Bridge River Project Water Use Plan

Carpenter Reservoir Riparian Vegetation Monitoring

Implementation Year 8

Reference: BRGMON-2

Annual Report

Study Period: April 2020 – March 2021

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BRGMON-2
Carpenter Reservoir Riparian Vegetation Monitoring
Year 8, 2020

Prepared for: **St'at'imc Eco Resources and BC Hydro**

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Cover photo: Monitoring planted Carex Kelloggii Patch on the Carpenter Reservoir Low Mud Flat, Photo June 10, 2020 by Awan Ned.

Executive Summary

The BRGMON-2 monitoring program was designed to study the effects of water management on riparian vegetation surrounding Carpenter Reservoir in the Bridge-Seton System, a major tributary of the Fraser River in South-Western B.C. Part of this 10-year monitoring program focused on assessing the effects of a seven-year riparian enhancement effort within the drawdown zone of the reservoir. The main objective was to determine if the enhancement effort had a positive effect on the quality and quantity of riparian vegetation when compared with control areas without treatments. Riparian enhancement treatments were carried out under the BRGWORKS-1 program, and 2020 was the final scheduled year of treatments. Annual monitoring carried out in 2020 looked at the effects of treatments on vegetation cover, richness, frequency and diversity. Standing crop biomass from seeding treatments was also assessed. In total, 21 polygons (18 treated, 6 controls) were sampled for site and vegetation characteristics. In addition, photo-monitoring was conducted at 18 locations representing 9 treatment and 9 control sites.

Assessing all of the treatments carried out over the seven-year period of BRGWORKS-1 was beyond the scope of the BRGMON-2 annual program. Emphasis was placed on assessing treatments carried out from 2016 to 2020. The BRGWORKS-1 program took an adaptive and iterative approach through its final year of treatments in 2020. Monitoring in 2020 cannot assess the 2020 treatments as time and inundation periods need to pass to determine success. Treatments monitored included machine mounding, planting native vegetation with an emphasis on Kellogg's sedge (*Carex kelloggii*), and seeding using both native and agronomic species fall rye (*Secale cereale).*

Naturally, the low elevation mud flats in the reservoir are sparsely covered by a suite of exotic annuals that can rapidly reach maturity and produce high numbers of seed. Native perennial species that reach furthest into the drawdown zone are Kellogg's sedge, horsetails (*Equisetum arvense* and *Equisetum palustre*), foxtail barley (*Hordeum jubatum*) and bluejoint reedgrass (*Calamagrostis canadensis*). These species, along with other native species, have thus been central to treatment trials in the drawdown zone of Carpenter Reservoir. Results from the 2020 monitoring indicate that mounding alone does not increase the quality and quantity of habitat. However, mounding and seeding, or mounding and planting did increase species richness of native species but has not as of yet resulted in high native plant cover values. Actual total vegetation cover values remain low in most polygons. Cover has been increased by the treatment trials in 2016 when dense stands of Kellogg's sedge were planted (30,000 stems per hectare). Plants have thrived where soils were deep enough, have reproduced and seedlings have established from parent plants. Wildlife species have been anecdotally observed utilizing these dense planted patches, including spotted sandpipers (*Actitis macularius*) (nesting), wandering terrestrial garter snakes (*Thamnophis elegans vagrans*) travelling through, and Canada geese (*Branta canadensis*) browsing and foraging.

Upper drawdown elevation treatments included planting riparian tree and shrub species within mounded areas. Monitoring in 2020 indicated good survival and vigor after three years, with increased native species richness due directly to planting. However, tree and shrub species are not yet providing a significant increase in vegetation cover. Due to the iterative approach used in the BRGWORKS-1 program, some treatments were implemented for the first time in 2020.

Recommendations for the final year of monitoring under the BRGMON-2 program in 2022 include emphasizing monitoring within planting and seeding treatments carried out in 2020 within polygons mounded in 2019. Successful establishment and resilience of treatments lie with water management within Carpenter Reservoir. Treatments have the best chance of success when inundation of the lowest elevations (639.5 metres above sea level [mASL]) occurs no earlier than mid July, thus ensuring a long enough growing season for vegetation. In years when water levels rise quickly in the late spring, such as in 2015, the growing season may be greatly reduced, with the potential to place significant stress for survival and establishment of vegetation.

Management question	**Summary of Key Monitoring Results**
Do reservoir operations have a negative, neutral or positive impact on the quality and quantity (species composition, biological productivity, spatial area) of the riparian vegetation surrounding Carpenter Reservoir?	Not yet addressed. Baseline data was collected in 2013, repeated sampling and comparative analysis scheduled for 2022.
Does the implementation of a short-term (seven year) intensive reservoir riparian enhancement program expand the quality (as measured by diversity, distribution, and vigour) and quantity (as measured by cover, abundance and biomass) of riparian habitats in the drawdown zone of the Carpenter Lake Reservoir?	The intensive riparian enhancement project carried out under the BRGWORKS-1 program was an adaptive and iterative program. Annual results of the program are dependent on the annual hydrograph of the reservoir. Some of the treatments carried out in the final year of the BRGWORKS-1 program were based on observations and lessons from the previous 5 years of monitoring and the recommendations from the 2019 BRGMON-2 program. The effectiveness of the final year's efforts will not be known until the 2022 monitoring. Result highlights from monitoring indicate that: • Vegetation needs to be above water until early to mid-July at a minimum, for optimum resilience. Drawdown zone plants will not sustain repeated years of short growing seasons. • Kellogg's sedge can survive direct planting at low elevations (639.5 mASL) into mud flats and can reproduce and produce seedlings that are able to establish. • Kellogg's sedge can survive and reproduce in mounded terrain, and will grow from direct seeding. • Mounding alone does not lead to increased native species diversity or cover. • Mounding and planting will increase native species richness but as of yet has not resulted in high cover. The 2020 planting treatments may provide higher cover but it is too early to tell. Most increases in native species diversity were based on species being planted or seeded.

Management question	**Summary of Key Monitoring Results**
	• Horsetail showed potential to be successfully planted but needs longer monitoring to determine resilience beyond one year. • Mid elevation plantings of Canada wildrye have led to plants establishing and dispersing seed. Seedlings are spreading and establishing from seed. • Bluejoint reedgrass shows establishment at mid and upper elevations but has not yet provided much cover. • Planted native trees, shrubs and grasses in upper elevation mounded polygons are showing good survival and vigour, especially with irrigation to help establish plants through the arid growing season. • The null hypotheses for this management question all state whether there is a 'significant' difference between control and treatment areas. The interpretation of whether or not observations and results are 'significant' is open to interpretation. To the spotted sandpiper that nested within a patch of planted sedges these results were highly significant.
Does the implementation of a short-term seven-year intensive reservoir riparian enhancement program mitigate the effects of dust storms and increase the aesthetic quality of the drawdown zone in the Carpenter Lake Reservoir?	This management question was added to the TOR in 2017. This question is largely being addressed through the BRGWORKS-1 program with camera imagery data. Indications are that the majority of dust arises from the loose fines on instream gravel bars and steep cutbanks along the river channel. These areas currently do not support vegetation. Seeding fall rye and vegetating across the mud flats may reduce secondary, resuspension of dust in late June- July by trapping windblown particles. These aesthetics questions are also covered within the BRGWORKS-1 program.

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1.0 Introduction

The BRGMON-2 program arose from the Bridge-Seton Consultative Committee Report from 2003 (B.C. Hydro and Compass Resource Management, 2003) to fulfil the identified need to monitor riparian vegetation surrounding Carpenter Reservoir in relation to water management. The riparian vegetation monitoring for the drawdown zone of Carpenter Reservoir under BRGMON-2 has two specific goals as defined in the TOR (BC Hydro, 2017):

1. Monitor the effects of Carpenter Reservoir operating conditions on the (existing) riparian areas surrounding Carpenter Reservoir. (in Year 1 (2013) and Year 10 (2022)).

   Management question 1: Do reservoir operations have a negative, neutral or positive impact on the quality and quantity (species composition, biological productivity, spatial area) of the riparian vegetation surrounding Carpenter Reservoir?

2. Monitor the effectiveness of the reservoir riparian enhancement program (BRGWORKS-1; the objective of riparian enhancement is to create conditions in the drawdown zone that encourage the establishment of native species using a combination of revegetation and physical works treatments) with respect to Carpenter Reservoir operating conditions. This component links to a 7-year riparian enhancement project (BRGWORKS-1; Years 3 – 9 of BRGMON-2, 2015 to 2020).

   Management question 2: Does the implementation of a short term (7 years) intensive reservoir riparian enhancement program expand the quality (as measured by diversity, distribution, and vigour) and quantity (as measured by cover, abundance and biomass) of riparian habitats in the drawdown zone of the Carpenter Lake Reservoir.

This annual report addresses goal 2 and management question 2 with the following null hypotheses:

H3: Implementation of a riparian enhancement program between the Gun Creek Fan and the Tyaughton Lake Road Junction within the drawdown zone will support the basis for continued natural re-colonization of native vegetation communities and species.

The sub hypotheses are:

H3A: There is no significant difference in native vegetation establishment (based on species distribution, diversity, vigour, biomass and abundance) at control versus treatment locations.

H3B: There is no significant difference in the cover of native vegetation in control versus treatment locations.

H3C: There is no significant difference in native vegetation establishment and the cover of native vegetation communities (based on species distribution, diversity, vigour, biomass and abundance) arising from different revegetation prescriptions.

H3D: There is no significant difference in the species composition of naturally re-colonizing vegetation in treated versus control areas.

Year 2020 was the 8th year of the BRGMON-2 program and the 6th year of monitoring for Component 2. Treatments for riparian enhancement were carried out under the BRGWORKS-1 program in 2014, 2015, 2016, 2017, 2019 and 2020. BRGMON-2 field monitoring focused on sub-sampling BRGWORKS-1 treatments and control areas to inform the management question and null hypothesis.

As per the TOR (BC Hydro, 2017), this report contains:

- A summary of treatment methods employed in BRGWORKS-1 in 2019 and 2020[1],
- A summary of annual reservoir inundation patterns including previous year records and BRGWORKS-1 treatment dates on the graph;
- Highlights of annual treatment success and failures;
- Notes on annual weather patterns and observational; and
- Considerations for adaptive management and recommendations for future riparian enhancement treatments and monitoring.

There have been many diverse and compounding treatments under the BRGWORKS-1 program. We thus make recommendations for the final year of scheduled sampling (2022) for the BRGMON-2 program.

2.0 Background

Carpenter Reservoir is located 185 km north-east of Vancouver British Columbia. Carpenter Reservoir is the larger of two reservoirs constructed on the Bridge River. The Bridge River drainage area is over 4,728 km². La Joie Dam at the town of Gold Bridge British Columbia rises 87 m high and forms Downton Reservoir behind it, with a drainage area of 988 km² that includes the Bridge Glacier. Water released through La Joie Dam generates power and joins with the Hurley and Cadwallader River flows that enter Carpenter Reservoir Drawdown zone 2.5 km downstream of the dam. Carpenter Reservoir is formed by the 55 m high Terzaghi Dam that floods 50 km (35%) of the total length of the river, with a drainage area of 2,719 km². The project monitoring sites are located near the west end of Carpenter Reservoir, around the alluvial fan of Gun Creek tributary (Map 1). Terzaghi Dam was completed in 1960. The water storage

[1] Component 1 covers the riparian zone of the full reservoir and takes place in program year's 1 and 10, component 2 monitors and guides the BRGWORKS-1 riparian enhancement treatments.

levels in Carpenter Reservoir were managed to a full pool of 651.08 mASL (the absolute capacity of the reservoir) up until 2000 and the inception of the water use planning committee. Since 2000 water levels in Carpenter Reservoir have been managed between a low of 606.55 mASL and a targeted maximum of 648.00 mASL (BC Hydro, 2011). The maintenance of a 3 m zone between 648.00 mASL and 651.08 mASL was a key management target of the WUP program initiated in 2000. Any influx of water into the buffer zone is to not exceed eight weeks, although exceptions to the management objects are possible in accordance with established procedures.

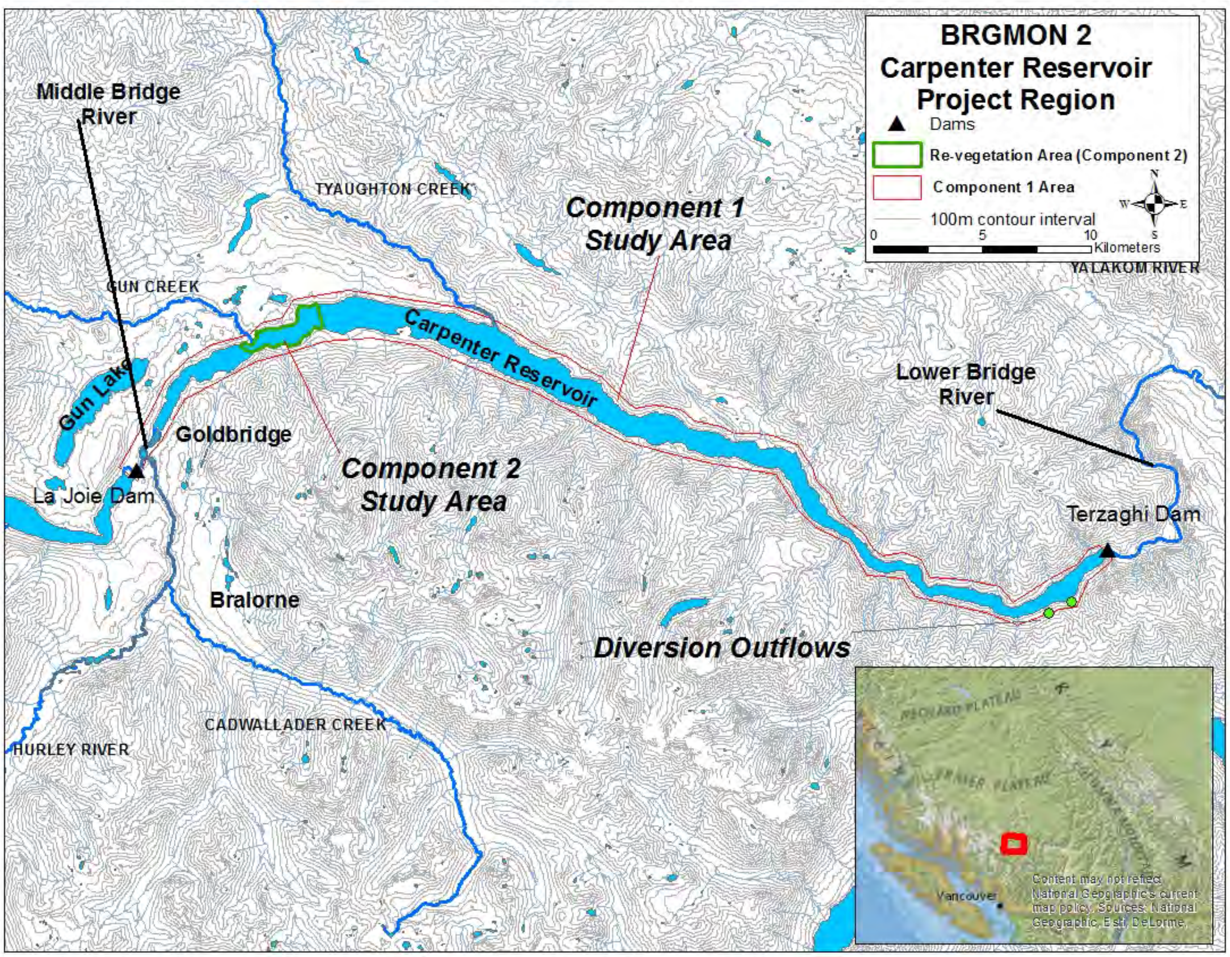
The drawdown zone occupies the Interior Douglas-fir very dry cold (IDFxc) biogeoclimatic zone (formerly IDFxh2, BEC Data Base Changes version 6, 2006) characterized by climax stands of Douglas-fir (*Pseudotsuga menziesii ssp. glauca*) and Ponderosa pine (*Pinus ponderosa*) on drier south facing slopes (BC Ministry of Forests, 1990).

Component 1 of BRGMON-2 looks at the effects of maintaining the buffer zone on the vegetation of Carpenter Riparian. This component will be addressed by repeating in 2022 the sampling completed during the baseline study of 2013. Component 2 of BRGMON-2 focuses on assessing and guiding the riparian enhancement treatments of BRGWORKS-1 performed within the Carpenter Reservoir drawdown zone near the west end of Carpenter Reservoir (Map 2). The area has shorelines characterized by upslope geomorphological processes and valley bottom or mud flats characterized by effect of reservoir inundation. Resulting silt layers deposited on the mud flats while under inundation were subsequently seasonally carved by the flows of the historic Bridge River channel. The mud flats extend east to Terzaghi dam and west to the village site of Gold Bridge. The Gun Creek Fan formed by historical alluvial deposits from centuries of Gun Creek flood events, and marks the western extent of the treatment area. The mud flats to the west rise from 644m ASL just west of the Gun Creek Fan, to peak full pool (651.08m) at Gold Bridge.

The mud flats to the immediate west of the Gun Creek Fan were classified as Mid Mud Flats (MMF) during the 2013 BRGMON-2 sampling (Scholz and Gibeau, 2014). The MMFs (644m-646m ASL) were well vegetated by horsetails (*Equisetum* sp.), sedges (*Carex* sp.) and bluejoint reedgrass (*Calamagrostis canadensis*) as well as a mix of other herbaceous species (Figure 1). Further west, higher elevation mud flats have more complex vegetation with shrubs and eventually cottonwood trees at the upper elevation near Gold Bridge. The area for riparian enhancement treatments extends east to the Tyaughton road junction with Hwy 40, i.e., 3.5 km east of Gun Creek. Mud flats form the greatest expanse of terrain within the area of riparian enhancement treatments. In the 2013 sampling, mud flats were classified as Low Mud Flats (LMF) below 644m ASL and were observed to be sparsely vegetated with weedy annuals and much exposed mineral soil (Figure 2). Mud flat soils were silty lacustrine deposits from years of inundation. The treatment area shoreline also includes a steep and shallow beach terrain type on the north shore and an alluvial fan on the south shore (see the 2014 report for detailed terrain type descriptions and associated vegetation assemblages).

Since 2000, the annual hydrograph for Carpenter Reservoir indicated that water levels are generally drawn down to their lowest levels by mid-late spring (Mid April to Mid May) prior to freshet. Water levels then typically rise in late spring and peak in late summer/fall (Mid August to November). Water levels are then slowly drawn down over late fall, winter, through to early spring.

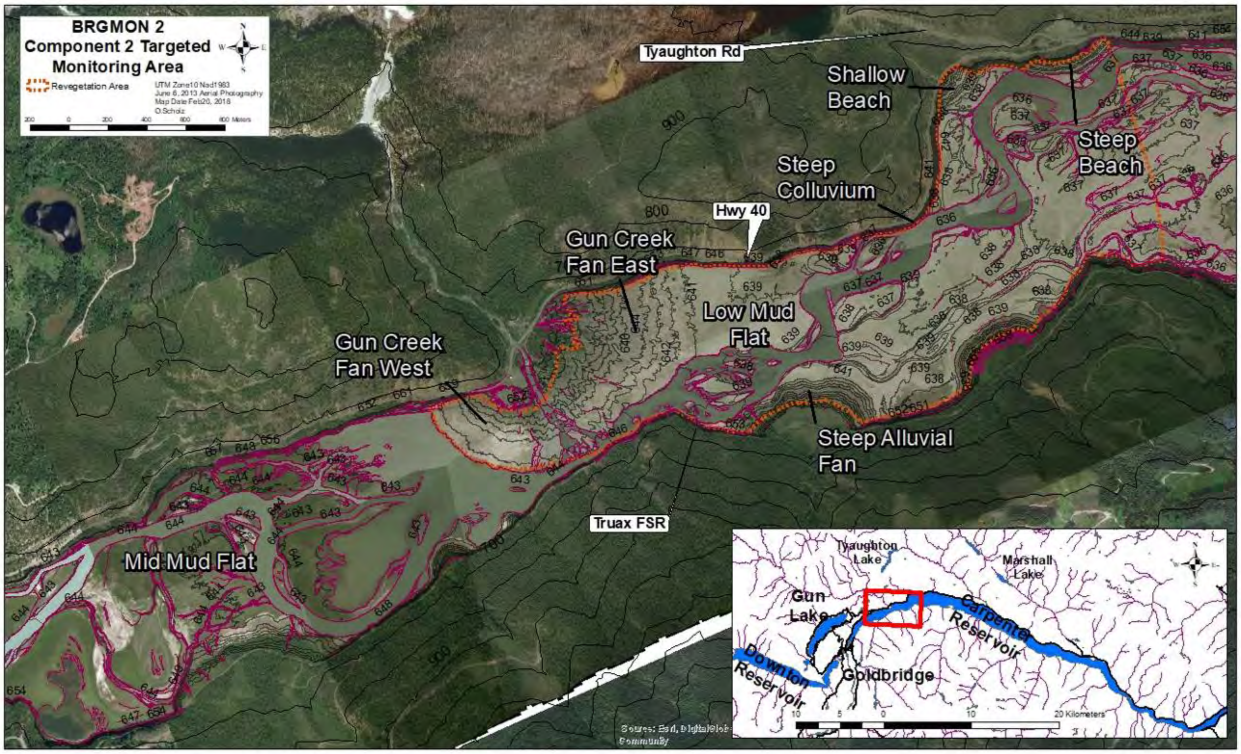
A key to the successful establishment of vegetation on the LMF is the length of growing season prior to inundation. In an average year, elevations below 642 mASL are exposed to air for less than 50% of the growing season (Scholz and Gibeau, 2014). Based on analysis of historic drafting and inundation timing, we have deemed it highly unlikely that perennial native vegetation could survive below 640 mASL. Restoration treatments under BRGWORKS-1 have thus concentrated on a 11m vertical range, between 639 mASL and 650 mASL.



Map 1. Targeted study areas for Components 1 and 2 of BRGMON-2.

Figure 1. Example of Mid elevation Mud Flats (MMF ≥644m) west of Gun Creek Fan (June 17, 2013).

Figure 2. Example of Low elevation Mud Flats (LMF) East of Gun Creek Fan (elevation approx. 637 mASL).

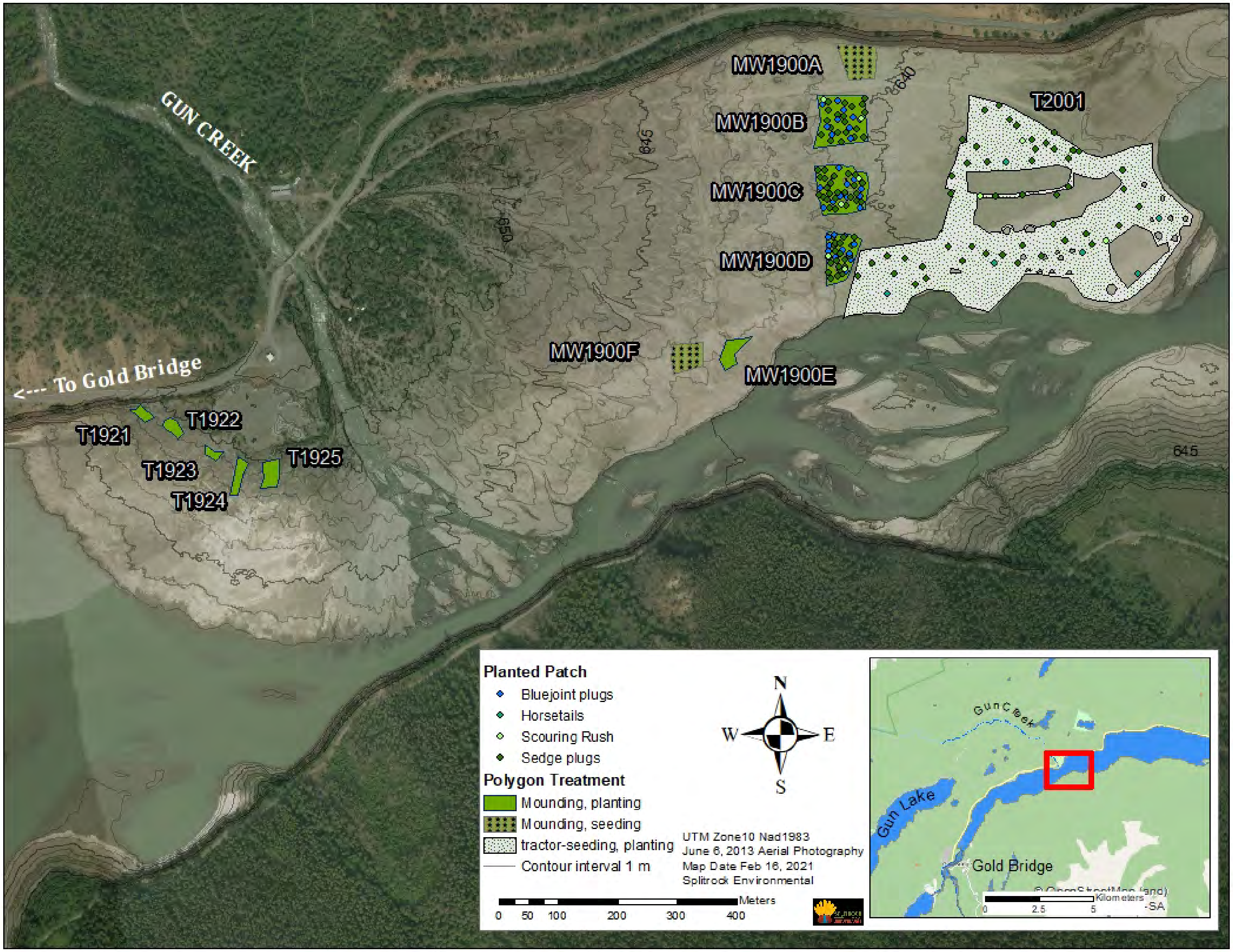


Map 2. Targeted monitoring area and associated terrain types for Component 2 of BRGMON-2.

2.1 Update on BRGWORKS-1 Treatments

Riparian enhancement treatments for BRGWORKS-1 were implemented in 2014-2017 and 2019-2020. No treatments were carried out in 2018. The intention of the lag year was to allow time to assess the 2017 treatments before making recommendations for the 2019 treatments. Year 2020 was the final year scheduled for riparian enhancement treatments. Recommendations for the 2020 treatments were made in the 2019 annual report for BRGMON-2 (Scholz and Gibeau, 2020).

Treatments in 2020 included machine mounding, seeding, and planting native sedge, grass, shrub, and tree species (Table 1). Planting was carried out in combination with either mounding or seeding. Seeding was carried out by tractor on the mud flats and by hand in mounded areas (Map 3).



