# Blanket Creek Provincial Park weedy field restoration plan

by

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## Declaration of Committee

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## Abstract

A key management concern for provincial parks is the establishment of invasive species due to their impacts on native biodiversity. Within Blanket Creek Provincial Park there is a 0.24 ha heavily invaded field dominated by hawkweed species and spotted knapweed which developed after a series of natural and anthropogenic disturbances. Restoration actions are required to renew the ecological process of natural succession and shift the vegetation community from its current state to one dominated by native species. The aim of this project was to determine the current site conditions which will inform a restoration plan for the site and act as baseline conditions for future monitoring. This site assessment focused on the characterization of the vegetation and soil conditions. Restoration recommendations focus on promoting the development of a deciduous forest characteristic of the Interior Cedar-Hemlock biogeoclimatic ecosystem classification zone. The restoration recommendations include invasive species management, decompaction, fertilization, mulching, and the planting of native trees and shrubs.

**Keywords**: restoration, alternative stable states, invasive species, forest succession

## Acknowledgements

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Finally, I would like to acknowledge and honour the First Nations whose traditional lands I, a settler Canadian, live, study, and work within: the Sinixt, the Ktunaxa, the Secwepmec, and the Syilx as well as the unceded Traditional Coast Salish Lands of the Kwikwetlem, Musqueam, Squamish, and Tsleil-Waututh Nations.

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# List of Acronyms

| | |
|---|---|
| BC | British Columbia |
| BEC | Biogeoclimatic Ecosystem Classification |
| Bm | Modified B horizon |
| CSISS | Columbia Shuswap Invasive Species Society |
| EC | Electrical Conductivity |
| IAPP | Invasive Alien Plant Program |
| ICHdw | Interior Cedar-Hemlock dry warm variant |
| ICHmw2 | Interior Cedar-Hemlock Columbia Shuswap moist warm variant |
| ICHmw3 | Interior Cedar-Hemlock Thompson moist warm variant |
| ICHxw | Interior Cedar-Hemlock very dry warm variant |
| IPCC | Intergovernmental Panel on Climate Change |
| LFH | Organic layer formed in well-drained conditions |
| MOTI | Ministry of Transportation and Infastructure |
| NDT | Natural Disturbance Regime |
| NMDS | Non-metric multidimensional scaling |
| NPK | Nitrogen, Phosphorus, Potassium |
| RCP | Representative Concentration Pathway |
| SCL | Shearing Consultants Limited |

# Chapter 1. Project Context

## 1.1. Project Rationale

Blanket Creek Provincial Park was established in 1982 on the Arrow Lake Reservoir south of Revelstoke, BC. The park is located at the base of the Monashee Mountains in the Columbia River valley within the ancestral territories of the Sinixt, the Ktunaxa, the Secwepmec, and the Syilx (AFSR 2020). The park is 318 ha in area where approximately 26% of the park (82 ha) is designated for intensive recreation (BC Parks 2003). The remaining 235 ha is designated as natural environment as to protect aesthetic values and provide recreation opportunities in a natural environment (BC Parks 2003). A critical management issue within the park is the establishment of invasive non-native plant species that threaten native species biodiversity and wildlife habitat (BC Parks 2003). This restoration project focuses on invasive species management in a heavily invaded 0.24 ha portion of the park (Figure 1).

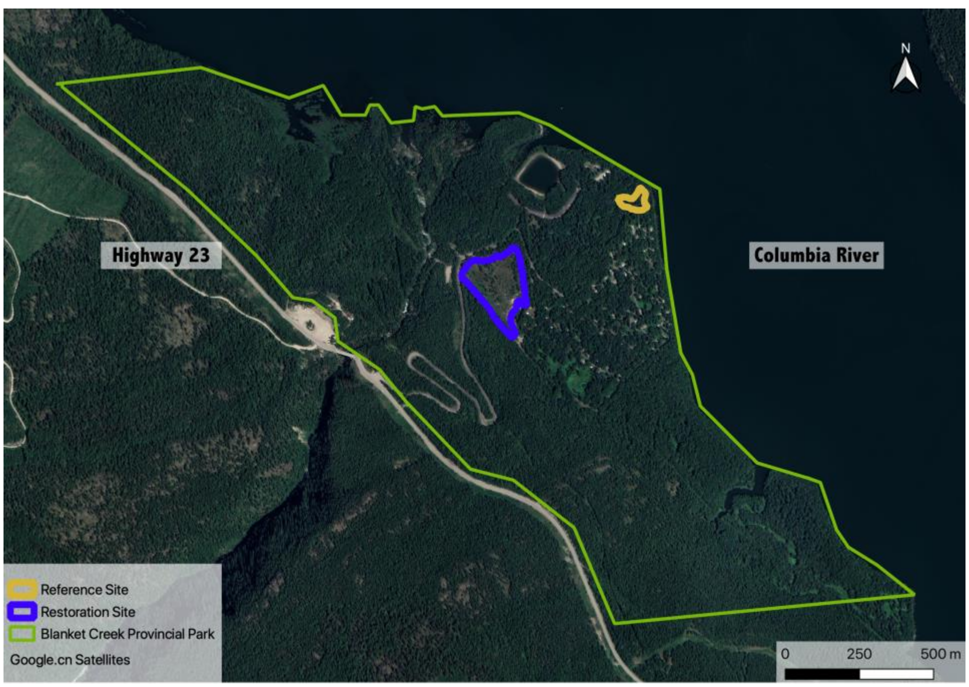


**Figure 1. Map of Blanket Creek Provincial Park outlined in green, with Highway 23 and the Columbia River labelled, as well as the restoration site is outlined in blue and the reference site in yellow. Aerial image from Google.cn Satellites 2021.**

Before establishment of the park in 1982, the site was cleared and left idle. It has since been invaded by weedy plant species, with yellow hawkweed species (*Hieracium* spp.) being dominant early in the growing season then spotted knapweed (*Centaurea stoebe*) taking over later in the growing season. Although the site was cleared over 30 years ago, it has not progressed past an early successional stage. The dominance of invasive hawkweed species and spotted knapweed may be inhibiting succession, keeping the site in its degraded state (Suding et al. 2004). BC Parks has identified that restoration actions are required to shift the vegetation community from its current state to one dominated by native species (A. Weber-Roy, BC Parks, pers. comm.)

The restoration of this site will provide many environmental and economic benefits to the Revelstoke area. The restoration of this site could eliminate an invasive species seed source which would reduce operating costs in the long term for BC Parks. In addition, Blanket Creek Provincial Park is advertised as a "great staging area for other recreational explorations" (BC Parks 2020) with nearby recreation areas including Mount Revelstoke and Glacier national parks, as well as Shelter Bay and Martha Creek provincial parks. Therefore, by eliminating this seed source of invasive species, the restoration of the Blanket Creek site will also reduce the spread of invasive species to nearby recreation areas by park visitors. The project will also create a deciduous forest, adding much needed habitat heterogeneity within the landscape largely dominated by managed conifer forests. Furthermore, this restoration project will help compensate for quality terrestrial habitat lost through the creation of the Arrow Lake Reservoir which, in 1968, flooded much of the valley bottom (BC Parks 2003).

## 1.2. Project Partners, Stakeholders, & Indigenous Peoples

Blanket Creek Provincial Park is managed by BC Parks, and this project was initiated at the request of Amanda Weber-Roy, the conservation specialist for the Interior Region of Kootenay and Okanagan. The day-to-day activities of the park are managed by West Kootenay Parks, which uses the area adjacent to the restoration site for various activities. The park is located in the Columbia Shuswap Regional District and its invasive species are managed by the Columbia Shuswap Invasive Species Society (CSISS). CSISS is one of 13 regional invasive species groups in BC who work in cooperation with the Invasive Species Council of BC to prevent the spread of invasive species within their jurisdictions (CSISS 2020). CSISS, as a registered non-for-profit, mandate is to educate and engage public and private landowners and managers, first nations, and others about invasive species and their impacts as well as to establish and carry out invasive species management programs (CSISS 2020).

In parallel with my applied research project, CSISS partnered with Shearing Consultants Limited (SCL), an environmental and project management consulting firm based in Revelstoke to develop a restoration prescription. In the fall of 2020 SCL implemented restoration efforts focusing on two areas within the site, totalling 650 $m^2$ (G. Shearing, SCL, pers. comm.). Their approach hopes to restore native plant assemblages in these areas through the addition of topsoil, reseeding, and planting of native shrubs and trees (G. Shearing, SCL, pers. comm.). Restoration actions were implemented on October 22nd 2020 and will be assessed this spring. The work implemented by SCL provides an opportunity to compare and contrast industry standard restoration practices with more experimental restoration strategies put forth in my applied research project.

Blanket Creek Provincial Park is within the traditional territories of the Sinixt, the Ktunaxa, the Secwepmec, and the Syilx. Many cultural values of the Columbia River were lost when the Arrow Lake Reservoir was created in 1968 (AFSR 2020). This restoration project entails a small step towards reconciliation, by repairing the degradation caused by European colonizers' agriculture and resource extraction activities.

## 1.3. Regional Conditions

### 1.3.1. Climate

The climate at Blanket Creek Provincial Park is considered temperate with significant amounts of rainfall based on the Köppen - Geiger climate classification system (Meidinger and Pojar 1991; Beck et al. 2018). The Columbia Mountains intercept the moist eastward flowing Pacific air, making the Monashee Mountains the wettest mountains in the interior of BC. Moist air will also often flow northward from the Columbia Basin in Washington into the region as well (Demarchi 2011). The mean annual precipitation is 1278 mm at the valley bottom, with an average of 1995 mm occurring in the subalpine zone (Braumandl 1992). This results in high humidity, with rain during the early summer and heavy snowfall in the winter (Demarchi 2011).

The northern Columbia Mountains act as a barrier to cold southerly flowing Arctic air masses, keeping winter temperatures mild, relative to the adjacent Rocky Mountains. Arctic air masses can only reach the valley during a large pressure system, so the mean minimum temperature in January, the coldest month of the year, is relatively mild at -11.6 ºC (Demarchi 2011). The number of Growing Degree Days where the temperature is above 5 ºC is 125 days (Lloyd et al. 1990). The growing season length is 202 days (Selkirk College 2021). During the summer, frost occurrences are uncommon, and the frost-free period ranges from 103 - 154 days (Lloyd et al. 1990). The mean temperature during the growing season is 13.8 ºC (Lloyd et al. 1990). These wet and mild conditions result in this area being highly productive, facilitating the formation of soil and vegetation growth.

### 1.3.2. Geology & Physiography

Blanket Creek Provincial Park is located at the base of the Monashee mountain range in the Columbia River Valley within the Columbia Mountains physiographic region. These mountains were formed through tectonic activity then further transformed by glaciation. The mountain peaks and ridges above 2100 m were not covered by the Cordilleran ice sheet during the Wisconsinan Fraser glaciation and remain as sharp bold peaks (Valentine et al. 1978). The lower summits and crest are rounded and flank deep u-shaped valleys. The Monashee and Selkirk mountain ranges are separated by glacially enlarged trenches which now contain the Arrow Lakes reservoirs and sections of the Columbia River (Valentine et al. 1978).

The Monashee mountains have a diverse geology with sedimentary, metamorphic, gneiss, and granitic batholiths rocks present throughout (Demarchi 2011). The weathering and erosion of these diverse types of bedrock influences the character of the surficial material. Surficial material is the unconsolidated sediments that have been deposited on top of the bedrock in geologically recent time (Valentine et al. 1978). The surface materials present in the Columbia River Valley were formed during and since the Wisconsinan Fraser glaciation.

At Blanket Creek Provincial Park the surficial material is primarily fluvial material (Canadian Soil Information System 2016a). Fluvial materials are transported and deposited by streams and rivers, and consist of gravel, sand, or silt. They are generally well-sorted with larger rock fragments settling closer to the bedrock and finer materials being deposited closer to the surface (Valentine et al. 1978). The gravels are typically rounded and contain interstitial sand such that the resultant texture class is coarse skeletal. Its pH is medium acid to neutral (5.6 – 7.4) (Canadian Soil Information System 2016b). This surficial material forms the mineral parent material for the soils in the park.

### 1.3.3. Soils

Within Blanket Creek Provincial Park the two dominant soil classes are orthic dystric brunisols and orthic regosols with small areas containing other types of soil (Canadian Soil Information System 2016a/b). The soil material is primarily composed of mineral particles from the weathering of surficial materials. The soils are well drained, but water drainage occurs slowly resulting in an intermediate available water storage capacity (Canadian Soil Information System 2016b). There is historically no root restricting layer that would impede water flow. Furthermore, the primary water source is precipitation and the water table is not present in the soil at any time (Canadian Soil Information System 2016b).

The effects of the soil formation processes create different horizontal layers, called horizons. Each horizon differs from the next due to their unique physical, chemical, and biological properties (Valentine et al. 1978). In mineral soils there are generally three major horizons: A, B, C (Table 1). Organic soil horizons form in well aerated environments when vegetation falls to the ground, accumulate, and decompose on top of the mineral soil layer to form the LFH layers (Valentine et al. 1978: Table 2). These layers are typically shallow and poorly incorporated into the mineral soil.

**Table 1. Major mineral soil horizons as defined by the Soil Classification Working Group (1998).**

| Horizon | Definition |
|---|---|
| A | Forms at or near the surface in the zone of either:<br>(1) leaching or eluviation of materials in solution or suspension<br>(2) maximum in situ accumulation of organic matter |
| B | Characterized by one or more of the following:<br>(1) enrichment in organic matter, sesquioxides, or clay<br>(2) development of soil structure<br>(3) change of color denoting hydrolysis, reduction, or oxidation |
| C | parent material with minimal modification |

**Table 2. Organic soil layers within a dry environment as defined by the Soil Classification Working Group (1998).**

| Layer | Definition |
|---|---|
| L | Accumulation of organic matter in which the original structures are easily discernible. |
| F | Accumulation of partly decomposed organic matter where some of the original structures are difficult to recognize. The material may be partly comminuted by soil fauna as in moder, or it may be a partly decomposed mat permeated by fungal hyphae as in mor. |
| H | Accumulation of decomposed organic matter in which the original structures are indiscernible. This horizon differs from the F by having greater humification due chiefly to the action of organisms. It is frequently intermixed with mineral grains, especially near the junction with a mineral horizon. |

Both brunisols and regosols soil types are typically found on geologically young sediments, relative to other soil types, so the time available for soil development since deposition has not been sufficient for anything more than a moderate amount of weathering to have taken place. Since the surficial materials present at the Blanket Creek Provincial Park generally consist of gravel and sand with a minor fraction of silt but minimal clay, little chemical weathering has taken place as the negative charge of clay particles promote chemical reactions (Canadian Soil Information System 2016b). Furthermore with a low fraction of clay in the parent material the water-holding capacity of the soil is low so chemical reactions that take place in aqueous solution are restricted

(Acton et al. 1976). Therefore, the primary method of weathering is physical. These soils are often regarded as being in a transitional stage of development, that given time translocation of weathering products will begin within the soil to produce podzols or luvisolic soils (Valentine et al. 1978).

