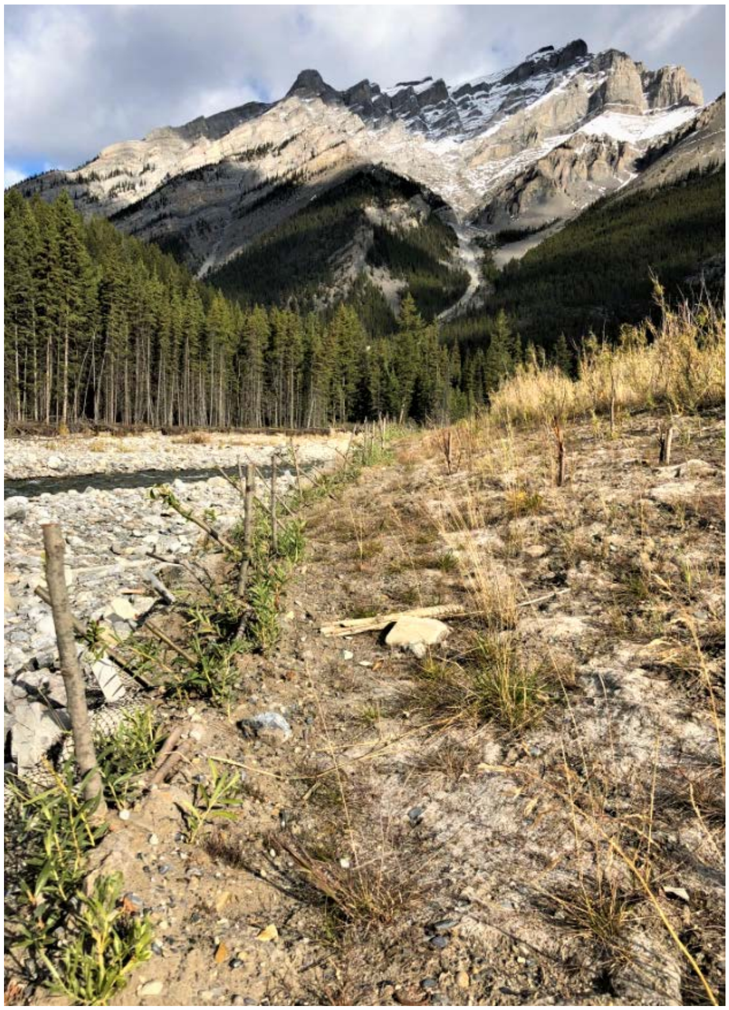
From Wasteland to Waterscape: Riparian Restoration of 40 Mile Landfill in Banff National Park



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1.0 Executive summary

The restoration of heavily disturbed sites, particularly those which no longer resemble their historical analogues, remains as both a technical challenge and urgent priority for the field of ecology. Within Banff National Park, though widely considered a model of conservation, there are nonetheless many novel systems which require intervention to reach a state of ecological integrity. This paper seeks to address the range of possible restoration scenarios for a degraded riparian site and former landfill along 40 Mile Creek, adjacent to the town of Banff. The site has been subject to a host of anthropogenic and natural disturbance vectors, including upstream structural impoundment, excavation, reoccurring flooding, as well as former restorative efforts. Prior restoration has failed to flourish due to abiotic barriers such as poor overburden soils which favour ruderal species. Data was primarily gathered using techniques from a standardized Riparian Health Assessment, as well as secondarily from historical archives and Parks' geospatial (ArcGIS) database. The site scored as 'extremely unhealthy' with only a few species or processes present which would be expected, reflecting a long history of interruption in normal ecological functioning. The central goal for restoration in the 2019 field season was to reconstitute representative species and ecological processes to riparian and upland ecosites. This was fulfilled through 3 objectives: bioengineering the streambank, initiating seral processes for aspen-grassland in the uplands, and managing invasive species throughout the site. Recommendations for future work includes several strategies borrowed from forest mine reclamation protocol, including creating topographic heterogeneity, promoting soil development and ecotype diversity, using optimal planting technique, natural regeneration, native materials, and adaptive management. In line with this final recommendation, future restoration efforts must take into consideration the presence of novel and interwoven systems in the Park, responding with cooperative management and experimental technique.

1.1 Acknowledgments

Project Cooperators

Brian Yakiwchuk: *Restoration Specialist*
Anna Brown: *Environmental Assessment Scientist*
Kelsey Tillapaugh: *Environmental Assessment Scientist*
Elise Martin: *2019 Resource Management Technician II*

Parks Canada and the author would like to respectfully acknowledge that Banff National Park, the Bow River Basin, and the restoration site itself lie within the territories of the Treaty 6, 7 and 8 First Nations, as well as within the Métis Nation Homeland. The lands and waters of modern-day Banff have been used for millennia by these and other Indigenous Peoples, for sustenance, ceremony, and travel and there is a unique and long-standing connection between these groups and the territory. First Nations people have had a storied relationship with the Banff-Bow River Valley for more than 10,000 years, with a complex history of occupation, relation, and exclusion from what is now known as Banff National Park (Mason, 2014; Binnema and Niemi, 2006).

2.0 Introduction

Impoundments, invasive species, and climate change are increasingly threatening the functionality of many riparian ecosystems across western North America (Poff et al., 2011). As systems which by their nature are based in movement through the landscape, riparian corridors have a disproportionate impact on habitat connectivity and overarching ecosystem resilience (Fremier et al, 2015). As a result of their disturbance and resource dynamics, riparian ecosystems are extremely susceptible to modification and invasion, providing an opportunity to address how these systems respond to underlying ecological gradients (Brummer et al, 2016).

Contrary to the widespread notion that nature reserves and national parks are a static 'window to the past' of historic conditions, eco-archaeological evidence suggests that Banff National Park - considered as one of the few remaining iconic wildlands of North America- is in fact an emergent ecosystem that has likely never existed before due to such factors as hydromodification and fire suppression, amongst other land use practices (Kay et al. 1999; Rogeau et al. 2016). Large scale hydroelectric development and diversion has had extensive impact on the riverine valleys, with over 40% of the Bow River catchment within the park directly affected by structural impoundment (Armstrong and Nelles, 2013; Schindler, 2000). For glaciated montane environments such as the Rocky Mountains, the gravel-bed river floodplains are extremely important to total ecosystem functioning, despite their paucity of protection from human impacts (Hauer et al, 2016).

The current legislation of the *Canada National Parks Act* sets a precedent for park managers to prioritize the maintenance or restoration of ecological integrity, by supporting an ecosystem's characteristic composition and abundance of native species and biological communities, rates of change and supporting processes (2000). Considering the scale of historical and ongoing disturbance regimes within the lowlying waterways of Banff National Park, it follows that a procedure of conservation or passive restoration is not sufficient to maintain ecological integrity. In the spirit of active restoration and for the purposes of the paper, the larger question becomes – what constitutes ecological integrity of a unique riparian system in Banff National Park, and how can this be judiciously intervened upon?

One possible technique for this approach with drastically altered sites is a focus on restoring seral processes and desired trajectories of function, not simply species (Polster, 2016). Rather than attempt to restore models of past systems using historical reference points, it is becoming increasingly relevant to recognize new amalgamations of species under anomalous abiotic conditions, otherwise known as 'novel' or 'hybrid' ecosystems (Hobbs et al. 2013). For the concept to be pragmatic to scientists, managers, and restoration ecologists, the novel ecosystem must be defined in a specific way that distinguishes it from other types of human-altered ecosystems, with a specific recognition that these systems are not merely degraded, but rather entirely distinct from those that have previously existed (Morse et. al, 2014). For example, while returning to an entirely natural flow regime may not be possible in highly managed rivers such as the Bow and its tributaries, ecological management must incorporate the novel flow regimes and diverse frequencies inherent these new systems (Bigelow, 2006). The successional trajectories of the Montane subregion under climate change projections will likely involved altered species composition, rendering a fixed referential approach less relevant (Schneider, 2013). To restore such ecosystems with expected future conditions in mind -however uncertain- is the challenge of resource managers worldwide (Millar and Brubaker, 2006).

2.1 Natural and Hydrological Systems of the Region

Banff National Park is located within the Rocky Mountain Natural Region, encompassing the Montane, Subalpine, and Alpine Natural Subregions (Fig 1). As part of a lowlying mountain valley system, the restoration site falls within the Montane Subregion. Pronounced microclimates are produced by an array of differing aspects, slope and exposures which engender abrupt changes in community composition. Broadly speaking, as characterized by the Natural Regions Committee, the area is predominantly characterized by Lodgepole Pine (*Pinus contorta*), Douglas fir (*Pseudotsuga menziesii*) and stands of Aspen (*Populus tremuloides*) on easterly and northerly aspects, as well as open grasslands on southerly and westerly aspect at lower elevations (2006).