Map 3. Map of the treatments carried out for BRGWORKS-1 in 2020.

Table 1. Summary of the 2019 and 2020 treatments through BRGWORKS-1 (See Map 3 for locations).

Polygon ID	Area (m^2)	2019 Treatment	2020 Treatment	2020 treatment species
T2001	89464	Seeding, Planting	Seeding, Planting	fall rye, planted patches of Kellogg's sedge, horsetail and scouring rush
MW1900D	3687	Mounding	Planting	Kellogg's sedge, bluejoint reedgrass, willow sp., scouring rush
MW1900C	6225	Mounding	Planting	
MW1900B	6700	Mounding	Planting	Kellogg's sedge, bluejoint reedgrass, scouring rush
MW1900A	3287	None	Mounding, Seeding	Kellogg's sedge
T1921	504	None	Mounding, Planting	bluejoint, red osier dogwood, black cottonwood, ponderosa pine, willow
T1922	682	None	Mounding, Planting	
T1923	401	None	Mounding, Planting	
T1924	980	None	Mounding, Planting	
T1925	1217	None	Mounding, Planting	
MW1900E	1411	Mounding	Planting	Kellogg's sedge, bluejoint, willow
MW1900F	2363	None	Mounding, Seeding	meadow bird's foot trefoil
MW1900Ds1	60	Mounding	Seeding	Kellogg's sedge
MW1900Ds2	64	Mounding	Seeding	Kellogg's sedge
MW1900Ds3	48	Mounding	Seeding	Kellogg's sedge
MW1900Cs1	40	Mounding	Seeding	Kellogg's sedge

MW1900Cs2	49	Mounding	Seeding	Kellogg's sedge
MW1900Cs3	48	Mounding	Seeding	Kellogg's sedge
MW1900Cs4	61	Mounding	Seeding	Kellogg's sedge

3.0 Methods

To maintain consistency with monitoring done in previous years for BRGMON-2, field work was conducted in early June 2020. This timing allowed the vegetation to have a reasonable growing season and for the sampling to happen prior to risk of inundation, which could occur by mid June in any given year. Treatments carried out in previous years under the BRGWORKS-1 program on the Gun Creek alluvial fan, and the adjacent mud flats to the east, were prioritized for monitoring in 2020 (Map 4). This included polygons treated in 2017 with machine mounding and combinations of planting and seeding (Scholz, 2018_b) that were monitored along with control areas. Monitoring was also carried out on the Low Mud Flats where fall rye seeding and native species planting was done in 2019. Sampling was carried out using randomly placed 50m² circular plots (3.99m radius). Smaller quadrats of 1m² were used to randomly sample within the 50m² plots, to increase the sensitivity for detecting very small colonizing seedlings. Polygons of planted cuttings were monitored for cutting survival, plant vigor and other native species establishment. Photo monitoring was also carried out on all sites.

Random x and y coordinates were generated within each polygon to locate plot centres for 50m² plots. Once plot centres were located, a tree planting shovel was placed at the ground and a 3.99m long cord was used to measure out the circular sampling plot. Wire flags were temporarily placed to mark out the circular plot and photos were taken of the plot. Photographs taken for each circular plot included oblique angles from a distance to capture the whole plot (Figure 3). Overhead perspective photos were captured for each 1m x 1m quadrat. Permanent photo-monitoring points established with the 2017 riparian enhancements were monitored in 2020. These photo-monitoring points were established to capture effects associated with the machine mounding and planting and to compare to control polygons. Permanent photo-monitoring marker pins were relocated using SXblue GPS. A Canon Power ShotD20 camera was used with a tripod set at 1m above ground and photos were taken at a set azimuth with a 1m X 0.10m board placed 10m from the camera

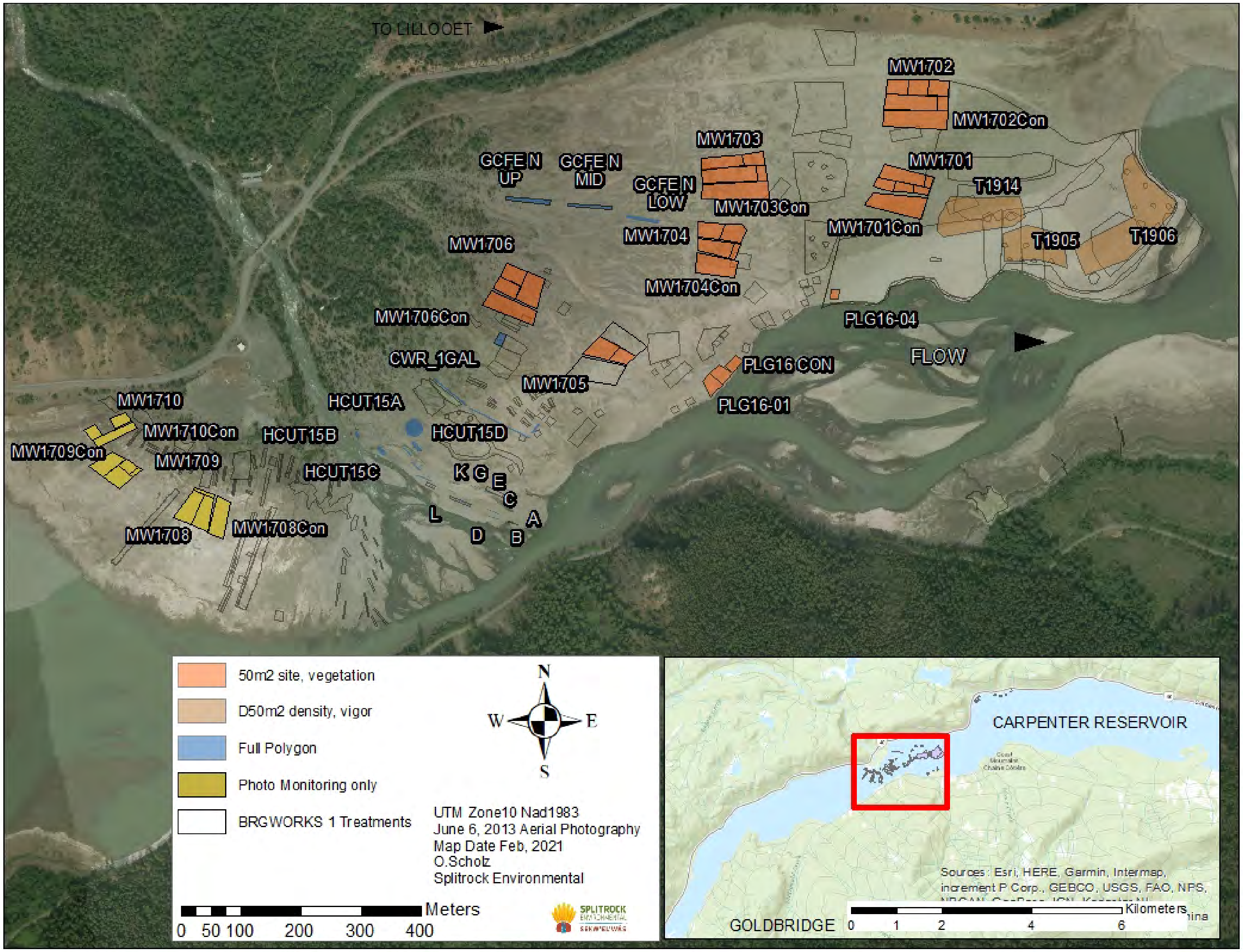
²Plots were sampled to record site, soil, and vegetation characteristics. Plot and quadrat data were digitally recorded in the field on sheets created using Doforms © software. Data was uploaded to Doforms web platform and later exported into Microsoft Excel for analysis (see appendix for lists of variables and species collected).

The absolute density of native perennial species was recorded for each 50m² plot. Density tally data was manually collected in field notebooks and later transferred to Microsoft Excel for summary and analysis.

Sampling of standing crop biomass was conducted on July 10, 2020. Sampling targeted growth of fall rye (*Cereale secale*) from seeding treatments done for BRGWORKS-1 in 2020, as well as natural vegetation growth in control areas. Plot frames (1m²) were subjectively placed to sample sites considered representative of vegetation growth in control areas and in areas seeded with fall rye. These clip plots were sampled by clipping above-ground vegetation using scissors. In addition, entire plants were sampled by digging up plants to sample both root and shoot biomass (Figure 4). The locations for biomass sampling were mapped with GPS and before/after photos were taken.

Figure 3. Example of a 50m² circular plot flagged out for monitoring (left); 1mX1m quadrat sub-sample (right).

Figure 4. Biomass sampling in treatment of fall rye seeding (polygon T2001, 10 July 2020).



Map 4. Sampling approaches for BRGMON-2 monitoring in 2020.

We compiled the water levels in Carpenter Reservoir for 2020 and previous years until 2000, based on data provided by BC Hydro Power Records. Data provided by the Ministry of Forests Range and Natural Resource Operations at the Fire Zone weather station (located on 5-Mile ridge) were used to analyse weather and calculate growing degree-days. The 5-Mile ridge station is within 5 km of the monitoring sites for Component 2 of BRGMON-2. Accumulated growing degree days (AGDD) were computed based on the BC government range readiness approach (Fraser, 2006). AGDD's were tabulated based on summing the daily growing degree days (GDD) beginning in spring after 5 days where GDD was above 0°C, and not earlier than March 15th.

Base temperature below which plant growth is impeded was conservatively presumed to be 0°C (as in range management). Daily GDD's were calculated using the following formula:

[daily Max. temp (°C) + Daily Min. temp (°C)] / 2 – base temperature 0 (°C).

GDD for many crop species recognize that plants do not grow any faster when temperatures are over 30°C (Rawson and Macpherson, 2000). Therefore, in order to use a conservative estimate of GDD, the mean daily temperatures were filtered to cap the high temperature days at 30°C. GDD highlight the length and proportion of growing season experienced by vegetation at different elevations within the drawdown zone of Carpenter Reservoir since 2014.

Statistical analyses

Species cover, frequency of occurrence (total, and for exotic and native species) and survival were assessed per planting trial and terrain types with a series of figures and maps to compare between control and treatment polygons. Data from embedded 1x1m^2 plots were merged within the larger 50m^2 plots to provide an overall assessment of vegetation characteristics. Differences in average cover among treatments were assessed with general linear models (GLM) fitted with beta regression (library betareg) to deal with continuous dependent variable between 0 and 1 such as cover values (Simas et al. 2010). All analyses were performed in the R language software (version 4.0.3).

The species composition was assessed using multivariate regression trees to look at the influence of a series of environmental and site variables on species cover and occurrence. Environmental variables included were: treatment type (Control, M, MP, MS, MPT, PLG[2]), terrain type, polygon, slope, microtopography, rock %, mineral soil %, organics %, soil compaction, soil texture, coarse fragment content, soil nutrient regime, disturbance, soil moisture regime, elevation, and heat load (a function of aspect). Multivariate regression trees are interesting methods since they deal well with continuous or discrete variables, nonlinear relationships, complex interactions, missing values in both dependent and independent variables, and outliers (Death and Fabricious 2000, Moisen 2008). A multivariate regression tree results from the recursive partitioning of the response variables into a series of boxes (the leaves) that contain the most homogeneous groups of objects (plots), constrained by the environmental variables (De'ath 2002, Legendre and Legendre 2012). Creating the splits is constructed by seeking the threshold levels of independent variables that account for the greatest similarity among plots, and each group also corresponds to a species assemblage and its associated habitat (De'ath 2002). The amount of variation in the data explained by the tree is expressed in terms of cross-validation error (CV error), corresponding to the ratio of variation unexplained by the tree to the total variation in the dependent variables (Legendre and Legendre 2012). The trees are read from the top to the bottom. The variables that create the splits at each node are labelled with the threshold at which the splits occur. By reading the tree, one can interpret the characteristics in terms of species composition and environmental variables that describe the plots that are grouped at each terminal leaf. The analysis was completed by looking for indicator species using the index *IndVal* (Dufrêne and Legendre 1997). The index is based on within-species abundance and occurrence comparisons, and tested with randomization procedures (Legendre and Legendre 2012). Its value is maximal (i.e. 1) when the species is observed at all the transects belonging to the same group.

[2] M=mounded, MP=Mounded and planted, MS=Mounded and seeded, MPT=Mounded, planted and replanted, PLG=planted

4.0 Results

4.1 Hydrograph and growing degree days in Carpenter Reservoir

In early May of 2020, the water levels in Carpenter Reservoir were drawn down to 617.55 m, which was close to the lowest 10th percentile of low pool levels from the past 21 years (Figure 5). Water levels rose and reached the lowest elevation of BRGWORKS-1 treatments (639.5-640 mASL) by July 18th, 2020, which was slightly later than the twenty-year average. The accumulated growing degree days (AGDD) in that period totaled 1282.4 or an estimated 47% of AGDD in 2020 (Table 2). Water levels rose to the 2020 full pool elevation of 647.6 mASL by Oct, 09th, which was very close to the target maximum for the reservoir of 648 mASL (BC Hydro, 2011). That elevation also corresponds to the low elevation of the buffer zone (Map 5). Upper drawdown and buffer treatment zones, particularly areas mounded within the buffer zone in 2017 and 2020, were either only partially or not directly affected by inundation in 2020. Water levels held above 647 mASL for just over two weeks in October and then slowly receded through the fall and winter. Water levels dropped back below the Low Mud Flat treatment areas (639.5m) by the end of January 2021. The lowest elevation treatments were inundated for over six months.

Table 2. Dates in 2019 and 2020 growing season and Carpenter Reservoir water levels. Growing degree days commence when average daily temperatures are >0°C for 5 consecutive days, end when Min temperature 0°C.

Date	Note	AGDD
18 Mar 2019	Start of growing season	7.4
1 July 2019	Inundate lowest 639.5 m BRGWORKS-1 treatments	1228.2
11 July 2019	Inundation 642m LMF	1385.95
31 July 2019	Inundation 644m Alluvial Fan/LMF transition	1736.95
24 Sept 2019	Peak Pool 644.10m	2657.5
8 Oct 2019	End of Growing season	2753.95
10 April 2020	Start Growing season	11.3
18 July 2020	Inundate lowest 639.5 m BRGWORKS-1 treatments	1282.4
15 Aug 2020	Inundation 642m LMF flooded	1829.5
3 Sept 2020	Inundate 644m Alluvial fan/LMF transition flooded	2160.85
9 Oct 2020	Peak inundation 647.6m	2714.55
15 Oct 2020	End growing season	2745.4

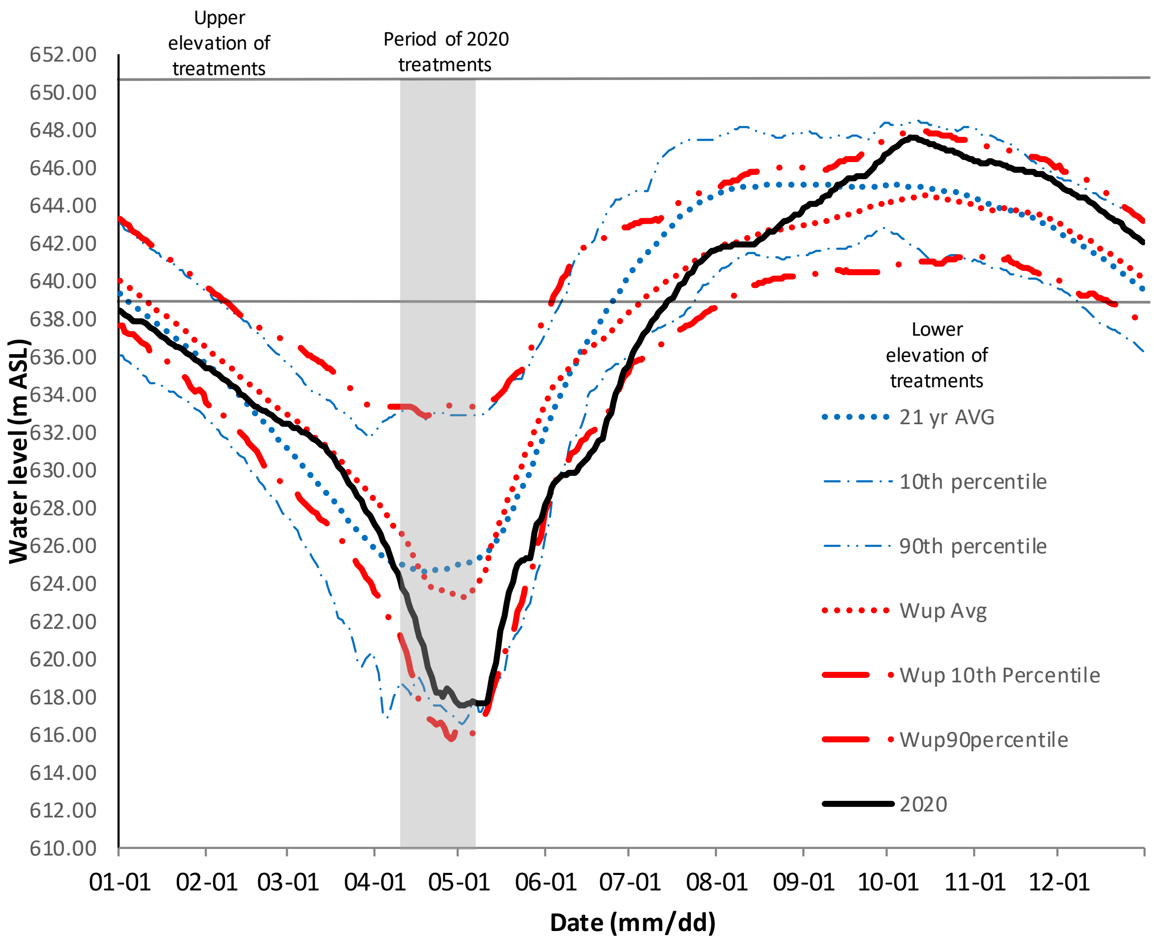
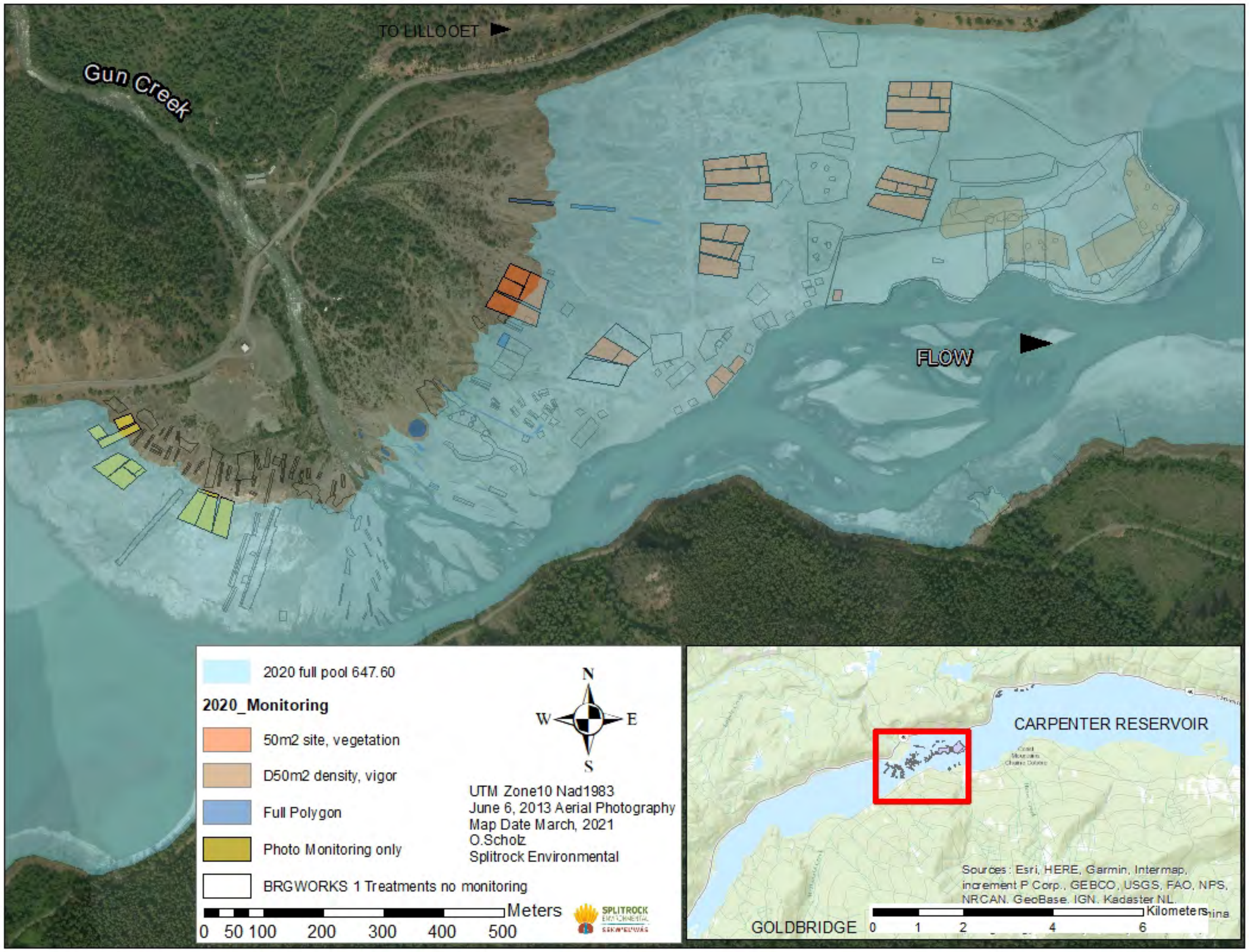


Figure 5. Hydrograph for Carpenter Reservoir with annual daily averages for the 21-year WUP period, as well as the averages for the period of BRGWORKS-1 treatments (2014-2020).

Table 3. Proportion of month (per cent of days) available for plant growth at elevation by year. Green: little effect of inundation on vegetation growth (Between 100% -75% of month), yellow: moderate impact of inundation on plant growing (25-75% of month available), red: high impact of inundation on vegetation growth < 25% per cent of growing days available that month. (Blue margin indicates peak inundation reached that month/year.)

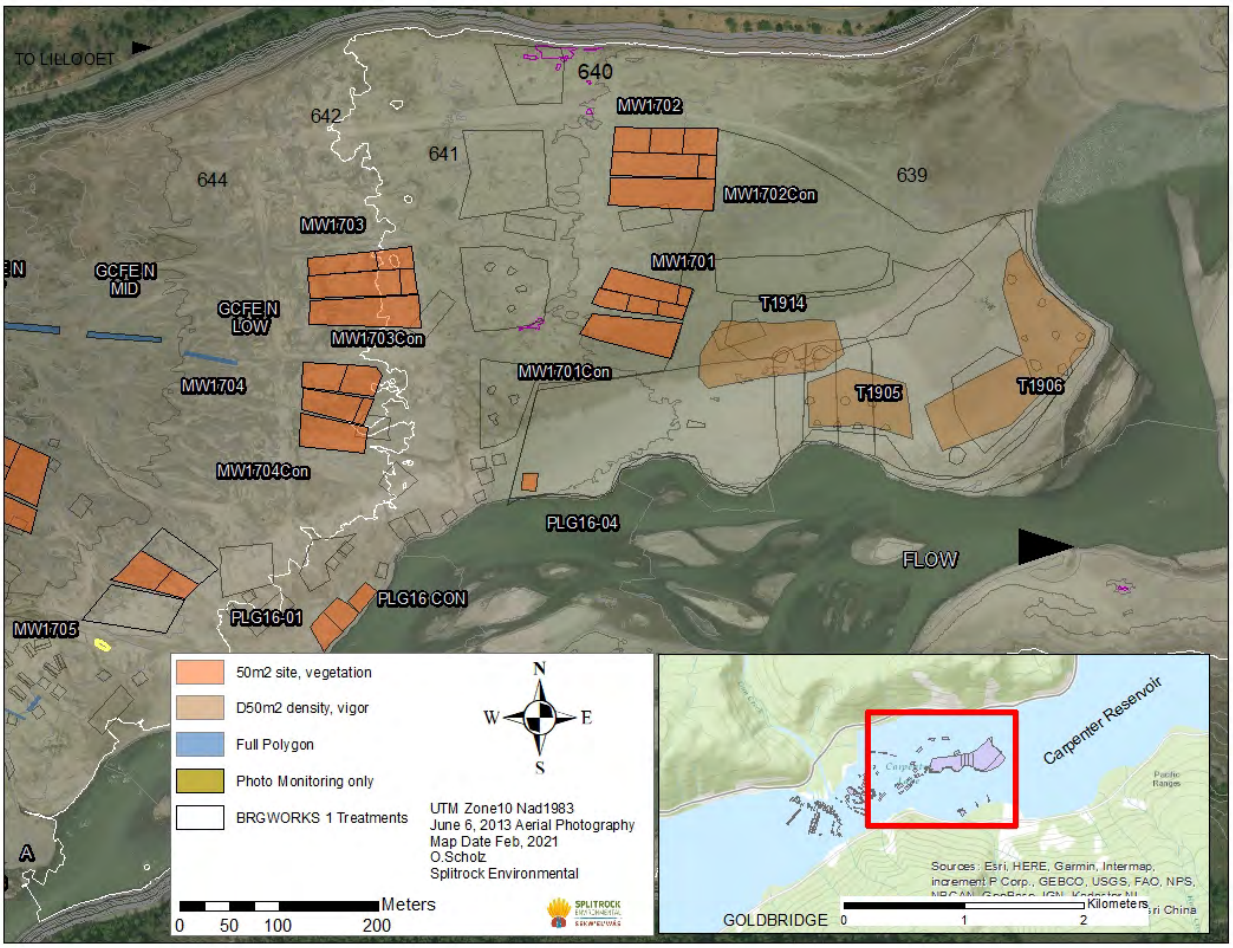
MONTH		Low (LMF)					Mid Drawdown		Upper Drawdown		Buffer		
		639	**640**	**641**	**642**	**643**	**644**	**645**	**646**	**647**	**648**	**649**	**650**
April	2014	100	100	100	100	100	100	100	100	100	100	100	100
	2015	100	100	100	100	100	100	100	100	100	100	100	100
	2016	100	100	100	100	100	100	100	100	100	100	100	100
	2017	100	100	100	100	100	100	100	100	100	100	100	100
	2018	100	100	100	100	100	100	100	100	100	100	100	100
	2019	100	100	100	100	100	100	100	100	100	100	100	100
	2020	100	100	100	100	100	100	100	100	100	100	100	100
May	2014	100	100	100	100	100	100	100	100	100	100	100	100
	2015	93.5	100	100	100	100	100	100	100	100	100	100	100
	2016	100	100	100	100	100	100	100	100	100	100	100	100
	2017	100	100	100	100	100	100	100	100	100	100	100	100
	2018	100	100	100	100	100	100	100	100	100	100	100	100
	2019	100	100	100	100	100	100	100	100	100	100	100	100
	2020	100	100	100	100	100	100	100	100	100	100	100	100
June	2014	23.3	40	73	100	100	100	100	100	100	100	100	100
	2015	0	3	13	23.3	33	50	100	100	100	100	100	100
	2016	100	100	100	100	100	100	100	100	100	100	100	100
	2017	100	100	100	100	100	100	100	100	100	100	100	100
	2018	100	100	100	100	100	100	100	100	100	100	100	100
	2019	90	100	100	100	100	100	100	100	100	100	100	100
	2020	100	100	100	100	100	100	100	100	100	100	100	100
July	2014	0	0	0	13	100	100	100	100	100	100	100	100
	2015	0	0	0	0	0	0	52	90	100	100	100	100
	2016	84	100	100	100	100	100	100	100	100	100	100	100
	2017	77	94	100	100	100	100	100	100	100	100	100	100
	2018	100	100	100	100	100	100	100	100	100	100	100	100
	2019	0	13	22.5	32	52	97	100	100	100	100	100	100
	2020	45	65	81	100	100	100	100	100	100	100	100	100
Aug	2014	0	0	0	55	100	100	100	100	100	100	100	100
	2015	0	0	0	0	0	0	0	0	39	100	100	100
	2016	0	10	58	100	100	100	100	100	100	100	100	100
	2017	0	0	19	65	100	100	100	100	100	100	100	100
	2018	100	100	100	100	100	100	100	100	100	100	100	100
	2019	0	0	0	0	0	0	71	100	100	100	100	100
	2020	0	0	0	45	74	100	100	100	100	100	100	100
Sept	2014	0	0	0	100	100	100	100	100	100	100	100	100
	2015	0	0	0	0	0	0	0	0	0	3	100	100
	2016	0	0	0	43	63	90	100	100	100	100	100	100
	2017	0	0	0	0	27	57	100	100	100	100	100	100
	2018	20	100	100	100	100	100	100	100	100	100	100	100
	2019	0	0	0	0	0	13	100	100	100	100	100	100
	2020	0	0	0	0	0	6	40	83	100	100	100	100
Oct	2014	0	0	0	100	100	100	100	100	100	100	100	100
	2015	0	0	0	0	0	0	0	0	0	0	100	100
	2016	0	0	0	0	0	0	19	100	100	100	100	100
	2017	0	0	0	0	0	29	100	100	100	100	100	100
	2018	0	22.5	97	100	100	100	100	100	100	100	100	100
	2019	0	0	0	0	35	100	100	100	100	100	100	100
	2020	0	0	0	0	0	0	0	0	39	100	100	100



Map 5. Full pool across the monitoring area of Gun Creek Fan in 2020.

