating Regime 1: Low Water Level Year Round [3]		Operating Regime 2: Low Maximum Water Level [4]		Operating Regime 3: High Water Level Year Round [5]		Operating Regime 4: Low Spring, High Summer-Fall [6]	
1 & 2	A1	438.4	Not inundated	0%	Not inundated	0%	Not inundated	0%	June 25 – July 29	16%	July 10 – Sept. 9	29%
	A2	437.7	July 15 – Aug. 4	10%	Not inundated	0%	Not inundated	0%	June 21 – Aug. 9	23%	July 4 – Sept. 28	41%
1	A3	437	July 5 – Aug. 21	22%	Not inundated	0%	Not inundated	0%	June 16 – Aug. 22	32%	June 29 – Oct. 27	57%
	A4	435.5	June 23 – Sept. 29	46%	Not inundated	0%	June 23 – Aug. 24	29%	June 6 – Sept. 19	50%	June 21 – Oct. 31	62%
	A5	435	June 20 – Oct. 19	57%	Not inundated	0%	June 18 – Sept. 16	43%	June 4 – Sept. 30	56%	June 19 – Oct. 31	63%
	A6	434.2	June 16 – Oct. 31	64%	Not inundated	0%	June 11 – Oct. 5	55%	May 30 – Oct. 31	72%	June 16 – Oct. 31	64%
	B1 - disconnected	436.2	June 27 – Sept. 11	36%	Not inundated	0%	Not inundated	0%	June 11 – Sept. 5	41%	June 25 – Oct. 31	60%
2	B1 - connected	434.4	June 17 – Oct. 31	64%	Not inundated	0%	June 13 – Oct. 2	52%	May 31 – Oct. 31	72%	June 17 – Oct. 31	64%
	AD1	434.8	June 19 – Oct. 31	63%	Not inundated	0%	June 16 – Sept. 20	45%	June 3 – Oct. 13	64%	June 18 – Oct. 31	64%
1 & 2	D1	432.3	June 6 – Oct. 31	69%	Not inundated	0%	May 24 – Oct. 31	75%	May 18 – Oct. 31	78%	June 9 – Oct. 31	68%

1. Inundation timing is based on interpolated average reservoir elevations for Burton flats based on Nakusp and Fauquier WSC gauges.
2. 214 days total from April 1 to October 31
3. Operating Regime 1 - Includes: 1973, 1977, 1992, 2001, 2004, 2015
4. Operating Regime 2 - Least common operating regime. Includes: 1979, 1987, 1993, and 1994
5. Operating Regime 3 - Most common operating regime in the last 15 years. Includes: 1981, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014
6. Operating Regime 4 - Most common operating regime 1970 - 2015. Includes all other years between 1970 and 2015

4.4 Regional Hydrology Analysis

Due to the observed influence of Burton Creek on site groundwater levels, a regional hydrology analysis was conducted to better understand the expected typical conditions for Burton Creek and thus the site groundwater. Understanding the fluctuations in groundwater levels is important as these levels determine the wetland excavation depths to achieve target water depths.

The regional hydrology analysis aimed to **answer three questions**:

1. **2017 Water Year**
   - Is 2017 a typical water year for Burton Creek (timing and quantity)?
2. **Low Flow Timing**
   - What time of year within the habitat window of interest of April to October 31 will have the lowest water levels in the creek (and thus lowest expected groundwater levels)?
3. **Low Water Level**
   - What could be expected for the typical lowest water level in Burton Creek at the location of the installed gauge?

Three nearby Water Survey of Canada (WSC) stream gauges were selected for comparison with Burton Creek based on the following selection criteria:

- Within or near same hydrologic zone (subzone g)
- Watershed area between ±100 km^2 of Burton Creek
- Similar basin characteristics (mean annual runoff, elevation, aspect)
- Historical data available for a minimum of 10 years
- Real time data available for 2017

Based on these criteria, three WSC stations were included in the analysis. The following table outlines the key characteristics of these watersheds and Burton Creek, and Figure 4-6 shows gauge locations, total stream catchments, and nearby climate and snow stations.

Table 4-3: Regional WSC Stream Gauges

Stream	WSC Station ID	Catchment Area (km^2)	Mean Basin Elevation (m)	Mean Annual Runoff (mm) [1]	Location (UTM)
Burton Creek (at confluence with Caribou Creek)	NA	289	1640	706	E 436289 N 5536730
Kuskanax Creek at Nakusp	08NE006	333	1680	1328	E 447672 N 5570345
Burrel Creek above Gloucester Creek	08NN023	224	1430	605	E 405193 N 5493777
Inonoaklin Creek above Valley Creek	08NE110	298	1445	401	E 414547 N 5527851

1. All values (except Burton Creek) calculated from historical flow records. Burton Creek MAR is based on provincial isoline interpolation.

Question 1: 2017 Water Year

Several sources of data were analyzed to evaluate whether the 2016- 2017 water year (October 2016- through June 2017 only) represents a typical water year or if and how the timing and quantity of discharge from Burton Creek is different than an average year. The water year was taken as October 1, 2016 to September 30, 2017. The analysis included:

- Review of 2016-2017 automated snow-pillow data at nearby stations
- Review of 2016-2017 climate data at nearby stations in comparison to climate normals
- Comparison of 2017 data at selected regional WSC stations with the average station characteristics (hydrographs, level)

The two closest snow stations were reviewed and the results are summarized as follows (graphs of station snowpack included in Appendix C):

- 2B08P St Leon Creek (approximately 50 km North, 1,822 m elevation)
    - Snowpack approximately average most of the year but above average prior to melt.
    - Faster melt rate than average, but within the typical freshet time window for the station of mid-June to late-July.
- 2B06P Barnes Creek (approximately 35 km West, 1,595 m elevation)
    - Snowpack well below average for most of the year but approaching average in the spring.
    - Slightly faster melt than average, but within the typical freshet time window for the station (mid-May to mid-July).

Climate data comparison was limited by available 2017 data at nearby Environment Canada Stations. Fauquier (17 km west), Nakusp (30 km north), and New Denver (37 km east) stations were reviewed; however, Fauquier did not have 2017 data, and Nakusp had large data gaps in the 2017 data. As a result, the New Denver station (Climate ID 1145460) was used for the regional climate comparison and was compared to the Fauquier station to assess whether there was reasonable regional continuity in climate. Appendix C contains graphs of climate normal and 2017 data for these stations. The results of this comparison indicate that Fauquier and New Denver experience similar patterns in seasonal climate, though New Denver receives greater precipitation in the winter and less in the spring and summer compared to Fauquier. The 2016-2017 climate shows below average temperatures in the winter and early spring and above average snow depth (particularly in the spring).

The results of the snowpack and climate data indicate that 2017 had normal to above average snowpack, a cooler and wetter spring, but a faster melt. Overall, this is expected to result in 2017 streamflow levels being similar to or slightly above normal for the period analyzed (October 2016 through June 2017). The timing of freshet for the region was within the typical range, though slightly late due to cool spring.

For the three regional WSC streamflow gauges selected, annual hydrographs were compared to 2017 real-time data (refer to Appendix C). This comparison has some data gaps, as historical data is largely available only as discharge until 2011, while real-time data for Inonoaklin and Burrell Creeks is available only for stream level. Provisional discharge data from Environment Canada was obtained for Burrell and Inonoaklin Creeks, but as this data has not been approved, its application is subject to uncertainty. The average annual hydrographs for these stations (Figure 4-7) show that Kuskanax Creek has notably greater unit discharge and higher late summer and fall flows than the other two stations, as is expected given its significantly higher MAR and elevation.

Comparing the 2017 data to the annual hydrographs, Kuskanax Creek experienced a fairly typical year for timing and discharge quantity. For 2017, Burrell and Inonoaklin Creeks appear to have had a high spring water year in terms of average and peak flows/levels, though discharge data is provisional and historical water level data has a short period of record for comparison (< 5 years). The peak flows are less significant for this analysis as groundwater levels at Burton Creek will not respond quickly to short and intense increases in creek levels.

In order to relate regional stream conditions to Burton Creek, water level hydrographs for early May to late June 2017 were compared for the WSC stations and Burton Creek, though water level is noted to be dependent on geometry at the stream gauge locations, which is not known for the WSC stations. At the Burton Creek gauge, the creek is a wide braided gravel channel. The 2017 water level hydrographs are shown in Figure 4-8 (original) and Figure 4-9 (shifted for overlay). This comparison indicates the following:

- Regional response to similar weather conditions is apparent at all stations.
- Kuskanax Creek has notably dampened flows with reduced peaks but higher sustained levels.
- Inonoaklin and Burrell Creek have notably higher water levels than Kuskanax and Burton Creek, this could be attributed to differences in creek geometry at gauges.
- Burton Creek water level response is generally more similar to Burrell and Inonoaklin Creeks, with similar decreases in water level in early summer and more noted peaks than Kuskanax Creek (could be partially attributed to creek geometry at gauges).
- Burton Creek water level is less peaky in the spring and has later peaks in early summer than Burrell and Inonoaklin Creeks, indicating a greater role of high elevation snow melt (or significant differences in creek geometry at the gauges).

Based on catchment characteristics (MAR isolines, catchment area, elevation, elevation, hydrologic subzone) and the water level comparison, Burton Creek is expected to behave similar to Burrell or Inonoaklin Creek, but with moderately higher sustained flows and a slightly later freshet due to a greater MAR and higher elevation watershed.

Based on the above analyses, the 2016-2017 water year (October 2016 through June 2017) for Burton Creek was likely an above average year in terms of peak flow and moderately above average with relation to average water level and flow. During detailed design, additional data for the remainder of 2017 could be analyzed to further support the design.

Question 2: Low Flow Timing

As mentioned above, Burton Creek is expected to behave similarly to Burrell or Inonoaklin Creek, but with higher sustained flows and a slightly later freshet. The timing of low flows in Burton Creek is significant because it describes the lowest expected groundwater levels and thus the most conservative design condition. In order to estimate the timing of low flows in Burton Creek, 7-day low flows were estimated for the three regional WSC stations from April 1 to October 31 (habitat window of interest), and the minimum annual 7-day low flows are shown in Figure 4-10 with the corresponding monthly average reservoir level at Burton Flats.

For Burrell and Inonoaklin Creeks, the majority of the April-October minimum flows occur in September and October (75-85% of the years of record), while for Kuskanax Creek minimum flows generally occur in April (60% of the years of record). Burton Creek is expected to have low flow timing similar to Burrell and Inonoaklin, but with a higher watershed, April may have a greater proportion of Burton Creek minimum flows. Though lowest flows are expected most frequently in September and October, late summer and early fall correspond to significantly higher reservoir levels than April (on average approximately 10 m higher than April levels). Lower reservoir levels will result in a lower groundwater table, which indicates that early April is the most conservative design condition for the groundwater fed wetlands.

Question 3: Low Water Level

The final question for this analysis is what is the expected typical Burton Creek low water level adjacent to the Burton Flats site? Burton Creek is not expected to run dry, and at present, the lowest observed water level in Burton Creek at the installed gauge is 50-60 cm (June 21, 2017). As stated above, late September and October flows and levels in Burton Creek are typically expected to be lower than those in early April, though April is the most conservative design condition due to low reservoir levels. Additional monitoring data from the summer and fall of 2017 may be collected by BC Hydro at their discretion and analyzed at a later stage of design.

Based on these conclusions, Burton Creek water levels in late summer and through the fall are expected to be lower than or similar to those in April and could provide a conservative estimate of water levels in April (the selected design condition). Continued monitoring at the site in the summer and fall could then provide low water levels to refine the design based on the lowest expected conditions.

4.5 Erosion and Waves

As mentioned in the design basis, flow between the wetland is expected to be minimal as the surface water runoff to the wetlands is minimal due to the flat topography and very limited drainage area. The one exception to this condition would be a large flood event on Burton Creek and resulting overland flow through the highway embankment culverts, which the wetland design will not consider due to its low likelihood of occurrence and overly conservative design. The likelihood of occurrence is expected to be low based on site observations and the regional hydrology analysis. Burton Creek has a relatively high bank near the primary culvert, which would require an extreme event to exceed the banks and cause overland flow. There was no evidence on site that this had occurred in the recent past. An even larger event would be required to drive significant flow through the culvert. Based on the regional hydrology analysis, peak flows for the region in 2017 were significantly higher than the average annual flood (though only provisional discharge data is available), and there was still more than 1 m of freeboard from the top of bank.

As a result, water flow and velocity at the inlets and outlets of the wetlands are expected to be relatively low given that it is groundwater sourced. Groundwater flow through the wetlands is expected to be on the order of 0.01 m^3/s when gradients are high (highest groundwater flows expected), though this does not necessarily result in water flow over the outlets.

The highest typical flow condition in the wetland channel is expected to occur when high Burton Creek levels result in high groundwater levels and drainage in combination with local surficial runoff. High Burton Creek levels would typically occur in spring during the freshet. Surface water contributions are expected to be more significant during snowmelt on the site (likely preceding the highest Burton Creek levels) or during early summer convective storms (prior to inundation). Due to the limited flows expected, a frequency analysis of flows has not been conducted, instead erosion protection has been sized based on existing channel dimensions. Where it is narrow and more channelized, the existing drainage is typically 1.5 m wide at the base, with low slopes of 1-2%. Typical maximum velocities just downstream of the outlets are conservatively estimated to be less than 1 m/s, so the excavated portions of the channel just downstream of the outlet would be protected against erosion with cobble (D50 of between 75 and 100 mm). In detailed design, limited additional analysis of extreme storm events may be completed to confirm the outlet capacity is sufficient for the design intent.

KWL previously conducted a wave assessment for BC Hydro at a site to the south at Edgewood in 2014[3]. At this location, the 200-year significant wave height was estimated to be on the order of 1.5 m; however, waves of this magnitude are not expected at the proposed project site on Burton Flats for several reasons:

- The Edgewood site is located farther south on the reservoir and is exposed to a significant southern fetch. For preliminary purposes, the fetch from the southwest is on the order of 10 km to Burton, which is expected to produce lower wave heights than at Edgewood. The Burton Flats site is on northeast side of the Burton Creek and Caribou Creek fan, which spans more than half of the reservoir width at that location at low reservoir levels. The Burton Flats site is sheltered from waves originating from the southwest by either exposed beach flats or shallow waters depending on reservoir level.
- The Burton Flats site is more exposed to the northwest where there is approximately 12 km of fetch, which is also expected to produce lower wave heights than at Edgewood. The existing terrain of Burton Flats site is a gently sloping bench, which will naturally dissipate waves as they approach the site, however this will occur to a greater or lesser extent depending on the reservoir level.

The design philosophy is to use shallow slopes (6H:1V or shallower) that mimic the existing relatively stable slopes of the shoreline of Burton Flats, and accept some erosion and reshaping of slopes rather than constructing extensive riprap (or other armouring) to limit costs and maintain a more natural surface of the works.

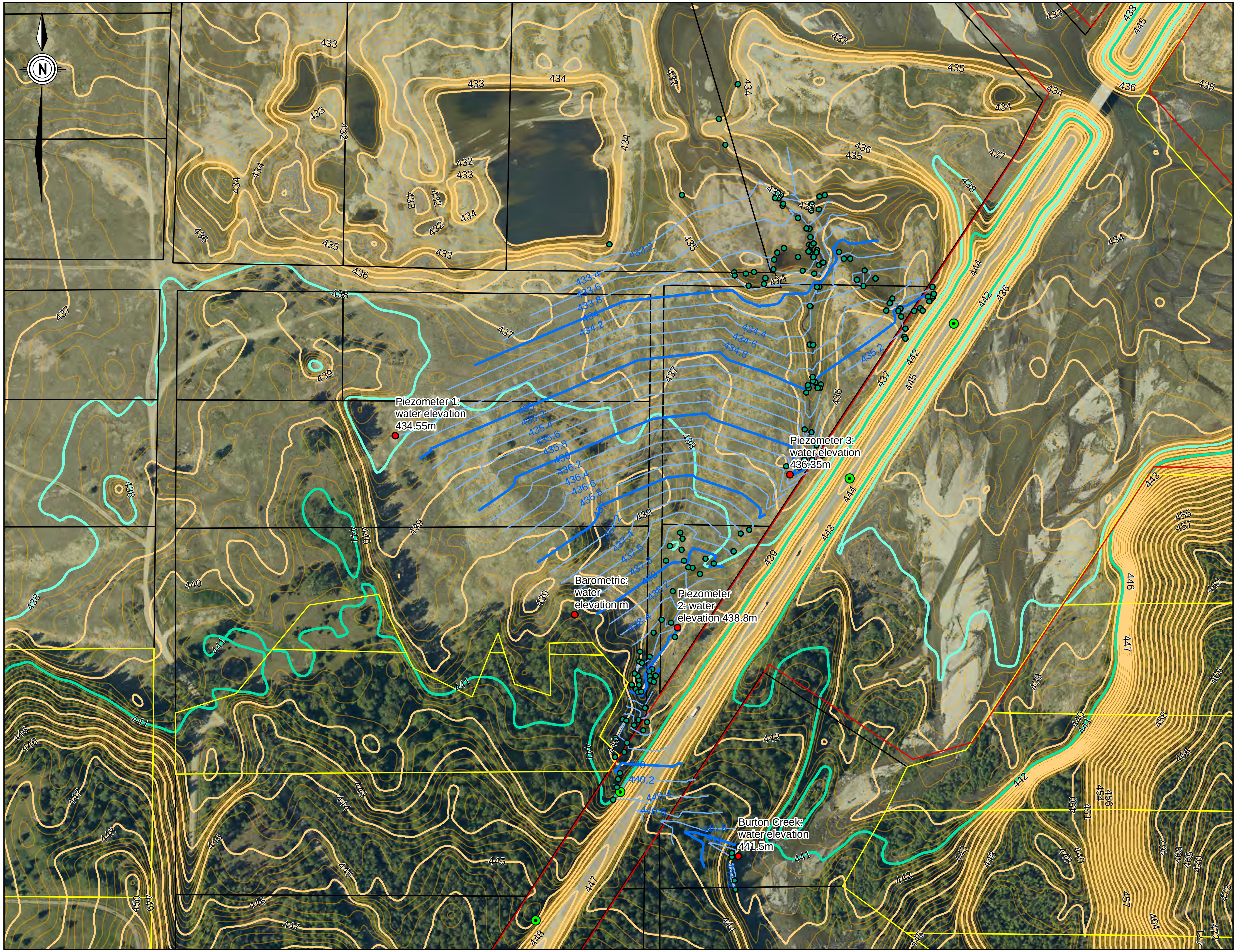
In addition, the mounds have been positioned to act as informal breakwaters for the wetlands, the primary habitat features of the proposed works. It is expected that the mounds are the most likely features of the design to experience some erosion and reshaping due to waves. This is considered acceptable since the planting mounds are not structural works and do not act as wetland containment berms. The shallow slopes will be re-vegetated after construction with native plants for habitat, further limiting surficial erosion. The side slopes of the mounds could be made even shallower during detailed design, but this would reduce the area at higher elevation for planting and increase the overall footprint.

[3] 2014, KWL, Edgewood Breakwater Review, Report to BC Hydro, KWL File No. 0478.176

4.6 Summary

In summary, a hydrology and hydrogeology analysis was conducted for the Burton Flats site, focusing on the habitat window of April 1 to October 31, which included the following key components and conclusions:

- Three piezometers with water levels sensors were installed on Burton Flats and one stream level sensor was installed on Burton Creek. The initial results from May-June 2017 show that groundwater levels at Burton Flats are higher closer to Burton Creek and rise and fall in accordance with Burton Creek and the reservoir, with dampened effects. As expected based on site observations, this indicates that shallow groundwater at Burton flats is subsurface flow from Burton Creek, with the reservoir and Burton Creek acting as boundary conditions for the site groundwater.
- A reservoir level frequency analysis was conducted to determine the expected lower boundary condition for groundwater levels and to estimate the timing of inundation for the proposed wetlands.
    - The lowest reservoir levels are expected in March to April, with average minimum reservoir levels of approximately 426 m.
    - The lowest wetlands will typically be inundated at the beginning of June and the remaining wetlands will be inundated mid-June to mid-July, though A1 may not be inundated most years (depending on reservoir operation). Wetlands D1, A5, A6, AD1, and B2 (connected) are inundated more than 50% of the habitat window on average.
- A regional hydrology analysis was completed for Burton Creek, analyzing regional climate, snowpack, and WSC stream data. This analysis concluded:
    - The 2016-2017 water year (October 2016 through June 2017) for Burton Creek was likely an above average year in terms of peak flow due to a cold spring and rapid melt and moderately above average with relation to average water level and flow.
    - Lowest water levels on Burton Creek are expected in April, August, September, and October with September and October having the lowest levels and greatest frequency of low flows.
    - Burton Creek adjacent to the site is not expected to run dry, and continued monitoring for August to October could provide a conservative low water level estimate that could be applied for the April design condition.
- A groundwater balance was conducted by Piteau considering expected evapotranspiration and groundwater flow rates, which concluded that there is sufficient groundwater flow to maintain the wetlands. Seepage rates between the ponds, which are controlled by the head difference, were further analyzed, and it was concluded that groundwater recharge will largely compensate for seepage from ponds. Wetland water levels are estimated to be approximately equal to the pre-excavation groundwater level.
- Excavated portions of the channel below the outlets between ponds will be protected against erosion with cobble.
- Wave height acting on the proposed physical works will depend on the water level and the local topography in the vicinity of the works in the direction of the wave path. Waves reaching the site are expected much small than those estimated at Edgewood (farther south on the reservoir) due to the much shorter fetch, relatively sheltered site location (for waves from the southwest), and energy dissipation along the shallow Burton Flats slope.
- Waves are mitigated in the design through a combination of shallow design slopes and an acceptance of some erosion / reshaping in lieu of riprap, as well as the use of habitat mounds as informal breakwaters for the wetlands.



WILDLIFE ENHANCEMENT PROGRAM AT BURTON, FLATS BC

Legend

- Surface Water Survey Points - May 16, 2017
- Culverts
- Water Level Sensors
- Railways, Highways, and Roads
- Other Ownership
- Private Property
- 438 m - Annual Average High Water
- 441 m - Maximum High Water
- Contour 1m
- Contour 0.25 m

Contours from 2016 Digital Terrain Model (Source: Terasaurus Aerial Mapping Ltd.)

Service Layer Credits:
Surveyed Railways, Highways, and Roads - DataBC, ParcelMap BC Parcel Fabric - DataBC, ESRI, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN and the GIS User Community 2009/05/24

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50 0 50
(m)

Project No.	Date
478-203	July 2017

Groundwater Contours Preliminary May 2017 1:3,000

Figure 4-1

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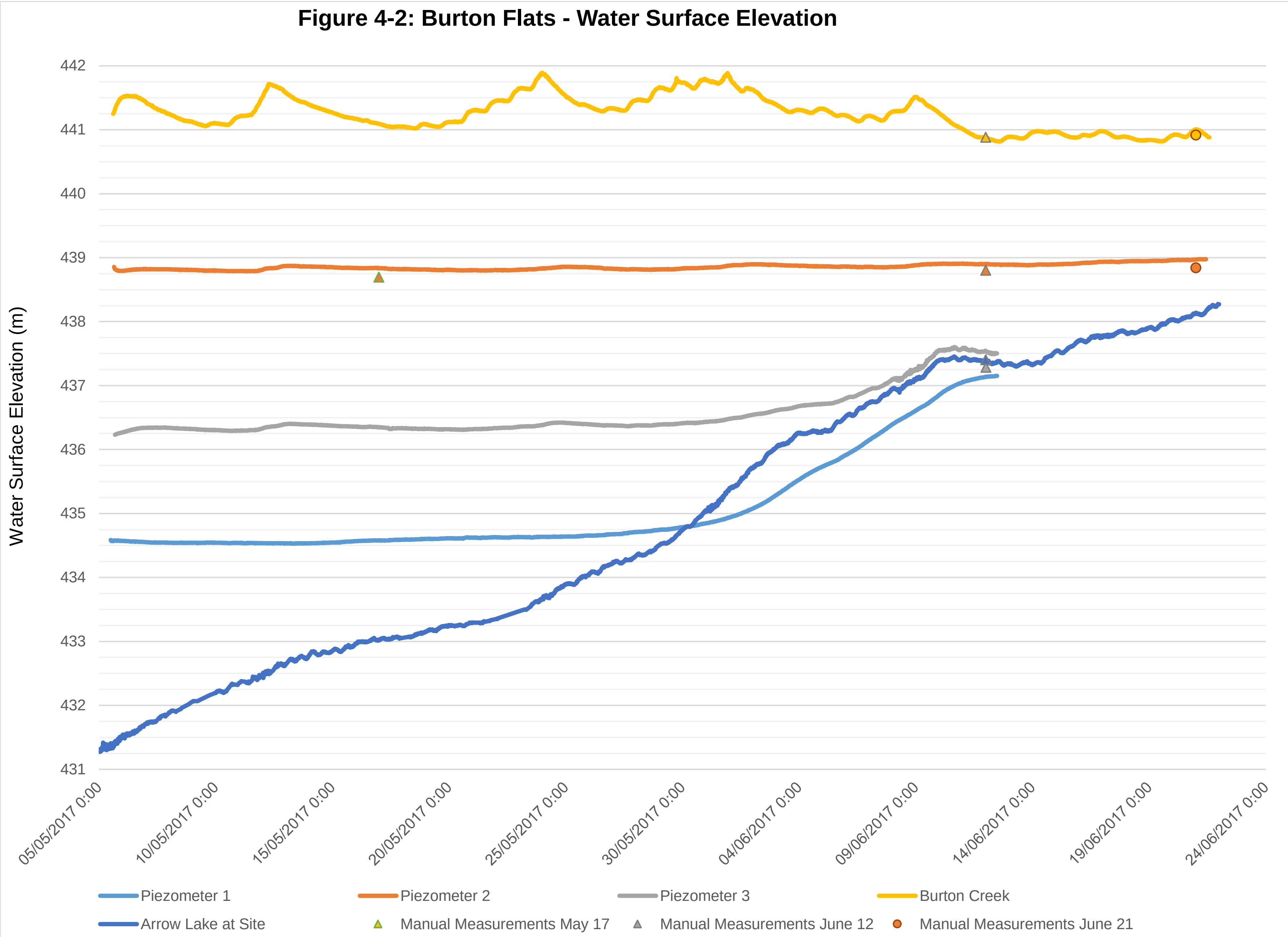
Author: AMatfin



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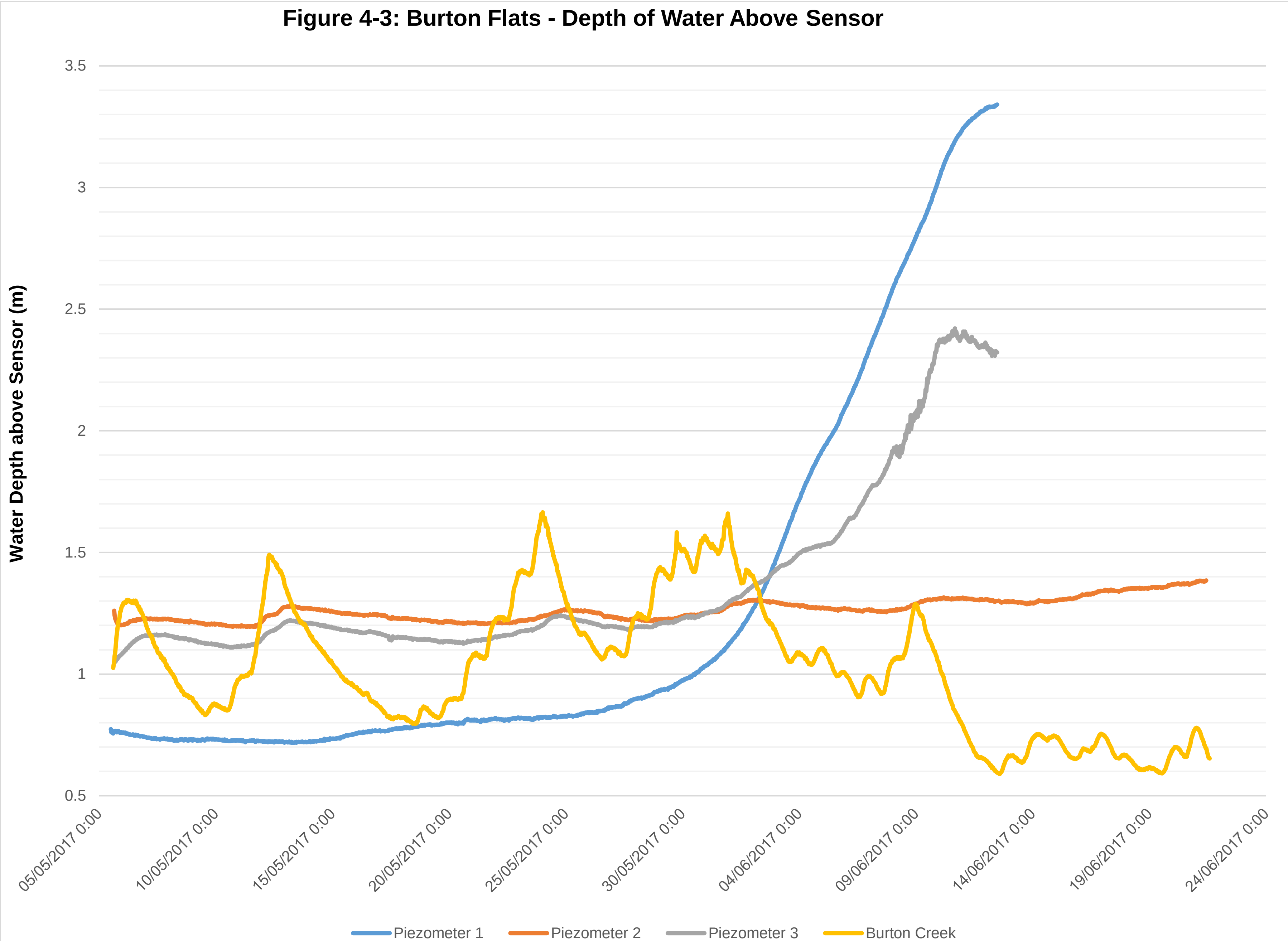


