DWB Consulting Services Ltd.

Identification of Flood and Drought Tolerant Plant Species

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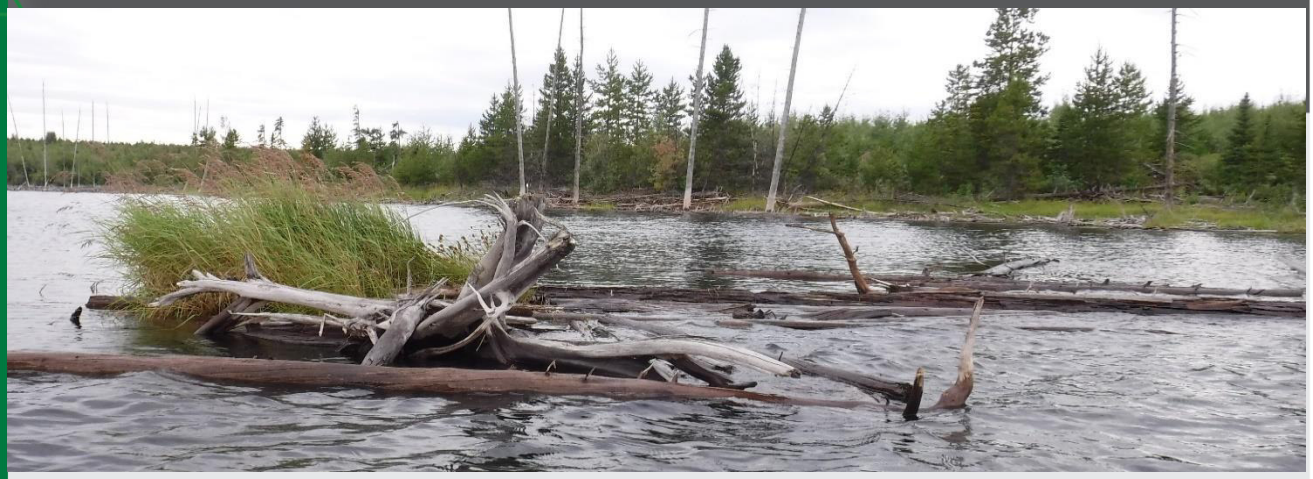

Engineering | Environmental | Forestry

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OQM | Organizational Quality Management Program

Signature Page

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REPORT TITLE: Identification of Flood and Drought Tolerant Plant Species

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Executive Summary

Fluctuations in water levels of the Williston reservoir as a result of seasonal variability in water inflow and outflow create a zone of continuous changes in area and depth of flooding along its shoreline, defined as the drawdown zone. Within this zone, growing conditions for terrestrial and aquatic vegetation are challenging and often highly inhospitable requiring plant species that can survive both drought like conditions and often extended inundation as well as in impoverished soils. Efforts by BC Hydro to establish or enhance existing vegetation cover in upper portions of the drawdown zone of reservoirs in British Columbia (BC) have tested a variety of species, both native and non-native. Species employed have included agronomic and native, wetland graminoids and native tree and shrub species.

The initial stage of this project outline in this report had two objectives. The first objective was to identify candidate flood and drought tolerant native plant species for use in the revegetation of the upper drawdown zone in the Williston Reservoir. Candidate species were selected from a comprehensive list of plant species known to naturally colonize the drawdown zone. The second was to assess the potential to collect seed and propagate seedlings for each of the candidate species. Identifying candidate species and assessing the potential for seed collection and propagation was conducted using relevant literature and discussions with native plant seed collectors and propagation experts, revegetation specialists and local First Nations. These objectives have been developed to support action 2a-1 of BC Hydro's Peace Basin Riparian and Wetlands Action Plan, which aims to identify flood and drought resistant plant species for bank stabilization.

A comprehensive list of native plant species known to naturally colonize the upper drawdown zone of the Williston reservoir was developed. The list was created based on personal observations of drawdown zone vegetation in the reservoir and from plant species lists developed from vegetation surveys as part of previous BC Hydro vegetation monitoring projects. Candidate species were selected through a process of elimination. The process used specific criteria to eliminate species that were either unlikely to tolerate growing conditions in the upper drawdown zone or were identified as challenging to propagate. To help further refine the list of candidate plant species, feedback was solicited from select professionals experienced in the practice of revegetation, native seed collection and nursery propagation as well as with aboriginal traditional knowledge holders. In addition, an preliminary review of factors related to seed collection and propagation of seedlings for each of the candidate species was completed utilizing information from previous revegetation trials, recommendations from relevant literature and feedback from native plant nurseries.

