Columbia River Project Water Use Plan

Kinbasket and Arrow Reservoirs Revegetation Management Plan

Arrow Lakes and Kinbasket Reservoirs Plant Response to Inundation

Implementation Year 1

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CLBMON-35 ARROW LAKES AND KINBASKET RESERVOIRS PLANT RESPONSE TO INUNDATION




Final Report 2017

Prepared for

BC Hydro
Bid Station (main floor)
6911 Southpoint Drive
Burnaby, BC V3N 4X8, Canada

Sumbitted by

LGL Limited
environmental research associates
9768 Second Street
Sidney, British Columbia, V8L 3Y8

Contact

Virgil C. Hawkes, M.Sc. R.P.Bio.
Vice-President & Senior Wildlife Biologist
vhawkes@lgl.com
1.250.656.0127

June 20, 2018

LIMITED
environmental research associates

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Cover photos:

From left to right: Black cottonwood (*Populus balsamifera subsp. trichocarpa*) live stakes at Lower Inonoaklin Road, Arrow Lakes Reservoir; Kellogg's Sedge *(Carex lenticularis var. lipocarpa*) at Burton Creek, Arrow Lakes Reservoir; vegetation growing in the drawdown zone of Arrow Lakes Reservoir, and live staking at the Bush Arm Causeway, Kinbasket Reservoir.

Executive Summary

BC Hydro has undertaken studies on the vegetation of the drawdown zones of Kinbasket and Arrow Lakes Reservoirs since 2007. These studies, which were undertaken in lieu of operational changes to reservoir management, were variously designed to assess the impacts of reservoir operations on existing vegetation (CLBMON-10 and -33) and to determine the effectiveness of revegetation efforts (CLBWORKS-1 and -2; CLBMON-9 and -12). Key assumptions tested were: that existing vegetation conditions could be maintained over the long term; that the current operating regime could maintain the existing riparian and wetland vegetation communities and associated ecosystems at the landscape scale; and that the drawdown zone of each reservoir could be revegetated under the current operating regime. Studies also addressed the intra-community responses of existing vegetation in the two drawdown zones to the continued implementation of the operating regime at the local (site) level. CLBMON-35 (this report) catalogues in detail the revegetation treatments that have been applied to Kinbasket and Arrow Lakes drawdown zones since 2008, and documents the biotic and abiotic variables that contributed to the successes or failures of each type of revegetation treatment. The goal of cataloguing and analyzing these data was to provide a permanent, integrated record of the revegetation techniques applied at each site, and to help determine the treatments and associated factors that were effective.

To assess species-specific responses to reservoir operations in Kinbasket and Arrow Lakes Reservoirs, four species (*Carex lenticularis* var. *lipocarpa*), *C. aperta, Sciprpus atrocinctus*, and *Populus balsamifera* ssp. *Trichocarpa*) were selected for analyses. These four species were selected because they were used extensively in the revegetation program and occur across the elevation range considered in each reservoir (Kinbasket: 740 to 754 m ASL; Arrow Lakes Reservoir: 434 to 440 m ASL). The association between the inundation regime and its effect on growing degree days and plant communities in the drawdown zone was examined in Arrow Lakes and Kinbasket Reservoirs. Using regression trees, GLMMs, and Wald tests, we observed that inundation variables were associated with all modelled species; however, the nature of the association (positive or negative) varied between species, environmental conditions, and reservoir. Further, one- and two-year lags in response were observed, suggesting that inundation events can have delayed impacts on vegetation. The lack of association between species-specific cover and revegetation treatment is likely a product of low survival of planted plants. At this point it is not possible to directly link low survival to inundation regimes, however, a relationship seems likely given the known impact of reservoir operation upon plant survival.

Findings are summarized below. All variables listed were associated with the observed cover of that species, while +/- indicates if the generalized linear mixed model (GLMM) and Wald tests revealed a positive or negative relationship with plant cover. Plant cover data were used as they represented the most robust dataset. A positive and negative relationship suggest that these variables were associated with increasing or decreasing plant cover, respectively. Variables without a +/- were identified as of interest by the regression trees, but not by the GLMM or Wald test.

Arrow Lakes Reservoir

Carex lenticularis var *lipocarpa*

- August growing degree days (two-year lag)
- April growing degree days (two-year lag); **"+"**
- July growing degree days (two-year lag); **"- "**
- Duration of inundation (one-year lag); **"- "**
- Maximum depth of inundation (one-year lag); **"- "**
- Inundation depth coefficient of variation (one and two-year lags); **"+"**
- Inundation timing (two-year lag); **"+"**
- Inundation depth (one and two-year lags); **"+"**

Carex aperta

- July growing degree days (one-year lag)
- August growing degree days (two-year lag); **"- "**
- October growing degree days (one-year lag); **"- "**
- Duration of inundation (one-year lag)
- Maximum depth of inundation (one-year lag)
- Inundation depth coefficient of variation (one and two-year lags)
- Maximum depth of inundation (two-year lag); **"- "**
- Inundation depth (two-year lag); **"+"**

Scirpus atrocinctus

- May growing degree days (one-year lag); **"+"**
- Inundation depth (one-year lag); **"- "**
- Duration of inundation (one-year lag); **"- "**
- Maximum depth of inundation (one-year lag); **"+"**

Populus balsamifera ssp. *trichocarpa*

- October growing degree days (one-year lag); **"- "**
- April growing degree days (two-year lag); **"- "**
- May growing degree days (two-year lag); **"- "**
- Duration of inundation (two-year lag); **"- "**
- Inundation timing (one-year lag); **"- "**

Kinbasket Reservoir

Carex lenticularis var *lipocarpa*

- July growing degree days (two-year lag)
- August growing degree days (one-year lag) **"- "**
- May growing degree days (two-year lag); **"- "**
- April growing degree days (one-year lag); **"+"**
- June growing degree days (two-year lag); **"+"**
- Inundation depth coefficient of variation (two-year lag)
- Maximum depth of inundation (one-year lag); **"- "**
- Average depth of inundation (one-year lag); **"+"**

Carex aperta

- April growing degree days (one-year lag)
- July growing degree days (two-year lag); **"+"**
- August growing degree days (two-year lag); **"+"**
- Inundation depth coefficient of variation (one and two-year lags); **"- "**
- Inundation timing (one and two-year lags); **"- "**
- Maximum depth of inundation (one-year lag); **"- "**
- Duration of inundation (two-year lag); **"+ "**

Scirpus atrocinctus

- May growing degree days (two-year lag)
- April growing degree days (one-year lag); **"+"**
- June growing degree days (two-year lag); **"- "**
- Inundation depth (two-year lag)
- Duration of inundation (one-year lag); **"- "**

Populus balsamifera ssp. *trichocarpa*

- August growing degree days (two-year lag)
- May growing degree days (two-year lag); **"+"**
- September growing degree days (two-year lag); **"+"**
- April growing degree days (two-year lag); **"- "**
- June growing degree days (two-year lag); **"- "**
- Inundation timing (two-year lag); **"+"**

In lieu of wholesale changes to the management of Arrow Lakes and Kinbasket Reservoirs, the following recommendations are made regarding existing vegetation and revegetation efforts in the drawdown zones of Kinbasket and Arrow Lakes Reservoir:

Existing Vegetation

1. Define the desired plant communities relative to elevation for the drawdown zone of Kinbasket and Arrow Lakes Reservoirs. Lower elevations in both Arrow Lakes and Kinbasket Reservoir are likely to be inundated earlier and longer than those closer to the normal operating maxima. As such, vegetation targets for lower elevations should differ from those at higher elevations. Previous

work has shown that species richness increases with elevation in both Kinbasket and Arrow Lakes Reservoir. These findings support defining vegetation targets by elevation. In each reservoir, pioneering communities dominate the drawdown zone at lower elevations with species richness and cover increasing with elevation. The upper two to three metres of the drawdown zone in each reservoir could be targeted for vegetation communities defined by high species richness, high cover, and a greater percentage of woody stemmed species. The species occurring in each reservoir, and within reaches of each reservoir, should be dictated by the local flora at those sites.

2. To facilitate defining desired plant communities in the drawdown zone, a decision tree could be developed to help identify the type of community defined for a given reservoir, reach, and elevation in the drawdown zone. The decision tree could incorporate knowledge of existing vegetation in each reservoir by elevation (e.g., the results of CLMBON-10 and -33), the reported success of previous revegetation trials (see the Kinbasket and Arrow Lakes Reservoirs Revegetation Prescription Catalogues that accompany this report), and any of the biotic and abiotic variables known to influence the cover of specific species of plants. The decision tree could also guide future revegetation efforts in each reservoir by providing the means to quickly identify the kind of community that would be appropriate to attempt to establish at a given location.
3. Define hard constraints for the management of Kinbasket and Arrow Lakes Reservoirs that are designed to promote the establishment and development of existing vegetation in the drawdown zone. This aligns with the published literature that supports affording vegetation the time to establish, grow, and transition towards later succession stages. In addition to increasing vegetation cover in the drawdown zone, wildlife habitat suitability will increase. The hard constraints developed for vegetation could be modelled off of the soft constraints for Arrow Lakes Reservoir to ensure that future reservoir management doesn't unduly affect wildlife, such as ground-nesting birds, in favour of vegetation growth.
4. Continue to assess the effectiveness of wood debris removal as a way to increase the cover of existing vegetation in the drawdown zone, particularly in Kinbasket Reservoir (as per Hawkes 2016, 2017). Because wood tends to settle higher in the drawdown zone, removal of wood will benefit the upper two to three metres of the drawdown zone, helping achieve targets identified above.

Revegetation

1. Local site conditions should be considered when developing a revegetation plan for a given reservoir. This should include an assessment of the current distribution of vegetation (by elevation) and an assessment of the local flora, which can guide the selection of plant species to use in a revegetation program. The revegetation plan should be developed after visiting the site to determine the best prescription to implement at the site.
2. When planting in the drawdown zone of a hydroelectric reservoir, do not use upland species. Doing so will reduce the probability of success as these species are likely to be less tolerant of wet and dry stress. Use the local flora in the drawdown zone as a cue for the species that more likely to survive in the drawdown zone.
3. In some instances, it might not be possible to revegetate parts of the drawdown zone because of the slope, aspect, exposure, existing soil, or some other abiotic factor that precludes vegetation growth. In these cases effort should be spent elsewhere. Having a decision tree (or similar tool) will be helpful in this regard.
4. In some cases, augmenting existing vegetation with nursery-grown or locally sourced (collected) stock may be desirable, particularly if doing so will increase the total cover of vegetation.

5. Revegetation efforts may require multiple entries/planting sessions before vegetation establishes on the site. A determination of the number of times a site might need to be treated should form part of the revegetation prescription, which can provide guidance on whether to plant the site.
6. The four species modelled (*Carex lenticularis* var. *lipocarpa, C. aperta, Scirpus atrocinctus*, and *Populus balsamifera ssp. Trichocarpa*) represent the most commonly used species in both CLBWORKS-1 and 2. Many more plant species could be investigated for revegetation potential aside from the ones already trialed. The existing flora of the KIN and ALR drawdown zones provides more than 200 well-adapted species to draw from. Among these, emphasis should be on (preferably native) species that (1) provide clear discernable benefits in terms of ground cover, dust control, slope stabilization, and/or wildlife habitat structure, and (2) have demonstrated "staying power," either via a persistent root system (perennials) or a persistent seed bank (annuals). Also of interest are species that are either adapted to a wide variety of conditions (i.e., are relatively ubiquitous) or are habitat specialist that are known to do particularly well in a specific habitat type, such as dry and sandy soil, debris mounds, mudflats, or recovering wetlands. One such species, swamp horsetail (*Equisetum fluviatile*), is tolerant of extreme variations in water depth and high rates of sedimentation and can colonize exposed mineral soils. It has been used to revegetate the extreme environment of the drawdown zones of reservoirs, but has not been explored as a potential option for the revegetation programs in CLBWORKS-1 or -2. The following is a partial list of plant species that would appear, based on field observations, to meet one or more of these criteria:

   Mountain alder (*Alnus incana*), Pacific willow (*Salix lucida*), short-fruited willow (*S. brachycarpa*), bluejoint reedgrass (*Calamgrostis canadensis*), tufted hairgrass (*Deschampsia cespitosa*), annual hairgrass (*D. danthoniodes*), moss grass (*Coleanthus subtilis*), fowl bluegrass (*Poa palustris*), little meadow-foxtail (*Alopecuris aequalis*), beaked sedge (*Carex utriculata*), slender sedge (*C. lasiocarpa*), common horsetail (*Equisetum arvensis*), swamp horsetail (*E. fluviatile*), marsh yellow cress (*Rorippa palustris*), dagger-leaf rush (*Juncus ensifolius*), thread rush (*Juncus filiformis*), buckbean (*Menyanthes triofoliata*), marsh cinquefoil (*Comarum palustre*), small spike-rush (*Eleocharis parvula*), Norwegian cinquefoil (*Potentilla norvegica*), Scouler's popcornflower (*Plagiobothrys scouleri*), and fireweed (*Epilobium angustifolium*).

7. In addition to considering which species to include in a more in-depth analysis, other aspects of the revegetation programs should be considered. For example, the propagation of plants requires further investigation in terms of seed collection and sourcing, the size of plugs or live stakes to use, or whether rooted live stakes are used (rather than cuttings). The size and/or age of sedge plugs used in a revegetation program may influence success. In 2013, LGL Limited planted ~68,000 sedge plugs at Bear Island (*C. lenticularis and C. aperta*) in the drawdown zone of Kinbasket Reservoir. The size of the sedge plugs was similar to that of plugs used previously (i.e., between 2008 and 2011 for CLBWORKS-1), but they were one year older and had (presumably) larger and better established roots. This treatment continues to thrive while others that were treated with younger plugs between 2008 and 2011 have died. The planting of live stakes may also require further experimentation with the depth of planting, which is an important consideration along with the timing of planting. A recent small-scale trial in Kinbasket Reservoir revealed that live stakes planted in the fall had much higher survival rates than those planted in the spring.

Filling Data Gaps

1. It is evident that certain types of data need to be collected or derived for each reservoir to improve our ability to assess the species-specific responses of plants to inundation. In Kinbasket Reservoir,

a more fulsome assessment of surface topography, micro-topography, soil moisture, substrate type and size), and water source is required in those locations previously treated under CLBWORKS-1. These data should be collected prior to the next update for CLBMON-35 (planned for 2019) so the results for Kinbasket Reservoir can be updated.

2. Erosion and sediment deposition will affect vegetation in the drawdown zones of both reservoirs. As such, metrics describing erosion and sediment deposition are required. These are likely to be categorical, and could potentially be derived from the existing time series of aerial photographs.
3. Data regarding the potential influence of wood debris on the occurrence and distribution of existing vegetation and effects on revegetation treatments is not widely available and should be derived for both Kinbasket and Arrow Lakes Reservoirs. These data are currently being tested/observed in a trial phase at various locations throughout Kinbasket Reservoir. Wood debris will have a greater impact on vegetation in Kinbasket Reservoir. The Kinbasket revegetation catalogues can be used in conjunction with other data (e.g., aerial photography) to determine where wood debris removal would be most effective with respect to increasing vegetation cover in the drawdown zone.
4. The non-replicated design of the planting program, combined with annually variable reservoir operations, limits our ability to test assumptions around factors affecting revegetation success. We thus recommend that future revegetation treatments be experimentally replicated in space and time. This will assist in identifying the most successful combinations of methods and site conditions, while allowing future physical works prescriptions to evolve within an adaptive management framework.

KEYWORDS: Kinbasket Reservoir; Arrow Lakes reservoir; inundation, revegetation; plant community; existing vegetation; drawdown zone; operating regime; reservoir elevation.

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Table of Contents

List of Tables

List of Figures

List of Appendices

1 Introduction

Shorelines of reservoirs managed for power production can undergo seasonal and diurnal water level changes that far surpass those associated with natural flood regimes. Usually measured in tens of vertical metres, reservoir drawdown zones (area between low- and high-water lines) tend to be highly dynamic, ruderal environments whose vegetation bears little similarity to that which existed prior to river impoundment (Abrahams 2005, Lu *et al.* 2010). Submergence of the original shoreline requires that new shoreline vegetation develop at higher elevations, often on poorer soils that lack a riparian seed bank. The cycle of winter drawdown, followed by rising water levels through the spring, summer, and fall months, runs counter to the natural flood regime (spring/summer freshet) and results in an abbreviated growing window. Prolonged inundation during the growing season produces a repeating cycle of succession consisting of establishment, growth, and disturbance that can serve to retain vegetation in an early (often depauperate or weedy) seral state. Steep and unstable banks, long fetches and associated wave action, loss of organic matter, low soil nutrients, accumulations of woody debris and associated mechanical scouring, erosion and sediment deposition provide additional challenges to vegetation establishment in the drawdown zone (Johnson 2002, Abrahams 2005, Miller et al. 2017). Despite these challenges, vegetation does grow in the drawdown zones of reservoirs, with some species adapting and persisting in the drawdown zone over time (Hawkes and Gibeau 2017; Miller et al. 2017).

In Arrow Lakes Reservoir, an impoundment of the Columbia River in British Columbia, water level elevations are managed by BC Hydro under a regime that permits a normal annual minimum of 418.64 metres above sea level (m ASL), and a normal maximum of 440.1 m ASL—a difference of 21.46 m. The approximately 216 km long Kinbasket Reservoir is located in southeastern B.C., and is surrounded by the Rocky and Monashee Mountain ranges. The Mica hydroelectric dam, located 135 km north of Revelstoke, B.C., spans the Columbia River and impounds Kinbasket Reservoir (Hawkes and Miller 2016). 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 2008; Hawkes and Miller 2016). 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. Between the annual allowance in each reservoir, water levels change daily throughout the growing season (Miller et al. 2017). Primary drawdown occurs during the winter, with reservoir elevations reaching their minimum in April. With the arrival of warmer spring temperatures comes snow melt and the freshet along with a reduced need to produce power that results in the refilling of the reservoir until the maximum elevation for the year is achieved in later summer or early fall. At this time power production increases and drawdown recommences. While the overall pattern is predictable, the timing, depth, and duration of inundation experienced by each elevation band varies markedly from year to year. The resulting stress on vegetation establishing within those elevation bands is exacerbated by processes of wave action, sediment deposition, and erosion (Miller et al. 2017). Because of these difficult growing conditions, much of the foreshore is barren or only lightly vegetated. Where conditions do support plant growth, hydrological gradients or topographic relief can produce strong patterns of plant community zonation, resulting in a mosaic of vegetation types that includes wetland complexes, pioneering annual forb, perennial sedge and graminoid associations, shrub and treed communities, and driftwood zones (Miller et al. 2017).

The cumulative impacts on reservoir shoreline vegetation communities, and associated impacts on ecosystem functioning, wildlife values, and aesthetics, were not addressed until 2001 when BC Hydro entered into the Water Use planning process (WUP) for its mainstem Columbia River facilities (Miller et al. 2017). During this process, the WUP Consultative Committee (WUP CC) recognized the value of vegetation in improving aesthetic quality, controlling dust storms, protecting cultural heritage sites from erosion and human access, and enhancing littoral productivity and wildlife habitat (BC Hydro 2005). The WUP identified a set of "soft constraint targets" for Arrow Lakes Reservoir to balance the wildlife, recreation, fisheries, culture and heritage, shoreline conditions, and power generation interests on this reservoir (BC Hydro 2005). The consultation process acknowledged that these objectives may conflict with each other and that in any given hydraulic year, it would be unlikely that all objectives would be met simultaneously (BC Hydro 2005).

The soft constraint targets identified for vegetation (BC Hydro 2005) were to:

- Maintain current level of vegetation in the drawdown zone by maintaining lower reservoir water levels during the growing season. No specific operating targets were identified to meet this general objective.
- Target lower reservoir levels in the fall to allow exposure of plants during the latter part of the growing season if vegetation is showing signs of stress because of inundation during the early part of the growing season (May to July).
- Preserve current levels of vegetation at and above elevation 434 m (1424 ft).

BC Hydro has undertaken studies related to vegetation in the drawdown zones of Kinbasket and Arrow Lakes Reservoirs since 2007. These projects were designed to study the effects of reservoir operations on existing vegetation (CLBMON-10, -33) and to determine the methods of revegetation that were the most successful in each reservoir (CLBWORKS-1, and -2, and CLBMON-9 and -12). These studies were undertaken in lieu of any operation changes to reservoir management and to test the key assumption that existing vegetation conditions could be maintained over the long term, and that the current operating regime maintains the existing riparian and wetland vegetation communities and associated ecosystems at the landscape scale. Similarly, assumptions about revegetation effectiveness were also tested to determine whether the drawdown zone of each reservoir could be revegetated under the current operating regime and to address the intra-community responses of existing vegetation in the drawdown zone of Kinbasket Reservoir to the continued implementation of the operating regime at the local (site) level.

In Kinbasket Reservoir, ~2234 ha of existing vegetation has been mapped and monitored since 2007 (CLBMON-10; Hawkes et al. 2015), and a total of 72.45 ha were planted with sedges, grasses, and live stakes between 2008 and 2013. The efficacy of the revegetation trials was assessed from 2008 to 2013, although most of the treatments failed (Hawkes et al. 2013). Additional revegetation with sedge plugs at KM88 continue to thrive and live staking and sedge transplants established at the Bush Arm Causeway had high rates of survivorship one year following planting (Hawkes 2016), In Arrow Lakes, ~ 2067 ha of existing vegetation have been monitored since 2008, and several areas of the ~106 ha that were treated (revegetated) have had moderate success [as discussed in Hawkes et al. (2014) and Miller et al. (2016)]. While a substantial volume of work has been completed in both reservoirs, there is a need to synthesize the data collected to date and distill the results of the revegetation program into a user-friendly and informative catalogue. The concept for the cataloguing of existing data was presented at the Revegetation Technical Review (RTR) in 2014[1], and it was subsequently supported by the participants of the RTR.

The purpose of the cataloguing exercise (CLBMON-35) was to document site conditions, revegetation methods, and revegetation success to elucidate variables (biotic and abiotic) that contributed to the successes or failures of each type of vegetation treatment at a given site within Arrow Lakes and Kinbasket Reservoirs. The goal of cataloguing and analyzing these data was to provide a record of the revegetation

[1] The concept for the cataloguing of existing data was developed by Virgil Hawkes, Dr. Michael Miller, and Douglas Adama of LGL Limited and presented at the Revegetation Technical Review by Virgil Hawkes.

techniques applied at each site, and help determine the treatments and associated factors that were effective. These variables included the presence (accumulation) of species planted, site preparation, planting method, stocking density, woody debris, erosion and sediment deposition, wave and wind action, soil characteristics, ecological suitability, soil compaction, human activity, and physicochemical parameters such as soil anoxia. Data analyses and results also aimed to address existing uncertainties regarding the relative contribution and importance of timing, frequency, depth, and duration of inundation on survival of plants of different sizes and ages, and the effect of multi-year stresses on trends in plant viability. This report is part of a three-volume compendium that includes the revegetation prescription catalogues for Kinbasket and Arrow Lakes Reservoirs, which are available as stand-alone documents.

1.1 Key Operating Decision

The key operating decision affected by the original CLBMON-35 monitoring program is the maintenance of the soft constraints operating regime for Arrow Lakes Reservoir. The decision of the Water Use Plan Consultative Committee to implement a revegetation program in lieu of operational changes in Arrow Lakes Reservoir assumed that such a program could be successful under the soft constraints operations. A key objective of the soft constraints is maintaining (or enhancing) existing vegetation communities and associated ecosystems in the drawdown zone by maintaining lower water levels during the growing season.

In accepting the soft constraints operating regime for Arrow Lakes Reservoir, the WUP CC recognized the uncertainty associated with the response of existing vegetation communities to flexible operations on a yearly basis, and consequently recommended a monitoring program comprised of a series of interlinked studies at different spatial scales to investigate the effects of the operating regime on riparian and wetland vegetation communities. The monitoring program CLBMON-35 was originally set up to address existing uncertainties regarding the relative contribution and importance of timing, frequency, depth and duration of inundation on the survival of plants of different sizes and ages, and the effect of multi-year stresses on trends in plant viability. This revised Terms of Reference will aim to still address these uncertainties using monitoring data collected under CLBMON-9, -10, -12, and -33.

1.2 Management Questions

Under the Terms of Reference (Revision 1) for CLBMON-35, data from CLBWORKS-1 and -2, and results from the four vegetation monitoring programs (CLBMON-9, -10, -12, and -33; CLBWORKS-1 and -2), will be assimilated into two catalogue-style databases (one for each of Arrow Lakes and Kinbasket Reservoirs). These will be developed to answer four management questions. Analyses already completed for the monitoring programs will not be replicated in this study but may be used to augment additional analyses. Management questions will be answered separately for each reservoir; these questions assume the data are sufficient and available to answer these questions (which will be determined during the data gap analysis). The four management questions addressed by CLBMON-35 are:

1. What trends are apparent in the responses of plant species used for revegetation to the operating regimes to date with respect to timing, frequency, duration and depth of inundation?
2. Do plant species respond differently from one another to variables of the operating regime, including timing, frequency, duration and depth of inundation?
3. How do the responses of plant species to the operating regime interact with other biotic and abiotic factors (e.g. substrate, climate, reservoir filters, and presence of other plant species)?
4. What recommendations may be made to more effectively maintain existing vegetation, help persisting species, and establish new plant communities at different spatial scales (i.e. community versus species scale) in the future?

1.3 Objectives

This report summarizes the work completed on CLBMON-35 to date (Year 1), including conclusions from the four previous monitoring studies, and expands those analyses and conclusions by incorporating data from the physical works programs. The development of a common database and two catalogues (one for each reservoir) is described, as well as additional analyses that were conducted to identify data gaps, and recommendations made to address these gaps. Upon completion, this work will have addressed reasons for why the physical works revegetation programs failed or succeeded, and why other existing plant communities or species are successful in persisting in reservoir drawdown zones. By organizing the investigation around the management questions posed above, the aim is to resolve key uncertainties regarding the influence of operating conditions of Arrow Lakes and Kinbasket Reservoirs on vegetation. Where appropriate, conclusions made in CLBMON-9, -10, -12, and -33 reports will be used to support our conclusions.

2 Study Area

The Mica Dam, located 135 km north of Revelstoke, British Columbia, spans the Columbia River and impounds Kinbasket Reservoir (Figure 2-1). Completed in 1973, the Mica powerhouse has a generating capacity of 1,805 MW. The Mica Dam is one of the largest earth fill dams in the world and was built under the terms of the Columbia River Treaty to provide water storage for flood control and power generation. Kinbasket Reservoir is 216 km long and has a licensed storage volume of 12 MAF[2] (BC Hydro 2007). Of this, seven MAF are operated under the terms of the Columbia River Treaty. The normal operating elevation of the reservoir ranges from 754.38 m ASL to 707.41 m ASL. However, application may be made to the Comptroller of Water Rights for additional storage for economic, environmental, or other purposes if there is a high probability of spill.

Two Biogeoclimatic (BEC) zones are represented in the lower elevations of Kinbasket Reservoir: the Interior Cedar-Hemlock (ICH) zone and the Sub-Boreal Spruce (SBS) zone. Four subzone/variants characterize the ICH and one subzone/ variant characterizes the SBS zone (Table 2-1).

Table 2-1: Biogeoclimatic Zones, subzones and variants occurring in the Kinbasket Reservoir study area.

Zone Code	Zone Name	Subzone & Variant	Subzone/Variant Description	Forest Region & District
ICHmm	Interior Cedar – Hemlock	mm	Moist Mild	Prince George (Robson Valley Forest District)
ICHwk1	Interior Cedar – Hemlock	wk1	Wells Gray Wet Cool	Prince George (Robson Valley Forest District) and Nelson Forest Region
ICHmw1	Interior Cedar – Hemlock	mw1	Golden Moist Warm	Nelson Forest Region (Columbia Forest District)
ICHvk1	Interior Cedar – Hemlock	vk1	Mica Very Wet Cool	Nelson Forest Region (Columbia Forest District)
SBSdh1	Sub-Boreal Spruce	dh1	McLennan Dry Hot	Prince George (Robson Valley Forest District)

[2] MAF = Million Acre Feet. An acre foot is a unit of volume commonly used in the United States in reference to large-scale water resources, such as reservoirs, aqueducts, canals, sewer flow capacity, and river flows. It is defined by the volume of water necessary to cover one acre of surface area to a depth of one foot. Since the area of one acre is defined as 66 by 660 feet then the volume of an acre foot is exactly 43,560 cubic feet. Alternatively, this is approximately 325,853.4 U.S. gallons, or 1,233.5 cubic metres or 1,233,500 litres.

Arrow Lakes Reservoir is situated on the Columbia River between Revelstoke and Castlegar, BC (**Figure** *2-2*). The reservoir is ~230 km long and was formed in 1968 by the completion of Hugh Keenleyside Dam, 8 km west of Castlegar. The reservoir includes three main sections: Lower and Upper Arrow Lakes in the south, and Revelstoke Reach in the north. It has a north-south orientation and lies between the Monashee Mountains in the west and the Selkirk Mountains in the east. Two Biogeoclimatic zones occur within the study area: the Interior Cedar Hemlock (ICH) and the Interior Douglas-fir (IDF). Further details on the study area physiology, geology, and soils are provided in Enns et al. (2007).

2.1 Physiography[3]

The Columbia basin is situated in southeastern British Columbia. The basin is characterized by steep valley side slopes and short tributary streams that flow into Columbia River from all directions. The headwaters of the Columbia River begin at Columbia Lake in the Rocky Mountain Trench. The river flows northwest along the Trench for about 250 km before it empties into Kinbasket Reservoir behind Mica Dam (BC Hydro 1983). From Mica Dam, the river continues southward for about 130 km to Revelstoke Dam and then flows almost immediately into Arrow Lakes Reservoir behind Hugh Keenleyside Dam. The entire drainage area upstream of Hugh Keenleyside Dam is approximately 36,500 km^2.

The Columbia River valley floor elevation falls from approximately 800 m ASL near Columbia Lake to 420 m ASL near Castlegar. Approximately 40 per cent of the drainage area within the Columbia River basin is above 2000 m ASL. Permanent snowfields and glaciers predominate in the northern high mountain areas above 2500 m ASL; about 10 per cent of the Columbia River drainage area above Mica Dam exceeds this elevation.

Most of the watershed remains in its original forested state. Dense forest vegetation thins above 1500 m ASL and tree lines are generally at about 2000 m ASL. The forested lands around Kinbasket Reservoir have been and are being logged, with recent and active logging (i.e., 2007–2014) occurring on both the east and west sides of the reservoir.

2.2 Climate[4]

Precipitation in the basin occurs from the flow of moist low-pressure weather systems that move eastward through the region from the Pacific Ocean. More than two-thirds of the precipitation in the basin falls as winter snow, resulting in substantial seasonal snow accumulations at middle and upper elevations in the watersheds. Summer snowmelt is complemented by rain from frontal storm systems and local convective storms.

Temperatures in the basin tend to be more uniform than precipitation. With allowances for temperature lapse rates, station temperature records from the valley can be used to estimate temperatures at higher elevations. The summer climate is usually warm and dry, with the average daily maximum temperature for June and July ranging from 20°C to 32°C. The average daily minimum temperature ranges from 7°C to 10°C. The coldest month is January, when the average daily maximum temperature in the valleys is near 0°C and average daily minimum is near -5°C.

During the spring and summer months, the major source of stream flow in the Columbia River is water stored in large snow packs that developed during the previous winter months. Snow packs often accumulate above 2000m through the month of May and continue to contribute runoff long after the snow pack has depleted at lower elevations. Runoff begins to increase in April or May and usually peaks in June

[3] From BC Hydro (2007) after BC Hydro (1983).

[4] From BC Hydro 2007 after BC Hydro 1983.

to early July, when approximately 45 per cent of the runoff occurs. Severe summer rainstorms are not unusual in the Columbia Basin. Summer rainfall contributions to runoff generally occur as short-term peaks superimposed upon high river levels caused by snowmelt. These rainstorms may contribute to annual flood peaks. The mean annual local inflow for the Mica, Revelstoke, and Hugh Keenleyside projects is 577 m^3/s, 236 m^3/s, and 355 m^3/s, respectively.

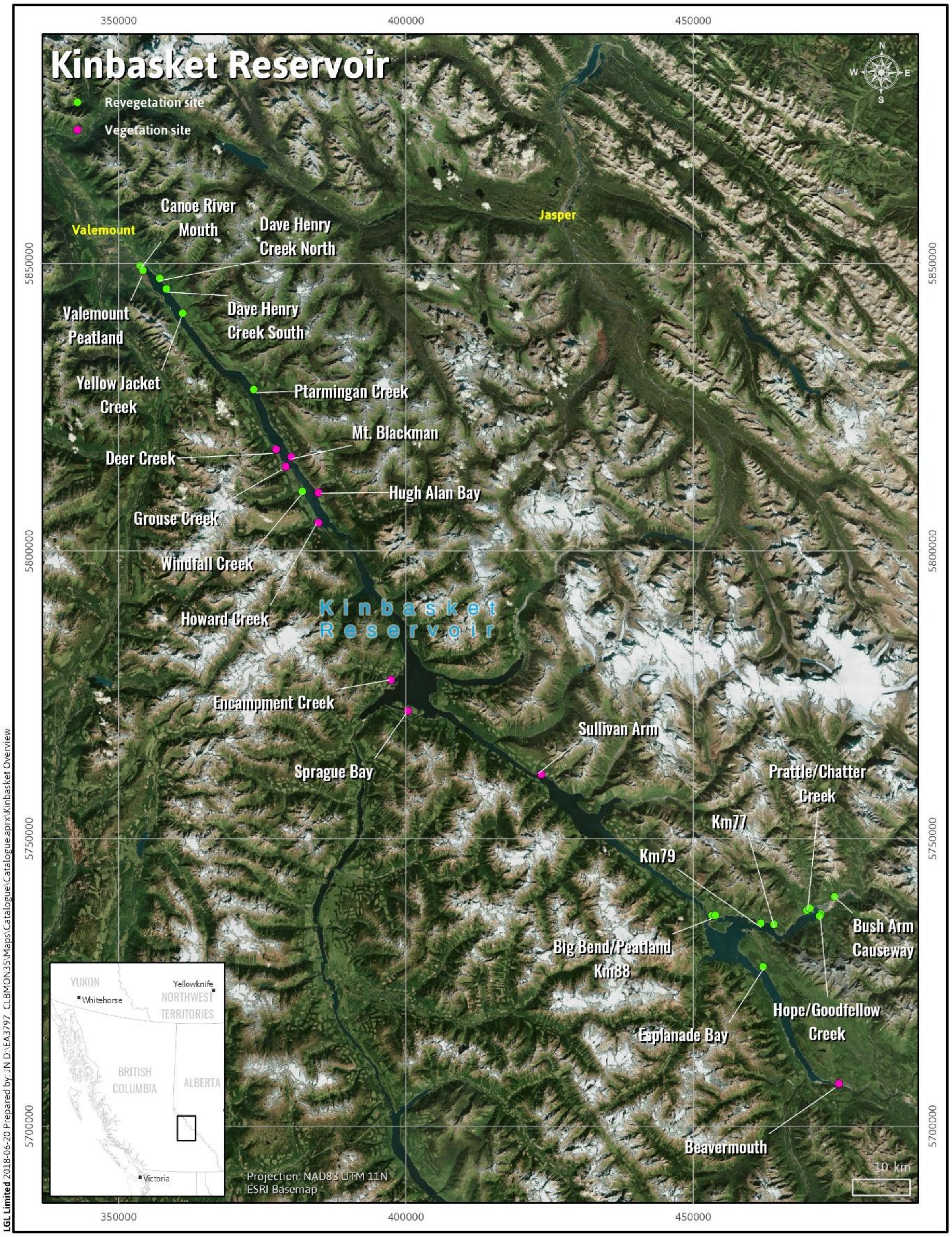

Figure 2-1: Location of Kinbasket Reservoir vegetation monitoring locations (pink). Revegetation trials and/or vegetation monitoring occurred at all locations indicated in green.

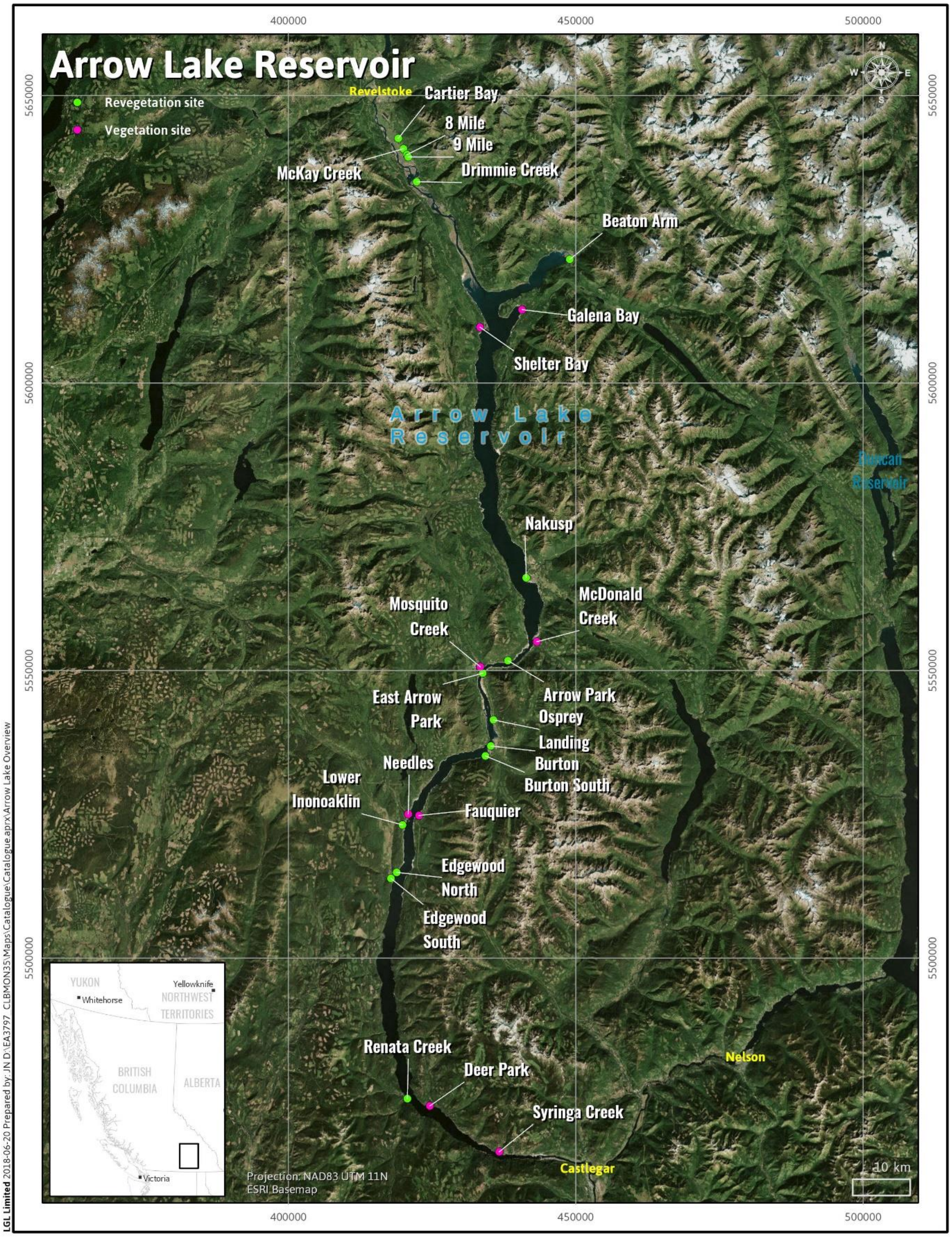

Figure 2-2: Location of Arrow Lakes Reservoir vegetation monitoring locations (pink). Revegetation trials and/or vegetation monitoring occurred at all locations indicated in green.

3 Methods

3.1 Database Creation

For each reservoir, Kinbasket and Arrow, data were categorized into three distinct data sets: CLBWORKS-1 or -2 (revegetation), CLBMON-9 or -12 (revegetation monitoring), and CLBMON-10 or -33 (vegetation inventory). Data categories and study methodology for a specific project type were not always consistent between reservoirs or within a specific project. As such, each project within a reservoir contains nuances in the data that are unique from other projects and within a project. For this reason, a well-formulated and methodical approach to collation and database design was necessary. To this end, the following required data steps were identified and carried out:

- Requirement 1: The collated data store (a repository for storing and managing data) was created as a relational database. This database contains project data spanning Arrow and Kinbasket CLBMON and CLBWORKS projects, including GIS data (shapefiles, BC Hydro and LIDAR DEMs, and orthophotos). GIS data were associated with field data, where applicable. along with meteorological data from the Canadian government and BC Wildfire Service and BC Hydro reservoir elevation data.
- Requirement 2: A well-structured pipeline (a series of sequential and well-defined steps), including a comprehensive QA/QC process, was used to move data from original source files to a single collated data store.
- Requirement 3: The database was designed to allow secure, password protected and encrypted, external connections that would allow for data visualization using ArcGIS, or similar, and data analysis using statistical languages such as R.
- Requirement 4: Any modifications to the data were contained within an audit log, in addition to the database being subject to rolling backups and being hosted on fully redundant hardware.
- Requirement 5: Analysis scripts were created.
- Requirement 6: Data were made available as an MS Access database upon request.

The approach to achieving each of these requirements is described below.

3.1.1 Database Creation: Requirement 1

The collated data store will be a relational database containing project data spanning Arrow and Kinbasket CLBMON and CLBWORKS projects

All CLBMON projects and CLBWORKS projects were previously stored individually, precluding compound queries spanning more than one project. Furthermore, queries that integrated GIS data and field data were not possible for a single project or multiple projects. By implementing a single relational database as the data store, all project data, spanning all years and each reservoir, can now be co-located and queried. This complexity of ordering and structuring data in a relational way has tangible benefits in that it allows for complex queries and analysis. Additionally, the chosen database system (PostgreSQL) is designed to be easily integrated with GIS software. It also provides a relatively simple extensibility mechanism to enable the addition of other projects, projects types, and data. The source data included 68 GIS shapefiles, 12 metadata files and 8 project datasets. The final database contains17 tables with associated project- and meta-data, containing 33,347 individual plot and transect surveys spanning 9 projects and 10 years (2007-2016) and including 71,534 species observations and 68 tables with GIS data (Table 3-1).

Table 3-1. **Summary of projects and data sources contained in the CLBMON-35 database.** '●' indicates data availability; '--' data not available or not relevant. Tran = Transect; DEM = Digital Elevation Model; MET = meteorological data; Ortho = georeferenced orthomosaics; Spatial = shapefiles, polygons, points, etc.; LiDAR = Light Detection and Ranging; Surveys = the individual plot and transect surveys

Project	Short Title	Year	Tran	Plot	DEM	Met	Ortho	Spatial	LiDar	Surveys
CLBMON-10	Existing vegetation inventory: Kinbasket	2007	●	--	●	●	●	●	--	836
		2008	●	--	●	●	●	●	--	814
		2010	●	--	●	●	●	●	--	968
		2012	●	--	●	●	●	●	--	648
		2014	●	--	●	●	●	●	●	960
		2016	●	--	●	●	●	●	--	719
CLBMON-9	Revegetation effectiveness: Kinbasket	2008	--	●	●	●	--	●	--	671
		2009	--	●	●	●	--	●	--	790
		2011	--	●	●	●	--	●	--	486
		2013	--	●	●	●	--	●	--	485
		2014	--	●	●	●	--	●	--	443
		2015	--	●	●	●	--	●	--	627
CLBMON-9 Fall Survey	Post-inundation assessment: Kinbasket	2015	--	●	--	--	--	--	--	9
CLBMON-9/11A	Revegetation effectiveness: Kinbasket	2016	--	●	--	--	--	--	--	118
CLBMON-33	Existing vegetation inventory: Arrow	2010	--	●	●	●	●	●	--	4251
		2012	--	●	●	●	●	●	--	3562
		2014	--	●	●	●	●	●	--	3681
		2016	--	●	●	●	●	●	--	4525
CLBMON-12	Revegetation effectiveness: Arrow	2011	--	●	●	●	--	●	--	2954
		2013	--	●	●	●	--	●	--	3101
		2015	--	●	●	●	--	●	--	2481
CLBMON-12 Fall Survey	Post-inundation assessment: Arrow	2015	--	●	--	--	--	--	--	174
CLBWORKS-1	Revegetation: Kinbasket	2008	--	--	--	--	--	●	--	--
		2009	--	--	--	--	--		--	--
		2010	--	--	--	--	--	●	--	--
		2011	--	--	--	--	--	●	--	--
		2013	--	--	--	--	--	●	--	--
		2016	--	●	●	●		●		44
CLBWORKS-2	Revegetation: Arrow	2008	--	--	--	--	--	●	--	--
		2009	--	--	--	--	--	●	--	--
		2010	--	--	--	--	--	●	--	--
		2011	--	--	--	--	--	●	--	--

3.1.2 Database Creation: Requirement 2

A well-structured pipeline (a series of sequential and well-defined steps), including a comprehensive QA/QC process will be used to move data from original source files to a single collated data store

For each project type the general pipeline created was identical; however, differences existed within each step due to inherent differences in data collected, study design and geographical location. The general process is described below:

Census, Validation, and Normalization: All data types were catalogued within a project type, for all years; this included both reservoirs where the methodology was applied. Next a validation process was followed. This ensured that entries for each data type were consistent for the type. It also included, but was not limited to, identification of:

- invalid dates and date ranges
- invalid/improbable numerical values
- inconsistent magnitudes and measurement units
- inconsistent spelling
- missing/null values
- duplications

Issues identified by the validation process were resolved before proceeding to the next step.

Merge 1: Once data were validated, the data for each project were merged for all years. The total number of data points following the merge was compared to the original number of data points to ensure completeness of the merge.

Database Schema Creation and Mapping of Project Data to Schema: The first phase of the merge process produced a single dataset for a project, which allowed the generation of relational schema. The schemas for the individual project datasets were compared, and the final database schema was designed to be able to accommodate the existing data for all projects in a common format without any information loss. To populate the database, a mapping from data within the files to specific columns within the database was constructed. This assigned each datatype in the merged data set to a specific column within the relational database. Interim CLBMON/WORKS Data: The mapping allowed the project data set to be collated into an interim database for that project.

Merge 2: GIS data, including LIDAR DEM data and orthophotos were merged with the interim data. Field data were linked to associated polygons, points, and lines within shapefiles, where applicable

CLBWORKS/CLBMON Final Data: All project collations were completed, and field and GIS data were contained within a relational database. Data can be now queried and are securely stored.

Data Migration Tool: The data migration pipeline was designed/implemented as a Python 3 script that would ingest the project-based and metadata data files and populate the final database.

Merge 3: Databases for each project were collated into a single database. Site names and reservoirs were appended data points to simplify queries and associate multi-year/multi-project study data. Meteorological data and reservoir elevation data were added. This merge is the final step and resulted in a completed Final Vegetation Database.

3.1.3 Database Creation: Requirement 3

The database will allow secure, password protected and encrypted, external connections via the internet to enable data visualization using ArcGIS, or similar, and data analysis using statistical languages such as R.

Modern GIS and statistical analysts can interact directly with relational databases, thereby removing the need to export data into an intermediate format, such as csv or Excel. However, unfettered access to a database is a major security concern. To facilitate a secure data environment, the BC Hydro database was password protected and made accessible only to users with a valid username and password and connected to LGL's internal network. Furthermore, connections between the server and a client were encrypted to ensure data cannot be intercepted enroute to either endpoint. User permissions were enabled ensuring that the ability to change data is separate from an ability to read data, allowing only specific users the ability to change data.

3.1.4 Database Creation: Requirement 4

Any changes made after the initial collation will be contained within an audit log. This will ensure that a sequential path from original data to current data exists, logging who made the change and at what date.

Hardware failure potential was mitigated by a backup plan that ensures the integrity and persistence of the data. This is in addition to hosting the database on hardware that features fail-over, thereby ensuring the data are very unlikely to require a restore from backup. Additionally, the data migration pipeline is fully encapsulated in the Python-based migration tool. In case of failure, the final database can be easily recreated by running the migration tool on the source project and metadata data files.

3.1.5 Database Creation: Requirement 5

Analysis scripts will be provided

All analysis scripts written, but not limited to, those in the statistical programming language R, were provided. These scripts were written such that they securely connect as per Requirement 3, and thus allow analysis of all data collated within the database

3.1.6 Database Creation: Requirement 6

Data will be provided as an MS Access database

On request, the database used internally by LGL Limited can be converted into an MS Access database that is compatible with BC Hydro's database systems. This conversion will retain all relational data, except for GIS data, which will be extracted to an ESRI File Geodatabase format because MS Access has certain limitations when storing these types of data (e.g., 500 MB size limit, only works in MS Windows). The result of this conversion will be two separate sets of files: one MS Access database file (*.mdb) containing all field, meteorological, and reservoir elevation data, and an ESRI File Geodatabase containing orthophotos, LIDAR-derived digital elevation models, and shapefiles. Additionally, the following caveats will apply:

- Security features from Requirement 3 will be removed, however, the MS Access database will be password protected
- Analysis scripts will have to be modified if the preference is to interface with the MS Access database rather than the connection detailed in Requirement 3
- Queries spanning GIS and field data will not be possible

3.2 Data Gap Analysis

All data associated with each reservoir was assessed to determine if the necessary data were present to answer the four management questions identified above. Several key databases were considered in the overall gap analysis: (1) the original prescription data from CLBWORKS-1 and -2 for location, species planted, density of planting, and specific planting methods used; (2) the field ground data that were collected by LGL Limited and Delphinium Holdings Inc. over the years for a random subsample of existing and planted sites (i.e., the CLBMON-9, -10, -12, and -33 data); (3) the orthomosaic data (which contain some useful information about the spatial extent of vegetation in the areas treated under CLBWORKS-1 and -2); and (4) reservoir operations and climate data. The gap analysis focused on identifying data gaps in these datasets that might prevent answering the MQs as currently stated, and emphasis was placed on the relationships between data in (1) and (2) above.

3.3 Response and Explanatory Variables

Numerous variables (biotic and abiotic) have been identified as potentially contributing to the success or failure of vegetation treatments within Arrow Lakes and Kinbasket Reservoirs. We grouped the important variables of interest as follows:

(A) Response variables:

- **Survivorship** of planted stock, including seedlings/plugs and live stakes, over time (1-yr, 2-yr, 3-yr, 5-yr, 6-yr, and 7-yr following planting). Based on work completed to date, survivorship must be inferred indirectly by comparing surviving numbers against reported stocking rates, because non-surviving individuals generally do not persist in the drawdown zone long enough to be enumerated.
- **Cover** of vegetation 1-yr, 2-yr, 3-yr, 5-yr, 6-yr, and 7-yr following planting. Because planted stock can be indistinguishable from native vegetation where it has been interplanted with the latter, cover of planted stock has typically been measured indirectly, by comparing the joint covers of planted and existing vegetation with those of existing vegetation in adjacent, non-treated (control) areas.
- **Size and vigour** of vegetation. “Size” in the database is usually represented by height (cm), while “vigour” has been reported using categorical variables such as “poor,” “moderate,” “good,” and “excellent.”
- **Presence/absence** of surviving planted stock at given sites 1-year, 2-year, 3-year, 5-year, 6-year, and 7-year following planting. For remotely derived data (i.e., orthophotos), this will likely be the most straightforward obtainable metric in many cases. This will yield binomial data that can analyzed using Chi-square or logistic regression to relate establishment success to other variables (e.g., location).
- **Community response** to planting. In the CLBMON-9 and -12 programs, this has usually been inferred through hypothesis testing around observed increases/decreases in plant cover and diversity, as well as species turnover rate or constancy, relative to non-treated controls.

(B) Explanatory variables*:*

Explanatory variables are further divided into the following categories:

Operational

- Species planted
- Propagation/collection method (e.g., nursery-potted or wild; age of nursery stock)

- Transplant methods, including but not limited to timing (year, month), planting depth, manual versus machine-assisted, size of cuttings used, and planting density. We anticipate that data gaps regarding reported planting procedures used from site to site, along with the lack of experimental replication, will be one of the major challenges for the catalogue exercise.
- Fertilizer: applied or not, type, timing, frequency of application

Reservoir effects

- *Frequency, timing, depth, and duration of inundation*. To date these variables have been examined on their own because of the observational nature of the CLBMON monitoring programs. Because the frequency, timing, duration and depth of reservoir operations are highly correlated, it is not statistically possible to assign a value of variation to each of them in isolation from the others. To infer the effects of the frequency, timing, duration, and depth or reservoir operations on vegetation growing in the drawdown zone we have used integrative measures such as growing degree days, which weights exposure time to the ambient growing conditions (temperature) during the period of exposure. This approach will be used in CLBMON-35.
- Exposure to wave action: This can be predicted based on topographic features (e.g., protected coves versus exposed headlands) in combination with fetch (wind travel).
- Erosion and deposition: This information has been recorded for some field plots over time; it can also be assessed remotely from aerial imagery.
- Woody debris movement and deposition: We have previously used fetch to predict woody debris movements in KIN. Debris deposition events in the drawdown zone can be tracked spatially over time using available time series of orthophotos to determine potential correlations with establishment failures.

Abiotic

- Location in reservoir (reach, sub-reach)
- Elevation band: obtained from available data or, if not available, from the digital elevation model (DEM)
- Topography: meso-slope position and microtopography (convex, straight, concave)
- Slope and aspect: indicators of slope stability and heat load
- Substrate texture: e.g., cobble, gravel, sand, silt, or clay
- Soil nutrient regime
- Soil moisture regime: e.g., saturated, mesic, xeric
- Drainage: Is soil well-drained or poorly drained, etc.
- Water inputs: Are there external water sources (e.g., creek, seepage, ponds) aside from the reservoir?

Biotic

- **Human activity:** Many seedlings on sandy soils were destroyed by off-road vehicles, and in some places (e.g., Edgewood), live stakes were deliberately removed by the public. While there are data on some types of disturbance (e.g., presence of ATV tracks on monitored plots), some effects are difficult to observe or quantify. Nevertheless, anthropogenic effects need to be accounted for to the extent possible when cataloguing factors that limit revegetation success.

- **Pests:** e.g., herbivory. Girdling of live stakes by voles has been identified as a potential source of mortality at certain revegetation sites such as Duncan Flats in Arrow Lakes Reservoir.
- **Associated species** will be used to assess questions like: What is the existing vegetation community type at each revegetation site? How sparse or dense was the existing vegetation at the time of planting? Is there evidence of in-growth by competitor species? The existing CLBMON-9 and -12 databases contain community typing for treatment sites that have been field-monitored; for non-sampled areas, it should be possible to obtain this information remotely through a study of aerial imagery and the existing vegetation mapping associated with CLBMON-10 and -33.

3.4 Data Gaps

Data were not available for all variables in both reservoirs. In particular, very few abiotic variables (soil, substrate, drainage) were available (consistently) for Kinbasket Reservoir and reliable metrics of wave action, erosion, deposition, and wood debris movement could not be calculated for either reservoir. As such, the modelling of species-specific response to reservoir operations was constrained to only those variables associated with reliable and complete data for each reservoir, some of which were derived from the data (e.g., Heat Load and Growing Degree Days). The variables used to model the species-specific response of plants to inundation in each reservoir are shown in Table 3-2.

Table 3-2. Variables used to assess the species-specific response of plants to inundation in each reservoir

Reservoir	Variables included	
Arrow Lakes	type of plot (control/treated)	
	landscape units	
	surface topography	
	micro-topography	
	soil moisture	
	water source	
	slope	
	heat load	
	GDDs (per month April-October)	Per elevation band
	timing of inundation	
	duration of inundation	
	average depth of water	
	median depth of water	
	maximum depth of water	
	CV depth of water	
Kinbasket	type of plot (control/treated)	
	landscape units	
	Vegetation communities	
	slope	
	heat load	
	GDDs (per month April-September)	Per elevation band
	timing of inundation	
	duration of inundation	
	average depth of water	
	median depth of water	
	maximum depth of water	
	CV depth of water	

3.5 Management Questions 1 to 4: Species-specific Modelling

Management questions 1, 2, and 3 were addressed using statistical methods. The answer to Management Question 4 was derived from the results associated with answering questions 1, 2, and 3, but did not require statistical analyses. Four species were modelled separately in the two reservoirs: *Carex lenticularis*, *C. aperta*, *Scirpus atrocinctus*, and *Populus balsamifera* ssp. *trichocarpa*. See Appendix A for a discussion regarding the selection of these species for the modelling. Data from CLBMON-9 and -10 (Kinbasket Reservoir) and CLBMON-12 and -33 (Arrow Lakes Reservoir) were used. Data included 0's (i.e. no cover) only for plots and transects that were sampled more than once, and where species either appeared or disappeared over time. Therefore, plots and transects where a species was never observed were not analyzed with respect to that species. This enhanced the model's ability to assess the biotic and abiotic variables that influenced cover of the species, and not simply presence/absence.

For Arrow Lakes Reservoir, site-specific physical environmental variables such as type of plot (control or treated), landscape unit, surface and micro-topography, soil moisture, water source, slope, and heat load (aspect) were included in the model. All site-specific variables were consistent between years, and the most recent data were used to populate all years (usually from 2016, but not always). In Kinbasket Reservoir, the only available site-specific variables were transect type, landscape unit, vegetation community, slope, and heat load. In Kinbasket Reservoir, data from all quadrats were averaged per transect. In both reservoirs, quantitative data were screened for outliers. Heat load was computed from aspect by using the following formula: (1- cos(θ-45))/2, where θ is the aspect in degrees east of north (McCune and Keon 2002). Aspects of 999 and slopes of 0 (i.e. flat plots) were given a median heat load of 0.5.

Elevation-specific variables were also included for all plots and transects. Elevation-specific variables were growing degree days (GDDs) and inundation variables that related to reservoir operations over time. GDDs were computed for each month of the growing season using the following formula:

$$GDD = \frac{T_{max} + T_{min}}{2} - T_{base}$$

Where GDD = Growing degree days, T_{max} = maximum daily temperature, T_{min} = minimum daily temperature, and T_{base} = a base temperature, which was set to 10°C for all days. The minimum temperature was set to 10°C for all instances where T_{max} or T_{min} were less than this value. Similarly, a maximum of 30°C was used because most plants do not grow any faster at temperatures > 30°C (McMaster and Wilhelm 1997). The number of GDDs was corrected for reservoir inundation by reducing the GDDs for a given elevation band based on the date of inundation in each year.

Inundation variables included timing of inundation (number of days under water since April 1), duration of inundation (total number of days for which a given elevation band was under water for a growing season), average depth of water, median depth of water, and maximum depth of water above each elevation band. Median depth was computed in case extreme values of depth were skewing values of mean depth. The coefficient of variation (standard deviation/mean) of the depth of water was also computed to provide an idea of the variation in depth over each elevation band over the growing season. Growing seasons were defined as the period April 1 to September 30th in Kinbasket Reservoir and April 1 to October 31st in Arrow Lakes Reservoir. Elevation ranges considered in the analyses were 741 to 754 m ASL and from 434 to 440m ASL for Kinbasket and Arrow Lakes Reservoir, respectively. Because GDDs and inundation variables are derived from elevation, elevation could not be included in models that contained these variables, therefore, elevation was omitted. Finally, as GDDs are influenced by inundation regimes, we considered them as inundation variables.

Three series of models were built for each species in each reservoir, with different time lags associated with the elevation-specific variables (GDDs and inundation variables) to allow for the possibility that vegetation is affected by conditions occurring in years prior to the year of sampling (sampling typically occurred in late spring/early summer, prior to inundation, and thus would not reflect the current year's inundation). The first series of models was computed with a 1-year lag (t-1), while a 2-year lag (t-2) was used for the other series, and the final series of models included both 1- and 2-year lags. In this report we only evaluated and discuss models that initially included both one and two-year lags. Both lags were evaluated as this enables us to assess the impact of multiple years of reservoir operation upon plant communities, instead of only assessing operations of the preceding year. For instance, a large inundation event may have substantial impacts upon vegetative communities for several years. If such an extreme event is followed by normal periods of inundation the following year, models that only incorporate the preceding year's data will fail to identify biologically significant relationships, and may even erroneously conclude that vegetative changes are occurring independently of reservoir operations. Therefore, by including both lags, we maximize our ability to detect if reservoir operations from one year prior, two years prior, or both, are impacting vegetative communities in the drawdown zone.

