

Glacier National Park: Restoration Monitoring Report

2012

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Division of Resource Management
December 2012



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I. INTRODUCTION

The Revegetation Monitoring Program, established in 1991, is designed to provide a systematic framework for describing a site prior to disturbance and for monitoring the success of seeded and planted species after revegetation. The goals of the monitoring program (Kurth and Potter, 1991) are to:

- (1) Develop revegetation techniques based on collected information;
- (2) Set feasible expected levels of success for revegetation and set reasonable time frames in which to expect those levels;
- (3) Establish appropriate site-specific goals for projects;
- (4) Determine the degree to which a project meets predetermined goals or expected levels of success;
- (5) Determine cause and effect relationships from revegetation treatments;
- (6) Determine spatial requirements for specific environments;
- (7) Identify sensitive areas where impacts must be avoided because revegetation is too costly or impossible;
- (8) Identify needs and methods for remedial work at a site; and
- (9) Reduce time and money spent on revegetation.

Based on these goals, four levels of monitoring have been established to document the success of revegetation projects. These levels range from a simple, quick assessment of a site (Level I) to complex experiments that test revegetation techniques (Level IV). Table 1 summarizes the main variables that are monitored within each level.

Table 1. Levels of Monitoring

Monitoring Level	Variables monitored
Level I	• soil erosion • estimated canopy cover of (1) mature, pole, sapling, and seedling trees; (2) tall, medium, and low shrubs; (3) native and exotic grasses; and (4) native and exotic forbs • ground cover description (% soil, rock, gravel, litter, moss/lichen, wood, and basal vegetation) • disturbance history • evidence of animal use
Level II	• data from Level I • species list of at least the dominant native and exotic species and their respective canopy covers • description of planted and seeded material (estimated density, mean height, phenology, vigor)
Level III	• data from Level II • permanent transects and microplots established to monitor the number of species, and their respective canopy covers, densities, and mean heights • permanent circular plots established to monitor height, width, vigor and damage of planted shrubs and trees
Level IV	• experiment using replicate and control plots to evaluate revegetation techniques

In addition, a site analysis procedure has been designed to collect information on revegetation sites prior to disturbance. Site analysis data includes information on:

- Parent material (weathered mineral or organic material from which the soil develops)
- Slope shape and aspect;
- Soil surface status and soil texture analysis
- Ground cover description (% soil, rock, gravel, litter, moss/lichen, down wood and basal vegetation)
- Estimated canopy cover of (1) mature, pole, sapling, and seedling trees; (2) tall, medium, and low shrubs; (3) native and exotic grasses; and (4) native and exotic forbs
- Species list of at least the dominant exotic and native species and their respective canopy covers
- Evidence of animal use
- Disturbance history

- List of species or cultural resources of special concern
- Recommendations for revegetation (target plant community, site preparation, use of plant or soil salvage, use restrictions and safety considerations)

Revegetation areas are listed in Table 2. The monitoring report for the appropriate year should be referenced for further information.

Table 2. Monitoring projects to date

LOCATION	Monitoring Level	Monitoring Dates
303-B: Lake McDonald segment of GTSR	Level III	1992, 1993, 1994, 1996, 2001, 2011
303-B Road shoulders	Level II	1993, 1994, 1995, 1998
303-C: St. Mary segment of GTSR	Level II	1993, 1994, 1995, 1998, 2003
303-C Road shoulders	Level II	1994, 1995, 1998, 2003
Two Dog Flats	Level IV	1993, 1995, 1997, 2002
303-D: Rising Sun segment of GTSR	Site Analysis, Level IV	1993-1997, 1999, 2004, 2005
303-D: Road shoulders	Level II	1996, 1997
303-E: Logan Pass and Oberlin Bend	Site Analysis, Level IV	1993, 1996, 1997, 1998, 1999, 2001, 2006, 2011
303-E: Logan Pass Seeding/ Planting Plots	Site Analysis, Level IV	1997, 1998, 1999, 2000, 2008
303-F: McDonald Creek segment of GTSR	Site Analysis, Level II	1994, 2000, 2001, 2002, 2009
303-F: Avalanche Campground & Picnic Area	Site Analysis	1995, 1996
Phase VI: West Tunnel to Haystack section of GTSR	Site Analysis, Level II	2007, 2010, 2011, 2012
Phase VII: Avalanche to West Tunnel section of GTSR	Site Analysis	2004, 2010
Phase VIII: Big Bend to Logan Pass section of GTSR	Site Analysis	2010
Phase IX: Haystack to Big Bend section of GTSR	Site Analysis	2010
Phase XI: Logan Pass to Siyeh Bend section of GTSR	Site Analysis	2010
Phase XII: Siyeh Bend to Rising Sun section of GTSR	Site Analysis	2010
Apgar Transit Center	Site Analysis, Levels II & IV	2006, 2007, 2008, 2009, 2010, 2012
Bowman Creek Campground	Level II	1993, 1998
Camas Road - Revegetation	Site Analysis, Level II	1995, 2000, 2002, 2003, 2008
Camas Road - Hydromulch	Level II	2004, 2005, 2007, 2009
Granite Park Chalet	Site Analysis	1994
Grinnell Point Picnic Area	Site Analysis	2010
Herbicide / Revegetation Experimental Plots	Level IV	2008, 2009, 2010, 2012
Hidden Lake Social Trails	Level II	2003, 2005, 2010
Lake McDonald Lodge dorm site	Site Analysis, Level II	2007, 2009, 2010, 2011
Logan Pass Comfort Station	Level II	1993
Polebridge Bridge	Level II	1993, 1998
Polebridge Ranger Station	Level II	1993, 1998
River Campground	Level II	1993, 1998
Sperry Chalet	Site Analysis	1996
St. Mary housing area	Level II	1993
St. Mary Visitor Center	Site Analysis, Level II	2006, 2010, 2011
Swiftcurrent Apartments	Level II	1993
Three Bears Lake	Level II	1993, 2000
Two Medicine housing area	Site Analysis	1994
West Glacier Bike Path	Level II	2005, 2007, 2009
West Glacier Entrance Station	Level II	2009, 2010, 2011

The objectives of this report are to document the results of the 2012 season. The report includes: (1) data from two revegetation projects (Apgar Transit Center and Phase VI of the GTSR reconstruction); (2) year four results of herbicide impacts and restoration success at one site from the weed treatment-revegetation project; (3) results from whitebark and limber pine restoration projects; (4) results from whitebark and limber pine plus tree monitoring; and (5) overall recommendations for the monitoring program, including a schedule for future monitoring. All road projects are based on and are evaluated against the following revegetation goals and objectives (Lange, 1988; Lapp, 1994):

Overall goal: Within 5 years following construction, a vegetative cover of native plants will be established that will potentially blend with the adjacent plant communities, is ecologically compatible with the surrounding community, and is consistent with maintenance and safety requirements. Within 20 years following construction, the color and structure of the vegetation will blend into the adjacent plant community and diversity of native species will resemble the plant community prior to disturbance.

Objectives:

- (1) Preserve genetic integrity of native floral populations.
- (2) Provide for optimum survival of plant material by using species collected at or near the disturbed site.
- (3) Quickly provide plant cover to stabilize soil and prevent erosion.
- (4) Keep coverage of exotic plants low in cut and fill slopes, and prevent invasion into undisturbed vegetation.
- (5) Restore aesthetic value of vegetation within disturbed area that blends in with adjacent undisturbed plant communities.
- (6) Use roadside vegetation that will not be a long-term food attraction to wildlife.
- (7) Select appropriate vegetation for cut slopes, ditches, and a turf shoulder that is low maintenance, durable, safe, and able to stand up under heavy visitor foot and automobile traffic.
- (8) Provide opportunity for research and technology transfer.

II. APGAR TRANSIT CENTER

A. BACKGROUND AND PURPOSE

Construction of the Apgar Transit Center (ATC) took place in 2007 as part of a new transit system designed to reduce traffic on the Going to the Sun Road (GTSR) during road construction. It is located at the “T” intersection of the GTSR and Camas Road approximately one mile past the West Entrance. The project includes a 4,200 ft² information building with restrooms, a parking lot that accommodates 132 vehicles and 15 recreational vehicles, as well as the connection of water and sewer lines from the ATC to the existing utilities in Apgar Campground. Paved sidewalks and additional paved bike trails that lead to other visitor use areas in Apgar are also part of the project.

Overall, nearly 6 acres of former lodgepole forest were cleared, including an understory of hemlock, pine, fir and other maritime species. It is very evident that this was a cedar/hemlock forest prior to the stand-replacing 1929 fire. In total, 3.74 acres of this area required native plant restoration, in addition to 2.1 acres along the Camas Road that required hydroseeding. Figure 1 outlines the areas of disturbance requiring restoration, as well as the specific planting and seeding prescription areas.

As part of the construction process, 44 tall trees and 520 containers of trees, shrubs, and herbs were salvaged in 2006, including difficult to propagate species such as *Vaccinium membranaceum*, the rare *Vaccinium myrtilloides*, and *Xerophyllum tenax*. In addition, 778 ft² of moss/shrub/herbaceous mats were salvaged at the same time. Most of this salvaged material was replaced during the spring and fall of 2007 within the parking lot islands, east of the transit center, and along the sewer/water line swath that runs from the transit center to Loop E of Apgar campground (Figure 1). Mats of salvaged vegetation were also planted in various small locations along the bike path (Figure 1). Additionally, 7,035 nursery propagated plants were planted in the large islands within the parking lot, around the transit center and transit pickup area, along the edges of the parking lot, along the entrance driveway, and near Loop E of Apgar Campground (Figure 1). Finally, all of the area except the parking lot islands and landscaped areas around the transit center were seeded under five distinct seeding prescriptions (Figure 1). Hydroseeding was done on bike path shoulders and Camas Road utility disturbances but all other seeding was done by hand broadcasting and raking in seed.

It was recognized that the sewer/water line, existing as a linear swath that is uniform in topography and sun availability, would lend itself well to the installation of research monitoring plots that could evaluate a number of different revegetation treatments. In 2007, monitoring plots were installed within the swath to test seven revegetation strategies. These strategies focus on key revegetation species that the Park has had difficulty with in the past.

In 2012, only the research plots along the old sewer/water line were monitored. These plots have been monitored in 2008, 2009, 2010, and 2012. The remaining restoration monitoring plots within the ATC parking lot, near the transit center, along the bike path, and near the sewer line were not monitored this year. Please review the 2010 Revegetation Monitoring Report (Asebrook et. al. 2010) for the most current data on these plots.

It should also be noted that the ATC parking area is slated for expansion in 2013, including the area occupied by these revegetation research plots. Given the plans of the expansion, this year will be the last year that these plots are monitored.

B. METHODS

1. Research Monitoring Plots

In June 2007, research monitoring plots were installed along the sewer/water line that runs from the ATC to Loop E in Apgar Campground (purple area in Figure 1). In total, 56 plots were installed that each measured 2m x 2m (Figure 2). These plots represent eight replicates of seven different treatments. The seven treatments are as follows:

1. seeding *Xerophyllum tenax* at 25 seeds/ft²
2. seeding *Rubus parviflorus* at 25 seeds/ft²
3. seeding *Calamagrostis rubescens* at 50 seeds/ft²
4. seeding *Calamagrostis rubescens* at 30 seeds/ft² with a forb mix of 56 seeds/ft² (8 seeds/ft² of *Spiraea betulifolia*, *Chamerion angustifolium*, *Solidago canadensis*, *Achillea millefolium*, *Geum macrophyllum*, *Anaphalis margaritacea*, and *Symphyotrichum laeve*)
5. seeding *Carex athrostachya* at 30 seeds/ft² with *Achillea millefolium* at 20 seeds/ft² and *Spiraea betulifolia* at 20 seeds/ft²
6. planting *Calamagrostis rubescens* plugs at 1 plant/ft² (43 plants/plot)
7. control plot

Figure 1. Apgar Transit Center: Planting and Seeding Units

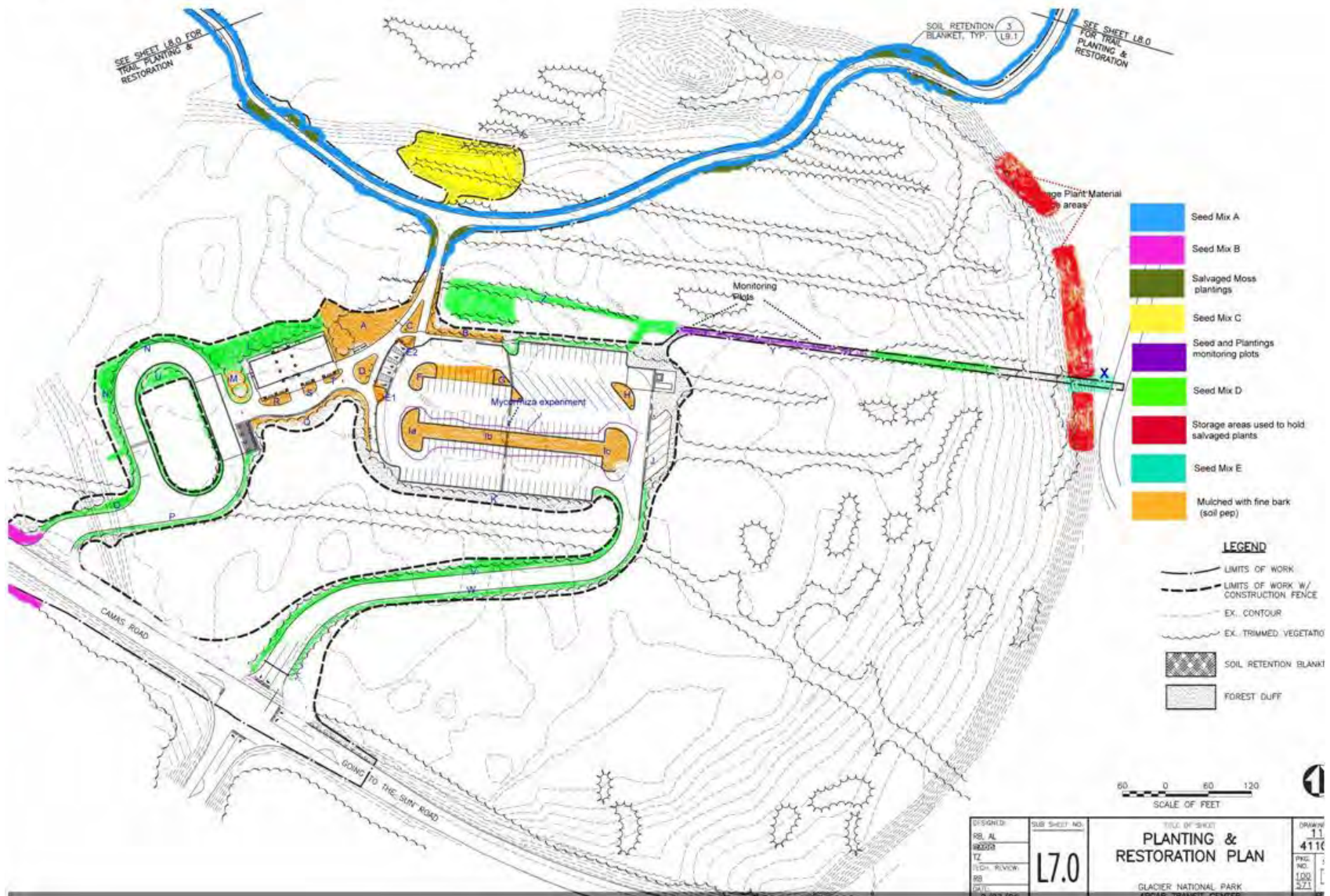
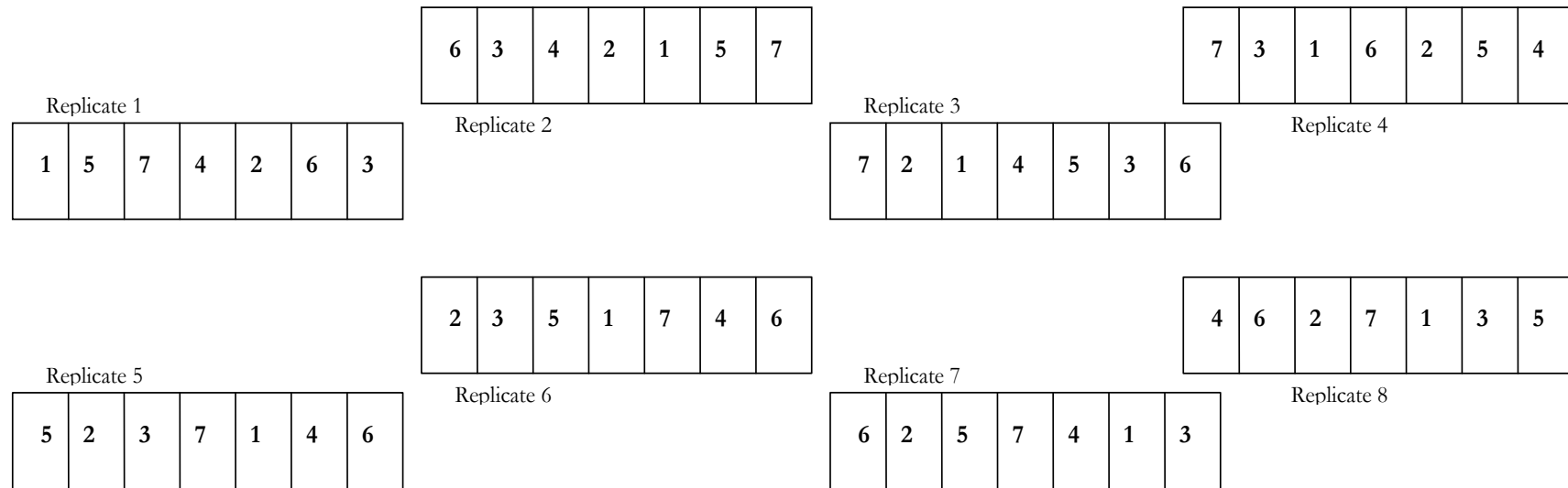


Figure 2. Apgar Transit Center: Schematic Layout of Research Monitoring Plots



*Plots are offset in the field just slightly. This diagram does not accurately represent the spacing or offset of the replicates.

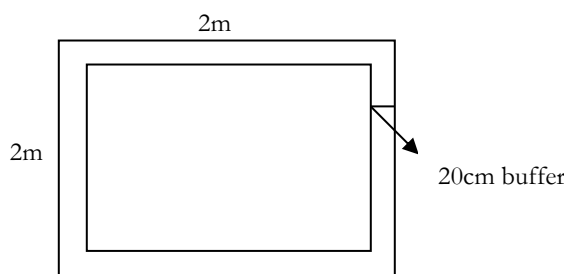


TREATMENTS:

1. seeding *Xerophyllum tenax* at 25 seeds/ft²
2. seeding *Rubus parviflorus* at 25 seeds/ft²
3. seeding *Calamagrostis rubescens* at 50 seeds/ft²
4. seeding *Calamagrostis rubescens* at 30 seeds/ft² with a forb mix of 56 seeds/ft²
5. seeding *Carex athrostachya* at 30 seeds/ft² with *Achillea millefolium* at 20 seeds/ft² and *Spiraea betulifolia* at 20 seeds/ft²
6. planting *Calamagrostis rubescens* plugs at 1 plant/ft² (43 plants/plot)
7. control plot

The plots were installed in a linear layout with one replicate of each treatment in each linear plot (Figure 2). Treatments were randomly located within each replicate plot. Nails mark the four corners of each plot and the upper left corner (when facing north) is marked with a tag describing the replicate number and treatment type. Although each plot measures 2m x 2m, there is a 20cm buffer along the inside of each plot (Figure 3) that was not included in monitoring to address any overlap from seed treatments and edge effect.