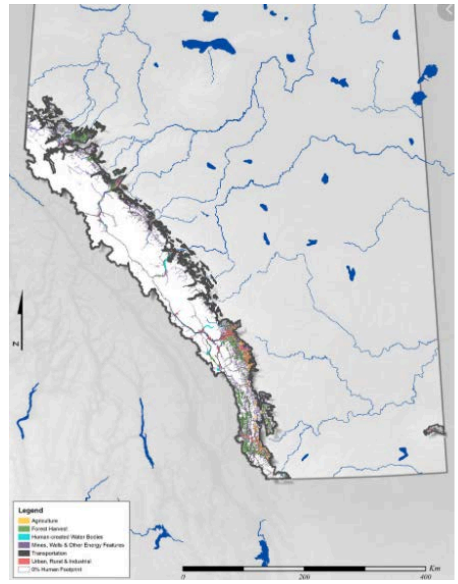


Figure 1- Rocky Mountain Natural Region (ABMI)

In terms of hydrology, the restoration site falls within the broader Bow River Basin, specifically in the Upper Bow sub-basin, which originates above Bow Lake and flows southeast to the Banff National Park boundary (Fig 2). In river valleys such as the Bow, fluvial and glaciofluvial sands and gravels form level to gently undulating terraces on valley bottoms. Regosols are typical of both terraces adjacent to the rivers and side slopes where erosion or slope movement has recently occurred.

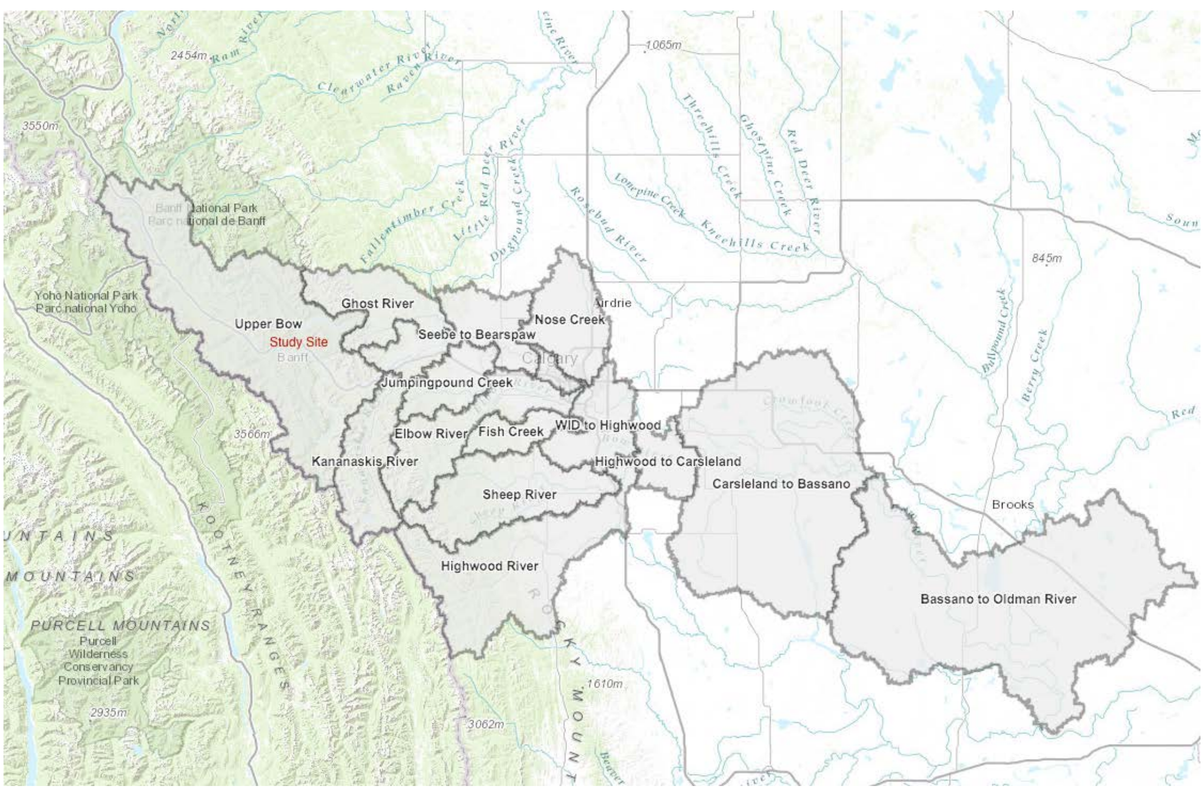


Figure 2- Map of the Bow River Basin (Source: BRBC State of the Watershed)

2.2 Ecological Land Classification

Forty Mile Creek is part of the broader Hillsdale (HD) Ecosection, which encompasses fluvial landforms dominated by Regosolic soils in the Montane Ecoregion, with surficial veneers of Eolian material. HD occurs on lower slopes and valley floors, where channeled surfaces are common. Specifically, 40 Mile Creek falls within the Hillsdale Ecosite 2 (HD2), found in the Commercial Service District, including where the Town of Banff is located. Landforms are typically alluvial fans, with slopes from 0 to 5% (Holland and Coen, 1983).

2.3 Site Location and History

Forty Mile Creek is a 133 km^2 stream system which originates in the Sawback Range in Banff National Park and meanders for approximately 25km southeast before disemboguing into the Bow River. The creek is a naturally high-energy system characterized by an intermittently braided channel with an average gradient of 3.1%, where water velocities are fast, turbulent and subject to flooding (Bartlett, 2004). Beyond this natural tendency towards fluvial perturbations, human influence and pressure on the site is longstanding and extensive, due to its proximity and relationship to the Town of Banff and as an ongoing restoration project site (Table 1). The site itself is approximately 4 km upstream of the confluence of 40 Mile Creek and the Bow, north of the TransCanada Highway and the Town of Banff at 51°11'52.0"N 115°33'41.2"W (Fig 3).

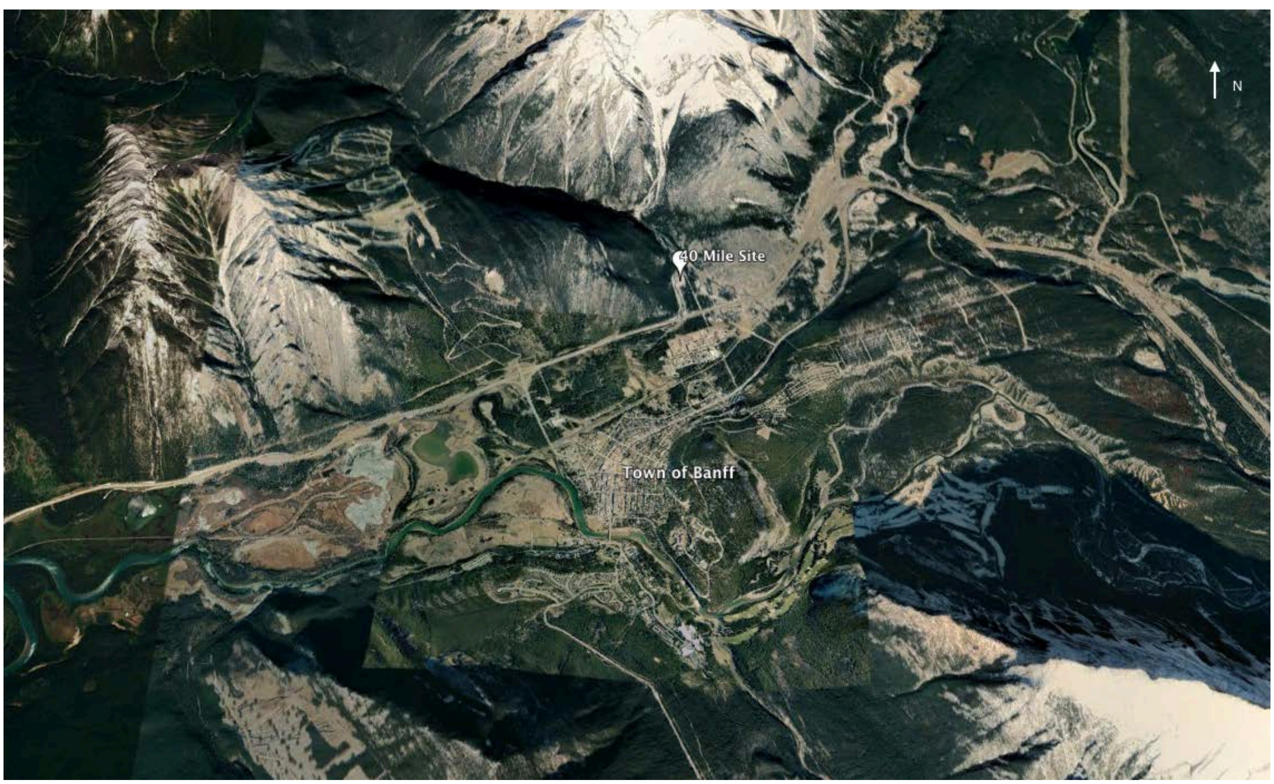


Figure 3- Location of site relative to Town of Banff (Google Earth Pro, 2020)

The site is roughly 2 hectares in size, averaging 1420m elevation, and conspicuously contrasted with its surroundings in aerial photographs due to its lack of vegetation (Fig 4), in spite of former restorative efforts (Table 1)