4.2 Monitoring of treatments in Low Mud Flat (LMF) terrain

The Low Mud Flat (LMF) terrain is characterized by the effects of inundation, as well as by the settling and accumulation of fine silts over coarser fluvial substrate. Treatments monitored on the LMF terrain in 2020 focussed on assessing polygons mounded in 2017 (i.e. MW1701, MW1702, MW1703) and in 2016 (PLG 16-01, PLG1604), as well as adjacent untreated control polygons (Map 6). Those polygons were either planted and/or seeded, or solely mounded. We also assessed areas seeded with fall rye combined with planting sedges and horsetails (T1906, T1905, T1914) for survival and vigor of planted native perennials. Biomass samples were collected within polygons seeded with fall rye in April and May 2020, as well as in untreated control areas, to assess how seeded fall rye growth compared to naturally recruited vegetation.

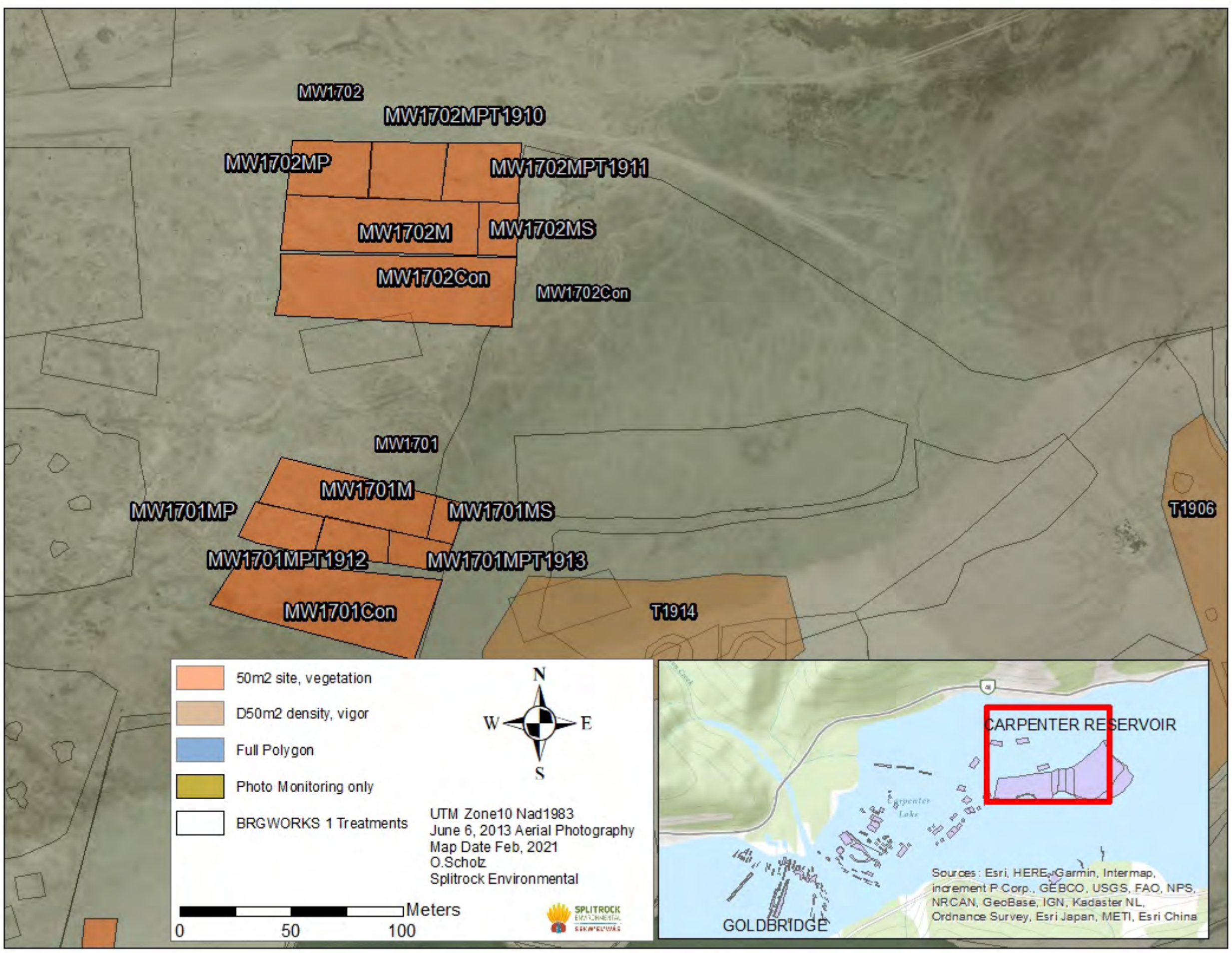


Map 6. Polygons monitored in the Low Mud Flat (LMF) terrain in 2020. The 642 mASL contour represents the top edge of the LMF terrain, where it transitions to alluvial fan.

Monitoring treatments in polygon MW1701 included multiple sub-polygons based on the type of treatments applied (Table 4, Map7).

Table 4. Treatments monitored in polygon MW1701 in 2020.

Polygon	Treatment	Year of treatments
MW1701CON	Designated control area, no treatment	--
MW1701M	Mounded only	2017
MW1701MS	Mounded and seeded with Kellogg's sedge	2017
MW1701MP	Mounded and planted with Kellogg's sedge	2017
MW1701MPT1912	Mounded, planted with Kellogg's sedge, re-planted (fill planted) with Kellogg's sedge	2017, 2019
MW1701MPT1913	Mounded, planted with Kellogg's sedge, over sown with lotus seed	2017, 2019



Map 7. Treatments on the sub-polygons of MW1702 in the LMF terrain monitored in 2020.

Cover of exotic species was generally higher than that of native species for all sub-polygons, but particularly in the control plots and in MPT1913 (Figure 6). Cover of native species was, on average, significantly lower than exotic (Z=-4.7, p=0.00000315) and cover of vegetation in MPT1913 and MS was significantly higher than in controls (Z=3.3, p=0.001, and Z=3.26, p=0.001, respectively) (when two outliers of big cover of exotic in control plots[3] were removed to improve fit).

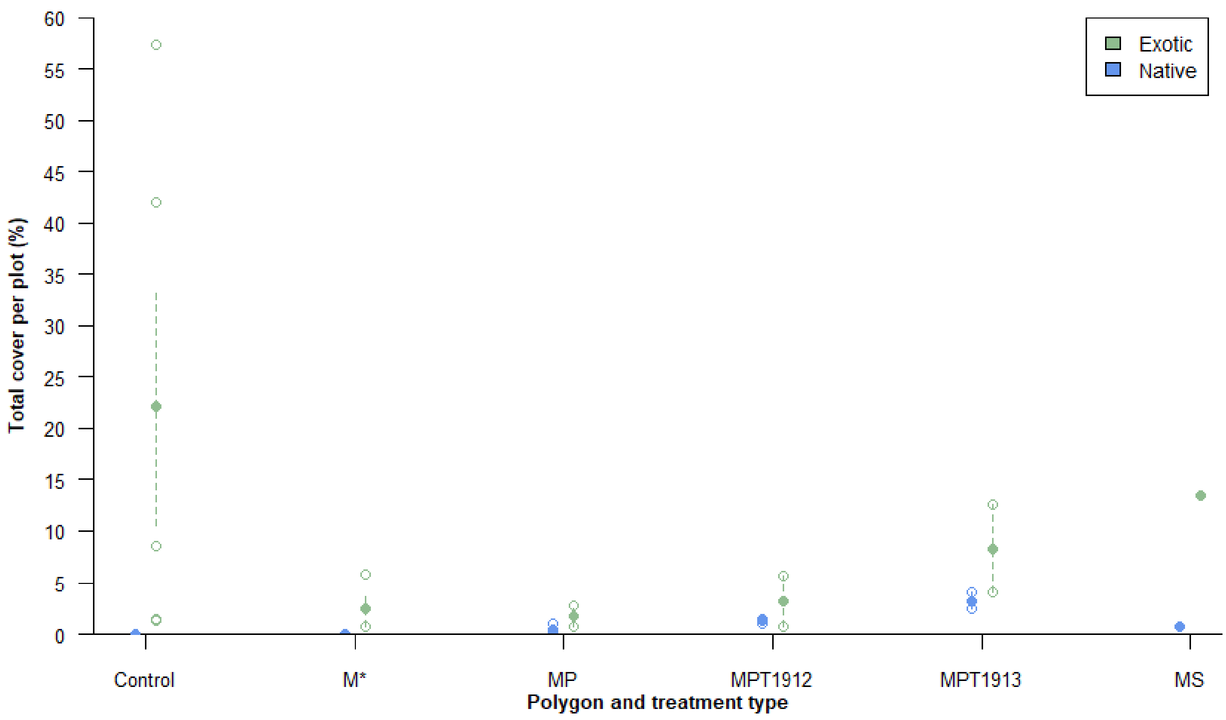


Figure 6. Total cover of native or exotic vegetation per plot (per cent) in the herb layer of each type of polygon of MW1701. Filled dots and error bars show average cover and standard error per polygon, while open dots are cover for each plot. * indicates that a very low cover of native vegetation at the low shrub layer was seen in one plot of that polygon.

Two exotic annuals species, sand spurry (*Spergalina rubra*) and lamb's quarters (*Chenopodium album*), were the dominant species colonizing the control polygon of MW1701 (Figure 7, Figure 9). Trace occurrences of meadow horsetail (*Equisetum pratense*) and bluejoint reedgrass (*Calamagrostis canadensis*) indicated some natural colonization of native perennial species in untreated control area. Horsetail was the only established perennial native species found in the control area. Kellogg's sedge planted in 2017 had established well in MW1701MP,

[3] The high covers in those two control plots stemmed from sand spurry and lambs quarters, two exotic annual species that are ubiquitous and predominant across the lower mud flat elevations.

MPT1912 and MPT1913. No Kellogg's sedge plants were observed in Control plots. MW1701MS had the highest density of sedges, followed by treatment polygons MW1701MPT1913 and MW1701MPT1912 (Figure 8). Seeded sedges MW1701MS were small caliper at base of plant, measuring on average 2cm diameter. Planted plants averaged 10-11 cm diameter in MW1701MPT1912 and MW1701MPT1913.

Figure 7. Left image; Polygon MW1701CON in 2020, Right; MW1701M and MP metre board in center of mounded and mounded planted polygons, Note the tufts of planted Kellogg's sedge plants to the right of meter board.

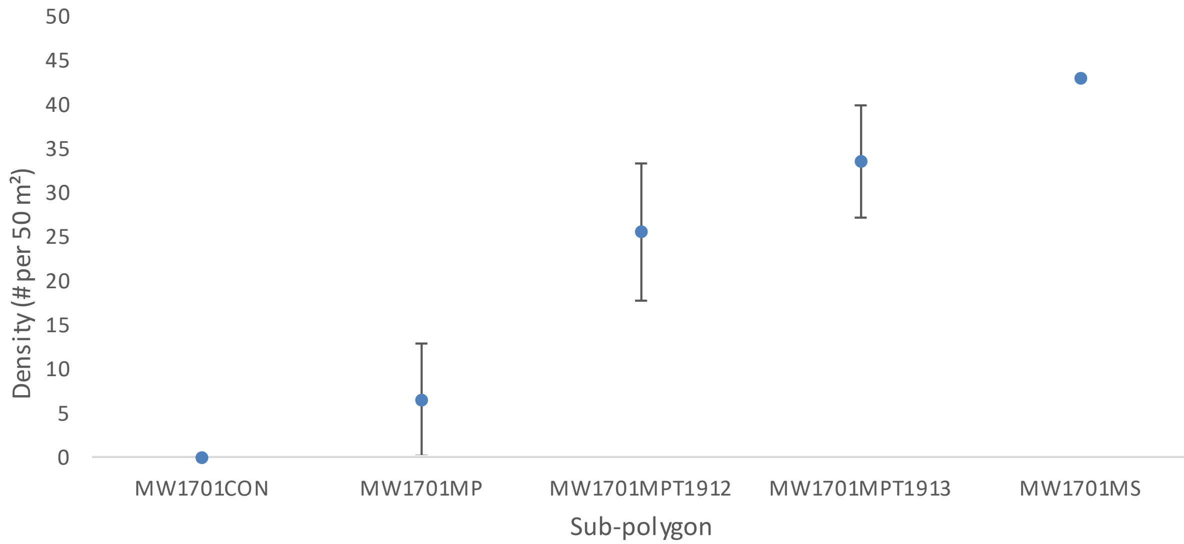


Figure 8. Average density of planted Kellogg's sedge growing in sub-polygons of MW1701 (error bars are standard deviation).

Figure 9. Example of dominant cover of exotic annual species (left; MW1701CON Plot 5); Right; Plot 1 (foreground) and plot 2 (background) of sub-polygon MW1701MPT1913, planted sedges very apparent (right, June 1, 2020).

Monitoring in MW1702

Five treated and one control sub-polygons were monitored in polygon MW1702, which was mounded in 2017 (Table 5).

Table 5. Treatments monitored in polygon MW1702 in 2020.

Polygon	Treatment	Year of treatment	Observations
MW1702CON	Designated control area, no treatment		Minimal vegetation
MW1702M	Mounded only	2017	Exotic annuals, one site has Kellogg's sedge recruitment
MW1702MS	Mounded and seeded with Kellogg's sedge	2017	Several Kellogg's sedge seedlings observed
MW1702MP	Mounded and planted with Kellogg's sedge	2017	Low cover, Kellogg's sedge established
MW1702MPT1910	Mounded, planted with Kellogg's sedge, re-planted (fill plant) with Kellogg's sedge	2017, 2019	Low cover, Kellogg's sedge established
MW1701MPT1911	Mounded, planted with sedges, over sown with meadow birds-foot trefoil (*L. denticulatus*)	2017, 2019	Higher cover exotics, Kellogg's sedge established, *L. denticulatus* with low cover

The total cover of vegetation in control sub-polygon MW1702Con was negligible, while mounded sub-polygons showed higher vegetation covers, though with mainly exotic annuals colonizing (Figure 10). On average, cover of native species was significantly lower than that of exotic species (Z=-8.7, p<2e-16) for the same type of sub-polygon and covers of vegetation in all treated sub-polygons were significantly higher than in controls (for constant origin of vegetation;

M: Z=3.5, p=0.0004; MP: Z=2.5, p=0.012; MPT1910: Z=3.1, p=0.002; MPT1911: Z= 5.8, p=5.47 e-9; MS: Z=4.5, p=7.5e-6)[4].

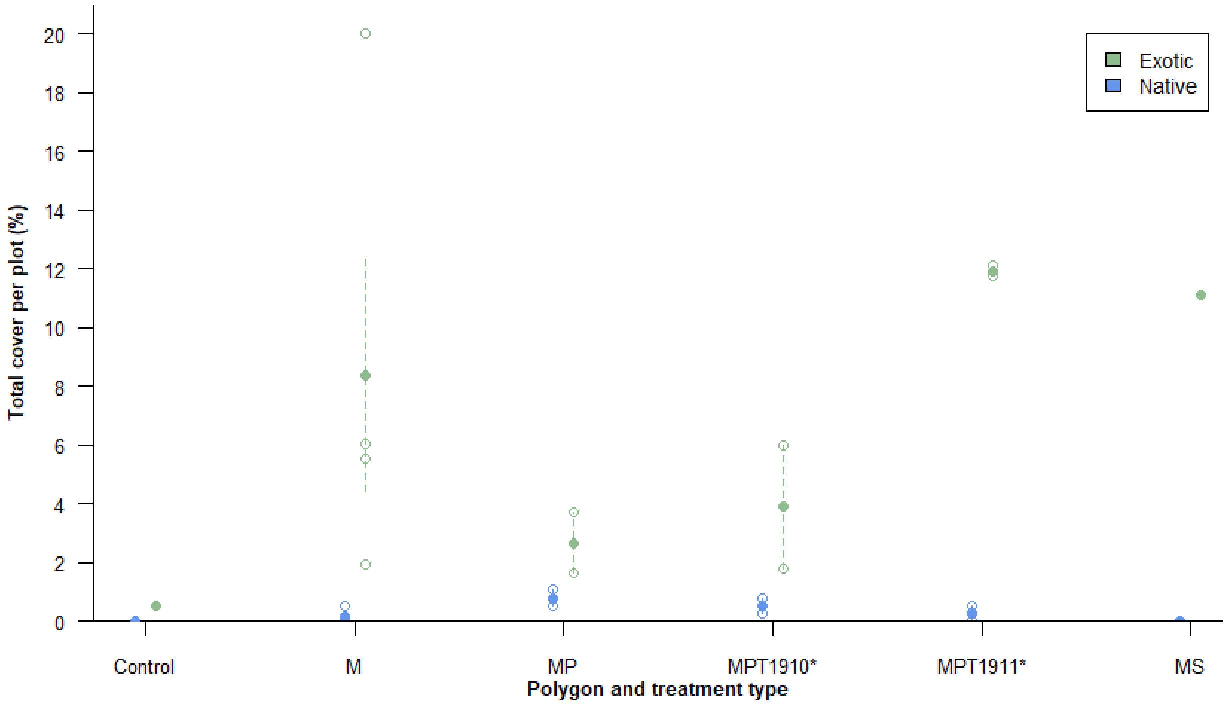


Figure 10. Total cover of native or exotic vegetation per plot (per cent) in the herb layer of each type of polygon of MW1702. Filled dots and error bars show average cover and standard error per polygon, while open dots are cover for each plot. * indicates that a very low cover of native vegetation at the low shrub layer was seen in one plot of that polygon.

Lady's thumb (*Persicaria maculosa*), lamb's quarters (*Chenopodium album*), and common knotweed (*Polygonum aviculare*) were dominant in mounded treatments of MW1702. Planted Kellogg's sedge also established in sub-polygons where it was planted (Figure 11). No sedges were observed in the control sub-polygon, and one naturally occurring sedge seedling was observed sub-polygon where mounding alone was the treatment. The high density of sedges recorded in MW1702MP were the result of seedlings germinating from seed produced by mature sedges planted in 2017 (Figure 12). Often dense patches of native perennial grass, foxtail barley (*Hordeum jubatum*), were observed colonizing within mounded polygons. One occurrence of a choke cherry (*Prunus virginiana*) seedling was observed in one plot in MW1702MPT1910, likely the result of zoochory. A small patch of meadow horsetail was recorded in MW1702MPT1911, and meadow bird's-foot trefoil was observed in both sampling plots in MW1702MPT1911.

[4] Relatively high cover in one MW1702M plot stemmed from the presence of lamb's quarters, lady's thumb and common knotweed, three exotic annual species commonly occurring across the LMF.

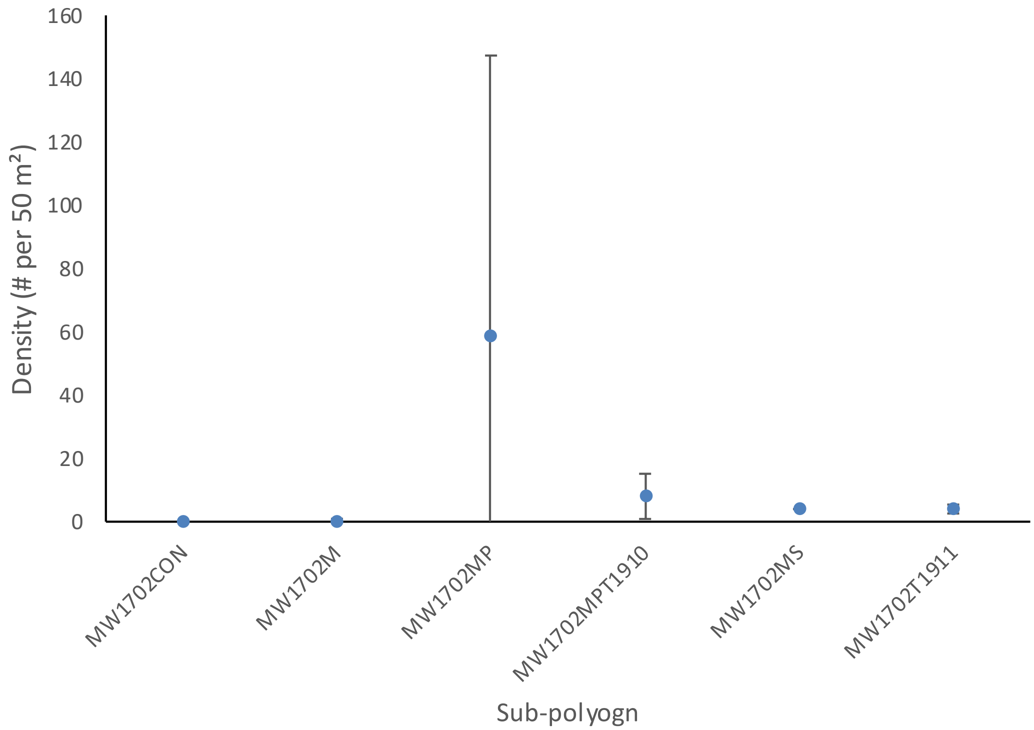


Figure 11. Average density of planted Kellogg's sedge growing in sub-polygons of MW1702 (error bars are standard deviation).

