# Columbia River Project Water Use Plan

## Kinbasket and Arrow Reservoirs Revegetation Management Plan

## Debris Mounds and Wind Row Construction Pilot Program

## Implementation Year 8

## Reference: CLBWORKS-1

***Final Annual Report***

**Study Period: 2016**

**LGL Limited environmental research associates**

**Sidney, BC**

**February 1, 2017**

**KINBASKET AND ARROW LAKES RESERVOIRS REVEGETATION MANAGEMENT PLAN**

**CLBWORKS-1 Kinbasket Reservoir Revegetation Program**




# *Year 8 – 2016*
# *Debris Mounds and Wind Row Construction Pilot Program*
# *Fall 2016 Update*

## *Final Report*

*Prepared for*

**British Columbia Hydro and Power Authority**

**Vancouver, B.C.**

*Prepared by*


**Virgil C. Hawkes, M.Sc., R.P.Bio.**
**LGL Limited environmental research associates**
**9768 Second Street**
**Sidney, British Columbia, V8L 3Y8**


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LIMITED
environmental research associates

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**Cover photos**

From left to right: Debris in the drawdown zone of Kinbasket Reservoir at Hope Creek, Chatter Creek, and in Bush Arm. Photos © Virgil C. Hawkes.

# EXECUTIVE SUMMARY

To mitigate for the varied effects of reservoir operations on vegetation establishment and development in the drawdown zone of Kinbasket Reservoir, BC Hydro implemented CLBWORKS-1, a 10-yr, reservoir-wide restoration program to enhance sustainable vegetation growth in the drawdown zone of Kinbasket Reservoir for ecological and social benefits. In 2015, a physical works trial was initiated to test the efficacy of mound creation in functioning both as a receptor site for revegetation (live stakes and sedge plugs) and to protect habitats cleared of wood debris, which should promote the natural re-establishment of vegetation in the drawdown zone. The removal of wood debris from the drawdown zone also addresses safety and recreational concerns raised by the Consultative Committee. The physical works included the removal of wood debris, the use of wood debris to construct mounds, and the removal of wood from existing ponds in the drawdown zone. If successful, these physical works could function to increase vegetation cover and in turn help improve aesthetics, control dust, contribute to the protection of known cultural heritage sites from erosion and human access, enhance littoral productivity and create wildlife habitat.

The areas treated in 2015 were evaluated in 2016 (spring, summer, and fall) for erosion, live stake survival, and sedge transplant survival following the winter. Live stakes planted in fall 2015 survived much better than those planted in the spring of 2016 (~ 93 per cent survival vs. 20 per cent). Overall, ~ 71 per cent of the live stakes planted were surviving up to one year following planting. All sedge transplants survived (i.e., 100 per cent survival achieved). Due to lower than expected reservoir elevations between November 2015 and October 2016, we were unable to assess the effects of reservoir inundation on the integrity of the mounds. This will have to wait until reservoir elevations exceed 753.5 m ASL. To protect wetland habitats and wood debris mounds at the Bush Causeway North site, a 312 m long log boom was installed in June 2016. The log boom should function to ensure wood debris doesn't deposit on the recently cleared wetlands and degrade the interiority of the mounds.

Performance measures generated following the implementation of the physical works in fall 2015 were assessed in 2016. Overall, the removal of wood debris from the drawdown zone and wetland habitat as a habitat enhancement technique appears to have great potential. Not only can the wood debris be used to construct mounds in the drawdown zone, thereby increasing topographic heterogeneity, but the removal of the wood from the drawdown zone promotes the natural establishment of vegetation. Revegetating of the mounds involved the use of live stakes as a means to expedite the revegetation process, but as with the areas cleared of wood debris, native vegetation also began to establish on the mound. This emphasizes the utility of wood removal and mound creation as a tool to increase the cover of vegetation in the drawdown zone of Kinbasket Reservoir. Despite these early signs of success, additional data are required before the widespread removal and mounding of wood is considered for Kinbasket Reservoir. The mounds and cleared areas need to be inundated by Kinbasket Reservoir so that the integrity of the mounds can be assessed following inundation and to determine if additional wood will deposit on those previously cleared sites.

Following work completed in 2015 and 2016, the following recommendations are made:

1. Re-assess the mounds, wetlands, and areas cleared of wood debris following inundation, or when the reservoir has exceeded at least 753.5 m ASL. This may happen in 2017. If it

does, an assessment should occur as soon as possible following inundation, which may mean a fall 2017 visit to the causeway to make the assessment.

2. Consider planting additional stakes and native transplanted vegetation on existing mounds.
3. Consider clearing wood from the northwest corner of the Causeway (Figure 6-3) in 2017. This wood covers an area of ~ 2,204.5 $m^2$ and removing the wood would reduce the potential for it to impact the nearby mounds or get deposited on the cleaned wetlands. Removing the wood will also promote the natural re-establishment of vegetation in that area.
4. Consider cleaning the ponds indicated in Figure 6-3 of wood debris in 2017. As shown in Figure 3-8 and Figure 6-2, cleaning wood from ponds increases water clarity and overall suitability. Removing wood from the ponds indicated in Figure 6-3 will increase the total wetland area that could be used by wildlife by an additional 934 $m^2$. The total wetland area cleared would almost double from 977 $m^2$ in 3 locations to a total of 1,911.7$m^2$ in 4 locations. Cleaning the wood from terrestrial and wetland habitats in the drawdown zone would increase the total area manipulated at Bush Causeway North to 8,986,5 $m^2$, an increase of 3,183.5 $m^2$.
5. Consider collecting additional wildlife data (through the CLBMON-11A program) in 2017 at potential future mounding treatment sites (at Chatter Creek, Hope Creek, Goodfellow Creek and Canoe Reach) to establish a baseline to compare pre- and post-treatment response. Assessments of wildlife use at the sites treated in 2015 could be made during work for other programs (e.g., CLBMON-58, CLBMON-61)
6. Consider the CLBWORKS-16 woody debris removal program and align future mounding areas (including the collection of pre-treatment baseline data) with woody debris removal and burning areas as much as possible.

Key Words: CLBWORKS-1, physical works, restoration, revegetation, mounds, topographic heterogeneity, drawdown zone, Kinbasket Reservoir; live stakes

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# 1 INTRODUCTION

The drawdown zone of a hydroelectric reservoir is a challenging environment for plants and animals, particularly when the annual change in reservoir elevation can be as much as 39 m. Flooding and flow alteration resulting from varied reservoir operations create complex disturbances that can modify entire ecosystems, with effects extending upstream and downstream of the dam (Nilsson *et al.* 1991; Hill *et al.* 1998; Luken and Bezold 2000; Van Geest *et al.* 2005, Poff and Zimmerman 2010, Ye *et al.* 2012). Currently, little is known about the influence of dam operations on the structural and functional components of the terrestrial and semi-terrestrial plant communities that establish on reservoir shorelines within the zone of water level fluctuation (i.e. the drawdown zone). In 2007, BC Hydro initiated a monitoring program (CLBMON-10) to assess the distribution and spatial extent of existing vegetation communities in the drawdown zone of Kinbasket Reservoir. The results of that study indicate that substantial portions of the drawdown zone are vegetated to some degree, with habitats higher in elevation associated with a higher cover of vegetation and increased species richness and diversity (Hawkes and Gibeau 2015). Despite this, vast areas of the drawdown remain sparsely vegetated or completely devoid of vegetation. Several factors contribute to this lack of vegetation including the timing, duration, and frequency of inundation, substrate type, soil moisture and nutrient regimes, erosion and deposition of sediment associated with wave action and reservoir flows, and wood debris accumulation and scouring.

To mitigate for the varied effects of reservoir operations on vegetation establishment and development in the drawdown zone of Kinbasket Reservoir, BC Hydro implemented CLBWORKS-1, a 10-yr, reservoir-wide restoration program to enhance sustainable vegetation growth in the drawdown zone of Kinbasket Reservoir for ecological and social benefits (BC Hydro 2008). Between 2008 and 2011, a total of 69.15 ha in 19 treatment areas in the drawdown zone of Kinbasket Reservoir was planted by Keefer Ecological Services (Keefer et al. 2007, 2008, 2010, 2011). Eight different revegetation prescriptions were applied during this time, but plug seedling treatments, particularly those involving Kellogg's sedge (*Carex lenticularis*) alone or mixed with other species, dominated the planting regime (Hawkes et al. 2013). CLBMON-9, an effectiveness monitoring study of the revegetation efforts, occurred between 2008 and 2013 (Yazvenko 2008; Yazvenko et al. 2009; Fenneman and Hawkes 2012, Hawkes et al. 2013). The results of CLBMON-9 indicate that the revegetation program was unsuccessful and did not contribute to enhancing sustainable vegetation growth in the upper elevations of the reservoir.

More recent efforts to enhance the vegetation in the upper elevations of Kinbasket Reservoir appear to have achieved greater short-term success. For example, larger sedge plugs (i.e., larger than those used between 2008 and 2011) planted at an ecologically suitable site in Bush Arm in 2013 (Adama 2015) and a log boom installed around a wetland in the Valemount Peatland following the clearing of wood debris in 2014 (Hawkes 2015a) have both contributed to either an increased cover of vegetation (sedge transplants) or the re-establishment of native vegetation in drawdown zone (wood removal and protection with a log boom).