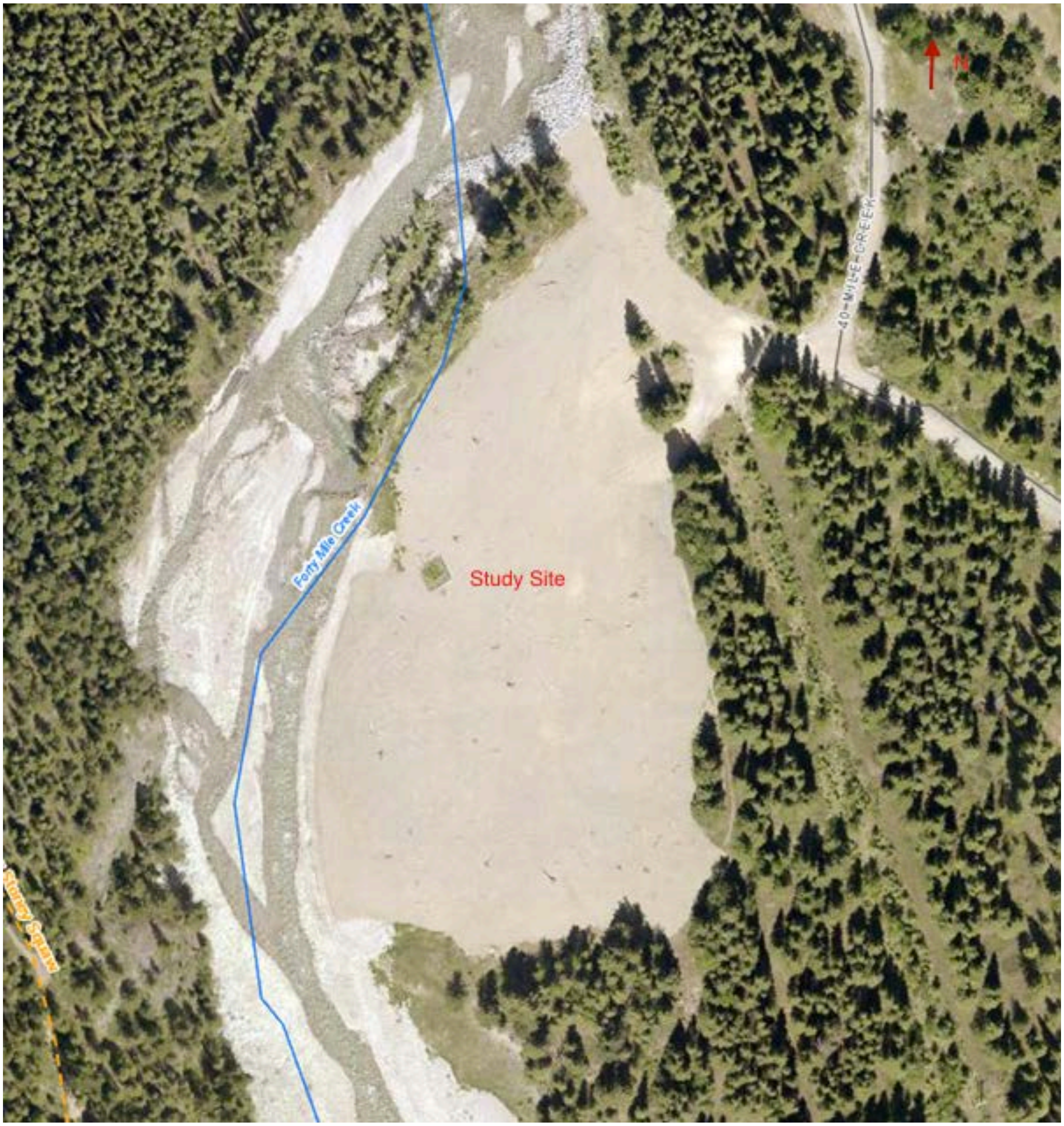
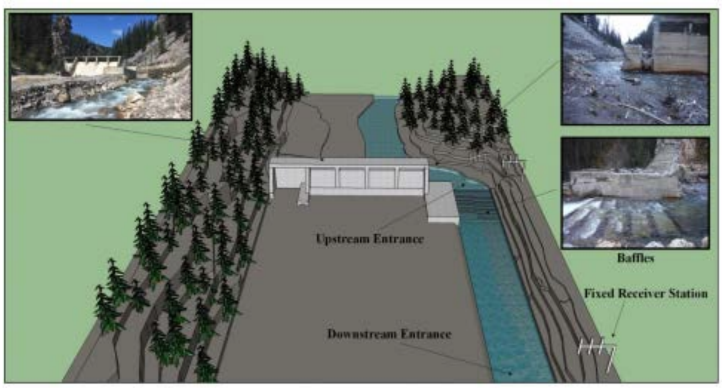
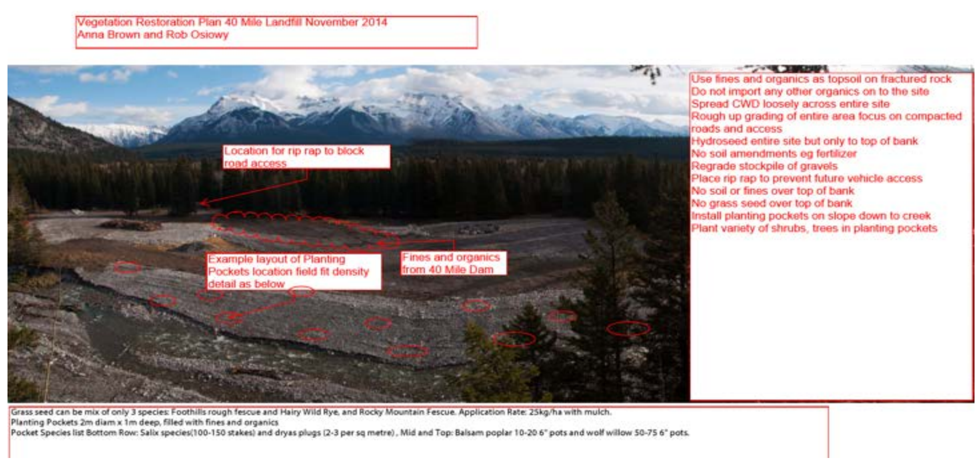
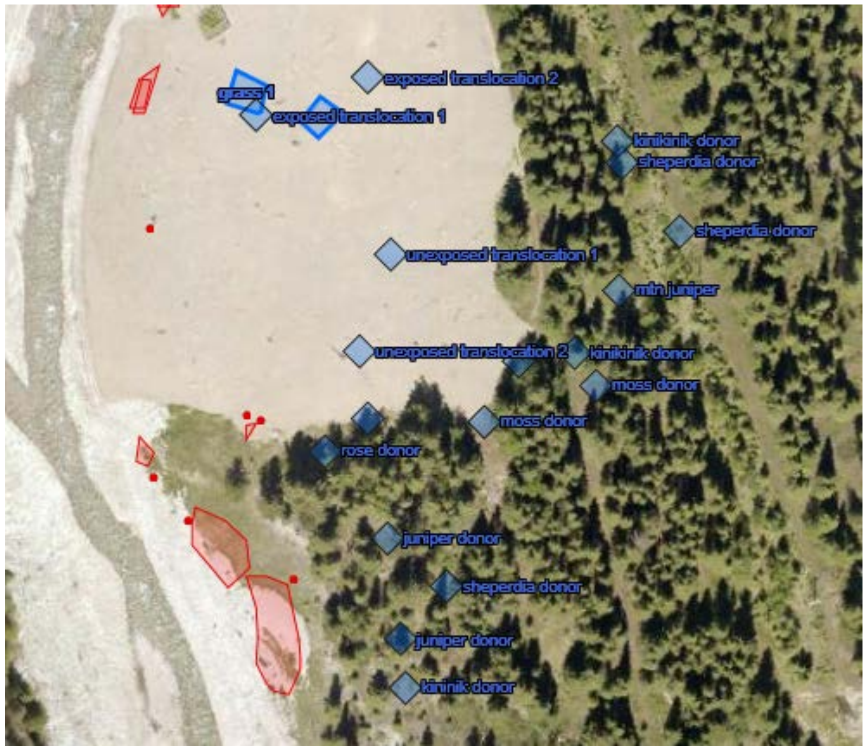


Figure 4- Aerial view of site prior to restoration, incl. 40 Mile Creek, and access road (ArcGIS, 2019)

Table 1: History of 40 Mile Restoration Site

1946	The 40 Mile Creek Dam (a few kilometres upstream of the restoration site at 50° 07'N; 96° 01'W) was built to supply the Town of Banff with drinking and firefighting water, ceasing use after deep-water wells were drilled in the 1980's.
1966-1968	A landfill was operated by the Town of Banff on the site, primarily composed of construction refuse from municipal building projects, and eventually capped.
2012	A medium-scale flood event displaced materials from the landfill downstream. In response, Parks Canada implemented a 10M wide X 50 M long riprap berm with an internal geo-membrane liner adjacent to the eroded edge of the landfill and keyed into the uplands.
2013	Catastrophic and anomalous spring flooding occurred throughout southern Alberta as a result of snowpack melt and heavy rainfall. As a result, the Bow River and its tributaries flooded much of the sub-basin, including the restoration site, which was deeply incised on the eastern slope with considerable damage to both man-made and natural structures. This was followed by a series of internally developed plans with the objectives of revegetation in the new creek bank, dealing with non-native vegetation and restoring heavily disturbed areas.
Summer 2014	 Parks Canada and Town of Banff removed a portion of the upstream 40 Mile dam creating a 'nature-like fishway' for greater connectivity (Sullivan et. al, 2019)
Fall 2014	Initial post-flood terrestrial restoration efforts included soil amendment, hydroseeding, application of coarse woody debris, as well as pocket planting of Wolf Willow (*Elaeagnus commutata*) and Sandbar Willow (*Salix exigua*). 

