Columbia River Project Water Use Plan

Arrow Lakes Reservoir Wildlife Management Plan

Arrow Lakes Reservoir Wildlife Enhancement Program – Physical Works

Implementation Year 1

Reference: CLBWORKS-30B (Phase 1)

CLBWORKS-30B Arrow Lakes Reservoir Wildlife Enhancement Program

Burton Flats Planting Project (Phase 1)

Study Period: 2019

LGL Limited environmental research associates
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CLBWORKS-30B Arrow Lakes Reservoir Wildlife Enhancement Program
Burton Flats Planting Project (Phase 1)




Final Report
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Cover photos

From left to right: Pond B1, Mound C2, Mound C2, Pond A2. Photos © LGL Limited: Mike Miller.

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CLBWORKS-30B planting crew, October 2019. Left to right: Melissa Zeleznik, Wanda Buerge, Marlowe Nicholson, and Kevin Schiller.

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1.0 Introduction

As part of its continued implementation of Water License Requirements for the Arrow Lakes Reservoir (ALR), BC Hydro is undertaking a wildlife enhancement project (as per CLBWORKS-30B) in the mid-reservoir drawdown zone at Burton flats. 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 (coordinates: 11 U 435757 E and 5536952 N) is located south of Burton, B.C. on the east side of the Arrow Lakes Reservoir, just northwest of Highway 6 and is accessed by Robazzo Road.

The idea for a wetland construction project at Burton Flats was initially proposed by Hawkes and Howard (2012). Burton Flats was one of three reservoir drawdown sites (together with Lower Inonoaklin Road and Edgewood South) prioritized for wildlife physical works following an assessment of wildlife data collected for the CLBMON-11B1 program (*Wildlife Effectiveness Monitoring and Enhancement Area Identification for the Lower and Mid Arrow Lakes Reservoir*) and evaluations of where physical works projects could feasibly be implemented. Feasibility assessments for each of the three sites included an assessment of topography, elevation, hydrology, substrate, disturbance potential, existing wildlife use, site ownership, and access. The physical works prescriptions were updated in 2016 under CLBWORKS-29B (Hawkes and Tuttle 2016), and the Burton Flats prescription was developed and formalized into the current project by BC Hydro, LGL Limited, and Kerr Wood Leidal (KWL) in 2018 (KWL 2018).

Prior to construction, the project area at Burton Flats consisted of a shallowly undulating (nearly flat) expanse of annually inundated drawdown zone. The terrain supported sparse to dense graminoid cover (consisting primarily of non-native reed canarygrass intermixed with native sedges), interspersed with some small stands of black cottonwood on higher ground (Figure 1-1). The site is bounded to the east by Highway 6, to the south (above full pool) by a mixedwood forest, to the north by Burton Creek, and to the west by the reservoir. From the height of land at the northeast corner, the site slopes gently towards the creek and reservoir, with some old gravel mining pits creating additional depressions at low elevations. An existing watercourse runs along the site parallel to Highway 6, which is fed by shallow subsurface flow from Burton Creek. At its southern (upland end), this flow supports a shallow wetland/wet meadow dominated by emergent grasses and sedges (e.g., bluejoint reedgrass [*Calamagrostis canadensis*], small-flowered bulrush [*Scirpus microcarpus*], and beaked sedge [*Carex utriculata*]) with a minor component of wetland forbs (e.g., marsh cinquefoil [*Comarum palustre*]; Figure 1-1).

Sedge plug, fertilization, and cottonwood planting trials were undertaken between 2008 and 2011 in areas adjacent to the project footprint by BC Hydro under CLBWORKS-2, and the success of these treatments was monitored under CLBMON-12 (*Arrow Lakes Reservoir Monitoring of Revegetation Effectiveness and Vegetation Composition Analysis*). This prior revegetation effort produced slightly higher sedge covers for the area but resulted in minimal increases in shrub cover (Keefer Ecological Services 2010, Miller et al. 2018b).

The aim of the CLBWORKS-30B project is to increase the spatial and temporal availability of wetland habitat for wildlife in the drawdown zone of the reservoir by creating a series of excavated pools between elevations 434 masl (metres above sea level) and full pool (440 masl), and enhancing riparian and wetland vegetation on the banks of the pond features via a planting program. The wetland design includes shallow and deep pool configurations as well as pools with and without surface flow connectivity to allow a comparative assessment of the effectiveness of different types of configurations. Elevated, planted mounds that create nesting and other habitat at higher elevations (>439 masl) are also incorporated into the design for continued learning about habitat enhancement within, and adjacent to, the drawdown zone (KWL 2018).

Figure 1-1. Burton Flats project site (pre-enhancement). Left: northern portion of site, looking northeast towards highway and Burton Creek bridge. Right: Existing shallow wetland (future pond A1/A2 feature) at southeast corner of site. Photographed September 2019 when reservoir level was <435 masl. Photos: M. Miller.

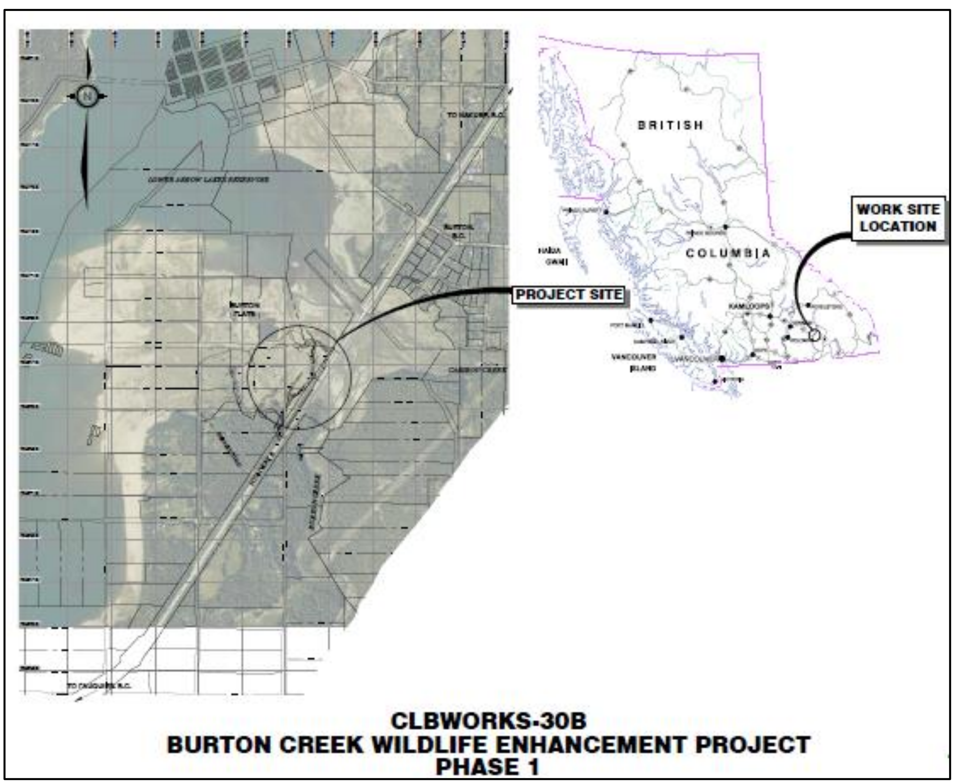

Figure 1-2. Burton Wetland Enhancement Project Location, Arrow Lakes Reservoir (KWL Detailed Design 2018).

Wetland construction and the associated revegetation is scheduled to occur in two phases. Phase 1 occurred in the fall of 2019 and is the subject of this report. Phase 2, involving the expansion of some phase 1 ponds along with the construction of several additional pond and mound features, and revegetation of those features, will occur in 2020 or 2021 (schedule still to be determined). Depending on the survival and vigor of phase 1 plantings and the timing of phase 2 construction, an additional restocking of phase 1 features may be incorporated into the phase 2 construction plan.

2.0 Revegetation Goals and Approach[1]

The goal of the vegetation planting program is to create long-term, self-sustaining native plant communities that improve the available habitat for several wildlife species, including migratory birds, nesting birds, pond-breeding amphibians, reptiles, and mammals (e.g., bats). This goal will be accomplished by establishing emergent native vegetation and shrub habitat to promote foraging and nesting, and by encouraging submergent native vegetation to colonize wetland bottoms that can be used by amphibians, migrating waterfowl, and shorebirds. Elevation-specific planting of shrubs and trees will be carefully planned to avoid creating ecological traps at lower elevations, which become inundated by the reservoir during the bird nesting season.

The revegetation program associated with CLBWORKS-30B will augment the existing (naturally occurring) emergent vegetation community at high elevation ponds; promote submergent vegetation in ponds staggered across elevations; and attempt to establish a riparian habitat consisting of graminoids, shrubs, and trees along the wetland edges and on top of constructed mounds.