Two models were built for each series: a regression tree and generalized linear mixed effects models (GLMM). Regression trees were utilized as they deal well with continuous or discrete variables, nonlinear relationships, complex interactions, missing values, and outliers (De'ath and Fabricius 2000). A regression tree is built by partitioning independent variables (e.g., GDD, soil moisture) into a series of boxes (leaves) that contain the most homogeneous groups of objects (i.e. plots or transects). Splits are created by seeking the threshold levels of independent variables that produce groups that maximize homogeneity, by minimizing the sums of squares within groups (De'ath and Fabricius 2000). Lengths of the vertical lines associated with each split graphically approximate the proportion of total sum of squares explained by each split; the longer the line is, the more variance the split is explaining (De'ath and Fabricius 2000). The value shown at each terminal leaf corresponds to the average value of the dependent variable (here, plant cover). The method allows computing a R^2 that corresponds to the proportion of variance explained by the tree ((1-the deviance of the tree) / by overall sum of squares).

GLMMs were built with the form:

log (cover + 0.05) ~ X1 + X2 + (...), random= ~1|plot (or transect in Kinbasket), method = "ML".

This allowed for an explicit consideration of the repeated nature of the data by including plots/transects as a random effect. Cover was log-transformed to ensure models were fitted to a positive scale. The value of 0.05 was added to compute the log of samples with no cover (0), and corresponds to half the smallest cover value observed, therefore, well below our detection threshold. Continuous explanatory variables varied with respect to units and dimensions, and were standardized prior to inclusion (Legendre and Legendre 2012). During model selection, diagnostic plots were reviewed to determine how data aligned with fitting assumptions. Non-significant variables were removed, and models were compared using AIC (Akaike information criterion). Models with the lowest AIC were selected (if differences between models were at least ΔAIC < 2 (Burnham and Anderson 2002), otherwise the full model was kept). Results were displayed as coefficient plots showing the value of regression coefficients (effect size) for each explanatory variable, along with a measure of their variation (± 2 SE with confidence interval). The width of the confidence intervals gives an indication of the confidence in both the magnitude and sign (positive or negative) of the coefficient. Intervals that cross the 0 line indicate lack of confidence in the effect described by the coefficient. Significance of GLMMs was tested via a Wald test that approximates the likelihood ratio test, and tests each coefficient against the full model (containing all coefficients). Smaller datasets were used to compute the GLMMs because they cannot handle missing values (while regression trees can). In all analyses an $\alpha = 0.1$ was used to denote statistical significance, and any variables identified as significant were further explored in this report. Base levels for the qualitative variables in the GLMMs were control plots or transects, BR (vegetation community in Kinbasket Reservoir only), Bear Island (landscape unit in Kinbaset) or Applegrove (Arrow Lakes), concave surface topography, channelled microtopography, and hygric soil moisture. An outlier was removed, based on residuals of the full GLMM, for *Carex aperta* (09-12-167) in 2010. Plot 08-12-06 was removed for all four species as there were replicates from several years that couldn't be reconciled.

All analyses were performed in R (vers. 3.3.1), using package "tree" for the regression trees and "nlme" for the GLMMs.

4 Results

4.1 Management Questions 1 and 2

What trends are apparent in the responses of plant species used for revegetation to the operating regimes to date with respect to timing, frequency, duration and depth of inundation? Do plant species respond differently from one another to variables of the operating regime, including timing, frequency, duration and depth of inundation?

For the four species modeled (*Carex lenticularis*, *C. aperta*, *Scirpus atrocinctus*, and *Populus balsamifera* subsp. *trichocarpa*), a few general trends regarding inundation variables with respect to naturally occurring plants emerged in Arrow Lakes Reservoir (Figure 4-1 to Figure 4-4). Regression trees (Figure 4-1 and Figure 4-2) for the sedge species (*C. lenticularis*, and *C. aperta*) indicate that inundation variables were strongly associated with sedge cover (present in the first or second split); however, results varied between sedge species and were a mixture of one and two-year lags. For *C. lenticularis*, growing degree days in August (at $t-2$), duration of inundation (at $t-1$), and maximum depth of inundation (at $t-1$) were associated with plant cover (Figure 4-1). For *C. aperta*, growing degree days in August (at t - 2) as well as maximum depth (at $t-1$), duration (at $t-1$), and the coefficient of variation (at $t-1$ and at $t-2$) for inundation depth influenced plant cover (Figure 4-2). The regression tree for *S. atrocinctus* included inundation variables from the one year-lag (second split, growing degree days in May; Figure 4-3). *P.b.* ssp. *trichocarpa*, on the other hand, was not associated with any inundation variables in the regression tree (Figure 4-4); however, inundation variables were associated in the GLMM (Figure 4-4). In general, regression trees suggest that inundation variables influenced all modelled plant species except *P.b.* ssp. *trichocarpa*, and that growing degree days, as well as duration, depth (maximum and variation) and timing of inundation were variables of interest. Further, sedges (*C. lenticularis* and *C. aperta*) were impacted by inundation conditions from one and two years prior to sampling, while *S. atrocinctus* was only impacted by inundation conditions from the preceding year.

Results of the GLMMs and Wald tests (see tables in Appendix B) offer more detail regarding the relationship between inundation variables and plant cover in Arrow Lakes Reservoir. The coefficient of variation for inundation depth (at $t-1$ and at $t-2$), as well as timing (at $t-2$) and depth (at $t-1$ and at $t-2$) of inundation were positively associated with *C. lenticularis* cover. Maximum depth of inundation (at $t-1$) was negatively associated with *C. lenticularis* cover. Depth of inundation (at $t-2$) was positively associated with *C. aperta* cover, while maximum depth of inundation (at $t-2$) was negatively associated. Therefore, with regards to sedges in Arrow Lakes Reservoir, greater average depths of inundation were associated with increased plant cover for both *C. lenticularis* and *C. aperta* one and two years post inundation. Increased *C. lenticularis* cover was further associated with more variable inundation depths one and two years post inundation, as well as by inundations that occurred later in the growing season two years previously. Increased maximum inundation depths one and two years previously were associated with decreased cover of *C. lenticularis* and *C. aperta* respectively.

In Arrow Lakes Reservoir, increasing maximum depth (at $t-1$) of inundation was associated with increases in *S. atrocinctus* cover, while increasing depth of inundations (at $t-1$), and longer inundations (at $t-1$) were associated with decreasing *S. atrocinctus* cover (Figure 4-3). Only inundation variables from the previous year ($t-1$) were associated with *S. atrocinctus* cover. Duration (two-year lag) and timing (one-year lag) of inundation were negatively associated with *P.b. ssp. trichocarpa* cover. Therefore, longer inundations, as well as inundations that occurred later in the growing season, were associated with decreased *P.b.* ssp. *trichocarpa* cover.

While growing degree days were associated with all modelled species in Arrow Lakes Reservoir, few clear patterns were obvious in the GLMMs or Wald Tests (Figure 4-1 to Figure ***4-4***; Appendix B). Growing degree days in April (at *t* – 2) were positively associated with *C. lenticularis,* while growing degree days in July (at *t* – 2) were negatively associated. *C. aperta* was negatively associated with growing degree days in July (at *t* – 1), Oct (at *t* – 1), and Aug (at *t* – 2). *S. atrocinctus* was only positively associated with growing degree days from May of the previous year (at *t* – 1), while *P.b.* ssp. *trichocarpa* was only negatively associated with growing degree days (Oct, *t* – 1; April and May, at *t* – 2).

In Kinbasket Reservoir, very different trends were observed when compared to Arrow Lakes Reservoir. Regression trees indicated that the sedge *C. lenticularis* (Figure 4-5) was associated with the coefficient of inundation depth (at *t* – 2), and growing degree days (May and July, *t* – 2). *C. aperta* was only correlated with growing degree days (April, *t* – 1; Figure 4-6), while *S. atrocinctus* was correlated with duration (at *t* – 1), and depth (at *t* – 2) of inundation, as well as growing degree days (April, at *t* – 1, and May, at *t* – 2; Figure 4-7). Finally, *P.b.* ssp. *trichocarpa* was associated with timing of inundation (at *t* – 2), and growing degree days (August, *t* – 1; Figure 4-8).

As for Arrow Lakes, results of the GLMMs and Wald tests (Figure 4-5 to Figure ***4-8***; Appendix B) offer additional insight into the inundation variables that influenced plant cover in Kinbasket Reservoir. The sedge *C. lenticularis* in Kinbasket Reservoir was negatively associated with maximum inundation depth (at *t* – 1), and positively associated with average depth of inundation (at *t* – 1). As such, inundation events with a greater maximum depth were associated with lower *C. lenticularis* cover in the following year. *C. aperta*, the other modelled sedge species, was negatively associated with the coefficient of variation (at *t* – 1 and at *t* – 2), timing (at *t* – 1 and at *t* – 2), and the maximum depth of inundation (at *t* – 1), and was positively associated with duration of inundation (at *t* – 2). Therefore, *C. aperta* cover appeared to increase two years after a longer inundation event; however, decreasing *C. aperta* cover was associated with increasing maximum inundation depths (at *t* – 1), and variation of inundation depth and timing (one and two year lags). GLMMs did not identify any inundation variables that were associated with *S. atrocinctus*; however, the Wald test (Table 7) identified a negative association with duration of inundation (at *t* – 1 and at *t* – 1), suggesting that longer periods of inundation decreased *S. atrocinctus* cover. Finally, *P.b. ssp. trichocarpa* was positively associated with timing of inundation (two-year lag), suggesting that in Kinbasket Reservoir, later inundations increased *P.b. ssp. trichocarpa* cover two years post inundation.

As in Arrow Lakes Reservoir, the relationship between plant cover and growing degree days in Kinbasket Reservoir exhibited few general trends. *C. lenticularis* was negatively (Aug, *t* – 1, and May, at *t* – 2) and positively (April, *t* – 1, and June, *t* – 2) associated with growing degree days. *S. atrocinctus* was also positively (April, at *t* – 1), and negatively (June, at *t* – 2) associated with growing degree days. *C. aperta* was only positively (Aug, and July, at *t* – 2) associated with growing degree days, while no association was observed between *P.b. ssp. trichocarpa* and growing degree days in the GLMM. However, the Wald test identified both positive (May and Sept, *t* – 2) and negative associations (April and June, *t* – 2).

When examined together, regression trees, GLMMs, and Wald tests suggest that all modelled species in Arrow Lakes and Kinbasket Reservoirs were associated with inundation variables; however, the nature of these relationships varied greatly between reservoir and species. In both reservoirs, sedge cover was positively and negatively influenced by inundation variables from one and two years previously, but the nature of the relationships varied between species and reservoir. Conversely, *S. atrocinctus* in Arrow Lakes Reservoir was only associated with inundations variables from the previous year, while in Kinbasket Reservoir it was associated with inundation variables from one and two years previous. Finally, *P.b. ssp. trichocarpa* was associated with inundation variables from one and two years previous, but these associations were predominantly negative in Arrow Lakes Reservoir, and positive in Kinbasket Reservoir.

The above findings are summarized below (Table 4-1). All variables listed were associated with the observed cover of that species, while +/- indicates if the GLMM and Wald tests revealed a positive or negative relationship with plant cover. Positive and negative relationships suggest that these variables were associated with increasing and decreasing plant cover respectively. Variables without a +/- were identified as of interest in the regression trees, but not in the GLMM or Wald test.

Table 4-1. Relationships between naturally occurring vegetation species and the effect of inundation variables on the percent cover of those species in Arrow Lakes and Kinbasket Reservoir. Variables without a +/- were identified as of interest in the regression trees, but not in the GLMM or Wald test

Arrow Lakes Reservoir

Carex lenticularis var. *lipocarpa*

- August growing degree days (two-year lag)
- April growing degree days (two-year lag); **"+"**
- July growing degree days (two-year lag); **"- "**
- Duration of inundation (one-year lag); **"- "**
- Maximum depth of inundation (one-year lag); **"- "**
- Inundation depth coefficient of variation (one and two-year lags); **"+"**
- Inundation timing (two-year lag); "**+"**
- Inundation depth (one and two-year lags); **"+"**

Carex aperta

- July growing degree days (one-year lag)
- August growing degree days (two-year lag); **"- "**
- October growing degree days (one-year lag); **"- "**
- Duration of inundation (one-year lag)
- Maximum depth of inundation (one-year lag)
- Inundation depth coefficient of variation (one and two-year lags)
- Maximum depth of inundation (two-year lag); **"- "**
- Inundation depth (two-year lag); **"+"**

Scirpus atrocinctus

- May growing degree days (one-year lag); **"+"**
- Inundation depth (one-year lag); **"- "**
- Duration of inundation (one-year lag); **"- "**
- Maximum depth of inundation (one-year lag); **"+"**

Populus balsamifera ssp. *trichocarpa*

- October growing degree days (one-year lag); **"- "**
- April growing degree days (two-year lag); **"- "**
- May growing degree days (two-year lag); **"- "**
- Duration of inundation (two-year lag); **"- "**
- Inundation timing (one-year lag); **"- "**

Kinbasket Reservoir

Carex lenticularis var. *lipocarpa*

- July growing degree days (two-year lag)
- August growing degree days (one-year lag) **"- "**
- May growing degree days (two-year lag); **"- "**
- April growing degree days (one-year lag); **"+"**
- June growing degree days (two-year lag); **"+"**
- Inundation depth coefficient of variation (two-year lag)
- Maximum depth of inundation (one-year lag); **"- "**
- Average depth of inundation (one-year lag); **"+"**

Carex aperta

- April growing degree days (one-year lag)
- July growing degree days (two-year lag); **"+"**
- August growing degree days (two-year lag); **"+"**
- Inundation depth coefficient of variation (one and two-year lags); **"- "**
- Inundation timing (one and two-year lags); **"- "**
- Maximum depth of inundation (one-year lag); **"- "**
- Duration of inundation (two-year lag); **"+ "**

Scirpus atrocinctus

- May growing degree days (two-year lag)
- April growing degree days (one-year lag); **"+"**
- June growing degree days (two-year lag); "- "
- Inundation depth (two-year lag)
- Duration of inundation (one-year lag); **"- "**

Populus balsamifera ssp. *trichocarpa*

- August growing degree days (two-year lag)
- May growing degree days (two-year lag); **"+"**
- September growing degree days (two-year lag); **"+"**
- April growing degree days (two-year lag); **"- "**
- June growing degree days (two-year lag); **"- "**
- Inundation timing (two-year lag); **"+"**

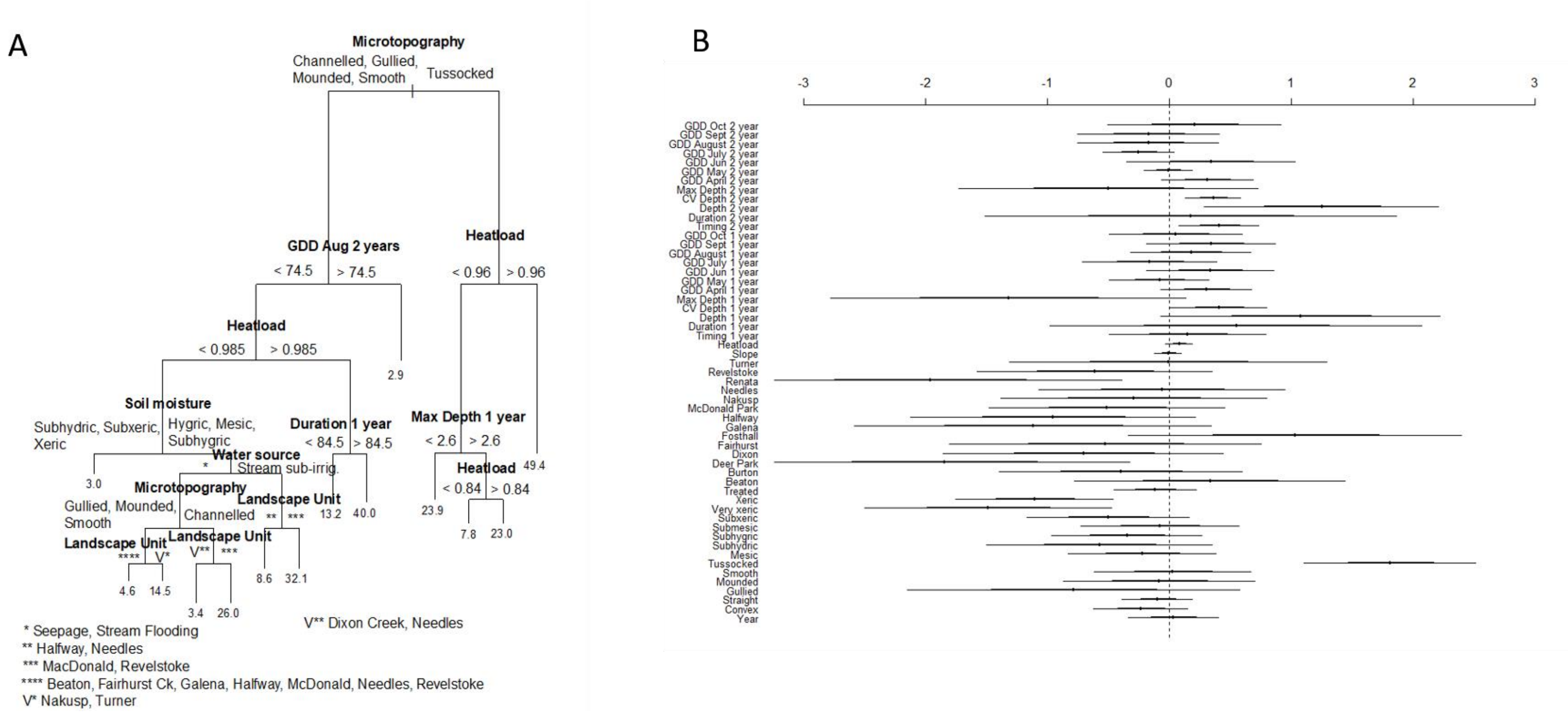

Figure 4-1. **Regression tree (A) and coefficient plot (B) showing the variables associated with cover of *Carex lenticularis* over time in Arrow Lakes Reservoir.** Numbers at each leaf in (A) indicate the predicted cover based on the split. R^2 was 0.56 (total n=2083). In (B), the value of the standardized regression coefficient ± 2 SE for each fixed effect included in the GLMM (generalized linear mixed effects model), along with the 95 per cent confidence interval for fixed effects (n=1855) is shown. Inundation variables were modeled with a one and two-year lag.

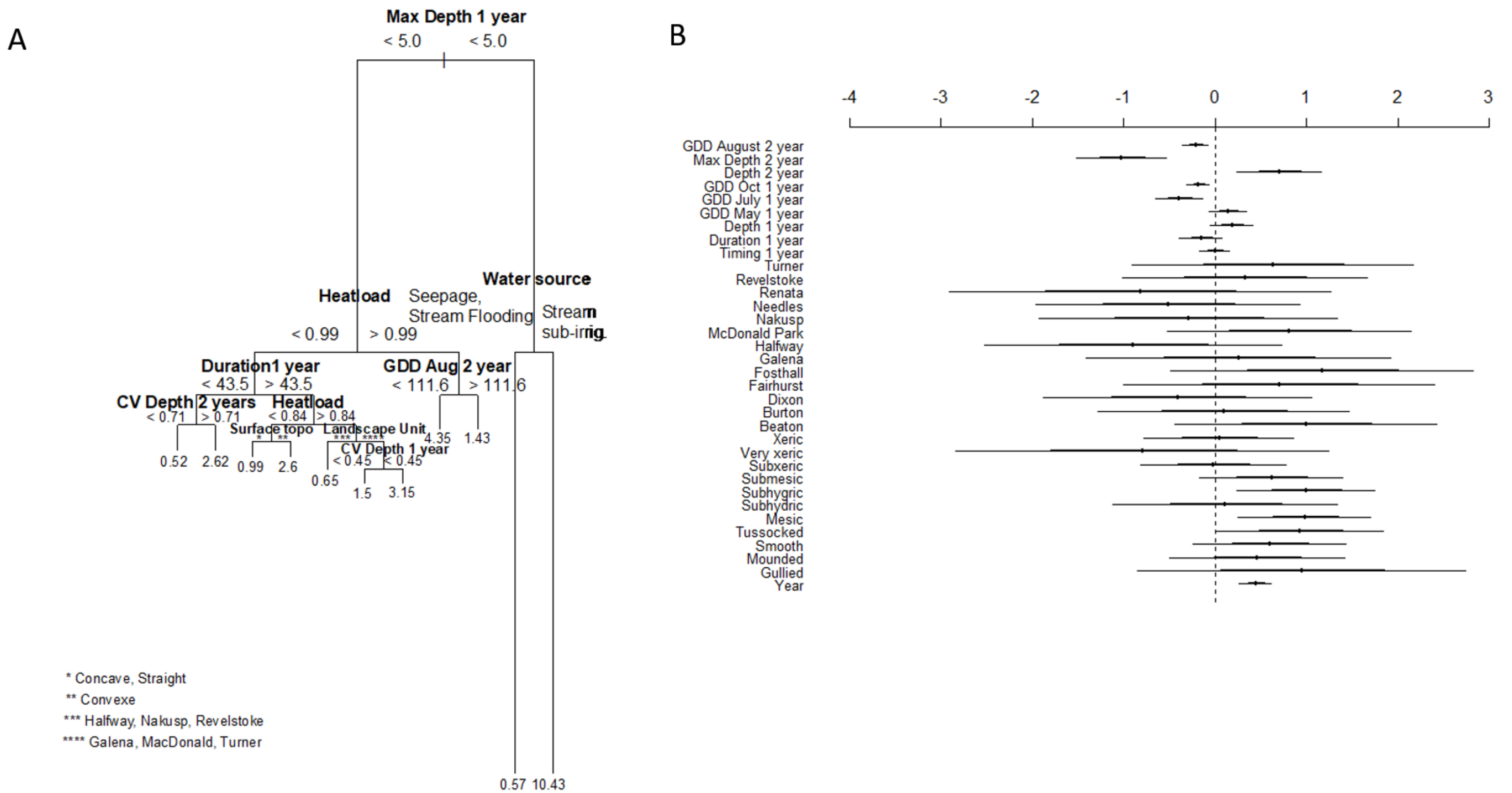

Figure 4-2. **Regression tree (A) and coefficient plot (B) showing the variables associated with cover of *Carex aperta* over time in Arrow Lakes Reservoir.** Numbers at each leaf in (A) indicate the predicted cover based on the split. R^2 was 0.67 (total n=1402). In (B), the value of the standardized regression coefficient ± 2 SE for each fixed effect included in the GLMM (generalized linear mixed effects model), along with the 95 per cent confidence interval for fixed effects (n=1267) is shown. Inundation variables were modeled with a one and two-year lag.

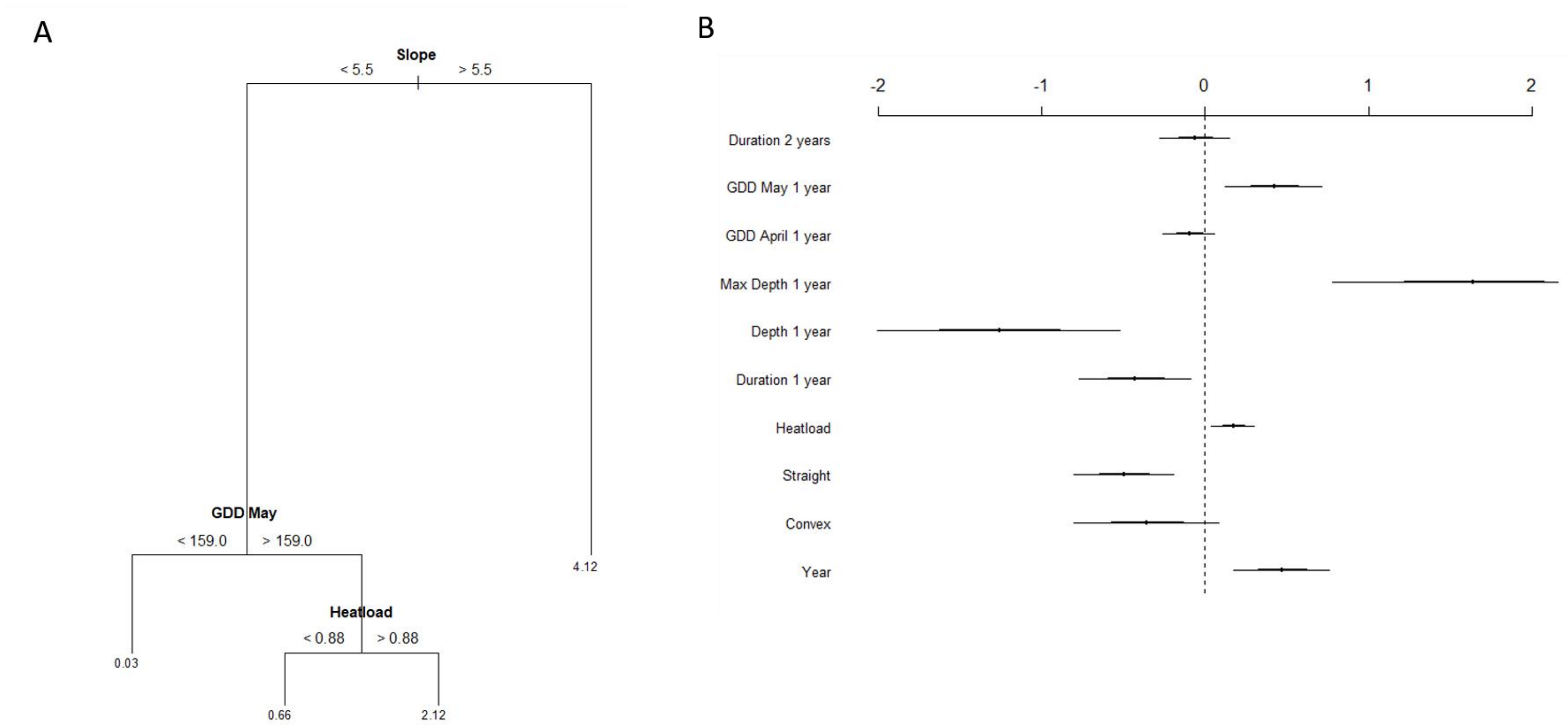

Figure 4-3. **Regression tree (A) and coefficient plot (B) showing the variables associated with cover of *Scirpus atrocinctus* over time in Arrow Lakes Reservoir.** Numbers at each leaf in (A) indicate the predicted cover based on the split. R^2 was 0.21 (total n=217). In (B), the value of the standardized regression coefficient ± 2 SE for each fixed effect included in the GLMM (generalized linear mixed effects model), along with the 95 per cent confidence interval for fixed effects (n=213) is shown. Inundation variables were modeled with a one and two-year lag.

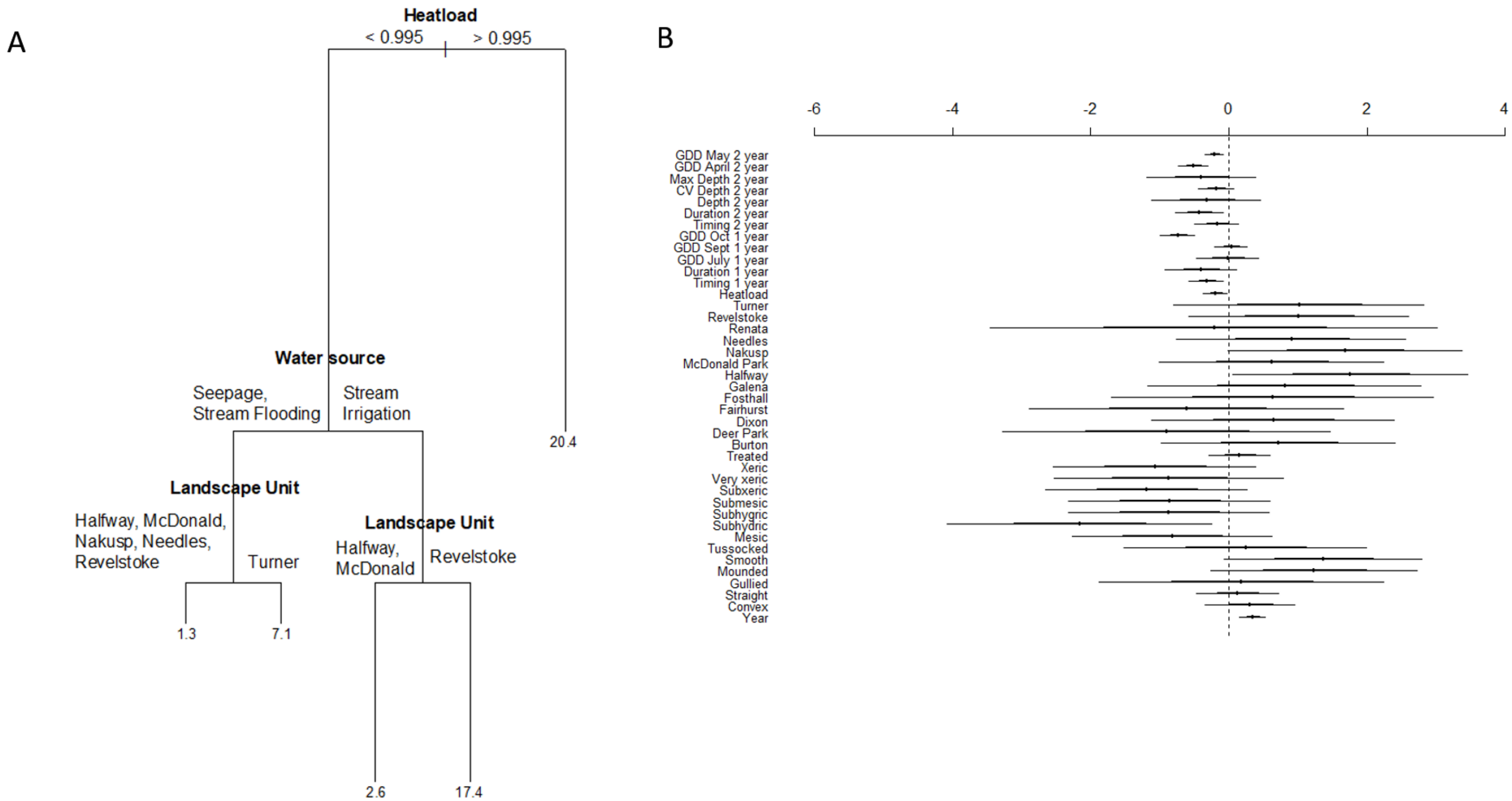

Figure 4-4. **Regression tree (A) and coefficient plot (B) showing the variables associated with cover of *Populus balsamifera* subsp. *trichocarpa* over time in Arrow Lakes Reservoir.** Numbers at each leaf in (A) indicate the predicted cover based on the split. R^2 was 0.45 (total n=1026). In (B), the value of the standardized regression coefficient ± 2 SE for each fixed effect included in the GLMM (generalized linear mixed effects model), along with the 95 per cent confidence interval for fixed effects (n=902) is shown. Inundation variables were modeled with a one and two-year lag.

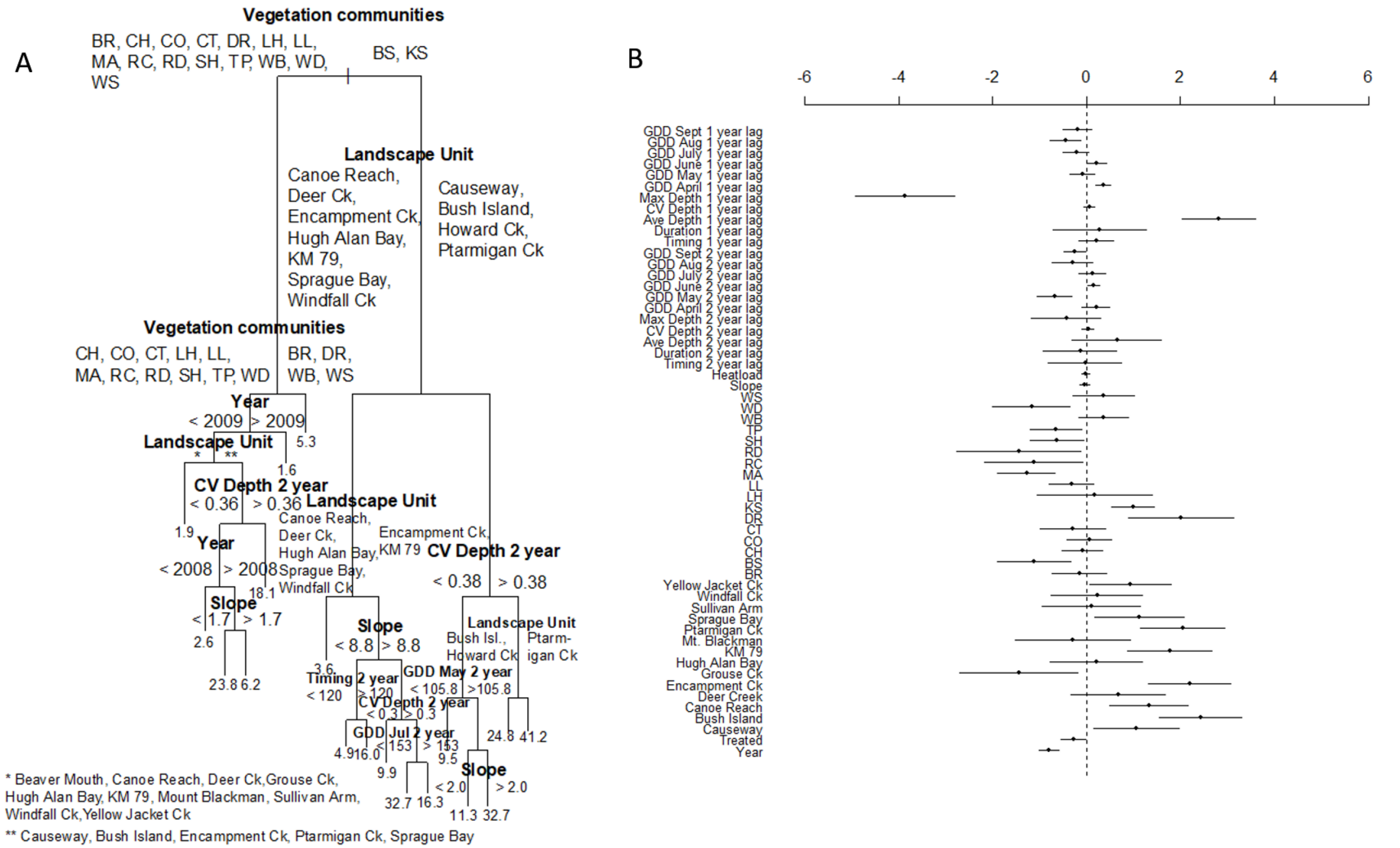

Figure 4-5. **Regression tree (A) and coefficient plot (B) showing the variables associated with cover of *Carex lenticularis* over time in the drawdown zone of Kinbasket Reservoir.** Numbers at each leaf in (A) indicate the predicted cover based on the split. R^2 was 0.48 (total n=777). In (B), the value of the standardized regression coefficient ± 2 SE for each fixed effect included in the GLMM (generalized linear mixed effects model), along with the 95 per cent confidence interval for fixed effects (n=768) is shown. Inundation variables were modeled with a one and two-year lag.

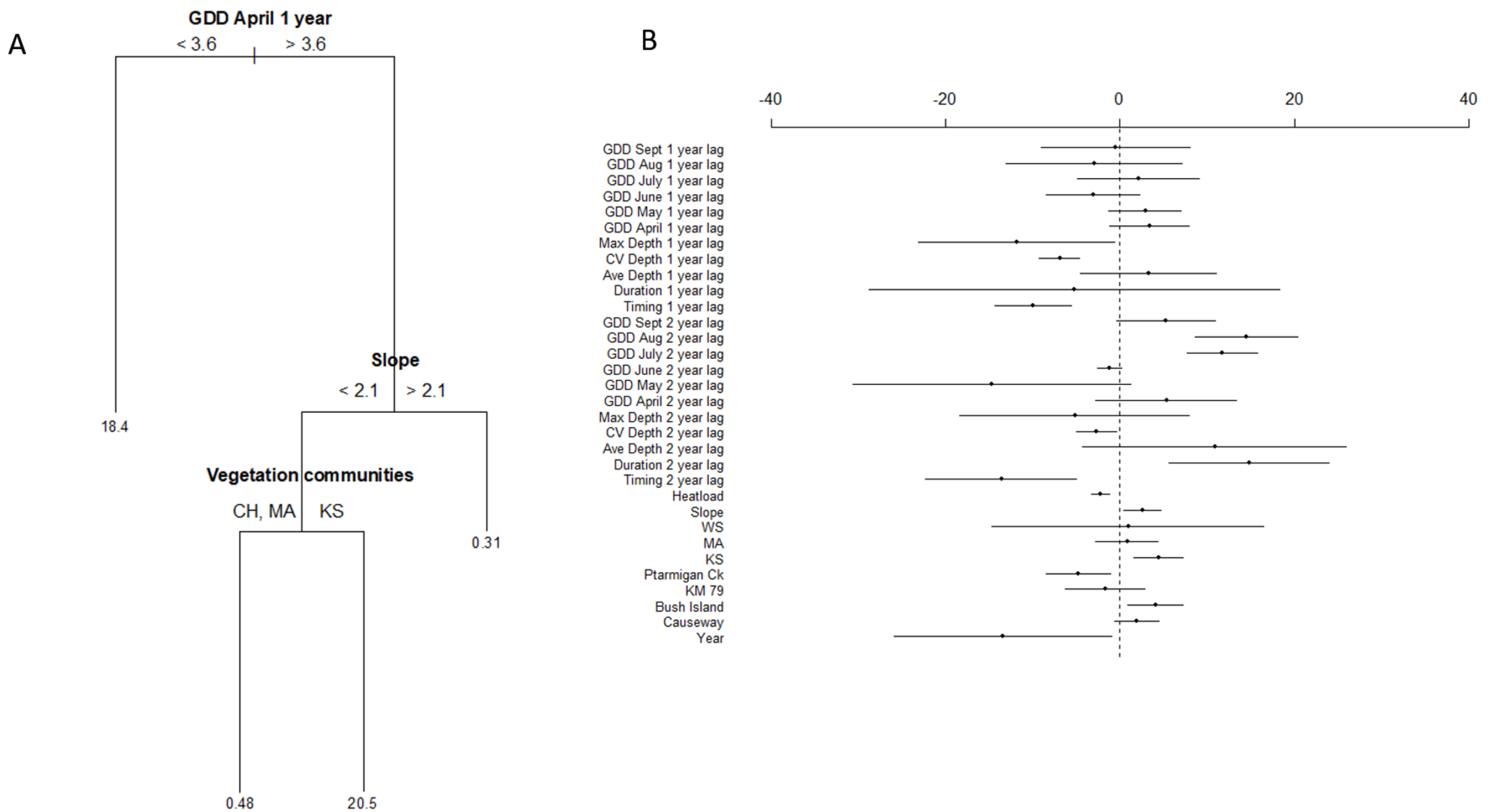

Figure 4-6. **Regression tree (A) and coefficient plot (B) showing the variables associated with cover of *Carex aperta* over time in the drawdown zone of Kinbasket Reservoir.** Numbers at each leaf in (A) indicate the predicted cover based on the split. R^2 was 0.45 (total n=53). In (B), the value of the standardized regression coefficient ± 2 SE for each fixed effect included in the GLMM (generalized linear mixed effects model), along with the 95 per cent confidence interval for fixed effects (n=48) is shown. Inundation variables were modeled with a one and two-year lag.

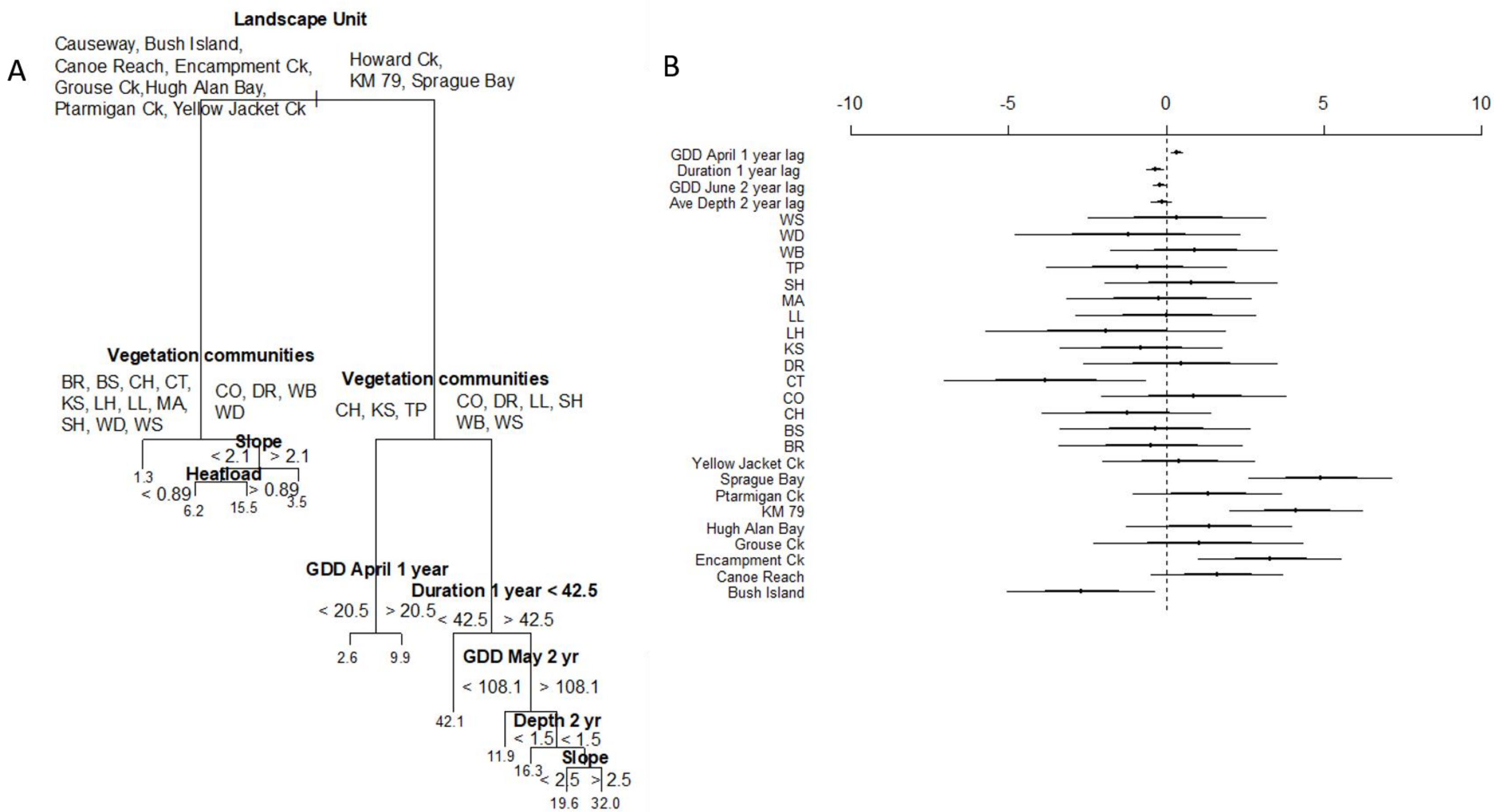

Figure 4-7. **Regression tree (A) and coefficient plot (B) showing the variables associated with cover of *Scirpus atrocinctus* over time in the drawdown zone of Kinbasket Reservoir.** Numbers at each leaf in (A) indicate the predicted cover based on the split. R^2 was 0.70 (total n=325). In (B), the value of the standardized regression coefficient ± 2 SE for each fixed effect included in the GLMM (generalized linear mixed effects model), along with the 95 per cent confidence interval for fixed effects (n=322) is shown. Inundation variables were modeled with a one and two-year lag.

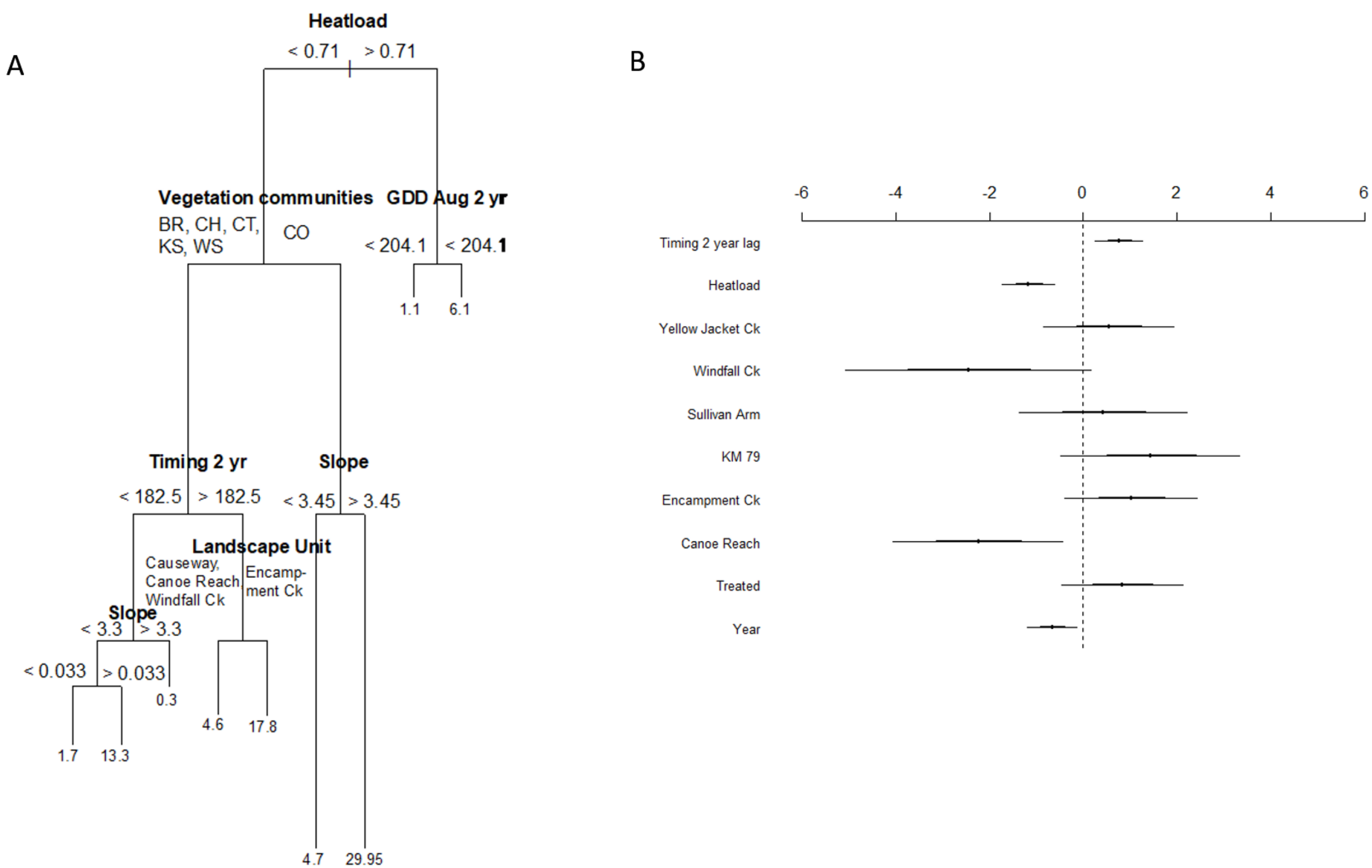

Figure 4-8. **Regression tree (A) and coefficient plot (B) showing the variables associated with cover of *Populus balsamifera* subsp. *trichocarpa* over time in the drawdown zone of Kinbasket Reservoir.** Numbers at each leaf in (A) indicate the predicted cover based on the split. R^2 was 0.52 (total n=116). In (B), the value of the standardized regression coefficient ± 2 SE for each fixed effect included in the GLMM (generalized linear mixed effects model), along with the 95 per cent confidence interval for fixed effects (n=98) is shown. Inundation variables were modeled with a one and two-year lag.

4.2 Management Questions 3

How do the responses of plant species to the operating regime interact with other biotic and abiotic factors (e.g. substrate, climate, reservoir filters, and presence of other plant species)?

In Arrow Lakes Reservoir, environmental variables were associated with the observed cover of all four plant species (Figure 4-1 to Figure ***4-8***; Appendix B). Factors such as heat load, water source, surface topography, microtopography, slope, soil moisture, and landscape unit were associated with plant cover. Environmental factors strongly influenced the importance of inundation variables. As shown in the regression tree (Figure 4-1), microtopography, and to lesser extents heat load and soil moisture, influenced the relationship between *C. lenticularis* cover and inundation variables. *S. atrocinctus*'s relationship with inundation variables was also strongly influenced by environmental factors (slope; Figure 4-3). The influence of environmental variables was present but to a lesser degree in *C. aperta*, as an inundation variable (maximum inundation depth) was the first split in the regression tree (Figure 4-2). Nevertheless, heat load and landscape unit influenced the association of inundation variables with *C. aperta* cover. Finally, as no inundation variables were identified in the regression tree for *P.b. spp. trichocarpa* (Figure 4-4), we are not able to determine if environmental variables influenced the relationship between this plant and inundation variables using the regression tree. However, the GLMM and Wald test identified associations between environmental factors and *P.b. ssp. trichocarpa* cover, implying that variables such as microtopography, soil moisture, landscape unit, and heat load (Figure 4-4, Appendix B) could influence the importance of inundation variables on *P.b. ssp. trichocarpa* cover.

Similar results were obtained for Kinbasket Reservoir. As shown by the regression trees (Figure 4-5), vegetation community, landscape unit, year, and slope influenced the relationship between *C. lenticularis* cover and inundation variables. Conversely, the first split in the regression tree for *C. aperta* (Figure 4-6) was an inundation variable (growing degree days), and environmental variables did not influence the relationship between inundation and *C. aperta*. The relationships between *S. atrocinctus* cover and inundations variables was influenced by landscape unit and vegetative community (Figure 4-7). Finally, *P.b. ssp. trichocarpa*'s response to inundation variables was influenced by heat load and vegetative community (Figure 4-8).

4.3 Management Question 4

Management Question 4: What recommendations may be made to more effectively maintain existing vegetation, help persisting species, and establish new plant communities at different spatial scales (i.e., community versus species scale) in the future?

For the response to management question 4, see the Discussion and Recommendations.

5 Discussion

The association between inundation regime and plant communities in the drawdown zone was examined in Arrow Lakes and Kinbasket Reservoirs. Using regression trees, GLMMs, and Wald tests, we observed that inundation variables were associated with all modelled species; however, the nature of the association (positive or negative) varied with species, variable, environmental conditions, and reservoir. Further, one and two-year lags were observed, suggesting that inundation events have delayed impacts on vegetation.

The association between plant performance and inundation variables was not a surprise; previous studies have also observed that duration, depth, timing, and frequency of flooding have substantial impacts upon individual plant species and community composition (Blom 1999; Garssen et al. 2015). Similarly, the impact of reservoir operations upon plant communities has also been observed to vary by soil conditions, habitat type and typography, at both broad and fine spatial scales (Blom 1999; Johnson 2002; Rains et al. 2004; Abrahams 2006). Furthermore, previous studies have also observed that grasslands, sedges, and meadows change rapidly in response to reservoir operations (Rains et al. 2004), supporting our observations of plant community changes one to two years post-inundation in Arrow Lakes and Kinbasket Reservoirs. While we only examined the effect of a two-year lag on each species, the impact of inundation events can often still be identified after several decades, especially in the case of woody species (Hill et al. 1998; Rains et al. 2004). Not only do fluctuating water levels associated with reservoir operations impact plants directly (drowning and desiccation), but reservoir operations also alter stream/lake hydrology and disturbance dynamics (Stevens and Waring 1985; Hill et al. 1998; Johnson 2002; Rains et al. 2004; Abrahams 2006). As such, reservoir operations may change the physical characteristics of freshwater systems such that plant succession is truncated, and early successional plant communities not only persist in the area, but these communities may also be divergent from natural early successional communities as well (Rains et al. 2004). Even if hydrology reverts to pre-disturbance conditions, these divergent communities can continue to persist well into the future (Rains et al. 2004).

With regard to revegetation treatments, neither GLMMs nor Wald tests identified a statistically significant relationship between treatment and any plant species. The lack of association between plant cover and revegetation treatment is likely a product of low survival of planted plants (Hawkes et al. 2013). Due to a lack of experimental replication in treatments, it is not possible to directly link low survival to inundation regimes; however, a relationship seems likely given the known impact of reservoir operation upon plant survival (Blom 1999; Rains et al. 2004; Garssen et al. 2015). Therefore, inundation that occurs before planted seedlings have established or during the growing season, or that exceeds the height of the plant (see below), will likely have strong negative impacts upon the success of revegetation treatments.

One of the main goals of this work was to answer the following management question (management question four): what recommendations may be made to more effectively maintain existing vegetation, help persisting species, and establish new plant communities at different spatial scales in the future? To answer this question several factors must be considered. As discussed above, the impact of inundation varies by soil conditions, habitat type and topography (Blom 1999; Johnson 2002; Rains et al. 2004; Abrahams 2006), variables that vary over small spatial scales. While microhabitats will vary over a small spatial scale, reservoir operation occurs at a broad spatial scale. Therefore, it may be impossible to manage reservoir operations in a way that sustains plant life in all microhabitats, and active restoration (e.g., physical works) may be required to create functioning habitat in some circumstances (Rains et al. 2004).

Further, the nature of the desired plant community (early or late successional stage) must also be explicitly considered (Abrahams 2006; Miller et al. 2016). Plant species vary as to when they are most susceptible to flooding and desiccation, and timing of inundation can therefore greatly impact the plant community that develops (Hill et al. 1998; Johnson 2002; Rains et al. 2004; Abrahams 2006). The present composition of drawdown zone vegetation is the cumulative outcome of the hydroperiod experienced over the last five decades, dating from the impoundment of the Columbia River by the Mica and Hugh Keenleyside Dams in 1973 and 1968, respectively. This decadal regime has resulted in communities whose species composition, a substantial proportion of which is non-native, is maintained in a persistent seral state by a frequent but variable disturbance regime. Most of the plant species that thrive in the drawdown zone environment of the two reservoirs are adapted to, and may even depend on, a certain amount of seasonal flooding as part of their annual moisture requirements. Thus, is no *a priori* reason to suspect that targeting consistently lower reservoir levels is an effective strategy for maintaining the existing vegetation status quo. For example, successive years of below-average reservoir levels could eventually lead to a more shrub-dominated system supporting lower overall covers of herbaceous groups such as forbs and sedges (Miller et al. 2017).

In light of these considerations, based upon our work and upon the recommendations of previous studies, we suggest the following changes in reservoir operations be implemented to ensure long-term vegetation persistence. First, and whenever possible, reservoir operations should be conducted in a way that produces hydrological conditions that match the natural hydrology (timing, duration, frequency, and depth of inundation events) of the natural (i.e., non-impounded) system (Stevens and Waring 1985; Hill et al. 1998; Johnson 2002; Rains et al. 2004; Abrahams 2006; Miller et al. 2016). In general, delaying flooding until after senescence of plants (outside of the growing season), varying time of flooding and drawdown among years, keeping the plant community completely dry some years, fluctuating water levels while flooded, never scheduling the same depth or duration of flooding in consecutive years, and avoiding permanent inundation can minimize negative impacts upon plant communities (Abrahams 2006; Miller et al. 2017). Allowing the plant community the time needed to establish and transition towards later successional stages before inundating the area again will assist in vegetative recovery and persistence (Hill et al. 1998; Johnson 2002; Rains et al. 2004; Abrahams 2006). If the above conditions cannot be met, Garrssen et al. (2015) suggested that inundation depths that do not exceed the height of plants in the inundation zone may decrease the negative impact of flooding upon plant communities. This may hold especially for recently revegetated habitats.

If the objective is to enhance existing vegetation types, rather than simply maintain the current status quo, the findings from this and other studies (e.g., CLBMON-33) provide a useful operational roadmap for effecting desired changes within the soft constraints framework. For example, models suggest that both cover and structural diversity at all elevations can be maximized in the following way: (i) by delaying inundation in the spring (preferably until June or later) to allow time for germination, establishment, and the completion of reproductive cycles; (ii) by increasing the depth and duration of July inundation at low and mid elevations, to reduce summer drought stress; and (iii) by minimizing (but not eliminating) the depth and duration of inundation at high elevations, to maintain herbaceous cover while facilitating woody shrub establishment and growth (Miller et al. 2017).

6 Recommendations

In lieu of wholesale changes to the management of Arrow Lakes and Kinbasket Reservoirs, the following recommendations are made regarding existing vegetation and revegetation efforts in the drawdown zones of Kinbasket and Arrow Lakes Reservoir:

Existing Vegetation

1. Define the desired plant communities relative to elevation for the drawdown zone of Kinbasket and Arrow Lakes Reservoirs. Lower elevations in both Arrow Lakes and Kinbasket Reservoir are likely to be inundated earlier and longer than those closer to the normal operating maxima. As such, vegetation targets for lower elevations should differ from those at higher elevations. Previous work has shown that species richness increases with elevation in both Kinbasket and Arrow Lakes Reservoir. These finding support defining vegetation targets by elevation. In each reservoir, pioneering communities dominate the drawdown zone at lower elevations with species richness and cover increasing with elevation. The upper two to three metres of the drawdown zone in each reservoir could be targeted for vegetation communities defined by high species richness, high cover, and a greater percentage of woody stemmed species. The species occurring in each reservoir, and within reaches of each reservoir, should be dictated by the local flora at those sites.
2. To facilitate defining desired plant communities in the drawdown zone, a decision tree could be developed to help identify the type of community defined for a given reservoir, reach, and elevation in the drawdown zone. The decision tree could incorporate knowledge of existing vegetation in each reservoir by elevation (e.g., the results of CLMBON-10 and -33), the reported success of previous revegetation trials (see the Kinbasket and Arrow Lakes Reservoirs Revegetation Prescription Catalogues that accompany this report), and any of the biotic and abiotic variables known to influence the cover of specific species of plants. The decision tree could also guide future revegetation efforts in each reservoir by providing the means to quickly identify the kind of community that would be appropriate to attempt to establish at a given location.
3. Define hard constraints for the management of Kinbasket and Arrow Lakes Reservoirs that are designed to promote the establishment and development of existing vegetation in the drawdown zone. This aligns with the published literature that supports affording vegetation the time to establish, grow, and transition towards later succession stages. In addition to increasing vegetation cover in the drawdown zone, wildlife habitat suitability will increase. The hard constraints developed for vegetation could be modelled off of the soft constraints for Arrow Lakes Reservoir to ensure that future reservoir management doesn't unduly affect wildlife, such as ground-nesting birds, in favour of vegetation growth.
4. Continue to assess the effectiveness of wood debris removal and mounding as a way to increase the cover of existing vegetation in the drawdown zone, particularly in Kinbasket Reservoir (as per Hawkes 2016, 2017). Because wood tends to settle higher in the drawdown zone, removal of wood will benefit the upper two to three metres of the drawdown zone, helping achieve targets identified above.

Revegetation

1. Local site conditions should be considered when developing a revegetation plan for a given reservoir. This should include an assessment of the current distribution of vegetation (by elevation) and an assessment of the local flora, which can guide the selection of plant species to use in a revegetation program. The revegetation plan should be developed after visiting the site to determine the best prescription to implement at the site.