Figure 3. Apgar Transit Center: Diagram of individual monitoring plot



Plant material was installed in the experimental plots in October 2007. Seed plots were first lightly scarified using pulaskis, then seeded with appropriate species at the prescribed seed rate, and finally raked in within the first 1-3 inches of the surface soil. Treatment plots with *C. rubescens* plugs were lightly scarified with pulaskis and then each plot was planted with 43 conetainer-sized grasses at 1 plant/ft². Plants were planted at random within each plot. Finally, the control plot had no treatment installed or scarification of soil.

In October 2007, cover estimates were made for the plots planted with *C. rubescens* plugs. All *C. rubescens* plug plots were photographed to visually show plant cover in the plot.

Monitoring of all experimental plots took place in 2008, 2009, 2010, and 2012. Monitoring involved reading subsamples of three ¼ m² microplots within each individual monitoring plot. Random number tables were used to determine the placement of microplots within a plot. Microplots could share an edge but could not overlap, and as stated above, were not allowed to sample within the 20cm buffer zone along the edge of each plot. Ocular canopy cover determinations for all species within the plot were made and density for each seeded species in a given treatment was calculated by counting seeded germinants within each microplot. Ground cover estimates were also made. All plots were photographed to visually illustrate plant cover in the plots.

2. Revegetation Plots Monitored by Ocular Cover

Ten additional Level II revegetation monitoring plots were installed during August and October 2007. As stated above, these plots were not monitored this year due to time constraints and a lack of high value data concerning effective revegetation techniques. Please review the 2010 Revegetation Monitoring Report (Asebrook et. al. 2010) for three years of data for these plots.

C. RESULTS AND DISCUSSION

In July 2012, experimental plots were monitored, five years after seeding and planting. Each of 56 plots were read, including canopy cover estimates for each species. Three ¼ m² microplots were read per plot and percent cover was averaged per plot. Density counts for each seeded or planted species were not conducted this year due to time constraints and the inability to determine an original germinant for certain species. Results are listed in Tables 3, 4, 5, and 6.

1. Treatments

From 2008 to 2010, all treatments increased in both native and exotic cover. From 2010 to 2012, however, only native lifeforms continued to increase in all treatments, while exotic forbs actually decreased or remained the same on five treatments. The highest native cover five years after revegetation was produced by treatment 5, specifically seeded *Carex athrostachya* and a forb/shrub mix. Treatment 6 or planted *Calamagrostis rubescens* plugs, the

treatment that had the highest native cover in 2008 and 2010, was a very close second for overall native cover. Both of these treatments increased in native cover by 10-12% for 33.77% and 33.35% native cover, respectively. Native cover of seeded *C. rubescens* with a forb and *Spiraea betulifolia* mix, which had the highest overall native cover in 2009, also has relatively high native cover at 31.43%. The remaining four treatments had moderate native covers ranging from 20.81% to 22.92%. Currently, seeding *Rubus parviflorus* alone has resulted in the lowest overall native cover at 20.81%. The control plot, where nothing was seeded or planted, remained similar to last year with the fourth highest native cover of the seven treatments at 22.31%.

a) *Calamagrostis rubescens* plugs (Treatment 6)

Although initially, planted *Calamagrostis rubescens* plugs had at least double the vegetation cover at year one after planting, other treatments have been catching up to the cover of this treatment over the past four years. This treatment, however, has remained one of the most successful treatments of the experiment with consistently high overall vegetation cover and consistently high native cover. Through year three after planting, this treatment also had the lowest exotic cover, although non-native forbs have become more established over the past two years resulting in moderate exotic cover under this treatment. Currently, overall cover of this treatment is 45.48%, the second highest overall total cover, with 33.35% native cover, the second highest native cover of any treatment. Although this treatment has the fourth highest exotic cover of all the treatments, the overall high native cover results in the second highest native to exotic ratio at 73.3%, slightly higher than last year. It is significant that this treatment has also had the highest native to exotic ratio one year after planting at 98.4%, two years after planting at 83.8%, and three years after planting at 72.1%. It is likely that this very high initial cover during the first few years maintains a higher percent native cover over time.

Native grass cover under the *C. rubescens* plug treatment remains far higher than any other treatment and remains the dominant lifeform on this treatment. Native grass cover increased from 16.29% in 2010 to 23.83% in 2012, two to nearly five times as high as native grass cover on other treatments. Most of this is due to cover of *C. rubescens* plugs which were estimated to be 22.46% this year, increasing from 13.79% in 2010. Data from year three after planting indicated that the density of *C. rubescens* plugs is not decreasing, suggesting that the grass plugs are growing in size to achieve greater cover. In addition, *Carex rossii* continues to maintain notable cover on this treatment with 1.04% cover this year. This sedge species, along with *Agrostis scabra*, *Carex concinnoides*, *Danthonia spicata*, and *Festuca occidentalis*, are naturally recruiting to a number of treatments within this experiment.

While native forb cover under this treatment did significantly increase from 2008 to 2010 and increased slightly from 3.11% in 2010 to 4.38% in 2012, native forb cover is currently the lowest of all the treatments. Species diversity and individual forb cover is very low with most forb cover resulting from *Chamerion angustifolium*, *Anaphalis margaritacea* (that may be seeding into this treatment from other treatments that were seeded), and *Hieracium albiflorum* that each have 1% to 2% cover. The lack of seeded forbs is clearly driving the low forb cover, but naturally recruited forbs may also have a difficult time getting established due to the higher grass cover. Certain naturally regenerating forbs, such as *Chamerion angustifolium* and *Hieracium albiflorum* that are maintaining notable cover on this treatment this year, may offer a change to that trend.

Tree cover, similar to several other treatments, increased this year from 3.82% to 5.0%. Also like other treatments, most of the increase in tree cover is due to increases of *Pinus contorta* and *Populus balsamifera* seedlings that currently have 2.51% and 2.43% cover, respectively. At present, there is trace shrub cover in this treatment due to trace cover of naturally colonizing *Amelanchier alnifolia* and *Linnaea borealis*.

Lastly, as stated above, this treatment has the fourth highest cover of exotic species, different from 2010 when this treatment had the lowest cover of exotic species. This change is the largest increase of exotic cover this year compared to all other treatments. Currently, exotic grass has 0.72% cover, increasing from 0.13% cover in 2010. This is the second lowest exotic grass cover of all treatments, although in 2010 this treatment had the lowest overall exotic grass cover, indicating a small negative trend. Similar to the last few years, *Agrostis stolonifera* accounts for all of the exotic grass cover. In addition, this treatment was one of only two treatments where exotic forbs increased from 2010 to 2012. While exotic forb cover on five other treatments decreased or generally remained the same, exotic forbs increased on this treatment from 8.55% in 2010 to 11.42% this year. Increases were due primarily to increases of clover species *Trifolium hybridum* and *Medicago lupulina*. Similarly, *M. lupulina* tended to increase slightly on several other treatments over the past two years, although, conversely, *T. hybridum* typically decreased on other treatments in the same time period. *Veronica officinalis* also increased slightly since 2010, maintaining notable cover.

It is not clear what caused the increase of exotic species on this treatment at this later time frame. Overall vegetation cover was adequately high from year one after planting and exotic species cover remained low, indicating that quick establishment of native species could prevent the establishment of exotic species. Native cover continued to increase over time as well, providing even less ground space for weed invasion. As the two most dominant weeds are clover species that can be variable over time, perhaps the increase of these species has been delayed as these species took longer to become established. As this planting experiment will likely not be monitored in the future, it is hard to predict if this increase in exotic cover is merely temporal or these weeds will be a continued presence despite the high native grass cover.

b) *Calamagrostis rubescens* seeded with forb mix and *Spiraea betulifolia* (Treatment 4)

This treatment, overall, has had the most pronounced shifts in lifeforms over time, making it sometimes difficult to assess the trend of this treatment. In 2009, all lifeforms except exotic grass significantly increased since 2008. In 2010, only exotic forb cover significantly increased, although tree and native forb cover did have notable increases in cover that year. This year, native grasses and trees showed the biggest increases in cover, while native forbs, shrubs and exotic grasses had slight increases in cover. Conversely, exotic forbs dramatically decreased in cover. The overall result is that this treatment, despite having the third lowest overall vegetation cover, is dominated by native plants. This treatment has the third highest native cover at 31.43% and the lowest exotic cover at 4.54%, resulting in the highest native to exotic ratio at 87.4%. This is an improvement over last year when this treatment had the second highest native to exotic ratio at 69.4% and improves over its 2009 status when it had the third highest native to exotic ratio of all treatments. While this treatment is not proportionally changing in overall native cover as quickly as some other treatments, it had the second largest decrease in exotic cover, supporting its success as a restoration treatment. It should be noted that this treatment had the highest seed rate of any of the treatments at 925 seeds/m² (Table 6), perhaps enhancing its success.

Native forb cover under this treatment increased from 17.17% in 2010 to 20.13% in 2012, after a notable increase from 10.31% cover in 2009. Since 2009, native forbs have been and continue to be the dominant lifeform under this treatment. This also remains the highest native forb cover of any of the treatments, similar to 2009 and 2010. Increases in 2012 were due to increases of two seeded forb species, specifically *Achillea millefolium* and *Solidago canadensis* which both increased by approximately 2% since 2010. Currently, *Achillea millefolium*, *Solidago canadensis*, *Anaphalis margaritacea*, and *Symphyotrichum laeve*, all seeded species, remain with the highest native forb cover on this treatment. *Geum macrophyllum* and *Chamerion angustifolium*, the remaining seeded forbs under this treatment, actually decreased in cover on this treatment and remain with low cover. Native forb cover was dramatically higher than forb cover of all other treatments except seeded *C. athrostachya* with a similar seeded forb mix. Similar to 2009 and 2010, native forb cover under this treatment was slightly higher than the seeded sedge treatment with forbs but results were not dramatically different and likely not statistically significant. Correspondingly, covers of *Anaphalis margaritacea*, *Solidago canadensis*, and *Symphyotrichum laeve* were also higher under this treatment than all other treatments, while *Achillea millefolium* had higher cover than all other treatments except the sedge/forb mix treatment (Table 4). Finally, naturally recruited species *Hieracium albiflorum* and *Gnaphalium macounii* had notable increases in cover from 2010 and several new native forbs recruited for the time to this treatment.

After maintaining its cover from 2009 to 2010, native grass cover increased dramatically from 2010 to 2012, similar to other treatments. Native grass cover increased from 2.44% in 2010 to 6.21% in 2012, due almost exclusively to an increase of *Calamagrostis rubescens*, the only seeded grass on this treatment. Currently, the only other native grasses within this treatment that have notable cover include *Carex* spp. and *Festuca occidentalis*, each of which has established naturally. Although last year this treatment had the lowest overall native grass cover of all treatments, this year this treatment has the second lowest overall native grass cover, including two treatments that were not seeded with native grass.

There may be two reasons for this low grass cover despite seeding a grass species on this treatment. First, density data through year three of this project indicated that the density of *C. rubescens* seed significantly decreased on this treatment from 2009 to 2010, dropping from 148.5 germinants/m² to 75.2 germinants/m² (Table 6). Initial germinants were clearly not surviving to the third year after seeding, perhaps from competition of other establishing vegetation but also because it is unlikely that all germinants survive. This trend was also observed in treatment 3 where *C. rubescens* was seeded alone; at year three after seeding, the density of *C. rubescens* was almost identical whether it is seeded alone or with a forb mix. The difference, however, is that similar to 2010, cover of *C. rubescens* under this

mixed seed treatment is almost half the cover of *C. rubescens* when it is seeded alone. It is also much lower than cover of planted *C. rubescens* plugs. While the surviving germinants under this treatment are clearly growing since half the density is continuing to increase in cover, they are not, however, growing as quickly as other treatments, specifically treatment 3 where *C. rubescens* was seeded alone and has similar densities. As *C. rubescens* requires mineral soil and low competition to germinate and survive (Steele, 1995; Hassell, 1983), a higher native forb and shrub cover may be providing enough competition to curtail growth of this grass on this treatment, particularly one that requires room to establish rhizomes. Second, there may have been more room for naturally regenerating grasses to establish on other treatments with few to no seeded species, leading to higher cover of native grass on other treatments. The control plots, for example, have the third highest native grass cover after *C. rubescens* plugs and *C. rubescens* seeded alone despite no seeded grass species. Most of this cover is due to naturally regenerating grasses that had little competition with other seeded plants. While *Festuca occidentalis*, *Carex rossii*, *Agrostis scabra*, and *Danthonia spicata* have been naturally regenerating on all treatments within the project, they have the highest covers on treatments with little to no competing seeded material. Currently, there is very little cover of naturally regenerating grasses on this treatment, again, perhaps due to competition from higher native forb and shrub cover. The result is lower overall native grass cover on this treatment despite seeding a grass species.

While shrub and tree cover did not significantly increase from 2009 to 2010, both lifeforms increased slightly since 2010. Native shrub cover increased slightly from 0.31% in 2010 to 0.93% in 2012, due exclusively to an increase of *Spiraea betulifolia* cover, the only seeded shrub in this treatment. Although *S. betulifolia* was seeded in a mix under this treatment and treatment 5, cover of *S. betulifolia*, similar to 2010, remains significantly higher on treatment 5 where it was seeded with a sedge species and fewer forb species. Cover of *S. betulifolia* is the second highest cover of any treatment, although overall shrub cover remains the third highest of any treatment after treatment 5 and treatment 2 where *Rubus parviflorus* was seeded. Two reasons may explain why this shrub is not increasing in cover like treatment 5 where it was also seeded. First, this shrub had higher competition from more forb species since the onset of the project, perhaps impeding germination and growth. Second, and perhaps more importantly, *S. betulifolia* also had a higher seed rate on treatment 5, adding to its success, compared to this treatment. Both treatments with seeded *S. betulifolia* decreased somewhat in density at year three after seeding but density of plants remained higher on treatment 5 than on this treatment. This higher density is likely contributing to the higher cover of this shrub. Strangely, density of the *R. parviflorus* on treatment 2 was lower than density of *S. betulifolia* on this treatment at year three after seeding yet cover of *R. parviflorus* remained higher. As *R. parviflorus* is a larger shrub with a larger leaf size, it may be that this shrub, despite fewer individuals, is growing faster and is already larger than *S. betulifolia* plants, resulting in higher cover.

Similar to other treatments, tree cover increased since 2010 from 1.88% to 4.17% in 2012, although this is the lowest tree cover of all the treatments. The increase was due mostly to an increase of *Pinus contorta*. *Populus balsamifera* also maintains notable cover under this treatment. Both tree species have naturally colonized throughout the project and provide the most consistent cover across all treatments.

As stated above, this treatment currently has the lowest overall exotic cover of any treatment. Although exotic forbs had been consistently increasing over the first three years of the project, exotic forbs surprisingly decreased on four treatments, including this treatment, from 2010 to 2012. Exotic forb cover decreased from 9.65% in 2010 to 3.9% in 2012, now the lowest of any treatment and the second biggest loss of exotic forbs over the past two years. This is an improvement over 2010 and 2009 when exotic forb cover was the third and fourth lowest, respectively, of all treatments. Most of the decrease was due to decreases of *Trifolium hybridum* and *Veronica officinalis*, the same species that increased dramatically from 2010 to 2012. While cover of clover species can be cyclic in relation to rainfall levels, it is unusual for *V. officinalis* to decrease in cover once it has become established. Reasons for this decrease are unknown. Exotic grass cover has remained low, only increasing slightly from 0.18% in 2010 to 0.64% in 2012, the lowest of any treatment. All exotic grass cover is due to the presence of *Agrostis stolonifera*.

c) ***Carex athrostachya* seeded with *Achillea millefolium* and *Spiraea betulifolia* (Treatment 5)**

Treatment 5, where *Carex athrostachya* was seeded with *Achillea millefolium* and *Spiraea betulifolia*, had the highest overall vegetation cover at 48.47% for the third time in a row and the highest native cover at 33.77% for the first time this year. These are dramatic increases in cover where overall cover was 33.75% and native cover was 21.36% in 2010. While all native lifeforms increased in cover, this treatment was one of three treatments to also increase in exotic forb cover. With this increase, this treatment now has the highest exotic cover of any of the treatments at

14.80%, resulting in a native to exotic ratio of 69.5%. Clearly, native vegetation, particularly native forbs, continues to dominate the vegetation, however, the native to exotic ratio drops from third to fourth highest since 2010 with the increase in exotic cover. Of note, this treatment had the second highest seed rate of the project with 753 seeds/m² (Table 6).

Despite the fact that native forb cover continues to increase over time on this treatment (12.5% in 2010 to 16.04% in 2012), native forb cover still remains somewhat higher on treatment 4 where forbs were also seeded, similar to results of 2008, 2009, and 2010. This is primarily due to the fact that three seeded species on treatment 4, none of which were seeded on this treatment, continue to have higher covers on treatment 4 compared to treatment 5. These species include *Anaphalis margaritacea*, *Solidago canadensis*, and *Symphyotrichum laeve*. Only *Achillea millefolium*, seeded in a larger mix in treatment 4 and as the lone seeded forb species in treatment 5, had dramatically higher cover on this treatment at 12.58% compared to treatment 4 where cover of *A. millefolium* is only 5.56%. *A. millefolium* has and continues to make up the majority of native forb cover on this treatment, increasing from 6.13% in 2009 to 11.46% in 2010 to 12.58% in 2012, resulting in approximately 78% of the native forb cover. This continues to be the second highest cover of any individual native species on the project, other than the planted *C. rubescens* plugs. Several species had small increases in cover from 2010 to 2012, contributing to the overall increase in native forb cover. These include *A. millefolium*, *Antennaria rosea*, *Antennaria howellia*, and *Hieracium albiflorum*. Currently, three species other than *A. millefolium* have notable cover on this treatment, including *Chamerion angustifolium* with 1.18% cover, *H. albiflorum* with 0.92% cover, and *A. margaritacea* with 0.63% cover. It is important to note that several forb species that have become established under this treatment may be due windblown seed from other treatments, confusing the results of this experiment. *A. margaritacea*, *C. angustifolium*, and *S. laeve* likely have become established by windblown seed. Other species, such as *H. albiflorum*, *A. howellia*, *A. rosea*, *Maianthemum stellatum*, and *Viola orbiculata*, continue to naturally recruit to this treatment. It is the combination of these species that have resulted in the second highest native forb cover compared to all other treatments except treatment 4.

