Tobacco Plains Ecological Restoration

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Executive Summary

Tobacco Plains Indian Reserve (TPIR) is located within the southern Rocky Mountain Trench and spans 5,261 ha of historically fire-regulated grassland and open forested ecosystems. The reserve provides winter range for mule deer (*Odocoileus hemionus*), white-tailed deer (*Odocoileus virginianus*), and elk (*Cervus canadensis*). As well, TPIR is home to several federally listed species at risk, including American badger (*Taxidea taxus*), Lewis's woodpecker (*Melanerpes lewis*), long-billed curlew (*Numenius americanus*), and the Spalding's campion (*Silene spaldingii*) plant. Forest encroachment and ingrowth threaten each of these species and invasive plant species directly threaten Spalding's campion and long-billed curlew habitat and also reduce habitat quality for ungulates.

Keefer Ecological Services Ltd. (KES) and Tobacco Plains Indian Band (TPIB) have worked to recover critical grassland and open forest habitat on TPIR since 2006. Efforts in 2018 focused on invasive plant management, including herbicide application and targeted goat grazing, and forest thinning. Efforts align with the Upper Kootenay Ecosystem Enhancement Plan (UKEEP), specifically, actions under the Upland and Dryland Areas and Species of Interest Action Plans. Under these Action Plans, conducting ecosystem restoration efforts, such as forest thinning, to support species of interest, including American badger, Lewis's woodpecker, long-billed curlew, mule deer, white-tailed deer, and elk, as well as invasive plant monitoring and management, are priorities.

Invasive plant management involved continued management of the leafy spurge (*Euphorbia esula*) infestation, located in a large subpopulation of Spalding's campion. Monitoring found the density and distribution of leafy spurge had not changed from a distribution of 5 (a few patches or clumps of a species) to 6 (several well-spaced patches or clumps) with a density of 3 (6 to 10 plants / m^2) to 4 (> 10 plants/m^2). However, this is not unexpected as leafy spurge is known to form dense patches. A notable decline in mature leafy spurge plants was observed; however, dense patches of plants approximately 1 inch in height were found throughout the site. The infestation area was found to have been reduced from approximately 2.7 ha to 2.1 ha. The infestation was treated in late June and late August.

Orange hawkweed (*Hieracium aurantiacum*) has typically been found within the Edwards Lake area, TPIB sawmill, east-northeast corner of the reserve in a forested area, northeast of Indian Lake, the southeastern reserve access road, and Roosville Cemetery. Treatment of infestations with Milestone has been found to be successful; however, re-treatment in some areas is necessary to manage the plant. Orange hawkweed has been found adjacent to water which requires the application of glyphosate between 1-10m from the high water mark. The flower heads of orange hawkweed plants found within 1m of the high water mark were removed as application of herbicide within this area is prohibited. New infestations were identified in the Edwards Lake area and in the southeastern reach of the reserve, in addition to an infestation identified on a Band Member's property and along Dorr Road.

Spotted knapweed (*Centaurea stoebe*) management has focused on controlling the spread of the weed throughout the reserve. Spotted knapweed re-sprouted in a few areas that were sprayed in 2015. These infestations were re-sprayed with Milestone in 2018 to continue management efforts. Treatment

success of roadsides sprayed in 2017 was low. Re-treatment of roadsides is critical to manage the spread of spotted knapweed. As well, two new infestations were identified in the Edwards Lake area. Management of sulphur cinquefoil (*Potentilla recta*) through target goat grazing continued for the third consecutive year on 13 ha of land within an area of the reserve known as the "Golf Course." However, research is needed to identify mechanisms driving sulphur cinquefoil's dominance on grasslands within TPIR and the effectiveness of target goat grazing and other strategies (e.g., herbicide, native seeding) in managing sulphur cinquefoil. In response, KES and TPIB initiated a partnership with the University of Saskatchewan to implement a research study to examine sulphur cinquefoil management on disturbed grasslands in the East Kootenay.

Invasive plant management efforts have also focused on working to eradicate field bindweed (*Convolvulus arvensis*), scentless chamomile (*Tripleurospermum inodorum*), and yellow toadflax (*Linaria vulgaris*) infestations from the reserve. The field bindweed infestation was not monitored in 2018 due to time constraints. Future monitoring is necessary to assess if re-treatment is necessary. The scentless chamomile infestations have only been identified on the reserve in the sawmill area. However, new scentless chamomile patches within the sawmill area were identified in 2018. Treatment in 2019 is needed to prevent the invasive plant from spreading to other areas of the reserve. Further, treatment success of the yellow toadflax infestation sprayed with herbicide in 2017 was low. As such, the infestation was re-sprayed in 2018.

Blueweed (*Echium vulgare*) and Dalmatian toadflax (*Linaria genistifolia*), weeds not previously found on TPIR, were located on the reserve. Blueweed was found on a Band Member's property and within a ditch adjacent to Highway 93 and a reserve road. Dalmatian toadflax was found along Dorr Road as it passed through a grassland. Time constraints prevented treatment of these plants. Future treatment is necessary to prevent their spread throughout the reserve. As well, Canada thistle (*Cirsium arvense*) and bull thistle (*Cirsium vulgare*) were establishing within an area that was eco-mulched for open forest restoration in 2017. Part of the area was sprayed with herbicide in 2018; however, continued treatment is needed to prevent Canada and bull thistle from dominating the area, outcompeting native species.

Forest thinning carried out by the band forestry crew continued to address ecological restoration objectives of restoring habitat for a wide variety of local species both rare and common. Forest thinning was accomplished in the southernmost portion of the reserve. Manual thinning occurred on 4.9 ha, while treatment using an eco-mulcher occurred on 1.4 ha. Pile burning of last season's thinning slash was carried out on 10.4 ha. Monitoring of pre- and post-treatment densities showed that target densities were attained in some areas of the manual treatment but was also slightly exceeded in other areas. However, the area treated by the eco-mulcher achieved target densities (<400 stems per hectare of >12.5 cm diameter at breast height).

Future work on TPIR will continue with invasive plant management efforts, including the implementation of a research study in partnership with the University of Saskatchewan, and forest thinning to further recovery of critical grassland and open forest habitat for ungulates and species at risk.

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Introduction

Tobacco Plains Indian Reserve (TPIR) is located within the southern Rocky Mountain Trench and spans 5,261 ha of historically fire-regulated grassland and open forested ecosystems. As a result of fire-suppression practices, which have been in place since the early 20th century, the region has experienced heavy encroachment of ponderosa pine (*Pinus ponderosa*) and Douglas fir (*Pseudotsuga menziesii*; Crowley and Gall, 2011). Additionally, invasive species, such as leafy spurge (*Euphorbia esula*), spotted knapweed (*Centaurea stoebe*), sulphur cinquefoil (*Potentilla recta*), and orange hawkweed (*Hieracium aurantiacum*), are threatening grasslands and open forests on the reserve (Juckers and Moody, 2016).

As TPIR is federal land, it has been excluded from the provincially led, highly-successful, Rocky Mountain Trench Ecosystem Restoration (ER) Program, which has been in effect since the late 1990s (Bond *et al*., 2013). Located adjacent to 10,466 ha of core grassland areas of the Provincial ER program (Harris, 2014), on the east side of the Koocanusa reservoir, TPIR represents a significant area of critical grassland and open forest habitat for many species. The reserve provides winter range for mule deer (*Odocoileus hemionus*), white-tailed deer (*Odocoileus virginianus*), and elk (*Cervus canadensis*). As well, TPIR is home to several federally listed species at risk, including American badger (*Taxidea taxus*), Lewis's woodpecker (*Melanerpes lewis*), long-billed curlew (*Numenius americanus*), and the Spalding's campion (*Silene spaldingii*) plant. Forest encroachment and ingrowth threaten each of these species (Environment Canada, 2013, 2016a,b; Jeffersonii Badger Recovery Team, 2008) as it directly results in the loss of habitat which increases pressure on remaining habitat, reducing habitat quality. In addition to forest encroachment and ingrowth, invasive plants directly threaten Spalding's campion and long-billed curlew habitat and also reduce habitat quality for ungulates.

Keefer Ecological Services Ltd. (KES) has been working with Tobacco Plains Indian Band (TPIB) since 2006, conducting Spalding's campion recovery and ecosystem restoration efforts on critical grassland and open forest habitat on the reserve to enhance critical habitat for wildlife in the region. Over the years, work has involved:

In 2006 (Keefer, 2009)

- Preliminary survey of high potential Spalding's campion habitat on TPIR;
- Surveying individual Spalding's campion plants;
- Installing fencing over 2 ha to exclude horse and cattle grazing from Spalding's campion habitat;
- Removing invasive plants surrounding Spalding's campion; and
- Thinning a conifer stand within Spalding's campion habitat.

In 2007 (Keefer, 2009)

- Raising community awareness about Spalding's campion;
- Updating the TPIB Integrated Land Management Plan; and
- Thinning ponderosa pine on approximately 1.5 ha of Spalding's campion habitat.

In 2008 (Keefer, 2009)

- Conducting a presence/absence survey of Spalding's campion populations in July and August.

In 2010 (Keefer and Kennedy, 2010)

- Establishing permanent monitoring transects to assess Spalding's campion;
- Conducting a randomized Spalding's campion survey of the reserve;
- Identifying habitat preferences for Spalding's campion;
- Recording new species occurrences of Spalding's campion; and
- Inventorying invasive plants threatening known Spalding's campion sub-populations.

In 2011-2012

- Efforts were not conducted in 2011 and 2012 as funding was not acquired.

In 2013 (Seher, 2014)

- Revisiting permanent transects established in 2010 in early summer (June) and late summer (August) to assess Spalding's campion population dynamics;
- Conducting a reconnaissance in the southern Rocky Mountain Trench from TPIR northward to Skookumchuck to identify possible Spalding's campion locations off reserve;
- Initiating development of prescriptions for designated grassland and open forest ER treatment units on TPIR to initiate a multi-year habitat recovery program for Spalding's campion; and
- Drafting the federal Spalding's campion recovery strategy.

In 2014-2015 (Carignan et al., 2015)

- Revisiting permanent transects established in 2010 in early summer (June) and late summer (August) to assess population dynamics;
- Securing a multi-year herbicide treatment permit from Environment Canada to treat the leafy spurge infestation present at a large Spalding's campion site;
- Implementing an open forest restoration prescription on 7 ha of land in the southern reach of the reserve;
- Creating a 2014-2015 Site Action plan outlining the goals, priority areas, training, and safety of ER prescription implementation;
- Developing and sharing a presentation on ER treatment objectives with TPIB crew members to facilitate effective treatment implementation and better understanding of the purpose of ER;
- Developing 11 additional prescriptions for treatment units on TPIR using data collected in 2013;
- Writing a 2015-2016 Site Action plan to outline next steps and coordinate collaboration with new funding partners (BC Hydro Fish and Wildlife Compensation Program); and
- Presenting the project at the East Kootenay Invasive Species Council 2015 Annual General Meeting.

In 2015-2016 (Juckers and Moody, 2016)

- Holding an invasive plant management workshop, led by the East Kootenay Invasive Species Council, at the TPIB office;
- Conducting an invasive plant survey of the reserve and developing an invasive plant management report based on survey results;
- Applying herbicide to various infestations on the reserve, including the 2.7 ha leafy spurge infestation identified in 2009, and small infestations (< 1 ha) of spotted knapweed, orange hawkweed, field bindweed, and yellow hawkweed.
- Implementing open forest ER prescriptions on approximately 16.4 ha of land in the southern reach of the reserve;
- Conducting a site visit post-thinning to assess thinned areas and to determine whether prescriptions have been met;
- Creating a draft prescribed burn plan for prescription units that have received thinning treatment; and
- Writing a 2016-2017 Site Action Plan to outline next steps.

In 2016-2017 (Juckers, 2017)

- Conducting a survey of orange hawkweed infestations throughout the reserve and mapping the extent of the infestations;
- Continued application of herbicide on the 2.7 ha leafy spurge infestation and small infestations (< 1 ha) of spotted knapweed, orange hawkweed, and field bindweed;
- Conducting targeted goat grazing on 48 ha of grassland habitat infested with sulphur cinquefoil using approximately 300 goats;
- Conducting a Lewis's woodpecker nesting survey;
- Developing an ER prescription for long-billed curlew habitat;
- Implementing an open forest ER prescription on approximately 8.8 ha of land in the southern reach of the reserve; and
- Conducting a site visit post-thinning to assess thinned areas and to determine whether prescriptions have been met.

In 2016-2017 (Juckers and Carignan, 2018)

- Conducting a survey of spotted knapweed infestations throughout the reserve and mapping the extent of the infestations;
- Monitoring invasive plant infestations sprayed in 2015 and 2016 to assess efficacy of herbicide application;
- Continuing application of herbicide on the 2.7 ha leafy spurge infestation and small infestations (< 1 ha) of spotted knapweed and orange hawkweed;
- Conducting targeted goat grazing on 13 ha of grassland habitat infested with sulphur cinquefoil using approximately 50 goats;
- Participating in the Ktunaxa Nation Annual General Assembly to bring awareness to ER initiatives occurring on TPIR;

- Implementing open forest ER prescriptions on approximately 12.4 ha of land in the southern reach of the reserve; and
- Conducting a site visit post-thinning to assess thinned areas and determine whether prescriptions have been met.

The following report is a summary of the invasive plant management and forest thinning efforts conducted in 2018 to restore critical grassland and open forest habitat on TPIR. These efforts align with the Upper Kootenay Ecosystem Enhancement Plan (UKEEP), which places focus on restoring and enhancing upland and dryland ecosystems, including grasslands and open forests, impacted by threats such as invasive plants and forest encroachment and ingrowth. Specifically, the project aligns with the actions of the Upland and Dryland Areas and Species of Interest Action Plans under UKEEP, as conducting ecosystem restoration efforts, such as forest thinning, to support species of interest, including American badger, Lewis's woodpecker, long-billed curlew, mule deer, white-tailed deer, and elk, as well as invasive plant monitoring and management, are priorities under these Action Plans.

Goals and Objectives

The goal in 2018 was to continue efforts to recover critical grassland and open forest habitat on TPIR through invasive plant management and forest thinning (Figure 1). Objectives for 2018 included:

- Monitoring invasive plant infestations sprayed between 2015-2017 to assess efficacy of herbicide application;
- Continuing application of herbicide on the leafy spurge infestation and small infestations (< 1 ha) of spotted knapweed and orange hawkweed;
- Continue conducting targeted goat grazing on 13 ha of grassland habitat infested with sulphur cinquefoil using approximately 50 goats;
- Developing a research study design, in partnership with the University of Saskatchewan, that will identify mechanisms driving sulphur cinquefoil dominance in grasslands within the East Kootenay and best management practices to control the invasive plant;
- Conducting rangeland health assessments on three grassland sites on TPIR and collecting soil samples to perform seedbank and soil nutrient analyses to gather baseline data to support the sulphur cinquefoil research study;
- Participating in Aboriginal Day to bring awareness to community members of the sulphur cinquefoil research study that will be initiated on grasslands on TPIR in partnership with the University of Saskatchewan;
- Continuing implementation of open forest ER prescriptions within the southern reach of the reserve through manual thinning and eco-mulching; and
- Conducting a site visit pre- and post-thinning to assess the thinned areas using 5.64 m fixed-radius plots to gather data on tree species and stems per hectare (sph) of saplings, poles, co-dominant, and dominant trees. As well, determining the density and species of seedlings within each radius plot and percent cover of species in the understory.

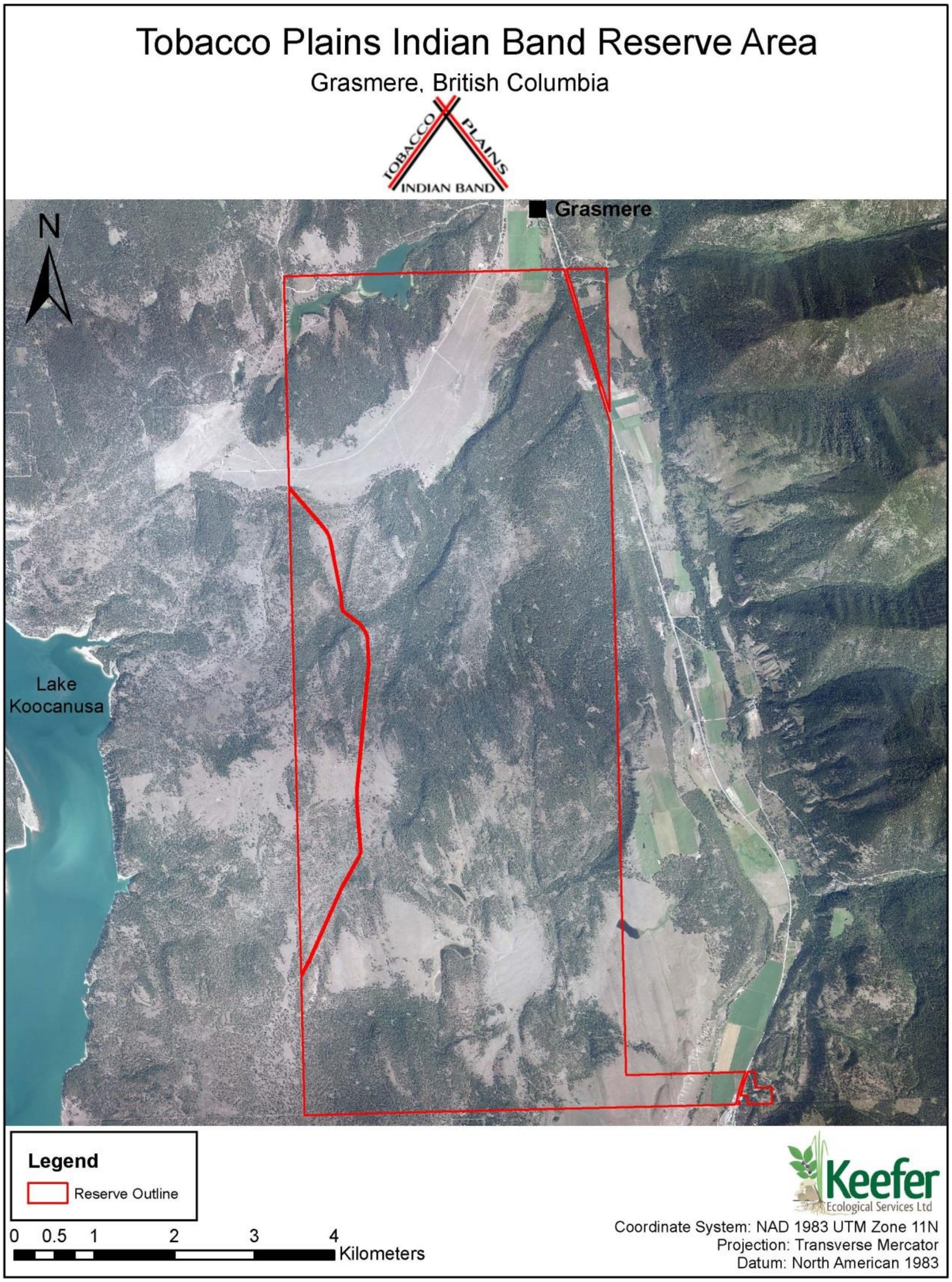

Figure 1: Map of Tobacco Plains Indian Reserve

Invasive Plant Management

Grassland and open forest ecosystems occupy a small percentage of British Columbia's (BC) land base; yet, they represent an important ecological, economic, and cultural component of the province (Gayton, 2004). They are also known to provide critical habitat for a large number of provincially and federally listed species at risk (Gayton, 2004). Presently, the ecological integrity of these critical ecosystems is at risk due to the threat of non-native plants.

In 1995, over 100,000 ha of grassland and open forest habitat was estimated to be infested with invasive plant species in British Columbia and over 10 million hectares of Crown Land was determined to be susceptible to invasion (FPB, 2006). Approximately 20% of vascular plant species in BC are non-native and many of these species are found within grasslands and dry forests (Wikeem and Wikeem, 2004). Numerous invasive plants are adapted to hot, dry conditions and are commonly shade intolerant (FPB, 2006). Grasslands and open forests provide ideal habitat for these plants, making them vulnerable to invasion.

In the Southern Rocky Mountain Trench, the threat of invasive, non-native plants present major problems as many species are extremely aggressive and spread easily, displace native vegetation, and are unpalatable to wildlife and domestic stock (Trench Committee, 2006). Invasive plants are common throughout grasslands and open forests on TPIR, with up to 10 invasive plant species invading grassland sites and up to 17 invasive plant species invading open forest sites (Juckers and Keefer, 2016). Invasive plant management is imperative to maintain the natural integrity of these systems and to reduce their threat to native plants and animals (Wikeem and Miller, 2006).

To address the threat of invasive plants on grasslands and open forests throughout TPIR, an invasive plant survey was conducted during the summer of 2015 from which an invasive plant management report was written (Juckers and Keefer, 2016). Based on the survey, invasive plant treatment efforts over the past four years have been concentrated on managing a 2.7 ha leafy spurge (*Euphorbia esula*) infestation and the spread of spotted knapweed (*Centaurea stoebe*) and orange hawkweed throughout the reserve (Juckers, 2017; Juckers and Carignan, 2018). Further, focus has been placed on documenting new invasive plant infestations, such as field bindweed (*Convolvulus arvensis*), scentless chamomile (*Tripleurospermum inodorum*), and yellow toadflax (*Linaria vulgaris*), and identifying management techniques to prevent the spread of these infestations.

The following outlines management of the leafy spurge, orange hawkweed, spotted knapweed, field bindweed, scentless chamomile, and yellow toadflax infestations on the reserve. As well, new infestations are highlighted.