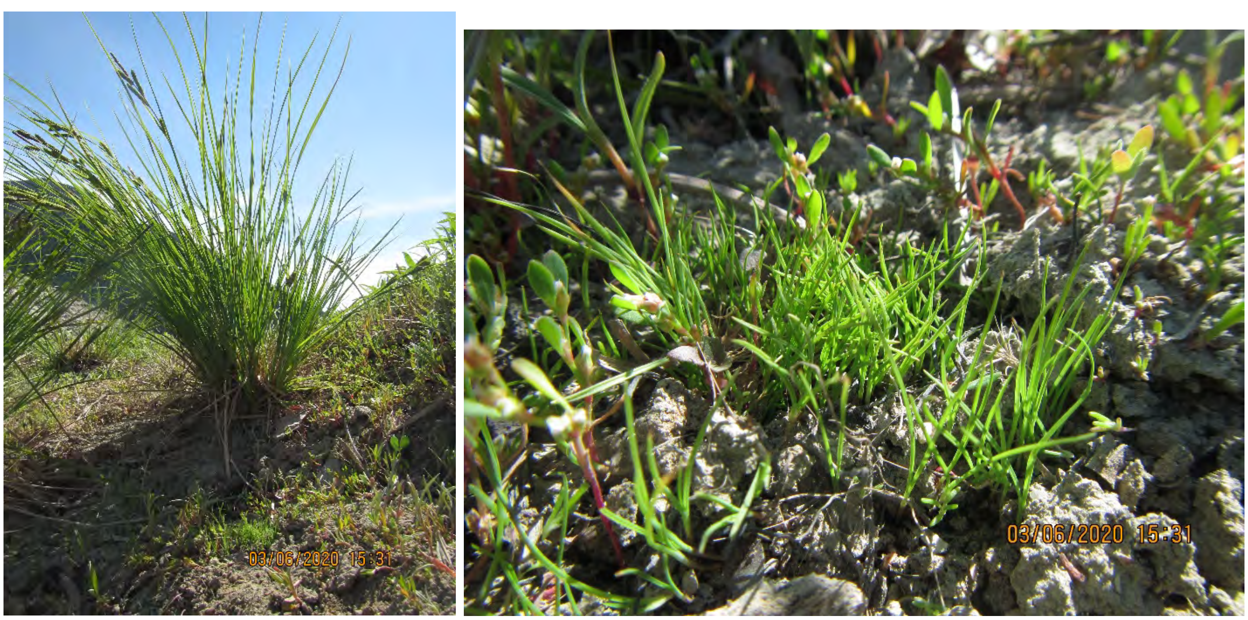


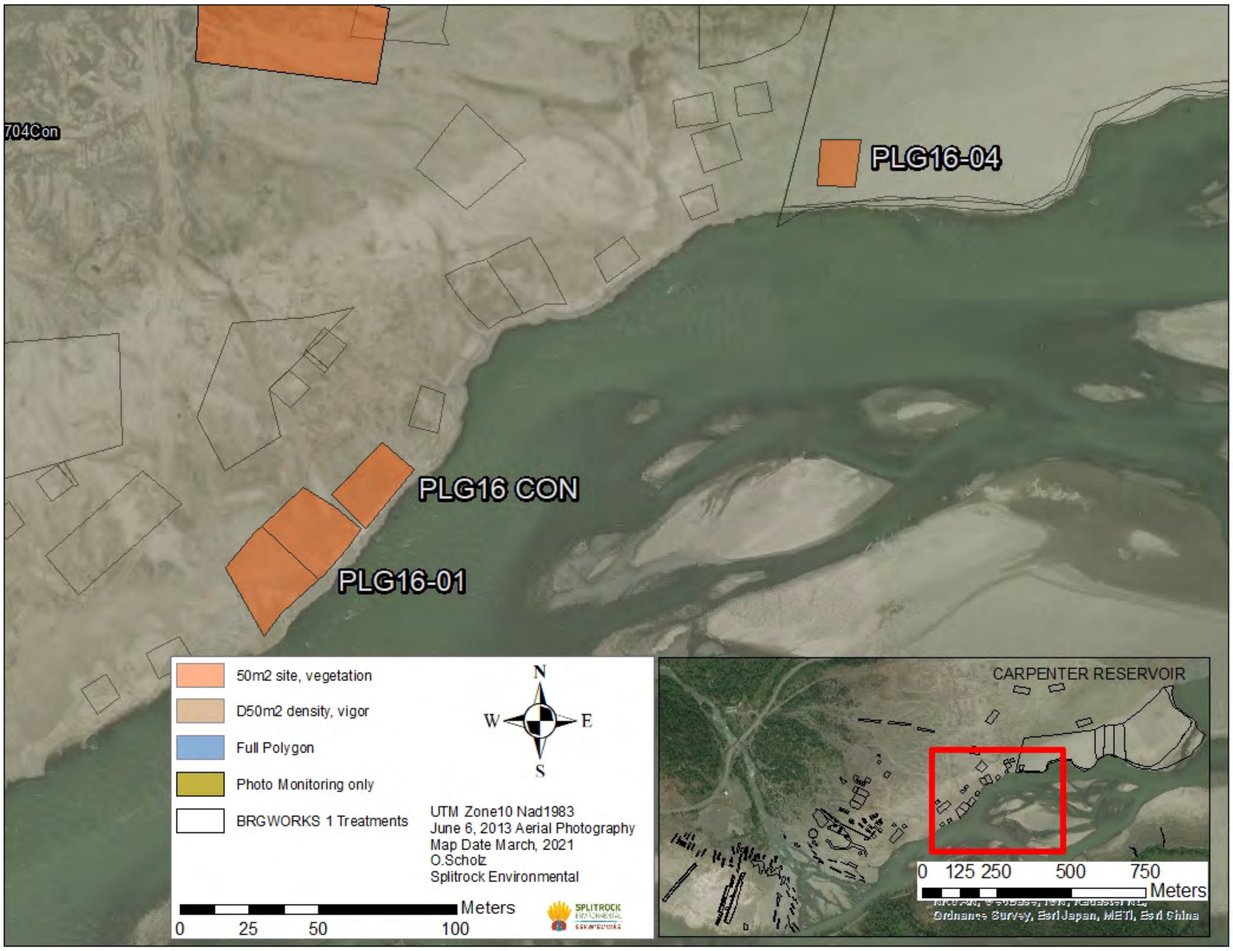
Figure 12. Mature Kellogg's sedge fruiting, planted in 2017 (left); dense patch of sedge seedlings sprouting near base of planted sedge (right).

Monitoring in PLG 16-01

Sub-polygons of PLG 16 were treated by planting dense patches of sedges in 2016, without prior mounding (Table 6, Map 8). Sub-polygon PLG1604 was also seeded with fall rye (*Cereale secale*) prior to being planted with Kellogg's sedge plugs.

Table 6. Treatments monitored in polygon PLG16 in 2020.

Polygon	Treatment	Year of treatments	Observations
PLG16-CON	Designated control area, no treatment		High cover in exotic species (sand spurry), one Kellogg's sedge seedling
PLG1601	Planted with Kellogg's sedge plugs	2016	Kellogg's sedge established and dominant, evident recruitment of second-generation seedlings growing.
PLG1604	Seeded with fall rye, planted with Kellogg's sedge plugs, sown with *L.denticulatus*	2016 2019	Kellogg's sedge established. *L. denticulatus* growing.



Map 8. Sub-polygons of PLG 16 planted with sedges in 2016 and monitored in 2020.

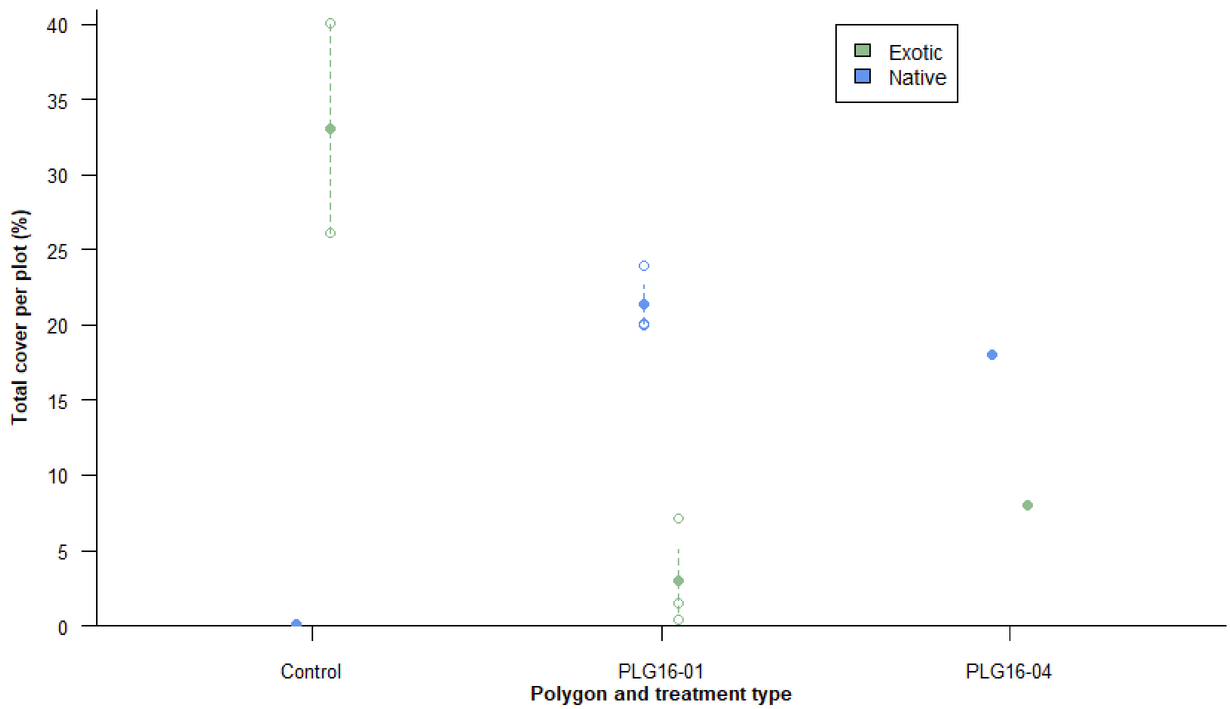


Figure 13. Total cover of native or exotic vegetation per plot (per cent) in the herb layer of each type of polygon of PLG. Filled dots and error bars show average cover and standard error per polygon, while open dots are cover for each plot.

Planted sedges were established well and providing upwards of 20% cover (Figure 13). Polygon PLG1601 was observed to have seedlings growing in all 50m² plots in 2020, and seedlings were also observed in the 2018 and 2019 surveys (Scholz and Gibeau, 2019, Scholz and Gibeau, 2020). Density of planted sedges was high in planted plot and included mature planted plants, seedlings and juvenile recruits (Figure 14). Colonizing seedlings and recruits were generated from prolific seed produced by mature planted plants (Figure 15). Meadow birds foot trefoil was observed growing in PLG16-04 where seed of the species was sown in 2019. Relatively high cover in control area is attributable to dense Sand spurry cover (exotic annual). Two exotic perennial species, quack grass (*Elytrigia repens*) and Canada bluegrass (*Poa compressa*), were establishing in treatment sub-polygon PLG1601 and control sub-polygon PLG16CON. A native grass, foxtail barley, was the other perennial species naturally recruited and found in high densities in all three sub-polygons.

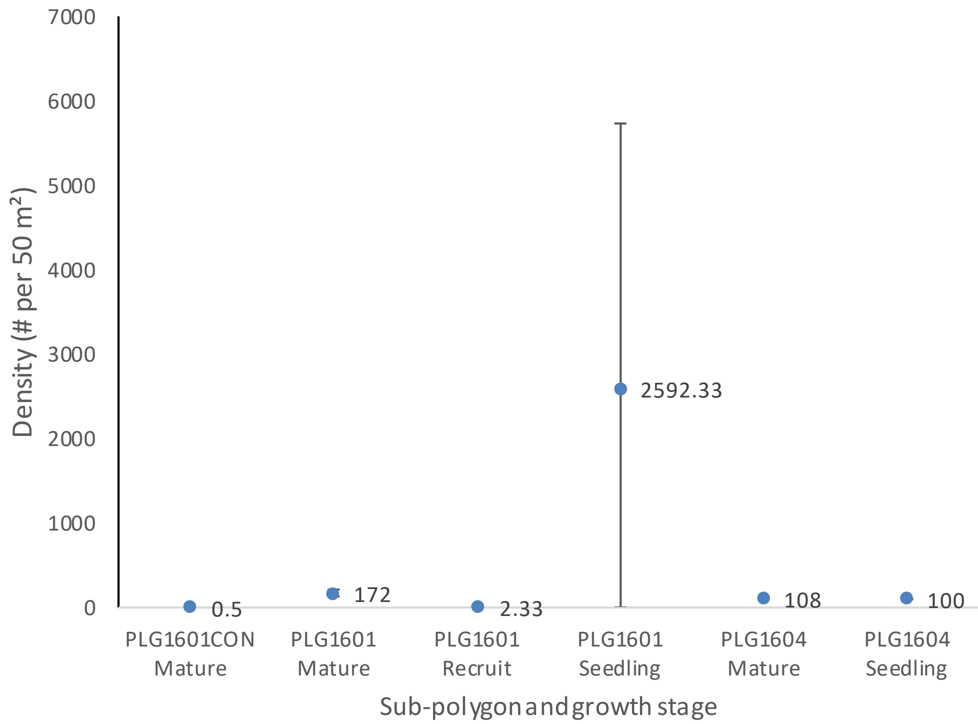


Figure 14. Average density of planted Kellogg's sedge growing in sub-polygons of PLG16, classified by Mature (planted plug), Recruit (established from seed), and seedling (colonized from seed) (error bars are standard deviation).

Figure 15. Examples of recruitment of Kellogg's sedge : established juvenile plants 2-3 years old from seed produced by mature plants planted in 2016 (PLG16-01).

Monitoring of planting and seeding

Patches of Kellogg's sedge were planted on the low mud flat in 2019, into polygons T1905 and T1914 that were seeded with fall rye prior to planting and areas where there was no other prior treatment (T1906)Figure 16). A low density of horsetail (*Equisetum arvense*) had been planted in 2019, into some of the patches of sedges in polygon T1906. Monitoring found initial survival of sedges between 6700 and 8000 stems per hectare (Figure 16). Several planted horsetails were observed surviving and in good vigor (Figure 17). Both sedges and horsetail plants were small and in fair to good vigor.

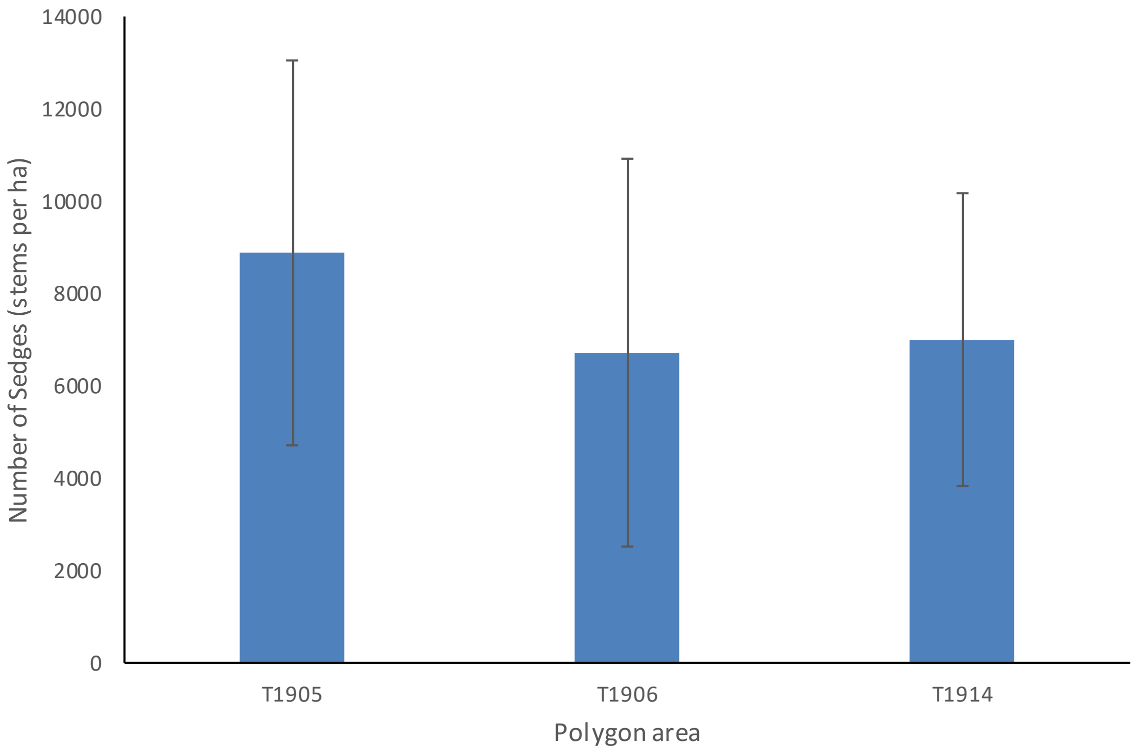
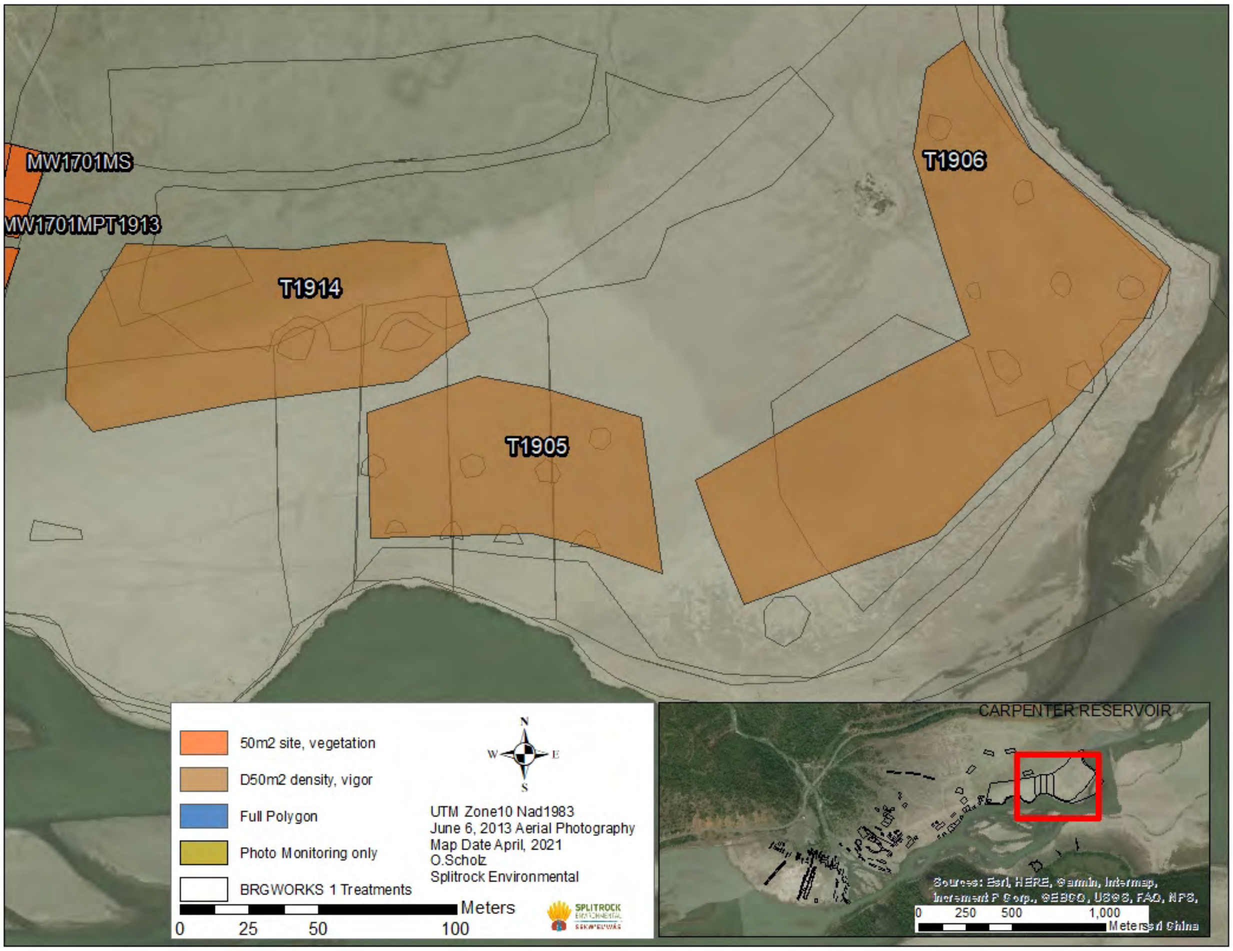


Figure 16. Density of surviving Kellogg's sedge plants one year after planting in Low mud Flat area polygons. T1905 and T1914 were seeded with fall rye before planting, while only planting was conducted in T1906. (n=5 for each polygon, error bars are standard deviation).



Map 9. Polygons seeded and planted with patches of sedges in 2019 in the Low Mud Flat. Sedge patches were targeted for monitoring focussing on survival and vigor of planted plants.

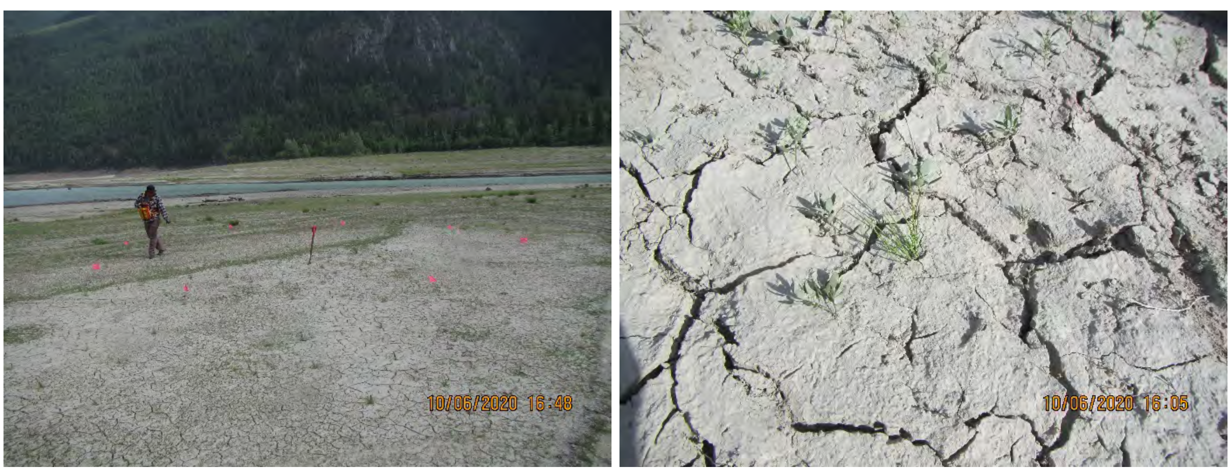


Figure 17. 2020 sampling of a patch of Kellogg's sedge planted in 2019 in polygon T1905 (left); horsetail planted in 2019 and resprouting in 2020 (polygon T1906, right).

Biomass sampling

The fall rye (*Cereale secale*) mechanically sown across the LMF between April 27th and May 6th 2020 under the BRGWORKS-1 program (Scholz, 2021) had at minimum 73 days of growth prior to inundation (i.e.1054.4 AGDD). We estimated that roughly 1-5% of sprouted fall rye plants were in the reproductive or 'heading' stage of growth (Zadoks et al, 1974) by mid July 2020, meaning that most plants were still in the vegetative or 'tillering' stage by the time of inundation. Sampling of standing crop was conducted on July 10th 2020, which was eight days prior to inundation (Figure 19). Average weights of above-ground biomass was 1276 kg/ha in control plots and 1111 kg/ha in fall rye treatments (Figure 18). No significant differences in average above-ground or excavated biomass were detected using student t-tests ($p>0.05$). We observed that fall rye had slightly less shoot biomass than control plots, and that excavated fall rye samples had slightly more root and shoot mass than in controls plots. Fall rye tended to have a higher production of root mass vs top growth (32% of biomass average in shoot growth) when compared with vegetation growing in control plots (43% biomass in shoot growth). Sand spurry was the dominant species sampled in the control area plots with lamb's quarters, another exotic annual species (Figure 20). Biomass sampling of above-ground vegetation in 2019, at a mid mud flat reference site, averaged standing crop biomass over 1700kg/ha. Similar weights were observed in Kellogg's sedge planted in 2015 in Polygon PLG1601 (Scholz and Gibeau, 2020).

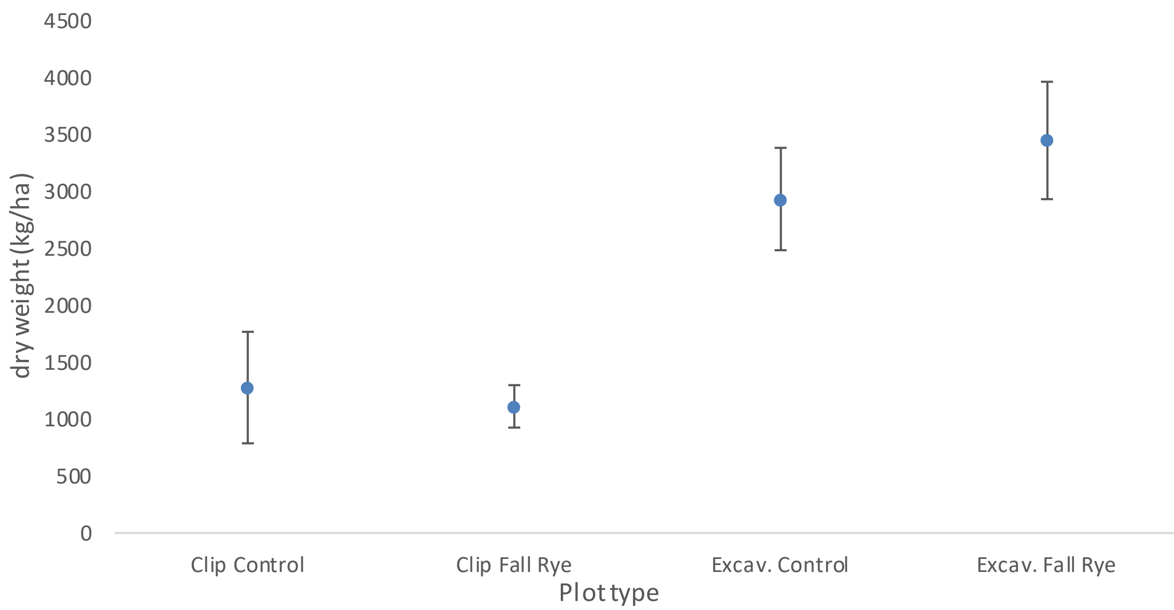


Figure 18. Biomass sampled in above-ground and excavated samples in control plots and plots seeded with fall rye (n=3, kg/ha) (error bars represent standard deviation).

Figure 19. Example of fall rye growth by July 1 2020 (left) and on date of biomass sampling (9 July 10th 2020, right).

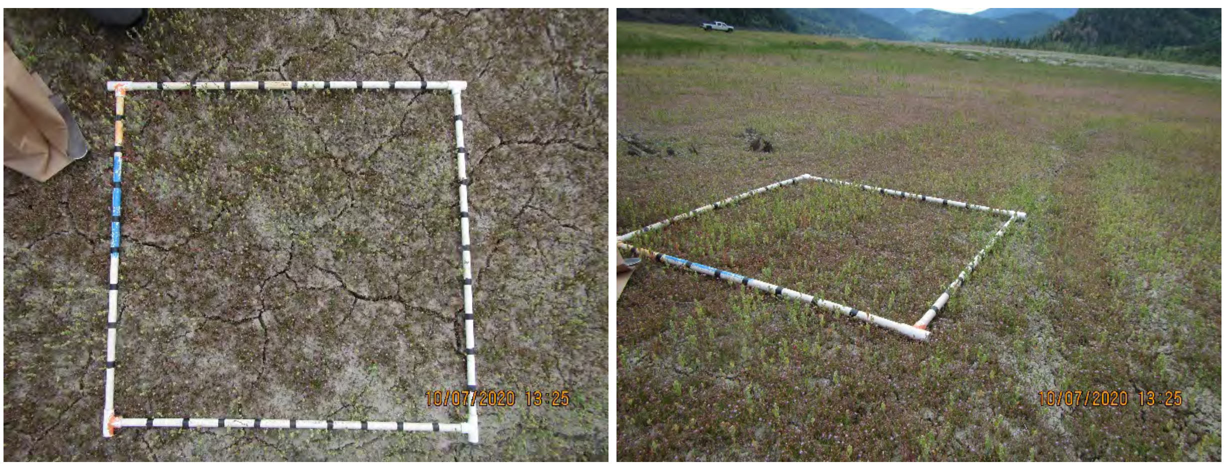


Figure 20. Above-ground vegetation sampled for biomass in control plots with sand spurry and lamb's quarters.