A total of ten species were identified as candidates for revegetation of the drawdown zone. They include bluejoint (*Calamagrostis Canadensis*), common spike-rush (*Eleocharis palustris*), common horsetail (*Equisetum arvense*), swamp horsetail (*Equisetum fluviatile*), dwarf scouring-rush (*Equisetum scirpoides*), lakeshore sedge (*Carex lenticularis*), water sedge (*Carex aquatilis*), water smartweed (*Persicaria amphibia*), willow (*Salix spp.*) and hardhack (*Spiraea douglasii*).

A preliminary review of information in regards to plant propagule collection and propagation for the candidate species identified some considerations for future efforts. Propagule collection would include collecting seed or rhizomes; timing for seed collection would be specific (early summer to autumn) whereas timing for rhizomes for propagation would likely be the most appropriate in the early spring. In regards to propagation approaches, much of the details of these approaches remain propriety to plant nurseries and thus details collected are limited.

Future work for this project will work towards the establishment and monitoring of revegetation trials in the upper drawdown zone of Williston Reservoir. The work will be completed in stages, each building on the success of the previous stage. Following this initial stage, in which candidate species have been identified, stage two of the project will aim to collect and/or acquire propagules for each species and initiate seedling propagation with a native plant nursery. Stage three of the project work towards the

design and implementation of planting trials at a few select locations in the reservoir. Monitoring of the planting trials will follow with further stages.

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1.0 INTRODUCTION

1.1 BACKGROUND

Fluctuations in water levels of the Williston reservoir as a result of seasonal variability in water inflow and outflow create a zone of continuous changes in area and depth of flooding along its shoreline, defined as the drawdown zone. Within this zone, growing conditions for terrestrial and aquatic vegetation are challenging and often inhospitable. Most terrestrial species are intolerant to flooding for prolonged periods and when established in the drawdown zone, do survive past the initial growing season. Emergent aquatic plant species often establish readily in shallow water in the early growing season, but for some, do not have the ability to respond to quick changes in water depth or complete submergence. And submergent and floating aquatic species are unlikely to survive in areas where they are at risk of complete exposure out of water. Due to these dynamics between the fluctuating water levels and life history of terrestrial and aquatic plant species, upper portions of the drawdown zone remain sparsely vegetated mid to lower portions are for the most part devoid of vegetation.

In addition to fluctuating water levels, fluctuating surface conditions as a result of water erosion, surface scouring from the movement and placement of coarse woody debris and ice can also significantly impede vegetation establishment and survival in the drawdown zone. Where substrates within the drawdown zone are subject to repeated wave action, vegetation cover can be negatively impacted. Wave action can remove large portions of undisturbed shoreline along with its existing vegetation cover (e.g., step erosion in Kinbasket Reservoir [Keefer Ecological Services 2012]) and Williston Reservoir (e.g., Cutthumb Bay Recreation Site in 2015). Wave action can also remove planted vegetation (e.g., wave scouring planted wetland plugs planted in buttle lake (Jackson et al. 1995). Accumulations of large and coarse woody debris in the upper drawdown zone can reduce substrate availability for vegetation establishment by blanketing large areas of the surface (Adama 2015). And during the winter, fragmentation and movement of lake ice and woody debris can cause physical damage to vegetation, particularly shrubs.

The receptivity of substrates (i.e., texture) has also been identified as a major factor limiting vegetation establishment in the drawdown zone (Miller et al. 2015, Keefer Ecological Services 2011). Overall, in past revegetation trials, shrub and herbaceous seedlings tend to show high survival rates in stable and well anchored substrates such as gravel/sand beaches and substrates with existing vegetation. In comparison, highly mobile substrates, such as fine sand and clays tend to result in planting failures. Heavy clays, though less erodible create a barrier to root development and as such plant survival (Michael Keefer pers com 2016). In the Williston Reservoir, areas where erosion has yet to remove pre-existing forest soils in the upper drawdown zone (identified as organic veneers; GMSMON 15), natural colonization of native plant species is commonly observed, particularly during years following low reservoir levels. These organic veneers are indicative of less erosive conditions and better substrates for plant growth.