Key features of the planting program are as follows:

1. It will be carried out in phases to align with the phased approach for wetland construction.
2. Planting within polygons will be iterative, so that initial low-density stocking and subsequent monitoring of plant survival can be used to adaptively guide a replanting investment in later years to maximize revegetation success in terms of both density and diversity of plant species. The phase 1 restoration objective is to achieve initial transplant establishment of all planted species in at least one elevation band. “Establishment” is here defined as continued species presence and persistence for one year following the first high water event.
3. In addition to planting purchased plug and rooted stock, the planting program will depend heavily on opportunities to transplant salvaged plants and will utilize nearby sources of black cottonwood and willow stakes (e.g., from transmission rights-of-way). Beaked sedge, Kellogg’s sedge, Columbia sedge and (to a lesser degree) small-flowered bulrush are available for salvage directly from within the project footprint.
4. The program will take a soft approach to target stocking density and diversity because revegetation success is challenging in drawdown zone environments, and due to uncertainties regarding the availability of both salvaged stock and purchased stock.
5. Detailed documentation of planting effort (spatially explicit density for each stock category) will be emphasized and adopted as a responsibility of the planting contractor.

[1] Section adapted from *Planting Plan for Phase 1 Construction* (BC Hydro 2018)

2.1 Treatment Areas

The proposed phase 1 physical works enhancements are described in detail in KWL (2018) and included the excavation of ponds and the mounding of excavated material into elevated hillocks (Figure 2-1). Revegetation prescriptions were developed for each feature and for the various elevation zones spanned by each feature. The proposed features, and the corresponding goals for revegetation, are briefly summarized below. A more detailed description of the planting prescriptions for different features and elevations appears in Section 2.2.5.

<u>A1-A4</u>: Shallow Pond Wetland Complex

- A1, A2, A3, and A4 are a series of four shallow ponds (~0.3 to 0.5 m deep) intended to enhance an existing shallow (un-ponded), stream-fed wetland that currently has low value for wildlife. The four ponds progress in steps downstream along the watercourse ending at the A4 pond (~436.5 masl). The uppermost pond, A1 (~439 masl), is just downstream from a natural sedge-alder riparian wetland flowing towards the drawdown zone from a culvert under the highway.
- The upper two ponds, A1 and A2, are intended to support both emergent wetland plants as well as a cover of riparian vegetation (both herbaceous and woody), thereby improving wetland complexity and value for riparian/wetland wildlife, including nesting habitat for birds.
- The lower ponds, A3 and A4, will support a lighter cover of riparian vegetation and (potentially) emergents, with the objective of increasing wildlife habitat while minimizing attractants for nesting birds.

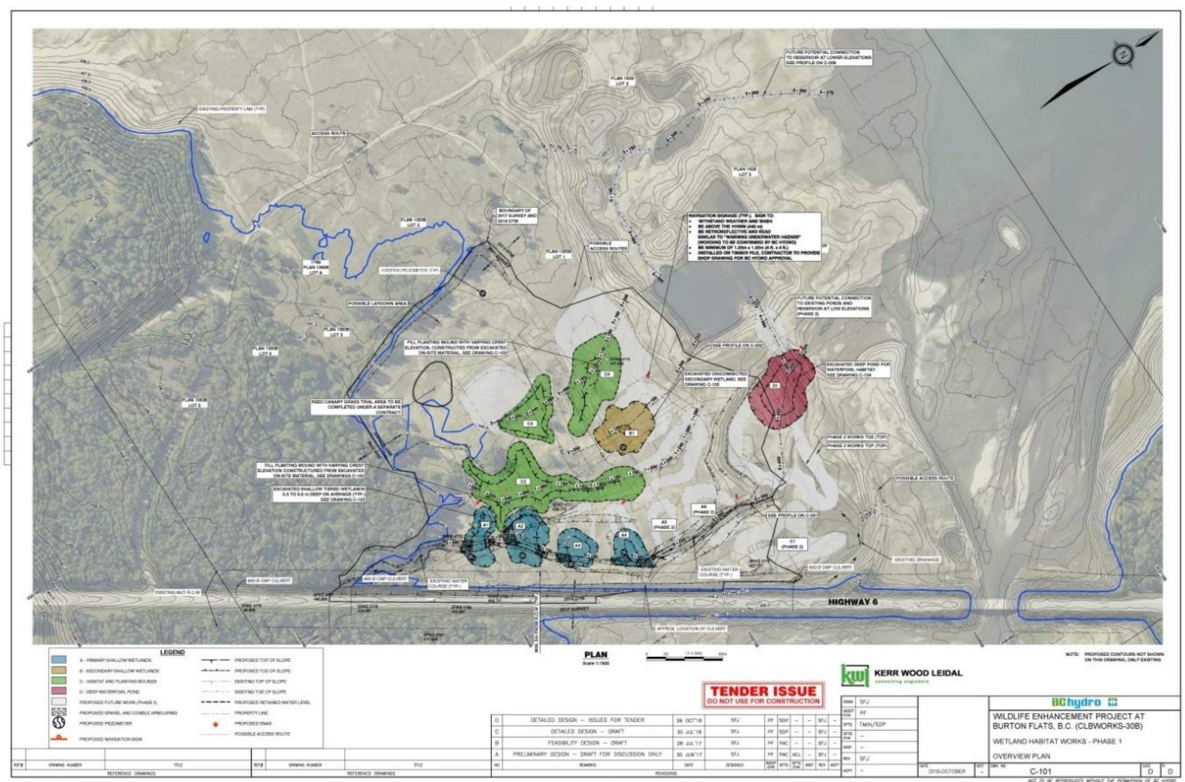

Figure 2-1. Burton Flats Wetland Enhancement Project Design Components – Phase 1 (KWL Detailed Design 2018). Features A1-A4 (Shallow Pond Wetland Complex) are shown in blue (A1 is the

southern-most pond and A4 is the northern-most pond); the B1 feature (Isolated Pond) is beige; features C1-C3 (Mounds) are green; and Feature D1 (Large Deep Low-elevation Pond) is red. The blue line represents the full pool shoreline of Arrow Lakes Reservoir.

B1: Isolated Pond

- This feature is somewhat experimental and attempts to create suitable pond habitat for wildlife (e.g., Western Toad, shorebirds) by excavation to the water table. Initially, this (possibly ephemeral) pond may be left disconnected from other wetland features to test the success of a disconnected system.
- Like A3 and A4, this pond will support a lighter cover of riparian vegetation and (potentially) emergents, with the objective of increasing wildlife habitat while minimizing attractants for nesting birds.

C2-C4: Mound Features[2]

- The design of mounds using material excavated from the ponds (described above) attempts to maximize crest elevation habitat near or above the normal operating full pool elevation (440.1 masl), thereby creating more safe nesting habitat and potentially an increased diversity of plants bordering the wetlands.
- Mounds will be staked and planted to promote nesting, as well as shading to promote RCG suppression/removal.
- C2 is positioned next to the wetland water course (i.e., ponds A1-A4); due to its expected high organic soil content, C2 is being prioritized as the leading mound feature in terms of planting effort.

D1: Large Deep Low-elevation Pond[3]

- A large deep wetland (up to 1.2 m deep with shallow fringes) created from the existing depression at the north end of the watercourse (positioned at ~433 masl).
- There is no current plan to restore vegetation around D1, although sedges such as Kellogg's sedge could be effective at this elevation. Addition of submergent plants (macrophytes) may also be effective.

2.2 Considerations of the Revegetation Plan

The goal of the planting program is to establish native species with high wildlife habitat value in and around the wetlands. To the extent possible, the planting composition will support development of a vegetation community that approaches, in richness and complexity, what might establish along a natural (unregulated) riparian course at this location. The nearest unregulated riparian area (and likely best basis for comparison) is the riparian zone of Burton Creek upstream of the reservoir full pool elevation(east of the highway bridge).

In designing the revegetation plan, key considerations included:

1. plant species' relative value for wildlife;

[2] C4 was not constructed in 2019 but instead will be completed during phase 2.
[3] D1 was not constructed in 2019 but instead will be completed during phase 2.

2. the risk of bird nest flooding associated with different revegetation prescriptions across elevations;
3. plant tolerances to inundation;
4. the management of invasive weeds; and
5. the suitability of conditions for transplanted species at each microsite.

2.2.1 Valued Plants for Wildlife

Anticipated benefits of the wetland construction at Burton Flats will be for wildlife including birds (songbirds, waterfowl, and shorebirds), amphibians, reptiles, mammals (bats), insects (dragonflies) and fish (among others) (Hawkes and Tuttle 2016). Species with provincial or federal conservation designation that will benefit from this project include the provincially blue-listed and COSEWIC species of Special Concern, Western Toad (*Anaxyrus boreas*); the provincially blue-listed Townsend's Big-eared Bat (*Corynorhinus townsendii*) and Fringed Myotis (*Myotis thysanodes*); and the Endangered Little Brown Myotis (*Myotis lucifugus*) (SARA-listed November 26, 2014). The relatively homogeneous habitat that will be replaced with wetland habitat suggests low risk with this particular physical works. While notable wildlife value observed under baseline conditions in the existing sedge/*Scirpus* habitat includes usage by Columbia spotted frog (Hawkes and Tuttle 2013) and Wilson's Snipe (H. van Oort, pers. obs.), it is anticipated that a considerable proportion of habitat will remain for such species and others (see below) regardless of project success. However, there is always a risk of net habitat loss if the created habitat does not function as desired. Under such an outcome, future interventions can be considered to increase productivity or habitat suitability for wildlife and vegetation. The treatments (described in Section 2.1) have considered the relationships between vegetation cover and the creation/suitability of wetland habitat for pond-breeding amphibians, shorebirds, certain songbirds, and waterfowl.