Orthic dystric brunisol are within the brunisolic soil order which are characterized by having only undergone moderate development from the original parent material. Physical, chemical, and biological weathering has proceeded far enough to change the morphology of the parent material but there are no drastic translocation or transformations of the material. The main process involved in the formation of brunisolic soils are (1) the leaching of soluble salts and carbonates, (2) the in situ weathering of the mineral fraction to form secondary minerals, and (3) the development of soil structure of the parent material (Acton et al. 1976). These are the processes that form the Bm horizon which is the diagnostic horizon of brunisolic soils. Orthic dystric brunisol soils typically have three main horizons, the organic LFH layer, the modified B horizon (Bm), and the C horizon (Valentine et al. 1978). The Bm horizon is typically over 5 cm thick, with a pH of less than 5.5, and brownish coloured (Canadian Soil Information System 2016b). This soil type lacks an eluvial horizon and mottles as it is well drained (Canadian Soil Information System 2016b).

Orthic regosols soils are weakly developed as they typically sit on very young fluvial deposits often in the flood plains of river valleys such as the Columbia River valley (Valentine et al. 1978). They have a small amount of organic matter in the LFH layer but thin or absent A and B horizons. The C horizon is the diagnostic horizon with no evidence of gleying within the upper 50 cm of the soil profile as the soil is well drained (Canadian Soil Information System 2016a).

### 1.3.4. Vegetation

At 400 – 600 m in elevation, Blanket Creek Provincial Park occurs within the Thompson moist warm variant (ICHmw3) of the Interior Cedar - Hemlock Biogeoclimatic Zone. The Interior Cedar Hemlock forest of the central Columbia Mountains hosts the highest tree diversity of all the BEC zones in BC (Braumandl 1992). The valleys and lower slopes are dominated by moist Interior Cedar Hemlock forests which grades into a moist Engelmann Spruce – Subalpine Fir forest at higher elevations. (Demarchi 2011).

The Biogeoclimatic Ecosystem Classification (BEC) system delineates ecological zones by climate, soils, and vegetation, and is mostly used in forestry (Banner 2016). This classification system provides the basis for characteristic vegetation that should be found at Blanket Creek Provincial Park.

Mature forest stands are dominated by western red cedar (*Thuja plicata*) and western hemlock (*Tsuga heterophylla*) in this BEC zone. Seral tree species include Douglas-fir (*Pseudotsgua menziesii*), lodgepole pine (*Pinus contorta*), and paper birch (*Betula papyrifera*), as well as the western white pine (*Pinus monticola*) which is found particularly on drier sites (Lloyd et al. 1990). The shrub and herb layers are typically sparsely vegetated as the dense forest canopy shades the forest floor. The few herbaceous species present are usually falsebox (*Paxustima myrsinites*), prince's pine (*Chimaphila umbellate*), twinflower (*Linnaea borealis*), and queen's cup (*Clintonia uniflora*) (Lloyd et al. 1990).

## 1.4. Site-Specific Impacts & Stressors

The area now known as Blanket Creek Provincial Park has had a complex history of disturbance which has led to a suite of site-specific impacts and potential stressors that may influence restoration efforts. The Columbia River Valley's primary old growth forest was logged in the 1800s, leaving behind large stumps of western red cedar and western hemlock (BC Parks 2003). A fire then burnt through the valley in 1907 which resulted in a thick regrowth of devil's club. This condition was noted by the homesteaders Oscar and Asaph Domke who settled the area in 1933 (BC Parks 2003). They collectively purchased 65 hectares within today's park boundary to raise cows, horses, chickens, geese, and ducks. They also had hay fields, large vegetable gardens, and fruit trees. In order to farm the land they had cleared the remaining western red cedar and western hemlock stumps using dynamite and then used a small caterpillar pull to help clear the remaining vegetation and work the soil (A. Weber-Roy, BC Parks, pers. comm.).

In the early 1960s, the homesteaders' land was purchased by BC Hydro in preparation for the flooding of the Columbia River Valley after the construction of the Kinnleyside Dam at Castlegar, however this area remained above the new water level. Following this, areas within the park were used for gravel quarrying development by the

BC Ministry of Transportation and Highways (now the Ministry of Transportation and Infrastructure (MOTI)). Prior to the gravel extraction, the remaining trees on site were removed and either used as firewood in the park or piled into slash piles and burnt (MOTI unpub. data.). The overburden was stripped to a depth of 20 cm and stockpiled. The gravel pit depth was 3.5 to 4.0 meters below the original ground elevation, and the extracted gravel was removed from the site and stockpiled in another area outside the park closer to highway 23. The pit faces were reduced to a ratio of 1 to 2 after the completion of the extraction and the stripped overburden was spread evenly throughout the excavation area. It is unlikely that further restoration efforts were undertaken (A. Weber-Roy, BC Parks, pers. comm.).

In 1997, all remaining homesteading buildings present within the park were either burned or dismantled and relocated. This burn site became the service yard of the park, where debris has continued to be burnt by park staff (A. Weber-Roy, BC Parks, pers. comm.). Presently, the only remnants of the heritage homestead are a variety of orchard trees located nearby the restoration site (BC Parks 2003). Currently, BC Parks is engaged with MOTI to discuss the extinguishment of the permits for gravel extraction within the park allowing for this area to be protected in perpetuity (A. Weber-Roy, BC Parks, pers. comm.). These primarily anthropogenic disturbances have been discrete pulse events in the past, but once the gravel extraction permit has expired and BC Parks is able to protect the site from further development, this source of anthropogenic disturbance will no longer be impacting the restoration site.

In addition to this history of impacts, the site is also under the pressure of two persistent stressors; changes to the natural disturbance regime and anthropogenic climate change. In BC, since the settlement of the area by European colonizers, there have been changes to the natural disturbance regimes. While, this definition of natural disturbances includes Indigenous Peoples land management activities, it is unknown what, if any, pre-contact land management activities occurred in the area now known as Blanket Creek Provincial Park (Gayton 2001). In general, as the land became managed by settlers, the historic patterns of fire, insect, wind, landslides, and other natural processes in the area changed (Banner 2016). Furthermore, anticipated climate change will likely increase the natural disturbances, such as from fire and pests, further altering the historical natural disturbance regime (Selkirk College 2021). The Natural Disturbance Types (NDT) as defined by the Forest Practices Code Biodiversity Guidebook indicate the landscape level patterns of disturbance prior to colonization (FSBC 1995). The ICHmw3 BEC zone is considered to be in the NDT3 category as an ecosystem with frequent stand-initiating events. These forests typically experience frequent wildfires that range from small spot fires to some of the largest fires in the province often exceeding 100 000 hectares. There are also frequent outbreaks of defoliating insects and extensive presence of root diseases. The mean disturbance return interval is approximately 150 year. Successional stage classification are divided into ‘early’ at less than 40 years, ‘mature’ at greater than 100 years and ‘old’ at greater than 140 years since the stand-initiating disturbance event (FSBC 1995). With the last known natural disturbance event having occurred in 1907, when a fire burnt the valley, a mature vegetation community should be present at the restoration site if anthropogenic disturbances had not occurred.

Additionally, climate change will be a persistent press disturbance affecting the site. The Canadian Columbia basin, which encompasses Blanket Creek Provincial Park, is already experiencing hotter, drier summers, with warmer, wetter winters, as well as more extreme weather, relative to the 1951 – 1980 baseline conditions, with these trends expected to continuing into the future (Selkirk College 2021). The Intergovernmental Panel on Climate Change (IPCC) ‘business as usual model’ of the Representative Concentration Pathway 8.5 (RCP 8.5), indicates that by 2050 there will be changes to the mean daily temperature, total precipitation, and growing season length. The mean daily temperature in the summer will have increased from 16.8 to 19.4 ºC with days having a maximum temperature above 25 increasing by 42 days from 48.5 to 73.3 days (Selkirk College 2021). Total summer precipitation will have decreased 24% from 169 to 150 mm with the longest average dry spell remaining 16 days (Selkirk College 2021). The length of the growing season will increase from 201.8 to 223.3 days (Selkirk College 2021). These changes to the growing conditions of the area will impact both the vegetation and soil formation processes. Climate change can also reduce a systems capacity for recovery from other impact events (Palmer et al. 2016). The combined effects of multiple stressors and impacts act synergistically, shifting ecological dynamics towards hysteresis, a degraded alternative stable state (Tockner et al. 2010). Therefore this site appears to be unable to undergo the expected ecological process of succession and remains in its degraded state.

# Chapter 2. Current Site Conditions

In order to determine the current site conditions, I undertook an assessment of the soil and vegetation present on site. This section outlines the methods I used for the assessment and the results obtained, followed by a brief discussion of the implications. A portion of the assessment was carried out weekly from June 24th until August 21st 2020, and then the remainder of the assessment was completed during a field visit on October 9th and 10th 2020.

## 2.1. Vegetation

### 2.1.1. Vegetation Density, Distribution, & Cover

Vegetation density, distribution, and percent cover were assessed with 1$m^2$ quadrats for the herb layer and 16 $m^2$ quadrats for the shrub and tree layer. For the herb layer, all herbaceous plants were considered in this layer. For the shrub and tree layer the woody species of all heights were assessed. The density of plants and relative abundance was assessed as the number of stems within the quadrats over the entire restoration site. The distribution of herbaceous and woody plant species within the quadrats was determined using British Columbia's Invasive Alien Plant Program (IAPP) designation of distribution categories (Table 3). This classification method was selected as the IAPP database is used by a wide variety of governmental agencies and non-government organizations (R. Hooper, CSISS, pers. com.). Percent cover, the proportion of an area covered by a species of interest, was visually estimated using overlapping cover estimates to determine the plant species of structural importance.

**Table 3. Distribution codes as specified by the provincial IAPP to categorize the distribution of plants in an area.**

| Code | Description |
|---|---|
| 1 | rare individual, a single occurrence |
| 2 | few sporadically occurring individuals |
| 3 | single patch or clump of a species |
| 4 | several sporadically occurring individuals |
| 5 | a few patches or clumps of a species |
| 6 | several well-spaced patches or clumps |
| 7 | continuous uniform occurrence of well-spaced individuals |
| 8 | continuous occurrence of a species with a few gaps in the distribution |
| 9 | continuous dense occurrence of a species |


**Figure 2. Map of the vegetation sampling points (*n = 14*) within the restoration site at Blanket Creek Provincial Park. Aerial image from Google.cn Satellites 2021.**

Within the restoration site, 14 survey locations as shown in Figure 2 were randomly selected using the Unstratified Sampling Design research tool in QGIS (QGIS Development Team 2020). At each survey location the bottom left corner of both the 1m$^2$ and 16 m$^2$ quadrats were placed (Figure 3). Plant species were identified using Plants of Southern Interior British Columbia & the Inland Northwest (Parish et al. 1996) and Northwest Weeds: The Ugly and Beautiful Villains of Fields, Gardens, and Roadsides (Taylor 1990). Within the herb layer vegetation surveys, many quadrats contained grasses, sedges, and mosses, however they were not identified due to lack of expertise.

**Figure 3. Example of the nested quadrats used for the vegetation assessment, with the smaller 1m$^2$ quadrat used to evaluate the herb layer and the larger 16 m$^2$ quadrat to evaluate the shrub and tree layer.**

### *Herbaceous Layer Results*

Within the restoration site, all 14 vegetation survey locations contained herbaceous plants that were surveyed using 1 m$^2$ quadrates. A full species list can be found in the Appendix. The most frequently observed plants were from the genus hawkweed (*Hieracium* spp.), the hawkweed plants were not distinguishable to the species level as the plants had gone to seed during the survey period. The hawkweed species were found in 9/14 quadrats (67%) and had the highest relative abundance (44%) and cover (24%) across all plots (Figures 4, 5, 6, & 7). While, most species were distributed as clumps within the quadrat, the hawkweed species displayed the most continuous distribution, categories 7 and 8 within the IAPP distribution scale, in the plots in which they were detected. The next most common species was spotted knapweed (*Centaurea stoebe*; formerly *Centaurea maculosa*) found in 7/14 quadrats (50%) with a relative abundance of 33% and cover of 19%. Spotted knapweed was the only species to achieve 100% cover in one of the 1 m$^2$ quadrats where 243 stems were counted and its distribution was categorized as a continuous dense occurrence of a species (Figure 5). Spotted knapweed also showed evidence of a biocontrol species on many of the plants examined, which were likely to be either *Larinus minutus* or *Larinus obtusus* based on the observed beetle location on the flower head (Figure 8). The next most frequently observed herbaceous species was bird's foot trefoil (*Lotus corniculatus*) and oxeye daisy (*Leucanthemum vulgare*) in 4/14 quadrats (27%), then pearly everlasting (*Anaphalis margaritacea*) and spreading dogbane (*Apocynum androsaemifolium*) in 2/14 quadrats (14%). The remaining species, hairy vetch (*Vicia villosa*), aslike clover (*Trifolium hybridium*), black medick (*Medicago lupulina*), bracken fern (*Pyeridium aquilinum*), sheep sorrel (*Rumex acetosella*), St John's wort (*Hypericum perforatum*), and white clover (*Trifolium repens*) were only found in 1/14 quadrat (7%).

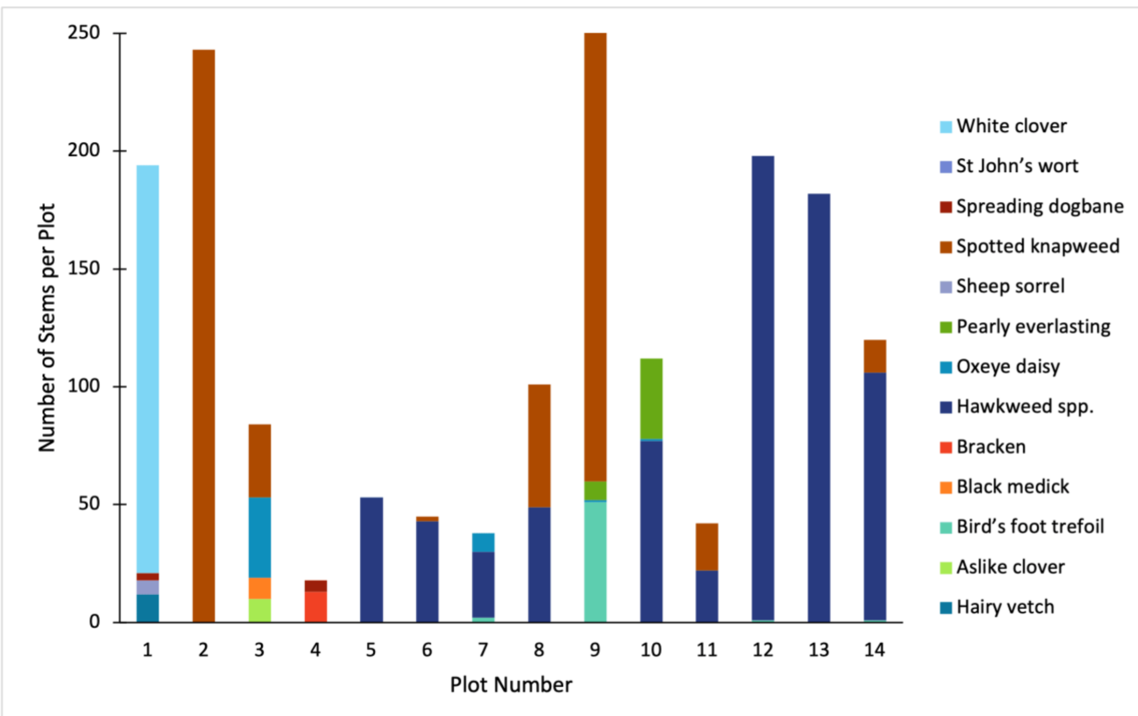


**Figure 4.** **Density (number of stems per 1 m$^2$) of herbaceous species sampled between June 24th and August 21st 2020 at the restoration site in Blanket Creek Provincial Park.**