In 2015, a physical works trial was initiated to test the efficacy of mound and windrow[1] creation to function both as a receptor site for revegetation (live stakes and sedge plugs) and to protect habitats cleared of wood debris, which should promote the natural re-establishment of vegetation in the drawdown zone. This physical works prescriptions implemented in Bush Arm of Kinbasket Reservoir during fall 2015 are discussed in Hawkes (2016). The physical works included the removal of wood debris, the use of wood debris to construct mounds, and the removal of wood from existing ponds in the drawdown zone. If successful, these physical works could function to increase vegetation cover and in turn help improve aesthetics, control dust, contribute to the protection of known cultural heritage sites from erosion and human access, enhance littoral productivity, and create wildlife habitat. The enhancements align with BC Hydro's Water Use Plan Consultative Committee's (WUP CC) support of a reservoir-wide planting and enhancement program in lieu of operational changes (BC Hydro 2005). This document reports on additional work that occurred during 2016, including the installation of a log boom around the physical works at one of the Bush Causeway sites along with an assessment of live stake and sedge survival.

For project rationale, goals, objectives, and scope, refer to Hawkes (2016).

# 2 STUDY AREA

## 2.1 Kinbasket Reservoir

The approximately 216 km long Kinbasket Reservoir is located in southeastern B.C., and is surrounded by the Rocky, Selkirk, and Monashee Mountain ranges (Figure 2-1). The Mica hydroelectric dam, located 135 km north of Revelstoke, B.C., spans the Columbia River and impounds Kinbasket Reservoir. The Mica powerhouse, completed in 1973, has a generating capacity of 1,805 MW and Kinbasket Reservoir has a licensed storage volume of 12 million acre feet (MAF; BC Hydro 2007). The normal operating range of the reservoir is between 707.41 m and 754.38 m elevation, but can be operated to 754.68 m ASL with approval from the Comptroller of Water Rights. A hydrograph of Kinbasket Reservoir between 2008 and 2015 is shown in Figure 2-2. The location of locations where physical works were constructed in 2015 is shown in Figure 2-1.

[1] A mound is defined as the systematic piling of wood debris and substrate into a tetrahedron-shaped pile. A wind row is similar to a mound, but is more linear in shape.

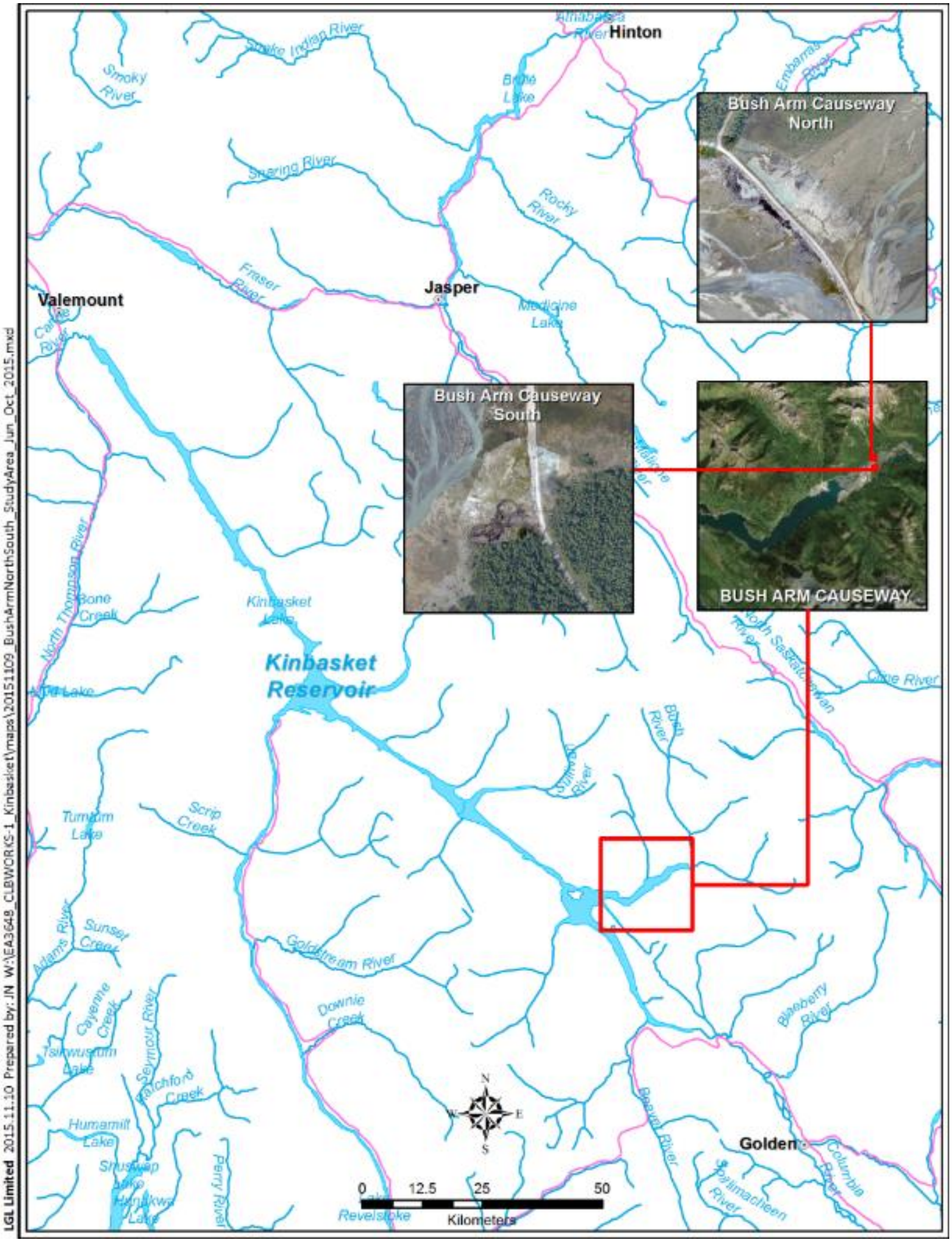


**Figure 2-1: Location of 2015 physical works project locations relative to Kinbasket Reservoir.**

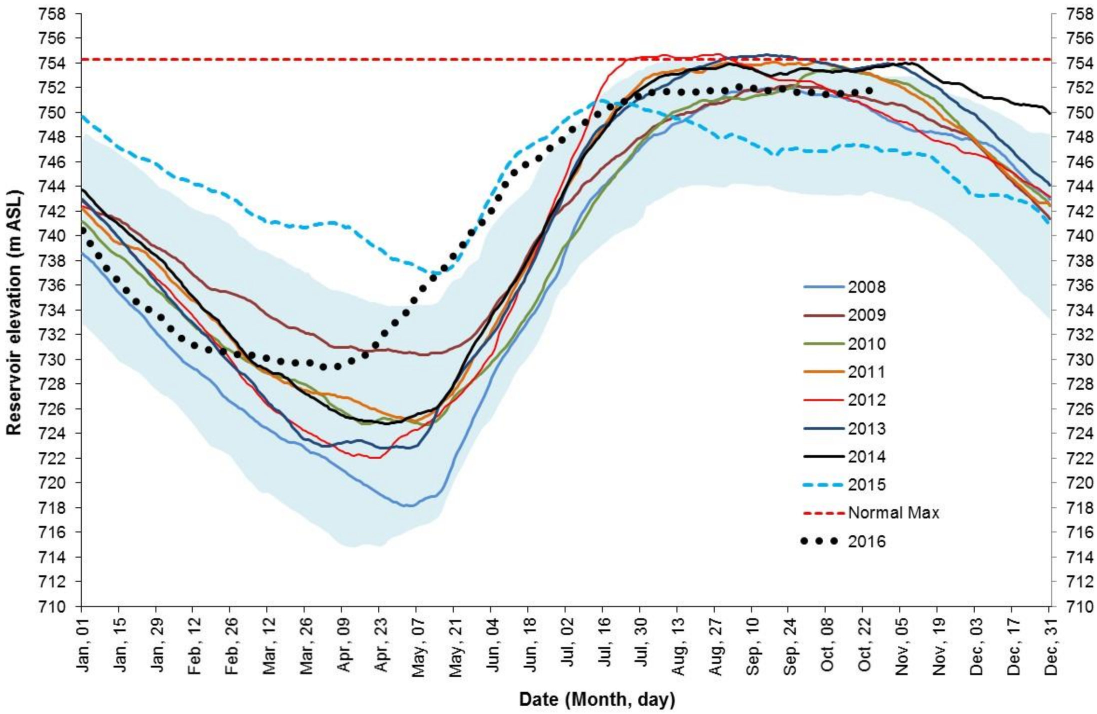


**Figure 2-2: Kinbasket Reservoir elevations 2008 to October 25, 2016.** The shaded region delineates the 10th and 90th percentile in reservoir elevation (1977 to 2015).

# 3 2016 WORK SUMMARY

Work in 2016 focused on the installation of a log boom at the Bush Causeway North site, planting of live stakes at one of the mounds at the Bush Causeway South site, assessing short-term survival of stakes planted in fall 2015, of sedges transplanted in fall 2015, and within-year survival of stakes planted in May 2016. Cleared wetlands were assessed for aquatic macrophytes and use by pond-breeding amphibians. Because the mounds have not been inundated since construction, an assessment of mound integrity did not occur.

## 3.1 Log Boom Installation

Data from the post-installation assessment of the log boom installed in the Valemount Peatland suggests that a log boom is an effective means of reducing the amount of wood debris that settles in the drawdown zone behind the log boom following a high water event. To protect the areas cleared (particularly the wetlands) from wood debris accumulation at Bush Causeway North, a log boom was installed in June 2016 in the drawdown zone (Figure 3-1).