Figure 4-3: Burton Flats - Depth of Water Above Sensor
Water Depth above Sensor (m)
3.5
3
2.5
2
1.5
1
0.5
05/05/2017 0:00
10/05/2017 0:00
15/05/2017 0:00
20/05/2017 0:00
25/05/2017 0:00
30/05/2017 0:00
04/06/2017 0:00
09/06/2017 0:00
14/06/2017 0:00
19/06/2017 0:00
24/06/2017 0:00
Piezometer 1
Piezometer 2
Piezometer 3
Burton Creek

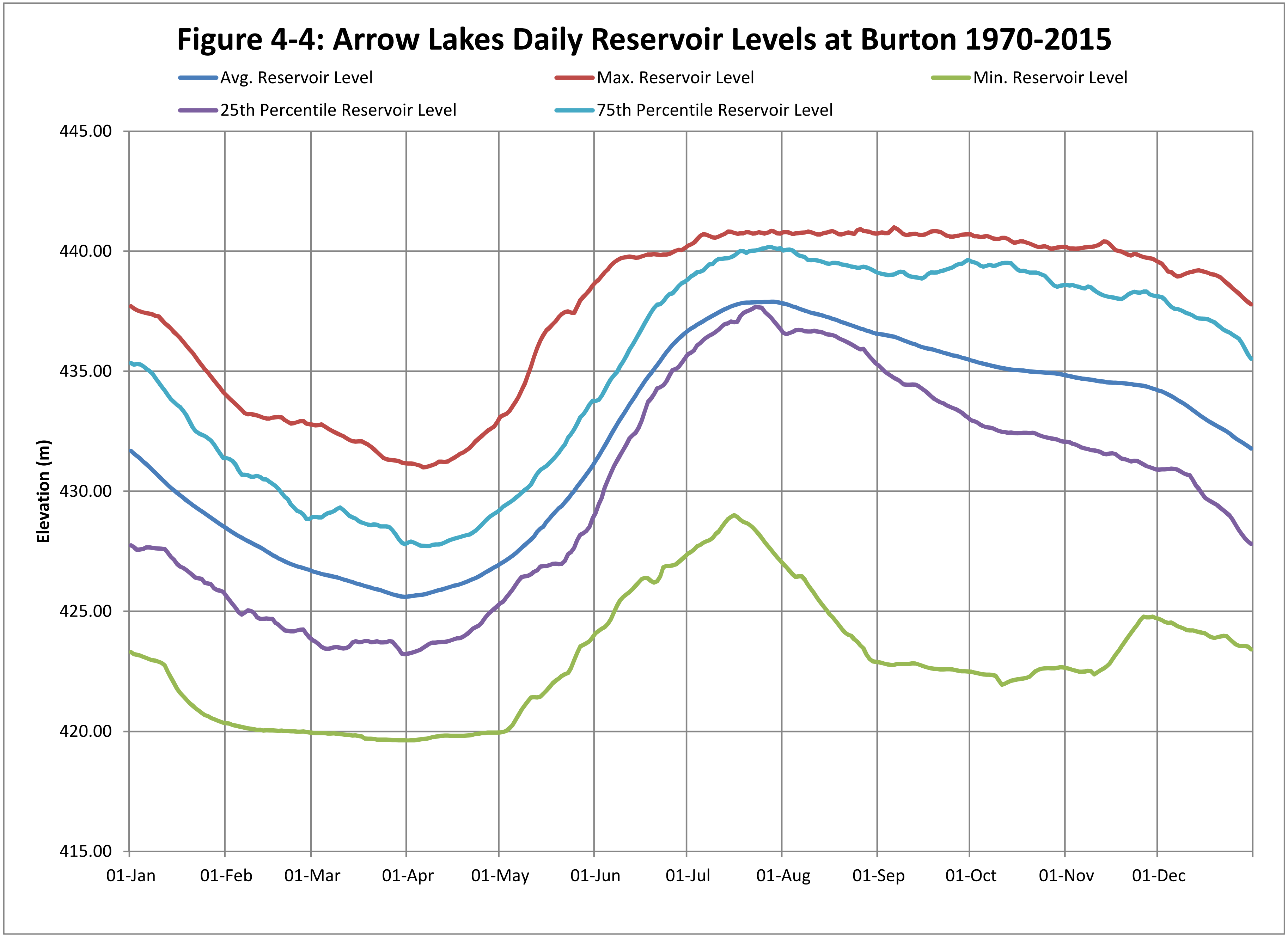
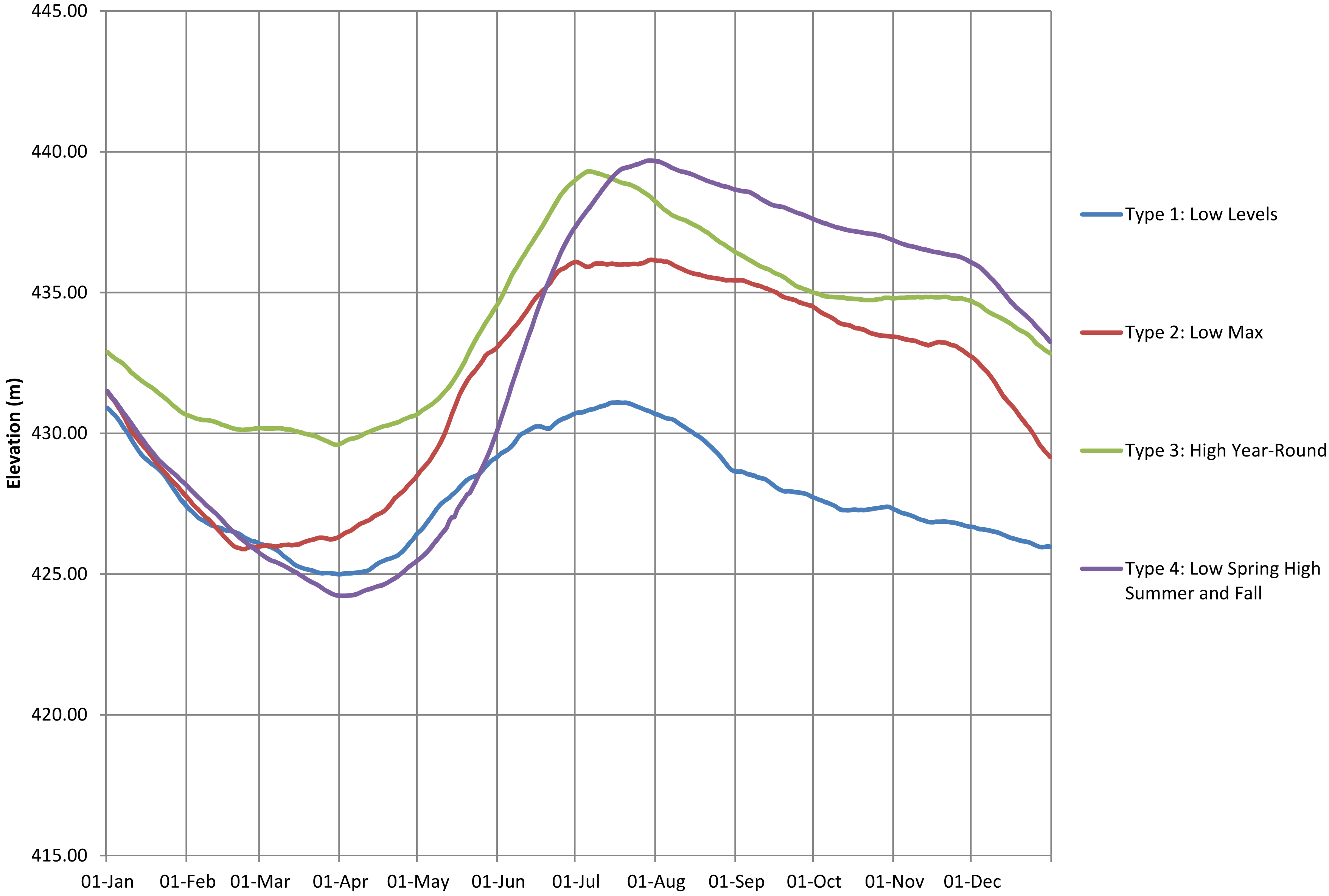


Figure 4-4: Arrow Lakes Daily Reservoir Levels at Burton 1970-2015
Avg. Reservoir Level
Max. Reservoir Level
Min. Reservoir Level
25th Percentile Reservoir Level
75th Percentile Reservoir Level
Elevation (m)
445.00
440.00
435.00
430.00
425.00
420.00
415.00
01-Jan
01-Feb
01-Mar
01-Apr
01-May
01-Jun
01-Jul
01-Aug
01-Sep
01-Oct
01-Nov
01-Dec

Figure 4-5: Daily Reservoir Levels (Burton) - Operating Regimes



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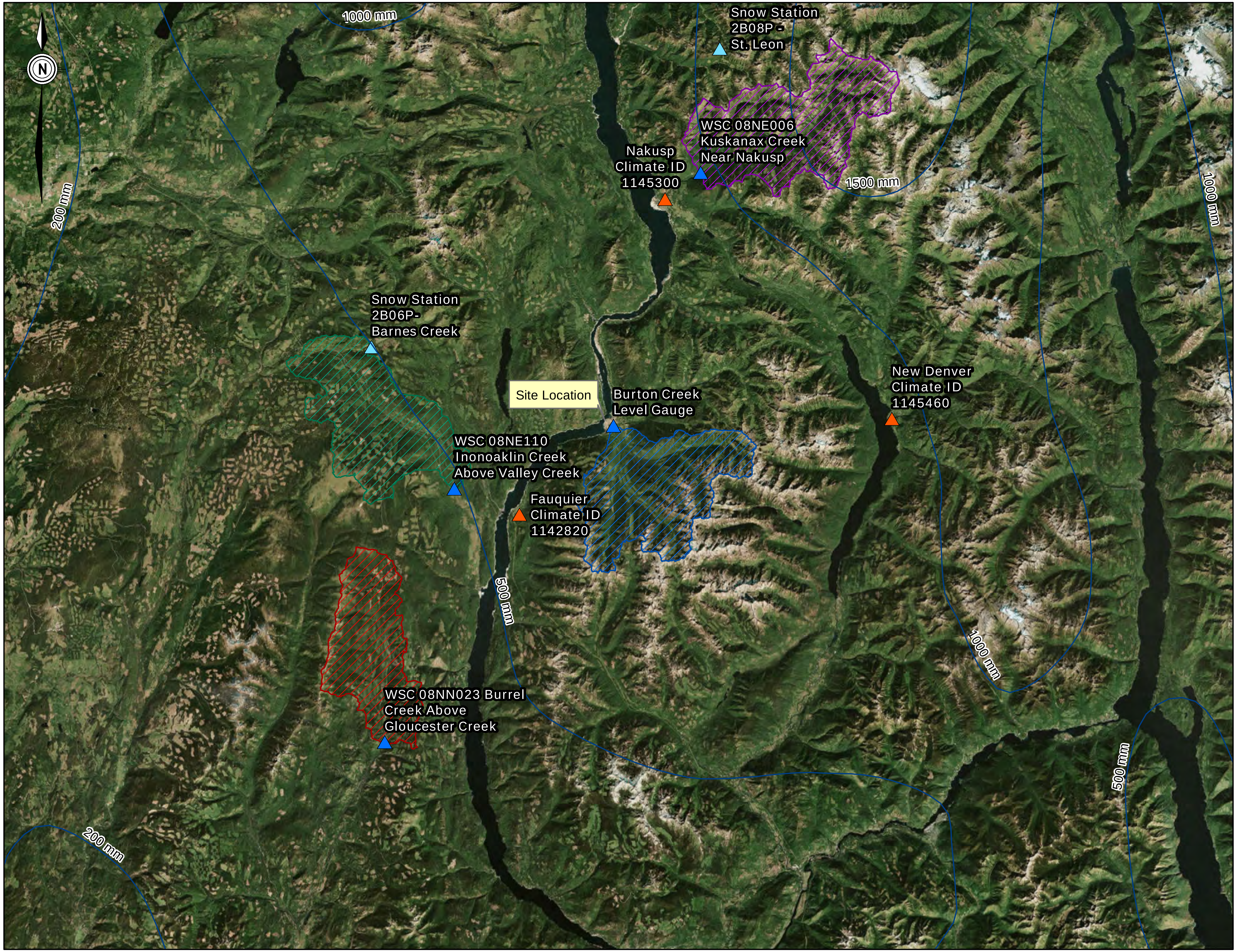

WILDLIFE ENHANCEMENT PROGRAM AT BURTON, FLATS BC

Legend

WHSE Annual Runoff Isolines

Nearby Hydrologic Stations

- Climate
- Snow
- Stream

Freshwater Named Watersheds

Watershed Name

- Inonoaklin Creek
- Burrell Creek
- Burton (Trout) Creek
- Kuskanax Creek

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Surveyed Railways, Highways, and Roads - DataBC, ParcelMap BC
Parcel Fabric - DataBC, ESRI, DigitalGlobe, GeoEye, Earthstar

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10 0 10
Kilometers

Project No.	Date
478-203	July 2017

Burton Creek Regional Hydrology 1:500,000

Figure 4-6

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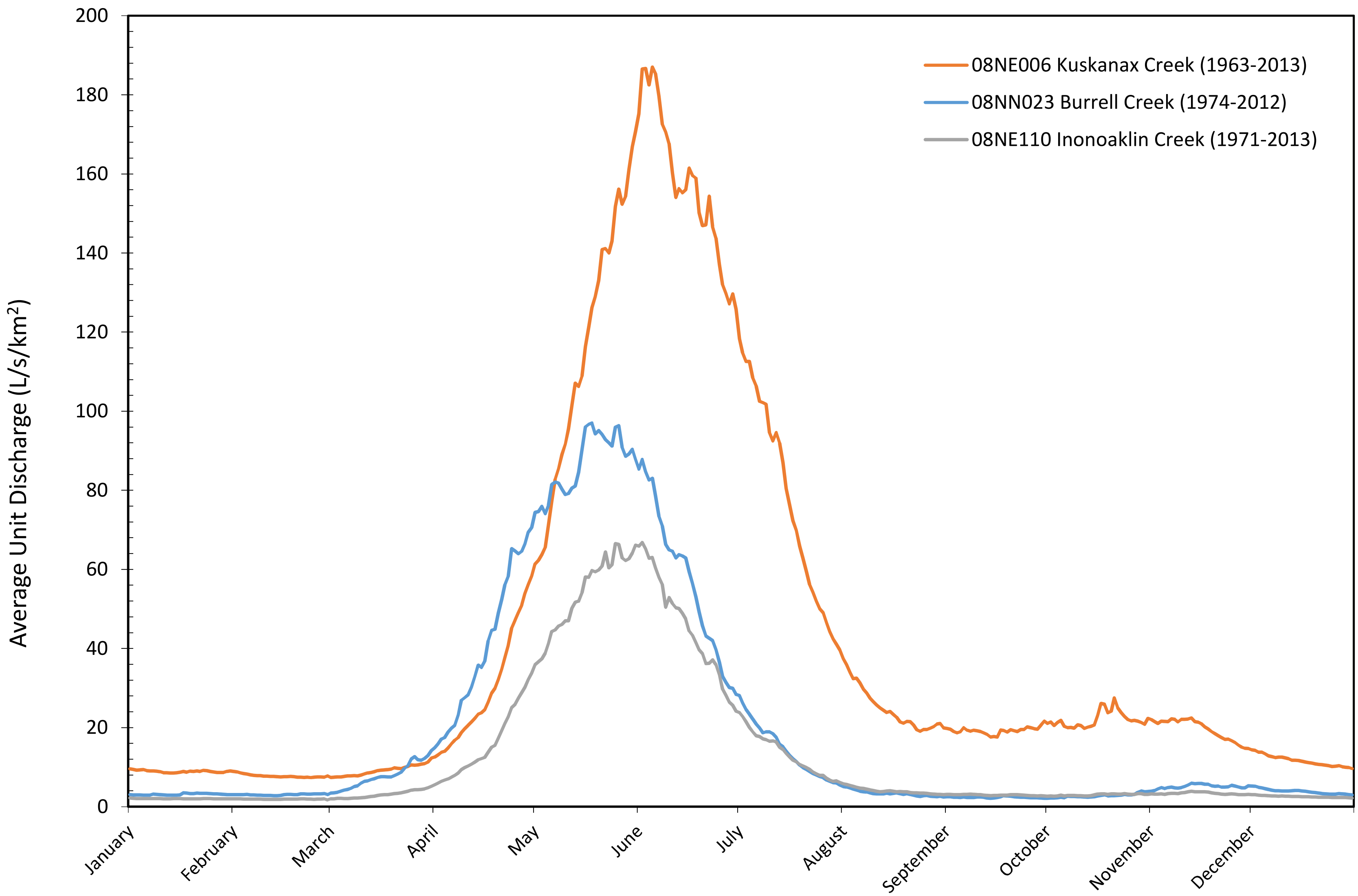
Author: dleung

Figure 4-7: Regional Hydrographs



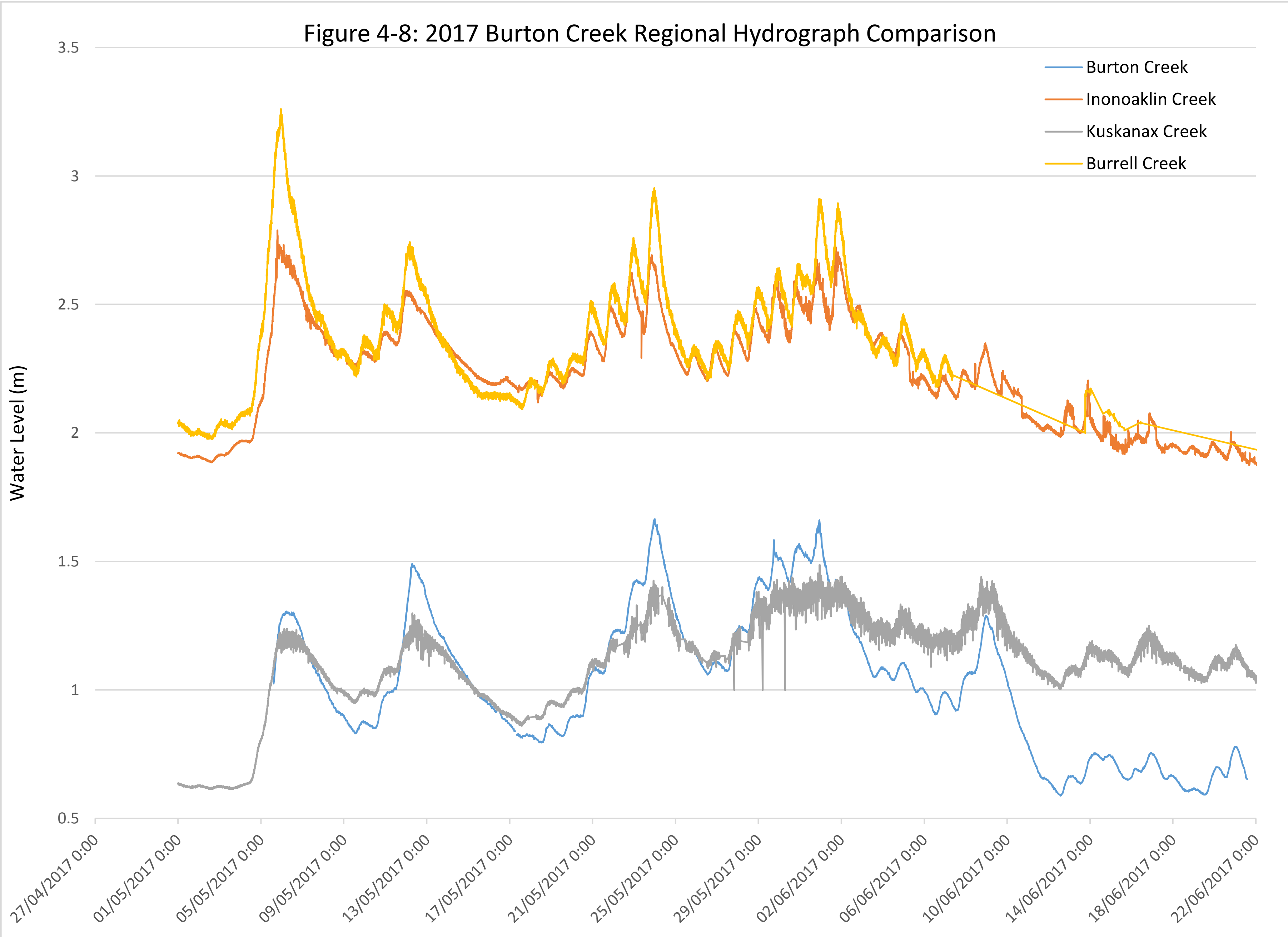


Figure 4-8: 2017 Burton Creek Regional Hydrograph Comparison
Burton Creek
Inonoaklin Creek
Kuskanax Creek
Burrell Creek
Water Level (m)
3.5
3
2.5
2
1.5
1
0.5
27/04/2017 0:00
01/05/2017 0:00
05/05/2017 0:00
09/05/2017 0:00
13/05/2017 0:00
17/05/2017 0:00
21/05/2017 0:00
25/05/2017 0:00
29/05/2017 0:00
02/06/2017 0:00
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18/06/2017 0:00
22/06/2017 0:00

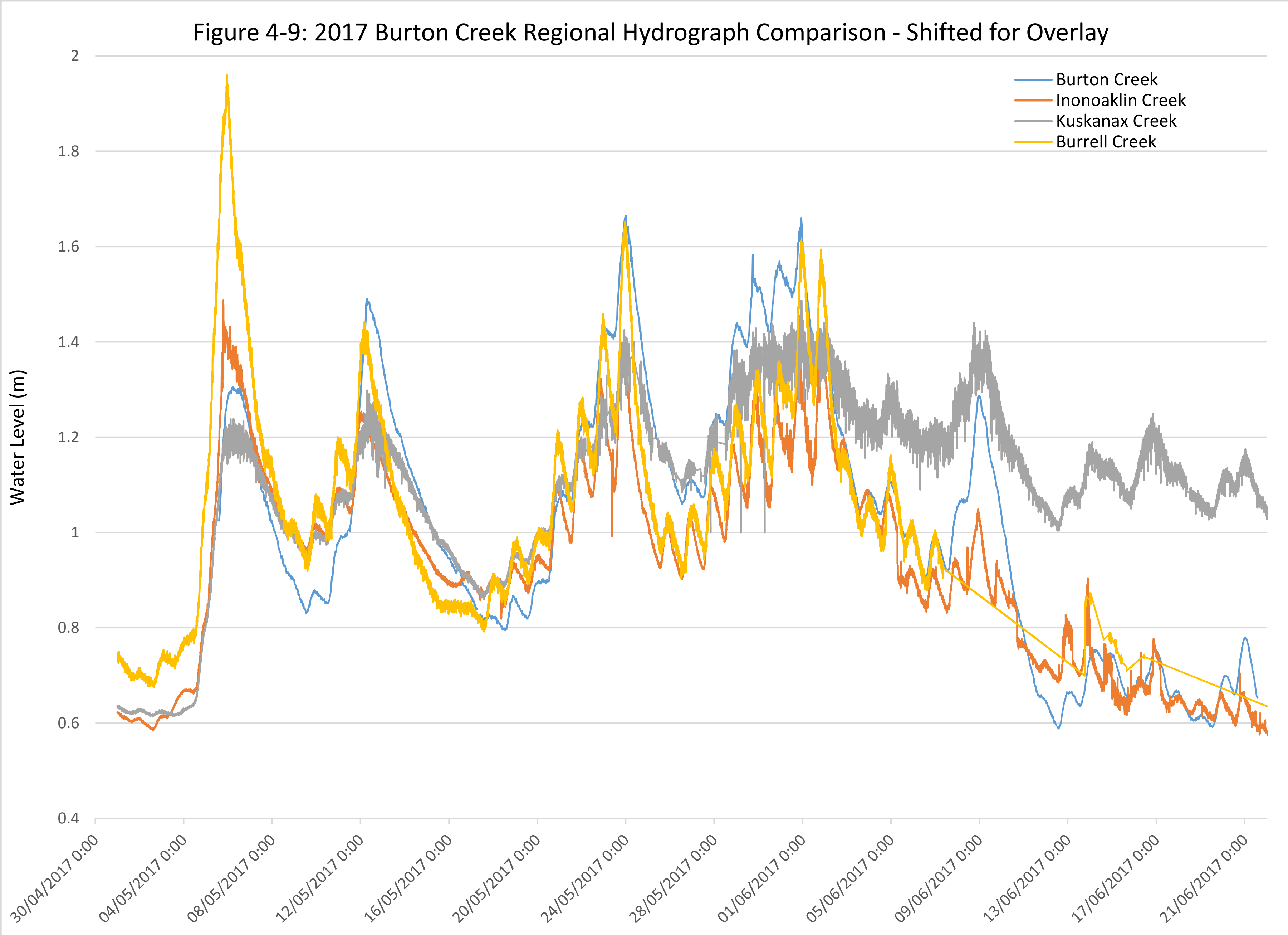
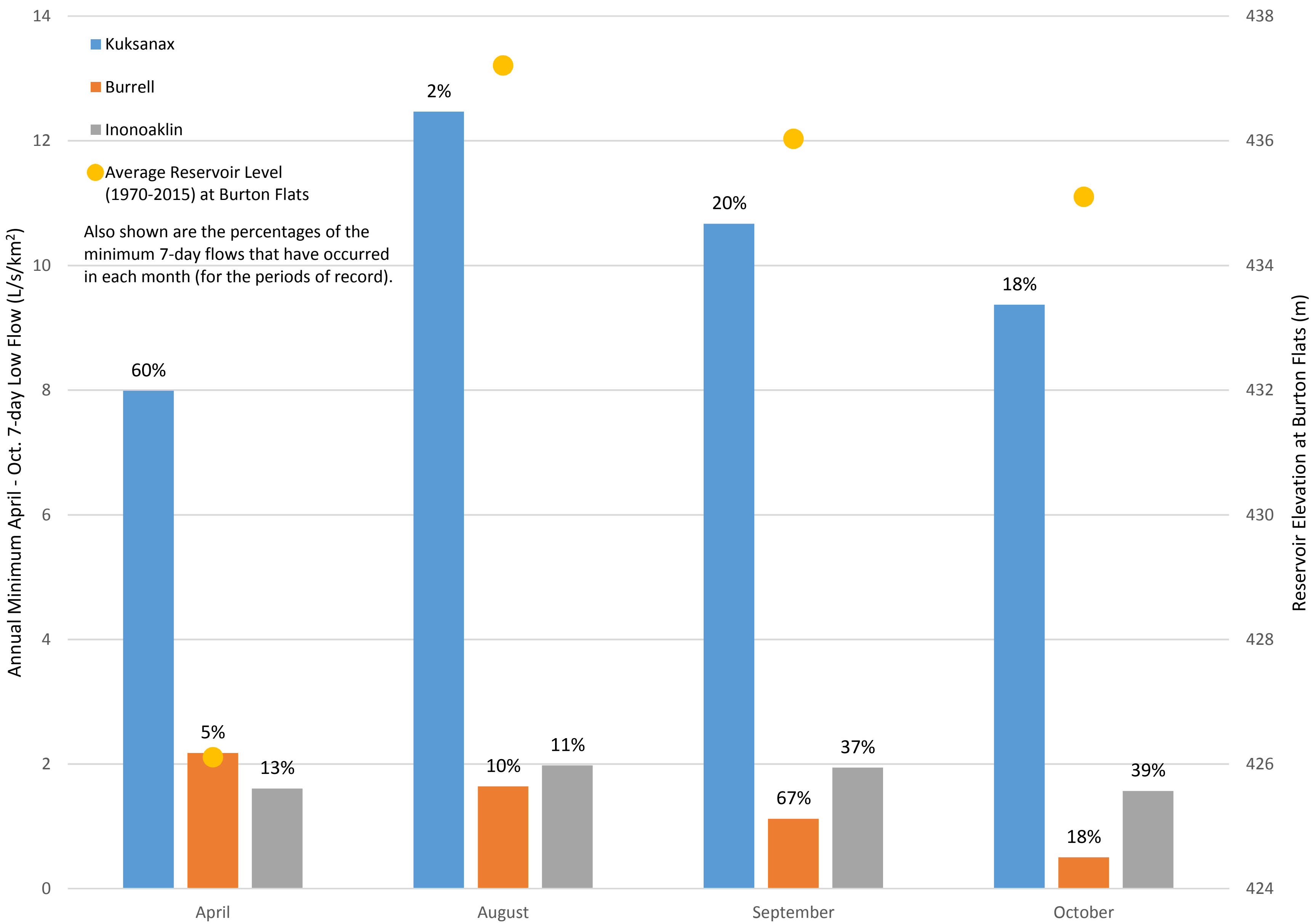


Figure 4-9: 2017 Burton Creek Regional Hydrograph Comparison - Shifted for Overlay
Water Level (m)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
Burton Creek
Inonoaklin Creek
Kuskanax Creek
Burrell Creek
30/04/2017 0:00
04/05/2017 0:00
08/05/2017 0:00
12/05/2017 0:00
16/05/2017 0:00
20/05/2017 0:00
24/05/2017 0:00
28/05/2017 0:00
01/06/2017 0:00
05/06/2017 0:00
09/06/2017 0:00
13/06/2017 0:00
17/06/2017 0:00
21/06/2017 0:00

Figure 4-10: Low Flows at Regional WSC Stations and Reservoir Levels



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5. Feasibility Design Concept Description

Two primary design concepts have been prepared for the wildlife enhancement physical works at the Burton Flats Site. The footprint of the proposed works is approximately 5.7 to 6.1 ha. The Feasibility Design Drawings are attached in Appendix D.