Native grass cover continued to increase from 0.94% in 2009 to 3.13% in 2010 to 8.22% in 2012, resulting in the fourth highest native grass cover of all the treatments. This is an improvement for this treatment that historically had one of the lowest native grass covers, even lower than several treatments that had no grass seed application. Currently, *C. rubescens* planted plugs, *C. rubescens* seeded alone, and the control plots have higher native grass cover than this treatment. The increase in cover over the last two years on this treatment was due to a notable increase of *Festuca occidentalis*, a naturally recruiting grass that increased from 0.2% cover in 2010 to 2.89% cover in 2012. As stated in other sections, this grass has increased throughout the project regardless of treatment. The second biggest increase came from *C. rubescens* that increased from 0.08% to 1.5% cover. As this grass species was not seeded within this treatment, the presence of *C. rubescens* is either due to seed rain from other treatments or due to natural regeneration of this grass that is present in the adjacent forest. Curiously, the cover of *C. rubescens* within these plots is the highest of all the treatments that were not seeded or planted with *C. rubescens*. It is uncertain why it is establishing on its own in higher amounts than in other treatments. The only seeded grass within this treatment, *Carex athrostachya*, continues to increase as well, increasing from 1.0% cover to 2.03% cover in 2012. It is interesting to note that although *C. athrostachya* had the same seed rate as *C. rubescens* on treatment 4 (323 seeds/m²), the germination rate of the sedge species at years two and three after seeding was 2%-3%, compared to 23%-47.0% of *C. rubescens* (Table 6). This low germination rate for *C. athrostachya* appears to be low for this species in comparison to nursery testings. While density data for seeded species was not collected in 2012, observations of the plots indicate that there is little additional germination of the seeded sedge species but that the existing plants are growing to produce more substantial cover. Finally, naturally occurring *Danthonia intermedia* continues to increase in cover as well.

Shrub cover is currently higher on this treatment than all treatments except treatment 2 where *Rubus parviflorus* was seeded. Cover of *Spiraea betulifolia*, a seeded species under this treatment, increased from 0.65% in 2009 to 1.79% in 2010 to 3.51% in 2012. This comprises 93% of the total shrub cover, estimated at 3.76%, on this treatment. This is the highest cover for this shrub species of all the treatments and the second highest cover of any shrub species under any treatment (*R. parviflorus* has slightly higher cover at 3.81%). As discussed above, cover of *S. betulifolia* is now higher under this treatment than on treatment 4 where it was also seeded. One contributing factor is likely the seed rate that was higher on this treatment (215 seeds/m²) compared to treatment 4 (86 seeds/m²). The result is a higher density of *S. betulifolia* plants on this treatment (Table 6) even though the actual germination rates have remained somewhat similar. In the end, more plants (42.3 plants/m² on this treatment vs. 22.33 plants/m² on treatment 4) are creating higher cover on this treatment. It is interesting to note that two other shrub species, *Linnaea borealis* and

Vaccinium membranaceum, have recruited to this treatment five years after seeding. Finally, like other treatments, tree cover increased due to increases of *Pinus contorta* and *Populus balsamifera*.

As stated above, this treatment has the highest overall exotic cover of all the treatments due to the second largest change in exotic cover since 2010. While several other treatments decreased in exotic forb cover, this treatment was one of two that increased in exotic forb cover from 11.98% in 2010 to 13.8% in 2012. The increase was due primarily to increases of *Trifolium hybridum* and *Medicago lupulina*, clover species that can vary in cover over time and with precipitation levels. Currently, this treatment has the highest cover *T. hybridum* and one of the highest covers of *M. lupulina* compared to all other treatments. Like several other treatments, however, cover of *Veronica officinalis* decreased in cover. It is uncertain why this shade-tolerant weed species is decreasing on some treatments and continuing to increase on others. Exotic grasses increased slightly from 0.39% in 2010 to 1.0% in 2012. All cover is due to the presence of *Agrostis stolonifera*.

d) Control plots (Treatment 7)

While the control plots had the highest native to exotic ratio in 2009 at 81.3%, the lack of native seed is continuing to result in very little increase in native cover and subsequently, larger increases in exotic cover. This has culminated in a dramatic decrease in the native to exotic ratio to 62.1% in 2012 (although up from an all-time low of 49.8% native to exotic ratio in 2010). While the control plots are now slightly dominated by native plants, different from 2010 when exotic plants dominated this treatment, the native to exotic plant ratio is now the lowest of all the treatments, illustrating the importance of native plant restoration. Despite having the third highest overall vegetation cover this year, most of this cover is due to non-native plants with this treatment having the second highest exotic cover of all treatments. While most other treatments had a decrease in native forb cover, this control treatment maintained its exotic forb cover and increased in exotic grass cover, resulting in the second highest cover of exotic forbs two years in a row and one of the highest exotic grass covers. Similarly, this treatment had the third biggest positive change in exotic cover and the third lowest change in native cover. While some of the species within control plots have naturally recruited, it appears that seed from some of the adjacent treatments may have blown into the control plots, confounding the results. Overall vegetation cover has increased from 8.16% in 2009 to 26.22% in 2010 to 36.25% this year, with total native cover increasing from 6.63% to 13.06% to 22.9% and total exotic cover increasing from 1.53% to 13.16% to 13.94%.

Like all other treatments, native forbs have been consistently increasing on this control treatment as well. Native forbs have increased from 2.57% in 2009 to 3.96% in 2010 to 6.42% this year. To confound results, these small increases are due primarily to increases in cover of seeded species of adjacent treatments. *Chamerion angustifolium* exhibited the largest increase in cover this year with smaller increases from *Achillea millefolium* and *Anaphalis margaritacea*. All of these species are seeded forbs on nearby treatments that have likely blown in from adjacent areas. In addition, *Solidago canadensis*, another seeded forb, just became established within this treatment this year with low cover. The cover of these four species makes up 75% of the native forb on this treatment, falsely increasing the overall native cover and preventing true comparison of methods. If these four species were removed from analysis, native forb cover would only be 1.63%, the lowest native forb cover of all treatments (for this comparison, these same species were also removed from other treatments that they were not intended for). While several other native forb species have naturally recruited to this treatment with trace cover, the only naturally establishing native forb with notable cover is *Hieracium albiflorum*.

For the second time, native grasses increased more noticeably than native forbs, nearly doubling in cover since 2010. Native grasses increased from 1.93% in 2009 to 4.48% in 2010 to 8.79% this year, giving them the highest cover of any of the native lifeforms under this treatment and the second highest of all lifeforms on this treatment after exotic forbs. This increase was due to small increases of *Carex rossii*, *Festuca occidentalis*, *Agrostis scabra*, and *Danthonia spicata*, all species that have naturally recruited to this treatment. Other native grasses that have naturally recruited to this treatment, including *Carex concinnoides* and *Deschampsia elongata*, remain with low cover.

While tree cover continues to increase on the control plots, shrub cover remains negligible. *Linnaea borealis* has naturally established on this treatment with trace cover, while a small amount of *Spiraea betulifolia* has also established, perhaps from seed rain from adjacent treatments. Like other treatments, tree cover increased from 3.90% in 2010 to 7.54% this year, due mainly to an increase in cover of *Pinus contorta* and a slight increase in cover of *Populus balsamifera*. Surprisingly, this is the highest tree cover of any of the treatments, although it could be speculated that these woody species have fewer species to compete with for resources, encouraging their success.

As stated above, exotic species cover is currently the second highest of all the treatments, a declining trend since exotic species cover was only the third highest of all treatments in 2010 and the lowest of any treatment in 2009. Like the other treatments, cover of exotic grasses remains relatively low with 1.31% cover of *Agrostis stolonifera*, although this is a 1% increase over 2010 and one of the largest exotic grass increases of any of the treatments. Cover of exotic forbs remained similar to 2010 estimates at 12.63% after significantly increasing from 1.48% in 2009 to 12.64% in 2010. While *Trifolium hybridum* increased significantly from 2009 to 2010 and was clearly the dominant exotic forb on this treatment in 2010, cover of *T. hybridum* actually decreased by 2012, similar to other treatments. While this clover species still remains the dominant exotic forb on the control plots with 7.83% cover, other exotic forb species, such as *Veronica officinalis*, *Medicago lupulina*, and to a lesser degree, *Trifolium agrarium*, are actually on the rise, maintaining this higher overall exotic forb cover.

e) ***Rubus parviflorus* seeded alone (Treatment 2)**

In general, all lifeforms on this treatment have been steadily increasing over time except exotic forbs which decreased in cover from 2010 to 2012. Without a native grass or forb seed treatment, however, overall native forb and native grass covers remain some of the lowest of all treatments. Similar to last year, this resulted in the lowest overall vegetation cover of all the treatments. It also had the smallest change in native cover since 2010, resulting in the third lowest overall native cover, similar to results of 2010. This is still an improvement over 2009 when this treatment had the lowest overall native cover of any treatment. At the same time, this treatment also had the second lowest exotic cover for the second time in a row. Despite low native cover, the low exotic cover is resulting in two trends: 1) the native to exotic ratio changed dramatically from 55.8% in 2010 to 69.7% in 2012, indicating that native vegetation clearly dominates this treatment; and 2) this native to exotic ratio is now the third highest of all treatments compared to the fourth highest status in 2010 and the fifth highest status in 2009. Despite low cover of native forbs and grasses, native plants on this treatment are not only holding their ground, but improving their dominance.

In keeping with seeding only a shrub species and similar to 2009 and 2010, treatment 2 had the highest shrub cover of any treatment. Shrub cover increased from 2.96% in 2010 to 4.15% this year. This shrub cover is much greater than all other treatments except treatment 5 where *Spiraea betulifolia* was seeded in its mix. This high shrub cover is due exclusively to cover of *R. parviflorus* which had 3.81% cover, up slightly from 2.79% cover last year. It is important to note that cover of *R. parviflorus* is increasing despite a continual drop in density of this shrub species that was counted at three years after seeding (Tables 5 and 6). It was clear when monitoring that *R. parviflorus* germinants were bigger in size, adding to increased cover despite fewer individuals. Like other treatments, tree cover also increased from 2.16% to 6.21% due to increases in cover of *Pinus contorta* and *Populus balsamifera*.

Native forbs continued to have a moderate increase in cover, increasing from 1.43% in 2009 to 3.61% in 2010 to 5.31% in 2012. The biggest increase in cover was from *Hieracium albiflorum*, a naturally recruited forb species that increased in cover from 0.41% in 2010 to 1.28% in 2012. The overall increase in native forb cover was also due to small increases in cover of *Achillea millefolium*, *Anaphalis margaritacea*, *Conyza canadensis*, *Epilobium brachycarpum*, and *Solidago canadensis*. *Chamerion angustifolium* did not increase in cover over the past two years but remains the dominant native forb species on this treatment, similar to 2010. Like other treatments, some of these species may have become established due to windblown seed from adjacent treatments. At the same time, naturally regenerating species from the adjacent forest, such as *Antennaria howellia*, *Antennaria rosea*, *Campanula rotundifolia*, and *Viola orbiculata*, have become established as well with low cover. Although native grass cover increased from 3.60% in 2010 to 5.14% this year, this treatment has the lowest overall native grass cover of all the treatments. Despite small increases in cover from *Carex rossii*, *Festuca occidentalis*, *Agrostis scabra*, and *Danthonia spicata*, all naturally regenerating grasses, native grasses are not increasing on this treatment at a similar rate as other treatments, even the control.

As stated above, this treatment had the second lowest overall exotic cover. Unlike 2009 when exotic forbs were clearly the dominant lifeform on this treatment, exotic forbs decreased from 9.58% in 2010 to 7.07% this year, resulting in the second lowest exotic forb cover of all the treatments. The decrease in cover was due primarily to a decrease of *Veronica officinalis* that had subsequently increased dramatically from 2009 to 2010. As stated above, it is unusual for *V. officinalis* to decrease in cover once it has become established and reasons for this decrease are unknown. At the same time, there were small increases in cover from *Trifolium hybridum* and *Medicago lupulina*, clover species that can vary in cover over time. Like all other treatments, exotic grass cover generally remains low, although this treatment currently has the highest exotic grass cover of all treatments. Exotic grass cover increased from 0.30% in 2010 to 2% in 2012, due primarily to increases of *Agrostis stolonifera*.

f) *Xerophyllum tenax* seeded alone (Treatment 1)

Similar to 2010, both total vegetation cover and total native cover increased under this treatment. Total vegetation cover increased from 27.66% to 36.0% and total native cover increased from 12.11% to 22.63% over the last two years. These increases in native cover have resulted in native plants finally dominating this treatment, the first time since the project started. Seeding *Xerophyllum tenax* alone resulted in the fourth highest overall vegetation cover and fourth highest overall native cover, an improvement over 2010 when this treatment had the second lowest native cover. And although it remains with the second lowest native to exotic ratio of all the treatments at 62.9%, this is a big improvement over 2010 when the native to exotic ratio was 43.8%. In addition, this ratio is not far off from several other treatments indicating its progress. For perspective, this treatment in 2009 had the lowest overall vegetation cover, the lowest native cover, and the lowest native to exotic ratio of all the treatments.

The main success of treatment 1, however, continues to show that seeding *X. tenax* by itself at a seed rate of 269 seeds/m² can result in 4.35% cover at year five and approximately 31 plants/m² at only year three. While those numbers may sound relatively low, these results are much more promising than other projects where *X. tenax* was seeded within a larger seed mix. *X. tenax* increased from 1.37% cover in 2010 to 4.35% cover this year, its largest increase in cover to date for this project. As it is unlikely that new germinants are establishing, *X. tenax* seedlings are clearly growing in size to achieve this increase in cover, a result that was very visible during monitoring. Overall, native forb cover increased from 5.14% to 9.75%, currently having the third highest cover of native forbs of all the treatments. This increase was due primarily from increases of *X. tenax* but also from smaller increases of *Achillea millefolium*, *Antennaria rosea*, *Antennaria bowellia*, *Hieracium albiflorum*, and *Viola orbiculata*. After *X. tenax* cover, *Chamerion angustifolium*, *Anaphalis margaritacea*, *Antennaria rosea*, and *Hieracium albiflorum* are the native forbs with the most notable cover, each having approximately 1% cover. It is possible that some cover of *C. angustifolium* and *A. margaritacea* is due to seed rain from adjacent treatments.

Native grass also continues to increase from 1.17% in 2009 to 3.78% in 2010 to 6.39% in 2012. This increase was due primarily to increases of *Agrostis scabra* and *Festuca occidentalis* that have naturally regenerated within this treatment. *Carex rossii* remains the native grass with the highest cover on this treatment, naturally establishing at the onset of the project. Overall native grass remains relatively low with the third lowest cover of all the treatments.

Like other treatments, tree cover continued to increase from 2.68% to 6.43%. Increases of *Pinus contorta* and *Populus balsamifera* seedlings resulted in the higher tree cover. Shrub cover remained at a low 0.07%, similar to last year.

Unlike previous years when exotic forb cover continued to increase, cover of exotic forbs decreased slightly in cover from 13.79% in 2010 to 11.97% in 2012. Despite this small decrease in cover, exotic forbs remain the lifeform with the highest cover on this treatment for the third year in a row and have the third highest cover for this lifeform of all the treatments. This is a slightly improvement over 2010 when exotic forbs on this treatment had the second highest cover of all the treatments. Currently, most of the exotic forb cover is due to 8.3% cover of *Trifolium hybridum*, which decreased slightly from 2010 to 2012, and 3.58% cover of *Veronica officinalis*, which conversely increased slightly from 2010 to 2012. *Cirsium vulgare* and *Taraxacum officinale* remain present on this treatment with low cover.

Finally, despite an increase of exotic grasses from 2009 to 2010, exotic grass cover remained about the same in 2012 as 2010 estimates. Overall, exotic grass cover remains relatively low at 1.4%, dominated exclusively by *Agrostis stolonifera*, an aggressive rhizomatous grass. This, however, is the second highest exotic grass cover of all the treatments. Given the invasive nature of *A. stolonifera*, it could very likely increase over time.

g) *Calamagrostis rubescens* seeded alone (Treatment 3)

Overall, positive changes are finally happening on this treatment that for the first few years had less native cover than the control plots. In 2010, this treatment had the lowest native cover at 11.33%, the highest exotic cover at 17.61%, resulting in the lowest native to exotic ratio at 39.1%. From 2010 to 2012, however, this treatment had the largest decrease in exotic cover and the second highest increase in native cover. In 2012, this treatment now has a tie for the fourth highest native cover at 22.92%, the third lowest exotic cover at 10.65%, resulting in the fifth highest native to exotic ratio at 68.38%. This ratio is very close to the third and fourth highest native to exotic ratios and is a dramatic improvement over 2010 results. While exotic cover still remains relatively high, this treatment is now dominated by native vegetation, the opposite trend in 2010 when exotic plants dominated these plots. Overall vegetation remains the second lowest of all treatments, perhaps a result from the decreasing exotic cover. Currently,

on the *Rubus parviflorus* seed treatment has lower overall vegetation cover than this treatment.

As expected, native grasses are showing the most success. In fact, this is the first year that native grasses are the dominant lifeform on this treatment, surpassing exotic forbs that dominated these plots over the past two years. Native grass cover remains the second highest for three years in a row compared to the other treatments, second only to planted *C. rubescens* plugs. Native grass cover increased from 5.72% in 2010 to 11.58% in 2012 due to increases of *C. rubescens* that was seeded as well as *Danthonia spicata* and *Festuca occidentalis* that are naturally regenerating. Like total native grass cover, *C. rubescens* has the second highest cover on this treatment than all other treatments other than *C. rubescens* plugs. It is interesting to note that *C. rubescens* seeded alone continues to have higher cover at 9.25% than *C. rubescens* seeded with a forb/shrub mix that has 5.54% cover. This is the second year that cover of *C. rubescens* seeded alone is higher than *C. rubescens* seeded with a forb/shrub mix. As literature and past revegetation experiments have suggested, *C. rubescens* seed does better without competition. Comparative results may be somewhat difficult, however, as *C. rubescens* was seeded at 538 seeds/m² under this treatment and only seeded at 323 seeds/m² under treatment 4.

While native forbs doubled their cover from 2.53% in 2010 to 5.13% in 2012, native forb cover currently ranks the second lowest of all of the treatments. This is a slight improvement over 2010 when native forb cover was the lowest of all treatments. Although no forbs were seeded on this treatment, it is likely that seed rain is resulting in the establishment of certain forb species. Currently, the dominant forbs within this treatment are *Chamerion angustifolium*, *Hieracium albiflorum*, and *Anaphalis margaritacea*, two of which are seeded forb species on adjacent treatments. *Achillea millefolium*, *Solidago canadensis*, and *Symphytotrichum laeve* are also present, indicating possible seed rain from nearby plots. The increase in cover since 2010 is due mostly to increases of *H. albiflorum* and *A. margaritacea*. Smaller increases were observed for *A. millefolium* and *C. angustifolium*. Overall diversity of forb species on this treatment is actually average considering no forb species were seeded. Forb cover may show larger increases in the future due to this higher diversity.

As under most other treatments, tree cover increased due to increases of *Pinus contorta* and *Populus balsamifera*. With no shrub species seeded on this treatment, shrub cover remains negligible.