Using logs salvaged from the Windy Creek debris slide of 2015, a log boom was installed over a period of 2 days in June 2016 (June 22 and 23). A total of 22 logs and 12 lock blocks were used to create a 312 m long log boom that extended from the causeway just northwest of the bridge over the Bush River to a high point just above the drawdown zone 312 m away to the northwest (Figure 3-2). The installation of the log boom does not preclude an assessment of the integrity of the mounds following a high water event as the mounds would still be inundated and subject to wind and wave action.

**Figure 3-1: Installation of Log boom at Bush Causeway North, June 2016.** Left: placing logs and lock block; top right: lining up logs; bottom right: burying lock blocks.

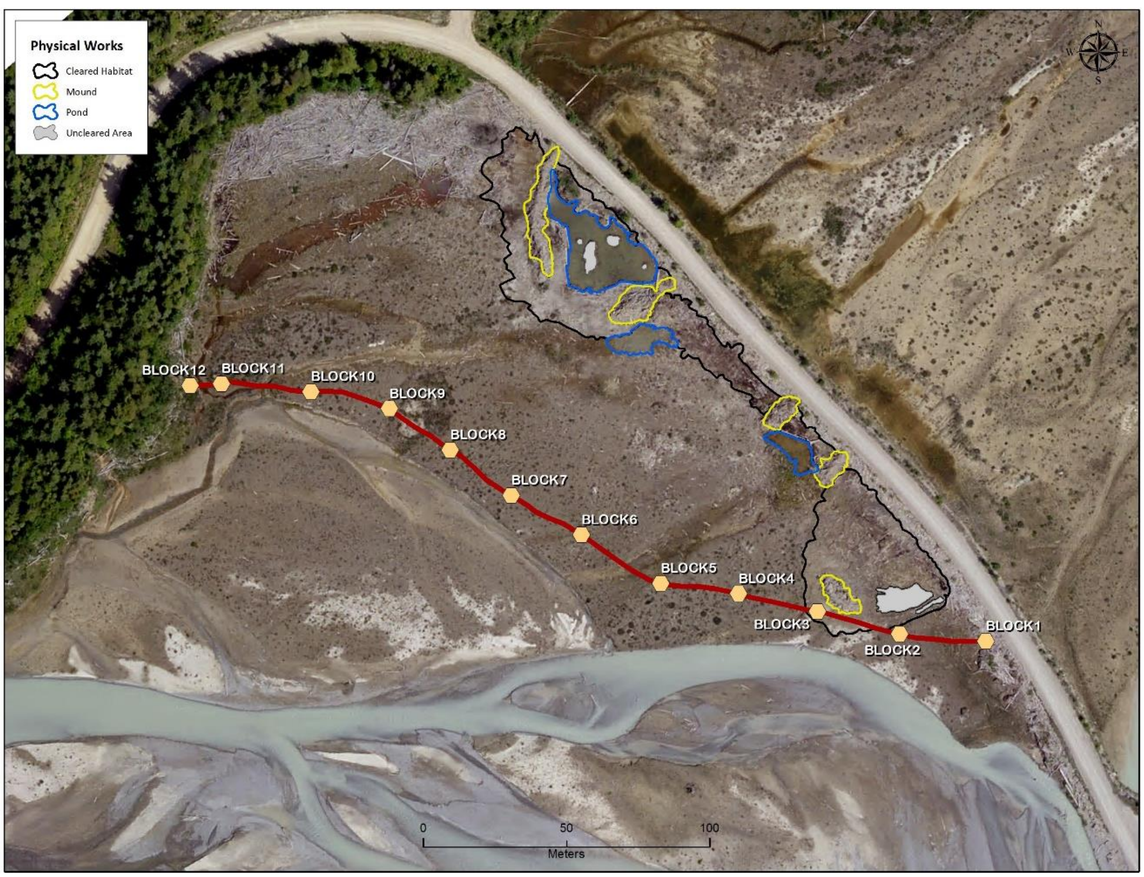


**Figure 3-2. Location of log boom and lock blocks installed in June 2016 at the Bush Causeway North physical works site.**

## 3.2 Live Stake Survival

A total of 106 live stakes (primarily black cottonwood) were planted between fall 2015 and fall 2016 (fall 2015: n=46; spring 2016=20; fall 2016: n=40). Live stakes planted in fall 2015 survived better than those planted in spring 2016. Overall, live stakes planted in fall 2015 had a 93.5 per cent survival rate 327 days after planting while those planted in the spring had a 20 per cent survival rate 112 days following planting (Figure 3-3). The reason for differences in survival is not known, but could be related to reduced moisture following planting. The depth of planting and size of live stakes did not vary somewhat between fall 2015 and fall 2016 (Figure 3-4; Table 3-1). Additional stakes (n=40) were planted in fall 2016 (October 13, 2016; Figure 3-5) at a depth similar to those planted in fall 2015 and spring 2016. The fall 2016 live stakes were planted in the Bush Causeway north mounds and cleared areas. Based on the survival of the live stakes planted in fall 2015 additional stakes were planted in fall 2016.

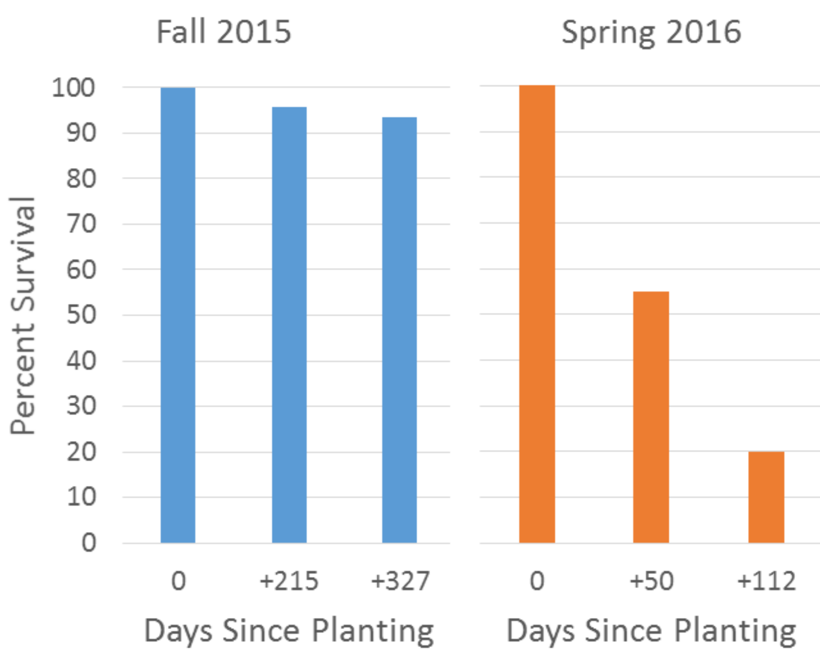


**Figure 3-3: Survival of live stakes planted in fall 2015 and spring 2016.** Day 0 in 2015 was October 1, 2015 and May 3, 2016 for spring.

**Table 3-1: Summary of planting depth for live and dead stakes planted in fall 2015 and 2016 and spring 2016.** Fall 2-016 planting occurred in October 2016 and survivorship has not been assessed

| | **Fall** | | | | **Spring** | |
|---|---|---|---|---|---|---|
| | **2015** | | **2016** | | **2016** | |
| **Metric** | **Dead** | **Live** | **Dead** | **Live** | **Dead** | **Live** |
| *n* | 3 | 43 | -- | 40 | 16 | 4 |
| Mean depth (cm) | 44.0 | 51.7 | -- | 80.0 | 51.0 | 57.8 |
| Max. depth (cm) | 56.0 | 104.0 | -- | 130.0 | 86.0 | 96.0 |
| Min. depth (cm) | 31.0 | 29.0 | -- | 35.0 | 23.0 | 16.0 |