2017	Restoration projects focused on translocation, specifically of Moss communities (various spp, mats), Bearberry (*Arctostaphylos uva-ursi)*, Juniper (*Juniperus communis),* Buffaloberry (*Sheperdia candensis)*, and Common wild rose (*Rosa woodsii)* across 4 planting islands. Donor sites were selected based on the presence of more than 10 individuals of desired species; where maximum 10% of donor area/individuals was harvested. Harvesting and planting were carried out via standardized guidelines from Ontario Extension Notes (2000). Seeding was completed on two 10m diameter circular areas and on all donor sites at 50kg/ha.  Showing donor sites; and receptor sites (blue). Areas in red show known NNV (Canada thistle) infestations- seeding areas have blue borders. In addition to the above activities, Management Effectiveness Monitoring (MEM) was initiated for the site, where a variety of monitoring methods were planned to determine the effectiveness of these restoration activities.
2018	A volunteer-based project aimed at enhancing vegetative cover, by working the ground, seeding with native grasses and transplanting native species and improving site conditions for germination of pioneering grasses / forbs that will in turn allow other early successional species to establish on this exposed site (island planting). Activities included removal of non-native vegetation; preparation of soils surface by de compacting, raking, using shovels, moving debris; seeding by hand or with hand held seeders, digging of holes to receive transplants; placing amendment material with shovels and by hand; installing transplanted plants; moving pieces of coarse woody debris onto site; removing donor species from surrounding area; moving plant materials from trucks and surrounding areas.

3.0 2019 Assessment Methods and Results

3.1 Overview

Prior efforts to restore the 40 mile landfill, while certainly contributing to overall health of the site, have failed to initiate self-sustaining ecological integrity. This is reflected in a conspicuous lack of characteristic native vegetation cover and a riparian zone especially vulnerable to disturbance. In order to establish baseline data through which past and future restoration activities can be framed and monitored, standardized assessments were undertaken in both the riparian zone and the uplands (Fig 5). This included Riparian Health Assessment, geospatial vegetation mapping with a focus on percent cover, historical reference and photomonitoring, literature reviews on technique in highly disturbed sites, as well as a small research trial on abiotic amendment.

Figure 5- Rough boundaries of 40 Mile restoration zones

3.2 Riparian Health Assessment

Figure 6- 40 Mile RHA reach (2019)

To characterize the riparian area, a standardized Riparian Health Assessment (RHA) was undertaken for the site through the parameters set out by Alberta Riparian Habitat Management Society, comprising 13 scoring methods with visual survey techniques (Fitch, Adams and Hale, 2009). The assessment was completed in July when plants were in the active aerial growth phase for identification and flow conditions were close to average. Following their definitions of small streams, I evaluated up to bankfull width, or twice the depth of existing high water, along a ~125 m stretch of streambank, determined by pacing (Fig 6). Only the east side was assessed.

Streambank stability was evaluated by assessing species with deep binding root mass present within 10M up the floodplain. Structural alteration by human presence was estimated in percent cover, as well as stages of stream channel incisement. The first set of scoring questions quantify vegetation abundance and composition, including total percent vegetation cover of the floodplain and streambanks, as well as percent cover and density distribution of disturbance-dependant and invasive species. The latter were defined according to Cows and Fish tables as well as crossreferenced with the invasive species priority matrix obtained through internal BNP documents (see Appendix). The RHA heavily typifies the health of woody plants, taking into account the concept of 'preferred' trees and shrubs, which excludes those exclusively associated with heavy disturbance. For seedling/sapling percent cover, I estimated what percentage of the total woody canopy cover is composed the youngest age classes with guidelines of 12.5 cm stem diameter for trees, and growth that below knee height for shrubs. To establish the amount of browse I first randomly selected 2 to 3 plants of each of the preferred woody species found on the reach, finding accessible branches, and determining the browse percentage. Standing decadent and dead woody material - where decadence is >30% dead branches - was assessed. Finally, beyond quantitative scoring methods, the 'comments' section of the field sheets was used to expand on qualitative site data including a species list, rough sketch, broader visual impressions, and noting the vulnerabilities or sensitivities of the area beyond the riparian zone.

3.3 Riparian Health Assessment Results

The Riparian Health score for the delineated reach at the site was 15/60, or the extreme low end of 'unhealthy' within the scoring system (Fig 7). 5 of 13 parameters scored a zero, meaning they failed base criterion for riparian health. The site scored poorly for total vegetative cover at 35%, and consequently for the paired question of human-caused bare ground. Of especial note, structural alterations of both the reach and the streambank, particularly hardscape materials such as riprap and the subsequent absence of native woody vegetation brought the overall score down significantly. Previously planted *Salix exigua* in the high-water mark of the reach, however, contributed to a higher score for preferred tree and shrub establishment. Full scoring was only present for one question, concerning the presence of 'disturbance' species, which here included Dandelion (*Taraxacum officinale*), Yarrow (*Achillea millefolium*), Black Medic (*Medicago lupulina*), Tufted Vetch (*Vicia cracca*) and Clover (*Trifolium pratense*) in minimal abundance. Invasive species included Oxeye Daisy (*Leucanthemum vulgare*), Bluebur (*Lappula squarrosa*), and Canada Thistle (*Cirsium arvense*), which at a Class 4 distribution ranking are in the middle range of concern (see Appendix).

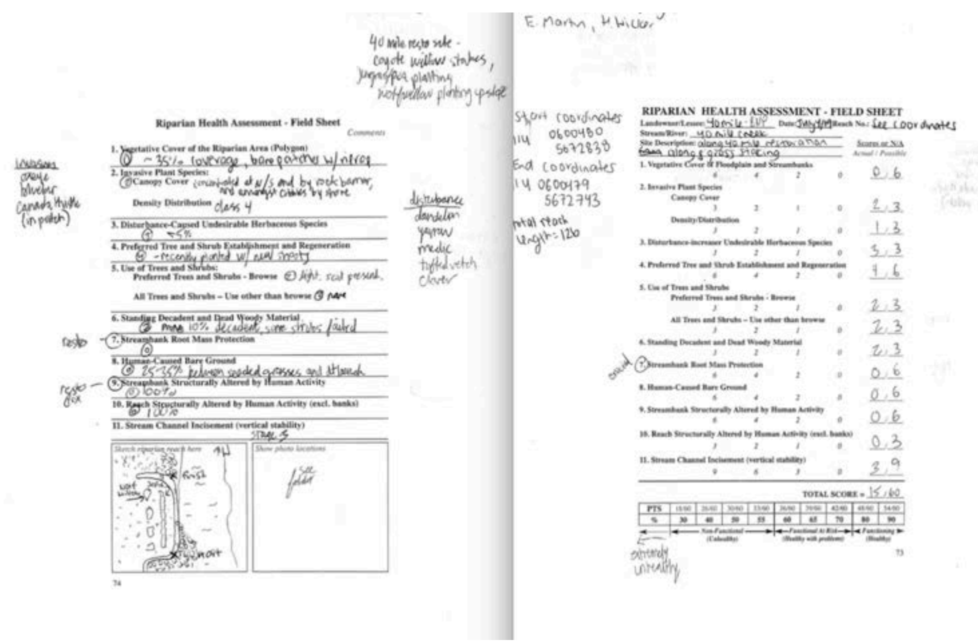


Figure 7 - RHA Field Sheets for 40 Mile Site

3.4 Uplands Assessment

A survey of the uplands (a capped landfill) was completed to determine site characteristics, abiotic barriers, as well as existent and potential species for restoration purposes. Historical reference data, particularly for characterizing the soil type of the overburden, was gathered using a 2001 Environmental Site Assessment, internal Parks documents, and referenced against Ecological Land Classification (ELC) guidelines for the broader ecosite.

Given the failures of prior restoration in establishing growth of hydroseeded grass species, a field research project undertaken in May 2019 at 40 Mile aimed to determine the amount of engineered soil medium that is required to establish native grass species on reclamation sites. A grassland seed mix from GPEC Environmental was obtained and comprised of 57% *Elymus innovatus*, 38% *Agropyron trachycaulum*, and 5% *Koeleria macranth*. Treatments included mixed soil and unmixed soil plots at depths of 1, 3, and 5 centimeters, and two controls.

Eight plot diameters (1.14 m) were drawn into the soil surface using a string (0.57 m) attached to a wooden stake. In the middle of each plot the wooden stake was secured into place, the string was pulled taught and a circle was made by walking around the stake, creating a plot perimeter. Soil depth was then measured with a ruler in each plot and dug with a spade to the appropriate depth, the soil exhumed was placed to the side for mixing. In unmixed soil plots, soil was placed back in to plots and measured to ensure proper depth. In mixed soil plots, soil was placed in a bucket where Nutriloam was added at a ratio of 1:1, the combination was thoroughly mixed, placed back into plots, and depth measured. A seeding rate of 25 kg/ha was predetermined and 13 grams of seed was hand broadcast on the soil surface of each plot and raked in (Fig 8).

Figure 8- Soil Amendment Test Plots 2019

Emergence counts (plants/0.25 m2) were tallied by placing a quarter meter squared quadrat in the middle of each plot, all emerged plants within the area of the quadrat were counted. Above ground biomass sampling was completed 120 days after planting. All emerged grass plants from within each plot (1.14m2) were cut at the crown using scissors and each plot placed separately into a paper bag to be weighed and dried. Bags were weighed immediately using a Newton Scale and left to dry in a warm well-ventilated area, and once again after biomass was deemed dry.