Efforts to establish or enhance existing vegetation cover in upper portions of the drawdown zone of reservoirs in British Columbia (BC) have tested and or simply employed a variety of species, both native and non-native. Species tested have included agronomic grass such as fall rye (*Secale cerale*), reed canarygrass (*Phalaris arundinacea*), and a variety of native grasses (e.g., bluejoint reedgrass [*Calamagrostic canadensis*], Slender wheatgrass [*Agropyron pauciflorum*], fowl bluegrass [*Poa palustris*] and Rocky Mountain fescue [*Festuca saximontana*]). Wetland species tested have included various native sedges (e.g., slough sedge [*Carex obnupta*], beaked sedge [*Carex utriculata*]), lakeshore sedge [*Carex lenticularis*] and water sedge [*Carex aquatilis*] and rushes (e.g., soft stemmed bulrush [*Schoenoplectus tabernaemontani*]). Additionally, native tree and shrub species, including willow (*Salix spp.*), red-osier dogwood (*Cornus stolonifera*), black cottonwood (*Populus balsamifera*), western hemlock (*Tsuga heterophylla*), western red-cedar (*Thuja plicata*), red-alder (*Alnus* rubra) and twinberry (*Lonicera involucrata*) have also been tested in coastal reservoirs (e.g., Buttle Lake). What follows is a brief summary of the history of revegetation research conducted in the reservoirs throughout BC to date.

In the late 1980's and early 1990's, revegetation efforts in the Arrow Lakes reservoir included seeding of fall rye and a small component of perennial grasses (e.g. reed canary grass), planting seedlings of a variety of wetland plant species (sedges and rushes) and planting live cuttings of shrubs (i.e., willow and cottonwood; Carr et al. 1993; Jackson et al. 1995). Seeding of annual rye and perennial grasses (particularly reed canarygrass) was successful in establishing a vigorous vegetation cover in previously unvegetated areas of the drawdown zone; this drastically reduced the incidence of wind erosion and the generation of dust storms, which was a significant issue for the local community of Revelstoke. For the tested wetland plants, survival during the initial few years of monitoring was greatest for sedge species, including Columbia sedge (*Carex aperta*) slough sedge, beaked sedge, and in particular, lakeshore sedge. Planting of live cuttings of native and non-native willow at various elevations within the drawdown zone had mixed results; with moderate survival after the first year of inundation and with survival confined mostly to the uppermost portion of the drawdown zone (Carr et al. 1993).

In 2002, a revegetation research trial was established at the south end of Buttle Lake in Stathcona-Westmin Provincial Park. The research trial consisted of native tree and shrub seedlings, including western hemlock, western red-cedar, red alder, twinberry and Sitka willow, at three elevations within the drawdown zone (*Salix sitchensis*; Roderick 2003). Observations by many observers in other reservoirs conclusively demonstrate that conifers cannot survive inundation in reservoir environments. Due to the absence of flooding in the year following planting, the effect of inundation on seedling survival was inconclusive; however, information survivorship in relation to other stressed factors were monitored (e.g., herbivory, drought).

Between 2008 and 2011, a significant planting effort was completed in the drawdown zone of Arrow Lakes reservoir, which included planting seedling of various native sedges, grasses and shrubs. During the 4 year effort, approximately 1 million sedge seedlings and grass plugs and approx. 40,000 shrub seedlings and live cuttings (willow, black cottonwood and red-osier dogwood were planted at selected sites in the Arrow Lakes Reservoir. As of 2015, results of monitoring have indicated that survival was highest for one particular species of sedge (Kellogg's sedge [*Carex lenticularis* var. *lipocarpa*]) and black cottonwood; success overall was highly dependant on site conditions (Miller et al. 2016).

A similar revegtation effort to that completed in the Arrow Lakes reservoir was also completed in the Kimbasket Reservoir between 2008 and 2010 (Keefer Ecological Services Ltd. 2012). The effort included planting of live stakes of willow, black cottonwood and red-osier dogwood, seedlings of deciduous shrubs (mountain alder [*Alnus incana* sbsp. *tenuifolia*] and three species of willow), seedlings of sedge (lenticular [*Carex lenticularis*], columbia and water sedge [*Carex aquatilis*]) and rush (small-fruited bulrush [*Scirpus microcarpus*] as well as direct seeding of three native grass seed mixes (mixes included bluejoint reedgrass and alsike clover *Trifolium hybridum*]) in the drawdown zone of Canoe Reach and Bush Arm. Survival of live stakes declined rapidly over time following planting (believed to be the result of planting cuttings in fine clay substrates where anoxic conditions limited oxygen availability to roots); survival for deciduous shrub seedlings was higher in comparison to the live stakes. Seedlings of lenticular sedge and woolgrass (*Scirpus atrocintus*) appeared to have the highest survival of sedges tested. This project was far less successful than that of the work in the Arrow Reservoir, mostly likely due to a different water regime, a colder climate, more impoverished and finer textured alkaline soils.