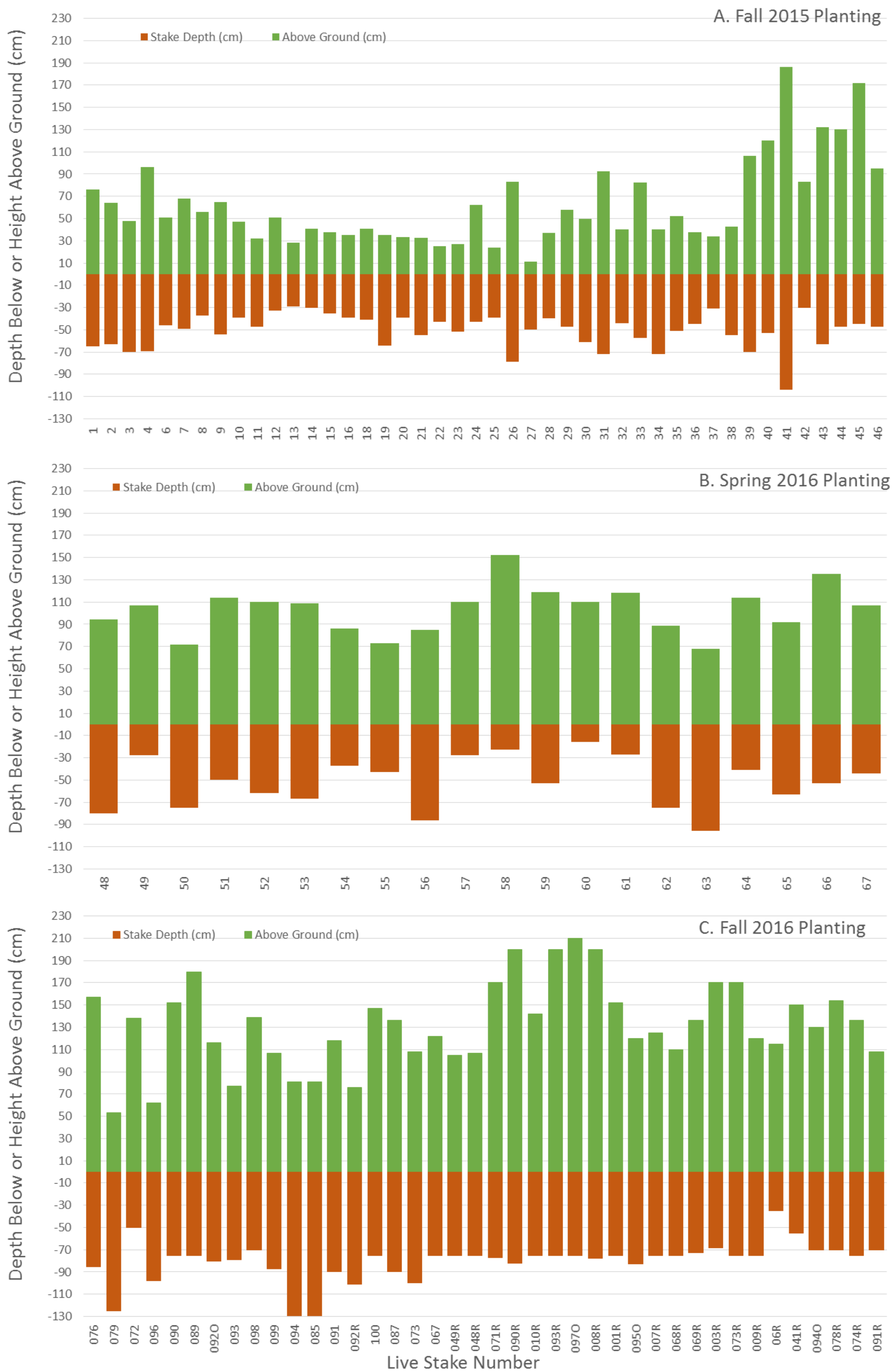


**Figure 3-4: Planting depth and height above ground for live stakes planted in fall 2016, spring 2016, and fall 2016.** Live stake diameter ranged from 8.0 to 40.0 mm, mean = 21.5 mm (all seasons combined).

**Figure 3-5. Live stakes planted at the Bush Causeway North and south sites: top row fall 2015 stakes assessed in (left to right) May, June, and August 2016; middle row: spring 2016 stakes planted in May were assessed in June and August 2016 and (bottom row) live stakes planted in fall 2016.**

## 3.3 Sedge Transplants

In fall 2015, ~43 sedges of three species (*Carex utriculata, C. aquatilis,* and *C. lasiocarpa*) were transplanted into an area cleared of wood debris and on the edge of one of the rehabilitated wetlands. The majority of the transplants (appears to be 100 per cent) were surviving one year following transplant (Figure 3-6). Sedge transplants were not tracked as closely as the live stakes, but all indications suggest that all plants survived.

**Figure 3-6: Sedge transplants following transplanting in fall 2015 (top left) and after one year (fall 2016; bottom left and right).** Arrows indicate location of sedges.

## 3.4 Vegetation Establishment

One of the performance measures associated with CLBWORKS 1 was *Successful natural establishment of vegetation common to the site at the wood debris removal sites and on the mound*. Vegetation surveys were completed in July 2016 at the two causeway sites treated in 2015 (i.e., Causeway North and Causeway South). Linear transects 20 m in length were established in both treatment areas and sampled as per Hawkes and Gibeau (2015). In total, 41 species and three genera were documented from treatment areas (areas cleared of wood debris) and from the mounds. Of these, 15 are exotics; the remainder are native (including the three genera). All plants documented had been documented during field surveys associated with CLBMON-10 (Hawkes and Gibeau 2015). Twenty-two species and two genera of vascular plant were documented growing in areas cleared of wood debris at the Bush Causeway North site, 21 species and 1 genus in the Bush Causeway South site, and 20 species and 1 genera were documented growing in the mounds at the Causeway North site (Table 3-2). Examples of natural regrowth are provided in Figure 3-7.

The per cent cover of all plants growing in the cleared areas and the mounds was low (trace or 1 per cent), which is expected given that this is the first growing season post wood removal.

**Table 3-2. Species of vascular plants observed growing in the mounds and treatment areas of Bush Causeway North (NC) and south (SC) during July 2016 (9 months following clearing and mound creation.** See appendix for plant common names.

| Origin | Row Labels | NC Mounds | NC Treat | SC Treat | Total Sites |
|---|---|---|---|---|---|
| Exotic | *Agrostis gigantea* | | | 1 | 1 |
| | *Cirsium vulgare* | | 1 | 1 | 2 |
| | *Elymus repens* | | | 1 | 1 |
| | *Erucastrum gallicum* | 1 | 1 | 2 | 3 |
| | *Leucanthemum vulgare* | 1 | 1 | 1 | 3 |
| | *Medicago lupulina* | | | 1 | 1 |
| | *Melilotus alba* | | | 1 | 1 |
| | *Phalaris arundinacea* | 1 | 1 | 1 | 3 |
| | *Poa compressa* | | | 1 | 1 |
| | *Poa palustris* | | 1 | | 1 |
| | *Taraxacum officinale* | | 1 | | 1 |
| | *Trifolium hybridum* | | | 1 | 1 |
| | *Trifolium pratense* | | | 1 | 1 |
| | *Verbascum thapsus* | 1 | | 1 | 2 |
| | *Vicia cracca* | | | 1 | 1 |
| Native | *Braya humilis* | 1 | | | 1 |
| | *Calamagrostis canadensis* | 1 | 1 | 1 | 3 |
| | *Calamagrostis stricta* | 1 | | | 1 |
| | *Carex aquatilis* | 1 | 1 | | 2 |
| | *Carex lasiocarpa* | 1 | 1 | | 2 |
| | *Carex lenticularis ssp.lipocarpa* | | 1 | | 1 |
| | *Carex sp.* | | | 1 | 1 |

| Origin | Row Labels | NC Mounds | NC Treat | SC Treat | Total Sites |
|---|---|---|---|---|---|
| | *Carex utriculata* | 1 | | | 1 |
| | *Comarum palustre* | 1 | 1 | | 2 |
| | *Deschampsia cespitosa* | 1 | 1 | | 2 |
| | *Equisetum arvense* | 1 | 1 | 1 | 3 |
| | *Equisetum variegatum* | | 1 | | 1 |
| | *Erysimum cheiranthoides* | | | 1 | 1 |
| | *Lysimachia thyrsiflora* | 1 | 1 | | 2 |
| | *Mentha arvensis* | | 1 | | 1 |
| | *Packera pauciflora* | | 1 | | 1 |
| | *Plantago major* | | | 1 | 1 |
| | *Populus trichocarpa ssp.balsamifera* | | | 1 | 1 |
| | *Potentilla anserina* | 1 | | | 1 |
| | *Potentilla norvegica* | 1 | 1 | 1 | 3 |
| | *Rhinanthus minor* | | 1 | 1 | 2 |
| | *Rhinanthus minor* | 1 | | | 1 |
| | *Rosa acicularis* | | 1 | | 1 |
| | *Rosa sp.* | 1 | 1 | | 2 |
| | *Salix brachycarpa* | 1 | 1 | | 2 |
| | *Salix sitchensis* | | | 1 | 1 |
| | *Salix sp.* | | 1 | | 1 |
| | *Symphyotrichum ciliolatum* | 1 | | | 1 |
| | *Symphyotrichum eatonii* | 1 | 1 | | 2 |
| | | **21** | **24** | **22** | **44** |

**Figure 3-7. Examples of natural vegetation establishment in mounds [top panels; *Rosa* sp.; *Populus trichocarpa ssp.balsamifera* seedlings, and *Salix* sp.) and in cleared areas at Bush Causeway North (middle panel; Equisetum sp.)] and Bush Causeway South (bottom panel; *Equisetum* sp. and *Calamagrostis* sp.).** Natural vegetation establishment occurred within the first growing season following clearing in October 2015.

## 3.5 Wetlands

During fall 2015, three ponds were cleared of wood debris (see Hawkes 2016). When the ponds were first cleared, turbidity was high as the water column filled with clay-like silt. This material settled out and by the following spring, the clarity of the water had improved considerably (Figure 3-8).

**Figure 3-8. Wetlands cleared of wood debris at the Bush Causeway North physical works site in fall 2015 (left) and June 2016 (right).**

To determine the suitability of the ponds for aquatic life (e.g., pond-breeding amphibians), data loggers were installed to collect data on dissolved oxygen (DO; mg/L), water temperature (C), and specific conductivity (µS/cm; Figure 3-9). Dissolved oxygen and temperature were recorded every 10 minutes and specific conductivity was recorded hourly.