4.3 Monitoring of treatments in Gun Creek Alluvial Fan

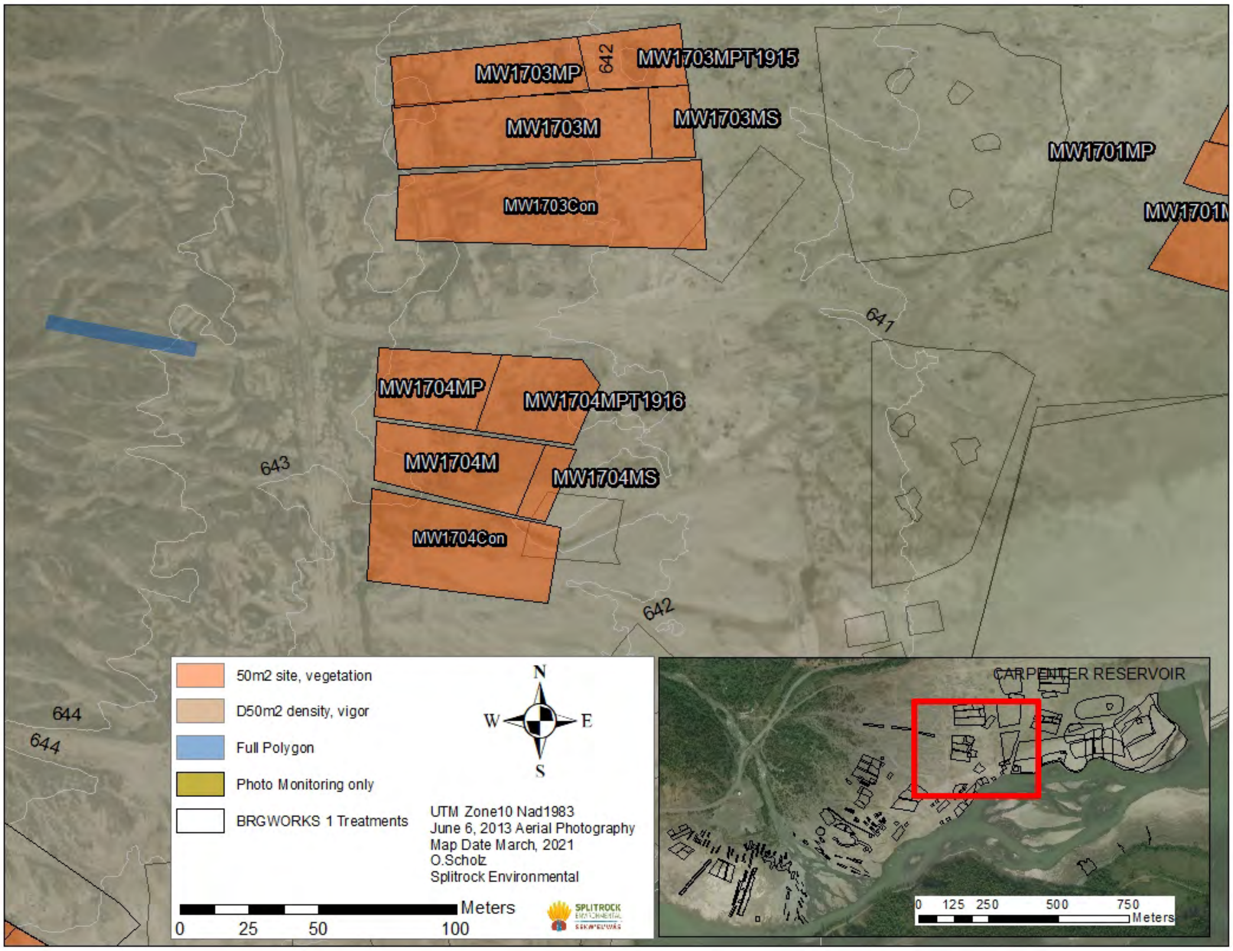
Between the elevations of 642 mASL and 644 mASL, the terrain shifts from the fine textured, lacustrine deposits of the Low Mud Flat terrain to the coarse, rocky sands of the Gun Creek alluvial fan. Polygons MW1703 and MW1704 are located at the transition from the silty mud flats to the rocky fan, and therefore have mixed substrate and soil elements. Both sub-polygons that were treated with mounding in 2017 were within the historic town site of Minto, as evidenced by old broken glass, metal, and concrete.

Monitoring in MW1703

Four treated and one control sub-polygons composed polygon MW1703, straddling the transition between the Gun Creek alluvial fan and the Low Mud Flat (Table 7, Map 10). All sampled plots had very low to negligible vegetation cover, with e.g. less than 1 per cent total cover of vegetation in the control sub-polygon (Figure 21). Soils were moderately coarse with rounded rock making up 40 % of substrate cover. Mounded substrates were typically coarse and loose and the pits more compact fines, the combined disturbances of mounding followed by repeated inundation has washed and sorted the fines into the pits (Figure 22). Cover of native species was barely significantly lower than that of exotic species ($Z=-1.9$, $p=0.054$) and covers of vegetation in all treated polygons were significantly higher than in controls (for constant origin of vegetation; M: $Z=3.1$, $p=0.002$; MP: $Z=2.7$, $p=0.007$; MPT1915: $Z=2.7$, $p=0.007$; MS: $Z=3.4$, $p=0.054$).

Table 7. Treatments monitored in polygon MW1703 in 2020.

Polygon	Treatment	Year of treatment	Observations
MW1703CON	None		Negligible vegetation cover
MW1703M	Machine mounded	2017	Very low vegetation cover
MW1703MP	Machine mounded and planted	2017	Planted Kellogg's sedge established, low density and cover.
MW1703MPT1915	Mounded, planted with Kellogg's sedge and native grasses, replanted with Kellogg's sedge	2017 2019	Low cover of mature Kellogg's sedge and seedlings associated with planted sedges. Sedges very sparse
MW1703MS	Machine mounded and seeded with Kellogg's sedge	2017	Low cover and density of established Kellogg's sedge



Map 10. Treatment and control sub-polygons of MW1703 and MW1704 at the transition zone between the Gun Creek alluvial fan and the Low Mud Flat terrain.

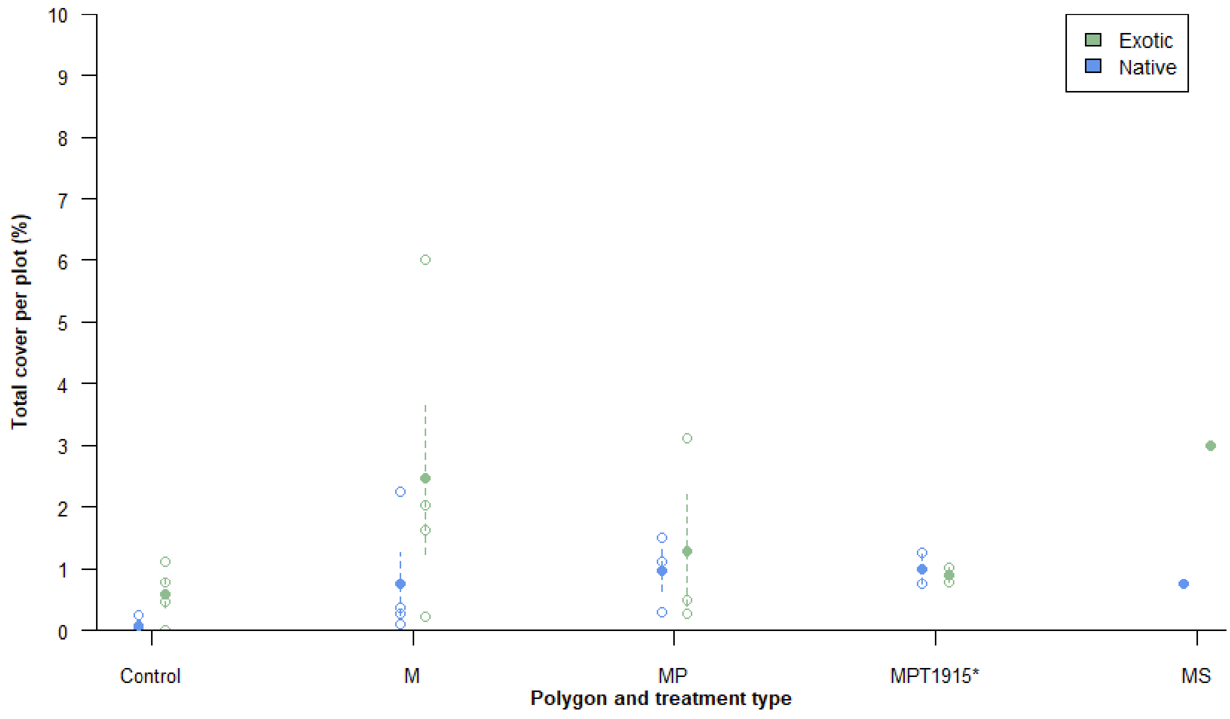


Figure 21. Total cover of native or exotic vegetation per plot (per cent) in the herb layer of each type of polygon of MW1703. Filled dots and error bars show average cover and standard error per polygon, while open dots are cover for each plot. * indicates that a very low cover of native vegetation at the low shrub layer was seen in one plot of that polygon.

Figure 22. Example of photo monitoring: MW1703Con on left, MW1703M and MW1703MP on right, with evident coarse rocky substrate.

Planted Kellogg's sedges have established in low densities within planted sub-polygons MW1703MP and MW1703MPT1915 (Figure 23). A low recruitment of sedge plants was also observed in MW1703MS (also seeded with sedge in 2017). Seedlings were observed in MP and MPT sub-polygons, likely colonizing from mature planted plants as was observed in PLG polygons. Seedlings of foxtail barley were observed colonizing in high densities in all treatment polygons, while only low densities of foxtail barley were observed in the control sub-polygon. Quack grass was observed in low density in MW1703M. An individual occurrence of native perennial grass spangle top (*Scholochola festucacea*) was recorded in MW1703M as was a seedling of red-osier dogwood (*Cornus stolonifera*). There was also a rare occurrence of fall rye (*Cereale secale*) whose seed was likely cached by birds.

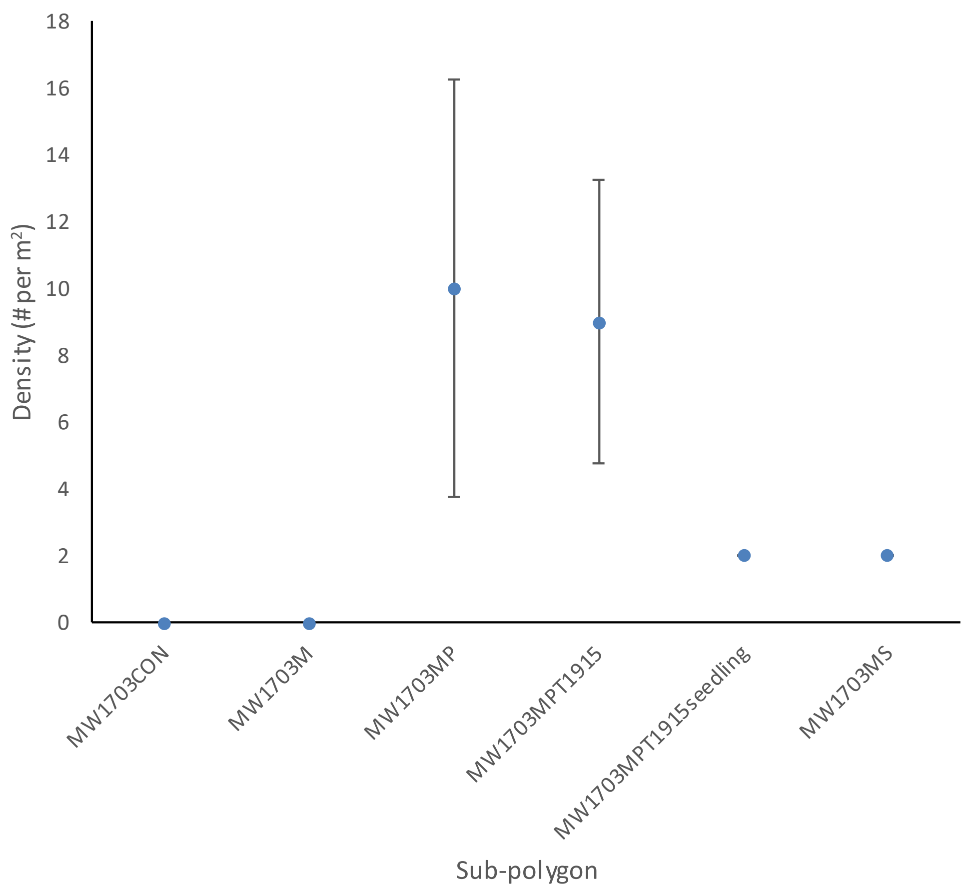


Figure 23. Average density of planted Kellogg's sedge growing in sub-polygons of MW1703 (all plants are mature except for MW1703MPT1915seedlings) (error bars are standard deviation).

Monitoring in MW1704

The treated polygon MW1704 was comparable to MW1703, as it had similar treatments from 2017 (Table 8) and similar site conditions, including coarse substrate texture, elevation and polygon location (Map 10). Kellogg's sedge was the main species planted, along with some native grass species, including bluejoint reedgrass. Native vegetation cover in the control sub-polygon (MW1704CON) was higher than in any treated sub-polygon (Figure 24), and dominated by a large patch of meadow horsetail (*Equisetum pratense*).

Table 8. Treatments monitored in polygon MW1704 in 2020.

Polygon	Treatment	Year of treatments	Observations
MW1704CON	None		Negligible vegetation cover
MW1704M	Machine mounded	2017	Very low vegetation cover
MW1704MP	Machine mounded and planted	2017	Established planted Kellogg's sedge, low density and cover.
MW1704MPT1916	Machine mounded, planted with Kellogg's sedge and native grasses, replanted with bluejoint reedgrass	2017 2019	Low cover of mature Kellogg's sedge and seedlings associated with planted sedges. Sedge plants sparse
MW1704MS	Machine mounded and seeded with Kellogg's sedge	2017	Low cover and low density of established Kellogg's sedge

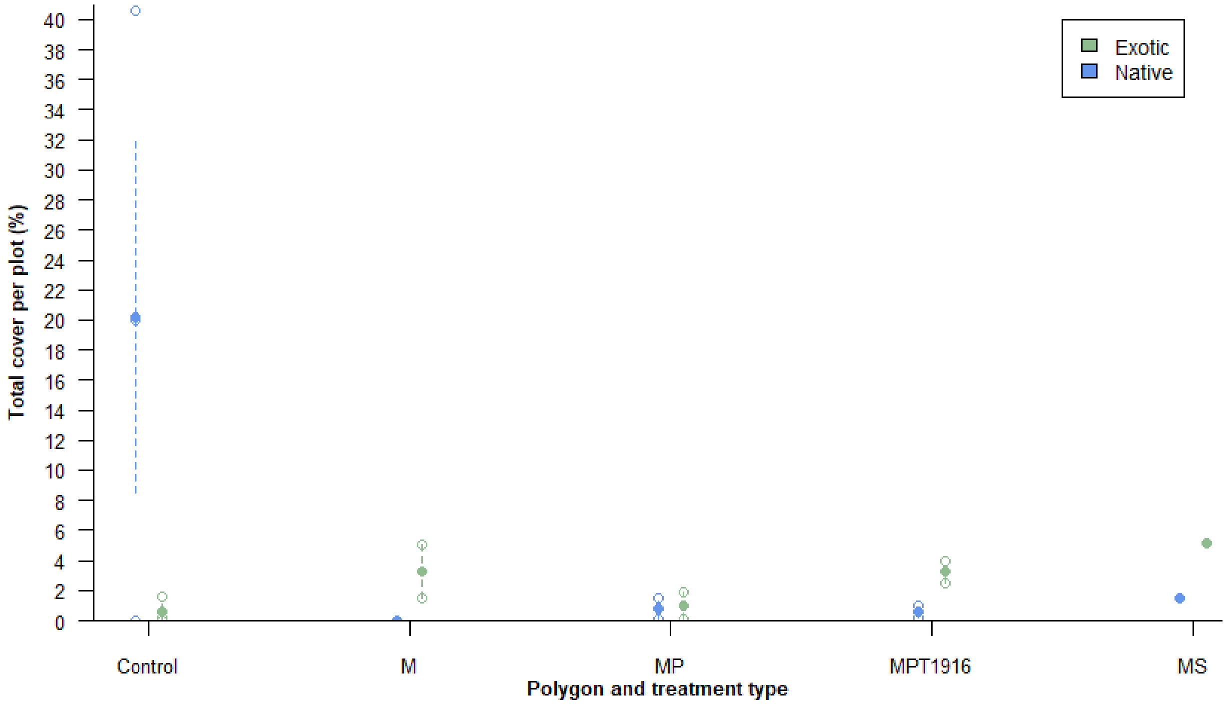


Figure 24. Total cover of native or exotic vegetation per plot (per cent) in the herb layer of each type of polygon of MW1704. Filled dots and error bars show average cover and standard error per polygon, while open dots are cover for each plot.

On average, cover of native species was significantly lower than exotics (Z=-3.9, p=0.00011; once the two outliers with high cover of native species were removed to improve fit) and covers of vegetation in all treated polygons were significantly higher than in controls (for constant origin of vegetation; M: Z=2.2, p=0.025; MPT1916: Z=3.5, p=0.0005; MS: Z=4.1, p=0.000039), except for MP (p >0.05).

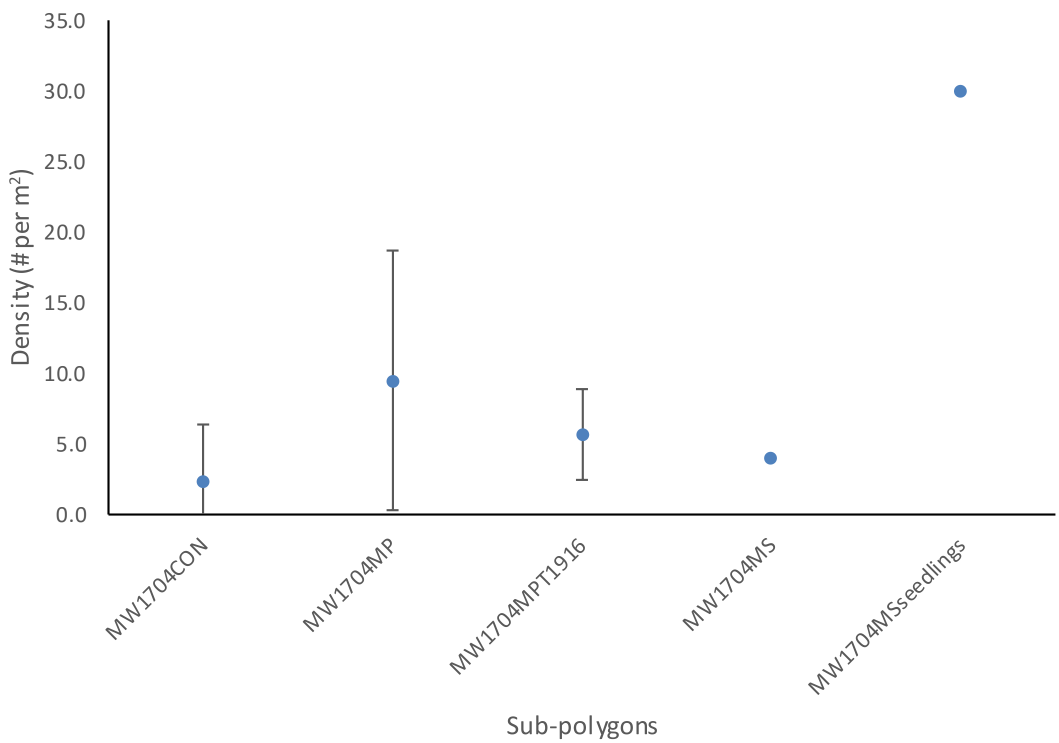
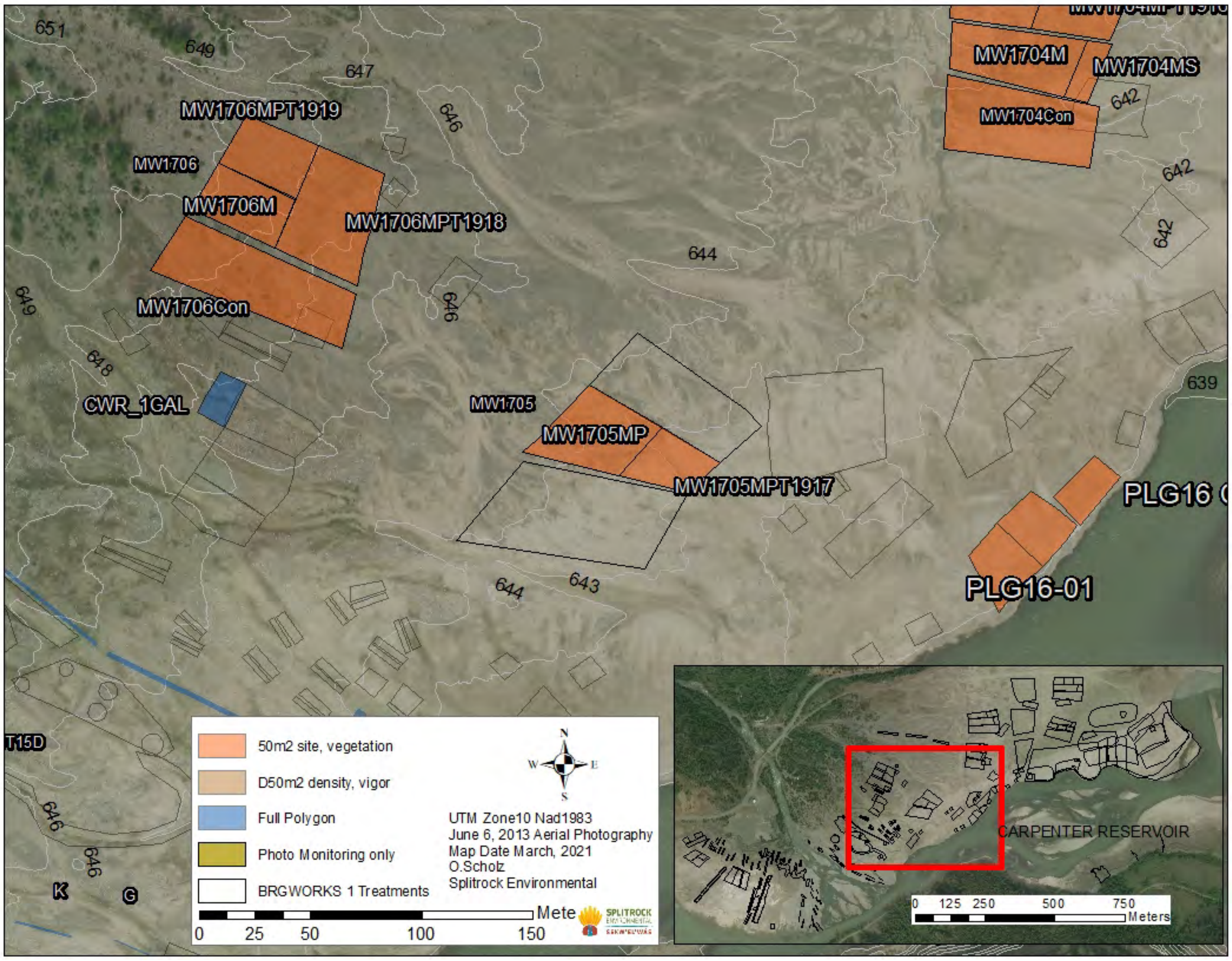


Figure 25. Average density of planted Kellogg's sedge growing in sub-polygons of MW1704 (all plants are mature except for MW1704MSseedlings) (error bars are standard deviation).

Planted Kellogg's sedge were recorded in all polygons with densities below 20 individuals per m^2 (Figure 25). Sedge seedlings established from seeds were also observed in polygon MW1704MS. One natural Kellogg's sedge plant was observed in the control sub-polygon MW1704CON.

Monitoring in MW1705

Polygon MW1705 covers part of the lower elevation of the Gun Creek Alluvial fan between 643 and 644m ASL (Map 11), slightly higher than MW1703 and MW1704. Substrate cover is predominantly coarse with cobbles and boulders that were brought to the surface through machine mounding (Figure 27). These coarse textures reduce the productive and growing capacities of the area. The polygon was planted with Kellogg's sedge as well as a mix of native grasses (Table 9).Only two plots were sampled in MW1705: one in MP (about 1% of cover of exotic and native species, 1 planted Kellogg's sedge per m^2) and one in MPT1917 (3.35% cover of exotic species, 0.35% cover of native species, 4 plants per m^2 (Figure 26).



Map 11. Location of two polygons treated for riparian enhancement sampled on the Gun Creek Fan East at lower (MW1705) and upper (MW1706) elevations.

Table 9. Treatments monitored in polygon MW1705 in 2020.

Polygon	Treatment	Year of treatments	Observations
MW1705MP	Mounded and planted primarily with Kellogg's sedge, and bluejoint reedgrass, fowl bluegrass, Canada wildrye, foxtail barley. Site watered 2017.	2017	Planted Kellogg's sedge established, though sparse and low density and cover.
MW1705MPT1917	Mounded, planted primarily with Kellogg's sedge, and bluejoint, fowl bluegrass, Canada wildrye, foxtail barley; replanted with bluejoint reedgrass. Site watered 2017 and 2019	2017 2019	Low cover of mature Kellogg's sedge and seedlings associated with planted sedges. Low bluejoint establishment.

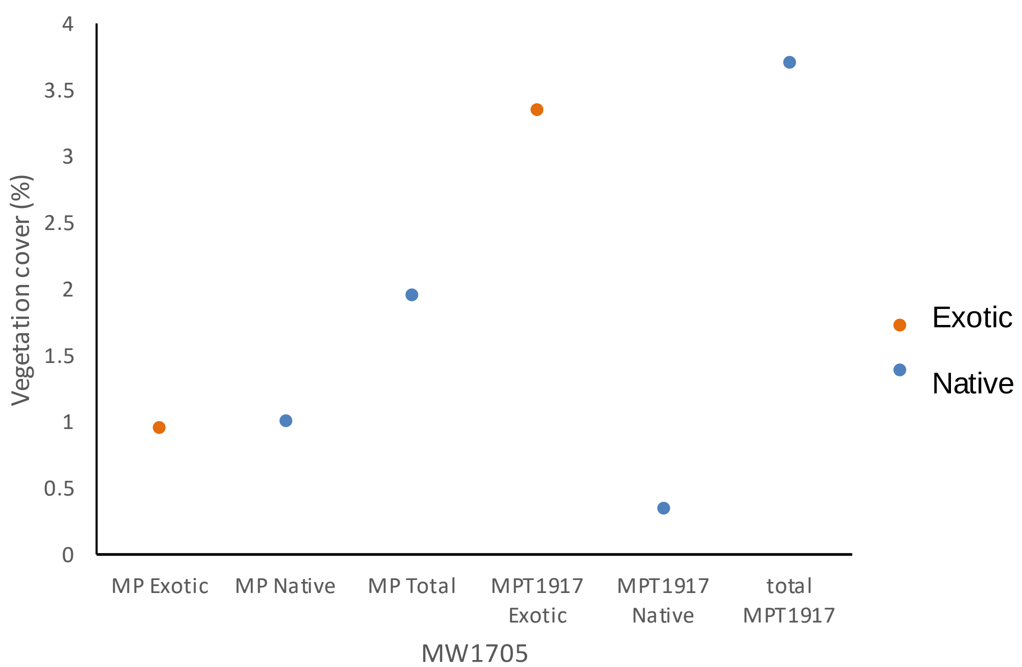


Figure 26. Vegetation cover of native and exotic species sampled in polygon MW1705.