In 2009, revegetation trials involving a large diversity of native grasses, horsetails and graminoids, in addition to willow cuttings, were established in the drawdown zone of Williston Reservoir near the community of Tsay Key Dene (Vaartou 2010). Native grasses tested included slender wheatgrass, violet wheatgrass (*Aropyron violaceum*), hair bentgrass (*Agrostis scabra*), alpine bluegrass (*Poa alpine*), fowl bluegrass, Macrourum's wheatgrass (*Agropron macrourum*), bearded wheatgrass (*Agropyron subsecundum*), tufted hairgrass (*Deschampsia caespitose*), Rocky Mountain fescue and glaucous bluegrass (*Poa glauca*). Horsetails included common horsetail (*Equisetum arvense*), swamp horsetail (*Equisetum fluviatile*), scouring rush (*Equisetum hyemale*), dwarf scouring rush (*Equisetum* scirpoides) and common mare's tail (*Hippuris vulgaris*). Graminoids tested included hairy wildrye (*Elymus Innovatus*), northern

mannagrass (*Glyceria borealis*), water sedge, awned sedge (*Carex atherodes*), golden sedge (*Carex aurea*), long stoloned sedge (*Carex interior*), Scandinavian sedge (*Carex media*), beaked sedge, arctic rush (*Juncus arcticus*), two-flowered rush (*Juncus biglumis*), Drummond's rush (*Juncus drummondii*) and small-flowered bulrush. Willow species tested included felt leaf willow (*Salix alaxensis*), northern bush-willow (*Salix arbusculoides*), grey-leaved willow (*Salix glauca*) and Scouler's willow (*Salix scouleriana*). Observations of the various trials in the following year (2010) suggested limited success. Native grass seed trials had moderate success; slender wheatgrass, violet wheatgrass, bearded wheatgrass, alpine bluegrass, glaucous bluegrass and fowl bluegrass were highlighted as the most successful. Horsetail and graminoid test trials were unsuccessful as there were no signs of plants in any of the plots in the year following planting. Most of the willow cuttings planted did not survive the first year (possibly due timing of collection and methods of planting).

In May 2010, seeding and planting trials of a few native grasses were established in the drawdown zone of Williston Reservoir as part of dust control research program (Abiola 2011). Seeding trials consisted of a grass seed mix that included Kentucky bluegrass (*Poa pratensis*), fescue (*Festuca spp.*) and ryegrass (*Lolium spp.*). Planting trials consisted of plugs of bentgrass (*Agrostis spp.*). Results of seedling following the first year of inundation have not yet been reported.

In 2014, test plots consisting of seven native shrubs and wetland plants, were established at various elevations and terrain types within the drawdown zone of Carpenter Lake reservoir (Scholz 2015). Species tested included lakeshore sedge, foxtail barely (*Hordeum jubatum*), blue wildrye (*Elymus glaucus*), bluejoint reedgrass, slender wheatgrass, fowl bluegrass, Baltic rush (*Juncus balticus*) and Canada Wildrye (*Elymus canadensis*). Results of seedling survival following the first year of inundation (2015) have not yet been reported.

1.2 Rationale and Objectives

Past revegetation trials within the drawdown zone of reservoirs throughout BC have tested a variety of shrubs, grasses and graminoids, some of which have been observed naturally colonizing the drawdown zone. In regards to the Williston Reservoir, past trials have focused mostly on testing agronomic and native grass species that would be used to establish extensive vegetation cover to mitigate wind and water erosion. Less effort has been made to test wetland species, particularly semi-aquatic and aquatic species (e.g., water smartweed, common spikerush [*Eleocharis palustris*]). For wetland plant species, their establishment in the drawdown zone would aim to mitigate erosion, but would also have the potential to benefit wildlife utilizing riparian and aquatic habitats (e.g., waterfowl and amphibians).

The initial stage of this project outline in this report had two objectives. The first objective was to identify candidate flood and drought tolerant native plant species for use in the revegetation of the upper drawdown zone of the Williston Reservoir. Candidate species were selected from a comprehensive list of species known to naturally colonize the drawdown zone. The second was to evaluate factors related to seed collection and propagation of seedlings for each of the candidate species and identify any potential challenges to producing seedlings for future revegetation efforts. These objectives have been developed to support action 2a-1 of BC Hydro's Peace Basin Riparian and Wetlands Action Plan, which aims to identify flood and drought resistant plant species for bank stabilization.

The objectives of this initial stage of the project were completed through a review of relevant literature and discussions with native plant seed collectors and propagation experts, revegetation specialists and local First Nations.

2.0 METHODS

2.1 PLANT SPECIES NATURALLY COLONIZING THE DRAWDOWN ZONE

A comprehensive list of native plant species known to naturally colonize the upper drawdown zone of the Williston reservoir was developed. The list was created based on personal observations of drawdown zone vegetation in the reservoir (between 2011-2016) and from plant species lists developed from vegetation surveys as part of BC Hydro's GMSMON 15 (Reservoir Wetland Habitat Monitoring; MacInnis et al. 2011-2015) and GMSMON 17; MacInnis et al. 2014-2015) projects. The comprehensive list of native plant species is outlined in appendix 1.