As discussed earlier in this report, the concepts have focused on excavation as opposed to berm construction. Each concept has a variety of diverse habitat features with variations between concepts, which can be excluded or phased as desired for flexible design approach. The design components and features are described in the 'Alignment and Geometry' subsection of Section 3.3 Wetland Design. These components are shown in italics below with a discussion of design features.

5.1 Option 1

Option 1 includes a larger amount of wetland habitat than Option 2. It is presented in Drawings C-102, C-104, and C-301. This concept includes:

- Six *Primary Shallow Wetlands* (labelled as A1 to A6) with 0.3 to 0.5 m water depth in a tiered alignment along the existing drainage paralleling the highway totalling approximately 0.7 ha of shallow wetland area.
- One *Deep Waterfowl Pond* (D1) with 1 m water depth and an area of 0.8 ha below the shallow wetlands.
- One disconnected *secondary shallow wetland* (B1) with 0.3 to 0.5 m water depth northwest of the shallow wetlands with an area of approximately 0.2 ha.
- Several *Habitat and Planting Mounds* (C1 through C3) with two providing some shelter for the shallow wetlands from waves.
- A drainage swale connection from the *Deep Waterfowl Pond* to the existing ponds and the reservoir at a low elevation (see Drawing C-104).
- The total wetland surface area in this concept is approximately 1.7 ha.
- In the present concept, all the wetland ponds individually have less than 10,000 m^3 of retained water. The total combined retained water is approximately 11,200 m^3.

Pond areas and estimated retained water volumes are summarized in a table on Drawing C-102.

Seepage loss between wetlands A2, A3, and A4 have been considered given the gradient of the groundwater and the proximity of the excavated wetlands. There may be a risk of loss of water from upper wetlands to lower wetlands; however, it is expected that groundwater inflow will make-up for seepage losses (see Section 4 and Appendix C).

5.2 Option 2

Option 2 has less extensive shallow habitat construction that Option 1, and some other differentiating features. As noted above, the ultimate design could incorporate features of both Option 1 and 2. Option 2 is presented in Drawings C-103, C-104, and C-302. This concept includes:

- Two *Primary Shallow Wetlands* (labelled as A1 and A2) with 0.3 to 0.5 m water depth in a tiered alignment along the existing drainage paralleling the highway totalling approximately 0.2 ha of shallow wetland area.
- Potential minor channel improvements including widening, planting, and LWD between A2 and AD1.
- One *Variable Depth Pond* (labeled AD1) with water depths of 0.5 to 1 m and an area of approximately 0.3 ha in the vicinity of A5 from Option 1.
- One *Deep Waterfowl Pond* (labeled D1), with 1 m water depth and approximately 0.8 ha, which is the same as in Option 1.
- One connected *Secondary Shallow Wetland* (B1) with 0.3 to 0.5 m water depth northwest of the shallow wetlands with an area of 0.1 ha. In Option 2, this wetland would drain to the existing wetland below.
- Several *Habitat and Planting Mounds* (C1 through C3) with two providing some shelter for the shallow wetlands from waves.
- A drainage swale connection from the *Deep Waterfowl Pond* to the existing ponds and the reservoir at a low elevation, as per Option 1.
- The total wetland surface area in this concept is approximately 1.4 ha.
- In the present concept all the wetland ponds individually have less than 10,000 m^3 of retained water. The total combined retained water is approximately 10,500 m^3.

Pond areas and estimated retained water volumes are summarized in a table on Drawing C-103.

5.3 Design Details

Wetlands

The wetlands are designed to access the existing shallow groundwater at the site by excavation. The main design features of the wetlands are described and discussed below:

- **Excavation Depth:** Wetland excavation depth is based on the estimated groundwater levels from May 2017, with each wetland being excavated into the groundwater surface to achieve the target wetland depth. To maintain a natural appearance and create varied depth, the bottom of the wetlands will be uneven with base elevation variations of up to 20 cm above the target elevation.
  - For connected wetlands, the water level in the finished wetland is expected to be equal to the lowest pre-excavation groundwater level intersected by the wetland.
  - For disconnected wetlands, the water level in the finished wetland is expected to be the average of the pre-excavation groundwater level intersected by the wetland.

- **Slopes**: The wetland side slopes are 6H:1V or shallower. These gentle slopes are stable, reduce the risk of damage by wave impact, and allow for easy planting. To maintain a natural appearance, the excavations would have slight variations in slope to create a more uneven surface. Side slopes at the pond outlets are 3H:1V or shallower.
- **Inlets**: The wetland inlets have a shallower slope of 10H:1V and are proposed to have gravel or cobble surfacing to reduce the potential for erosion. The D50 of the inlet erosion protection material is 75 to 100 mm (gradation limits to be set in detailed design), which would be placed 300 mm thick and bucket compacted in place. These inlet sections are sized based on the existing channel dimensions entering the wetland (1.5-8 m typically), which will be refined in detailed design. As discussed previously, low velocities are expected, which could allow for no erosion protection at the inlets, though this may increase the likelihood of maintenance.
- **Geometry:** The proposed wetland geometry is shown in the Feasibility Design Drawings and was developed considering existing topography and groundwater elevations to create the greatest amount of habitat possible. The geometry can be adjusted during detailed design or construction as desired, while ensuring that the total amount of wetland area created and the tiered elevations remains approximately the same. The wetlands range in width from approximately 50 to 120 m along the length following the existing watercourse.
- **Planting:** The wetlands will be planted with native vegetation appropriate for wetlands conditions, such as sedges and bluejoint reedgrass and cottonwood stakes where elevations allow.
- **Reed Canary Grass:** During excavation, RCG sod will be removed and side cast for use as surfacing material on excavation side slopes and berms.

Habitat and Planting Mounds

The habitat and planting mounds make use of the fill that will be produced from wetland excavation to create higher areas around the site that can serve as nesting habitat, create elevated terrain for a variety of plant species, and act as a breakwater against waves. The main design details of the mounds are as follows:

- **Reed Canary Grass Stripping:** All RCG sod in the mound footprints will be excavated and side cast for use as mound surfacing. The sod from the ponds and mounds will be flipped over (root mass up) when placed on the mounds to suppress RCG growth.
- **Fill and Compaction:** Based on the geotechnical investigations, excavated material is expected to be suitable for mound construction, with finer-grained soils being used for wetland outlets (see below). The remainder of the fill will be used for mound construction, excluding any oversized material (greater than 150 mm diameter), surficial organic, or other deleterious materials. Material will be placed in 300 mm lifts and compacted to 95% Standard Proctor Maximum Dry Density (SPMDD). To allow for staking, the top 60 cm of the placed fill will only be loosely compacted.
- **Crest elevation:** The mound crest elevation will be 439 to 440 m (approximately full pool reservoir elevation) to enable planting of trees that will increase shade cover but cannot survive significant inundation.
- **Slopes:** Similar to the wetlands, the mound side slopes will generally be 6H:1V or shallower to ensure stability, reduce the risk of damage by wave impact, and allow for easy planting. This will include variations in slope topography to create a naturalized appearance.

- **Surfacing and Planting:** Over-turned RCG sod will be used for mound surfacing (expected 30-40 cm sod depth). Mounds will be planted with a variety of species based on elevation according to the planting plan.
- **Geometry:** The mound geometry has been designed to tie into existing high ground, act as a breakwater for waves where possible, have variability for a natural appearance, and to use all excavated material. As a result, the mound geometry can be adjusted in construction as desired for habitat purposes and to ensure all fill is used on site. The mounds range in total width from approximately 20 to 80 m.

Outlets

The wetland outlets are designed to maintain the target wetland depths, create a naturalized appearance, and convey excess flows from storms and snowmelt. Two concepts have been developed in feasibility design for consideration by BC Hydro and stakeholders. Components of these designs can be combined in various manners provided sufficient log burial and ballast is provided to prevent structure buoyancy. For these designs, logs are assumed to be 300 mm in diameter and 6 m long maximum, smaller or larger logs can be used provided the total volume and weight is comparable. The main design details of the outlets are as follows:

- **Option 1 - Bundled Logs**: For this option, the main component of the outlet structure is a set of three bundled logs (300 mm diameter) set perpendicular to the outlet flow direction that act as a weir. The logs would be cabled together and buried such that the top log is at the design wetland water level. The wetted weight of the two lower logs in the bundle and compacted fill over the ends act as ballast to prevent buoyancy. The logs must be embedded a minimum of 1 m on each side with at least 0.5 m of fill compacted to 95% SPMDD in 200 mm lifts (using finer-grained soils excavated from wetlands). For low flows, the centre of the upper log could be notched to create a low flow v-notch weir.
    - Option 1 includes two additional logs for complexity and to create a more natural appearance. These logs rest atop the bundled logs with root wads facing downstream at skewed angles and are embedded in the bank 2.4 m with 0.5 m compacted fill above.
- **Option 2 - Rock Ballasted Logs**: For this option, the wetland water level control is accomplished with two logs set next to each other at opposing angles to create a v-notch weir. The logs are cabled to four partially-embedded 600 mm diameter boulders that act as ballast, or alternatively soil anchors could be used. Unlike Option 1, ballast for Option 2 is a combination of soil anchors, boulders, and/or embedment, to be finalized in detailed design. As with Option 1, embedded logs must have at least 0.5 m of fill compacted to 95% SPMDD in 200 mm lifts (using finer-grained soils excavated from wetlands).
    - Option 2 includes two additional logs for complexity and to create a more natural appearance. These logs are buried underneath the main logs with root wads facing upstream into the wetland, cabled to four partially-embedded 600 mm diameter boulders that act as ballast, or alternatively soil anchors could be used.
- **Outlet Channel** (included in both options): The outlet channel is designed to tie into the existing watercourse downstream of the excavated ponds (1.5 to 8 m wide), which will require field fit during construction. The outlet channel includes erosion protection to protect the outlet structures and prevent channel erosion (not expected to be a significant concern). The D50 of the inlet erosion protection material is 75 to 100 mm (gradation limits to be set in detailed design), which would be placed 300 mm thick and bucket compacted in place (same design as inlets).

Drainage Swale

The drainage swale is a simple addition to the project which includes only limited excavation to connect the lower deep proposed wetland to the existing old gravel pit and onwards to the reservoir. The swale is intended to have shallow 6H:1V side slopes and an even grade to connect the wetland features without draining the pools.

5.4 Materials

Section 3 of this report described potential materials based on the design basis and initial concepts. This section provides quantified materials for construction. Construction materials for the feasibility design largely include the use of on-site materials, with some imported materials for the log outlet structures and erosion protection at the pond outlets and inlets. These materials are listed below.

- **Cut and fill:**
    - Excavated material will be used for mound construction, excluding overly large material, organics, and other deleterious substances. The mound geometry will be adjusted in order to use all of the excavated material so no material is required for off-site disposal. The total cut volume is estimated to be 34,000 to 37,000 m^3, and the cut and fill for each design component is shown in Section 6.
    - Fine-grained excavated materials (silty sand or sand with some silt) will be used primarily around the wetland outlets. Coarser materials and any remaining fine-grained material will be used for mound construction.
- **Erosion protection at inlets and outlets:**
    - Erosion protection at wetland inlets and outlets is proposed to be a cobble or gravel material with an approximate D50 of 75 to 100 mm, placed 300 mm thick. The total estimated volume required is 60-70 m^3 assuming 5 m wide and 6 m long armoured inlet and outlet channels (to be refined in detailed design). This material will likely be imported, unless suitable and sufficient cobble or gravel is excavated from the wetlands. Though test pits indicate that gravel and cobble underlays the site, the amount excavated may not be sufficient and would require sorting from finer-grained materials.
- **Log outlet structures:**
    - The outlet structures require four to five 300 mm diameter logs (cedar preferably, fir as an alternate). Depending on the size of logs available, the number of logs will vary. Two of the logs need to have root wads.
    - Soil anchors or cabled boulders are required to anchor the logs and act as ballast.
- **Habitat Logs:**
    - Additional logs will be incorporated into the wetlands and mounds as desired to create habitat complexity. The design assumes a total of 15 to 20 logs arranged in the shallow ponds and along the mound slopes.
- **Planting stock**:
    - Native plants in the project footprint will be salvaged prior to construction for replanting.
    - Some nursery stock and stakes will be required as on-site salvage is not expected to be sufficient for all of the required planting.

5.5 Comparison of Options

The key differences between Options 1 and 2 are the number and arrangement of primary shallow wetlands, with the additional difference of pond B1 connecting to the existing ponds below in Option 2. In either option, pond B1 could initially be disconnected, and if it did not function well, it could be connected to the lower ponds as a later phase (requires deeper excavation).

The main benefit of Option 1 in comparison to Option 2 is that it creates greater total shallow wetland area by fully utilizing the space along the existing watercourse. However, there is a risk associated with this arrangement as the expected water level difference between ponds A2, A3, and A4 is significant (greater than 1 m) over a relatively short horizontal distance. As a result, seepage between these ponds is an important consideration as there is a risk of draining the upper ponds due to the large head difference. Option 2 reduces this risk by removing ponds A3 and A4 and replacing them with potential minor channel improvements (widening, planting, LWD). The seepage from A3 and A4 was evaluated by Piteau (refer to Appendix C), as these ponds have the greatest head difference over a relatively short distance. Based on Piteau's assessment, seepage from A3 is expected to be slightly greater than lateral inflow and seepage from pond A2; however, the small difference in outflow and inflow is expected to be offset by vertical upward flow from the aquifer. This concludes that seepage for both options is acceptable for wetland performance.

Option 2 also incorporates a variable depth wetland in place of shallow wetland A5. This feature takes advantage of the relatively flat groundwater surface in this location and creates a pond with a greater variety of habitat, which may be useful to further increase understanding of habitat success in the drawdown zone.

With respect to timing of inundation, the two options share some of the same features (A1, A2, D1). However, Option 1 has a greater number of primary tiered shallow wetlands located higher in elevation (A3-A4), and the disconnected B1 pond in Option 1 has a higher ground level, which limits inundation. Due to this, Option 1 has a greater area of habitat with delayed inundation than Option 2.

At the interim stage of feasibility design, Option 2 was preferred as it reduced the risk of draining the upper shallow wetlands due to seepage. However, the hydrogeological analysis concluded that seepage between the shallow ponds is expected to be offset by groundwater inflows, indicating that the upper ponds will not be drained by the lower shallow ponds. Based on this assessment, Option 1 is preferred as it creates the largest amount of habitat and has additional habitat at higher elevations that will be inundated less often. Alternatively, components of Options 1 and 2 could be combined and adjusted as desired to create a preferred hybrid option that includes the best components of each. This could include reducing the scope of works at lower elevations that are significantly impacted by inundation, selecting components that provide the best value for cost, or changing the arrangement and design of features to optimize the creation of diverse habitat.

5.6 Phasing and Implementation

As mentioned previously, phasing of construction is recommended to observe the performance of wetlands in smaller initial areas (those most likely to succeed) prior to expanding the scale of the works. Following initial phases, the later phases could be initiated after a period of monitoring (potentially 1-2 years) that showed successful habitat. The monitoring of the first phase would allow for adjustments to be made to the design of later phases based on lessons learned or observed success.

Below is a general outline for potential phasing, noting that this can be adjusted as desired.

1. **Phase 1:** This could include one or two of the upper primary shallow wetlands (A1 and A2), as they are viewed as being the most likely to succeed. A small portion of mound C2 could be constructed with excavated material and planted. In addition, phase 1 could include a small trial RCG cardboard-staking area (smaller than shown on the drawings) to test the success of this method before it is applied to a larger area.
2. **Phase 2:** The second phase could include construction of the disconnected secondary shallow wetland (B1) and additional shallow primary wetlands, depending on monitoring conclusions. Initially, B1 could be disconnected to assess the success of such a feature. The remainder of mound C2 and part of C3 would be completed with the excavated material and planted. Based on the RCG trial with cardboard and staking, RCG suppression could be expanded to a larger area or altered to try a different technique if it was unsuccessful. During this phase, the deep waterfowl pond (D1) could also be constructed, or it could be deferred to phase 3 (assumed construction in Phase 3 for the purposes of the cost estimate).
3. **Phase 3:** The third phase could connect disconnected wetland B1 to the lower gravel ponds, if the disconnected pond did not function well during the monitoring period. In addition, this phase could include construction of the deep waterfowl pond (D1), the remainder of mound C3, and mound C1. If D1 was constructed in phase 2, phase 3 could connect this wetland to the gravel excavation ponds and these ponds to the reservoir. Alternatively, the swale to connect D1, the gravel ponds, and the reservoir could be completed as Phase 4.

5.7 Construction Timing and Access

Access

Construction access is expected to be from the existing dirt road that leads towards the reservoir off Robazzo Road. Access routes and construction storage would avoid the archaeological site to the west of the dirt road. Access would avoid the vegetated wetland area wherever possible, particularly the high value habitat that already exists along the natural drainage above the proposed works.

Trafficability is somewhat dependent on the water level at the time of construction, and the largest concern for trafficability is soft saturated material in the existing slough. Equipment may need to use granular borrow material or swamp pads / logs to create a working surface as they move over these areas.

Timing

Construction timing will need to consider reservoir elevation and site inundation, snow cover, site soil saturation, as well as environmental considerations. It was noted that the spring season is important for bird nesting and is the highest value habitat window. During site investigations, the project team and BC Hydro discussed a potential construction window of late winter, once the site is free of snow. Alternatively, the fall could be considered for construction, once reservoir levels have decreased sufficiently to have access to the site. Existing sedges and trees in the project footprint will be salvaged prior to construction, and if the construction window selected is late winter, the plants for salvage will need to be flagged in the fall.

5.8 Considerations for Detailed Design

The following are items that may be considered in detailed design:

- Public amenities and changes to the design based on stakeholder input;
- Revised excavation depths based on continued monitoring of groundwater and Burton Creek;
- Based on groundwater levels throughout the year, refine excavation depths to have the targeted water levels during habitat windows of importance;
- Detailed planting plan to be developed by other parties;
- Consideration of potential mitigation measures for salt from highway 6 runoff; and
- Determination of preferred construction timing window.

6. Class C Construction Cost Opinion

Based on the feasibility 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 25-40% accuracy, though this level of accuracy is not guaranteed.

This Class C construction cost opinion has been prepared with limited site 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 feasibility and detailed design, BC Hydro requires a construction cost estimate of +50%/-15%. A 30% contingency on the construction cost is included in the estimate, and the costs have erred on the conservative side in accordance with BC Hydro's requested +50/-15% estimate range.

The feasibility design proposes the construction of a series of varied habitat features, which can be combined in phases to evaluate the effectiveness of the design prior to completion of the entire proposed works. Two Class C construction cost opinions have been prepared for each design option, with consideration for three phases of construction. Due to the relatively small scale of phase 1, the mobilization/demobilization and the allowance for engineering review, environmental monitoring, and documentation during construction are proportionally increased in comparison to phases 2 and 3 (3% vs. 1.5% and 50% vs. 20% of construction costs respectively). These allowances are different because the level of effort is expected to be proportionally higher for phase 1 and some construction costs do not scale down. Planting costs are an allowance developed in discussion with LGL assuming vegetation salvage, which will be revised once a detailed planting plan is developed. Following detailed design, a construction cost estimate should be prepared for engineering review, environmental monitoring, documentation, and planting once the phases and scope of construction are known with certainty.

Option 1 and 2 and the estimated costs for the three phases are summarized in Tables 6-3 and 6-4 respectively. The breakdown of the costs per component are presented in Tables 6-1 and 6-2.

The cost estimates for the two design options are slightly greater than the estimate provided in the 2016 Concept Design Report ($1,032,630); however, the proposed feasibility design requires excavation to access groundwater rather than berm construction as originally proposed, due to the limited surficial runoff on site. In addition, the project includes the reed canary grass trial area, which was not considered in the original concept.

If BC Hydro wishes to reduce costs, the following options could be considered:

- Reduce the size of the RCG trial area, or explore the possibility of completing these works with community volunteers if there is interest.
- Reduce the scale of some of the larger works (AD1, D1, B1) to reduce excavation and mound construction costs.
- Evaluate the habitat benefits in relation to inundation frequency to determine if the cost of investment is worth the value provided for lower features (D1 in particular, though also relevant for A5, A6, B1, and AD1).

Class 'C'
Table 6-1: Option 1 Component Cost Estimates

Item	Description	Unit	Estimated Quantity	Unit Rate	TOTAL PRICE $	Comment
1	**Wetland Outlets**					
1.01	Logs	each	2	150	300	0.5m D, 6m L, = **1.2 m³**, $125/m³
1.02	Logs with Rootwads	each	3	213	639	0.5m D, 6m L, = **1.7 m³**, $125/m³
1.03	Boulders	m³	6	50	300	
1.04	Excavation/Placement/Compaction	days	1	3639	3,639	
1.05	Outlet armouring	m³	9	60	540	0.3 m depth, 6 m length, 5 m channel width
	SUBTOTAL FOR COMPONENT				**5,418**	
2	**Primary Pond A1**					
2.01	Excavation, clearing, grubbing, and stockpiling	m³	704	8.5	5,984	Includes part of the hauling costs
2.02	Wetland Outlet	each	1	5,418	5,418	
2.02	Habitat Log Supply & Placement	each	2	1,123	2,246	
2.03	Marsh Planting Allowance	m²	355	1.5	533	Salvage and transplant vegetation, above wetted area only
2.04	Inlet armouring	m³	9	60	540	0.3 m depth, 6 m length, 5 m channel width
	SUBTOTAL FOR COMPONENT				**14,720**	
3	**Primary Pond A2**					
3.01	Excavation, clearing, grubbing, and stockpiling	m³	1,134	8.5	9,639	Includes part of the hauling costs
3.02	Wetland Outlet	each	1	5,418	5,418	
3.03	Habitat Log Supply & Placement	each	3	1,123	3,368	
3.04	Marsh Planting Allowance	m²	390	1.5	585	Salvage and transplant vegetation, above wetted area only
3.05	Inlet armouring	m³	9	60	540	0.3 m depth, 6 m length, 5 m channel width
	SUBTOTAL FOR COMPONENT				**19,551**	
4	**Primary Pond A3**					
4.01	Excavation	m³	1,922	8.5	16,337	Includes part of the hauling costs
4.02	Wetland Outlet	each	1	5,418	5,418	
4.03	Habitat Log Supply & Placement	each	3	1,123	3,368	
4.04	Marsh Planting Allowance	m²	752	1.5	1,128	Salvage and transplant vegetation, above wetted area only
4.05	Inlet armouring	m³	9	60	540	0.3 m depth, 6 m length, 5 m channel width
	SUBTOTAL FOR COMPONENT				**26,792**	
5	**Primary Pond A4**					
5.01	Excavation, clearing, grubbing, and stockpiling	m³	2,217	8.5	18,845	Includes part of the hauling costs
5.02	Wetland Outlet	each	1	5,418	5,418	
5.03	Habitat Log Supply & Placement	each	2	1,123	2,246	
5.04	Marsh Planting Allowance	m²	1,073	1.5	1,610	Salvage and transplant vegetation, above wetted area only
5.05	Inlet armouring	m³	9	60	540	0.3 m depth, 6 m length, 5 m channel width
	SUBTOTAL FOR COMPONENT				**28,658**	
6	**Primary Pond A5**					
6.01	Excavation, clearing, grubbing, and stockpiling	m³	2,161	8.5	18,369	Includes part of the hauling costs
6.02	Wetland Outlet	each	1	5,418	5,418	
6.03	Habitat Log Supply & Placement	each	2	1,123	2,246	
6.04	Marsh Planting Allowance	m²	1,090	1.5	1,635	Salvage and transplant vegetation, above wetted area only
6.05	Inlet armouring	m³	9	60	540	0.3 m depth, 6 m length, 5 m channel width
	SUBTOTAL FOR COMPONENT				**28,207**	
7	**Primary Pond A6**					
7.01	Excavation, clearing, grubbing, and stockpiling	m³	3,300	8.5	28,050	Includes part of the hauling costs
7.02	Wetland Outlet	each	1	5,418	5,418	
7.03	Habitat Log Supply & Placement	each	2	1,123	2,246	
7.04	Marsh Planting Allowance	m²	1,708	1.5	2,562	Salvage and transplant vegetation, above wetted area only
7.05	Inlet armouring	m³	9	60	540	0.3 m depth, 6 m length, 5 m channel width
	SUBTOTAL FOR COMPONENT				**38,816**	
8	**Secondary Wetland B1**					
8.01	Excavation, clearing, grubbing, and stockpiling	m³	7,599	8.5	64,592	Includes part of the hauling costs
8.02	Wetland Outlet	m³	0	5,418	0	
8.03	Habitat Log Supply & Placement	each	2	1,123	2,246	
8.04	Marsh Planting Allowance	m²	2,812	1.5	4,218	Salvage and transplant vegetation, above wetted area only
	SUBTOTAL FOR COMPONENT				**71,055**	
9	**Deep Waterfowl Pond D1**					
9.01	Excavation, clearing, grubbing, and stockpiling	m³	16,224	8.5	137,904	Includes part of the hauling costs
9.02	Wetland Outlet	each	2	5,418	10,836	Outlet to reservoir and to existing pond
9.03	Habitat Log Supply & Placement	each	0	1,123	0	
9.04	Marsh Planting Allowance	m²	0	1.5	0	Assumes no plantings at this elevation
9.05	Inlet armouring	m³	9	60	540	0.3 m depth, 6 m length, 5 m channel width
	SUBTOTAL FOR COMPONENT				**149,280**	
10	**Habitat and Planting Mound C1**					
10.01	Material Placement and Compaction	m³	8,980	9.5	85,310	Assumes no plantings at this elevation. Includes part of the hauling costs
10.02	Habitat Log Supply & Placement	each	2	1,123	2,246	
10.03	Mound Staking Allowance	m²	380	2.0	760	Includes scraping RCG sod, collecting cuttings, and staking assuming 0.5m spacing. Top of mound only.
10.04	Marsh Planting Allowance	m²	1,657	1.5	2,486	Salvage & transplant vegetation, 40% of mound slopes only. Mechanically assisted salvage.
	SUBTOTAL FOR COMPONENT				**90,801**	
11	**Habitat and Planting Mound C2**					
11.01	Material Placement and Compaction	m³	7,429	9.5	70,576	Includes part of the hauling costs
11.02	Habitat Log Supply & Placement	each	5	1,123	5,614	
11.03	Mound Staking Allowance	m²	3,520	2.0	7,040	Includes scraping RCG sod, collecting cuttings, and staking assuming 0.5m spacing. Top of mound only.
11.04	Marsh Planting Allowance	m²	1,780	1.5	2,669	Salvage & transplant vegetation, 40% of mound slopes only. Mechanically assisted salvage.
	SUBTOTAL FOR COMPONENT				**85,899**	
12	**Habitat and Planting Mound C3**					
12.01	Material Placement and Compaction	m³	19,819	9.5	188,281	Includes scraping RCG & cardboard staking (0.5 m spacing). Assumes cardboard is donated and cuttings are collected.
12.02	Habitat Log Supply & Placement	each	2	1,123	2,246	
12.03	Mound Staking Allowance	m²	8,330	2.0	16,660	Includes scraping RCG sod, collecting cuttings, and staking assuming 0.5m spacing. Top of mound only.
12.04	Marsh Planting	m²	2,118	1.5	3,176	Salvage & transplant vegetation, 40% of mound slopes only. Mechanically assisted salvage.
	SUBTOTAL FOR COMPONENT				**210,363**	
13	**Deep Waterfowl Pond Connection to Existing Pond & Reservoir**					
13.01	Excavation	m³	1,680	8.5	14,280	Assumes no plantings at this elevation. Includes part of the hauling costs.
	SUBTOTAL FOR COMPONENT				**14,280**	
14	**Reed Canary Grass Cardboard-Staking**					
14.01	Reed Canary Grass Cardboard-Staking Allowance	m²	4,417	2.5	11,043	Includes scraping RCG & cardboard staking (0.5 m spacing). Assumes cardboard is donated and cuttings are collected.
	SUBTOTAL FOR COMPONENT				**11,043**	

Note: Estimates have been prepared with little or no site information and as such indicates the approximate magnitude of the cost of the capital tasks, for project planning purposes only. The estimate has been derived from unit costs for similar projects.