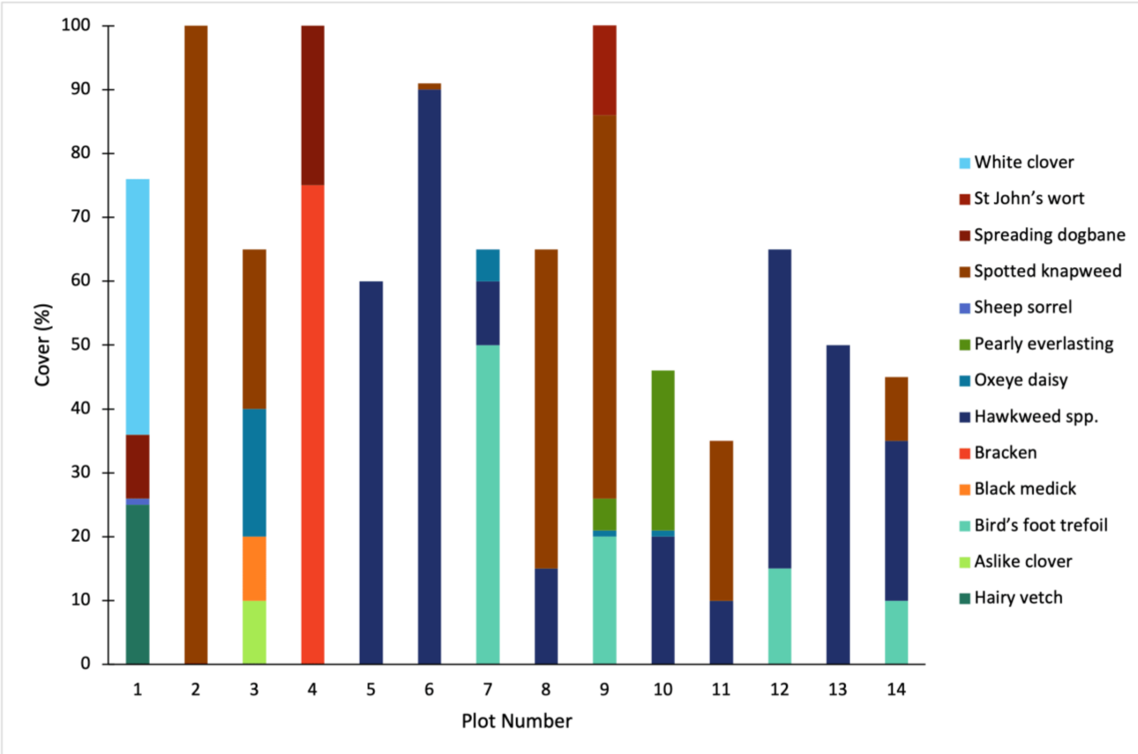


**Figure 5.** **Percent cover of each herbaceous species in each 1 $m^2$ plot sampled between June 24th and August 21st 2020 at the restoration site in Blanket Creek Provincial Park. Plots with less than 100% cover contained mosses, grasses, sedges, and bare ground which were not considered.**

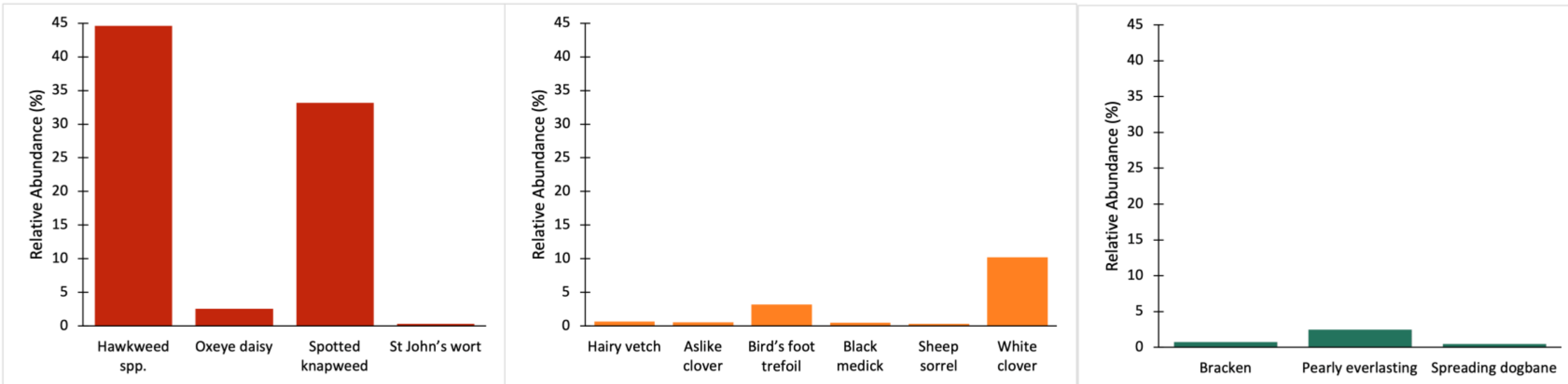


**Figure 6.** **Mean relative abundance of herbaceous plant species in three groups: invasive species in red, non-native species in orange, and native species in teal. Results are from vegetation surveys (*n = 14* quadrats of 1 $m^2$ size) of the restoration site in Blanket Creek Provincial Park, conducted between June 24th and August 21st 2020.**

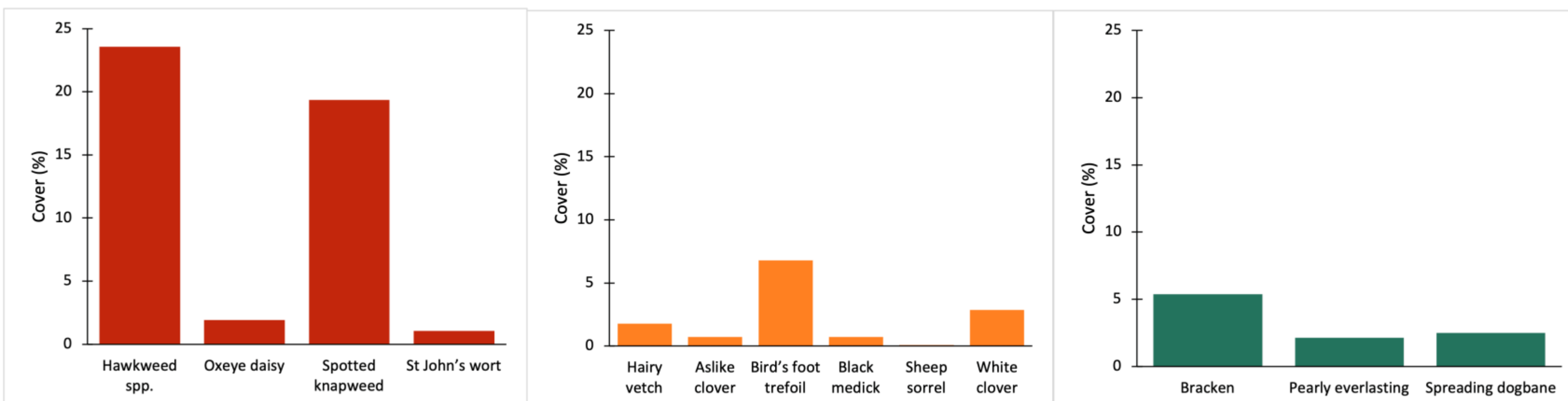


**Figure 7.** **Mean percent cover of herbaceous plant species in three groups: invasive species in red, non-native species in orange, and native species in teal. Results are from vegetation surveys (*n = 14* quadrats of 1 $m^2$ size) of the restoration site in Blanket Creek Provincial Park, conducted between June 24th and August 21st 2020.**

**Figure 8. Spotted knapweed (*Centaurea stoebe*) with beetles congregating on the flower head observed on August 6th 2020 at the restoration site in Blanket Creek Provincial Park. The beetles are likely a biocontrol agent, either *Larinus minutus* or *Larinus obtusus* (Powell et al. 1994).**

Within the herb layer vegetation surveys, many quadrats contained grasses, sedges, mosses, and bare ground. While two dominant species of mosses were identified as false haircap moss (*Timmia austriaca*) and golden star moss (*Campylium stellatum*), several other types were observed but were not identifiable. False haircap moss was identified in 2/14 of quadrats (14%) covering an average of 11 % of the 1 $m^2$ area with a distribution of a few patches or clumps of a species. Golden star moss was identified in 3/14 of quadrats (21%), covering an average 37% of the 1 $m^2$ area with a distribution of several well-spaced patches or clumps. Grasses and sedges were found in 8/14 quadrats (57%) but unfortunately were not identified due to lack of expertise.

### *Shrub & Tree Layer Results*

Of the 14 vegetation survey locations, only nine contained woody species in the shrub and tree layer. The most common species observed was the western white pine (*Pinus monticola*) occurring in all quadrats containing woody species and 9/14 of all 16 $m^2$ quadrats assessed (65%) (Figure 9). Western white pine was found to have the highest relative abundance at 32% and highest cover at 14% (Figures 10, 11, 12). The next most common woody species identified was interior Douglas fir (*Pseudotsuga menziesii*) 3/14 quadrats (21%), followed by black cottonwood (*Populus trichocarpa*) in 2/14 of quadrats (14%). The remaining species, Bebb's willow (*Salix bebbiana*), Nootka rose (*Rosa nutkana*), saskatoon (*Amelanchier alnifolia*), and tea-leaved willow (*Salix planifolia*) were present in only 1/14 quadrats (7%). Black cottonwood, Nootka rose, and tea-leaved willow were found growing in clumps, while the other species were distributed as few sporadically occurring individuals and has less than 4% cover at the restoration site (Figure 12). So while the composition of the shrub and tree layer was all desirable native species, the overall coverage was low. In addition many of the western white pine trees appeared unhealthy with dead needles, the presence of galls and evidence of fungal rot (Figure 13). This could be indicative of the presence of western gall rust (*Endocronartium harknessii*), commandra blister rust (*Cronartium comandrae*), atropellis canker (*Atropellis piniphila*), and/or pine needle cast (*Lopherdermella concolor*) (Allen et al. 1996).

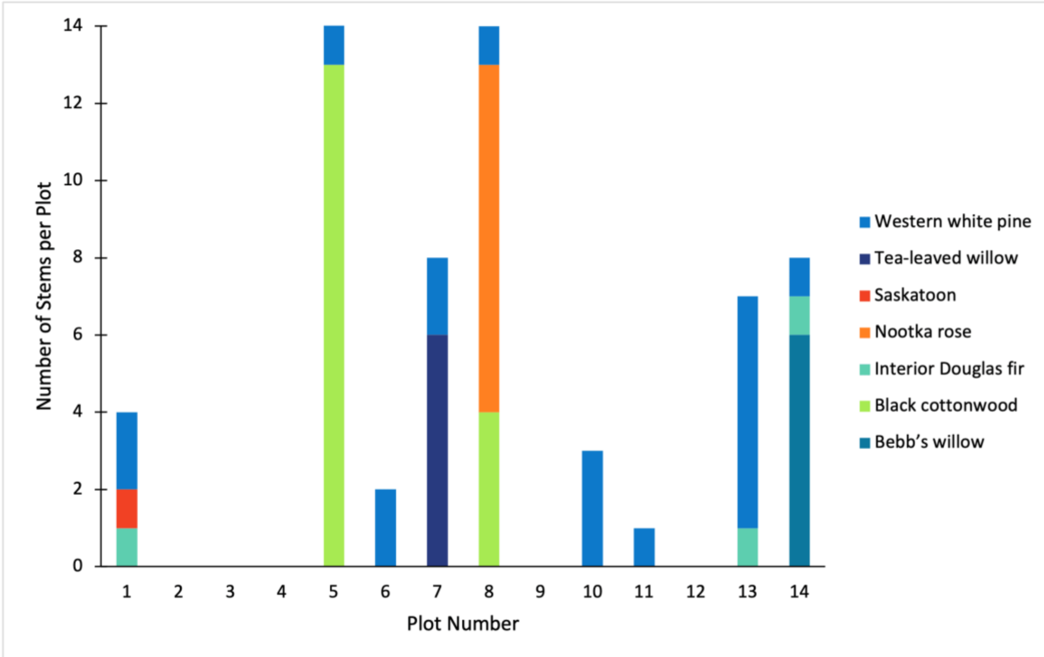


**Figure 9.** **Density (number of stems per 16 $m^2$) of woody species sampled between June 24th and August 21st 2020 at the restoration site in Blanket Creek Provincial Park.**

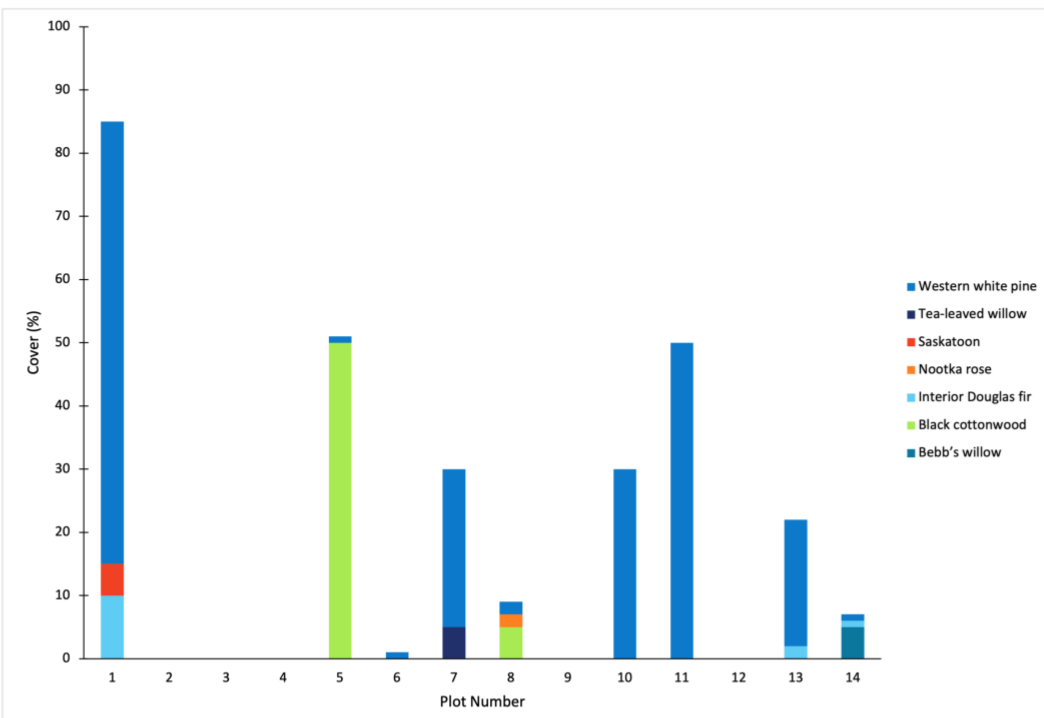


**Figure 10.** **Percent cover of each woody species within each 16 $m^2$ plot sampled between June 24th and August 21st 2020 at the restoration site in Blanket Creek Provincial Park. Plot with less than 100% cover contained areas without woody species, while plots with 0% cover contained no woody species.**