Attention was paid to the types of plants used to revegetate the physical works completed in 2019 that would be of most benefit to birds. CLBMON-36, a BC Hydro project that monitored bird nesting in Revelstoke Reach of Arrow Lakes Reservoir, assessed 1000's of nests in the drawdown zone over several years (Craig et al. 2018). Nests occurred in a variety of shrub and tree species including mountain alder, hardhack, birch, cedar, dogwood, elderberry, fir, hazel, pine, rose, snowberry, spruce, thimbleberry, twinberry, black cottonwood and willow (CLBMON-36 unpublished data). However, three shrubs were overwhelmingly more commonly used as nesting substrates: hardhack (*Spiraea douglasii*), willow (*Salix* spp.), and mountain alder (*Alnus incana* ssp. *tenuifolia*).

Hardhack and mountain alder were not widely distributed in the drawdown zone, and likely have relatively low tolerance to inundation; however, where they persist they are favoured for nesting by a wide variety of species including Common Yellowthroat, Song Sparrow, Chipping Sparrow, Willow Flycatcher, Alder Flycatcher, Cedar Waxwing and Yellow Warbler (over 250 nests for these species alone have been recorded occurring in these shrub species). On the other hand, willow (primarily *Salix sitchensis* but including other *Salix* spp.) is relatively tolerant of inundation and is widely used by the same species listed above that use alder (over 801 nests recorded in willow).

Baseline bird use of the Burton Flats area was assessed in 2018 as part of CLBMON-11B1 through a combination of songbird point counts, nest searches, and spring and autumn waterbird surveys (Hentze et al. 2019). Fourteen observations of six songbird species were recorded in the wildlife physical works area at Burton Flats during summer 2018: American Robin, Common Yellowthroat, Dusky Flycatcher, Lazuli Bunting, Rufous Hummingbird, and Yellow Warbler. Several of these were detected from the forest edge, such as the Dusky Flycatcher and Lazuli Bunting. Both the Common Yellowthroat and Yellow Warbler are marsh and riparian species.

In total, 92 bird species were recorded during spring through autumn waterbird surveys. Within the proposed physical works location, there were four species recorded in the spring survey: American Crow, Common Yellowthroat, Belted Kingfisher, and Mallard. In August, sightings within the physical works location included Great Blue Heron, Killdeer, Bald Eagle, and for waterfowl, Common Merganser and Canada Goose. In September the only detection within the wildlife physical works location was 175 Canada Goose.

Evidence of nesting in the Burton Flats area was low with only four nests of an unknown species observed. The current lack of shrub and tree species at Burton Flats may be contributing to the low density of nests observed in the drawdown zone. Shrub and tree species found to be important in other studies (i.e., CLBMON-36) are of relevance to the planting program at Burton Flats.

2.2.2 Nest Flooding

Within a reservoir, the ecological benefit of revegetating the drawdown zone as nesting habitat is reduced by the risk of nests flooding due to reservoir operations. Low elevation habitats have higher flooding risk and so the net benefit to birds is maximal at high elevations. Based on experience and findings from the CLBMON-36 monitoring program, it was determined that creating high quality nesting habitat should only be attempted at elevations greater than 438.5 masl (1.5 m below the full pool elevation; see also Hawkes and Tuttle 2016). It is recognized that this is an estimate, and in truth the reality depends on species, plant morphology, and annual variability in reservoir operations. Below this elevation, the focus should be on establishing vegetation communities that are not commonly associated with high nests densities in the reservoir (e.g., Kellogg's sedge). Black cottonwood can also be used below 438.5 masl because this species does not typically provide suitable nesting habitat within 1.5 m of the ground.

2.2.3 Plant Tolerance for Inundation

The operation of Arrow Lakes Reservoir has created vegetation bands stratified by elevation, reflecting differing tolerance for inundation among plant species. The distribution of these vegetation communities is also affected by other factors including substrate type and morphology, hydrology, and influence of reservoir operations on seed germination and establishment (Miller et al. 2018a). The complex interaction between local site conditions, reservoir operations, and plant habitat preferences create some uncertainty around the local responses of particular plant species and the outcome of revegetation efforts. For example, previous work in Arrow Lakes and Kinbasket Reservoirs (Hawkes and Gibeau 2017, Hawkes et al. 2018, Miller et al. 2018a, Miller and Hawkes 2019) indicates that two terrestrial sedge species, Kellogg's sedge and Columbia sedge, both of which naturally occur in the drawdown zone, are amenable to transplantation and also relatively tolerant of fluctuating water levels, as long as the site is topographically sheltered and the substrate is stable (not subject to frequent erosion), not overly coarse or fine, contains sufficient nutrients, and remains appropriately saturated through the growing season. Not surprisingly, given these requirements, field observations of revegetated areas indicate that the success of individual plantings has been highly variable: some areas have seen good establishment from seedling plugs, while others have failed completely (Hawkes et al. 2018).

Similarly, work has shown that willows and black cottonwood are relatively inundation-tolerant (compared to other woody species), but that instances of successful establishment decline sharply with decreasing elevation in the drawdown zone (and, by extension, with increased depth and duration of inundation). These species also have low drought tolerance and require saturated or periodically inundated soils. Thus, their utility for revegetation is generally restricted to upper portions of the drawdown zone on sites with a high water table and/or fine (moisture-retaining) sediments (Hawkes et al. 2018).

The approach taken in this project is that initial stocking effort should: (1) be experimental; and (2) reflect confidence in success, with higher stocking densities applied in high-confidence settings. Given their demonstrated tolerances for inundation, sedges, willows, and black cottonwood were emphasized in the phase 1 planting prescriptions. Wetland sedges and grasses already thriving at site (e.g., small-flowered bulrush, beaked sedge, bluejoint reedgrass) have the capacity to spread and populate the enhanced pond margins that will be created. Stocking of these species was done using locally salvaged plants and distributed evenly throughout new shorelines. In other instances, a lower stocking effort was used to experimentally learn where different riparian and upland species can be successfully planted. By testing inundation and substrate tolerances for a wide diversity of species and monitoring interim survival during phase 1, the project will be positioned to undertake strategic restocking of successful species at specific sites and elevations under an updated planting plan in phase 2.

2.2.4 Invasive Weeds

The existing reservoir drawdown zone plant communities are a combination of native and non-native species arrayed by habitat preferences and by competitive tolerances. On many open terrestrial substrates, reed canarygrass (*Phalaris arundinaceae*) is a dominant invasive species where it out-competes most other herbaceous plants, and likely suppresses establishment of many other species. Much of the planting for this project occurred in fresh overturned topsoil, allowing woody shrubs a chance to become established prior to reed canarygrass reinvasion. The eventual development of an overhead canopy will, it is expected, reduce the competitive edge of reed canarygrass and allow other herbaceous species to become established. Aside from promoting a canopy of native shrubs and trees, no further effort is being made to control invasive plant species via stocking; however, the Environmental Management Plan for the project had explicit control measures to prevent the spread of noxious weeds (e.g., ensuring that all machinery is cleaned of dirt, debris, and plant parts; minimizing ground disturbance; and reseeding with an appropriate native seed mix following disturbance).

2.2.5 Planting Prescriptions

The existing wetland/watercourse at the site supports emergent sedges and mountain alder. Above full pool, the wetland is largely enclosed by forest canopy. The drawdown zone has limited potential to be shaded by a forest canopy even after habitat enhancement. A preferred vegetation community—one that extends the naturally existing wetland into a non-shaded opening—is a ponded complex supporting emergent and terrestrial sedges; shrubs such as hardhack and alder; and nearby conifers and birch growing sporadically on hummocks, with occasional dead conifers (cedar, pine) acting as coarse woody debris. This describes the basic vision for the upper elevation riparian zones (Ponds A1-A2 and associated matrix habitat/banks).

The phase 1 mound features (C2-C4) present a novel situation for revegetation attempts in Arrow Lakes Reservoir and pose a specific set of challenges. Over the course of a growing season, these microsites will alternate between being well-drained and hot, and saturated, due to the highly variable water table controlled by the reservoir. The approach here is to experiment with a diversity of upland species; especially those which can potentially tolerated drought and periodically raised water tables. The revegetation goal is to establish a diverse and dense multi-storied vegetation community, but the target species assemblage is not strictly defined.

At lower elevations (those < ~438.5 masl), species that are conducive to bird nesting near the ground (e.g., most shrubs other than cottonwood) will be avoided. The focus at these elevations will be on establishing an initial ground cover of sedges.