For the past two monitoring events, exotic forbs dominated this treatment, particularly after exotic forb cover significantly increased from 4.74% in 2009 to 15.99% in 2010. From 2010 to 2012, however, exotic forb cover decreased from 15.99% to 9.26%, the largest decrease in exotic forb of any treatment over the two year time period. While exotic forbs on this treatment had the highest cover of all the treatments in 2010, exotic forbs currently have the third lowest cover of all the treatments in 2012. All of this change is due almost exclusively to the changes in cover of *Trifolium hybridum*. This same clover species that significantly increased from 2009 to 2010 is the same species that dramatically decreased in cover in 2012, declining from 14.23% to 6.51%. As stated above, cover of clover species can be cyclic with levels of precipitation, although there appears to be no distinct trend concerning the increases or decreases of this species across all treatments. Small increases were noted for two additional exotic forb species, including *Veronica officinalis* and *Taraxacum officinale*. These two weed species have consistent cover in all other treatments as well. Exotic grass cover remains relatively low at 1.39% with *Agrostis stolonifera* comprising most of that cover. Similar to other treatments, this aggressive grass could increase in the future.

2. Success of individual species

Five years after seeding, cover of several individual seeded species greatly increased with several species attaining cover over 1%. Due to the fact that most germination rates either decreased or did not significantly change by three years after seeding (Table 6), the increased cover is primarily due to plants growing larger in size since 2010. Success of individual species are described by lifeform below.

a) Native Forbs

Treatments 4 and 5, where native forbs were seeded, continued to have higher covers of native forbs at 20.13% and 16.04%, respectively, than all other treatments. These increased from 17.17% and 12.5% covers last year, each treatment continuing to increase in native forb cover each year for the past five years. Covers of other treatments where either no forbs were seeded or *Xerophyllum tenax* was seeded remain between 4.38% and 5.83% cover, well below native forb covers of treatments that were seeded with forb species.

Similar to 2009 and 2010, *Achillea millefolium* remains the most successful seeded species under both treatments. *A. millefolium* increased from 3.69% to 5.56% cover on treatment 4 and increased from 11.46% to 12.58%

cover on treatment 5. These remain the highest covers of any native species other than the planted *Calamagrostis rubescens* plugs (although cover of *Pinus contorta* is also close). Currently, *Anaphalis margaritacea* with 4.71% cover and *Symphytotrichum laeve* with 4.88% cover are two other seeded forbs that have the highest cover on this treatment. Although density data was not collected in 2012, it is interesting to note again the high germination rate that *A. millefolium* had on treatment 4 at three years after seeding. *A. millefolium* was sown at only 86 seeds/m², resulting in 61.5 *A. millefolium* plants/ m² or a very high 71.5% germination rate at three years after seeding. *A. millefolium* was sown at a higher rate of 215 seeds/m² on treatment 5, and while this species currently has 104.0 plants/m² on this treatment, the overall germination rate was much lower at 48.4%. The higher seed rate did produce both higher cover and density, but in terms of germination of seed, there may be a ‘point of no return’ with *A. millefolium* that is closer to the seed rate on treatment 4.

As stated above, other successful seeded forbs on treatment 4 include *Anaphalis margaritacea* that has 4.71% cover and *Symphytotrichum laeve* that has 4.88% cover. *Solidago canadensis* also increased in cover from 1.88% to 3.44% since 2010. Coincidentally, two of these species, *A. margaritacea* and *S. canadensis*, had notable increases in their germination rates in 2010 that is likely contributing to their increase in cover. *S. laeve* had a decrease in density in 2010, indicating that some initial germinants may be dying off but that the surviving plants are clearly continuing to grow in size. *A. margaritacea* has the highest germination rate of any seeded species at 83.2% three years after seeding. *S. laeve* and *S. canadensis* had moderate germination rates at 42.7% and 31.2%, respectively, three years after seeding. Despite being seeded at the same rate as *A. margaritacea*, *S. laeve*, and *S. canadensis*, *Geum macrophyllum* and *Chamerion angustifolium*, the remaining seeded forbs on treatment 4, had the lowest overall germination rates at three years after seeding. Correspondingly, their covers remain a low 0.53% and 0.36%, respectively. The overall lower density is likely preventing these species from greater increases in cover, although some plants are noticeably larger in size. Covers of *A. margaritacea*, *S. laeve*, *S. canadensis*, and *G. macrophyllum* are significantly higher or generally higher on treatment 4 than any other treatment, indicating that seeding these species is the most efficient way to get these plants established. Conversely, cover of *C. angustifolium* remains the lowest under treatment 4, the only treatment where it was seeded, indicating it does not need to be seeded if this species is in the seed bank. Similar to last year, the highest cover of *C. angustifolium* remains under treatments 7 (control) and 3 (*C. rubescens* seed) where it was not seeded.

In general, species continue to naturally recruit to all of the plots within each treatment. Most of this recruitment is due to the existing seed bank and seeding into the plots from the adjacent forest. There may be, however, some plants that became established due to blowing seed from seeded treatments. This may be particularly true of *Geum macrophyllum*, *Solidago canadensis*, and *Symphytotrichum laeve* which do not naturally occur in the adjacent forest type. Native forbs that have already naturally recruited to this project in the past include *Chamerion angustifolium*, *Hieracium albiflorum*, *Epilobium brachycarpum*, *Viola orbiculata*, *Antennaria howellia*, *Antennaria rosea*, *Campanula rotundifolia*, *Conyza canadensis*, *Maianthemum stellatum*, *Penstemon confertus*, and *Osmorhiza berteroi*. New naturally recruiting species observed this year include *Fragaria vesca*, *Melampyrum lineare*, and *Galium triflorum*. *Epilobium brachycarpum*, *Hieracium albiflorum*, *Conyza canadensis*, *Antennaria howellia*, *Antennaria rosea*, and *Viola orbiculata* continue to increase in cover in the treatments where they are present.

Lastly, treatment 1 where *Xerophyllum tenax* was seeded had significantly higher cover of *X. tenax* than any other treatment. There has been difficulty getting *X. tenax* established from seed in previous projects, particularly those projects with a diverse seed mix of grasses. This treatment may show us that it indeed is possible to get *X. tenax* established from seed with less competition. The germination rate for *X. tenax* remained low at approximately 11.4% three years after seeding, illustrating that, while possible, it is difficult to get this species to grow from seed. Despite the low germination rate, cover of this species continues to increase, however, documenting that those germinated plants are growing. Observations in the field noted much larger beargrass plants.

b) Native Grasses

Similar to last three year, the strategy to achieve the highest native grass cover at year five remains to plant *Calamagrostis rubescens* plugs. This treatment resulted in 23.8% native grass cover in 2012, higher than all other treatments and much higher than seeding *C. rubescens* alone, the treatment with second highest native grass cover at 11.6%. Cover of *C. rubescens* plugs increased from 2.31% in 2007 to 7.21% in 2008 to 9.54% in 2009 to 13.79% in 2010 to 22.46% in 2012. Native grass cover increased across all treatments, however, with increases ranging from 1.5% to 7% cover.

The long term question of these treatments is whether grass seed cover will eventually ‘catch up’ to planted

grass cover. *Calamagrostis rubescens* that was seeded alone had the highest grass seed rate at 538 seeds/m², resulting in 9.25% cover this year and increasing from 4.19% cover last year. This cover is higher than *C. rubescens* cover when it is seeded at a lower seed rate with a forb/shrub mix. *C. rubescens* sown at 323 seeds/m² along with a forb/shrub mix resulted in 5.54% cover, increasing from 1.75% cover last year. At the same time, however, *C. rubescens* at this lower seed rate currently has a higher germination rate at 23.3% three years after seeding, in comparison to *C. rubescens* seeded alone with a higher seed rate that had a 14.6% germination rate. By this third year after seeding, the densities of *C. rubescens* are virtually the same under both treatments regardless of seed rate. *C. rubescens* had a density of 78.3 plants/m² on treatment 3 with a higher seed rate and 75.2 plants/m² on treatment 4 with a lower seed rate. Like *Achillea millefolium* described above, there appears to be a 'point of no return' with seed for this species as the higher seed rate is not returning the highest germination rate or densities. As for answering the question about whether grass seed will eventually 'catch up' with grass planting, the answer could have been answered in a few years if the study could have continued. Considering, on average, there are only 33 plants per macroplot (almost 4m²) when *C. rubescens* is planted in comparison to 75 to 78 plants/m² when *C. rubescens* is seeded, it is anticipated that the seeding will eventually equal the cover of planted material if it survives. As *C. rubescens* is a rhizomatous grass, it will be interesting to note when planted material begins to send out rhizomes within the planted area, adding to the complexity of which method leads to the success of restoring this species.

The other seeded grass within this project is *Carex athrostachya*. Due to the lack of seed heads on many *Carex* plants at the time of monitoring, it is currently difficult to assess exactly how much *C. athrostachya* is actually present. Besides some *Carex rossii* and *Carex concinnoides* that were evident, most sedges were necessarily lumped as *Carex* spp. While sedge cover has not been significantly different by treatment in the past, cover of *Carex* spp. in 2012 is clearly higher on treatment 5 where it was seeded, in all cases two to ten times higher. More specifically, cover of *Carex* spp. on treatment 5 continues to double at each monitoring event while cover of *Carex* spp. on other treatments decreases or remains relatively the same over time. Density of *Carex* sp. on treatment 5 continued to increase through three years after seeding, perhaps indicating that seeding this sedge species takes several years to germinate and start increasing in cover. Despite the increase in density, the overall germination rate of *C. athrostachya* was 3.3% three years after seeding, the lowest of all seeded species in the project, indicating its difficulty to establish from seed. The established germinants are continuing to increase in cover each year, although increases in cover tend to be less or slower than other seeded native grasses. For now, naturally regenerating *C. rossii* has over 2% cover on several treatments, equaling or surpassing the cover of seeded *C. athrostachya* on treatment 5. It may be that restoration in forest types with *C. rossii* does not require the seeding of additional sedge species since this species is recovering so well. Finally, it is clear that seeding *Calamagrostis rubescens* results in higher germination, density and cover in comparison to seeding *Carex athrostachya*. Seeding *C. rubescens* at a rate of 323 seeds/m² resulted in a 23.3% germination rate and 75.2 plants/m² three years after seeding and 9.25% cover five years after seeding. By comparison, seeding *C. athrostachya* at a rate of 323 seeds/m² resulted in a 3.3% germination rate and 10.5 plants/m² three years after seeding and 2.03% cover five years after seeding.

Finally, natural regeneration of native grasses continued in all treatments throughout the project. The two naturally occurring native grasses that have shown the biggest success are clearly *Festuca occidentalis* and *Carex rossii*. Each of these species is present on all treatments with cover generally ranging from 0.2% to over 3%. As stated in past reports, both of these species are doing especially well in the control treatment where their cover was noticeably higher. This may be due to the lack of competition here from other seeded or planted species. Other species that are consistently present in all treatments with low cover include *Agrostis scabra* and *Danthonia spicata*. *Carex concinnoides*, *Deschampsia cespitosa*, *Elymus glaucus*, *Poa palustris*, and *Trisetum canescens* are also present with low cover in a few treatments. *C. rubescens* remains present in all treatments regardless of whether it was seeded or planted. There is a chance that some seed from adjacent treatments has become established in neighboring treatments, however, *C. rubescens* naturally occurs adjacent to the treatment plots and is likely naturally regenerating throughout the project. Currently, cover of *C. rubescens* is significantly lower in areas where it was not seeded or planted, indicating that seeding or planting is the more efficient way to reestablish this grass.

c) Trees and Shrubs

As in 2008, 2009, and 2010, shrubs remain negligible on the project unless seeded. Covers of total native shrub, *Rubus parviflorus* and *Spiraea betulifolia* remain highest in the treatments in which they are seeded. In treatment 2 where it was seeded, *R. parviflorus* remains significantly higher than all other treatments. At year five after seeding,

cover of *R. parviflorus* is about the same as cover of *S. betulifolia* on treatment 5, each with approximately 3.5% cover. Cover of *S. betulifolia* is much lower on treatment 4 where it was also seeded. A few other shrub species are naturally regenerating but remain with low cover.

As discussed in the 2010 report, seed rates differed for *Spiraea betulifolia* on treatments 4 and 5 where it was seeded. *S. betulifolia* was seeded at 86 seeds/m² on treatment 4, resulting in a 26.0% germination rate at year three, while *S. betulifolia* was seeded at 215 seeds/m² on treatment 5 with a 19.7% germination rate at year three. Similar to *Achillea millefolium* and *Calamagrostis rubescens* described above, there appears to be a 'point of no return' with seed for this species as the higher seed rate is not returning the highest germination rate. That said, cover of *S. betulifolia* is now significantly higher on treatment 5 than treatment 4. Similar to *A. millefolium* seed, the higher seed rate of *S. betulifolia* is still resulting in higher cover and density of this shrub species. It may be that *S. betulifolia* has more competition with more seeded forb species and higher *C. rubescens* cover on treatment 4, but generally it is unclear why *S. betulifolia* is so much higher on treatment 5 than treatment 4. Observations in the field were noted that *S. betulifolia* germinants on treatment 5 were much larger than treatment 4, adding to the higher cover.

In contrast, tree species have demonstrated high recruitment rates in the project. No trees were planted in the project but total native tree cover continues to increase under all treatments this year. This is due to increases of *Pinus contorta* and *Populus balsamifera* seedlings under all treatment. Currently, *Pinus contorta* accounts for most of the tree cover, virtually doubling in cover in almost all treatments since 2010. While tree covers between treatments are generally not significantly different from each other, it is interesting that the highest native tree cover remains on the control plots.

Interestingly, cover of *R. parviflorus* on treatment 2 continues to increase each year while the density of this shrub decreased through year three after seeding. The overall germination rate of this shrub was a low 5.8% three years after seeding. It appears that *R. parviflorus* may be difficult to grow from seed in the field given its low germination rate and die-off of year-one and year-two germinants may occur given the decline in density at year three. However, those germinants that do survive seem to grow dramatically, providing significant cover.

d) Exotic Species

Unfortunately, much of the natural regeneration in the project continues to come from exotic species. However, unlike the first three years of the project where exotic forb cover continued to significantly increase under all treatments each year, exotic forb cover decreased in cover on 4 of 7 treatments and remained the same on 1 of the 7 treatments in 2012. Cover of exotic forbs now ranges from 3.9% to 13.8%, lower than the range of cover in 2010 that was estimated at 8.55% to 15.99%. Where exotic forbs had the highest lifeform cover on 4 treatments in 2010, exotic forbs now only have the highest lifeform cover on treatments 1, 2, and 7, the treatments that were not seeded or planted with grass. Exotic forbs had the second highest lifeform cover on treatments 3, 5, and 6. While exotic forb cover had the lowest on treatment 6 for the first three years of the project where *C. rubescens* plugs were planted, the lowest exotic forb cover is currently on treatment 4 where *C. rubescens* and a forb/shrub mix was seeded.

Veronica officinalis and *Trifolium hybridum* consistently have the highest cover of any exotic forb species, similar to 2009 and 2010. While *Trifolium hybridum* significantly increased under all treatments in 2010, *T. hybridum* decreased on 4 treatments this year by 4% to 8% cover. Where it increased on the remaining three treatments, it only increased by 1% to 2%. Although it was predicted in the 2010 report that cover of *Veronica officinalis* would likely continue to increase, this result has not been consistently true. In 2012, cover of *V. officinalis* only increased on 3 of the 7 treatments by 0.5% to 2.5%. It actually decreased in cover on three other treatments by 1% to 5% and remained the same cover on the last treatment. While *V. officinalis* spreads in mats, is often tolerant of shade, and can be difficult to control, it may not increase as consistently as we thought. Similarly, *Trifolium hybridum* is also ephemeral and may potentially be less of a problem than other weeds. Other weed species that have become established and are maintaining their low cover include *Medicago lupulina*, *Taraxacum officinale*, and *Cirsium vulgare*. Most of these other weeds are not overly aggressive and do not displace native vegetation. *Lactuca serriola* and *Filago arvensis* are disappearing from the project area.

Overall exotic grass cover has remained much lower, ranging from 0.6% to 1.4%, however, exotic grasses are increasing slightly in cover each year under most treatments. Similar to 2010, *Agrostis stolonifera* is the most consistent exotic grass on the project, present under all treatments. Although it generally increased on 5 of the 7 treatments, none of these increases were very large. *Agrostis stolonifera* is of concern due to its rhizomatous nature and inability to be controlled with herbicide. All other exotic grasses remain with very low cover.

D. Conclusions

At year five after planting, some of the treatments, in terms of overall native cover, are beginning to be similar to each other. Even the treatments that have had lower overall cover are increasing in native cover and showing positive results with specific planting schemes. In 2008, one year after seeding, *Calamagrostis rubescens* plugs clearly showed the biggest success at one year after planting with the highest overall cover, highest native cover, and lowest exotic cover. Similar to 2009 and 2010, however, the treatments are becoming more complicated in 2012. One on hand, *C. rubescens* plugs are still providing by far the highest native grass cover, the second highest overall native cover, and the second highest native to exotic ratio in comparison to all other treatments. At the same time, however, this treatment has low overall native diversity. Seeding *C. rubescens* with a forb and shrub mix is currently the treatment with the highest native to exotic ratio, the third highest native cover, and the lowest exotic cover. Native forbs clearly dominate this treatment but its native grass cover is relatively low despite seeding this treatment with native grass. Besides *Geum macrophyllum*, seeded only on treatment 4 and currently with 0% cover, all seeded and planted species on all treatments are showing positive trends by increasing in cover. Like in other restoration projects, exotic species continue to be an issue. While exotic forb cover actually declined on four treatments from 2010 to 2012, exotic forbs remain the dominant lifeform on three treatments and have the second highest lifeform cover on three other treatments. Exotic grass cover remains fairly low on all treatments, although it is increasing slightly on most treatments over time.

Most previous revegetation projects involving seeding *Calamagrostis rubescens* and *Xerophyllum tenax* have not proven to be very successful. It was speculated that competition from other seeded species inhibited their success in those projects. In a 1987 study at the Coram Experimental Forest, *C. rubescens* seeded alone at 646 seeds/m² resulted in 49% canopy cover three years later, while *C. rubescens* seeded with native mix (including aggressive mountain brome) resulted in 5% canopy cover. While seeded *C. rubescens* did not attain 49% cover at the three year mark of this project as it did in the Coram study, results are showing positive trends concerning seeded *C. rubescens* alone or with a forb/shrub mix. Cover of *C. rubescens* is certainly higher on this project than cover results of *C. rubescens* on earlier roadside projects that were mixed with aggressive nurse grasses. *C. rubescens* cover only reached 0.3% ten years after planting under that scenario, where cover has reached 5.54% and 9.25% five years after planting under two different treatments of this project.

The same study at the Coram Experimental Forest determined that *Xerophyllum tenax* dislikes competition. When beargrass was seeded alone, 29% of seeds established the first year and 49% established the second year. When beargrass was seeded with a native mix, 22% of seeds established the first year with no further increase. This could explain the low germination of *X. tenax* in Apgar Transit Center plots at year one and the continuing decline in density in years two and three. It does appear, however, that the surviving seedlings are thriving and growing within this project as they increased by 3% cover over the past two years to 4.35% at five years after seeding. For comparison, *X. tenax* cover only reached an average of 1% ten years after seeding on a nearby road revegetation project.