2. When planting in the drawdown zone of a hydroelectric reservoir, do not use upland species. Doing so will reduce the probability of success as these species are likely to be less tolerant of wet and dry stress. Use the local flora in the drawdown zone as a cue for the species that more likely to survive in the drawdown zone.
3. In some instances, it might not be possible to revegetate parts of the drawdown zone because of the slope, aspect, exposure, existing soil, or some other abiotic factor that precludes vegetation growth. In these cases effort should be spent elsewhere. Having a decision tree (or similar tool) will be helpful in this regard.
4. In some cases, augmenting existing vegetation with nursery-grown or locally sourced (collected) stock may be desirable, particularly if doing so will increase the total cover of vegetation.
5. Revegetation efforts may require multiple entries/planting sessions before vegetation establishes on the site. A determination of the number of times a site might need to be treated should form part of the revegetation prescription, which can provide guidance on whether to plant the site.
6. The four species modelled (*Carex lenticularis* var. *lipocarpa, C. aperta, Scirpus atrocinctus*, and *Populus balsamifera ssp. Trichocarpa*) represent the most commonly used species in both CLBWORKS-1 and 2. Many more plant species could be investigated for revegetation potential aside from the ones already trialed. The existing flora of the KIN and ALR drawdown zones provides more than 200 well-adapted species to draw from. Among these, emphasis should be on (preferably native) species that (1) provide clear discernable benefits in terms of ground cover, dust control, slope stabilization, and/or wildlife habitat structure, and (2) have demonstrated "staying power," either via a persistent root system (perennials) or a persistent seed bank (annuals). Also of interest are species that are either adapted to a wide variety of conditions (i.e., are relatively ubiquitous) or are habitat specialist that are known to do particularly well in a specific habitat type, such as dry and sandy soil, debris mounds, mudflats, or recovering wetlands. One such species, swamp horsetail (*Equisetum fluviatile*), is tolerant of extreme variations in water depth and high rates of sedimentation and can colonize exposed mineral soils. It has been used to revegetate the extreme environment of the drawdown zones of reservoirs, but has not been explored as a potential option for the revegetation programs in CLBWORKS-1 or -2. The following is a partial list of plant species that would appear, based on field observations, to meet one or more of these criteria:

   Mountain alder (*Alnus incana*), Pacific willow (*Salix lucida*), short-fruited willow (*S. brachycarpa*), bluejoint reedgrass (*Calamgrostis canadensis*), tufted hairgrass (*Deschampsia cespitosa*), annual hairgrass (*D. danthoniodes*), moss grass (*Coleanthus subtilis*), fowl bluegrass (*Poa palustris*), little meadow-foxtail (*Alopecuris aequalis*), beaked sedge (*Carex utriculata*), slender sedge (*C. lasiocarpa*), common horsetail (*Equisetum arvensis*), swamp horsetail (*E. fluviatile*), marsh yellow cress (*Rorippa palustris*), dagger-leaf rush (*Juncus ensifolius*), thread rush (*Juncus filiformis*), buckbean (*Menyanthes triofoliata*), marsh cinquefoil (*Comarum palustre*), small spike-rush (*Eleocharis parvula*), Norwegian cinquefoil (*Potentilla norvegica*), Scouler's popcornflower (*Plagiobothrys scouleri*), and fireweed (*Epilobium angustifolium*).

7. In addition to considering which species to include in a more in-depth analysis, other aspects of the revegetation programs should be considered. For example, the propagation of plants requires further investigation in terms of seed collection and sourcing, the size of plugs or live stakes to use, or whether rooted live stakes are used (rather than cuttings). The size and/or age of sedge plugs used in a revegetation program may influence success. In 2013, LGL Limited planted ~68,000 sedge plugs at Bear Island (*C. lenticualris and C. aperta*) in the drawdown zone of Kinbasket Reservoir.

The size of the sedge plugs was similar to that of plugs used previously (i.e., between 2008 and 2011 for CLBWORKS-1), but they were one year older and had (presumably) larger and better established roots. This treatment continues to thrive while others that were treated with younger plugs between 2008 and 2011 have died. The planting of live stakes may also require further experimentation with the depth of planting, which is an important consideration along with the timing of planting. A recent small-scale trial in Kinbasket Reservoir revealed that live stakes planted in the fall had much higher survival rates than those planted in the spring. Further assessments of the conditions that foster the natural establishment of plants in the drawdown zone would also be informative.

Filling Data Gaps

1. It is evident that certain types of data need to be collected or derived for each reservoir to improve our ability to assess the species-specific responses of plants to inundation. In Kinbasket Reservoir, a more fulsome assessment of surface topography, micro-topography, soil moisture, substrate type and size), and water source is required. These data should be collected prior to the next update for CLBMON-35 (planned for 2019) so the results for Kinbasket Reservoir can be updated.
2. Erosion and sediment deposition will affect vegetation in the drawdown zones of both reservoirs. As such, metrics describing erosion and sediment deposition are required. These are likely to be categorical, and could potentially be derived from the existing time series of aerial photographs.
3. Data regarding the potential influence of wood debris on the occurrence and distribution of existing vegetation and effects on revegetation treatments is not widely available and should be derived for both Kinbasket and Arrow Lakes Reservoirs. Wood debris will have a greater impact on vegetation in Kinbasket Reservoir.
4. The non-replicated design of the planting program, combined with annually variable reservoir operations, limits our ability to test assumptions around factors affecting revegetation success. We thus recommend that future revegetation treatments be experimentally replicated in space and time. This will assist in identifying the most successful combinations of methods and site conditions, while allowing future physical works prescriptions to evolve within an adaptive management framework.

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8 Appendices

Appendix A. Justification for species selected for statistical modelling.

Based on our experience with the revegetation programs in Kinbasket and Arrow Lakes Reservoirs, and on our expertise in vegetation ecology and studies of effects on vegetation communities in the drawdown zones of large hydroelectric reservoirs, the following plant species are considered to be appropriate candidates for more in-depth analyses: Kellogg's sedge (*Carex lenticularis* var. *lipocarpa*), Columbia sedge (*C. aperta*), wool-grass (*Scirpus atrocinctus*), and black cottonwood (*Populus balsamifera* ssp. *trichocarpa*). Other species planted in the drawdown zone of Kinbasket Reservoir (e.g., water sedge [*C. aquatilis*] and small-fruited bulrush [*Scirpus microcarpus*]) have been used in revegetation trials, but for reasons pointed out in Fenneman and Hawkes (2012), they are not considered to be ideal candidates (relative to Kellogg's sedge, Columbia sedge, wool-grass, and black cottonwood). Willow (*Salix*) species have also been planted (via live staking), but results to date suggest that they may not be ideal candidates for revegetation. However, if they are planted under the right combination of conditions (e.g., elevation, exposure, and moisture), they will likely flourish; therefore, site selection will be important for *Salix* spp.

Fenneman and Hawkes (2012) summarized the physiological and ecological characteristics of the most commonly planted species in Kinbasket Reservoir and Arrow Lakes Reservoirs.

Kellogg's sedge occurs in areas where water levels fluctuate, such as lakeshores, riverside pools, and the margins of reservoirs (Wilson et al. 2008). This species has medium anaerobic capacity and low drought tolerance, and is adapted to medium- and coarse-textured soils but not finer substrates (USDA-NRCS 2011). It is a common, naturally occurring species in the drawdown zone of Kinbasket Reservoir, and its capacity to tolerate fluctuating water levels made it a logical choice for revegetation. Kellogg's sedge is known to establish on disturbed sites (Wilson et al. 2008), which lends further credence to its use for revegetation. Furthermore, once established, this species has the potential to form a dominant cover if the tussocks are densely packed enough to exclude competition and the substrate remains appropriately saturated (Wilson et al. 2008). Field observations of revegetated areas have indicated that the success of individual plantings in the reservoir is highly variable: some are highly successful in establishing from seedling plugs, while others fail completely. This is likely related to the hydrology and substrate at each site because these factors are integral to the success of revegetation.

Kellogg's sedge is said to have a low seed spread rate, low seedling vigour, and slow vegetative spread (USDA-NRCS 2011). A contrasting account claims this species has the ability to produce a large number of seeds that readily sprout on exposed soils along receding water lines (Wilson et al. 2008). This latter reference agrees with field observations around Kinbasket Lake, where seedlings of this species are common on areas of bare substrate that are exposed as the reservoir's water level drops. The fate of these seedlings is not known, but presumably prolonged periods of inundation or sediment deposition results in extremely low survivorship.

Kellogg's sedge has been less intensively studied than Water sedge, but it likely shares many adaptations and physiological responses. It should be noted, however, that Kellogg's sedge is considered to be a facultative wetland species and it has short, ascending rhizomes that form individual large tussocks, whereas water sedge is considered to be an obligate wetland plant and it has long, rapidly spreading rhizomes originating from a genet leading to a series of ramets. Regardless of their differences in growth form, it is expected that Kellogg's sedge undergoes similar responses to that of Water sedge when it experiences prolonged anoxic or hypoxic conditions; i.e., translocation of resources from aboveground biomass to the roots, formation of aerenchyma, and a decrease in leaf gas exchange. Direct observations and indirect evidence pertaining to other *Carex* species with similar hydrologic requirements seem to add weight to this suggestion (e.g., Visser et al. 2000, Steed et al. 2002, Wilson 2006).

Columbia sedge like Kellogg's sedge, occurs on wet lakeshores, floodplains, reservoir margins, riverbanks, and wet sedge meadows (Douglas et al. 2001, Wilson et al. 2008). It is similarly drought-intolerant, but in contrast to Kellogg's sedge, it has minimal anaerobic capacity and is adapted to medium- and fine-textured soils but not coarser substrates (USDA-NRCS 2011). A long-lived species, Columbia sedge spreads primarily through deep rhizomes and over time can form large, monospecific stands. Wilson et al. (2008) note that it was once a dominant community along the lower Columbia River bottomlands, where it was harvested for hay, but populations have been greatly reduced by hydrologic changes associated with Columbia River dams. In Kinbasket and Arrow Lakes Reservoirs, Columbia sedge co-occurs frequently with Kellogg's sedge at mid to high elevations in the drawdown zone, although at generally lower densities. It does not presently form large monocultures in these reservoirs; it usually occurs as scattered tussocks mixed in with other vegetation. However, it is possible that stands were more extensive in the region prior to dam construction. Columbia sedge is one of the few plants that can persist in wetlands dominated by Reed Canarygrass (*Phalaris arundinacea*). For this reason, in combination with its tolerance for fluctuating water levels, low nutrient requirements, and ease of transplantation, the species shows considerable potential for restoration of reservoir riparian areas (Wilson et al. 2008, Adama 2015). Broadcast seeding of Columbia sedge in the lower Columbia basin (U.S.) has met with limited success, while survival of vegetative plantings has been variable (Newhouse et al. 1995). Results achieved at Blue River Reservoir (Oregon) inspired researchers to label this plant "an unqualified success" (Newhouse et al. 1995), although establishment elsewhere has been less exemplary (Comes and McCreary 1986). In Kinbasket and Arrow Reservoirs, previous revegetation treatments using Columbia sedge (Keefer et al. 2010) have shown similarly variable success rates as those involving Kellogg's sedge.

Wool-grass occurs naturally in marshes, moist meadows, ditches, and disturbed areas (Whittemore and Schuyler 2002), and it is known to have a high anaerobic tolerance (USDA-NRCS 2011). The *Biogeoclimatic Ecosystem Classification* database indicates that in B.C., this species tolerates a soil moisture regime ranging from mesic to hydric, with the average being subhydric (Klinkenberg 2011). Subhydric soils maintain a water table at or near the surface for most of the year, experience poor drainage, and occur on very shallow slope gradients (BC MOE 1998). Like small-fruited bulrush, wool-grass is adapted to fine-, medium- and coarse-textured soils, and it does not tolerate drought (USDA-NRCS 2011). Compared to small-fruited bulrush, wool-grass inhabits areas that are, on average, wetter during the early portion of the growing season and have lower water level fluctuations throughout the growing season (Cooke and Azous 1997). It occurs frequently throughout much of the drawdown zone of Kinbasket Reservoir, particularly in areas of saturated soils (e.g., seepage areas, pond margins).

Information on the effects of flooding on wool-grass is limited because the species was recently split from *S. cyperinus*, but studies have used congeners, and the results should be applicable to the target species. However, studies on *S. cyperinus* have shown that in response to inundation, net photosynthesis decreases over the first several days of inundation, but within a week the plants begin to recover (Spencer 1994). After two weeks, individuals nearly recover to pre-inundation net photosynthesis rates. Thus, this species (and by proxy, *S. atrocinctus*) appears to be very well adapted to the widely fluctuating inundation regimes that occur in the drawdown zone. However, because this species does best on moist microsites, site selection should factor into the decision-making process regarding revegetation.

Black cottonwood typically occurs along streams and in other very moist conditions, is well adapted to seasonal water fluctuations, and has a high tolerance for flooding (Polzin 1998). Cottonwoods are adapted to fine-, medium-, and coarse-textured soils (USDA-NRCS 2011) that maintain a saturated water table (Polzin 1998). Despite this inherent capacity to withstand flooding and periodic inundation, this species has only a moderate tolerance to anaerobic conditions and a low tolerance to both water stress and exposure to drought (USDA-NRCS 2011). Black cottonwood is a common component of upland forested communities adjacent to the drawdown zone of Kinbasket Reservoir, and commonly occurs into the upper elevation bands (although these individuals rarely reach maturity). Low drought tolerance is the primary concern in using this species to revegetate areas of the drawdown zone of Kinbasket Reservoir (Rood et al. 2003).

A study on the physiological response of black cottonwood to flood conditions identified several changes that occurred over the flooding period: (1) altered nutrient uptake and transport, (2) production of adventitious roots originating from the stem, (3) production of aerenchyma, (4) dieback of roots, (5) production of lenticels, and (6) decreased water xylem potential and root hydraulic conductance (Harrington 1987). Due to the numerous adaptations exhibited by black cottonwood, the species has excellent potential for revegetating sites with saturated or periodically inundated water tables.

Although black cottonwood is subject to drought mortality (Rood et al. 2003), and is only moderately tolerant of anaerobic conditions created by inundation, it appears to be a suitable choice for revegetating upper portions of the drawdown zone with woody vegetation. Its low drought tolerance, however, will limit its applicability to sites with a high water table and/or fine sediments because coarse sediments and a low water table would result in rapid draining and subsequent drought conditions, even adjacent to a large water body such as Kinbasket Reservoir.

Appendix B. Results associated with Wald tests for each species assessed in Arrow Lakes and Kinbasket Reservoirs.

Table 8-1: Results of the Wald test for *Carex lenticularis*, in Arrow Lakes Reservoir. Significant and interpretable variables are denoted in bold (α = 0.1).

Variable	Coefficient	Standard Error	df	t	*p*
Year	0.03	0.19	1130	0.18	0.86
Surface Topo: Convex	-0.23	0.19	690	-1.21	0.23
Surface Topo: Straight	-0.10	0.15	690	-0.66	0.51
Microtopography: Gullied	-0.78	0.68	690	-1.15	0.25
Microtopography: Mounded	-0.08	0.39	690	-0.21	0.83
Microtopography: Smooth	0.03	0.32	690	0.09	0.93
Microtopography: Tussocked	**1.81**	**0.35**	**690**	**5.13**	**0.00001**
Soil Moisture: Mesic	-0.22	0.31	690	-0.72	0.47
Soil Moisture: Subhydric	-0.57	0.46	690	-1.23	0.22
Soil Moisture: Subhygric	-0.35	0.31	690	-1.12	0.26
Soil Moisture: Submesic	-0.08	0.33	690	-0.24	0.81
Soil Moisture: Subxeric	-0.50	0.33	690	-1.50	0.13
Soil Moisture: Very Xeric	**-1.48**	**0.51**	**690**	**-2.92**	**0.004**
Soil Moisture: Xeric	**-1.10**	**0.33**	**690**	**-3.39**	**0.0007**
Treated: True	-0.12	0.17	690	-0.68	0.50
Landscape Unit: Beaton	0.34	0.56	690	0.60	0.55
Landscape Unit: Burton Creek	-0.40	0.50	690	-0.79	0.43
Landscape Unit: Deer Park	**-1.84**	**0.76**	**690**	**-2.42**	**0.02**
Landscape Unit: Dixon Creek	-0.70	0.58	690	-1.22	0.22
Landscape Unit: Fairhurst Creek	-0.52	0.64	690	-0.82	0.41
Landscape Unit: Fosthall	1.03	0.68	690	1.51	0.13
Landscape Unit: Galena	-1.12	0.73	690	-1.53	0.13
Landscape Unit: Halfway	-0.95	0.59	690	-1.62	0.11
Landscape Unit: McDonald Narrows	-0.51	0.49	690	-1.05	0.29
Landscape Unit: Nakusp	-0.29	0.55	690	-0.53	0.59
Landscape Unit: Needles Edgewood	-0.06	0.51	690	-0.12	0.91
Landscape Unit: Renata Creek	**-1.96**	**0.79**	**690**	**-2.49**	**0.01**
Landscape Unit: Revelstoke	-0.61	0.48	690	-1.26	0.21
Landscape Unit: Turner	-0.01	0.65	690	-0.01	0.99
Slope	-0.01	0.06	690	-0.14	0.89
Heat load	0.08	0.06	690	1.42	0.16
Timing (1year)	0.15	0.32	1130	0.47	0.64
Duration (1year)	0.55	0.76	1130	0.72	0.47
Depth (1year)	**1.08**	**0.57**	**1130**	**1.88**	**0.06**
CV Depth (1year)	**0.41**	**0.20**	**1130**	**2.04**	**0.04**
Max Depth (1year)	**-1.32**	**0.73**	**1130**	**-1.80**	**0.07**
GDD April (1year)	0.30	0.19	1130	1.62	0.11
GDD May (1year)	-0.08	0.21	1130	-0.39	0.70
GDD June (1year)	0.34	0.26	1130	1.28	0.20
GDD Julu (1year)	-0.16	0.28	1130	-0.57	0.57

Variable	Coefficient	Standard Error	df	t	*p*
GDD Aug (1year)	0.18	0.25	1130	0.73	0.47
GDD Sept (1year)	0.34	0.27	1130	1.29	0.20
GDD Oct (1year)	0.05	0.27	1130	0.20	0.84
Timing (2year)	**0.41**	**0.17**	**1130**	**2.48**	**0.01**
Duration (2year)	0.18	0.84	1130	0.21	0.83
Depth (2year)	**1.25**	**0.48**	**1130**	**2.60**	**0.01**
CV Depth (2year)	**0.36**	**0.11**	**1130**	**3.16**	**0.002**
Max Depth (2year)	-0.50	0.61	1130	-0.81	0.42
GDD April (2year)	**0.31**	**0.19**	**1130**	**1.65**	**0.10**
GDD May (2year)	-0.01	0.10	1130	-0.08	0.93
GDD June (2year)	0.34	0.35	1130	0.99	0.32
GDD July (2year)	**-0.25**	**0.15**	**1130**	**-1.70**	**0.09**
GDD Aug (2year)	-0.17	0.29	1130	-0.59	0.55
GDD Sept (2year)	-0.17	0.29	1130	-0.57	0.57
GDD Oct (2year)	0.21	0.36	1130	0.58	0.56

Table 8-2: Results of the Wald test for *Carex aperta*, in Arrow Lakes Reservoir. Significant and interpretable variables are denoted in bold (α = 0.1).

Variable	Coefficient	Standard Error	df	t	*p*
Year	**0.44**	**0.09**	**762**	**4.84**	**0.00001**
Microtopography: Gullied	0.95	0.90	470	1.05	0.29
Microtopography: Mounded	0.46	0.48	470	0.96	0.34
Microtopography: Smooth	0.60	0.42	470	1.41	0.16
Microtopography: Tussocked	**0.93**	**0.46**	**470**	**2.00**	**0.05**
Soil Moisture: Mesic	**0.98**	**0.37**	**470**	**2.69**	**0.01**
Soil Moisture: Subhydric	0.11	0.62	470	0.18	0.86
Soil Moisture: Subhygric	**1.00**	**0.38**	**470**	**2.61**	**0.01**
Soil Moisture: Submesic	0.62	0.39	470	1.57	0.12
Soil Moisture: Subxeric	-0.02	0.40	470	-0.05	0.96
Soil Moisture: Very Xeric	-0.79	1.02	470	-0.77	0.44
Soil Moisture: Xeric	0.04	0.41	470	0.11	0.92
Landscape Unit: Beaton	1.00	0.72	470	1.39	0.17
Landscape Unit: Burton Creek	0.09	0.69	470	0.13	0.90
Landscape Unit: Dixon Creek	-0.41	0.74	470	-0.56	0.58
Landscape Unit: Fairhurst Creek	0.70	0.86	470	0.82	0.41
Landscape Unit: Fosthall	1.17	0.83	470	1.41	0.16
Landscape Unit: Galena	0.26	0.84	470	0.31	0.76
Landscape Unit: Halfway	-0.90	0.82	470	-1.10	0.27
Landscape Unit: McDonald Narrows	0.81	0.67	470	1.22	0.22
Landscape Unit: Nakusp	-0.29	0.82	470	-0.35	0.72
Landscape Unit: Needles Edgewood	-0.52	0.72	470	-0.71	0.48
Landscape Unit: Renata Creek	-0.82	1.05	470	-0.78	0.43
Landscape Unit: Revelstoke	0.33	0.67	470	0.48	0.63
Landscape Unit: Turner	0.63	0.77	470	0.82	0.41
Timing (1year)	-0.002	0.09	762	-0.02	0.98
Duration (1year)	-0.15	0.12	762	-1.28	0.20
Depth (1year)	0.19	0.12	762	1.55	0.12
GDD May (1year)	0.15	0.11	762	1.37	0.17
GDD July (1year)	**-0.39**	**0.13**	**762**	**-2.99**	**0.003**
GDD Oct (1year)	**-0.18**	**0.06**	**762**	**-2.88**	**0.004**
Depth (2year)	**0.70**	**0.23**	**762**	**3.01**	**0.003**
Max Depth (2year)	**-1.02**	**0.25**	**762**	**-4.13**	**0.00001**
GDD Aug (2year)	**-0.21**	**0.08**	**762**	**-2.85**	**0.005**

Table 8-3: Results of the Wald test for *Scirpus atrocinctus*, in Arrow Lakes Reservoir. Significant and interpretable variables are denoted in bold (α = 0.1).

Variable	Coefficient	Standard Error	df	t	*p*
Year	**0.47**	**0.15**	**134**	**3.17**	**0.002**
Surface Topo: Convex	-0.36	0.22	68	-1.60	0.11
Surface Topo: Straight	**-0.50**	**0.15**	**68**	**-3.22**	**0.002**
Heat load	**0.17**	**0.07**	**68**	**2.56**	**0.01**
Duration (1year)	**-0.43**	**0.17**	**134**	**-2.48**	**0.01**
Depth (1year)	**-1.26**	**0.37**	**134**	**-3.38**	**0.0009**
Max Depth (1year)	**1.64**	**0.43**	**134**	**3.80**	**0.0002**
GDD April (1year)	-0.10	0.08	134	-1.21	0.23
GDD May (1year)	**0.42**	**0.15**	**134**	**2.85**	**0.005**
Duration (2year)	-0.06	0.11	134	-0.57	0.57

Table 8-4: Results of the Wald test for *Populus balsamifera* ssp. *trichocarpa*, in Arrow Lakes Reservoir. Significant and interpretable variables are denoted in bold (α = 0.1).

Variable	Coefficient	Standard Error	df	t	*p*
Year	**0.34**	**0.10**	**599**	**3.52**	**0.0005**
Surface Topo: Convex	0.31	0.33	261	0.94	0.35
Surface Topo: Straight	0.13	0.30	261	0.42	0.68
Microtopography: Gullied	0.18	1.03	261	0.18	0.86
Microtopography: Mounded	**1.23**	**0.75**	**261**	**1.64**	**0.10**
Microtopography: Smooth	**1.36**	**0.72**	**261**	**1.90**	**0.06**
Microtopography: Tussocked	0.24	0.88	261	0.28	0.78
Soil Moisture: Mesic	-0.82	0.73	261	-1.13	0.26
Soil Moisture: Subhydric	**-2.16**	**0.96**	**261**	**-2.25**	**0.03**
Soil Moisture: Subhygric	-0.87	0.73	261	-1.19	0.23
Soil Moisture: Submesic	-0.86	0.73	261	-1.18	0.24
Soil Moisture: Subxeric	-1.19	0.74	261	-1.62	0.11
Soil Moisture: Very Xeric	-0.87	0.83	261	-1.04	0.30
Soil Moisture: Xeric	-1.07	0.74	261	-1.45	0.15
Treated: True	0.16	0.22	261	0.70	0.48
Landscape Unit: Burton Creek	0.72	0.85	261	0.85	0.40
Landscape Unit: Deer Park	-0.90	1.19	261	-0.75	0.45
Landscape Unit: Dixon Creek	0.64	0.88	261	0.73	0.47
Landscape Unit: Fairhurst Creek	-0.61	1.14	261	-0.53	0.60
Landscape Unit: Fosthall	0.63	1.17	261	0.54	0.59
Landscape Unit: Galena	0.81	0.99	261	0.82	0.41
Landscape Unit: Halfway	**1.76**	**0.85**	**261**	**2.07**	**0.04**
Landscape Unit: McDonald Narrows	0.62	0.82	261	0.76	0.45
Landscape Unit: Nakusp	**1.68**	**0.85**	**261**	**1.98**	**0.05**
Landscape Unit: Needles Edgewood	0.91	0.83	261	1.09	0.28
Landscape Unit: Renata Creek	-0.21	1.62	261	-0.13	0.90
Landscape Unit: Revelstoke	1.01	0.80	261	1.27	0.20
Landscape Unit: Turner	1.02	0.91	261	1.12	0.27
Heat load	**-0.19**	**0.09**	**261**	**-2.11**	**0.04**
Timing (1year)	**-0.32**	**0.13**	**599**	**-2.54**	**0.01**
Duration (1year)	-0.40	0.26	599	-1.53	0.13
GDD Julu (1year)	-0.01	0.23	599	-0.06	0.95
GDD Sept (1year)	0.03	0.12	599	0.28	0.78
GDD Oct (1year)	**-0.74**	**0.13**	**599**	**-5.74**	**0.00001**
Timing (2year)	-0.17	0.16	599	-1.06	0.29
Duration (2year)	**-0.42**	**0.18**	**599**	**-2.37**	**0.02**
Depth (2year)	-0.32	0.40	599	-0.81	0.42
CV Depth (2year)	-0.18	0.13	599	-1.40	0.16
Max Depth (2year)	-0.40	0.40	599	-0.99	0.32
GDD April (2year)	**-0.51**	**0.11**	**599**	**-4.57**	**0.00001**
GDD May (2year)	**-0.21**	**0.07**	**599**	**-2.99**	**0.003**

Table 8-5: Results of the Wald test for *Carex lenticularis*, in Kinbasket Reservoir. Significant and interpretable variables are denoted in bold (α = 0.1).

Variable	Coefficient	Standard Error	df	t	*p*
Year	**-0.79**	**0.22**	**400**	**-3.63**	**0.0003**
Treated	-0.27	0.28	310	-0.97	0.34
Landscape Unit: Causeway	1.07	0.92	310	1.16	0.25
Landscape Unit: Bush Island	**2.43**	**0.90**	**310**	**2.71**	**0.007**
Landscape Unit: Canoe Reach	1.34	0.85	310	1.59	0.11
Landscape Unit: Deer Creek	0.67	1.01	310	0.66	0.51
Landscape Unit: Encampment Ck	**2.20**	**0.89**	**310**	**2.49**	**0.01**
Landscape Unit: Grouse Ck	-1.44	1.27	310	-1.13	0.26
Landscape Unit: Hugh Alan Bay	0.21	0.99	310	0.21	0.83
Landscape Unit: KM 79	**1.77**	**0.91**	**310**	**1.96**	**0.05**
Landscape Unit: Mt. Blackman	-0.29	1.24	310	-0.23	0.82
Landscape Unit: Ptarmigan Ck	**2.05**	**0.91**	**310**	**2.24**	**0.03**
Landscape Unit: Sprague Bay	1.13	0.96	310	1.17	0.24
Landscape Unit: Sullivan Arm	0.10	1.05	310	0.10	0.92
Landscape Unit: Windfall Ck	0.23	0.98	310	0.24	0.81
Landscape Unit: Yellow Jacket Ck	0.94	0.88	310	1.07	0.28
Vegetation Community: BR	-0.15	0.60	400	-0.25	0.81
Vegetation Community: BS	-1.11	0.79	400	-1.40	0.16
Vegetation Community: CH	-0.09	0.44	400	-0.20	0.84
Vegetation Community: CO	0.06	0.48	400	0.12	0.91
Vegetation Community: CT	-0.29	0.71	310	-0.40	0.69
Vegetation Community: DR	**2.02**	**1.14**	**400**	**1.78**	**0.08**
Vegetation Community: KS	**0.99**	**0.47**	**400**	**2.11**	**0.04**
Vegetation Community: LH	0.18	1.24	400	0.14	0.89
Vegetation Community: LL	-0.32	0.49	400	-0.64	0.52
Vegetation Community: MA	**-1.27**	**0.63**	**400**	**-2.04**	**0.04**
Vegetation Community: RC	-1.11	1.06	400	-1.05	0.30
Vegetation Community: RD	-1.43	1.33	310	-1.08	0.28
Vegetation Community: SH	-0.63	0.58	310	-1.08	0.28
Vegetation Community: TP	-0.65	0.56	400	-1.15	0.25
Vegetation Community: WB	0.37	0.54	400	0.69	0.49
Vegetation Community: WD	-1.17	0.84	400	-1.39	0.16
Vegetation Community: WS	0.37	0.66	310	0.57	0.57
Slope	-0.03	0.11	310	-0.26	0.79
Heat load	-0.01	0.10	310	-0.11	0.91
Timing (2 year)	-0.02	0.79	400	-0.03	0.98
Duration (2 year)	-0.13	0.79	400	-0.17	0.87
Ave Depth (2 year)	0.65	0.96	400	0.68	0.50
CV Depth (2 year)	0.04	0.13	400	0.30	0.77
Max Depth (2 year)	-0.43	0.75	400	-0.57	0.57
GDD April (2 year)	0.20	0.31	400	0.65	0.51
GDD May (2 year)	**-0.68**	**0.38**	**400**	**-1.79**	**0.07**

Variable	Coefficient	Standard Error	df	t	*p*
GDD June (2 year)	0.15	0.14	400	1.11	0.27
GDD July (2 year)	0.14	0.30	400	0.45	0.65
GDD Aug (2 year)	-0.29	0.44	400	-0.66	0.51
GDD Sept (2 year)	-0.24	0.24	400	-0.99	0.32
Timing (1 year)	0.22	0.39	400	0.56	0.58
Duration (1 year)	0.29	1.00	400	0.29	0.77
Avg Depth (1 year)	**2.82**	**0.80**	**400**	**3.54**	**0.0004**
CV Depth (1 year)	0.06	0.13	400	0.50	0.62
Max Depth (1 year)	**-3.86**	**1.07**	**400**	**-3.62**	**0.0003**
GDD April (1 year)	**0.36**	**0.17**	**400**	**2.06**	**0.04**
GDD May (1 year)	-0.08	0.27	400	-0.31	0.76
GDD June (1 year)	0.22	0.21	400	1.03	0.30
GDD July (1 year)	-0.22	0.29	400	-0.74	0.46
GDD Aug (1 year)	-0.44	0.33	400	-1.33	0.19
GDD Sept (1 year)	-0.19	0.31	400	-0.60	0.55

Table 8-6: Results of the Wald test for *Carex aperta*, in Kinbasket Reservoir. Significant and interpretable variables are denoted in bold (α = 0.1).

Variable	Coefficient	Standard Error	df	t	*p*
Year	-13.42	12.58	11	-1.07	0.31
Landscape Unit: Causeway	1.95	2.64	4	0.74	0.50
Landscape Unit: Bush Island	4.12	3.21	4	1.28	0.27
Landscape Unit: KM 79	-1.66	4.64	4	-0.36	0.74
Landscape Unit: Ptarmigan Ck	-4.75	3.72	4	-1.28	0.27
Vegetation Community: KS	4.46	2.87	11	1.55	0.15
Vegetation Community: MA	0.81	3.66	11	0.22	0.83
Vegetation Community: WS	0.94	15.69	4	0.06	0.96
Slope	2.59	2.24	4	1.16	0.31
Heat load	-2.20	1.11	4	-1.98	0.12
Timing (2 year)	-13.59	8.73	11	-1.56	0.15
Duration (2 year)	14.88	9.25	11	1.61	0.14
Avg Depth (2 year)	10.88	15.17	11	0.72	0.49
CV Depth (2 year)	-2.66	2.40	11	-1.11	0.29
Max Depth (2 year)	-5.19	13.26	11	-0.39	0.70
GDD April (2 year)	5.32	8.10	11	0.66	0.52
GDD May (2 year)	-14.68	16.03	11	-0.92	0.38
GDD June (2 year)	-1.17	1.43	11	-0.82	0.43
GDD July (2 year)	**11.76**	**4.13**	**11**	**2.85**	**0.02**
GDD Aug (2 year)	**14.54**	**5.97**	**11**	**2.44**	**0.03**
GDD Sept (2 year)	5.31	5.74	11	0.93	0.37
Timing (1 year)	**-9.95**	**4.49**	**11**	**-2.22**	**0.05**
Duration (1 year)	-5.22	23.64	11	-0.22	0.83
Avg Depth (1 year)	3.32	7.88	11	0.42	0.68
CV Depth (1 year)	**-6.92**	**2.33**	**11**	**-2.97**	**0.01**
Max Depth (1 year)	-11.85	11.36	11	-1.04	0.32
GDD April (1 year)	3.40	4.65	11	0.73	0.48
GDD May (1 year)	2.90	4.19	11	0.69	0.50
GDD June (1 year)	-3.09	5.44	11	-0.57	0.58
GDD July (1 year)	2.13	7.07	11	0.30	0.77
GDD Aug (1 year)	-2.94	10.21	11	-0.29	0.78
GDD Sept (1 year)	-0.47	8.63	11	-0.05	0.96

Table 8-7: Results of the Wald test for *Scirpus atrocinctus*, in Kinbasket Reservoir. Significant and interpretable variables are denoted in bold (α = 0.1).

Variable	Coefficient	Standard Error	df	t	*p*
Landscape Unit: Bush Island	**2.65**	**1.18**	**105**	**2.24**	**0.03**
Landscape Unit: Canoe Reach	1.62	1.06	105	1.53	0.13
Landscape Unit: Encampment Ck	**3.30**	**1.14**	**105**	**2.90**	**0.005**
Landscape Unit: Grouse Ck	1.04	1.67	105	0.62	0.53
Landscape Unit: Hugh Alan Bay	1.37	1.33	105	1.04	0.30
Landscape Unit: KM 79	**4.14**	**1.07**	**105**	**3.88**	**0.0002**
Landscape Unit: Ptarmigan Ck	1.32	1.19	105	1.11	0.27
Landscape Unit: Sprague Bay	**4.91**	**1.15**	**105**	**4.29**	**0.00001**
Landscape Unit: Yellow Jacket Ck	0.40	1.21	105	0.33	0.74
Vegetation Community: BR	-0.48	1.46	105	-0.33	0.74
Vegetation Community: BS	-0.34	1.51	188	-0.22	0.82
Vegetation Community: CH	-1.25	1.35	188	-0.92	0.36
Vegetation Community: CO	0.88	1.47	188	0.60	0.55
Vegetation Community: CT	**-3.84**	**1.61**	**105**	**-2.38**	**0.02**
Vegetation Community: DR	0.46	1.54	188	0.30	0.76
Vegetation Community: KS	-0.80	1.30	188	-0.62	0.54
Vegetation Community: LH	-1.91	1.91	188	-1.00	0.32
Vegetation Community: LL	0.01	1.43	105	0.01	1.00
Vegetation Community: MA	-0.22	1.47	105	-0.15	0.88
Vegetation Community: SH	0.79	1.38	105	0.57	0.57
Vegetation Community: TP	-0.93	1.43	188	-0.65	0.52
Vegetation Community: WB	0.90	1.32	188	0.68	0.50
Vegetation Community: WD	-1.21	1.79	105	-0.68	0.50
Vegetation Community: WS	0.35	1.41	188	0.25	0.80
Avg Depth (2 year)	-0.14	0.17	188	-0.83	0.41
GDD June (2 year)	**-0.18**	**0.11**	**188**	**-1.69**	**0.09**
Duration (1 year)	**-0.34**	**0.14**	**188**	**-2.46**	**0.01**
GDD April (1 year)	**0.34**	**0.10**	**188**	**3.48**	**0.0006**

Table 8-8: Results of the Wald test for *Populus balsamifera* ssp. *trichocarpa*, in Kinbasket Reservoir. Significant and interpretable variables are denoted in bold (α = 0.1).

Variable	Coefficient	Standard Error	df	t	*p*
Year	0.47	0.56	42	0.84	0.41
Treated	0.50	0.68	29	0.74	0.47
Landscape Unit: Canoe Reach	-0.14	1.36	29	-0.11	0.92
Landscape Unit: Encampment Cl	0.29	0.99	29	0.29	0.77
Landscape Unit: KM 79	0.46	1.18	29	0.39	0.70
Landscape Unit: Sullivan Arm	-0.76	1.16	29	-0.65	0.52
Landscape Unit: Windfall Ck	**-3.61**	**1.38**	**29**	**-2.62**	**0.01**
Landscape Unit: Yellow Jacket Ck	-0.47	0.93	29	-0.50	0.62
Vegetation Community: CH	-0.82	2.05	29	-0.40	0.69
Vegetation Community: CO	0.59	1.71	29	0.34	0.73
Vegetation Community: CT	0.05	1.87	29	0.03	0.98
Vegetation Community: KS	2.53	2.75	29	0.92	0.37
Vegetation Community: WS	-1.57	1.28	29	-1.23	0.23
Slope	**0.60**	**0.29**	**29**	**2.12**	**0.04**
Heat load	**-1.43**	**0.34**	**29**	**-4.27**	**0.0002**
Timing (2 year)	**4.10**	**2.10**	**42**	**1.95**	**0.06**
Duration (2 year)	2.52	2.07	42	1.22	0.23
Avg Depth (2 year)	1.96	2.71	42	0.72	0.47
CV Depth (2 year)	0.67	0.69	42	0.98	0.33
Max Depth (2 year)	-2.46	2.90	42	-0.85	0.40
GDD April (2 year)	**-1.85**	**0.74**	**42**	**-2.49**	**0.02**
GDD May (2 year)	**2.60**	**0.87**	**42**	**3.00**	**0.005**
GDD June (2 year)	**-1.56**	**0.84**	**42**	**-1.86**	**0.07**
GDD July (2 year)	0.60	0.93	42	0.65	0.52
GDD Aug (2 year)	-0.95	1.05	42	-0.90	0.37
GDD Sept (2 year)	**1.23**	**0.64**	**42**	**1.94**	**0.06**

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BRITISH COLUMBIA HYDRO AND POWER AUTHORITY
CLBMON-35 ARROW LAKES AND KINBASKET RESERVOIRS PLANT RESPONSE TO INUNDATION




Revegetation Prescription Catalogue
Arrow Lakes Reservoir Reservoir

Final

Prepared for

BC Hydro

Prepared by

LGL Limited
environmental research associates
9768 Second Street
Sidney, British Columbia, V8L 3Y8

Contact

Virgil C. Hawkes, M.Sc. R.P.Bio.
Vice-President & Senior Wildlife Biologist
vhawkes@lgl.com
1.250.656.0127

June 20, 2018

LGL LIMITED
environmental research associates

Cover photos:

From left to right: black cottonwood (*Populus balsamifera* subsp. *trichocarpa*) live stakes at Lower Inonoaklin Road, Arrow Lakes Reservoir; Kellogg's sedge *(Carex Kellogg'sis var. lipocarpa*) at Burton Creek, Arrow Lakes Reservoir; vegetation growing in the drawdown zone of Arrow Lakes Reservoir, and live staking at the Bush Arm Causeway, Kinbasket Reservoir.

Table of Contents

List of Tables

List of Figures

List of Maps

1 Introduction

To mitigate for the varied effects of reservoir operations on vegetation establishment and development in the drawdown zone of Arrow Lakes Reservoir, in 2007 BC Hydro implemented CLBWORKS-2, a 5-yr, reservoir-wide restoration program to enhance sustainable vegetation growth for ecological and social benefits (BC Hydro 2008). Between 2008 and 2011, a total of 106 ha in 22 treatment units in the drawdown zone of Arrow Lakes Reservoir were planted by Keefer Ecological Services (Keefer et al. 2008, 2009, Keefer Ecological Services 2010, 2011). Seven different revegetation prescriptions were applied during this time, but graminoid plug seedling treatments, particularly those involving Kellogg's sedge (*Carex lenticularis* var. *lipocarpa*) alone or mixed with other species, dominated the planting regime. CLBMON-12, an effectiveness monitoring study of the revegetation efforts, occurred between 2008 and 2017 (Gibeau and Enns 2008, Enns et al. 2009, Enns and Enns 2012, Enns and Overholt 2013, Miller et al. 2016, Miller et al. 2018 draft). Results of CLBMON-12 indicate that the revegetation program has met with mixed success to date. A portion of the stock (primarily Kellogg's sedge, Columbia sedge, and black cottonwood) planted between 2009 and 2011 has survived and taken root and, in limited areas, is growing vigorously. The plantings in these areas may now be providing some ancillary ecological services such as increased erosion control, browse for waterfowl, and perching habitat for birds. In other areas, survival of plantings has been minimal to non-existent. Establishment failures can probably be ascribed to a combination of environmental factors including prolonged inundation, infertile or unstable substrates, wave action and erosion/deposition, soil moisture deficits, and human disturbance.

The purpose of CLBMON-35, of which this catalogue is one component, is to document site conditions, revegetation methods, and revegetation success to elucidate variables (biotic and abiotic) that contributed to the successes or failures of each type of vegetation treatment at a given site within Arrow Lakes and Kinbasket Reservoirs. The goal of cataloguing and analyzing these data is to provide a record of the revegetation techniques applied at each site, and help determine the treatments and associated factors that were effective. These variables included the presence (accumulation) of species planted, site preparation, planting method, stocking density, woody debris, erosion and sediment deposition, wave and wind action, soil characteristics, ecological suitability, soil compaction, human activity, and physicochemical parameters such as soil anoxia. Data analyses and results also aimed to address existing uncertainties regarding the relative contribution and importance of timing, frequency, depth, and duration of inundation on survival of plants of different sizes and ages, and the effect of multi-year stresses on trends in plant viability.

The three documents produced for CLBMON-35 include this catalogue, which pertains specifically to CLBWORKS-2 (Arrow Lakes Reservoir revegetation); a companion catalogue for CLBWORKS-1 (Kinbasket Reservoir revegetation); and a report (Hawkes et al 2018) linking the two reservoirs and describing, among other things, species-specific responses of key four species (*Carex lenticularis* var. *lipocarpa*, *C. aperta*, *Sciprus atrocinctus*, and *Populus balsamifera* ssp. *trichorcarpa*) to reservoir operations.

2 Study Area

Arrow Lakes Reservoir is situated on the Columbia River between Revelstoke and Castlegar, BC (Figure 2-1). The reservoir is ~230 km long and was formed in 1968 by the completion of Hugh Keenleyside Dam, 8 km west of Castlegar. The reservoir includes three main sections: Lower and Upper Arrow Lakes in the south, and Revelstoke Reach in the north. It has a north-south orientation and lies between the Monashee Mountains in the west and the Selkirk Mountains in the east. Two Biogeoclimatic zones occur within the study area: the Interior Cedar Hemlock (ICH) and the Interior Douglas-fir (IDF). Further details on the study area physiology, geology, and soils are provided in Enns et al. (2007).

2.1 Physiography[1]

The Columbia basin is situated in southeastern British Columbia. The basin is characterized by steep valley side slopes and short tributary streams that flow into Columbia River from all directions. The headwaters of the Columbia River begin at Columbia Lake in the Rocky Mountain Trench. The river flows northwest along the Trench for about 250 km before it empties into Kinbasket Reservoir behind Mica Dam (BC Hydro 1983). From Mica Dam, the river continues southward for about 130 km to Revelstoke Dam and then flows almost immediately into Arrow Lakes Reservoir behind Hugh Keenleyside Dam. The entire drainage area upstream of Hugh Keenleyside Dam is approximately 36,500 km^2.

The Columbia River valley floor elevation falls from approximately 800 m ASL near Columbia Lake to 420 m ASL near Castlegar. Approximately 40 per cent of the drainage area within the Columbia River basin is above 2000 m ASL. Permanent snowfields and glaciers predominate in the northern high mountain areas above 2500 m ASL; about 10 per cent of the Columbia River drainage area above Mica Dam exceeds this elevation.

Most of the watershed remains in its original forested state. Dense forest vegetation thins above 1500 m ASL and tree lines are generally at about 2000 m ASL. The forested lands around Kinbasket Reservoir have been and are being logged, with recent and active logging (i.e., 2007–2014) occurring on both the east and west sides of the reservoir.

[1] From BC Hydro (2007) after BC Hydro (1983).

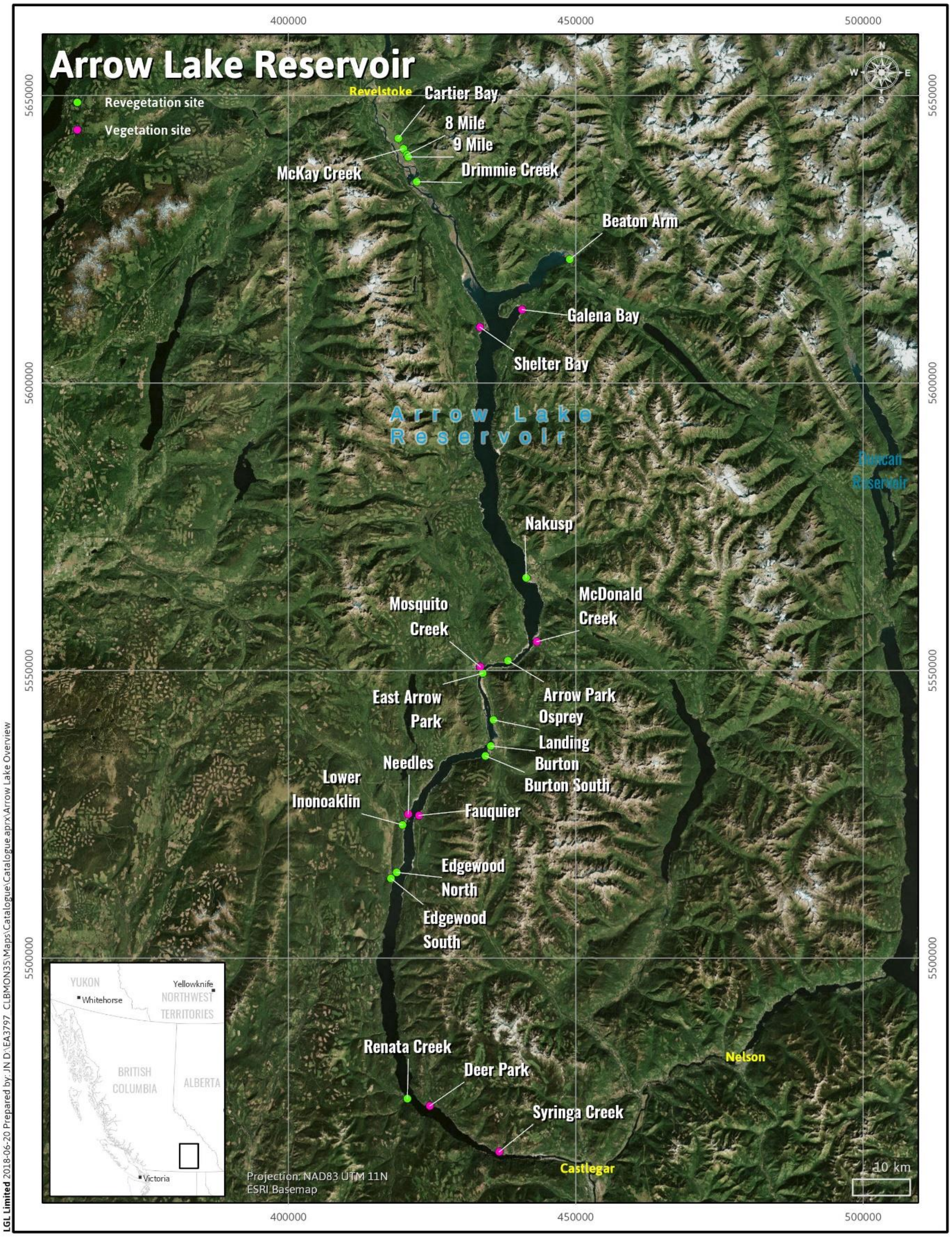


Figure 2-1. Location of Arrow Lakes Reservoir and revegetation locations (red areas).

2.2 Climate[2]

Precipitation in the basin occurs from the flow of moist low-pressure weather systems that move eastward through the region from the Pacific Ocean. More than two-thirds of the precipitation in the basin falls as winter snow, resulting in substantial seasonal snow accumulations at middle and upper elevations in the watersheds. Summer snowmelt is complemented by rain from frontal storm systems and local convective storms.

Temperatures in the basin tend to be more uniform than precipitation. With allowances for temperature lapse rates, station temperature records from the valley can be used to estimate temperatures at higher elevations. The summer climate is usually warm and dry, with the average daily maximum temperature for June and July ranging from 20°C to 32°C. The average daily minimum temperature ranges from 7°C to 10°C. The coldest month is January, when the average daily maximum temperature in the valleys is near 0°C and average daily minimum is near -5°C.

During the spring and summer months, the major source of stream flow in the Columbia River is water stored in large snow packs that developed during the previous winter months. Snow packs often accumulate above 2000m through the month of May and continue to contribute runoff long after the snow pack has depleted at lower elevations. Runoff begins to increase in April or May and usually peaks in June to early July, when approximately 45 per cent of the runoff occurs. Severe summer rainstorms are not unusual in the Columbia Basin. Summer rainfall contributions to runoff generally occur as short-term peaks superimposed upon high river levels caused by snowmelt. These rainstorms may contribute to annual flood peaks. The mean annual local inflow for the Mica, Revelstoke, and Hugh Keenleyside projects is 577 m^3/s, 236 m^3/s, and 355 m^3/s, respectively.

3 Methods

Data in this catalogue were retrieved from several sources including CLBMON-12, CLBMON-33, and CLBWORKS-2 datasets, reports, and GIS data. The CLBWORKS-2 data were summarized to generate treatment summaries by reach and year and the CLBMON-12, 33, and WORKS-2 reports were used to summarize planting activities and success. Data from Moody and Carr (2005) were used to cross-reference the CLBWORKS-2 treatment areas with the areas identified for vegetation establishment in Arrow Lakes Reservoir by Moody and Carr.

The following fields are used to summarize the revegetation treatments applied in each reach and site:

Site description: general description of site in terms of location and planting history.

Site information: summary of the site.

Reach: name of reach (revegetation location) in Arrow Reservoir (see Figure 2-1).

MC Unit: These codes correspond to the original treatments units defined by Moody and Carr (2005) and Moody (2005) in the Columbia water Use Plan (BC Hydro 2005).

UTM's: Spatial coordinates (easting and northing) of approximate centroid of the treatment areas.

BEC: Biogeoclimatic Ecosystem Classification. Biogeoclimatic zone, subzone, and variant in which the treatment occurred.

[2] From BC Hydro 2007 after BC Hydro 1983.

Vegetation Communities: as per Miller et al. (2017). Community types were initially defined by Enns et al. (2007) and revised by Enns et al. (2010). Commencing in 2015, Miller et al. (2017 draft) introduced further refinements to the community classification to make it align more closely with conditions observed on the ground. See Table 3-1.

Area (ha): Two values for area are provided. The first is the size of all of the treatment polygons treated. The second is the total of all the treatments applied, and may include multiple treatments across individual treatment polygons.

Elevation (m): elevation range (lowest and highest) of the treatment polygon.

No. of Polygons: Count of treatment areas (polygons) at each site.

Years: years in which treatments were applied.

Treatment summary: overview of the revegetation treatments applied. A second set of tables summarizes the specific treatment areas in terms of polygon label, elevation (centroid of polygon), treatment type, species used in treatments, the density or rate of planning, and total area of treatment.

Summary of planting success: brief discussion of planting success reflecting results of the most recent CLBMON-12 surveys (Miller et al. 2018 draft).

Documents: listing of relevant documents. Full citations are provided in the References section.

Table 3-1: **List of vegetation communities classified for the drawdown zone of Arrow Lakes Reservoir.** Original names (from Enns *et al.* 2010) are shown along with modifications to the classification (in bold) introduced in 2015 (Miller *et al.* 2017). Note that not all community types (e.g., BB, SF, SS) are typically vegetated. Low elev. band = 434-436 masl; mid elev. band = 436-438 masl; high elev. band = 438-440 masl.

Original VCT code	Original name	New name (in bold)	Typical elevation band
BB	Boulders, steep	Boulders, steep	all
BE	Sandy beach	Sandy beach	low
BG	Gravelly beach	Gravelly beach	mid to low
CL	Saskatoon–cliffs and rock	Saskatoon–cliffs and rock	high
CR	cottonwood riparian	cottonwood riparian **Shrub riparian**	high high
IN	Industrial/ residential/recreational	Industrial/ residential/recreational	all
LO	Log zone	Log zone	high
PA	Redtop upland	Redtop upland **PC–Willow**	high mid
PC	Reed Canarygrass mesic	**PC–Reed canarygrass**	mid
		PC–Foxtail/horsetail	low
		PC–Sedge	mid to low
PE	Horsetail lowland	**PE–Foxtail** **PE–Sedge**	low low
PO	Pond	Pond	mid
RR	Reed–rill	Reed–rill	all
RS	Willow stream entry	Willow stream entry	Mid to high
SF	Failing slope	Failing slope	mid to low
SS	Steep sand	Steep sand	mid to low
WR	River entry	River entry	all

4 Arrow Lakes Reservoir Revegetation Summaries, 2008 to 2011

Revegetation of the Arrow Lakes Reservoir drawdown zone through CLBWORKS-2 commenced in 2008. By 2011, approximately 106 ha of the drawdown zone had been treated. The treatment types applied in the drawdown zone of Arrow Lakes Reservoir between 2008 and 2011 are as follows:

Seed Mix: Two multi-species seed mixes (Upland and Wetland; Table 4-1) were developed using native species and applied either through hydro-seeding or hand seeding using an Earthway Ev-n-spread hand spreader.

Table 4-1: Multi-species seed mixes used in revegetation trials of the drawdown zone of Arrow Lakes Reservoir.

Upland Seed Mix	Seed in Mix (%)
Blue wildrye	39
Annual ryegrass	25
California brome	15
tufted hairgrass	11
white Dutch clover	7
inert matter	2
Canada goldenrod	1
Wetland Seed Mix	**Seed in Mix (%)**
sterile wheat	30
annual ryegrass	20
Columbia sedge	9
Kellogg’s sedge	8
sawbeak sedge	8
beaked sedge	8
water sedge	5
Cusick’s sedge	5
fowl mannagrass	3
small-flowered bullrush	2
common spikerush	2

Graminoid Seed: Seed from native graminoids (primarily Kellogg’s sedge) were sown either by hand or by drill seeding (sandy sites only).

Graminoid Seedling: Nursery grown seedlings of Kellogg’s sedge (*Carex Kellogg’sis* var. *lipocarpa*), Columbia sedge (*Carex aperta*), water sedge (*Carex aquatilis*), wool-grass (*Scirpus atrocinctus*), small-flowered bulrush (*Scirpus microcarpus*), and bluejoint reedgrass (*Calamagrostis canadensis*) were hand planted by professional tree planting crews using planting shovels.

Shrub Seedling: Nursery grown seedlings of mountain alder (*Alnus incana*), black cottonwood (*Populus balsamifera*), chokecherry (*Prunus virginiana*), red-osier dogwood (*Cornus stolonifera*), wild rose (*Rosa acicularis*), and willow (*Salix* spp.) were hand planted by professional tree planting crews using planting shovels.

Shrub Stakes: Live stakes of black cottonwood, red-osier dogwood, and willow (primarily Scouler’s and Bebb’s Willow) were either hand planted or planted with the aid of a mini-excavator. Stakes were planted to depths of 30 to 50 cm with the aid of a planting bar to create a pocket for the stake.

Modified Brush Layers (MBLs): MBLs is a site stabilization technique constructed of live stakes and other materials such as logs and boards. MBLs are often utilized in erosion prone areas by providing a stable terrace to facilitate the establishment of native vegetation. Several MBL's were planted in Arrow Lakes and Kinbasket Reservoir as trials.

Fertilization: In the early years of CLBWORKS-01 and -2, fertilizer was applied by hand or with the aid of ATV (quad mounted Vicon 303 fertilizer spreader) in treatment polygons to increase establishment survival and plant biomass production. Fertilizer was initially applied in trial plots but it was also used across large areas planted with seed mixes, seedlings, and stakes. The application of fertilizer was discontinued in later years as it was suspected to have a greater effect on competing weeds and native annuals that on target species.

The stated objectives of CLBWORKS-2 were: (1) to enhance littoral productivity; (2) to improve physical, structural, and biological features of wildlife habitat; (3) to assist in the protection of cultural heritage sites; (4) to provide benefits to recreation and shoreline stability; and (5) to provide aesthetic benefits. Results from the 10-year effectiveness monitoring study (CLBMON-12), which concluded in 2017, indicated that transplants have met with highly variable success in the drawdown zone, with survivorship of sedge seedling plugs, shrub seedlings, and shrub live stakes ranging from zero (treatment failure) eight years post-planting up to 100 per cent (full survival) depending on site and habitat. Factors limiting transplant establishment success included operational effects related to inundation regimes (e.g., erosion, deposition, wave scouring, wood debris scouring, and drought conditions) and non-operational effects (e.g. substrates, nutrients, rodent damage, ATV traffic, other human disturbances).

There was a general lack of change in both total cover and species richness in treatment polygons since 2011, mirroring a similar trend in control plots. With some notable exceptions (e.g., an increase in shrub cover at certain locations), there were few statistically significant differences between treatment and control plots either in per cent cover of total vegetation, species richness, or species diversity within any plant community, elevation band, or region of the reservoir. It thus does not appear that either the quality or quantity of native vegetation in the Arrow Lakes Reservoir drawdown zone had increased as a result of the planting program. The mixed success of revegetation efforts in meeting the stated remediation objectives suggests that changes are needed either to the planting program or the operating regime, or both. It is apparent from the effectiveness monitoring that without some level of adaptive management, the program will likely continue to struggle and any successes in establishing vegetation in the drawdown zone will be relatively minor and/or localized.

The following tables and sections detail the revegetation trials in the drawdown zone of Arrow Lakes Reservoir between 2008 and 2011. This catalogue is an addendum to the CLBMON-35 report (Hawkes et al. 2018) that describes the history the revegetation program and details species-specific responses to reservoir operations in both Kinbasket and Arrow Lakes Reservoirs.

Cartier Bay — Arrow Lakes Reservoir

Site Description:

Cartier Bay is located in Revelstoke Reach at the north end of the Arrow Lakes Reservoir. The bay is situated on the east side of the reservoir 10 km south of Revelstoke, B.C. and consists of a large basin that lies below 436.0 m ASL. Within the bay, an old oxbow of the Columbia river forms a large 23.4 ha wetland, which becomes inundated when reservoir levels exceed 433.8 m ASL (Hawkes et al 2015). The outer (southeast) banks of the bay are steep with course soils of boulders, gravel, or sand. Soils within the basin consists of fines (clay, silt) and were imperfectly drained (Keefer and Moody 2010). Reed canarygrass forms dense stands over much of the area, interspersed with patches of Kellogg's sedge, Columbia sedge, and water smartweed (Hawkes et al 2015).

A treatment prescription was developed in early 2010 (Keefer and Moody 2010). Planting occurred in 2010 and no other year (KES 2010).

Site information:

Reach	Revelstoke Reach
MC Unit	K
UTM's	11U 419119 E 5642534 N
BEC	ICH mw 3
Vegetation Communities see Table 3-1	PC
Area (ha)	0.74
Elevation (m)	Min: 433.8 Max: 434.7
# of Polygons:	1
Years:	2010

Treatment Summary

Treatments were undertaken in 2010 in a single 0.74 ha treatment polygon. Approximately, 4000 water sedge plugs were planted.