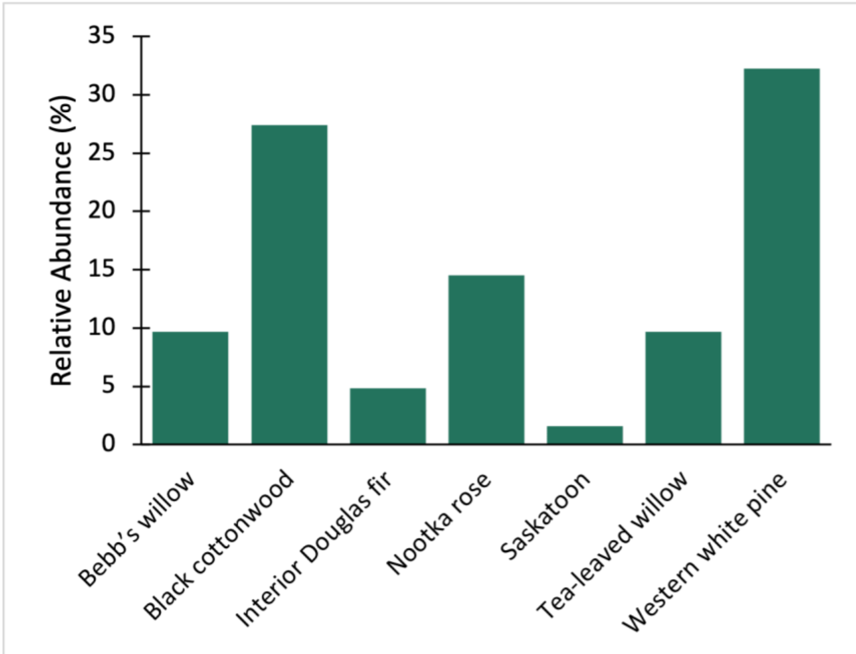


**Figure 11.** **Relative abundance of each woody species observed during vegetation surveys (*n* = *14* 16 $m^2$ quadrats) of the restoration site in Blanket Creek Provincial Park, between June 24th and August 21st 2020. All woody species observed were native so are represented in teal.**

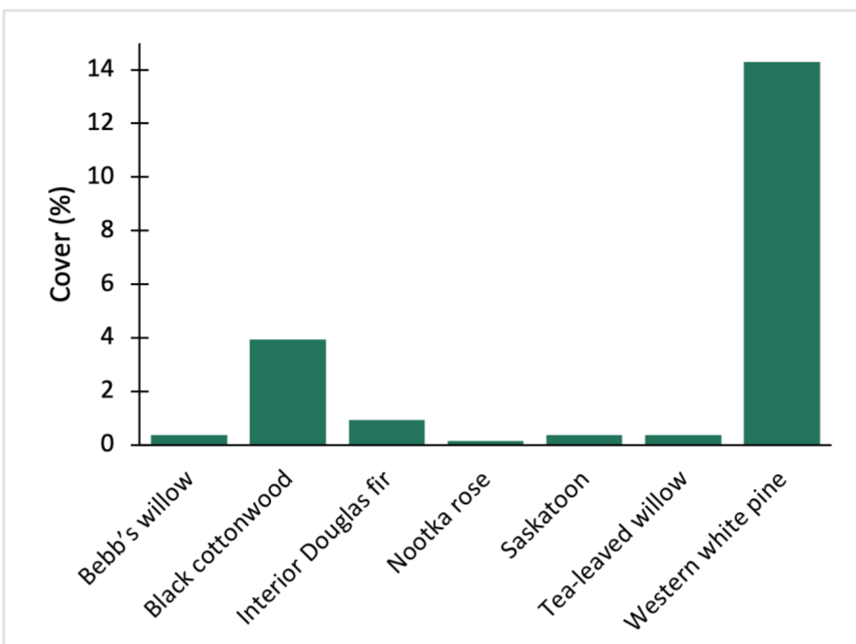


**Figure 12.** **Mean percent cover of woody plant species observed during vegetation surveys (*n* = *14* 16 $m^2$ quadrats) of the restoration site in Blanket Creek Provincial Park, between June 24th and August 21st 2020. All woody species observed were native so are represented in teal.**

**Figure 13. Select observations made between June 24th and August 21st 2020 of unhealthy western white pine trees found at the restoration site within Blanket Creek Provincial Park. This could be indicative of the presence of western gall rust, commandra blister rust, atropellis canker, and/or pine needle cast (Allen et al. 1996).**

## 2.1.2. Implications of the Vegetation Assessment

Within the herb layer there were three categories of vegetation detected, priority invasive species, non-native species, and native species (Figures 6 & 7). Priority invasive species are those which have been highlighted by the provincial government for their risk of establishment and spread resulting in economic, social, or environmental harm (CSISS 2020). All priority invasive species identified on site are considered 'established' in the Revelstoke invasive plant management area. This means that the species are widespread beyond landscape-level control and/or have relatively low impact and may have a biocontrol available (CSISS 2020). The Columbia Invasive Species Society recommends that these species be treated based on land management objectives. As this site is within a provincial park, ecological integrity is a priority therefore these invasive species will be controlled. The priority invasive species were hawkweed spp., oxeye daisy, spotted knapweed, and St John's wort.

There are 13 species of invasive hawkweed in BC, twelve of which have yellow flowers and one with orange flowers, orange hawkweed (*Hieracium aurantiacum*) (ISC 2017). While identification of hawkweeds to the species level is challenging their characteristics and management are similar. All species of invasive hawkweed prefer well-drained and coarse textured soils with low organic matter (ISC 2017). These perennials are capable of long distance dispersal by wind borne seeds but will also reproduce vegetatively by stolons (ISC 2017). In addition its high germination ability makes hawkweed species effective competitors especially in early successional communities (ISC 2017).

Oxeye daisy infestations are known to decrease local plant biodiversity and may decrease vegetative ground cover due to the growth form of this perennial plant (ISC 2019b). In BC these plants have often been found growing in association with invasive hawkweeds in meadows and the fringe areas of forest canopy (Province of BC 2002). While shading can reduce oxeye daisy biomass, a single plant can produce up to 26 000 seeds so even rare occurrences of this plant should be managed (ISC 2019b).

Spotted knapweed is an invasive biennial or short-lived perennial forb widespread throughout the province. Generally found in open areas and well-drained soils, spotted knapweed becomes established in grasslands, open forests, and along roadsides and right of ways (ISC 2019a). It reproduces exclusively by seed that are typically dispersed within the immediate vicinity of the parent plant, forming infestations with areas having up to 40 000 seeds per square meter in the soil (Gayton and Miller 2012). Large infestations tend to be sparse compared to most native vegetation due to the growth form of spotted knapweed, this can increase surface runoff and erosion (ISC 2019a). In addition, allelopathic properties of spotted knapweed can alter soil chemistry preventing the growth of other plants and reducing overall biodiversity (ISC 2019a).

St John's wort is perennial forb typically invades grazed and disturbed lands. It reproduces both vegetatively and by seed, with individual plants producing between 15 000 to 30 000 seeds that can remain viable for up to 10 years in the soil (Province of BC 2002). Additionally, its deep root system is capable of accessing water that other species may be unable to reach in dry, gravelly, or sandy soils (Province of BC 2002). While not currently dominant on site St John's wort could be an effective competitor on site.

While not a priority invasive plant species in the Revelstoke IPMA, sheep sorrel is non-native and commonly occupies disturbed habitats, especially on sandy soils, so its potential to become infested on this site should be considered (Province of BC 2002). With both the potential to create a large seedbank and a creeping rhizome network, a small infestation can quickly become a dense patch (Province of BC 2002). Heavy infestations may inhibit re-establishment of native species but it is intolerant of shade (Leege et al. 1981).

The rest of the non-native species noted in the vegetation assessment were agronomic legumes, hairy vetch, aslike clover, black medick, bird’s foot trefoil, and white clover. Agronomic species, while typically a type of forage bred for agriculture and crop production, are often recommended for seeding disturbed sites. It is possible that these were purposely seeded, but they are also widespread in BC so may have arrived on site by accidental means. Hairy vetch has low longevity but is otherwise a hardy legume with high competitiveness and the potential to become invasive if not managed properly. However hairy vetch has low tolerance to shade (Dobb et al. 2013). Aslike clover is not long lived, but has moderate persistence and competitiveness as well as a fairly good tolerance of shade (Dobb et al. 2013). Black medick is typically found in waste places with sandy and gravelly soil and is similar to alfalfa (*Medicago sativa*) (Parish et al. 1996). Bird’s foot trefoil is a strong competitor in low fertility soils and its deep taproot allows for tolerance of drought, individual plants can persist for as long as 18 years but has poor tolerance of shade (Dobb et al. 2013). White clover has high invasiveness potential but low longevity and moderate persistence, it also has poor shade tolerance (Dobb et al. 2013). Sheep sorrel, hairy vetch, aslike clover, black medick, bird’s foot trefoil, and white clover need to be monitored and managed at the restoration site.

The native species found within the herb layer were bracken fern, pearly everlasting, and spreading dogbane. Bracken, while native to the region, is often considered an aggressive weedy species that invades disturbed areas (Parish et al. 1996). Each plant has large solitary leaves but it typically forms dense colonies up 2 m tall stemming from a deep branched network of rhizomes (Parish et al. 1996). Pearly everlasting is a rhizomatous perennial growing 20-90 cm tall locally common on rocky slopes, open forests, meadows, roadsides, it is also considered weedy native species (Parish et al. 1996). Spreading dogbane a rhizomatous perennial, 20-50 cm tall that is common throughout low to mid elevations in the region, preferring the warm well-drained soil conditions of open hillsides, ridges, roadsides, clearings, and dry open forests (Parish et al. 1996). These three native species share common characteristics of having rhizomatous root systems, a tall stem, and a tendency to grow in early successional conditions. These characteristics allow these native plants to occupy this site and compete with the invasive and non-native species present.

All the woody species found in the shrub and tree layer were native species so will make good candidates for revegetation. However, due to the presence of diseases on western white pine, the planting of western white pines should be avoided on site as they may become damaged as well. Instead, revegetation should incorporate black cottonwood, Bebb's willow, Nootka rose, saskatoon, and tea-leaved willow as these species are adapted to the site's current conditions.

### 2.1.3. Vegetation Communities

Throughout the restoration site vegetation communities were delineated using the GIS Pro app for iPad and the built in GPS. These polygons were created by walking the perimeter of the associations where edges were determined visually. This additional assessment of the vegetation was done after becoming more familiar with the site when more accurate distinctions in vegetation communities could be delineated visually.

Each of these associations had their own distinct characteristics. The conifer slope, bracken hill, and deciduous forest stand, illustrated in hashed lines in Figure 13, appeared to have more native species present than the solid-coloured areas. The conifer slope was a thin band of mature conifer trees that appeared to be in better health than the ones found throughout the rest of the site. They were also found on a small east facing slope between the old road and clover central. Further along this same small east facing slope was a large patch of mostly bracken. The deciduous forest stand on a slight west facing slope on the other side of the restoration site merits further assessment and could be considered a reference site if conditions are suitable. The remaining three vegetation associations seemed to be more dominated by invasive and non-native species. The smallest area, the old road association, was a distinct linear feature at the top of the slope along the east side of the restoration site where no mature trees grew but a more even mix of hawkweed species, spotted knapweed, and other non-native species occurred. The clover central vegetation association was dominated by non-native legume species within the Fabaceae family and few trees or shrubs. This area was likely more recently disturbed by the ongoing park maintenance activities, including the burning of excess woody materials cleared from the campgrounds (A. Weber-Roy, BC Parks, pers. comm.). The final largest vegetation association was the hawkweed-knapweed meadow. This area was dominated by these two invasive species but also had a scattering of mostly western white pine which was noted as the dominant species in the shrub and tree layer vegetation assessment.

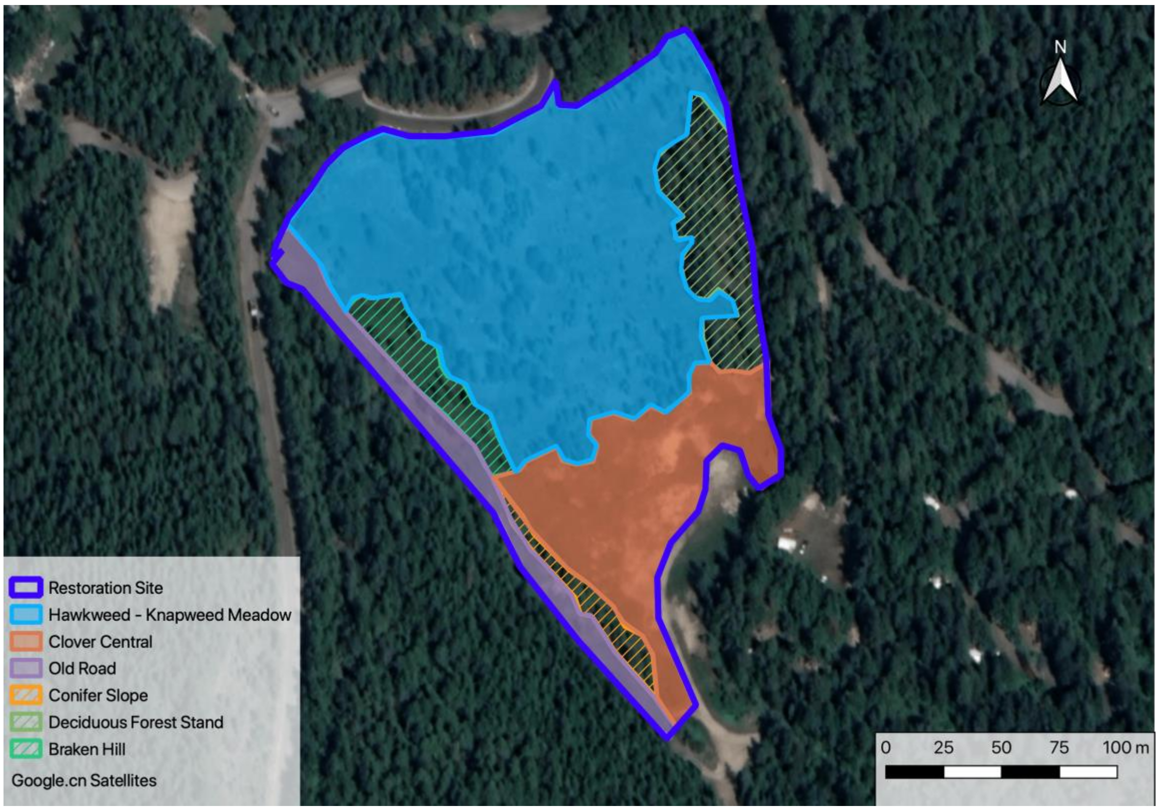


**Figure 14. Vegetation associations outlined within the restoration site at Blanket Creek Provincial Park. Vegetation communities were delineated visually on October 10th 2020. Aerial image from Google.cn Satellites 2021.**