3.5 Uplands Assessment Results

In line with the nature of the site as a novel system, 40 Mile soil/overburden is characterized by high proportions of silt and sandy gravel (Fig 9) which reflects in vegetation groupings characteristic of poor soils – i.e. nitrogen fixing and disturbance dependant species such as Alfalfa (*Medicago sativa)* and Locoweeds (*Oxytropis spp*), and limited growth of previously hydroseeded bunchgrasses and trial plantings from prior restoration, with predominantly weedy ruderal species (Fig 10).

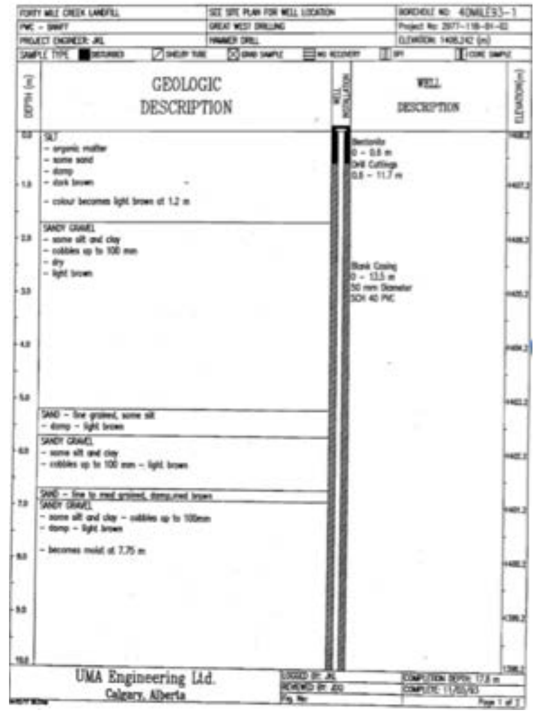


Figure 9- 2001 ESA for 40 MIle

Figure 10- Typical biotic conditions at uplands

The soil amendment plot study demonstrated that grass plants found within the control (non-amended) plots were stunted, with a marked increase in the above ground biomass in amended plots (Fig 11). In addition, more growth was observed in the plants adjacent to and in the area surrounding of the test plots, which could be a response to the increase of nutrients from the amendment and the loosening of soil allowing moisture to infiltrate into the substrate.

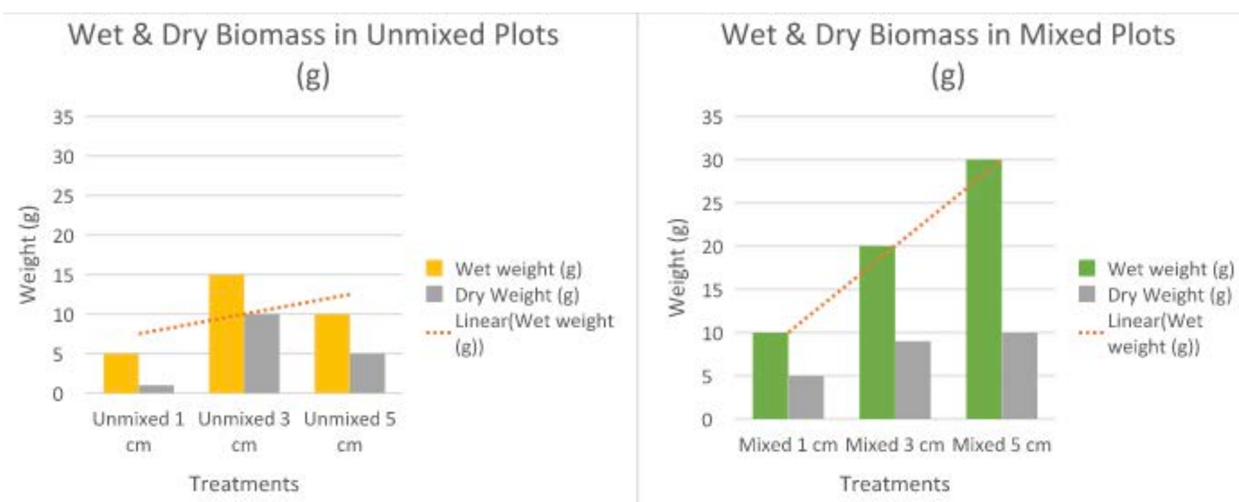


Figure 11- Biomass Results for 40 Mile Amendment Trial Plots

4.0 Restoration Methods and Materials

Given the nature of 40 Mile as a complex restoration site with layered disturbance regimes, the overarching goal for restoration in the 2019 field season was to assess and restore critical ecological processes and representative species in the riparian and upland zones. Recognizing that complete restoration would not be possible without unlimited time and materials, the focus was on initiating healthy seral processes which can be expanded upon in future seasons. An abridged restoration plan and exact timetable of 2019 activities can be found in the appendix.

4.1 Riparian Restoration

Figure 12- Live willows and poplars bundled for use on site

The objective for riparian restoration in 2019 was to stabilize and enhance the functioning of streambank and riparian reach using a living wall. There is a need to move beyond conservative factors promoted by traditional engineering for flood mitigation in Alberta, and the narrative of 'biological uncertainties' used to minimize the validity of using live materials vs. hard elements- in fact, bioengineering treatments can be integrated with geotechnical treatments to provide effective, affordable and sound bank stabilization (Barrett et al., 2006). The mechanical contribution to the soil stabilization of mature willows (*Salix spp*) and balsam poplars (*Populus balsamifera*) can increase soil cohesion up to around 0.3 m deep (Ishii, 2019). We used live willow (*Salix spp*.) and Balsam Poplar (*Populus balsamifera*) contributed via materials collected for a BFU Aquatics project (Fig 12).


Figure 13- 40 Mile living wall- successfully sprouting

Stakes and fascines were planted according to the palisade protocol set out by Polster and Bio (2016). The palisade was planted throughout the125M of riprap previously laid out in RHA boundaries (Fig 6). Excess stakes were opportunistically planted in 'pockets' of around 50 stakes at either end of the reach, as well as further upstream. Later in the season, we seeded the disturbed soil of the living wall. River beauty (*Chamaenerion latifolium*) was chosen due to its nature as a native pioneer species in riparian zones. The seed was wild-harvested from a gravel bar at nearby Cascade Ponds (Location in Appendix). Finally, we applied rooting hormone, Stim-root #2 for hardwood, diluted in water. In addition, this hand watering assured sprouting materials were kept viable during the fall season before entering dormancy.

4.2 Uplands Restoration

The objective for uplands restoration was to promote succession towards characteristic species, in this case determined through ecosite assessment to be a Montane aspen-grassland mosaic. Trembling aspen (*Populus tremuloides*) was specifically chosen for this project as an early seral species growing in parklands, forest and along forest edges, often used in restoration of riparian zones by reducing soil erosion and increasing soil nutrient from decaying leaves (Wood et al., 2013). For heavily disturbed sites with little topsoil, the best conditional framework for aspen survival involves the use of transplanted saplings from local sources with fresh soil directly removed and placed from local aspen stands (Musselman et al., 2012). As a disturbance dependent species, vegetative regeneration of Aspen can be initiated through manipulations that provide hormonal stimulation, proper growth environment, and sucker protection—the three elements of the aspen regeneration triangle (Shepperd, 2001) Small seedlings of Aspen with high RSR (root to stem ratio) appear to display the greatest stem growth and leaf area under drought stress (Kulbaba, 2014). In addition, plants were collected in guilds considering that many species directly benefit from closely associated neighbours, known as facilitation or 'nurse plants' - a phenomena which has a practical application to the restoration of degraded environments (Padilla and Pugnaire, 2006). Aspen for the 40 mile project was collected offsite with this indication in mind (Fig 14) at an offsite location with good community composition and a relatively low proportion of invasive or disturbance species (see Appendix).

Figure 14- Harvesting Aspen guild offsite for use at 40 mile

After harvesting the aspen guilds, we created 3 experimental planting islands in a depression within the uplands (Fig 15), digging in deeper depressions to encourage moisture collection. Soil was amended with Nutriloam planting medium according to the results of field test plots (~3cm) and topped with native 'hay' collected nearby to encourage moisture retention and live propagule deployment. Finally, the aspens were caged to prevent herbivory from ungulates.

Figure 15- Location of Aspen plantings, aerial (Google Earth Pro) and terrestrial view

4.3 Integrated Pest Management

In addition to the above, we managed invasive species present throughout and around site using Integrated Pest Management. Non-native vegetation pose a significant threat for sustaining ecological, cultural, and recreational values within protected areas (Foxcroft et al. 2013) and hinder populations of native species and natural ecological processes, by extension are compromising the maintenance of ecological integrity (Parks, 2008).

Figure 16- ArcGIs mapping of IPMP actions at 40 Mile 2019

As a front country site with heavy amounts of disturbance, 40 Mile is located within the Integrated Management Zone, with internal management goals of: no net increase in spatial extent/density of Rank 1-2 species or total number of NNV species where Rank 1 species for 40 Mile included Canada Thistle (*Cirsium arvense*), and Oxeye Daisy (*Leucanthemum vulgare*), and opportunistic control of Rank 3-4 species as needed according to BFU's species risk matrix (see Appendix B).

We surveyed species using the internal Parks ArcGIS spatial database, employed mechanical and chemical control at appropriate windows, and seeded with native ruderal species Fireweed (*Chamaenerion angustifolium*) and Mountain Avens (*Dryas drummondii)* late season (Fig 16).