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Class 'C'
Table 6-2: Option 2 Component Cost Estimates

Item	Description	Unit	Estimated Quantity	Unit Rate	TOTAL PRICE $	Comment
1	**Wetland Outlets**					
1.01	Logs	each	2	150	300	0.5m D, 6m L, = **1.2 m³**, $125/m³
1.02	Logs with Rootwads	each	3	213	639	0.5m D, 6m L, = **1.7 m³**, $125/m³
1.03	Boulders	m³	6	50	300	
1.04	Excavation/Placement/Compaction	days	1	3639	3,639	
1.05	Outlet armouring	m³	9	60	540	0.3 m depth, 6 m length, 5 m channel width
	SUBTOTAL FOR COMPONENT				**5,418**	
2	**Primary Pond A1**					
2.01	Excavation, clearing, grubbing, and stockpiling	m³	704	8.5	5,984	Includes part of the hauling costs
2.02	Wetland Outlet	each	1	5,418	5,418	
2.02	Habitat Log Supply & Placement	each	2	1,123	2,246	
2.03	Marsh Planting Allowance	m²	355	1.5	533	Salvage and transplant vegetation, above wetted area only
2.04	Inlet armouring	m³	9	60	540	0.3 m depth, 6 m length, 5 m channel width
	SUBTOTAL FOR COMPONENT				**14,720**	
3	**Primary Pond A2**					
3.01	Excavation, clearing, grubbing, and stockpiling	m³	1,134	8.5	9,639	Includes part of the hauling costs
3.02	Wetland Outlet	each	1	5,418	5,418	
3.03	Habitat Log Supply & Placement	each	3	1,123	3,368	
3.04	Marsh Planting Allowance	m²	390	1.5	585	Salvage and transplant vegetation, above wetted area only
3.05	Inlet armouring	m³	9	60	540	0.3 m depth, 6 m length, 5 m channel width
	SUBTOTAL FOR COMPONENT				**19,551**	
4	**Primary Pond AD1**					
4.01	Excavation, clearing, grubbing, and stockpiling	m³	5,943	8.5	50,516	Includes part of the hauling costs
4.02	Wetland Outlet	each	1	5,418	5,418	
4.03	Habitat Log Supply & Placement	each	2	1,123	2,246	
4.04	Marsh Planting Allowance	m²	1,699	1.5	2,549	Salvage and transplant vegetation, above wetted area only
4.05	Inlet armouring	m³	9	60	540	0.3 m depth, 6 m length, 5 m channel width
	SUBTOTAL FOR COMPONENT				**61,268**	
5	**Secondary Shallow Wetland B1**					
5.01	Excavation, clearing, grubbing, and stockpiling	m³	7,856	8.5	66,776	Channel connecting to existing lower pond not included. Includes part of the hauling costs
5.02	Wetland Outlet	m³	0	5,418	0	
5.03	Habitat Log Supply & Placement	each	2	1,123	2,246	
5.04	Marsh Planting Allowance	m²	3,297	1.5	4,946	Salvage and transplant vegetation, above wetted area only
5.05	Inlet armouring	m³	9	60	540	0.3 m depth, 6 m length, 5 m channel width
	SUBTOTAL FOR COMPONENT				**74,507**	
6	**Deep Waterfowl Pond D1**					
6.01	Excavation, clearing, grubbing, and stockpiling	m³	16,224	8.5	137,904	Includes part of the hauling costs
6.02	Wetland Outlet	each	2	5,418	10,836	Outlet to reservoir and to existing pond
6.03	Habitat Log Supply & Placement	each	0	1,123	0	
6.04	Marsh Planting Allowance	m²	0	1.5	0	Assumes no plantings at this elevation.
6.05	Inlet armouring	m³	9	60	540	0.3 m depth, 6 m length, 5 m channel width
	SUBTOTAL FOR COMPONENT				**149,280**	
7	**Habitat and Planting Mound C1**					
7.01	Material Placement and Compaction	m³	8,980	9.5	85,310	Includes part of the hauling costs
7.02	Habitat Log Supply & Placement	each	2	1,123	2,246	
7.03	Mound Staking Allowance	m²	230	2.0	460	Includes scraping RCG sod, collecting cuttings, and staking assuming 0.5m spacing. Top of mound only.
7.04	Marsh Planting Allowance	m²	1,498	1.5	2,246	Salvage & transplant vegetation, 40% of mound slopes only. Mechanically assisted salvage
	SUBTOTAL FOR COMPONENT				**90,262**	
8	**Habitat and Planting Mound C2**					
8.01	Material Placement and Compaction	m³	7,429	9.5	70,576	Includes part of the hauling costs
8.02	Habitat Log Supply & Placement	each	5	1,123	5,614	
8.03	Mound Staking Allowance	m²	3,560	2.0	7,120	Includes scraping RCG sod, collecting cuttings, and staking assuming 0.5m spacing. Top of mound only.
8.04	Marsh Planting Allowance	m²	1,783	1.5	2,675	Salvage & transplant vegetation, 40% of mound slopes only. Mechanically assisted salvage
	SUBTOTAL FOR COMPONENT				**85,984**	
9	**Habitat and Planting Mound C3**					
9.01	Material Placement and Compaction	m³	19,820	9.5	188,290	Includes part of the hauling costs
9.02	Habitat Log Supply & Placement	each	2	1,123	2,246	
9.03	Mound Staking Allowance	m²	8,330	2.0	16,660	At top of mound
9.04	Marsh Planting Allowance	m²	1,974	1.5	2,960	Salvage & transplant vegetation, 40% of mound slopes only. Mechanically assisted salvage
	SUBTOTAL FOR COMPONENT				**210,156**	
10	**Deep Waterfowl Pond Connection to Existing Pond & Reservoir**					
10.01	Excavation	m³	1,680	9.5	15,960	Assumes no plantings at this elevation. Includes part of the hauling costs
	SUBTOTAL FOR COMPONENT				**15,960**	
11	**Secondary Shallow Wetland Connection to Existing Pond**					
11.01	Excavation	m³	1,792	9.5	17,024	Assumes no plantings at this elevation. Includes part of the hauling costs
	SUBTOTAL FOR COMPONENT				**17,024**	
12	**Reed Canary Grass Cardboard-Staking**					
12.01	Reed Canary Grass Cardboard-Staking Allowance	m²	4,417	2.5	11,043	Includes scraping RCG & cardboard staking (0.5 m spacing). Assumes cardboard is donated and cuttings are collected.
	SUBTOTAL FOR COMPONENT				**11,043**	

Note: Estimates have been prepared with little or no site information and as such indicates the approximate magnitude of the cost of the capital tasks, for project planning purposes only. The estimate has been derived from unit costs for similar projects.

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Class 'C'
Table 6-3: Option 1 Construction Cost Estimate

Item	Description	Unit	Estimated Quantity	Unit Rate	TOTAL PRICE $	Comment
1	**Phase 1**					
1.01	*Mobilization and demobilization*	LS	1	3.0%	1,747	% of construction items
1.02	*Sediment and water control allowance*	LS	1	5.0%	2,912	% of construction items
1.03	*Quality control (testing and construction survey)*	LS	1	5.0%	2,912	% of construction items
1.04	*Bonding and insurance*	LS	1	2.0%	1,165	% of construction items
1.05	Primary Pond A1	each	1	14,720	14,720	
1.06	Primary Pond A2	each	1	19,551	19,551	
1.07	25% of Habitat and Planting Mound C2	each	25%	85,899	21,475	
1.08	Reed Canary Grass Cardboard-Staking Allowance	m²	1000	2.5	2,500	25% of the trial area
1.09	*Engineering Review, Environmental Monitoring & Completion Documentation Allowance*	LS	1	50%	33,491	% allowance of construction including general LS % items
1.10	*Contingencies*	LS	1	30%	30,142	% of all items
	SUBTOTAL FOR PHASE 1				**131,000**	rounded to nearest $1,000
2	**Phase 2**					
2.01	*Mobilization and demobilization*	LS	1	1.5%	5,838	% of construction items
2.02	*Sediment and water control allowance*	LS	1	5.0%	19,458	% of construction items
2.03	*Quality control (testing and construction survey)*	LS	1	5.0%	19,458	% of construction items
2.04	*Bonding and insurance*	LS	1	2.0%	7,783	% of construction items
2.05	Secondary Wetland B1	each	1	71,055	71,055	
2.06	75% of Habitat and Planting Mound C2	each	75%	85,899	64,424	
2.07	Primary Pond A3	each	1	26,792	26,792	
2.08	Primary Pond A4	each	1	28,658	28,658	
2.09	Primary Pond A5	each	1	28,207	28,207	
2.10	Primary Pond A6	each	1	38,816	38,816	
2.11	60% of Habitat and Planting Mound C3	each	60%	210,363	126,218	
2.12	Reed Canary Grass Cardboard-Staking Allowance	m²	2000	2.5	5,000	Additional area
2.13	*Engineering Review, Environmental Monitoring & Completion Documentation Allowance*	LS	1	20%	88,341	% allowance of construction including general LS % items
2.14	*Contingencies*	LS	1	30%	159,015	% of all items
	SUBTOTAL FOR PHASE 2				**689,000**	rounded to nearest $1,000
3	**Phase 3**					
3.01	*Mobilization and demobilization*	LS	1	1.5%	5,134	% of construction items
3.02	*Sediment and water control allowance*	LS	1	5.0%	17,113	% of construction items
3.03	*Quality control (testing and construction survey)*	LS	1	5.0%	17,113	% of construction items
3.04	*Bonding and insurance*	LS	1	2.0%	6,845	% of construction items
3.05	Deep Waterfowl Pond Connection	each	1	14,280	14,280	
3.06	Deep Waterfowl Pond D1	each	1	149,280	149,280	
3.07	40% of Habitat and Planting Mound C3	each	40%	210,363	84,145	
3.08	Habitat and Planting Mound C1	each	1	90,801	90,801	
3.09	Reed Canary Grass Cardboard-Staking Allowance	each	1500	2.5	3,750	Additional area
3.10	*Engineering Review, Environmental Monitoring & Completion Documentation Allowance*	LS	1	20%	77,692	% allowance of construction including general LS % items
3.11	*Contingencies*	LS	1	30%	139,846	% of all items
	SUBTOTAL FOR PHASE 3				**606,000**	rounded to nearest $1,000
						Additional area
	TOTAL AMOUNT (excl. GST)				**1,426,000**	**rounded to nearest $1,000**

Note: Estimates have been prepared with little or no site information and as such indicates the approximate magnitude of the cost of the capital tasks, for project planning purposes only. The estimate has been derived from unit costs for similar projects.

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Class 'C'
Table 6-4: Option 2 Construction Cost Estimate

Item	Description	Unit	Estimated Quantity	Unit Rate	TOTAL PRICE $	Comment
1	**Phase 1**					
1.01	*Mobilization and demobilization*	LS	1	3.0%	1,748	% of construction items
1.02	*Sediment and water control allowance*	LS	1	5.0%	2,913	% of construction items
1.03	*Quality control (testing and construction survey)*	LS	1	5.0%	2,913	% of construction items
1.04	*Bonding and insurance*	LS	1	2.0%	1,165	% of construction items
1.05	Primary Pond A1	each	1	14,720	14,720	
1.06	Primary Pond A2	each	1	19,551	19,551	
1.07	25% of Habitat and Planting Mound C2	each	25%	85,984	21,496	
1.08	Reed Canary Grass Cardboard-Staking Allowance	m²	1000	2.5	2,500	25% of the trial area
1.09	*Engineering Review, Environmental Monitoring & Completion Documentation Allowance*	LS	1	50%	33,504	% allowance of construction including general LS % items
1.10	*Contingencies*	LS	1	30%	30,153	% of all items
	SUBTOTAL FOR PHASE 1				**131,000**	rounded to nearest $1,000
2	**Phase 2**					
2.01	*Mobilization and demobilization*	LS	1	1.5%	4,340	% of construction items
2.02	*Sediment and water control allowance*	LS	1	5.0%	14,466	% of construction items
2.03	*Quality control (testing and construction survey)*	LS	1	5.0%	14,466	% of construction items
2.04	*Bonding and insurance*	LS	1	2.0%	5,787	% of construction items
2.05	Secondary Wetland B1	each	1	74,507	74,507	
2.06	75% of Habitat and Planting Mound C2	each	75%	85,984	64,488	
2.07	Primary Pond AD1	each	1	61,268	61,268	
2.08	40% of Habitat and Planting Mound C3	each	40%	210,156	84,062	
2.09	Reed Canary Grass Cardboard-Staking Allowance	m²	2000	2.5	5,000	Additional area
2.10	*Engineering Review, Environmental Monitoring & Completion Documentation Allowance*	LS	1	20%	65,677	% allowance of construction including general LS % items
2.11	*Contingencies*	LS	1	30%	118,218	% of all items
	SUBTOTAL FOR PHASE 2				**512,000**	rounded to nearest $1,000
3	**Phase 3**					
3.01	*Mobilization and demobilization*	LS	1	1.5%	5,796	% of construction items
3.02	*Sediment and water control allowance*	LS	1	5.0%	19,321	% of construction items
3.03	*Quality control (testing and construction survey)*	LS	1	5.0%	19,321	% of construction items
3.04	*Bonding and insurance*	LS	1	2.0%	7,728	% of construction items
3.05	Deep Waterfowl Pond Connection	each	1	15,960	15,960	
3.06	Secondary Shallow Wetland Pond Connection	each	1	17,024	17,024	
3.07	Deep Waterfowl Pond D1	each	1	149,280	149,280	
3.08	Habitat and Planting Mound C1	each	1	90,262	90,262	
3.09	60% of Habitat and Planting Mound C3	each	60%	210,156	126,094	
3.10	Reed Canary Grass Cardboard-Staking Allowance	each	1500	2.5	3,750	Additional area
3.11	*Engineering Review, Environmental Monitoring & Completion Documentation Allowance*	LS	1	20%	90,907	% allowance of construction including general LS % items
3.12	*Contingencies*	LS	1	30%	163,633	% of all items
	SUBTOTAL FOR PHASE 3				**709,000**	rounded to nearest $1,000
	TOTAL AMOUNT (excl. GST)				**1,352,000**	**rounded to nearest $1,000**

Note: Estimates have been prepared with little or no site information and as such indicates the approximate magnitude of the cost of the capital tasks, for project planning purposes only. The estimate has been derived from unit costs for similar projects.

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7. Operation, Maintenance, and Monitoring

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

Operation and maintenance requirements for the design are expected to include:

- Periodic inspection of physical works (outlets, mounds, etc.).
- Potential sediment removal if required for wetland function.
- Periodic environmental monitoring to assess the success of the habitat creation.
- Repair of damage to physical works that may be noted during inspections.

A formal access route will not be included in an effort to maintain a more 'natural' site.

During the phased construction, inspections should occur annually to evaluate the success of the initial phases. Following completion of the full works, inspections should continue to occur annually for the first 5 years, and then less frequently (perhaps every 2 to 5 years) depending on function and recommendations at that time. The goals of inspections are to assess the integrity of engineering works and the success of habitat creation. As the design focuses on creating naturalized structures, the amount of engineering inspection required is minimal. The physical works will require inspection to assess if there is any deterioration or damage to:

- Mound crest and slopes (slumping, erosion from wave action, cracking, vegetation success, RCG suppression success),
- Erosion protection (loss of rock, settlement, slumping, wave damage, vegetation or soil loss for potential bioengineering approaches),
- Outlet control structures (inlet and outlets, structure, deterioration, sediment build up), and
- Wetland side slopes and habitat logs (slumping, wood loss, vegetation),
- Reed Canary Grass suppression trials.

Inspection requirements to monitor success of habitat creation should be developed with project biologists (LGL and BC Hydro).

Maintenance is expected to be minimal for the proposed physical works, with the main focus being the outlet structures, as minor damage to mounds and the ponds is not a significant concern. To support inspection and maintenance, these items will be developed further during the design.

8. Conclusion

KWL prepared feasibility design for the Burton Flats Wildlife Enhancement Program 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 create a mixture of shallow and deep wetland habitat in the drawdown zone of the Lower Arrow Lakes Reservoir. The proposed site on Burton flats slopes gently north and northwest towards the reservoir, with some old gravel mining pits that currently serve as habitat at low elevations. An existing slough/watercourse runs along the site parallel to Highway 6, which is fed by shallow subsurface flow from Burton Creek. As the amount of surficial runoff reaching the site is minimal, the design utilizes the high groundwater levels at the site, which already come to surface in several areas. Three piezometers and one surface water gauge were installed during site investigation to monitor groundwater conditions on site and Burton Creek water levels.

The feasibility design proposes the construction of a series of habitat features, which can be combined in phases to evaluate the effectiveness of the design and habitat establishment prior to completion of the entire proposed works. The design focuses on excavation of wetlands to reach the groundwater surface, rather than berms as was originally proposed in the 2016 Concept Design Report, due to limited surface water availability. Two options were developed which included variations on the main design features shown below:

- Primary shallow tiered wetlands along the existing watercourse
- A secondary shallow disconnected wetland
- Habitat and planting mounds constructed (from excavated material) to full pool elevation
- A deep waterfowl pond at the lower end of the tiered wetlands
- A Reed Canary Grass trial removal area to test suppression techniques
- Drainage channels to connect the above wetlands to the existing gravel pond and the reservoir

The total footprint of the proposed works is 5.7 to 6.1 ha. The full design would retain a total 10,000-12,000 m^3 of water, and create 1.4-1.7 ha of wetland area (wetted surface). The deep waterfowl pond may be considered a dam by regulators due to the large volume; however, given the excavated and simple nature of the pond, it could be exempt. Hydrologic and hydrogeologic analyses support that there is sufficient available groundwater for the wetlands from Burton Creek, though further monitoring is recommended.

A construction cost opinion was prepared based on the feasibility design for each design option, including a potential three-phase approach to construction. The cost estimate is minimally higher than the 2016 Concept Design Report estimate; however, the project includes additional components not originally considered and cost saving options have been included for BC Hydro's consideration.

Following feasibility design, BC Hydro plans to undertake stakeholder consultation. Detailed design will consider the inputs from public consultation, BC Hydro review, and operation and maintenance requirements to further refine the preferred design option based on ongoing groundwater and surface water monitoring and project objectives.

Report Submission

This document has been prepared in draft for BC Hydro's review prior to proceeding with the detailed design of the Burton Flats habitat improvement works. Please contact the undersigned with any questions or comments.

Prepared by:

KERR WOOD LEIDAL ASSOCIATES LTD.KERR WOOD LEIDAL ASSOCIATES LTD.

Prepared by:

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 PROVINCE S.F. JOYCE 27627 BRITISH COLUMBIA ENGINEER

August 30, 2017

Allison Matfin, EIT
Junior Environmental Engineer

Stefan Joyce, PEng
Hydrotechnical Engineer/Project Manager

Reviewed by:

Peter Fearon, PEng
Technical Reviewer

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 Wildlife Enhancement Program at Burton Flats. 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.

Copyright Notice

Revision History

Revision #	Date	Status	Revision	Author
0	Aug. 29, 2017	Final	Final Feasibility Design Report	ARM/SFJ
A	July 28, 2017	Draft	Draft for BC Hydro Review	ARM/SFJ

OQM | Organizational Quality Management Program

Appendix A

Geotechnical Report
(Thurber Engineering Ltd.)

THURBER ENGINEERING LTD.

celebrating 60 YEARS

BURTON FLATS WILDLIFE ENHANCEMENT PROJECT
GEOTECHNICAL INVESTIGATION

Report

to

Kerr Wood Leidal

PROFESSIONAL ENGINEER PROVINCE OF BRITISH COLUMBIA S. M. BEAN Aug 28/17

Stephen M. Bean, M.Eng., P. Eng.
Review Principal

PROFESSIONAL ENGINEER PROVINCE OF BRITISH COLUMBIA M. E. WOYTIUK # 36178 August 28, 2017

Date: August 28, 2017
File: 17216

Melanie E. Woytiuk, M. Eng., P.Eng.
Project Engineer

THURBER

60 YEARS

TABLE OF CONTENTS

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 Burton Flats Wildlife Enhancement project near Burton, BC.

The scope of work was outlined in our proposal letter dated February 9, 2017.

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 Burton Flats site, the focus of this project is detailed in the CLBWORKS 29B report, updated in August 2016.

Based on this document we understand the project is intended to create a series of shallow wetland habitat pools at the location adjacent to Highway 6. The project is highly visible, and wildlife use includes birds, amphibians, reptiles, mammals (bats), insects and fish. While some of the existing human-excavated ponds provide habitat, they are prone to early inundation. These constructed wetlands would provide stable shallow wetland habitat in the Arrow Lake reservoir drawdown zone.

1.3 Concept Description

KWL's concept includes a series of shallow wetlands, habitat and planting mounds, and deeper waterfowl ponds. This work can be phased, if necessary. The shallow wetlands will be 0.3 m to 0.5 m deep, 30 m to 40 m long and 60 m to 80 m wide. Outlets between the shallow wetlands will likely consist of log sills, surrounded by compacted finer grained material and the difference in water level between the ponds will likely be no more than 0.5 m. Habitat and planting mounds will be a few meters high. The waterfowl ponds would be up to 1 m deep.

1.4 Scope

The scope of our work was outlined in a letter dated February 9, 2017, and consisted of the following tasks:

- Review available geotechnical information and provide input into the initial design basis report being prepared by KWL.
- A geotechnical investigation consisting of about 5 test pits to a maximum depth of about 4 m to collect samples for moisture content determination, visual identification and grain size analysis/Atterberg Limits testing (as required).
- Provide a preliminary memo outlining the geotechnical investigation and preliminary findings.
- Assess the soils and substrate for material construction suitability, loading, and seepage considerations as well as control structure foundation as they apply to the design options.
- Provide input into the hazard log regarding potential risks during and post-construction.
- Preparation of a geotechnical report finalized once a review by KWL and BC Hydro has been completed.

An allowance to complete additional seepage analysis was included if required as part of the detailed design phase of the project.

2. METHODOLOGY

The geotechnical investigation was completed under a Safety Management Plan prepared by Kerr Wood Leidal and an existing BC Hydro Permission Land Use Policy. 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 six test pits were excavated on May 5, 2017, using an excavator operated by Crescent Bay Construction Ltd. of Nakusp, BC. The test pits were terminated at depths between 1.1 m and 3.3 m. Test pits were backfilled with bucket packed excavated material, and standpipe piezometers were installed in TP17-1, TP17-5, and TP17-6. These standpipes consisted of 50 mm PVC pipe with the lower 1.5 m hand-slotted immediately before installation.

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 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 site is relatively flat and covered in grasses with intermittent stands of trees and shrubs. The area is bounded to the north by Arrow Lake, to the east/southeast by Highway 6 and to the west/southwest by a tree covered topographical high. Highway 6 is constructed on embankment fill about 5 m high which is heavily riprapped. The limited topographical relief that does occur on the site is consistent with an alluvial environment, and standing water was evident in the lowest areas.

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.

At all the test pits locations except TP17-6, organic topsoil was encountered at surface ranging from 0.2 m to 0.6 m in thickness. This material is generally moist and contained significant amounts of organics and rootlets. At TP17-1, TP17-3, TP17-4 and TP17-5 the topsoil was underlain by loose to compact, moist sand with some silt to silty sand. This unit ranged in thickness from 0.3 m to 0.8 m and, two gradation analyses suggested fines content of 15% and 23%. At all the test pits, these layers, if present, were underlain by loose to compact poorly graded sand, gravel and sand, or gravel. Cobbles were often present. Sand is typically medium to coarse grained, and gravel is sub-round to round.

Woody debris was encountered at a depth of 0.9 m at TP17-6, and black staining on gravel pieces consistent with a fire was noted at a depth of 1.0 m at TP17-4. This suggests that the alluvial environment was relatively active recently.

3.3 Groundwater Conditions

Free water was encountered at all the test pit locations during excavation except at TP17-1. Free water was encountered at depths ranging from 2.2 m to 0.8 m below surface. As noted earlier, standing water was apparent at surface in topographically low areas. Piezometers were installed in three of the test pits (TP17-1, TP17-5 and TP17-6) and will be monitored by KWL on an on-going basis, as part of a larger assessment of surface and groundwater flow.

4. GEOTECHNICAL DISCUSSION

4.1 General

KWL's concept includes the following:

- A series of shallow wetlands 0.3 m to 0.5 m deep, 30 m to 40 m long and 60 m to 80 m wide.
- Outlets between the shallow wetlands will likely consist of log sills, surrounded by compacted finer grained material and the difference in water level between the ponds will likely be no more than about 1.5 m. We anticipate the log sills will consist of relatively large (i.e. greater than 0.3 m in diameter) logs being stacked 3 or 4 logs high and buried at outlet locations.
- A few habitat and planting mounds that will be a few meters high.
- Deep waterfowl ponds would be up to 1 m deep that take advantage of previously human-excavated areas.

We understand that this work may be phased, and successive phases may be modified to take advantage of aspects that were successful.

4.2 Seepage Considerations

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. The anticipated hydraulic gradient is low due to the relatively small difference in water elevation (i.e. 1.5 m or less). Given the low hydraulic gradient, piping is not a concern, and placing the finer grained material available on site (i.e. silty sand) around the log sills will reduce the seepage rate marginally.

4.3 Wetland Excavation

It is assumed that excavated material from the wetlands will be used to construct the habitat mounds. All topsoil, organic material or debris encountered within the wetlands and the habitat mound should be removed and stockpiled for reuse as reclamation material.