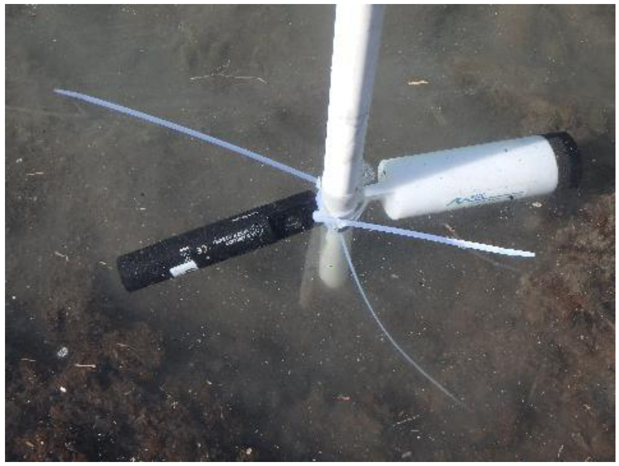

**Figure 3-9. Onset conductivity (µS/cm) and PME dissolved oxygen (mg/L) data loggers installed in one of the cleared wetlands at the Bush Causeway North site, May 2016.** Both data loggers also logged water temperature (°C).

Dissolved oxygen (DO) is the amount of oxygen dissolved in water, and is essential for respiratory metabolism of most aquatic organisms. The concentration of DO is a function of daily and seasonal factors such as temperature, photosynthetic activity and river discharge. Higher concentrations of DO are generally considered better for supporting diverse animal communities. Specific Conductivity is a measurement of the ability of water to conduct an electric current. Conductivity is affected by temperature, and specific conductance is temperature corrected conductivity. Specific conductance values increase with greater ion concentration in the water, and can be used as an alternative measure of dissolved solids. It can be used to indicate potential pollution. Water temperature is the intensity of heat stored in a volume of water. Temperature affects the solubility of compounds which can exacerbate the effects of pollutants.

Dissolved oxygen values measured in the Bush Causeway North site trended higher over time compared to DO measured at a drawdown zone pond at KM79 km. The main difference between the two locations is the elevation of the DO logger at KM79, which was situated at 751.5 m ASL (vs. 752.4 m ASL at BCN), which means it was inundated by the reservoir starting at the end of July. As is evident in Figure 3-10, DO values at KM79 started to decline in June and continued to decline through September, likely as a result of reservoir inundation. A slight increase in DO values is apparent in October, which coincides with the retreat of the reservoir and cooler temperatures. The effects on water temperature were not as evident with values varying in a similar pattern at both locations. The data obtained at BCN are consistent with the values identified as being suitable for aquatic life (MoE 2016). Dissolved oxygen values measured at KM79 drop below the minimum values identified in MoE (2016) as being suitable (i.e., 5 mg/L instantaneous measurement). However, a minimum of 5 mg/L is achieved in all months except for August and September, which could be related to the effects of inundation. Similarly, specific conductivity values were consistently between 200 and 400 µS/cm; data not shown), which is indicative of pollution-free water.

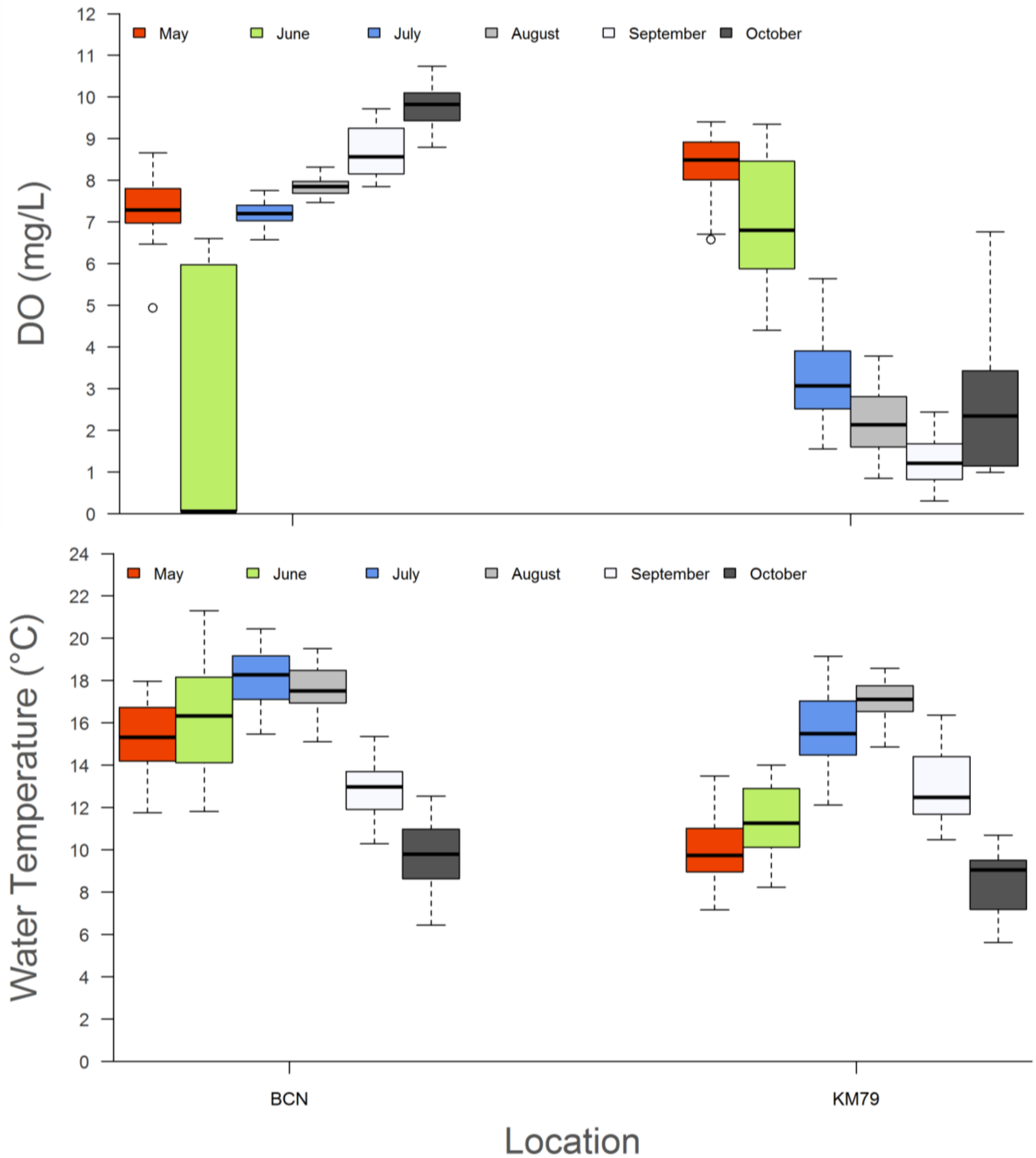


**Figure 3-10. Monthly variation in dissolved oxygen (mg/L; top) and water temperature (°C), between May 4 and October 12, 2016 in the largest of the three cleared wetlands at Bush Causeway North (BCN) and in the drawdown zone at KM79 km.** Zero values for DO occurred when the data loggers were above the water level. Data logger elevation BCN: 752.4 m ASL; KM79: 751.5 m ASL.

Each of the three ponds was visited in 2016 to determine if they were being used by pond-breeding amphibians and to assess whether aquatic macrophytes were growing. Evidence of use by pond-breeding amphibians was documented from two of the three ponds in May and June 2016 (egg strings and tadpoles were documented; Figure 3-11 ). The number of egg strings was low (estimated at 5), but more toads are expected in future years. Long-toed salamanders may also use the cleared wetland for breeding, but that might depend on the growth of aquatic macrophytes.

**Figure 3-11. Western Toad egg string in one of the wetland that was cleared of wood debris in fall 2015. Photo date May 3, 2016.**

During the first growing season following clearing (i.e., May to August 2016) aquatic macrophytes and wetland-associated plants and charophytic green algae (Chara) were observed growing in two of the three wetlands. Wetland-associated plants were also observed in wet areas cleared of wood debris and where water was pooling. The most frequently observed plants were *Carex utriculata*, *Alisma triviale*, and *Myriophyllum* sp. Chara was observed in one of the three wetlands (Figure 3-12). *Alisma triviale* had not been previously documented from wetlands in the drawdown zone of Kinbasket Reservoir.

**Figure 3-12. Examples of wetland plants and charophytic green algae algae growing in the recently cleared wetlands at Bush Causeway North.** Top left: *Carex utriculata*, top right: *Alisma triviale*; bottom left: Chara; and bottom right: *Myriophyllum Spp* .

# 4 Performance Measures

Performance measures to assess the effectiveness of physical works prescriptions implemented in the drawdown zone of Kinbasket Reservoir were developed for Bush Causeway North and South (Hawkes 2016). The physical works implemented in both locations are summarized relative to those performance measures in Table 4-1. Overall, the creation of mounds and clearing of wood debris from the drawdown zone and ponds has improved habitat quality in the drawdown zone by allowing vegetation to naturally re-establish in areas cleared of wood debris as well as on the mounds. Live stakes in the fall are surviving better than those planted in the spring, but overall, the goal of at least 50 per cent survival was achieved one year following mound creation and physical work. Wetland habitat suitability and water quality has improved in those ponds cleared of wood, and aquatic macrophytes and pond-breeding amphibians are growing in and returning to the wetlands that were cleared. Because reservoir elevations did not inundate the mounds in 2016, additional monitoring is required to assess the integrity of the mounds following inundation. This will need to occur when Kinbasket Reservoir is filled to > 753 m ASL.