Specific conclusions and recommendations are listed below:

- At year five after planting, planting *Calamagrostis rubescens* plugs remains the quickest way to achieve a high cover of native grass which is two to four times as high as on other treatments. While exotic forb species are becoming established within this treatment despite the high grass cover, this treatment has the second highest native to exotic ratio at 73.3%. It also had the second highest overall vegetative cover. At the same time, this treatment has a relatively low overall diversity in terms of numbers of native plant species. While it may be preventing weed establishment to a certain extent, it may also be preventing natural regeneration of native species as well. If forb cover were an important part of the restoration project, it would be interesting in the future to add a forb seed mix after plugs were planted.
- Another treatment with excellent results is seeding *Calamagrostis rubescens* with a forb and *Spiraea betulifolia* mix. Overall, it appears that *C. rubescens* can have moderate to moderately high germination when seeded with other species as long as they are not fast-growing, aggressive colonizers. Cover of *C. rubescens* is lower when seeded with a forb/shrub mix as it is when seeded alone. But the forb/shrub mix results in significantly higher native forb cover and overall native diversity than no forb seed at all.
- If forb cover is not as important, seeding *Calamagrostis rubescens* alone remains a good option to achieve high native

grass cover. Cover of *C. rubescens* was higher than cover of *C. rubescens* when seeded with a forb/shrub mix. Considering, on average, there are only 33 plants per macroplot (almost 4m²) when *C. rubescens* is planted in comparison to 75 to 78 plants/m² when *C. rubescens* is seeded, it is anticipated that the seeding will eventually equal the cover of planted material if it survives.

- Shrubs of this forest type do not appear to naturally regenerate, and if they do, they recolonize slowly. Seeding is necessary to recolonize *Rubus parviflorus* and *Spiraea betulifolia*. Currently, seeding *R. parviflorus* and *S. betulifolia* result in the same overall cover after five years despite a higher germination rate of *S. betulifolia*. It may be that *R. parviflorus* plants are able to grow faster.
- Conversely, trees appear able to recolonize on their own. *Pinus contorta* and *Populus balsamifera* have each colonized in each treatment and currently provide the most consistent tree cover throughout the project.
- Until all *Carex* germinants can be identified to species, it is difficult to tell the effectiveness of seeding *Carex athrostachya*. Currently, it appears to only be having moderate success. *Carex rossii*, on the other hand, has been effective at recolonizing into six of the seven treatments. As this sedge is a natural part of the surrounding forest, it is showing better signs of being a productive native sedge species to use in this type of west-side forest.
- Seeding a mix of forbs is the most efficient way to get the highest cover of forbs. *Achillea millefolium*, *Anaphalis margaritacea*, *Solidago canadensis*, and *Symphytotrichum laeve* appear to be the most successful species on this project, having the highest germination rates and the highest covers. If *Chamerion angustifolium* is nearby, there appears no need to seed it. It naturally recolonized all treatments and remains with the lowest cover on the treatment where it was seeded.
- There may be a ‘point of no return’ in terms of seeding for several species. *Achillea millefolium*, *Calamagrostis rubescens*, and *Spiraea betulifolia* had lower germination rates (and sometimes lower densities in the case of *C. rubescens*) when seeded at a higher seed rate.
- As several replicates will be removed with the expansion the ATC parking area in 2013, it is anticipated that these experimental plots will not be monitored again.

Table 3. Apgar Transit Center Experimental Plots: Average canopy cover for each treatment by species, 2008-2012. * = Seeded species. Orange cells indicate that cover within treatments are significantly different (90% CI) between 2008/2009, 2009/2010, or 2008/2010.

TREATMENT#	1				2				3				4				5				6					7			
TREATMENT TYPE	XERTEN				RUBPAR				CALRUB				CALRUB seed				CARATH seed				CALRUB					control			
	seed				seed				seed				with forb + SPIBET				with forb + SPIBET				plugs								
	2008	2009	2010	2012	2008	2009	2010	2012	2008	2009	2010	2012	2008	2009	2010	2012	2008	2009	2010	2012	2007	2008	2009	2010	2012	2008	2009	2010	2012
Basal vegetation	0.10	0.50	1.14	1.45	0.10	0.45	1.40	1.13	0.10	0.91	1.34	1.08	0.22	0.97	1.63	1.29	0.10	0.88	1.52	1.51		0.63	1.15	2.80	2.26	0.10	0.47	1.66	1.33
Litter/Duff	47.75	64.25	72.42	63.68	44.54	61.04	64.79	72.58	53.29	70.50	72.04	72.61	52.33	65.50	77.04	77.40	58.96	70.25	73.13	77.95		31.71	55.67	64.54	73.99	62.88	79.33	78.58	75.93
Moss	0.12	5.08	8.56	23.83	0.18	5.77	10.08	15.88	0.13	2.48	9.54	16.96	0.96	4.01	5.04	12.13	0.07	2.31	13.61	14.17		0.02	1.98	6.88	14.04	0.56	4.58	10.48	18.30
Bare Soil	24.58	9.54	3.04	0.18	22.71	10.58	4.67	0.04	21.58	9.33	2.90	0.21	20.25	7.29	1.66	0.05	17.08	9.38	2.19	0.13		26.88	14.75	2.75	0.08	17.50	6.29	1.31	0.01
Gravel	25.42	18.63	13.92	4.92	32.29	22.29	18.71	6.33	23.96	16.63	13.79	4.89	24.71	21.67	13.42	3.92	23.38	16.63	9.63	2.67		38.29	25.26	20.25	5.54	18.63	9.21	7.92	1.97
Rock	1.00	0.25	0.00	4.33	0.29	0.00	0.21	2.75	1.08	0.25	0.46	3.80	1.04	0.50	0.63	4.75	0.54	0.38	0.00	3.21		2.67	1.25	2.83	4.04	0.46	0.13	0.00	1.13
Wood	1.17	1.88	0.83	1.58	0.00	0.42	0.08	1.29	0.00	0.00	0.00	0.38	0.63	0.13	0.63	0.46	0.00	0.25	0.00	0.38		0.00	0.00	0.00	0.00	0.00	0.13	0.00	1.17
Other	0.00	0.00	0.17	0.04	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.04	0.00	0.00	0.17	0.18
TOTAL NATIVE TREE	0.18	0.47	2.68	6.43	0.20	0.87	2.16	6.21	0.33	1.04	2.55	6.05	0.22	0.96	1.88	4.17	0.31	1.16	2.40	5.75		0.35	0.91	3.82	5.00	0.38	2.04	3.90	7.54
Abies lasiocarpa							0.01																						
Betula papyrifera								0.30				0.13												0.05	0.09			0.09	0.13
Generic conifer seedlings	0.05	0.23	0.21	0.08	0.03	0.26	0.13	0.13	0.16	0.26	0.21	0.05	0.05	0.17	0.13		0.06	0.25	0.23			0.05	0.29	0.14	0.07	0.07	0.28	0.17	
Larix occidentalis										0.08													0.13				0.04		
Picea engelmannii			0.01																					0.01					
Pinus contorta		0.19	2.01	4.09		0.10	1.36	3.67		0.22	1.87	5.18		0.11	1.31	3.01		0.40	1.53	3.83			0.10	2.28	2.51		0.59	2.22	5.21
Pinus monticola			0.04					0.05																					
Populus balsamifera	0.13	0.05	0.58	2.29	0.18	0.51	0.83	1.93	0.17	0.48	0.61	1.28	0.18	0.68	0.71	1.20	0.26	0.51	0.78	1.81		0.30	0.39	1.44	2.43	0.31	1.13	1.53	2.23
Populus tremuloides				0.08				0.04				0.08																	
Pseudotsuga menziesii								0.17				0.01								0.05									
TOTAL NATIVE SHRUB	0.01	0.01	0.03	0.07	0.21	1.45	2.96	4.15	0.004	0.01	0.07	0.15	0.05	0.41	0.31	0.93	0.19	0.67	1.86	3.76		0.00	0.00	0.04	0.13	0.00	0.08	0.32	0.14
Acer glabrum																0.04													
Amelanchier alnifolia				0.01																					0.04				
Linnaea borealis								0.02				0.01								0.06					0.01				0.03
Rubus idaeus																				0.04				0.04					
Rubus parviflorus*	0.01		0.01	0.06	0.21	1.45	2.79	3.81						0.01				0.01											
Shepherdia canadensis		0.01					0.04																						
Spiraea betulifolia*			0.01			0.01	0.11	0.10		0.01	0.05	0.07	0.05	0.40	0.31	0.81	0.19	0.65	1.79	3.51						0.08	0.18	0.13	
Symphoricarpos albus					0.004				0.004				0.004					0.01											
Vaccinium caespitosum							0.04																						
Vaccinium membranaceum							0.13					0.04				0.04				0.21					0.08				
Vaccinium myrtilloides												0.04				0.04			0.05										
Unknown shrub			0.01								0.02				0.01									0.01			0.02		
TOTAL NATIVE GRASS	0.11	1.17	3.78	6.39	0.05	0.78	3.60	5.14	1.08	3.07	5.72	11.58	1.01	2.48	2.44	6.21	0.28	0.94	3.13	8.22	2.31	7.29	10.43	16.29	23.83	0.18	1.93	4.48	8.79
Agrostis scabra			0.05	0.72			0.06	0.70		0.01	0.14	0.05		0.09	0.21	0.03		0.27	0.93	0.16				0.06			0.21	0.23	0.81
Carex athrostachya*																													
Carex concinnoides			0.09	0.08			0.13					0.05			0.08				0.09	0.08				0.17				0.13	0.09
Carex russiai		0.17	2.17	2.17		0.13	1.08	2.00				0.50	0.46		0.09	0.04		0.04	0.34	0.42			0.13	1.92	1.04		0.08	1.47	2.83
Carex sp.	0.11	0.73	0.70	0.71	0.05	0.49	0.57	0.12	0.08	0.29	0.50	0.18	0.05	0.50	0.31	0.27	0.27	0.52	1.00	2.03		0.12	0.76	0.14	0.48	0.13	0.74	0.68	0.73
Calamagrostis rubescens*		0.07	0.24	0.38	0.004	0.10	0.63	0.52	1.08	2.70	4.19	9.25	1.01	1.63	1.75	5.54	0.02	0.03	0.08	1.50	2.31	7.21	9.54	13.79	22.46		0.02	0.01	0.13
Danthonia spicata		0.10	0.35	0.52		0.04	0.38	0.82		0.03	0.29	0.62		0.08	0.13	0.05	0.004	0.08	0.26	0.78				0.08	0.05	0.004	0.29	0.23	0.56
Deschampsia elongata			0.04	0.13								0.04																0.05	0.33
Elymus glaucus				0.01			0.22					0.13	0.38									0.004		0.06					
Festuca occidentalis		0.10	0.23	1.74		0.03	0.34	1.09	0.004	0.04	0.01	0.68		0.08	0.01	0.34			0.20	2.89		0.004	0.01	0.13	0.27	0.04	0.58	1.81	3.34
Poa palustris			0.05									0.04			0.01				0.31	0.38									
Trisetum canescens			0.01																0.01	0.09									
TOTAL NATIVE FORB	0.25	1.75	5.14	9.75	0.20	1.43	3.61	5.31	0.13	1.17	2.53	5.13	1.20	10.31	17.17	20.13	1.61	7.50	12.50	16.04		0.07	0.98	3.11	4.38	0.36	2.57	3.96	6.42
Achillea millefolium*		0.04	0.04	0.21	0.05	0.04	0.03	0.38	0.004		0.03	0.28	0.95	3.56	3.69	5.56	1.53	6.13	11.46	12.58			0.04	0.06	0.18			0.12	0.73
Adenocaulon bicolor		0.05																											
Anaphalis margaritacea*	0.03	0.15	1.25	1.23	0.01	0.15	1.00	1.14	0.02	0.08	0.37	0.95	0.16	2.54	5.95	4.71	0.01	0.11	0.63	0.63			0.05	0.33	1.02	0.01	0.36	0.88	1.06
Antennaria howellii		0.08	0.13	0.21		0.04	0.08	0.01				0.01				0.01				0.13				0.01	0.01				

Table 3 con'd. Apgar Transit Center Experimental Plots: Average canopy cover for each treatment by species, 2008-2012. **Orange** cells indicate that cover within treatments are significantly different (90% CI) between 2008/2009, 2009/2010, or 2008/2010.

TREATMENT#	1				2				3				4				5				6					7				
TREATMENT TYPE	XERTEN				RUBPAR				CALRUB				CALRUB seed with forb + SPIBET				CARATH seed with forb + SPIBET				CALRUB plugs					control				
	2008	2009	2010	2012	2008	2009	2010	2012	2008	2009	2010	2012	2008	2009	2010	2012	2008	2009	2010	2012	2007	2008	2009	2010	2012	2008	2009	2010	2012	
Antennaria rosea			0.01	0.79				0.08				0.01				0.04			0.13	0.38					0.22				0.04	0.02
Caryophyllaceae sp.								0.01																						
Campanula rotundifolia				0.01				0.02				0.17			0.04											0.004	0.05	0.13	0.08	
Chamerion angustifolium*	0.08	0.65	1.20	1.27	0.12	1.09	1.85	1.35	0.12	0.83	1.55	1.73	0.09	0.31	0.49	0.36	0.15	1.08	1.46	1.18		0.06	0.62	1.28	1.28	0.31	1.79	1.60	2.93	
Chimaphila umbellata																												0.14		
Coryza canadensis			0.08	0.21		0.01		0.38		0.04	0.02	0.08			0.01	0.03		0.01		0.13				0.02			0.01	0.02	0.04	
Epilobium brachycarpum		0.01	0.21	0.08	0.04	0.04	0.29	0.13	0.01	0.04	0.07	0.03	0.01	0.06	0.10	0.02	0.004	0.04	0.08	0.03		0.01	0.09	0.52	0.02	0.004	0.17	0.28	0.03	
Epilobium brachycarpum (wide lvs.)				0.23				0.50				0.28				0.03				0.12				0.18					0.20	
Fragaria vesca																													0.04	
Galium triflorum				0.04																										
Gnaphalium macounii			0.33				0.01			0.08	0.04			0.04		1.04											0.04	0.13		
Geum macrophyllum*													0.07	0.68	0.88			0.01										0.04		
Hieracium albiflorum		0.06	0.62	1.07		0.05	0.41	1.28		0.02	0.45	1.53	0.004	0.09	0.18	0.53		0.04	0.25	0.92		0.004	0.13	0.75	1.50	0.01	0.10	0.96	1.03	
Maianthemum stellatum				0.04			0.01												0.01	0.01										
Melampyrum lineare												0.04														0.04	0.04		0.01	
Osmorhiza berteroi										0.01	0.08							0.04												
Penstemon confertus						0.04				0.04		0.04				0.04				0.04										
Solidago canadensis*		0.04						0.21	0.004			0.13	0.06	0.88	1.88	3.44		0.04		0.05									0.08	
Symphyotrichum laeve*		0.01	0.04	0.01		0.09	0.01				0.13	0.17	0.13	2.12	4.22	4.88				0.01	0.04		0.01	0.29	0.05					
Viola adunca																0.01													0.01	
Viola orbiculata	0.02	0.05	0.08	0.21		0.02	0.03	0.01			0.02	0.04	0.004	0.04		0.01	0.01	0.01	0.05	0.04			0.04	0.01	0.01				0.17	
Xerophyllum tenax *	0.21	0.61	1.37	4.35						0.01												0.004						0.01		
TOTAL EXOTIC GRASS	0.21	0.21	1.66	1.40	0.05	0.21	0.30	2.00	0.18	0.26	1.48	1.39	0.004	0.30	0.18	0.64	0.28	0.39	1.00		0.04	0.04	0.13	0.72	0.01	0.04	0.47	1.31		
Agrostis stolonifera	0.21	0.21	1.66	1.40		0.13	0.26	1.96	0.17	0.25	1.48	1.31	0.004	0.22	0.13	0.64		0.05	0.30	1.00		0.04	0.04	0.13	0.72	0.004	0.04	0.42	1.31	
Elymus repens						0.08																								
Phleum pratense					0.004		0.04	0.04																						
Poa compressa									0.004		0.02	0.08						0.04												
Poa pratensis														0.08	0.05			0.19												
Triticum aestivum	0.004				0.05				0.01	0.01																0.004				
TOTAL EXOTIC FORB	0.38	4.03	13.79	11.97	0.11	3.12	9.58	7.07	0.16	4.74	15.99	9.26	0.19	3.85	9.65	3.90	0.33	4.25	11.98	13.80		0.06	2.35	8.55	11.42	0.20	1.48	12.64	12.63	
Cerastium fontanum							0.04																							
Cirsium vulgare		0.03	0.05	0.25				0.04		0.01	0.02	0.04			0.01	0.04							0.01	0.04	0.13					
Filago arvensis		0.05	0.13			0.03	0.06	0.01	0.004	0.01	0.04			0.004	0.01		0.004	0.02	0.03				0.05	0.02			0.08	0.13		
Hieracium sp.												0.13													0.04					
Lactuca serriola		0.01	0.02				0.08				0.01				0.01		0.04							0.02						
Medicago lupulina		0.13			0.004	0.21	0.83	1.33	0.004			0.04		0.13		0.13	0.004	0.08	0.42	1.63			0.04	0.71	1.88	0.01	0.15	0.21	1.04	
Taraxacum officinale		0.02	0.11	0.32		0.03	0.22	0.13		0.01	0.08	0.28			0.05	0.08	0.01	0.09	0.23	0.39			0.03	0.18	0.15	0.13	0.05	0.08	0.10	
Tragopogon dubius								0.04																	0.08				0.05	
Trifolium agrarium				0.01				0.01		0.04		0.13		0.01		0.22	0.004		0.01	0.08	0.004	0.04			0.05				0.26	
Trifolium hybridum	0.37	3.44	12.06	8.27	0.06	1.43	3.39	4.73	0.14	4.46	14.23	6.51	0.10	2.74	7.39	2.26	0.06	2.97	7.81	9.86		0.05	1.96	7.00	8.16	0.05	1.15	11.52	7.83	
Trifolium pratense																0.21							0.08	0.01	0.13					
Veronica officinalis	0.03	0.38	1.51	3.58	0.06	1.44	5.06	0.98	0.02	0.20	1.72	2.17	0.10	0.96	2.23	1.01	0.22	1.08	3.59	1.88		0.01	0.13	0.97	1.04	0.01	0.06	0.80	3.38	
UNK. ORIGIN GRASS	0.01	0.01							0.004				0.00				0.01					0.01								
unknown grass	0.01	0.01							0.004								0.01					0.01								
UNK. ORIGIN FORB	0.01	0.02	0.01		0.01	0.01			0.03	0.02	0.01		0.03				0.05	0.01				0.02		0.02		0.004	0.01			
unknown forb	0.01	0.02	0.01		0.01				0.03	0.02	0.01		0.02				0.05	0.01				0.02		0.02		0.004	0.01			
TOTAL NATIVE CVR	0.63	3.40	12.11	22.63	0.69	4.54	12.55	20.81	1.65	5.29	11.33	22.92	2.84	14.16	22.40	31.43	2.50	10.28	21.36	33.77		7.77	12.32	23.48	33.35	0.93	6.63	13.06	22.90	
TOTAL VEG COVER	1.25	7.67	27.66	36.00	0.87	7.88	22.49	29.88	2.03	10.30	28.94	33.57	3.07	18.31	32.28	35.98	2.90	14.80	33.75	48.57		7.90	14.71	32.58	45.48	1.15	8.16	26.22	36.84	
% NATIVE COVER	50.0%	44.3%	43.8%	62.9%	79.2%	57.6%	55.8%	69.7%	81.1%	51.4%	39.1%	68.3%	92.4%	77.3%	69.4%	87.4%	86.4%	69.5%	63.3%	69.5%		98.4%	83.8%	72.1%	73.3%	81.1%	81.3%	49.8%	62.1%	

Table 4. Apgar Transit Center Experimental Plots: Comparison of canopy cover between treatments. * = Seeded species.