5.0 Discussion and Recommendations

5.1 Use and Limitations of RHA

'Health' conveys functioning condition: parts working well. Riparian health connotes the ability of a waterscape, whether a stream or a watershed composed of many streams, to perform a number of key ecological functions (Fitch, Adams and Hale, 2009). In the context of the 40 mile project, health scores provided guidelines for the triage of restoration activities. The RHA is heavily focused on vegetation, and vegetation is an excellent indicator of riparian health (Modrak et al., 2017). However, while a useful tool for creating a 'snapshot' of a riparian area in time, RHA are subject to several limitations and errors, including an almost exclusive reliance on aerial/visual estimation techniques and by extension, human estimation error. Designed for landowner use, they are a less rigorous version of Riparian Health Inventories (RHI), an assessment methodology which takes into account larger sections of stream, abiotic measures such as soil status and more comprehensive measurement of bank stability. A full inventory should be included in future work at 40 Mile for ongoing data collection. Future monitoring of the riparian zone would benefit from incorporating emerging concepts in ecology to assess recovery of functionality, enhanced comparisons among projects, and longer term evaluations (>6yr) at larger spatial scales (>meander) (González et al., 2015).

5.2 Restoration Review and Monitoring

Sandy subsoil overburden at 40 mile has created an abiotic barrier for healthy seral processes. Species survival is reduced by harsh growing conditions and poor soil quality at these types of heavily disturbed sites – it is not an easy task to grow a tree on a landfill (Athy et al., 2006). Harsh conditions imply that survival of the aspen transplants in particular are uncertain. In the riparian zone, due to acquiring fresh bioengineering materials at the height of summer, planting was also done with inopportune timing for live stake success- which would ideally take place in the ephemeral seasons (Polster and Bio, 2016). Thankfully, the Banff field unit had an unusually wet season with 313 mm of precipitation, which should contribute to survival. However, considering that changing streamflow conditions in the Bow Basin create chronic stress on riparian cottonwoods and willows and restrict seedling recruitment (Perry et al., 2020; Rood et al, 2008), this must be taken into account for any riparian restoration. In the case of our 2019 project, this looked like hand-watering and applying rooting hormone throughout the season.

Future monitoring will consider 'survival as success' of live materials such as stakes and aspens, with an overarching aim of higher native vegetation cover. Quantifying success is relatively simple with the experimental aspen trial, given that there are only 3 plots. Live wall survival is more complex, but a survey of emergent live sprouts in 2020 should indicate success or failure. In addition, photo-referencing throughout the site will continue in Parks' internal folders.

The BFU Program Management Effectiveness Monitoring (MEM) assesses management in the field unit by attempting to determine if management objectives are being met. For Non Native Vegetation (NNV) we monitor trends of a) NNV diversity in each management zone b) percent cover and density of NNV species in each management zone and c) spatial extent of occurrences (infestations) in each management zone. Secondly, we track control actions for each management zone and assess the overall effectiveness of the current management plan, by monitoring the quantity of herbicide used annually and total area treated, person hours dedicated to mechanical control, and other actions taken as part of the *IPMP* (biocontrol releases or restoration activities). In terms of managing invasive plants at 40 Mile, total eradication or control of these species present at and around the site was not possible for the 2019 season given the extent of overlapping infestations, but management goals were met for no net increase.

Successful vegetation control within the site and the broader field unit will require long-term ecosystem management that addresses the underlying invasion susceptibility, as opposed to the ensuing symptoms of establishment and spread. A holistic Ecologically Based Invasive Plant Management (EBIPM) framework would aim to integrate ecosystem health assessment such as Rangeland Health Assessment, in-depth knowledge of the site's ecological processes and components, and adaptive management into a successional model (James et al., 2010). This approach emphasizes moving away from strategies focused exclusively on controlling invasive plant species and towards strategies for repair of damaged ecological processes that facilitate invasion. At 40 mile, this might look like studying the life cycle of invasive or disturbance species and what this indicates for site conditions – i.e. leguminous or nitrogen-fixing species indicate a need for fertile soil development in the uplands. Species such as Hairy goldenaster (*Heterotheca villosa*) or heavy seeding of 3-5 native forbs that are functionally similar can replace the ecological niche filled by Canada Thistle (Juneau and Tarasoff, 2013; Fasching, 2013). Controlled, repeatable field plots for these types of experiments are crucial components of EBIPM, in terms of maintaining a scientifically rigorous yet methodologically pliant approach.

5.4 Targeted Recommendations

Given the scale of disturbance which affects both the riparian zone, uplands, and surrounding areas, future restoration priorities can follow the excellent protocol set out by Macdonald et al. for forest restoration following heavy disturbance such as mining (2015).

(1) *Creating topographic heterogeneity modelled on natural systems*. Restoring landscape microtopographic features has the potential to enhance species survival and promote community development. Microtopographic restoration may be as important in riparian forest restoration as proper species selection and hydrologic reestablishment, especially at severely degraded sites (Simmons et al., 2012). In the case of 40 Mile, while total landform reconstruction may not be possible, the creation of simple microsites is within scope (i.e. using one or two loads of soil materials to create additional planting depressions in the uplands, coarse woody debris).

(2) *Facilitate soil development processes*. A moderate application rate of surface-applied amendment appears to be sufficient for aiding the development of grasses in landfill remediation (Biederman and Whisenant, 2009). This was echoed in the parallel 2019 research project field trials of soil amendment at 40 Mile, which showed that when planting native grasses onsite, it would be advisable to loosen and mix the amendment to a depth of 1cm - 5cm. Future efforts might also consider biochar as a soil amendment for marginal soils, which appears effective for increasing vegetative growth, through increasing nutrient bioavailability, contaminants immobilization, and microbial activities (Chen et al, 2016). Co-amending soils with compost plus biochar (20 T/ha + 10 T/ha) in post-mine grassland environments has been shown as more beneficial than other amendment combinations (Ohsowski et al, 2018). Biochar also has

demonstrable success for establishing and remediating tree plantings- addition of water as well as compost at the amendment site may help minimize health risks for applicators from dustiness (Lehmann and Joseph 2015).

(3) *Focus on a diversity of target ecotypes*; Rivers have coevolved and coadapted with riverine organisms, and riparian restoration must provide the opportunity for plants and animals to do something only they can do: build, maintain, and adaptively manage habitat (Johnson et al., 2020). Riparian wildlife is equally as crucial as vegetation for watercourse ecological integrity, and a 50 m-wide riparian buffer (measured from the high water mark) in its natural state (intact native vegetation) is the minimum area for supporting the majority of riparian obligate species (Stoffyn-Egli and Willison, 2011). This specification points to the potential of cross-departmental collaboration with staff from Wildlife as well as Aquatics on appropriate species lists and habitat indications for the site.

(4) *Optimize stock type and early planting techniques*; Coyote willow (*Salix exigua*) cuttings harvested in a dormant state during the fall and soaked in cold water for 14 d prior to planting had significantly greater root production after 70 d than did spring-harvested cuttings soaked for 14 d or non-soaked cuttings harvested in fall or spring (Tilley and Hoag, 2009). Collecting cuttings from multiple plants and from a known ratio of males and females will ensure that the resultant community will be able to reproduce and achieve the ultimate goal of a sustainable plant community (Landis et al, 2003). Cuttings for 2020 field season should ideally be harvested in early spring.

(5; 6) *Encourage natural regeneration/ utilization of forest floor material combined with seeding of native species*. While it is acknowledged that characteristic understory species will eventually become established through the transport of seeds by wind and animals, practitioners can accelerate the process so that the partially-restored ecosystem can more rapidly approach functionality. The use of native plant plugs is an effective means of introducing certain species to a partially-revegetated site, especially species that spread vegetatively by rhizomes or stolons. It is hypothesized that the establishment of a "nucleus" by means of a plug is likely to engender two beneficial phenomena – the spread of the species itself, and the establishment of new species within its sphere of influence (Winterhalder, 2004). Continuing to use 'island planting' methodology at 40 mile to transplant species from nearby areas is in line with best practice.

(7) *Adaptive management to encourage desired successional trajectory*. Adaptive management is a method of using monitoring to iteratively examine management alternatives (James et al. 2010). Contemporary ecological restoration practitioners must consider (1) disturbances as catalysts of rapid ecological change, (2) interactions among disturbances, (3) relationships between disturbance and society, especially the intersection of land use and disturbance, and (4) feedbacks from disturbance to other global drivers (Turner, 2010). Considering the dynamic nature of the riparian ecotone, the central question within riparian management is the 'permissible' amount of cumulative disturbance caused by either natural or anthropogenic vectors (Lee and Smyth, 2003). The historically layered 'stressor legacies' of modified riparian areas must be taken into account (Philippe et al., 2020) which in the case of 40 mile are outlined in Table 1 as well as within MEM monitoring, which should be continued onsite.

To accommodate future climate and streamflow projections, coupled with considerable uncertainty, riparian planners need to design projects with flexibility, adjust standardized methods for planting, thoughtfully control invasive species, as well as consider channel and floodplain reconstruction (Perry et al, 2015). While the latter lies outside of the scope of work for Banff's terrestrial restoration department alone, it is worth noting that bioengineering, however sound the technique, cannot not mitigate larger scale environmental degradations- riverbank restoration projects must be considered at a catchment scale (Janssen et al, 2019). This is echoed in former and current work being done within Parks to restore aquatic system health to the 40 mile site, such as the partial dam removal which successfully enhanced habitat connectivity (Sullivan et al, 2019) as well as larger projects on prescribed fire and fuel management in the area. The future of restoration within the Park lies in coherent interdisciplinary efforts.