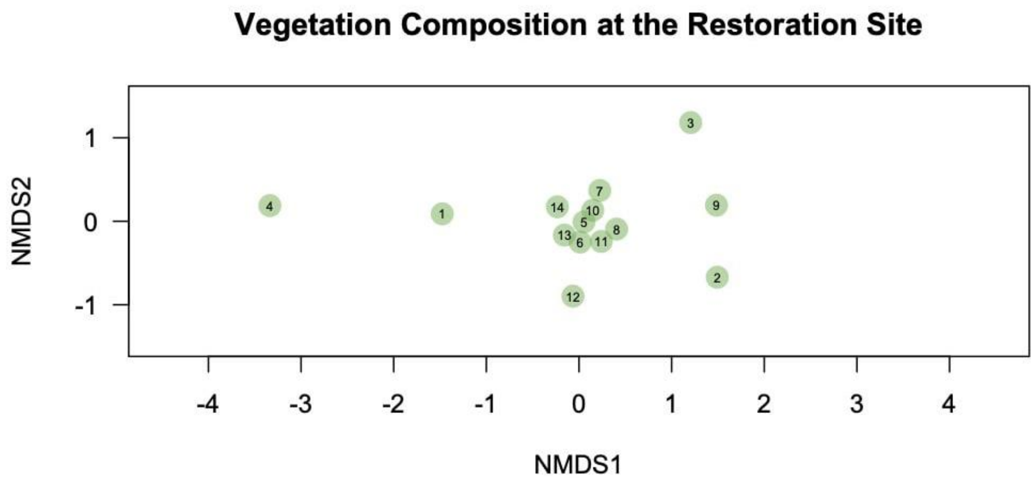


**Figure 15. The first two axis 'components' of a non-metric multidimensional scaling analysis of vegetation for the 14 vegetation plots sampled between June 24th and August 21st 2020 within the restoration site at Blanket Creek Provincial Park. Plots that are clustered together are more similar, whereas further spaced plots are least similar.**

These associations were loosely confirmed by a non-metric multidimensional scaling (NMDS) analysis, based on the abundance data of the vegetation and woody species (Figure 14). NMDS is a multivariate statistical method that helps to interpret information from multiple dimensions (multiple community measures), using ranked orders of vegetation abundance (Fowler et al. 2015). However, the sampling design for my restoration site did not cover all the associations effectively. By random chance, most of the vegetation sampling effort was concentrated in the hawkweed-knapweed meadow association. This is represented in the NMDS by the central cluster of sampling point all belonging to this community. Sample point 4 on the far left, is distinct and represents the bracken hill association. Sample points 9 and 3 are also further from the other points showing differences in the vegetation community which corresponds to the mapped associations. Sample point 2, while within the hawkweed-knapweed meadow was entirely spotted knapweed so was distinct from the vegetation at the other sampling points within the association. Future effort to assess vegetation will need to take into account these distinct communities. In hindsight, a stratified random sampling design may be more appropriate for this site to ensure sufficient data was collected from each of the vegetation associations. An improved sampling design is outlined in section 6.1 Pre-Implementation Monitoring.

## 2.2. Soil Conditions

### 2.2.1. Soil Profiles

#### *Summer Soil Assessment for Soil Profile A & B*

Over the two sampling efforts, (i) weekly between June 24th and August 21st 2020, and (ii) October 9th and 10th 2020, three soil profiles were assessed in pit excavated at the restoration site (Figure 16). During the summer field season, two pits were dug at randomly selected vegetation sampling points. The depth of the organic layers and the mineral soil texture was assessed. Soil texture was determined by hand texturing methods outlined in the Soils Illustrated – Field Descriptions (Watson 2007). Other soil parameters were not assessed at this time since the COVID-19 pandemic restrictions limited access to equipment.

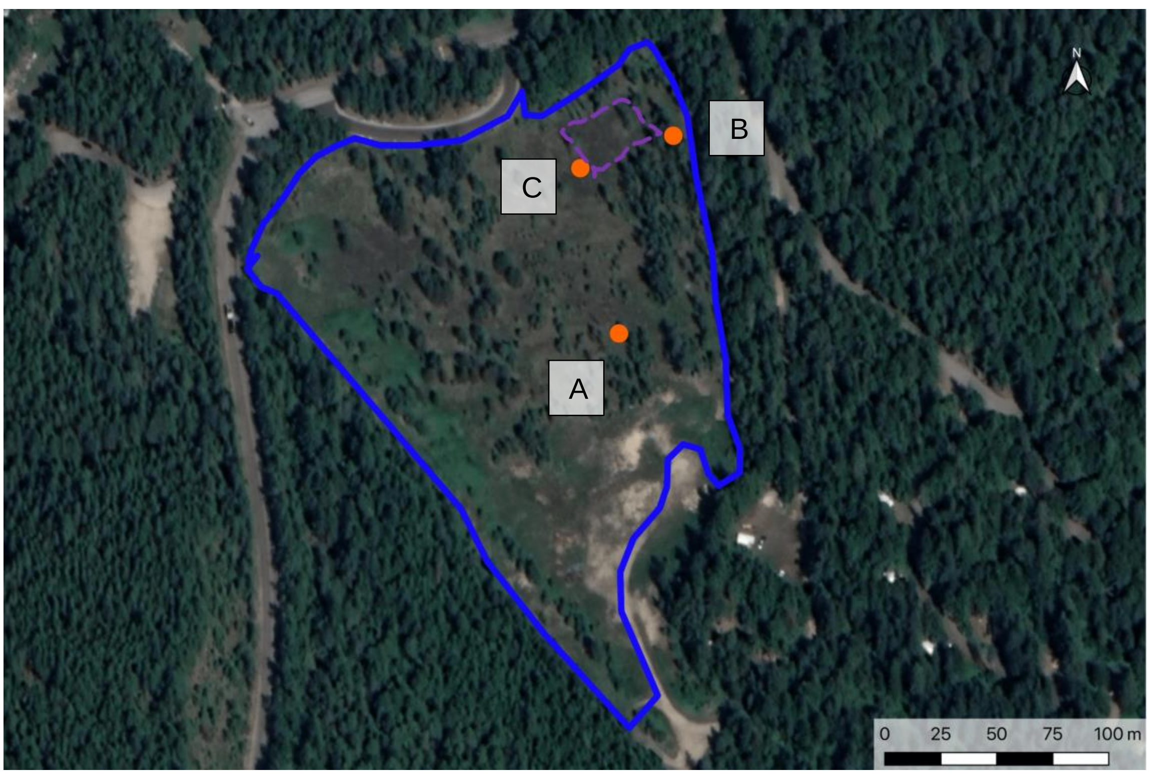


**Figure 16. Map of the soil profile sampling points (*n = 3*) within the restoration site outlined in blue at Blanket Creek Provincial Park. The purple dashed line indicates the trial planting area that Shearling Consultants Limited selected for their fall 2020 work. Aerial image from Google.cn Satellites 2021.**

### *Fall Soil Assessment for Soil Profile C*

A third soil profile was dug at the restoration site on October 9th. The location within the restoration site was selected for its proximity to the planned trial planting area which was conducted by Shearing Consultants Limited (Figure 16 - C). This would serve to provide baseline soil conditions prior to the trial plantings. During the fall field session, a more extensive soil analysis was performed as COVID-19 restrictions were reduced and permitted the borrowing of equipment. The soil pH, electrical conductivity, nitrogen, phosphorus, potassium, moisture, and temperature were assessed using a ProCheck Soil Sensor, soil pH meter, and soil nutrient test kits.

The ProCheck Handheld reader from METER Group was used according to the manual instructions. The ProCheck was set to 5TE Mineral in live update mode. Three readings of the soil moisture, temperature, and electrical conductivity were taken for the top 10 cm of mineral soil in the soil pits and recorded by hand.

The soil pH was measured using the waterproof palm pH meter model PH220 by Extech Instruments. It was calibrated using buffered solution of 4.0, 7.0, and 10.0 prior to use as per the 3 point calibration manual specifications. The soil sample from the top 10 cm of the mineral soil was diluted with six times the volume of soil with distilled water in a paper cup in the field. The pH meter electrode was rinsed with distilled water then submerged in the solution for 30 seconds or until the measurement stabilized then the pH was recorded by hand.

For the soil nutrient test the Soil Test Kit from HoldAll Decorative was used. Samples were collected from the mineral soil at 10 cm of depth from the surface by scarping the side of the soil pit with the container to avoid touching the soil with our hands. The soil was diluted with five times the volume of soil with distilled water. The soil solution was mixed then allowed to settle for 1 minute. The solution was then added to the sample nitrogen, phosphorus, and potassium containers using a clean eye dropper to the fourth line. The corresponding coloured capsule for each test was then split open and added to the container. The containers were sealed then shaken vigorously for 30 seconds, then the colour was allowed to develop for 10 minutes. Soil colour was determined by comparing moist samples to the Munsell soil colour chart to determine the hue, value, and chroma visually. The colours were then compared to the appropriate portion of the plant food colour chart.

***Soil Conditions at Soil Profile A***

Throughout the 65 cm depth of the soil profile assessed at this location, six distinct layers were observed (Figure 17). The colour of the layers ranged from a darker and redder brown, to more yellow, and then lighter and greyer. However these colours were estimated and were not assessed using the Munsell soil colour chart as it was not available to reference in the field during the summer sampling period. The LFH layer is thin measuring less than 1 cm in thickness. The pH, NPK, moisture, temperature, and EC were not measured at this pit as it was dug during the summer field session.

**Table 4. Depth, thickness, texture, percent by volume of total coarse fragments, percent by volume of the gravel and cobble fractions respectively of soil profile A excavated August 14th 2020 within the restoration site at Blanket Creek Provincial Park.**

| Layer | Depth (cm) | Thickness (cm) | Texture | Total Coarse Fragments (%V) | Gravel (%V) | Cobbles (%V) |
|---|---|---|---|---|---|---|
| 1 | 0 – 17 | 17 | Loamy sand | 15 | 15 | 0 |
| 2 | 17 – 27 | 10 | Sandy loam | 55 | 5 | 50 |
| 3 | 27 – 39 | 12 | Sand | 25 | 20 | 5 |
| 4 | 39 - 48 | 9 | Sand | 20 | 15 | 5 |
| 5 | 48 - 53 | 5 | Sand | 70 | 70 | 0 |
| 6 | 53 - > 65 | > 12 | Clay loam | 0 | 0 | 0 |

**Figure 17. Soil profiles for soil pit A showing six layers further described in Table 4 on the left; soil pit B showing no distinct layers in the middle; and soil profile of soil pit C showing 4 distinct layers further described in Table 5. Soil pit A and B were excavated August 14th 2020 while soil pit C was excavated October 9th 2020 at the restoration site within Blanket Creek Provincial Park.**

### *Soil Conditions at Soil Profile B*

Throughout the entire 75 cm depth of the soil profile dug, no distinct horizons were found. Coarse fragments made up 40% of the material by volume with gravel and cobbles in equal proportions. Overall the mineral soil texture was loamy sand and there seemed to be a mix of soil colours and compositions mixed together with root or vegetation fragments present throughout the profile. This may be evidence of prior soil mixing and disturbance. The LFH layer is thin measuring less than 1 cm in thickness.

The pH, NPK, moisture, temperature, and EC were not measured at this pit as it was dug during the summer field session.

### *Soil Conditions at Soil Profile C*

The soil texture was only assessed through hand texturing for the top mineral layer, the texture was sandy loam. To capture the conditions of the root layer the pH, moisture, temperature, and electrical conductivity was measured. The average pH (± SE) was 5.8 ± 0.1 , the average moisture (± SE) was 0.082 ± 0.011 $m^3/m^3$, the average soil temperature was 16.4 ± 0.3 ºC, and the average electrical conductivity (± SE) was 0.000 ± 0.000 bulk ds/m. Nutrient concentrations were quite low, with nitrogen and phosphorus being very low and potassium being low.

**Table 5. Depth, thickness, and colour of the four soil layers found in soil pit C excavated October 9th 2020 within the restoration site at Blanket Creek Provincial Park.**

| Layer | Depth (cm) | Thickness (cm) | Matric Hue Value / Chroma | Munsell Colour Name |
|---|---|---|---|---|
| 1 | 0 – 19 | 19 | 7.5 YR 4/4 | Brown |
| 2 | 19 – 36 | 17 | 7.5 YR 4/4 | Brown |
| 3 | 36 – 58 | 22 | 7.5 YR 3/2 | Dark brown |
| 4 | > 58 | - | 10 YR 5/6 | Yellowish brown |

## 2.2.2. Soil Compaction

Soil compaction was measured throughout the restoration site. Thirty survey locations were randomly selected using the Unstratified Sampling Design research tool in QGIS (Figure 18) (QGIS Development Team 2020). At each survey location three measurements of soil compaction were taken using a soil compaction meter with a half inch diameter tip inserted vertically in a triangle formation. Soil compaction was measured manually for soil depths of 0 – 10 cm, 10 – 20 cm, and 20 – 30 cm, to a cone penetration resistance greater than 200 PSI. The median of the three measurements of soil compaction was determined for each soil depth category at each sampling location.

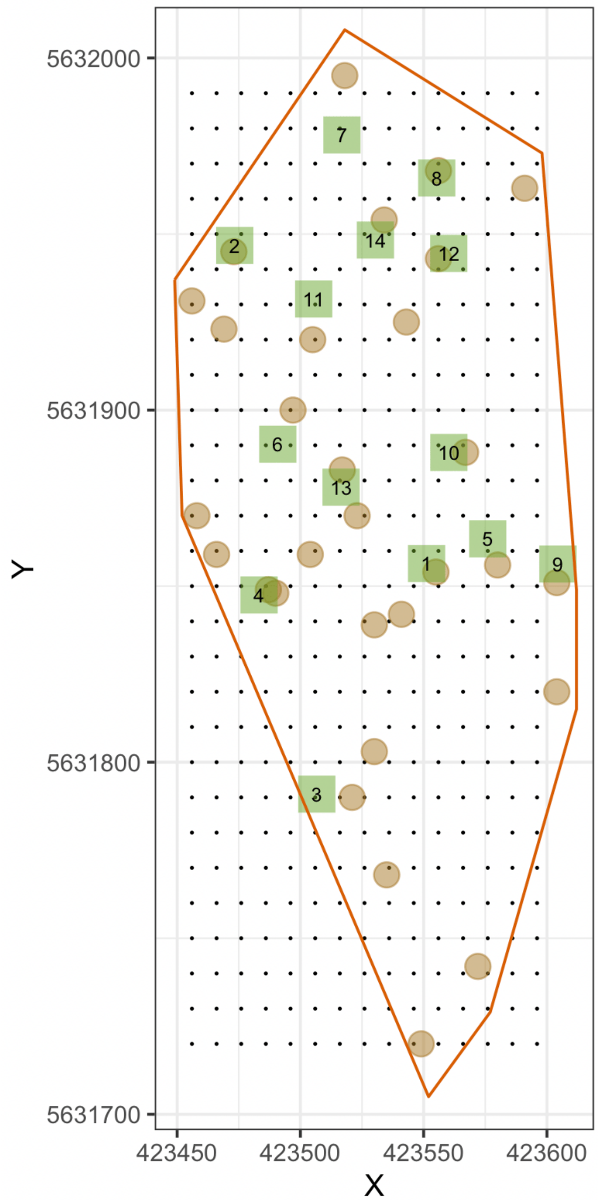


**Figure 18. Green points correspond to the vegetation sampling locations (*n = 14*) assessed between June 24th and August 21st 2020 and the brown points correspond to the soil compaction sampling locations (*n = 30*) assessed on October 10th 2020. The orange polygon is the sampling boundary which extends 1% beyond the sampling region within the restoration site at Blanket Creek Provincial Park. Units are in meters, and the underlying black dots show 10 m east and north units.**

There was a trend of increasing soil compaction with depth, with almost the entire site being compact by 30 cm of depth (Figure 19). Since 80% of the sampling locations had a cone penetration resistance of greater than 200 PSI the site is considered to be severely compacted at 30 cm in depth (Murdock et al 1995).