TREATMENT#	1				2				3				4				5				6				7			
TREATMENT TYPE	XERTEN seed				RUBPAR seed				CALRUB seed				CALRUB seed with forb + SPIBET				CARATH seed with forb + SPIBET				CALRUB plugs				control			
	2008	2009	2010	2012	2008	2009	2010	2012	2008	2009	2010	2012	2008	2009	2010	2012	2008	2009	2010	2012	2008	2009	2010	2012	2008	2009	2010	2012
TOTAL NATIVE TREE	0.18	0.47	2.68	6.43	0.20	0.87	2.16	6.21	0.33	1.04	2.55	6.05	0.22	0.96	1.88	4.17	0.31	1.16	2.40	5.75	0.35	0.91	3.82	5.00	0.38	2.04	3.90	7.54
<i>Pinus contorta</i>		0.19	2.01	4.09		0.10	1.36	3.67		0.22	1.87	5.18		0.11	1.31	3.01		0.40	1.53	3.83		0.10	2.28	2.51		0.59	2.22	5.21
<i>Populus balsamifera</i>	0.13	0.05	0.58	2.29	0.18	0.51	0.83	1.93	0.17	0.48	0.61	1.28	0.18	0.68	0.71	1.20	0.26	0.51	0.78	1.81	0.30	0.39	1.44	2.43	0.31	1.13	1.53	2.23
TOTAL NATIVE SHRUB	0.01	0.01	0.03	0.07	0.21	1.45	2.96		0.004	0.01	0.07	0.15	0.05	0.41	0.31	0.93	0.19	0.67	1.86	3.76	0.00	0.00	0.04	0.13	0.00	0.08	0.32	0.14
<i>Rubus parviflorus</i> *	0.01		0.01	0.06	0.21	1.45	2.79							0.01				0.01										
<i>Spiraea betulifolia</i> *			0.01			0.01	0.11			0.01	0.05	0.07	0.05	0.40	0.31	0.81	0.19	0.65	1.79	3.51						0.08	0.18	0.13
TOTAL NATIVE GRASS	0.11	1.17	3.78	6.39	0.05	0.78	3.60	5.14	1.08	3.07	5.72	11.58	1.01	2.48	2.44	6.21	0.28	0.94	3.13	8.22	7.29	10.43	16.29	23.83	0.18	1.93	4.48	8.79
<i>Agrostis scabra</i>			0.05	0.72			0.06	0.70		0.01	0.14	0.05		0.09	0.21	0.03		0.27	0.93	0.16			0.06			0.21	0.23	0.81
<i>Calamagrostis rubescens</i> *		0.07	0.24	0.38	0.004	0.10	0.63	0.52	1.08	2.70	4.19	9.25	1.01	1.63	1.75	5.54	0.03	0.03	0.08	1.50	7.21	9.54	13.79	22.46		0.02	0.01	0.13
<i>Carex rossii</i>		0.17	2.17	2.17		0.13	1.08	2.00			0.50	0.18		0.09		0.04		0.04	0.34	0.42		0.13	1.92	1.04		0.08	1.47	2.83
<i>Festuca occidentalis</i>		0.10	0.23	1.74		0.03	0.34	1.09		0.04	0.01	0.68		0.08	0.01	0.34			0.20	2.89		0.01	0.13	0.27	0.04	0.58	1.81	3.34
TOTAL NATIVE FORB	0.25	1.75	5.14	9.75	0.20	1.43	3.61	5.31	0.13	1.17	2.53	5.13	1.20	10.31	17.17	20.13	1.61	7.50	12.50	16.04	0.07	0.98	3.11	4.38	0.36	2.57	3.96	5.83
<i>Achillea millefolium</i> *		0.04	0.04	0.21	0.05	0.04	0.03	0.38	0.004		0.03	0.28	0.95	3.56	3.69	5.56	1.53	6.13	11.46	12.58		0.04	0.06	0.18			0.12	0.73
<i>Anaphalis margaritacea</i> *	0.03	0.15	1.25	1.23	0.01	0.15	1.00	1.14	0.02	0.08	0.37	0.95	0.16	2.54	5.95	4.71	0.01	0.11	0.63	0.63		0.05	0.33	1.02	0.01	0.36	0.88	1.06
<i>Chamerion angustifolium</i> *	0.08	0.65	1.20	1.27	0.12	1.09	1.85	1.35	0.12	0.83	1.55	1.73	0.09	0.31	0.49	0.36	0.15	1.08	1.46	1.18	0.06	0.62	1.28	1.28	0.31	1.79	1.60	2.93
<i>Geum macrophyllum</i> *													0.07	0.68	0.88			0.01									0.04	
<i>Solidago canadensis</i> *		0.04						0.21	0.004			0.13	0.06	0.88	1.88	3.44		0.04		0.05								0.08
<i>Symphyotrichum laeve</i> *		0.01	0.04	0.01				0.01			0.13	0.17	0.13	2.12	4.22	4.88			0.01	0.04		0.01	0.29	0.05				
<i>Xerophyllum tenax</i> *	0.21	0.61	1.37	4.35						0.01											0.004						0.01	
TOTAL EXOTIC FORB	0.38	4.03	13.79	11.97	0.11	3.12	9.58	7.07	0.16	4.74	15.99	9.26	0.19	3.85	9.65	3.90	0.33	4.25	11.98	13.80	0.06	2.35	8.55	11.42	0.20	1.48	12.64	12.63
<i>Trifolium hybridum</i>	0.37	3.44	12.06	8.27	0.06	1.43	3.39	4.73	0.14	4.46	14.23	6.51	0.10	2.74	7.39	2.26	0.06	2.97	7.81	9.86	0.05	1.96	7.00	8.16	0.05	1.15	11.52	7.83
<i>Veronica officinalis</i>	0.01	0.38	1.51	3.58	0.06	1.44	5.06	0.98	0.02	0.20	1.72	2.17	0.01	0.96	2.23	1.01	0.22	1.08	3.59	1.88	0.01	0.13	0.97	1.04	0.01	0.06	0.80	3.38

Table 5. Apgar Transit Center Experimental Plots: Density (# plants/0.25m²) of seeded plants, 2008-2010. * = Seeded species. **Orange** indicates significant difference (90% CI) between treatments. **Yellow** indicates significant difference (90% CI) between years of same treatment.

TREATMENT #	1			2			3			4			5			6			7		
TREATMENT TYPE	XERTEN seed			RUBPAR seed			CALRUB seed			CALRUB seed with forb			CARATH seed with forb			CALRUB plugs			control		
	2008	2009	2010	2008	2009	2010	2008	2009	2010	2008	2009	2010	2008	2009	2010	2008	2009	2010	2008	2009	2010
NATIVE SHRUB	0	0	0	10.08	6.67	3.92	0	0	0	2.96	7.04	5.58	17.33	13.67	10.58	0	0	0	0	0	0
<i>Rubus parviflorus</i> *				10.08	6.67	3.92															
<i>Spiraea betulifolia</i> *										2.96	7.04	5.58	17.33	13.67	10.58						
NATIVE GRASS	0	0	0	0	0	0	42.67	29.21	19.58	38.00	37.33	18.79	2.46	1.58	2.63	4.00	3.875		0	0	0
<i>Carex sp.</i> (assumed <i>athrostachya</i> *)										0.04			2.42	1.58	2.63						
<i>Calamagrostis rubescens</i> *							42.67	29.21	19.58	37.96	37.13	18.79	0.04								
CALRUB plugs/microplot																4.00	3.88	3.17			
CALRUB plugs total per macroplot																	32	32			
NATIVE FORB	9.75	8.96	7.67	0	0	0	0	0	0	39.20	54.63	53.81	20.13	21.17	26.00	0	0	0	0	0	0
<i>Achillea millefolium</i> *										14.08	16.71	15.38	19.67	20.25	26.00						
<i>Anaphalis margaritacea</i> *										9.46	16.71	17.88		0.92	-						
<i>Chamerion angustifolium</i> *										0.79	2.13	1.38	0.46								
<i>Geum macrophyllum</i> *										2.54	3.58	3.29									
<i>Solidago canadensis</i> *										3.08	4.21	6.71									
<i>Symphyotrichum laeve</i> *										9.25	11.29	9.17									
<i>Xerophyllum tenax</i> *	9.75	8.96	7.67																		
TOTAL DENSITY OF SEEDED SPECIES	9.75	8.96	7.67	10.08	6.67	3.92	42.67	29.21	19.58	80.17	99.00	78.18	39.92	36.42	39.21				0	0	0.00

Table 6. Apgar Transit Center Experimental Plots: Denisty (# plants/m²) and percent germination for seeded species, 2008-2010. * = Seeded species. **Orange** indicates significant difference (90% CI) between treatments. **Yellow** indicates significant difference (90% CI) between years of same treatment.

Treatment #	1							2							3						
Treatment Type	XERTEN seed							RUBPAR seed							CALRUB seed						
	density			seed rate	density			density			seed rate	density			density			seed rate	density		
	per m ²			per m ²	percent			per m ²			per m ²	percent			per m ²			per m ²	percent		
	2008	2009	2010		2008	2009	2010	2008	2009	2010		2008	2009	2010	2008	2009	2010		2008	2009	2010
NATIVE SHRUB								40.3	26.7	15.7	269	15.0%	9.9%	5.8%							
<i>Rubus parviflorus</i> *								40.3	26.7	15.7	269	15.0%	9.9%	5.8%							
<i>Spiraea betulifolia</i> *																					
NATIVE GRASS															170.7	116.8	78.3	538	31.7%	21.7%	14.6%
<i>Carex sp.</i> (assumed <i>athrostachya</i> *)																					
<i>Calamagrostis rubescens</i> *															170.7	116.8	78.3	538	31.7%	21.7%	14.6%
NATIVE FORB	39.0	35.8	30.7	269	14.5%	13.3%	11.4%														
<i>Achillea millefolium</i> *																					
<i>Anaphalis margaritacea</i> *																					
<i>Chamerion angustifolium</i> *																					
<i>Geum macrophyllum</i> *																					
<i>Solidago canadensis</i> *																					
<i>Symphyotrichum laeve</i> *																					
<i>Xerophyllum tenax</i> *	39.0	35.8	30.7	269	14.5%	13.3%	11.4%														
SEED RATE/TRTMNT	269							269							538						

Treatment #	4							5						
Treatment Type	CALRUB seed with forb							CARATH seed with forb						
	density			seed rate	density			density			seed rate	density		
	per m ²			per m ²	percent			per m ²			per m ²	percent		
	2008	2009	2010		2008	2009	2010	2008	2009	2010		2008	2009	2010
NATIVE SHRUB	11.8	28.2	22.3	86	13.8%	32.7%	26.0%	69.3	81.0	42.3	215	32.2%	25.4%	19.7%
<i>Rubus parviflorus</i> *														
<i>Spiraea betulifolia</i> *	11.8	28.2	22.3	86	13.8%	32.7%	26.0%	69.3	54.7	42.3	215	32.2%	25.4%	19.7%
NATIVE GRASS	152.0	148.5	75.2	323	47.0%	46.0%	23.3%	9.9	6.3	10.5	323	3.0%	2.0%	3.3%
<i>Carex sp.</i> (assumed <i>athrostachya</i> *)	0.2							9.7	6.3	10.5	323	3.0%	2.0%	3.3%
<i>Calamagrostis rubescens</i> *	151.8	148.5	75.2	323	47.0%	46.0%	23.3%	0.2						
NATIVE FORB	156.8	218.5	215.2	516	30.4%	42.3%		80.5	84.7	104.0	215	36.6%	37.7%	48.4%
<i>Achillea millefolium</i> *	56.3	66.8	61.5	86	65.5%	77.7%	71.5%	78.7	81.0	104.0	215	36.6%	37.7%	48.4%
<i>Anaphalis margaritacea</i> *	37.8	66.8	71.5	86	44.0%	77.7%	83.2%		3.7					
<i>Chamerion angustifolium</i> *	3.2	8.5	5.5	86	3.7%	9.9%	6.4%	1.8						
<i>Geum macrophyllum</i> *	10.2	14.3	13.2	86	11.8%	16.7%	15.3%							
<i>Solidago canadensis</i> *	12.3	16.8	26.8	86	14.3%	19.6%	31.2%							
<i>Symphyotrichum laeve</i> *	37.0	45.2	36.7	86	43.0%	52.5%	42.7%							
<i>Xerophyllum tenax</i> *														
SEED RATE/TRTMNT	925							753						

III. HERBICIDE/REVEGETATION EXPERIMENTAL PROJECTS

A. BACKGROUND AND PURPOSE

Noxious weeds have become an immense problem in our native ecosystems. Herbicide treatment is a common and effective way to reduce and sometimes eradicate weed populations. In populations with a high weed density and a persistent seed bank, repeat applications are necessary for many years, sometimes decades. However, with numerous applications many problems arise with native plant populations. While each herbicide application is killing the target weed and in theory depleting its seed bank, it leaves open spaces in the habitat for new colonization. Repeat herbicide applications may not only diminish the seed bank of the target weed, but of desirable species as well. Certain native forb species can especially be affected. This often leads to an increase in *colonization by aggressive non-native species, due to opportunistic seeding by prolific weed species or quick colonization by non-native rhizomatous grasses*. Once this happens there is very limited space for natives to return.

The purpose of this project is to test the effects of repeated weed control in combination with seeding desirable native species to see if the habitat can be more effectively restored to a native population than weed control alone. The overall aim is to seed native plants after the target weed species and its seed bank has been reduced, in hope that the native seeds will be able to fill the recently opened spaces. The goals for this study are as follows.

1. To reduce noxious weed species using a combination of herbicide and revegetation.
2. To restore native vegetation to areas opened up by the removal of non-native species, thus preventing other exotic plant invasion.
3. To document changes in species composition and cover over time.

B. METHODS

Two different sites were chosen for this experiment. Sites were chosen based on six criteria:

1. **Sites were of manageable size for revegetation and monitoring.** Sites need to be large enough to merit revegetation and monitoring efforts ($\geq 200\text{m}^2$) but not too large (≤ 1 acre) so that revegetation and monitoring assessment becomes difficult.
2. **Weed species must not include *Linaria vulgaris* or *Euphorbia esula*.** Currently, Tordon is the only effective herbicide to use on these two weed species. Both require high concentrations of herbicide that likely have negative impacts on certain native species. It was decided that these areas would be not be the best locations to test this experimental protocol.
3. **Weed species must have at least moderate cover and fairly even distribution at a site.** Very low, scattered cover of a weed species would not create enough open spaces when removed to provide for effective reseeding treatment. Areas with extremely high cover of a weed species usually had little to no native cover and were determined difficult to restore. To best test this experimental treatment, it was determined that moderate cover and even distribution of a weed species best fit our criteria.
4. **Site must have some concentration of native species that are able to be seeded.** Since we are interested in seeding native species as a revegetation treatment (due to lower cost and time involved), native species must be present in the target community that can be restored through seeding. A minor amount of planting from containers may be considered.
5. **Site must have low cover of non-native grasses.** As non-native grasses are usually aggressive, often rhizomatous, and have no controls, areas with high to moderately high cover of these exotic grasses were not considered as study sites. From past research, areas with high cover of non-native grasses generally increase in cover dramatically after the decrease in cover of a weed forb species such as spotted knapweed (Tyser and Asebrook, in press). Sites with high cover of non-native grasses are difficult to restore and were not considered for this study.
6. **Site must be relatively accessible.** Since these areas must be sprayed several times, revegetated, and monitored several times, it is best that these sites be accessible (within $\frac{1}{4}$ mile) from a road.

To date, two sites have met the above-listed criteria. The first site is located above the St. Mary Campground. This site was dominated by moderate cover of *Centaurea maculosa*. The second site is located off the Camas Road at the Camas Creek Overlook. The dominant weed species at this site was *Hieracium piloselloides*. Permanent level III experimental plots were set up in each location to evaluate pre-treatment canopy cover, ground cover, and to obtain a species list for each location. Plot locations were selected to sample representative vegetation. Plots were also photo-monitored to see a visual change over time.

1. St. Mary Campground

This site is at the end of a small social trail on a hill just north of the St. Mary Campground (Figure 4). In 2008, two experimental macroplots, 08-01 and 08-02, were set up at this location, one on a flat spot at the top of the hill and one on the slope of the hill to capture the change in microhabitat with slope change. In 2009, an additional plot, 09-01, was established just north of plot 08-01 on the flat spot at the top of the hill. This additional area seemed to have higher shrub cover than the other plots, even after herbicide application, which we wanted to document. All three plots are permanent 100m² macroplots, measuring 20m by 5m and marked at all four corners with 12" spikes. In 2008, 2009, 2010, and 2012, 20 ¼-meter microplots have been monitored within each plot, re-randomized each year using the x and y axis of the plot. There is no overlap of the microplots to prevent double sampling.

Herbicide has been applied to the entire site or a portion of the site six times. On July 10, 2008, Milestone was sprayed on 0.48 acres of the site at 5 oz/acre. The entire site was not treated at this juncture, including half of plot 08-01, because of time and herbicide limitations. On Aug 25, 2008, 0.98 acres was sprayed with Milestone at the same rate and with Curtail at a rate of 64 oz/acre. The second treatment encompassed both plots, as well as the area that we established plot 09-01 in 2009. The third herbicide treatment occurred on June 15, 2009 just prior to the monitoring of these plots. The entire area was sprayed with Milestone at a rate of 5 oz/acre. This site was spot sprayed for a fourth treatment on July 12, 2010 a few weeks before monitoring took place with Milestone at a rate of 5 oz/acre. Despite not monitoring these plots in 2011, the entire area was sprayed on August 16, 2011 with Milestone at the same rate. Low cover of both Canada thistle and bull thistle was spot sprayed in this meadow at the same time. Finally, with lower cover of spotted knapweed currently within the meadow, these plots were only spot sprayed on June 28, 2012 using Milestone at 5 oz/acre.

Although these plots were originally scheduled to be seeded in 2009 or 2010, lack of appropriate seed prevented them from getting seeded until October 2011. A total of 39,204 ft² was seeded with the seed mix below (Table 7). Areas that had bare ground were raked for better seed contact, however, not all areas could be raked due to higher cover of existing vegetation.

Table 7. Seed mix with seed rates for St. Mary Camground meadow.