2.2 CANDIDATE PLANT SPECIES FOR REVEGETATION

Candidate species for revegetation in the drawdown zone were selected from the comprehensive list of plant species through a process of elimination. The process used specific criteria to eliminate species that were either unlikely to tolerate growing conditions in the upper drawdown zone (i.e., period of inundation and exposure), or were identified as challenging to propagate from seed in a nursery environment. In addition, the process included the elimination of non-native (exotic or invasive) species. The specific criteria and rationale for eliminating non-candidate plant species are outlined in Table 1.

TABLE 1. CRITERIA AND RATIONALE FOR THE ELIMINATION OF NON-CANDIDATE PLANT SPECIES.

ELIMINATED	RATIONALE FOR ELIMINATION
Non-native (exotic or Invasive) species	Five species identified as non-native included Reed Canarygrass (*Phalaris arundinacea*), Lady's thumb (*Persicaria maculosa*), smooth hawksbeard (*Crepis capillaris*), lamb's-quarters (*Chenopodium album ssp. Striatum*) and great mullein (*Verbascum thapsus*).
Genera	Vegetation surveys conducted in the Williston Reservoir identified some genera's (e.g., *Carex spp.*). The objective of this project is to identify specific plant species. Thus, all genera's were eliminated.
Tree species	Tree cannot survive complete submersion (including foliage) for extended periods; trees can be damaged or killed by floating debris.
Bryophytes	Difficult to harvest/transplant/transport and propagate; limited effect on substrate stabilization.
Annuals	Annual plants must re-establish each year from seed. Flooding may reduce the availability of seed for annual establishment and persistence with some exceptions (e.g., Lady's thumb).
Floating and Submergent Plants	Floating and submergent plants may not establish and/or survive outside of a permanent standing water.
Identified as having a Low Tolerance to Stress	Each species was scored on their potential level of tolerance stress from flooding or drought. Species were provided with a score of "Low", "Med" or "High". A species with "Low" tolerance of one kind or another could be considered an improper choice given the adaptability required for the final candidates and was eliminated.

2.3 FEEDBACK FROM PROFESSIONALS

To help further refine the list of candidate plant species for revegetation in the drawdown zone, feedback was solicited from select professionals experienced in the practice of revegetation, native seed collection and nursery propagation as well as with aboriginal traditional knowledge holders. Based on their area of knowledge, Individuals solicited were asked to review the list of candidate species and provide comments for each species some of the following topics:

- Propagation
- Seed collection
- Potential flood and drought tolerance

- Examples (if available) where used for revegetation
- Positive or negative impacts to wildlife

2.4 Evaluation of Seed Acquisition and Propagation for Candidate Plant Species

An evaluation of factors related to seed collection and propagation of seedlings for each of the candidate species was completed utilizing information/lessons learned from previous revegetation trials conducted in reservoirs throughout BC and from feedback provided by expert staff at BC native plant nurseries. This assessment was qualitative and aimed to identify any potential challenges, if present, to producing seedlings for use in revegetation efforts in the drawdown zone. Factors evaluated included:

- Propagule Collection: type and size of propagule, timing of collection (e.g., ripeness, dormancy) and cleaning/preparation requirements (if required).
- Propagation Approach: propagule longevity, germination (e.g., stratification requirements), period of propagation and seedling plug size.

In addition, general recommendations for seed collection and propagation provided from past revegetation trials were reviewed and summarized.

3.0 PROJECT OUTCOMES

3.1 Candidate Plant Species List

Candidate species identified for future revegetation efforts in the drawdown zone of Williston Reservoir and rationale for their selection are outlined in Table 2. The candidate list is the result of both the process of elimination exercise and refinements based on feedback received select professionals and First Nations.

TABLE 2. CANDIDATE SPECIES FOR USE IN THE REVEGETATION OF THE WILLISTON RESERVOIR UPPER DRAWDOWN ZONE.