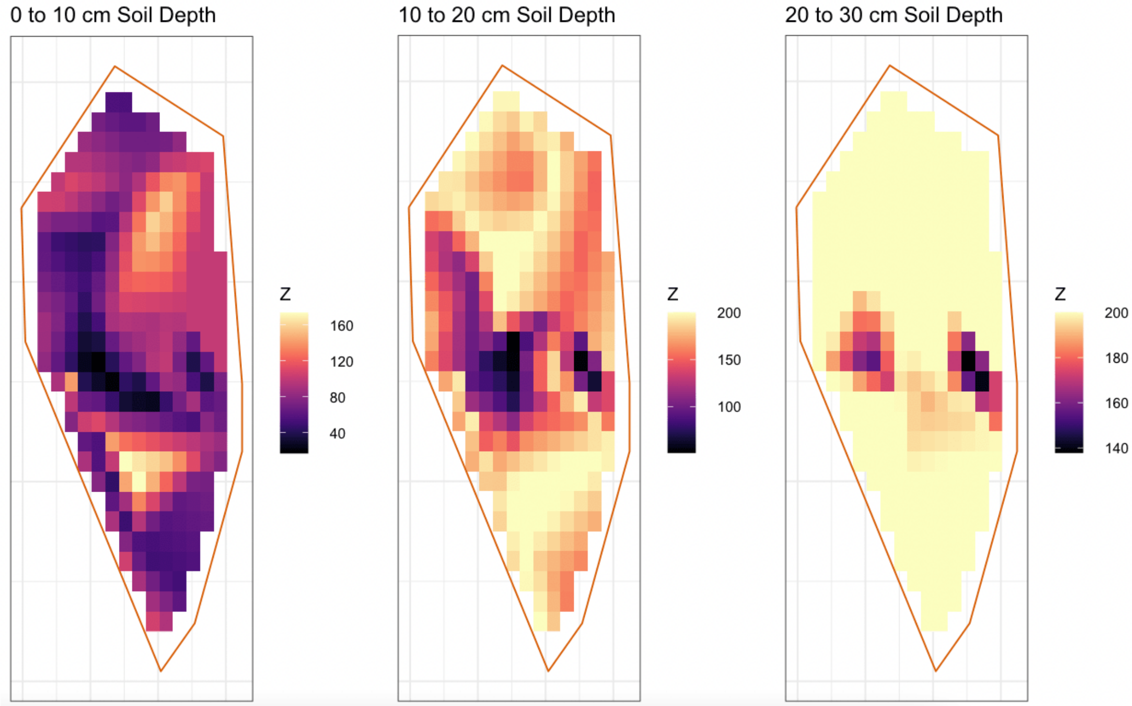


**Figure 19** **Map of the median soil compaction throughout the site at soil depths of 0 – 10 cm, 10 – 20 cm, and 20 – 30 cm, up to a force of greater than 200 PSI. The red polygon boundary corresponds to sampling boundary that extends 1% beyond the sampling region within the restoration site at Blanket Creek Provincial Park.**

### 2.2.3. Implications of Soil Conditions

The three soil pits show that the soil conditions within the restoration site are variable, as all three pits had somewhat different profiles. While variation in soil profiles within a site is common, the presence of small root fragments observed throughout the entire depth of soil profile B could be indicative of mixing through anthropogenic activities. However this mixing does not indicate sufficient evidence of anthropogenic influences to be considered within the anthroposolic soil order (Naeth et al. 2012). The soil retains some of its natural characteristics of the orthic dystric brunisol that had previously blanketed the site, such as a modified B horizon (Bm) that is over 5 cm thick observed in all three soil profiles (Canadian Soil Information System 2016b). The distinction between the B and C horizons are most evident in soil profile A (Figure 16). The low pH of the upper layer in soil profile C is also indicative of a Bm layer within orthic dystric brunisols. No mottling was observed in any of the soil profiles, which indicates that the water table rarely if ever fluctuates above a depth of 55 cm, this is also a characteristic of orthic dystric brunisols (Canadian Soil Information System 2016b).

While the site retains several characteristics of a natural orthic dystric brunisol soil, it may still be inhibiting plant growth on site. Overall the volume of soil available for plant growth is limited (M. Schmidt, SFU, pers. comm.). The high percent of coarse fragments, coupled with increasing compaction with depth means the volume of suitable soil for plants to acquire water and nutrients is limited (M. Schmidt, SFU, pers. comm.). Plant growth is determined to a great extent by the ability of the root system to grow and capture water and nutrients (Therrell et al. 2006). The coarse texture of the soil and the low soil moisture relative to the reference site (Section 3), could indicate that the water-holding capacity of the soil at the restoration site is limited. Soil compaction also prevents the roots growth reducing access to water and could be contributing to water stress (Therrell et al. 2006). This was shown in Figures 18, 19, where the vegetation sampling location 4 and 9 correspond to the less compact areas at 20 – 30 cm in depth. These vegetation sampling points were also found to be the most different in the NMDS analysis of the vegetation shown in Figure 15. Further suggesting a potential link between soil compaction and plant community composition. The thin organic LFH layer and low levels of nitrogen, phosphorus, and potassium could indicate a disruption of the organic matter cycle. Low clay content, depleted soil organic matter, and minimal soil biota can also limit the availability of nutrients for plant growth (M. Schmidt, SFU, pers. comm.). The disruption of the ecological process of organic matter cycling and the soil’s water-holding capacity may be inhibiting native plant growth on site (Therrell et al. 2006).

# Chapter 3. Reference Site Conditions

During a walk-through of Blanket Creek Provincial Park, potential reference sites were identified and ultimately one was selected for a further assessment. This site was a patch of deciduous forest located in the campground along the Columbia River Trail between the day use and group camping sites and the individual camping sites. This site was notable as the only early successional plant community patch within the park that was easily accessible. Its canopy of predominantly deciduous trees and minimal presence of herbaceous invasive and non-native species serve as a potential natural community target. In this section the methods for assessing this reference site and its current conditions will be addressed, then the results and their implications will be discussed. However, my results showed that the soil at the reference site was a silty clay which was unlike the soil found at the restoration site. This difference in soil texture may result in different vegetation communities developing so this reference site may not serve as a good potential natural community target (Therrell et al. 2006).

## 3.1. Vegetation

The reference site was only selected and assessed during the fall field session so minimal vegetation data was collected. By October 9th 2020, most plants had senescenced and were unidentifiable, with only the conifer trees still identifiable. Therefore the vegetation density, distribution, and percent cover were not assessed. However, the mature tree density was assessed in order to determine a target tree density for the restoration site. This crucial piece of information was difficult to determine in the literature as planting densities guidelines in BC tend to focus on planting densities for managed conifer forests. The deciduous forest tree density was assessed with five 10 $m^2$ plots, where all trees assessed were greater than 2 m in height. Survey locations were randomly selected using the Unstratified Sampling Design research tool in QGIS, shown in Figure 20 (QGIS Development Team 2020). Using a 1.78 m rope anchored to the center of the survey location, all mature trees found in the circle were counted. The tree density at all five sites was averaged to give an overall mature tree density (trees/hectares) for the reference site.

At the reference site, the average tree density was 2.8 ± 0.7 trees per $10m^2$ which scales up to a reference tree density of 2065 to 3535 trees per hectare. This will guide planting density estimates for the restoration site. However since tree density data was not collected for the woody species at the restoration site there is no direct comparison that can be made. In hindsight sampling the vegetation of the reference site using the same methods as the restoration over the same time period would be beneficial for developing a restoration prescription. An improved sampling design that can be used for both restoration and reference sites is outlined in section 6.1 Pre-Implementation Monitoring.

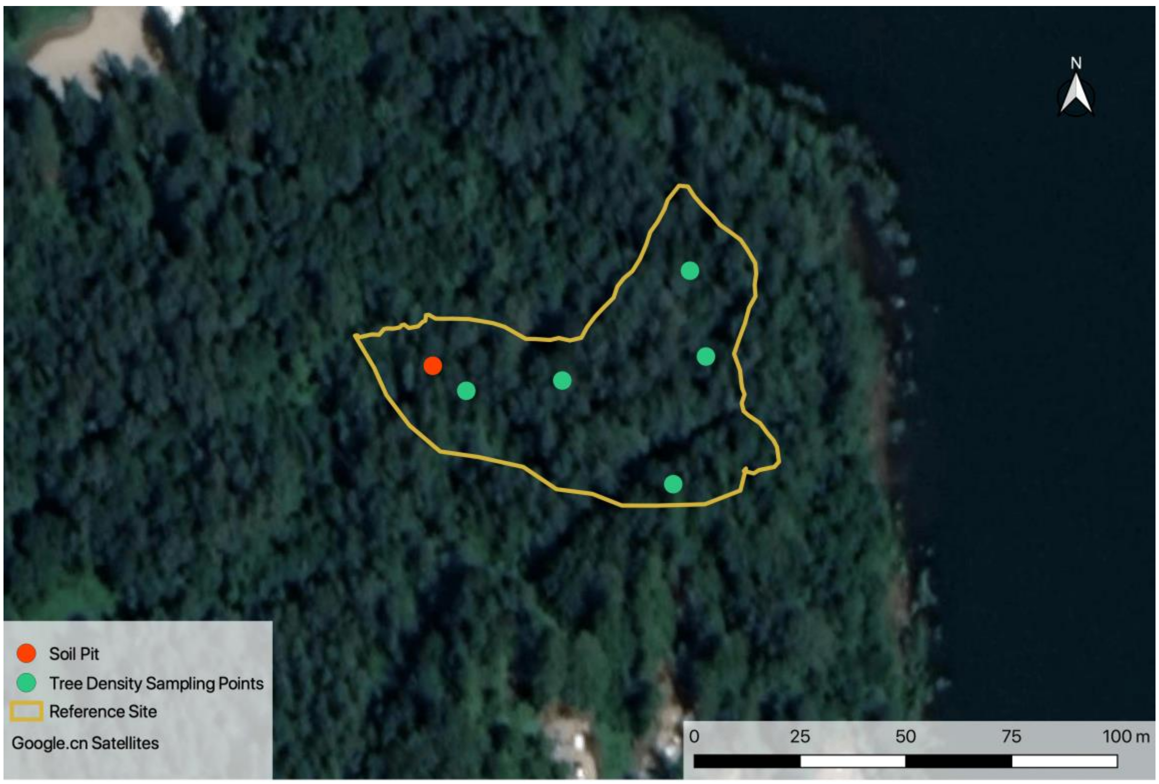


**Figure 20. Sampling site locations for tree density (*n = 5* density ± SE per $10\ m^2$ plot), soil profile D, and soil penetration resistance (*n = 3* PSI), for the reference site located in Blanket Creek Provincial Park. Aerial image from Google.cn Satellites 2021.**

## 3.2. Soil Conditions

### 3.2.1. Soil Profile

The location for the final soil pit during the fall field session was randomly selected using the Unstratified Sampling Design research tool in QGIS, shown in Figure 20 (QGIS Development Team 2020). For the soil profile, the depth of the organic layers and the mineral soil texture was assessed. Soil texture was determined by hand texturing methods outlined in the Soils Illustrated – Field Descriptions (Watson 2007). Then the soil pH, electrical conductivity, nitrogen, phosphorus, potassium, moisture, and temperature were assessed using a ProCheck Soil Sensor, soil pH meter, and soil nutrient test kits, following the same methods as at soil profile C at the restoration site.

The ProCheck Handheld reader from METER Group was used according to the manual instructions. The ProCheck was set to 5TE Mineral in live update mode. Three readings of the soil moisture, temperature, and electrical conductivity were taken for the top 10 cm of mineral soil in the soil pits and recorded by hand.

The soil pH was measured using the waterproof palm pH meter model PH220 by Extech Instruments. It was calibrated using buffered solution of 4.0, 7.0, and 10.0 prior to use as per the 3 point calibration manual specifications. The soil sample from the top 10 cm of the mineral soil was diluted with six times the volume of soil with distilled water in a paper cup in the field. The pH meter electrode was rinsed with distilled water then submerged in the solution for 30 seconds or until the measurement stabilized then it was recorded by hand.

For the soil nutrient test the Soil Test Kit from HoldAll Decorative was used. Samples were collected from the mineral soil at 10 cm of depth from the surface by scarping the side of soil pit with the container as to avoid touching the soil with our hands. The soil was diluted with five times the volume of soil with distilled water. The soil solution was mixed then allowed to settle for 1 minute. The solution was then added to the sample nitrogen, phosphorus, and potassium containers using a clean eye dropper to the fourth line. The corresponding coloured capsule for each test was then split open and added to the container. The containers were sealed then shaken vigorously for 30 seconds, then the colour was allowed to develop for 10 minutes. Soil colour was determined by comparing moist samples to the Munsell soil colour chart to determine the hue, value, and chroma visually. The colours were then compared to the appropriate portion of the plant food colour chart.

**Figure 21. Soil profile D showing no distinct layers in the mineral soil. Soil pit D was excavated October 9th 2020 at the reference site within Blanket Creek Provincial Park.**

A soil pit was dug within the reference site to a depth of 63 cm. There were no visible layers present besides a LFH litter layer which had a depth of 4 – 5 cm. For the mineral soil, the overall colour was dark yellowish brown (10 YR 4/4) and the soil texture was silty clay. To capture the conditions of the root layer the pH, moisture, temperature, and electrical conductivity were measured. The average pH (± SE) was 6.1 ± 0.2 , the average moisture (± SE) was 0.172 ± 0.003 $m^3/m^3$, the average soil temperature was 16.1 ± 0.3 ºC, and the average electrical conductivity (± SE) was 0.000 ± 0.000 bulk ds/m. Nutrient concentrations were low, with nitrogen and phosphorus being very low and potassium being low.

### 3.2.2. Soil Compaction

At the soil profile survey location, shown in Figure 20, three measurements of soil compaction were taken using a soil compaction meter with a half inch diameter tip inserted vertically in a triangle formation. Soil compaction was measured manually for soil depths in increments of 10 cm up to a depth of 80 cm. The median of the three measurements of soil compaction was determined for each soil depth category. No impassable compaction layer was reached in the upper 80 cm of the soil profile, however there was a band of higher compaction between 20 – 50 cm (Figure 22).