Figure 27. Example of coarse substrate and boulders in polygon MW1705; MW1705 M and MP (left), MW1705CON (right).

Monitoring in MW1706

Polygon MW1706 is in the Upper Drawdown on the Gun Creek Fan East (Map 11). This mounded polygon also has very coarse substrate (35% to 90%), predominantly consisting of alluvial cobble and boulders, with coarse sands and limited fines, which limited plant establishment. Sampling in 2020 indicates good establishment of planted trees, shrubs, and some grasses (Table 10). Many trees and shrubs were observed in good to excellent vigor (Figure 28), although there was sparse and low distribution and cover of natural and planted plants (Figure 29). As expected, there was more frequent occurrence of upland species than at other polygons, including exotic species like mullein (*Verbascum thapsus*), spotted knapweed (*Centaurea stoebe*), and silvery cinquefoil (*Potentilla argentea*), and native species like yarrow (*Achillea millefolium*). Canada bluegrass was observed more frequently and in higher densities in the upper drawdown. Moss was the only native species observed in the control and did not occur in mounded sub-polygons (see tables in Appendix). Quack grass was the only exotic species observed in control sub-polygon. Interestingly, Canada wildrye was recorded establishing in the control sub-polygon, as it is only been recorded on the alluvial fan from plantings. It is likely that it colonized from a seed source in the dense patch of Canada wildrye planted in polygon CWR-1gal, located to the south of the MW1706CON (Map 11).

Table 10. Treatments monitored in polygon MW1706 in 2020..

Polygon	Treatment	Year of treatments	Observations
MW1706CON	No treatment		Patch of Canada wildrye naturally established from seed source in neighboring planted treatments
MW1706M	Mounded	2017	Very low and sparse cover, rare meadow lotus plant seeded.
MW1706MPT1918	Mounded, planted with mix bluejoint reedgrass, fowl bluegrass, Canada wildrye, foxtail barley; black cottonwood, overseeded with meadow bird's foot trefoil. Mulched, watered 2017 and 2019	2017 2019	Planted plants establishing well; some excellent growth; Canada wildrye reproducing via self-seeding.
MW1706MPT1919	Mounded, planted with mix bluejoint reedgrass, fowl bluegrass, Canada wildrye, foxtail barley; black cottonwood, fill planted with Cottonwood, Ponderosa pine, willow, mountain and green alder. Mulched, watered 2017 and 2019	2017, 2019	Low cover but planted plants establishing well, sparsely occurring meadow lotus, upland exotics mullein and one knapweed present.

Figure 28. Example of planted tree, shrub and herb establishment in MW1706MPT (left); black cottonwood, mountain alder, Canada wildrye and foxtail barley exhibiting good to excellent vigor. Planted Canada wildrye established and thriving with straw-coloured stems and all previous years' stems (right; Polygon CWR-1gal).

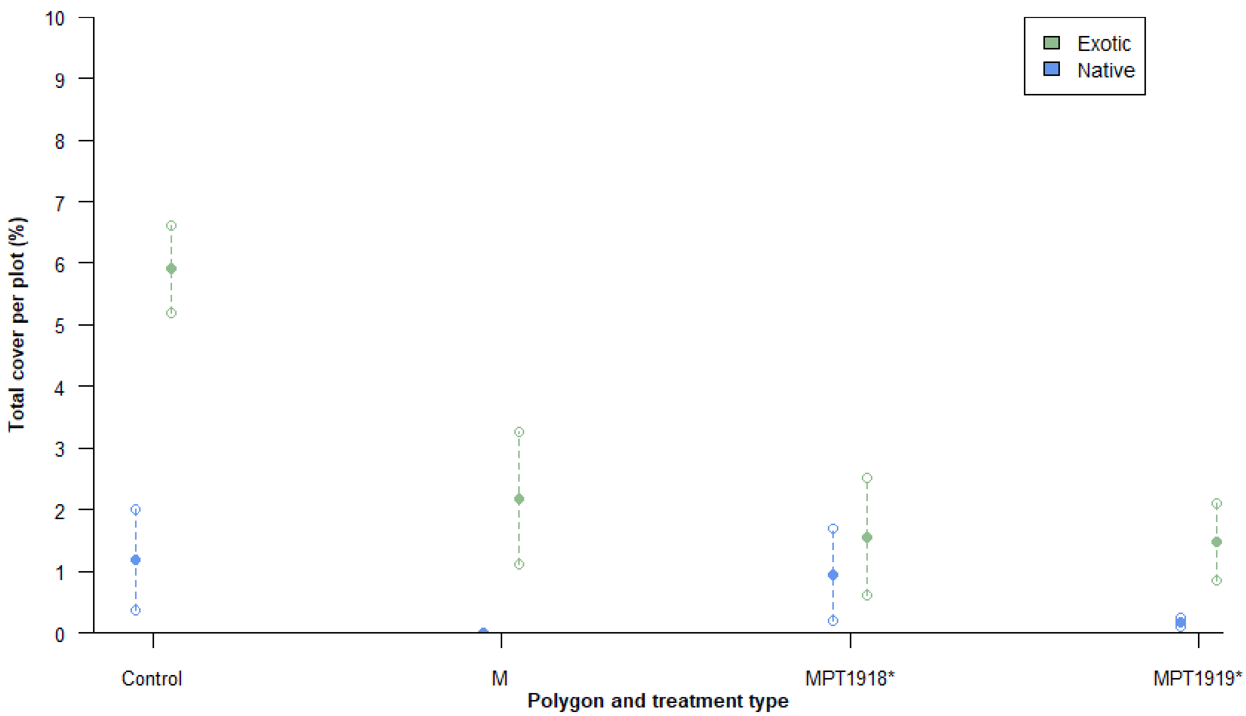


Figure 29. Total cover of native or exotic vegetation per plot (per cent) in the herb layer of each type of polygon of MW1706. Filled dots and error bars show average cover and standard error per polygon, while open dots are cover for each plot. * indicates that a very low cover of native vegetation at the low shrub layer was seen in one plot of that polygon.

Cover of vegetation was generally very low, with all total vegetation covers but one below 3% (Figure 29). On average, cover of native species was significantly lower than exotic (Z=-4.8, p=0.0000018) and covers of vegetation in all treated polygons were significantly lower than in controls (for constant origin of vegetation; M: Z=-3.6, p=0.0003; MPT1918: Z=-3.0, p=0.00275; MPT1919: Z=-3.2, p=0.0016).

4.4 Physical site conditions

The type and average cover of substrate changed with location and elevation (Figure 30). The LMF terrain was dominated by lacustrine deposited fine sand and silt loam deposits. The only deviation from that dominant mineral soil was found in the PLG16 polygons, where planted Kellogg's sedge have created a buildup of organic material (Figure 15, Figure 31). At the Alluvial Fan/Low Mud Flat transition, there was an increase in rock cover, particular after mounding treatment (Figure 32). Rock and mineral soil cover were observed equally throughout the study area, but on the alluvial fan, rock (rounded alluvial cobbles, boulders, gravels) was the predominant substrate cover.

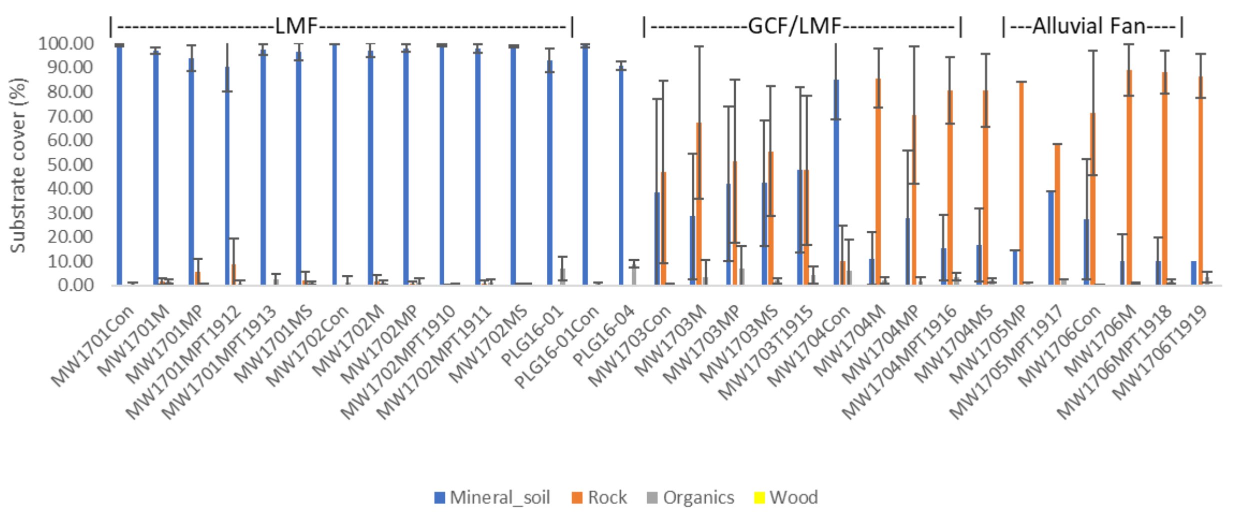


Figure 30. Average cover per category of substrate for each sampled polygon (error bars are standard deviation).

Figure 31. Varying examples of substrate in treated sub-polygons: layer with high organic litter developing under mature Kellogg's sedge plants in PLG16-01 (LMF; top left); high rock cover in MW1706M (GCFE; top right); cover of silt loam in mineral soil, with low organics (LMF; bottom right); mineral soil with 60%rock and 40% gravel/sands (MW1704MP, bottom right).

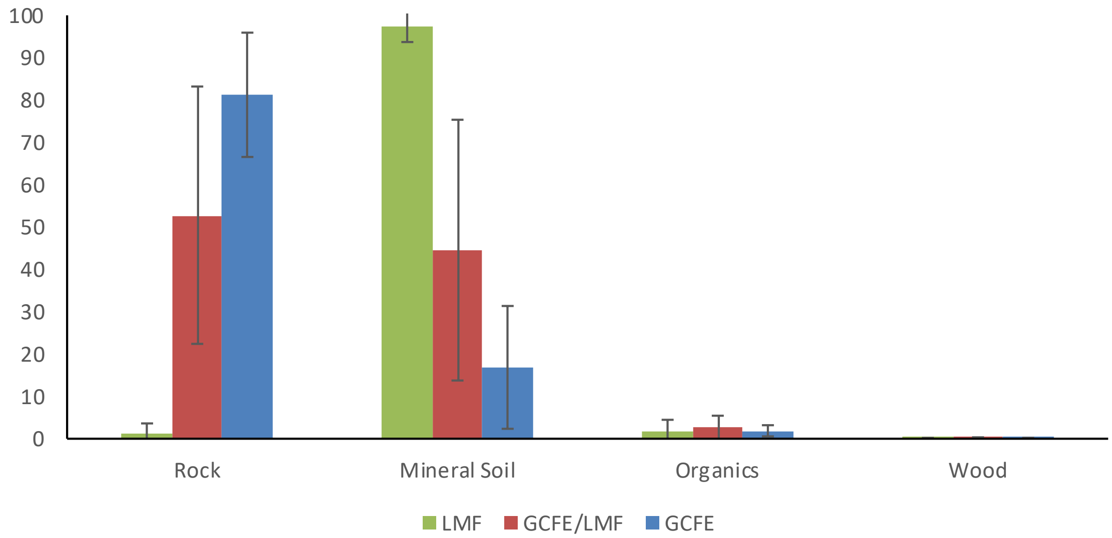


Figure 32. Overall average cover (per cent) for each type of substrate at each terrain class. Low Mud Flat=LMF, Alluvial fan-mud flat transition= GCFE/LMF, and Alluvial fan=GCFE (error bars are standard deviation).

4.5 Changes in species composition

Except for sub-polygons PLG1601 and PLG1604, vegetation covers of native species were very low throughout all treatment and control sub-polygons surveyed in 2020. Overall, species diversity was slightly higher in the herb and low shrub layers in treatment than in control sub-polygons.

On average, there was a higher number of exotic species than native species in both control and treated plots (Figure 33; generally, 1-5 native species for 3-6 exotic species). The diversity of exotic species was also higher than that of native species in both control and treated plots (Figure 34).

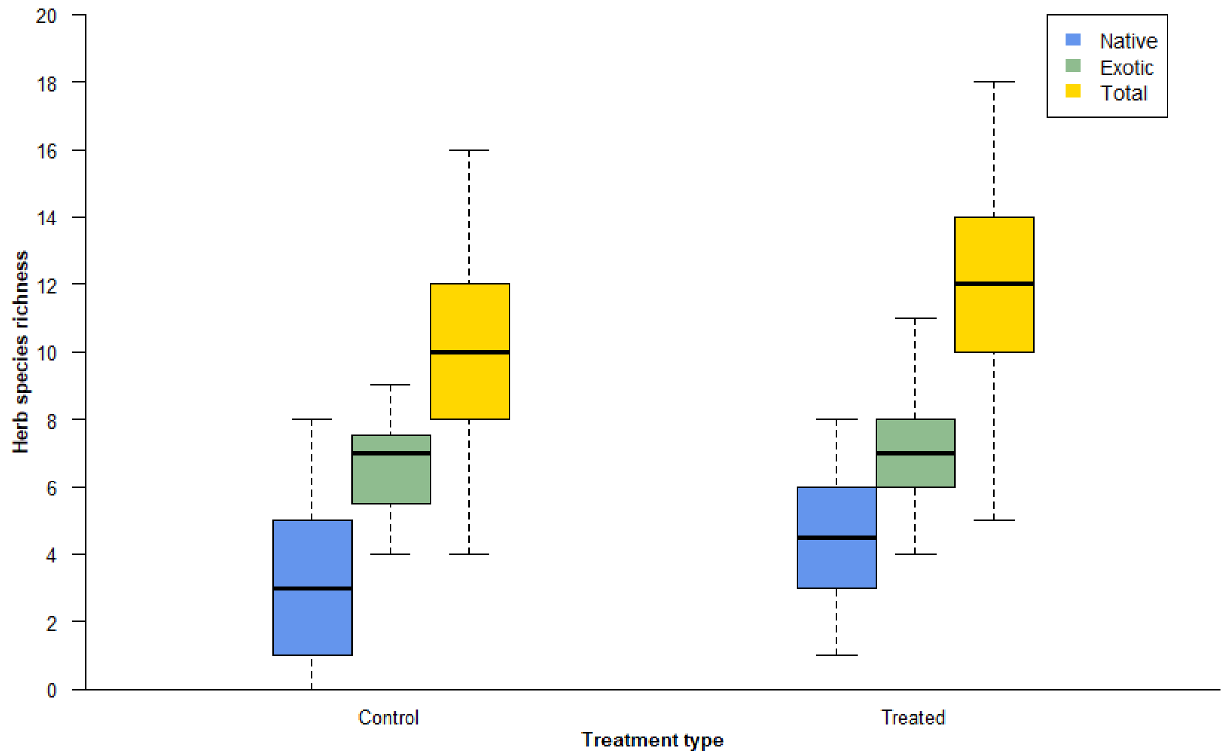


Figure 33. Species richness in the herb layer in control or treated plots for native (blue), exotic (green) or all (yellow) species.

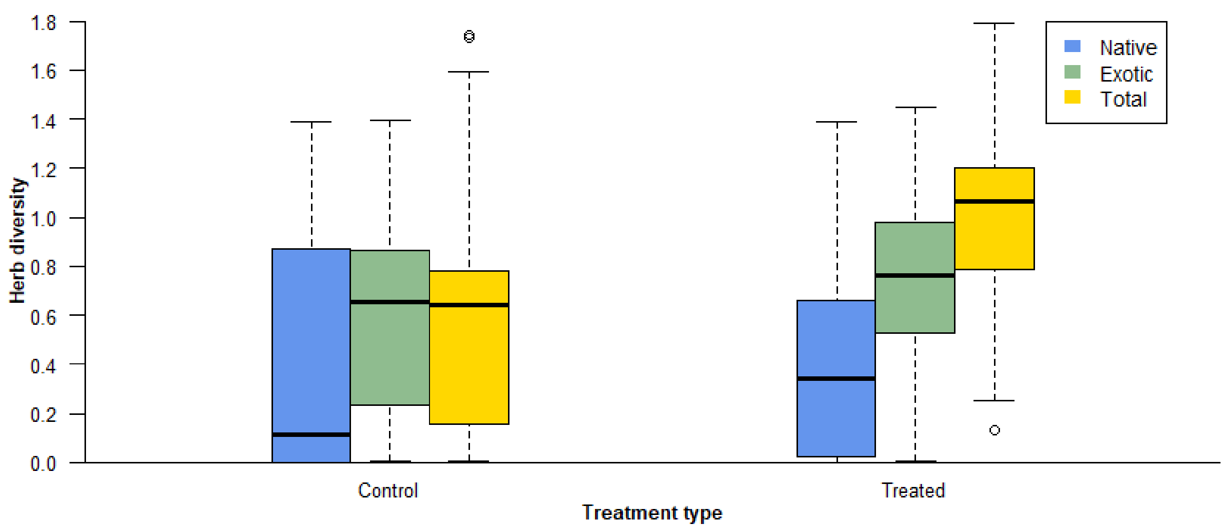


Figure 34. Diversity (Shannon's index) in the herb layer in control or treated plots for native (blue), exotic (green) or all (yellow) species.

A total of eight native species were sampled with low cover in the low shrub layer in all sub-polygons (Bebb's willow, black cottonwood, choke cherry, Douglas-fir, green alder, mountain alder, ponderosa pine, red-osier dogwood). With the rare, fleeting occurrences of choke cherry and Douglas-fir, all of the species and diversity in the low shrub layer were the result of planted riparian enhancement treatments. All planted low shrubs were found in MW1706 (MPT1918 and MPT1919) with some rare individual occurrences observed in MW1701M, MW1702MPT1910-1911, and MW1703MPT1915.

Results of the multivariate regression tree (MRT) done to look at species composition in relation to environmental and site variables show that species composition was primarily influenced by the polygons in which plots were sampled, with polygon MW1706 being different than all others (but plots within that polygon being quite similar, as shown by low relative error) and polygons MW1703 and MW1704 splitting right after (Figure 35). Control plots of polygons MW1701, MW1702, and PGL were more like each other in terms of species composition than to their respective treated plots.

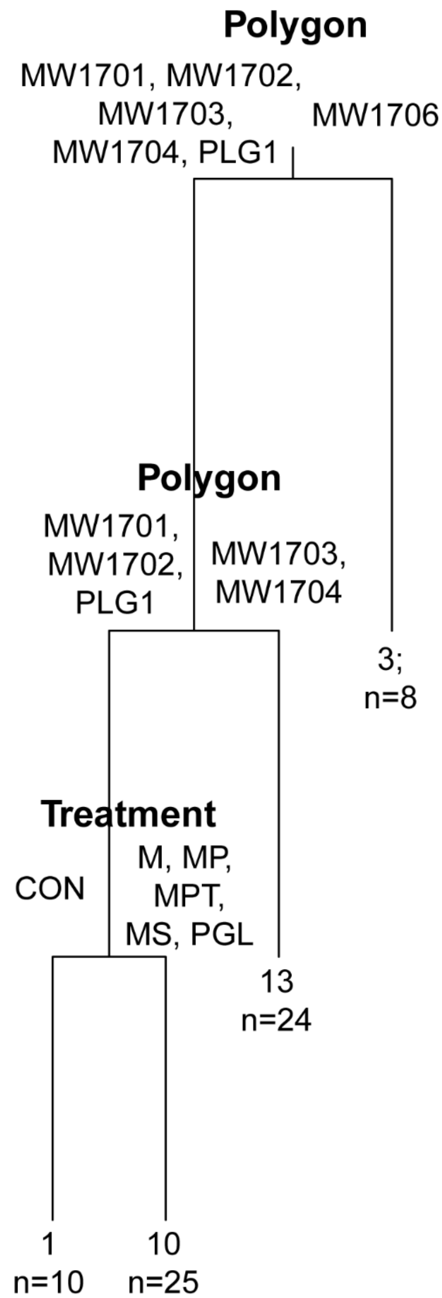


Figure 35. Multivariate regression tree (MRT) showing the partition of plots and a series of environmental and site variables. Number below bars are relative errors and number of plots per group. The tree explains 37% of the variance in herb species cover.

Table 11. Indicator species associated with each leaf of the multivariate tree (Figure 35).

Leaf	Species	Origin	Indval	p-value	Characteristics
1	SPERRUB	Exotic	0.69	0.001	CON plots of MW1701, MW1702 and PLG
2	CAREKEL	Native	0.53	0.002	Treated plots of MW1701, MW1702 and PLG
	PERSMAC	Exotic	0.77	0.001	
	POLYAVI		0.685	0.001	
3	HORDJUB	Native	0.8	0.001	Plots of polygons MW1703 and MW1704
	PLAGSCO		0.67	0.001	
	AMSILYC		0.58	0.004	
	ERYSCHE		0.48	0.022	
	MATRDIS	Exotic	0.8	0.001	
	SISYALT		0.54	0.02	
	MELIALB		0.5	0.031	
	CHENALB		0.37	0.021	
	MEDILUP		0.33	0.014	
4	POTERIV	Native	0.73	0.001	Plots of polygons MW1706
	ELYMCAN		0.62	0.001	
	CREPOCC		0.5	0.001	
	LEPIDEN		0.5	0.001	
	EPILCIL		0.46	0.028	
	LOTUDEN		0.44	0.001	
	ACHIMIL		0.375	0.002	
	COLLLIN		0.31	0.033	
	VERBTHA	Exotic	0.995	0.001	
	FILAARV		0.88	0.001	
	POA COM		0.8	0.001	
	POTEARG		0.75	0.001	
	LACTSER		0.625	0.001	
	TARAOFF		0.625	0.001	
	TRAGDUB		0.625	0.001	

Many native and exotic species were indicative of polygons in the alluvial fan (MW1703, MW1704, and MW1706), whereas four species were indicative of the Low Mud Flats (MW1701, MW1702 and PLG, and their respective control sub-polygons; (Table 10). The exotic annual sand spurry (SPERRUB) can be considered ubiquitous across the mud flats). Sand spurry is a facultative wetland species, grows rapidly and is drought tolerant; it is hermaphrodite, self-fertile and pollenated by flies, which all are characteristics beneficial in the reservoir drawdown zone. Plants successful in the drawdown zone must have rapid germination and growth, as well as a short time from germination through seed dispersal. Other exotic annuals that are commonly observed colonizing the low mud flats are lady's thumb (PERSMAC) and common knotweed (POLYAVI), which ware indicative of treated sub-polygons MW1701 and MW1702 as well as PLG. The presence of the native species Kellogg's sedge as indicative of treated sub-polygons and is directly due to planting and seeding treatments.

With an increase in elevation onto alluvial fan of Gun Creek, but with some of the characteristics of the low mud flats remaining, foxtail barley (*Hordeum jubatum*) is the sole native perennial species that is indicative of polygons MW1703 and MW1704. Cover values for all species were low and sparse with slightly higher importance of native annual Scouler's popcorn flower (*Plagiobothrys scouleri*) (PLAGSCO) and exotic pineapple weed. While foxtail barley was planted int MW1703 polygons, much of the occurrence is from natural colonization. Two exotic species, white sweet clover (*Melilotus alba*) and black medic (*Medicago lupulina*), commonly found in the upper drawdown and buffer zone, also occurred in the alluvial fan-low mud flat transition zone.

Species of the upper elevation polygon MW1706 species assemblage analysis, are typical for dry, open disturbed spaces; mullein (*Verbascum thapsus*), field filago (*Filago arvense*), dandelion (*Taraxacum officinale*), silvery cinquefoil (*Potentilla argentea*) and salsify (*Tragopogon dubius*) are common weeds. Brook cinquefoil is a predominant native species indicative of the polygon as is Canada wildrye. Canada wildrye was planted as part of the treatments in MW1706.

Richness and diversity of exotic species was higher than that of native species in the herb layer for all groups of polygons from the MRT analysis, but especially in group 1 and 2, that grouped the control and treated plots of the low mud flats (Figure 36, Figure 37, Figure 38). A greater number of exotic species are suited to persist in the artificially controlled environment of Carpenter Reservoir than native species.

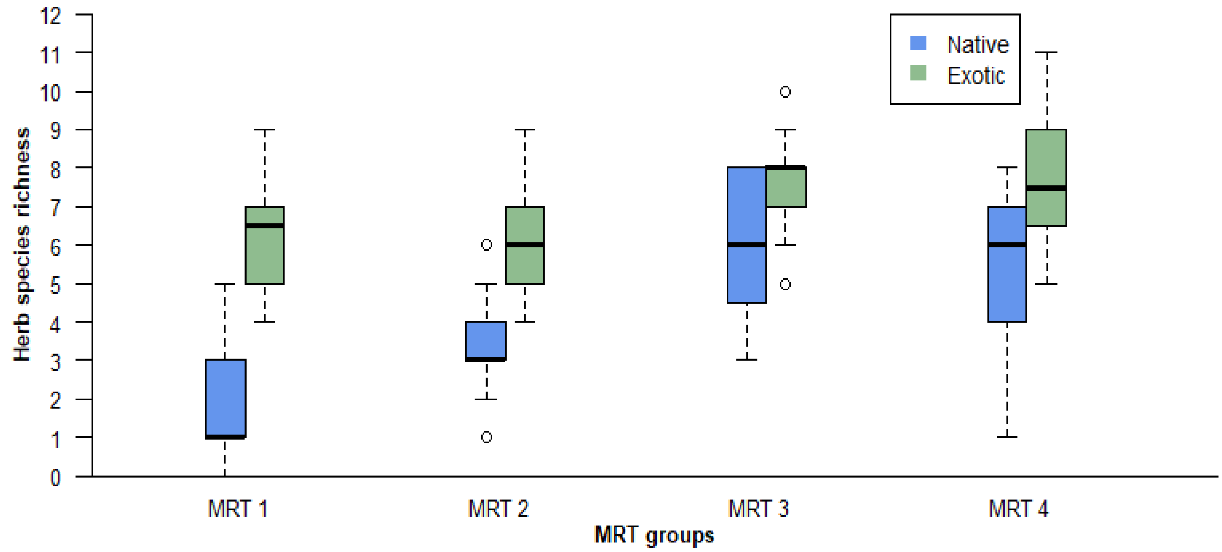


Figure 36. Species richness in the herb layer for native (blue) or exotic (green) species for each of the four groups defined in the MRT. MRT 1 = control plots of MW1702, MW1702, and PLG16; MRT 2 = treated plots of MW1702, MW1702, and PLG16; MRT 3= plots of MW1703 and MW1704; MRT 4= plots of MW1706.