Trafficability will be an issue as this is a natural wetland and much the material at surface is in a loose state and saturated. Careful planning of excavation equipment procedures will be required to take advantage of firmer ground or placement of dry granular materials will be required for padding into soft areas.

4.4 Material Placement

Based on the depth of the shallow wetlands, it is anticipated that excavated material from these areas will primarily consist of silty sand or sand with some silt. This material was encountered at depths of around 0.2 m to 1.0 m at TP17-3, TP17-4, and TP17-5. This material should primarily be used as fill around the log sill outlet structures, but any remaining material can be used to construct the habitat mounds. The coarser sands and gravel with little or no fines that are encountered in the shallow or deeper wetlands should be directed to the habitat mounds.

Any oversized material (i.e. cobbles and boulders greater than 150 mm), surficial organic or other deleterious material should be removed before placing the material around the outlet structures or in the habitat mounds. All placed material should be compacted to a minimum of 95% Standard Proctor Maximum Dry Density (SPMDD). The material used to construct the mounds should be placed in lifts no greater than 300 mm thick. We anticipate that working space will be limited near the log sills, and recommend lift thickness be no greater than 200 mm.

Note that compaction specifications do not apply to organic/reclamation material, and we anticipate that some thickness of planting substrate (i.e. stripped and stockpiled organic soils) will be placed loosely over the compacted fill to allow for vegetation growth.

4.5 Slope Stability Considerations

The proposed slope angle for the habitat mound side slopes and wetland cut slopes is 6H:1V or shallower. Given the height of the mounds, depth of the wetlands, proposed construction material, and existing ground conditions, stability is not considered a concern for slopes at this angle and no additional analysis is required.

5. CLOSURE

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

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.

2. COMPLETE REPORT

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.

IN ORDER TO PROPERLY UNDERSTAND THE SUGGESTIONS, RECOMMENDATIONS AND OPINIONS EXPRESSED HEREIN, REFERENCE MUST BE MADE TO THE WHOLE OF THE REPORT. THURBER IS NOT RESPONSIBLE FOR USE BY ANY PARTY OF PORTIONS OF THE REPORT WITHOUT REFERENCE TO THE WHOLE REPORT.

3. BASIS OF REPORT

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.

4. USE OF THE REPORT

The information and opinions expressed in the Report, or any document forming part of the Report, are for the sole benefit of the Client. NO OTHER PARTY MAY USE OR RELY UPON THE REPORT OR ANY PORTION THEREOF WITHOUT THURBER'S WRITTEN CONSENT AND SUCH USE SHALL BE ON SUCH TERMS AND CONDITIONS AS THURBER MAY EXPRESSLY APPROVE. Ownership in and copyright for the contents of the Report belong to Thurber. Any use which a third party makes of the Report, is the sole responsibility of such third party. Thurber accepts no responsibility whatsoever for damages suffered by any third party resulting from use of the Report without Thurber's express written permission.

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. 17216-1

NOTES:

1. Test Pits were located using a hand-held G.P.S. unit; locations are approximate only.
2. Digital base plans provided by Kerr Wood Leidal.

0 20 40 60 80 100 120m

SCALE 1:2000

THURBER ENGINEERING LTD.

KERR WOOD LEIDAL

TEST PIT LOCATION PLAN

BURTON FLATS WILDLIFE ENHANCEMENT PROJECT
GEOTECHNICAL INVESTIGATION

BURTON, B.C.

DESIGNED	DRAWN	APPROVED	DATE	SCALE	PROJECT No.	DWG. NO.	REV.
MEW	RRS	MEW	AUGUST 28, 2017	1:2000	17216	1	-

17216-CAD001.dwg

APPENDIX B

Unified Classification System for Soils (ASTM D2487)

Symbols and Terms used on the Test Pit Logs

Test Pit Logs

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TEST PIT LOGS

TP17-1

DEPTH (m)	DESCRIPTION	SAMPLE DEPTH (m)	USCS	M.C. (%)
0.0 – 0.3	Organic, moist, brown, TOPSOIL. Organics and rootlets encountered.		OL	
0.3 – 0.6	Compact, moist, grey with oxide staining, silty SAND; trace to some clay, low plastic, trace to some rootlets.	0.6	SM	
0.6 – 3.3	Compact, moist, brown GRAVEL and SAND; trace silt, medium to coarse grained sand, gravel rounded. Cobbles encountered. At 1.9 m: some silt, less cobbles. At 2.3 m: Gravel = 56%, Sand = 43%, Fines = 2%	0.8 1.9 2.3 3.2	GP/SP	4.6
3.3	End of Pit -Pit terminated at 3.3 m. -No free water encountered. -Sloughing from below 0.6 m. -Backfilled with excavated material. -50 mm diameter PVC Piezometer installed to base of test pit. Lower 1.5 m hand slotted.			

TP17-2

DEPTH (m)	DESCRIPTION	SAMPLE DEPTH (m)	USCS	M.C. (%)
0.0 – 0.6	Moist, black, organic SILT (Topsoil). Organics and rootlets encountered.	0.3	OL	46.6
0.6 – 2.3	Compact, moist, dark grey GRAVEL and SAND.; trace silt and cobbles encountered.	1.0 2.2	GP/SP	-
2.3	End of Pit -Pit terminated at 2.3 m. -Free water encountered at 2.2 m. -Sloughing from below 0.6 m. -Backfilled with excavated material.			

TP17-3

DEPTH (m)	DESCRIPTION	SAMPLE DEPTH (m)	USCS	M.C. (%)
0.0 – 0.2	Moist, dark brown, organic SILT (Topsoil). Organics and rootlets encountered.	-	OL	-
0.2 – 0.8	Soft, moist, dark grey, SAND; Some silt. At 0.5 m: Gravel = 0%, Sand = 85%, Fines = 15%	0.5	SM	34.1
0.8 – 1.1	Loose to compact, wet, brown, SAND; some rounded gravel to gravelly, trace fines. Cobbles encountered.	1.0	SP	-
1.1	End of Pit -Pit terminated at 1.1 m. -Free water encountered at 0.8 m. -Backfilled with excavated material			

TP17-4

DEPTH (m)	DESCRIPTION	SAMPLE DEPTH (m)	USCS	M.C. (%)
0.0 – 0.2	Soft, moist, brown, organic SILT (Topsoil). Organics and rootlets encountered.	-	OL	-
0.2 – 1.0	Loose to compact, moist, brown silty SAND; fine to medium grained sand. At 1.0 m: black staining.	0.9	SM	
1.0 – 1.4	Compact, wet, brown, sandy GRAVEL.	-	GP	-
1.4	End of Pit -Pit terminated at 1.4 m. -Free water encountered at 1.1 m. -Backfilled with excavated material.			

TP17-5

DEPTH (m)	DESCRIPTION	SAMPLE DEPTH (m)	USCS	M.C. (%)
0.0 – 0.2	Soft, moist, dark brown, organic SILT (Topsoil). Organics and rootlets encountered.	-	OL	-
0.2 – 1.0	Loose to compact, moist, mottled grey and brown SAND, some silt, trace organics. At 0.4 m: Gravel = 1% Sand 76% Fines 23%	0.4	SM	31.2
1.0 – 1.4	Compact, wet, grey, GRAVEL and SAND, trace silt, cobbles encountered.	1.0	GP/SP	-
1.4	End of Pit -Pit terminated at 1.4 m. -Free water encountered at 0.9 m. -Backfilled with excavated material. -50 mm diameter PVC Piezometer installed to base of test pit. Lower 1.5 m hand slotted.			

TP17-6

DEPTH (m)	DESCRIPTION	SAMPLE DEPTH (m)	USCS	M.C. (%)
0.0 – 0.1	GRAVEL. Rootlets encountered.	-	GP	-
0.1 – 1.8	Compact, moist, grey SAND and GRAVEL; trace to some fines, sub-round to round, maximum diameter 200 mm. Interbedded sand and gravel seams. At 0.9 m: woody debris.	0.9 1.5 1.7	GP/SP	-
1.8	End of Pit -Pit terminated at 1.8 m. -Free water encountered at 1.4 m. -Backfilled with excavated material. -50 mm diameter PVC Piezometer installed to base of test pit. Lower 1.5 m hand slotted.			

APPENDIX C

Laboratory Testing Results

SIEVE ANALYSIS REPORT
BURTON FLATS
GSA 17-1

Attn:

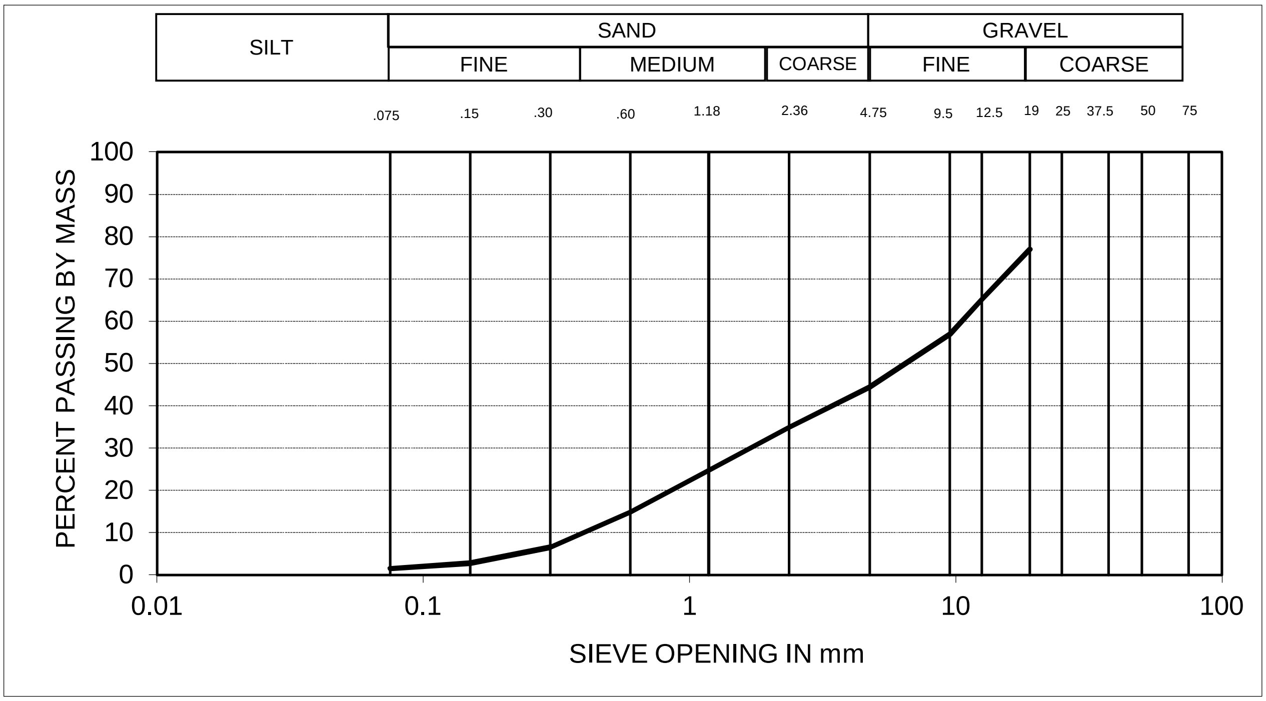
KWL

File Number: 17216
Date Reported: 24-May-17

Sampled: 5-May-17 By: MEW
Received: 17-May-17 By: MBH
Tested: 17-May-17 By: MBH
Checked By:

Sample Source: TP17-1 Sa 4 @ 2.3 m
Description: SAND AND GRAVEL, trace silt
Test Method: ASTM C 136 & C 117

Remarks: Gravel = 55.7 % Sand = 42.8 % Fines = 1.6 %
As Received Moisture Content = 4.6 %



Gravel Size Inches	mm	Percent Passing	Specifications Upper	Lower	Check	Sand Size Inches	mm	Percent Passing	Specifications Upper	Lower	Check
3	75	100				#4	4.75	44			
2	50	100				#8	2.36	35			
1.5	37.5	100				#16	1.18	25			
1	25	86				#30	0.6	15			
.75	19	77				#50	0.3	7			
.5	12.5	65				#100	0.15	3			
.375	9.5	57				#200	0.075	1.5			

104, 1383 McGill Road, Kamloops, BC V2C 6K7 T: 250 372 1058
thurber.ca

THURBER ENGINEERING LTD.

SIEVE ANALYSIS REPORT
BURTON FLATS
GSA 17-2

Attn:

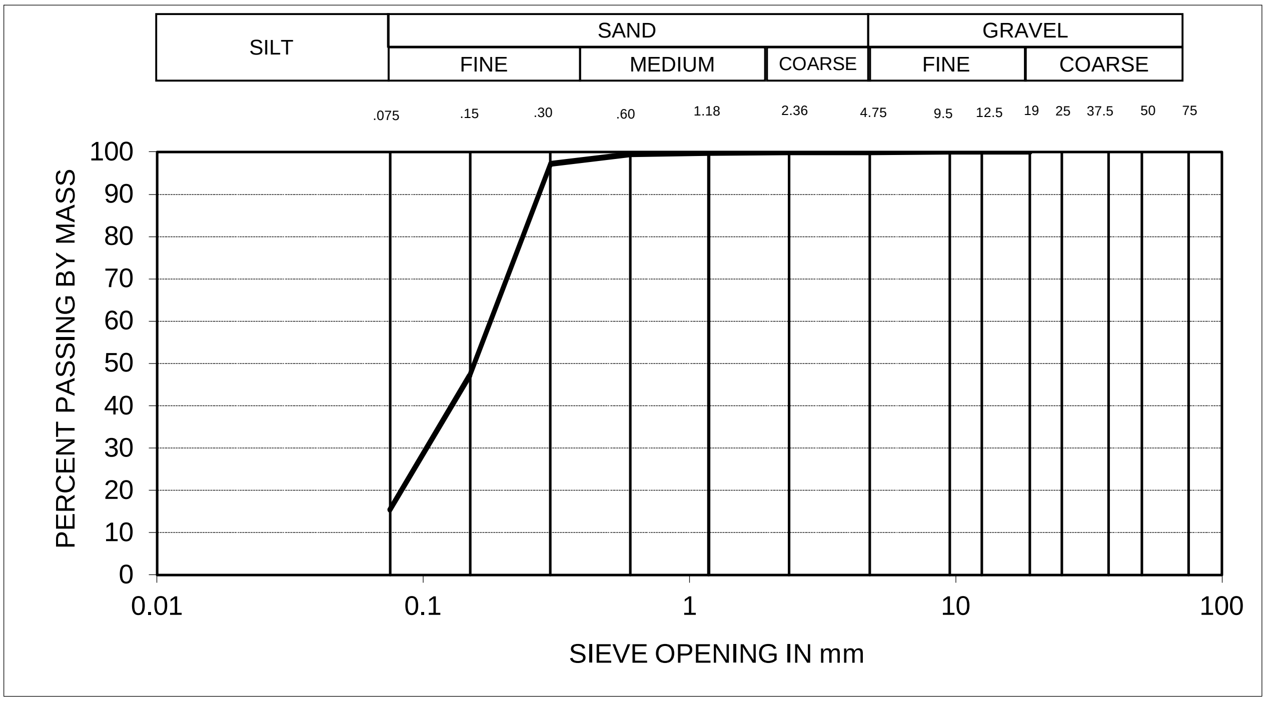
KWL

File Number: 17216
Date Reported: 24-May-17

Sampled: 5-May-17 By: MEW
Received: 17-May-17 By: MBH
Tested: 17-May-17 By: MBH
Checked By: ______________

Sample Source: TP17-3, Sa 1 @ 0.5 m
Description: Silty SAND
Test Method: ASTM C 136 & C 117

Remarks: Gravel = .1 % Sand = 84.6 % Fines = 15.4 %
As Received Moisture Content = 34.1 %



Gravel Size		Percent	Specifications			Sand Size		Percent	Specifications		
Inches	mm	Passing	Upper	Lower	Check	Inches	mm	Passing	Upper	Lower	Check
3	75	100				#4	4.75	100			
2	50	100				#8	2.36	100			
1.5	37.5	100				#16	1.18	100			
1	25	100				#30	0.6	99			
.75	19	100				#50	0.3	97			
.5	12.5	100				#100	0.15	47			
.375	9.5	100				#200	0.075	15.4			

THURBER ENGINEERING LTD.

SIEVE ANALYSIS REPORT
BURTON FLATS
GSA 17-3

Attn:

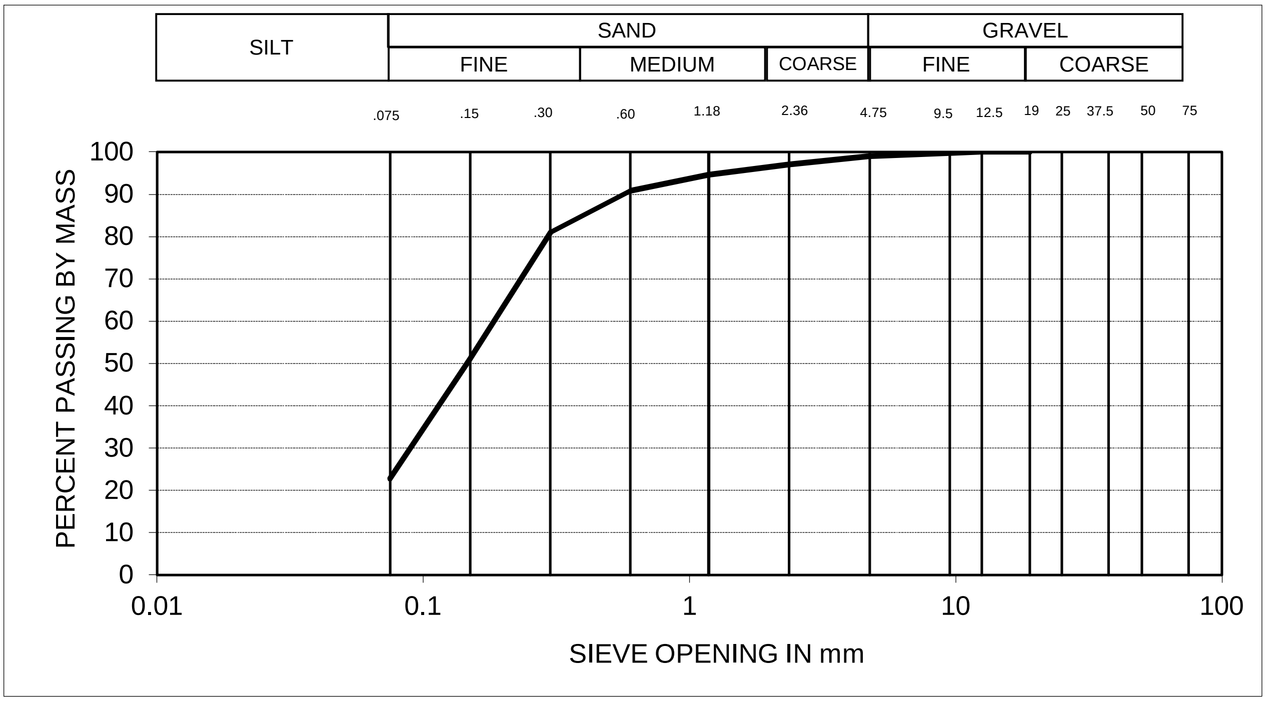
KWL

File Number: 17216
Date Reported: 24-May-17

Sampled: 5-May-17 By: MEW
Received: 17-May-17 By: MBH
Tested: 17-May-17 By: MBH
Checked By:

Sample Source: TP 17-5 Sa 1 @ 0.4 m
Description: Silty SAND
Test Method: ASTM C 136 & C 117

Remarks: Gravel = .9 % Sand = 76.3 % Fines = 22.7 %
As Received Moisture Content = 31.2 %



Gravel Size Inches	mm	Percent Passing	Specifications Upper	Lower	Check	Sand Size Inches	mm	Percent Passing	Specifications Upper	Lower	Check
3	75	100				#4	4.75	99			
2	50	100				#8	2.36	97			
1.5	37.5	100				#16	1.18	95			
1	25	100				#30	0.6	91			
.75	19	100				#50	0.3	81			
.5	12.5	100				#100	0.15	51			
.375	9.5	100				#200	0.075	22.7			

APPENDIX D

Selected Photographs

PHOTO 1: Excavated material from TP17-1.

PHOTO 2: Excavation of TP17-2.

PHOTO 3: TP17-2.

PHOTO 4: TP17-3.

PHOTO 5: TP17-4.

PHOTO 6: Excavation of TP17-6.

PHOTO 7: Piezometer installation at TP17-6.

PHOTO 8: Wood debris encountered at TP17-6.

PHOTO 9: Location of proposed wetland and the adjacent highway embankment.

KERR WOOD LEIDAL
consulting engineers

Appendix B

Hydrogeology Memorandum (Piteau Associates Ltd.)

PITEAU ASSOCIATES
GEOTECHNICAL AND
WATER MANAGEMENT CONSULTANTS

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KELOWNA, B.C.
CANADA - V1Y 9S9
TEL: +1.778.484.1777 / FAX: +1.604.985.7286

www.piteau.com

MEMORANDUM

TO:	Mr. Stefan Joyce, P. Eng. Senior Hydrotechnical Engineer Kerr Wood Leidal Associates	Our File: 3741 (3741-M001) Date: July 27, 2017
FROM:	Remi Allard, M. Eng., P. Eng. Email: rallard@piteau.com	
COPY:	Allison Matfin, EIT	
RE:	Burton Flats Wildlife Enhanced Project - Hydrogeology	

Piteau Associates Engineering Limited (Piteau) was retained by Kerr Wood Leidal Associates (KWL) to provide hydrogeological support on the Burton Flats Wildlife Enhancement Project. The project is a wetland enhancement initiative along the eastern shore of Arrow Lake at Burton. The project is being completed for BC Hydro. The scope of work for Piteau included assistance during field investigations to determine groundwater and surface water conditions at the site, support during the monitoring of water levels in the area and provision of a technical memorandum regarding the sustainability of groundwater for inundation of the planned tiered wetlands in the area. Field investigations were documented by Thurber Engineering Ltd. (Thurber) in a draft report entitled “Burton Flats Wildlife Enhancement Project - Geotechnical Investigation”, issued June 23, 2017. Temporal plots for surface water and groundwater level data were prepared by KWL using manual water level measurements and datalogger data collected by other sub-consultants.

Mr. Remi Allard from Piteau was present during field investigations on May 5, 2017. Work in the field included the excavation of test pits, sampling of excavated materials for grain size analysis, installation of piezometers at four test pit locations and a surface water monitoring station on Burton Creek, and installation of water level transducers/loggers in the piezometers and surface station.

KWL issued a technical memorandum to BC Hydro on June 30, 2017, which is an interim report entitled “Wildlife Enhancement Project Burton Flats Design Basis and Feasibility Design Concepts – Interim report”. The following discussion regarding the hydrogeology in the area is based on information provided in the Thurber and KWL reports.

1.0 Overview of Hydrogeology

The wetland is positioned on an alluvial/fluvial fan complex associated with Burton Creek. Groundwater recharge to the fan is via stream loss along Burton Creek, which has an extensive upland watershed to the east. The fan complex is comprised of interlayered silt, sand and gravel. Groundwater levels are at or near ground surface throughout the area. The depth to groundwater increases to the west, approaching the Arrow Lake Reservoir, indicating recharge from streambed losses along the Creek and groundwater flow towards the Reservoir. The aquifer in the silt, sand and gravel is unconfined in nature and may exhibit semi-confined behavior at some locations where surficial organics exceed 0.5 m thickness. Owing to the unconfined nature, the aquifer has a high degree of hydraulic connection with surface water.

Based on water level data for the Reservoir from 1970 to 2016 provided by KWL, the reservoir level fluctuates by as much as 8 m, with the lowest levels typically during April and highest levels in mid-July. As the field investigations were completed in May, approximately one month into the freshet period, the groundwater levels encountered are assumed to be approaching, but not representative of the lowest groundwater level conditions. The preliminary design for the tiered ponds has been based on the May 2017 groundwater levels, with the assumption that they may be approximately 0.5 m lower during pre-freshet.

During the field investigations, groundwater depth ranged from <1 m depth near the southeast portion of the fan (Piezometer 2) to 3.5 m deep at a point 250 m to the west (Piezometer 1). Based on the measured surface water and groundwater levels, flow in the aquifer is generally to the west and northwest with a groundwater flow gradient in the order of 0.015. This is the maximum gradient expected for the area, corresponding to the head difference between the lowest level in the Reservoir and highest creek level at the onset of freshet.

Based on the water level data collected from May to June, the depth to groundwater at the east (upper) end of the fan fluctuates 1 m to 2 m as a function of the relatively constant seepage losses from the Creek. Groundwater levels fluctuate more towards the west end of the fan, approaching the Reservoir. The level at Piezometer 1 increased by 3.5 m over the monitoring period, indicating water levels towards the west end of the fan may seasonally fluctuate this amount and are more influenced by the level in the Reservoir.

In terms of the seasonal fluctuation in water levels, the highest groundwater levels are expected when the Reservoir is full during the period July through September. At such time, the groundwater flow gradient is expected to be in the order of 0.01, which will be the lowest gradient. With the Reservoir at the 25th percentile level, the gradient is still expected to be in the range of 0.010 to 0.012. Therefore, groundwater levels in the area of the tiered ponds will be very near the current ground surface elevation and in some cases above ground when the Reservoir is full from mid-June through September. The intent of the outlet structures between ponds is to control the surface water elevations in each pond during the important wetland habitat period from April to June.

A plot of the piezometer and hydrometric station locations, along with a contour of groundwater levels from the May 2017 field investigation is presented in the attached Figure 1, reproduced from the interim design report by KWL. The KWL report also presents temporal plots of water levels from early May to mid-June in Burton Creek, the Reservoir and the piezometers. While the period of record shown in the temporal plots does not extend to expected full reservoir level (mid-July), the trends in water levels indicate the flow gradient through the wetland area decreases as the Reservoir level increases.

The results of grain size analyses on samples collected during test pit excavation were used to estimate saturated hydraulic conductivity of the aquifer materials. Using the Hazen Approximation Method, which is based on the diameter of the 10^{th} percentile of grain size for the material tested, the hydraulic conductivity of the aquifer ranges from 1 x 10^{-2} cm/s (lowest) to 1 x 10^{-1} cm/s (highest).

2.0 Groundwater Balance in Wetland Area

Using the above-noted hydraulic properties for the aquifer, a groundwater balance was calculated based on the dry summer period typically encountered during July, August and September. Using the lower estimated hydraulic conductivity of 1 x 10^{-2} cm/s (10 m/day), a saturated thickness of 0.6 m at the base of all ponds, an aquifer width of 450 m (perpendicular to flow) and a gradient of 0.01 (representing low flow during full reservoir conditions), the lowest volume of ambient groundwater flow through the area during the summer period is in the order of 25 m^3/day. The relatively flat groundwater flow gradient is the most influential factor which limits the volume of flow.

Using the interactive BC Climate Atlas (www.climatewna.com/ClimateBC_Map.aspx), the precipitation in the wetland area during the summer period is estimated to be 47 mm/month. Assuming the rate of direct infiltration of precipitation is 30 percent, an additional 63 m^3/day is estimated to recharge the aquifer during this period.

The total daily volume of flow through the aquifer during the dry summer period under average conditions is therefore 88 m^3/day.

An estimate of daily evapotranspiration (Et) for the wetland area was obtained from www.farmest.com, which is a website for precipitation and evapotranspiration data for agricultural producers in British Columbia. The nearest station with representative data is Nakusp, located roughly 35 km to the north of the site. Given that maximum Et is anticipated during the driest months of the year, the daily Et of 4.7 mm/day for July was used. This daily rate was applied to the open water and shallow wetland areas for the maximum number of ponds proposed in the KWL interim design, equivalent to 17,000 m^2 including ponds A1, A2, A3, A4, A5, A6, B1 and D1. The calculation is considered to be conservative as it over-estimates Et for open water. This is expected to be offset by water consumption by non-wetland vegetation at ground surface within the footprint of the aquifer. The daily volume of Et for the wetlands during summer months is therefore 77 m^3/day.

The net water balance during the driest summer months is 88 m^3/day minus 77 m^3/day, equivalent to roughly 10 m^3/day. The water balance does not account for storage in the aquifer and vertical upward flow, which will both contribute recharge to the ponds and make the balance more favorable. Furthermore, the water balance does not represent unusually dry years, when precipitation may be lower than normal and the level in the Reservoir below the 25^{th} percentile.