COMMON NAME	LATIN NAME	TYPE	FLOOD TOLERANCE	DROUGHT TOLERANCE	RATIONALE FOR SELECTION
bluejoint	*Calamagrostis Canadensis*	herb	Moderate	Moderate	Rhizomatous plant species that inhabits clay soils (Wynia 2006); commonly observed in the forming extensive vegetation cover in the upper drawdown zone of many reservoirs in BC; moderate tolerance to inundation and drought conditions.
common spike-rush	*Eleocharis palustris*	herb	High	Low	Adapted to wet soils and areas prone to annual flooding; rhizomatous root mass provides good erosion control; commonly observed in undisturbed wetland complexes within the drawdown zone (Ogle et al. 2012).
common horsetail	*Equisetum arvense*	herb	High	High	One of the most common plant species observed in the drawdown zone of reservoirs throughout BC; common to disturbed soils soils, sometimes even on dry sites.
Swamp horsetail	*Equisetum fluviatile*	herb	High	Low	Common to areas prone to flooding; observed in the drawdown zone of some reservoirs;
dwarf scouring-rush	*Equisetum-scirpoides*	herb	High	Low	Adapted to wet soils; commonly observed in the upper drawdown zone; rhizomatous plant may be advantageous.
lakeshore sedge	*Carex lenticularis*	herb	High	Moderate	Commonly observed in the drawdown zone of many reservoirs in BC; easily propagated from seed; high rates of survival for seedlings planted in past revegetation efforts (Keefer Ecological Services 2011 and 2012).
water sedge	*Carex aquatalis*	herb	High	Moderate	Commonly observed in the drawdown zone of many reservoirs in BC; relatively easy propagation; high rates of survival for seedlings planted in past revegetation efforts (Keefer Ecological Services 2011 and 2012); rhizomatous root system provides good erosion control (Tilley et al. 2011).
water smartweed	*Persicaria amphibia*	herb	High	Moderate	Commonly observed in the upper drawdown zone, sometime forming dense matts, surviving periods of exposure and inundation; recommended as a good candidate by native plant nurseries.
willow	*Salix spp.*	shrub	High	Moderate	Commonly observed in the upper drawdown zone, mostly at an elevation near full pool; utilized in previous drawdown zone revegetation efforts with some success.
hardhack	*Spiraea douglasii*	shrub	High	Moderate	Observed along the lake margins (particularly pothole lakes) in areas around the Williston Reservoir; adapted to wet soils; tolerates fluctuating groundwater tables.

Comments on potential candidate species was received from select individuals at NATS Nursery Ltd., Tipi Mountain Native Plants Ltd., Polster Environmental Services Ltd., Twin Sisters Native Plant Nursery and McLeod Lake Indian Band. A brief summary of the main comments received is provided below:

- Some species identified are challenging to propagate or propagating has not yet been attempted. Examples include small bedstraw (*Galium trifidum*) and tower mustard (*Turritis glabra*).
- Some species were identified as unlikely to tolerate period of inundation (e.g., anoxia intolerance) or exposure. Examples include field mint (*Mentha arvensis*), green sedge (*Carex viridula*), Pensylvania buttercup (*Ranunculus pensylvanicus*).
- Concern was raised in regards to attracting ungulates to the shoreline, which could result in accidental drowning. A suggestion was made to avoid the use browse species (e.g., willow). However, this risk identified in regards to browse species utilizing areas of the upper drawdown zone is likely to be low and thus willow was retained as a candidate species.
- Rhizomatous species may have an advantage to inhabiting the drawdown zone in comparison to non-rhizomatous species. Rhizomatous species have the potential to propagate through the extension of its rhizomes and development of new shoots or through rhizome fragmentation. Species that do not have the ability of vegetative reproduction rely entirely on successful seed dispersal. Annual flooding in the mid to late growing season often prohibits plant species from developing mature seed and seed that does mature often does not reach a suitable receptive surface.

3.2 Propagule Collection and Propagation

The preliminary review of information in regards to plant propagule collection and propagation for the candidate species identified some considerations for future efforts (Table 3). Propagule collection would include collecting seed or rhizomes; timing for seed collection would be specific (late summer to fall) whereas timing for rhizomes for propagation would likely be the most appropriate in the early spring. In regards to propagation approaches, much of the details of these approaches remain propriety to plant nurseries and thus detailed collected are limited.

TABLE 3. DETAILS OF PROPAGULE COLLECTION AND PROPAGATION APPROACHES FOR CANDIDATE PLANT SPECIES.