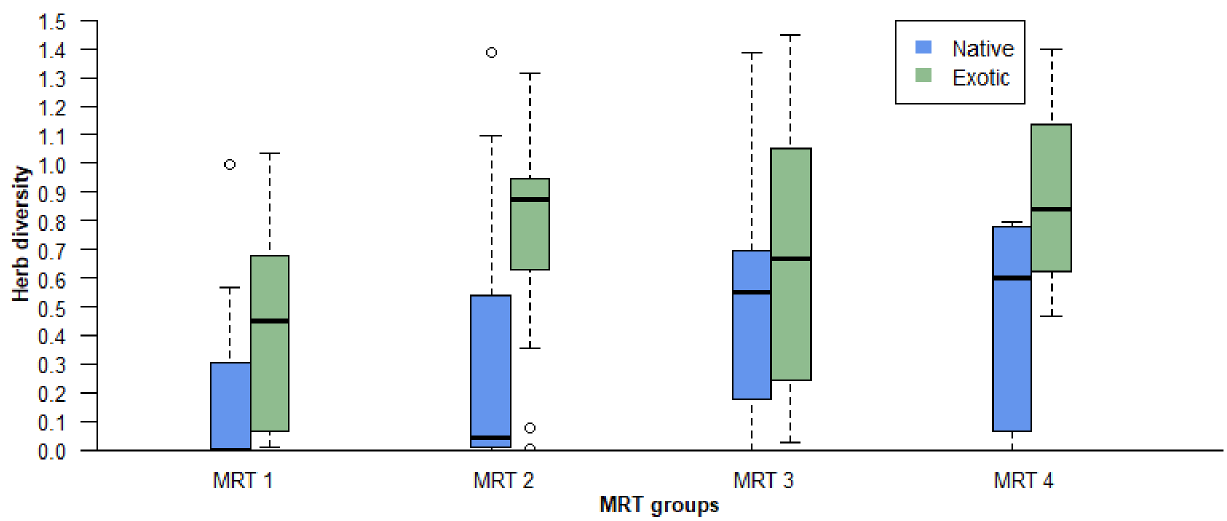


Figure 37. Diversity in the herb layer for native (blue) or exotic (green) species for each of the four groups defined in the MRT. MRT 1 = control plots of MW1702, MW1702, and PLG16; MRT 2 = treated plots of MW1702, MW1702, and PLG16; MRT 3= plots of MW1703 and MW1704; MRT 4= plots of MW1706.

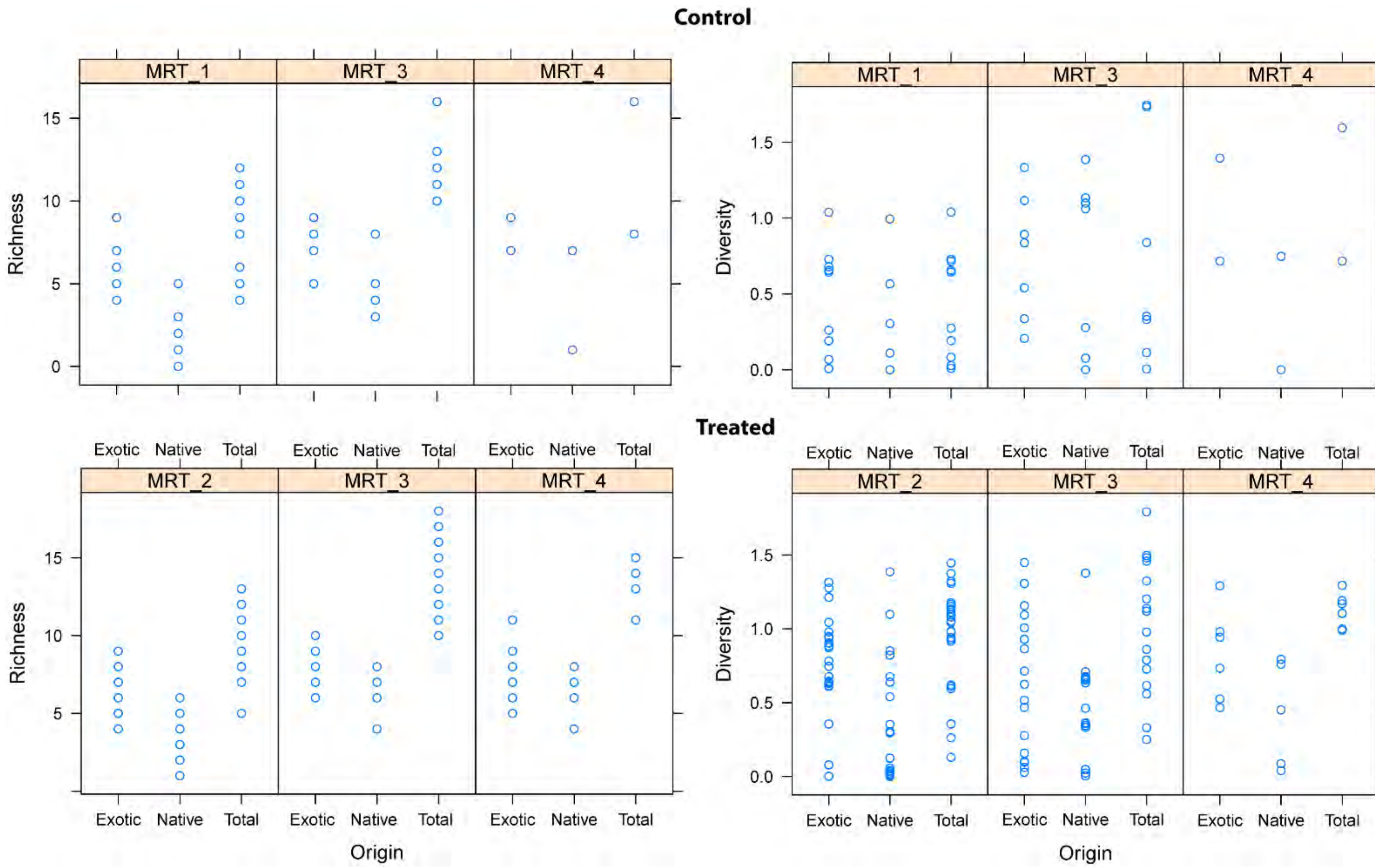
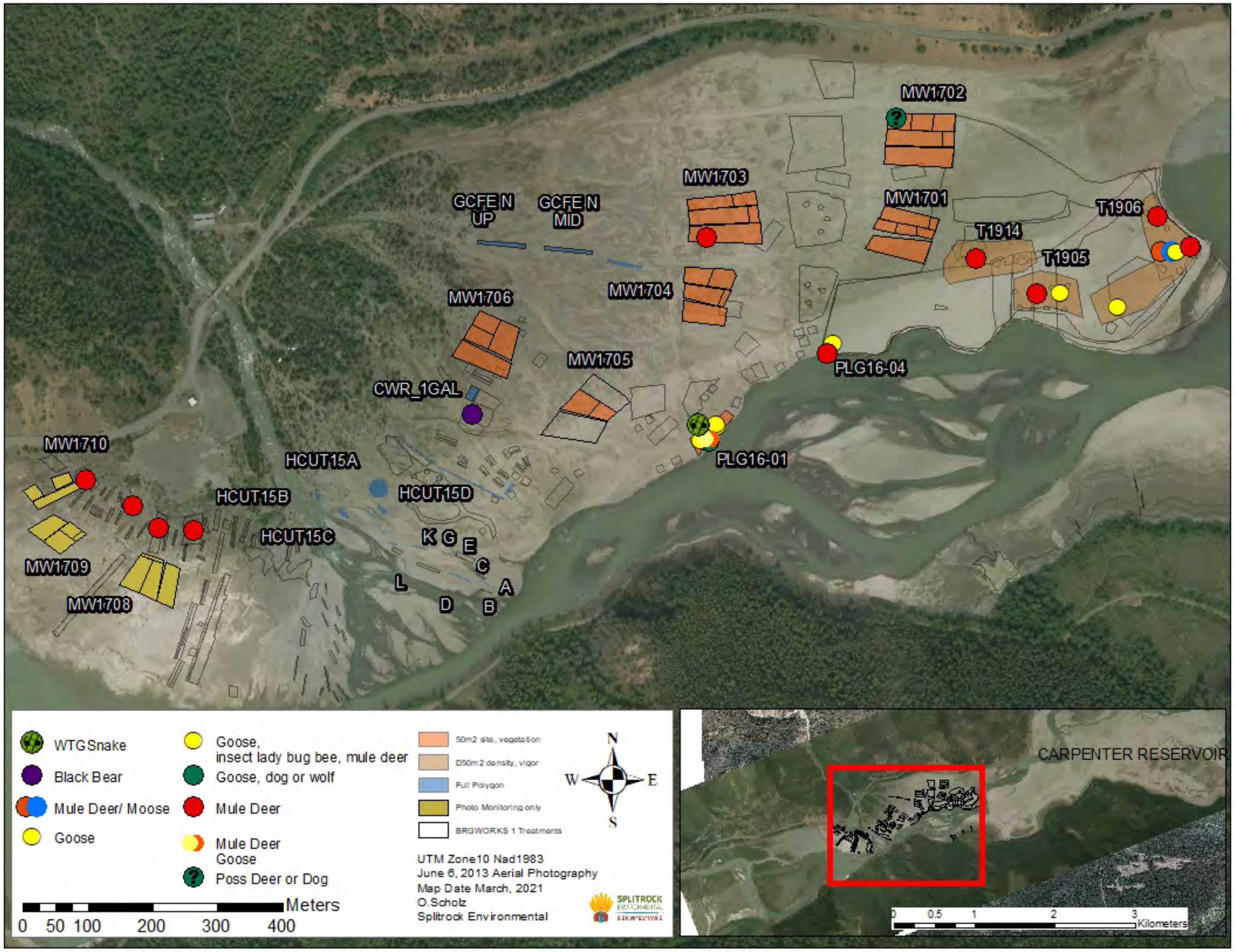


Figure 38. Richness and diversity of exotic, native and total species in control (top panel) and treated (bottom panel) plots of the four groups created by MRT.

4.6 Wildlife Observations

The highest concentration of wildlife observations was in polygons PLG16-01 and PLG16-04, where Kellogg's sedge plugs were planted in 2016 (Map 12). Mature sedge plants showed sign of browse likely from Canada geese (*Branta canadensis*), as well as high concentration of goose scat. Goose scat revealed that sedge seed heads were also being grazed (Figure 39). Mule deer and possibly wolf or dog tracks were also observed in PLG-1601. In addition, a juvenile western terrestrial garter snake was observed at the edge of Polygon 16-01 where it moved into while being watched. Lastly spotted sandpipers were heard along the waters edge near the same polygon. Mule deer tracks were observed on the low mud flats to the east and two deer were observed crossing the area during the surveys. Black bear scat was observed in the upper drawdown on the Gun Creek fan east and a single set of moose (*Alces alces*) tracks were observed on the eastern edge of the low mud flats. Moose was travelling from north east to south west across the low mud flats. Several other species including a juvenile Western toad (Anaxyrus boreas) (Sara schedule1 special concern, Jan12, 2005) was reported in the 2020 BRGWORKS-1 annual report (Scholz, 2021).



Map 12. Locations of wildlife observations during surveys for BRGMON-2 in 2020.

Figure 39. Image of the Canada goose scat with Kellogg's sedge seed besides sedge seedlings (Polygon PLG16-01, left); Western terrestrial garter snake observed just outside PLG16-01 in 2020 (right).

5.0 Discussion

5.1 Hydrograph influence

The timing and depth of filling and drafting of Carpenter Reservoir is a major environmental factor influencing the survival and growth of vegetation in its drawdown zone. The level of low pool in early spring and the rate of subsequent filling influence the length of the growing season for the vegetation, and therefore the spatial extent of the drawdown zone that is hospitable to vegetation. Since the rapid inundation of the elevations targeted for the BRGWORKS-1 treatments in 2015 (Table 12), the timing and peak inundation levels in Carpenter Reservoir have provided at least 50% of the growing season to vegetation even at the lowest treatment elevations (Table 12). Five years of relatively long growing seasons have passed since 2015, as the 2019 growing season was the shortest over this period and vegetation growing on the Low Mud Flat experienced almost exactly 50% of the growing season. Between 2014 and 2020, peak pool levels have reached the 648 mASL maximum only twice; in 2015 when it was slightly over (648.8 mASL) and in 2020 when it was slightly under target (647.4 mASL).

Observations in 2020 show that most Kellogg's sedge and horsetail planted in patches across the Low Mud Flat, as part of the 2019 BRGWORKS-1 program (Scholz, 2020), survived to 2020. We note that plants grown in Lillooet (situated at 205 mASL) and planted in the Low Mud Flat (639.5 mASL) in late April/early May experienced a head start on the growing season before planting. It appears that planted Kellogg's sedge survived in the riparian enhancement treatments around Gun Creek when water levels remained below 639 mASL long enough for the growing season to accumulate approximately 1350 GDD, which happened within the first week or two in July on most years (weather depending). It is likely that horsetails will also persist under these conditions, as they were observed to survive in the LMF after the treatments in 2019. We are also currently testing the potential of Scouring rush (*Equisetum hymale*) to establish in the drawdown zone, as it was planted for the first time in 2020. One of the best results from the BRGWORKS-1 project so far is the successful growth, establishment, seed production, seed dispersal, seedling colonization, and subsequent establishment within patches of Kellogg's sedge plants planted in 2016 in polygon PLG1601. The plants in that polygon experienced over 2500 AGDD annually, and a key to successful survival was the ability of the plants to withstand not only inundation, but also drought, such as the one experienced in 2018.

Table 12. Annual timing of inundation and effects of riparian enhancement treatments and growing season.

Year	Hydrograph	Effects on BRGWORKS-1 treatments	AGDD in LMF (<642m ASL)	Annual AGDD (total)
2014	Full pool was relatively low (643 mASL).	Very few of the treatments were inundated but **drought** conditions were a big stressor during the growing season.	1832	2080
2015	Full pool level was high (648.8 mASL). Timing of rising water was relatively early in growing season.	**Short establishment and growing season** for planted plants in LMF (**inundation**). High full pool levels affected most treatments. Significant losses on Steep and Shallow beach plantings. Damage from flooding, wave action, ice.	829	2999
2016	Slow gradual filling to average high water level (646 mASL) in late summer.	**Long growing season**, late inundation for most treatments. Drought and heat stress for many treatments.	2538	2869
2017	Low drawdown, inundation in late July. Average full pool 645 mASL.	Good growing season for most treatments; **drought** was a factor for upper elevation treatments.	2643	3492
2018	Low drawdown, slow fill with relatively late and low full pool (640 mASL)	Full growing season for most treatments; **drought** biggest stressor for all treatments.	3466	3466
2019	Slow fill and full pool below target levels (644.1 mASL) reached early fall	**50% of growing season** or greater for all treatments	1386	2754
2020	Slow fill, and fall full pool at 647.6 mASL	**66% of growing season** or greater for all treatments.	1830	2745

At the higher elevations in the drawdown zone, treatments situated at and above the 648 mASL target full pool (polygons MW1706, MW1709 and MW1710) experienced inundation for the first time in 2020 (with peak pool at 647.6 mASL). We expect that there will be varying impact to establishing vegetation in future years, particularly in areas where substrate is loose and unconsolidated such as in polygons MW1708 and MW1709, as the less consolidated substrates (sand and fine gravels) are highly susceptible to leveling action of waves and inundation (Figure 40). Fine silty soils tended to settle and pack in place, which helped in maintaining mounds at a reduced scale and with a smoothed finish. Coarse rocky substrates (skeletal soils) maintain physical structure of the mounding, but finer soils are sorted and settled out to the base of pits. Monitoring the mounded polygons of the upper elevations in 2021 will inform on the effects of the high waters of 2020 on these treatment sites.

Figure 40. Image of polygon MW1701 immediately after mounding in 2017 (left); same site in 2020, after three inundation and drawdown cycles (right). Note in 2020 the mounds smoothed and reduced, with planted Kellogg's sedge on the right side (MW1701MP).

5.2 Riparian Enhancements

The monitoring in 2020 was largely focused on assessing site and vegetation conditions in polygons initially treated in 2017. Monitored polygons that had been mounded only, mounded and seeded, mounded and planted, or mounded/planted and replanted, as well as untreated control areas, were all compared. Mounding treatments were intended to provide unique microsites for seeds and propagules to be captured and for seedlings (native species) to colonize and grow.

Results of comparisons of treatment with control polygons indicate that vegetation cover and composition have changed over time. The mounding treatments in 2017 were spaced from the Low Mud Flat to the Upper buffer zone on the Gun Creek Fan East and upper elevations of the Gun Creek Fan west side. Overall, plant diversity and richness has increased in treatments as compared to controls, though vegetation cover remains consistently low throughout most plots and polygons. This is not surprising since the baseline study from 2013 found low cover within the lower elevations of the drawdown zone (Scholz and Gibeau, 2014). Technically vegetation cover that is < 5 % is considered as non-vegetated successional status (BCMFR and BCMOE, 2010), which is the cover values seen in many of the drawdown zone polygons. Exotic species consistently dominated the vegetation cover in most plots, in both treatment and control polygons. The ongoing annual flooding cycle of Carpenter Reservoir places stresses on terrestrial vegetation that increase as elevation decreases within the drawdown zone. An ecological limit, if not the key ecological limit, is the reduced growing season observed at lower elevations. The length of the growing season can vary dramatically from year to year, as it depends on factors like the annual inundation cycle of the reservoir and annual weather patterns. Small exotic annuals are the species most adapted to survive the variable inundation constraints of the Carpenter Reservoir's environment.

Treatments in Low Mud Flats

We found little vegetation at and below 639 mASL in the Low Mud Flats during the 2013 survey, and any vegetation cover was provided by exotic species (Scholz and Gibeau, 2014). Fast growing exotic annuals continue to be the predominant species found in the Low Mud Flats in 2020 (<642 mASL) (Table 13). On the other hand, the mud flats west of the Gun Creek Fan (≥ 644 mASL, labelled the Mid Mud Flats (MMF) in 2013; Scholz and Gibeau, 2014) had high vegetation cover with dominant naturally occurring species like Kellogg's sedge, horsetails and bluejoint reedgrass. These native perennial species are the core species that have been planted by the BRGWORKS-1 program on the Low Mud Flat and the lower alluvial fan (639-644 mASL).

The introduction of Kellogg's sedge to the Low Mud Flat vegetation east of the Gun Creek fan has occurred through planting and seeding treatments, and to a lesser degree via natural colonization. Sedge recruitment has occurred in both mounding and non-mounded trials. Seeding treatments were effective to promote sedge colonization in mounded treatments, whereas seeding trials in 2015 on the un-mounded mud flats showed low densities of sedge colonization (Scholz and Gibeau, 2019). High density seeding may result in higher colonization. Both high density polygon (MW1900A) and patch seeding (MW1900D) was conducted in 2020 within polygons mounded in 2019 (Scholz, 2021 in progress). These polygons were not monitored in 2020 but would be high priority sites to monitor in 2021 under BRGMON-2. Mounding only has naturally recruited few rare individual sedge plants, indicating that seeding or planting is required to speed up colonization on mounds. It is possible that the seeds from the plants recruited in the polygons that were just mounded originated from seed produced by planted sedges in surrounding polygons.

We consider that under the reservoir conditions of the last four years (2017-2020), planted and established Kellogg's sedge provided the basis for continued natural re-colonization of native vegetation species. This has been most evident at treatments situated along the edge of the Bridge River (PLG16-01, PLG 16-04), where densely planted Kellogg's sedge plants (>30,000 stems per hectare) have survived, established, and are reproducing. The same was observed in mounded areas though at lower cover and densities (3000-8000 sph). Treatments in PLG1601 and PLG1604 have been the most successful to date, with moderate native plant covers (mean of 20%) and good biomass (1500 kg/ha, measured in 2017; Scholz and Gibeau, 2019). We remain concerned that the unconsolidated and fine lacustrine deposits of the Low Mud Flat are highly susceptible to erosion from the Bridge River flows (Figure 41), which has an impact on PLG1601 and PLG1604.

Table 13.Dominant species in of the drawdown zone of Carpenter Reservoir in 2020.

Terrain	Species latin name	Species common name	Origin
Low Mud Flat	*Chenopodium album*	Lamb's quarters	Exotic, annual
	Persicaria maculosa	Lady's thumb	Exotic, annual
	Polygonum aviculare	Common knotweed	Exotic, annual
	Spergularia rubra	Red sand spurry	Exotic, annual
Low Mud Flat with seeding and or planting	*Carex kelloggii*	Kellogg's sedge	Native, perennial (planted)
Alluvial fan mud flat, transition	*Hordeum jubatum*	Foxtail barley	Native, perennial
	Matricaria discoidea	Pineapple weed	Exotic, annual
	Melilotus alba	White sweet clover	Exotic, annual/biennial
	Sisymbrium altissimum	Tall tumble mustard	Exotic, annual
	Poa compressa	Canada bluegrass	Exotic, perennial
Upper drawdown	*Verbascum thapsus*	Mullein	Exotic, biennial
	Poa compressa	Canada bluegrass	Exotic, perennial
	Potentilla argentea	Silvery cinquefoil	Exotic, perennial
	Potentilla rivalis	Brook cinquefoil	Native, annual
	Elymus canadensis	Canada cinquefoil	Native, perennial (planted)

Figure 41. Examples of erosion taking place in the Low Mud Flat along the Bridge River bank: PLG1604 in 2017, one-year post planting (top left); PLG1604 in June 2020 (top right); tractor seeder tracks formed during fall rye seeding five weeks earlier (June 10, 2020, lower image).

Exotic species common in the control polygons colonized the mounded polygons several years after treatments, the mounds did recruit a few additional species, usually exotics typically found at higher elevations like white sweet clover (*Melilotus alba*) and Canada bluegrass (*Poa compressa*). The increased colonization by exotics lead to an increase in species richness within mounded polygons as compared to control polygons. Planting and seeding Kellogg's sedge had the greatest effect of increased native species cover and richness in lower elevation and mud flat polygons. treatment polygons have high cover of exotic species

Horsetail (*Equisetum arvense*) was planted in small trials in 2020 (within polygons mounded in 2019), and monitoring done in 2020 indicates its survival at 639.5 mASL, the lowest elevation of treatments under reservoir operations. It remains to be seen if plants can establish on the long term, and spread. As such, it would be informative to include monitoring of the MW1900A-F polygons in the final year of the BRGMON-2 program.

Seeding of fall rye was carried out in 2019 and again in 2020 across a broader region of the mud flats (Scholz, 2020 and Scholz, 2021 in progress). Fall rye was planted for its rapid production of cover and biomass, which is highly dependant on the length of the growing season. Although sampling was limited and targeted to representative plots in 2020, results showed that there was not a significant difference in the amount of biomass produced by seeded fall rye relative to non seeded areas dominated by exotic annuals. It is inconclusive whether seeding fall rye in treated plots has benefits over control areas, though it is likely that, if growing seasons were longer, there would be a greater impact from added biomass. Adding fertilizer to trials may produce greater biomass. However, the length of the growing season on each year is unpredictable and on any given year, treatments could fail. It may be that the fibrous roots of fall rye add slightly more organic matter to the soil horizons than is contributed annually by the exotic annual guild of the Low Mud Flat, which are all tap rooted. We also speculate that the physical disturbance to the soil surface during planting assist with colonization of Kellogg’s sedge (Scholz and Gibeau, 2019b), and areas seeded with fall rye seeded indicated a slightly higher recruitment of sedge seedlings in 2017 (Scholz and Gibeau, 2019a). It would be more desirable if a suitable native annual species could be sown onto the low mud flats, a species that could reproduce quickly and persist on site, such as bird’s foot trefoil (*Lotus denticulatus*).

Seeding treatments using meadow bird’s foot trefoil in 2018 and 2019 have shown some promise with sparse growth of the plants arising within hand-seeded treatment polygons one- and two-years post seeding. We could not find other studies that had used this species in restoration, further study and experimentation my be warranted to address low germination rates. Trials looking at seeding densities, seed scarification prior to sowing and/or inoculation with appropriate rhizobium, may work to increase germination rates and improve growth as is common for other legume species (Duvauchelle, 2014). As polygon MW1900F was treated with a denser seeding of lotus seed in 2020 (Scholz, 2021), we recommend that it be monitored for persistence of this native annual species in either 2021 or 2022 under the BRGMON-2 program.

Treatments in alluvial fans

The coarse soils of the Gun Creek Alluvial fan limit the area available to vascular plant growth. Control areas at the lower elevations of the Gun Creek Fan East (644-642 mASL) had in 2020 minimal vegetation cover, except for a patch of horsetail that occurred at the MW1704Con. Three years post treatment, there has been very little recruitment of native species across the mounded polygons at lower elevations on the Gun Creek Alluvial fan east (MW1703, MW1704, MW1705), except for foxtail barley (*Hordeum jubatum*) that occurred frequently across these polygons. Foxtail barley was planted in numerous BRGWORKS-1 trials in 2015, 2016, and 2017, and was observed occurring naturally on the Gun Creek Fan. While some of the foxtail may have arisen from planted stock, its high number and frequency of occurrence suggest most of its spread was from natural recruitment.

Planted individuals persisted to 2020 where planting or seeding was coupled with mounding at low elevation polygons on the Gun Creek alluvial fan (MW1703, MW1704 and MW1705). Kellogg's sedge was found in low densities where it was planted and seeded (200-2000 stems per ha), with higher densities found at polygons that were fill-planted two years after the initial treatment. Rare examples were observed where mature planted Kellogg's sedge had reproduced, as shown by seedlings observed around parent plants. Bluejoint reedgrass was detected in one plot, which suggested it had persisted in rare cases in the low alluvial fan. It may be that in these very coarse substrates, the greatest potential for gaining any significant cover for native plants rests with bluejoint and horsetail, whose rhizomatous growth could provide expanding clonal islands of vegetation. If treatments were to continue, we recommend planting *equisetum* species at the lower elevation of the alluvial fan in mounded and non mounded locations, perhaps transplanting in early spring from on-site sources to speed up plant dispersal.