One performance measure was developed to assess whether the ponds could form in front or behind mounds and potentially entrain fish. There were no ponds observed in front, on, or behind the mounds at Bush Causeway North or South. However, one of the three existing wetlands cleared in fall 2015 at Bush Causeway North became connected to the reservoir when the reservoir was at its maximum elevation in fall 2016 (752.09 m ASL). This wetland has a minimum elevation of 752.10 m ASL and while the reservoir was high, ~ 40 fish (kokanee, *Oncorhynchus nerka*) made their way into the wetland and were trapped when the reservoir receded (Figure 4-1). While unintended, the stranding of fish in ponds and wetlands of Kinbasket Reservoir is the focus of another study (CLBMON-4) and although that study's primary focus is on elevations ≤ 740 m ASL, this observation is likely of relevance, as there are areas of the drawdown zone between 740 m and 754 m ASL that have the potential to contribute to fish stranding.

**Figure 4-1. Stranded kokanee (*Oncorhynchus nerka*) in one of the wetlands cleared of wood debris at the bush Causeway North physical works site.** Water was flowing out of the wetland, but the channel it was flowing through was shallow, filled with vegetation and woody debris, and didn't appear to be passable by fish**.** Red oval indicates location of fish**.**

**Table 4-1. Status of performance measures developed for the Bush Causeway South and North physical works locations in Kinbasket Reservoir.** The 2015 status was reported in Hawkes (2016). The 2016 status is the status determined as of 13 October 2016.

| Location | Performance Measure | 2015 Status | 2016 Status |
|---|---|---|---|
| Bush Causeway South | 1. Creation of a mound as described in Hawkes (2015b) that persists during all seasons and following inundation | Two mounds were built following the specification in Hawkes (2015b). Assessments in 2016 and 2017 are required to determine how well the mounds persist during all seasons and during inundation | No change from 2015 |
| | 2. Little to no erosion of the mound following inundation and winter. Erosion will be determined using aerial photos obtained from a drone. Photos will be acquired immediately following mound creation and again following inundation or the winter season | Assessments of erosion and mound integrity following the winter season will be made in early 2016. Aerial photos were obtained pre- and post-construction and should be acquired again in the spring and fall 2016 to assess post-winter integrity, integrity following a growing season, and if the reservoir exceeds the base elevation of the mounds, photos should be acquired as soon as the water retreats to elevations below the base of the mound | Not tested in 2016 as reservoir elevations reached a maximum of 752.09 m ASL. The mounds at Bush Causeway South were built to a minimum elevation of 753.18 m ASL so they have not yet been inundated. There was no evidence of erosion that would have been attributed to winter conditions. There was compaction of soil on the mound closest to the causeway road. |
| | 3. Survival of at least 50 per cent for all planted live stakes for all species | This performance measure will not be assessed until spring 2016 (in part). | Live stake survival varied between the two mounds with stakes planted in the fall surviving better than those planted in the spring (93.5% vs. 20%). Overall, live stake survivorship was 71% (all stakes, all seasons). |
| | 4. Successful natural establishment of vegetation common to the site at the wood debris removal sites and on the mound | Preliminary assessments of vegetation establishment will commence in late spring/early summer 2016 | Preliminary assessments indicate that vegetation (Rose, black cottonwood, sedges, horsetail, grasses) are growing on the mounds and in areas cleared of wood debris. See Table 3-2**)** |
| | 5. Successful protection / retention of currently vegetated areas adjacent to the mound | This performance measure will not be assessed until spring 2016 (in part) | Vegetated areas that were unaffected by physical works continue to be vegetated. |
| | 6. Provision of wildlife habitat for insects, songbirds, and small mammals | This performance measure will not be assessed until spring 2016 (in part) | These data will be reported on in the 2016 annual report for CLBMON-11A. |
| | 7. Continued evidence of use of the Bush Arm Causeway South area by wildlife (e.g., mule deer, moose, and black bear) | This performance measure will not be assessed until spring 2016 (in part) | These data will be reported on in the 2016 annual report for CLBMON-11A. |
| | 8. No evidence of pond creation around the base or behind the mound (to avoid fish stranding); and | This performance measure will not be assessed until spring 2016 (in part) | No evidence of ponding on or adjacent to the mounds at Bush Causeway South was observed in 2016. |
| | 9. No negative impacts to existing wetland habitat near the proposed construction site | This performance measure will not be assessed until spring 2016 (in part) | Not directly assessed, but see annual report for CLBMON-11A (2016). |

| Location | Performance Measure | 2015 Status | 2016 Status |
|---|---|---|---|
| Bush Causeway North | 1. Creation of a windrow and mound as described in Hawkes (2015b) that persists during all seasons and following inundation | Five mounds were constructed, one of which is a stand-alone island. The islands and mounds are armored using local materials. Assessment of mound and island integrity are required to determine how well the mounds persist during all seasons and during inundation | No changes from 2015. |
| | 2. Little to no erosion of the windrow and mound following inundation and winter. Erosion will be determined using aerial photos obtained from a drone. Photos will be acquired immediately following mound creation and again following inundation or the winter season | Assessments of erosion and mound integrity following the winter season will be made in early 2016. Aerial photos were obtained pre- and post-construction and should be acquired again in the spring and fall 2016 to assess post-winter integrity, integrity following a growing season, and if the reservoir exceeds the base elevation of the mounds, photos should be acquired as soon as the water retreats to elevations below the base of the mound | Not tested in 2016 as reservoir elevations reached a maximum of 752.09 m ASL. The mounds at Bush Causeway North were built to a minimum elevation of 752.19 m ASL so they have not yet been inundated. There was no evidence of erosion that would have been attributed to winter conditions. There was compaction of soil on the mound closest to the causeway road<br>A drone was used to capture video and photographic imagery of the Bush Causeway North site in June 2016. These images can be used in future assessments (i.e., following inundation). |
| | 3. Survival of at least 50 per cent for all trans planted sedges | This performance measure will not be assessed until spring 2016 (in part). | All sedges transplanted appeared to be surviving as of October 2016 (i.e., 100 per cent survival). |
| | 4. Successful natural establishment of vegetation common to the site at the wood debris removal sites and on the mound | Preliminary assessments of vegetation establishment will commence in late spring/early summer 2016 | Preliminary assessments indicate that vegetation (Rose, black cottonwood, sedges, horsetail, grasses) are growing on the mounds and in areas cleared of wood debris. See Table 3-2) |
| | 5. Successful protection / retention of currently vegetated areas adjacent to the mound | This performance measure will not be assessed until spring 2016 (in part) | Vegetated areas that were unaffected by physical works continue to be vegetated. |
| | 6. Provision of wildlife habitat for amphibians, insects, songbirds, and small mammals | This performance measure will not be assessed until spring 2016 (in part) | These data will be reported on in the 2016 annual report for CLBMON-11A. |
| | 7. Continued evidence of use of the area by wildlife (e.g., mule deer, moose, elk, black, and grizzly bear) | This performance measure will not be assessed until spring 2016 (in part) | These data will be reported on in the 2016 annual report for CLBMON-11A. |
| | 8. Reduction of wood debris in the wetlands and ponds such that the cover of native aquatic macrophytes increases by at least 10 percent | This performance measure will not be assessed until spring 2016 (in part). A full assessment of this performance measure will not be possible until after at least one growing season | Aquatic macrophytes are returning to the wetlands that were cleared of wood debris. The increase in cover will be difficult to quantify as we do not have baseline data (but assume it was 0 based on field assessments and cover of wood debris). Regardless, native aquatic macrophytes are growing in and adjacent to the wetlands that were cleared in fall 2016. |
| | 9. Evidence of amphibian breeding in ponds with a reduced volume of wood debris (amphibians do not currently breed here, but they do breed across the causeway in existing ponds that are largely devoid of wood debris) | This performance measure will not be assessed until spring 2016 (in part) | Western Toad eggs and tadpoles were observed in two of the three ponds cleared in fall 2016. No evidence of use of ponds that were not cleared was obtained. |

# 5 2015 Objectives

Nine recommendations were made following the completion of the physical works in 2015 (Hawkes 2016 and repeated below). The status of the recommendations following work completed in 2016 is summarized in Table 5-1.

**Table 5-1. Status of recommendations made in 2015 following work completed in 2016.**

| 2015 Recommendation | 2016 Status |
|---|---|
| 1. The removal of wood from ponds should provide highly suitable wetland habitat in the drawdown zone of Kinbasket Reservoir. However, there is a high probability that wood could cover the wetlands again if the ponds are not adequately protected. The installation of a log boom around the Bush Arm Causeway North site is recommended to ensure the protection of the ponds, mounds, and islands built in this location. Alternatively, additional mounds could be built to keep wood out of the wetlands. If additional mounds are built, wood debris will likely need to be transported from other areas of the drawdown zone and existing ecological values (e.g., high plant diversity), and other monitoring programs (e.g., CLBMON-61) will need to be considered. | A log boom was installed in June 2016 (see Section 3.1) at the Bush Causeway North site. |
| 2. For future iterations of CLBWORKS-1, the use of at least two excavators is recommended. This will reduce the amount of time required to construct the physical works at each location and create efficiencies in terms of wood debris movement and mounding. Multiple excavators are recommended whenever mounds are being constructed in specific locations to protect shoreward values. Using additional machinery will reduce the overall impact to the ground and ensure materials are delivered and piled in specific locations. | Recommendation retained for future consideration. |
| 3. Sites not treated in 2015 (Chatter Creek, Hope Creek, Goodfellow Creek) should be considered for future iterations of CLBWORKS-1. However, it is recommended that these works be postponed until the ability of existing mounds to withstand high reservoir levels can be assessed. | Recommendation retained for future consideration. |
| 4. The prescriptions developed in 2015 focused solely on Bush Arm. Additional opportunities exist in other parts of Kinbasket Reservoir (e.g., Valemount Peatland) and site-specific prescriptions for future consideration could be prepared for those locations. | Recommendation retained for future consideration. |
| 5. An assessment of live stakes and sedge transplants is recommended in 2016 to assess the utility of either or both of these methods to jump start the revegetation process on the mounds and in the drawdown zone surrounding the mounds (i.e., in the areas cleared of wood debris). | Assessments occurred in 2016. See Section 3.2. |