COMMON NAME	LATIN NAME	PROPAGULE COLLECTION	PROPAGATION APPROACH	SPECIFIC CHALLENGES
bluejoint	*Calamagrostis canadensis*	Collect seeds in late fall (September/October); Collect whole inflorescence and lay to dry before extracting seed.	No benefits found for pre-treatment (e.g., scarification, stratification);	Difficult to collect seed; may be purchased commercially; seed is hard to separate from chaff (tufts of hair attached to lemmas) but also may not be necessary to produce seedlings.
common spike-rush	*Eleocharis palustris*	Collect seeds in late fall; seed forecasting may be required to determine the most appropriate time for collection.	Can be propagated using seed or rhizome cuttings; suggested grow time for seedlings (7-8 months).	Identifying the appropriate time for seed or rhizome collection; seeds can be difficult to germinate.
common horsetail	*Equisetum arvense*	Collect rhizomes in the spring; collect 6 inch sections with healthy shoots emerging from their joints; may be semi dormant in late summer and could be collected then and cold stored.	Planting rhizome cuttings in an appropriate medium; NATS Nursery is conducting planting trials using 50p plugs.	Further research on the timing of propagule collection and methods for propagation would be beneficial; NATS Nursery currently conducting propagation trials with *Equisetum spp.* to identify effective procedures.
swamp horsetail	*Equisetum fluviatile*			
dwarf scouring-rush	*Equisetum scirpoides*			
lakeshore sedge	*Carex lenticularis*	Collect inflorescence in early summer (June/July) and lay materials to dry for a few weeks prior to extraction (seed for lakeshore sedge collected in Kinbasket Reservoir in late June had excellent viability); extract seed from inflorescence by stripping; an air separator has been suggested for easy cleaning.	Past propagation for revegetation trials utilized a peat moss medium; Seed pre-treatment may or may not be required.	For cleaning, seed can be difficult to separate from similar sized chaff (non-seed material); Seeds are delicate and can shatter; germination limited to proper seed handling and propagation protocols. Old/poorly handled seed has very low viability; seeds planted below the soil surface won't germinate as sedge seed is believed to need light; overwatering can blow seed out.
water sedge	*Carex aquatilis*			
water smartweed	*Persicaria amphibia*	Collection of rhizomes or seed in the fall.	NATS Nursery has developed a successful propagation approach.	Seed stratification may require long periods (e.g., 6 months).
willow	*Salix spp.*	Collection seeds or stem cuttings; timing for seed collection varies between species; stem cuttings collected during winter dormancy (for best results).	Plant cuttings in appropriate medium; avoid overgrowing seedlings as they may become root bound.	Identification of species can be difficult and flood and drought tolerance can vary between species.
hardhack	*Spiraea douglasii*	Collect seeds or stem cuttings; collect inflorescence between August to October; lay materials to dry for a few weeks to allow follicles to split open and release seed; shake and screen to collect unreleased seed; collect cuttings during winter dormancy.	Cold stratification for dry seed is suggested; propagate seedlings in peat medium.	Seed must be collected before being released from follicles, thus forecasting (site visit prior to collection) may be required.

3.3 Conclusions/Recommendations

During this initial stage of the project, a list of candidate flood and drought tolerant plant species for revegetation efforts in the drawdown zone of Williston Reservoir was successful completed. It is recommended that the project proceed to the next stage, which includes the acquisition of propagules and propagation of for the candidate species identified. It is the intention of this proponent to submit an application for small project in fall 2017 to complete stage two of the project. Future stages of the project are outlined in following section of the report.

3.4 Future Work

Future work for this project will work towards the establishment and monitoring of revegetation trials in the upper drawdown zone of Williston Reservoir. The work will be completed in stages, each building on the success of the previous stage. Following this initial stage, in which candidate species have been identified, stage two of the project will aim to collect and/or acquire propagules for each species and initiate seedling propagation with a native plant nursery. Stage three of the project work towards the design and implementation of planting trials at a few select locations in the reservoir. Monitoring of the planting trials will follow with further stages.

Collection of propagule for candidate species will be completed at a few locations on the reservoir. Since most of the species identified occur commonly in the drawdown zone, the collection effort will likely focus in areas that are easily accessible (e.g., Airport Lagoon). Depending on the species, seed or rhizomes will be collected at the appropriate time in the growing season. Propagules collected will then be sent to an experienced native plant nursery for propagation. If deemed appropriate, other sources of propagule (e.g., seeds provided by a collector or nursery) may be considered to help reduce seed collection efforts/costs. The seed collection effort will include an opportunity for First Nations involvement by incorporating a training program, such as the Growing Our Futures: Native Plant Horticultural Program developed by Keefer Ecological Services and Royal Roads University.

Design of planting trials will build on the lessons of past trials revegetation trials conducted in reservoirs throughout BC. Recommendations from past trials that may be incorporated include elevation specific planting (e.g., grasses at the uppermost portion and sedges in lower portion of the upper drawdown zone), propagation approaches (e.g., seedling age, fertilization regime) and experimental treatments (e.g., seedling size and/or age; timing, duration and depth of inundation; planting substrate).