Summary of Planting Success

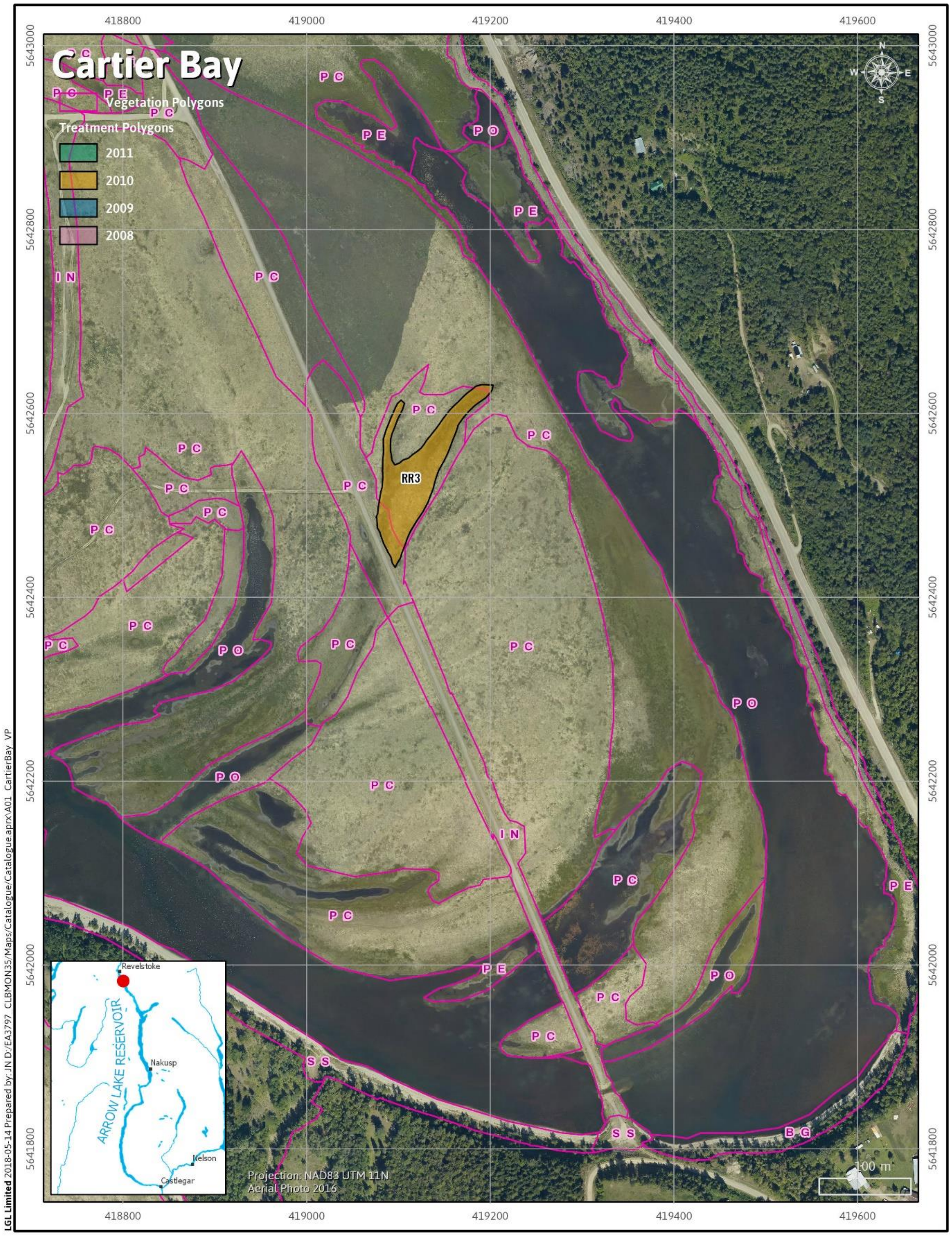
No water sedge plants were recorded within CLBMON-12 permanent monitoring plots in 2011, 2013, or 2015, implying the treatment here was unsuccessful.

Documents

Type	Year	Author	Short Title
Prescription	2005	Moody	Potential Areas for Vegetation Establishment in Arrow Reservoir
Prescription	2010	Keefer and Moody	Arrow Reservoir Planting Plan for 2010
Summary	2010	KES	Arrow Revegetation Report 2010
Impact Assessment	2015	Hawkes et al.	CLBWORKS-30 Ecological Impact Assessment

Year 2010

MC#	Polygon	Elev	Treatment Type	Species	Density/Rate	Area (ha)
K	RR3	434.16	graminoid seedling	water sedge	5392 sph	0.74



Map 4-1.Distribution of revegetation treatment areas at Cartier Bay, Arrow Lakes Reservoir, 2010.

McKay Creek Arrow Lakes Reservoir

Site Description:

McKay Creek is located on the east side of Arrow Lakes Reservoir, 11 km south of Revelstoke, B.C. The site is situated in a small bay 1 km south of Cartier Bay and 1 km north of the 8-mile site. Soils between McKay and Drimmie Creeks tended to be sandy or fine textured (silts and clays) and moderately well drained.

Treatment prescriptions were developed in early 2010 (Keefer and Moody 2010) and early 2011 (Keefer and Moody 2011). Planting was undertaken in 2010 and 2011 (KES 2010 and 2011).

Site information:

Reach	Revelstoke Reach
MC Unit	M1
UTM's	11U 420006 E 5640719 N
BEC	ICH mw 3
Vegetation Communities see Table 3-1	BE, CR, PA, PC, RS, and SS
Area (ha)	6.13 / 9.41
Elevation (m)	Min: 438.0 Max: 439.8
# of Polygons:	16
Years:	2010, 2011

Treatment Summary

Plantings were undertaken in 2010 and 2011 totaling 6.13 ha across 16 treatment polygons. In 2010, live stakes of black cottonwood and red-osier dogwood were excavator- and hand-planted in eleven treatment polygons totaling 2.80 ha. In 2011, four treatment polygons in total were planted (4.70 ha): wool-grass, and Kellogg's and water sedge seedlings plugs were planted in four sites (3.33 ha) and black cottonwood seedlings were planted in a single polygon (1.37 ha).

Summary of Planting Success

An assessment of CLBWORKS-2 planting survivorship in 2017 (Miller et al. 2018 draft) indicated a low success rate for Kellogg's sedge seedlings (25 %), nil success for black cottonwood seedlings, and moderate success rates for black cottonwood stakes (38 %) at McKay Creek. Survivorship for red-osier dogwood stakes, wool-grass, and water sedge seedlings at McKay Creek were very low to nil. Note: "success rate" is defined here as the percentage of sample plots containing at least one surviving transplant.

Documents

Type	Year	Author	Short Title
Prescription	2005	Moody	Potential Areas for Vegetation Establishment in Arrow Reservoir
Prescription	2010	Keefer and Moody	Arrow Reservoir Planting Plan for 2010
Summary	2010	KES	Arrow Revegetation Report 2010
Prescription	2011	Keefer and Moody	Arrow Reservoir Planting Plan for 2011
Summary	2011	KES	Arrow Revegetation Report 2011
Monitoring	2017	Miller et al	Arrow Monitoring Report

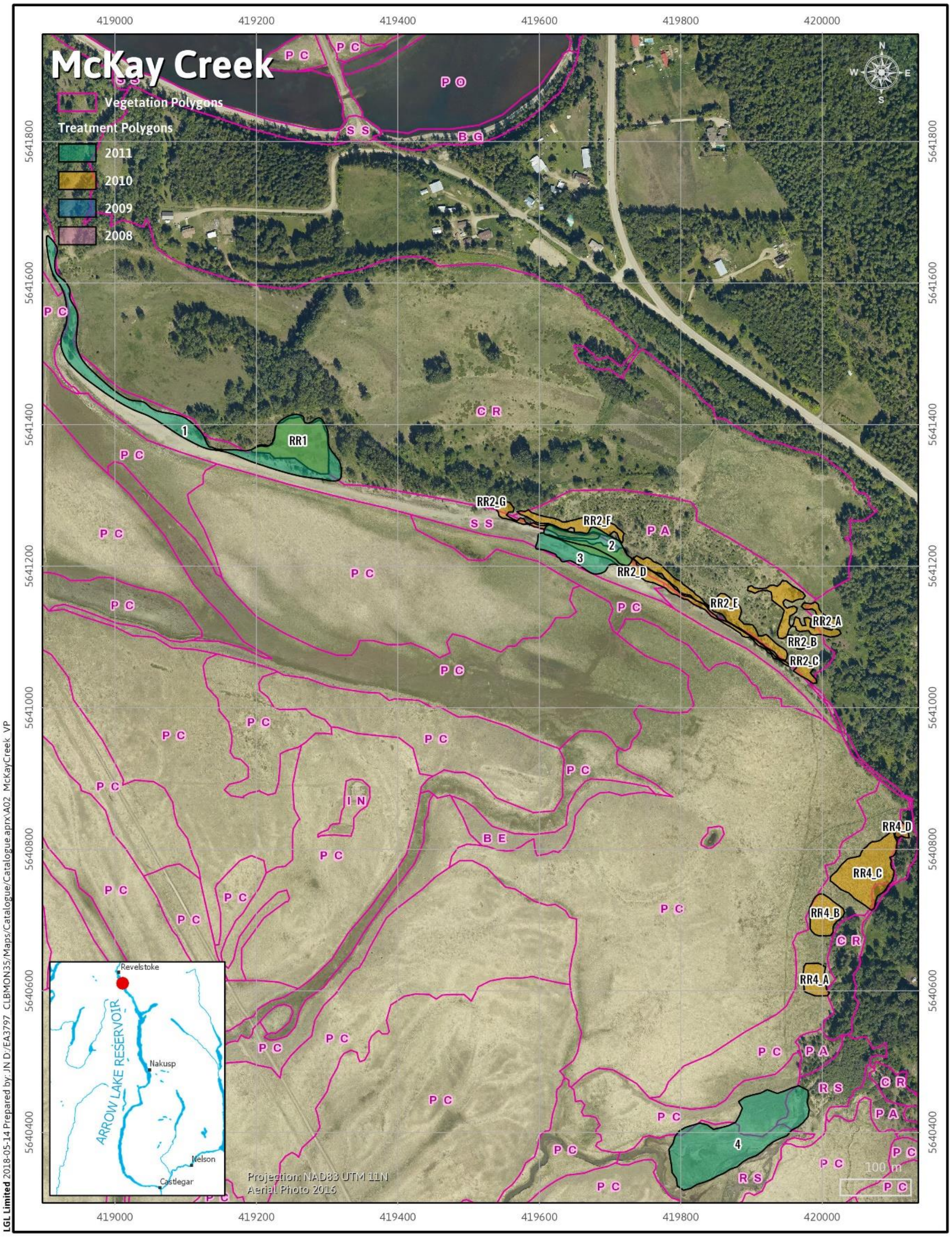
McKay Creek Arrow Lakes Reservoir

Year 2010

MC#	Polygon	Elev	Treatment Type	Species	Density/Rate	Area (ha)
M1	RR1	438.90	shrub stake	black cottonwood	852 sph	0.50
M1	RR2_A	439.45	shrub stake	black cottonwood	834 sph	0.31
M1	RR2_B	439.12	shrub stake	black cottonwood	971 sph	0.03
M1	RR2_C	439.71	shrub stake	black cottonwood	881 sph	0.06
M1	RR2_D	437.81	shrub stake	black cottonwood	849 sph	0.33
M1	RR2_D	437.81	shrub stake	Red-osier Dogwood	122 sph	0.33
M1	RR2_E	438.62	shrub stake	black cottonwood	837 sph	0.32
M1	RR2_F	438.65	shrub stake	black cottonwood	862 sph	0.21
M1	RR2_G	438.50	shrub stake	black cottonwood	829 sph	0.13
M1	RR2_G	438.50	shrub stake	Red-osier Dogwood	603 sph	0.13
M1	RR4_A	438.33	shrub stake	black cottonwood	1110 sph	0.14
M1	RR4_B	438.40	shrub stake	black cottonwood	1049 sph	0.20
M1	RR4_C	438.64	shrub stake	black cottonwood	1073 sph	0.55
M1	RR4_D	438.47	shrub stake	black cottonwood	1180 sph	0.04
M1	RR4_D	438.47	shrub stake	Red-osier Dogwood	4472 sph	0.04

Year 2011

MC#	Polygon	Elev	Treatment Type	Species	Density/Rate	Area (ha)
M1	1	438.53	graminoid seedling	Kellogg's sedge	15103 sph	1.37
M1	1	438.53	shrub seedling	black cottonwood	5707 sph	1.37
M1	2	437.98	graminoid seedling	Kellogg's sedge	20747 sph	0.25
M1	3	436.68	graminoid seedling	Kellogg's sedge	40774 sph	0.30
M1	4	435.35	graminoid seedling	water sedge	2101 sph	1.40
M1	4	435.35	graminoid seedling	wool-grass	6601 sph	1.40



Map 4-2. Distribution of revegetation treatment areas at Mackay Creek, Arrow Lakes Reservoir, 2010 and 2011.

Figure 4-1. Examples of revegetation prescriptions trialed at Mackay Creek in 2010 and 2011. A and B: live staking with moderate success; C and D, live staking with good success. Photo credit: Mike Miller.

8 Mile Arrow Lakes Reservoir

Site Description:

8 Mile is located at the north end of the Arrow Lakes Reservoir in Revelstoke Reach. It is situated on the east side of the reservoir 12.5 km south of Revelstoke, B.C. just north of the 9-mile spit. Soils between McKay and Drimmie Creeks tended to be sandy or fine textured (silts and clays) and moderately well drained (Keefer and Moody 2010).

Treatment prescriptions were developed in early 2010 (Keefer and Moody 2010) and early 2011 (Keefer and Moody 2011). Planting occurred in 2010 and 2011 (KES 2010 and 2011).

Site information:

Reach	Revelstoke Reach
MC Unit	M1
UTM's	11U 420636 E 5639712 N
BEC	ICH mw 3
Vegetation Communities see Table 3-1	BE, IN, PA, and PC
Area (ha)	7.04 / 9.95
Elevation (m)	Min: 437.6 Max: 439.3
# of Polygons:	7
Years:	2010, 2011

Treatment Summary

Plantings were undertaken in 2010 and 2011 totaling 7.04 ha across eleven treatment polygons. In 2010, live stakes of black cottonwood and red-osier dogwood were excavator- and hand-planted in four treatment polygons totaling 3.17 ha.

In 2011, black cotton stakes were excavator- and hand-planted in three polygons (3.87 ha). Kellogg's sedge seedlings were planted at a small site interspersed between the black cottonwood live stakes (0.21 ha).

Summary of Planting Success

An assessment of CLBWORKS-2 planting survivorship in 2017 (Miller et al. 2018 draft) indicated moderate success rates for both Kellogg's sedge seedlings (50%) and black cottonwood stakes (40%) and high success for black cottonwood seedlings (100%) at 8 Mile. Survivorship for red-osier dogwood stakes was very low to nil. Note: "success rate" is defined here as the percentage of sample plots containing at least one surviving transplant.

Documents

Type	Year	Author	Short Title
Prescription	2005	Moody	Potential Areas for Vegetation Establishment in Arrow Reservoir
Prescription	2010	Keefer and Moody	Arrow Reservoir Planting Plan for 2010
Summary	2010	KES	Arrow Revegetation Report 2010
Prescription	2011	Keefer and Moody	Arrow Reservoir Planting Plan for 2011
Summary	2011	KES	Arrow Revegetation Report 2011
Monitoring	2017	Miller et al	Arrow Monitoring Report

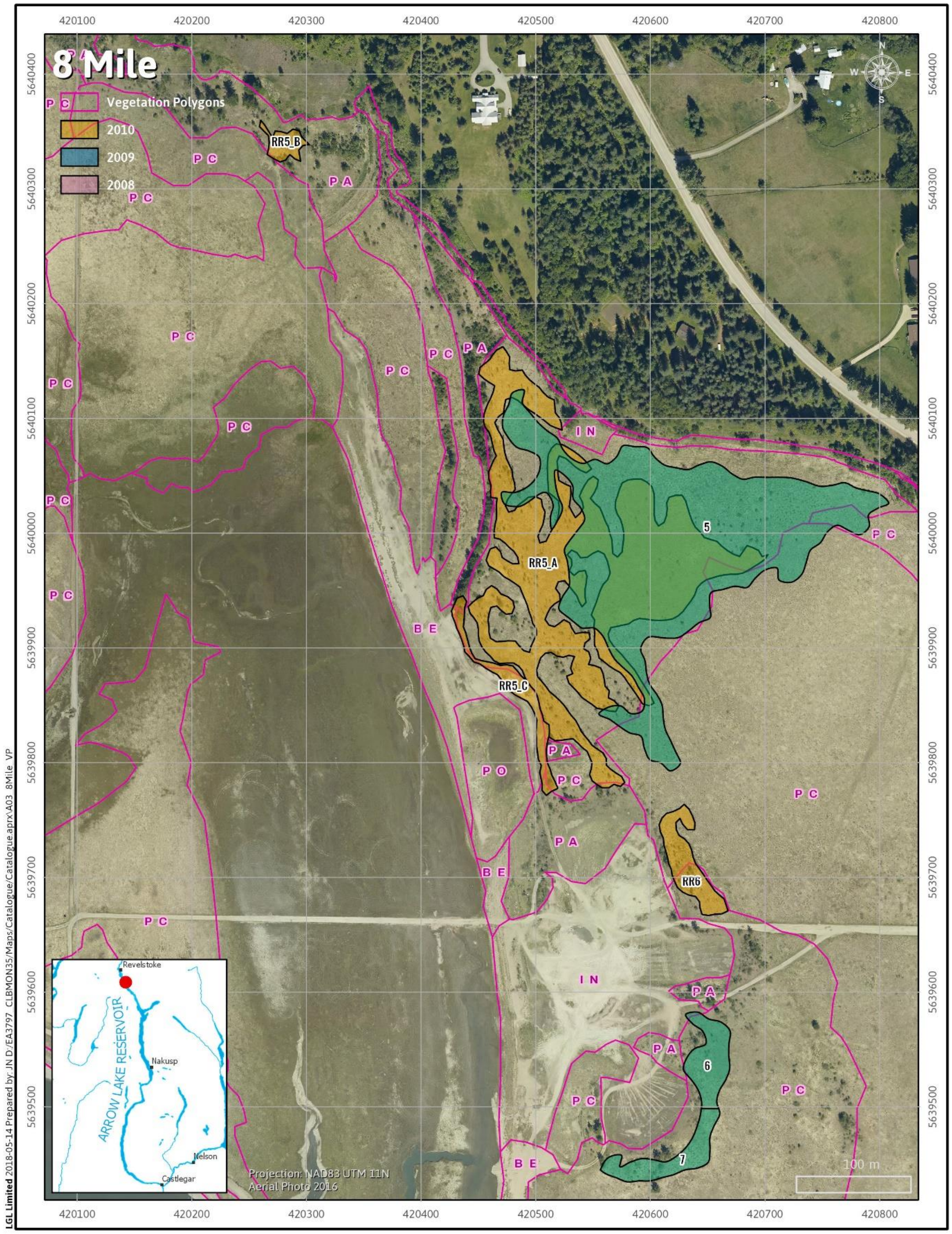
8 Mile Arrow Lakes Reservoir

Year 2010

MC#	Polygon	Elev	Treatment Type	Species	Density/Rate	Area (ha)
M1	RR5_A	438.59	shrub stake	black cottonwood	924 sph	2.70
M1	RR5_A	438.59	shrub stake	Red-osier Dogwood	63 sph	2.70
M1	RR5_B	438.89	shrub stake	black cottonwood	1257 sph	0.07
M1	RR5_C	438.27	shrub stake	black cottonwood	1414 sph	0.18
M1	RR6	438.54	shrub stake	black cottonwood	679 sph	0.22

Year 2011

MC#	Polygon	Elev	Treatment Type	Species	Density/Rate	Area (ha)
M1	5	438.41	shrub stake	black cottonwood	1124 sph	3.44
M1	6	438.11	shrub stake	black cottonwood	1125 sph	0.21
M1	7	438.16	shrub stake	black cottonwood	1127 sph	0.21
M1	7	438.16	graminoid seedling	Kellogg's sedge	2482 sph	0.21



Map 4-3. Distribution of revegetation treatment areas at 8 Mile, Arrow Lakes Reservoir, 2010 and 2011.

Figure 4-2. Examples of revegetation prescriptions trialed at 8 mile in 2010 and 2011. A through D: variable success of live staking. Photo credit: Mike Miller.

9 Mile Arrow Lakes Reservoir

Site Description:

9 Mile is located at the north end of the Arrow Lakes Reservoir in Revelstoke Reach. It is situated on the east side of the reservoir 13 km south of Revelstoke, B.C. near the 9-mile spit. Soils between McKay and Drimmie Creeks tended to be sandy or fine textured (silts and clays) and moderately well drained. (Keefer and Moody 2010)

Treatment prescriptions were developed in 2009 (Keefer and Ross 2009), 2010 (Keefer and Moody 2010), and 2011 (Keefer and Moody 2011). Planting was undertaken in 2009, 2010, and 2011 (Keefer et al 2009, KES 2010 and 2011).

Site information:

Reach	Revelstoke Reach
MC Unit	M1
UTM's	11U 420849 E 5639296 N
BEC	ICH mw 3
Vegetation Communities see Table 3-1	CR, IN, PC, PO, and SS
Area (ha)	13.94 / 18.68
Elevation (m)	Min: 437.6 Max: 439.3
# of Polygons:	14
Years:	2009, 2010, 2011

Treatment Summary

Plantings were undertaken in 2009 (7.63 ha), 2010 (5.83 ha), and 2011 (0.47 ha) totaling 13.04 ha across fourteen treatment polygons. In 2009, wool-grass, Columbia, Kellogg's, and water sedge seedlings plugs were planted in five polygons (6.78 ha), and black cottonwood and chokecherry seedlings were planted in two polygons (0.85 ha).

In 2010, Columbia, Kellogg's, and water sedge seedlings plugs were planted in two polygons (2.65 ha), black cottonwood seedlings were planted in two polygons (0.68 ha), and black cottonwood and red-osier dogwood live stakes were hand-planted planted in two polygons (2.51 ha).

In 2011, wool-grass, and Kellogg's sedge seedlings plugs were planted in two polygons (0.47 ha) and black cottonwood seedling plugs were planted in a single small polygon (0.06 ha).

Summary of Planting Success

An assessment of CLBWORKS-2 planting survivorship in 2017 (Miller et al. 2018 draft) indicated a moderate success rate for Kellogg's sedge seedlings (53%), high success for black cottonwood seedlings (100%), good success for black cottonwood stakes (75%), moderate success for red-osier dogwood stakes (33%), and low success for Columbia sedge seedlings (9%). Survivorship of water sedge and wool-grass seedlings was very low to nil. The survival rate of chokecherry seedlings was not reported. Note: "success rate" is defined here as the percentage of sample plots containing at least one surviving transplant.

Documents

Type	Year	Author	Short Title
Prescription	2005	Moody	Potential Areas for Vegetation Establishment in Arrow Reservoir
Prescription	2009	Keefer and Ross	Arrow Reservoir Planting Plan for 2009
Summary	2009	Keefer et al	Arrow Revegetation Report 2009
Prescription	2010	Keefer and Moody	Arrow Reservoir Planting Plan for 2010
Summary	2010	KES	Arrow Revegetation Report 2010
Prescription	2011	Keefer and Moody	Arrow Reservoir Planting Plan for 2011
Summary	2011	KES	Arrow Revegetation Report 2011
Monitoring	2017	Miller et al	Arrow Monitoring Report

9 Mile Arrow Lakes Reservoir

Year 2009

MC#	Polygon	Elev	Treatment Type	Species	Density/Rate	Area (ha)
M1	66	434.00	graminoid seedling	water sedge	sph	0.31
M1	66	434.00	graminoid seedling	wool-grass	sph	0.31
M1	67	438.96	shrub seedling	Chokecherry	12083 sph	0.07
M1	68	437.52	shrub seedling	black cottonwood	4145 sph	0.77
M1	69	433.83	graminoid seedling	water sedge	sph	1.57
M1	69	433.83	graminoid seedling	wool-grass	sph	1.57
M1	70	435.18	graminoid seedling	water sedge	sph	0.20
M1	70	435.18	graminoid seedling	wool-grass	sph	0.20
M1	71	435.52	graminoid seedling	mixed graminoid species	13925 sph	0.92
M1	72	437.08	graminoid seedling	mixed graminoid species	13925 sph	3.79

Year 2010

MC#	Polygon	Elev	Treatment Type	Species	Density/Rate	Area (ha)
M1	RR7	434.57	graminoid seedling	water sedge	4031 sph	2.46
M1	RR8	437.83	shrub stake	black cottonwood	441 sph	2.41
M1	RR8	437.83	shrub stake	Red-osier Dogwood	147 sph	2.41
M1	RR13	436.01	graminoid seedling	Kellogg's sedge	10080 sph	0.19
M1	RR13	436.01	graminoid seedling	Columbia sedge	8181 sph	0.19
M1	RR14	437.91	shrub seedling	black cottonwood	6343 sph	0.68
M1	RR15	440.00	shrub stake	Red-osier Dogwood	1034 sph	0.10

Year 2011

MC#	Polygon	Elev	Treatment Type	Species	Density/Rate	Area (ha)
M1	8	433.28	graminoid seedling	wool-grass	12175 sph	0.41
M1	9	439.05	graminoid seedling	Kellogg's sedge	39789 sph	0.06
M1	9	439.05	shrub seedling	black cottonwood	13341 sph	0.06

Map 4-4. Distribution of revegetation treatment areas at 9 Mile, Arrow Lakes Reservoir, 2009, 2010 and 2011.

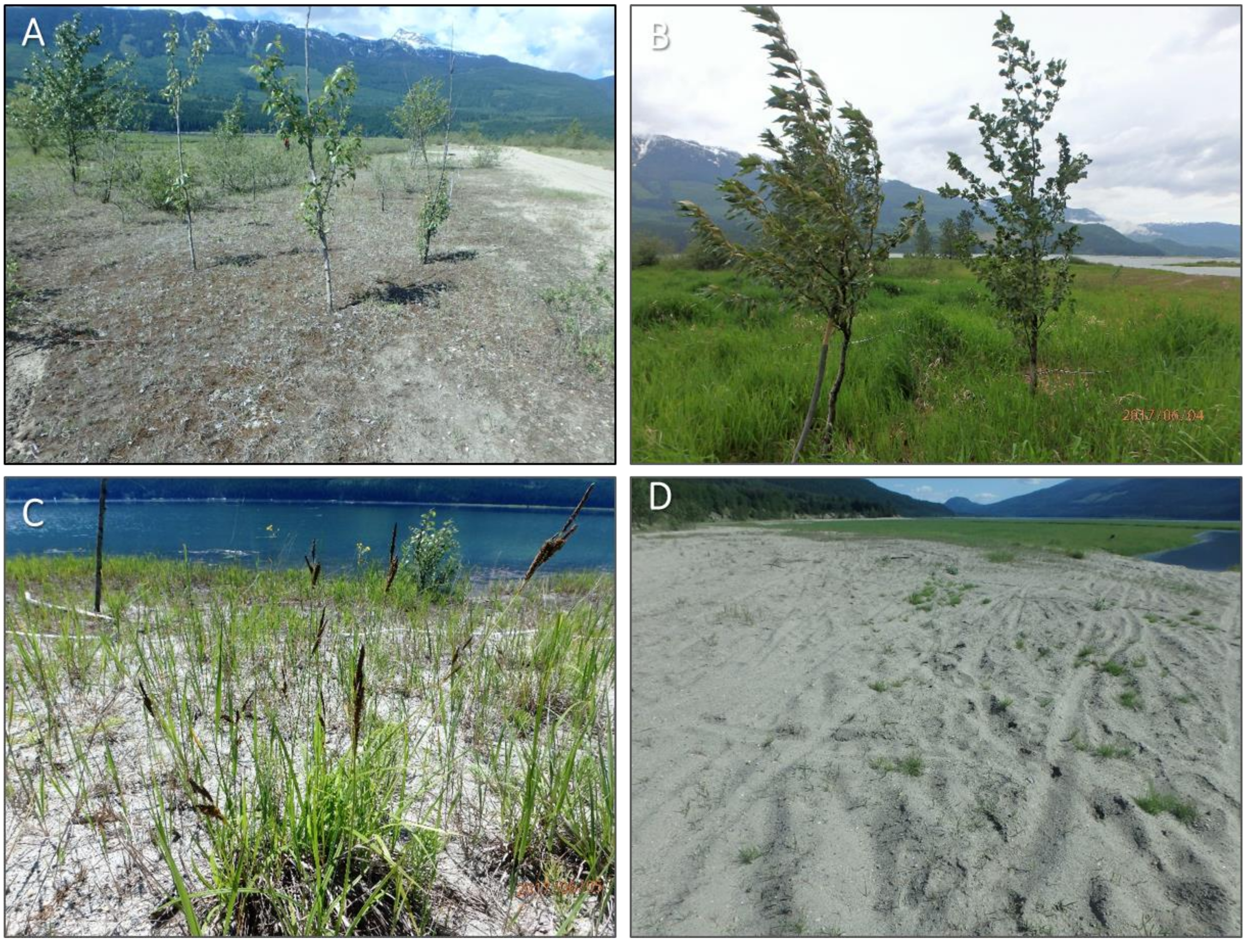


Figure 4-3. Examples of revegetation prescriptions trialed at 9 mile in 2009 and 2010. A and B: live staking; C and D: sedge seedlings. Photo credit: Mike Miller.

Drimmie Creek — Arrow Lakes Reservoir

Site Description:

Drimmie Creek (12 mile) is located in Revelstoke Reach at the north end of the Arrow Lakes Reservoir. It is situated on the east side of the reservoir 17 km south of Revelstoke, B.C. Soils between McKay and Drimmie Creeks tended to be sandy or fine textured (silts and clays) and moderately well drained (Keefer and Moody 2010).

Treatment prescriptions were developed in 2009 (Keefer and Ross 2009), and 2010 (Keefer and Moody 2010). Planting occurred in 2009 and 2010 (Keefer et al 2009, and KES 2010).

Site information:

Reach	Revelstoke Reach
MC Unit	P
UTM's	11U 422311 E 5634984 N
BEC	ICH mw 3
Vegetation Communities see Table 3-1	BE, PA, PC, and RS
Area (ha)	6.49 / 8.10
Elevation (m)	Min: 432.3 Max: 439.3
# of Polygons:	22
Years:	2009, 2010

Treatment Summary

Plantings were undertaken in 2009 (3.59 ha) and 2010 (2.90 ha) totaling 6.49 ha across twenty-two treatment polygons. In 2009, Columbia, Kellogg's, and water sedge seedlings plugs were planted in thirteen polygons (2.54 ha); black cottonwood seedlings were planted in four polygons (1.60 ha). In 2010, live black cottonwood and red-osier dogwood stakes were excavator and hand-planted planted in four polygons (2.37 ha). Two modified brush layers were installed using black cottonwood stakes.

Summary of Planting Success

An assessment of CLBWORKS-2 planting survivorship in 2017 (Miller et al. 2018 draft) indicated high success rates for black cottonwood and Kellogg's sedge seedlings (100%), Columbia sedge seedlings (90%), and black cottonwood stakes (91%). The vigour of established black cottonwood stakes was exceptionally high at this site. Survivorship for water sedge seedlings and red-osier dogwood stakes was very low to nil. Note: "success rate" is defined here as the percentage of sample plots containing at least one surviving transplant.

Documents

Type	Year	Author	Short Title
Prescription	2005	Moody	Potential Areas for Vegetation Establishment in Arrow Reservoir
Prescription	2009	Keefer and Ross	Arrow Reservoir Planting Plan for 2009
Summary	2009	Keefer et al.	Arrow Revegetation Report 2009
Prescription	2010	Keefer and Moody	Arrow Reservoir Planting Plan for 2010
Summary	2010	KES	Arrow Revegetation Report 2010
Monitoring	2017	Miller et al.	Arrow Monitoring Report

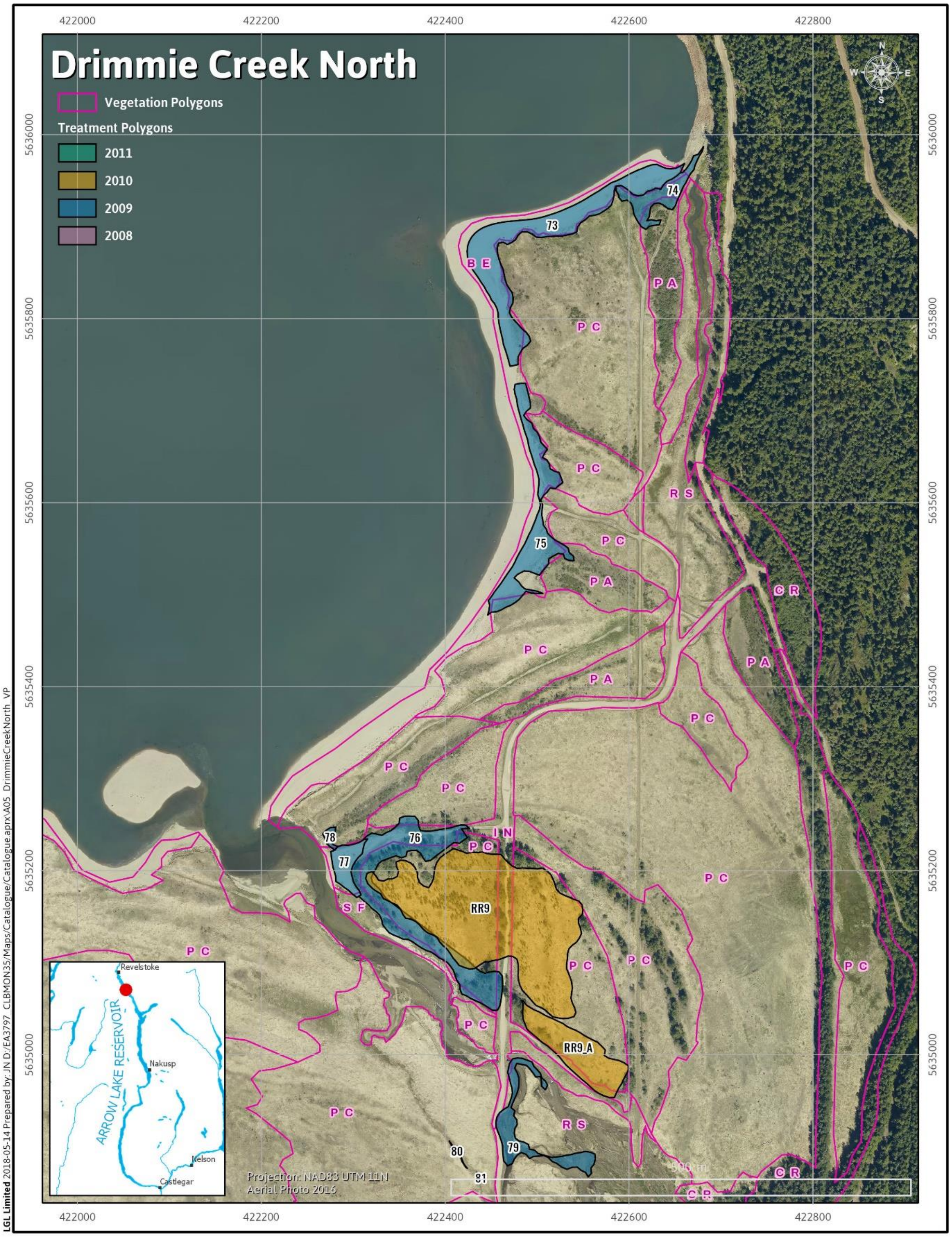
Drimmie Creek Arrow Lakes Reservoir

Year 2009

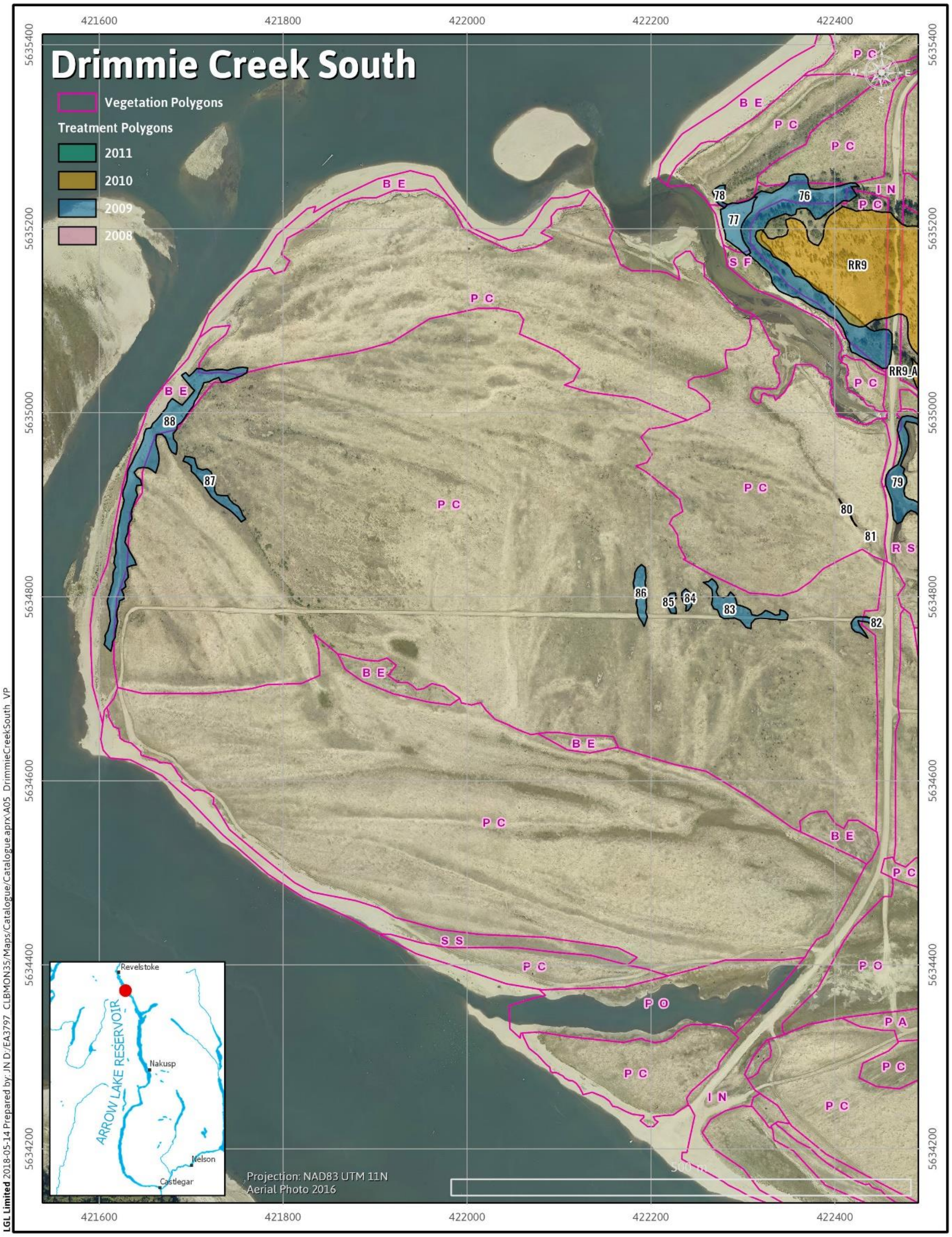
MC#	Polygon	Elev	Treatment Type	Species	Density/Rate	Area (ha)
P	73	435.01	graminoid seedling	Kellogg's sedge	10756 sph	0.80
P	73	435.01	graminoid seedling	Columbia sedge	6109 sph	0.80
P	74	436.30	shrub seedling	black cottonwood	614 sph	0.19
P	75	434.35	graminoid seedling	Kellogg's sedge	10756 sph	0.48
P	75	434.35	graminoid seedling	Columbia sedge	6109 sph	0.48
P	76	437.85	shrub seedling	black cottonwood	614 sph	0.84
P	77	436.89	graminoid seedling	Kellogg's sedge	10756 sph	0.12
P	77	436.89	graminoid seedling	Columbia sedge	6109 sph	0.12
P	78	436.16	shrub seedling	black cottonwood	614 sph	0.02
P	79		graminoid seedling	water sedge	3396 sph	0.26
P	80	434.07	graminoid seedling	water sedge	3396 sph	0.00
P	81		graminoid seedling	water sedge	3396 sph	0.00
P	82	435.89	graminoid seedling	Kellogg's sedge	10756 sph	0.03
P	82	435.89	graminoid seedling	Columbia sedge	6109 sph	0.03
P	83	436.45	graminoid seedling	Columbia sedge	6109 sph	0.13
P	84	436.35	graminoid seedling	Columbia sedge	6109 sph	0.02
P	85	436.23	graminoid seedling	Columbia sedge	6109 sph	0.01
P	86	436.11	graminoid seedling	Columbia sedge	6109 sph	0.06
P	87	436.69	graminoid seedling	Kellogg's sedge	10756 sph	0.09
P	87	436.69	graminoid seedling	Columbia sedge	6109 sph	0.09
P	88	435.27	shrub seedling	black cottonwood	614 sph	0.54
P	88	435.27	graminoid seedling	Kellogg's sedge	10756 sph	0.54

Year 2010

MC#	Polygon	Elev	Treatment Type	Species	Density/Rate	Area (ha)
P	RR9	438.01	shrub stake	black cottonwood	771 sph	2.17
P	RR10	437.92	shrub stake	Red-osier Dogwood	5417 sph	0.01
P	RR11	438.91	shrub stake	black cottonwood	1734 sph	0.09
P	RR11	438.91	shrub stake	black cottonwood	sph	0.09
P	RR11	437.97	shrub stake	black cottonwood	3432 sph	0.11
P	RR12	440.16	shrub stake	black cottonwood	sph	0.09



Map 4-5. Distribution of revegetation treatment areas at Drimmie Creek North, Arrow Lakes Reservoir, 2009 and 2010.



Map 4-6. **Distribution of revegetation treatment areas at Drimmie Creek South, Arrow Lakes Reservoir, 2009 and 2010.** RR9_A indicates an untreated archeology polygon.

Figure 4-4. Examples of revegetation prescriptions trialed at Drimmie Creek in 2009 and 2010. A: sedge seedling; B–C: live staking. Photo credit: Mike Miller.

Beaton Arrow Lakes Reservoir

Site Description:

The Beaton site is located at the east end of Beaton Arm in the Arrow Lakes Reservoir near the mouth of the Incomappleux River. Substrates were sand and gravel with high amount of wood debris (Keefer and Moody 2011).

Draft treatment prescriptions were developed in 2011 (Keefer and Moody 2011). Planting was undertaken in 2011 (KES 2011).

Site information:

Reach	Beaton Arm
MC Unit	Site 1
UTM's	11U 448961 E 5621497 N
BEC	ICH wk 1
Vegetation Communities see Table 3-1	BE, BG, LO, and PC
Area (ha)	1.46 / 1.46
Elevation (m)	Min: 435.3 Max: 438.0
# of Polygons:	3
Years:	2011

Treatment Summary

Plantings were undertaken in 2011 in three treatment polygon totaling 1.46 ha. Kellogg's sedge seedling plugs were planted in a single 1.17 ha polygon. Black cottonwood seedlings plugs were planted in two small polygons (0.29 ha)

Summary of Planting Success

The success of these plantings has not been recently documented. In 2015, there were no surviving sedge plugs observed in the single location sampled (Miller et al. 2016). Black cottonwood seedlings were not assessed in 2015.

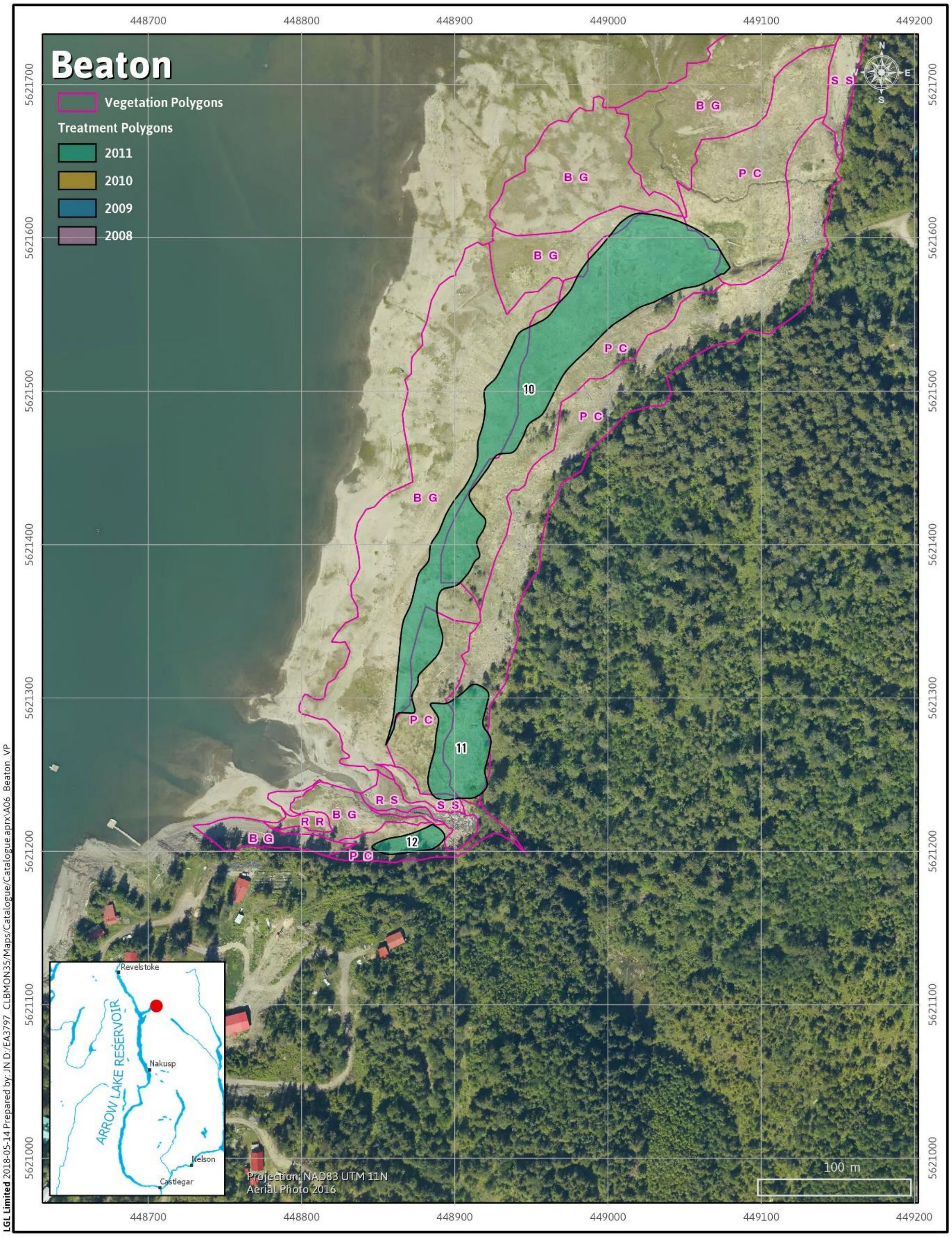
Documents

Type	Year	Author	Short Title
Prescription	2011	Keefer and Moody	Arrow Reservoir Planting Plan for 2011
Summary	2011	KES	Arrow Revegetation Report 2011

Beaton Arrow Lakes Reservoir

Year 2011

MC#	Polygon	Elev	Treatment Type	Species	Density/Rate	Area (ha)
A 1	10	436.64	graminoid seedling	Kellogg's sedge	8211 sph	1.17
A 1	11	438.96	shrub seedling	black cottonwood	5551 sph	0.24
A 1	12	437.78	shrub seedling	black cottonwood	5543 sph	0.05



Map 4-7. Distribution of revegetation treatment areas at Beaton, Arrow Lakes Reservoir, 2011.

Nakusp Arrow Lakes Reservoir

Site Description:

Five treatment polygons were planted in the Arrow Lakes Reservoir at Nakusp. Sites planted in 2008 were located at the end of Kuskanax Rd and a site planted in 2009 is located at south side of Kuskanax Creek near 10th Avenue NW. Soils at the 2008 sites were characterized as silty sand to sandy in texture (Keefer et al 2008). Soils at the 2009 sites was characterized as course textured sand and gravel (Moody 2005).

Seedling planting trials were undertaken in 2008 (Keefer and Ross 2008, Keefer et al 2008). Planting prescriptions were prepared and implemented in 2009 (Keefer and Ross 2009, Keefer et al 2009).

Site information:

Reach	Mid-Arrow
MC Unit	Site 5 A and B
UTM's	11U 441374 E 5566130 N
BEC	ICH mw 2
Vegetation Communities see Table 3-1	BE, BG, CR, IN, PE, and RR
Area (ha)	7.73 / 22.42
Elevation (m)	Min: 437.9 Max: 439.3
# of Polygons:	5
Years:	2008, 2009

Treatment Summary

Kellogg's sedge seedling plugs were planted and fertilized in the fall of 2008 in four trial polygons totaling 0.26 ha at the end of Kuskanax Rd. In 2009, seedling plugs of bluejoint reedgrass, and Columbia and Kellogg's sedge were planted in a single 7.47 ha polygon at the mouth of Kuskanax Creek. Following planting in 2009, fertilizer (16-20-12-7% S blend granular) was applied using a quad at rate of 370 kg/ha.

Summary of Planting Success

An assessment of CLBWORKS-2 planting survivorship in 2017 (Miller et al. 2018 draft) indicated a high success rates for Kellogg's sedge seedlings (100 %). Survivorship for Columbia sedge was nil. Survival of bluejoint reedgrass was not reported. Note: "success rate" is defined here as the percentage of sample plots containing at least one surviving transplant.

Documents

Type	Year	Author	Short Title
Prescription	2005	Moody	Potential Areas for Vegetation Establishment in Arrow Reservoir
Prescription	2008	Keefer and Ross	Arrow Reservoir Experimental Design 2008
Summary	2008	Keefer et al	Arrow Revegetation Report 2008
Prescription	2009	Keefer and Ross	Arrow Reservoir Planting Plan for 2009
Summary	2009	Keefer et al	Arrow Revegetation Report 2009
Monitoring	2017	Miller et al	Arrow Monitoring Report

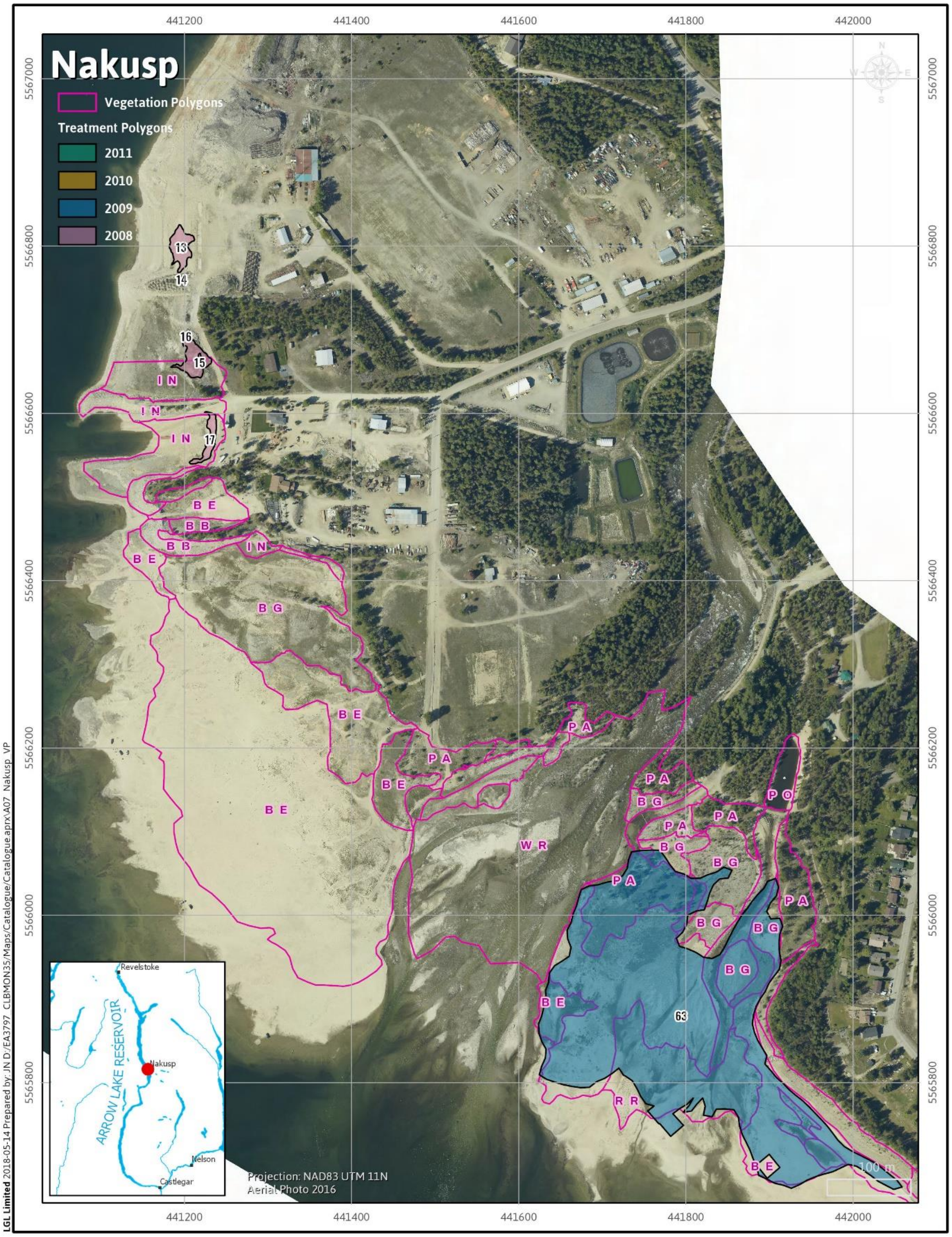
Nakusp Arrow Lakes Reservoir

Year 2008

MC#	Polygon	Elev	Treatment Type	Species	Density/Rate	Area (ha)
A 5A	13	438.50	graminoid seedling	Kellogg's sedge	19068 sph	0.09
A 5A	14	438.27	graminoid seedling	Kellogg's sedge	19068 sph	0.00
A 5A	15	438.94	graminoid seedling	Kellogg's sedge	19068 sph	0.00
A 5A	16	438.76	graminoid seedling	Kellogg's sedge	19068 sph	0.10
A 5A	17	438.40	graminoid seedling	Kellogg's sedge	19068 sph	0.06
A 5A	17	438.40	graminoid seedling	Columbia sedge	7813 sph	0.06

Year 2009

MC#	Polygon	Elev	Treatment Type	Species	Density/Rate	Area (ha)
A 5B	63	435.79	graminoid seedling	Kellogg's sedge	4195 sph	7.47
A 5B	63	435.79	graminoid seedling	Columbia sedge	3131 sph	7.47
A 5B	63	435.79	graminoid seedling	bluejoint reedgrass	482 sph	7.47
A 5B	63	435.79	Fertilizer	Fertilizer	370 kg/ha	7.47



Map 4-8. Distribution of revegetation treatment areas at Nakusp, Arrow Lakes Reservoir, 2009.

Figure 4-5. Examples of revegetation prescriptions trialed at Nakusp in 2009. Graminoid seedlings were planted in all areas photographed. Photo credit: Mike Miller.

Arrow Park

Arrow Lakes Reservoir

Site Description:

Arrow Park is located in the west side of the Arrow Lake Reservoir and is accessed from a ferry 22 km south of Nakusp on Highway 23. Treatment polygons extend from McDonald Creek Provincial Park, 5 km north of the ferry crossing, to 500 m south of the ferry crossing. Soils were characterized as mixed sand, clay, gravels, and cobbles (Keefer and Moody 2011).

Treatment prescriptions were developed in 2009 (Keefer and Ross 2009) and 2011 (Keefer and Moody 2011) followed by planting in those years (Keefer et al 2009, KES 2011).

Site information:

Reach	Mid-Arrow
MC Unit	Site 7
UTM's	11U 438193 E 5551718 N
BEC	ICH mw 2
Vegetation Communities see Table 3-1	BE, LO, PA, PC, RS, and SS
Area (ha)	8.55 / 12.88
Elevation (m)	Min: 431.6 Max: 437.1
# of Polygons:	13
Years:	2009, 2011

Treatment Summary

Plantings were undertaken in 2009 (2.77 ha), and 2011 (5.87 ha) totaling 8.55 ha across thirteen treatment polygons. In 2009, small-flowered bulrush, and Columbia and water sedge seedlings plugs were planted in three polygons (1.17 ha). In three polygons (1.59 ha), black cottonwood, red-osier dogwood, and willow live stakes were hand planted; modified brush layers of black cottonwood stakes were installed in each of these polygons.

In 2011, bluejoint reedgrass, wool-grass, and Kellogg's sedge seedling plugs were planted in 5.67 ha in six polygons; black cottonwood and red-osier dogwood seedlings were planted in one polygon (0.13 ha).

Summary of Planting Success

An assessment of CLBWORKS-2 planting survivorship in 2017 (Miller et al. 2018 draft) indicated a high success rate for Kellogg's sedge (100%), moderate success for Columbia sedge (66%), and low success for black cottonwood stakes (11%), and willow (10%). There was no evidence of small-flowered bulrush, water sedge, or red-osier dogwood survival. The survival rate for bluejoint reedgrass seedling plugs was not reported. Note: "success rate" is defined here as the percentage of sample plots containing at least one surviving transplant.