A printout of the spreadsheet for the water balance results is provided as an attachment to this technical memorandum.

3.0 Seepage Losses and Water Retention in Tiered Wetland Ponds

The interim design for tiered wetland ponds by KWL attempts to optimize the spacing between ponds and incorporate design features to promote water retention. Outlet structures will be utilized to convey surface water between each pond and to regulate water levels. Each pond will be excavated from ground surface directly into the aquifer and due to the granular nature of the aquifer materials, there will be seepage between each pond. The rate of seepage will be partly due to the head difference between water levels in adjacent ponds and partly due to the difference in the pond water level and the surrounding ambient groundwater levels.

Based on the cross section presented in the KWL report for Option 1, the maximum possible gradient of 0.045 would occur between Pond A3 and Pond A4. A preliminary estimate of seepage between these ponds was completed using Dupuit-Forcheimer theory for inflow into open excavations in an unconfined aquifer. The maximum potential seepage rate from Pond A3 to Pond A4 is on the order of 30 m^3/day. The seepage will be mostly offset by flow into Pond A3 including contributions of roughly 5 m^3/day of groundwater flow within the bottom 0.6 m (saturated) portion of the pond. An additional 15 m^3/day of inflow to the pond is expected due to seepage between Pond A2 and A3. A further 7 m^3/day of seepage will be contributed along the east and southeast side slopes of the pond due to the roughly 0.4 m difference in head between the pond elevation and the ambient groundwater level. The net difference of 3 m^3/day between inflow and outflow in Pond A3 is relatively small and is expected to be offset by vertical upward flow within the base of the pond and the availability of water derived from aquifer storage.

Similar flow into and out of each pond is expected to occur. In summary, groundwater flow through the lowest saturated portion of each pond and seepage from the eastern and southeastern slopes in each pond recharged by the ambient groundwater flow in the area, will largely compensate for the seepage losses between adjacent ponds.

Pond D1 is the last tiered pond and at the lowest elevation. The design is for 1.0 m of water in the bottom of this pond and therefore groundwater flow through the base of this pond will be higher. Similarly, any seepage losses from this pond to the nearby Reservoir will be offset by inflow to the pond from eastern and southeastern side slopes, upward flow and water derived from aquifer storage.

During periods when the Reservoir level is highest, groundwater water levels may exceed the elevation of the outlet structure in some ponds.

The rate of seepage between ponds will decrease with time due to sedimentation and infilling of voids in aquifer materials in the base of each pond.

The seepage estimates can be refined with numerical flow modeling.

4.0 Recommendations

Monitoring of water levels in the piezometers, Arrow Lake Reservoir and Burton Creek should continue for the longest period possible to verify the temporal and spatial relationship in water levels at these locations.

5.0 Limitations and Closure

We trust the above is adequate for your present needs. Please contact the undersigned if you have any questions, comments or concerns.

Respectfully submitted,

PITEAU ASSOCIATES ENGINEERING LTD.

PROFESSIONAL ENGINEER PROVINCE OF BRITISH COLUMBIA R.J.P. ALLARD 27 JUL 2017

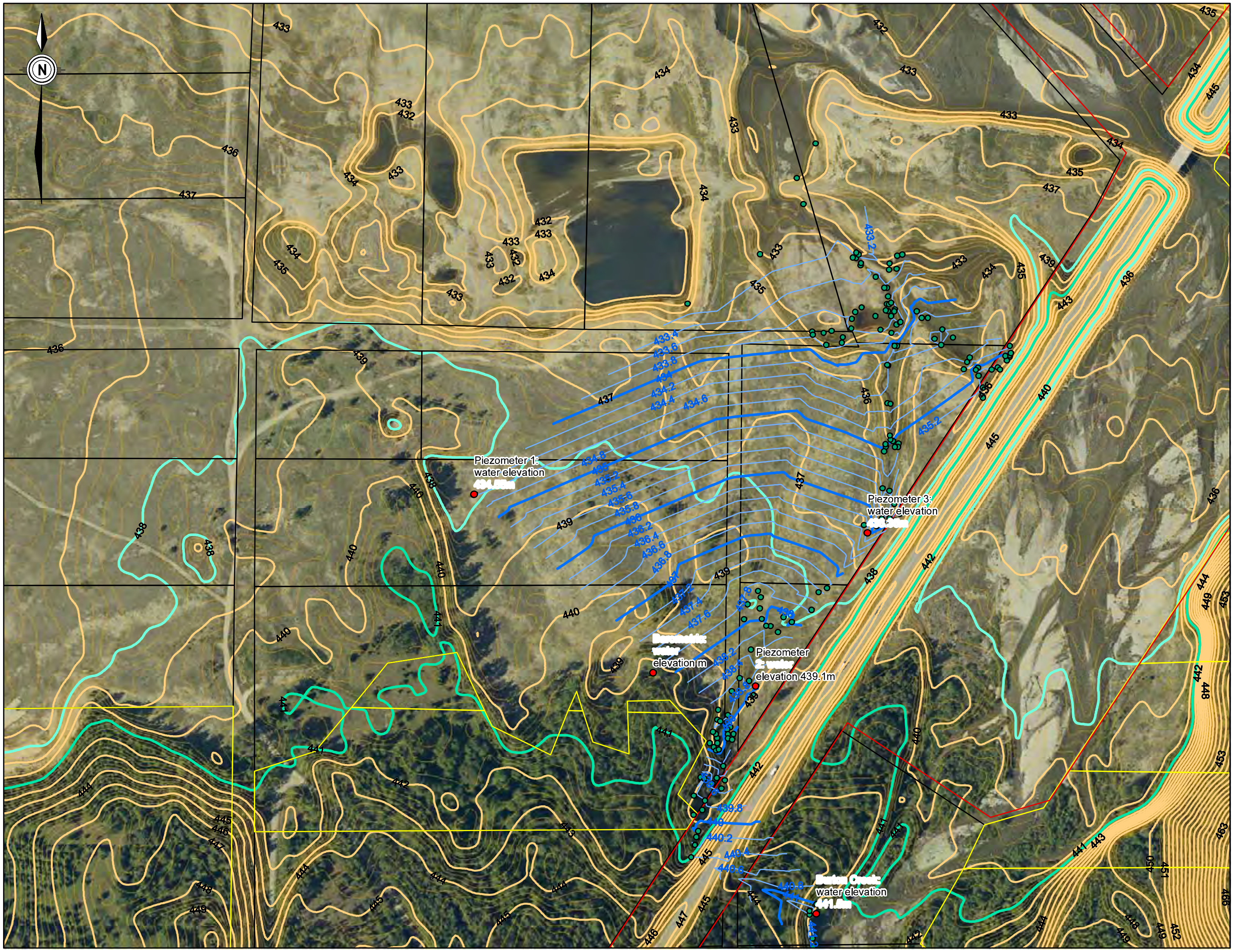
Remi Allard, M.Eng., P.Eng.

RJPA/skn

Att.

FIGURES

1. Figure 1 from KWL report - Groundwater Contours Preliminary May 2017.
2. Spreadsheet for Groundwater Flow and Preliminary Water Balance Calculations.



Surface Water Survey Points - May 16, 2017

Culverts

Water Level Sensors

Railways, Highways, and Roads

Private Property

438 m - Annual Average High

441 m - Maximum High Water

Surveyed Railways, Highways, and Roads - DataBC, ParcelMap BC
Parcel Fabric - DataBC, ESRI, DigitalGlobe, GeoEye, Earthstar
GIS User Community 2009/05/24

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Path: O:\0400-0499\478-203\430-GIS\MXD-Rp\478203_MayGroundwaterContours_Preliminary.mxd Date Saved: 6/30/2017 12:42:20 PM
Author: jlau

Burton Creek Wetland Enhancement
Groundwater Flow and Preliminary Water Balance Calculation

Piteau Project : 3741

1 Calculation of Hydraulic Conductivity (k-value) based on Thurber seives

	cm/s	m/day	round off	not used	comments
k upper	9.90E-02	85.54	150		
k lower	1.10E-02	9.50	10		

2 Calculation of gradient based on KWL plan of GW levels (these are from spring when gradient highest and water level relatively low)

	dist P2 to P3 (m)	delta level (m)	gradient	not used	comments
grad upper	160	2.6	0.016		used gradient between P2 and P3, P2 is relatively constant.
grad lower	160	1.5	0.009		this is more related to summer levels

3 Dry Month (August = Worst Case) Precipitation (direct infiltration over wetland area)

wetland area (m2)	Precip (mm/month) driest is Aug/Sept	Infiltration Proportion (%)	infiltration (m3/day)	not used	comments
135000	47	30	63.450		from BC Climate Atlas. No need to adjust for net mositure as Et accounts for this

4 Groundwater Flow Wetland Area (to depth of ponds)

k value (m/day)	open water depth (m)	gradient	width (m)	flow (m3/day)	comments
150	0.6	0.016	450	648	assume high K and highest gradient (pre-freshet = spring)
10	0.6	0.016	450	43.2	assume low K and highest gradient (pre-freshet = spring)
150	0.6	0.009	450	364.5	assume high K and lowest gradient (summer)
10	0.6	0.009	450	24.3	assume low K and lowest gradient (summer)

5 Evapotranspiration

mm/day	area of ponds (m2)	volume lost (m3/day)	unused	unused	comments
4.5	17000	76.5			worst case daily ET rate (Jun/Jul/Aug) from Farmwest.com website (for Nakusp)
3	17000	51			lowest rate during wetland season (April)

wetland operates april and september
Et for Nakusp from Farmwest.com

	mm/day (mean)
j	0.4
f	0.6
m	1.2
a	2.2
m	3.9
j	4.5
j	4.7
a	4.5
s	2.4
o	1.1
n	0.5
d	0.3

approximate areas of ponds for option 1

pond	width (m)	length (m)	area (m2)
A1	35	24	840
A2	44	32	1408
A3	48	33	1584
A4	47	20	940
A5	41	25	1025
A6	41	32	1312
D1	116	68	7888
B1	60	30	1800
		total area >	16797

worst case water balance (august) = groundwater flow + direct infiltration of precip - evapotranspiration

= 11.250 (if number is positive, then water balance is ok)

(note calculation does not include water available from aquifer storage)

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Appendix C

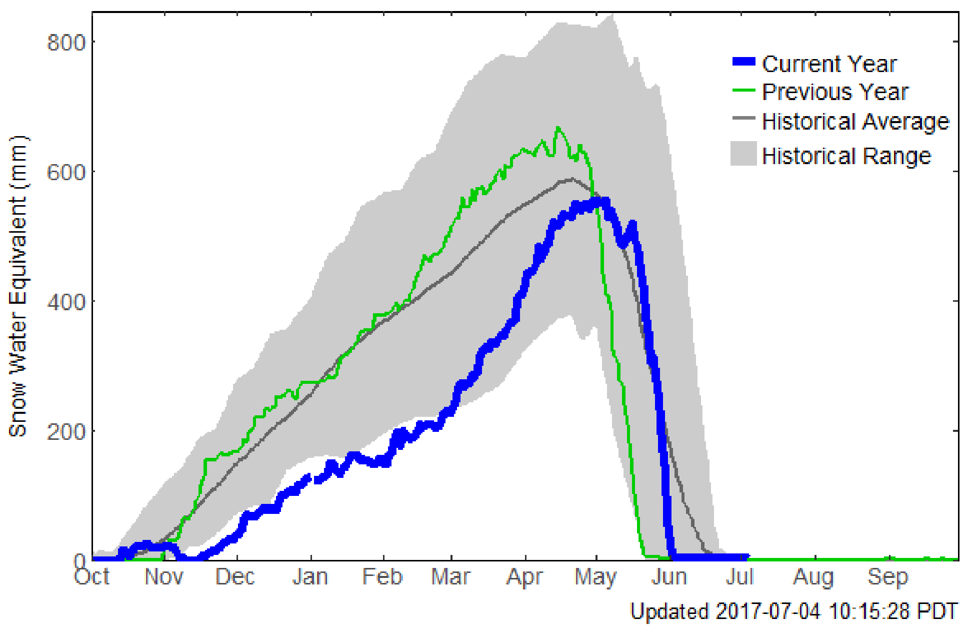
Hydrology Supplementary Figures

Automated Snow Weather Station Real-Time Data

2B06P - BARNES CREEK

Drainage:	Lower Columbia	Owner:	BC Hydro Power smart
Latitude:	50° 04' N	Year Established:	1992
Longitude:	118° 21' W	Variables:	Air temperature, precipitation, and snow water equivalent
Elevation:	1,595 m		

Download last 7 days of hourly real-time data*: Click here
Download daily archive data: Click here



Disclaimer

* The data you have selected have not been verified. The data are collected by automated monitors from numerous remote locations in B.C. It is not uncommon for individual monitors to give false readings due to temporary local conditions or equipment malfunction and on occasion the readings can be grossly inaccurate. Observations are given at hourly resolution for the last seven days in Greenwich Mean Time (GMT/UTC). To convert to Pacific Standard Time (PST), subtract 8 hours. To convert to Pacific Daylight Time (PDT), subtract 7 hours.

TOP

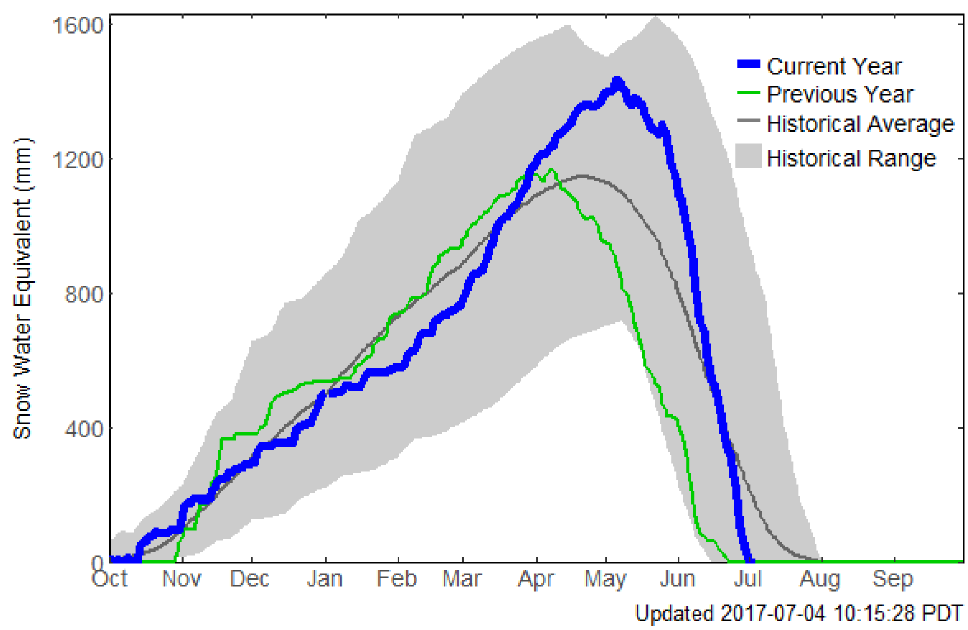
Automated Snow Weather Station Real-Time Data

2B08P - ST. LEON CREEK

Drainage:	Lower Columbia	Owner:	BC Hydro Power smart
Latitude:	50° 26' N	Year Established:	1992
Longitude:	117° 42' W	Variables:	Air temperature, precipitation, and snow water equivalent
Elevation:	1,822 m		

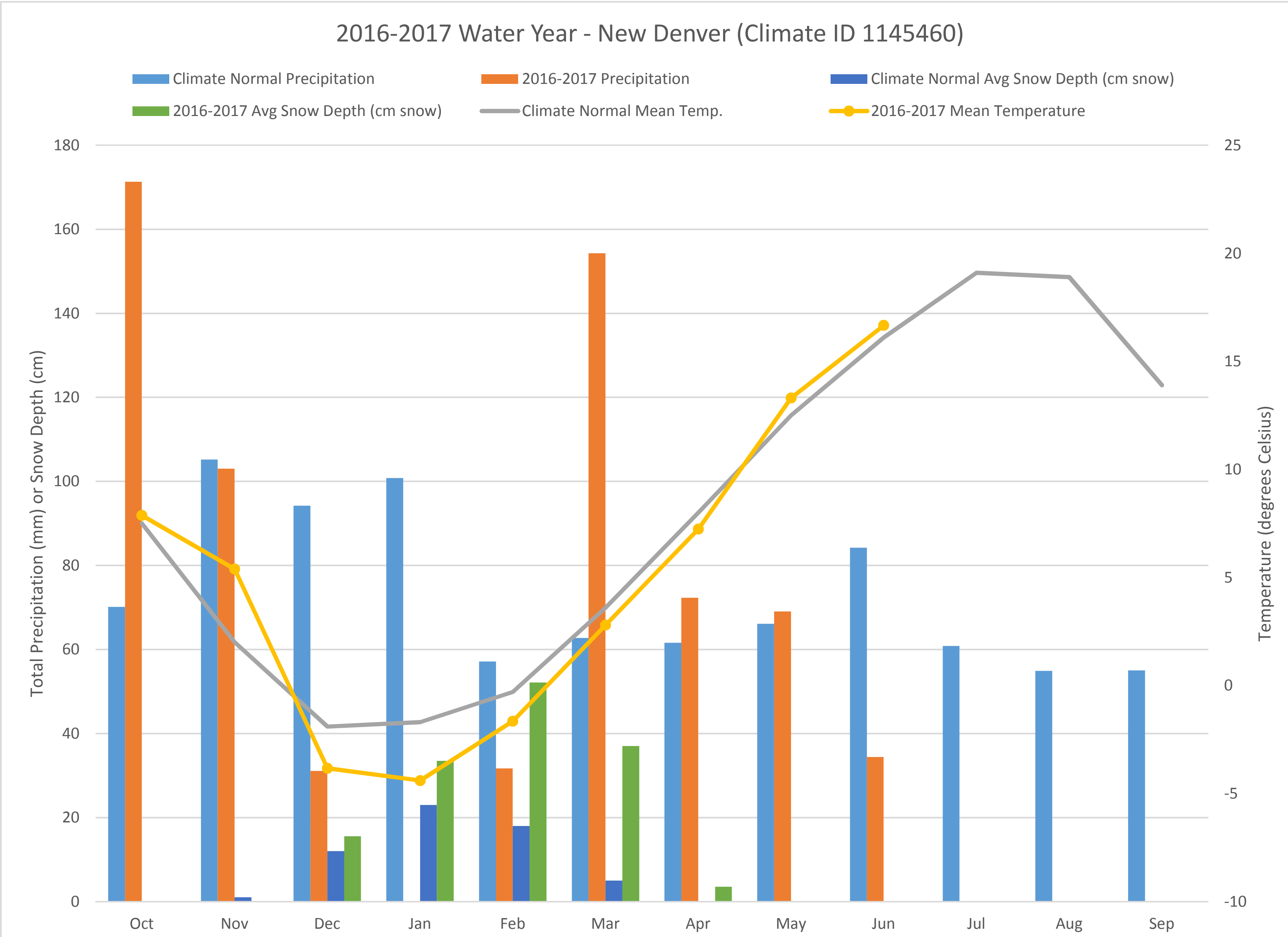
Download last 7 days of hourly real-time data*: Click here

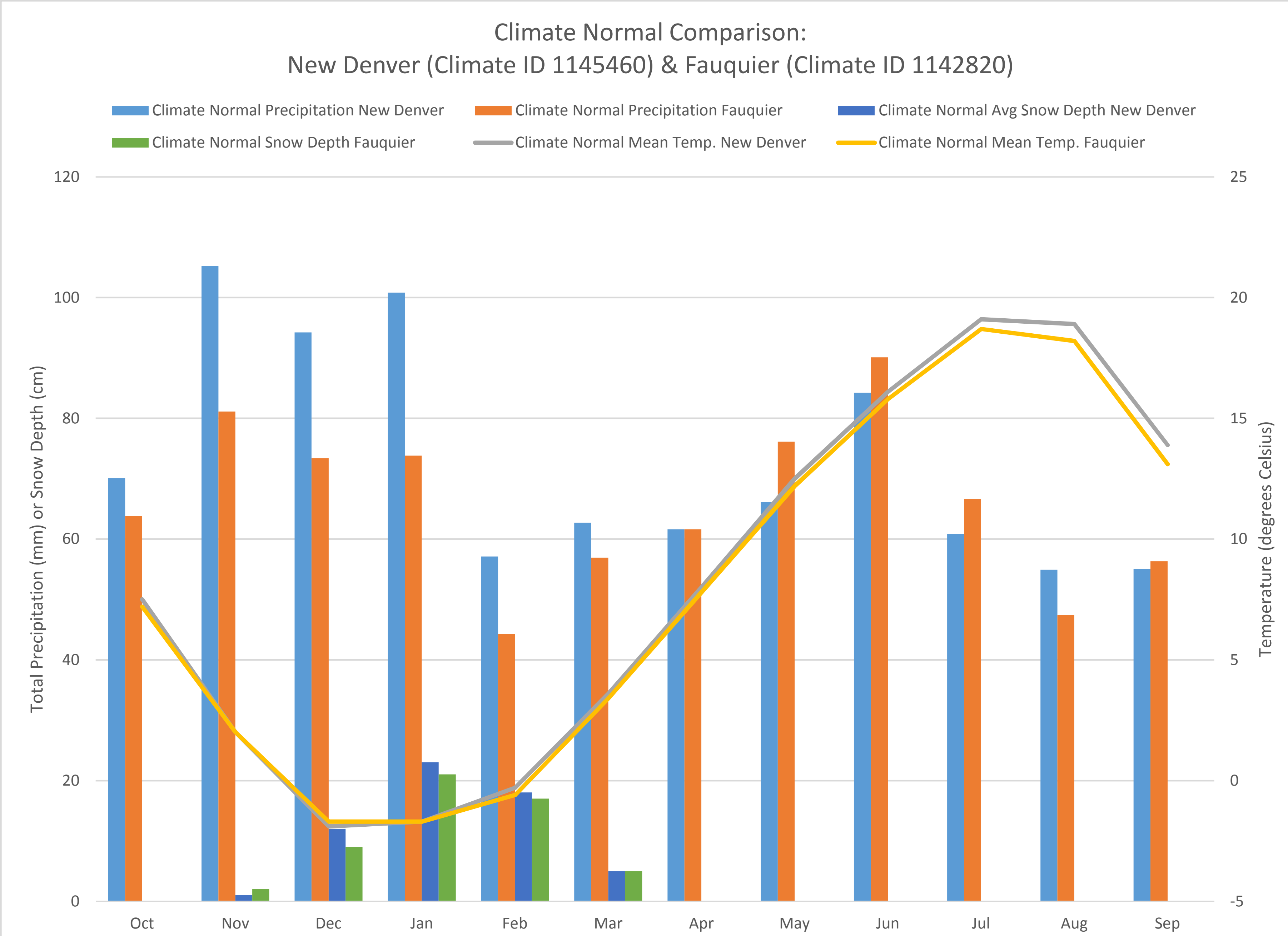
Download daily archive data: Click here



Disclaimer

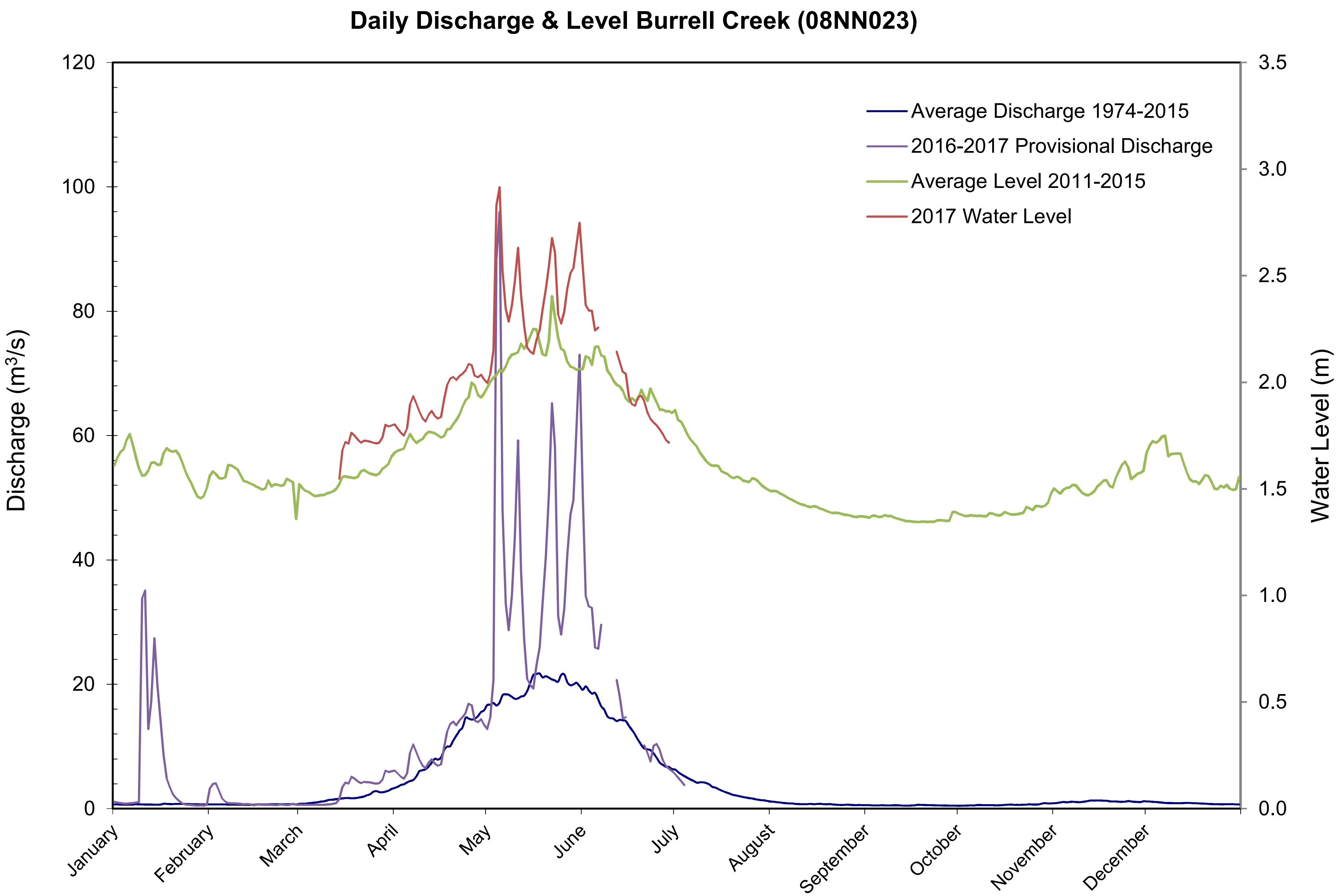
* The data you have selected have not been verified. The data are collected by automated monitors from numerous remote locations in B.C. It is not uncommon for individual monitors to give false readings due to temporary local conditions or equipment malfunction and on occasion the readings can be grossly inaccurate. Observations are given at hourly resolution for the last seven days in Greenwich Mean Time (GMT/UTC). To convert to Pacific Standard Time (PST), subtract 8 hours. To convert to Pacific Daylight Time (PDT), subtract 7 hours.