Observations from the treatments tried at upper elevations indicate that tree and shrub species can be successfully planted into the upper buffer zone, under conditions provided by the past four years of reservoir management. However, earlier trials, where rooted stock of black cottonwood and trembling aspen were planted into the upper buffer zone, resulted in minimal to no survival. Black cottonwood, Ponderosa pine, Mountain alder, Green alder, Canada wildrye, and willow planted into the mounded upper drawdown zone have survived well on the Gun Creek Fan East. Again, mounding alone resulted in little desirable species but mounding and planting in combination led to some good establishment of planted species. We highlight however that plants in MW1706 and the MW polygons on the western fan were maintained with watering through two growing seasons, were mulched with wood chips when they were planted, and water levels have not yet reached the elevation of that treatment polygon. We thus recommend continued monitoring and one more season of maintenance for this polygon. A sparse distribution of meadow birds foot trefoil was observed growing where seeded in MW1706MPT1918 and MW1706T1919, indicating there may be potential for use of this native annual species as mentioned more study is recommended.

Canada wildrye plants were observed establishing in the control area of MW1706 in the upper elevations of the alluvial fan. This native perennial grass species was sparingly planted into the mounded polygons to the north, and densely planted in a patch directly south (CWR-1gal) in 2016 (Figure 28). We assume that the plants growing in the control polygon originated from seed produced from the polygon to the south. Canada wildrye was also planted from 1-gallon pots into polygons on the east and west side of the Gun Creek Fan, and plants were established and spreading at least on the east side. Canada wildrye is a robust grass that can provide good cover for small mammals and birds, as well as limited browse (Simonin, 2000), and thus increasing its cover on the upper alluvial fan would increase habitat values. As such, it would be useful to grow plants in plugs for out planting and/or conduct more direct seeding trials across the upper elevations of the alluvial fan. Canada wildrye was seeded in early treatment trials for the BRGWORKS-1 program and monitoring indicated good, consistent colonization at mid and upper elevations (Scholz and Gibeau, 2016), but poor germination in Low Mud Flats (Scholz and Gibeau, 2019a).

Treatments on the west side of the Gun Creek Fan were monitored by photo-monitoring and only visual observations recorded. It appears that planted cottonwoods are establishing and growing very well, as observed on the on the east side of the upper alluvial fan (polygon MW1706). These plants were irrigated for two growing seasons post-planting, and it also appears that mounding, using rooted stock, mulching, and irrigating increased the success of establishment. Willow (*Salix* sp.) planted into the mounded polygons were also surviving well in MW1708 and MW1709, and some were surviving in the higher elevations (polygon MW1710). Invasive species, including the noxious weeds spotted knapweed and yellow toadflax, were pervasive species on the west side of the fan and were reinvading the mounded polygons. We recommend that the noxious weeds be controlled at a minimum within the polygons (e.g. hand removal prior to seeding).

6.0 Recommendations

While 2020 was the final year of treatments for BRGWORKS-1, it will take time for plants to establish, and thus for us to measure the success or failure of treatments. Ideally, three growing seasons are needed to determine if treatments are stable and robust enough to persist. Treatments carried out in 2020 were iterative and based on adaptive management approach. Ideally sites treated in 2020 would be monitored in 2022. The upper elevation polygons that, in 2020, were inundated for the first time (up to 647.6 metres) since treatment in 2017 should be monitored at least visually in 2022. Each year the effects of inundation timing, depth and duration are variable. More specifically, we recommend:

- Monitoring polygon MW1900A-F for 2022 at a minimum. This includes assessing:
    - Density and vigor of planted plugs including sedges, horsetails, grasses, and shrubs;
    - Colonization of seeded meadow bird's foot trefoil and Kellogg's sedge.
- At a minimum, one more year of maintenance for polygons at upper elevations on the West and East side of the Gun Creek Fan, including irrigation and management of noxious weeds.
- Monitor upper elevation polygons on Gun Creek Fan East and West in 2022, 2021 if feasible.
- Monitoring of patches of planted Kellogg's sedge and horsetails from 2019 and 2020 on the Low Mud Flats at least on the final year of the BRGMON-2 program (2022).
- Expanding seeding trials with meadow birds foot trefoil and Canada wildrye, particularly with the trefoil, as it has the potential to improve soils and enhance existing treatments by fixing nitrogen on what are mostly nutrient poor soils.
- Planting horsetail in the polygons at low elevations on the alluvial fan could be beneficial if there was a desire to continue the riparian enhancement treatments.

- Monitoring effort that targets the sites of erosion along the Bridge River would help inform and guide any future riparian enhancement efforts. Investigating the erosion rate in relation to flows in the middle Bridge River including discharge flows from La Joie Dam, would be informative. Aerial imagery capture may provide an opportunity to address this question in the final year of the project.
- Monitoring 2017 polygons that were seeded with Kellogg's sedge to determine if plants have establishment of seeded Kellogg's sedge plugs.
- Continuing to observe and consider trials with other native species, including rivergrass (*Scolochloa festucacea* (Willd.) and American sloughgrass (*Beckmannia syzigachne* (Steud.), which are two native species observed incidentally on treatment sites in 2020.

7.0 Conclusion

Year 2020 was the final year of planned treatments under the BRGWORKS-1 program. Component 2 of the BRGMON-2 program monitored the riparian enhancement treatments to address whether the 7-year riparian enhancement treatments could "expand the quality (as measured by diversity, distribution, and vigour) and quantity (as measured by cover, abundance and biomass) of riparian habitats in the Carpenter Reservoir drawdown zone". The BRGWORKS-1 program conducted numerous treatments with a variety of species over seven years. Some treatments with native species resulted in an increase in native species diversity, and, in some cases, treatments have led to natural colonization by these species, thus addressing a primary goal of the program (e.g., Kellogg's sedge at the elevations of the Low Mud Flat, foxtail barley at mid elevations, and Canada wildrye in the upper drawdown zone). The BRGWORKS-1 program has been an iterative process, and the treatments in 2020 were based on adapting and combining observations and lessons from earlier treatments and monitoring results. Monitoring from these sites in the final scheduled year of the BRGMON-2 program will further inform management questions, whereas continued monitoring beyond 2022 would assess if the treatments have continued success over time. Restoration in the drawdown zone of Carpenter Reservoir is overshadowed by annual water management that may or may not in any given year impose severe disturbance to treatments.

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Appendix

List of variables assessed in 50m² plots and 1x1m² quadrats.

General:

- Date,
- Surveyors,
- GPS coordinates,
- Terrain type,
- Polygon name,
- Unique plot or quadrat ID,
- Plot size

Site data:

- Aspect
- Slope (%)
- microtopography shape (Smooth, Channelled, gullied, mounded, tussocked)
- Primary water source (Precipitation, groundwater, stream sub-irrigation, flooding)
- Substrate cover Totalling 100 % (water, rock, mineral soil, bedrock, organics, wood)

Soils:

- Compaction (compact, moderate, loose, other)
- Texture (Sand, Loamy Sand, Sandy Loam, Silt loam, Silt clay, other)
- Coarse fragment content (classes <10%, 10-30%, 35-65%, 65-85%, >85%)
- Estimate of nutrient regime (very poor, poor, medium, rich, very rich)
- Drainage class (very rapid, rapid, well, moderately well, imperfectly, poorly, very poorly)
- Moisture regime (very xeric, xeric, submesic, mesic, subhygric, hygric, subhydric, hydric)

Wildlife sign:

- Scat, Tracks, Bone, Browse, Hair, Feather, Creature observed, none, other
- Species (mule deer, black bear, grizzly bear, Rocky mountain bighorn, mountain goat, beaver, goose, horse, cow, insect, other, none)

Disturbance:

- ATV, 4X4, Motorbike, Other, None

Vegetation:

  - Species name,
  - Structural layer (D=Moss, C=herb and grass, B2=low shrub, B1=tall shrub)
  - Estimate of per cent cover.
- Distribution within quadrat (9 categories: rare individual single occurrence, a few sporadically occurring individuals, a single patch or clump, several sporadically occurring individuals, a few patches or clumps, several well-spaced patches or clumps, continuous uniform occurrence of well-spaced individuals, continuous uniform occurrence of a species with a few gaps in distribution, continuous dense occurrence of a species).
- Density per m^2 (<=1, 2-5, 6-10, >10)
- Plant vigor (5 classes: 0=dead, 1= poor, 2= fair, 3= good, 4=excellent),
- Utilization (degree of browse: 0=0%, 1=1-15 %, 2= 16-36%, 3=36-65%, 4= 66-80%, 5=>80%),
- Whether individuals were planted or naturally occurring.

BRGWORKS 1 treatment summary table

TERRAIN TYPE	CODE	Total Terrain Area (ha)	Treatment Year	Machine Work Area (ha)	Sedge Plugs	BJ Plugs	Foxtail Plugs	Fowl bluegrass	CWR	Horsetail	Mix Native Grasses	Aspen trees	cottonwood trees	Ponderosa Pine	Alder sp.	Willow sp.	Red Osier dogwood	Rooted Cuttings	Number Cuttings Willow	Number Cuttings Cottonwood	Area Seeded Fall Rye (ha)	Area Seeded Fall Rye/Carex Lenticularis (ha)	Area Seeded Carex Lenticularis (ha)	Area Mechanical treatment only (ha)	Meadow Bird's foot trefoil seed (ha)	Area seeded Upper Reservoir Grass Mix (ha)	Area seeded Upper Reservoir Grass Mix and Fall Rye (ha)
Low Mud Flat	LMF	192 (35ha polygon off Gun Creek Fan)	2014	NO TREATMENTS																							
			2015	0	1,647	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1457	0.1457	0.1457	0.1457	0	0	0
			2016	0	10,312	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9.6	0.4	0.32	0.3	0	0	0
			2017	0.88	5,629	168	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			2018	NO TREATMENTS*																							
			2019	1.9	7,295	0	0	0	0	50	0	0	0	0	0	0	0	0	0	0	3.3	0	0.2	0.78	0.13	0	0
			2020	0.32	17,602	1,990	0	0	0	100	0	0	220	0	0	240	0	0	0	0	8.9	0.36	0.32	0	0	0	0
Gun Creek Fan East	GCFE	35	2014	0	1,570	0	0	0	0	0	486	0	0	0	0	0	0	0	220	530	0	0	0	0	0	0	0
			2015	0	2,610	1,253	0	0	0	0	0	0	0	0	0	0	0	0	482	266	0.143	0	0	0	0	469	219
			2016	0	0	2,360	2960	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			2017	2.08	4,758	1,554	282	288	50	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			2018	NO TREATMENTS*																							
			2019	0.04	300	450	0	0	0	0	0	0	25	25	25	25	0	12	0	0	0	0	0	0	0.084	0	0
			2020	0.24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.24	0	0
Gun Creek Fan West	GCFW	19	2014	0	2,692	0	0	0	0	0	126	0	0	0	0	0	0	0	262	0	0	0	0	0	0	0	0
			2015	0	1,263	3512	50	50	1050	0	0	0	0	0	0	0	0	0	308	243	0	0	0	0	0	0	0
			2016	0	0	9225	0	0	0	0	0	25	25	0	0	0	0	0	360	629	0	0	0	0	0	0	0
			2017	0.54	0	738	240	150	91	0	0	0	75	0	0	0	0	0	246	0	0	0	0	0	0	0	0
			2018	NO TREATMENTS*																							
			2019	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			2020	0.38	0	822	0	0	0	0	0	0	130	125	0	74	50	0	0	0	0	0	0	0	0	0	0
Shallow Beach	SHB	3.85	2014	0	453	0	0	0	0	0	288	0	0	0	0	0	0	0	86	0	0	0	0	0	0	0	0
			2015	0	2864	1956	0	0	0	0	0	0	0	0	0	0	0	0	22	94	0	0	0	0	0	0	0
			2016	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	132	73	0	0	0	0	0	0	0
			2017	NO TREATMENTS																							
			2018	NO TREATMENTS *																							
			2019	NO TREATMENTS																							
			2020	NO TREATMENTS																							
Steep Alluvial Fan	SAF	22.3	2014	0	1,136	0	0	0	0	0	0	0	0	0	0	0	0	0	245	0	0	0	0	0	0	0	0
			2015	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	500	33	0	0	0	0	0	0	0
			2016	NO TREATMENTS																							
			2017	NO TREATMENTS																							
			2018	NO TREATMENTS*																							
			2019	NO TREATMENTS																							
			2020	NO TREATMENTS																							
Steep Beach	STB	3.8	2014	0	658	0	0	0	0	0	261	0	0	0	0	0	0	0	178	0	0	0	0	0	0	0	0
			2015	0	991	1219	0	0	0	0	0	0	0	0	0	0	0	0	185	30	0	0	0	0	0	0	0
			2016	NO TREATMENTS																							
			2017	NO TREATMENTS																							
			2018	NO TREATMENTS*																							
			2019	NO TREATMENTS																							
			2020	NO TREATMENTS																							
TOTAL		267.65		6.38	61,780	25,247	3532	488	1241	150	1161	25	575	150	25	339	50	12	3226	1898	22.0887	0.9057	0.9857	1.2257	0.454	469	219

* 2018 was a lag year for the project with no field treatments.

Vegetation Composition and Cover Tables

Control Polygons

	Low Mud Flat			Alluvial Fan Lower		Alluvial Upper		
Richness	MW1701Con	MW1702Con	Plg1601Con	MW1703Con	MW1704Con	MW1706Con	Plot Freq	Sub polygon Frequency
Native								
Achillea millifolium						1	1	1
Amsinckia lycopsoides	2	3		4	1		10	4
Calamagrostis canadensis	1						1	1
Carex kelloggii			1		1		2	2
Collomia linearis						1	1	1
Crepis occidentalis						2	2	1
Elymus canadensis			1			1	2	2
Epilobium minutum				2	2		4	2
Equisetum pratense	1						1	1
Erysimum cheiranthoides				3			3	1
Hordeum jubatum			2	4	3	1	10	4
Lepidium densiflorum						1	1	1
moss						1	1	1
Plagiobothrys scouleri	1		2	3	3		9	4
Potentilla rivalis				1	1	1	3	3
Rorippa palustris	2			1	2		5	3
Equisetum arvense					2		2	1
Native sp. Richness	5	1	4	7	8	8	58	
Exotic								
Capsella bursa-pastoris				2	1		3	2
Chenopodium album	5	3	2	4	2		16	5
Elytrigia repens			2		1	1	4	3
Filago arvensis						2	2	1
Matricaria discoidea	3	2	2	4	3	1	15	6
Melilotus alba	4	3	1	4	3	2	17	6
Persicaria maculosa	5	2	2	1	2		12	5
Poa compressa	1		2	3	3	2	11	5
Polygonum aviculare	5	3	1	4	3		16	5
Potentilla argentea						2	2	1
Rumex crispus			2		1		3	2
Secale cereale		1					1	1
Sisymbrium altissimum	1			2	1		4	3
Spergalina rubra	5	3	2	3	3		16	5
Taraxacum officinale						2	2	1
Tragopogon dubius						2	2	1
Verbascum thapsus						2	2	1
Exotic sp. Richness	8	7	9	9	11	9	128	
Grand total	13	8	13	16	19	17	186	

	Low Mud Flat													
	MW1701					MW1702					PLG16			
Richness	M	MP	MPT1912	MPT1913	MS	M	MP	MPT1910	MPT1911	MS	01	04	Plot Frequency	Polygon Frequency
Native														
Amsinckia lycopsoides	3	1	1		1	4	2	2	1	1			16	9
Carex kelloggii	1	2	2	2	1	1	2	2	2	1	3	1	20	12
Epilobium minutum						2	2	1					5	3
Equisetum pratense				1	1				1				3	3
Erysimum cheiranthoides	1	1					1	1			1		5	5
Hordeum jubatum	2	1				4	2	2	1	1	1	1	15	9
Lotus denticulatus									2			1	3	2
Plagiobothrys scouleri,	1					3	1	1			1	1	8	6
Prunus virginiana								1	1				2	2
Rorippa palustris	3	1	1	1	1	2	1	1	1		1		13	10
Populus balsamifera ssp. trichocarpa	1												1	1
Native species Richness	7	5	3	3	4	6	7	8	7	3	5	4	91	
Exotic														
Capsella bursa-pastoris						1		1					2	2
Chenopodium album	3	2	2	2	1	4	2	2	2	1	3	1	25	12
Chenopodium capitatum								1					1	1
Elytrigia repens											3		3	1
Fallopia convolvulus						1							1	1
Matricaria discoidea	2		2			1	1	1	2		2	1	12	8
Medicago lupulina											1		1	1
Melilotus alba	2	1	2	1	1	2	1	1	1		2		14	10
Persicaria maculosa	3	2	2	2	1	4	2	2	2	1	3	1	25	12
Poa compressa						1					3		4	2
Polygonum aviculare	3	2	2	2	1	4	2	2	2	1	3	1	25	12
Rumex crispus	2										2		4	2
Secale cereale					1	1			2	1			5	4
Sisymbrium altissimum	3	1	1	1		2	2		2	1			13	8
Spergalina rubra	3	2	2	2	1	3	1	2	2	1	3	1	23	12
Exotic species Richness	8	6	7	6	6	11	7	8	8	6	10	5	158	
Total Species richness	15	11	10	9	10	17	14	16	15	9	15	9		

Alluvial Fan Lower Elevation

Species	MW1703				MW1704				MW1705		Plot	Sub polygon
	M	MP	MPT1915	MS	M	MP	MPT1916	MS	MP	MPT1917	Frequency	Freq
Native												
Amsinckia lycopsoides	3	3	2	1	1	2		1			13	7
Calamagrostis canadensis			1								1	1
Carex kelloggii		3	2	1		2	2	1	1	1	13	8
Collomia linearis	3	1	2	1							7	4
Cornus stolonifera			1								1	1
Erysimum cheiranthoides	3	1		1	2	1	2	1	1		12	8
Hordeum jubatum	4	3	2	1	2	2	2	1	1	1	19	10
Lepidium densiflorum									1		1	1
Mentzelia albicaulis			1				1				2	2
Plagiobothrys scouleri,	3	3	2	1	2	2	2	1	1	1	18	10
Potentilla rivalis	2	1			2	2		1		1	9	6
Rorippa palustris	1	1	1	1	2		1	1	1		9	8
Scolochloa festucacea	1						2				3	2
Equisetum arvense											0	0
Epilobium minutum	3	2	1	1	2	2	3	1			15	8
Native sp. Richness	9	9	10	8	7	7	8	8	6	4		
Exotic												
Capsella bursa-pastoris				1	1						2	2
Chenopodium album	4	2	2	1	2	2	2	1	1	1	18	10
Elytrigia repens	1										1	1
Matricaria discoidea	5	2	2	1	1	2	2		1		16	8
Persicaria maculosa	2	3	3	2		1		1	1		13	7
Poa compressa	3	1	2	1	2	1	2	1	1	1	15	10
Polygonum aviculare	3	3	2	1	2	2	2	1	1	1	18	10
Rumex crispus						1					1	1
Secale cereale			1								1	1
Sisymbrium altissimum	3	3	2	1	1	2	3	1		1	17	9
Spergalina rubra	3	2	1	1	2	2	2		1	1	15	9
Verbascum thapsus	2	3			1	2					8	4
Melilotus alba	4	3	2		2	2	2	1	1	1	18	9
Medicago lupulina	2	1	1				2				6	4
Exotics sp Richness	11	10	10	8	9	10	8	6	7	6		
Total Richness	20	19	20	16	16	17	16	14	13	10		

		MW1706				Sub
					Plot	Polygon
Richness	CON	M	MPT1918	MPT1919	Frequency	Freq
Native						
Achillea millifolium	1		1	1	2	2
Alnus crispus			2	1	3	2
Alnus incana			1		1	1
Collomia linearis	1	1	1		2	2
Crepis occidentalis	2	1		1	2	2
Elymus canadensis	1		2	2	4	2
Erigeron compositus				1	1	1
Hordeum jubatum	1		2		2	1
Lepidium densiflorum	1	1		2	3	2
Lotus denticulatus		1	2	1	4	3
Mentzelia albicaulis			1		1	1
moss	1				0	0
Pinus ponderosa			1	2	3	2
Plagiobothrys scouleri,		1	2		3	2
Potentilla rivalis	1	1	2	2	5	3
Pseudotsuga menziesii			1	1	2	2
Salix bebbiana			1		1	1
salix species				1	1	1
Epilobium minutum		2	2	2	6	3
Populus balsamifera ssp. trichocarpa			2	1	3	2
Grand Total	8	7	15	13		
Exotic						
Centaurea stoebe				2	2	1
Chenopodium album		1			1	1
Elytrigia repens	1				0	0
Filago arvensis	2	1	2	2	5	3
Lactuca serriola		2	1	2	5	3
Matricaria discoidea	1				0	0
Poa compressa	2	2	2	2	6	3
Potentilla argentea	2	2		2	4	2
Rumex crispus				1	1	1
Sisymbrium altissimum		1	2	2	5	3
Taraxacum officinale	2	1		2	3	2
Tragopogon dubius	2	2	1		3	2
Verbascum thapsus	2	2	2	2	6	3
Melilotus alba	2	2	1	1	4	3
Medicago lupulina		1			1	1
Plantago major		1			1	1
Grand Total	9	12	7	10		
Total Richness	17	19	22	23		

Permanent photo-monitoring

Low Mud Flat

MW1701

Figure 42. MW1701 before treatment top left, immediately post treatment 2017 top right, lower left 2019 two years post treatment and 2020 three years post (lower right).

MW1701Control

Figure 43. MW1701Con: left in 2017, right in 2019.

MW1702

Figure 44. MW1702: after treatment 2017 (left), one year later post inundation 2018 (right).

Figure 45. MW1702: Control plot, one year apart

Alluvial fan mud flat transition

MW1704

Figure 46. MW1704: before treatment on the left, one year later on the right.

Figure 47. MW1704CON: May 31, 2017 (top left); one year later May 08, 2018 (top right); 09 June 2020 (bottom left).

MW1705

Figure 48. MW1705: before treatment (top left); one year post treatment (top right), three years post (lower Left).

Figure 49. MW1705CON: 31 May 2017 (top left); 02 June 2018 (top right); 11 June 2020 (bottom left).

Upper Drawdown Gun Creek Fan East

MW1706

Figure 50. MW1706: before treatment in 2017 (left); one year later (right), three years post treatment (lower left)

Upper Drawdown Gun Creek Fan West

MW1709CON

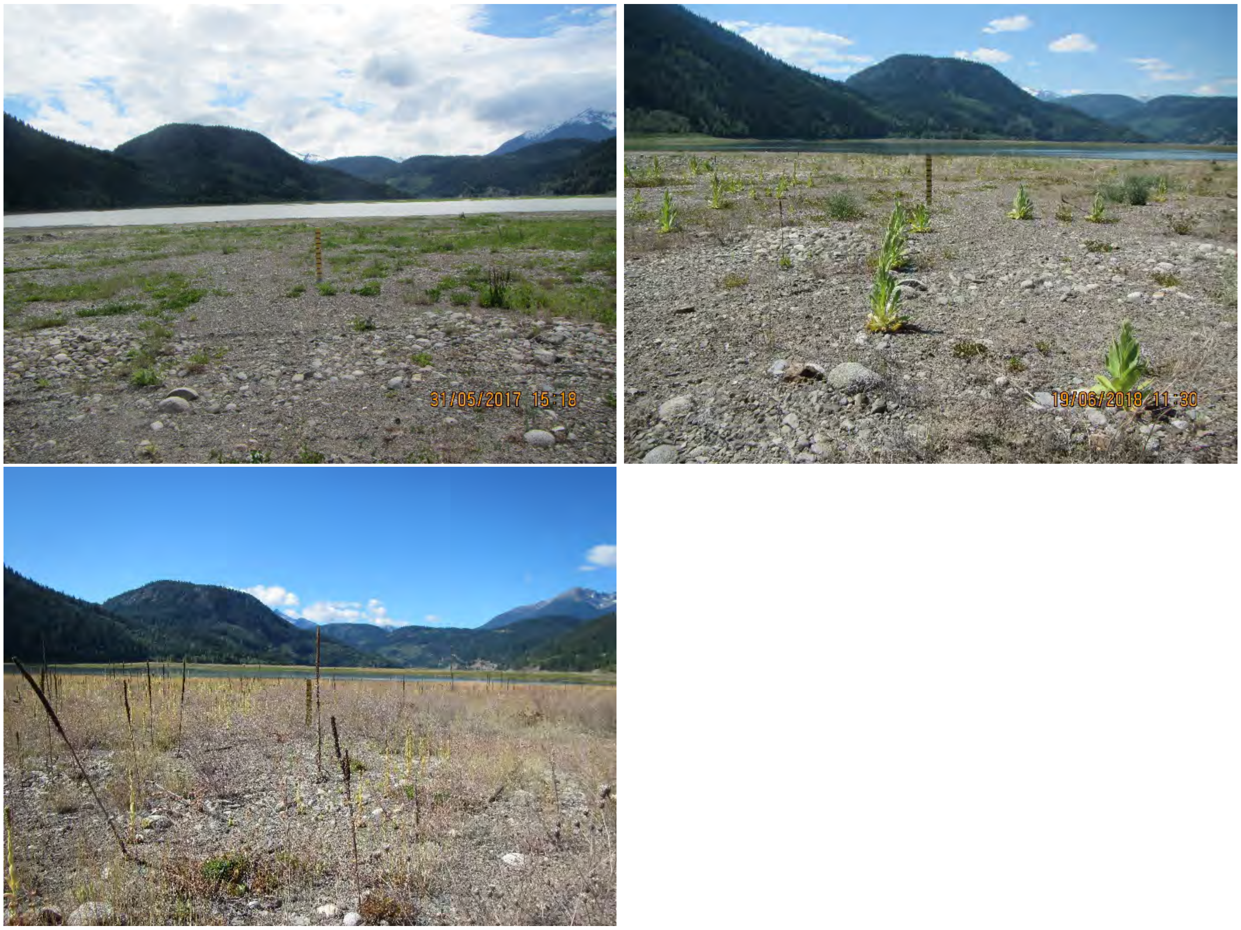

Figure 51. MW1709Con: in 2017 (top left), in 2018 (top right), in 2020 (bottom left).

MW1709

Figure 52. MW1709: before treatments in 2017 (top left); one year later in 2018 (top right); Aug 25, 2020 (bottom left).