Documents

Type	Year	Author	Short Title
Prescription	2005	Moody	Potential Areas for Vegetation Establishment in Arrow Reservoir
Prescription	2009	Keefer and Ross	Arrow Reservoir Planting Plan for 2009
Summary	2009	Keefer et al	Arrow Revegetation Report 2009
Prescription	2011	Keefer and Moody	Arrow Reservoir Planting Plan for 2011
Summary	2011	KES	Arrow Revegetation Report 2011
Monitoring	2017	Miller et al	Arrow Monitoring Report

Arrow Park

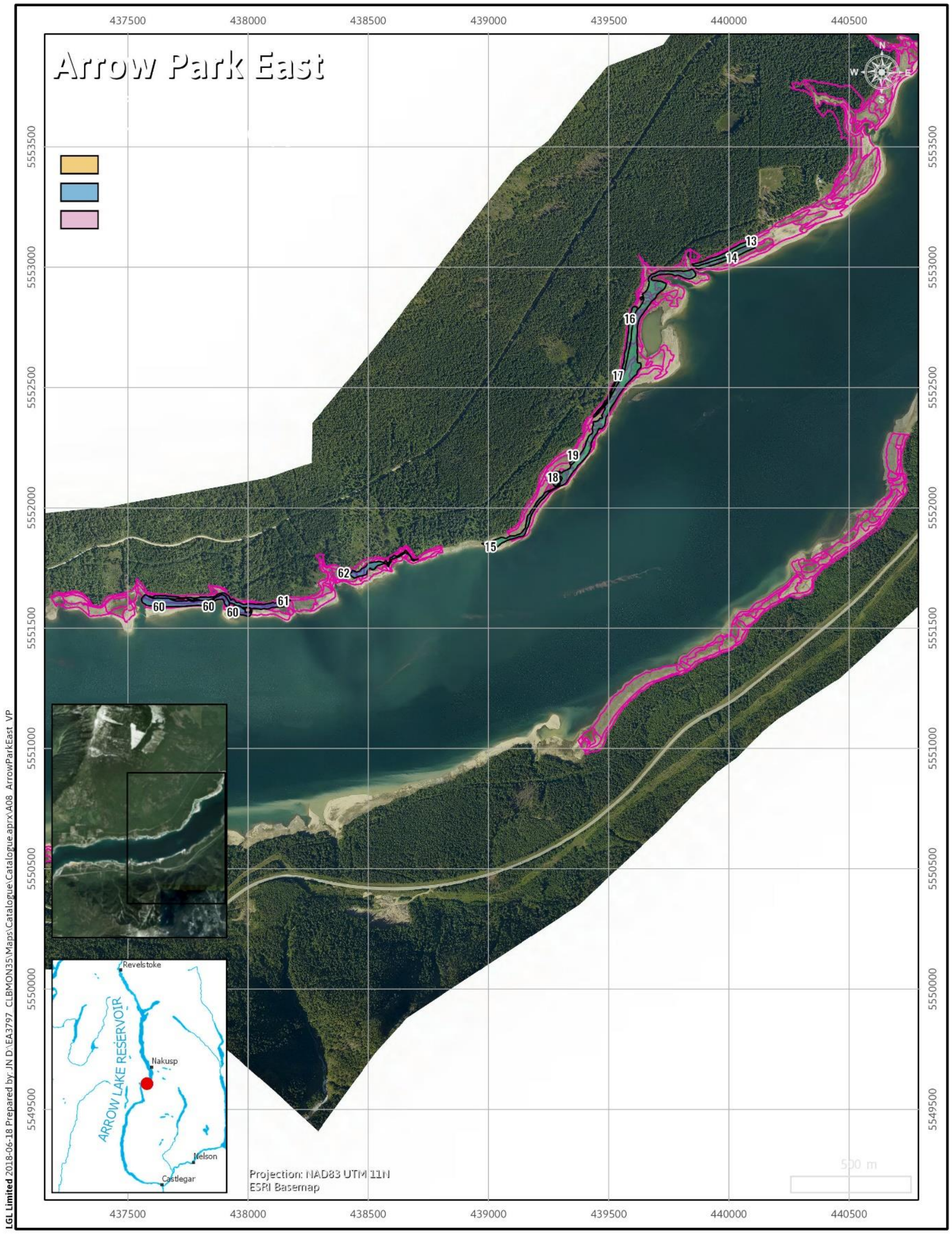
Arrow Lakes Reservoir

Year 2009

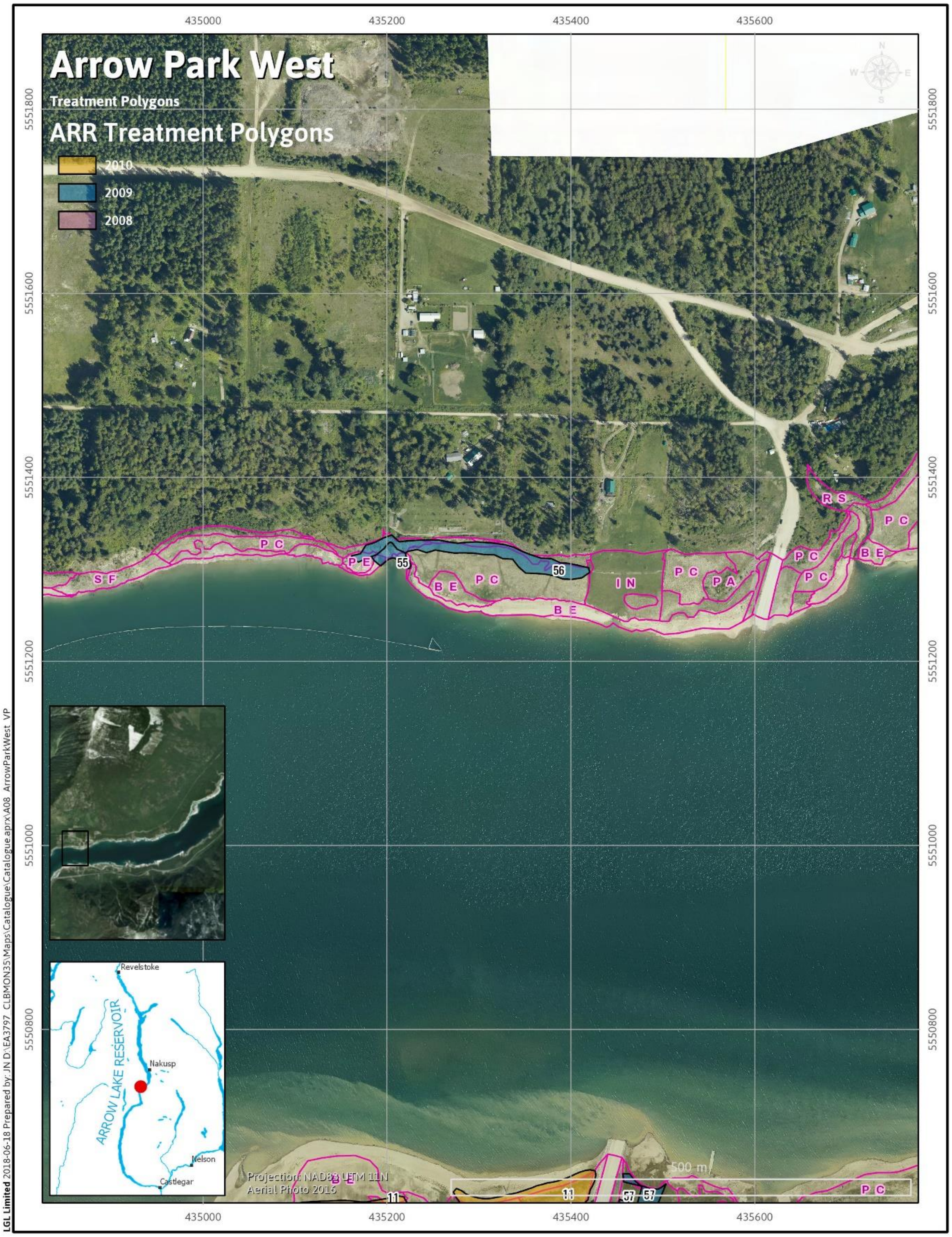
MC#	Polygon	Elev	Treatment Type	Species	Density/Rate	Area (ha)
A 7	?		graminoid seedling	small-flowered bulrush	sph	
A 7H	60	435.31	graminoid seedling	Columbia sedge	9249 sph	1.12
A 7H	61	438.28	shrub stake	black cottonwood	1189 sph	0.77
A 7H	61	438.28	shrub stake	willow sp.	209 sph	0.77
A 7H	61	438.28	shrub stake	Red-osier Dogwood	175 sph	0.77
A 7H	61	438.28	shrub stake	black cottonwood	sph	0.77
A 7H	62	436.87	shrub stake	black cottonwood	1189 sph	0.48
A 7H	62	436.87	shrub stake	willow sp.	209 sph	0.48
A 7H	62	436.87	shrub stake	Red-osier Dogwood	175 sph	0.48
A 7H	62	436.87	shrub stake	black cottonwood	sph	0.48
A 7J	55	434.55	graminoid seedling	water sedge	64680 sph	0.05
A 7J	56	438.52	shrub stake	black cottonwood	1189 sph	0.34
A 7J	56	438.52	shrub stake	willow sp.	209 sph	0.34
A 7J	56	438.52	shrub stake	Red-osier Dogwood	175 sph	0.34
A 7J	56	438.52	shrub stake	black cottonwood	sph	0.34

Year 2011

MC#	Polygon	Elev	Treatment Type	Species	Density/Rate	Area (ha)
A 7F	13	438.45	graminoid seedling	Kellogg's sedge	10368 sph	0.38
A 7F	13	438.45	graminoid seedling	bluejoint reedgrass	4033 sph	0.38
A 7F	14	436.87	graminoid seedling	Kellogg's sedge	8812 sph	0.47
A 7F	15	436.08	graminoid seedling	Kellogg's sedge	8797 sph	4.02
A 7F	16	438.41	graminoid seedling	Kellogg's sedge	10366 sph	0.54
A 7F	16	438.41	graminoid seedling	bluejoint reedgrass	4034 sph	0.54
A 7F	17	438.79	shrub seedling	Red-osier Dogwood	4669 sph	0.13
A 7F	17	438.79	shrub seedling	willow sp.	1964 sph	0.13
A 7F	18	435.57	graminoid seedling	wool-grass	9268 sph	0.16
A 7F	19	438.59	graminoid seedling	Kellogg's sedge	10371 sph	0.08
A 7F	19	438.59	graminoid seedling	bluejoint reedgrass	4031 sph	0.08



Map 4-9. Distribution of revegetation treatment areas at Arrow Park East, Arrow Lakes Reservoir, 2009 and 2011.



Map 4-10. Distribution of revegetation treatment areas at Arrow Park West, Arrow Lakes Reservoir, 2009.

Figure 4-6. **Examples of revegetation prescriptions trialed at Arrow Park in 2009 and 2010.** A, B: live stakes; C to E: sedge seedlings; F: wool-grass. Photo credit: Mike Miller.

East Arrow Park

Arrow Lakes Reservoir

Site Description:

East Arrow Park treatment polygons are located on the east side of the Arrow Lake Reservoir. They begin at the Arrow Park Ferry crossing, 22 km south of Nakusp on Highway 23, and extend south 5 km to Makinson along the reservoir shoreline. Soils were characterized as mixed sand, clay, gravels and cobbles and rapidly drained (Keefer and Ross 2009, Keefer and Moody 2011).

Treatment prescriptions were developed in 2009 (Keefer and Ross 2009) and 2011 (Keefer and Moody 2011) with planting in those two years (Keefer et al 2009, KES 2011).

Site information:

Reach	Mid-Arrow
MC Unit	Site 8
UTM's	11U 433811 E 5549541 N
BEC	ICH dw 1
Vegetation Communities see Table 3-1	BE, CR, IN, LO, PA, PC, and SS
Area (ha)	16.68 / 27.86
Elevation (m)	Min: 436.5 Max: 440.0
# of Polygons:	31
Years:	2009, 2010

Treatment Summary

Plantings were undertaken in 2009 (12.66 ha) and 2010 (4.02 ha) totaling 16.68 ha across thirty-one treatment polygons. In 2009, seven seeding trials (1.38 ha) were undertaken using BC Hydro upland and wetland seed mixes; 9.63 ha were planted in eleven polygons with bluejoint reedgrass, wool-grass, Columbia sedge, Kellogg's sedge, and water sedge seedling plugs; and 1.65 ha were hand planted in six polygons with black cottonwood, red-osier dogwood, and willow stakes. Following planting in 2009, fertilizer (16-20-12-7% S blend granular) was applied to planted sites using a quad at rate of 370 kg/ha.

In 2010, seven treatment polygons (4.02 ha) were planted with Columbia and Kellogg's sedge seedlings plugs.

Summary of Planting Success

Local residents pulled approximately 90% of the live stakes planted in East Arrow park in 2009, resulting in poor survival and low establishment in some sites (Keefer et al 2009). An assessment of CLBWORKS-2 planting survivorship in 2017 (Miller et al. 2018 draft) indicated good success rates for Kellogg's sedge and Columbia sedge seedlings (74%), good success for wool-grass seedlings (100 %), and nil success for small-flowered bulrush and water sedge. The survival of bluejoint reedgrass seedlings and establishment of seeding trials were not reported. Note: "success rate" is defined here as the percentage of sample plots containing at least one surviving transplant.

Documents

Type	Year	Author	Short Title
Prescription	2005	Moody	Potential Areas for Vegetation Establishment in Arrow Reservoir
Prescription	2009	Keefer and Ross	Arrow Reservoir Planting Plan for 2009
Summary	2009	Keefer et al	Arrow Revegetation Report 2009
Prescription	2010	Keefer and Moody	Arrow Reservoir Planting Plan for 2010
Summary	2010	KES	Arrow Revegetation Report 2010
Monitoring	2017	Miller et al	Arrow Monitoring Report

East Arrow Park Arrow Lakes Reservoir

Year 2009

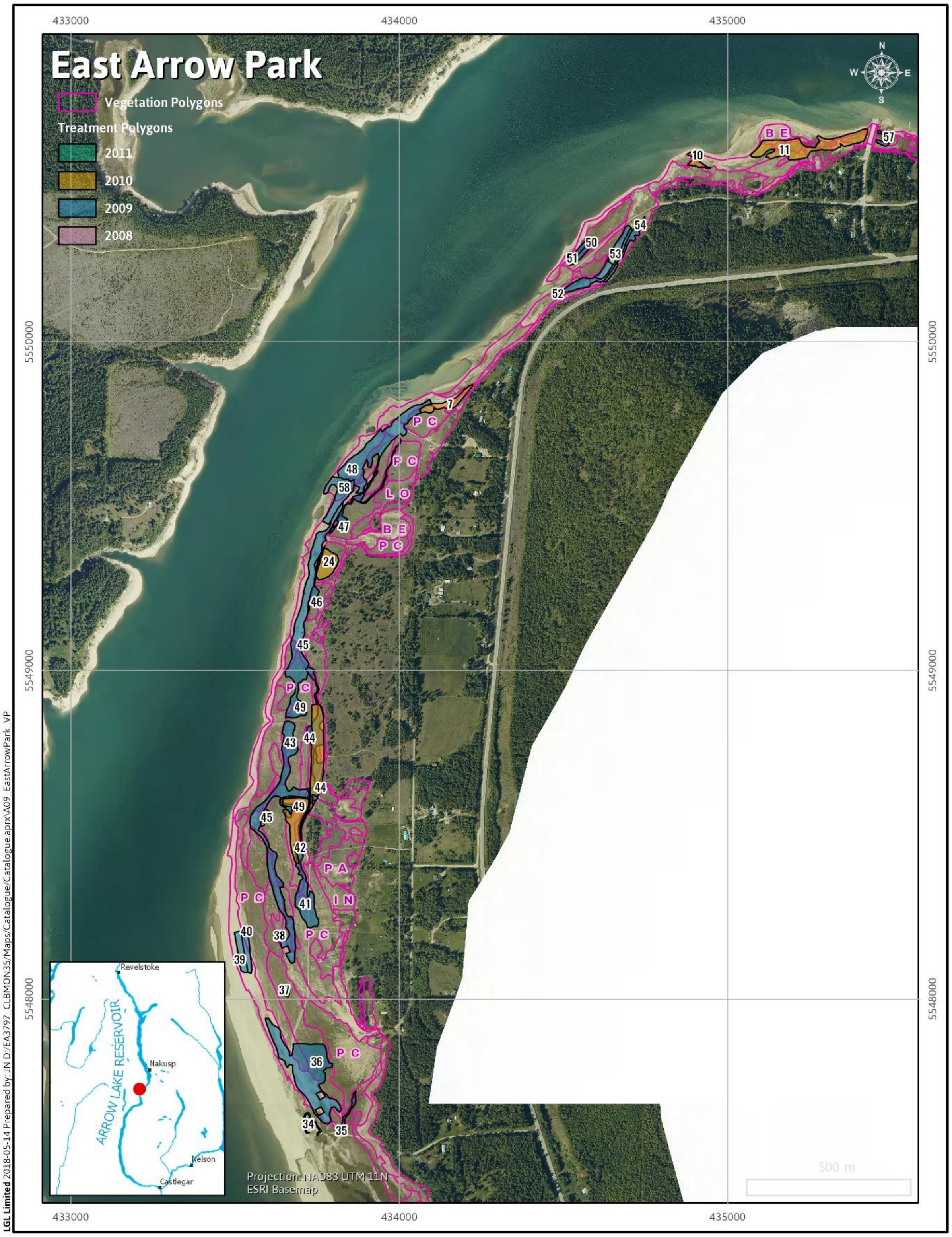
MC#	Polygon	Elev	Treatment Type	Species	Density/Rate	Area (ha)
A 8D	50	434.52	graminoid seed	BC Hydro upland seed mix	kg/ha	0.11
A 8D	51	434.54	graminoid seed	Kellogg's sedge	kg/ha	0.09
A 8D	52	436.37	graminoid seed	BC Hydro upland seed mix	kg/ha	0.37
A 8D	53	436.61	graminoid seed	BC Hydro upland seed mix	kg/ha	0.32
A 8D	54	439.11	shrub stake	Red-osier Dogwood	42 sph	0.21
A 8F	34	433.17	graminoid seedling	water sedge	3114 sph	0.05
A 8F	35	433.61	graminoid seedling	water sedge	3114 sph	0.09
A 8F	36	434.09	graminoid seedling	mixed graminoid species	11729 sph	2.31
A 8F	37	433.62	graminoid seedling	mixed graminoid species	11729 sph	0.07
A 8F	38	435.61	graminoid seed	Columbia sedge	kg/ha	0.02
A 8F	39	434.78	graminoid seed	Kellogg's sedge	kg/ha	0.24
A 8F	40	434.68	graminoid seed	BC Hydro wetland seed mix	kg/ha	0.22
A 8F	41	436.84	graminoid seedling	Columbia sedge	1920 sph	0.74
A 8F	42	438.66	graminoid seedling	Columbia sedge	1920 sph	0.20
A 8F	43	436.19	graminoid seedling	Kellogg's sedge	8736 sph	2.12
A 8F	44	437.79	shrub stake	black cottonwood	1290 sph	0.79
A 8F	44	437.79	shrub stake	willow sp.	260 sph	0.79
A 8F	44	437.79	shrub stake	Red-osier Dogwood	42 sph	0.79
A 8F	45	438.56	shrub stake	black cottonwood	1290 sph	0.01
A 8F	45	438.56	shrub stake	willow sp.	260 sph	0.01
A 8F	45	438.56	shrub stake	Red-osier Dogwood	42 sph	0.01
A 8F	46	438.44	shrub stake	black cottonwood	1290 sph	0.14
A 8F	46	438.44	shrub stake	willow sp.	260 sph	0.14
A 8F	46	438.44	shrub stake	Red-osier Dogwood	42 sph	0.14
A 8F	47	438.67	shrub stake	black cottonwood	1290 sph	0.28
A 8F	47	438.67	shrub stake	willow sp.	260 sph	0.28
A 8F	47	438.67	shrub stake	Red-osier Dogwood	42 sph	0.28
A 8F	48	436.38	graminoid seedling	Columbia sedge	1920 sph	1.59
A 8F	48	436.38	graminoid seedling	Kellogg's sedge	8736 sph	1.59
A 8F	49	436.92	graminoid seedling	Kellogg's sedge	8736 sph	1.80
A 8F	49	436.92	graminoid seedling	Columbia sedge	1920 sph	1.80
A 8F	54	439.11	shrub stake	black cottonwood	1290 sph	0.21
A 8F	54	439.11	shrub stake	willow sp.	260 sph	0.21
A 8F	57	434.98	graminoid seedling	water sedge	3114 sph	0.10
A 8F	58	435.52	graminoid seedling	Kellogg's sedge	8736 sph	0.56
A 8F	58	435.52	graminoid seedling	Columbia sedge	1920 sph	0.56

MC#	Polygon	Elev	Treatment Type	Species	Density/Rate	Area (ha)
A 8F	58	435.52	graminoid seedling	water sedge	3114 sph	0.56

East Arrow Park Arrow Lakes Reservoir

Year 2010

MC#	Polygon	Elev	Treatment Type	Species	Density/Rate	Area (ha)
A 8C	10	434.86	graminoid seedling	Kellogg's sedge	8995 sph	0.13
A 8C	10	434.86	graminoid seedling	Columbia sedge	7299 sph	0.13
A 8C	11	435.19	graminoid seedling	Kellogg's sedge	17762 sph	1.31
A 8C	11	435.19	graminoid seedling	Columbia sedge	17762 sph	1.31
A 8F	7	437.71	graminoid seedling	Kellogg's sedge	7112 sph	0.32
A 8F	7	437.71	graminoid seedling	Columbia sedge	5774 sph	0.32
A 8F	24	437.69	graminoid seedling	Kellogg's sedge	4941 sph	0.41
A 8F	24	437.69	graminoid seedling	Columbia sedge	4012 sph	0.41
A 8F	44	437.87	graminoid seedling	Kellogg's sedge	6890 sph	1.03
A 8F	44	437.87	graminoid seedling	Columbia sedge	5594 sph	1.03
A 8F	45	436.25	graminoid seedling	Kellogg's sedge	8720 sph	0.08
A 8F	45	436.25	graminoid seedling	Columbia sedge	7085 sph	0.08
A 8F	49	437.24	graminoid seedling	Kellogg's sedge	32977 sph	0.74
A 8F	49	437.24	graminoid seedling	Columbia sedge	2679 sph	0.74



Map 4-11. Distribution of revegetation treatment areas at East Arrow Park, Arrow Lakes Reservoir, 2009 and 2010.

Osprey Landing — Arrow Lakes Reservoir

Site Description:

Osprey landing is located 32 km south of Nakusp and 4 km north of Burton along Highway 23 on the east side of Arrow Lake Reservoir. Soil textures range from fine-clayey to fine-loamy to fine-silty (Miller et al. 2017, draft)

Treatment prescriptions were developed in 2009 (Keefer and Ross 2009) and planting was undertaken in 2009 (Keefer et al 2009).

Site information:

Reach	Mid-Arrow
MC Unit	Site 10c
UTM's	11U 435676 E 5541418 N
BEC	ICH dw 1
Vegetation Communities see Table 3-1	PC
Area (ha)	1.10 / 1.10
Elevation (m)	Min: 433.9 Max: 434.8
# of Polygons:	4
Years:	2009

Treatment Summary

Treatments in 2009 included small-flowered bulrush and Columbia sedge seedling plugs planted in three polygons (0.87 ha) and a single seeding trial of BC Hydro wetland seed mix (0.23 ha).

Summary of Planting Success

An assessment of CLBWORKS-2 planting survivorship in 2017 (Miller et al. 2018 draft) indicated a high success rate for Columbia sedge (100%) and no survival of small-flowered bulrush at Osprey Landing. The success of seeding trials was not reported. Note: “success rate” is defined here as the percentage of sample plots containing at least one surviving transplant.

Documents

Type	Year	Author	Short Title
Prescription	2005	Moody	Potential Areas for Vegetation Establishment in Arrow Reservoir
Prescription	2009	Keefer and Ross	Arrow Reservoir Planting Plan for 2009
Summary	2009	Keefer et al	Arrow Revegetation Report 2009
Monitoring	2017	Miller et al	Arrow Monitoring Report

Year 2009

MC#	Polygon	Elev	Treatment Type	Species	Density/Rate	Area (ha)
A 10A	30	434.31	graminoid seedling	Small-flowered bulrush	11912 sph	0.06
A 10A	31	435.65	graminoid seedling	Columbia sedge	6794 sph	0.60
A 10A	32	435.20	graminoid seed	BC Hydro wetland seed mix	kg/ha	0.23
A 10A	33	436.16	graminoid seedling	Small-flowered bulrush	11912 sph	0.22

Map 4-12. Distribution of revegetation treatment areas at Osprey Landing, Arrow Lakes Reservoir, 2008.

Burton Creek — Arrow Lakes Reservoir

Site Description:

The Burton Creek treatment area is located on the east side of the Arrow Lakes Reservoir at the mouth of Caribou Creek, 3 km south of Burton, B.C. Soils texture ranged from silt loams to sands, gravel, and cobble. Soil samples indicate deficiencies in nitrogen, phosphorous, potassium, boron, chlorine, sulphur and manganese (Keefer et al 2008). All treatment polygons except three were located south of Caribou Creek at Robazzo Rd. A polygon north of Caribou Creek is located between the Old Cemetery and Lakeview Park roads and two treatment polygons occur two km south of Robazzo Rd.

Planting trials were undertaken in 2008 (Keefer and Ross 2008, Keefer et al 2008). Treatment prescriptions were developed in 2009 (Keefer and Ross 2009), 2010 (Keefer and Moody 2010), and 2011 (Keefer and Moody 2011). Planting was undertaken in 2009, 2010 and 2011 (Keefer et al 2009, KES 2010 and 2011).

Site information:

Reach	Mid-Arrow
MC Unit	Sites 10 D, E, G, and H
UTM's	11U 435224 E 5536884 N
BEC	ICH mw 2
Vegetation Communities see Table 3-1	BE, PA, PC, and SS
Area (ha)	17.82 / 24.28
Elevation (m)	Min: 432.5 Max: 436.2
# of Polygons:	25
Years:	2008, 2009, 2010, 2011

Treatment Summary

Twenty-three polygons were treated totaling 17.82 ha: twelve in 2008 (1.87 ha), six in 2009 (6.18 ha), three in 2010 (2.1 ha), and two in 2011 (7.68 ha). In the spring of 2008, two fertilization trials (1.64 ha) and a Kellogg's sedge seedling/fertilization trial (0.06 ha) were undertake. In the fall of 2008, nine polygons were planted with Columbia and Kellogg's sedge seedlings plugs (0.16 ha). In 2009, small-flowered bulrush, wool-grass and Columbia, Kellogg's, and water sedge seedlings plugs were planted in five polygons (4.81 ha) and live stakes of black cottonwood, red-osier dogwood, and willow sp. were planted in two polygons (1.37 ha). Following planting in 2009, fertilizer (16-20-12-7% S blend granular) was applied to planted sites using a quad at rate of 370 kg/ha. In 2010, three polygons were planted with Columbia and Kellogg's sedge seedlings plugs (2.10 ha). In 2011, Kellogg's sedge seedlings plugs were planted in one polygons (3.83 ha) and black cottonwood seedling plugs were planted in a second polygon (3.85 ha).

Summary of Planting Success

Results from the fertilization studies revealed an immediate response to fertilizer treatment by existing vegetation (KES 2010). No significant treatment effects were observed in planted sedge seedlings and cottonwood live stakes (KES 2010 and 2011). An assessment of CLBWORKS-2 planting survivorship in 2017 (Miller et al. 2018 draft) indicated a high success rate for Kellogg's sedge seedlings (95%), low success for wool-grass seedlings (13%), and moderate success for Columbia sedge (73%) and black cottonwood (50%) seedlings. No surviving water sedge, red-osier dogwood, or willow seedlings were recorded. Success rates for black cottonwood stakes were good (63%), and were nil for red-osier dogwood and willow stakes. Note: "success rate" is defined here as the percentage of sample plots containing at least one surviving transplant.

Documents

Type	Year	Author	Short Title
Prescription	2005	Moody	Potential Areas for Vegetation Establishment in Arrow Reservoir
Prescription	2008	Keefer and Ross	Arrow Reservoir Experimental Design 2008
Summary	2008	Keefer et al	Arrow Revegetation Report 2008
Prescription	2009	Keefer and Ross	Arrow Reservoir Planting Plan for 2009
Summary	2009	Keefer et al	Arrow Revegetation Report 2009
Prescription	2010	Keefer and Moody	Arrow Reservoir Planting Plan for 2010
Summary	2010	KES	Arrow Revegetation Report 2010
Prescription	2011	Keefer and Moody	Arrow Reservoir Planting Plan for 2011
Summary	2011	KES	Arrow Revegetation Report 2011
Monitoring	2017	Miller et al	Arrow Monitoring Report

Burton Creek Arrow Lakes Reservoir

Year 2008

MC#	Polygon	Elev	Treatment Type	Species	Density/Rate	Area (ha)
A 10D	5	439.39	graminoid seedling	Columbia sedge	7813 sph	0.01
A 10D	6	438.88	graminoid seedling	Kellogg's sedge	19068 sph	0.03
A 10D	7	438.11	graminoid seedling	Kellogg's sedge	19068 sph	0.03
A 10D	8	438.38	graminoid seedling	Kellogg's sedge	19068 sph	0.00
A 10D	9	438.11	graminoid seedling	Kellogg's sedge	19068 sph	0.03
A 10D	10	438.03	graminoid seedling	Kellogg's sedge	19068 sph	0.00
A 10D	11	438.24	graminoid seedling	Kellogg's sedge	19068 sph	0.00
A 10D	12	438.27	graminoid seedling	Kellogg's sedge	19068 sph	0.01
A 10G	1	436.54	Fertilizer	Fertilizer	344 kg/ha	0.82
A 10G	2	437.04	Fertilizer	Fertilizer	344 kg/ha	0.82
A 10G	3	436.31	Fertilizer	Fertilizer	344 kg/ha	0.06
A 10G	3	436.31	graminoid seedling	Kellogg's sedge	sph	0.06
A 10G	4	438.87	graminoid seedling	Kellogg's sedge	19068 sph	0.05

Year 2009

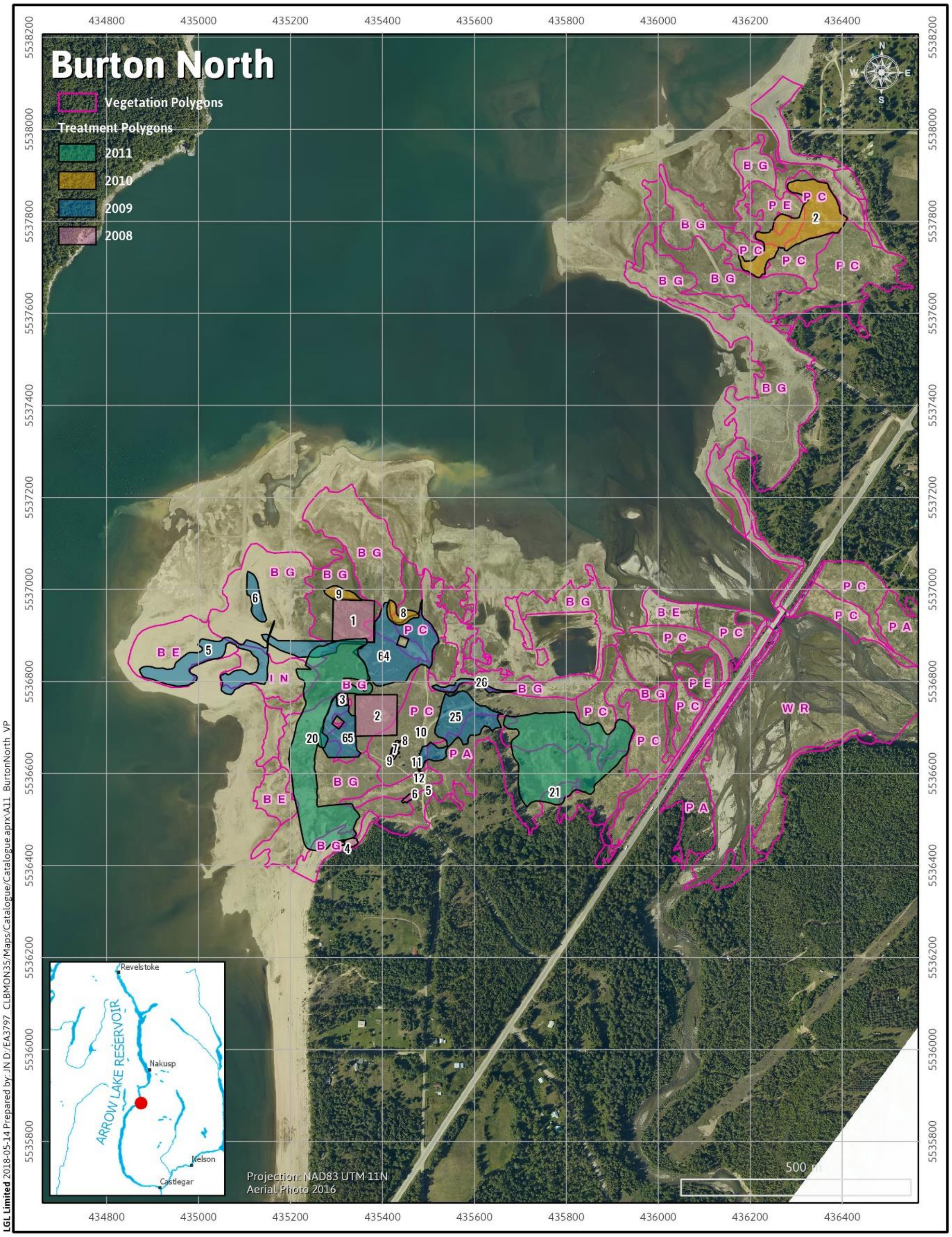
MC#	Polygon	Elev	Treatment Type	Species	Density/Rate	Area (ha)
A 10D	25	439.07	shrub stake	black cottonwood	1109 sph	1.22
A 10D	25	439.07	shrub stake	willow sp.	200 sph	1.22
A 10D	25	439.07	shrub stake	Dogwood	51 sph	1.22
A 10D	26	438.08	shrub stake	black cottonwood	1109 sph	0.15
A 10D	26	438.08	shrub stake	willow sp.	200 sph	0.15
A 10D	26	438.08	shrub stake	Dogwood	51 sph	0.15
A 10G	5	434.08	graminoid seedling	Kellogg's sedge	8209 sph	1.30
A 10G	5	434.08	graminoid seedling	Columbia sedge	4479 sph	1.30
A 10G	6	434.22	graminoid seedling	water sedge	1017 sph	0.24
A 10G	6	434.22	graminoid seedling	wool-grass	1762 sph	0.24
A 10G	64	436.78	graminoid seedling	mixed graminoid species	14026 sph	2.34
A 10G	65	436.35	graminoid seedling	mixed graminoid species	14026 sph	0.74
A 10H	21	435.65	graminoid seedling	Small-flowered bulrush	13421 sph	0.03
A 10H	22	435.03	graminoid seedling	water sedge	10062 sph	0.13
A 10H	23	435.75	graminoid seedling	water sedge	10062 sph	0.03
A 10H	23	435.75	graminoid seedling	Small-flowered bulrush	13421 sph	0.03

Year 2010

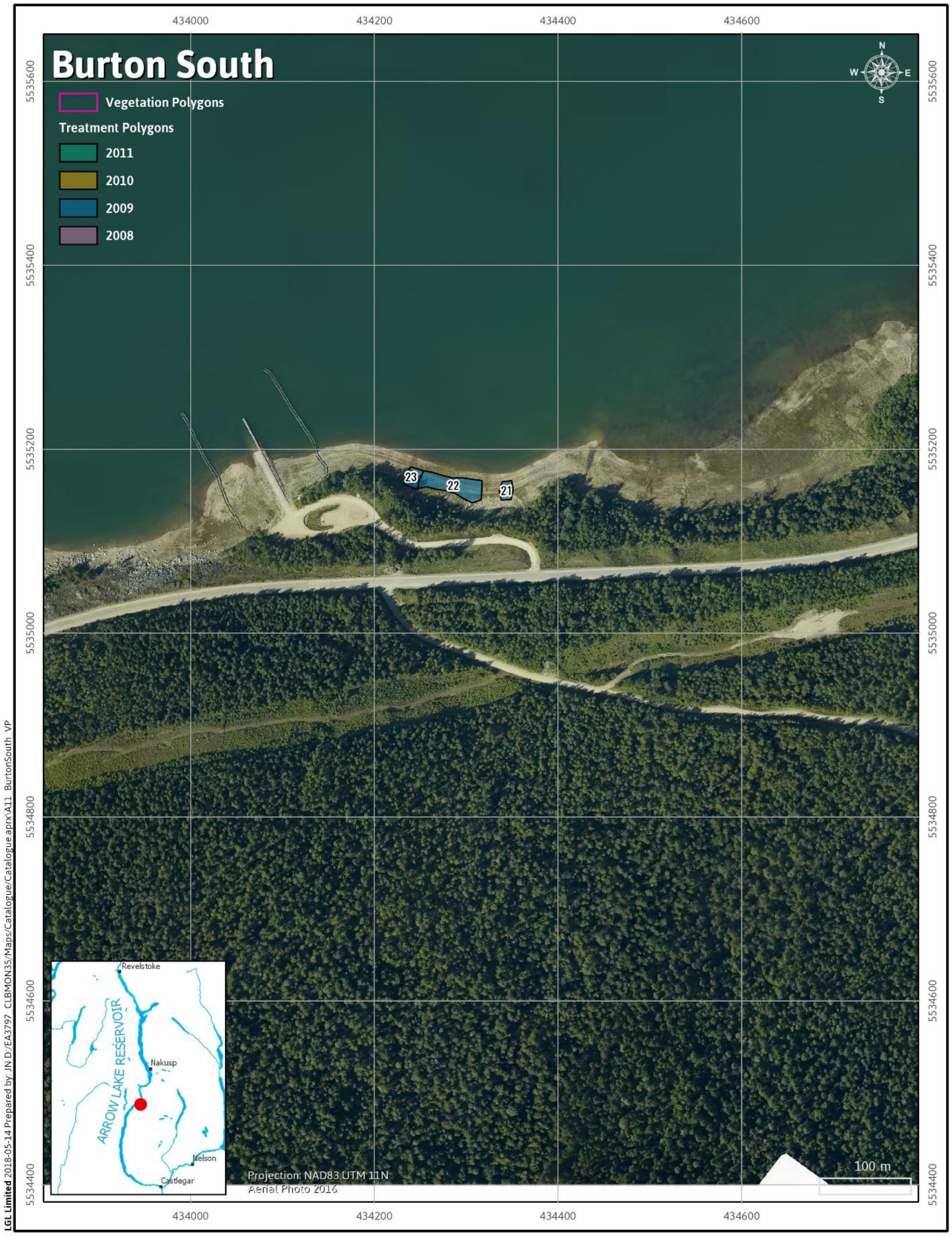
MC#	Polygon	Elev	Treatment Type	Species	Density/Rate	Area (ha)
A 10E	2	436.53	graminoid seedling	Kellogg's sedge	4800 sph	1.76
A 10E	2	436.53	graminoid seedling	Columbia sedge	3897 sph	1.76
A 10G	8	436.11	graminoid seedling	Kellogg's sedge	6348 sph	0.18
A 10G	8	436.11	graminoid seedling	Columbia sedge	5155 sph	0.18
A 10G	9	436.11	graminoid seedling	Kellogg's sedge	10658 sph	0.16
A 10G	9	436.11	graminoid seedling	Columbia sedge	8654 sph	0.16

Year 2011

MC#	Polygon	Elev	Treatment Type	Species	Density/Rate	Area (ha)
A 10D	21	438.72	shrub seedling	black cottonwood	1383 sph	3.85
A 10G	20	435.68	graminoid seedling	Kellogg's sedge	13397 sph	3.83



Map 4-13. Distribution of revegetation treatment areas at Burton Creek North, Arrow Lakes Reservoir, 2008, 2009, 2010, and 2011.



Map 4-14. Distribution of revegetation treatment areas at Burton Creek South, Arrow Lakes Reservoir, 2009.

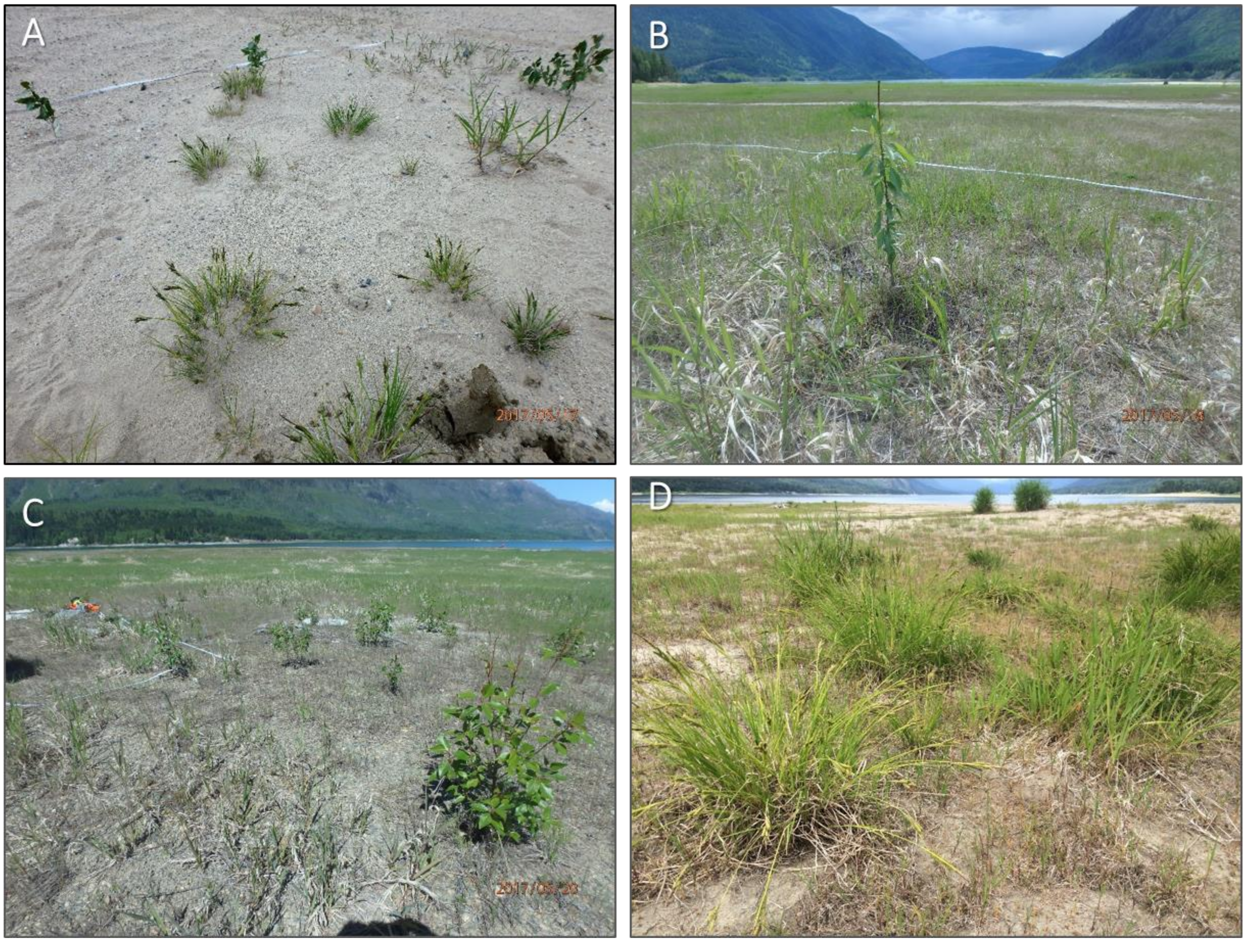


Figure 4-7. Examples of revegetation prescriptions trialed at Burton Creek in 2008, 2009, 2010, and 2011. A: sedge seedlings, B; cottonwood stake; C naturally regenerating cottonwood, and D: close-up of sedge. Photo credit: Mike Miller.

Lower Inonoaklin   Arrow Lakes Reservoir

Site Description:

The Lower Inonoaklin treatment area is located on the west side of the Arrow Lakes Reservoir, 1.5 km south of the Needles ferry crossing. Soils texture included sands, silts, and gravel (Keefer and Moody 2011).

Treatment prescriptions were developed in 2009 (Keefer and Ross 2009) and 2011 (Keefer and Moody 2011). Planting was undertaken in 2009 and 2011 (Keefer et al 2009, KES 2011).

Site information:

Reach	Lower-Arrow
MC Unit	Site 11
UTM's	11U 420346 E 5523965 N
BEC	ICH dw 1
Vegetation Communities see Table 3-1	BE, IN, LO, PA, PE, and PC
Area (ha)	7.92 / 14.12
Elevation (m)	Min: 435.3 Max: 441.4
# of Polygons:	17
Years:	2009, 2011

Treatment Summary

Seventeen polygons were treated totaling 7.92 ha: ten in 2009 (3.37 ha), and seven in 2011 (4.54 ha). In 2009, bluejoint reedgrass, small-flowered bulrush, and Columbia, Kellogg's, and water sedge seedlings plugs were planted in five polygons (1.74 ha). Live stakes of black cottonwood and willow sp. were planted in five polygons (1.63 ha) with the aid of a mini excavator; modified brush layers of black cottonwood stakes were installed in two of these polygons. Following planting in 2009, fertilizer (16-20-12-7% S blend granular) was applied to planted sites using a quad at rate of 370 kg/ha.

In 2011, bluejoint reedgrass, wool-grass, and Columbia, Kellogg's, and water sedge seedlings plugs were planted in six polygons (4.47 ha) and red-osier dogwood and willow sp. seedlings plugs were planted in a single polygon (0.07 ha).

Summary of Planting Success

An assessment of CLBWORKS-2 planting survivorship in 2017 (Miller et al. 2018 draft) indicated moderate success rates for Columbia sedge (43%), small-flowered bulrush (33%), and water sedge (40%) seedlings, and good success for Kellogg's sedge (68%). The success rate for wool-grass establishment was 26 %, although this species performed exceptionally well in some microsites (see accompanying photo). No surviving shrub seedlings were recorded at Lower Inonoaklin. Despite the evidence of live stakes pulled by people in 2009, the success rate for black cottonwood stakes was high (86%); the vigour of surviving stakes was also exceptional good. However, there was no evidence of willow stake survival. Survival rates for bluejoint reedgrass seedling plugs were not reported. Note: "success rate" is defined here as the percentage of sample plots containing at least one surviving transplant.

Documents

Type	Year	Author	Short Title
Prescription	2005	Moody	Potential Areas for Vegetation Establishment in Arrow Reservoir
Prescription	2009	Keefer and Ross	Arrow Reservoir Planting Plan for 2009
Summary	2009	Keefer et al	Arrow Revegetation Report 2009
Prescription	2011	Keefer and Moody	Arrow Reservoir Planting Plan for 2011
Summary	2011	KES	Arrow Revegetation Report 2011
Monitoring	2017	Miller et al	Arrow Monitoring Report

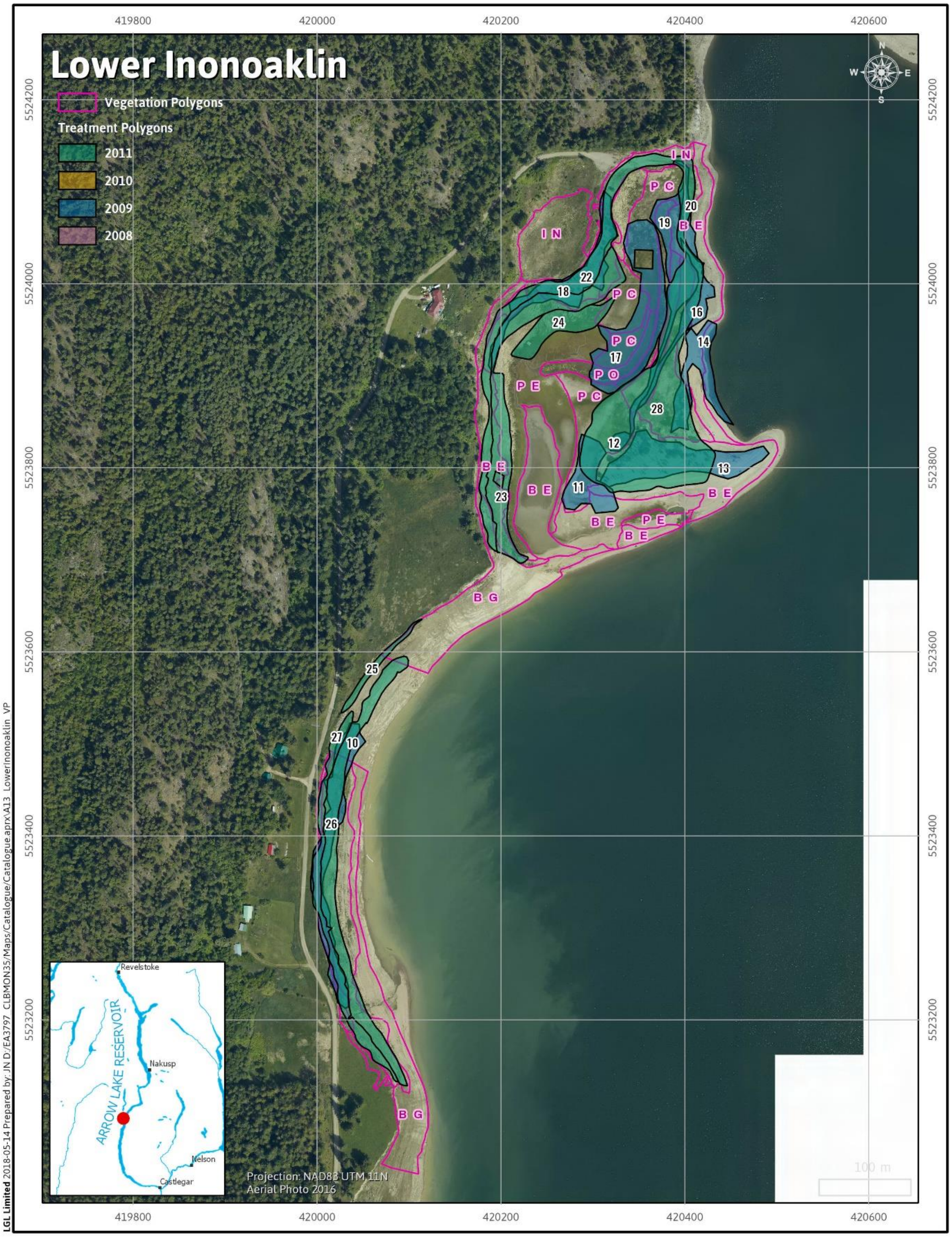
Lower Inonoaklin Arrow Lakes Reservoir

Year 2009

MC#	Polygon	Elev	Treatment Type	Species	Density/Rate	Area (ha)
A 11	10	437.93	shrub stake	black cottonwood	2017 sph	0.49
A 11	10	437.93	shrub stake	willow sp.	357 sph	0.49
A 11	10	437.93	shrub stake	black cottonwood	sph	0.49
A 11	11	435.55	graminoid seedling	Columbia sedge	2809 sph	0.28
A 11	12	435.74	graminoid seedling	water sedge	4549 sph	0.03
A 11	12	435.74	graminoid seedling	Small-flowered bulrush	1308 sph	0.03
A 11	13	437.26	shrub stake	black cottonwood	2017 sph	0.54
A 11	13	437.26	shrub stake	willow sp.	357 sph	0.54
A 11	14	434.46	graminoid seedling	mixed graminoid species	11922 sph	0.28
A 11	16	437.49	shrub stake	black cottonwood	2017 sph	0.18
A 11	16	437.49	shrub stake	willow sp.	357 sph	0.18
A 11	18	438.30	shrub stake	black cottonwood	2017 sph	0.39
A 11	18	438.30	shrub stake	willow sp.	357 sph	0.39
A 11	19	437.39	graminoid seedling	Columbia sedge	2809 sph	0.43
A 11	19	437.39	graminoid seedling	bluejoint reedgrass	2514 sph	0.43
A 11	20	437.41	shrub stake	willow sp.	357 sph	0.05
A 11	20	437.41	shrub stake	black cottonwood	sph	0.05
A 11D	17	434.92	graminoid seedling	mixed graminoid species	11922 sph	0.72

Year 2011

MC#	Polygon	Elev	Treatment Type	Species	Density/Rate	Area (ha)
A 11	22	438.60	graminoid seedling	Kellogg's sedge	18436 sph	0.60
A 11	23	436.95	graminoid seedling	Kellogg's sedge	40170 sph	0.72
A 11	24	435.21	graminoid seedling	water sedge	6236 sph	0.25
A 11	24	435.21	graminoid seedling	wool-grass	3922 sph	0.25
A 11	25	439.78	shrub seedling	willow sp.	6228 sph	0.07
A 11	25	439.78	shrub seedling	Red-osier Dogwood	4009 sph	0.07
A 11	26	437.04	graminoid seedling	Kellogg's sedge	14015 sph	0.67
A 11	27	438.75	graminoid seedling	Kellogg's sedge	12996 sph	0.34
A 11	28	436.75	graminoid seedling	Kellogg's sedge	4861 sph	1.89
A 11	28	436.75	graminoid seedling	bluejoint reedgrass	3210 sph	1.89
A 11	28	436.75	graminoid seedling	Columbia sedge	499 sph	1.89
A 11D	31	436.71	graminoid seedling	wool-grass	439 sph	0.21



Map 4-15. Distribution of revegetation treatment areas at Lower Inonoaklin Road, Arrow Lakes Reservoir, 2009 and 2011.

Figure 4-8. Examples of revegetation prescriptions trialed at Lower Inonoaklin Road 2009 and 2011. A: successful cottonwood live staking; B" live-staking treatment affected by wood debris deposition; C: mixed sedge plug trial in lower elevations, D: close-up of a Kellogg's sedge, E: close-up of wool-grass, and F cottonwood staking with people for scale. Photo credit: Mike Miller.

Edgewood — Arrow Lakes Reservoir

Site Description:

Edgewood is located 11 km south of the Needles ferry crossing on the west side of the Arrow Lakes Reservoir. Treatment polygons extend from 1 km northeast of the community of Edgewood near the mouth of Inonoaklin Creek to 0.5 km south of Edgewood near the mouth of Eagle Creek. Sites northeast of Edgewood have been referred to as Edgewood North and sites south of Edgewood have been referred to as Edgewood South or Eagle Creek. Miller et al. (2017 draft) treats the two treatment areas as a single site.

Treatment prescriptions were developed in 2009 (Keefer and Ross 2009) and 2011 (Keefer and Moody 2011). Planting was undertaken in 2009 and 2011 (Keefer et al 2009, KES 2011).

Site information:

Reach	Lower-Arrow
MC Unit	Site 12E
UTM's	11U 418838 E 5514907 N
BEC	ICH dw 1
Vegetation Communities see Table 3-1	BB, BE, CL, PC, PE, RS, and SS
Area (ha)	5.00 / 7.91
Elevation (m)	Min: 433.4 Max: 441.2
# of Polygons:	11
Years:	2009, 2011

Treatment Summary

Plantings were undertaken in 2009 (3.98 ha) and 2011 (1.02 ha) totaling 5.00 ha across seven treatment polygons. In 2009, bluejoint reedgrass, small-flowered bulrush, and Columbia, Kellogg's, and water sedge seedlings plugs were planted in two polygons (2.71 ha). Live stakes of black cottonwood and willow were planted with the aid of a mini excavator in five polygons (1.27 ha). In one of those polygons a modified brush layer of black cottonwood stakes was installed. Fertilizer (16 -20-12-7% S blend granular) was applied to planted sites in 2009 using a quad at rate of 370 kg/ha following planting.

In 2011, wool-grass, and Kellogg's and water sedge seedling plugs were planted in two polygons (0.72 ha). Black cottonwood, red-osier dogwood, and willow seedlings were also planted in two polygons (0.30 ha).

Summary of Planting Success

An assessment of CLBWORKS-2 planting survivorship in 2017 (Miller et al. 2018 draft) indicated a good success rate for Kellogg's sedge (56%), but low to nil success for Columbia sedge and water sedge. Survival of shrub seedlings was high (black cottonwood: 100%) to nil (red-osier dogwood and willow sp). Despite the evidence of live stakes pulled by people in 2009, the success rate for black cottonwood stakes was 63%; however, there was no evidence of red-osier dogwood or willow stake survival. Survival rates for bluejoint reedgrass seedling plugs were not reported. Note: "success rate" is defined here as the percentage of sample plots containing at least one surviving transplant.

Documents

Type	Year	Author	Short Title
Prescription	2005	Moody	Potential Areas for Vegetation Establishment in Arrow Reservoir
Prescription	2009	Keefer and Ross	Arrow Reservoir Planting Plan for 2009
Summary	2009	Keefer et al	Arrow Revegetation Report 2009
Prescription	2011	Keefer and Moody	Arrow Reservoir Planting Plan for 2011
Summary	2011	KES	Arrow Revegetation Report 2011
Monitoring	2017	Miller et al	Arrow Monitoring Report

Edgewood Arrow Lakes Reservoir

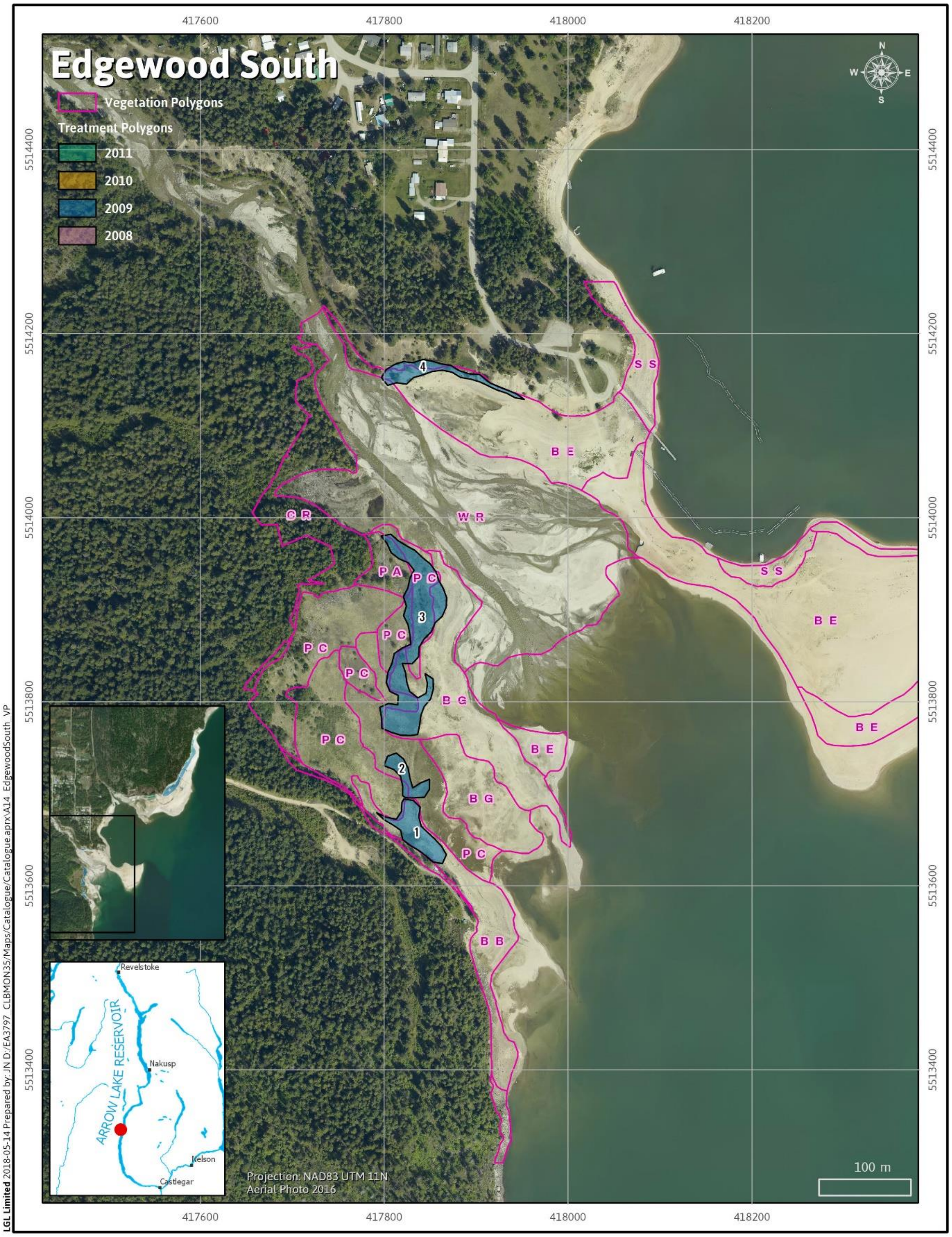
Year 2009

MC#	Polygon	Elev	Treatment Type	Species	Density/Rate	Area (ha)
A 12D	7	435.19	graminoid seedling	mixed graminoid species	13159 sph	1.45
A 12D	8	438.40	shrub stake	black cottonwood	2439 sph	0.19
A 12D	8	438.40	shrub stake	willow sp.	98 sph	0.19
A 12D	8	438.40	shrub stake	black cottonwood	sph	0.19
A 12D	9	436.96	graminoid seedling	mixed graminoid species	13159 sph	1.27

Year 2011

MC#	Polygon	Elev	Treatment Type	Species	Density/Rate	Area (ha)
A 12D	29	439.90	shrub seedling	black cottonwood	11010 sph	0.10
A 12D	30	438.72	graminoid seedling	Kellogg's sedge	32759 sph	0.51
A 12D	30	438.72	graminoid seedling	water sedge	733 sph	0.51
A 12D	30	438.72	graminoid seedling	wool-grass	147 sph	0.51
A 12D	31	436.71	graminoid seedling	Kellogg's sedge	8310 sph	0.21
A 12D	31	436.71	graminoid seedling	water sedge	2339 sph	0.21
A 12D	31	436.71	shrub seedling	Red-osier Dogwood	439 sph	0.21
A 12D	31	436.71	shrub seedling	willow sp.	1462 sph	0.21

Map 4-16. Distribution of revegetation treatment areas at Edgewood North, Arrow Lakes Reservoir, 2009 and 2011.



Map 4-17. Distribution of revegetation treatment areas at Edgewood South, Arrow Lakes Reservoir, 2009.

Figure 4-9. Examples of revegetation prescriptions trialed at Edgewood South in 2009. A to C: photos showing variable success of live staking treatment and D; C: sedge plug trial in lower elevations, and D: failed graminoid seedling trial. Photo credit: Mike Miller.