A total of six different planting prescriptions (PPs) were developed to reflect these differing site priorities and elevational requirements: (1) Emergent Sedges; (2) Riparian; (3) Terrestrial Sedges (Upper); (4) Terrestrial Sedges (Lower); (5) Terrestrial Mix (general); and (6) Mound Mix (Table 2-1). The development of these prescriptions was informed by results coming out CLBMON-12 and CLBMON-33 as summarized in the CLBMON-35 Prescription Catalogue for Arrow Lakes Reservoir (Hawkes et al. 2018, Miller and Hawkes 2020).

A second, detailed table (Table 2-2) specifies how, and in what combinations, the prescriptions are to be applied at each of the constructed phase 1 features. For example, Pond A3 is prescribed to receive a combination of PPs 1 and 3; Mound C2 is prescribed to receive a combination of PPs 3, 5, and 6 (Table 2-2). The spatial layout of the various planting prescriptions is mapped out in the detailed construction plan (KWL 2018). An example of this mapping is provided in (Figure 2-2).

A quantitative summary of species-specific target numbers for each PP is provided in Table 2-3.

Table 2-1. Phase 1 planting prescriptions applied to constructed ponds and mounds at Burton Flats.

Planting Prescription (PP)	Description
1: Emergent Sedges	High elevation pond emergent sedges (beaked sedge, small-flowered bulrush). Salvaged, and supplemented by plugs. At ponds positioned below elevations where these emergents are growing naturally, a low density of plugs will be planted as a trial.
2: Riparian	A dense irregular mix of riparian shrubs (e.g., hardhack, twinberry, Sitka willow, mountain alder, red-osier dogwood) intermixed with graminoids (e.g., Kellogg's and Columbia sedge, bluejoint reedgrass).
3: Terrestrial Sedges (upper)	High elevation terrestrial prescription that can include species to encourage nesting. Variable density stocking with salvaged sedges (Kellogg's and Columbia sedge), and stakes of three species (black cottonwood, red-osier dogwood, Sitka willow) stocked to a density target. Restock microsites in future where survivorship is observed.
4: Terrestrial Sedges (lower)	Low elevation terrestrial prescription that should not include species to encourage nesting. Variable density stocking with salvaged Kellogg's sedge); this is a more reliable species at low elevations. Restock microsites in future where survivorship is observed.
5: Terrestrial Mix (general)	These polygons span elevations and will be planted with PP3 or PP4, depending on site elevations.
6: Mound Mix	Moderate density and high diversity terrestrial vegetation mix (e.g., soopalallie, paper birch, white pine, hazelnut, twinberry, Bebb's willow, saskatoon, snowberry, black cottonwood, red-osier dogwood, and/or prickly rose). This is very much experimental to see which species thrive on the likely arid conditions on mound summits.

Table 2-2. Feature- and elevation- specific planting prescriptions for constructed ponds and mounds at Burton flats.

Elevation Range (masl)	Area (m^2)	Planting Prescription (PP)	Description	Features
A1 – Pond Feature				
Wetland Fringe	~199.5	1: Emergent Sedges	This treatment will extend/merge with natural emergents that exist along the water course. Salvaged emergent sedge (*Carex utriculata, Scirpus microcarpus*) transplanted in a 1 to 1.5 m pond edge of shallow water (< 25 cm deep), possibly stocked with additional plug stock. Moderate density,	Logs, preferably cedar, which are anchored down. Positioned as if fallen into the pond. Ideally steps will be taken to colonize these logs with typical wetland log plants (e.g., mosses, small woody shrubs, etc.). Not more than 4 major logs. Minor logs or stumps can be added.
438.4 to TOB (approx. 439)	648	2: Riparian	Surrounding the ponds, the shorelines will be planted to encourage a rich wetland riparian community, including a dense irregular mix of riparian shrubs (e.g., *Spiraea douglasii*, *Lonicera involucrata*, *Salix* spp.*, Alnus incana*, *Cornus stolonifera*) intermixed with graminoids (e.g., *Carex kelloggii*, *C. aperta, Calamagrostris canadensis*). To foster a rich habitat, these areas have the highest priority for augmentation with the best growing soils available on site.	Snags (e.g., cedar with branches), specimen trees (e.g., white pine, birch), logs or brush, stumps.
Perimeter Disturbance Allowance	702			
A2 – Pond Feature				
Wetland Fringe	~152	1: Emergent Sedges	This treatment will extend/merge with natural emergents that exist along the water course. Salvaged emergent sedge (*Carex utriculata, Scirpus microcarpus*) transplanted in a 1 to 1.5 m pond edge of shallow water (< 25 cm deep), possibly stocked with additional plug stock. Moderate density.	Possibly some logs – well anchored.
437.75 to TOB (approx. 438.5)	884	2: Riparian	Surrounding the ponds, the shorelines will be planted to encourage a rich wetland riparian community. The elevation of this site will be challenging environment for many plants which may nor survive; a low-density trial and error approach should be adopted in the first year of planting. The species may include an irregular mix of riparian shrubs (e.g., *Spiraea douglasii*, *Lonicera involucrata*, *Salix* spp.*, Alnus incana*, *Cornus stolonifera*) intermixed with graminoids (e.g., *Carex kelloggii, C. aperta, Calamagrostris canadensis*). To foster a rich habitat, these areas have the second highest priority for augmentation with the best growing soils available on site.	Snags (e.g., cedar with branches), specimen trees (e.g., white pine, birch), logs or brush, stumps.
Perimeter Disturbance Allowance	705			
A3 – Pond Feature				
Wetland Fringe	~71.1	1: Emergent Sedges	Low density. Salvaged emergent sedge (*Carex utriculata, Scirpus microcarpus*). Experimental stocking.	Not prescribed
436.9 to TOB (approx. 437.5)	339	3: Terrestrial Sedges (upper)	Low density stocking with even mix of sedge plugs from two species (*Carex kelloggii, C. aperta*). Both species can be salvaged and/or stocked with plugs. Low density cottonwood stakes. Experimental staking.	Not prescribed
Perimeter Disturbance Allowance	390			
A4 – Pond Feature				

Wetland Fringe	~90.7	1: Emergent Sedges	Low density. Salvaged emergent sedge (*Carex utriculata, Scirpus microcarpus*). Experimental stocking.	Not prescribed
435.6 to TOB approx. 436.5)	390	4: Terrestrial Sedges (lower)	Low density stocking of sedge plugs from (*Carex kelloggii*). This species can survive inundation at this band of the drawdown zone, but success depends on substrate. Experimental stocking.	Not prescribed
Perimeter Disturbance Allowance	387			
B1 – Pond Feature (disconnected)				
434.9 to 436	690	4: Terrestrial Sedges (lower)	Low density stocking of sedge plugs from (*Carex kelloggii*). This species can survive inundation at this band of the drawdown zone, but success depends on substrate. Experimental stocking.	Not prescribed
436 to TOB (approx. 437.5)	1480	3: Terrestrial Sedges (upper)	Low density stocking with even mix of sedge plugs from two species (*Carex kelloggii, C. aperta*). Both species can be salvaged and/or stocked with plugs. Low density cottonwood stakes. Experimental staking.	Not prescribed
Perimeter Disturbance Allowance	1268			
C2 – Mound				
Perimeter Disturbance Allowance	2217	5: Terrestrial Mix	Low density stocking of willow, dogwood, cottonwood, and sedge with reduced diversity at low elevations. Experimental staking.	Not prescribed
438.5 to Toe (approx. 438)	848	3: Terrestrial Sedges (upper)	Low density stocking with even mix of sedge plugs from two species (*Carex kelloggii, C. aperta*). Both species can be salvaged and/or stocked with plugs. Low density cottonwood stakes. Experimental staking.	Not prescribed
>438.5	5847	6: Mound Mix	The summit of this mound is a high priority for attempting to foster a diverse upland community of multi-layer vegetation, suitable for nesting birds, roosting bats, and other terrestrial wildlife. Moderate density and high diversity terrestrial vegetation mix (e.g., *Symphoricarpos albus*, *Betula papyfera*, *Pinus monticola*, *Lonicera involucrata*, *Salix bebbiana*, *Amelanchier alnifolia*, *Shepherdia canadensis*, *Populus balsamifera* ssp. *trichocarpa*, *Cornus stolonifera*, and/or *Rosa acicularis*). Experimental staking, but at a relatively high density and diversity of stocked plants. This site is the third most priority for augmentation with the best available soils.	Snags, specimen trees (e.g., cedar, hemlock), logs, stumps. This site will be suitable for nest boxes (all types) and bat roost boxes.
C3 – Mound				
Perimeter Disturbance Allowance	2149	5: Terrestrial Mix	Low density stocking of willow, dogwood, cottonwood, and sedge with reduced diversity at low elevations	Not prescribed
>438.5 to Toe (approx. 439)	2445	6: Mound Mix	Moderate density and high diversity terrestrial vegetation mix (e.g., *Symphoricarpos albus*, *Betula papyfera*, *Pinus monticola*, *Lonicera involucrata*, *Salix bebbiana*, *Amelanchier alnifolia*, *Shepherdia canadensis*, *Populus balsamifera* ssp. *trichocarpa*, *Cornus stolonifera*, and/or *Rosa acicularis*). Experimental staking.	Snags, specimen trees (e.g., cedar, hemlock), logs, stumps. Nest boxes for Mountain Bluebird and Tree Swallow would be appropriate at this site.
C4 – Mound				
Perimeter Disturbance Allowance	1284	5: Terrestrial Mix	Low density stocking of willow, dogwood, cottonwood, and sedge with reduced diversity at low elevations	Not prescribed