Beyond this, restoration in protected areas must not be limited to only the scientific aspects of the biology of the restored system, but should be extended to and integrated with the social, cultural, and spiritual dimensions with which the ecological dimension are entwined (Parks Canada, 2008). For 40 Mile and other riverine systems in need of repair, attending to riparian health is much more than a technical task, being more in line with care of a composite living organism (Brierley, 2020). This approach might look like a larger 'biomic' framework (Johnson et al., 2020), or gathering local ecological knowledge. As well, it is becoming increasingly important to favour stratagem that promote reversible and incremental steps, or reflexive resource management with a capacity to modify direction as conditions continuously change. Fluvial systems such as 40 Mile Creek embody movement; so too must riparian restoration.

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7.0 Appendices

Appendix A: Cows and Fish Invasive and Disturbance Species List

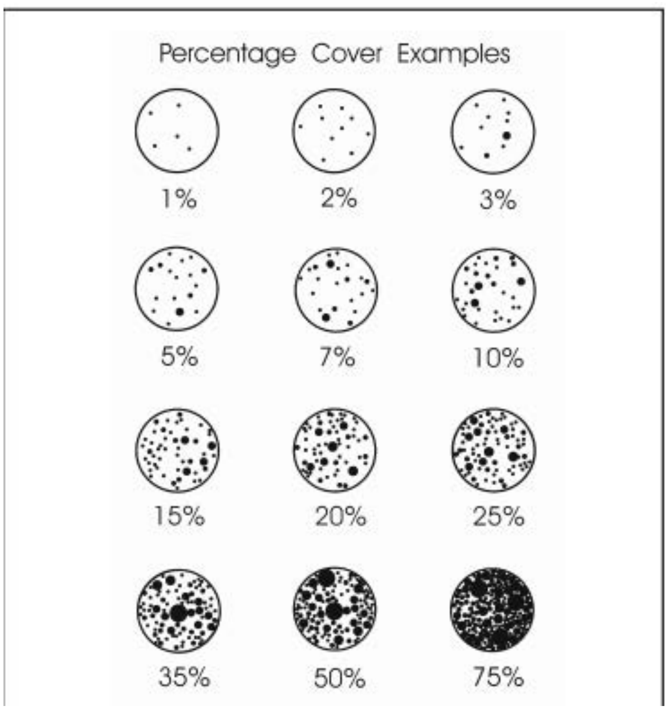
ID Code	Latin Name	Common Name	Regulated^{+}	Suggested^{x}
BROMTEC	*Bromus tectorum*	downy chess/brome	3	I
CARDCHA	*Cardaria chalepensis*	hoary cress	2	I
CARDPUB	*Cardaria pubescens*	globe-podded hoary cress	2	I
CARDNUT	*Carduus nutans*	nodding thistle	1	I
CENTDIF	***Centaurea diffusa***	**diffuse knapweed**	1	I
CENTMAC	***Centaurea maculosa***	**spotted knapweed**	1	I
CENTREP	*Centaurea repens*	Russian knapweed	2	I
CENTSOL	***Centaurea solstitialis***	**yellow star thistle**	1	I
CHRYLEU	*Chrysanthemum leucanthemum*	ox-eye daisy	2	I
CIRSARV	*Cirsium arvense*	Canada thistle	2	I
CONVARV	*Convolvulus arvensis*	field bindweed	2	I
CUSCGRO	***Cuscuta gronovii***	**common dodder**	1	I
CYNOOFF	*Cynoglossum officinale*	hound's tongue	2	I
ECHIVUL	*Echium vulgare*	viper's-bugloss; blueweed	2	I
ELAEANG	*Elaeagnus angustifolia*	Russian olive	0	I
ERODCIC	*Erodium cicutarium*	stork's bill	2	I
EUPHCYP	*Euphorbia cyparissias*	cypress spurge	2	I
EUPHESU	*Euphorbia esula*	leafy spurge	2	I
GALIAPA	*Galium aparine*	cleavers	2	I
GALISPU	*Galium spurium*	false cleavers	2	I
KNAUARV	*Knautia arvensis*	blue buttons, field scabious	2	I
LINADAL	*Linaria dalmatica*	broad-leaved/Dalmatian toadflax	3	I
LINAVUL	*Linaria vulgaris*	butter-and-eggs/ toadflax	2	I
LOLIPER	*Lolium persicum*	Persian darnel	2	I
LYCHALB	*Lychnis alba*	white cockle	2	I
LYTHSAL	*Lythrum salicaria*	purple loosestrife	2	I
MATRPER	*Matricaria perforata*	scentless chamomile	2	I
MYRISPI	***Myriophyllum spicatum***	**Eurasian water milfoil**	1	I
ODONSER	***Odontites serotina***	**late-flowering eyebright/ red bartsia**	1	I
RANUACR	*Ranunculus acris*	tall buttercup	2	I
SILECUC	*Silene cucubalus*	bladder campion	2	I
SONCARV	*Sonchus arvensis*	perennial sow thistle	2	I
TANAVUL	*Tanacetum vulgare*	common tansy	2	I
POTEREC	*Potentilla recta*	sulfur cinquefoil	0	D*
SONCOLE	*Sonchus oleraceus*	annual sow thistle	3	D
AGROREP	*Agropyron repens*	quack grass	3	D
AMARRET	*Amaranthus retroflexus*	red-root pigweed	3	D
ANTESPP	*Antennaria spp*	pussy-toes and everlastings	0	D
APOCAND	*Apocynum androsaemifolium*	spreading dogbane	2	D*
ARCTMIN	*Arctium minus*	common burdock	0	D
AVENFAT	*Avena fatua*	wild oat	3	D
BRASKAB	*Sinapis arvensis* (*Brassica kaber*)	wild mustard	3	D
BROMINE	*Bromus inermis*	smooth brome	0	D
BROMJAP	*Bromus japonicus*	Japanese brome	0	D
CAMPRAP	*Campanula rapunculoides*	creeping bellflower/garden bluebell	0	D
CAPSBUR	*Capsella bursa-pastoris*	shepherd's purse	3	D
CERSALB	*Cerastium album*	lamb's quarters	0	D
CERSARV	*Cerastium arvense*	field mouse-ear chickweed	3	D
CERSNUT	*Cerastium nutans*	long-stalked chickweed	0	D
CERSVUL	*Cerastium vulgatum*	common mouse-ear[ed] chickweed	3	D
CONVSEP	*Convolvulus sepium*	hedge bindweed/wild morning-glory	3	D
CREPTEC	*Crepis tectorum*	narrow-leaved/annual hawk's beard	3	D
DESCPIN	*Descurainia pinnata*	green tansy mustard	3	D
DESCSOP	*Descurainia sophia*	flixweed	3	D
ERUCGAL	*Erucastrum gallicum*	dog mustard	3	D
ERYSCHE	*Erysimum cheiranthoides*	wormseed mustard	3	D
FAGOTAR	*Fagopyrum tartaricum*	tartary buckwheat	3	D
FRAGSPP	*Fragaria spp*	strawberries	0	D
GALETET	*Galeopsis tetrahit*	hemp-nettle	3	D
HORDJUB	*Hordeum jubatum*	foxtail barley	0	D
LAMIAMP	*Lamium amplexicaule*	henbit	3	D
LAPPECH	*Lappula echinata*	bluebur	3	D
MALVROT	*Malva rotundifolia*	round-leaved mallow	3	D
MELISPP	*Meliotus officinalis* and *alba*	sweet clovers	0	D
NESLPAN	*Neslia paniculata*	ball mustard	3	D
PHLEPRA	*Phleum pratense*	timothy	0	D
PLANSPP	*Plantago spp*	plantains	0	D
POACOMP	*Poa compressa*	Canada bluegrass	0	D
POAPRAT	*Poa pratensis*	Kentucky bluegrass	0	D
POLYCON	*Polygonum convolvulus*	wild buckwheat	3	D
POLYPER	*Polygonum persicaria*	lady's thumb	3	D
POTENOR	*Potentilla norvegica*	rough cinquefoil	3	D
RAPHRAP	*Raphanus raphanistrum*	wild radish	3	D
SALSKAL	*Salsola kali*	Russian thistle	3	D
SCLEANN	*Scleranthus annuus*	knawel	2	D*
SETAVIR	*Setaria viridis*	green foxtail	3	D
SILECSE	*Silene cserei*	smooth catchfly/biennial campion	3	D
SILENOC	*Silene noctiflora*	night-flowering catchfly	3	D
SINAARV	*Sinapis arvensis*	wild mustard	3	D
SPERARV	*Spergula arvensis*	corn spurry	3	D
STELMED	*Stellaria media*	common chickweed	3	D
TARAOFF	*Taraxacum officinale*	common dandelion	3	D
THLAARV	*Thlaspi arvense*	stinkweed	3	D
TRIFSPP	*Trifolium spp*	clovers	0	D
VACCPYR	*Vaccaria pyramidata*	cow cockle	3	D