Leafy Spurge (*Euphorbia esula*)

Leafy spurge (*Euphorbia esula*) is one of the most unwanted invasive plants within BC (ISC BC, 2017a). It is a long-lived perennial that is known to form dense stands, displacing vegetation in rangeland, pasture, and native habitats (ISC BC, 2017a). Leafy spurge was identified on TPIR in 2009 within a large sub-population of Spalding's campion (Keefer, 2009), a federally endangered species only found in Canada within and adjacent to TPIR (Environment Canada, 2016a).

Management of the noxious weed on TPIR using herbicide began in 2015, where the infestation was estimated to span approximately 2.7 ha. In 2015 and 2016, mild doses of the herbicide Trillion were applied twice a year during the growing season of leafy spurge. The application of Trillion was selected because Trillion was expected to reduce the risk of herbicide adversely impacting Spalding's campion plants in comparison to other herbicides known to effectively manage leafy spurge, such as Tordon 22K. However, a notable decline in the leafy spurge infestation was not observed between years 1 and 2. In response, the herbicides Tordon 22K and glyphosate were used in replace of Trillion in 2017 and 2018.

Tordon 22K is recognized as a well-known, effective herbicide to manage small leafy spurge infestations (Scott and Robbins, 2000; Pachkowski and Thorton, 2011). However, the herbicide can remain in the soil for 5 years because of the active ingredient picloram (Dow AgroSciences, n.d.), presenting an adverse risk to Spalding's campion plants. Tordon 22K was therefore applied using a backpack sprayer 5 m from Spalding's campion plants. Within 5 m of Spalding's campion plants, a perimeter was delineated (Figure 2), within which glyphosate was applied by wicking the herbicide onto the leafy spurge plants. The major pathway of glyphosate is through the foliage and once absorbed glyphosate is translocated throughout all plant parts where it prevents regrowth (Schuette, 1998). Glyphosate also has moderate persistence with a soil field dissipation half-life averaging 44-60 days (Schuette, 1998). As such, the application of glyphosate on leafy spurge plants near Spalding's campion presented a lower risk to the species at risk than Tordon 22K.

Over the years the distribution and density of the leafy spurge infestation has not changed from a distribution of 5 (a few patches or clumps of a species) to 6 (several well-spaced patches or clumps) with a density of 3 (6 to 10 plants / m^2) to 4 (> 10 plants/m^2) (Juckers, 2017; Juckers and Carignan, 2018). This is not unexpected as Rodney G. Lym and Calvin G. Messersmith, Plant Scientists at North Dakota State University, have stated leafy spurge patches may have more than 200 stems per square yard in sandy soil and greater densities in heavy clay soil (Lym and Messersmith, 2013). However, declines in the leafy spurge infestation have been observed, which has been captured at the photo monitoring locations (Figure 3).

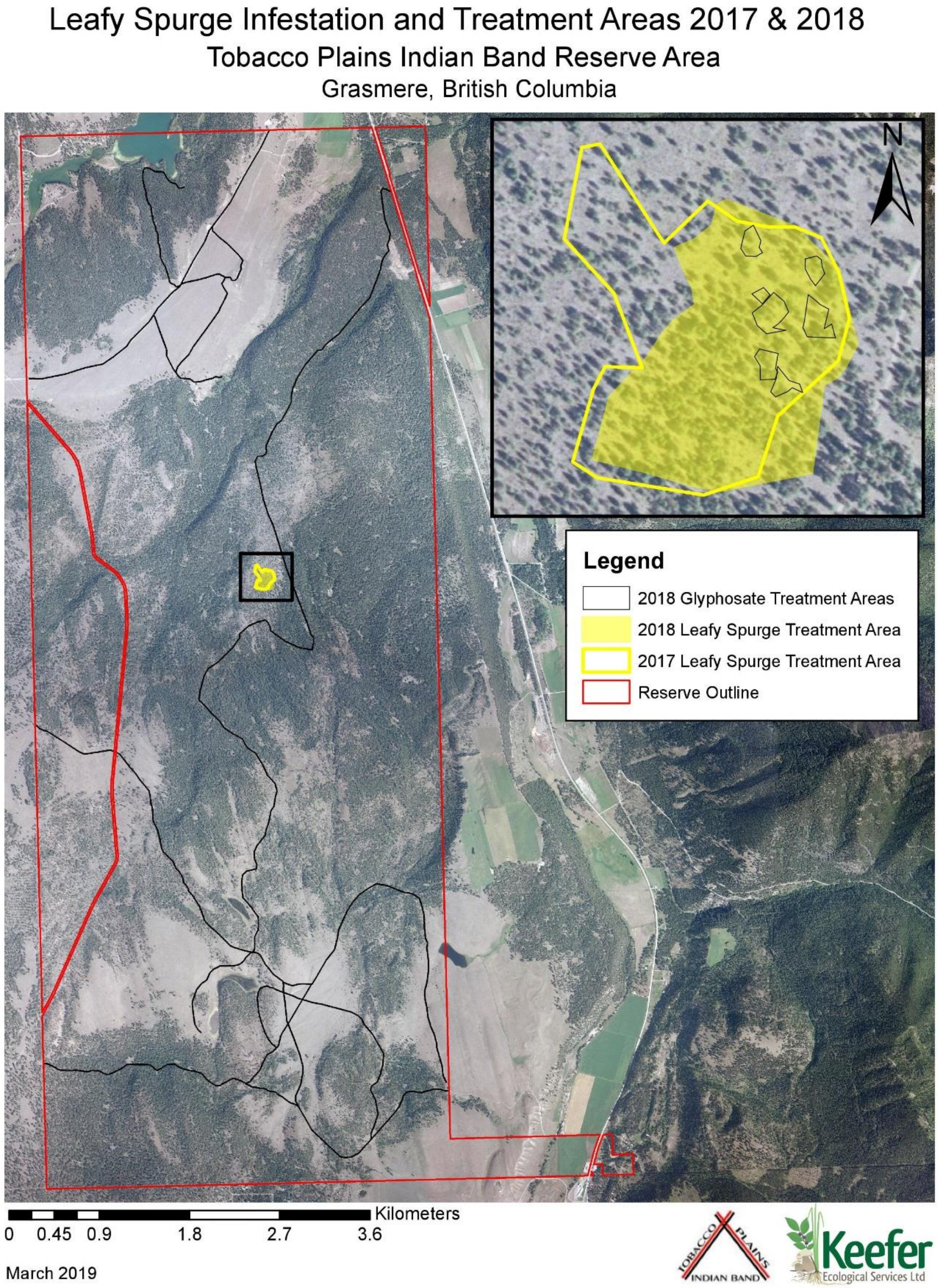

Figure 2: Leafy spurge (*Euphorbia esula*) treatment area on Tobacco Plains Indian Reserve

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A) Photo Point 1: 11U 639011E 5435159N
Bearing: 035°

Pre-treatment 2015

Photo of a leafy spurge patch within the leafy spurge infestation area taken on July 13, 2015 prior to the first application of herbicide

Pre-treatment 2016

Photo of a leafy spurge patch within the leafy spurge infestation area taken on June 13, 2016 prior to the first application of herbicide

Pre-treatment 2017

Photo of a leafy spurge patch within the leafy spurge infestation area taken on June 27, 2017 prior to the first application of herbicide

Pre-treatment 2018

Photo of a leafy spurge patch within the leafy spurge infestation area taken on June 13, 2018 prior to the first application of herbicide

B) Photo Point 2: 11U 638999E 5435233 N

Bearing: 329°

Pre-treatment 2015

Photo of a leafy spurge patch within the leafy spurge infestation area taken on July 13, 2015 prior to the first application of herbicide

Pre-treatment 2016

Photo of a leafy spurge patch within the leafy spurge infestation area taken on June 13, 2016 prior to the first application of herbicide

Pre-treatment 2017

Photo of a leafy spurge patch within the leafy spurge infestation area taken on June 27, 2017 prior to the first application of herbicide

Pre-treatment 2018

Photo of a leafy spurge patch within the leafy spurge infestation area taken on June 13, 2018 prior to the first application of herbicide

Figure 3: Photo documentation at Photo Point 1 (A) and 2 (B) of the leafy spurge (*Euphorbia esula*) infestation pre-treatment between 2015-2018 on Tobacco Plains Indian Reserve

During summer 2018, mature leafy spurge plants were not found as abundantly as previous years; however, dense patches of plants approximately 1 inch in height were found throughout the site (Figure 4). As a result, a treatment efficacy rating of only 1 (0% to 19% efficacy) was given, which is a decline in efficacy from 2017, in which an efficacy rating of 3 (30% to 39% reduction in infestation) was given (Juckers and Carignan, 2017). The presence of these immature plants present a challenge as it is more difficult to locate them amongst the other vegetation onsite. As well, the immature leafy spurge plants were particularly dense amongst a group of Spalding's campion plants. The application of glyphosate in this dense patch of leafy spurge may result in available ground for other species to invade, particularly cheatgrass (*Bromus tectorum*), which is becoming increasingly prevalent in the area. To mitigate the establishment of the cheatgrass in replace of leafy spurge, the following seed mix was applied within the glyphosate plot:

39% bluebunch wheatgrass (*Pseudoroegneria spicata*)
25% slender wheatgrass (*Elymus trachycaulus*)
17% annual ryegrass (*Lolium multiflorum*)
8% Idaho fescue (*Festuca idahoensis*)
5% Rocky Mountain fescue (*Festuca saximontana*)
1% Sandberg's bluegrass (*Poa secunda*)

Figure 4: Immature leafy spurge (*Euphorbia esula*) plants, approximately 1 inch in height that have emerged at the leafy spurge infestation site on Tobacco Plains Indian Reserve

Following herbicide application, the perimeter of the infestation was walked using a handheld GPS to determine the infestation area. The infestation area was found to be approximately 2.1 ha, which is less than the infestation area of approximately 2.7 ha reported in previous years.

Continued herbicide application will be conducted in summer 2019 to sustain efforts of reducing and subsequently eradicating leafy spurge on TPIR. To continue assessing changes in the leafy spurge infestation, photo documentation will carry on at the two photo points within the infestation area. As well, the density and distribution of the infestation and an herbicide efficacy rating between 1 and 10 will be recorded to assess changes (Ministry of Forests and Range, 2010). Further, the perimeter of the infestation will continue to be walked using a hand-held GPS to document any changes in the infestation area.

Orange hawkweed (*Hieracium aurantiacum*)

Orange hawkweed (*Hieracium aurantiacum*) is a regionally noxious weed in the East Kootenay. It is a perennial that spreads through windborne seeds and vegetatively by horizontal stolons and rhizomes (AISC, 2015). Orange hawkweed prefers sites with well-drained and coarse textured soils low in organic matter, such as fields, forest clearings, pastures, and farmland (ISC BC, 2017b). Orange hawkweed prefers sun; however, it successfully grows in shade, including a coniferous forest canopy (AISC, 2015).

Since 2015, orange hawkweed infestations have been identified throughout the reserve, primarily within open forest, forested, and disturbed sites. Between 2015-2017, orange hawkweed has been identified in the following areas on the reserve (Figure 5):

- Edwards Lake,
- TPIB sawmill,
- East, northeast corner of the reserve in a forested area,
- Northeast of Indian Lake, within an old burn,
- Southeastern reserve access road, known as the Proudfoot access road, and
- Roosville Cemetery.

Because orange hawkweed is commonly found at these locations, monitoring areas have been delineated at these sites (Figure 5).

Over the years, orange hawkweed infestations identified in these areas have been treated with the herbicide Milestone to control the spread of orange hawkweed throughout the reserve. Treatment success of orange hawkweed patches sprayed with Milestone has been met with high success (Table 1). However, new infestations continue to emerge, particularly within the Edwards Lake area and in the southeastern reach of the reserve, reducing overall treatment efficacy within monitoring areas (Table 1; Table 2). As well, some infestations are adjacent to a water source, which presents a management challenge.

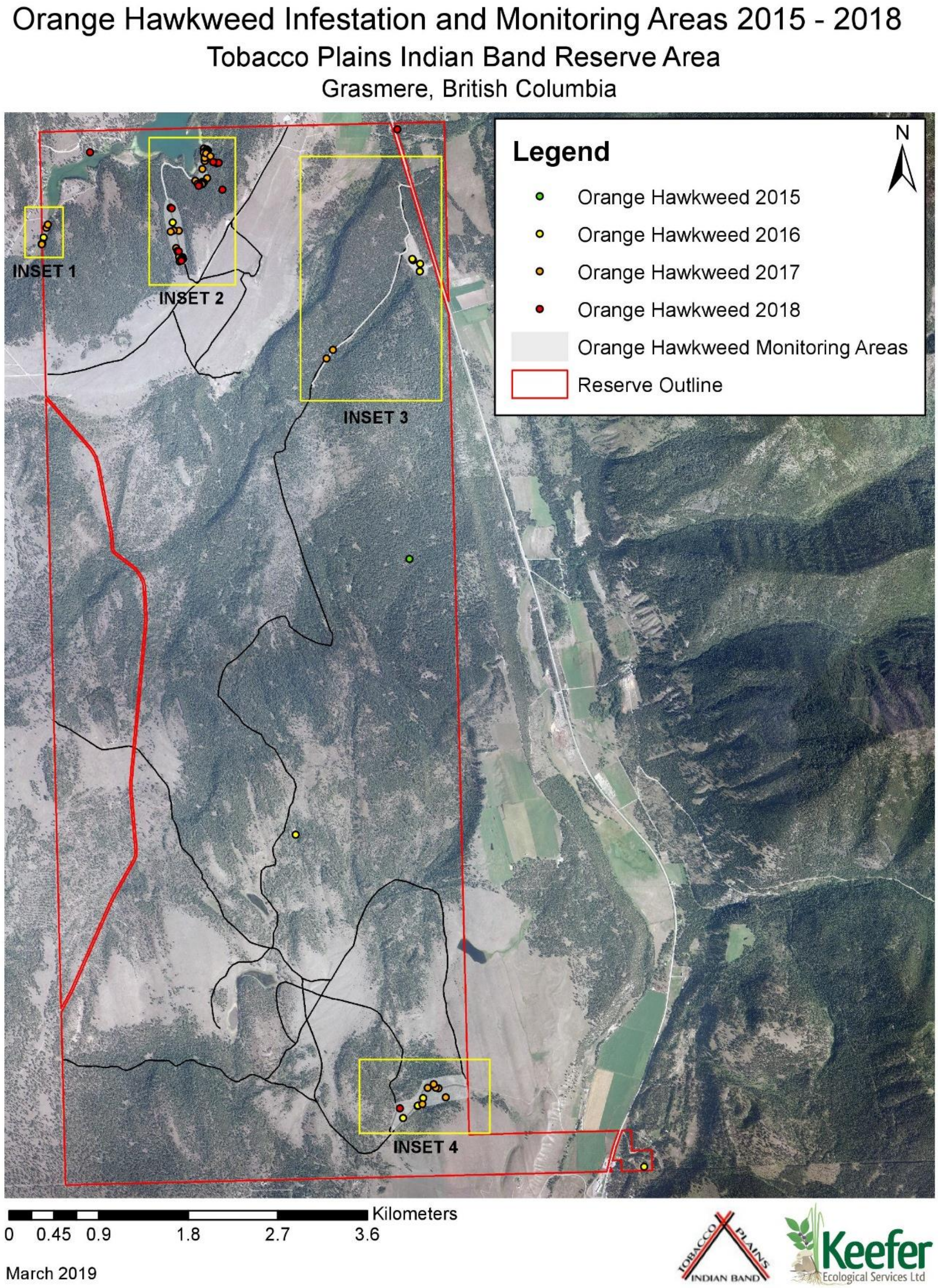

Figure 5: Orange hawkweed (*Hieracium auranriacum*) sites identified on Tobacco Plains Indian Reserve between 2015-2018 and specific areas to monitor. See Appendix A for insets

The *Integrated Pest Management Act* specifies herbicide cannot be applied within 1 m of the high water mark and only glyphosate may be applied between 1 m to 10 m of the high water mark (Government of British Columbia, 2018). To manage plants found on the reserve within 1 m of the high water mark, flower heads are removed. However, orange hawkweed is known to spread vegetatively as well as by seed. As such, complete removal of all plant parts adjacent to water is needed to eradicate the plant. Glyphosate was applied to plants present within 1 m to 10 m of the high water mark; however, glyphosate is only considered to provide short term control of orange hawkweed (ISC BC, 2014a). As a result of these circumstances, a longer time period of treatment will be necessary to effectively manage orange hawkweed at these sites. Assessment of the priorities of orange hawkweed management on the reserve is necessary to determine if infestations adjacent to water are to be eradicated or if management efforts should focus on controlling the spread of these infestations.

In addition to new infestation sites found in the Edwards Lake area and in the southeastern reach of the reserve, an infestation, approximately 15 m x 10 m in size, was found in the northeastern corner of the reserve on a Band Member's property in 2018 (Figure 5, Table 2). As well, a notable orange hawkweed infestation was found along Dorr Road, which passes through the reserve (Figure 5, Table 2). The full extent of this infestation is unknown as time constraints prevented measuring the area of the infestation. However, approximately 0.2 ha of area was sprayed with Milestone.

Continued monitoring of areas known to contain orange hawkweed is critical to ensure herbicide treatment of these infestations is successful and orange hawkweed does not re-establish. As well, continued surveying of the reserve for orange hawkweed is needed to manage its spread. Band members are encouraged to report any sightings of orange hawkweed to the band office to aid in the management of this noxious weed.

Table 1: Treatment efficacy of orange hawkweed (*Hieracium aurantiacum*) infestations sprayed with herbicide between 2015-2017 on Tobacco Plains Indian Reserve

General Location	Monitoring Area	UTM Zone	UTM Easting	UTM Northing	Year Treated	Efficacy Monitoring (1-10)		Comments
						2017	2018	
Edwards Lake Rd S	8.1539	11	637898	5438524	2016, 2017	8*	6	Plants sprayed with Milestone in previous years did not reemerge; however, new plants are emerging in the monitoring area. As such, an efficacy rating of 6 was given for this monitoring area in 2018.
Edwards Lake area, side roads	3.9947	11	638139	5439254	2016, 2017	7*	7	OH remains present in this monitoring area. Several OH sites sprayed with Milestone in previous years did not reemerge; however, a few notable OH sites are still present in the area and new OH sites emerged. Some OH patches are within 10 m of a water source and thus spraying with glyphosate is required to manage these patches. Flowers heads of plants found within 1 m of a water source were removed to prevent seed spread.
Stream feeding into SW end of Edwards Lake	0.6827	11	636585	5438572	2016, 2017	9	2	A site more than 10 m from the stream was sprayed with Milestone in 2016. In 2017, a few stray OH were observed at this patch. In 2017, sites within 10m of the stream were treated with glyphosate. In 2018, OH was not observed to have reemerged from a couple of these sites; however, new sites emerged and were sprayed with glyphosate. Treatment in this area is challenging because OH patches are within 10 m of a water source. Flowers heads of plants found within 1 m of a water source were removed to prevent seed spread.
TPIB sawmill	4.7304	11	640325	5438196	2016	unknown	10	Area was sprayed with Milestone in 2016. In 2017, treatment efficacy was unknown as OH had gone to seed when monitoring was conducted and YH is present in the area; therefore it is difficult to determine if OH was effectively managed as OH and YH rosettes are similar. In 2018, OH was not observed in the monitoring area.
Reserve road behind TPIB sawmill	2.5 km	11	640220	5439039	2017	-	unknown	Area was sprayed with Milestone in 2017. Due to time constraints, the road was not monitored in 2018.
NE of Indian Lake, old burn	0.7277	11	639088	5432585	2016, 2017	6	8	Area was sprayed with Milestone in 2016 and 2017. Decline in OH has been notable. Infestation area decreased by approximately 0.3 ha.

General Location	Monitoring Area	UTM Zone	UTM Easting	UTM Northing	Year Treated	Efficacy Monitoring (1-10)		Comments
						2017	2018	
NEE corner of reserve in forested area	0.1697	11	640222	5435331	2015	unknown	unknown	Area was sprayed with Milestone in 2015. OH had gone to seed when monitoring was conducted in 2017 and YH is present in area; therefore, it was difficult to determine if OH was effectively managed as OH and YH rosettes are similar. In 2018, the site was not monitored due to time constraints.
Proudfoot Access Rd	15.6141	11	640366	5429951	2015, 2016, 2017	9	8	Area was sprayed with Milestone between 2015-2017. Although the monitoring area is large, OH patches are sporadic throughout the area and small, primarily less than 1 m^2. Several OH sites sprayed in previous years did not reemerge. New, small (less than 1 m^2) OH sites were found in the monitoring area in 2018.
Proudfoot Access Rd, cleared area, old landing	0.0001	11	640303	5429883	2015	10	10	Area was sprayed with Milestone in 2015. OH did not reemerge in 2017 or 2018.
Roosville Cemetery	0.0509	11	642562	5429278	2016	10	unknown	Area was sprayed with Milestone in 2016. In 2017, OH was not observed. In 2018, the cemetery was not assessed due to time constraints.

* Represents an average efficacy rating based on the success of OH patches treated within the monitoring area

Table 2: New orange hawkweed (*Hieracium aurantiacum*) infestations found in 2018 on Tobacco Plains Indian Reserve

General Location	Estimated Infestation Size (ha)	UTM Zone	UTM Easting	UTM Northing	Density	Distribution
Edwards Lake Rd S	<0.0001	11	637935	5438353	3	4
	< 0.0001	11	637852	5438822	3	4
Edwards Lake area, side roads	< 0.0001	11	638120	5439047	3	3
	0.005	11	638265	5439284	4	3
	0.009	11	638358	5439009	5	3
Edwards Lake – Leased Properties	0.0025	11	637037	5439381	3	4
Dorr Rd	0.2*	11	637616	5434593	8	4
Proudfoot Access Rd	< 0.0001	11	640126	5429859	3	2
Northeastern corner of the reserve, Band Member Property	0.015	11	640101	5439610	5	4

* Represents area sprayed. Infestation size is currently unknown.