Grass Species	Seeds/ft² or grams
<i>Carex hoodii</i>	5.78 s/ft ²
<i>Carex filifolia</i>	7g
<i>Carex geyeri</i>	4g
<i>Carex petasata</i>	41g
<i>Festuca campestris</i>	24.8 s/ft ²
<i>Festuca idahoensis</i>	25 s/ft ²
<i>Koeleria macrantha</i>	8.76 s/ft ²
<i>Elymus trachycaulus</i>	25 s/ft ²
<i>Pseudoroegneria spicata</i>	10.63 s/ft ²
<i>Achnatherum (Stipa) nelsonii</i>	19.9 s/ft ²
<i>Achnatherum (Stipa) richardsonii</i>	0.34 s/ft ²
Forb Species	Seeds/ft²
<i>Geranium viscosissimum</i>	0.29 s/ft ²
<i>Geum triflorum</i>	1.66 s/ft ²
<i>Penstemon confertus</i>	12.46 s/ft ²
<i>Polemonium pulcherrimum</i>	0.45 s/ft ²
<i>Potentilla gracilis</i>	8.59 s/ft ²

Figure 4. St. Mary Weed Revegetation Site: Location of Plots



2. Camas Creek Overlook

This site consists of a small area alongside the Camas Creek Overlook pullout. This site is along the road shoulder and was originally revegetated in 1998 with the pullout reconstruction. Due to size constraints, only one permanent 50m² rectangular plot, 08-03, was set up in this location. The plot is 10m by 5m with all four corners marked using 12" spikes. Plot location was chosen to best represent the weed population in the area. In 2008, 2009, and 2010, data was collected from 20 ¼-meter microplots in the plot, re-randomized each year using the x and y axis of the plot. This plot was not monitored in 2012, however, due to time constraints and uncertainty about the value of the data being collected. Currently, there are no future plans to continue monitoring this plot. The 2010 Revegetation Monitoring Report should be referenced for reviewing data for this site from 2008 to 2010.

That said, this area was seeded in October 2011 and continues to be sprayed to control noxious weeds. A total of 4,356 ft² was seeded with the seed mix below (Table 8). The yellow hawkweed at this site has also been sprayed from 2008 to 2012 with Milestone at a rate of 5 oz/acre.

Table 8. Seed mix with seed rates for Camas Road turnout.

Grass Species	Seeds/ft ² or grams
<i>Festuca idahoensis</i>	72.52 s/ft ²
<i>Koeleria macrantha</i>	21.18 s/ft ²
<i>Elymus trachycaulus</i>	25 s/ft ²
Forb Species	Seeds/ft ²
<i>Penstemon confertus</i>	6 s/ft ²
<i>Solidago canadensis</i>	6 s/ft ²
<i>Symphytotrichum laeve</i>	6 s/ft ²

C. RESULTS OF ST. MARY CAMPGROUND

Although the amount of non-native plant colonization at this site makes association typing difficult, this area was likely a *Festuca campestris* – (*Festuca idahoensis*) – *Achnatherum richardsonii* grassland prior to dominance of spotted knapweed. The area resembles an open dry grassland – aspen parkland type with a fair amount of *Populus tremuloides* beginning to encroach around the edges of the site. These sites contain a large variety of native forbs and low occurrence of non-native grasses, particularly rhizomatous species, making them ideal conditions for this project.

1. Prior to herbicide:

Prior to spraying herbicide in spring 2008, plot 08-01 was forb dominated, particularly by non-native forbs. Non-native forbs had an average cover of 45% and native forbs had 24% average cover (Table 9). *Centaurea maculosa* had the highest cover of all species present at 44.3%. The only other exotic forbs present were *Taraxacum officinale* and *Tragopogon dubius*. The most predominant native forb species in this plot were *Cerastium arvense* at 4.7%, *Lupinus sericeus* at 3.9%, *Fragaria virginiana* at 3.7%, *Erigeron speciosus* at 2.6%, and *Lomatium triternatum* at 2.2%. There were no tree species present in the microplots, however, *Populus tremuloides* was present in the area. Native shrub cover was low at 4.3%. *Rosa acicularis* and *Rosa woodsii* were the most frequently occurring shrub species at 1.7% and 1.2% cover, respectively. Native grasses were also low with 3.2% cover, dominated by a variety of *Carex* species at 1.5% cover. *Carex rossii* was the only species that could be positively identified; all others were in a vegetative phase and could not be keyed. Exotic grass cover was extremely low with only 0.5% cover. *Poa pratensis* was the most common exotic grass at 0.2% cover while *Agrostis stolonifera* was present with 0.1% cover.

Plot 08-02 was also primarily dominated by *Centaurea maculosa* with 37.2% canopy cover (Table 9). *Taraxacum officinale* and *Tragopogon dubius* each had trace cover, resulting in 37.4% total exotic forb cover. Native forbs had 19.5% cover, dominated by *Hedysarum sulphurescens* at 4.3% cover, *Erigeron caespitosus* at 3.1% cover, and *Cerastium arvense* at 2.6% cover. Shrubs made up 3.8% cover with 2.0% cover of *Amelanchier alnifolia* and 1.8% cover of *Rosa woodsii*. Native grass cover was 7.4%, dominated by *Carex sp.* at 2.8% cover and *Koeleria macrantha* at 1.4% cover.

Exotic grasses have a slightly higher cover in this plot with 2.6% cover, consisting of 1.4% *Pbleum pratense* and 1.2% *Poa pratensis*.

No data was not collected on plot 09-01 prior to herbicide treatment. It is assumed that conditions were similar on this plot to plot 08-01 described above.

Table 9. St. Mary Weed Revegetation Project: Canopy Cover (%) by Species for all plots, 2008-2012.

(1) Ocular cover estimated for species found in macroplot but not in microplots (2) Orange cells are significantly different (90% CI) between years within individual plot; did not run statistics in 2010 or 2012.

	WEED REVEG 08-01								WEED REVEG 08-02								WEED REVEG 09-01					
	2008		2009		2010		2012		2008		2009		2010		2012		2009		2010		2012	
Species	Ocular Cover	Mean Cover	Ocular Cover	Mean Cover	Ocular Cover	Mean Cover	Ocular Cover	Mean Cover	Ocular Cover	Mean Cover	Ocular Cover	Mean Cover	Ocular Cover	Mean Cover	Ocular Cover	Mean Cover	Ocular Cover	Mean Cover	Ocular Cover	Mean Cover	Ocular Cover	Mean Cover
TOTAL NATIVE TREE		0		0		0		0		0		0		0		0		0		0		0
<i>Populus tremuloides</i>	T																					
TOTAL NATIVE SHRUB		4.30		0.56		12.56		5.80		3.80		1.80		1.65		5.96		3.91		3.00		1.8
<i>Amelanchier alnifolia</i>	T				T	0.48	T		1.95		1.60	1	0.50		4.91		0.85					0.05
<i>Arctostaphylos uva-ursi</i>		0.55		0.35		0.85		0.15				T				0.80		0.25				
<i>Dasiphora floribunda</i>		0.90	1.5	0.06		10.51		5.05	T				T		0.05		1.75		0.75			0.55
<i>Rosa acicularis</i>		1.65				0.25								0.30								
<i>Rosa woodsii</i>		1.20		0.16		0.95		0.75		1.85		0.20		0.85		1.00		0.51		2.35		1.1
<i>Prunus virginiana</i>	T								T				T		T							
TOTAL NATIVE GRASS		3.24		10.12		19.00		15.60		7.40		21.74		25.85		29.82		9.01		14.90		14.85
<i>Carex sp. *</i>		1.48		4.51		5.45		3.26		2.81		5.85		3.95		4.95		4.10		2.82		3.55
<i>Danthonia intermedia</i>		0.01		0.01	T					0.07		0.41		0.22		0.27						0.35
<i>Pseudoroegneria spicata</i>		0.05								0.39		2.61		3.61		9.51						
<i>Elymus lanceolatus</i>							0.35															
<i>Elymus trachycaulus ssp. subs.</i>				0.76		1.41		0.31		0.06		0.40		0.05		0.40		0.10		0.30		0.35
<i>Festuca campestris</i>		0.67		2.31		2.35		2.30		0.51		1.36		0.02		0.31		0.90		2.05		2.72
<i>Festuca idahoensis</i>		0.81		1.11		4.90		4.05		0.77		2.46		4.17		4.86		1.95		2.15		4
<i>Helictotrichon hookeri</i>										0.15				0.05								
<i>Koeleria macrantha</i>		0.13		0.95		2.05		2.66		1.41		3.01		5.81		2.56		1.41		3.60		2.27
<i>Poa secunda ssp. juncifolia</i>										0.20					0.25							
<i>Stipa comata</i>																						0.5
<i>Stipa nelsonii</i>		0.01		0.11		0.86		2.40		0.33		0.56		0.81		0.66		0.05		0.53		0.15
<i>Stipa richardsonii</i>		0.10		0.38		2.00		0.85		0.73		5.11		7.12		6.05		0.50		3.50		1.2
TOTAL NATIVE FORB		23.76		13.57		23.40		16.30		19.45		13.59		18.30		17.81		14.94		26.00		13.05
<i>Achillea millefolium</i>		0.48	T		T			0.36		0.57		0.06		0.05	T							0.1
<i>Agoseris glauca</i>				0.11		0.30		0.36									0.21		0.25			1.21
<i>Allium cernuum</i>										0.11		0.11		0.35		0.06						
<i>Androsace septentrionalis</i>						1.07		0.01		0.86												
<i>Anemone multifida</i>		0.36	T		T	0.01						0.40		1.40		1.20	T	0.05				
<i>Antennaria anaphaloides</i>		0.05		0.25													0.15					
<i>Antennaria rosea</i>		0.15		0.05				0.10	T													
<i>Arabis glabra</i>						0.01	T													0.65		
<i>Arabis nuttallii</i>	T			0.01		0.01		0.10				0.05		0.05				0.01				0.01
<i>Arenaria capillaris</i>										0.71		0.70		0.05								

* includes *Carex rossii*, *petaseta*, and *obtusata*

Table 9 (cont.). St. Mary Weed Revegetation Project: Canopy Cover (%) by Species for all plots, 2008-2012.

Species	WEED REVEG 08-01								WEED REVEG 08-02								WEED REVEG 09-01					
	2008		2009		2010		2012		2008		2009		2010		2012		2009		2010		2012	
	Ocular Cover	Mean Cover	Ocular Cover	Mean Cover	Ocular Cover	Mean Cover	Ocular Cover	Mean Cover	Ocular Cover	Mean Cover	Ocular Cover	Mean Cover	Ocular Cover	Mean Cover	Ocular Cover	Mean Cover	Ocular Cover	Mean Cover	Ocular Cover	Mean Cover	Ocular Cover	Mean Cover
TOTAL NATIVE FORB con'd																						
<i>Arnica sororia</i>										0.46												
<i>Aster campestris</i>											1.05		0.55	T								
<i>Aster laevis</i>		0.56		0.10	T	0.01		1.10							0.40		0.05					0.55
<i>Campanula rotundifolia</i>		1.01		0.05		0.05		0.05		0.46		0.01		0.22	0.10		0.01		0.25			
<i>Cerastium arvense</i>		4.66		2.91		10.11		1.62		2.55		1.26		2.56	1.90		8.31		10.16			4.05
<i>Comandra umbellata</i>			T							0.06		0.25		0.10	0.05							
<i>Dodecatheon conjugens</i>																						0.01
<i>Dracocephalum parviflorum</i>																			0.1			
<i>Epilobium</i> sp.																			0.01			
<i>Erigeron speciosus</i>		2.62		0.20		1.15		0.50		0.05			T	0.40		T				T		
<i>Erigeron caespitosus</i>										3.06		1.50		5.18	3.45							
<i>Erysimum inconspicuum</i>																						0.05
<i>Fragaria virginiana</i>		3.70		2.65		4.60		1.15									1.70		7.55			0.6
<i>Gaillardia aristata</i>		0.26								0.30		0.01		0.20	0.35							
<i>Galium boreale</i>		0.71		0.05		0.25		0.35		1.21		0.20		1.55	2.16	T			1.75			0.2
<i>Galium triflorum</i>										0.35												
<i>Geranium viscosissimum</i>	T		T		T	0.25	T										0.20					0.75
<i>Geum triflorum</i>										0.45		0.50		0.05	4.10							
<i>Hedysarum sulphurescens</i>		0.10								4.30		0.50		0.10	T							
<i>Heterotheca villosa</i>									T		T			0.10	T							
<i>Lithospermum rudemale</i>		0.65		0.80	T	1.05		4.85		1.45		0.86		0.85	2.16		0.05			T		
<i>Lupinus sericeus</i>		3.86		1.90		1.33		0.15		0.95		0.45	T		0.40		0.15		0.55			0.5
<i>Lomatium triternatum</i>		2.21		3.30		2.40		3.55			T						3.25		1.85			2.9
<i>Monarda fistulosa</i>									T					0.20	0.10							
<i>Penstemon confertus</i>		1.35		0.35		0.55		0.65		0.11		0.15		0.50	0.66		0.10		0.05			0.5
<i>Polemonium pulcherrimum</i>											T											
<i>Potentilla gracilis</i>		0.86		0.31		0.60		2.55			T		T		T		0.41		1.65			1.1
<i>Potentilla hippiana</i>			T			0.01	T									T						0.6
<i>Potentilla pensylvanica</i>										0.06					T							
<i>Selaginella densa</i>											3.60		1.56		0.25							
<i>Senecio canus</i>		0.20								0.20	T		T		T							
<i>Sisyrinchium montanum</i>		0.06								0.06	T		T						0.10			
<i>Solidago multiradiata</i>		0.15		0.55	T			0.20		1.05		1.80		2.21	0.30		0.31					
<i>Viola adunca</i>										0.11					0.02							
<i>Zigadenus venenosus</i>									T			0.15		0.01	0.05							
unknown forb								0.10														0.04

Table 9 (cont.). St. Mary Weed Revegetation Project: Canopy Cover (%) by Species for all plots, 2008-2012.

	WEED REVEG 08-01								WEED REVEG 08-02								WEED REVEG 09-01					
	2008		2009		2010		2012		2008		2009		2010		2012		2009		2010		2012	
Species	Ocular Cover	Mean Cover	Ocular Cover	Mean Cover	Ocular Cover	Mean Cover	Ocular Cover	Mean Cover	Ocular Cover	Average Cover	Ocular Cover	Average Cover	Ocular Cover	Average Cover	Ocular Cover	Average Cover	Ocular Cover	Average Cover	Ocular Cover	Average Cover	Ocular Cover	Average Cover
TOTAL EXOTIC GRASS		0.53		1.11		8.27		39.45		2.57		6.76		9.86		19.60		2.32		5.10		38.7
<i>Agrostis stolonifera</i>		0.12																				
<i>Phleum pratense</i>		0.22		0.36		1.47		22.25		1.37		5.21		9.06		14.30		0.17		1.97		25.1
<i>Poa compressa</i>		0.01																		0.15		
<i>Poa pratensis</i>		0.19		0.75		6.81		17.86		1.20		1.55		0.80		5.78		2.16		3.00		14.81
TOTAL EXOTIC FORB		44.68		0.10		11.11		5.21		37.37		0.05		4.95		2.03		0.36		12.90		5.26
<i>Alyssum alyssoides</i>					T		0.36							0.15		0.12						
<i>Centaurea maculosa</i>		44.25				9.96		1.00		37.15	T			4.80		1.93		0.01		11.30		2.25
<i>Chenopodium album</i>					T																	
<i>Decurainia sophia</i>						0.02																
<i>Taraxacum officinale</i>		0.06		0.10		0.71		3.81		0.06						0.05		0.35		0.86		2.6
<i>Tragopogon dubius</i>		0.38				0.47		0.25		0.16		0.05				0.01	T			0.51		0.4
# of CENMAC plants		118.65		0		41.2		0.4		97.05		0		4.2		1.1		0.10		4.95		3.55

2. Post-herbicide but prior to re-seeding:

Plots were monitored in July 2010, after most of the area had been spot sprayed in the spring and had been sprayed three times in prior years. Similar trends for all three plots include increases in all lifeforms, both native and exotic, except for shrubs which remained the same in plots 08-02 and 09-01. Unlike last year when both native and exotic forbs showed significant declines in cover, both lifeforms increased in cover this year. Both native and exotic grasses continued to increase in cover, similar to last year. There was no tree cover detected in any plot in any year.

The recovery of native forbs within this project is perhaps the most dramatic result of this year. Currently, native forbs are the dominant lifeform on all three plots. Native forbs on plot 08-01 increased by approximately 10%, on plot 08-02 by approximately 5%, and on plot 09-01 by approximately 11% (Table 32). This increase is due primarily to increases in cover of *Cerastium arvense*, *Fragaria virginiana*, and *Galium boreale* throughout the project and of *Potentilla gracilis*, *Androsace septentrionalis*, *Erigeron speciosus*, *Erigeron caespitosus*, and *Anemone multifida* on certain plots. The trend for these species is completely opposite of results last year when all of these species, except for *Anemone multifida*, decreased in cover. It appears that the change from blanket spraying to spot spraying, even in the period of one year, can allow certain species to recover. Other native forb species that continue to show some increase in cover, indicating their tolerance for herbicide application, include *Arabis glabra* and *Campanula rotundifolia*. *Achillea millefolium*, *Agoseris glauca*, *Allium cernuum*, *Heterotheca villosa*, *Lithospermum ruderales*, *Lupinus sericeus*, *Monarda fistulosa*, *Penstemon confertus*, *Senecio canus*, and *Sisyrinchium montanum* appear to maintain but not increase their cover with spot-spraying herbicide application. Finally, a few species had mixed results, increasing or maintaining cover on some plots while decreasing on other plots. These include *Arabis nuttallii*, *Gaillardia aristata*, *Geranium viscosissimum*, *Lomatium triternatum*, *Potentilla hippiana*, *Solidago multiradiata*, and *Zigadenus venenosus*. Only *Antennaria anaphaloides*, *Antennaria rosea*, *Arenaria capillaris*, *Arnica sororia*, *Aster campestris*, *Symphyotrichum laeve*, *Comandra umbellata*, *Galium triflorum*, *Geum triflorum*, *Hedysarum sulphurescens*, *Polemonium pulcherrimum*, *Potentilla pensylvanica*, and *Viola adunca* decreased or continued to decrease in cover throughout all plots. Many of these species belong to the aster and pea families that tend to be more sensitive to herbicide application.

Total native grass cover also increased on all three plots, resulting in the second highest lifeform cover on the project. Native grass cover increased by 9% on plot 08-01, by 4% on plot 08-02, and by 6% on plot 09-01. These increases were due primarily to increases of *Festuca idahoensis*, *Koeleria macrantha*, *Stipa nelsonii*, and *Stipa richardsonii* throughout the project and *Pseudoroegneria spicata* where it was present. *Elymus trachycaulus* ssp. *trachycaulus* is also slowly increasing where it is present. *Carex* spp., which significantly increased in cover last year, decreased in cover on two plots this year and increased in cover on one plot. Despite the decreases, it remains one of the dominant grass species of the project area with moderate cover on all three plots. *Festuca campestris* also had mixed results, maintaining cover on one plot, decreasing in cover on one plot, and increasing in cover on one plot. As this grass is not usually negatively impacted by herbicide, reasons for these results are unknown and future monitoring may better track the trend of this grass. *Danthonia intermedia* remained with low, unchanged cover on two plots where it has been present. Finally, while herbicide may have negatively impacted *Poa secunda* ssp. *juncifolia* which disappeared from plot 08-02, *Helictotrichon bookeri* has returned to plot 08-02 with low cover where it was originally documented.