2016-2017 Water Year - New Denver (Climate ID 1145460)
Climate Normal Precipitation
2016-2017 Precipitation
Climate Normal Avg Snow Depth (cm snow)
2016-2017 Avg Snow Depth (cm snow)
Climate Normal Mean Temp.
2016-2017 Mean Temperature
Total Precipitation (mm) or Snow Depth (cm)
Temperature (degrees Celsius)
180
160
140
120
100
80
60
40
20
0
25
20
15
10
5
0
-5
-10
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep



Climate Normal Comparison:
New Denver (Climate ID 1145460) & Fauquier (Climate ID 1142820)
Climate Normal Precipitation New Denver
Climate Normal Precipitation Fauquier
Climate Normal Avg Snow Depth New Denver
Climate Normal Snow Depth Fauquier
Climate Normal Mean Temp. New Denver
Climate Normal Mean Temp. Fauquier
Total Precipitation (mm) or Snow Depth (cm)
Temperature (degrees Celsius)
0
20
40
60
80
100
120
-5
0
5
10
15
20
25
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep

Wildlife Enhancement Program at Burton Flats
KWL Project No. 478.203



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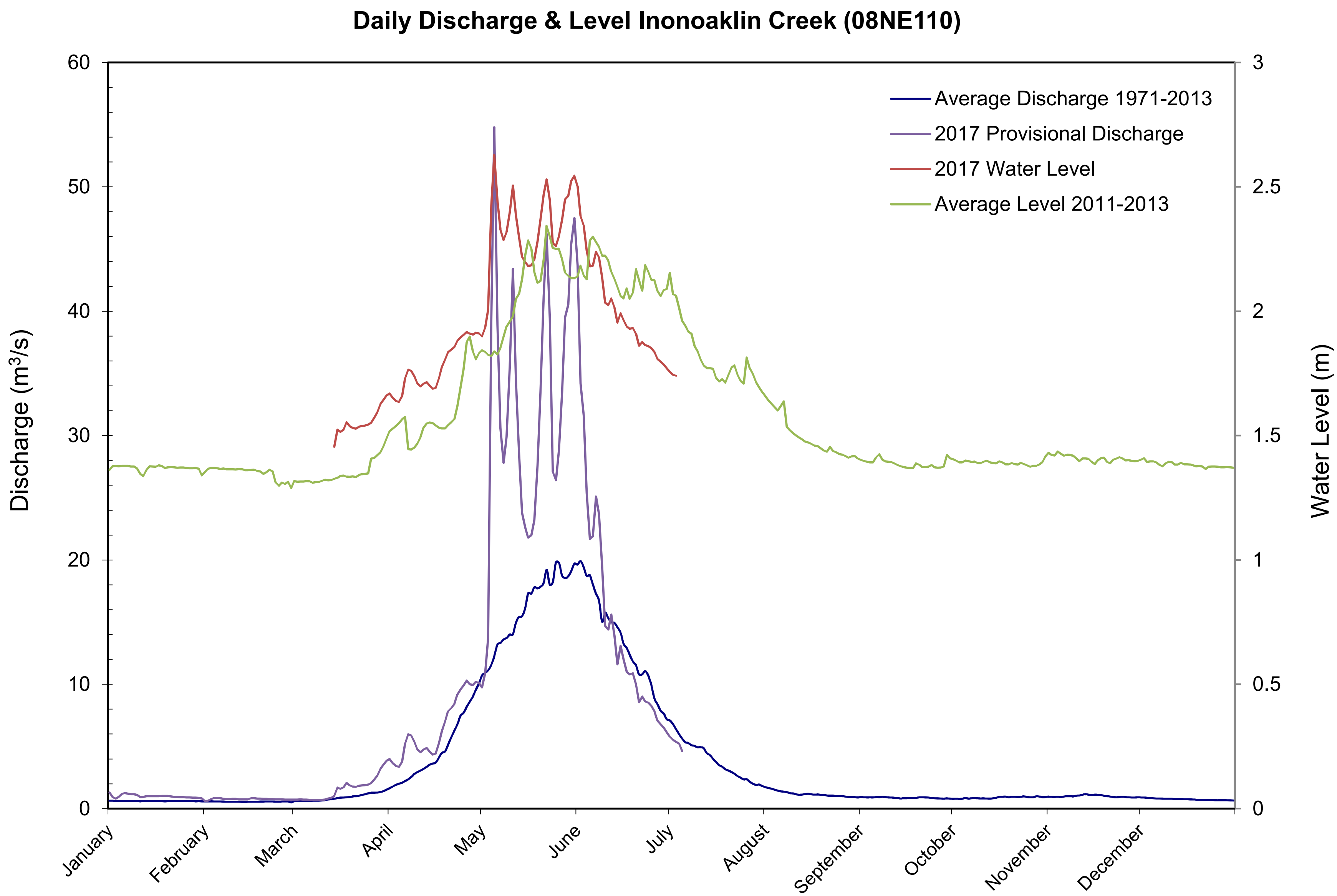
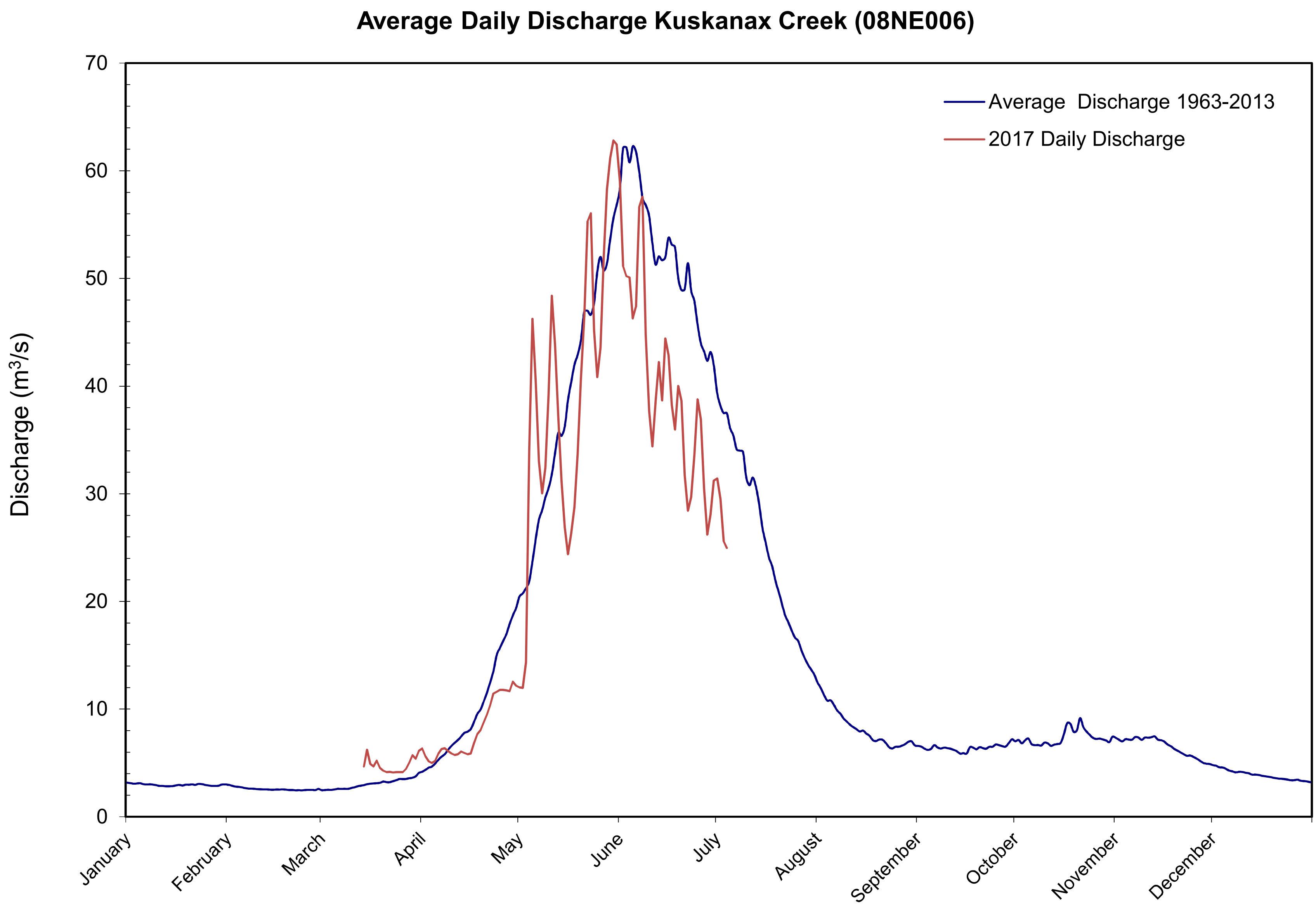
Wildlife Enhancement Program at Burton Flats
KWL Project No. 478.203



O:\0400-0499\478-203\400-Work\Hydrology\WSC\08NE110 - Inonoaklin\Inonoaklinl_08NE110


Average Daily Discharge Kuskanax Creek (08NE006)
Discharge (m3/s)
70
60
50
40
30
20
10
0
Average Discharge 1963-2013
2017 Daily Discharge
January
February
March
April
May
June
July
August
September
October
November
December

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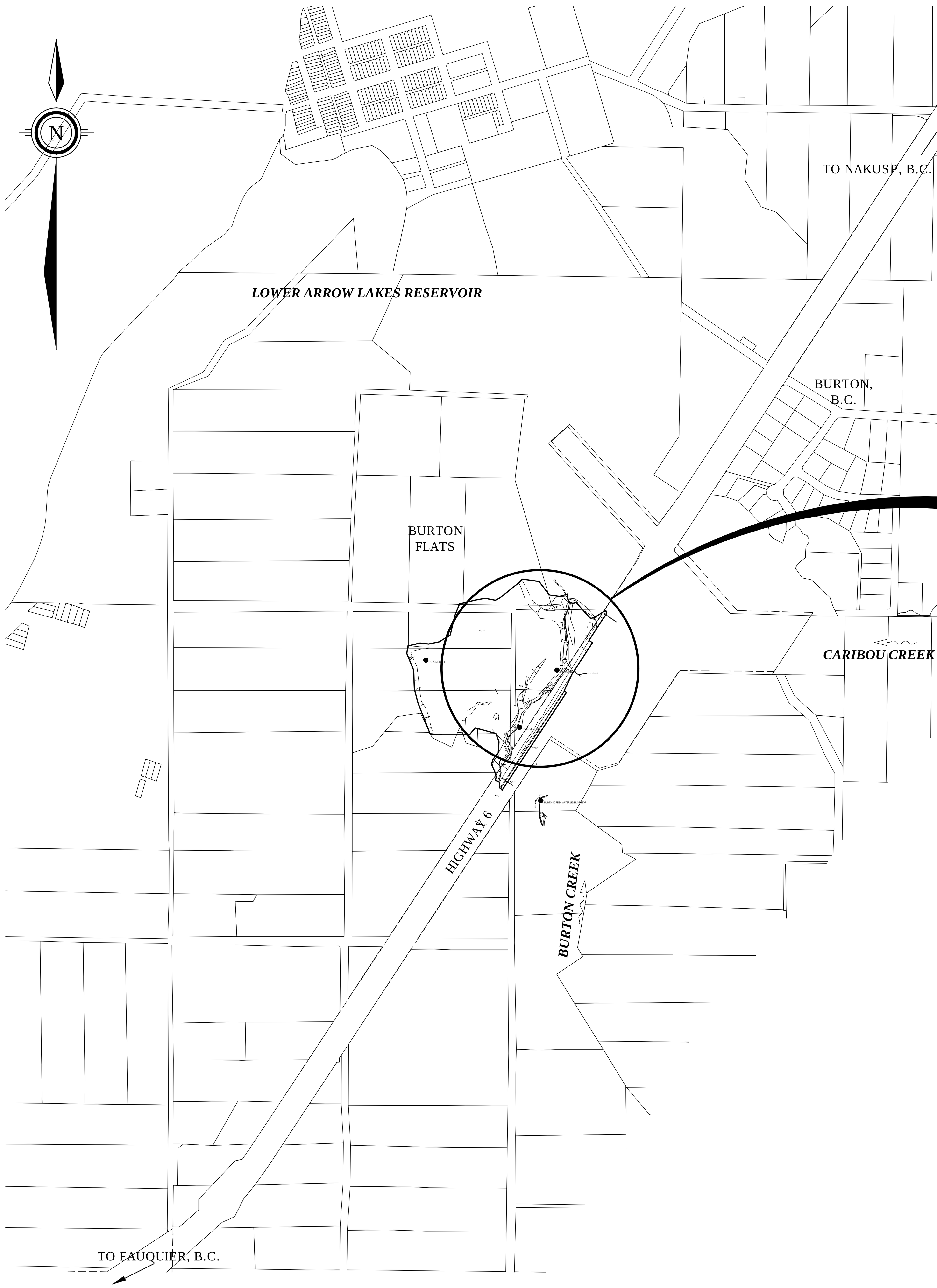
Appendix D

Feasibility Design Drawings



DRAWING LIST

SHEET NO.	DRAWING NO.	DESCRIPTION
1	G-101	LOCATION PLAN, KEY PLAN, AND DRAWING LIST
2	C-101	OVERVIEW PLAN
3	C-102	OPTION 1 - PLAN
4	C-103	OPTION 2 - PLAN
5	C-104	OPTION 1 & 2 CONNECTION TO EXISTING PONDS - PLAN
6	C-201	OPTION 1 - PROFILES
7	C-202	OPTION 2 - PROFILES
8	C-301	TYPICAL - SECTIONS
9	C-302	TYPICAL - OUTLET - DETAILS

PRELIMINARY PLANTING PLAN:
A PRELIMINARY PLANTING PLAN IS SHOWN BELOW FOR THE FEASIBILITY DESIGN. THIS PLAN WILL BE REVISED AND REFINED IN DETAILED DESIGN AND MAY BE MODIFIED DURING CONSTRUCTION. EXISTING SEDGES AND COTTONWOODS IN THE CONSTRUCTION AREA WILL BE SALVAGED PRIOR TO CONSTRUCTION. SOME NURSERY STOCK MAY BE REQUIRED TO COMPLETE VEGETATION OF THE DESIGN. PLANTING WILL OCCUR BASED ON FINISHED ELEVATION AS FOLLOWS:

- 433 TO 434 m: SEDGES (LENTICULAR, COLUMBIA, AND WATER) AND BLUEJOINT REEDGRASS,
- >436 m: COTTONWOOD TREES
- >439 m: WHITE PINE TREES, WILLOW, RED OSIER DOGWOOD, SNOWBERRY, HARDHACK, AND TWINBERRY.

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CLWORKS-30B
BURTON CREEK WILDLIFE ENHANCEMENT PROJECT

NOT FOR CONSTRUCTION
28/07/2017

NO	REMARKS	DATE	DESIGNED	INDEP CHK	DFTG	DFTG CHK	INSP	REV	ACPT
B	FEASIBILITY DESIGN – DRAFT	28 JUL'17	SFJ	PF	PAC	–	–	SFJ	–
A	PRELIMINARY DESIGN – DRAFT FOR DISCUSSION ONLY	30 JUN'17	SFJ	PF	PAC	ACL	–	SFJ	–

REVISIONS

REF#	DRAWING NUMBER	TITLE	REF#	DRAWING NUMBER	TITLE

REFERENCE DRAWINGS

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

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WILDLIFE ENHANCEMENT PROJECT AT BURTON FLATS, B.C. (CLWORKS-30B)

WETLAND HABITAT ENHANCEMENT WORKS

LOCATION PLAN, KEY PLAN, AND DRAWING LIST

DATE	DIST	DWG NO	SIZE	R
2017-JUNE	-	G-101	D	B

PLAN
Scale 1:2000

0 20 (1:2,000) 100m

SURVEY NOTES:

1. CONTOURS SHOWN ARE FROM BC HYDRO 2016 DIGITAL TERRAIN MODEL (DTM) AND 2017 SURVEY (CONDUCTED BY KERR WOOD LEIDAL) (16/05/17)
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 CONTROL NETWORK ESTABLISHED BY SETTING UP BASE GPS STATION ON POINTS 4764 & 4765 AND PPP USED FOR POINT LOCATION
4. OUTPUTS FROM PPP REDUCTION:

4764	5536807.586 N	436166.367 E	445.082	SPIKE#4764
4765	5536490.992 N	435958.717 E	445.123	SPIKE#4765

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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

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

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WILDLIFE ENHANCEMENT PROJECT AT BURTON FLATS, B.C. (CLWORKS-30B)

WETLAND HABITAT ENHANCEMENT WORKS

OVERVIEW-PLAN

DATE	DIST	DWG NO	SIZE	R
2017-JULY	-	C-101	D	B

LEGEND

- A - PRIMARY SHALLOW WETLANDS (6H:1V)
- B - SECONDARY WETLANDS (6H:1V)
- C - HABITAT AND PLANTING MOUNDS (6H:1V)
- D - DEEP WATERFOWL POND (6H:1V)
- E - CONNECTION TO EXISTING PONDS AND RESERVOIR AT LOW ELEVATIONS
- POTENTIAL COBBLE AT INLET & OUTLET
- LOG OUTLET SILL STRUCTURE
- LARGE WOODY DEBRIS (LWD)
- PROPOSED TOP OF SLOPE
- PROPOSED TOE OF SLOPE
- EXISTING TOP OF SLOPE
- EXISTING TOE OF SLOPE
- RETAINED WATER LEVEL
- APPROX. MAX. RESERVOIR LEVEL (440 m)
- PROPERTY LINE

LOCATION	ESTIMATED WATER SURFACE AREA (m²)	ESTIMATED RETAINED WATER VOLUME (m³)
A1	840	330
A2	1400	680
A3	1560	550
A4	940	420
A5	1020	510
A6	1320	570
D1	7960	7210
B1	1750	880

PLAN

Scale 1:750

0 10 (1:750) 40m

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28/07/2017

NO	REMARKS	DATE	DESIGNED	INDEP CHK	DFTG	DFTG CHK	INSP	REV	ACPT
B	FEASIBILITY DESIGN – DRAFT	28 JUL'17	SFJ	PF	PAC	–	–	SFJ	–
A	PRELIMINARY DESIGN – DRAFT FOR DISCUSSION ONLY	30 JUN'17	SFJ	PF	PAC	ACL	–	SFJ	–

REVISIONS

REF#	DRAWING NUMBER	TITLE	REF#	DRAWING NUMBER	TITLE

REFERENCE DRAWINGS — REFERENCE DRAWINGS

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

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WILDLIFE ENHANCEMENT PROJECT AT BURTON FLATS, B.C. (CLWORKS-30B)

WETLAND HABITAT ENHANCEMENT WORKS

OPTION-1-PLAN

DATE 2017-JUNE | DIST - | DWG NO C-102 | SIZE D | R B

LEGEND

- A - PRIMARY SHALLOW WETLANDS (6H:1V)
- B - SECONDARY WETLANDS (6H:1V)
- C - HABITAT AND PLANTING MOUNDS (6H:1V)
- D - DEEP WATERFOWL POND (6H:1V)
- E - CONNECTION TO EXISTING PONDS AND RESERVOIR AT LOW ELEVATIONS
- POTENTIAL COBBLE AT INLET & OUTLET
- LOG OUTLET SILL STRUCTURE
- LARGE WOODY DEBRIS (LWD)
- PROPOSED TOP OF SLOPE
- PROPOSED TOE OF SLOPE
- EXISTING TOP OF SLOPE
- EXISTING TOE OF SLOPE
- RETAINED WATER LEVEL
- APPROX. MAX. RESERVOIR LEVEL (440 m)
- PROPERTY LINE

LOCATION	ESTIMATED WATER SURFACE AREA (m²)	ESTIMATED RETAINED WATER VOLUME (m³)
A1	840	330
A2	1400	680
AD1	2650	1910
D1	7960	7210
B1	1190	400

PLAN
Scale 1:750

0 10 (1:750) 40m

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28/07/2017

REF#	DRAWING NUMBER	TITLE	REF#	DRAWING NUMBER	TITLE

REFERENCE DRAWINGS — REFERENCE DRAWINGS

NO	REMARKS	DATE	DESIGNED	INDEP CHK	DFTG	DFTG CHK	INSP	REV	ACPT
B	FEASIBILITY DESIGN – DRAFT	28 JUL'17	SFJ	PF	PAC	–	–	SFJ	–
A	PRELIMINARY DESIGN – DRAFT FOR DISCUSSION ONLY	30 JUN'17	SFJ	PF	PAC	ACL	–	SFJ	–

REVISIONS

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

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WILDLIFE ENHANCEMENT PROJECT AT BURTON FLATS, B.C. (CLWORKS-30B)

WETLAND HABITAT ENHANCEMENT WORKS

OPTION-2-PLAN

DATE	DIST	DWG NO	SIZE	R
2017-JUNE	-	C-103	D	B

LEGEND

A - PRIMARY SHALLOW WETLANDS (6H:1V)	LOG OUTLET SILL STRUCTURE
B - SECONDARY WETLANDS (6H:1V)	LARGE WOODY DEBRIS (LWD)
C - HABITAT AND PLANTING MOUNDS (6H:1V)	PROPOSED TOP OF SLOPE
D - DEEP WATERFOWL POND (6H:1V)	PROPOSED TOE OF SLOPE
E - CONNECTION TO EXISTING PONDS AND RESERVOIR AT LOW ELEVATIONS	EXISTING TOP OF SLOPE
POTENTIAL COBBLE AT INLET & OUTLET	EXISTING TOE OF SLOPE
	RETAINED WATER LEVEL
	APPROX. MAX. RESERVOIR LEVEL (440 m)
	PROPERTY LINE

PLAN

Scale 1:750

0 10 (1:750) 40m

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28/07/2017

NO	REMARKS	DATE	DESIGNED	INDEP CHK	DFTG	DFTG CHK	INSP	REV	ACPT
B	FEASIBILITY DESIGN – DRAFT	28 JUL'17	SFJ	PF	PAC	–	–	SFJ	–
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REVISIONS

REF#	DRAWING NUMBER	TITLE	REF#	DRAWING NUMBER	TITLE

REFERENCE DRAWINGS

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

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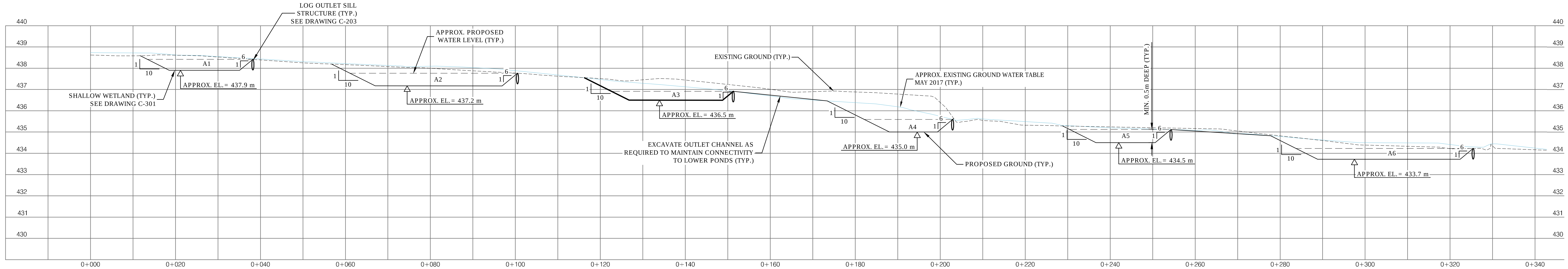
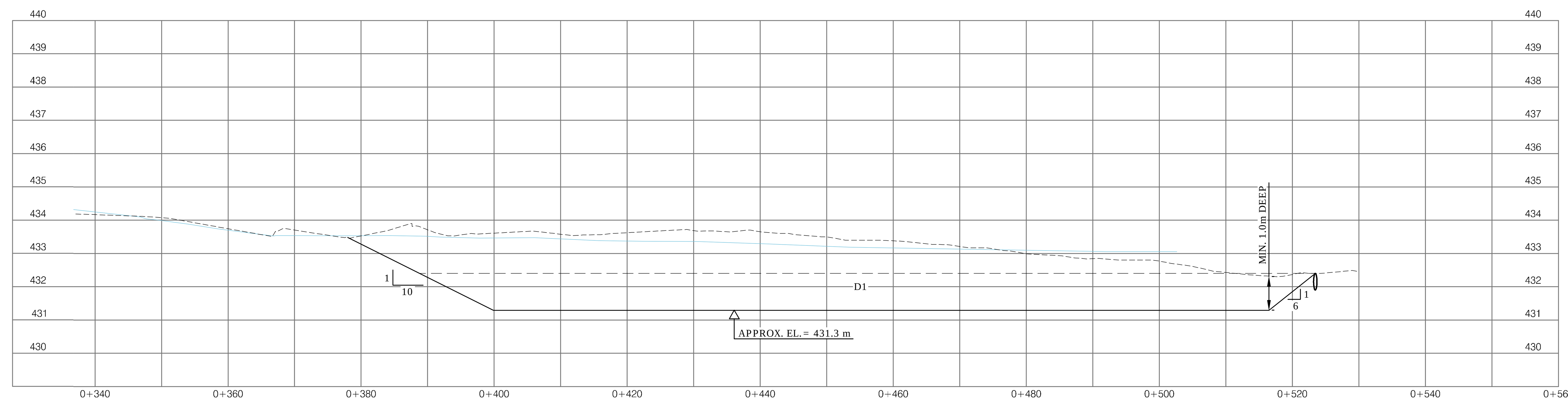
WILDLIFE ENHANCEMENT PROJECT AT BURTON FLATS, B.C. (CLWORKS-30B)

WETLAND HABITAT ENHANCEMENT WORKS

OPTION 1 & 2 CONNECTION TO EXISTING PONDS - PLAN

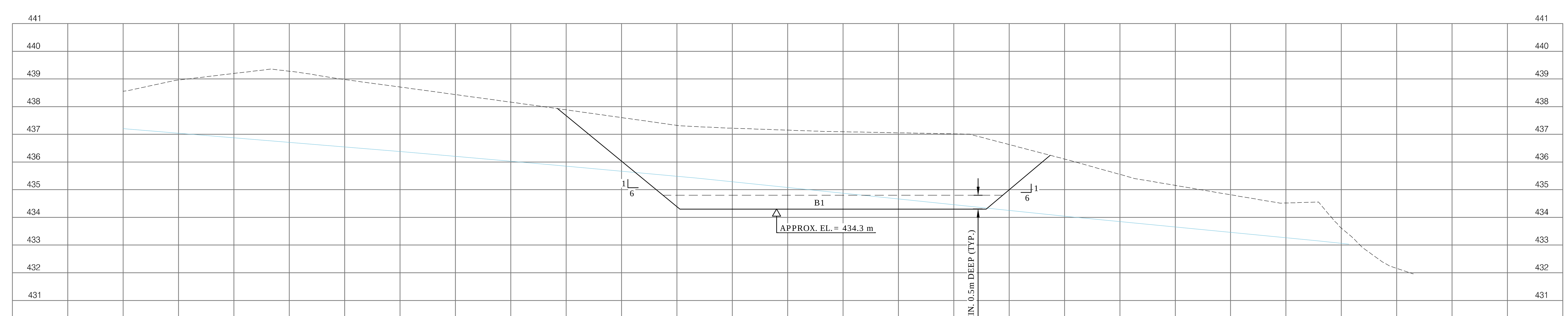
DATE	DIST	DWG NO	SIZE	R
2017-JUNE	-	C-104	D	B





SHALLOW & DEEP POND PROFILES

H 1:500 V 1:100



SECONDARY DISCONNECTED POND PROFILE

H 1:500 V 1:100

NOTE:

- BASE OF PONDS ARE SHOWN AS FLAT IN PROFILE FOR SIMPLICITY. THE CONSTRUCTED SURFACE WOULD VARY TO PROVIDE MORE 'NATURAL' DIVERSITY OF POND GEOMETRY AND HABITAT. THIS NOTE APPLIES TO ALL POND TYPES.
- THE GROUNDWATER LEVELS SHOWN ARE BASED ON SURVEYED WATER LEVELS ON MAY 16, 2017 AND PIEZOMETER DATA RECORDED IN MAY 2017

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28/07/2017

NO	REMARKS	DATE	DESIGNED	INDEP CHK	DFTG	DFTG CHK	INSP	REV	ACPT
B	FEASIBILITY DESIGN – DRAFT	28 JUL'17	SFJ	PF	PAC	–	–	SFJ	–
A	PRELIMINARY DESIGN – DRAFT FOR DISCUSSION ONLY	30 JUN'17	SFJ	PF	PAC	ACL	–	SFJ	–