Renata Arrow Lakes Reservoir

Site Description:

Renata is located on the west side of ArrowLakes reservoir 27 km upstream of the Hugh Keenleyside Dam. Access is by boat from a public dock at Anderson Point, or via forest service roads from Grand Forks or Edgewood. The treatment polygons were located on an alluvial fan at the mouth of Dog Creek adjacent private residences. Soils were characterized as loamy sand and sands and rapidly drained (Keefer and Ross 2009).

A treatment prescription was developed in early 2010 (Keefer and Moody 2010). Planting was undertaken in 2010 and no other year (KES 2010).

Site information:

Reach	Lower-Arrow
MC Unit	Site 13E
UTM's	11U 420698 E 5475561 N
BEC	ICH xw
Vegetation Communities see Table 3-1	BE, BG, IN, PA, PC, RR, and SS
Area (ha)	5.76 / 11.51
Elevation (m)	Min: 435.5 Max: 438.2
# of Polygons:	3
Years:	2010

Treatment Summary

Three polygons were planted with Columbia and Kellogg's seedling plugs in 2010 totaling 5.76 ha.

Summary of Planting Success

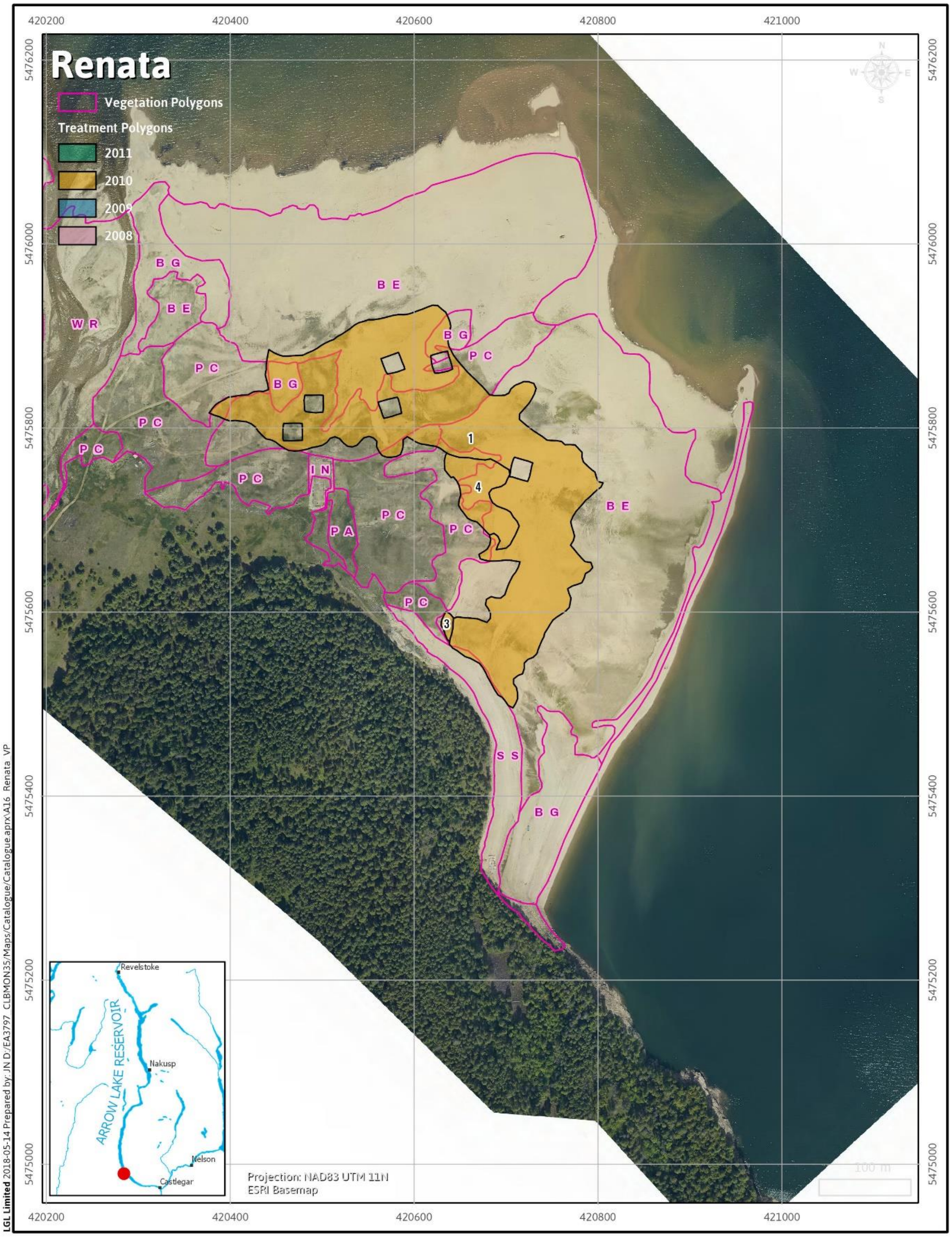
A preliminary assessment of CLBWORKS-2 planting treatments in 2015 (Miller et al. 2016) revealed only sporadic pockets of surviving Kellogg's sedge and Columbia sedge seedlings across the entire treated area. Across a sample of permanent monitoring plots (n=7), the success rate of Kellogg's sedge was 40%; that of Columbia sedge was 60%. Note: "success rate" is defined here as the percentage of sample plots containing at least one surviving transplant.

Documents

Type	Year	Author	Short Title
Prescription	2005	Moody	Potential Areas for Vegetation Establishment in Arrow Reservoir
Prescription	2010	Keefer and Moody	Arrow Reservoir Planting Plan for 2010
Summary	2010	KES	Arrow Revegetation Report 2010

Year 2010

MC#	Polygon	Elev	Treatment Type	Species	Density/Rate	Area (ha)
A 13A	1	436.94	graminoid seedling	Kellogg's sedge	10788 sph	5.31
A 13A	1	436.94	graminoid seedling	Columbia sedge	8826 sph	5.31
A 13A	3	438.08	graminoid seedling	Kellogg's sedge	25385 sph	0.03
A 13A	3	438.08	graminoid seedling	Columbia sedge	20786 sph	0.03
A 13A	4	438.25	graminoid seedling	Kellogg's sedge	10575 sph	0.42
A 13A	4	438.25	graminoid seedling	Columbia sedge	8892 sph	0.42



Map 4-18. Distribution of revegetation treatment areas at Renata, Arrow Lakes Reservoir, 2010.

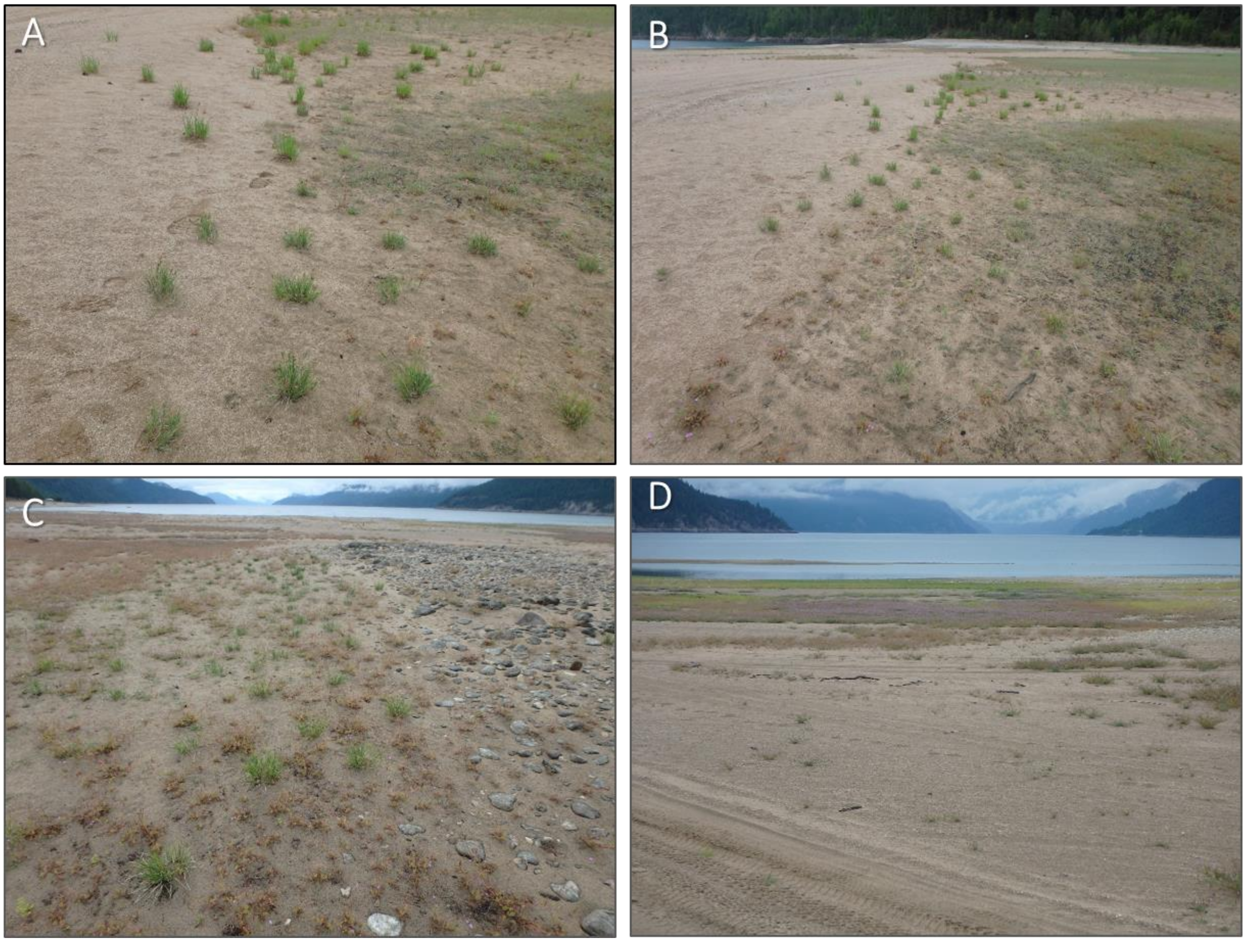


Figure 4-10. Examples of revegetation prescriptions trialed at Renata in 2010. A to D: graminoid (sedge) seedlings planted at Renata. Photo credit: Mike Miller.

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BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

CLBMON-35 ARROW LAKES AND KINBASKET RESERVOIRS PLANT RESPONSE TO INUNDATION

Revegetation Prescription Catalogue
Kinbasket Reservoir

Final

Prepared for

BC Hydro

Prepared by

LGL Limited
environmental research associates
9768 Second Street
Sidney, British Columbia, V8L 3Y8

Contact

Virgil C. Hawkes, M.Sc. R.P.Bio.
Vice-President & Senior Wildlife Biologist
vhawkes@lgl.com
1.250.656.0127

June 20, 2018

LGL LIMITED
environmental research associates

Cover photos:

From left to right: Black cottonwood (*Populus balsamifera subsp. trichocarpa*) live stakes at Lower Inonoaklin Road, Arrow Lakes Reservoir; Kellogg's sedge *(Carex lenticularis var. lipocarpa*) at Burton Creek, Arrow Lakes Reservoir; vegetation growing in the drawdown zone of Arrow Lakes Reservoir, and live staking at the Bush Arm Causeway, Kinbasket Reservoir.

Table of Contents

List of Tables

List of Figures

List of Maps

1 Introduction

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 (KM88 Big Bend, Adama 2015) have contributed to an increased cover of vegetation (sedge transplants) in drawdown zone.

The purpose of the cataloguing exercise (CLBMON-35) was to document site conditions, revegetation methods, and revegetation success to elucidate variables (biotic and abiotic) that contributed to the successes or failures of each type of vegetation treatment at a given site within Arrow Lakes and Kinbasket Reservoirs. The goal of cataloguing and analyzing these data was to provide a record of the revegetation techniques applied at each site, and help determine the treatments and associated factors that were effective. These variables included the presence (accumulation) of species planted, site preparation, planting method, stocking density, woody debris, erosion and sediment deposition, wave and wind action, soil characteristics, ecological suitability, soil compaction, human activity, and physicochemical parameters such as soil anoxia. Data analyses and results also aimed to address existing uncertainties regarding the relative contribution and importance of timing, frequency, depth, and duration of inundation on survival of plants of different sizes and ages, and the effect of multi-year stresses on trends in plant viability.

This catalogue is one of three documents produced for CLBMON-35, the other two being the Arrow Lakes Reservoir Revegetation catalogue and a report summarizing, among other things, the species-specific responses of four species (*Carex lenticularis*, *C. aperta*, *Sciprus atrocinctus*, and *Populus balsamifera* ssp. *trichorcarpa*) to reservoir operations (Hawkes et al 2018).

2 Study Area

The Mica Dam, located 135 km north of Revelstoke, British Columbia, spans the Columbia River and impounds Kinbasket Reservoir (Figure 2-1). Completed in 1973, the Mica powerhouse has a generating capacity of 1,805 MW. The Mica Dam is one of the largest earth fill dams in the world and was built under the terms of the Columbia River Treaty to provide water storage for flood control and power generation. Kinbasket Reservoir is 216 km long and has a licensed storage volume of 12 MAF[1] (BC Hydro 2007). Of this, seven MAF are operated under the terms of the Columbia River Treaty. The normal operating elevation of the reservoir ranges from 754.38 m ASL to 707.41 m ASL. However, application may be made to the Comptroller of Water Rights for additional storage for economic, environmental, or other purposes if there is a high probability of spill.

Two Biogeoclimatic (BEC) zones are represented in the lower elevations of Kinbasket Reservoir: the Interior Cedar-Hemlock (ICH) zone and the Sub-Boreal Spruce (SBS) zone. Four subzone/variants characterize the ICH and one subzone/ variant characterizes the SBS zone (**Error! Reference source not found.**). Of the six variants listed in **Error! Reference source not found.**, all but the ICHvk1 and ICHmk1 occurred in all landscape units selected for sampling.

Table 2-1. Biogeoclimatic Zones, subzones and variants occurring in the Kinbasket Reservoir study area.

Zone Code	Zone Name	Subzone & Variant	Subzone/Variant Description	Forest Region & District
ICHmm	Interior Cedar – Hemlock	mm	Moist Mild	Prince George (Robson Valley Forest District)
ICHwk1	Interior Cedar – Hemlock	wk1	Wells Gray Wet Cool	Prince George (Robson Valley Forest District) and Nelson Forest Region (Columbia Forest District)
ICHmw1	Interior Cedar – Hemlock	mw1	Golden Moist Warm	Nelson Forest Region (Columbia Forest District)
ICHvk1*	Interior Cedar – Hemlock	vk1	Mica Very Wet Cool	Nelson Forest Region (Columbia Forest District)
SBSdh1	Sub-Boreal Spruce	dh1	McLennan Dry Hot	Prince George (Robson Valley Forest District)

* Not in all landscape units sampled

2.1 Physiography[2]

The Columbia basin is situated in southeastern British Columbia. The basin is characterized by steep valley side slopes and short tributary streams that flow into Columbia River from all directions. The headwaters of the Columbia River begin at Columbia Lake in the Rocky Mountain Trench. The river flows northwest along the Trench for about 250 km before it empties into Kinbasket Reservoir behind Mica Dam (BC Hydro

[1] MAF = Million Acre Feet. An acre foot is a unit of volume commonly used in the United States in reference to large-scale water resources, such as reservoirs, aqueducts, canals, sewer flow capacity, and river flows. It is defined by the volume of water necessary to cover one acre of surface area to a depth of one foot. Since the area of one acre is defined as 66 by 660 feet then the volume of an acre foot is exactly 43,560 cubic feet. Alternatively, this is approximately 325,853.4 U.S. gallons, or 1,233.5 cubic metres or 1,233,500 litres.

[2] From BC Hydro (2007) after BC Hydro (1983).

1983). From Mica Dam, the river continues southward for about 130 km to Revelstoke Dam and then flows almost immediately into Arrow Lakes Reservoir behind Hugh Keenleyside Dam. The entire drainage area upstream of Hugh Keenleyside Dam is approximately 36,500 km^2.

The Columbia River valley floor elevation falls from approximately 800 m ASL near Columbia Lake to 420 m ASL near Castlegar. Approximately 40 per cent of the drainage area within the Columbia River basin is above 2000 m ASL. Permanent snowfields and glaciers predominate in the northern high mountain areas above 2500 m ASL; about 10 per cent of the Columbia River drainage area above Mica Dam exceeds this elevation.

Most of the watershed remains in its original forested state. Dense forest vegetation thins above 1500 m ASL and tree lines are generally at about 2000 m ASL. The forested lands around Kinbasket Reservoir have been and are being logged, with recent and active logging (i.e., 2007–2014) occurring on both the east and west sides of the reservoir.

2.2 Climatology[3]

Precipitation in the basin occurs from the flow of moist low-pressure weather systems that move eastward through the region from the Pacific Ocean. More than two-thirds of the precipitation in the basin falls as winter snow, resulting in substantial seasonal snow accumulations at middle and upper elevations in the watersheds. Summer snowmelt is complemented by rain from frontal storm systems and local convective storms.

Temperatures in the basin tend to be more uniform than precipitation. With allowances for temperature lapse rates, station temperature records from the valley can be used to estimate temperatures at higher elevations. The summer climate is usually warm and dry, with the average daily maximum temperature for June and July ranging from 20°C to 32°C. The average daily minimum temperature ranges from 7°C to 10°C. The coldest month is January, when the average daily maximum temperature in the valleys is near 0°C and average daily minimum is near -5°C.

During the spring and summer months, the major source of stream flow in the Columbia River is water stored in large snow packs that developed during the previous winter months. Snow packs often accumulate above 2000m through the month of May and continue to contribute runoff long after the snow pack has depleted at lower elevations. Runoff begins to increase in April or May and usually peaks in June to early July, when approximately 45 per cent of the runoff occurs. Severe summer rainstorms are not unusual in the Columbia Basin. Summer rainfall contributions to runoff generally occur as short-term peaks superimposed upon high river levels caused by snowmelt. These rainstorms may contribute to annual flood peaks. The mean annual local inflow for the Mica, Revelstoke, and Hugh Keenleyside projects is 577 m^3/s, 236 m^3/s, and 355 m^3/s, respectively.

[3] From BC Hydro 2007 after BC Hydro 1983.

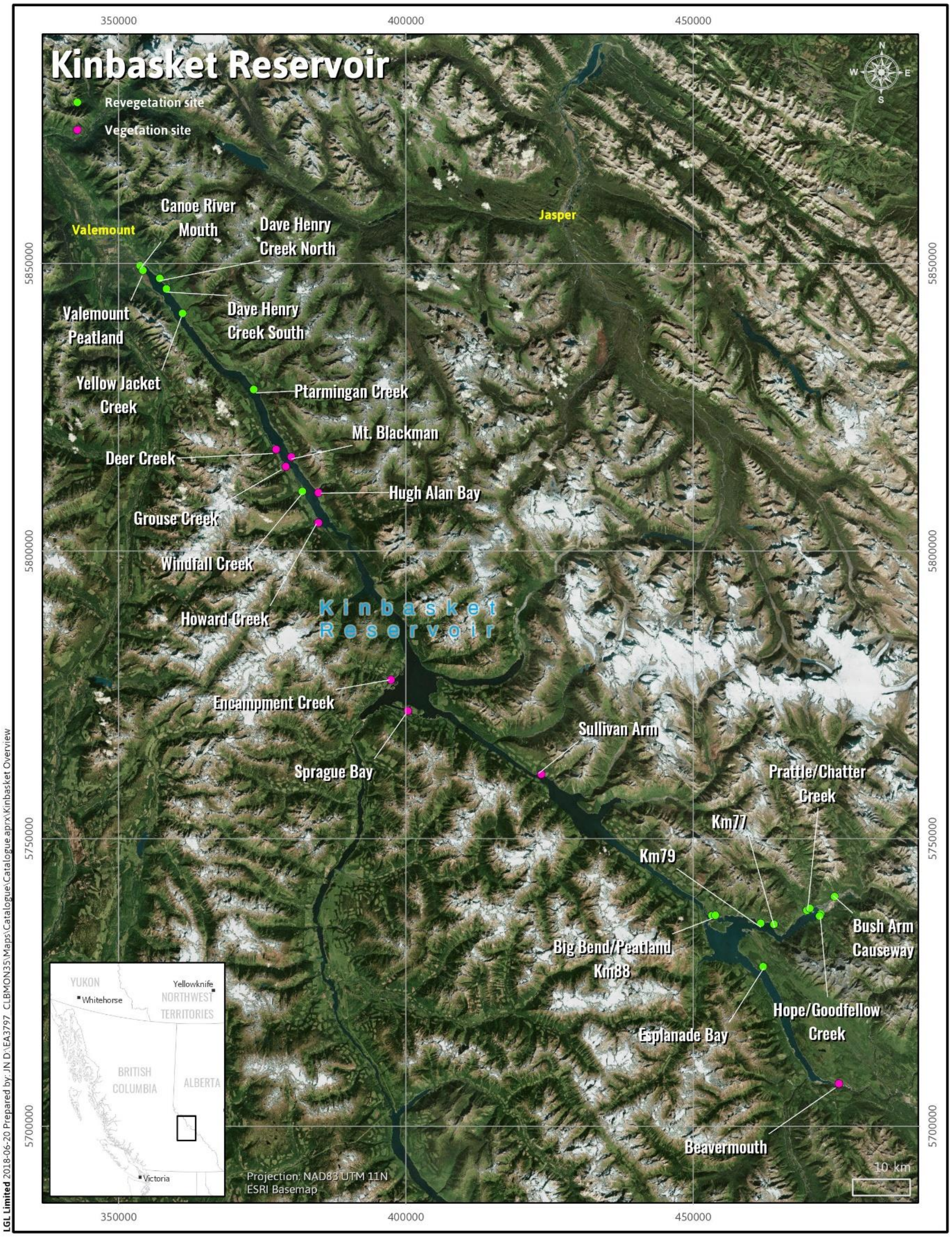


Figure 2-1. Location of Kinbasket Reservoir and revegetation locations (green). Pink locations are existing vegetation monitoring locations.

3 Methods

Data in this catalogue were retrieved from several sources including CLBMON-9, CLBMON-10, and CLBWORKS-1 datasets, reports, and GIS data. The CLBWORKS-1 data were summarized to generate treatment summaries by reach and year and the CLBMON-9, 10, and WORKS-1 reports were used to summarize planting activities and success. Data from Moody and Carr (2003) were used to cross-reference the CLBWORKS-1 treatment areas with the areas identified for vegetation establishment in Kinbasket Reservoir by Moody and Carr.

The following fields are used to summarize the revegetation treatments applied in each reach and site:

Site description: general description of site in terms of location and planting history.

Site information: summary of the site

Reach: name of reach in Kinbasket Reservoir (see **Error! Reference source not found.**).

MC Unit: These codes correspond to the original treatments units defined by Moody and Carr (2005) and Moody (2005) in the Columbia Water Use Plan (BC Hydro 2005)

UTM's: spatial data (UTM easting and northing) of approximate centroid of the treatment areas.

BEC: Biogeoclimatic zone, subzone, and variant in which the treatment occurred.

Vegetation Communities: as per Hawkes and Gibeau (2016). See Table 3-2.

Area (ha): Two values for area are provided. The first is the size of all of the treatment polygons treated. The second is the total of all the treatments applied, and may include multiple treatments across individual treatment polygons.

Elevation (m): elevation range (lowest and highest) of the treatment polygon.

# of Polygons: Count of treatment areas (polygons) at each site.

Years: years in which treatments were applied.

Treatment summary: overview of the revegetation treatments applied. A second set of tables summarizes the specific treatment areas in terms of polygon label, elevation (centroid of polygon), treatment type, species used in treatments, the density or rate of planning, and total area of treatment.

Summary of planting success: brief discussion of planting success.

Documents: listing of relevant documents. Full citations are provided in the References section.

A second set of tables summarizes the specific treatment areas in terms of polygon label, elevation (centroid of polygon), treatment type, species used in treatments, the density or rate of planning, and total area treatment. The treatment types applied in the drawdown zone of Kinbasket Reservoir between 2008 and 2013 are as follows:

Seed Mix

Several multi-species seed mixes (Buffer, Upland, and Wetland; Table 3-1) were developed using native species and applied either through hydro-seeding or hand seeding using an Earthway Ev-n-spread hand spreader.

Table 3-1: Multi-species seed mixes used in revegetation trials of the drawdown zone of Kinbasket Reservoir.

Buffer Seed Mix	Seed in Mix (%)
blue wildrye	30
annual ryegrass	25
tufted hairgrass	10
Columbia sedge	5
bluejoint	5
fowl mannagrass	5
awl-fruited sedge	3
thick-headed sedge	3
wool-grass	3
white clover	3
Cusick's sedge	2
dagger-leaf rush	2
small flowered bulrush	2
common spikerush	2
Upland Seed Mix	**Seed in Mix (%)**
Blue wildrye	39
Annual ryegrass	25
California brome	15
Tufted hairgrass	11
White Dutch clover	7
Inert matter	2
Canada goldenrod	1
Wetland Seed Mix	**Seed in Mix (%)**
Sterile Wheat	30
Annual ryegrass	20
Columbia sedge	9
Kellogg's sedge	8
Sawbeak sedge	8
Beaked sedge	8
water sedge	5
Cusick's sedge	5
Fowl mannagrass	3
Small flowered bullrush	2
Common spikerush	2

Graminoid Seed

Seed from native graminoid (primarily Kellogg's sedge) were sown either by hand or by drill seeding (sandy sites only).

Graminoid Seedling

Nursery grown seedlings of Kellogg's sedge (*Carex lenticularis*), Columbia sedge (*Carex aperta*), water sedge (*Carex aquatilis*), wool-grass (*Scirpus atrocinctus*), small-flowered bulrush (*Scirpus microcarpus*), and bluejoint reedgrass (*Calamagrostis canadensis*) were hand planted by professional tree planting crews using planting shovels.

Shrub Seedling

Nursery grown seedlings of mountain alder (*Alnus incana*), black cottonwood (*Populus balsamifera*), chokecherry (*Prunus virginiana*), red-osier dogwood (*Cornus stolonifera*), wild rose (*Rosa acicularis*), and willow (Salix spp.) were hand planted by professional tree planting crews using planting shovels.

Shrub Stakes

Live stakes of black cottonwood, red-osier dogwood, and Willow (primarily Scouler's and Bebb's Willow) were either hand planted or planted with the aid of a mini-exactor. Stakes were planted to depths of 30 to 50 cm with the aid of a planting bar to create a pocket for the stake.

Modified Brush Layers (MBLs)

MBLs is a site stabilization technique constructed of live stakes and other materials such as logs, and boards. MBLs are often utilized in erosion prone areas by providing a stable terrace to facilitate the establishment of native vegetation. Several MBL's were planted in Arrow Lakes and Kinbasket Reservoir as trials.

Fertilization

In the early years of CLBWORKS-01 and -02, fertilizer was applied by hand or with the aid of ATV (quad mounted Vicon 303 fertilizer spreader) in treatment polygons to increase establishment survival and plant biomass production. Fertilizer was initially applied in trial plots but it was also used across large areas planted with seed mixes, seedlings, and stakes. The application of fertilizer was discontinued in later years as it was found to have a greater effect on competing weeds and native annuals that on target species.

3.1 Vegetation Community Classification

Vegetation communities were defined in 2007 and included 16 vegetated and 2 non-vegetated types. These same 18 communities have been retained over time with the addition of a single community (the RD, or Common Reed community) in 2010 (Table 3-2). In 2014 two additional communities (not included in Table 3-2) were added: the DI (Disturbed) and SW (Shrub-Willow) communities. The vegetation community codes in Table 3-2 are referred throughout this document.

Table 3-2: **List of the 19 vegetation communities classified for the 13 m drawdown zone of Kinbasket Reservoir (741m to 754 m ASL).** Note that only the BS and SH communities align with site series classifications used in BC (Mackenzie and Moran 2004); the remainder are unique to the drawdown zone of Kinbasket Reservoir.

No.	Code	Common Name	Scientific Name	Drainage	Typical Location
1	LL	Lady's thumb - Lamb's quarter	*Polygynum persicaria - Chenopodium album*	imperfectly to mod well	lowest vegetated elevations
2	CH	Common Horsetail	*Equisetum arvense*	Well	above LL or lower elevation on sandy, well-drained soil
3	TP	Toad rush - Pond water-starwort	*Juncus bufonius - Callitriche stagnalis*	imperfectly	above LL, wet sites
4	KS	Kellogg's sedge	*Carex lenticularis* spp. *licocarpa*	imperfectly to mod well	above CH
5	BR	Bluejoint reedgrass	*Calamagrostis canadensis*	mod well	above CH, often above KS
6	MA	Marsh cudweed - Annual Hairgrass	*Gnaphalium uliginosum - Deschampsia danthonioides*	imperfectly-mod well	common in the Bush Arm area
7	RC	Canary Reedgrass	*Phalaris arundinacea*	imperfectly to mod well	similar elevation to CO community
8	RD	Common Reed	*Phragmites australis*	poor	Above BR and below CO
9	CO	Clover - Oxeye daisy	*Trifolium* spp. - *Leucanthemum vulgare*	well	typical just below shrub line and above KS
10	CT	Cottonwood - Clover	*Populus balsamifera* spp. *trichocarpa-Trifolium* spp	imperfectly to well drained	above CO, below MC and LH
11	MC	Mixed Conifer	*Pinus monticola, Pseudotsuga menziesii, Picea engelmanni X glauca, Tsuga heterophyla, Thuja plicata*	Well	above CT along forest edge
12	LH	Lodgepole Pine - Annual hawksbeard	*Pinus contorta - Crepis tectorum*	well to rapid	above CT along forest edge, very dry site
13	BS	Buckbean - Slender sedge	*Menyanthes trifoliata-Carex lasiocarpa-Scirpus atrocintus, S. microcarpus*	Very poor to poor	wetland association
14	WB	Woolgrass-Pennsylvania Buttercup	*Scirpus atrocinctus - Ranunculus pensylvanicus*	imperfectly to poor	wetland association
15	SH	Swamp horsetail association	*Equisetum variegatum,E. fluviatile, E. palustre*	poor	wetland association
16	WS	Willow - Sedge wetland	*Salix - Carex* species	Very poor to poor	wetland association
17	DR	Driftwood	Long linear bands of driftwood, very little vegetation	n/a	whole logs and large pieces of logs without bark
18	WD	Wood Debris	Thick layers of wood debris, no vegetation	n/a	typically small pieces similar to bark mulch
19	FO	Unclassified Forest	Any forested community	n/a	Above drawdown zone (>756 m ASL)

4 Kinbasket Reservoir Revegetation Summaries 2008 to 2013

The revegetation of the drawdown zone through CLBWORKS-1 was initiated in 2008, and by 2013, approximately 69 ha of the drawdown zone had been treated. The stated objectives of CLBWORKS-1 were: (1) to maximize plant species cover in the drawdown zone; (2) to increase plant species diversity in the drawdown zone; (3) to improve littoral productivity through increased plant diversity; (4) to improve shoreline stability; and (5) to protect known archaeological sites. Results from the effectiveness monitoring study (CLBMON-9) included: transplants had fared poorly overall in the drawdown zone, with survivorship of sedge seedling plugs declining to < 50 per cent on average after two years, and to < 10 per cent on average three or more years after planting. Virtually no deciduous stakes had survived over this time frame. Most transplanted plants were unable to cope with the combination of inundation timing, frequency, duration and depth, or with the by-products of these factors such as erosion, wood debris scouring, and drought conditions (Hawkes et al. 2013).

There was a general decrease in both total cover and species richness in treatment plots since 2011, mirroring a similar trend in control plots. Hawkes et al. (2013) found no statistically significant differences between treatment and control plots either in per cent cover of vegetation, species richness, or species diversity within any plant community, elevation band, or region of the reservoir. It thus does not appear that either the quality or quantity of native vegetation in the Kinbasket Reservoir drawdown zone had increased as a result of the planting program. The failure of revegetation efforts to meet the stated remediation objectives suggests that changes are needed either to the planting program or the operating regime, or both. It is apparent from the 2013 assessment that without some level of adaptive management, the program will likely continue to struggle and any successes in establishing vegetation in the drawdown zone will be relatively minor.

The following Sections detail the revegetation trials in the drawdown zone of Kinbasket Reservoir between 2008 and 2013. This catalogue is an addendum to the CLBMON-35 report (Hawkes et al. 2018, draft) that describes the history the revegetation program and details species-specific responses to reservoir operations in both Kinbasket and Arrow Lakes Reservoirs.

Canoe River Mouth Kinbasket Reservoir

Site Description:

Canoe Reach is located at the north end of Kinbasket Reservoir near the mouth of the Canoe River. This site was originally forested and lacks the wetland seed bank and peat deposits of the Valemount Peatland to the south (Moody and Carr 2033). In 2002, there was recent evidence of seeding activity of fall rye, clover, and reed canary grass. Well-developed patches of clover and reed canarygrass as well as other agronomic species were scattered throughout the site. A treatment area of 33.7 ha positioned north of the Valemount Peatland and west of the Canoe river was identified by Moody and Carr (2003) as Site 2. Soils were sandy and deficient in nutrients and organics (Keefer et al 2008).

Draft treatment prescriptions were developed in 2008 (Keefer et al 2008) and finalized in 2009 (Keefer and Ross 2009). Planting treatments were undertaken in 2009 and no other year.

Site information:

Reach	Canoe Reach
MC Unit	K 02
UTM's	11U 353749 E 5849627 N
BEC	SBS dh 1
Vegetation Communities see Table 3-2	CH, CO, DR, KS, SH, TP, WS
Area (ha)	3.82 / 3.88
Elevation (m)	Min: 746.7 Max: 758.9
# of Polygons:	28
Years:	2009

Treatment Summary

Treatments were undertaken in the spring of 2009, totaling 3.82 ha across 28 treatment polygons. Treatments consisted of sowing Kellogg's sedge seeds (0.89 ha) and BC Hydro seed mixes (0.54 ha) and planting of graminoid seedlings (1.30 ha), shrub seedlings (0.92 ha), and shrub stakes (0.23 ha). Graminoid seedlings species planted included bluejoint, wool-grass, small-fruited bulrush, and lenticular and Columbia sedge. Shrub seedlings planted included black cottonwood, willow sp., and mountain alder. Shrubs stakes included black cottonwood, willow sp., and red-osier dogwood. A modified brush layer was created from black cottonwood stakes at one locale. An unknown number of sites were fertilized at a rate of 370 kg/ha (Keefer et al 2010).

Summary of Planting Success

Hawkes et al (2013) concluded that all sedge plug and live stake plantings conducted in 2008 to 2011 were unsuccessful. Sedge plug survivorship declined from approximately 40 per cent in the two years following planting, to < 10 per cent three years post-planting, to less than five per cent four to five years post-planting. Live stakes of deciduous shrubs (willows, alder, and cottonwood) appear to have fared worse, with none found surviving five years after planting. Shrub seedling survival and the establishment of seeding treatments were not assessed.

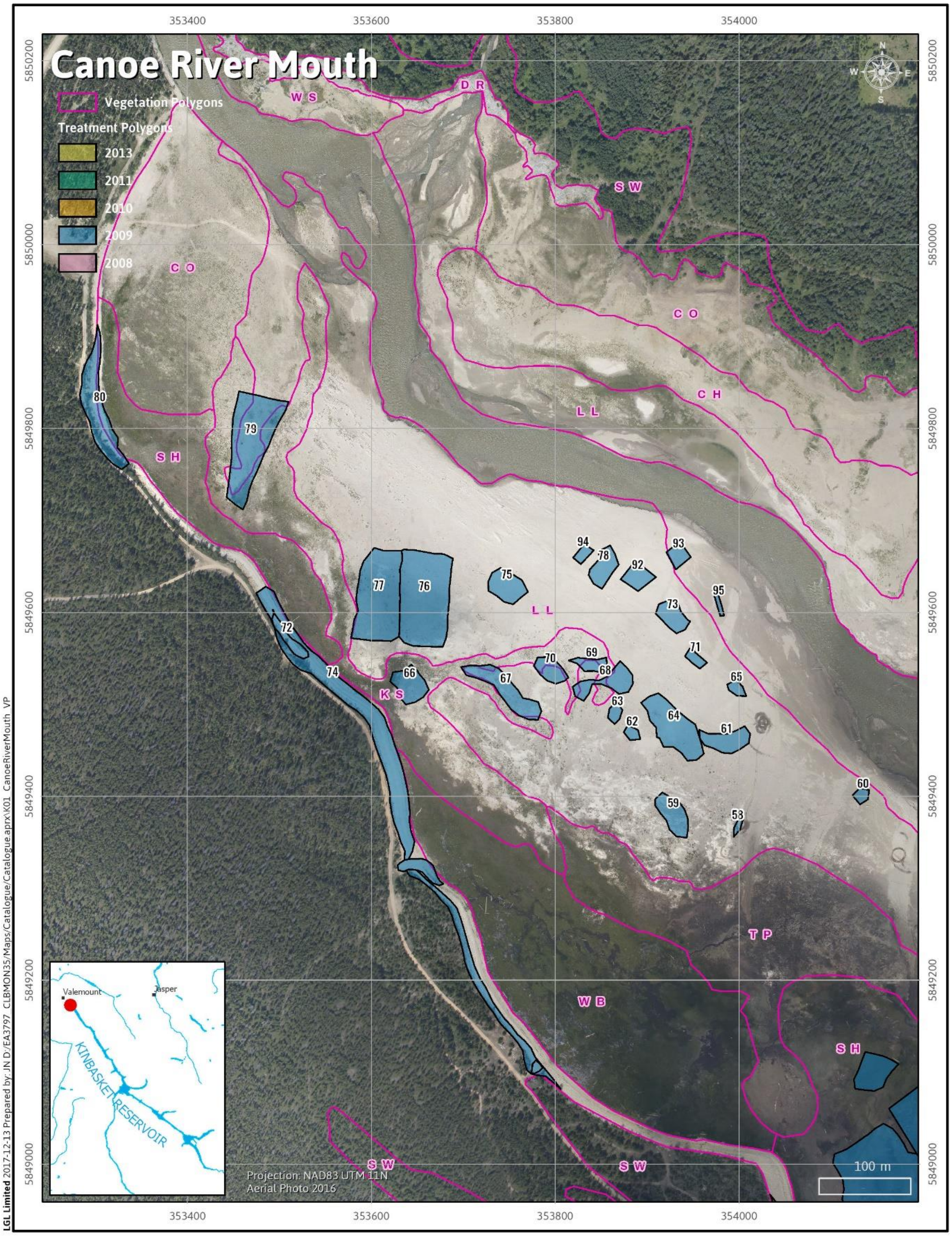
Documents

Type	Year	Author	Short Title
Prescription	2003	Moody and Carr	Potential Areas for Vegetation Establishment in Kinbasket
Prescription	2007	Keefer et al	Site Verification and Seed Collection 2007
Summary	2008	Keefer et al	Kinbasket Revegetation Report 2008
Prescription	2009	Keefer and Ross	Kinbasket Reservoir Planting Plan for 2009
Summary	2010	Keefer et al.	Kinbasket Revegetation Report 2009
Monitoring	2013	Hawkes et al.	Kinbasket Monitoring Report 2013

Canoe River Mouth Kinbasket Reservoir

Year 2009

MC#	Polygon	Elevation	Treatment Type	Species	Density/Rate	Area (ha)
K 02	58	747.65	graminoid seedling	bluejoint reedgrass	40909 sph	0.01
K 02	59	748.02	graminoid seedling	Kellogg's sedge	22679 sph	0.10
K 02	60	747.05	graminoid seedling	wool-grass	95786 sph	0.02
K 02	61	747.83	graminoid seedling	small-fruited bulrush	54040 sph	0.10
K 02	62	748.17	graminoid seedling	Columbia sedge	60268 sph	0.02
K 02	63	748.45	graminoid seedling	bluejoint reedgrass	40909 sph	0.02
K 02	64	748.07	graminoid seedling	Kellogg's sedge	22679 sph	0.25
K 02	65	747.63	graminoid seedling	wool-grass	84873 sph	0.02
K 02	66	749.49	shrub stake	black cottonwood	1645 sph	0.11
K 02	66	749.49	shrub stake	black cottonwood	493 sph	0.11
K 02	66	749.49	shrub stake	willow sp.	35 sph	0.11
K 02	66	749.49	shrub stake	red-osier dogwood	184 sph	0.11
K 02	67	749.00	graminoid seedling	Kellogg's sedge	22679 sph	0.17
K 02	68	748.63	graminoid seedling	Kellogg's sedge	22679 sph	0.11
K 02	69	748.50	graminoid seedling	small-fruited bulrush	54040 sph	0.04
K 02	70	748.91	shrub stake	black cottonwood	1645 sph	0.07
K 02	70	748.91	shrub seedling	mixed species: willow and alder	2725 sph	0.07
K 02	71	747.94	graminoid seedling	Columbia sedge	60268 sph	0.02
K 02	73	748.24	graminoid seedling	Kellogg's sedge	22679 sph	0.08
K 02	75	749.28	graminoid seedling	small-fruited bulrush	54040 sph	0.11
K 02	76	749.74	seed mix	BC Hydro wetland seed mix	19 kg/ha	0.54
K 02	77	750.00	graminoid seed	Kellogg's sedge - coated seed	36 kg/ha	0.45
K 02	78	748.82	graminoid seedling	small-fruited bulrush	54040 sph	0.08
K 02	79	750.93	graminoid seed	Kellogg's sedge	21 kg/ha	0.45
K 02	80	754.53	shrub seedling	mixed species: willow and alder	2725 sph	0.26
K 02	92	748.57	graminoid seedling	Kellogg's sedge	22679 sph	0.06
K 02	93	748.10	graminoid seedling	Kellogg's sedge	22679 sph	0.04
K 02	94	748.91	graminoid seedling	wool-grass	84873 sph	0.02
K 02	95	747.64	graminoid seedling	wool-grass	84873 sph	0.01
K 02	95	747.64	graminoid seedling	Columbia sedge	60268 sph	0.01
K 02	95	747.64	graminoid seedling	small-fruited bulrush	55629 sph	0.01



Map 4-1. **Distribution of revegetation prescription trials at Canoe River Mouth, Kinbasket Reservoir, 2009.** Vegetation communities are defined in Table 3-2.

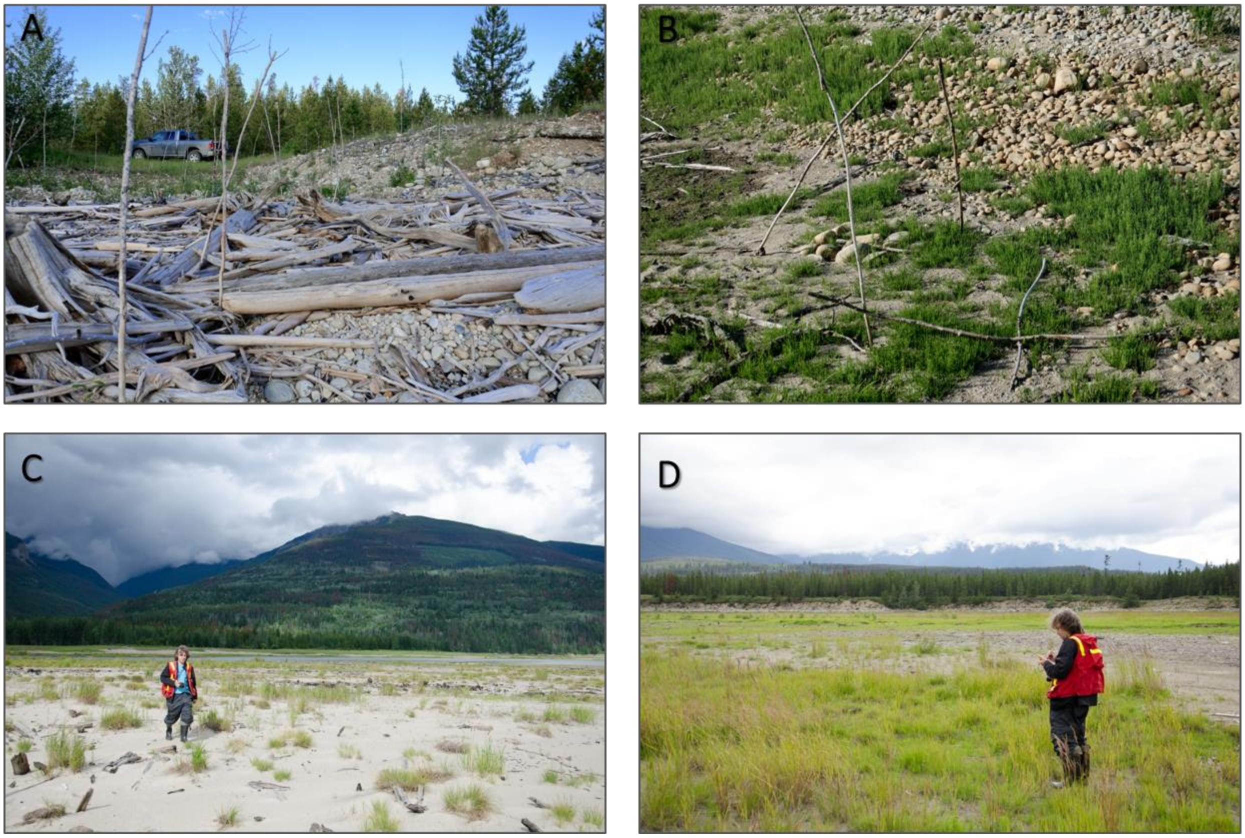


Figure 4-1. Examples of revegetation prescriptions trialed at Canoe River Mouth in 2009. A and B: live staking; C and D, graminoid seedlings. Photo credit: Doug Adama. Model: Guy Martel.

Valemount Peatland — Kinbasket Reservoir

Site Description:

The Valemount Peatland is a remnant fenland located at the north end of Kinbasket Reservoir just south of the mouth of the Canoe River. The Valemount Peatland is comprised of vegetation communities that reflect both the historic fen complex that existed prior to inundation and the elevation gradient within the reservoir (Moody and Carr 2003, Hawkes et al. 2010). As suggested in the site name, peat is the dominant substrate; however, wood debris and wood fragments blanket portions of the remnant fenland excluding vegetation growth (Hawkes et al. 2010).

Draft treatment prescriptions were developed in 2008 (Keefer et al 2008) and finalized in 2009 (Keefer and Ross 2009). Planting treatments were undertaken in 2009 and no other year.

Site information:

Reach	Canoe Reach
MC Unit	K 08
UTM's	11U 354234 E 5848803 N
BEC	SBS dh 1
Vegetation Communities see Table 3-2	BR, BS, DR, KS, LL, RD, SH, TP, WB, WD, WS
Area (ha)	4.34 / 4.37
Elevation (m)	Min: 746.3 Max: 756.3
# of Polygons:	20
Years:	2009

Treatment Summary

Treatments were undertaken in the spring of 2009, totaling 4.34 ha across 20 treatment polygons. Treatments consisted of sowing bluejoint/clover and BC Hydro seed mixes (1.89 ha) and planting of graminoid seedlings (1.48 ha), shrub seedlings (0.86 ha), and shrub stakes (0.13 ha). Graminoid seedlings species planted included wool-grass, small-fruited bulrush, and Columbia, lenticular and water sedge. Shrub seedlings planted included black cottonwood, willow sp., and mountain alder. Shrubs stakes included black cottonwood, willow sp., and red-osier dogwood. A modified brush layer was created from black cottonwood stakes at one locale. An unknown number of sites were fertilized at a rate of 370 kg/ha (Keefer et al 2010).

Summary of Planting Success

Hawkes et al (2013) concluded that all sedge plug and live stake plantings conducted in 2008 to 2011 were unsuccessful. Sedge plug survivorship declined from approximately 40 per cent in the two years following planting, to < 10 per cent three years post-planting, to less than five per cent four to five years post-planting. Live stakes of deciduous shrubs (willows, alder, and cottonwood) appear to have fared worse, with none found surviving five years after planting. Shrub seedling survival and the establishment of seeding treatments were not assessed.

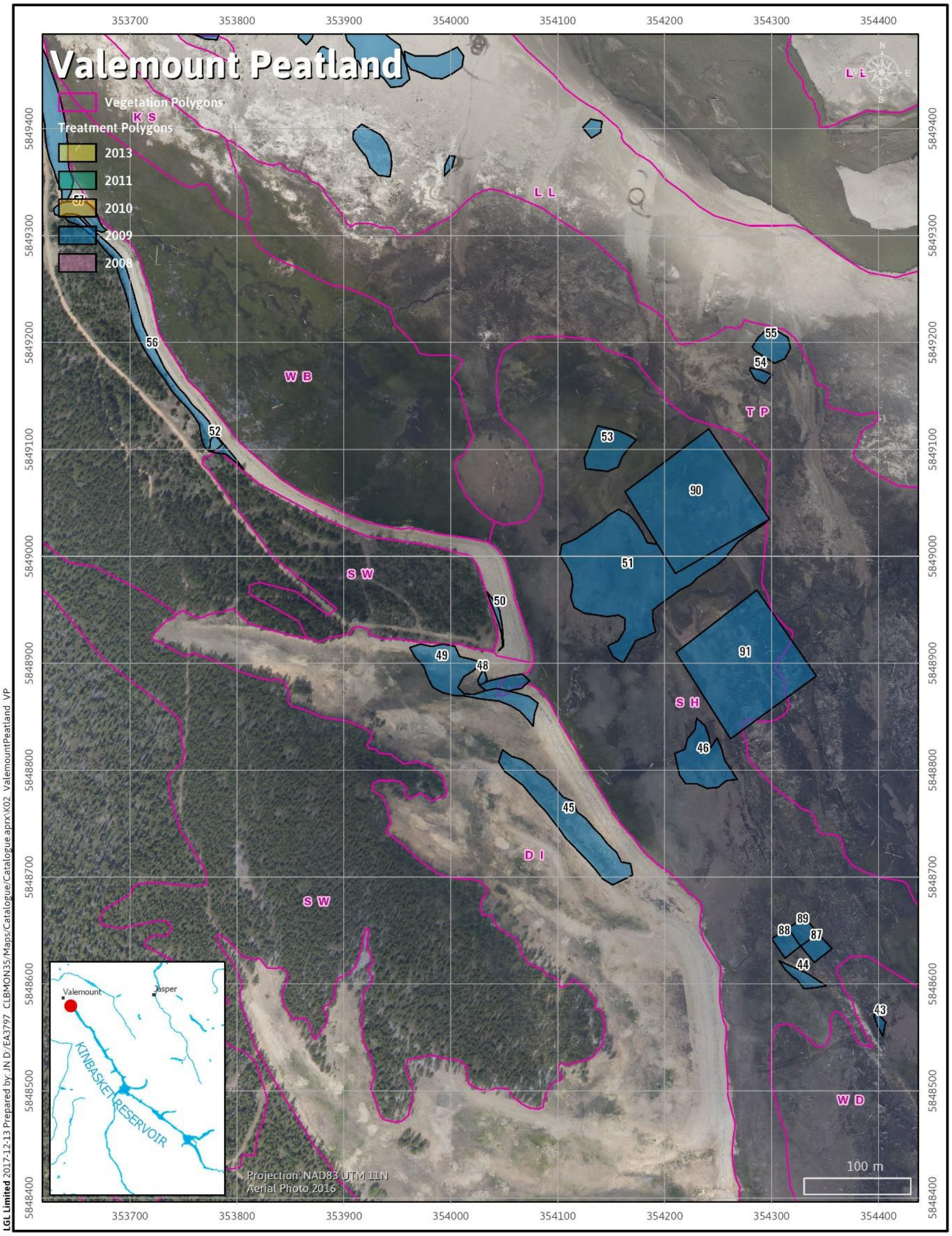
Documents

Type	Year	Author	Short Title
Prescription	2003	Moody and Carr	Potential Areas for Vegetation Establishment in Kinbasket
Prescription	2007	Keefer et al	Site Verification and Seed Collection 2007
Summary	2008	Keefer et al	Kinbasket Revegetation Report 2008
Prescription	2009	Keefer and Ross	Kinbasket Reservoir Planting Plan for 2009
Summary	2010	Keefer et al.	Kinbasket Revegetation Report 2009
Inventory	2010	Hawkes et al.	Kinbasket Vegetation Inventory 2010
Monitoring	2013	Hawkes et al.	Kinbasket Monitoring Report 2013

Valemount Peatland Kinbasket Reservoir

Year 2009

MC#	Polygon	Elevation	Treatment Type	Species	Density/Rate	Area (ha)
K 08	43	747.38	graminoid seedling	Columbia sedge	11890 sph	0.01
K 08	44	748.64	shrub stake	Mixed Species: Willow Red Osier	330 sph	0.04
K 08	44	748.64	shrub seedling	willow sp.	2513 sph	0.04
K 08	51	747.46	graminoid seedling	mixed graminoid species	11890 sph	0.93
K 08	53	747.13	graminoid seedling	small-fruited bulrush	11890 sph	0.13
K 08	53	747.13	graminoid seedling	water sedge	11890 sph	0.13
K 08	54	746.47	graminoid seedling	water sedge	11890 sph	0.02
K 08	55	746.42	graminoid seedling	small-fruited bulrush	11890 sph	0.07
K 08	87	747.92	graminoid seedling	water sedge	11890 sph	0.04
K 08	88	748.29	graminoid seedling	wool-grass	11890 sph	0.04
K 08	89	747.83	graminoid seedling	small-fruited bulrush	11890 sph	0.04
K 08	90	746.76	seed mix	bluejoint reedgrass	9 kg/ha	0.95
K 08	91	746.93	seed mix	BC Hydro wetland seed mix	20 kg/ha	0.94



Map 4-2. **Distribution of revegetation prescription trials at the Valemount Peatland, Kinbasket Reservoir, 2009.** Vegetation communities are defined in Table 3-2.

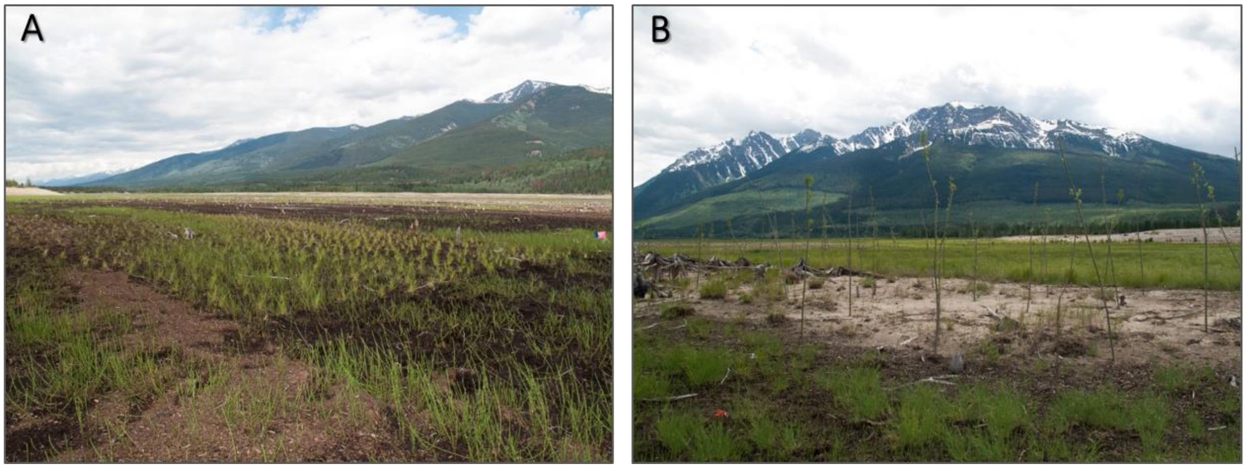


Figure 4-2. Examples of revegetation prescriptions trialed at Valemount Peatland in 2009. A: graminoid seedling; B: shrub staking. Photo credit: Doug Adama.

Dave Henry Creek North

Kinbasket Reservoir

Site Description:

The Dave Henry Creek North treatment area is located 2 km north of Dave Henry Creek on east side of the Kinbasket Reservoir in Canoe Reach. The site is approximately 13 km south of the Village of Valemount off the East Canoe FSR. Soils were silty and nutrient deficient. Blanket prescriptions prepared in 2008 (Keefer et al 2008) were applied refined for the site in 2009 (Keefer and Ross 2009).

Site information:

Reach	Canoe Reach
MC Unit	K 09
UTM's	11U 357180 E 5847409 N
BEC	SBS dh 1
Vegetation Communities see Table 3-2	CH, CO
Area (ha)	1.23 / 1.94
Elevation (m)	Min: 743.7 Max: 752.2
# of Polygons:	5
Years:	2009

Treatment Summary

Treatments were undertaken in the spring of 2009, totaling 1.23 ha across 5 treatment polygons. Treatments consisted of sowing bluejoint/clover and BC Hydro seed mixes (0.50 ha) and planting of graminoid seedlings (0.72 ha). Planted graminoid seedlings species included Kellogg's sedge and a mix of Kellogg's sedge, wool-grass, and blue joint.

Summary of Planting Success

Hawkes et al (2013) concluded that all sedge plug and live stake plantings conducted in 2008 to 2011 were unsuccessful. Sedge plug survivorship declined from approximately 40 per cent in the two years following planting, to < 10 per cent three years post-planting, to less than five per cent four to five years post-planting. Live stakes of deciduous shrubs (willows, alder, and cottonwood) appear to have fared worse, with none found surviving five years after planting. Shrub seedling survival and the establishment of seeding treatments were not assessed.