Spotted knapweed (*Centaurea stoebe*)

Spotted knapweed (*Centaurea stoebe*) is an invasive plant of concern among TPIB members and it is identified as a provincially noxious weed under the BC *Weed Control Act*. Spotted knapweed reproduces only by seed and prefers to inhabit open areas and well-drained soils, becoming established in grasslands, open forests, and roadsides (ISC BC, 2014b).

Through surveys conducted on the reserve since 2015, large (greater than 1 ha) infestations of spotted knapweed have been identified in the northeastern corner of the reserve by Upper Gravelle Road within a forest clearing and within and around the Roosville cemetery (Figure 6, Table 3). A large spotted knapweed infestation has also been located just outside of the reserve in the southeastern corner along the Proudfoot reserve access road. Further, spotted knapweed is abundant in the state of Montana, particularly near the US/Canada border crossing (USDA, 2006). Since large infestations of spotted knapweed are present on and off reserve, acting as seed sources, management efforts concerning the noxious weed are focused on controlling its spread rather than eradicating the plant from the reserve.

In addition to the large infestations, spotted knapweed has most commonly been found along roadsides on the reserve (Figure 6, Table 3). Roadsides were treated with Milestone in summer 2017; however, treatment success was low (Table 3). Re-treatment of roadsides is critical to manage the spread of spotted knapweed. Plants have also been sporadically found within the southeastern corner of the reserve where forest thinning has occurred to restore the area to an open forest. Treatment of plants with Milestone in this area has been met with high success (Table 3). Spotted knapweed has re-sprouted in a few areas sprayed in 2015, specifically at two locations in the Edwards Lake area and within a clearing along the Proudfoot access road (Table 3). These infestations were re-sprayed with Milestone in 2018 to continue management efforts. Spotted knapweed continues to be noted at the TPIB sawmill site (Figure 6). Management of this area in 2018 was not possible due to time constraints. However, treatment of this site is a priority because it is trafficked area.

Two new infestations of note were identified in the Edwards Lake Area (Figure 6, Table 4). A single plant was found along Edwards Lake Road South. This plant was of note as spotted knapweed had not been previously observed within this area of the road. Secondly, the spotted knapweed infestation within Edwards Lake Campground was surveyed. Treatment of this infestation prior to camping season is a priority to prevent the spread of spotted knapweed to other areas of the reserve by campers. At this site, spotted knapweed plants were observed within 10 m of the high water mark. Handpulling will need to be applied to manage plants near the water’s edge.

Continued monitoring of areas sprayed with herbicide is necessary to assess treatment success and ensure spotted knapweed does not re-establish. As well, continued surveying of the reserve for spotted knapweed, particularly along roadsides, is needed to manage its spread. Band members are encouraged to report any sightings of spotted knapweed to the band office to aid in the management of this noxious weed.

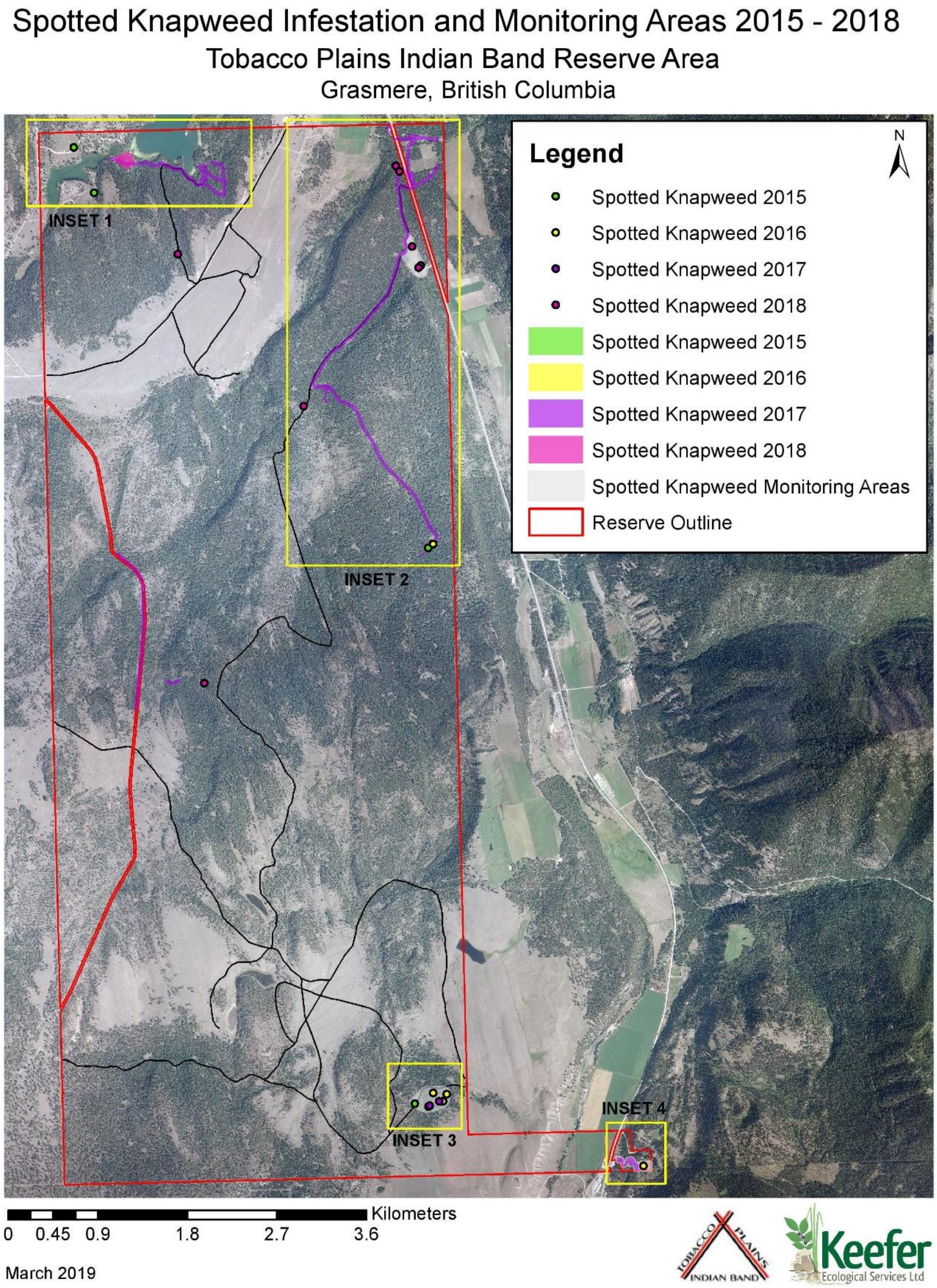

Figure 6: Spotted knapweed (*Centaurea stoebe*) sites identified on Tobacco Plains Indian Reserve between 2015-2018 and specific areas to monitor. See Appendix B for insets

Table 3: Treatment efficacy of spotted knapweed (*Centaurea stoebe*) infestations sprayed with herbicide between 2015-2017 on Tobacco Plains Indian Reserve

General Location	Monitoring Area	UTM Zone	UTM Easting	UTM Northing	Year Treated	Efficacy Monitoring (1-10)		Comments
						2017	2018	
Near internet/cell tower, NW of Edwards Lake	0.3 ha	11	636884	5439442	2015, 2018	10	8	Area was sprayed in 2015 with Milestone. SK did not reemerge until 2018. Area was re-sprayed to continue SK management.
SE of the Arbour, Edwards Lake Area	0.03 ha	11	637087	5438989	2015, 2018	10	9	Area was sprayed in 2015 with Milestone. SK did not reemerge until 2018. Plants were handpulled as a large number were not present.
Along Proudfoot Access Rd, landing, cleared area	0.3 ha	11	640284	5429905	2015, 2018	10	8	Area was sprayed in 2015 with Milestone. SK did not reemerge until 2018. Area was re-sprayed to continue SK management.
Edwards Lake Rd S and side road	2.3 km + 0.02 ha	11	637254	5439329	2017	-	1	SK remains present along roadside.
Previous Band Office along Hwy 93	0.1 ha	11	640011	5439625	2017	-	unknown	Due to time constraints, area was not monitored.
Upper Gravelle Rd	1.7 km	11	640256	5439037	2017	-	unknown	Due to time constraints, area was not monitored.
Upper Gravelle Rd Disturbed Field	0.5 ha	11	640250	5439133	2017	-	unknown	Due to time constraints, area was not monitored.
TPIB sawmill	4.7 ha	11	640344	5438265	2016, 2017	unknown	unknown	Due to time constraints, area was not monitored.

General Location	Monitoring Area	UTM Zone	UTM Easting	UTM Northing	Year Treated	Efficacy Monitoring (1-10)		Comments
						2017	2018	
Reserve roads west of Hwy 93	5.0 km + 0.4 ha	11	640219	5439039	2017	-	1	SK remains present along roadside.
Forested area, NEE side of reserve	0.3 ha	11	640467	5435486	2015, 2017	8	unknown	In 2017, SK was found along the road, which was contributing to SK encroachment onto the treated site, influencing treatment efficacy. In 2018, due to time constraints, the area was not monitored.
Dorr Rd	1.6 km	11	637319	5435375	2017	-	1	SK remains present along roadside.
Side road off of Dorr Rd	0.1 km	11	637810	5434117	2017	-	1	SK remains present along roadside.
Proudfoot Access Rd, forest thinned in 2014/15, open forest	3.9 ha	11	640512	5429957	2016, 2017	9*	10	-
Roosville Cemetery	2.0 ha	11	642502	5429275	2016, 2017	10	unknown	In 2016, approximately 0.4 ha within the monitoring area was sprayed and no SK was observed in that area in 2017. In 2017, an additional 0.1 ha was sprayed in the monitoring area. Due to time constraints, the area was not monitored in 2018.

* Represents an average efficacy rating based on the success of SK patches treated within the monitoring area

Table 4: New spotted knapweed (*Centaurea stoebe*) infestations found in 2018 on Tobacco Plains Indian Reserve

General Location	Estimated Infestation Size (ha)	UTM Zone	UTM Easting	UTM Northing	Density	Distribution
Edwards Lake Rd S	< 0.0001	11	637921	5438378	1	1
Edwards Lake Campground	1.93	11	637402	5439314	5	4

Sulphur Cinquefoil (*Potentilla recta*)

Sulphur cinquefoil (*Potentilla recta*) is widespread throughout TPIR, dominating over 700 ha of grassland. It is also found within open forest ecosystems, past burns, cleared/logged areas and along roadsides (Juckers and Keefer, 2016). Herbicide application has not been a treatment technique used to manage the weed because of its expanse across the reserve. Research has indicated that target grazing using goats is a viable option to control sulphur cinquefoil yield and seed production (Frost and Mosley, 2012; Frost *et al*., 2013). Target grazing is an invasive plant management technique in which domestic animals, such as goats, are trained to graze invasive plants at a time and frequency when the weed is most vulnerable (Launchbaugh and Walker, 2006; Frost and Launchbaugh, 2003). The goal of target grazing is to place an invasive plant at a competitive disadvantage within a plant community through herbivory.

TPIB has been interested in assessing the application of target goat grazing to manage sulphur cinquefoil on grasslands within the reserve to improve the health of these degraded systems and increase the presence and density of native vegetation. In 2018, target goat grazing was conducted by Vahana Nature Rehabilitation on 13 ha of grassland in an area of the reserve known as the “Golf Course” to manage sulphur cinquefoil (Figure 7). This marks the third year in which target goat grazing has occurred in this area of the reserve.

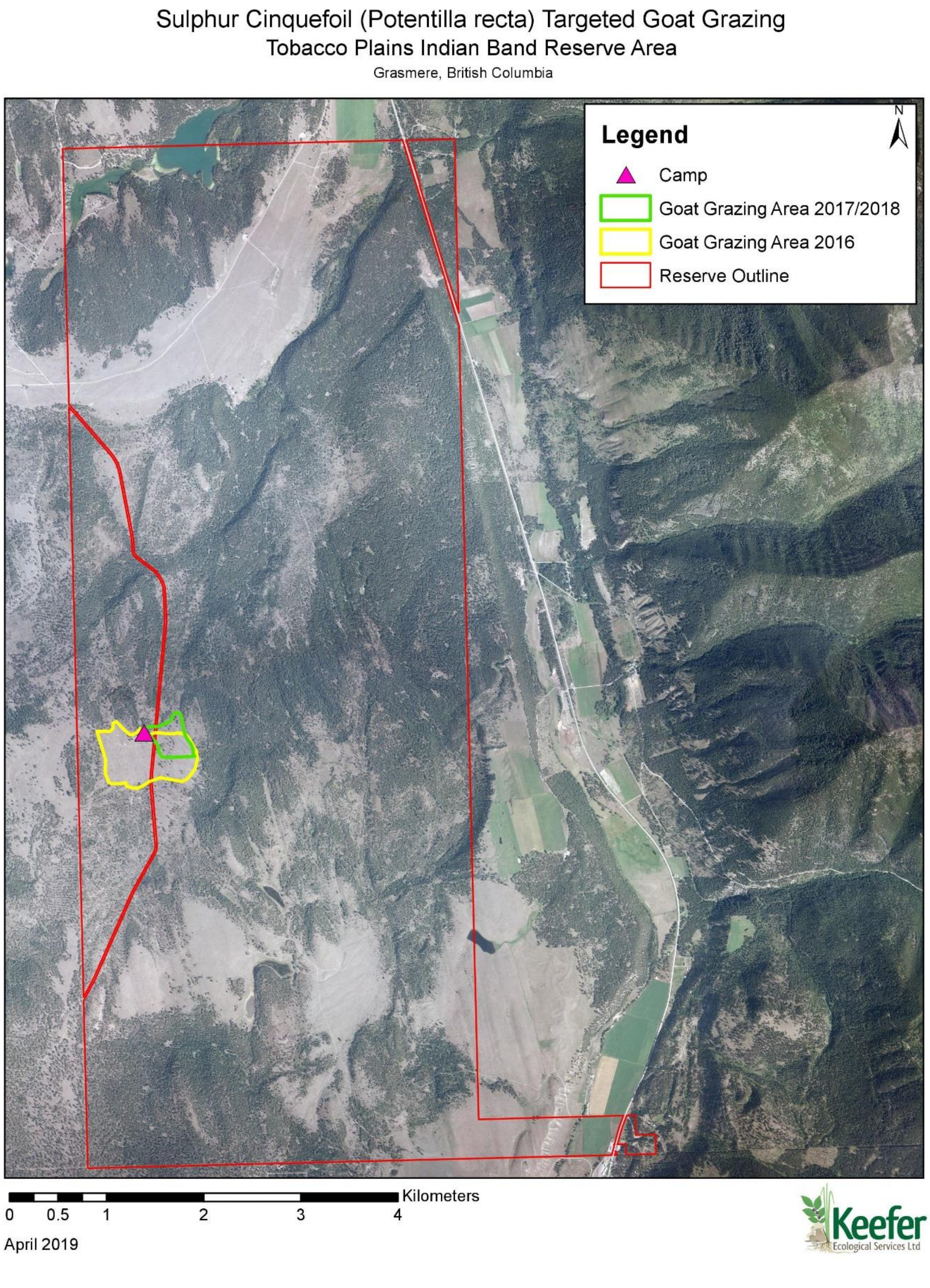

Figure 7: Area of grassland grazed by goats in 2016, 2017, and 2018 on Tobacco Plains Indian Reserve to manage sulphur cinquefoil (*Potentilla recta*)

In addition to TPIB, several stakeholders in the region have expressed interest in the effectiveness of target goat grazing to manage sulphur cinquefoil in grasslands/rangelands within the East Kootenay region of the Southern Rocky Mountain Trench, including the East Kootenay Invasive Species Council, the Ministry of Forests, Lands and Natural Resource Operations and Rural Development, and the Rocky Mountain Trench Natural Resources Society. Target goat grazing efforts on TPIR have shown the goats are preferentially targeting sulphur cinquefoil (Juckers and Carignan, 2018; Figure 8). The average height of sulphur cinquefoil has been observed to decrease after grazing and the number of sulphur cinquefoil plants with seed heads, the number of seed clusters, and the percent cover of this plant were all observed to decrease post-grazing compared to pre-grazing. These results indicate the goats are impacting the plant (Figure 8). However, further research is needed to understand the mechanisms driving sulphur cinquefoil's dominance in grasslands in the region. As well, more data needs to be gathered on the effectiveness of target goat grazing to manage sulphur cinquefoil in comparison to other management techniques, such as herbicide and native plant seeding. This information can then be utilized by stakeholders to identify best management approaches to address sulphur cinquefoil and improve grassland health. In response, KES and TPIB have partnered with the University of Saskatchewan to implement a research study to examine sulphur cinquefoil management on disturbed grasslands in the East Kootenay. A literature review of the ecology of sulphur cinquefoil, options to manage the plant, and further research needed concerning sulphur cinquefoil management is provided in Appendix C. A description of the research design of the sulphur cinquefoil management study that will be implemented on TPIR, as well as St. Mary's (ʔaq'am) Indian Reserve, in late spring 2019 is provided in Appendix D.

Figure 8: Before and after photos of a patch of sulphur cinquefoil (Potentilla recta) grazed by goats in 2018 within the "Golf Course" region on Tobacco Plains Indian Reserve. Photos were taken by Cailey Chase, owner of Vahana Goats

Other Invasive Plant Species

Field Bindweed (*Convolvulus arvensis*)

Field bindweed (*Convolvulus arvensis*) is a long-lived perennial vine that reproduces by seed and vegetatively (AISC, 2014a). Field bindweed can inhabit various environments as it successfully grows in dry to moist soils and is drought tolerant; however, it does not tolerate shade. In the East Kootenay region, field bindweed is considered an invasive plant of concern.

In 2015, a small infestation of field bindweed, less than 0.01 ha in size, was identified in the southeastern reach of the reserve on a stockpile in a cleared area (Figure 9, Table 5). This is the only infestation of field bindweed that has been identified on the reserve. In 2015 and 2016, the infestation was sprayed with Milestone to work towards eradicating the infestation. In 2017, field bindweed was not observed on the stockpile, suggesting management was effective (Table 5). In 2018, monitoring of the stockpile was not conducted due to time constraints. Future monitoring is necessary to assess whether field bindweed re-established.

Scentless Chamomile (*Tripleurospermum inodorum*)

Scentless chamomile (*Tripleurospermum inodorum*) is considered an annual, biennial, or short-lived perennial that establishes quickly on disturbed sites, inhabiting wet to dry sites and reproduces only by seed (ISC BC, 2014c). Scentless chamomile is considered a provincially noxious weed under the BC *Weed Control Act*. The noxious plant is of concern in agricultural areas as it reduces yields in hay fields, pastures, grain fields, and other cultivated crops by forming dense stands (Radio West, 2015). TPIR is home to grasslands which have been degraded by overgrazing. Establishment of scentless chamomile on these weak systems could further compromise the grasslands.

Scentless chamomile was identified within the TPIB sawmill site in 2017 (Figure 9, Table 5) and the site was sprayed with Milestone and Vantage XRT. In 2018, monitoring of the area identified the emergence of new scentless chamomile patches (Figure 9; Table 5). Time constraints prevented these patches from being treated. Future treatment and monitoring of this site is necessary to prevent the spread of scentless chamomile into the reserve.

Yellow Toadflax (*Linaria vulgaris*)

Yellow toadflax (*Linaria vulgaris*) is listed as a provincially noxious weed under the BC *Weed Control Act*. It is a perennial plant that produces seed; however, it primarily reproduces by sprouting from its creeping root system, enabling the plant to create large colonies (AISC, 2014b). Yellow toadflax commonly establishes in disturbed areas and rangeland, preferring coarse, well-drained soils.

In 2017, a small infestation of yellow toadflax, less than 0.001 ha in size, was identified in a clearing just off of Edwards Lake Road South (Figure 9, Table 5). The infestation was sprayed with Tordon 22K. The goal concerning yellow toadflax is to eradicate the infestation from the reserve to prevent the plant from invading grasslands. In 2018, the infestation was monitored and an efficacy rating of 1 (0-19% reduction in infestation) was given as a decline in plant density was not observed (Table 5). The infestation was re-sprayed with Tordon 22K to continue treatment efforts. Continued monitoring of the site is critical to assess whether re-treatment is necessary.