438.5 to Toe (approx. 438.5)	1644	3: Terrestrial Sedges (upper)	Low density stocking with even mix of sedge plugs from two species (*Carex kelloggii, C. aperta*). Both species can be salvaged and/or stocked with plugs. Low density cottonwood stakes. Experimental staking.	Not prescribed
>438.5	2486	6: Mound Mix	Moderate density and high diversity terrestrial vegetation mix (e.g., *Symphoricarpos albus*, *Betula papyfera*, *Pinus monticola*, *Lonicera involucrata*, *Salix bebbiana*, *Amelanchier alnifolia*, *Shepherdia canadensis*, *Populus balsamifera* ssp. *trichocarpa*, *Cornus stolonifera*, and/or *Rosa acicularis*). Experimental staking.	Snags, specimen trees (e.g., cedar, hemlock), logs, stumps. Nest boxes for Mountain Bluebird and Tree Swallow would be appropriate at this site.

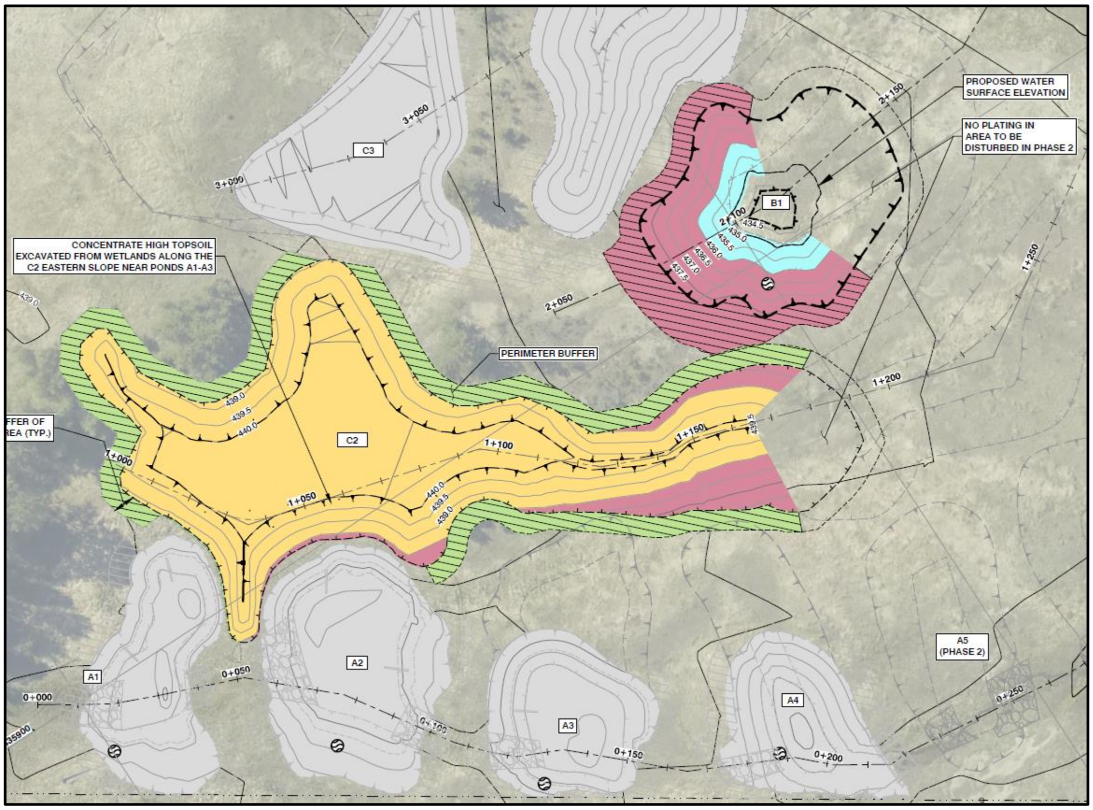

Figure 2-2. Sample schematic of planting prescription (PP) spatial layouts at Burton Flats. The colour-coded configurations for Pond B1 and Mound C2 are displayed. Turquoise = PP 4 (Terrestrial Sedges – lower), pink = PP 3 (Terrestrial Sedges – upper), green = PP 5 (Terrestrial Mix – general), yellow = PP 6 (Mound Mix).

Table 2-3. Suggested target numbers (and density/m^2) of each species, by prescription category. Numbers meant as guidance only; realized stocking densities will be influenced by the availability of nursery stock and salvaged material.

Species	Planting Prescription (PP)							Source
	1	2	3	4	5	6	Total	
Carex utriculata (beaked sedge)	102 (0.2)						102	Salvage
Scirpus microcarpus (small-flowered bulrush)	102 (0.2)						102	Salvage
Spiraea douglasii (hardhack)		59 (0.02)				91 (0.01)	150	Nursery
Lonicera involucrata (twinberry)		29 (0.01)				182 (0.02)	211	Nursery
Alnus incana (mountain alder)		29 (0.01)				91 (0.01)	120	Nursery
Calamagrostis canadensis (bluejoint reedgrass)		588 (0.2)	171 (0.05)		615 (0.2)	910 (0.1)	2284	Nursery
Persicaria amphibia (water smartweed)	26	29 (0.05)					55	Salvage
Carex aperta (Columbia sedge)		59 (0.02)	69 (0.02)		31 (0.01)	91 (0.01)	249	Salvage
Carex kelloggii (Kellogg's sedge)		147 (0.05)	171 (0.05)	57 (0.05)	154 (0.05)	91 (0.01)	620	Salvage
Cornus stolonifera (red-osier dogwood)		588 (0.2)	342 (0.1)			455 (0.05)	1385	Stake
Salix sitchensis (Sitka willow)		588 (0.2)	342 (0.1)			455 (0.05)	1385	Stake
Populus ssp. *trichocarpa* (black cottonwood)			342 (0.1)		154 (0.05)	0 (0.002)	496	Stake
Shepherdia canadensis (soopalallie)						455 (0.05)	455	Nursery
Betula papyrifera (paper birch)		6 (0.002)				455 (0.05)	461	Nursery
Pinus monticola (western white pine)		6 (0.002)				91 (0.01)	97	Nursery
Salix bebbiana (Bebb's willow)						455 (0.05)	455	Nursery
Amelanchier alnifolia (Saskatoon)						273 (03)	273	Nursery
Symphoricarpos albus (snowberry)						273 (0.03)	273	Nursery
Corylus cornuta (hazelnut)						91 (0.01)	91	Nursery

3.0 Methods

3.1 Sourcing of Planting Stock

3.1.1 Nursery Plugs and Rooted Stock

To ensure the required nursery stock would be available in time for the planting program, BC Hydro submitted pre-orders to three separate suppliers for graminoid plugs and rooted shrubs/trees in the winter of 2018/2019. The suppliers were: Spiral Farm and Nursery (Winlaw); Sagebrush Nursery (Oliver); and Tipi Mountain (Cranbrook). A total of 20+ species were ordered, including 6 graminoid species and 14+ woody species (Table 3-1). The orders were delivered to the site in late September and early October, in time for the commencement of planting. The delivered inventory generally matched the original orders in terms of species and numbers, with some minor deviations (Table 3-1).

Table 3-1. BC Hydro nursery stock order, including the number of each species ordered and the number delivered.

Item	Type	Supplier	No. ordered	No. delivered
Spiraea douglasii (hardhack)	1 gallon	Sagebrush	150	150
Lonicera Involucrata (twinberry)	1 gallon	Sagebrush	211	211
Shepherdia canadensis (soopalallie)	1 gallon	Sagebrush	455	455
Pinus monticola (western white pine)	1 gallon	Sagebrush	97	97
Amelanchier alnifolia (Saskatoon)	1 gallon	Sagebrush	273	273
Symphoricarpos albus (snowberry)	1 gallon	Sagebrush	273	273
Rosa acicularis (prickly rose)	1 gallon	Sagebrush	50	50
Betula papyrifera (paper birch)	1 gallon	Tipi	461	461
Corylus cornuta (hazelnut)	2 gallon	Tipi	91	91
Populus ssp. *trichocarpa* (black cottonwood)	2 gallon	Spiral	100	100
Alnus incana (mountain alder)	1 gallon	Spiral	120	120
Cornus stolonifera (red-osier dogwood)	2 gallon	Spiral	100	100
Salix bebbiana (Bebb's willow)	2 gallon	Spiral	455	see next line
Salix spp. (mixed willow)	2 gallon	Spiral	100	480 total mixed *Salix* species (*S. bebbiana*, *S. sitchensis*, *S. scouleri*, *S. lucida*, *S. prolixa*, *S.* sp.), including 160 x 1 gal. and 320 x 2 gal.
Carex kelloggii (Kellogg's sedge)	plugs	Sagebrush	620	620
Carex aquatilus (water sedge)	plugs	Sagebrush	50	50
Carex stipata (awl-fruited sedge)	plugs	Sagebrush	50	50
Carex rostrata (swollen beaked sedge)	plugs	Sagebrush	50	50
Carex aperta (Columbia sedge)	plugs	Tipi	349	349
Calamagrostis canadensis (bluejoint reedgrass)	plugs	Tipi	2284	2284

The delivered stock was stored in a shaded staging area and periodically watered until it was required for planting, at which time it was transported to the planting area with the aid of a skid steer (Figure 3-1).