| 2015 Recommendation | 2016 Status |
|---|---|
| 6. In addition to assessments of live stakes planted in the fall of 2015, additional live stakes and sedges could be planted in the spring of 2016 to assess whether there is a difference in growth and survivorship of fall vs. spring planted live stakes. | Additional live stakes were planted at the Bush Causeway North site in October 2016. See Section 3.2 |
| 7. The use of a drone to acquire site specific and timely aerial photography of the mounds was very useful and additional photos of the mounds should be acquired in the spring of 2016. Those photos could be compared to the photos taken immediately following mound construction and pond clearing to assess whether there was any erosion or other changes associated with the features created or enhanced. | A drone was used to capture video and still imagery over the Bush Causeway North site in June 2016. Post-construction imagery was collected via drone in October 2015. |
| 8. The productivity of the cleaned ponds should be determined. This could be accomplished during work associated with CLBMON-61. At a minimum, temperature, conductivity, and dissolved oxygen data loggers should be installed in at least one of the cleaned ponds to determine if the physicochemical properties of the cleaned pond are similar to other ponds in the drawdown zone. | Conductivity, dissolved oxygen and water temperature were assessed between May and October 2016. Visual assessment of water clarity occurred during the same period. Water physicochemical data collected at the Bush Causeway North site were compared to data collected from the drawdown zone at KM79 (see Section 3.5). |
| 9. Certain aspects of CLBWORKS-1 were not implemented completely in 2015. For example, testing various methods of vegetation establishment on the mounds was not possible in 2015 and should be considered for future iterations of CLBWORKS-1. | Aspects of this recommendation were assessed: fall vs. spring live staking and sedge transplants. Additional testing may not be needed, but additional revegetation efforts are warranted to increase the cover of vegetation on the mounds. |

# 6 Conclusions and Recommendations

The objective of the 2015 physical works pilot project was to create habitat features in the drawdown zone of Kinbasket Reservoir using existing materials (wood debris and soil) that would increase topographic heterogeneity in an otherwise homogenous environment. Doing so should lead to increased vegetation establishment and improvements to wildlife habitat suitability over time. The use of mounding to increase topographic heterogeneity (e.g., Larkin et al. 2006) has been used to reclaim brackish marshes (Armitage et al. 2011), freshwater wetlands (Bruland and Richardson (2005), and grasslands (Hough-Snee et al. 2011). While the success of the methods used to create the mounds appears to vary, the application of mound creation to the drawdown zone of a hydroelectric reservoir presented a novel approach to habitat restoration (SER 2004) that required testing.

The 2015 pilot project to construct mounds and wind rows and clean ponds of wood debris in the drawdown zone of Kinbasket Reservoir resulted in the construction of seven mounds in two locations, the cleaning of three previously wood-choked ponds in one location, and the removal of 6,957 $m^2$ of wood from all areas. An additional 763.3 $m^2$ of uncleared land was incorporated into the physical works features created at the Bush Arm Causeway.

The removal of wood debris from the drawdown zone and wetland habitat as a habitat enhancement technique appears to have great potential. Not only can the wood debris be used to construct mounds in the drawdown zone, thereby increasing topographic heterogeneity, but the removal of the wood from the drawdown zone promotes the natural establishment of vegetation (Figure 3-7). Revegetating of the mounds involved the use of live stakes as a means to expedite the revegetation process, but as with the areas cleared of wood debris, native vegetation also began to establish on the mounds (Figure 3-7). This emphasizes the utility of wood removal and mound creation as a tool to increase the cover of vegetation in the drawdown zone of Kinbasket Reservoir. Despite these early signs of success, additional data are required before the widespread removal and mounding of wood is considered for Kinbasket Reservoir. The mounds and cleared areas need to be inundated by Kinbasket Reservoir so that the integrity of the mounds can be assessed following inundation and to determine if additional wood will deposit on sites previously cleared (as occurred at Packsaddle Creek in Canoe Reach, Figure 6-1).

**Figure 6-1. Deposition of wood debris at the Packsaddle Creek south site following clearing in 2014 (left). Date of image on right: April 30, 2015.**

Clearing wood from wetlands also increases the suitability of those wetlands for wildlife by removing wood that prevented access to the water and by improving water quality (Figure 6-2). Aquatic macrophytes and pond-breeding amphibians were documented from the wetlands in 2016, and although fish were stranded in one of the wetlands, early indications are that the habitat suitability of the wetlands has improved. As stated previously, additional data are required to assess the longer-term benefits of wood removal from wetlands and to determine if inundation will cause the mounds surrounding the wetlands to break apart (and deposit wood on the wetlands). The addition of new wood on to the areas cleared is unlikely as a log boom was installed around the physical works locations at the Bush Causeway North site in June 2016 (Figure 3-2). Log booms have proven effective at preventing wood from depositing on areas cleared of wood debris elsewhere in Kinbasket Reservoir (e.g., Valemount Peatland; Hawkes 2015a).

**Figure 6-2. Differences in water clarity and habitat quality between a wetland choked with wood debris and one that was cleared of wood debris in fall 2015.** Both wetlands occur in the drawdown zone at the Bush Causeway North site. Photo Date: 12 October 2016. The wetland cleared in fall 2015 was used by pond-breeding amphibians (Western Toad) in 2016 and native aquatic macrophytes (*Myriophyllum Spp*) were starting to grow. Wetland-associated sedges (*Carex utriculata*, *C. aquatilis*, and *C. lasiocarpa)* were also growing around the margin of the cleared wetland.

Following work completed in 2015 and 2016, several recommendations are made:

1. Re-assess the mounds, wetlands, and areas cleared of wood debris following inundation, or when the reservoir has exceeded at least 753.5 m ASL. This may happen in 2017. If it does, an assessment should occur as soon as possible following inundation, which may mean a fall 2017 visit to the causeway to make the assessment.
2. Consider planting additional stakes and native transplanted vegetation on existing mounds.
3. Consider clearing wood from the northwest corner of the Causeway (Figure 6-3) in 2017. This wood covers an area of ~ 2,204.5 m$^2$ and removing the wood would reduce the potential for it to impact the nearby mounds or get deposited on the cleaned wetlands. Removing the wood will also promote the natural re-establishment of vegetation in that area.
4. Consider cleaning the ponds indicated in Figure 6-3 of wood debris in 2017. As shown in Figure 3-8 and Figure 6-2, cleaning wood from ponds increases water clarity and overall suitability. Removing wood from the ponds indicated in Figure 6-3 will increase the total

wetland area that could be used by wildlife by an additional 934 m$^2$. The total wetland area cleared would almost double from 977 m$^2$ in 3 locations to a total of 1911.7m$^2$ in 4 locations. Cleaning the wood from terrestrial and wetland habitats in the drawdown zone would increase the total area manipulated at Bush Causeway North to 8,986,5 m$^2$, an increase of 3,183.5 m$^2$.

5. Consider collecting additional wildlife data (through the CLBMON-11A program) in 2017 at potential future mounding treatment sites (at Chatter Creek, Hope Creek, Goodfellow Creek and Canoe Reach) to establish a baseline to compare pre- and post-treatment response. Assessments of wildlife use at the sites treated in 2015 could be made during work for other programs (e.g., CLBMON-58, CLBMON-61)
6. Consider the CLBWORKS-16 woody debris removal program and align future mounding areas (including the collection of pre-treatment baseline data) with woody debris removal and burning areas as much as possible.

**Figure 6-3. Areas that could be cleared of wood debris at the Bush Causeway North site. The red polygon indicates the terrestrial area that could be cleaned and the blue polygon is the wetland that could be cleaned.**

Recommendations retained from Hawkes (2016; original numbering used):

2. For future iterations of CLBWORKS-1, the use of at least two excavators is recommended. This will reduce the amount of time required to construct the physical works at each location and create efficiencies in terms of wood debris movement and mounding. Multiple excavators are recommended whenever mounds are being constructed in specific locations to protect shoreward values. Using additional machinery will reduce the overall impact to the ground and ensure materials are delivered and piled in specific locations.

3. Sites not treated in 2015 (Chatter Creek, Hope Creek, Goodfellow Creek) should be considered for future iterations of CLBWORKS-1. However, it is recommended that

these works be postponed until the ability of existing mounds to withstand high reservoir levels can be assessed.

4. The prescriptions developed in 2015 focused solely on Bush Arm. Additional opportunities exist in other parts of Kinbasket Reservoir (e.g., Valemount Peatland) and site-specific prescriptions for future consideration could be prepared for those locations.

# 7 References

Adama, D. 2015. CLBWORKS-1 Kinbasket Reservoir Revegetation Program, 2014 Post-planting Report. Unpublished report by LGL Limited environmental research associates, Sidney, BC, for BC Hydro Generations, Water License Requirements, Burnaby, BC. 20 pp + Appendices.

Armitage, A.R. C-K. Ho, E.N. Madrid, M.T. Bell, and A. Quigg. 2013. The influence of habitat construction technique on the ecological characteristics of a restored brackish marsh. Ecological Engineering 62: 33–42.