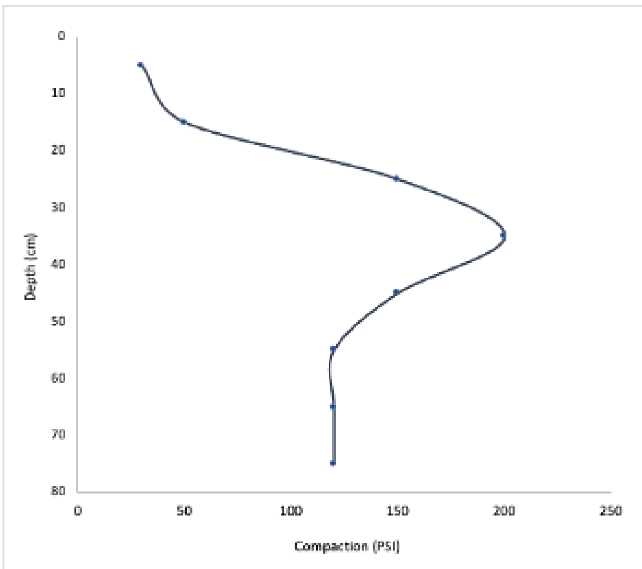


**Figure 22. Median penetration resistance (*n = 3 PSI* ) at 10 cm intervals measured at soil profile D on October 9th 2020 at the reference site within Blanket Creek Provincial Park.**

### 3.2.3. Implication of Soil Conditions

In comparison to the restoration site, the reference site has high pH, soil moisture, and lower soil temperature. The nutrients levels and electrical conductivity were similar. While the soil at the reference site showed a similar trend to that seen in the restoration site of increasing compaction with depth in the upper 30 cm, no compaction layer above 200 PSI was detected. Therefore the growth of root systems would not be restricted in depth. However, a critical differences between the reference soil and the soil at the restoration site is that at the reference site the (1) depth of the organic LFH layer was greater and (2) the soil texture was finer. The soil texture at the reference site was silty clay, which is indicative that these soil developed on different parent material than the coarser texture soil at the restoration site (M. Schmidt, SFU, pers. comm.). This may be due to proximity of the reference site to the Columbia River, the soil may have developed on very young fluvial deposits often found the flood plains of river valleys (Valentine et al. 1978). Therefore, the soils present at the restoration site could not develop into the soil found at the reference site. These differences in soil may result in different vegetation communities developing so this reference site may not serve as a good potential natural community target (Therrell et al. 2006). This reference site is likely unsuitable to serve as a reference for this particular restoration project, however it could be added to a library of potential reference sites for future projects. In the future selecting multiple reference sites to assess simultaneously would allow for the selection of the most suitable sites for a particular project and the development of a library of potential reference sites as recommended by Therrell et al. (2006).

# Chapter 4. Restoration Vision

## 4.1. Desired Future Conditions

The aim of this restoration project is to create a seral stage forest characteristic of the Interior Cedar-Hemlock (ICH) BEC zone. The forest will be composed primarily of deciduous trees in a co-dominant canopy, which is considered a rare forest stand type in the ICH BEC zone, because it occupies less than 2% of the landscape unit (FSBC 1995). To reach a mature seral stage it may take 80 to 120 years depending on the site conditions and tree species. The development of a mature seral stage forest will require the process of succession to be restored. This will require improvements to soil structure, soil organic matter cycling, and the reduction of invasive and non-native species. The restored mature seral stage forest should be more resistant to invasive species and resilient to routine disturbance. Therefore, the ecosystem within the park will be better suited to adapt to the synergistic effects of climate change.

## 4.2. Desired Goals and Objectives

Goal 1: Reduce the presence of invasive and non-native plant species

Objective 1.1: Reduce hawkweed to 10% cover in 10 years, and < 2% cover in 25 years.

Objective 1.2: Reduce spotted knapweed density to below 5 plants per $m^2$ in 10 years.

Objective 1.3: Eliminate all other priority invasive species in 25 years.

Objective 1.4: Reduce cover of all other non-native species to 10 % in 25 years.

Goal 2: Promote the development of a native deciduous forest vegetation community

Objective 2.1: Increase shrub cover to greater than 75% until tree canopy is established.

Objective 2.2: Increase the density of trees to a minimum of 2065 trees per hectare.

# Chapter 5. Restoration Plan

Overall, historical impacts and their associated disturbances resulted in a degraded state of the ecosystem at the site. The site assessment identified that the herb layer was dominated by invasive and non-native species, which may be holding the system in its degraded state of low woody species coverage in the shrub and tree layer. The high percent of coarse fragments and compaction of the soil are also potentially inhibiting plant growth. Therefore, restoration actions are required to renew the process of succession and shift the vegetation community from its current state to one dominated by native species.

Typically, the site assessment conducted at the restoration site and the reference are compared and contrasted to develop a restoration prescription (Rieger et al. 2014). However, the reference site is not a suitable target as the two sites developed on different parent materials that have created differences in soil properties at the two sites that will likely support different vegetation communities as a result. This places limitations on the precision and accuracy of this restoration prescription. Furthermore, the initial vegetation sampling effort conducted between June 24th and August 21st 2020 was concentrated in the hawkweed-knapweed meadow vegetation community delineated on October 10th 2020. In addition the three soil profile excavated at restoration site as well as the majority of the soil compaction sampling were all within the hawkweed-knapweed meadow association.  Therefore the restoration recommendations drawing from this data should only be applied to the hawkweed-knapweed meadow association area.

This restoration project is the first of its kind being undertaken by CSISS so will be implemented within the context of an adaptive management framework (R. Hooper, CSISS, pers. comm.). While the restoration vision is for the entire site, these following prescriptions should be carried out in small plots within the hawkweed-knapweed meadow association. Plot size will be assumed to be 100 $m^2$ but can be scaled depending on available funding.

## 5.1. Invasive Species Management

The initiation of the large-scale removal of the invasive and non-native species is based on the belief that these dominant invaders play a role in keeping the site in a degraded state (Suding et al. 2004). These non-native species inhibit succession by creating and maintaining conditions unsuitable to later successional native species, keeping the site in an alternative stable state (Connell and Slatyer 1977; Palmer et al. 2016). From the vegetation assessment I conducted, it was determined that hawkweed species and spotted knapweed are the dominant invasive species and are likely responsible for perpetuating the degraded state. Their management will require a combination of increasing shade and competition by native trees and shrubs, using biocontrol agents, manual removal, and amending soil.

For invasive hawkweed species the application of fertilizers may reduce the competitive advantage that these species have over perennial grasses, legumes, and other forbs (ISC 2017). Haeussler et al. (2017) found that in managed lodgepole pine forests, the decline of invasive hawkweed species cover was due to shading. Improving soil conditions for native vegetation to grow and shade out the invasive hawkweed species combines these two approaches. This will be expanded upon in section 5.2 Site Preparation and 5.3 Native Species.

There are twelve biocontrol agents available for the control of spotted knapweed in BC (Powell et al. 1994). These biocontrol agents have resulted in the greatest reduction of spotted knapweed infestations when both root feeders and seed feeders are present (Sheley and Jacobs 1997). The restoration site will need to be evaluated for the presence of both root and seed feeding biocontrol agents to determine if introductions are required. Some evidence of seed feeders was already noted on site but they may not be effective in reducing the cover of spotted knapweed if not coupled with root feeders. The biocontrol agents, when effective, are self-perpetuating and self-dispersing to provide continual control of weeds (Powell et al. 1994). Sheley and Jacobs (1997) found that a reduction in spotted knapweed density to 5 plants per $m^2$ was required to shift the competitive relationship towards a native bluebunch wheatgrass community, where a sharp increase in grass biomass was noted after a 90% reduction in spotted knapweed biomass. If biocontrol agents do not suppress spotted knapweed below the 5 plants per $m^2$, the addition of mechanical removal may be needed. However Maron and

Marler (2007) found that it was possible to eliminate knapweed infestations through the use of biocontrol agents and the establishment of a vigorous native plant community without the need for mechanical removal.

While the focus of invasive species management is on the invasive hawkweed species and spotted knapweed, it is important to discuss the other invasive plant species present on site which have the potential to become dominant if given the opportunity. All other priority invasive and non-native species, that are not agronomic legumes, should be removed manually. This should be done during site preparation, as decompaction techniques will make it easier to remove the whole root system from the soil. All invasive and non-native plant material must be bagged and removed from site to be disposed of in the landfill.

The agronomic legumes, hairy vetch, aslike clover, black medick, bird’s foot trefoil, and white clover, do not need to be removed but can be incorporated into the soil during site preparation (Dobb et al. 2013). However if it is found that the native planting are not growing they may need to be removed to reduce competition and facilitation. Facilitation occurs when earlier arriving species make it easier for other species to establish, resulting in an “invasional meltdown” (Connell and Slatyer 1977; Simberloff and Von Holle 1999). Since these agronomic legumes are strongly associated with nitrogen-fixing bacteria, the legacy of increased nitrogen in the soil can remain even after the plants die or are removed (Palmer et al. 2016).

Since both invasive hawkweed species and spotted knapweed, as well as the majority of the other invasive and non-native species, are shade intolerant, creating shade will provide long-term suppression of their growth and establishment. Planting shrubs and trees that can over top and shade out invasive herbaceous plants will help to suppress their growth and increase competition for resources (Polster et al. 2006). A healthy competitive plant community will be resistant to future invasions as well (ISC 2019a).

## 5.2. Site Preparation

Prior to site preparation, the 100 $m^2$ plot being restored will be marked and all native plants on site must be flagged to avoid trampling. To avoid disturbing other areas of the site, a walking path to and from the access point should also be flagged so volunteers and staff know where it is appropriate to walk and to work. The site preparation activities, manual decompaction, fertilization, and mulching should occur in conjunction with the native plantings (Section 5.3).

### 5.2.1. Manual Decompaction

Due to the trend of increasing soil compaction in the top 30 cm of the soil throughout the majority of the restoration site, decompaction is recommended. Avoiding the use of machinery will reduce the cost of the restoration efforts, prevent accidental re-compaction or further compaction of the soil, and will minimize the risks associated with working around machinery for volunteers. For the decompaction, the use of U-Bar digger is recommended (Therrell et al. 2006). This digger loosens the soil to a depth of 25.5 cm without turning over the soil layers (Lee Valley 2014). This technique will minimize the amount of soil disturbance while reducing compaction.

During decompaction oxeye daisy, St. John's wort, and sheep sorrel are to be removed by hand-pulling, taking care to remove the entire root system. These plants must be bagged in plastic and disposed of in the landfill. Volunteers can work in pairs, with one person using the U-bar digger and another removing the invasive and non-native plant species.

### 5.2.2. Soil Amendments and Fertilizer

The application of organic amendments and inorganic nitrogen fertilizer for restoration projects is highly debated in the literature. In restoration sites, soil amendments can alter natural soils to their detriment and may introduce foreign materials to the site (Polster 2009). The addition of finer textured material such as loamy topsoil over coarse textured soil found at the restoration site without mixing thoroughly results in the finer soil retaining more water, preventing water from percolating through the soil profile (Therrell et al. 2006). This can result in the formation of shallow root systems by the planted vegetation, reducing resilience to future drought conditions (Therrell et al. 2006)

Due to the widespread presence of hawkweed species on site, the application of some type of soil amendment or fertilizer is recommended. In order to reduce the amount of soil disturbance which could exacerbate the abundance of invasive and non-native species on site, the turning over and mixing of soil to incorporate soil amendments is not recommended (ISC 2019). Instead inorganic fertilizer should be applied to the surface of the decompacted soil. Since the soil is fairly sandy, the water leaches the nutrients through the soil profile when it rains heavily (Therrell et al. 2006). While the added nutrients may temporarily improve plant growth, native plants are adapted to the low nutrient content found in native soils. Added nutrients have been shown to reverse the pattern of natural selection favouring grasses, so should be used with caution (Belnap and Sharp 1995). Fertilizer should be applied throughout the plot, not just around new plantings, to encourage the development of spreading root systems (Therrell et al. 2006).

### 5.2.3. Mulch

The addition of mulch has many benefits for the prevention of invasive species establishment and improvement of soil conditions. Mulch is any type of material that is spread or laid over the surface of the soil as a protective cover. The mulch should mimic the natural litter layer of the ecosystem, in this case hog fuel, an unrefined mix of coarse chips of bark and wood fibre is a suitable option (Valley Carriers 2017; M. Schmidt, SFU, pers. comm.). Mulch shades the soil surface, inhibiting the germination of seeds which in this case is likely to be predominantly invasive and non-native species. When placed between planted native material, it will also prevent further access to the seed bed by invasive and non-native species (Polster et al. 2006). Furthermore, it provides some organic matter for soil building and prevents soil from crusting and recompacting (Therrell et al. 2006).

## 5.3. Native Species Selection and Planting Considerations

Native species were selected based on their structure, focusing on shrubs and trees that will be able to over top and shade out the invasive and non-native herbaceous plants. This has the added benefit of advancing the ecosystem along a successional path, improving resilience to invasion (Palmer et al. 2016). Shrub and tree species already found at the site will be good candidates for planting as they can already tolerate the environmental conditions present. Other species from the ICHmw3 BEC zone not found on site should also be selected in order to increase biodiversity (Table 6). Plant availability is based off the September 2020 supply at Hutchinson Nursey which was the nursery selected by Shearing Consultants Limited (G. Shearing, SCL, pers. comm.). While current availability is low, nurseries can be contracted to grow specific native species for a project, however this requires 2-3 years of lead time (Province of BC 2012).

**Table 6. Species of deciduous trees and shrubs typically found in ICHmw3 vegetation community in addition to species observed on the restoation site at Blanket Creek Provincial Park. (Lloyd et al. 1990). Their associated growth form, and nursery availability as of Spetember 2020 from either Hutchinson Nursery and/or Sagebrush Nursery is included.**

| Species | Common Name | Growth Form | Availability† |
|---|---|---|---|
| *Betula papyrifera* | Paper birch | tree | yes |
| *Populus trichocarpa** | Black cottonwood | tree | yes - live stakes |
| *Juniperus communis* | Common juniper | shrub | no |
| *Shepherdia canadensis* | Soopolallie | shrub | no |
| *Spiraea betulifolia* | Birch-leaved spirea | shrub | no |
| *Arctoashylos uva-ursi* | Kinnikinnick | shrub | no |
| *Mahonia aquifolium* | Tall oregon grape | shrub | yes |
| *Paxustima myrsinites* | Flasebox | shrub | no |
| *Vaccinium membranaceum* | Black huckleberry | shrub | no |
| *Vaccinium ovalifolium* | Oval-leaved blueberry | shrub | no |
| *Ribes lacustre* | Black gooseberry | shrub | no |
| *Salix bebbiana** | Bebb's willow | shrub | no |
| *Rosa nutkana** | Nootka rose | shrub | yes |
| *Amelanchier alnifolia** | Saskatoon | shrub | yes |
| *Salix planifolia** | Tea-leaved willow | shrub | no |

* Species observed on site during vegetation assessment between June 24th and August 21st 2020.
† From Hutchinson Nursery and Sagebrush Nursery Plant Availability September 2020.

Additional vegetation will be selected from three warmer and drier BEC zones, ICHmw2, ICHdw, and ICHxw (Table 7). Although ICHmw2 BEC zone is another variant of the moist warm Interior Cedar-Hemlock BEC zone, it has a slightly drier and warmer climate with more growing degree days and a longer frost-free period than the ICHmw3 (Lloyd et al. 1990). The dry warm subzone (ICHdw) is found south of the ICHmw3 and ICHmw2 zones, in the valley bottoms and lower slopes of Lower Arrowhead Lake, Columbia River, Slocan and Kootenay river valleys (Meidinger and Pojar 1991). Finally the very dry warm subzone (ICHxw) is found scattered throughout south central and south eastern BC. Adding these plant species typically found in warmer and drier BEC zones than ICHmw3 will increase biodiversity and may help to buffer the anticipated effects of climate change (Selkirk College 2021).