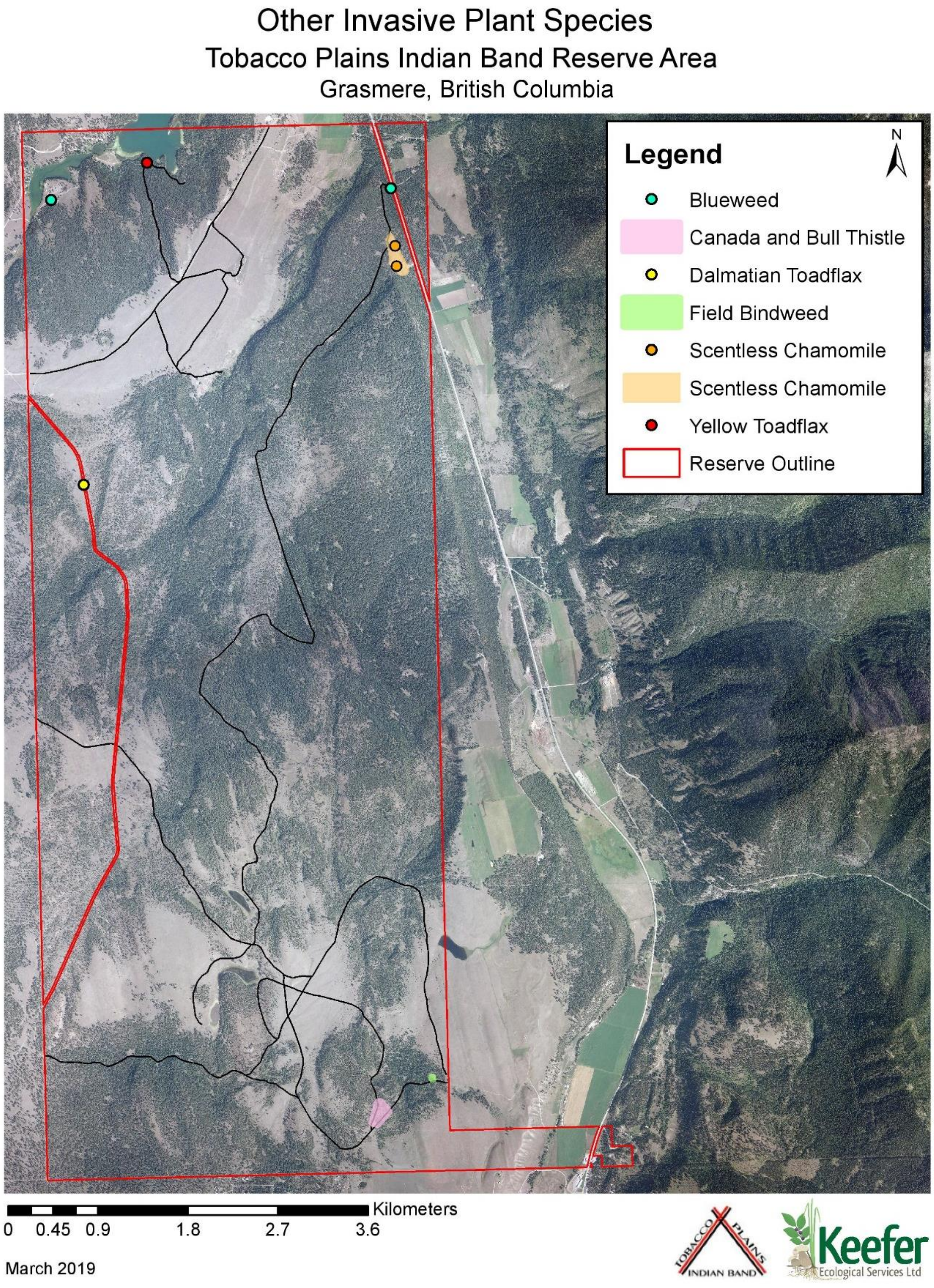

Figure 9: Other invasive plant infestation sites found on Tobacco Plains Indian Reserve

Table 5: Treatment efficacy of field bindweed (*Convolvulus arvensis*), scentless chamomile (*Tripleurospermum inodorum*), and yellow toadflax (*Linaria vulgaris*) infestations sprayed with herbicide between 2015-2017 on Tobacco Plains Indian Reserve

Species	General Location	Monitoring Area	UTM Zone	UTM Easting	UTM Northing	Year Treated	Efficacy Monitoring (1-10)	Comments
Field bindweed (*Convolvulus arvensis*)	Just off of the Proudfoot Access Rd in a clearing	0.001	11	640638	5430120	2015, 2016	2016: 1 2017: 10 2018: unknown	Field bindweed was found on a stockpile in a clearing just off of the Proudfoot Access Road in 2015. The infestation was sprayed with Milestone. Monitoring of the infestation area in 2016 found field bindweed had not declined and thus the infestation was resprayed. In 2017, monitoring found treatment was effective. Due to time constraints, the infestation was not monitored in 2018.
Scentless chamomile (*Tripleurospermum inodorum*)	TPIB Sawmill	4.3	11	640257	5438325	2017	unknown	Due to time constraints, the infestation sprayed in 2017 was not monitored. However, new patches of scentless chamomile were found at the sawmill site. A monitoring area encompassing the entire sawmill site was created.
Yellow toadflax (*Linaria vulgaris*)	Clearing off of Edwards Lake Rd S	<0.001	11	637786	5439279	2017	1	Tordon 22K was sprayed on the yellow toadflax infestation in 2017. Treatment success was low. Site was resprayed in 2018.

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Blueweed (*Echium vulgare*)

Blueweed (*Echium vulgare*) is a biennial or short-lived perennial that is considered regionally noxious in the East Kootenay. Blueweed reproduces by seed and commonly inhabits areas with well-drained soils, including disturbed sites such as roadsides, drainage ditches, fence lines, rangelands, and pastures (ISC BC, 2014d).

A single blueweed plant was identified in a ditch adjacent to Highway 93 and a reserve road (Figure 9, Table 6). Plants were also spotted on a Band Member's property along Edwards Lake Road South. The size, density, and distribution of the infestation on the Band Member's property are unknown as a site visit on the property was not conducted. Treatment of blueweed was also not conducted. Future treatment through hand-pulling or the application of herbicide is necessary to prevent blueweed from invading sensitive sites, including grasslands, on the reserve. Educating Band Members on blueweed identification and the ecological impacts of the plant are needed to prevent the plant from being used as an ornamental on properties, to urge Band Members to remove blueweed from their property if it is present, and to encourage Band Members to report sightings to the band office, which will help prevent the spread of blueweed on the reserve.

Dalmatian Toadflax (*Linaria genistifolia*)

Dalmatian toadflax (*Linaria genistifolia*) is a short-lived perennial plant that is considered provincially noxious under the BC *Weed Control Act*. It reproduces by seed and through creeping roots, growing best in full sun and coarse textured, well-drained soils that are pH neutral to slightly alkaline (AISC, 2014c). Dalmatian toadflax requires disturbance or degraded vegetation to establish. In the BC Interior, Dalmatian toadflax presents a threat to farms and grasslands (ISC BC, n.d.).

A small patch of Dalmatian toadflax, less than 0.001 ha, was found along Dorr Road as the road passed through a grassland (Figure 9, Table 6). The grasslands on TPIR are disturbed, making them more susceptible to invasion by species such as Dalmatian toadflax. Treatment of Dalmatian toadflax was not conducted. Future treatment using herbicide is recommended to work towards eradicating the plant from the reserve to prevent its spread into disturbed grasslands on TPIR. Educating band members on identification, ecology, and the threats of Dalmatian toadflax is important to bring awareness of the plant among the community and prompt band members to report sightings to the band office, which will help in the eradication of Dalmatian toadflax from the reserve.

Canada Thistle (*Cirsium arvense*) / Bull Thistle (*Cirsium vulgare*)

Canada thistle (*Cirsium arvense*) is considered provincially noxious under the BC *Weed Control Act* and bull thistle (*Cirsium vulgare*) is an invasive plant of concern in the East Kootenay. Canada thistle is a perennial plant that reproduces by seed and through its creeping root system (AISC, 2014d). Canada thistle grows well in a wide range of soils; however, it does not tolerate waterlogged soils or complete shade. It thrives best in disturbed areas and overgrazed pasture and rangeland (AISC, 2014d). Bull thistle is a biennial plant that reproduces by seed (BC Ministry of Agriculture, Food and Fisheries and Open Learning Agency, 2002). It grows in dry and moist habitats and is generally intolerant of shade. Both Canada and bull thistle have been identified throughout TPIR (Juckers and Keefer, 2016). However, they have not been considered a management priority until recently based on their potential threat to open forest restoration treatment areas.

Open forest restoration has occurred in the southern reach of the reserve since 2014. Efforts have involved manually thinning trees to re-create an open forest. In early spring 2018, an eco-mulcher was used, in addition to manual thinning, to manage forest encroachment within approximately 2 ha. Monitoring of the area during the summer identified the emergence of patches of Canada thistle and sporadic bull thistle plants (Figure 9, Table 6). Canada thistle is an aggressive plant that forms colonies (AISC, 2014d) and bull thistle is known to establish in clear-cuts and disturbed areas, becoming the dominant species for several years (BC Ministry of Agriculture, Food and Fisheries and Open Learning Agency, 2002). Treatment of the eco-mulched area is critical to prevent Canada and bull thistle from dominating the area, outcompeting native species. Approximately 0.09 ha of area was treated with Milestone to initiate invasive plant management in this area. Further treatment is necessary to continue management of Canada and bull thistle.

Table 6: New invasive plant infestations found in 2018 on Tobacco Plains Indian Reserve

Species	General Location	Estimated Infestation Size (ha)	UTM Zone	UTM Easting	UTM Northing	Density	Distribution
Blueweed (*Echium vulgare*)	Adjacent to Highway 93 and a reserve road in a ditch	<0.0001	11	640225	5439023	1	1
Blueweed (*Echium vulgare*)	Edwards Lake Rd S on a Band Member's property	unknown	11	636826	5438906	unknown	unknown
Dalmatian Toadflax (*Linaria genistifolia*)	Dorr Rd	<0.001	11	637153	5436056	3	4
Canada Thistle (*Cirsium arvense*)	Eco-mulched area off of the Proudfoot Access Rd	2	11	640106	5429745	5	4
Bull Thistle (*Cirsium vulgare*)	Eco-mulched area off of the Proudfoot Access Rd	2	11	640106	5429745	2	1

Ecological Restoration Forest Thinning

Tobacco Plains Indian Reserve is located within the very driest climate within the Interior Douglas-fir Biogeoclimatic Zone. These ecosystems are classified as belonging to the Natural Disturbance Type (NDT) 4, defined as an ecosystem with frequent stand-maintaining fires. The NDT 4 includes grassland, shrubland, and forest communities that frequently experience low intensity fires, which maintains the ecosystem state by limiting encroachment and ingrowth of woody trees and shrubs (Hall, 2010). In the Tobacco Plains region, studies have indicated fire frequency ranged from 6 to 8.7 years which coincides with oral history regarding First Nations use of fire (Heyerdahl *et al*., 2008). This environment is important to numerous species, including the federal at-risk species Spalding's campion, American badger, Lewis's woodpecker, and long-billed curlew. As well, it provides important grazing habitat for species such as mule deer and Rocky Mountain elk. Decades of fire suppression has led to forest encroachment and ingrowth within these grassland and open forest ecosystems, resulting in the following (Bond *et al*., 2013):

- A shift in tree density and tree age as grasslands are becoming open forests;
- Increased tree density in open forests and a shift to younger, smaller diameter trees which places competition on veteran trees;
- A shift in tree species from fire-tolerant ponderosa pine to less-fire adapted Douglas fir;
- Increased risk of severe fire as fuels build;
- Reduction and possible extirpation of native grassland plants as plants are out-shaded by encroaching trees; and
- Loss of forage for grazing animals, such as elk and mule deer, placing increased pressure on remaining grazing sites.

Removal of encroaching trees is imperative for improving and maintaining critical grassland and open forest habitat for wildlife on the reserve and to reduce the risk of severe fires.

Treatment Unit Delineation

Since 2006, KES has worked with TPIB to restore critical grassland and open forest habitat on the reserve. In 2013, KES delineated priority areas throughout the reserve to address tree encroachment on Spalding's campion habitat, which would also benefit other species at risk, including long-billed curlew, American badger, and Lewis's woodpecker, all of which thrive in grassland and open forest habitat. Prior to conducting field work, a desktop exercise was performed to identify priority sites. GIS mapping work completed for KES in 2010 produced ecosystem units by cover type (grassland, open forest, closed forest; Keefer and Kennedy, 2010). The data were overlain with Spalding's campion point occurrences, highlighting encroached grasslands and overstocked forest sites containing, or near, known Spalding's campion locations. Pre-treatment surveys in fall 2013 were targeted at these sites to characterize each treatment unit in its present state, develop appropriate stocking rates and describe the target plant community composition, post-treatment. Data were analyzed using MS Excel and subsequently used to create ecological restoration (ER) prescriptions using the Ministry of Forests, Lands and Natural

Resource Operations Rocky Mountain Forest District Ecological Restoration Prescription form (Appendix E). Prescription implementation began in 2014, in which approximately 7 ha of open forest habitat was thinned within treatment unit CATCHFLY 14-10. In 2015, work continued within CATCHFLY 14-10, with approximately 3.4 ha of open forest thinned. Additionally, approximately 13 ha of open forest were thinned in and around CATCHFLY 14-17. In 2016, efforts continued in CATCHFLY 14-17 with approximately 8.8 ha of land thinned. In 2017, efforts focused on completing thinning efforts in CATCHFLY 14-10 and CATCHFLY 14-17, with approximately 10.4 ha thinned. Eco-mulching also occurred in approximately 2 ha of area just outside CATCHFLY 14-17. In 2018, efforts focused on completing manual thinning in CATCHFLY 14-10 and initiating thinning efforts in CATCHFLY 14-04 through manual thinning and the application of the eco-mulcher.

2018 Ecological Restoration (ER) Implementation

Site Action Plan

A site action plan was developed in October 2018 to provide the forestry crew with the ER prescriptions to be implemented in the southern reach of the reserve to continue forest thinning efforts. Focus was placed on completing thinning efforts in ER units CATCHFLY 14-10 and CATCHFLY 14-04. The goal for each of these ER units was to restore the area to open forest. To reach this goal, the following was prescribed:

- Maintain 76 to 400 stems per hectare (sph) on site with a target of 150 sph while maintaining the largest trees on site, emphasizing trees greater than 20 cm diameter at breast height (dbh); and
- Remove most small diameter trees (less than 20 cm dbh), retaining an average of 10-20 sph of healthy poles for stand recruitment.

Manual thinning areas were located in areas with somewhat less-dense stands and on more sloping ground than those selected for the possible eco-mulcher treatment. Slash piles created during manual thinning in 2017 were slated for burning in winter of 2018.

ER Implementation

Manual thinning was conducted between January 5 and 15, 2019. Mechanical thinning using the eco-mulcher was accomplished in January 2019. All work was completed by the TPIB forestry crew.

Monitoring

Pre- treatment monitoring of the thinned area within the ER units was conducted in mid-November 2018 with post-treatment measurement conducted in March 2019. Five and three 5.64m radius fixed-area monitoring plots were measured in the manual and mechanical treatment areas, respectively.

Results

Pile burning was successfully completed on the 10.4 ha of area manually thinned in 2017 (Figure 10).

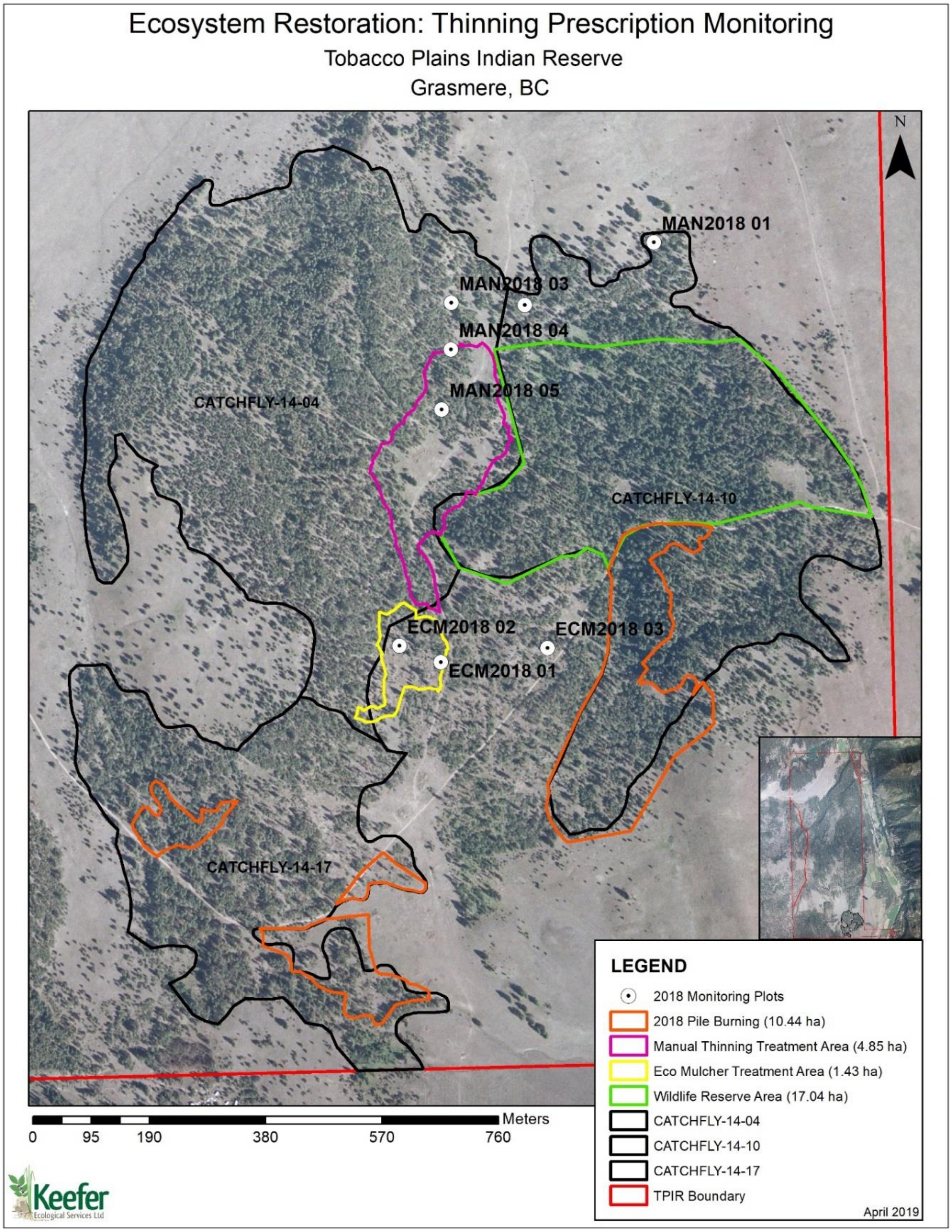

Figure 10: 2018 pile burning, manual thinning and eco-mulcher treatment areas on Tobacco Plains Indian Reserve

Pre-treatment density of trees targeted for removal in the manual treatment area averaged 3,440 sph of trees smaller than 12.5cm dbh (range 800 to 5,600 sph), 580 sph of trees 12.5 to 20 cm dbh (range 100 to 800 sph) and 160 sph of trees >20 cm dbh (range 0 to 500 sph). Pre-treatment density in the eco-mulcher treatment area averaged 10,467 sph of trees smaller than 12.5cm dbh (range 8,000 to 15,200 sph) and 333 sph of trees >12.5 cm dbh (range 0 to 700 sph).

A total of 4.9 ha were manually thinned this year, while the eco-mulcher mechanically treated 1.4 ha (Figure 10). Small patches of untreated stems were left within the eco-mulcher area to provide wildlife hiding cover. Of the five pre-treatment monitoring plots located within the manual treatment area, two plots were treated. Post-treatment measurements in the manually treated areas revealed that an average of 250 sph of <12.5 cm trees (range 100 and 400 sph) and 450 sph of trees >12.5cm (range 300 and 600 sph) remained. Anecdotally, the average remaining stems were fewer than that indicated by the two treatment plots.

In the eco-mulcher treated area, two of the three monitoring plots were treated and one of these plots had about half of the plot area treated. The one plot that was entirely treated contained 300 sph of trees < 12.5cm dbh with no trees >12.5cm remaining. This appeared to be a representative density for the eco-mulcher-treated area. This plot had almost 15,000 sph removed.

Within the manually treated area, almost all material was piled into piles measuring about 1.3 m in height and 2 meters in length and width. This was done in preparation for pile burning to be conducted in late fall/early winter.

Discussion

The upper end of the target density of 400 sph of the largest trees remaining was nearly achieved on the manually treated area and was reached at much of the eco-mulcher area. Progress was hampered by the high densities of material removed, necessitating numerous slash piles. The forestry crew did maintain small scale wildlife hiding cover within the treatment areas. As such, spatial heterogeneity, which is a desirable habitat feature, was maintained and enhanced. Further, discussions are ongoing regarding the use of prescribed fire to achieve ecosystem restoration goals more efficiently.

Community Engagement and Its Challenges

Aboriginal Day

KES was invited by Tom Phillips, the Lands and Resources Manager of TPIB, to set up a booth during Aboriginal Day on June 21, 2018 to discuss the proposed sulphur cinquefoil management study. Eleven people were reached during the event. An information page was distributed to individuals introducing them to the sulphur cinquefoil plant, techniques used to manage the invasive plant, and the aim of the research study. Discussions with individuals centered around the degraded state of grasslands on TPIR, sustained by the dominance of sulphur cinquefoil, and the desire of the Lands and Resources

Department of TPIB to improve the health of grasslands on the reserve through a scientifically supported research study. Individuals were informed the study will be implemented in 2019 with the study site located near the community village. Individuals were encouraged to come out and see the study in progress in 2019.

Community Engagement Challenges

Increasing community support and lack of Band resources have been challenges experienced during the grassland and open forest restoration project. A key component of ecological restoration efforts on TPIR has been training and employing members of the Tobacco Plains community to foster a long-term commitment to restoring grasslands and open forests on the reserve. Since 2015, band members have been involved with herbicide application and since 2016 members have assisted with target goat grazing. Forest thinning efforts over the past four years have also employed TPIB forest crews, providing workers with experience in implementing ecosystem restoration forest prescriptions. Direct involvement of Band Members in the project builds awareness of the goal to restore grassland and open forest habitat on the reserve and the importance of invasive plant management and forest thinning efforts to help achieve that goal. Although Band Members are directly involved in restoration efforts, a lack of awareness exists among the greater Tobacco Plains community concerning restoration efforts occurring on the reserve.