REVISIONS

REF#	DRAWING NUMBER	TITLE	REF#	DRAWING NUMBER	TITLE

REFERENCE DRAWINGS

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

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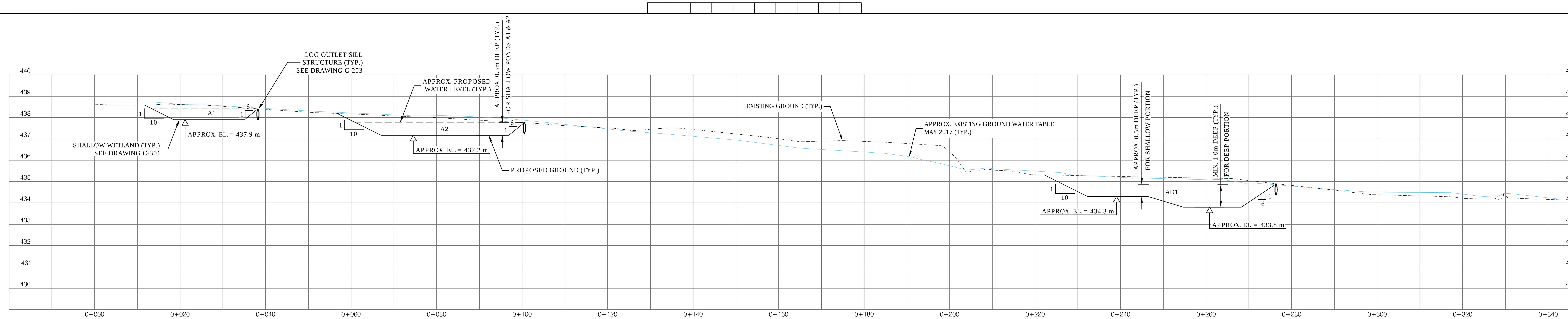
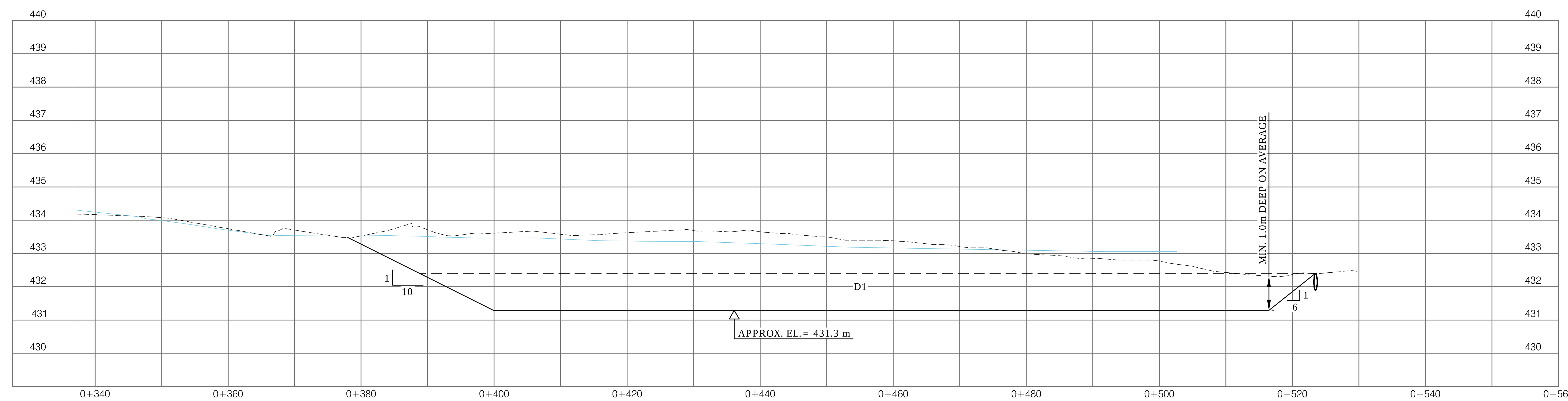
WILDLIFE ENHANCEMENT PROJECT AT BURTON FLATS, B.C. (CLWORKS-30B)

WETLAND HABITAT ENHANCEMENT WORKS

OPTION-1-PROFILES

DATE	DIST	DWG NO	SIZE	R
2017-JUNE	-	C-201	D	B



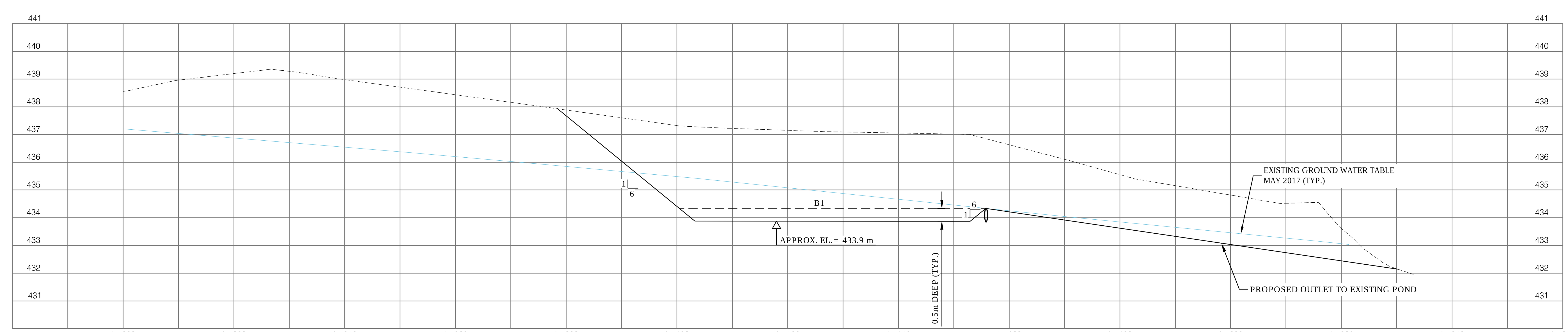


SHALLOW & DEEP POND PROFILES

H 1:500 V 1:100

NOTE:

- BASE OF PONDS ARE SHOWN AS FLAT IN PROFILE FOR SIMPLICITY. THE CONSTRUCTED SURFACE WOULD VARY TO PROVIDE MORE 'NATURAL' DIVERSITY OF POND GEOMETRY AND HABITAT. THIS NOTE APPLIES TO ALL POND TYPES.
- THE GROUNDWATER LEVELS SHOWN ARE BASED ON SURVEYED WATER LEVELS ON MAY 16, 2017 AND PIEZOMETER DATA RECORDED IN MAY 2017



SECONDARY POND PROFILE

H 1:500 V 1:100

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28/07/2017

NO	REMARKS	DATE	DESIGNED	INDEP CHK	DFTG	DFTG CHK	INSP	REV	ACPT
B	FEASIBILITY DESIGN – DRAFT	28 JUL'17	SFJ	PF	PAC	–	–	SFJ	–
A	PRELIMINARY DESIGN – DRAFT FOR DISCUSSION ONLY	30 JUN'17	SFJ	PF	PAC	ACL	–	SFJ	–

REVISIONS

REF#	DRAWING NUMBER	TITLE	REF#	DRAWING NUMBER	TITLE

REFERENCE DRAWINGS

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

BC hydro

WILDLIFE ENHANCEMENT PROJECT AT BURTON FLATS, B.C. (CLWORKS-30B)

WETLAND HABITAT ENHANCEMENT WORKS

OPTION-2-PROFILES

DATE	DIST	DWG NO	SIZE	R
2017-JUNE	-	C-202	D	A

(LOOKING DOWN STREAM)

SHALLOW WETLAND TYPICAL SECTION

Scale 1:50

* SAME FOR DEEP WETLAND TYPICAL, BUT DEPTH OF 0.8 - 1.0 m

TYPICAL MOUND SECTIONS

Scale 1:50

REED CANARY GRASS TRIAL TYPICAL SECTION

Scale 1:50

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0 0.5 (1:50) 2.5m

NOT FOR CONSTRUCTION
28/07/2017

NO	REMARKS	DATE	DESIGNED	INDEP CHK	DFTG	DFTG CHK	INSP	REV	ACPT
B	FEASIBILITY DESIGN – DRAFT	28 JUL'17	SFJ	PF	PAC	–	–	SFJ	–
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REVISIONS

REF#	DRAWING NUMBER	TITLE	REF#	DRAWING NUMBER	TITLE

REFERENCE DRAWINGS / REFERENCE DRAWINGS

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

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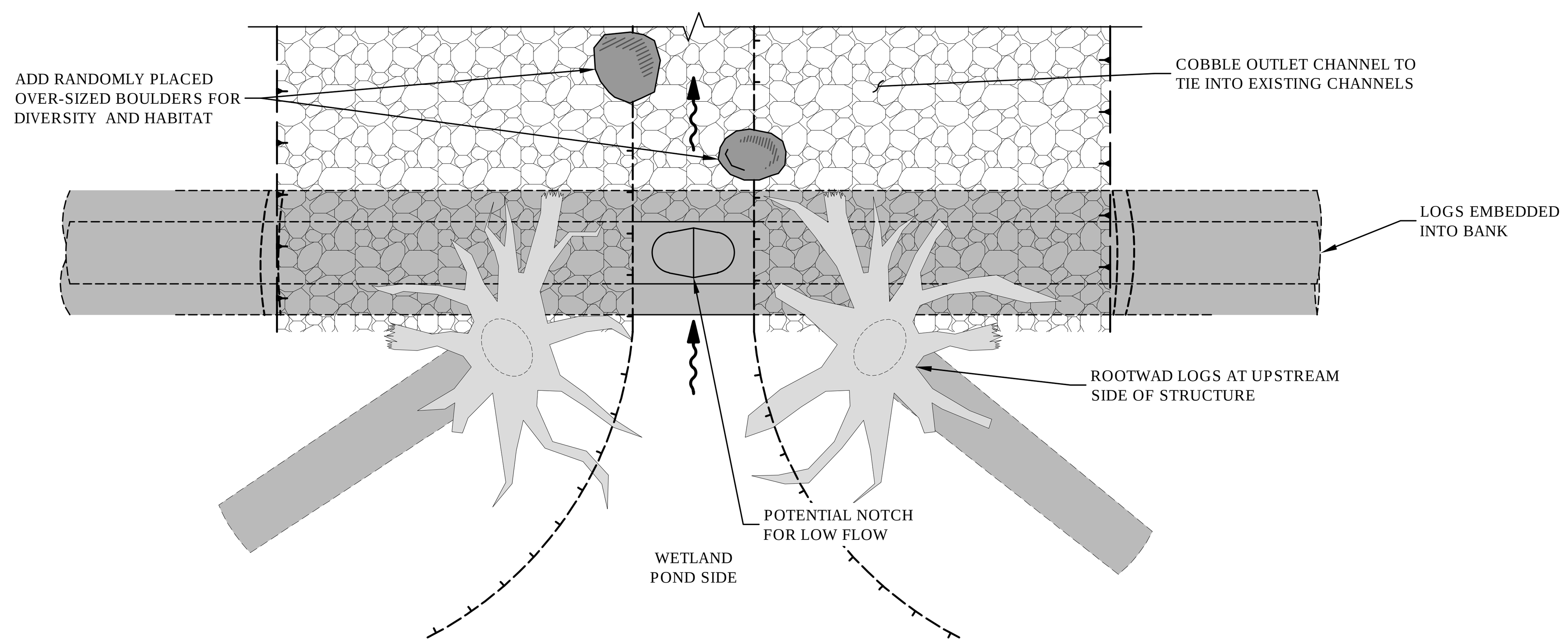
WILDLIFE ENHANCEMENT PROJECT AT BURTON FLATS, B.C. (CLWORKS-30B)

WETLAND HABITAT ENHANCEMENT WORKS

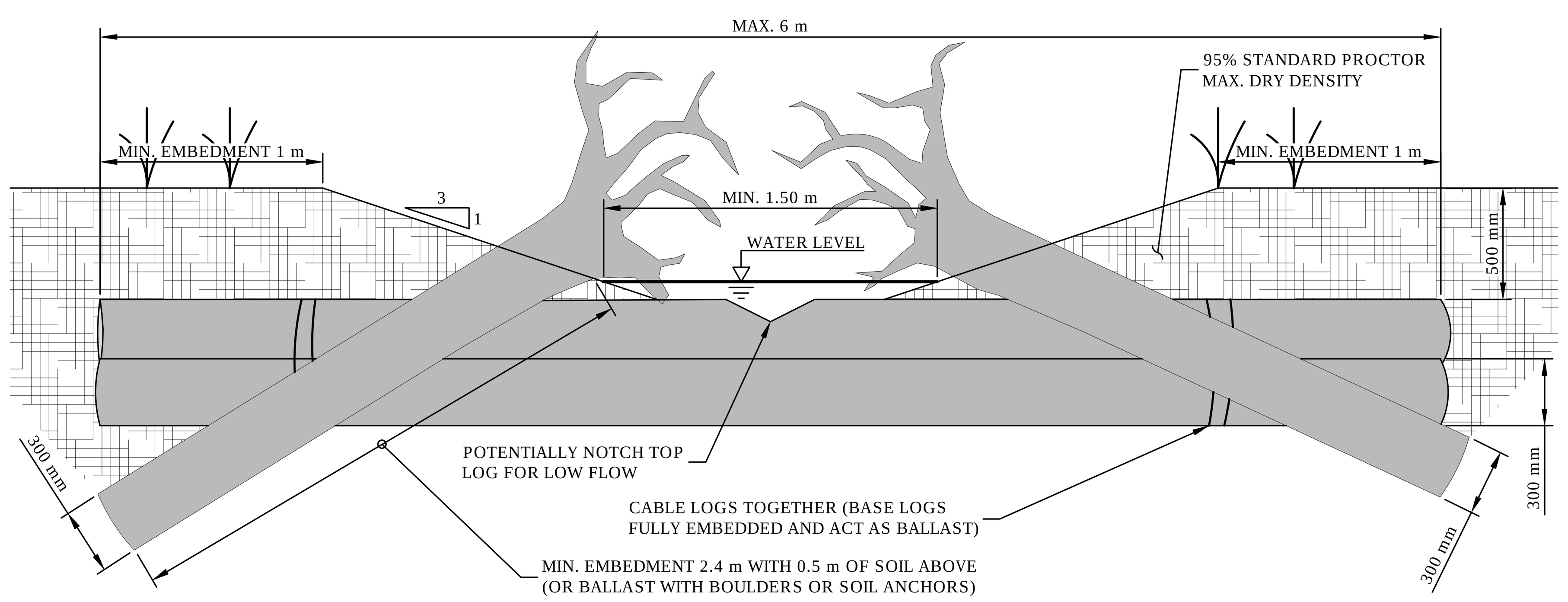
TYPICAL-SECTIONS

DATE	DIST	DWG NO	SIZE	R
2017-JUNE	-	C-301	D	B



OUTLET - PLAN - OPTION 1

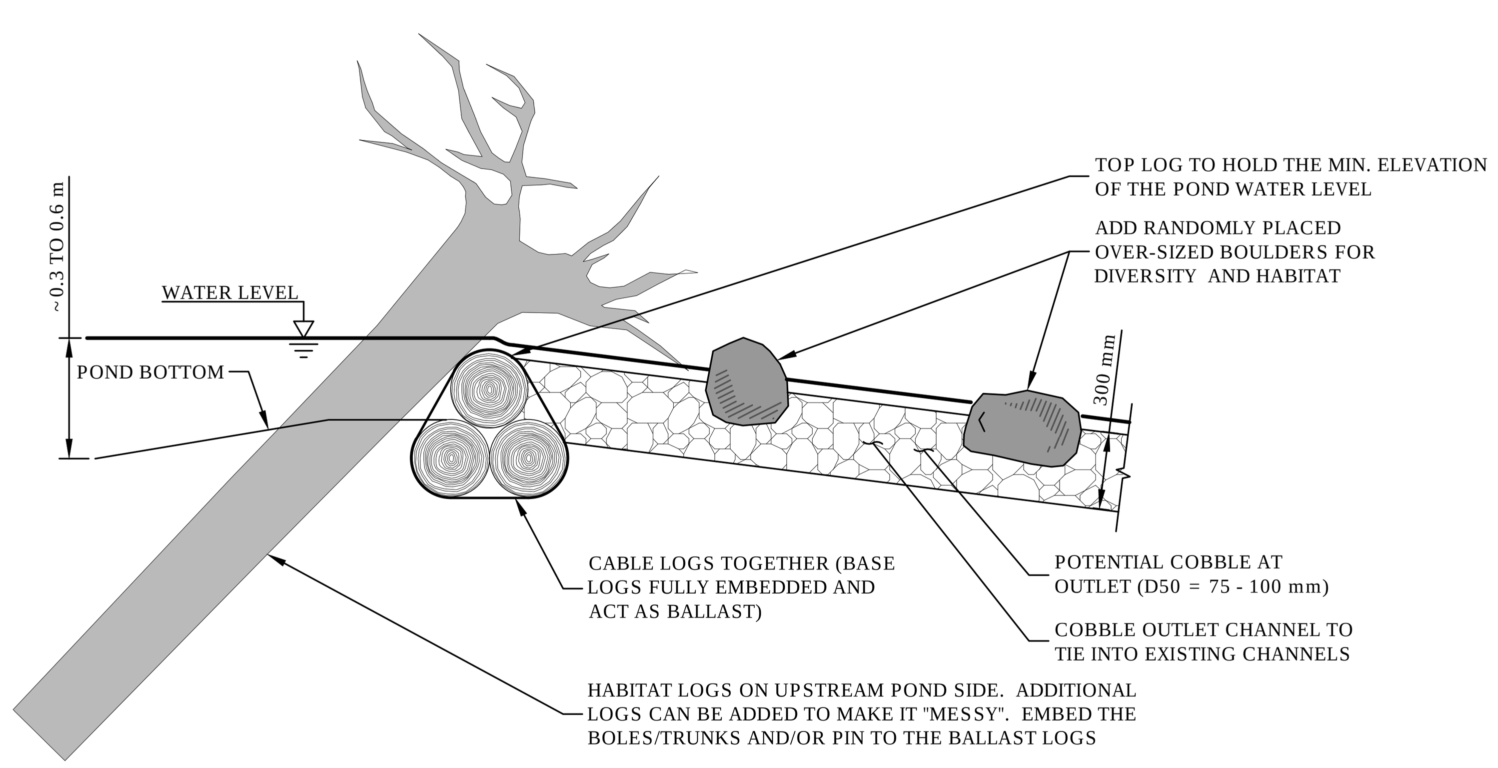
Scale 1:25



(LOOKING DOWN STREAM)

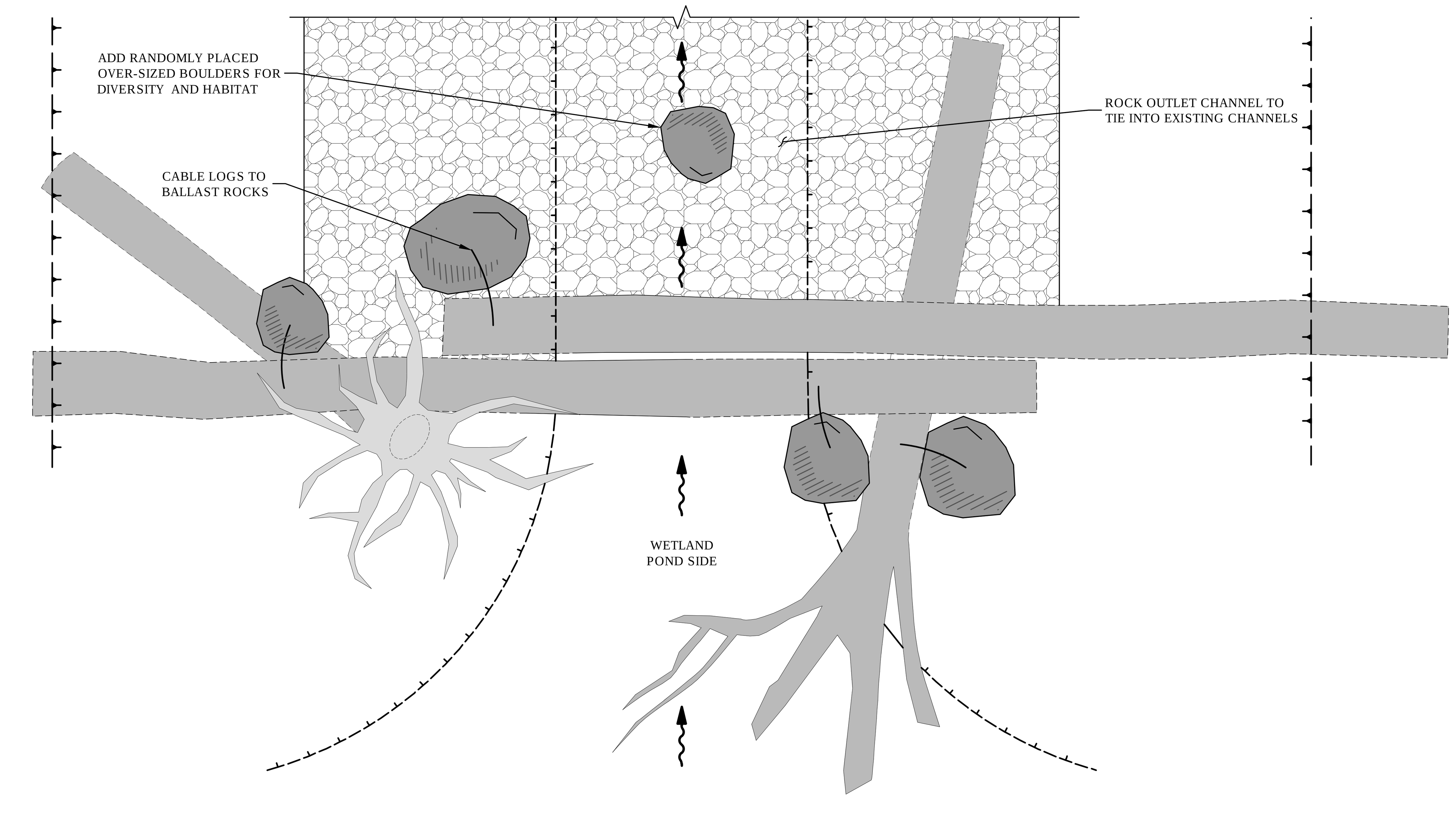
OUTLET - SECTION - OPTION 1

Scale 1:25



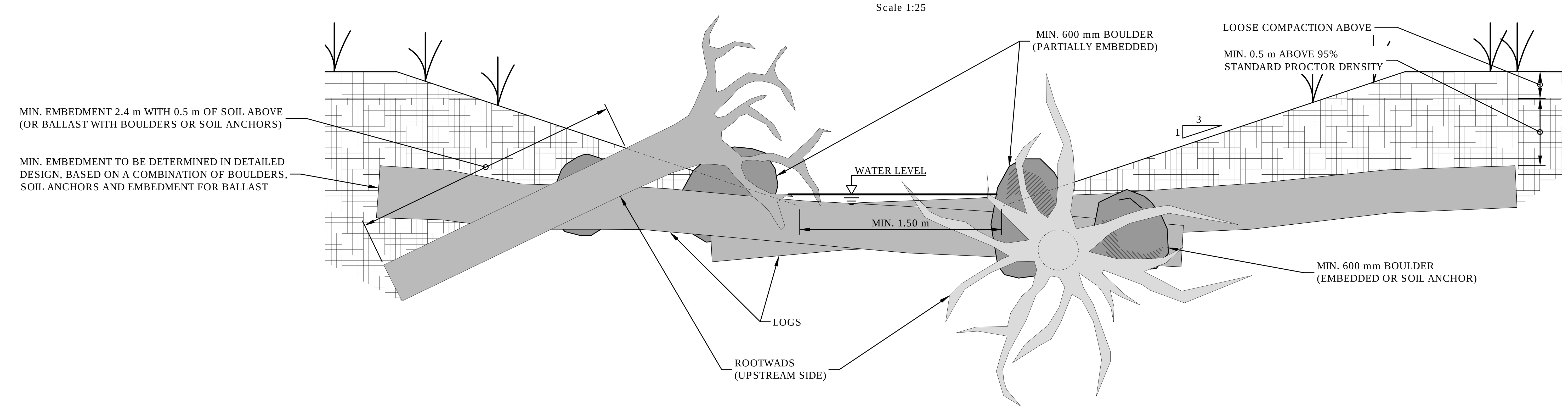
OUTLET - PROFILE - OPTION 1

Scale 1:25



OUTLET - PLAN - OPTION 2

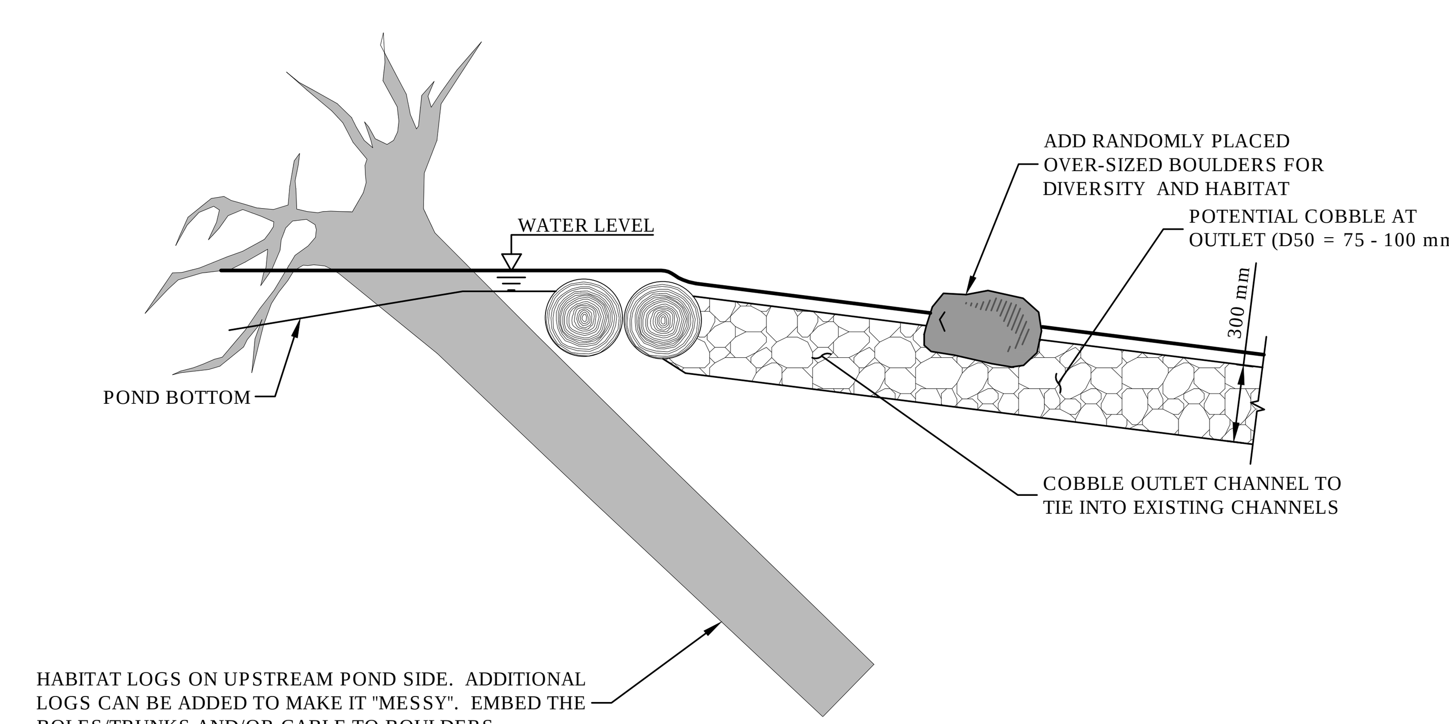
Scale 1:25



(LOOKING DOWN STREAM)

OUTLET - SECTION - OPTION 2

Scale 1:25



OUTLET - PROFILE - OPTION 2

Scale 1:25

NOTES:

- **LOGS TO BE 300 mm Ø, MAX 6 m LONG.**
- **ROOTWADS 300 mm Ø, MAX. 6 m LONG, MIN. 2.5 m EMBEDMENT.**
- **BOULDERS TO BE 600 mm Ø MIN.**
- COMPACT SOIL UP TO 500 mm ABOVE LOGS TO 95% STANDARD PROCTOR DENSITY IN 200 mm LIFTS, THEN MATERIAL CAN BE LOOSELY PACKED ABOVE.
- CAN USE EITHER BOULDERS OR SOIL ANCHORS FOR BALLAST, TO BE FINALIZED DURING DETAILED DESIGN.
- LOGS TO BE CEDAR PREFERABLY, OR FIR AS AN ALTERNATIVE.

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0 0.5 (1:50) 2.5m

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REVISIONS

REF#	DRAWING NUMBER	TITLE	REF#	DRAWING NUMBER	TITLE

REFERENCE DRAWINGS

REFERENCE DRAWINGS

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

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WILDLIFE ENHANCEMENT PROJECT AT BURTON FLATS, B.C. (CLWORKS-30B)

WETLAND HABITAT ENHANCEMENT WORKS

TYPICAL-OUTLET-DETAILS

DATE	DIST	DWG NO	SIZE	R
2017-JUNE	-	C-302	D	B