Figure 3-1. Stored nursery stock at staging area (left) and in transport to planting area (right). Photographed October 2019. Photos: M. Miller.

3.1.2 Plant salvage

In September 2019, native graminoid stock was salvaged from two areas of the project footprint for later replanting on/in constructed mounds and ponds. One area was the existing wetted feature (future A1 site) at the southeast corner of the site (Figure 1-1). The second area targeted was the sedge-rich depression comprising the footprint of the B1 feature. The first location supported a dense cover of wetland indicator plants including (in descending order of abundance) beaked sedge, bluejoint reedgrass, and small-flowered bulrush. The second area supported dense covers of Kellogg's and Columbia sedge—two terrestrial but hydrophytic *Carex* species with a high level of tolerance for reservoir inundation. Both are found widely in the Arrow Lakes drawdown zone (Miller et al. 2018a). Both sedge species and, to a lesser extent, bluejoint and small-flowered bulrush, have been employed previously in revegetation trials undertaken in Arrow Lakes Reservoir as part CLBWORKS-2 (Keefer Ecological Services 2011).

A long-armed excavator operated by the construction contractor (Landmark) was used to strip sod containing the target species along with the underlying topsoil (Figure 3-2). This material was set aside and later transported by skid steer to the salvage staging area for further processing. At the staging area, the oversized sod chunks were divided into manageable plug-sized clumps using shovels and other hand tools (Figure 3-3), then stored in watered wading pools until they could be out-planted (Figure 3-4). Several hundred plugs each of beaked, Kellogg's, and Columbia sedge were harvested, along with lesser numbers of bluejoint and small-flowered bulrush plugs.

Figure 3-2. Native plant salvage with excavator. Top: stripping of wetland vegetation from the footprint of pond A1. Bottom: stripping Kellogg's and Columbia sedge sod from the footprint of pond B1. Photos: M. Miller.

Figure 3-3. **Top: salvaged Kellogg's and Columbia sedge clumps awaiting processing at staging area.** Bottom: crew divides a salvaged clump of beaked sedge into plug-sized units. Photos: M. Miller.

Figure 3-4. After being processed into plugs, salvaged graminoids (and live cuttings) were stored in wading pools until they were out-planted. Pools were irrigated using drainage water produced during pond construction (bottom right). Photos: M. Miller.

3.1.3 Live stake collection and planting

Live stakes of two species were harvested: black cottonwood and Sitka willow. Approximately 110 cottonwood stakes were collected in early October (following onset of dormancy) from a BC Hydro transmission right-of-way near the project site, and ~150 stakes of inundation-adapted Sitka willow were collected from the reservoir drawdown zone in Revelstoke Reach south of Revelstoke. Cuttings ranged in diameter from 1-3 cm. Following removal from the parent plants, the cuttings were pruned down to one main stem, taking care not to damage the bark of the stem, then trimmed to ~1.5 m lengths. Live stakes were then soaked in watered wading pools for 3-5 days prior to transplanting.

Live staking was carried out over the second week of October after most of the other plantings had been completed (described below). Planting holes for the live stakes were made with the aid of mobile equipment due to the hardness of the gravel substrate. A skid steer bucket was used to drive an iron bar into the ground to a target depth of 75-100 cm (Figure 3-5). After the stake had been inserted in the hole, the hole was filled in and tamped down by hand.

Figure 3-5. **Creation of planting holes for live staking using a skid steer and iron bar.** Photo: Mike Miller

3.1.4 Planting of plugs and rooted stock

Planting occurred over 10 days between 30 September and 15 October. To enable planting to be completed prior to the reservoir filling, work occurred concurrently with the construction operation. As soon as construction ended on one feature (or on a section of a feature), planting of the feature commenced. Transplant stock was distributed among microsites in a pattern that followed as closely as practical (accounting for the specific stock available and various microsite constraints) the six elevation-specific planting prescriptions that had been mapped out for each constructed feature (Table 2-1, Table 2-2). Planting operations were directed by an onsite vegetation specialist (Dr. M. Miller, LGL Limited).

Planting holes for salvaged plugs and potted shrubs were initially dug by hand using spades and tree planting shovels (Figure 3-6). However, the nature of the constructed planting substrate, consisting in most locations of dense rooted mats of overturned sod on top of compacted parent material, made hand-excavation of deep holes impracticable. Therefore, a mini excavator was deployed to create the holes. Hole spacing was ~1 m. Use of a machine for this purpose had the added benefit of roughening and loosening the surface significantly, in the process creating conditions more amenable to future plant establishment and (potentially) less amenable to all-terrain vehicle use (Figure 3-7). Some holes were left unplanted, depending on the prescription and stock availability. Nursery-raised plugs of sedge and grass, which had considerably less root depth than salvaged material and potted stock and thus required smaller holes, were interplanted amongst the excavated holes by hand.

Where the surface sod was particularly dense, planting holes were backfilled with a coarser (sandier) subsoil mix, obtained from stockpiles set aside for mound C2 construction, in an attempt to provide better drainage and a more favourable rooting substrate (Figure 3-8).

Figure 3-6. **Top: application of topsoil at pond B1.** Topsoil is comprised of overturned reed canarygrass sod. Bottom: Hand-digging planting holes in sod substrate for rooted cottonwood stock. Photos: M. Miller.

Figure 3-7. Examples of heterogenous surface topography resulting from hole creation by mini excavator. Top: Partially planted bank of pond A2. Bottom: partially planted slope of mound C2. Photos: M. Miller.

Figure 3-8. **Stockpiled subsoil from pond A1 used to backfill planting holes.** Photo: M. Miller.

Salvaged wetland material (consisting primarily of beaked sedge) was transplanted around the edge of each constructed wetland at the anticipated shoreline elevation (based on engineers' projections) and (in the case of ponds A1 and A2) in the exposed littoral zones (Figure 3-9). Material included both prepared plugs (which were hand-planted) and larger, unprocessed clumps of sod that had been saved and set aside during the wetland stripping. The latter were placed around the margins of A1 and A2 using the excavator (Figure 3-9). In addition to the salvaged material, nursery-raised plugs of three emergent sedges (*Carex aquatilis*, *C. rostrata*, and *C. stipata*) not found naturally on site were also planted experimentally at the projected margin of A2. The ponds had not yet completed filling at the time of planting, which meant that wetland material was, for the most part, planted above the existing waterline. At pond B1, the waterline continued to rise another 1 m or so above the projected height after the wetland plugs had been transplanted, resulting in their premature inundation. Consequently, this planting treatment was repeated after the water elevation had stabilized. In the case of ponds A1-A3, the water level had not yet reached the elevation of the wetland plantings by the time the planting operation ended in mid-October.

The habitat enhancements undertaken by CLBWORKS-30B have not been attempted previously in the drawdown zone of Arrow Lakes Reservoir and the planting approaches used reflect the experimental nature of this endeavor. For example, when applying riparian and terrestrial sedge prescriptions (PP 2-4), such as around the banks of ponds, an effort was made to distribute individual species most densely within their inferred preferred elevation zone while also ensuring some representation across the full range of available elevation zones to maximize the likelihood of establishment in at least one zone (Figure 3-10). In the case of mound plantings (PP 6), the general strategy was to create a continuous cover of mixed graminoid species (Kellogg's sedge, Columbia sedge, and bluejoint) interspersed with denser clusters of shrubs comprised of a single species, with the aim of creating an array of different cover types and nesting options on each elevated feature (Figure 3-10). Woody species used for this purpose included Bebb's willow, prickly rose, saskatoon, soopalallie, snowberry, hardhack, hazelnut, and twinberry. Two larger-statured, inundation-tolerant species, black cottonwood and paper birch, were deployed around the mound aprons and tops of pond banks to provide habitat "curtains" between these features and the adjacent drawdown zone and/or highway embankment. The single stocked conifer species (western white pine) was distributed in loose clusters at the tops of mounds to provide additional large woody structure for nesting and perching.

Perimeter allowances were revegetated at low to moderate density using graminoids (sedges and bluejoint) at low elevations and graminoids mixed with woody stock at higher elevations. At certain locations, such as the allowance area linking the top of the pond B1 bank and the apron of mound C2, a somewhat denser and more diverse shrub treatment was applied to provide a continuous band of habitat between the two features (Figure 3-11).