Many outside parties seek the attention of community members concerning initiatives proposed or occurring within their traditional territory. Members are requested to attend information sessions, provide commentary, and so forth which may overwhelm Band Members, deterring them from learning about the ecological restoration initiatives occurring on the reserve. As well, lack of time and resources from the Band Administration has made it challenging to communicate to Band Members the importance of invasive plant management and forest thinning efforts on the reserve and how these efforts are working to improve the health of the land. Further, TPIB is understaffed. For example, only one person is employed under the Lands and Resources Department. Allocating time and resources to support invasive plant management and forest thinning efforts is challenging for the Lands and Resources Manager as he is coordinating multiple projects. TPIB is working to increase staff at the band office, which includes staff in the Lands and Resources Department. However, till then, communication with the Lands and Resources Manager is critical to identify opportunities to increase awareness among the greater Tobacco Plains community of grassland and open forest restoration efforts. In addition, memos concerning ecological restoration initiatives occurring on the reserve may be distributed through the TPIB newsletter and Facebook page to increase community awareness.

Treatment Effort Summary and Recommendations

In summary, approximately 50 ha of land and 10.7 km of roadside were monitored and approximately 4.2 ha of land and 2.5 km of roadside were sprayed with herbicide to continue management of leafy spurge, orange hawkweed, and spotted knapweed infestations. Approximately 13 ha of land was also treated using targeted goat grazing to manage sulphur cinquefoil. The yellow toadflax infestation (<0.001 ha) was retreated with herbicide to continue efforts to eliminate the infestation and herbicide treatment was initiated on approximately 0.09 ha of land to treat an infestation of Canada and bull thistle in the southern reach of the reserve that emerged following forest thinning efforts in the area. Small infestations (< 0.001 ha) of blueweed and Dalmatian toadflax, two invasive species not previously identified on the reserve, were also documented. Further, forest thinning efforts involved manual thinning 4.9 ha and eco-mulching 1.4 ha of land to enhance open forest habitat as well as pile burning of last season's slash within 10.4 ha.

Yearly monitoring of invasive plant infestations treated throughout the reserve is recommended to assess treatment efficacy and determine if retreatment is necessary. Conducting invasive plant surveys each year is also recommended to identify new infestations, which is critical to manage the spread of invasive plants currently present on the reserve, including spotted knapweed and orange hawkweed, and identify invasive plants not previously found on the reserve. Surveying can be done in combination with monitoring to increase project efficiency. Further, discussing invasive plant management efforts with Chief and Council is advised to ensure invasive plant efforts align with land management goals.

Next Steps

In 2019, restoration efforts will continue within critical grassland and open forest habitat on TPIR through invasive plant inventory, monitoring, and control measures and forest thinning. Specifically, efforts will include:

Invasive Plant Management

Monitoring and Herbicide Treatment

Based on invasive plant management efforts from 2015-2018, focus will continue on managing the leafy spurge infestation using herbicide to work towards eradicating the infestation from the reserve. Efforts will also focus on working to eradicate field bindweed, scentless chamomile, yellow toadflax, Dalmatian toadflax, and blueweed infestations using herbicide. Managing the spread of spotted knapweed and orange hawkweed will continue through herbicide treatment. As well, treatment of open forest restoration sites with herbicide to manage Canada and bull thistle will occur to prevent these invasive plants from dominating the understory. Monitoring infestations treated with herbicide between 2015-2018 will continue as it is imperative to assess the efficacy of herbicide treatment to determine if retreatment is necessary. Further, continued surveying for invasive plants throughout the reserve and treating new infestations identified is critical to contain the spread of invasive plants.

Sulphur Cinquefoil Management Study

Managing sulphur cinquefoil has come to the forefront in the invasive plant control industry for the region as it has degraded low elevation grasslands throughout the Southern Rocky Mountain Trench, including over 700 ha on TPIR. KES and TPIB will be initiating a three year study in partnership with the University of Saskatchewan on TPIR to assess mechanisms driving sulphur cinquefoil's dominance on grasslands and identifying which treatment strategy, including targeted goat grazing, herbicide, and native plant seeding, or combination of strategies, best manages sulphur cinquefoil to improve grassland quality. The study will be implemented in late spring 2019.

Long-term Maintenance Plan

Summer 2019 will mark the fifth year in which the FWCP has supported invasive plant management efforts on TPIR to recover grassland and open forest habitat on the reserve. The fifth year marks the final year of a five year program proposed to the FWCP to initiate invasive plant management efforts on the reserve. To sustain invasive plant management efforts that began in 2015, project results since 2015 will be summarized and a long-term maintenance plan will be developed for TPIB, which will be included in the 2019/2020 final report. The maintenance plan will highlight priority management areas on the reserve and the management strategies to be implemented to address the invasive plants present within these areas. As well, the plan will discuss the importance of monitoring to continue assessing management success and to identify new infestations so they may be addressed quickly. The plan will be developed in consultation with the Lands and Resources Manager of TPIB to ensure the plan includes strategies the Band may implement to continue invasive plant management efforts.

Ecological Restoration Forest Thinning

Forest Thinning

Slash piles created in areas manually-thinned in early 2019 will be left to cure until late fall/early winter at which time they will be spot burned. A variety of funding sources will be explored to continue thinning efforts in other ecosystem restoration polygons where prescriptions have been prepared. Local experts are being consulted and will visit proposed treatment areas to assess the feasibility of prescribed burning. If deemed feasible, treatment prescriptions to facilitate burning will be prepared and discussed with members responsible for treatments.

Maintenance and Monitoring

A long-term maintenance plan will be developed that highlights priority areas to be thinned to enhance open forest and grassland habitat. The plan will be developed in consultation with the Lands and Resources Manager of TPIB to ensure selection of priority areas aligns with land management goals. As well, monitoring plots, as described in the thinning sections of this report, will continue to be implemented and measured in areas that are proposed for treatment in the upcoming year(s).

Community and Stakeholder Engagement

The TPIB Forestry Crew will continue to conduct forest thinning efforts. As well, TPIB members will be employed to assist with herbicide treatment and the implementation of the sulphur cinquefoil study to provide training and employment opportunities in ecological restoration work. TPIB members will also be invited to learn about the sulphur cinquefoil study and the treatment methods being examined to manage sulphur cinquefoil. The study will occur adjacent to the community village, providing members with the opportunity to see the study in action. Conversations regarding the sulphur cinquefoil study will continue with the East Kootenay Invasive Species Council, the Ministry of Forests, Lands and Natural Resource Operations and Rural Development, and the Ministry of Agriculture. Engagement of these stakeholders will strengthen the study as each stakeholder can provide their insight concerning the objectives of the study and the data to be collected to meet these objectives. A presentation introducing the project goals, objectives, and research design will also be conducted in early May 2019 at the East Kootenay Invasive Species Council annual general meeting.

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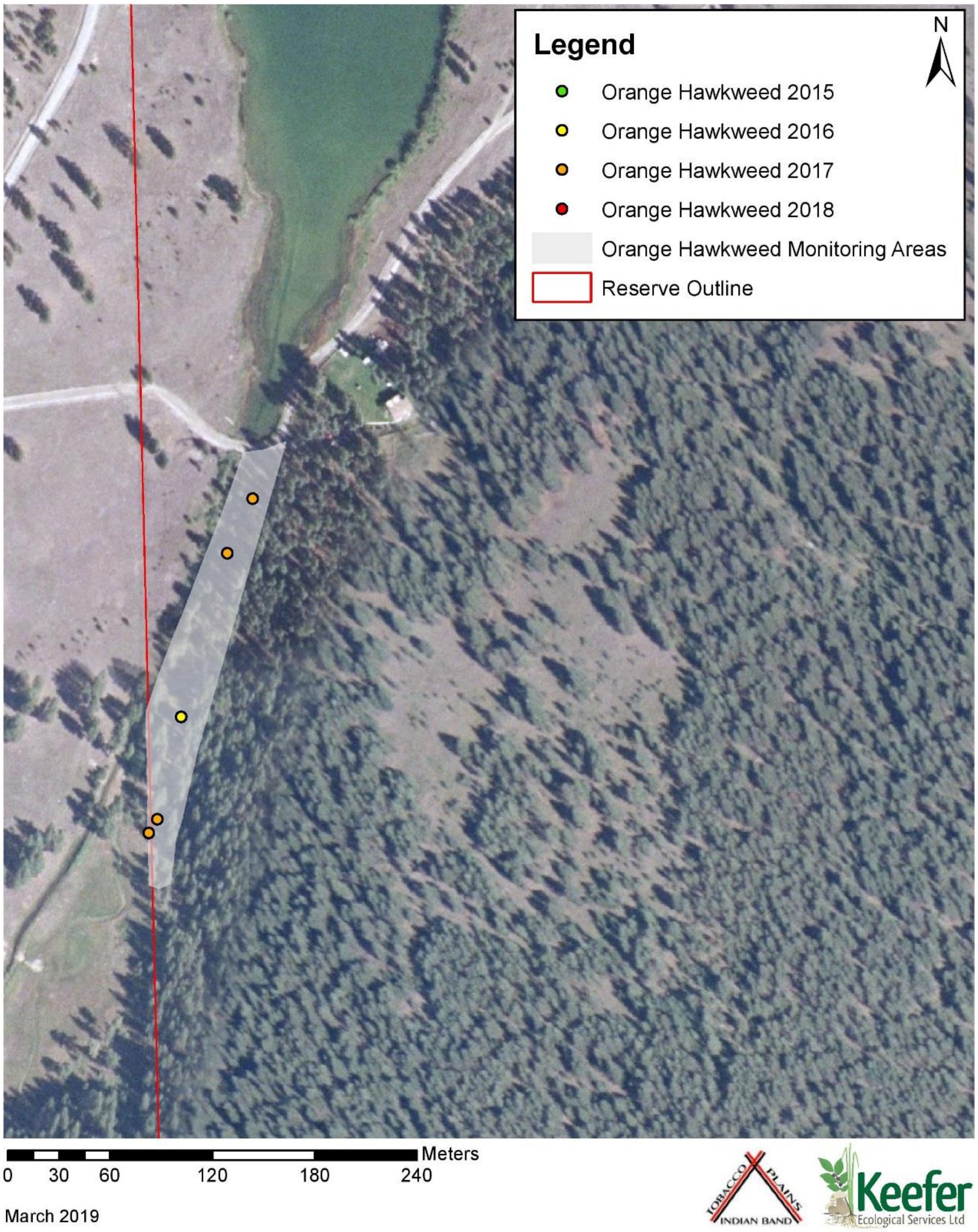
Appendix A

Maps Insets of Figure 5: Orange hawkweed (*Hieracium auranriacum*) sites identified on Tobacco Plains Indian Reserve between 2015-2018 and specific areas to monitor

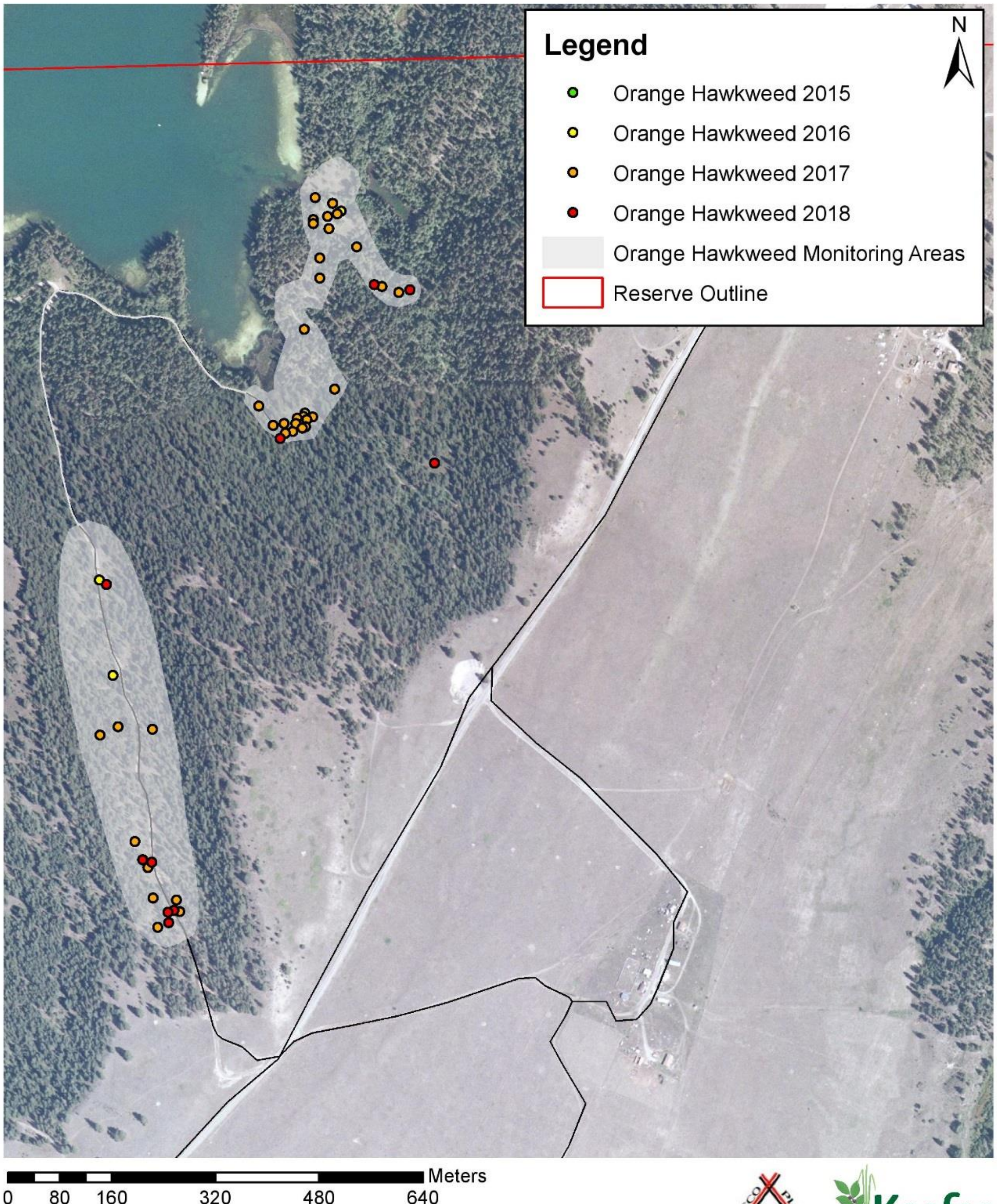
Orange Hawkweed Infestation and Monitoring Areas: Inset 1
Tobacco Plains Indian Band Reserve Area
Grasmere, British Columbia



Orange Hawkweed Infestation and Monitoring Areas: Inset 2

Tobacco Plains Indian Band Reserve Area

Grasmere, British Columbia



March 2019

Orange Hawkweed Infestation and Monitoring Areas: Inset 3

Tobacco Plains Indian Band Reserve Area

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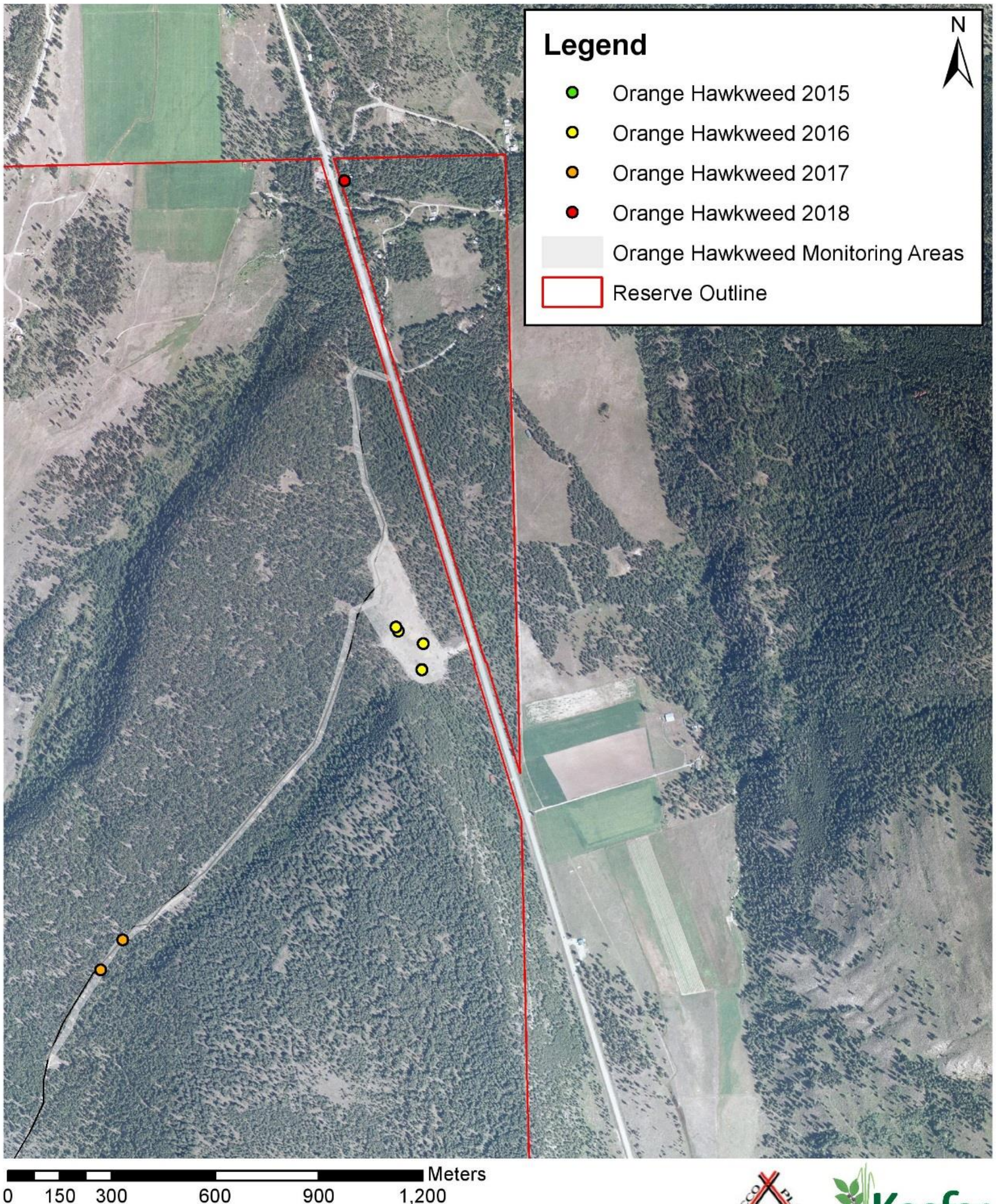
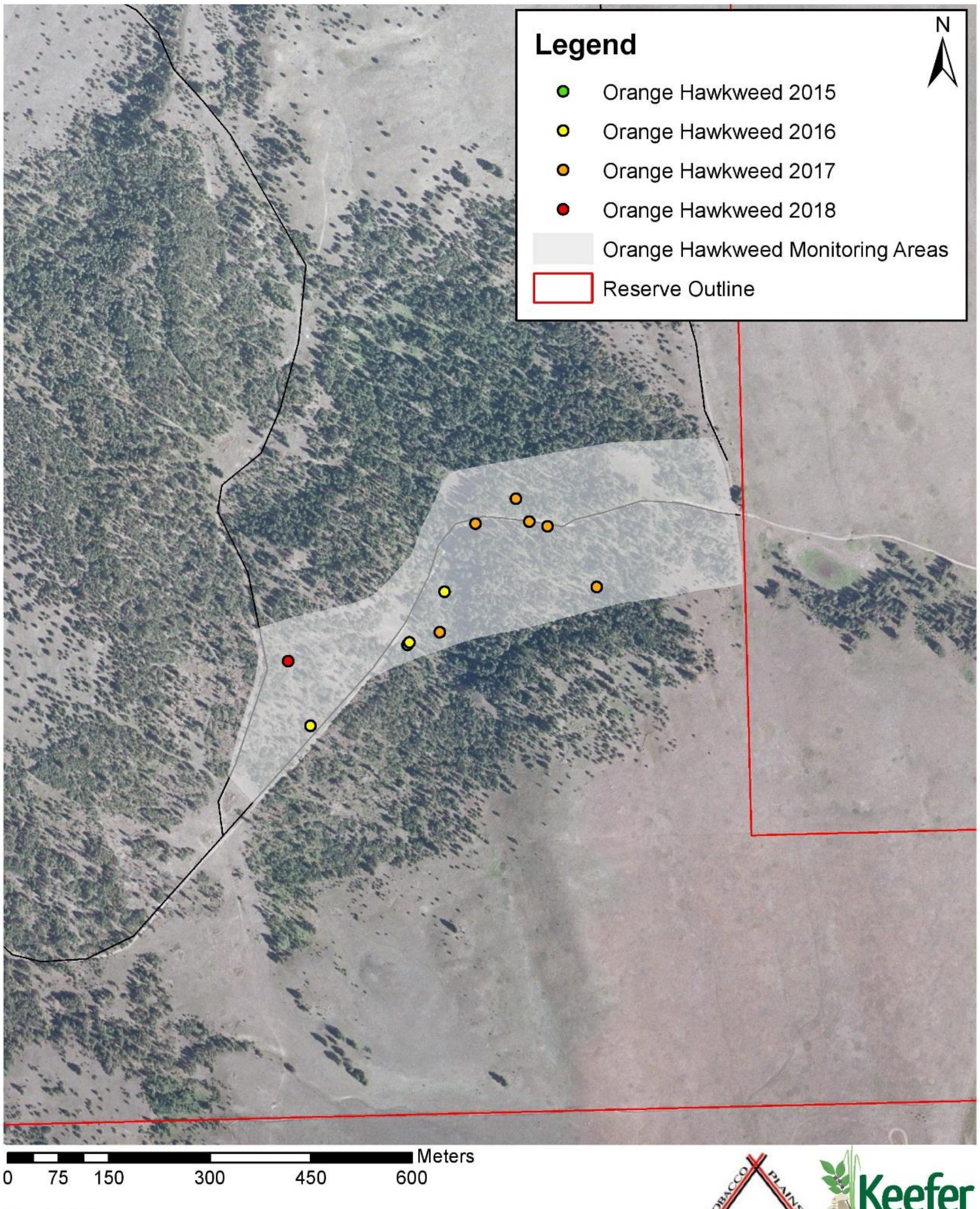