Appendix B: BFU Invasive Plant Ranking List

Rank (2019)	Species (Latin name)	Species (Common name)	Alberta Designation	BFU Species Target
1	*Hyoscyamus niger*	Black Henbane	Noxious	Eradicate
1	*Arctium minus*	Common Burdock	Noxious	Eradicate
1	*Tanacetum vulgare*	Common Tansy	Noxious	Eradicate
1	*Linaria dalmatica*	Dalmatian Toadflax	Noxious	Eradicate
1	*Hesperis matronalis*	Dame's Rocket	Noxious	Monitor
1	*Pilosella caespitosa*	Meadow Hawkweed	Prohibited Noxious	Control
1	*Carrdus nutals*	Nodding Thistle	Prohibited Noxious	Eradicate
1	*Pilosella aurantiaca*	Orange Hawkweed	Prohibited Noxious	Eradicate
1	*Carrdus acanthoides*	Plumeless Thistle	Prohibited Noxious	Eradicate
1	*Tripleurospermum perforatum*	Scentless Chamomile	Noxious	Control
1	*Centaurea maculosa*	Spotted knapweed	Prohibited Noxious	Eradicate
1	*Potentilla recta*	Sulphur Cinquefoil	Prohibited Noxious	Monitor
1	*Pastinaca Sativa*	Wild Parsnip	Not Listed	Eradicate
1	*Euphorbia esula*	Leafy spurge	Noxious	Eradicate
1	*Cynoglossum officinale*	Hounds-Tongue	Noxious	Eradicate
1	*Campanula rapunculoides*	Creeping Bellflower	Noxious	Eradicate
2	*Cirsium arvense*	Canada Thistle	Noxious	Containment
2	*Clematis tangutica*	Yellow Clematis	Noxious	Control
2	*Echium vulgare*	Blueweed	Noxious	Eradicate
2	*Linaria vulgaris*	Yellow Toadflax	Noxious	Containment
2	*Ranunculus acris*	Tall Buttercup	Noxious	Control
2	*Silene latifolia*	White Cockle	Noxious	Eradicate
2	*Silene vulgaris*	Bladder Campion	Not Listed	Eradicate
2	*Sonchus arvensis*	Perennial Sowthistle	Noxious	Containment
2	*Sonchus asper*	Annual Sowthistle	Not Listed	Containment
2	*Verbascum thapsus*	Common Mullein	Noxious	Eradicate
2	*Caragana pygmaea*	Pygmy Caragana	Not Listed	Control
2	*Caragana arborescens*	Common Caragana	Not Listed	Control
2	*Leucanthemum vulgare*	Oxeye Daisy	Noxious	Containment
2	*Bromus tectorum*	Downy Brome	Noxious	Containment
3	*Crepis tectorum*	Annual Hawksbeard	Not Listed	Assesment
3	*Lappula squarrosa*	Bluebur	Not Listed	Assesment
3	*Cirsium vulgare*	Bull Thistle	Not Listed	Control
3	*Senecio vulgaris*	Common Groundsel	Not Listed	Assesment
3	*Polygonum arenastrum*	Common Knotweed	Not Listed	Assesment
3	*Wester*	Dock	Not Listed	Assesment
3	*Descurainia sophia*	Flixweed	Not Listed	Assesment
3	*Brassica spp.*	Mustard	Not Listed	Assesment
3	*Papaver orientale*	Oriental Poppy	Not Listed	Assesment
3	*Matricaria discoidea*	Pineappleweed	Not Listed	Assesment
3	*Rheum rhabarbarum*	Rhubarb	Not Listed	Containment
3	*Tragopogon dubius*	Western Salsify	Not Listed	Assesment
3	*Melilotus albus*	White Sweet Clover	Not Listed	Assesment
3	*Carum carvi*	Wild Caraway	Not Listed	Assesment
3	*Melilotus officinalis*	Yellow Sweet Clover	Not Listed	Assesment
3	*Bromus inermis*	Smooth Brome	Not Listed	Assesment
3	*Phleum pratense*	Timothy	Not Listed	Assesment
3	*Chenopodium album*	Lamb's Quarters	Not Listed	Assesment
3	*Medicago sativa*	Alfalfa	Not Listed	Assesment
3	*Vicia cracca*	Tufted Vetch	Not Listed	Assesment
3	Capsella bursa-pastoris	Shepherds Purse	Not Listed	Assesment
3	*Astragalus cicer*	Cicer milkvetch	Not Listed	Assesment
3	*Papaver nudicaule*	Icelandic Poppy	Not Listed	Assesment
3	*Artemisia absinthium*	Wormwood	Not Listed	Assesment
4	*Taraxacum officinale*	Common Dandelion	Not Listed	Assesment
4	*Trifolium repens*	White Clover	Not Listed	Assesment
4	*Plantago major*	Common Plantain	Not Listed	Assesment
4	*Medicago lupulina*	Black Medic	Not Listed	Assesment
4	*Galium aparine*	Cleavers	Not Listed	Assesment
EDRR	*Pilosella spp., Hieracium spp.*	Invasive Hawkweed Complex	Prohibited Noxious	Detect/Eradicate
EDRR	*Centaurea diffusa*	Diffuse Knapweed	Prohibited Noxious	Detect/Eradicate
EDRR	*Knautia arvensis*	Field Scabious	Prohibited Noxious	Detect/Eradicate
EDRR	*Gypsophilia paniculata*	Baby's Breath	Noxious	Detect/Eradicate

Appendix C: Cows and Fish Abundance/Cover Scoring Methods

CLASS	DESCRIPTON OF ABUNDANCE	DISTRIBUTION PATTERN	SCORE
0	No invasive plants on the reach		3
1	Rare occurance		2
2	A few sporadically ocurring individual plants		
3	A single patch		
4	A single patch plus a few sporadically occurring plants		1
5	Several sporadically occurring plants		
6	A single patch plus several sporadically occurring plants		
7	A few patches		
8	A few patches plus several sporadically occurring plants		0
9	Several well spaced patches		
10	Continuous uniform occurrence of well spaced plants		
11	Continuous occurrence of plants with few gaps in the distribution		
12	Continuous dense occurrence of plants		
13	Continuous occurrence of plants associated with a wetter or drier zone within the reach		



Appendix D: Location of harvest site for River Beauty Seed

Appendix E: Location of salvage site for aspen guild clumps

Species List at Aspen Salvage Site

Grasses: *Hairy Wild Rye, Slender Wheatgrass, Smooth Brome, *Fringed Brome*	Trees/Shrubs : *Aspen, Wolf Willow, Buffaloberry, Salix spp, White Spruce, Larch, Bearberry, Common Juniper, Rocky Mountain Juniper, Snowberry, Prickly Rose*	Forbs: *Wild Strawberry, Creamy Peavine, Showy Aster, Northern Bedstraw, *Dandelion. Yarrow, American Vetch, Ragwort .*

*denotes disturbance species

Appendix F: Abridged 2019 Restoration Plan

2019 Goal: Assess and restore critical ecological processes and representative species in riparian and upland ecosites of the 40mile landfill site.

Objective 1: Stabilize and enhance the functioning of streambank and riparian reach.	*Objective 2*: Promote succession in uplands towards characteristic species.	*Objective 3:* Manage the invasive species present throughout and around site.

Strategy 1 Living wall	*Strategy 2* 'Island' planting	*Strategy 3* Integrated Pest Management
Activities: 1.1 Plant live stakes and fascines according to palisade protocol (Polster and Bio, 2016) along 125M of streambank previously laid out in RHA (Fig 6). Excess stakes planted in pockets. 1.2 Seed the disturbed soil of the living wall. River beauty (*Chamaenerion latifolium*) was chosen due to its nature as a native pioneer species in gravelly riparian zones. 1.3 Apply rooting hormone and maintain watering schedule later in season to ensure viability.	*Activities*: 2.1 Salvage species which suit site specifications 2.2 Create 3 experimental planting islands in deeper depressions to encourage moisture collection 2.3 Amend soil with planting medium according to field test plots 2.4 Top with native 'hay' collected offsite to encourage moisture retention/propagule deployment 2.5 Cage aspens to prevent herbivory from ungulates	*Activities*: 3.1 Track species – Using ArcGIS spatial database and monitoring methods 3.2 Mechanical Control- using hand pulling/whacking 3.3 Chemical Control – Using approved herbicides during appropriate window 3.4 Cultural Control – revegetation/seeding with native ruderal species appropriate to ecosite specs.
Materials: -Live willow (*Salix spp*.) and Balsam Poplar (*Populus balsamifera*) stakes contributed via excess materials collected for a BFU Aquatics project at nearby Cascade Ponds . -Planting bars/tools, loppers for cutting to length, twine, scissors for tying bundles. -River beauty (*Chamaenerion latifolium*) seed -Stim-root #2 and plastic handheld watering cans.	*Materials* -Aspen and Rose Guild, Native 'hay' (Full Species List/Salvage Location in Appendix) -Aspen cages (wire fencing, pole, zip ties, snips) -Nutriloam (10% sand, 40% peat moss, and 50% compost and pine bark) -Shovels, wheelbarrow/rolling cart, wooden stakes, twine, scissors, gloves	*Materials* -Trimble -Snips -Whackers -Garbage bags -Aminopyralid/Milestone -PPE -Seed mix with Fireweed (*Chamaenerion angustifolium*) and Mountain Avens (*Dryas drummondii)*

2019 Restoration Activities at 40 Mile

July 4	Riparian Health Assessment and site survey completed. Targeted discussion around restoration objectives for 40 Mile site amongst Fire/Vegetation staff.
July 17-18	Bioengineering of streambank using live stakes and fascines.
Aug 15	IPMP- Control of Invasive Species onsite. Mapping with Trimble/ArcGis.
Aug 20	Hand watering and photomonitoring of bioengineering project.
Oct 17	Aspen salvage offsite Upland 'island planting' of aspen guild River Beauty seeding on living wall.
Oct 24	Seeding uplands polygon (broadcast).
Ongoing/future	Monitoring and future projects.