BC Hydro. 2007. Columbia River Project Water Use Plan. BC Hydro Generation, Burnaby B.C. 41 pp.

Bruland, G.L. and C.J. Richardson. 2005. Hydrologic, edaphic, and vegetative responses to microtopographic reestablishment in a restored wetland. Restoration Ecology 13(3): 515–523.

Fenneman, J.D., and V.C. Hawkes. 2012. CLBMON-9 Kinbasket Reservoir Monitoring of Revegetation Efforts and Vegetation Composition Analysis. Annual Report – 2011. LGL Report EA3271. Unpublished report by LGL Limited, Sidney, B.C., for BC Hydro Generation, Water Licence Requirements, Castlegar, B.C. 78 pp. + Appendices.

Hawkes, V.C and P. Gibeau. 2015. CLBMON-10 Kinbasket Reservoir Inventory of Vegetation Resources. Annual Report – 2014. LGL Report EA3532. Unpublished report by LGL Limited environmental research associates, Sidney, B.C., for BC Hydro Generations, Water License Requirements, Burnaby, B.C. 74 pp + Appendices.

Hawkes, V.C. 2015b. CLBWORKS-1 Kinbasket Reservoir revegetation program: year 7 – 2015. Debris mound and wind row construction pilot program. Site Prescriptions. Unpublished report by LGL Limited environmental research associates, Sidney, B.C. for BC Hydro Generations, Water License Requirements, Burnaby, B.C., 49 pp.

Hawkes, V.C. 2016. CLBWORKS-1 Kinbasket Reservoir revegetation program: year 7 – 2015. Debris mound and wind row construction pilot program. Annual Report. Unpublished report by LGL Limited environmental research associates, Sidney, B.C. for BC Hydro Generations, Water License Requirements, Burnaby, B.C., 35 pp.

Hawkes, V.C., 2015a. LGL Limited Contract No. 77816 Release 3: Debris boom installation, Valemount Peatland. Letter report by LGL Limited environmental research associates, Sidney, BC, for BC Hydro Generations, Water License Requirements, Burnaby, B.C. February 18, 2015.

Hawkes, V.C., M.T. Miller, J.E. Muir, and P. Gibeau. 2013. CLBMON-9 Kinbasket Reservoir Monitoring of Revegetation Efforts and Vegetation Composition Analysis. Annual Report – 2013. LGL Report EA3453. Unpublished report by LGL Limited, Sidney, BC, for BC Hydro Generation, Water Licence Requirements, Castlegar, BC. 70 pp. + Appendices.

Hill, N.M., P.A. Keddy, and I.C. Wisheu. 1998. A hydrological model for predicting the effects of dams on the shoreline vegetation of lakes and reservoirs. Environmental Management, 22(5): 723–736

Hough-Snee, N., L.A. Long, L. Jeroue, and K. Ewing. 2011. Mounding alters environmental filters that drive plant community development in a novel grassland. Ecological Engineering 37(11): 1932–1936.

Keefer, M.E., R. Moody, K. Dixon, and A. Kennedy. 2011. Kinbasket Reservoir Revegetation Program Physical Works Report (2010). Report prepared by Keefer Ecological Services for BC Hydro. 41 pp. + Appendices.

Keefer, M.E., R. Moody, T.J. Ross, A. Chapman, and J. Meuleman. 2010. Kinbasket Reservoir Revegetation Program Physical Works Report (2009). Report prepared by Keefer Ecological Services for BC Hydro. 39 pp. + Appendices.

Keefer, M.E., T.J. Ross, and K. Kettenring. 2007. Kinbasket Reservoir Revegetation Program Physical Works (Phase 1) Site Verification and Seed Collection. Report prepared by Keefer Ecological Services for BC Hydro. 21 pp. + Appendices.

Keefer, M.E., T.J. Ross, T. Ehlers, and J. Meuleman. 2008. CLBWORKS-1 Kinbasket Reservoir Revegetation Program Physical Works Report (2008). Report prepared by Keefer Ecological Services for BC Hydro. 53 pp. + Appendices.

Larkin, D., G. Vivian-Smith, and J.B. Zedler. 2006. Chapter 7: Topographic heterogeneity theory and ecological restoration. Pages 142 – 164 *In*: D.A. Falk, M.A. Palmer, and J.B. Zedler (eds.). Foundations of Restoration Ecology. Society for Ecological Restoration International. Island Press. 364 pp.

Luken, J.O. and T.N. Bezold. 2000. Plant communities associated with different shoreline elements at Cave Run Lake, Kentucky. Wetlands, 20: 479–486.

Ministry of Environment. 2016. British Columbia approved water quality guidelines: aquatic life, wildlife & agriculture. Summary Report. Water Protection & Sustainability Branch, Ministry of Environment, Victoria, BC. 36 pp.

Nilsson; C. A. Ekblad, M. Gardfjell and B. Carlberg. 1991. Long-Term effects of river regulation on river margin vegetation. The Journal of Applied Ecology, 28: 963–987.

Poff, N.L. and J.K.H. Zimmerman. 2010. Ecological responses to altered flow regimes: a literature review to inform the science and management of regulated rivers. Freshwater Biology 55: 194–205.

Society for Ecological Restoration. 2004. The SER Primer on Ecological Restoration. Version 2. October, 2004. Science and Policy Working Group, October, 2004. Society for Ecological Restoration International. Washington DC. accessed on January 24, 2014 (http://www.ser.org/resources/resources-detail-view/ser-international-primer-on-ecological-restoration).

Van Geest, G.J., H. Coops, R.M.M. Roijackers, A.D. Buijse, and M. Scheffer. 2005. Succession of aquatic vegetation driven by reduced water-level fluctuations in floodplain lakes. Journal of Applied Ecology, 42: 251 – 260.

Yazvenko, S.B. 2009. CLBMON-9 Kinbasket Reservoir Monitoring of Revegetation Efforts and Vegetation Composition Analysis. Sampling Design. Prepared for BC Hydro by LGL Limited, Sidney, B.C. 19 pp. + Appendices.

Yazvenko, S.B., V.C. Hawkes, and P. Gibeau. 2010. CLBMON-9 Kinbasket Reservoir Monitoring of Revegetation Efforts and Vegetation Composition Analysis. Annual Report – 2009. LGL Report EA3073. Unpublished report by LGL Limited, Sidney, B.C., for BC Hydro Generation, Water Licence Requirements, Castlegar, B.C. 83 pp. + Appendices.

Ye, C., K. Zhang, Q. Deng, and Q. Zhang. 2012. Plant communities in relation to flooding and soil characteristics in the water level fluctuation zone of the Three Gorges Reservoir, China. Environmental Science and Pollution Research. DOI: 10.1007/s11356-012-1148-x.

# 8 Appendix

Latin and common names of plants included in this report.

| Latin Name | Common Name |
|---|---|
| *Agrostis gigantea* | redtop |
| *Alisma triviale* | northern water-plantain |
| *Braya humilis* | dwarf braya |
| *Calamagrostis canadensis* | bluejoint reedgrass |
| *Calamagrostis* sp. | *Calamagrostis* sp. |
| *Calamagrostis stricta* | slimstem reedgrass |
| *Carex aquatilis* | water sedge |
| *Carex lasiocarpa* | slender sedge |
| *Carex lenticularis* | Kellogg's sedge |
| *Carex lenticularis ssp.lipocarpa* | Kellogg's sedge |
| *Carex sp.* | *Carex sp.* |
| *Carex utriculata* | beaked sedge |
| *Cirsium vulgare* | bull thistle |
| *Comarum palustre* | marsh cinquefoil |
| *Deschampsia cespitosa* | tufted hairgrass |
| *Elymus repens* | quackgrass |
| *Equisetum arvense* | common horsetail |
| *Equisetum* sp. | *Equisetum* sp. |
| *Equisetum variegatum* | northern scouring-rush |
| *Erucastrum gallicum* | dog mustard |
| *Erysimum cheiranthoides* | wormseed mustard |
| *Leucanthemum vulgare* | oxeye daisy |
| *Lysimachia thyrsiflora* | tufted loostrife |
| *Medicago lupulina* | black medic |
| *Melilotus alba* | white sweet-clover |
| *Mentha arvensis* | field mint |
| *Myriophyllum* sp | *Myriophyllum* sp |
| *Packera pauciflora* | rayless alpine butterweed |
| *Phalaris arundinacea* | reed canarygrass |
| *Plantago major* | common plantain |
| *Poa compressa* | Canada bluegrass |
| *Poa palustris* | fowl bluegrass |
| *Populus trichocarpa ssp.balsamifera* | black cottonwood |
| *Potentilla anserina* | common silverweed |
| *Potentilla norvegica* | Norwegian cinquefoil |
| *Rhinanthus minor* | yellow rattle |
| *Rosa acicularis* | prickly rose |
| *Rosa sp.* | *Rosa sp.* |
| *Salix brachycarpa* | short-fruited willow |

| Latin Name | Common Name |
|---|---|
| *Salix sitchensis* | Sitka willow |
| *Salix* sp | *Salix* sp |
| *Symphyotrichum ciliolatum* | Lindley's aster |
| *Symphyotrichum eatonii* | Eaton's aster |
| *Taraxacum officinale* | common dandelion |
| *Trifolium hybridum* | alsike clover |
| *Trifolium pratense* | red clover |
| *Verbascum thapsus* | great mullen |
| *Vicia cracca* | tufted vetch |