March 2019

Orange Hawkweed Infestation and Monitoring Areas: Inset 4

Tobacco Plains Indian Band Reserve Area

Grasmere, British Columbia



March 2019

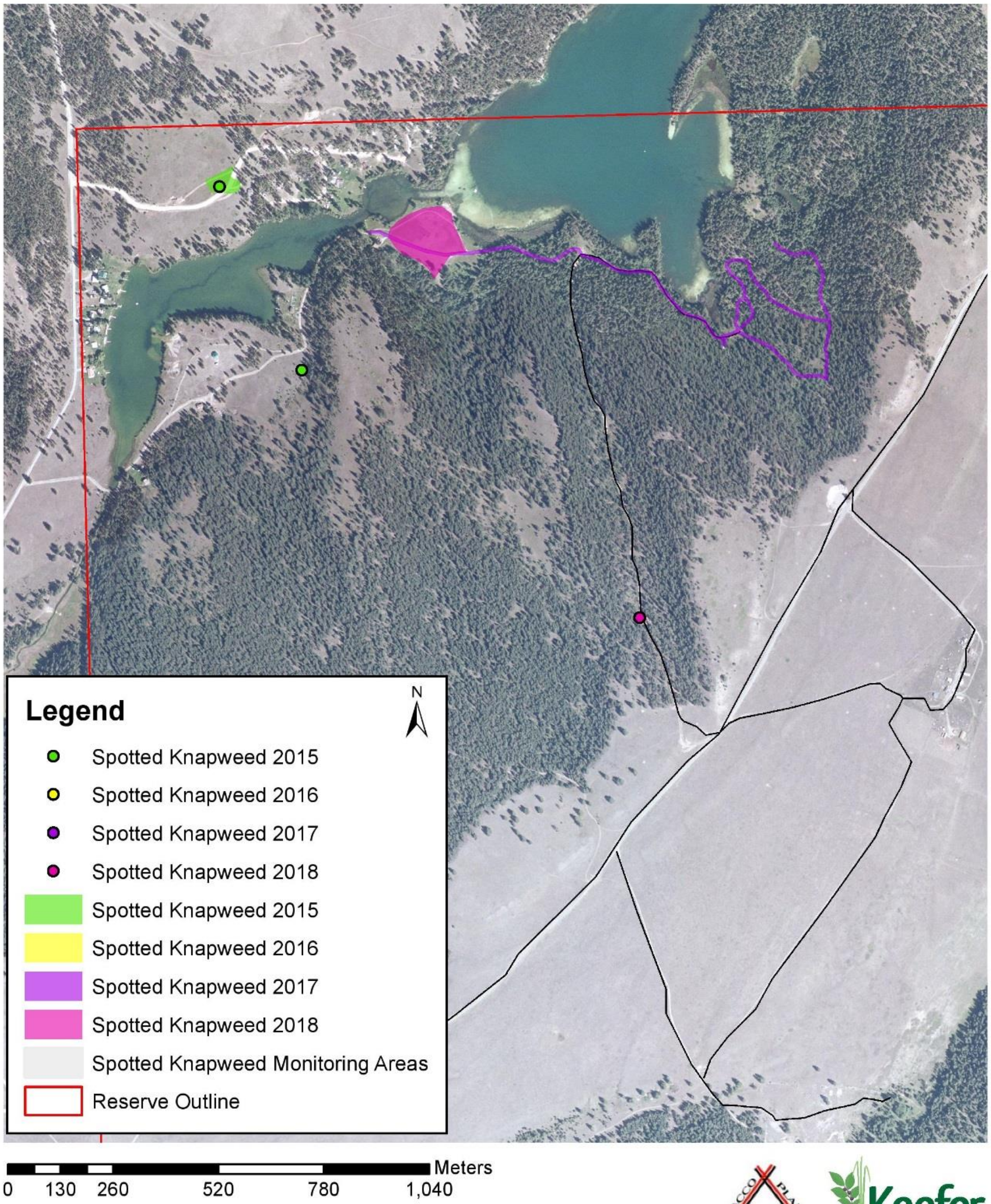
Appendix B

Maps Insets of Figure 6: Spotted knapweed (*Centaurea stoebe*) sites identified on Tobacco Plains Indian Reserve between 2015-2018 and specific areas to monitor

Spotted Knapweed Infestation and Monitoring Areas: Inset 1

Tobacco Plains Indian Band Reserve Area

Grasmere, British Columbia



March 2019

Spotted Knapweed Infestation and Monitoring Areas: Inset 2

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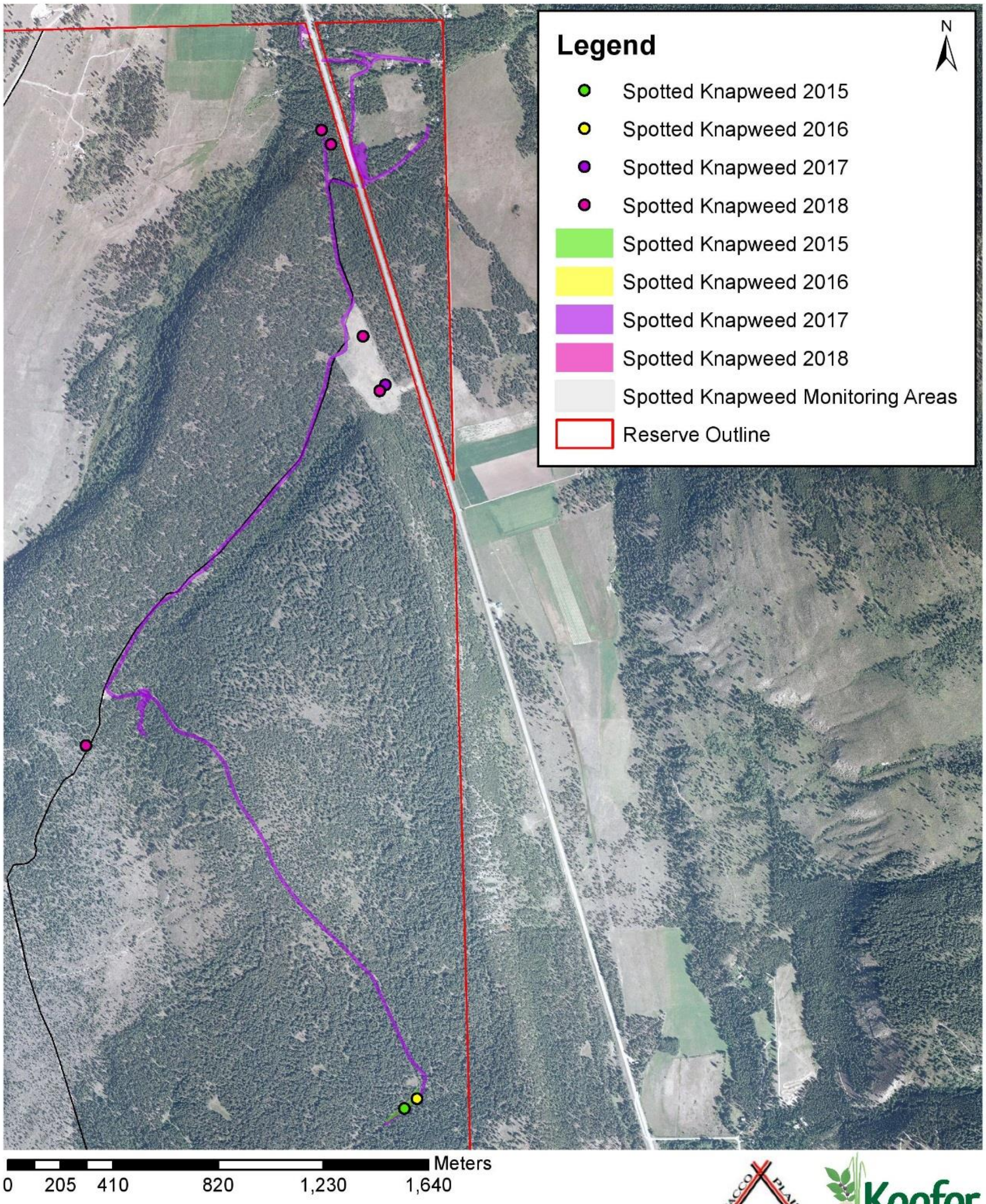
Grasmere, British Columbia

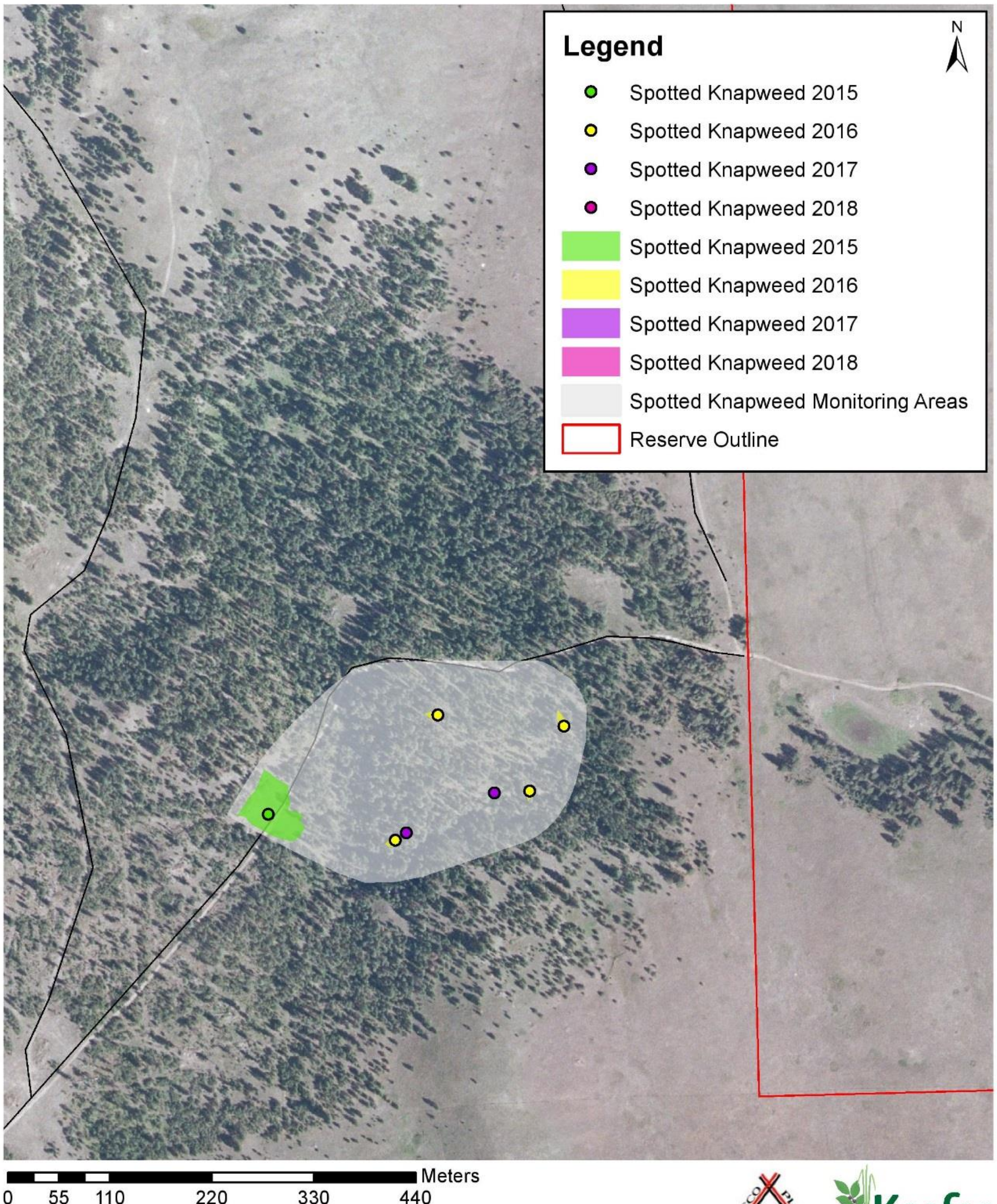


March 2019

Spotted Knapweed Infestation and Monitoring Areas: Inset 3

Tobacco Plains Indian Band Reserve Area

Grasmere, British Columbia



March 2019

Spotted Knapweed Infestation and Monitoring Areas: Inset 4

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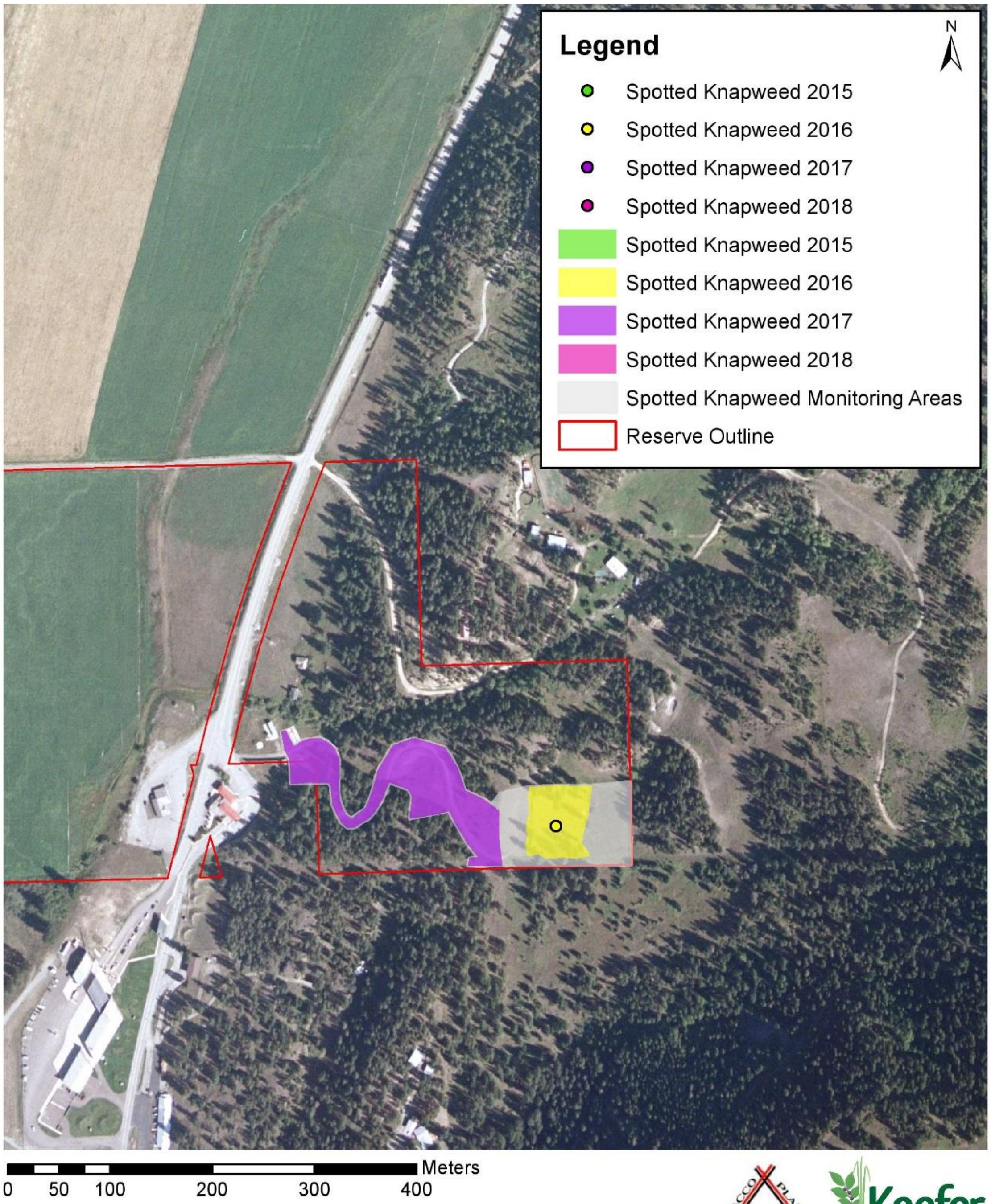
Grasmere, British Columbia



March 2019

Appendix C

Management of Invasive Sulphur Cinquefoil (*Potentilla recta*)

MANAGEMENT OF INVASIVE SULPHUR CINQUEFOIL

Prepared for Fish and Wildlife Compensation Program
April 2019

Alix Conway Ph.D., Teri Calver B.Sc., Katherine Stewart Ph.D.
University of Saskatchewan

Table of Contents

1.0 **Introduction**

Degradation of rangelands poses an on-going threat to these unique and productive ecosystems. Restoring degraded rangelands is a difficult task due to varying degrees of degradation and the multiple factors contributing to degradation. In the East Kootenays, forest in-growth and encroachment, invasive plant spread, land alienation, and increasing foraging pressures by wild and domestic ungulates are primary factors driving rangeland decline (Phillips and Crowley 2012). Invasive plant species are often superior competitors compared to native plants (Roche et al. 1986), spread across the landscape at a rapid rate (Wallace et al. 1992, Billings 1994, Whitson 1998), and are often low in palatability (Panter 1991). Furthermore, invasive plants can have long-lasting effects on ecosystems through changes to nutrient cycles, soil biogeochemistry, and microbial communities. In this review, we give a broad background on rangeland health and invasive species before highlighting sulphur cinquefoil (*Potentilla recta*) physiology, mechanisms of invasion, and invasion controls. Where information specific to sulphur cinquefoil is absent or limited, we provide references to similar invasive species.

*1.1 **Rangeland health***

Rangelands cover an estimated 40% of Earth's land surface. However, land degradation is a major challenge in rangelands. Rangeland health is often assessed based on a few key functions: net primary production, soil and site stability, hydrology, nutrient and energy cycling, and functional diversity of plant species (Adams et al. 2016). Thus the major indicators of rangeland degradation are shifts in species composition, loss of range biodiversity, a reduction in biomass production, and soil erosion. A number of factors are responsible for rangeland degradation, some of which include climate change (McCollum et al. 2017), grazing (Murphy 1986, Arnalds and Barkarson 2003), no grazing management plans or clear authority of ownership (Zerga 2015), and invasive species (DiTomaso 2000).

In the Rocky Mountain Trench, specifically the East Kootenay Trench south of Cranbrook, the quality and quantity of rangeland ecosystems is degraded (Phillips and Crowley 2012). Factors such as forest in-growth and encroachment, invasive plant spread, land alienation, and increasing foraging pressures by wild and domestic ungulates are suggested as primary drivers of rangeland decline in the East Kootenays (Phillips and Crowley 2012). Approximately half of the rangelands documented in the 1950s had transitioned into closed forests by 1997 which put further pressure on remianing rangelands due to increased cattle and elk foraging (Forest Practices Board 2016). In 1997, active restoration such as logging, burning, slashing, and spacing was implemented to remove or thin closed forest cover and restore rangelands. Rangeland conditions at 25 benchmark sites in the East Kootenay's were surveyed in 2015 and 76% were found to be unchanged or improved from baseline conditions assessed 20 years ago. While these results are promising the sites that were assessed were subject to a variety of treatments (including no treatment) thus no conclusive results on the effectiveness of restoration on East Kootenay rangelands can be made (Forest Practices Board 2016). Furthermore, management and restoration approaches will depend on rangeland conditions. For example, while degraded rangelands likely require active restoration, in less degraded areas active restoration may not be necessary but improved management practices are needed to maintain and improve the existing conditions. Managing and restoring degraded rangelands is complex not only due to varying degrees of degradation but multiple factors, such as forest encroachment, invasive plants, and land use changes, contributing to degradation.

1.2 Invasive species

There are a number of invasive species that cause significant problems on rangelands in America (DiTomaso 2000) and Canada. Interestingly, rangeland invasive species can be annuals, biennials, long-lived herbaceous perennials, shrubs, trees and are represented by several different plant families (DiTomaso 2000). Degraded rangelands are more susceptible to exotic invasion when plant diversity has been reduced (Kennedy et al. 2002, Van Ruijven et al. 2003, Zavaleta and Hulvey 2004, Maron and Marler 2008). One common theory behind the success of invasive plants is that they have escaped their natural enemies and can reach their full competitive potential in the new ecosystem. Invasive plant species are often superior competitors compared to native plants (Roche et al. 1986), spread across the landscape at a rapid rate (Wallace et al. 1992, Billings 1994, Whitson 1998), and are often low in palatability (Panter 1991) which can favour a more rapid shift from native to invasive dominance (Callihan and Evans 1991). A recent meta-analysis study of 125 invasive plant species found that overall invasive species had significantly higher performance-related traits (such as, physiology, leaf-area allocation, shoot allocation, growth rate, size and fitness) than non-invasive species (Van Kleunen et al. 2010). Additionally, some invasive plants have greater root biomass (Broadbent et al. 2018) and leaf nitrogen and photosynthetic nitrogen use efficiency (Drenovsky et al. 2008) than native species regardless of the nutrient availability of the environment. Not only do invasive species out-perform native species, eventually becoming dominant across the landscape, they also impact many belowground processes thus altering plant-soil feedbacks that reinforce their dominance.