Finally, prior to closure, the plant staging area, which experienced some surface disturbance during the project (Figure 3-3), was revegetated with a terrestrial graminoid mix of 63 Kellogg's sedge and 50 bluejoint reedgrass plugs (PP 3).

3.1.1 Colour-coded tagging for monitoring

To facilitate species identification of woody plants during future effectiveness monitoring and survivorship assessments (by which time some stakes and rooted stock will likely have died, leaving behind only hard-to-identify "sticks"), a subsample of stock of each species was temporarily tagged with colour-coded zap strap combinations (Figure 3-12). At least 50 individuals of each woody species were labeled (exceptions were rose and pine, which, we assumed, would be easily identifiable regardless of the plant's survival status). In two or three years, as these plants become established and their stems start to increase in girth, the tags will likely have to be removed to prevent choking of the stems. The species-specific colour combinations used for tagging are indicated in Table 3-2. Note that, due to the challenge of reliably separating staged plugs of Bebb's willow and Scouler's willow based on fall foliage, both species received the same labelling (Table 3-2).

Figure 3-9. Top: trial transplants of salvaged beaked sedge plugs at the projected water lines of ponds A4 (left) and B1 (right) and in the projected littoral zone of pond A2 (middle). Bottom: machine-placed wetland salvage mix (beaked sedge/bluejoint reedgrass/small-fruited bulrush sod) at the projected waterline of pond A2. Photos: M. Miller.

Figure 3-10. Top: Willow distributed across the elevation gradient from top-of-bank to shoreline at pond A2. Bottom: clustered planting of hazelnut at mound C3. Photos: M. Miller.

Figure 3-11. Mixed treatment on perimeter disturbance allowance connecting pond B1 with mound C2. Photo: M. Miller.

Table 3-2. Colour x length combinations of zap strap (or twist tie) labels used to distinguish different species of woody stock (to facilitate future species identifications). Where species were used both in the form of rooted stock and live stakes (i.e., Sitka willow and black cottonwood), each form received a unique tag combination.

Colour combination	Species
green zap strap (long)	Bebb's/Scouler's willows (*Salix bebbiana*/*S. scouleri*)
black zap strap (long)	Bebb's/Scouler's willows (*Salix bebbiana*/*S. scouleri*)
white + black zap strap	Bebb's/Scouler's willows (*Salix bebbiana*/*S. scouleri*)
green + green zap strap	MacKenzie's willow (*Salix prolixa*)*
black + red zap strap	Sitka willow pots (*Salix sitchensis*)*
black + black zap strap	Sitka willow live stakes (*Salix sitchensis*)
black zap strap (short)	Mountain alder (*Alnus incana*)
green zap strap	Snowberry (*Symphoricarpos albus*) (same tag as Bebb's willow)
green twist tie	Saskatoon (*Amelanchier alnifolia*)
green zap strap (short)	Hardhack (*Spiraea douglasii*)
red zap strap (short)	Soopalallie (*Shepherdia canadensis*)
green + black zap strap	Twinberry (*Lonicera involucrata*)
red zap strap	Red-osier dogwood (*Cornus stolonifera*)
red + red zap strap	White birch (*Betula papyrifera*)
green + red zap strap	Hazelnut (*Corylus cornuta*)
white zap strap (short)	black cottonwood live stakes (*Populus* spp. *trichocarpa*)
white zap strap (long)	black cottonwood pots (*Populus* spp. *trichocarpa*)
not tagged	Prickly rose (*Rosa acicularis*)
not tagged	Western white pine (*Pinus monticola*)

*Only a few (<15) individuals of this species were included with the nursery stock.

Figure 3-12. **Example of planted shrub (red-osier dogwood) labeled with colour-coded zap strap.** Photo: M. Miller.

4.0 Results

4.1 Completed planting

All the delivered nursery stock (totalling 2,861 woody and 3,403 herbaceous plants; Table 3-1) was successfully utilized in the planting. Another ~2,700 plugs comprised of locally salvaged sedges (Kellogg's, Columbia, and beaked sedge) were planted, along with 273 live stakes (black cottonwood and Sitka willow) for a planted total of ~9,235 plants. In addition, several large stockpiled clumps of salvaged wetland plant sod (containing various species including beaked sedge bluejoint reedgrass, small-flowered bulrush, water smartweed, and marsh cinquefoil) were redistributed around the margins of ponds A1 and A2 by excavator following pond construction.

The achieved stocking numbers and densities (Table 4-1) were in general agreement with the suggested targets for each prescription, although with some notable differences (Table 2-3).

Densities of sedges (Kellogg's, Columbia, and beaked) were substantially higher than the targeted densities, thanks partly to the much larger-than-anticipated harvest of salvage material and partly to the pre-ordering of extra nursery stock as a hedge against a possible shortage of salvage. On the other hand, realized densities of cottonwoods, Sitka willows and red-osier dogwoods were lower than targeted (Table 4-1). This is because there was a smaller than anticipated live stake harvest, which the extra nursery orders did not entirely make up for. The deficit in stakes was related mainly to crew capacity and time constraints on stake harvesting, rather than to a shortage of available harvestable material. On certain prescriptions (PP 2 & 3), we trialled nursery stock of some of the other willow species (e.g., Bebb's and Mackenzie's willow) as a partial replacement for Sitka willow stakes (Table 4-1).

Table 4-1. Number (and density/m^2) and source of each species planted per planting prescription in 2019 (phase 1 of CLBWORKS-30B).

Species	Planting Prescription (PP)						Total planted	Source
	1	2	3	4	5	6		
Alnus incana (mountain alder)		65 (0.02)				35 (0.04)	100	nursery
Amelanchier alnifolia (Saskatoon)						273 (0.03)	273	nursery
Betula papyrifera (paper birch)		10 (0.003)			included in totals for PP 6	445 (0.06)	455	nursery
Calamagrostis canadensis (bluejoint reedgrass)	n/a*	900 (0.31)	300 (0.1)		included in totals for PP 2/3/6	1084 (0.14)	2284	salvage + nursery
Carex aperta (Columbia sedge)		400 (0.14)	120 (0.04)		included in totals for PP 2/3/6	860 (0.11)	1380	salvage + nursery
Carex aquatilis (water sedge)	50 (0.1)						50	nursery
Carex kelloggii (Kellogg's sedge)		750 (0.26)	463 (0.16)	230 (0.2)	included in totals for PP 2/3/6	407 (0.05)	1850	salvage + nursery
Carex rostrata (swollen beaked sedge)	50 (0.1)						50	nursery
Carex stipata (awl-fruited sedge)	50 (0.1)						50	nursery
Carex utriculata (beaked sedge)	445 (0.87)						445	salvage
Comarum palustre (marsh cinquefoil)	n/a*						n/a*	salvage
Cornus stolonifera (red-osier dogwood)		40 (0.01)	45 (0.02)			15 (0.002)	100	nursery
Corylus cornuta (hazelnut)						91 (0.01)	91	nursery
Lonicera involucrata (twinberry)		70 (0.02)				144 (0.02)	214	nursery
Persicaria amphibia (water smartweed)	n/a*						n/a*	salvage
Pinus monticola (western white pine)		5 (0.002)				95 (0.01)	97	nursery

Populus ssp. *trichocarpa* (black cottonwood)		20 (0.01)	159 (0.05)	included in totals for PP 3/6	30 (0.004)	209	nursery + live stakes
Rosa acicularis (prickly rose)					50 (0.01)	50	nursery
Salix bebbiana (Bebb's willow) + mixed *Salix* spp.		100 (0.03)	292 (0.1)	included in totals for PP 3/6	147 (0.02)	539	nursery
Salix sitchensis (Sitka willow)		100 (0.03)	60 (0.02)	included in totals for PP 3/6	10 (0.001)	160	nursery + live stakes
Scirpus microcarpus (small-flowered bulrush)	n/a*					n/a*	salvage
Shepherdia canadensis (soopalallie)					455 (0.06)	455	nursery
Spiraea douglasii (hardhack)		70 (0.02)			80 (0.01)	150	nursery
Symphoricarpos albus (snowberry)				included in totals for PP 6	273 (0.03)	273	nursery

*Species reintroduced as part of excavator-assisted wetland sod transplants; exact plant count not available.

As per the guidance (Table 2-2), mounds C2 and C3 (Figure 4-1) were planted with the highest diversity of species (Table 4-2), followed by the riparian zone around ponds A1 and A2 (Figure 4-2). Pond A4, the lowest elevation site, received the fewest species (Table 4-2; Figure 4-3). Ponds B1 and A3, which are also at lower elevation, were inadvertently treated with a low density of willows and red-osier dogwoods in addition to black cottonwoods (Table 4-2; Figure 4-3). While consistent with the general "Terrestrial Shrubs (Upper)" prescription (PP 3; Table 2-1), this treatment was inconsistent with the modified version of PP 3 as it applied to these particular sites and which called for the avoidance of willow and dogwood plantings (to avoid the creation of unwanted nesting structures <437.5 masl). If, over the next 1-2 years, these shrubs succeed in becoming established and if they appear likely to create attractants for nesting birds, they will be removed (or translocated to higher ground) as part of the phase 2 work.