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Appendix 1

List of Plant Species Naturally Establishing in the Upper Drawdown Zone of Williston Reservoir

LATIN NAME	COMMON NAME	TYPE
Agrostis scabra	hair bentgrass	herb
Alnus viridus ssp. sinuata	Sitka alder	shrub
Alopecurus aequalis	Little Meadow Foxtail	herb
Barbarea orthoceras	American Winter Cress	herb
Betula papyrifera	paper birch	tree
Boechera divaricarpa	Spreading-pod Rockcress	herb
Bryum creberrimum	No Common Name	bryophyte
Bryum pseudotriquetrum	marsh thread moss	bryophyte
Calamagrostis Canadensis	Bluejoint	herb
Calliergon giganteum	giant calliergon moss	bryophyte
Callitriche palustris	spring water-starwort	herb
Callitriche spp.	water-starwort	herb
Cardamine pensylvanica	Pennsylvanian bitter-cress	herb
Carex aenea	bronze sedge	herb
Carex aquatilis ssp. Aquatilis	water sedge	herb
Carex lenticularis	Lakeshore Sedge	herb
Carex spp.	sedge	herb
Carex viridula	green sedge	herb
Ceratodon purpureus	Purple Horn-Toothed Moss	bryophyte
Ceratophyllum demersum	common hornwort	herb
Chara spp.	stonewort	herb
Chenopodium album ssp. Striatum	lamb's-quarters	herb
Climacium dendroides	tree moss	bryophyte
Corydalis sempervirens	pink corydalis	herb
Crepis Capillaris	smooth hawksbeard	herb
Crepis tectorum	annual hawksbeard	herb
Cryptantha torreyana	Torreys cryptantha	herb
Drepanocladus aduncus	common hook-moss	bryophyte
Drepanocladus polygamus	fertile feathermoss	bryophyte
Eleocharis palustris	common spike-rush	herb
Epilobium Angustifolium	Fireweed	herb
Epilobium ciliatum ssp. ciliatum	purple-leaved willowherb	herb
Epilobium spp.	willowherb	herb
Equisetum arvense	Common Horsetail	herb
Equisetum fluviatile	Swamp Horsetail	herb
Equisetum sylvaticum	Wood Horestail	herb
Equisetum scirpoides	Dwarf scouring-rush	herb
Eriophorum gracile	Slender Cottongrass	herb
Fragaria vesca	Wood Strawberry	herb
Galium spp.	Bedstraw	herb
Galium trifidum	Small Bedstraw	herb
Geum macrophyllum ssp. perincisum	Large-leaved avens	herb
Gramineae	grass family	herb
Hippuris vulgaris	Common Mare's-tail	herb
Juncus filiformis	Thread Rush	herb
Matricaria discoidea	Pineapple Weed	herb
Mentha arvensis	Field Mint	herb
Menyanthes trifoliata	Buckbean	herb
Myriophyllum verticillatum	verticillate water-milfoil	herb
Najas flexilis	wavy water nymph	herb
Nuphar Variegata	Variegated Yellow Pond-lily	herb
Persicaria amphibia	Water Smartweed	herb

LATIN NAME	COMMON NAME	TYPE
Persicaria maculosa	Lady's Thumb	herb
Phalaris arundinacea	Reed Canarygrass	herb
Philonotis fotana	aquatic apple moss	bryophyte
Poa abbreviata ssp. pattersonii	Abbreviated Bluegrass	herb
Populus tremuloides	Trembling Aspen	tree
Potamogeton foliosus	closed-leaved potamogeton	herb
Potamogeton praelongus	Long-stalked Potamogeton	herb
Potentilla norvegica	Norwegian Cinquefoil	herb
Potentilla palustris	Marsh Cinquefoil	herb
Ranunculus aquatilis	White Water-buttercup	herb
Ranunculus gmelinii	Small Yellow Water-buttercup	herb
Ranunculus pensylvanicus	Pensylvania Buttercup	herb
Ranunculus sceleratus	Celery-leafed Buttercup	herb
Rhinanthus minor	Little Yellowrattle	herb
Rorippa palustris	Marsh Yellow Cress	herb
Rorippa tenerrima	Yellow Cress	herb
Rubus Idaeus	Red Raspberry	shrub
Rumex Salicifolius ssp. triangulivalvis var. triangulivalvis	Willow Dock	herb
Sagina saginoides	Arctic Pearlwort	herb
Salix alaxensis	Alaska Willow	shrub
Salix barclayi	Barclay's Willow	shrub
Salix bebbiana	Bebb's Willow	shrub
Salix spp.	Willow	shrub
Scirpus atrocinctus	Blackgirdle Bulrush	herb
Scutellaria galericulata	marsh skullcap	herb
Spergularia rubra	red sand-spurry	herb
Stellaria umbellata	Umbellate Starwort	herb
Trifolium spp.	clover	herb
Turritis glabra	tower mustard	herb
Typha latifolia	Common Cattail	herb
Utricularia spp.	bladderwort	herb
Verbascum Thapsus	great mullein	herb
Veronica beccabunga	american speedwell	herb
Veronica peregrina var. xalapensis	purslane speedwell	herb