Invasive plants can have long-lasting effects on ecosystems through changes to nutrient cycles, soil biogeochemistry, and microbial communities. Nutrient dynamics can be altered due to changes in the physical properties of soil caused by the invasive species or simply the change in aboveground plant dominance (Grime 1998, Kelly et al. 1998, Ehrenfeld and Scott 2001). The soil environment can be modified by plants through litter inputs and root exudates that affect soil structure and nutrient mobilization. The characteristics of invasive plants, such as high growth rates and leaf nutrient concentrations, can increase decomposition rates and nutrient cycling (Allison and Vitousek 2004). Invasive plants can bring in new secondary metabolites such as allelopathic, defensive, or antimicrobial chemicals, (Mallik and Pellissier 2000, Callaway and Ridenour 2004, Callaway et al. 2008) that can uniquely affect soil biogeochemistry due to the novel biochemistry of their leachates, litter, volatiles and root exudates (Weidenhamer and Callaway 2010). In fact, chemical allelopathy has been thought to be a driving mechanism behind how invasive plant species eliminate native species (Bais et al. 2003, Hierro and Callaway 2003, Callaway and Ridenour 2004, Kimura et al. 2015). This has been proven experimentally as *Centaurea diffusa*, a noxious weed in North America, has an advantage in invaded ecosystems due to differences in the effects of its root exudates and how these exudates affect competition for resources (Callaway and Aschehoug 2000). Similarly, the invasive plant *Alliaria petiolata* can suppress growth of native plants by disrupting their mutualistic associations with belowground arbuscular mycorrhizal fungi through antifungal phytochemistry (Stinson et al. 2006). All of these associated differences in quantities and qualities of inputs to soils can also alter the soil microbial community (Grayston et al. 1998, Grierson and Adams 2000, Batten et al. 2008, Gibbons et al. 2017, McTee et al. 2017). Two invasive plants, *Centaurea solstitialis* and *Aegilops triuncialis*, have been shown to change the native microbial community by increasing the presence of sulfate reducing bacteria, which in turn can affect nutrient cycling, plant fitness, and ecosystem function (Batten et al. 2006).

2.0 Sulphur cinquefoil

2.1 Life history and growth

Sulphur cinquefoil (*P. recta*) is a perennial forb native to Eurasia that was introduced to North America prior to 1900 (Rice 1999). It has spread throughout much of the continent since its introduction becoming well-established by the 1950s (Rice 1999). Sulphur cinquefoil is a weed of particular concern in the rangelands and grasslands of the semi-arid intermountain region of the northwestern United States and southwestern Canada (Endress et al. 2008). The plant forms dense and continuous stands that can quickly dominate and outcompete native plants. Its invasion is highest in disturbed areas, such as roadsides, cutblocks, degraded rangelands, and previously cultivated sites (Rice 1999, Endress et al. 2007). Areas with high amounts of bare ground and low species diversity are most susceptible to colonization and rapid spread of the plant (Endress et al. 2007, Maron and Marler 2008). However, sulphur cinquefoil also presents itself in relatively undisturbed native plant communities (Rice 1999, Endress et al. 2007).

Sulphur cinquefoil is a long-lived perennial that is known to live up to 10 years (Perkins et al. 2006). It has a single woody rootstock, one to several stems, palmate leaves, is many-flowered, and reproduces primarily through seeds (Rice 1999, Dwire et al. 2006). The ability of sulphur cinquefoil to vegetatively reproduce is inconclusive between studies. Some authors state the plant reproduces exclusively through seed production, while others mention reproduction via sprouts from fragmented portions of the lower caudex (Goswami and Matfield 1975, Rice 1991, Powell 1996, Lesica and Martin 2003). Sulphur cinquefoil begins flowering in late June and continues until mid-July when flowers set to seed (Frost and Mosley 2012, Mosley et al. 2017). It is a prolific seed producer with an average annual production of 6000 seeds per plant (Dwire et al. 2006). Plants produce seeds throughout their lifespan at a constant rate beginning in the first year of growth (Perkins et al. 2006). Seeds are dispersed within a short distance (<3m) from the source plant and may remain viable in the seed bank for at least three years (Rice 1999, Dwire et al. 2006). Stands of sulphur cinquefoil have an unevenly distributed age population, with a higher proportion of young individuals (80% plants <5yrs of age) (Perkins et al. 2006).

2.2 Mechanisms of invasion

The spread of sulphur cinquefoil in the Pacific Northwest has been partly attributed to its close resemblance to native *Potentilla* species, which may have allowed its presence to remain undetected or misidentified (Rice 1999). The most important factors for explaining sulphur cinquefoil dominance is amount of bare ground and habitat type (Endress et al. 2007). Sites with higher proportion of bare ground are associated with higher sulphur cinquefoil dominance. Additionally, sites that were previously cultivated have higher sulphur cinquefoil dominance than undisturbed sites, such as native grasslands and forests. While numerous studies have described and quantified the types of landscapes where sulphur cinquefoil is found, experimental work on the mechanisms behind the persistence and spread of sulphur cinquefoil are limited.

Sulphur cinquefoil has been reported to produce up to 6000 seeds per plant (Dwire et al. 2006) with generally high viability and germinability rates (Baskin and Baskin 1990) suggesting sulphur cinquefoil can dominate a site quickly. Short-distance seed dispersal strategies are likely contributing to local expansion of dense sulphur cinquefoil patches (Dwire et al. 2006). As for long distance dispersal and new populations of sulphur cinquefoil, seeds are likely brought via livestock feces (Frost et al. 2013) and wild ungulates (Parks et al. 2008). Tuitele-Lewis (2004) reported that the seed bank has a considerable impact on seedling germination, more-so than the impact from seed rain. In contrast, a 2009 study found that seedling emergence was not closely related to seed bank numbers (Kiemnec and McInnis 2009). Instead, environmental factors were more important in seedling germination and population maintenance than seed rain or seed bank (Kiemnec and McInnis 2009). Thus, the role of the seed bank in contributing to the persistence of sulphur cinquefoil is currently inconclusive. Reduction of the seedbank is crucial for any management strategy to be successful; unfortunately preventing the accumulation of seed banks by limiting seed production is likely the most effective approach (Richardson and Kluge 2008). This is a more passive approach, as it will be dependent on how long seeds remain viable in the seed bank which highlights the importance of characterizing and understanding the role the seed bank plays in sulphur cinquefoil and native species invasion dynamics.

Fast growth rates and competitive advantage are often cited as factors contributing to successful plant invasions. Interestingly, sulphur cinquefoil growth rate has been found to be similar to those of native plants (Tuitele-Lewis 2004). However, growth rates were calculated from different environments as well as laboratory experiments and do not represent the growth rate of sulphur cinquefoil and any native plants when growing together. Sulphur cinquefoil growth is likely vulnerable to unsuitable environmental factors, for example Burkle and Runyon (2016) found drought to cause a decrease in plant size of sulphur cinquefoil compared to native forbs. Similar to the influence of seed bank, results on the importance of competitive advantage of sulphur cinquefoil are inconclusive. Sulphur cinquefoil has been found to exert strong competitive dominance over native species with no effect of increased resource supply on competitive ability (Maron and Marler 2008). Maron & Marler 2008 argue that the competitive advantage of sulphur cinquefoil on native species is the main factor driving their invasion success. In contrast, Endress et al. (2007) argue that sulphur cinquefoil is not driving the changes in invaded rangelands and is more so just a "passenger" and beneficiary of more fundamental environmental changes that are occurring in these ecosystems that limit native flora.

3.0 Management approaches for invasive plants

There are many different management approaches to control the invasion of exotic plants that have invaded rangelands. A variety of methods including targeted grazing, chemical control, and seeding of native plants, have been proposed for controlling invasive sulphur cinquefoil populations in North America. Biological control is one weed control method that is ineffective for use on sulphur cinquefoil due to the plant's close relation to strawberries and other species within the *Potentilla* genus (Duncan et al. 2004). To date there is no consensus regarding the most effective method or combination of methods for the control of sulphur cinquefoil.

3.1 Chemical control

Herbicides have been the most common method to control invasive plants on rangelands (Bovey 1995, Bussan and Dyer 1999, DiTomaso 2000). While herbicides have proven effective in suppressing invasive species there are adverse effects that need to be considered prior to application. Herbicide application has the potential for ground or surface water contamination, adverse effect on non-target native plants, and the cost of repeated application can increase quickly (Masters and Sheley 2001).

Negative effects on non-target plants can be lessened by ensuring the mode of action (system, process, or tissues affected by herbicide) and selectivity of the herbicide is appropriate for the given rangeland. Similarly, timing of herbicide applications can alter the effectiveness of the treatment and should be species and goal-specific (Young et al. 1998, DiTomaso et al. 1999, Masters and Sheley 2001). Lastly, proper herbicide application can reduce adverse effects to the environment, especially through minimizing herbicide drift which can occur through particle and vapour drift.

Herbicide application is the most commonly used approach and considered the most effective method available for the control of sulphur cinquefoil (Endress et al. 2008). The 2010 pest management plan for Southern British Columbia lists numerous herbicides that are commonly used on invasive plants such as Milestone, Tordon 22K, Round-up, Grazon, Escort, 2,4-D Amine, Clearview and Reclaim (Range Branch BC Ministry of Forests and Range 2010). The biggest difference between herbicides is the active ingredient with common ones including solely, or a combination of, aminopyralid, picloram, glyphosate, 2,4-D Amine, and metsulfuron. Active ingredients can be selective or non-selective and have different modes of action and soil persistence, thus the conditions of site and target species must be carefully considered before choosing an herbicide. For example, glyphosate is non-selective and will kill all plants it contacts, whereas picloram and aminopyralid are broad-leaf selective and will not kill grasses. Currently, DOW AgroSciences recommends applying Milestone specialty herbicide prior to vegetation bloom to treat Sulphur cinquefoil invasion (https://www.dowagro.com/en-us/vm/weeds-brush/broadleaf-weeds/s/sulfur-cinquefoil). The active ingredient in Milestone specialty herbicide is triisopropanolammonium salt as aminopyralid at 40%.

Endress et al. (2008) evaluated the effects of five herbicides (dicamba + 2,4-D, glyphosate, metsulfuron methyl, picloram, and triclopyr), two rates of applications (high and low), and three application times (early summer, fall, combined early summer/fall) in controlling sulphur cinquefoil. All herbicide applications significantly reduced sulphur cinquefoil cover compared to control treatments.

Picloram was the most effective herbicide for controlling sulphur cinquefoil in their study. Their findings are supported by others who also found that picloram was the most effective herbicide for the control of sulphur cinquefoil (Duncan 1993). Endress et al. (2008) also reported that glyphospate did little to reduce the plant's population and few differences existed between the other herbicides. The type of herbicide used was more important than the rate or timing of application in their study. Six-year post-treatment, sulphur cinquefoil cover remained significantly lower than the controls indicating that a one-time herbicide application can be effective in reducing sulphur cinquefoil abundance for a period of time (Endress et al. 2008).

3.2 Grazing

Targeted grazing by livestock, such as sheep, goats, and cattle, is a commonly used method for the suppression of invasive species. However, the use of livestock to suppress exotic plant species can have inconsistent results. Inconsistent results are likely due to how the targeted grazing was done, as there are four important factors to consider: timing (when in the season), duration, (length of time for grazing), intensity (how many animals), and frequency (number of grazing periods) (Rinella and Hileman 2009). The timing of grazing is important for plants as early season, pre-flower grazing has been shown to reduce the invaded plant and increase native plants over time (Rinella and Hileman 2009). Of course, the timing of grazing will be plant specific and the phenology and reproduction of the target plant must be considered. Duration and intensity determine the number individual plants are grazed based on the length of time grazing occurs and number of animals within a given area. The intensity of grazing can cause a range of plant responses, from a reduction (Eldridge et al. 2016) to an increase (Kurtz et al. 2016), in productivity and/or cover of plants. Increased plant productivity due to grazing is often due to the intermediate disturbance hypothesis. While one would want to have an intensity great enough to decrease the productivity of the invasive plant, if the intensity is too great then growth and success of native species might be suppressed due to trampling (Pulido et al. 2017). Lastly, the frequency of targeted grazing is important since invasive plants can remain dominant for multiple years by altering their colonizing strategy (Amiaud et al. 2008) and/or through a prolific seed bank (Witkowski and Wilson 2001, Goets et al. 2018).

Multiple reports suggest that sulphur cinquefoil is avoided by grazing animals (Parks et al. 2008), and the plant is regarded as having poor nutritional value and low palatability for livestock (Rice 1999, Frost et al. 2008). However, numerous studies have demonstrated that targeted livestock grazing is a successful approach for the suppression of sulphur cinquefoil. Mosley et al. (2017) reported that targeted sheep grazing during the early flowering and late flowering-early-seedset stages of sulphur cinquefoil removed over 95% of viable seeds and reduced yield by over 40% in the subsequent summer. It has recently been demonstrated that grazing sheep preferentially select sulphur cinquefoil over other exotic and native forbs (Masin et al. 2018). Parks et al. (2008) found that early summer grazing by cattle reduced the number of flowers and size of sulfur cinquefoil.

The importance of timing when using targeted grazing to control sulphur cinquefoil is demonstrated in a defoliation study completed by Frost & Mosley (2012). In their study, sulphur cinquefoil plants were hand-clipped to stubble heights of 7 or 15cm during seven distinct life cycle stages over the course of the growing season. Clipping during any stage or combination of stages decreased aboveground biomass and reproduction parameters. However, the greatest impacts were observed when clipping was done once at either flowering or seedset life stages. This eliminated 99-100% of floral production, total seed production, and viable seed production. Although the authors did not utilize targeted grazing, their results provide further evidence that annual defoliation by livestock is potentially an effective management approach for the suppression of sulphur cinquefoil (Frost and Mosley 2012).

Management by targeted grazing must also consider the viability and movement of sulphur cinquefoil seed in feces. This issue relates to timing and duration of grazing, is species-specific, and needs to be considered if implementing targeted grazing. This can be a serious ecological concern if grazing animals can further the spread of the targeted invasive species. For both sheep and goats, viable sulphur cinquefoil seeds are excreted for two days after initial consumption of seed (Frost et al. 2013). This was found for both immature and mature seeds. Frost et al. (2013) recommend that goats or sheep, that are used for targeted sulphur cinquefoil grazing during periods of seed viability (ie., during flowering or later phonological stages), should remain in a corral for at least three days to allow any viable seeds to be excreted before moving the livestock.

Lastly, the use of domestic goats for targeted sulphur cinquefoil grazing in the East Kootenays must safeguard against the transmission of disease from goats to native Rocky Mountain Bighorn sheep (*Ovi canadensis canadensis*). The majority of Rocky Mountain Bighorn sheep in British Columbia are found in herds distributed in the Rocky Mountains of the East Kootenay region (Demarchi 2004). Bacteria, specifically *Mannheimia* spp. and *Pasteurella* spp. are commonly present in domestic sheep (*Ovie aries*) and can induce fatal pneumonia in Bighorn sheep from nose-to-nose contact (Foreyt and Jessup 1982, Onderka and Wishart 1988, George et al. 2008). Clear physical separation of where goats are allowed to graze and wild Bighorn sheep habitat is the most viable current management option (Foreyt 1989, Schommer and Woolever 2008, Cahn et al. 2011, O'Brien et al. 2014). As another precautionary measure, domesticated goats can also be vaccinated as well as kept in pens when not grazing. The Wild Sheep Working group (2012) report provides management recommendations that should be followed by any management or organizations that are working with domestic sheep or goats.

3.3 Mixed control

Many successful cases of invasive species control on rangelands have come from integrated control strategies (Horton 1991, Masters and Nissen 1998, Whitson and Koch 1998, Enloe and DiTomaso 1999, DiTomaso 2000, Masters and Sheley 2001). The Pest Management Plan of Southern BC recommends all treatment options (mechanical and cultural, biological control agents, and herbicide application) should be considered either individually or in combination (Range Branch BC Ministry of Forests and Range 2010).

In a follow-up to their 2008 study, Endress et al. (2012) evaluated the effectiveness of post-herbicide seeding with native grasses to increase native plant abundance. Endress et al. (2012) noted that the combined herbicide-seeding method significantly increased native grass cover and significantly decreased cover of exotic species six years posttreatment. When herbicide was applied without post-seeding, sulphur cinquefoil cover remained low but was replaced by other exotic species. These results suggest that a combined herbicide-seeding treatment may be more effective for restoring native plant communities than a herbicide-only approach (Endress et al. 2012). This may hold particularly true if sites have low native species cover aboveground and/or in the seed bank to contribute sufficiently for natural reestablishment.

Little to no research has been completed on a combined herbicide-grazing method specifically for the control of sulphur cinquefoil. However, studies have assessed combined herbicide-grazing treatments in the control of other invasive species in range and grassland systems. Pywell et al. (2010) completed a six-year study assessing combinations of grazing, herbicide, and cutting treatments in the control of creeping thistle (*Cirsium arvense)* in grasslands of England. Herbicide treatments were the most effective at controlling thistle, but these impacts were only sustained during a short-time period. However, lenient grazing provided long-term thistle control with or without additional herbicide application (Pywell et al. 2010).

In contrast to the findings of Pywell et al. (2010) a study from 1997 reported that goat grazing combined with fall herbicide application yielded more rapid decline and sustained control of leafy spurge (*Euphorbia esula*) density than either treatment applied alone (Lym et al. 1997). Sheley et al. (2004) discovered that spring application of 2,4-D and grazing by sheep throughout the summer decreased spotted knapweed (*Centaurea maculosa*) rosette density by 99%. This is in comparison to 44% reduction when grazing and 28% reduction when 2,4-D was applied (Sheley et al. 2004).

4.0 Future work

A variety of methods including targeted grazing, chemical control, and seeding of native plants, have been proposed for controlling invasive sulphur cinquefoil populations in North America. Successful targeted grazing must consider the timing, duration, intensity and frequency of grazing. While some reports suggest that sulphur cinquefoil has poor nutritional value and low palatability for livestock (Rice 1999, Frost et al. 2008), numerous studies have seen success with targeted livestock grazing suppressing sulphur cinquefoil. If targeted goat grazing is used in the East Kootenays, clear physical separation of domestic goats and Rocky Mountain Bighorn sheep (*Ovi canadensis canadensis*) must be implemented to avoid disease transmission. Movement of viable sulphur cinquefoil seed off-site in grazing goat feces must also prevented. Herbicides have been the most common method to control invasive plants on rangelands (Bovey 1995, Bussan and Dyer 1999, DiTomaso 2000) and have been successful controlling sulphur cinquefoil. An important consideration for herbicide use is that active ingredients will vary between herbicides, as well as the selectivity of the herbicide, thus the conditions of site and target species must be carefully considered before choosing an herbicide. Many successful cases of invasive species control on rangelands have come from integrated control strategies. Little to no research has been completed on a combined herbicide-grazing method specifically for the control of sulphur cinquefoil, however many successful cases of invasive species control on rangelands have come from an integrated control strategy (Horton 1991, Masters and Nissen 1998, Whitson and Koch 1998, Enloe and DiTomaso 1999, DiTomaso 2000, Masters and Sheley 2001). There is a need to examine different management strategies, including integrated strategies, for the control of invasive sulphur cinquefoil in the East Kootenay region. In addition, further study of the mechanisms through which sulphur cinquefoil invades and persists can assist with developing effective management strategies and ensuring long-term rangeland health.

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Appendix D

Sulphur cinquefoil (*Potentilla recta*) research study design

Potentilla recta invasion of rangelands in East Kootenay, British Columbia: Identifying mechanisms of invasion and best management practices

Rationale

Rangelands cover approximately 40% of the Earth's land surface; however, land degradation poses a major threat to rangelands. The Rocky Mountain Trench, specifically the East Kootenay Trench south of Cranbrook, is one of many examples in which degradation of rangeland ecosystems has occurred (Phillips and Crowley, 2012). In addition to forest in-growth and encroachment, land alienation, and increasing foraging pressures by wild and domestic ungulates, invasive plants are a primary factor driving rangeland decline in the East Kootenays (Phillips and Crowley, 2012). The invasive plant, *Potentilla recta*, is of particular concern as it is a dominante species in these rangelands. *P. recta* is a perennial forb that is native to Eurasia and was introduced to North America prior to 1900 (Rice, 1999). *P. recta* is a prolific seed producer, producing up to 6,000 seeds per plant (Dwire et al., 2006) and it is known to live up to 10 years (Perkins et al., 2006). It is a weed of particular concern in the rangelands and grasslands of the semi-arid intermountain region of the northwestern United States and southwestern Canada (Endress et al., 2008), forming dense and continuous stands that can dominate and outcompete native plants. Areas with high amounts of bare ground and low species diversity are most susceptible to colonization and rapid spread of the plant (Endress et al., 2007; Maron and Marler, 2008). Management of the plant and improvement of rangeland health is a priority for many stakeholders in the East Kootenay region, including Tobacco Plains and ʔaq'am First Nations, the East Kootenay Invasive Species Council, and the Ministry of Forests, Lands and Natural Resource Operations and Rural Development.

Studies have examined methods to manage *P. recta* in rangelands of western North America, including through chemical control (Endress et al., 2008), targeted grazing (Frost and Mosley, 2012), and seeding of native plants (Endress et al., 2012). Results on which method or combination of methods is most effective in managing *P. recta* have been inconclusive thus far. Further, examination of the functional traits driving invasion of *P. recta* needs to be better understood to support the management of *P. recta* in rangelands.