**Table 7. Additional species of shrubs typically found in ICHmw2, ICHdw, and ICHxw vegetation communities. No additional species of deciduous trees were found in these BEC zones (Lloyd et al. 1990; Meidinger and Pojar 1991). Their associated growth form, and nursery availability as of Spetember 2020 from either Hutchinson Nursery and/or Sagebrush Nursery is included.**

| Species | Common Name | Growth Form | Availability† |
|---|---|---|---|
| *Acer glabrum* | Douglas maple | shrub | no |
| *Cornus sericea* | Red-osier dogwood | shrub | yes - 2 gallon |
| *Alnus incana* | Mountain alder | shrub | no |
| *Physocarpus malvaceuss* | Mallow ninebark | shrub | no |
| *Corylus cornuta* | Beaked hazelnut | shrub | no |
| *Philadelphus lewisii* | Mock orange | shrub | no |
| *Symphoricarpos albus* | Common snowberry | shrub | yes - 2 gallon |
| *Lonicera utahensis* | Utah honeysuckle | shrub | no |
| *Rubus parviflorus* | Thimbleberry | shrub | yes - 5 gallon |

† From Hutchinson Nursery and Sagebrush Nursery Plant Availability September 2020.

Trees and shrubs should be planted at higher densities than the final target, to account for potential mortality due to animals, disease, and drought (Polster et al. 2006). The trees should be planted at or above a density of 3535 trees per hectare to be within the range of tree density found at the reference site, between 2065 to 3535 trees per hectare. Therefore for a 100 $m^2$ plot, 36 trees are to be planted to achieve a density over 3535 trees per hectare. However, this target will need to be evaluated because the reference site may not be a suitable target vegetation community due to difference in soil texture. In the interim, shrub cover should be high (>75%) in order to prevent the growth of invasive and non-native herbaceous species. Shrubs should initially be planted spaced 1 m apart, then monitored to determine if planting density is sufficient to meet the target cover of 75% for the shrub layer. If shrub growth does not reach the targeted cover, the planting distance can be decrease to between 25 and 50 cm (Province of BC 2012). The initial number of shrubs planted must exceed 100 plants, with the same species planted in clumps to mimic natural vegetation appearance (Province of BC 2012). During the first growing season all nursery plant must be watered during dry periods until they are established (Province of BC 2012).

# Chapter 6. Monitoring

## 6.1. Pre-Implementation Monitoring

Further baseline data should be collected in order to assess vegetation and soil conditions from vegetation communities other than the hawkweed-knapweed association within the restoration site. To ensure all vegetation associations are represented in the data, a stratified random sampling approach should be employed. The areas with vegetation associations containing more native species, bracken hill, conifer slope, and deciduous forest stand, could serve as reference conditions for the remaining areas on site. Pre-implementation monitoring includes photo-monitoring, vegetation sampling, and soil assessment.

**Photo-monitoring**: Permanent photo monitoring plots throughout the site to monitor changes in the vegetation community. Rebar stakes should be placed in the location to increase photo consistency over the years.

**Vegetation:** The density and cover of each species should be measured, using the same size quadrats as previously, a 1 $m^2$ for forbs, and a 16 $m^2$ quadrat for woody species (Bonham 2013). Mosses, grasses, and sedges should also be identified at this time. Vegetation sampling should be repeated twice during the growing season to account for differences in plant phenology, once in June and again in August.

**Soil:** The depth of the organic LFH layer, the mineral soil texture, bulk density, organic matter content, available water holding capacity, and nutrient concentrations should being measured within each vegetation association for a more informed picture of the current soil conditions.

In addition more suitable reference sites should be identified and sampled following these methods. This will allow for a refinement of the restoration objectives and will contribute to the building of a reference site condition library for future work.

## 6.2. Effectiveness Monitoring

Effectiveness monitoring determines whether plans, prescriptions, projects and activities are meeting project objectives (Therrell et al. 2006). Monitoring should occur annually for the first 10 years of the project then every three years for the next 15 years and then every 5 years until a native deciduous forest community is established. The objective of the restoration plan requires the monitoring of plant cover and density for the herb, shrub, and tree layers, mirroring the pre-implementation monitoring protocols for consistency through time (Bonham 2013). The plant density in the herb layer should decrease with time until (1) hawkweed species are reduced to 10% cover in 10 years, and < 2% cover in 25 years, (2) spotted knapweed density is reduced to below 5 plants per $m^2$ in 10 years, (3) all other invasive species are eliminated in 25 years, and (4) all other non-native species are reduced to 10% cover in 25 years. Shrub density and cover should increase until shrub cover is greater than 75%. This cover must be sustained until a tree canopy is established, where tree density is a minimum of 2065 trees per hectare.

The composition of the vegetation community should be tracked and then illustrated using an ordination diagram such as the NMDS ordination plot where points represent the same plot at different dates (Palmer et al. 2016). Vegetation succession can be assessed by the presence of a directional change in the species composition or structure of a community over time. Small, temporary, reversible changes in composition may be observed as fluctuation in the community composition and structure which may be confused with succession if not monitored diligently over the decades (Palmer et al. 2016). Soil conditions will not be monitored as successional progression of the plant community will serve as a proxy for soil health (Therrell et al. 2006). This will also minimize the amount of soil disturbance on site after the implementation of the restoration efforts which could trigger the germination of invasive species.

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# Appendix. Vegetation Data

**Herbaceous Species List, Number of Stems, Distribution, and Cover**

**Table A.1. List of all herbaceous species observed at the restoration site and their respective common and scientific names. The origin status refers to where the plant species originates from, species local to the area are native, species on listed by the province as invasive for the region are considered invasive, while species that do not originate from the region but are not considered invasive in the Revelstoke Invasive Plant Management Area are listed as exotic.**

| Common Name | Scientific Name | Origin Status |
|---|---|---|
| Aslike clover | *Trifolium hybridium* | exotic |
| Alfalfa | *Medicago sativa* | exotic |
| Alumroot | *Heuchera spp.* | native |
| Tufted vetch | *Vicia cracca* | exotic |
| Bird's foot trefoil | *Lotus corniculatus* | exotic |
| Black medick | *Medicago lupulina* | exotic |
| Bracken fern | *Pteridium aquilinum* | native |
| Fireweed | *Epilobium angustifolium* | native |
| Hawkweed spp. | *Hieracium spp.* | invasive |
| Great mullein | *Verbascum thapus* | exotic |
| Orange hawkweed | *Hieracium aurantiacum* | invasive |
| Oxeye daisy | *Leucanthemum vulgare* | invasive |
| Pearly everlasting | *Anaphalis margaritacea* | native |
| Pink wintergreen | *Pyrola asarifolia* | native |
| Prince's pine | *Chimaphila umbellata* | native |
| Sheep sorrel | *Rumex acetosella* | exotic |
| Spotted knapweed | *Centaurea stoebe* | invasive |
| Spreading dogbane | *Apocynum androsaemifolium* | native |
| St John's wort | *Hypericum perforatum* | invasive |
| Sulfur cinqfoil | *Potentilla recta* | invasive |
| Tall hawkweed | *Hieracium piloselloides* | invasive |
| Tall oregon grape | *Mahonia aquifolium* | native |
| White clover | *Trifolium repens* | exotic |

**Table A.2. Herbaceous vegetation data sampled between June 24th and August 21st at the restoration site within Blanket Creek Provincial Park.**

| Species Name | Plot Number | Number of Stems | Distribution | Cover (%) |
|---|---|---|---|---|
| Hairy vetch | 1 | 12 | several sporadically occurring individuals | 25 |
| Aslike clover | 3 | 10 | single patch or clump of a species | 10 |
| Bird's foot trefoil | 9 | 2 | single patch or clump of a species | 50 |
| | 12 | 51 | single patch or clump of a species | 2 |
| | 15 | 1 | single patch or clump of a species | 15 |
| | 17 | 1 | single patch or clump of a species | 10 |
| Black medick | 3 | 9 | single patch or clump of a species | 10 |
| Bracken | 4 | 13 | continuous uniform occurrence of well-spaced individuals | 75 |
| False haircap moss | 5 | - | a few patches or clumps of a species | 10 |
| | 9 | - | a few patches or clumps of a species | 12 |
| Golden star moss | 5 | - | several well-spaced patches or clumps | 40 |
| | 8 | - | continuous uniform occurrence of well-spaced individuals | 60 |
| | 9 | - | a few patches or clumps of a species | 12 |
| Hawkweed spp. | 5 | 53 | continuous uniform occurrence of well-spaced individuals | 60 |
| | 8 | 43 | continuous uniform occurrence of well-spaced individuals | 90 |
| | 10 | 49 | several well-spaced patches or clumps | 15 |
| | 13 | 77 | several sporadically occurring individuals | 20 |

| Species Name | Plot Number | Number of Stems | Distribution | Cover (%) |
|---|---|---|---|---|
| | 14 | 22 | a few patches or clumps of a species | 10 |
| | 15 | 197 | continuous occurrence of a species with a few gaps in the distribution | 50 |
| | 16 | 182 | continuous occurrence of a species with a few gaps in the distribution | 50 |
| | 17 | 105 | continuous occurrence of a species with a few gaps in the distribution | 25 |
| Moss spp. | 10 | - | continuous occurrence of a species with a few gaps in the distribution | 70 |
| | 13 | - | continuous occurrence of a species with a few gaps in the distribution | 70 |
| | 14 | - | continuous occurrence of a species with a few gaps in the distribution | 70 |
| | 15 | - | continuous occurrence of a species with a few gaps in the distribution | 40 |
| | 16 | - | continuous occurrence of a species with a few gaps in the distribution | 50 |

| Species Name | Plot Number | Number of Stems | Distribution | Cover (%) |
|---|---|---|---|---|
| | 17 | - | continuous occurrence of a species with a few gaps in the distribution | 40 |
| Orange hawkweed | 9 | 1 | rare individual, a single occurrence | <1 |
| Oxeye daisy | 3 | 34 | a few patches or clumps of a species | 20 |
| | 9 | 8 | single patch or clump of a species | 5 |
| | 12 | 1 | rare individual, a single occurrence | <1 |
| | 13 | 1 | rare individual, a single occurrence | <1 |
| Pearly everlasting | 12 | 8 | single patch or clump of a species | 5 |
| | 13 | 34 | single patch or clump of a species | 25 |
| Sheep sorrel | 1 | 6 | single patch or clump of a species | <1 |
| Spotted knapweed | 2 | 243 | continuous dense occurrence of a species | 100 |
| | 3 | 31 | a few patches or clumps of a species | 25 |
| | 8 | 2 | few sporadically occurring individuals | <1 |
| | 10 | 52 | several well-spaced patches or clumps | 50 |
| | 12 | 200 | continuous occurrence of a species with a few gaps in the distribution | 60 |
| | 14 | 20 | several well-spaced patches or clumps | 25 |
| | 17 | 14 | a few patches or clumps of a species | 10 |
| Spreading dogbane | 1 | 3 | single patch or clump of a species | 10 |

| Species Name | Plot Number | Number of Stems | Distribution | Cover (%) |
|---|---|---|---|---|
| | 4 | 5 | several sporadically occurring individuals | 25 |
| St John’s wort | 12 | 6 | single patch or clump of a species | 15 |
| Tall hawkweed | 9 | 27 | several sporadically occurring individuals | 10 |
| White clover | 1 | 173 | several well-spaced patches or clumps | 40 |
| Grasses/Sedges | 4 | - | a few patches or clumps of a species | 5 |
| | 5 | - | a few patches or clumps of a species | 10 |
| | 8 | - | several sporadically occurring individuals | 10 |
| | 9 | - | continuous uniform occurrence of well-spaced individuals | 50 |
| | 13 | - | a few patches or clumps of a species | 10 |
| | 14 | - | a few patches or clumps of a species | 30 |
| | 15 | - | a few patches or clumps of a species | 15 |
| | 16 | - | a few patches or clumps of a species | 5 |
| | 17 | - | continuous occurrence of a species with a few gaps in the distribution | 40 |

**Shrub and Tree Species List, Number of Stems, Distribution, and Cover**

**Table A.3. List of all woody species observed at the resotoration site and their respective common and scientific names. The origin status refers to where the plant species originates from, species local to the area are native, species on listed by the province as invasive for the region are considered invasive, while species that do not originate from the region but are not considered invasive in the Revelstoke Invasive Plant Management Area are listed as exotic.**

| Common Name | Scientific Name | Origin Status |
|---|---|---|
| Beaked hazelnut | *Corylus cornuta* | native |
| Bebb's willow | *Salix bebbiana* | native |
| Black cottonwood | *Populus trichocarpa* | native |
| Creeping snowberry | *Gaultheria hispidula* | native |
| Engelmann spruce | *Picea engelmannii* | native |
| Interior douglas-fir | *Pseudotsuga menziesii* | native |
| Sitka mountain ash | *Sorbus sitchensis* | native |
| Nootka rose | *Rosa nutkana* | native |
| Pacific willow | *Salix lucida* | native |
| Paper birch | *Betula papyrifera* | native |
| Prickly rose | *Rosa acicularis* | native |
| Red elderberry | *Sambucas racemosa* | native |
| Saskatoon | *Amelanchier alnifolia* | native |
| Snowberry | *Symphoricarpos albus* | native |
| Tea-leaved willow | *Salix planifolia* | native |
| Thimbleberry | *Rubus parviflorus* | native |
| Trembling aspen | *Populus trichocarpa* | native |
| Water birch | *Betula occidentalis* | native |
| Western white pine | *Pinus monticola* | native |

**Table A.4. Woody vegetation data sampled between June 24th and August 21st at the restoration site within Blanket Creek Provincial Park.**

| Species Name | Plot Number | Number of Stems | Distribution | Cover (%) | Diameter at Breast Height (cm) |
|---|---|---|---|---|---|
| Bebb's willow | 17 | 6 | several sporadically occurring individuals | 5 | - |
| Black cottonwood | 5 | 13 | several well-spaced patches or clumps | 50 | - |
| | 10 | 4 | single patch or clump of a species | 5 | - |
| Interior Douglas fir | 1 | 1 | rare individual, a single occurrence | 10 | 35 |
| | 16 | 1 | rare individual, a single occurrence | 2 | - |
| | 17 | 1 | rare individual, a single occurrence | <1 | - |
| Nootka rose | 10 | 9 | single patch or clump of a species | 2 | - |
| Saskatoon | 1 | 1 | rare individual, a single occurrence | 5 | |
| Tea-leaved willow | 9 | 6 | single patch or clump of a species | 5 | - |
| Western white pine | 1 | 1 | few sporadically occurring individuals | 60 | 42.3 |
| | 1 | 1 | few sporadically occurring individuals | 10 | 8 |
| | 5 | 2 | few sporadically occurring individuals | <1 | - |
| | 8 | 1 | few sporadically occurring individuals | <1 | - |
| | 8 | 1 | few sporadically occurring individuals | <1 | 4 |
| | 9 | 1 | few sporadically occurring individuals | 25 | 24.7 |
| | 9 | 1 | few sporadically occurring individuals | <1 | - |
| | 10 | 1 | rare individual, a single occurrence | 2 | 6 |
| | 13 | 1 | single patch or clump of a species | 20 | 37.3 |

| Species Name | Plot Number | Number of Stems | Distribution | Cover (%) | Diameter at Breast Height (cm) |
|---|---|---|---|---|---|
| | 13 | 1 | single patch or clump of a species | 5 | 12.1 |
| | 13 | 1 | single patch or clump of a species | 2 | - |
| | 14 | 1 | rare individual, a single occurrence | 50 | 73.2 |
| | 16 | 6 | continuous uniform occurrence of well-spaced individuals | 20 | - |
| | 17 | 1 | rare individual, a single occurrence | <1 | - |