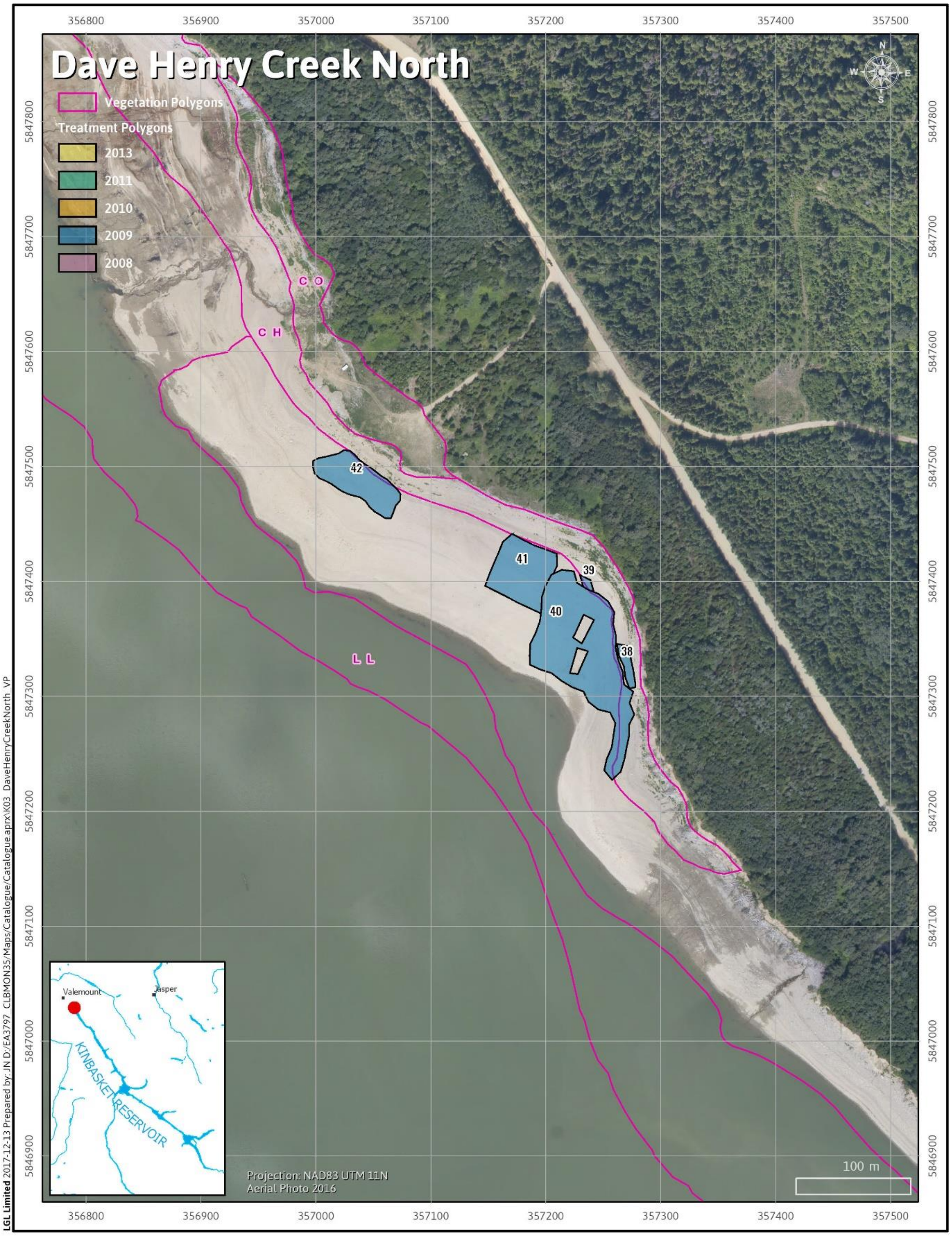
Documents

Type	Year	Author	Short Title
Prescription	2003	Moody and Carr	Potential Areas for Vegetation Establishment in Kinbasket
Prescription	2007	Keefer et al	Site Verification and Seed Collection 2007
Summary	2008	Keefer et al	Kinbasket Revegetation Report 2008
Prescription	2009	Keefer and Ross	Kinbasket Reservoir Planting Plan for 2009
Summary	2010	Keefer et al.	Kinbasket Revegetation Report 2009
Inventory	2010	Hawkes et al.	Kinbasket Vegetation Inventory 2010
Monitoring	2013	Hawkes et al.	Kinbasket Monitoring Report 2013

Dave Henry Creek North *Kinbasket Reservoir*

Year 2009

MC#	Polygon	Elevation	Treatment Type	Species	Density/Rate	Area (ha)
K 09	38	750.75	seed mix	BC Hydro upland seed mix	kg/ha	0.03
K 09	39	749.70	graminoid seedling	bluejoint reedgrass	24583 sph	0.01
K 09	40	747.30	graminoid seedling	mixed graminoid species	24583 sph	0.71
K 09	40	747.30	graminoid seedling	Kellogg's sedge	24583 sph	0.71
K 09	40	747.30	graminoid seedling	Kellogg's sedge	24583 sph	0.71
K 09	41	748.84	seed mix	BC Hydro upland seed mix	kg/ha	0.26
K 09	42	749.23	seed mix	bluejoint reedgrass	kg/ha	0.22



Map 4-3. Distribution of revegetation prescription trials at Dave Henry Creek North, Kinbasket Reservoir, 2009. Vegetation communities are defined in Table 3-2.

Dave Henry Creek South Kinbasket Reservoir

Site Description:

The Dave Henry Creek South is located on east side of the Kinbasket Reservoir, 15 km south of the Village of Valemount. The treatment area is situated on the alluvial fan at the mouth of Dave Henry Creek. Soils were silty and nutrient deficient. Blanket prescriptions prepared in 2008 (Keefer et al 2008) were applied refined for the site in 2009 (Keefer and Ross 2009).

Site information:

Reach	Canoe Reach
MC Unit	K 12
UTM's	11U 358343 E 5845572 N
BEC	ICH mm
Vegetation Communities see Table 3-2	CH, CO, LL, TP
Area (ha)	3.82 / 3.86
Elevation (m)	Min: 738.3 Max: 753.8
# of Polygons:	16
Years:	2009

Treatment Summary

Treatments were undertaken in the spring of 2009, totaling 3.82 ha across 16 treatment polygons. Treatments consisted of sowing bluejoint/clover and BC Hydro seed mixes (1.79 ha) and planting of graminoid seedlings (0.83 ha) The species of graminoid seedlings planted included bluejoint, wool-grass, small-fruited bulrush, and Columbia, lenticular and water sedge. An unknown number of sites were fertilized at a rate of 370 kg/ha (Keefer et al 2010)

Summary of Planting Success

Hawkes et al (2013) concluded that all sedge plug and live stake plantings conducted in 2008 to 2011 were unsuccessful. Sedge plug survivorship declined from approximately 40 per cent in the two years following planting, to < 10 per cent three years post-planting, to less than five per cent four to five years post-planting. Live stakes of deciduous shrubs (willows, alder, and cottonwood) appear to have fared worse, with none found surviving five years after planting. Shrub seedling survival and the establishment of seeding treatments were not assessed.

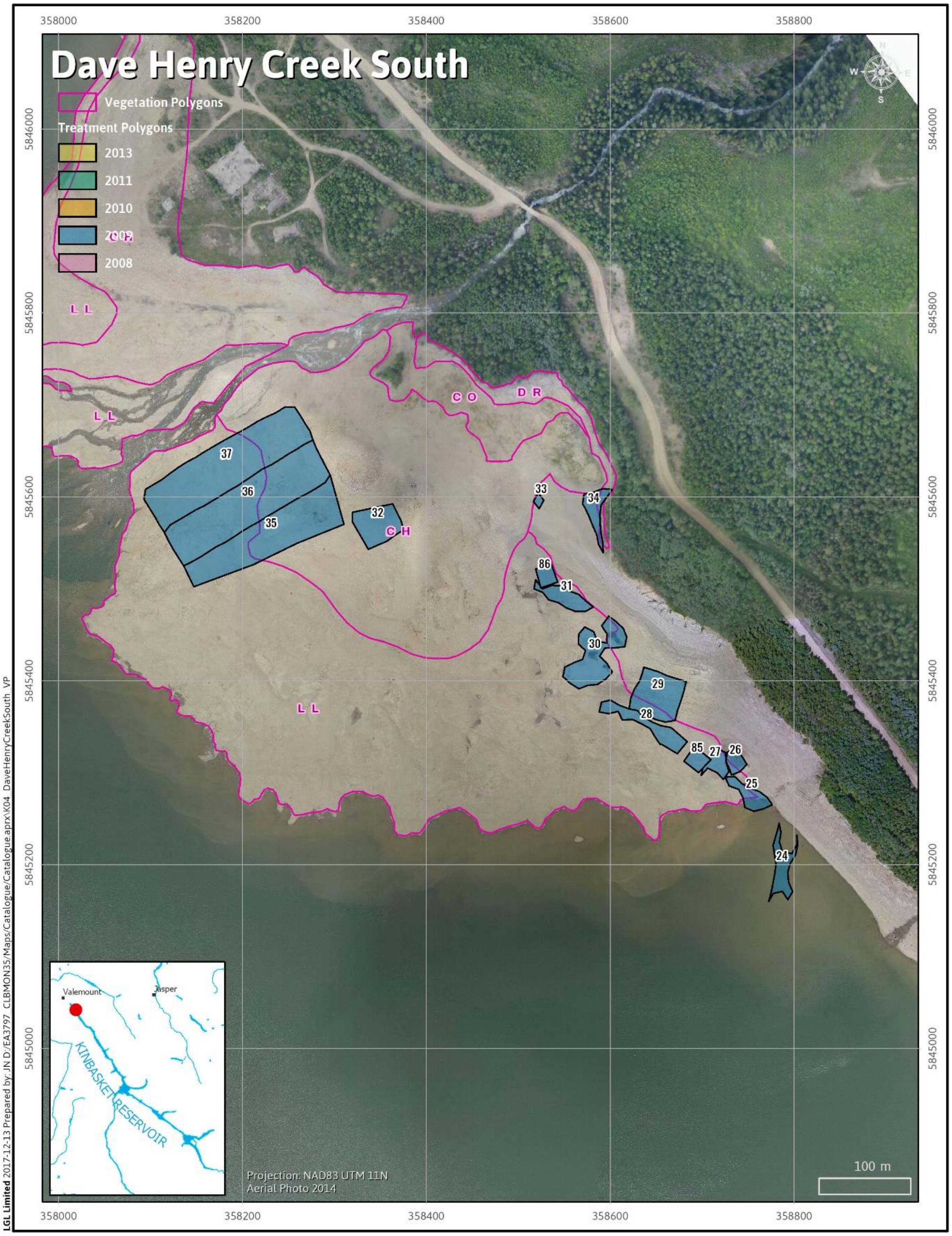
Documents

Type	Year	Author	Short Title
Prescription	2003	Moody and Carr	Potential Areas for Vegetation Establishment in Kinbasket
Prescription	2007	Keefer et al	Site Verification and Seed Collection 2007
Summary	2008	Keefer et al	Kinbasket Revegetation Report 2008
Prescription	2009	Keefer and Ross	Kinbasket Reservoir Planting Plan for 2009
Summary	2010	Keefer et al.	Kinbasket Revegetation Report 2009
Inventory	2010	Hawkes et al.	Kinbasket Vegetation Inventory 2010
Monitoring	2013	Hawkes et al.	Kinbasket Monitoring Report 2013

Dave Henry Creek South *Kinbasket Reservoir*

Year 2009

MC#	Polygon	Elevation	Treatment Type	Species	Density/Rate	Area (ha)
K 12	24	738.65	graminoid seedling	small-fruited bulrush	24390 sph	0.10
K 12	25	738.79	graminoid seedling	wool-grass	24390 sph	0.08
K 12	26	739.57	graminoid seedling	water sedge	24390 sph	0.04
K 12	26	739.57	graminoid seedling	small-fruited bulrush	24390 sph	0.04
K 12	27	739.55	graminoid seedling	Kellogg's sedge	24390 sph	0.05
K 12	27	739.55	graminoid seedling	Kellogg's sedge	24390 sph	0.05
K 12	28	740.95	graminoid seedling	Kellogg's sedge	24390 sph	0.13
K 12	28	740.95	graminoid seedling	Kellogg's sedge	24390 sph	0.13
K 12	29	743.26	seed mix	bluejoint reedgrass	11 kg/ha	0.24
K 12	30	743.12	graminoid seedling	mixed graminoid species	24390 sph	0.25
K 12	31	745.01	graminoid seedling	Kellogg's sedge	24390 sph	0.09
K 12	31	745.01	graminoid seedling	Kellogg's sedge	24390 sph	0.09
K 12	32	747.22	seed mix	bluejoint reedgrass	? kg/ha	0.18
K 12	33	749.27	graminoid seedling	Kellogg's sedge	24390 sph	0.01
K 12	33	749.27	graminoid seedling	Kellogg's sedge	24390 sph	0.01
K 12	34	752.84	seed mix	bluejoint reedgrass	kg/ha	0.08
K 12	35	744.10	seed mix	BC Hydro upland/wetland seed mix	kg/ha	0.70
K 12	36	743.60	graminoid seed	Kellogg's sedge - coated seed	26 kg/ha	0.87
K 12	37	743.57	graminoid seed	Kellogg's sedge	16 kg/ha	0.92
K 12	85	739.64	graminoid seedling	Columbia sedge	? sph	0.04
K 12	86	746.02	graminoid seedling	bluejoint reedgrass	? sph	0.04



Map 4-4. Distribution of revegetation prescription trials at Dave Henry Creek South, Kinbasket Reservoir, 2009. Vegetation communities are defined in Table 3-2.

Yellowjacket Creek Kinbasket Reservoir

Site Description:

Yellowjacket Creek is located on the east side of Canoe Reach, 20 km south of the Village of Valemount. The treatment area is located on the alluvial fan formed by Yellowjacket creek. Soils varied from sand to coarse rock and were rapidly drained. Vegetation occurred predominantly in slight depressions between beach ridges and consisted Kellogg's sedge, sawbeak sedge, water horsetail and Crawford's sedge.

Draft treatment prescriptions were developed in 2008 (Keefer et al 2008) and finalized in 2009 (Keefer and Ross 2009). Planting treatments were undertaken in 2009 and no other year.

Site information:

Reach	Canoe Reach
MC Unit	K 15,16
UTM's	11U 361150 E 5841324 N
BEC	ICH mm
Vegetation Communities see Table 3-2	BR, CH, CO
Area (ha)	16.07 / 19.13
Elevation (m)	Min: 738.5 Max: 755.4
# of Polygons:	13
Years:	2009

Treatment Summary

Treatments were undertaken in the spring of 2009, totaling 16.07 ha across 13 treatment polygons. Treatments consisted of sowing bluejoint/clover and BC Hydro seed mixes (4.40 ha) and Kellogg's sedge seeds (0.48 ha), planting of graminoid (10.62 ha) and shrub (1.08 ha) seedling, and fertilization (3.06 ha). Graminoid seedlings species planted included bluejoint, wool-grass, small-fruited bulrush, and Columbia, lenticular and water sedge. Shrub seedlings planted included willow sp., and mountain alder. An unknown number of sites were fertilized at a rate of 370 kg/ha (Keefer et al 2010).

Summary of Planting Success

Hawkes et al (2013) concluded that all sedge plug and live stake plantings conducted in 2008 to 2011 were unsuccessful. Sedge plug survivorship declined from approximately 40 per cent in the two years following planting, to < 10 per cent three years post-planting, to less than five per cent four to five years post-planting. Live stakes of deciduous shrubs (willows, alder, and cottonwood) appear to have fared worse, with none found surviving five years after planting. Shrub seedling survival and the establishment of seeding treatments were not assessed.

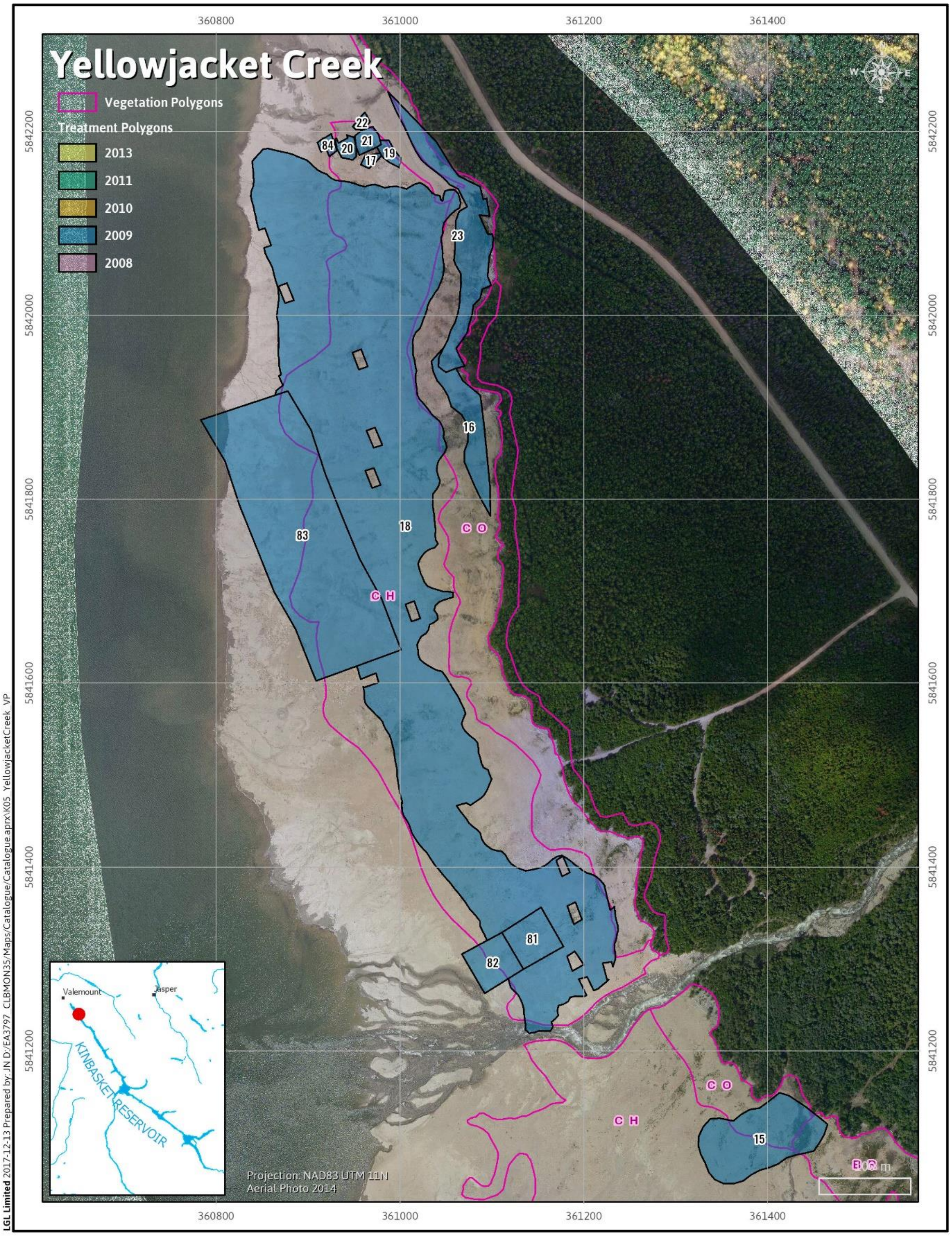
Documents

Type	Year	Author	Short Title
Prescription	2003	Moody and Carr	Potential Areas for Vegetation Establishment in Kinbasket
Prescription	2007	Keefer et al	Site Verification and Seed Collection 2007
Summary	2008	Keefer et al	Kinbasket Revegetation Report 2008
Prescription	2009	Keefer and Ross	Kinbasket Reservoir Planting Plan for 2009
Summary	2010	Keefer et al.	Kinbasket Revegetation Report 2009
Inventory	2010	Hawkes et al.	Kinbasket Vegetation Inventory 2010
Monitoring	2013	Hawkes et al.	Kinbasket Monitoring Report 2013

Yellowjacket Creek Kinbasket Reservoir

Year 2009

MC#	Polygon	Elevation	Treatment Type	Species	Density/Rate	Area (ha)
K 15/16	15	751.49	seed mix	bluejoint reedgrass	24 kg/ha	0.83
K 15/16	16	752.72	shrub seedling	mixed species: willow and alder	4031 sph	0.35
K 15/16	17	745.65	graminoid seedling	bluejoint reedgrass	4805 sph	0.02
K 15/16	18	746.34	graminoid seedling	mixed graminoid species	4805 sph	10.41
K 15/16	19	746.73	graminoid seedling	Kellogg's sedge	4805 sph	0.04
K 15/16	20	744.31	graminoid seedling	water sedge	4805 sph	0.04
K 15/16	21	745.69	graminoid seedling	Columbia sedge	4805 sph	0.06
K 15/16	22	746.62	graminoid seedling	small-fruited bulrush	4805 sph	0.02
K 15/16	23	752.87	shrub seedling	mixed species: willow and alder	4031 sph	0.72
K 15/16	81	746.18	graminoid seed	Kellogg's sedge - coated seed	83 kg/ha	0.24
K 15/16	82	743.93	graminoid seed	Kellogg's sedge - pellet seed	84 kg/ha	0.24
K 15/16	83	742.48	Fertilizer	Fertilizer	333 kg/ha	3.06
K 15/16	83	742.48	seed mix	BC Hydro upland/wetland seed	13 kg/ha	3.06
K 15/16	84	742.95	graminoid seedling	mixed graminoid species	4805 sph	0.03



Map 4-5. Distribution of revegetation prescription trials at Yellowjacket Creek, Kinbasket Reservoir, 2009. Vegetation communities are defined in Table 3-2.

Ptarmigan Creek — Kinbasket Reservoir

Site Description:

The Ptarmigan Creek site is located on the east side of Canoe Reach, 37 km south of the Village of Valemount. The treatment area is a glacial fluvial terrace of sand and gravel. Soils were sandy in texture, rapidly drained, and nutrient deficient (Keefer et al 2008). Active erosion is apparent on the western slope of the terrace and wood debris accumulates in the lee of the small sheltered bay. A small pond (1 ha), which occurs at the head of the bay, supports a robust breeding population of western toads. A wet meadow supporting hydrophilic vegetation occurs down slope of the pond. On more than one occasion, wood debris has been removed from the site by BC Hydro though the WLR and FWCP programs.

Draft treatment prescriptions were developed in 2008 (Keefer et al 2008) and finalized in 2009 (Keefer and Ross 2009). Planting treatments were undertaken in 2009 and no other year.

Site information:

Reach	Canoe Reach
MC Unit	K 24, 25
UTM's	11U 373520 E 5828094 N
BEC	ICH mm
Vegetation Communities see Table 3-2	CO, KS, TP
Area (ha)	2.16 / 3.31
Elevation (m)	Min: 745.0 Max: 753.8
# of Polygons:	4
Years:	2009

Treatment Summary

Treatments were undertaken in the spring of 2009, totaling 2.16 ha across 4 treatment polygons. Treatments included the planting of graminoid seedlings (2.12 ha) and live stakes of black cottonwood and willow sp. (0.37 ha). Graminoid seedlings species planted included bluejoint, wool-grass, and Columbia, lenticular and water sedge. Shrub stakes planted included willow sp., and mountain alder. An unknown number of sites were fertilized at a rate of 370 kg/ha (Keefer et al 2010).

Summary of Planting Success

Hawkes et al (2013) concluded that all sedge plug and live stake plantings conducted in 2008 to 2011 were unsuccessful. Sedge plug survivorship declined from approximately 40 per cent in the two years following planting, to < 10 per cent three years post-planting, to less than five per cent four to five years post-planting. Live stakes of deciduous shrubs (willows, alder, and cottonwood) appear to have fared worse, with none found surviving five years after planting. Shrub seedling survival and the establishment of seeding treatments were not assessed.

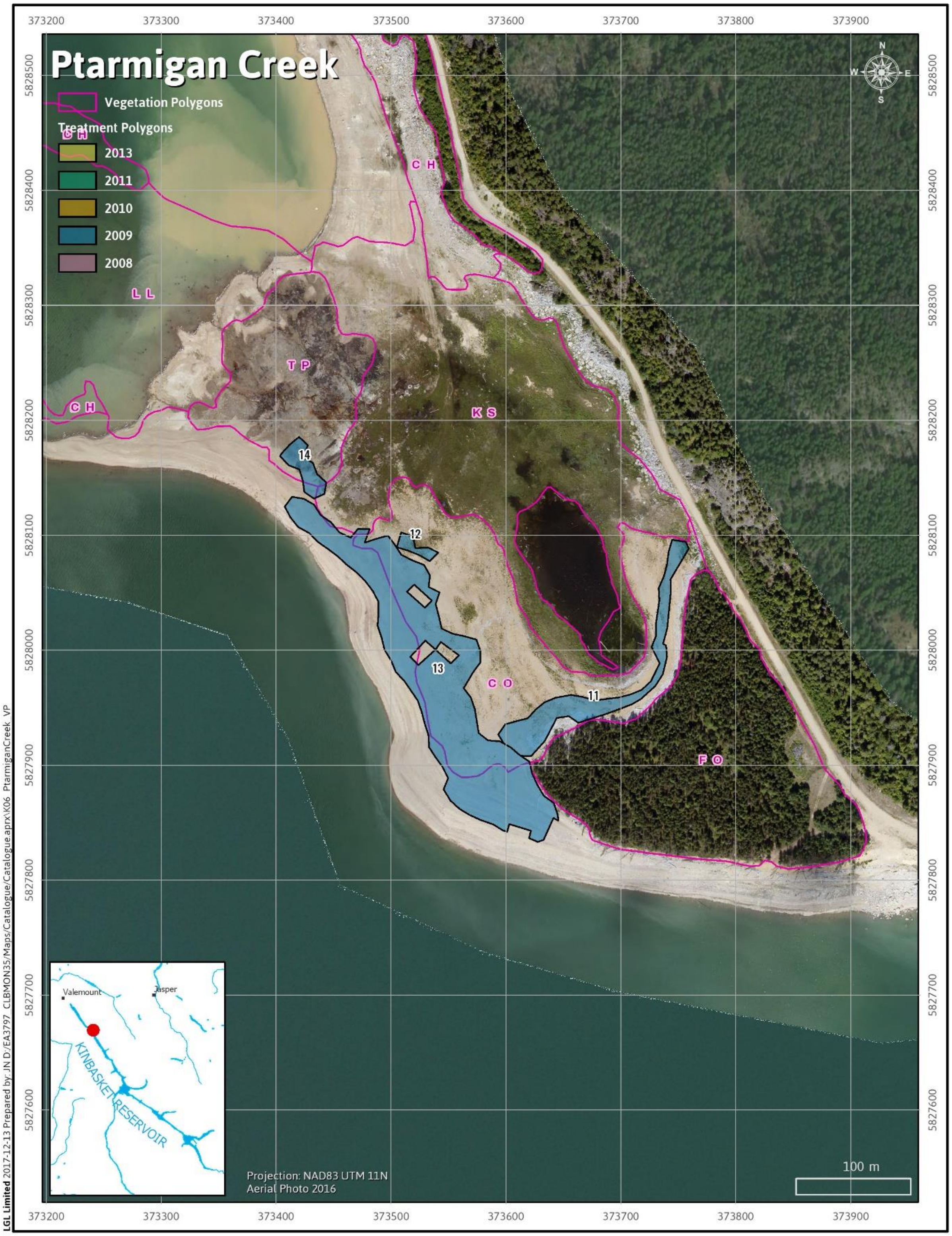
Documents

Type	Year	Author	Short Title
Prescription	2003	Moody and Carr	Potential Areas for Vegetation Establishment in Kinbasket
Prescription	2007	Keefer et al	Site Verification and Seed Collection 2007
Summary	2008	Keefer et al	Kinbasket Revegetation Report 2008
Prescription	2009	Keefer and Ross	Kinbasket Reservoir Planting Plan for 2009
Summary	2010	Keefer et al.	Kinbasket Revegetation Report 2009
Inventory	2010	Hawkes et al.	Kinbasket Vegetation Inventory 2010
Monitoring	2013	Hawkes et al.	Kinbasket Monitoring Report 2013

Ptarmigan Creek Kinbasket Reservoir

Year 2009

MC#	Polygon	Elevation	Treatment Type	Species	Density/Rate	Area (ha)
K 24/25	11	752.58	shrub stake	black cottonwood	563 sph	0.37
K 24/25	11	752.58	shrub stake	willow sp.	1341 sph	0.37
K 24/25	11	752.58	graminoid seedling	bluejoint reedgrass	8406 sph	0.37
K 24/25	11	752.58	graminoid seedling	Kellogg's sedge	8406 sph	0.37
K 24/25	12	748.36	graminoid seedling	water sedge	8406 sph	0.03
K 24/25	12	748.36	graminoid seedling	wool-grass	8406 sph	0.03
K 24/25	13	750.10	graminoid seedling	mixed graminoid species	8406 sph	1.66
K 24/25	14	745.56	graminoid seedling	Mixed wetland seedling	8406 sph	0.09



Map 4-6. **Distribution of revegetation prescription trials at Ptarmigan Creek, Kinbasket Reservoir, 2009.** Vegetation communities are defined in Table 3-2.

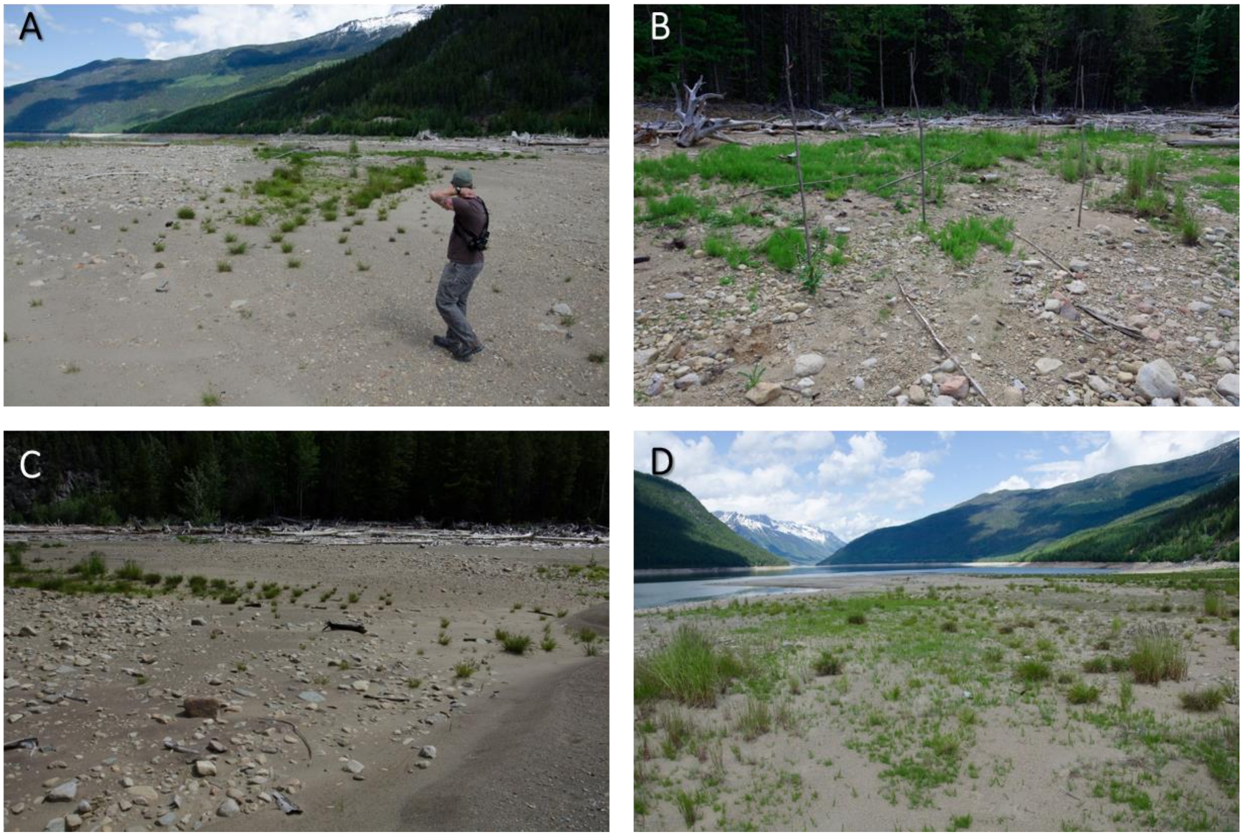


Figure 4-3. Examples of revegetation prescriptions trialed at Ptarmigan Creek in 2009. A: graminoid seedling; B: shrub staking. The challenging terrain associated with some revegetation sites is highlighted in these photos. Photo credit: Doug Adama. Model: Virgil Hawkes.

Windfall Creek   Kinbasket Reservoir

Site Description:

Windfall Creek is located on the west shore of Kinbasket Reservoir, 56 km south of the Village of Valemount. Treatment areas were located on the north and south side of Windfall Creek. Soils were silty or sandy and drained rapidly or imperfectly (Keefer et al 2008). The site is prone to wood debris accumulation and wood debris removal in 2011 by BC Hydro wood debris program resulted in complete loss of 2009 revegetation effort (Hawkes et al 2013).

Draft treatment prescriptions were developed in 2008 (Keefer et al 2008) and finalized in 2009 (Keefer and Ross 2009). Planting treatments were undertaken in 2009 and no other year.

Site information:

Reach	Canoe Reach
MC Unit	K 33,34
UTM's	11U 381984 E 5810359 N
BEC	ICH mm
Vegetation Communities see Table 3-2	CH, CO, CT, DR, KS, LL
Area (ha)	3.77 / 3.77
Elevation (m)	Min: 740.3 Max: 752.6
# of Polygons:	9
Years:	2009

Treatment Summary

Treatments were undertaken in the spring of 2009, totaling 3.77 ha across 9 treatment polygons. Five treatment polygons were located north of Windfall Creek and four treatment polygons were located to the south of Windfall Creek. Treatments consisted of sowing bluejoint/clover seed mixes (2.24 ha) and planting of graminoid seedlings (1.53 ha). Graminoid seedlings species included bluejoint, wool-grass, and Columbia and Kellogg's sedge.

Summary of Planting Success

The 2009 revegetation efforts at Windfall Creek were almost entirely destroyed by the wood debris removal program in 2011 (Hawkes et al 2013).

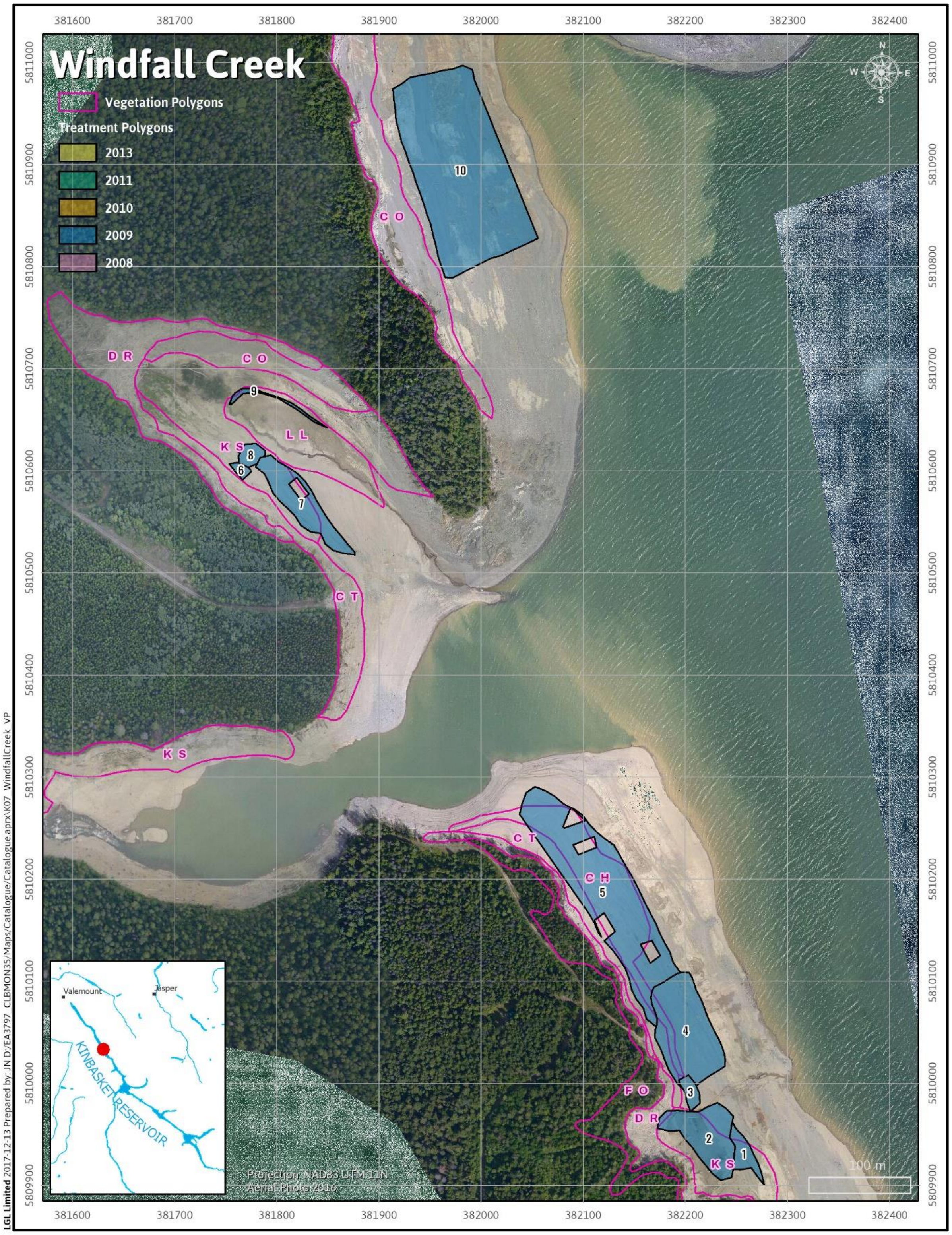
Documents

Type	Year	Author	Short Title
Prescription	2003	Moody and Carr	Potential Areas for Vegetation Establishment in Kinbasket
Prescription	2007	Keefer et al	Site Verification and Seed Collection 2007
Summary	2008	Keefer et al	Kinbasket Revegetation Report 2008
Prescription	2009	Keefer and Ross	Kinbasket Reservoir Planting Plan for 2009
Summary	2010	Keefer et al.	Kinbasket Revegetation Report 2009
Inventory	2010	Hawkes et al.	Kinbasket Vegetation Inventory 2010
Monitoring	2013	Hawkes et al.	Kinbasket Monitoring Report 2013

Windfall Creek Kinbasket Reservoir

Year 2009

MC#	Polygon	Elevation	Treatment Type	Species	Density/Rate	Area (ha)
K 33	6	751.29	graminoid seedling	bluejoint reedgrass	26812 sph	0.02
K 33	7	749.19	graminoid seedling	Kellogg's sedge	17385 sph	0.26
K 33	8	749.82	graminoid seedling	Columbia sedge	20438 sph	0.04
K 33	9	745.98	graminoid seedling	wool-grass	27507 sph	0.03
K 33	10	745.15	seed mix	bluejoint reedgrass	kg/ha	1.72
K 34	1	749.81	graminoid seedling	bluejoint reedgrass	8752 sph	0.08
K 34	3	750.84	graminoid seedling	Kellogg's sedge	8752 sph	0.04
K 34	4	748.92	seed mix	bluejoint reedgrass	kg/ha	0.51
K 34	5	749.30	graminoid seedling	mixed graminoid species	8752 sph	1.06



Map 4-7. **Distribution of revegetation prescription trials at Windfall Creek, Kinbasket Reservoir, 2009.** Vegetation communities are defined in Table 3-2.

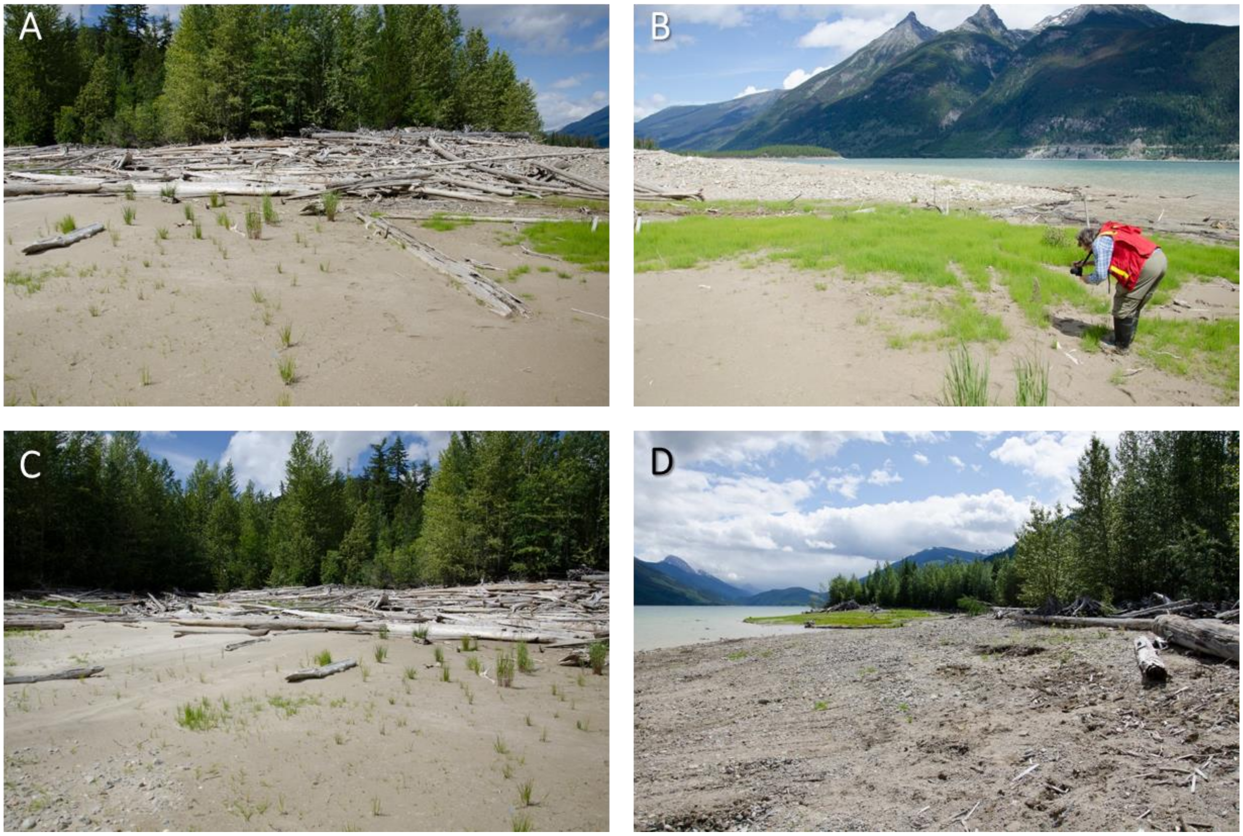


Figure 4-4. Examples of revegetation prescriptions trialed at Windfall Creek in 2009. A to C: graminoid seedling; D: the challenging terrain associated with some revegetation sites. Photo credit: Doug Adama.

Km88 Big Bend Kinbasket Reservoir

Site Description:

The Km88 Big Bend site is located on the east side of the Kinbasket Reservoir, 7.5 km northwest of Bush Harbour, and 1.0 km north of Bear Island. The site is bisected by an old section of the Trans-Canada known as the Big Bend Highway that connected Golden to Revelstoke prior to the flooding of the reservoir. The site has a warm south aspect and is positioned on a bench of glacial lacustrine fines. Soils were fine textured silty clay loams with little to no sand or rock. LFH layers were thin (< 1 cm) and the A horizon was poorly developed at the lower elevations (< 2 cm) but were much more established in the RC community (12 cm). B horizons were gleyed likely as a result of frequent and prolonged inundation. Rooting depths were restricted to the upper 15 cm (Adama 2013).

A planting plan was prepared in 2013 (Adama 2013) and planting was conducted in the spring of 2013 (Adama 2015). The site was identified as having high archaeological potential.

Site information:

Reach	Bush Arm
MC Unit	K 80A
UTM's	11U 453285 E 5736630 N
BEC	ICH mw 1
Vegetation Communities see Table 3-2	BS, KS, LL, MA, and WB
Area (ha)	3.27
Elevation (m)	Min: 746.0 Max: 750.5
# of Polygons:	3
Years:	2013

Treatment Summary

BC Hydro sought to plant 68,020 sedge plants that were held in cold storage from previous CLBWORKS-01 plantings. Five potential treatment polygons were identified near the Old Big Bend Highway of which two were retained as controls and three were planted. Two sites (polygons 1 and 3) were planted with Kellogg's sedge and polygon 5 was planted with Columbia and Kellogg's sedge. The planting objectives were to (1) plant at a site that had the greatest likelihood of success for establishment, (2) increase the extent of the Kellogg's sedge (KS) community down to 746 m ASL and, (3) increase the overall abundance of sedges in the proposed planting areas (Adama 2013). The sedge was planted at 20,000 plugs per hectare across the three treatment subunits (0.5, 0.82, and 1.95 ha) (Adama 2015).

Summary of Planting Success

In 2015, the sedge seedlings appeared to perform well (Hawkes 2016). Average estimated surviving plug densities (per ha) were approximately 29,000, 15,000, and 9,000 in the three treatment polygons (SU-1,SU-3,and SU-5 respectively). Sampling at SU-1 indicated negligible mortality and the establishment rate exceeded the targeted project goal of 10,000 -20,000 individuals/ha. At SU-3 and SU-5, sample densities in 2015 were lower than the original stocking densities implying that some attrition has occurred in the first two years following planting; however, in both subunits, densities were still well within the targeted range of 10,000-20,000 plugs/ha (for SU-3) and 5,000-10,000 plugs/ha (for SU-5;).

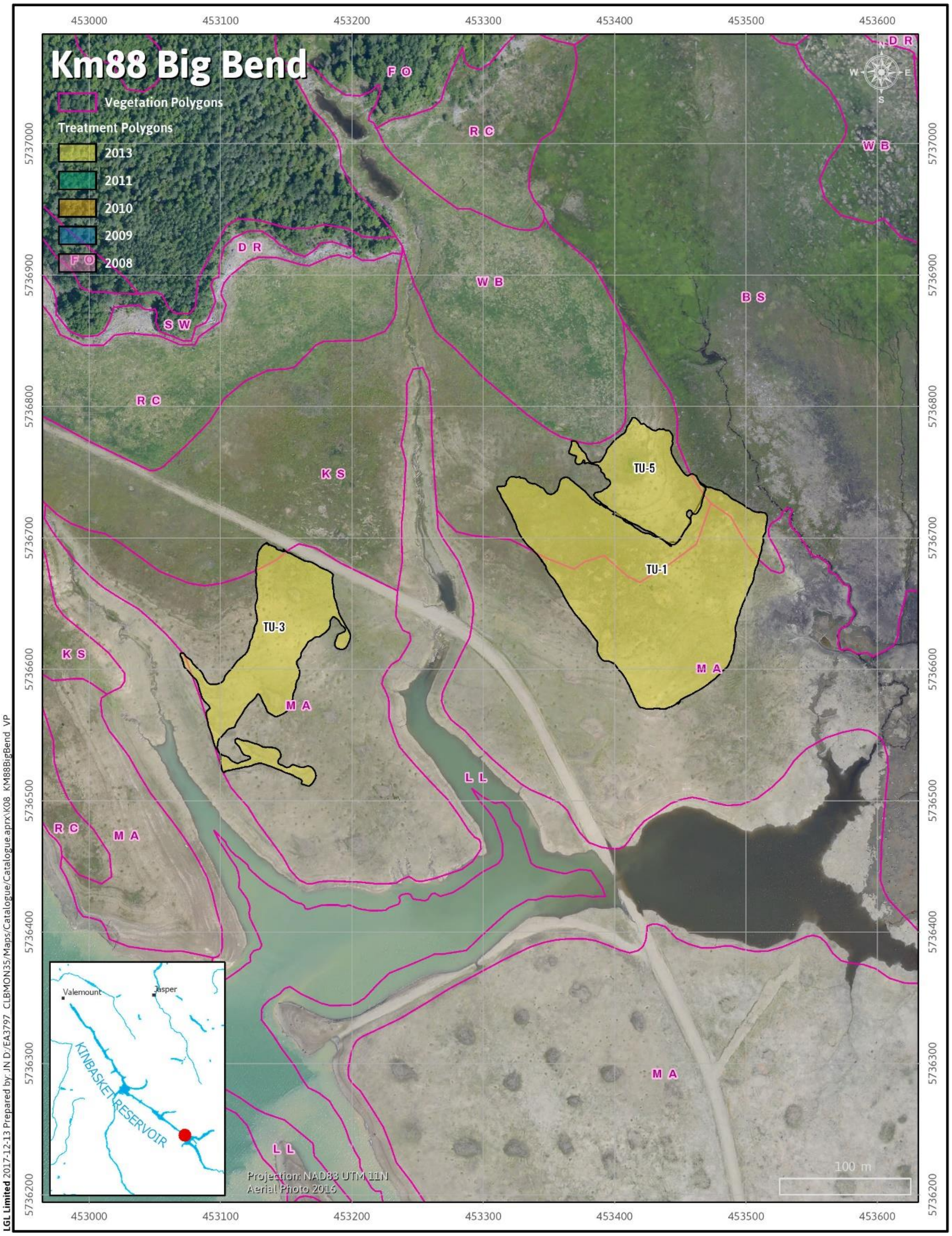
Documents

Type	Year	Author	Short Title
Monitoring	2013	Hawkes et al.	Kinbasket Monitoring Report 2013
Prescription	2013	Adama	Kinbasket Revegetation Plan 2013
Summary	2015	Adama	Kinbasket Post Planting Report 2014
Monitoring	2016	Hawkes and Miller	Kinbasket Monitoring Report 2015

Km88 Big Bend Kinbasket Reservoir

Year 2013

MC#	Polygon	Elevation	Treatment Type	Species	Density/Rate	Area (ha)
K 80A	TU-1	747.50	graminoid seedling	Kellogg's sedge	21632 sph	1.93
K 80A	TU-2	NA	Control	No Treatment	0 sph	0.36
K 80A	TU-3	746.75	graminoid seedling	Kellogg's sedge	21632 sph	2.36
K 80A	TU-4	NA	Archaeology	No Treatment	0 sph	0.60
K 80A	TU-5	749.50	graminoid seedling	Columbia sedge	16200 sph	0.60



Map 4-8. Distribution of revegetation prescription trials at Km88 Big Bend, Kinbasket Reservoir, 2013. Vegetation communities are defined in Table 3-2.

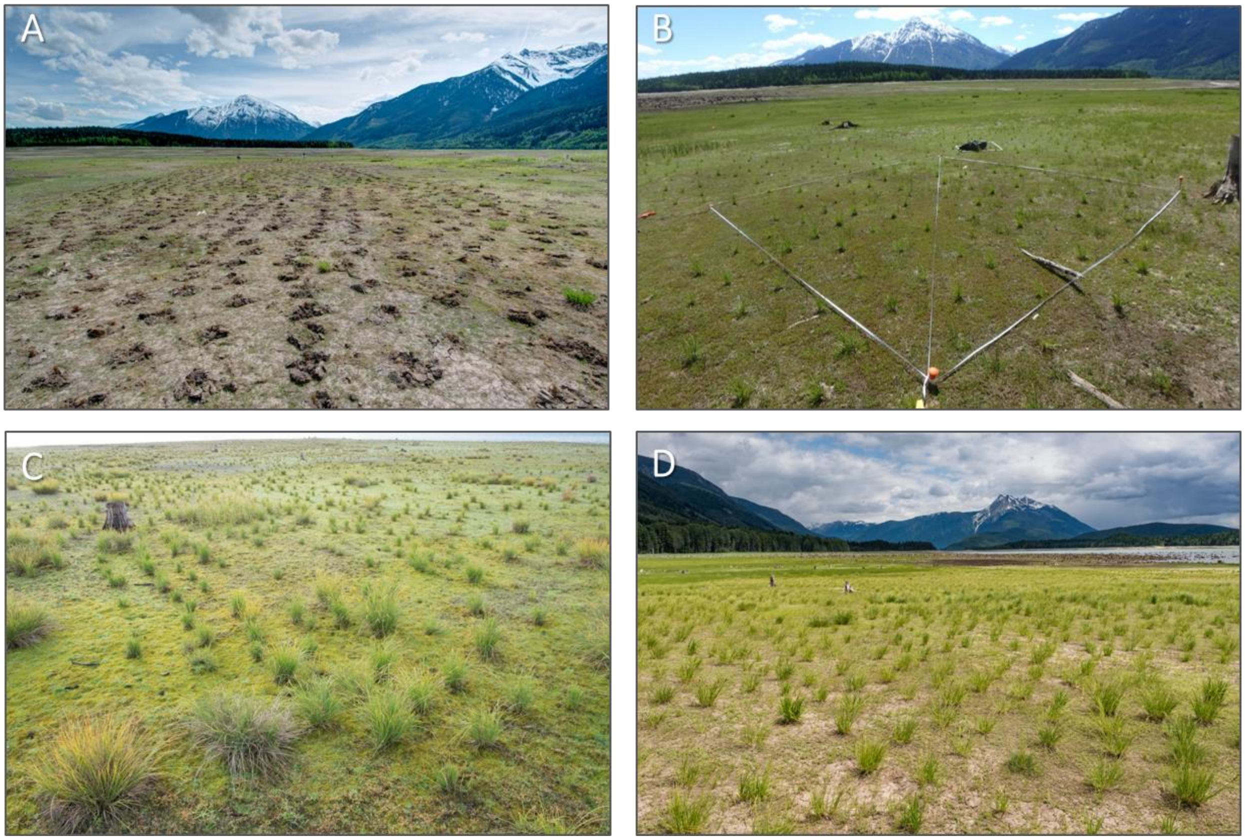


Figure 4-5. Examples of the revegetation prescription trialed at Km88 Big Bend in 2013. Only graminoid seedlings were planted in 2013. A: site following planting in 2013; B: assessing growth and survivorship in 2015; C: continued growth in 2015; and D: growth and cover in 2017. Photo credit: Doug Adama.

Km88 Peatland Kinbasket Reservoir

Site Description:

The Km88 Peatland site is located on the east side of the Kinbasket Reservoir 7.5 km northwest of Bush Harbour and 1.0 km north of Bear Island. The Km88 Peatland site is 1 km east of the Km8m Big Bend site and is ecological quite different. Below 751 m ASL soils were dominated by peat and highly organic; vegetation in this zone was sparse (Keefer et al 2008, Keefer et al 2010). Above 751 m ASL, the vegetation transition to 100 per cent cover of Reed Canary Grass. Soils in the peat zone were very poorly drained and deficient in potassium and phosphorous (Keefer et al 2007). Old stumps scattered across the site indicate the site was formerly forested.

Draft treatment prescriptions were developed in 2010 (Keefer and Moody 2010) and updated in 2011 (Moody and Keefer 2011). Planting treatments were undertaken in 2010 and 2011.

Site information:

Reach	Bush Arm
MC Unit	K 80B
UTM's	11U 453851 E 5736670 N
BEC	ICH mw 1
Vegetation Communities see Table 3-2	BS, MA, RC, and WB
Area (ha)	3.17 / 5.29
Elevation (m)	Min: 744.8 Max: 751.8
# of Polygons:	13
Years:	2010 and 2011

Treatment Summary

A total of 3.17 ha were treated across 13 polygons; 0.39 ha in 8 polygons in 2010 and 2.77 ha in 5 polygons in 2011. Planting in 2008 consisted of trial plantings of graminoid seedlings including small fruited bulrush, wool-grass, Kellogg's sedge, and water sedge. Planting in 2011 consisted of plantings of graminoid seedlings (2.69 ha) including wool-grass, Columbia sedge, Kellogg's sedge, and water sedge and willow sp. seedlings (0.08 ha).

Summary of Planting Success

Hawkes et al (2013) concluded that all sedge plug and live stake plantings conducted in 2008 to 2011 were unsuccessful. Sedge plug survivorship declined from approximately 40 per cent in the two years following planting, to < 10 per cent three years post-planting, to less than five per cent four to five years post-planting. Live stakes of deciduous shrubs (willows, alder, and cottonwood) appear to have fared worse, with none found surviving five years after planting. Shrub seedling survival and the establishment of seeding treatments were not assessed.

Documents

Type	Year	Author	Short Title
Prescription	2003	Moody and Carr	Potential Areas for Vegetation Establishment in Kinbasket
Prescription	2007	Keefer et al	Site Verification and Seed Collection 2007
Summary	2008	Keefer et al	Kinbasket Revegetation Report 2008
Prescription	2010	Keefer and Moody	Kinbasket Reservoir Planting Plan for 2010
Prescription	2010	Keefer and Moody	Kinbasket Reservoir Planting Plan for 2011
Inventory	2010	Hawkes et al.	Kinbasket Vegetation Inventory 2010
Monitoring	2013	Hawkes et al.	Kinbasket Monitoring Report 2013

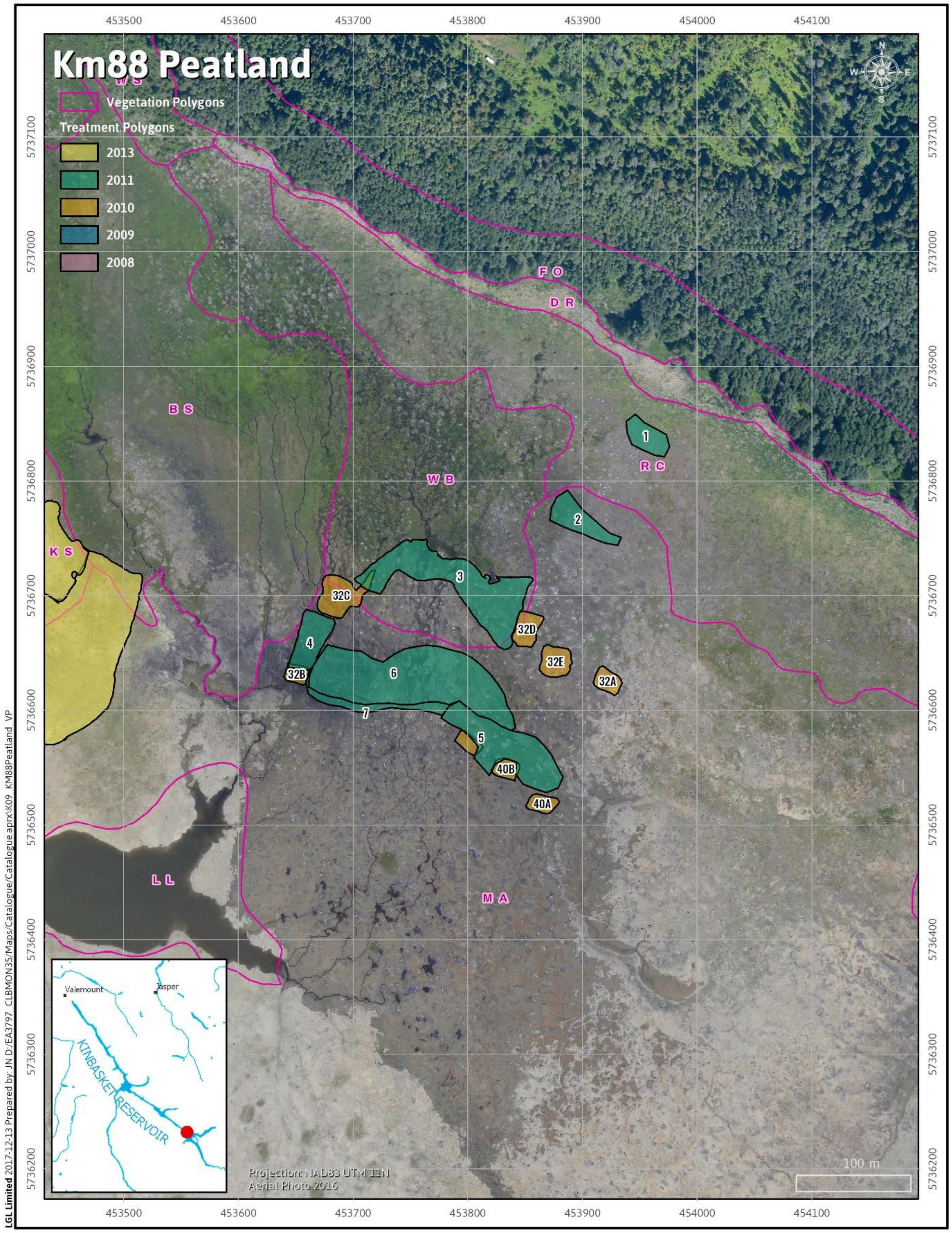
Km88 Peatland Kinbasket Reservoir

Year 2010

MC#	Polygon	Elevation	Treatment Type	Species	Density/Rate	Area (ha)
K 80B	32A	746.90	graminoid seedling	wool-grass	22939 sph	0.04
K 80B	32B	746.03	graminoid seedling	small-fruited bulrush	20418 sph	0.03
K 80B	32C	747.17	graminoid seedling	small-fruited bulrush	19282 sph	0.11
K 80B	32D	747.26	graminoid seedling	Kellogg's sedge	15462 sph	0.06
K 80B	32E	746.95	graminoid seedling	water sedge	14182 sph	0.06
K 80B	40A	745.04	graminoid seedling	wool-grass	26556 sph	0.03
K 80B	40B	745.38	graminoid seedling	water sedge	26668 sph	0.03
K 80B	40C	745.61	graminoid seedling	Kellogg's sedge	31790 sph	0.03

Year 2011

MC#	Polygon	Elevation	Treatment Type	Species	Density/Rate	Area (ha)
K 80B	1	751.25	shrub seedling	willow sp.	5319 sph	0.08
K 80B	2	749.17	graminoid seedling	Columbia sedge	21003 sph	0.12
K 80B	3	747.43	graminoid seedling	Kellogg's sedge	26801 sph	1.31
K 80B	4	745.71	graminoid seedling	Kellogg's sedge	19932 sph	0.42
K 80B	4	745.71	graminoid seedling	wool-grass	2373 sph	0.42
K 80B	5	746.23	graminoid seedling	Kellogg's sedge	25481 sph	0.85
K 80B	5	746.23	graminoid seedling	wool-grass	2006 sph	0.85
K 80B	5	746.23	graminoid seedling	water sedge	3063 sph	0.85



Map 4-9. **Distribution of revegetation prescription trials at Km88 Peatland, Kinbasket Reservoir, 2010 and 2011.** Vegetation communities are defined in Table 3-2.