The **overall goal** of the proposed project is to **identify mechanisms driving *Potentilla recta* invasion in rangelands in East Kootenay, British Columbia and best management practices to control *P. recta***. This will be achieved through the following **objectives i)** Assess targeted goat grazing (grazing once vs grazing twice per season), herbicide application, and seeding with native rangeland plants (with and without fertilizer addition) as management strategies for *P. recta* control over two growing seasons; and **ii)** Examine the role of competition between *P. recta* and native rangeland species under different soil nutrient conditions (fertilizer vs no fertilizer addition) and how this may influence *P. recta* establishment and growth.

Project Description

Field Study (Objectives 1 and 2)

The field study will occur on degraded rangeland on the reserves of the Tobacco Plains and ?aq'am First Nations, located in the East Kootenay, BC. Over two field seasons, three management treatments will be applied at each site (reserve), including i) targeted goat grazing ii) herbicide application (if approved at both sites) and iii) native species seeding. A total of 6 individual treatments will be examined: i) targeted goat grazing once in early June, ii) targeted goat grazing twice per season (early June and mid-July) iii) targeted goat grazing once with herbicide application in mid-July, iv) targeted goat grazing twice with herbicide application in mid-July, v) herbicide application in mid-July only and vi) undisturbed controls (Figure 1). At each site, an 8 hectare area will be divided in half with one half grazed once and the other half grazed twice at the same grazing intensity over the growing seasons (Figure 1). All herbicide treatment plots will be 6 m^2. A split-split experimental design will be used to exclude goat grazing from the area with herbicide only and control plots. Portable electric fencing as well as active goat herding will be used to separate the grazed and ungrazed areas (Figure 1).

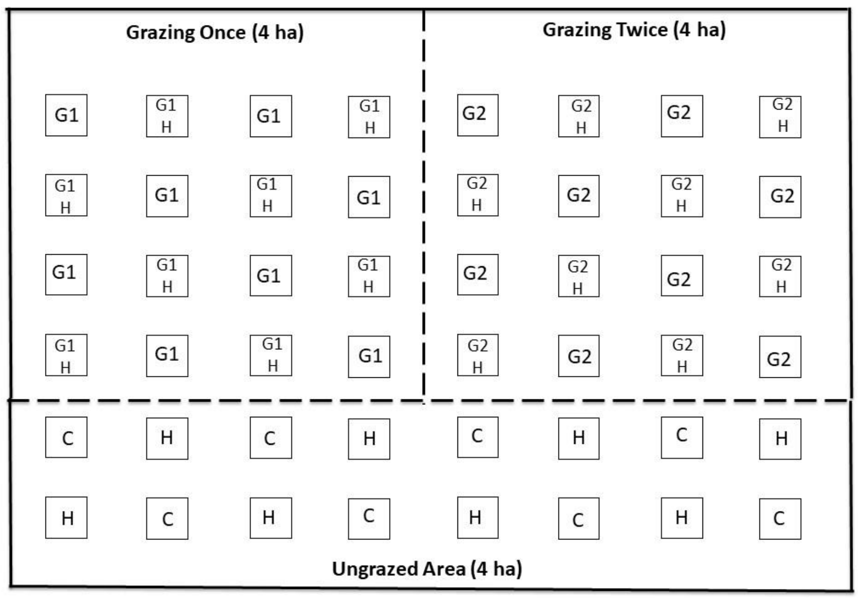

Figure 1. Experimental design for the proposed field experiment at each site including targeted goat grazing once per season (G1), targeted goat grazing twice per season (G2), targeted goat grazing once per season with herbicide application (G1H), targeted goat grazing twice per season with herbicide application (G2H), herbicide application only (H) and undisturbed controls (C). Each grazed and ungrazed area will be approximately 4 ha. Portable electric fencing (dashed lines) as well as active herding will be used to separate the grazed and ungrazed areas. Permanent sampling plots and herbicide treatment plots will be 6 m^2 (boxes) and assigned systematically at each site.

For each treatment and control plot, a permanent 6 m x 6 m plot will be established, and all plant and soil sampling will occur within this 6 m^2 plot (Figure 2). A permanent 1m x 1m plot will be established prior to treatments and percent cover of all plants will be visually estimated. The density and height of *P. recta,* as well as phenology metrics (i.e. number of flowers/flower buds/seed heads), will be recorded in a separate 0.25m x 0.5m plot. Aboveground biomass will then be sampled from the 0.25m x 0.5m plot

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and sorted as: *P. recta*, other non-native forbs, nonnative grasses, native forbs, and native grasses (Figure 2). A soil sample (0-10 cm) will also be collected for physiochemical soil properties (i.e. texture, pH, total organic carbon, dissolved organic nitrogen, ammonium, and nitrate) below each biomass plot. Following application of all treatments (mid-July) the above sampling procedures will be carried out again. The project will occur over two field seasons and thus a total of two treatment years and four sampling periods will occur. A total of 48 cover plots ($1m^2$), 48 biomass samples, and 48 soil samples will be taken per site per sampling period in year one.

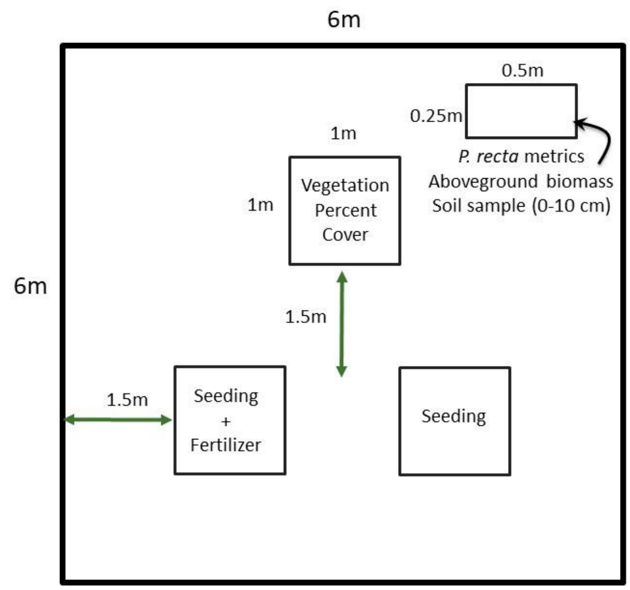

Figure 2. For each treatment a $6m^2$ permanent sampling plot will be established. In each plot a permanent $1m^2$ vegetation cover plot will be used to estimate percent cover of all plant species by visual estimation. A 0.25 x 0.5 m plot will be established at each sampling period and used to measure *P. recta* metrics (phenology, height, density), aboveground biomass (*P. recta*, other non-native forbs, non-native grasses, native forbs, and native grasses) and a soil sample (0-10 cm). In addition, in fall 2019 a $1m^2$ seeding plot and $1m^2$ seeding and fertilizer plot will be established. *P. recta* metrics and percent cover of all plant species will be estimated visually in year 2.

Within each of the management treatments seeding of native rangeland species with and without fertilizer addition will be examined (Figure 2; Table 1). Following application of all other management treatments in summer 2019, a native species seed mix will be seeded in late fall 2019 at a rate of 40kg/ha ($4g/m^2$) in two 1 m x 1 m plots. Half of the plots will receive fertilizer (N-P-K at a formulation of 19-19-19) at a rate of 60kg/ha ($6g/m^2$) (Figure 2). The native seed mix will be composed of *Pseudoroegneria spicata, Festuca idahoensis, Festuca campestris, Koeleria macrantha, Achillea millefolium, Gaillardia aristate* and *Antennaria rosea* (Table 1).

Tobacco Plains and ?aq'am rangeland are both located within the Kootenay Very Dry Very Hot Interior Douglas-fir (IDFxx2) biogeoclimatic zone. Based on the *Field Guide to Ecosystem Classification and Identification for Southeast British Columbia*, rangelands on these reserves occupy the grassland site series, Gg01, of which *Pseudoroegneria spicata* is identified as the dominant grassland species (MacKillop et al., 2018). As well, the Rocky Mountain Trench Ecosystem Restoration Program considers

Festuca campestris / *Festuca idahoensis* / *Pseudoroegneria spicata* to be the default community to be increased within rangelands in the region (Harris, 2011). *Pseudoroegneria spicata* is drought-tolerant, adapted to sites with thin, unproductive soils and is highly preferred forage for livestock and wildlife (Goodwin et al., 2006). Once *Pseudoroegneria spicata* is established and dominate within a community, the plant-soil feedback associated with the grass has been shown to suppress the growth of invasive species (Kulmatiski, 2018). *Festuca idahoensis* has been shown to resist invasion of *P. recta* (Maron and Marler, 2008). *Festuca idahoensis* is also used as a forage species from spring to fall and shows drought tolerance (Goodwin et al., 2006). *Festuca campestris* establishes on a wide variety of soils (Goodwin et al., 2006); however, it prefers mesic sites (Fleenor, 2011). *Festuca campestris* is excellent forage for livestock and wildlife (Goodwin et al., 2006). *Koeleria macrantha* is a common grass species in rangelands within the Rocky Mountain Trench (MacKillop et al., 2018). *Koeleria macrantha* is drought tolerant and a spring and summer forage grass for livestock and wildlife (Goodwin et al., 2006). *Achillea millefolium* is a drought tolerant and aggressive herb (Goodwin et al., 2006) which has displayed competitive resistance to *P. recta* (Maron and Marler, 2008). *Gaillardia aristata* is a fairly drought tolerant herb (Goodwin et al., 2006) that shows some competitive resistance to *P. recta* under dry conditions (Maron and Marler, 2008). *Antennaria rosea* is a drought tolerant, mat forming perennial herb (Klinkenberg, 2017) that shows some competitive resistance to *P. recta* under dry conditions (Maron and Marler, 2008). Seeds for the seed mix will be sourced as locally to the field sites as possible.

Table 1. Proposed native rangeland species seed mix. The seed mix will be applied to seedling plots (1 m^2) with and without fertilizer in each management treatment in late fall 2019. The seed mix will be applied at a rate of 40kg/ha (4g/m^2) and fertilizer will be applied at a rate of 60kg/ha (6g/m^2). Percent cover all of species in the seedling plots will be visually estimated in spring and late summer of 2020.

Scientific Name	Common Name	% of Seed Mix by Weight
Pseudoroegneria spicata	Bluebunch wheatgrass	32
Festuca idahoensis	Idaho fescue	20
Festuca campestris	Rough fescue	15
Koeleria macrantha	Junegrass	10
Achillea millefolium	Yarrow	9
Gaillardia aristata	Brown-eyed Susan	7
Antennaria rosea	Rosy pussytoes	7

In year two prior and following the application of treatments, percent cover of all species in the 1m^2 seeding plots will be visually estimated and the density and height of *P. recta,* as well as number of flowers/flower buds/seed heads, will be recorded in a 0.25m x 0.5m subplot. A total of 80 seeding plots (1m^2) will be survey at each site in year two of the project. This will be in addition to data and sample collection from non-seeded plots.

Greenhouse Study (Objective 3)

The greenhouse study will be conducted in fall/winter of 2019-2020. The objective of the greenhouse experiment is to determine if functional groups (i.e. grasses and forb) and functional traits (i.e.

aboveground/belowground biomass, N and P in green biomass) of native rangeland species influence *P. recta* establishment and growth. *P. recta* seeds collected from the field sites and the native rangeland seed mix from the field trial will be used in the greenhouse study (Table 1). Experimental design of the greenhouse study is based on Kardol et al. (2013). Experimental units will consist of microcosms (12.5 cm long, 12.5 cm wide and 17 cm deep) filled with soils collected from either Tobacco Plains and ?aq'am rangelands. The soils will be mixed with 40% sand to reduce the amount of local soil required (~0.06 m3) and to assist with removal of plants for assessment of belowground traits. The greenhouse experiment will have four treatments: i) *P. recta* seeded solely, ii) *P. recta* seeded with grasses (*Pseudoroegneria spicata, Koeleria macrantha*) and fescues (*Festuca idahoensis, Festuca campestris)* only, iii) *P. recta* seeded with forbs (*Achillea millefolium, Gaillardia aristate* and *Antennaria rosea*) only, and iv) *P. recta* seeded with all species in the seed mix. Each arrangement will be examined with and without fertilizer addition, for a total of 8 treatments. Each treatment will be replicated 5 times for a total of 40 microcosms. Treatments will be grown for 120 days, after which specific leaf area and specific root length will be measured. Shoots will be clipped at soil surface and sorted to species to measure aboveground biomass and roots will be washed and separated to species to measure belowground biomass. Nitrogen and phosphorus of green biomass will be determined for each species per treatment.

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Appendix E

Ministry of Forests, Lands and Natural Resource Operations Rocky Mountain Forest District Ecological Restoration Prescription Form

ECOSYSTEM RESTORATION PRESCRIPTION

Rocky Mountain Forest District

☒ **Single** ☐ **multi-area**

AREA IDENTIFIER: CATCHFLY-14-XX UTM 11N XE XN	☒ORIGINAL ☐AMENDMENT Location:	DATE Y / M / D

GENERAL DESCRIPTION OF AREA

SU	TU	Treatment Regime	Gross Area (ha)	Reserve/No Treat Area (ha)	NP Area (ha)	Net TREATMENT AREA (ha)
OR	A,B..	Open Range				
Reserve	RES	Reserve from Treatment				
		Totals				

FIELD WORK BY:	TOTAL TREATMENT AREA TBD ON-SITE BEFORE TREATMENT IN YEAR ONE	DATE COMPLETED:

HIGHER-LEVEL PLANS

ARE THESE TREATMENT AREAS WITHIN LOCAL RESOURCE USE, TOTAL RESOURCE, INTEGRATED WATERSHED MANAGEMENT, OR OTHER SPECIFIC PLANNING AREAS? NO

ARE ANY OF THESE TREATMENT AREAS WITHIN A COMMUNITY WATERSHED? ☐YES ☒NO

SU number:

IF YES:	PLAN NAME
	No higher level plans applicable for reserve lands.
IF NO:	CONSULT WITH OTHER RESOURCE AGENCIES TO ASSIST IN DEVELOPING MANAGEMENT OBJECTIVES FOR THE PRESCRIPTION.

STAND-LEVEL OBJECTIVES

ARE CURRENT STAND-LEVEL OBJECTIVES AVAILABLE FROM SILVICULTURE PRESCRIPTIONS? ☐Yes ☒No

IF 'YES,' ARE CURRENT STAND-LEVEL OBJECTIVES STILL APPROPRIATE FOR THESE STANDS? ☐NA

Summary of objectives from higher-level plans or for developing or clarifying stand-level objectives

TIMBER	MANAGEMENT OBJECTIVES
SU All	1. Open Range stands are to maintain 0-75 stems/ha on site with a target of 20 stems/ha while maintaining largest trees on site emphasizing trees greater than 30cm DBH.

Details on access, availability of merchantable timber.

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UNDERSTORY (Grasses, Forbs, Shrubs)	MANAGEMENT OBJECTIVES
SU All	1. Increase the native grass and forb plant cover by 25% within ten years of initial treatment. Initially, until better inventory data is available, the rough fescue/ Idaho fescue/ blue bunch wheatgrass is to be used as the default community to be increased. 2. Increase forage biomass production by 5% within 5 years of initial treatment. 3. Increase the forage biomass of valuable decreaser (e.g. Saskatoon berry, rose spp., ceanothus, chokecherry) shrubs by 25% cover in treated areas within 5 years.
Details on potential for increase of native grasses, forbs, shrubs. Highlight any risk of increase in young regen.	

RIPARIAN (Streams, Wetlands, Lakes, Fisheries)	MANAGEMENT OBJECTIVES
SU All	n/a
No treatments are prescribed for sites including or adjacent to riparian areas on TPIR in year one.	
COMMUNITY WATERSHED	MANAGEMENT OBJECTIVES
SU All	n/a
Water license records show no consumptive use water licenses, water diversions or Community watersheds on this LBU.	
STAND LEVEL BIODIVERSITY (Patch Size, Old Growth & Wildlife Trees, CWD)	MANAGEMENT OBJECTIVES
SU All	1. Treatment will maintain and recruit 2 to 10 wildlife trees (over 30cm DBH, 40cm preferred) per hectare throughout treatment cycle on the treated area. Tree species in descending order of preference are Ponderosa pine, western larch, Douglas fir, trembling aspen and black cottonwood (the latter if available). 2. Maintain and recruit 3 cubic metres of CWD (over 30cm DBH and all rot stages not just sawlog grade) per hectare throughout treatment cycle on the treated area. Number and distribution shall, at least, meet minimums set by FPPR namely as minimum of 4 logs per hectare, greater than 5 metres long and 7.5cm diameter at small end.
Retention potential and targets (if any for Open Range). Details on existing CWD cover and amount to leave. Discussion of old growth retention.	
WILDLIFE SPECIES AT RISK	MANAGEMENT OBJECTIVES
SU All	Maintain or increase the species richness and population density of endemic wildlife species in treated areas; with special emphasis in species listed as being red or blue listed by the Conservation Data Centre (CDC).
RARE PLANT SPECIES OR PLANT COMMUNITIES	MANAGEMENT OBJECTIVES
SU All	Maintain or increase the species richness and population density of endemic plant species and plant communities in treated areas; with special emphasis in species listed as being red or blue listed by the Conservation Data Centre (CDC).
UNGULATE CONCERNS	MANAGEMENT OBJECTIVES
SU All	Enhance richness of grassland forage species and increase hectarage of Open Range

FOREST HEALTH	MANAGEMENT OBJECTIVES
SU All	n/a
INVASIVE PLANTS	MANAGEMENT OBJECTIVES
SU All	1. Invasive plant infestations of priority species should not increase from observations recorded and publicly available through the Invasive and Alien Plant Program (IAPP), managed by the BC MoFLNRO. New occurrences will be recorded in the IAPP database. 2. Prescription will address priority invasive plant infestations.
Discussion of invasive species observations, current and recommended treatment efforts. Description of introduced species populations.	
RECREATION	MANAGEMENT OBJECTIVES
SU All	n/a
No official recreation sites or trails in this TU.	
ACCESS	MANAGEMENT OBJECTIVES
SU All	Access control is to be considered in each prescription and appropriate action prescribed and implemented.
Description of access road.	
ARCHAEOLOGICAL	Archaeological Assessment Required? No Completed? No
SU All	1. All ER Prescriptions that overlay medium to high potential archaeological polygons will be considered for examination by an archaeologist acceptable to First Nations and recommendations for treatments (e.g. avoidance, treat only under sufficient snow pack) will be discussed with the archaeologist and incorporated into the ER Prescription. 2. Notwithstanding the above an archaeological assessment shall be completed for any ER operation that requires the exposure of earth (i.e. the construction of new road, landing, fireguard or reopening an existing road) within a medium to high archaeological polygon prior to work commencing. Operations shall respect the recommendations of the assessment.
CULTURAL AND HERITAGE CONCERNS	MANAGEMENT OBJECTIVES

SU All	ER prescribers shall note, in the ER prescription the occurrence of plant species noted by experts as being culturally important food plants, including: • Saskatoon • soopolallie • black gooseberry • choke cherry • nodding onion • arrowleaf balsamroot • sagebrush mariposa lily • wild strawberry • wild bergamot • bitterroot

It should be noted that the timing of pre-treatment survey did not necessarily correspond with the emergence and active growth phases for all species listed above. Survey observations may not have captured all cultural target species occurring in the treatment units.

Discussion of cultural species observations and potential for increase.

RANGE	CATTLE USE? ☒Yes ☐No	IF 'YES,' RANGE UNIT: n/a PASTURE: n/a
RANGE IMPROVEMENTS CATTTLE PRIMARYACCESS TRAILS? ☐Yes ☒No	IF 'YES,' LOCATE ON ATTACHED MAP	SEEDED? ☐Yes ☒No

SU All	MANAGEMENT OBJECTIVES
	ER treatment shall not open up closed forests that would change the distribution of cattle and shall ensure that any fence damaged by ER practices is repaired to acceptable standards.

PRESCRIBED BURN	MANAGEMENT OBJECTIVES
SU All	n/a

FUEL MANAGEMENT	MANAGEMENT OBJECTIVES
SU All	Prescribers shall estimate fuel loading by TU and propose hazard abatement strategy for the fuel.
Estimation of stems removed by class. Description of fuel management techniques.	
SMOKE MANAGEMENT	MANAGEMENT OBJECTIVES
SU All	Prescriber shall outline smoke control issue for information of burn plan and operations on site.
OTHER RESOURCE VALUES/INTERESTS (Public Utilities, research plots etc.)	MANAGEMENT OBJECTIVES
SU All	Conduct operations next to transmission and TELUS telephone lines as per attached "STANDARD OPERATING PROCEDURE FOR ECOSYSTEM RESTORATION PROJECTS CONDUCTED NEAR PUBLIC UTILITIES"

SPECIAL AREAS					
SPECIAL AREAS WITHIN STANDARDS UNIT? ☐Yes ☒No		TYPE OF SPECIAL AREA; (e.g., Riparian Reserve Zone, Riparian Mgmt Zone, Lakeshore Mgmt Zone, FENs, research installations, other)			
AREA NO.	SIZE	*Description of special area and significant features*			
DESCRIBE HOW MANAGEMENT ACTIVITIES DIFFER FROM THE REST OF THE STANDARDS UNIT					
COMMENTS			**INITIALS**		
			PREPARED BY	SENIOR REVIEWER	BAND MANAGER

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PRESCRIPTION APPROVAL			
PREPARATION			
PREPARED BY *(SIGNATURE)*			
PRINTED NAME		DATE SUBMITTED Y / M / D	
PRESCRIPTION REVIEW		FINAL APPROVAL	
Senior Reviewer: * SIGNATURE		Band Manager: * SIGNATURE	
PRINTED NAME	DATE SIGNED Y / M / D	DATE APPROVED Y / M / D	

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- May be mandatory if activity part of license agreement