Table 4-2. **Number of each species planted per constructed pond and mound feature, and for rehabilitation of the staging area, in 2019 (phase 1 of CLBWORKS-30B).** Numbers represent a combination of salvaged material, nursery stock, and/or live stakes.

Species	Feature							
	A1	A2	A3	A4	B1	C2	C3	Staging area
Alnus incana (mountain alder)	33	32				35		
Amelanchier alnifolia (Saskatoon)						213	60	
Betula papyrifera (paper birch)	10					369	76	
Calamagrostis canadensis (bluejoint reedgrass)	500	400	100	?	200	834	200	50
Carex aperta (Columbia sedge)	150	250	50		70	610	250	
Carex aquatilis (water sedge)		50						
Carex kelloggii (Kellogg's sedge)	400	250	100	130	400	307	100	63
Carex rostrata (swollen beaked sedge)		50						
Carex stipata (awl-fruited sedge)		50						
Carex utriculata (beaked sedge)	140	140	29	36	100			
Comarum palustre (marsh cinquefoil)	n/a*	n/a*						
Cornus stolonifera (red-osier dogwood)	20	20	15		30	15		
Corylus cornuta (hazelnut)						60	31	
Lonicera involucrata (twinberry)	30	40				100	44	
Persicaria amphibia (water smartweed)	n/a*	n/a*					34	
Pinus monticola (western white pine)	5					63		
Populus ssp. *trichocarpa* (black cottonwood)	20		34		53	70	32	
Rosa acicularis (prickly rose)						30	20	
Salix bebbiana (Bebb's willow) + mixed *Salix* spp.	50	50	9		56	227	82	
Salix sitchensis (Sitka willow)	50	50	36		24	10		
Scirpus microcarpus (small-flowered bulrush)	n/a*	n/a*					92	
Shepherdia canadensis (soopalallie)						363		
Spiraea douglasii (hardhack)	25	45				80		
Symphoricarpos albus (snowberry)						216	57	
Total species	16	16	8	3	8	17	13	2
Total plants (excluding *)	1433	1427	373	166	933	3602	1078	113

*Species reintroduced as part of excavator-assisted wetland sod transplants; exact plant count not available.

Figure 4-1. Planted mound features. Top and bottom rows: mound C2; centre: mound C3. Photographed October 2019. Photos: M. Miller.

Figure 4-2. Planted ponds. Top left: A1; top right: A2; centre: A1; bottom: A1 & A2. Photographed October 2019. Photos: M. Miller.

Figure 4-3. Planted ponds. Top: A4; centre left: A3; centre right: B1; bottom: A3. Photographed October 2019. Photos: M. Miller.

4.2 Potential limiting factors

Reservoir drawdown zones presents particularly challenging conditions within which to establish plant communities through revegetation efforts (Miller et al. 2018b, Miller and Hawkes 2019). This is due to a combination of factors:

- the prolonged seasonal inundation of most of the zone, and attendant anoxic conditions;

- the counter-seasonal fluctuation of water levels, in which the reservoir is held at low water during the spring and then the water gradually increases throughout the summer (opposite of the cycle that most plants are adapted to);
- summer moisture-deficits (prior to inundation);
- the powerful fetch and associated wave energy affecting exposed shorelines;
- shoreline freezing during winter drawdown as ice subsides onto the shore;
- the interannual variation in the rates and timing of inundation;
- the often-extreme rates of erosion and deposition;
- the low nutrient availability in many of the soils due to the removal of the organic soil layer; and
- the abundance of large woody debris that collects in some areas and precludes plant growth or scours existing vegetation.

Prevailing conditions in the reservoir can impact reclamation success to different degrees and in different ways, depending on the revegetation treatment in question. For example, live stakes are easily damaged by woody debris accumulations in upper elevation bands (Fenneman and Hawkes 2012). In turn, sedge plug treatments can be lost as a result of being buried under deposits of fine sediment transported over the course of inundation. Alternatively, plugs can undergo "pedestaling," whereby the substrate around the plug bases erodes away exposing the root wads and killing the plants (Miller and Hawkes 2019).

Aside from the impacts of reservoir inundation, which will not be assessable until after the next high water event (possibly occurring in the summer of 2020), various specific factors could act to limit the establishment success of transplants at Burton Flats over the short term. One factor that could impact on establishment is the quality of the planting substrate. The excavation process yielded only minor amounts of topsoil for purposes of resurfacing the banks and tops of mounds (C2 and C3) and low-elevation ponds (A3, A4, and B1). As a result, the planting substrates typically consisted of dense mats of overturned reed canarygrass sod laid directly on top of unconsolidated mineral soil. This top sod layer likely boasts good water holding capacity, which could help to limit premature root desiccation during periods of drought stress. Thanks to its general density and cohesiveness, the sod is also likely to be erosion resistant, at least in the short term. Assuming the sod does not float away under inundation, it should thus provide a relatively stable, nutrient-rich medium for plant establishment. On the other hand, it is unclear if developing roots will be able to penetrate the sod layer or if they will instead become rootbound (or waterlogged). Another unknown is whether the overturned sod will decompose into topsoil in a timely manner or if it will instead regenerate as dense stands of reed canarygrass that could potentially outcompete the establishing revegetation.

In the case of live stakes, which were inserted to depths of 75-100 cm, the rooting substrate was usually comprised of whatever material underlay the topsoil/sod mantel. In most cases, this consisted of unconsolidated mineral material (sand/gravel/cobble), with presumably limited water holding capacity or nutrient content. The prospects for successful live stake establishment are thus also unclear.

Wildlife interactions also have the potential to affect establishment success of both herbaceous and woody vegetation. For example, towards the end of the planting operation, a flock of Canada geese was observed to be grazing on recently planted sedges at pond B1. Similar geese-sedge interactions in the context of revegetation attempts have been reported for Kinbasket Reservoir (Hawkes and Miller 2016). Around the same time, we also found evidence of ungulate (elk) browse on recently planted shrubs, especially on mound C2 and the banks of ponds A1 and A2. Signs of early morning/overnight activity ranged from track imprints, to grazed stems and stripped leaves, to the uprooting of entire plants (Figure 4-4). Of note, by far the most frequently targeted species was twinberry (*Lonicera involucrata*), with roughly 80% of planted stock browsed by mid October (Figure 4-4). It can be hoped that, since the browsed stock had already begun to enter fall dormancy by this stage, overwinter survivorship rates will not be greatly affected. Basal stem girdling by voles has reportedly reduced the survivorship of planted live stakes elsewhere in Arrow Lakes Reservoir (Keefer Ecological Services 2011). Girdling was observed on cottonwood stakes one year post-planting in 2011 at 8-Mile, 9-Mile, and MacKay Creek. An estimated 17% of stakes (totalling 1,284 plants) was killed or damaged by voles at these sites (Keefer Ecological Services 2011). Stem girdling has not been observed yet at Burton Flats but is a potential concern and should be monitored.

Figure 4-4. Evidence of elk browse on twinberry (*Lonicera involucrata*) plantings. The plug on the right had been pulled from its hole during the act of being browsed. Photos taken mid-October 2019. Photos: M. Miller.

5.0 Summary and recommendations

As part of the CLBWORKS-30B physical works program to enhance wetland and riparian habitat in the drawdown zone at Burton Flats, approximately 1.8 ha of constructed terrain (5 ponds and 2 mounds) were revegetated at low to moderate densities in September and October of 2019. Planted terrain included pond margins, riparian banks < full pool, riparian banks > full pool, and disturbance allowances. Revegetation species consisted of a mix of locally salvaged material, harvested live stakes, and nursery stock. A minimum of 24 species (totalling >9,000 individuals) were translocated over the course of the project. To facilitate subsequent reidentifications of non-surviving woody stems, a subsample of the stock (at least 50 individuals per woody species) was temporarily tagged with colour-coded plastic labelling.

Habitat enhancements of this nature have not been trialled previously in Arrow Lakes Reservoir. Thus, the physical works undertaken at Burton Flats are experimental and there are numerous unknowns about how the translocated vegetation will respond to: (a) the planting methodologies employed, including the available planting mediums; (b) prolonged summer inundation (and various attendant factors including anoxia, wave action, and erosion); (c) competition from reed canarygrass once this species begins to re-establish on planted features; and (d) wildlife interactions (e.g., browsing). As such, the planting program was designed to be iterative, so that initial low-density stocking and subsequent monitoring of plant survival can be used to adaptively guide a replanting investment in later years to maximize revegetation success in terms of both density and diversity of plant species. It is therefore recommended that effectiveness monitoring commence in the spring of 2020 (to assess initial overwinter survivorship), with follow-up monitoring occurring in the fall of 2020 (to assess short-term impacts of summer reservoir inundation) and the spring of 2022 (to assess initial growing season responses to inundation). Integration of follow-up monitoring with CLBMON-11B1 should be considered to ensure that the vegetation data collected are compatible with proposed wildlife sampling of the physical works trial at Burton Flats.

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