KM 77 Kinbasket Reservoir

Site Description:

Km 77 site is located on the north side of Bush Arm, 77 km along the "B" FSR west of Robinson Point. The site is situated on a narrow strip of rocky shoreline punctuated with old stumps indicating the site was forested prior to the creation of the reservoir. Soils were a mosaic of sand, silt, and cobbles, silty in texture, moderately well drained, and deficient in sodium, nitrogen, and boron (Keefer et al 2007, Keefer et al 2008, Keefer and Moody 2010). Debris management was undertaken in 2007.

Planting opportunities were identified in 2007 (Keefer et al 2007) and planting was undertaken in 2008 and 2010 (Keefer et al 2008, Keefer and Moody 2010).

Site information:

Reach	Bush Arm
MC Unit	K 84
UTM's	11U 464056 E 5735097 N
BEC	ICH mw 1
Vegetation Communities see Table 3-2	CO, KS
Area (ha)	2.72 / 9.59
Elevation (m)	Min: 747.3 Max: 755.5
# of Polygons:	2
Years:	2008 and 2010

Treatment Summary

Plantings were undertaken in the spring of 2008 and 2010, totaling 2.72 ha across 2 treatment polygons. Planting in 2008 (1.38 ha) consisted of spreading of BC Hydro wetland and Buffer seed mixes and live staking of black cottonwood, red-osier dogwood, and willow sp. Treatment in 2010 (1.33 ha) consisted of planting Columbia and Kellogg's sedge seedling plugs.

Summary of Planting Success

Hawkes et al (2013) concluded that all sedge plug and live stake plantings conducted in 2008 to 2011 were unsuccessful. Sedge plug survivorship declined from approximately 40 per cent in the two years following planting, to < 10 per cent three years post-planting, to less than five per cent four to five years post-planting. Live stakes of deciduous shrubs (willows, alder, and cottonwood) appear to have fared worse, with none found surviving five years after planting. Shrub seedling survival and the establishment of seeding treatments were not assessed.

Documents

Type	Year	Author	Short Title
Prescription	2003	Moody and Carr	Potential Areas for Vegetation Establishment in Kinbasket
Prescription	2007	Keefer et al	Site Verification and Seed Collection 2007
Summary	2008	Keefer et al	Kinbasket Revegetation Report 2008
Monitoring	2016	Hawkes and Miller	Kinbasket Monitoring Report 2015

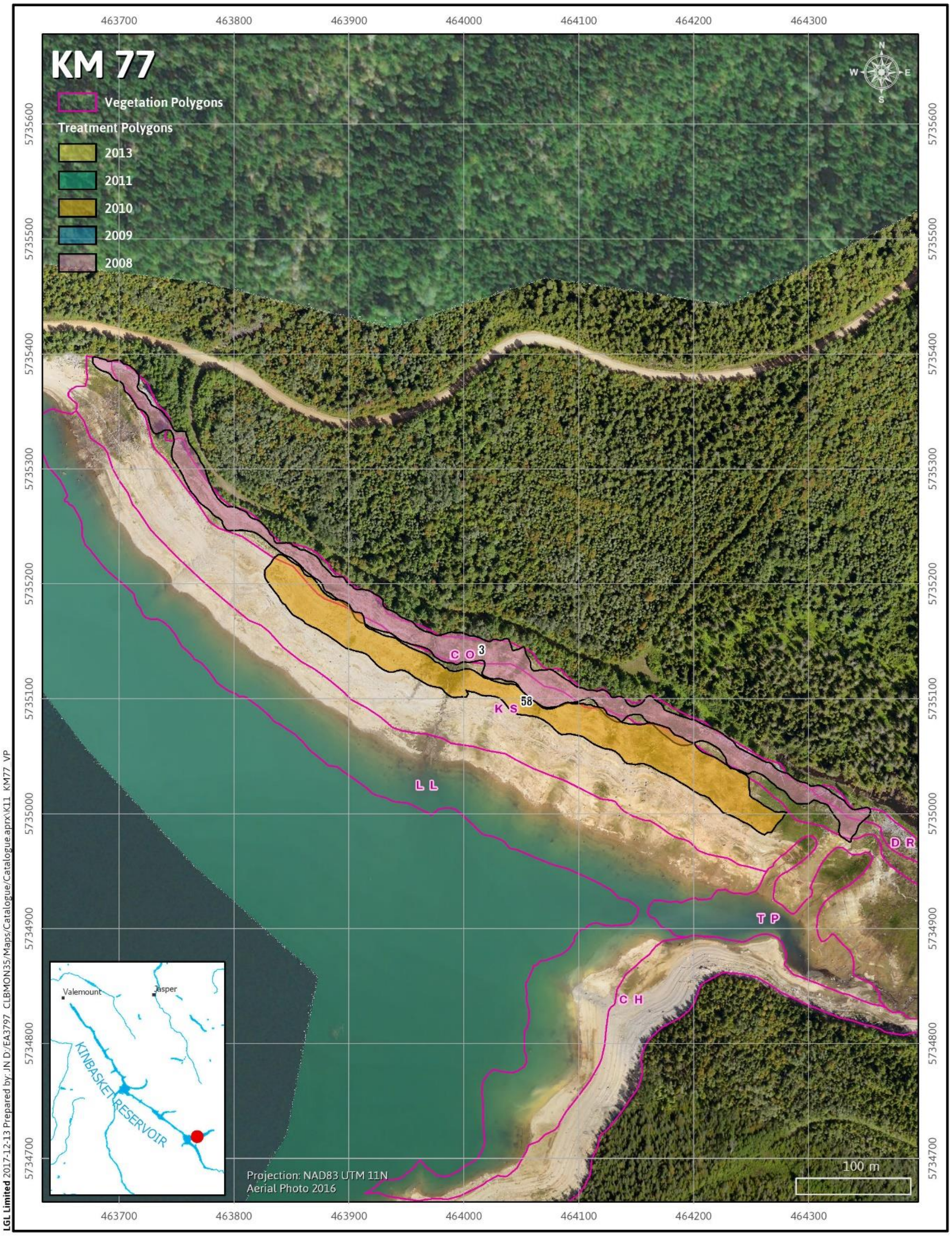
KM 77 Kinbasket Reservoir

Year 2008

MC#	Polygon	Elevation	Treatment Type	Species	Density/Rate	Area (ha)
K 84	3	752.47	seed mix	Buffer Seed Mix	18 kg/ha	1.38
K 84	3	752.47	seed mix	BC Hydro wetland seed mix	4 kg/ha	1.38
K 84	3	752.47	shrub stake	willow sp.	864 sph	1.38
K 84	3	752.47	shrub stake	black cottonwood	482 sph	1.38
K 84	3	752.47	shrub stake	red-osier dogwood	318 sph	1.38

Year 2010

MC#	Polygon	Elevation	Treatment Type	Species	Density/Rate	Area (ha)
K 84	58	749.67	graminoid seedling	Kellogg's sedge	3406 sph	1.33
K 84	58	749.67	graminoid seedling	Columbia sedge	3507 sph	1.33



Map 4-10. Distribution of revegetation prescription trials at Km77, Kinbasket Reservoir, 2008 and 2010. Vegetation communities are defined in Table 3-2.

KM 79 — Kinbasket Reservoir

Site Description:

Km 79 site is located on the north side of Bush Arm, 79 km along the "B" FSR and west of Robinson Point. The site is situated on an alluvial fan and consists of a large gently sloping bench with remnants beaver ponds and historical wetlands. An old alluvial terrace juts out from the east end forming a spit, which is actively eroding due to the annual filling and draining of the reservoir. The site was identified as having high archaeological potential and ecologically (Keefer et al 2008). Soils were variable and included organic decaying peat, fine silt, and sand and gravel. Soil drainage ranged from rapid to poor.

The site was deemed a priority for its ecological and archaeological significance. Planting opportunities were identified in 2007 (Keefer et al 2007) and planting was undertaken in 2008.

Site information:

Reach	Bush Arm
MC Unit	K 83
UTM's	11U 461756 E 5735294 N
BEC	ICH mw 1
Vegetation Communities see Table 3-2	CH, KS, LL, SH, TP, and WB
Area (ha)	1.48 / 2.83
Elevation (m)	Min: 740.7 Max: 754.6
# of Polygons:	9
Years:	2008

Treatment Summary

Planting was undertaken in the spring of 2008, totaling 1.48 ha across 9 treatment polygons. Treatments consisted of sowing BC Hydro seed mix (0.80 ha) and graminoid seed (0.33 h), planting of graminoid seedlings (0.45 ha), shrub seedlings (0.06 ha), and shrub stakes (1.18 ha). Graminoid seed included Alsike clover and Kellogg's sedge; graminoid seedlings included wool-grass, small-fruited bulrush, and Kellogg's sedge; and stake and seedlings of black cottonwood, willow sp., and red-osier dogwood (Keefer et al 2008).

Summary of Planting Success

Hawkes et al (2013) concluded that all sedge plug and live stake plantings conducted in 2008 to 2011 were unsuccessful. Sedge plug survivorship declined from approximately 40 per cent in the two years following planting, to < 10 per cent three years post-planting, to less than five per cent four to five years post-planting. Live stakes of deciduous shrubs (willows, alder, and cottonwood) appear to have fared worse, with none found surviving five years after planting. Shrub seedling survival and the establishment of seeding treatments were not assessed.

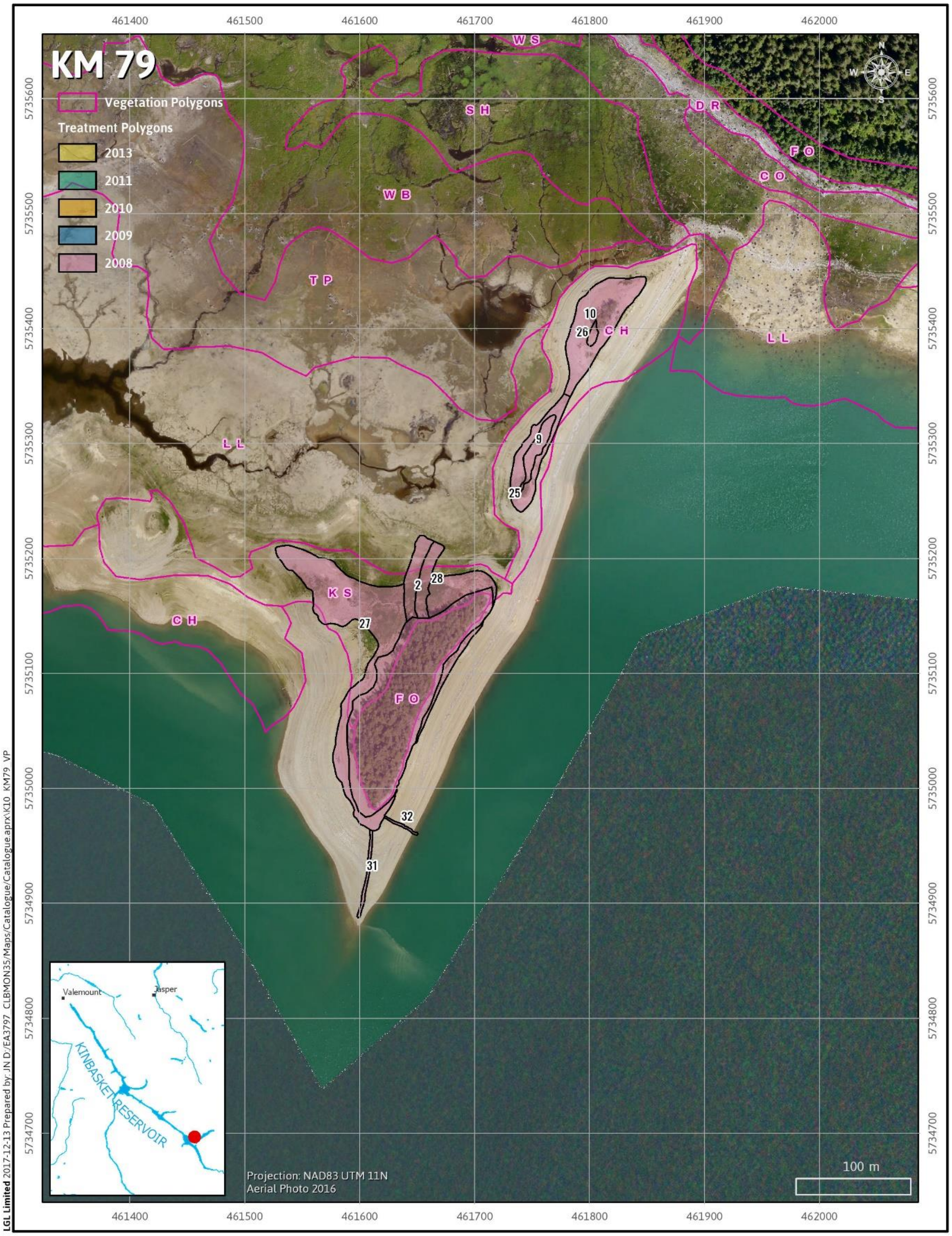
Documents

Type	Year	Author	Short Title
Prescription	2003	Moody and Carr	Potential Areas for Vegetation Establishment in Kinbasket
Prescription	2007	Keefer et al	Site Verification and Seed Collection 2007
Summary	2008	Keefer et al	Kinbasket Revegetation Report 2008
Monitoring	2016	Hawkes and Miller	Kinbasket Monitoring Report 2015

KM 79 Kinbasket Reservoir

Year 2008

MC#	Polygon	Elevation	Treatment Type	Species	Density/Rate	Area (ha)
K 83	26	753.48	Archaeology	Reserve Area	sph	0.01
K 83	9	752.24	shrub seedling	Mixed Species: Willow, Cottonwood,	66000 sph	0.06
K 83	9	752.24	graminoid seed	Kellogg's sedge	kg/ha	0.06
K 83	9	752.24	shrub stake	willow sp.	2024 sph	0.06
K 83	28	750.29	graminoid seedling	small-fruited bulrush	36712 sph	0.07
K 83	2	749.93	graminoid seedling	wool-grass	21195 sph	0.08
K 83	25	751.21	graminoid seed	Kellogg's sedge	36 kg/ha	0.14
K 83	25	751.21	graminoid seed	Alsike clover	15 kg/ha	0.14
K 83	10	752.47	graminoid seedling	Kellogg's sedge	72039 sph	0.30
K 83	10	752.47	shrub stake	willow sp.	2024 sph	0.30
K 83	27	751.99	seed mix	BC Hydro upland seed mix	31 kg/ha	0.80
K 83	27	751.99	shrub stake	mixed species: willow, cottonwood, and red-osier dogwood	2024 sph	0.80
K 83	31	746.14	shrub stake	mixed species: willow, cottonwood, and red-osier dogwood	2024 sph	0.02
K 83	32	746.39	shrub stake	mixed species: willow, cottonwood, and red-osier dogwood	2024 sph	0.01



Map 4-11. Distribution of revegetation prescription trials at Km79, Kinbasket Reservoir, 2008. Vegetation communities are defined in Table 3-2.

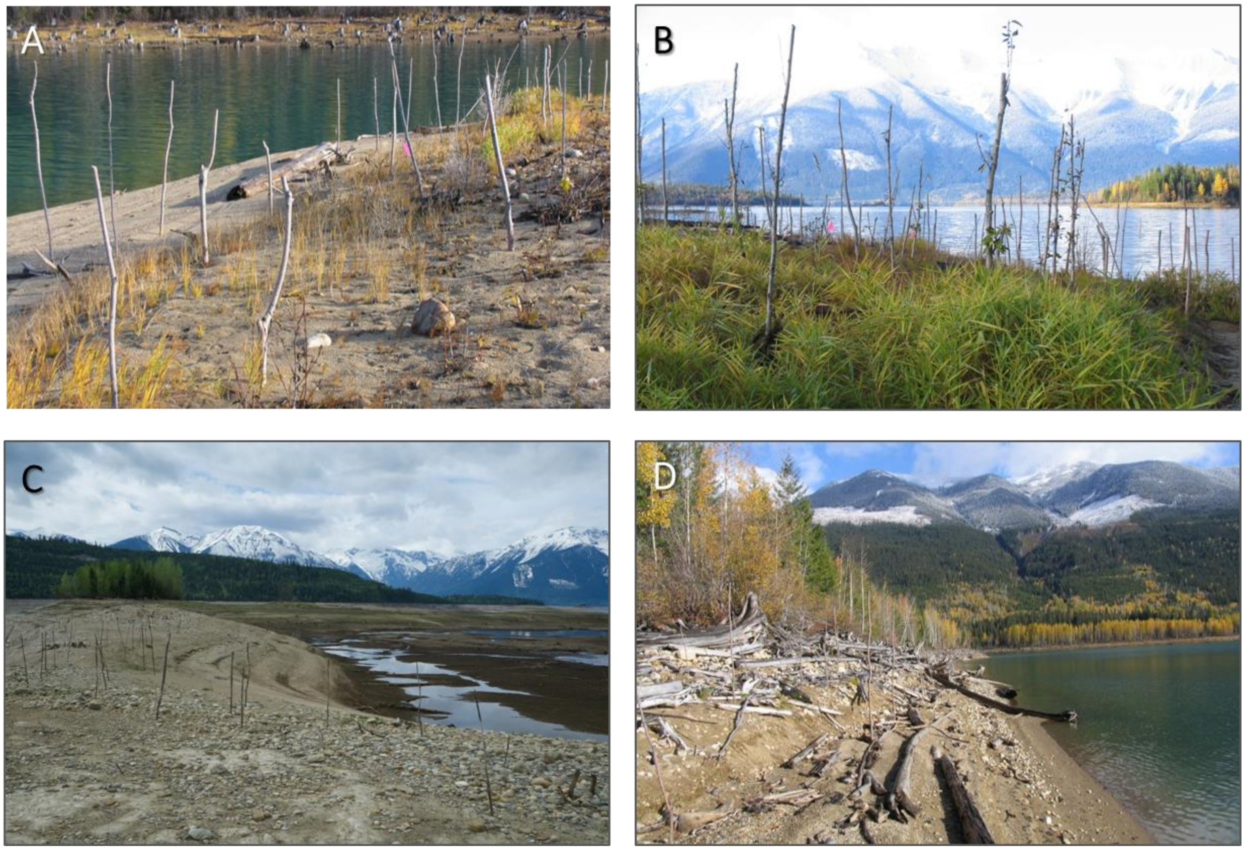


Figure 4-6. Examples of revegetation prescriptions trialed at Km79 in 2008. A to D: examples of live staking trials and the varying terrain. Photo credit: Doug Adama.

Chatter Creek Kinbasket Reservoir

Site Description:

The Chatter Creek site is located on the north side of Bush Arm on an alluvial fan at the mouth of Chatter Creek. Soils were a mosaic of sand, silt, and cobbles, silty in texture, moderately well drained, had little to no organic layer, and were deficient in nitrogen, phosphorous, potassium, zinc, and boron (Keefer et al 2008).

Planning and planting was both undertaken in 2008 (Keefer et al 2008).

Site information:

Reach	Bush Arm
MC Unit	K 85
UTM's	11U 469789 E 5737516 N
BEC	ICH mw 1
Vegetation Communities see Table 3-2	CH and LL
Area (ha)	1.61 / 4.83
Elevation (m)	Min: 747.6 Max: 755.5
# of Polygons:	1
Years:	2008

Treatment Summary

Planting was undertaken in the spring of 2008, totaling 1.61 ha across 1 primary treatment polygon and seven 10 x 20 trial plots. The primary treatment polygon was staked with black cottonwood, red-osier dogwood, and willow sp. and the trial plots were planted with small fruited bulrush, wool-grass and Kellogg's sedge seedling plugs.

Summary of Planting Success

Hawkes et al (2013) concluded that all sedge plug and live stake plantings conducted in 2008 to 2011 were unsuccessful. Sedge plug survivorship declined from approximately 40 per cent in the two years following planting, to < 10 per cent three years post-planting, to less than five per cent four to five years post-planting. Live stakes of deciduous shrubs (willows, alder, and cottonwood) appear to have fared worse, with none found surviving five years after planting. Shrub seedling survival and the establishment of seeding treatments were not assessed.

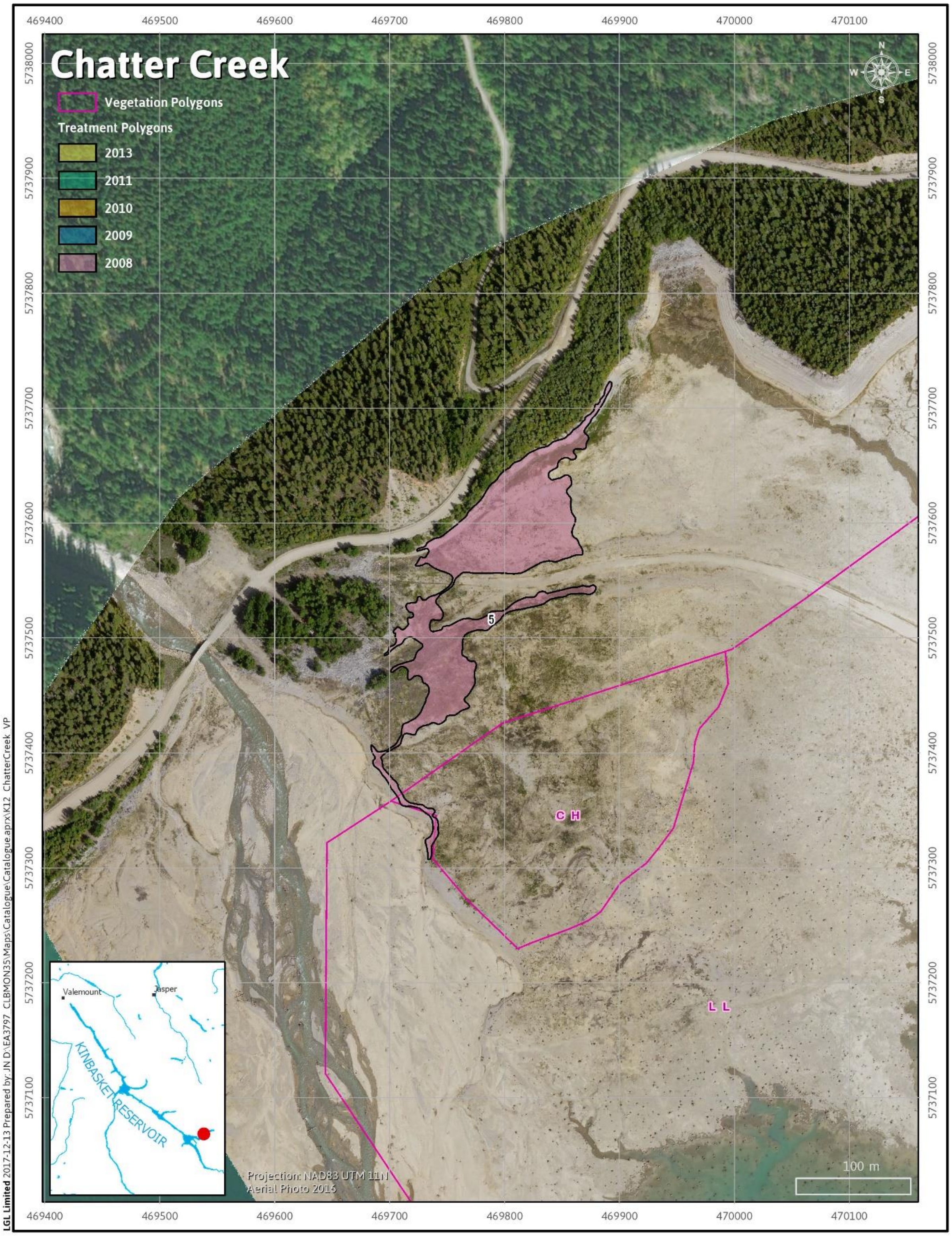
Documents

Type	Year	Author	Short Title
Prescription	2003	Moody and Carr	Potential Areas for Vegetation Establishment in Kinbasket
Summary	2008	Keefer et al	Kinbasket Revegetation Report 2008
Monitoring	2016	Hawkes and Miller	Kinbasket Monitoring Report 2015

Chatter Creek Kinbasket Reservoir

Year 2008

MC#	Polygon	Elevation	Treatment Type	Species	Density/Rate	Area (ha)
K 85	5	750.50	shrub stake	willow sp.	1246 sph	1.60
K 85	5	750.50	shrub stake	black cottonwood	108 sph	1.60
K 85	5	750.50	shrub stake	red-osier dogwood	16 sph	1.60
K 85	?		graminoid seedling	Kellogg's sedge	75000 sph	0.01
K 85	?		graminoid seedling	wool-grass	66000 sph	0.01
K 85	?		graminoid seedling	small-fruited bulrush	65000 sph	0.03



Map 4-12. Distribution of revegetation prescription trials at Chatter Creek, Kinbasket Reservoir, 2008. Vegetation communities are defined in Table 3-2.

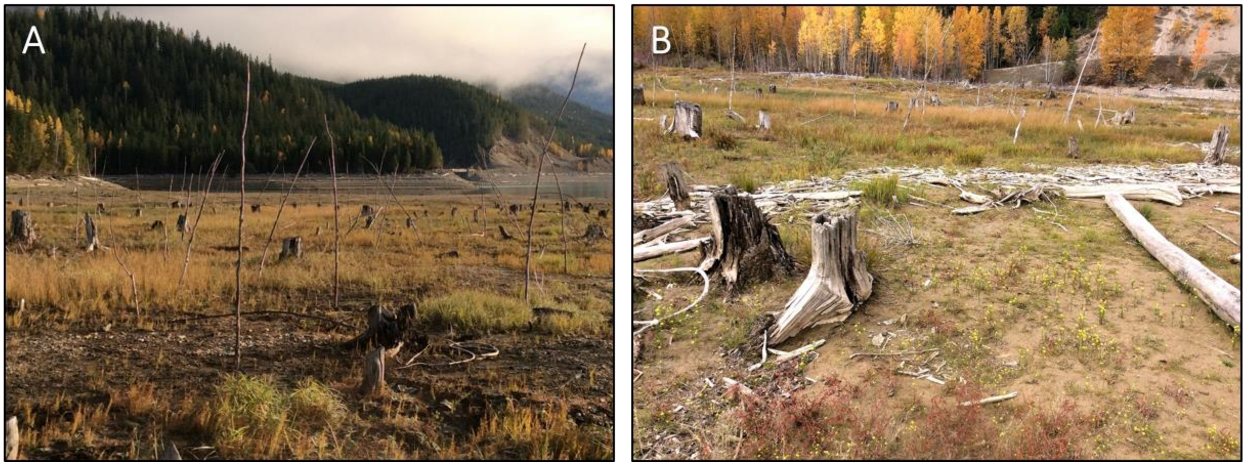


Figure 4-7. Examples of revegetation prescriptions trialed at Chatter Creek in 2008. A and B: examples of live staking trials and the varying terrain. Photo credit: Mike Miller.

Prattle Creek Kinbasket Reservoir

Site Description:

The Prattle Creek site is located on the north side of Bush Arm on an alluvial fan at the mouth of Chatter Creek. Soils consisted of a gravel and silt with little to no organic content, and were deficient in nitrogen, phosphorous, potassium, and boron (Keefer et al 2008).

Planning and planting were both undertaken in 2008 (Keefer et al 2008).

Site information:

Reach	Bush Arm
MC Unit	K 86
UTM's	11U 470288 E 5737880 N
BEC	ICH mw 1
Vegetation Communities see Table 3-2	Not classified
Area (ha)	0.09 / 0.09
Elevation (m)	Min: 746.0 Max: 751.0
# of Polygons:	1
Years:	2008

Treatment Summary

In 2008, a single treatment polygon (0.09) was planted with Kellogg's sedge seedling plugs along with three 10 x 20 m trials of seedling plugs planted at 746/747 m ASL of small fruited bulrush, wool-grass and Kellogg's sedge.

Summary of Planting Success

Hawkes et al (2013) concluded that all sedge plug and live stake plantings conducted in 2008 to 2011 were unsuccessful. Sedge plug survivorship declined from approximately 40 per cent in the two years following planting, to < 10 per cent three years post-planting, to less than five per cent four to five years post-planting. Live stakes of deciduous shrubs (willows, alder, and cottonwood) appear to have fared worse, with none found surviving five years after planting. Shrub seedling survival and the establishment of seeding treatments were not assessed.

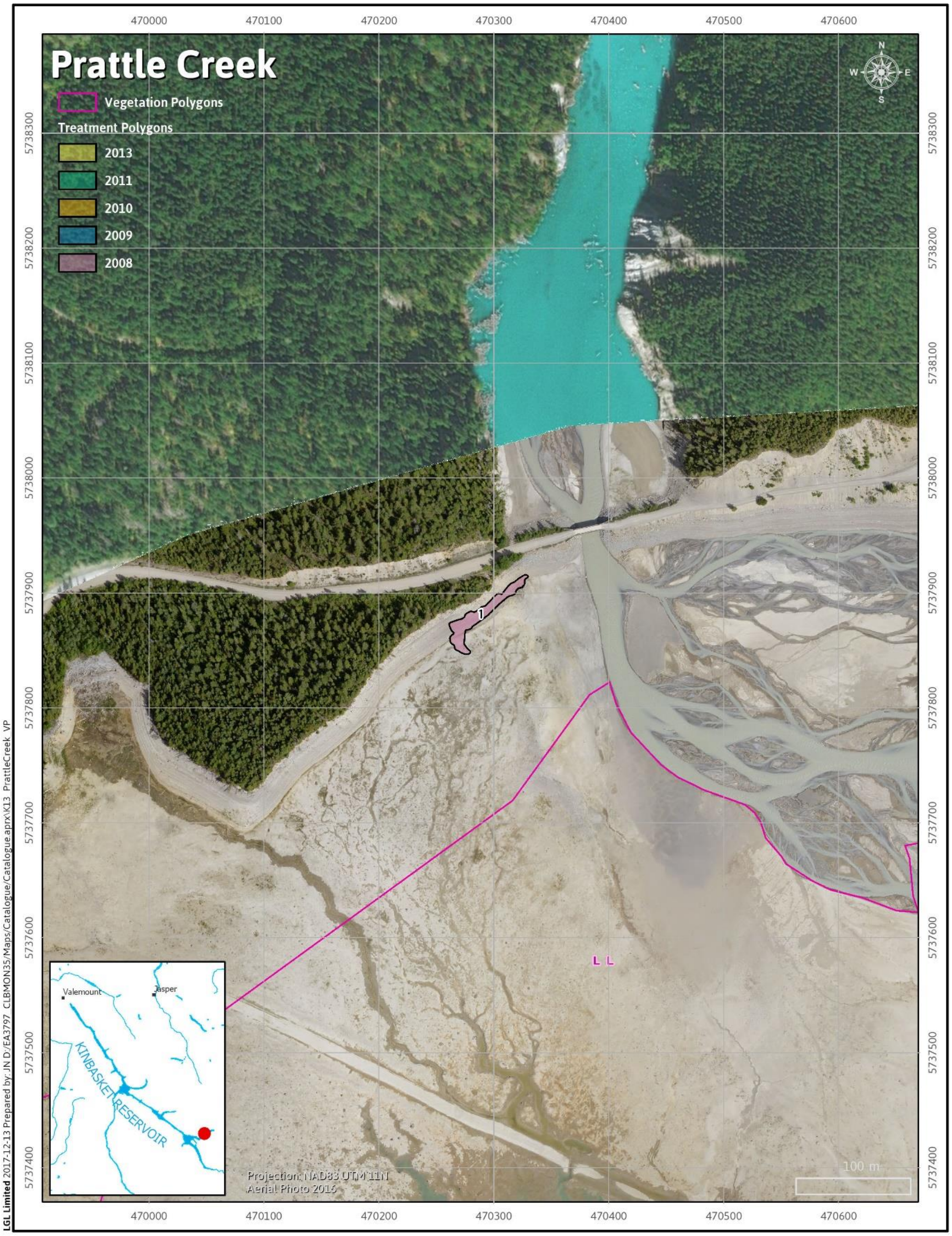
Documents

Type	Year	Author	Short Title
Prescription	2003	Moody and Carr	Potential Areas for Vegetation Establishment in Kinbasket
Summary	2008	Keefer et al	Kinbasket Revegetation Report 2008
Monitoring	2016	Hawkes and Miller	Kinbasket Monitoring Report 2015

Prattle Creek Kinbasket Reservoir

Year 2008

MC#	Polygon	Elevation	Treatment Type	Species	Density/Rate	Area (ha)
K 86	1	747.00	graminoid seedling	Kellogg's sedge	sph	0.01
K 86	4	747.00	graminoid seedling	small-fruited bulrush	56294 sph	0.00
K 86	4	747.00	graminoid seedling	wool-grass	74270 sph	0.00



Map 4-13. **Distribution of revegetation prescription trials at Prattle Creek, Kinbasket Reservoir, 2008.** Vegetation communities are defined in Table 3-2.

Hope Creek Kinbasket Reservoir

Site Description:

The Hope Creek site, one of the largest CLBWORKS-01 planting sites, is located on the south side of Bush Arm on an alluvial fan at the mouth of Hope Creek. Soils were a mosaic of sand, silt, and cobbles, silty in texture, moderately well drained, and had little to no organic layer (Keefer et al 2008). Old tree stumps occurred throughout the site indicting the site was forested prior to the construction of the reservoir. Debris management was undertaken in 2007.

Planting opportunities were identified in 2007 (Keefer et al 2007) and prescription were included in the 2008, 2010, and 2011 planting plans (Keefer et al 2008, Keefer and Moody 2010, Keefer and Moody 2011). Planting was undertaken in 2008, 2010, and 2011 (Keefer et al 2008, Keefer and Moody 2011, Keefer and Moody 2012).

Site information:

Reach	Bush Arm
MC Unit	K 87,93
UTM's	11U 472184 E 5736905 N
BEC	ICH mw 1
Vegetation Communities see Table 3-2	CH, CO, and CT
Area (ha)	16.14 / 32.24
Elevation (m)	Min: 743.0 Max: 754.4
# of Polygons:	17
Years:	2008

Treatment Summary

Plantings were undertaken in the spring of 2008, 2010, and 2011 totaling 16.14 ha across 17 treatment polygons. Planting in 2008 occurred in two treatment polygons totaling 0.91 ha and consisted of sowing of BC Hydro upland seed mix and bluejoint reedgrass seeds (0.91 ha) and live staking of black cottonwood, red-osier dogwood, and willow sp. (0.91 ha). Planting in 2010 (11.09 ha) occurred in twelve treatment polygons and included the planting of wool-grass, small-fruited bulrush, and Columbia, lenticular and water sedge seedlings plugs (9.08 ha) and the planting of black cottonwood, mountain alder, and willow sp. shrub seedling plugs (2.02 ha). Planting in 2011 (4.14 ha) included the planting of bluejoint and Kellogg's sedge seedlings plugs in three treatment polygons and machine

Summary of Planting Success

Hawkes et al (2013) concluded that all sedge plug and live stake plantings conducted in 2008 to 2011 were unsuccessful. Sedge plug survivorship declined from approximately 40 per cent in the two years following planting, to < 10 per cent three years post-planting, to less than five per cent four to five years post-planting. Live stakes of deciduous shrubs (willows, alder, and cottonwood) appear to have fared worse, with none found surviving five years after planting. Shrub seedling survival and the establishment of seeding treatments were not assessed.

Documents

Type	Year	Author	Short Title
Prescription	2003	Moody and Carr	Potential Areas for Vegetation Establishment in Kinbasket
Prescription	2007	Keefer et al	Site Verification and Seed Collection 2007
Summary	2008	Keefer et al	Kinbasket Revegetation Report 2008
Prescription	2010	Keefer and Moody	Kinbasket Reservoir Planting Plan for 2010
Prescription	2010	Keefer and Moody	Kinbasket Reservoir Planting Plan for 2011
Summary	2011	Keefer et al.	Kinbasket Revegetation Report 2010
Summary	2012	Keefer et al.	Kinbasket Revegetation Report 2011
Monitoring	2013	Hawkes et al.	Kinbasket Monitoring Report 2013

Hope Creek Kinbasket Reservoir

Year 2008

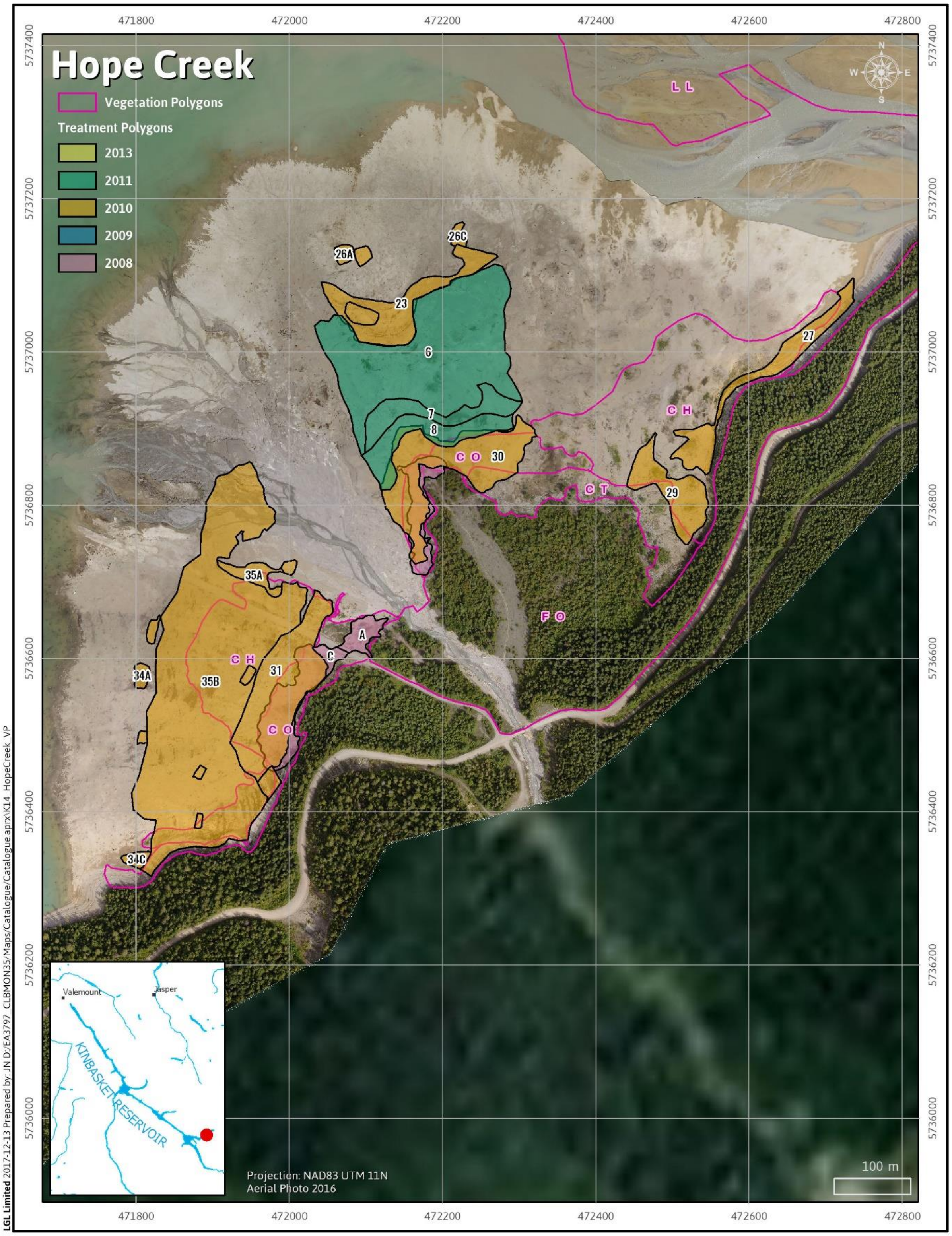
MC#	Polygon	Elevation	Treatment Type	Species	Density/Rate	Area (ha)
K 87/93	A	753.15	seed mix	bluejoint reedgrass	6 kg/ha	0.17
K 87/93	A	753.15	shrub stake	mixed species: willow, cottonwood, and red-osier dogwood	1100 sph	0.17
K 87/93	C	752.83	seed mix	BC Hydro upland seed mix	34 kg/ha	0.73
K 87/93	C	752.83	shrub stake	mixed species: willow, cottonwood, and red-osier dogwood	1100 sph	0.73

Year 2010

MC#	Polygon	Elevation	Treatment Type	Species	Density/Rate	Area (ha)
K 87/93	23	746.55	graminoid seedling	Kellogg's sedge	7154 sph	0.74
K 87/93	23	746.55	graminoid seedling	water sedge	4333 sph	0.74
K 87/93	23	746.55	graminoid seedling	Columbia sedge	1741 sph	0.74
K 87/93	23	746.55	graminoid seedling	wool-grass	1343 sph	0.74
K 87/93	27	748.24	graminoid seedling	Kellogg's sedge	1854 sph	0.66
K 87/93	27	748.24	graminoid seedling	water sedge	6196 sph	0.66
K 87/93	27	748.24	graminoid seedling	wool-grass	2148 sph	0.66
K 87/93	27	748.24	graminoid seedling	small-fruited bulrush	1447 sph	0.66
K 87/93	29	752.20	shrub seedling	black cottonwood	1538 sph	0.57
K 87/93	29	752.20	shrub seedling	mountain alder	583 sph	0.57
K 87/93	29	752.20	shrub seedling	willow sp.	194 sph	0.57
K 87/93	30	752.81	shrub seedling	black cottonwood	817 sph	1.45
K 87/93	30	752.81	shrub seedling	mountain alder	507 sph	1.45
K 87/93	30	752.81	shrub seedling	willow sp.	434 sph	1.45
K 87/93	31	751.86	graminoid seedling	Kellogg's sedge	1085 sph	1.41
K 87/93	26A	743.83	graminoid seedling	water sedge	17887 sph	0.05
K 87/93	26B	743.91	graminoid seedling	wool-grass	21689 sph	0.04
K 87/93	26C	745.55	graminoid seedling	Kellogg's sedge	19067 sph	0.05
K 87/93	34A	745.09	graminoid seedling	water sedge	24334 sph	0.05
K 87/93	34C	745.11	graminoid seedling	water sedge	21417 sph	0.06
K 87/93	35A	747.97	graminoid seedling	water sedge	21651 sph	0.16
K 87/93	35B	747.74	graminoid seedling	Kellogg's sedge	13542 sph	5.86
K 87/93	35B	747.74	graminoid seedling	wool-grass	3857 sph	5.86

Year 2011

MC#	Polygon	Elevation	Treatment Type	Species	Density/Rate	Area (ha)
K 87/93	6	748.78	graminoid seedling	Kellogg's sedge	21028 sph	3.06
K 87/93	7	751.12	graminoid seedling	Kellogg's sedge	25765 sph	0.49
K 87/93	7	751.12	graminoid seedling	bluejoint reedgrass	1839 sph	0.49
K 87/93	8	751.76	graminoid seedling	Kellogg's sedge	13316 sph	0.59
K 87/93	8	751.76	graminoid seedling	bluejoint reedgrass	4557 sph	0.59



Map 4-14. **Distribution of revegetation prescription trials at Hope Creek, Kinbasket Reservoir, 2008, 2010, 2011.** Vegetation communities are defined in Table 3-2.

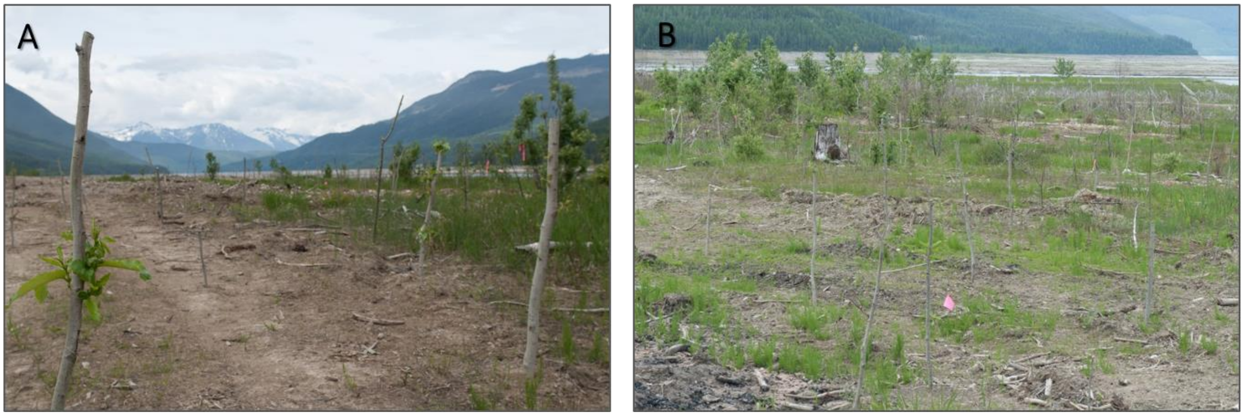


Figure 4-8. Examples of revegetation prescriptions trialed at Hope Creek in 2008. A and B: shrub stakes. Photo credit: Doug Adama.

Goodfellow Creek Kinbasket Reservoir

Site Description:

The Goodfellow Creek site is located on the south side of Bush Arm near the Bush River Causeway on an alluvial fan at the mouth of Goodfellow Creek. Soils were a mosaic of sand, silt, and cobbles, sandy/silty in texture, moderately well drained, and had little to no organic layer (Keefer et al 2008). Soils were deficient in macronutrients (nitrogen, phosphorous, and nitrogen) but not in micronutrients. Wood debris accumulation was prevalent at the upper elevations. Debris management was undertaken in 2007.

Planting opportunities were identified in 2007 (Keefer et al 2007) and prescription were included in the 2008, 2010, and 2011 planting plans (Keefer et al 2008, Keefer and Moody 2010, Keefer and Moody 2011). Planting was undertaken in 2008, 2010, and 2011 (Keefer et al 2008, Keefer and Moody 2011, Keefer and Moody 2012).

Site information:

Reach	Bush Arm
MC Unit	K 88,89
UTM's	11U 472005 E 5736540 N
BEC	ICH mw 1
Vegetation Communities see Table 3-2	CH, CO, CT, DR, and SH
Area (ha)	7.57 / 14.62
Elevation (m)	Min: 750.2 Max: 753.8
# of Polygons:	14
Years:	2008, 2010, and 2011

Treatment Summary

Plantings were undertaken in the spring of 2008, 2010, and 2011 totaling 7.57 ha across 14 treatment polygons. Planting in 2008 occurred in ten treatment polygons totaling 3.86 ha and consisted of sowing of BC Hydro upland and Buffer seed mixes, and live staking of black cottonwood, red-osier dogwood, and willow sp. (3.86 ha). Planting in 2010 (2.10 ha) occurred in a single treatment polygon planted with black cottonwood and mountain alder shrub seedling plugs (2.10 ha). In 2011 (1.61 ha), two polygons were planted with willow seedling plugs (0.51) and one polygon entailed the livestaking of black cottonwood with the aid of an excavator (1.10 ha).

Summary of Planting Success

Hawkes et al (2013) concluded that all sedge plug and live stake plantings conducted in 2008 to 2011 were unsuccessful. Sedge plug survivorship declined from approximately 40 per cent in the two years following planting, to < 10 per cent three years post-planting, to less than five per cent four to five years post-planting. Live stakes of deciduous shrubs (willows, alder, and cottonwood) appear to have fared worse, with none found surviving five years after planting. Shrub seedling survival and the establishment of seeding treatments were not assessed.

Documents

Type	Year	Author	Short Title
Prescription	2003	Moody and Carr	Potential Areas for Vegetation Establishment in Kinbasket
Prescription	2007	Keefer et al	Site Verification and Seed Collection 2007
Summary	2008	Keefer et al	Kinbasket Revegetation Report 2008
Prescription	2010	Keefer and Moody	Kinbasket Reservoir Planting Plan for 2010
Prescription	2010	Keefer and Moody	Kinbasket Reservoir Planting Plan for 2011
Summary	2011	Keefer et al.	Kinbasket Revegetation Report 2010
Summary	2012	Keefer et al.	Kinbasket Revegetation Report 2011
Monitoring	2013	Hawkes et al.	Kinbasket Monitoring Report 2013

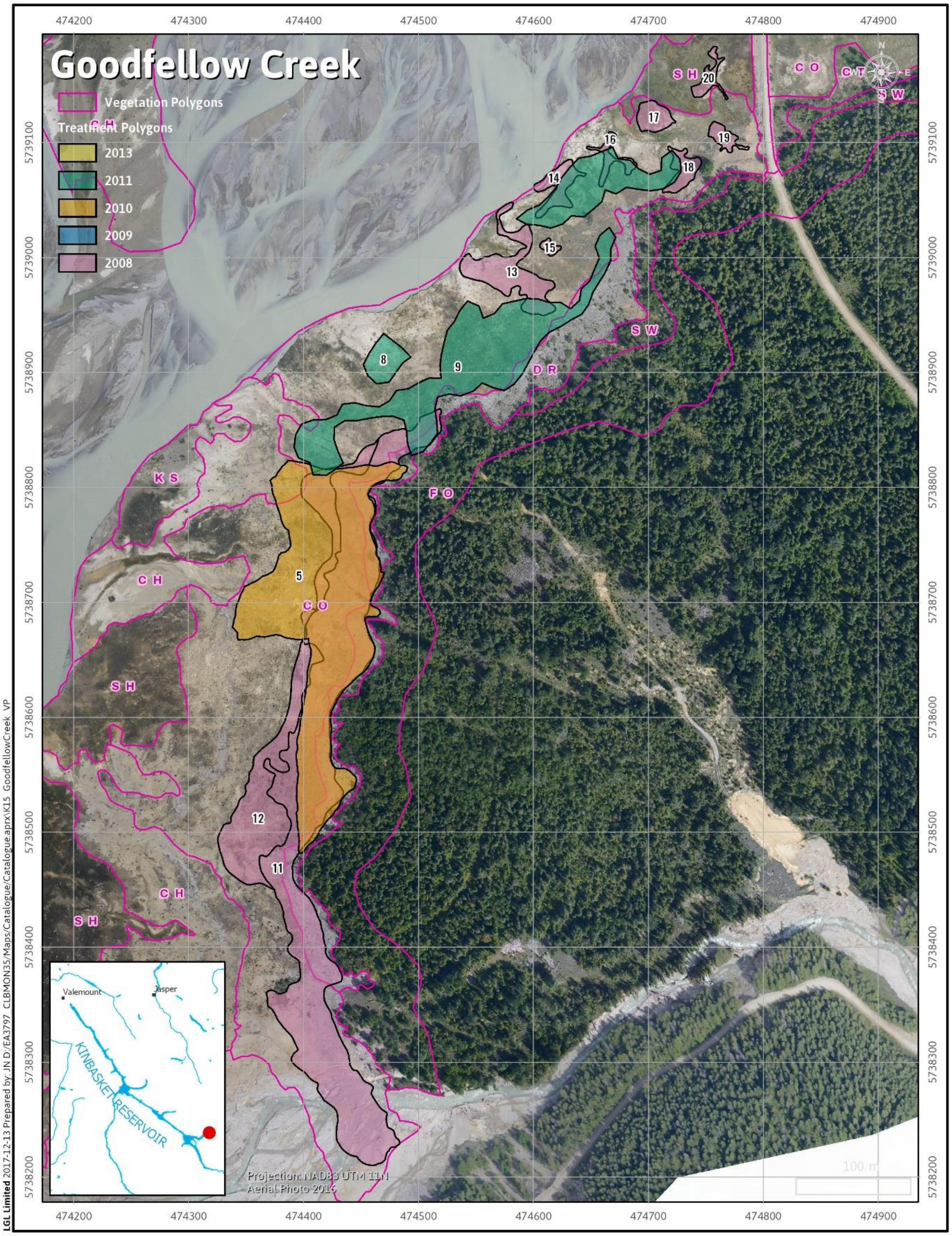
Goodfellow Creek Kinbasket Reservoir

Year 2008

MC#	Polygon	Elevation	Treatment Type	Species	Density/Rate	Area (ha)
K 88	11	753.36	shrub stake	Mixed Species: Willow, Cottonwood,	? sph	2.47
K 88	11	753.36	seed mix	Buffer Seed Mix	16 kg/ha	2.47
K 88	11	753.36	seed mix	BC Hydro upland seed mix	17 kg/ha	2.47
K 88	12	752.60	shrub stake	mixed species: willow, cottonwood, and red-osier dogwood	? sph	0.76
K 88	13	752.07	shrub stake	mixed species: willow, cottonwood, and red-osier dogwood	? sph	0.26
K 88	14	751.94	shrub stake	mixed species: willow, cottonwood, and red-osier dogwood	? sph	0.09
K 88	15	752.21	shrub stake	mixed species: willow, cottonwood, and red-osier dogwood	? sph	0.01
K 88	16	751.90	shrub stake	mixed species: willow, cottonwood, and red-osier dogwood	? sph	0.05

Year 2010

MC#	Polygon	Elevation	Treatment Type	Species	Density/Rate	Area (ha)
K 88	5	752.82	shrub seedling	black cottonwood	1051 sph	2.10
K 88	5	752.82	shrub seedling	Mountain Alder	640 sph	2.10
K 88	17	751.32	shrub stake	mixed species: willow, cottonwood, and red-osier dogwood	? sph	0.07
K 88	18	752.74	shrub stake	mixed species: willow, cottonwood, and red-osier dogwood	? sph	0.07
K 88	19	752.53	shrub stake	mixed species: willow, cottonwood, and red-osier dogwood	? sph	0.04
K 88	20	751.41	shrub stake	mixed species: willow, cottonwood, and red-osier dogwood	? sph	0.04



Map 4-15. **Distribution of revegetation prescription trials at Goodfellow Creek, Kinbasket Reservoir, 2008 and 2010.** Vegetation communities are defined in Table 3-2.

Figure 4-9. Examples of revegetation prescriptions trialed at Goodfellow Creek in 2008. A: shrub stakes (machine planted) and B: shrub stakes surrounded by wood debris in 2011. Photo credit: Doug Adama.

Esplanade Bay Kinbasket Reservoir

Site Description:

Esplanade Bay (Site 103) is located in Columbia Reach at the south end of the Kinbasket Reservoir. Soils at this site were characterized as silty/clay and coarse but were not characterized or analyzed further (Keefer et al 2008). The site was considered a priority due to high levels of recreational use (it is near a small group of cabins), and because it is highly exposed to wave and wind erosion.

Planning and planting was both undertaken in 2008 (Keefer et al 2008).

Site information:

Reach	Columbia Reach
MC Unit	K 103
UTM's	11U 462159 E 5727726 N
BEC	ICH mw 1
Vegetation Communities	Not Classified
Area (ha)	0.10
Elevation (m)	Min: 746.3 Max: 735.5
# of Polygons:	4
Years:	2008

Treatment Summary

Planting was undertaken in the spring and fall of 2008, totaling 0.10 ha across 5 treatment polygons. Treatments consisted of lenticular seeding trials (area treated was not reported), planting of graminoid seedlings (0.09 ha), and the planting of black cottonwood, willow sp., and rose plug seedlings (Keefer et al 2008). Two 50 x 50 m trial plots were planted; one with lenticular seedling plugs and the second with a mix of unspecified species

Summary of Planting Success

Hawkes et al (2013) concluded that all sedge plug and live stake plantings conducted in 2008 to 2011 were unsuccessful. Sedge plug survivorship declined from approximately 40 per cent in the two years following planting, to < 10 per cent three years post-planting, to less than five per cent four to five years post-planting. Live stakes of deciduous shrubs (willows, alder, and cottonwood) appear to have fared worse, with none found surviving five years after planting. Shrub seedling survival and the establishment of seeding treatments were not assessed.

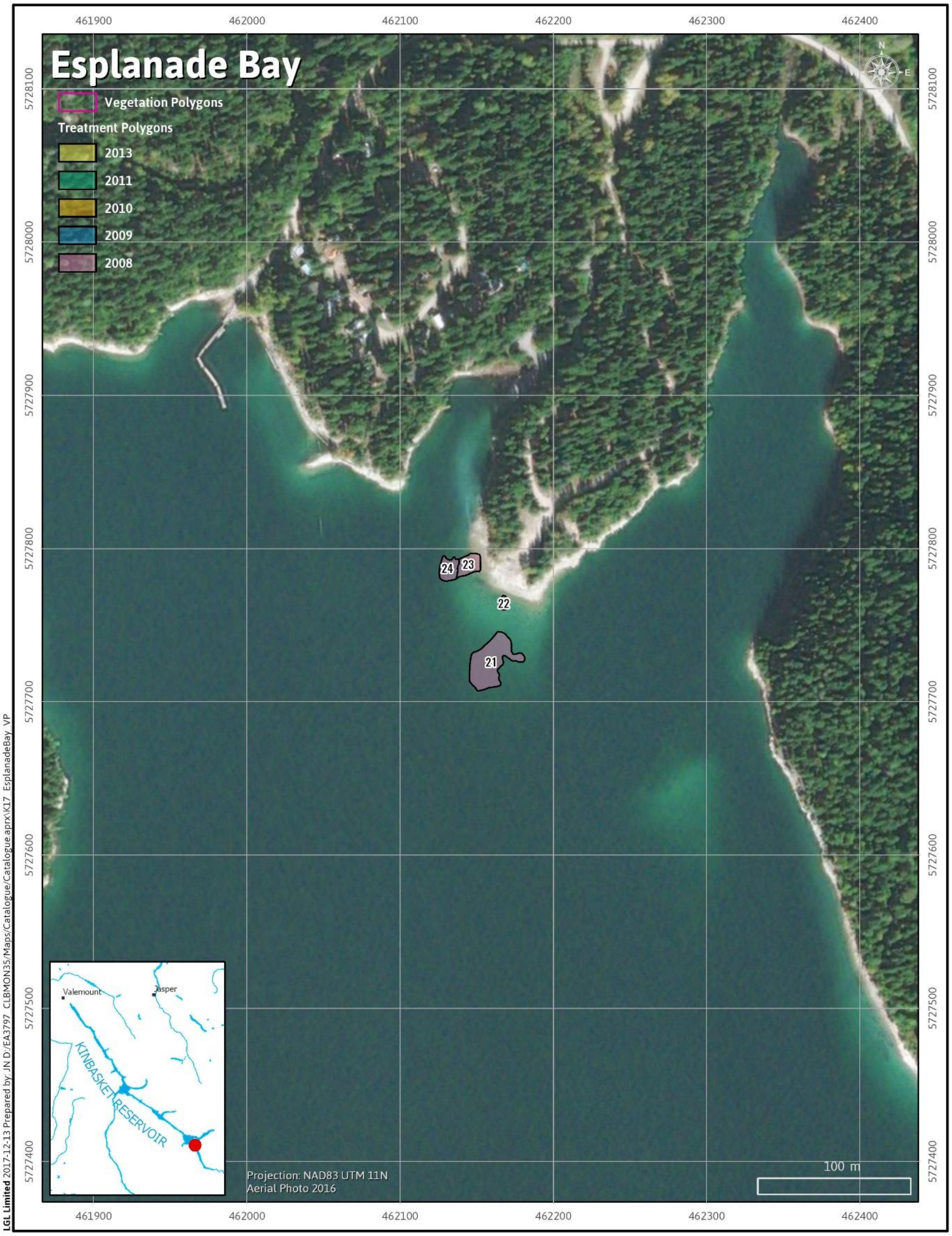
Documents

Type	Year	Author	Short Title
Prescription	2003	Moody and Carr	Potential Areas for Vegetation Establishment in Kinbasket
Summary	2008	Keefer et al	Kinbasket Revegetation Report 2008
Monitoring	2016	Hawkes and Miller	Kinbasket Monitoring Report 2015

Esplanade Bay Kinbasket Reservoir

Year 2008

MC#	Polygon	Elevation	Treatment Type	Species	Density/Rate	Area (ha)
K 103	21	748.07	graminoid seedling	Kellogg's sedge	66000 sph	0.07
K 103	22	752.52	shrub seedling	mixed species: cottonwood, willow,	66045 sph	0.00
K 103	23	748.07	graminoid seedling	mixed graminoid species	66000 sph	0.01
K 103	24	748.07	graminoid seedling	Kellogg's sedge	66000 sph	0.02



Map 4-16. Distribution of revegetation prescription trials at Esplanade Bay, Kinbasket Reservoir, 2008.

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