Another clear result of monitoring in 2010 is that spraying of *Centaurea maculosa* must continue on a regular schedule to control this noxious weed species over time. Although cover of exotic forbs, mostly comprised of *Centaurea maculosa*, significant declined last year from 37% - 44% down to 0.05% - 0.36%, cover has significantly increased this year to 4.8% - 11.3%. While this cover has not reached pre-treatment levels, the dramatic increase of *Centaurea maculosa* in such a short time frame reiterates the importance of consistent spot spraying. As stated, the increase of exotic forb cover is due almost exclusively to the significant increase of *Centaurea maculosa* which increased on all three plots and is the dominant exotic forb species. It is important to note, however, that this area had just been sprayed in July a few weeks prior to monitoring. It was clear that a fair amount of *Centaurea maculosa* was dying but it was still green at the time of monitoring and thus counted as live material. It is very possible that if we had monitored this area later in the summer, *Centaurea maculosa* and exotic forb cover would be much lower. In addition, it is important to note that no other exotic forb species have become established in this area, likely due to the low diversity of exotic forbs prior to treatment. *Taraxacum officinale* and *Taraxacum officinale*, the only other exotic forb species in the project area, remain with low cover where they are present.

Similarly, the diversity of exotic grasses in this project area also remains very low. Only three exotic grass species are present, including *Phleum pratense*, *Poa pratensis*, and *Poa compressa*. *Phleum pratense* and *Poa pratensis* dominate different plots and both are generally increasing throughout the project, resulting in the overall increase of exotic

grasses on all three plots. This is typical of these grasses under continued disturbance where they are opportunistic at filling in open spaces and outcompeting native species for resources. *Poa compressa* remains with low cover on one plot and *Agrostis stolonifera*, which disappeared from one plot two years ago, has not re-established in the area.

Finally, shrub cover, which was negatively impacted by herbicide application last year, generally maintained or increased in cover this year indicating that some of these shrub species may have the ability to recover after initial impacts from herbicide. Plot 08-01 had the biggest changes over the last two years with a decrease in *Dasiphora floribunda*, *Rosa acicularis*, and *Rosa woodsii* cover last year, which conversely this year, all increased in cover. Most of the increase was due to a significant increase of *Dasiphora floribunda* that increased from 0.56% cover last year to 10.51% cover this year. *Rosa woodsii* increased this year to near its pre-treatment cover and *Rosa acicularis* is slowly increasing in cover after disappearing from the plot. Cover of *Amelanchier alnifolia* decreased on plots 08-02 and 09-01, although an increase in cover of *Rosa woodsii* (after decreasing last year) resulted in similar overall shrub cover to last year on both plots. *Prunus virginiana*, which disappeared from both plots last year, re-established on plot 08-02 this year.

3. Post-herbicide with reseeding

Plots were monitored in July 2012, approximately 7 months after they were seeded with a native grass and forb mix (Table 7). All plots continued to be sprayed each year as well, controlling mainly for *Centaurea maculosa* but also for low cover of *Cirsium arvense* and *Cirsium vulgare*. During this monitoring event, only exotic grasses and exotic forbs exhibited similar trends across all three plots. Exotic grass cover dramatically increased on all three plots, clearly becoming the dominant lifeform on the northern-most plots on flat ground, while exotic forb cover dramatically declined on all three plots, due likely to herbicide application. Native shrubs, forbs, and grasses had variable trends within the three sample areas. No trees have yet to colonize the monitoring plots to date.

While the recovery of native forbs within this project was a positive trend in 2010, native forbs generally declined on all three plots in 2012, particularly on plots 08-01 and 09-01 on the northern, flat portion of the meadow. While native forbs were the dominant lifeform on all three plots in 2010, they now rank as the second or third most dominant lifeform behind exotic grasses and native grasses. After increasing by 5% to 12% cover from 2009 to 2010, native forbs decreased by approximately 7% on plot 08-01, approximately 1% on plot 08-02, and approximately 13% on plot 09-01 (Table 9). The decrease of native forbs on plots 08-01 and 09-01, adjacent plots on the upper, flat portion of the meadow, followed similar trends. Common native forb species that decreased on these plots include *Cerastium arvense* and *Fragaria virginiana*, while *Galium boreale*, *Androsace septentrionalis*, *Erigeron speciosus*, and *Lupinus sericeus* decreased on one of the two plots. Although certain species decreased slightly on plot 08-02, including *Cerastium arvense*, *Erigeron caespitosus*, *Selaginella densa*, and *Solidago multiradiata*, overall native forb cover increased on this plot 08-02 due to notable increases of *Galium boreale*, *Geum triflorum* and *Lithospermum ruderales*.

Strangely, many of the species that had cover decreases this year were many of the same species that showed dramatic increase in cover from 2009 to 2010 following a dramatic decrease in cover from 2008 to 2009. It appears that the change from blanket spraying to spot spraying back to heavier herbicide application, even in the period of one year, can allow certain species to decline but also recover. These species appear to be moderately intolerant of herbicide when herbicide application is heavier, but appear able to recover when herbicide application is light. These species include *Androsace septentrionalis*, *Aster laevis* (*Symphyotrichum laevis*), *Campanula rotundifolia*, *Cerastium arvense*, *Erigeron caespitosus*, *Erigeron speciosus*, *Fragaria virginiana*, *Gaillardia aristata*, *Galium boreale*, *Geum triflorum*, *Geranium viscosissimum*, *Lomatium triternatum*, *Lupinus sericeus*, and *Solidago multiradiata*. At the same time, other native forb species continue to show some increase in cover, indicating their tolerance for herbicide application. These include *Agoseris glauca*, *Allium cernuum*, *Lithospermum ruderales*, *Penstemon confertus*, and *Potentilla gracilis*. *Achillea millefolium*, *Antennaria rosea*, *Arabis nuttallii*, *Heterotheca villosa*, *Monarda fistulosa*, *Potentilla hippiana*, *Potentilla pensylvanica*, *Senecio canus*, *Viola adunca* and *Zigadenus venenosus* appear to maintain but not increase their cover with spot-spraying herbicide application. Only *Antennaria anaphaloides*, *Arenaria capillaris*, *Arnica sororia*, *Aster campestris*, *Comandra umbellata*, *Galium triflorum*, *Hedysarum sulphurescens*, *Polemonium pulcherrimum*, *Selaginella densa*, and *Sisyrinchium montanum* decreased or continued to decrease in cover throughout all plots. Many of these species belong to the aster and pea families that tend to be more sensitive to herbicide application. Currently, four of the five seeded species are present on the project with all four species having notable cover on at least one plot. Only *Polemonium pulcherrimum* was not observed in any of the plots, indicating that it may not have been successful germinating from seed.

Total native grasses generally maintained their cover on two plots and increased slightly on the slope plot. *Carex* spp., *Festuca idahoensis*, *Festuca campestris*, and *Koeleria macrantha* are the dominant native grasses on plots 08-01 and

09-02 on the upper flat part of the meadow. These grasses are generally maintaining their cover, resulting in similar overall native grass cover to 2010 on these two plots. Native grasses have the third and second highest lifeform cover on these plots, respectively. Conversely, *Pseudoroegneria spicata* dramatically increased on plot 08-02, resulting in the overall increase of native grasses on this plot. At 9.51%, it currently has the highest cover of any native species on the project. *Stipa richardsonii* maintained relatively high cover on this plot as well at 6.05%, the second highest cover of any native species on the project. With these results, native grasses are the dominant lifeform only on plot 08-02. Overall, most native grasses do not appear to be negatively impacted by herbicide application, with some continuing to increase despite herbicide. Diversity of native grasses has remained high and most established native grasses continue to increase or generally maintain notable cover. It is not yet apparent how effective seeded grasses have been on this project. Only *P. spicata* had a large increase in cover on one plot. It is uncertain whether that increase is due to seed or existing grasses increasing in cover over time. As this area was seeded less than a year ago, it may take one or two additional seasons of monitoring to assess the effectiveness of seeded grasses. Currently, all of the seeded species are present on the project.

Similar to results in 2010, spraying of *Centaurea maculosa* must continue on a regular schedule to control this noxious weed species over time. Cover of exotic forbs is currently on a cyclic period of decreases and increases based on the ability of *C. maculosa* to re-establish itself, as well as the intensity of herbicide that is applied. After dramatically decreasing in 2009 due to blanket spraying the areas, cover and density of *C. maculosa* effectively rebounded in 2010 when the area was only spot sprayed. The area was more consistently sprayed in 2011 and 2012, dramatically decreasing both the density and cover of *C. maculosa* in 2012. This decrease in cover of *C. maculosa* is the main cause of overall exotic forb decreases in all three plots. While *C. maculosa* remains the dominant exotic forb species on plot 08-02, *Taraxacum officinale* is currently the dominant exotic forb species on plots 08-01 and 09-01. This weed species dramatically increased on these plots since 2010. Overall, diversity of exotic forbs is very low and continued spraying should keep most of these exotic species under control.

While the diversity of exotic grasses in this project area also remains very low, exotic grass cover is now the biggest barrier to success for this restoration project. Although there are now only two species of exotic grass on all three plots, they have increased in cover two- to seven-fold since 2010. They are the dominant lifeform by far on the northern, flat plots and have the second highest lifeform cover on the slope plot. *Phleum pratense* had the most dramatic increases in cover and is currently the species with the highest cover on all three plots. *Poa pratensis* also increased dramatically on all three plots and is the species with the second highest cover on all three plots. This is typical of these grasses under continued disturbance where they are opportunistic at filling in open spaces and outcompeting native species for resources. While they were relatively slow to increase in cover during the first two years after herbicide application, they are now dominant features of the vegetation that may be impossible to control. The lack of native seed at the opportune time and the continued impact to existing native species from herbicide application allowed these aggressive exotic grasses to ultimately take over, similar to several other low-elevation restoration projects in the park. On a positive note, *Poa compressa* disappeared from two plots in 2012 and *Agrostis stolonifera*, which disappeared from one plot three years ago, has not re-established in the area.

Finally, shrub cover in 2012 is following trends similar to native forbs described above. From 2009 to 2010, similar to native forbs, shrub cover generally maintained or increased in cover after initially decreasing in cover from 2008 to 2009, indicating that some of these shrub species may have the ability to recover after initial impacts from herbicide. This year, following more intensive herbicide application, shrub cover decreased again by approximately 50% on the northern, flat plots while shrub cover notably increased on the slope plot, also similar to native forb trends. On plot 08-01, *Dasiphora floribunda* had the most notable decrease in cover after dramatically increasing in cover from 2009 to 2010. This shrub species has been slowly decreasing over time on the adjacent plot 09-01, indicating that it is moderately intolerant of herbicide but can generally recover or maintain some survival. At the same time, *Rosa acicularis*, *Rosa woodsii*, and *Arctostaphylos uva-ursi*, three other consistent shrub species on the project, also decreased slightly this year on both plots after increasing in cover from 2009 to 2010. They, too, appear negatively impacted during times of heavier herbicide application but appear able to recover or maintain a level of survival. Conversely, shrub cover increased on plot 08-02 due primarily to the dramatic increase of *Amelanchier alnifolia* that had almost disappeared from this plot in 2010. Cover of *A. alnifolia* is now twice as high as its pre-treatment cover prior to herbicide application, indicating its ability to recover after herbicide impact. *R. woodsii* also increased on this plot, lending credence to its ability to survive under moderate herbicide application.

D. CONCLUSIONS AND RECOMMENDATIONS

Overall, herbicide treatment at the selected project site has been effective at significantly reducing target weed populations. *Centaurea maculosa* at the St. Mary site had been reduced to trace cover in 2009 and has remained lower in cover than pre-treatment levels ever since. That said, notable cover of *C. maculosa* remains and it is clear that herbicide application must continue on an annual basis to assure the long-term control of this weed. Herbicide application has also reduced other non-target exotic forb species, providing additional benefit that would be good to continue. Finally, herbicide application has ‘released’ several native grasses that have far higher cover than pre-treatment levels. This project has also been able to document that several native forbs may initially be impacted by herbicide but have the ability to recover as herbicides are only spot sprayed.

Data have also documented negative impacts of herbicide application, particularly the loss of certain native forb and shrub species and the ‘release’ of certain exotic grasses that have opportunistically increased with additional space. While the loss of native species has been relatively less than other projects, the increase of exotic grasses has been dramatic in this meadow and may impede the success of this restoration project. In addition, seeding of native species happened one to two seasons too late, possibly reducing the impact that additional native species could have had competing with exotic species.

The challenge remaining to this project is threefold:

- (1) Maintain low cover of target weed species by ongoing weed control, including herbicide application and/or hand pulling. Herbicide application may now exist as spot spraying since cover of target weed species is lower.
- (2) Examine ways to reduce exotic grass cover. This could include hand pulling of *Phleum pratense* or the use of sethoxydim in areas of thick exotic grass (as this herbicide would also remove native grasses).
- (3) Continue monitoring this site to assess the initial seeding of 2011. Consider additional seeding to increase native cover and fill in open space as weed control continues. Continue to use appropriate native species that may withstand future herbicide application.

To address the first management item, this site should be sprayed again in the spring of 2013 and if possible, spot sprayed in the fall of 2013. Although *Centaurea maculosa* seeds can have viability for as long as ten years, studies show that the seed bank can decrease as much as 81% after 15 months of treatment (Chicoine, 1984). Density of *C. maculosa* is currently very low so additional spraying could remove the last remaining weeds.

To address the second management item, the park should continue to follow experiments that are attempting to control exotic perennial grasses in grassland communities. Experimental treatments that began in 2005 show that applications of grass-specific herbicide sethoxydim effectively reduces exotic perennial grasses. Combining sethoxydim with other treatments had added benefits: fall burning reduced thatch and moss cover, additional spraying of glyphosate application 1 to 2 weeks after burning reduced broadleaf weeds and seed addition increased native diversity (Stanley et al. 2008). The park should follow this research or experiment with small areas of control within the St. Mary site. While hand-pulling would be very time intensive, this method could be used in small areas within the meadow for *Phleum pratense*.

Finally, to address the third management item, it is important to continue to understand which of our local grassland species have shown the ability to persist under an herbicide spraying regime. In addition to data collected from these two projects sites, data concerning the response of both native and exotic species to clopyralid (“Stinger”) herbicide application was also collected during a study along the Going-To-The-Sun Road near Two Dog Flats from 1992 to 2002 (Tyser and Asebrook, in press). The combination of the data from the three sites is the basis for a preliminary table delineating the impacts of herbicide on native and exotic grassland plants of our area (Table 10). Please note in the “mixed impact” column that results were either mixed due to the use of two different herbicides (Stinger vs. Milestone) on the three projects or the fact that sometimes a plant was initially impacted by herbicide but was able to recover substantially over time. In the future with additional data, there may be another column assessing plant species ability to recover under no to little herbicide application.

Table 10. Herbicide Impacts on Certain Native and Exotic Plants in Glacier NP.

Herbicide Negatively Impacts	Herbicide Positively Impact	Herbicide has Neutral Impact	Herbicide has Mixed Impact: May be able to recover
Shrubs			
<i>Spiraea betulifolia</i>		<i>Arctostaphylos uva-ursi</i>	<i>Amelanchier alnifolia</i>
			<i>Dasiphora floribunda</i>
			<i>Symphoricarpos albus</i>
			<i>Rosa acicularis/ woodsii</i>
			<i>Prunus virginiana</i>
Native forbs			
<i>Achillea millefolium</i>	<i>Lithospermum ruderales</i>	<i>Allium cernuum</i>	<i>Agoseris glauca</i> (↑ Milestone, ↓ Stinger)
<i>Antennaria anaphaloides</i>	<i>Lomatium triternatum</i>	<i>Arabis nuttallii</i>	<i>Androsace septentrionalis</i> (↓ Milestone, ↔ Stinger)
<i>Arenaria capillaris</i>	<i>Potentilla glandulosa</i>	<i>Arenaria rubella</i>	<i>Anemone multifida</i> (can recover)
<i>Arnica sororia</i>	<i>Potentilla gracilis</i>	<i>Comandra umbellata</i>	<i>Antennaria rosea</i>
<i>Astragalus spp.</i>	<i>Potentilla hippiana</i>	<i>Geranium viscosissimum</i>	<i>Aster campestris</i>
<i>Epilobium brachycarpum</i>		<i>Geum triflorum</i>	<i>Campanula rotundifolia</i> (can recover)
<i>Galium triflorum</i>		<i>Heuchera cylindrica</i>	<i>Cerastium arvense</i> (can recover)
<i>Hedysarum sulphurescens</i>		<i>Heterotheca villosa</i>	<i>Collinsia parviflora</i>
<i>Oxytropis spp.</i>		<i>Polygonum douglasii</i>	<i>Collomia linearis</i>
<i>Rhinanthus crista-galli</i>		<i>Potentilla pensylvanica</i>	<i>Erigeron caespitosus</i> (can recover)
<i>Solidago canadensis</i>		<i>Senecio canus</i>	<i>Erigeron speciosus</i> (can recover)
<i>Vicia americana</i>		<i>Sisyrinchium montanum</i>	<i>Fragaria virginiana</i> (↓ Milestone, ↑ Stinger)
			<i>Gaillardia aristata</i> (may recover)
			<i>Galium boreale</i> (can recover)
			<i>Lupinus sericeus</i> (can recover)
			<i>Microsteris gracilis</i> (↓ Milestone, ↔ Stinger)
			<i>Monarda fistulosa</i>
			<i>Penstemon confertus</i> (can recover)
			<i>Polemonium pulcherrimum</i>
			<i>Solidago multiradiata</i>
			<i>Symphyotrichum laeve</i>
			<i>Viola adunca</i>
			<i>Zigadenus venenosus</i>
Native grasses			
<i>Elymus lanceolatus</i>	<i>Agrostis scabra</i>		<i>Danthonia intermedia</i> (can recover)
<i>Festuca occidentalis</i>	<i>Bromus carinatus</i>		<i>Elymus glaucus</i>
<i>Helictotrichon bookeri</i>	<i>Carex spp.</i>		<i>Poa secunda</i>
<i>Poa interior</i>	<i>Elymus trachycaulus spp. trachycaulus</i>		
	<i>Pseudoroegneria spicata</i>		
	<i>Elymus trachycaulus spp. subsecundus</i>		
	<i>Festuca campestris</i>		
	<i>Festuca idahoensis</i>		
	<i>Koeleria macrantha</i>		
	<i>Stipa nelsonii</i>		
	<i>Stipa richardsonii</i>		
Exotic forbs			
<i>Centaurea maculosa</i>		<i>Alyssum alyssoides</i>	<i>Taraxacum officinale</i>
<i>Cirsium arvense</i>		<i>Arenaria serpyllifolia</i>	<i>Tragopogon dubius</i>
<i>Hieracium piloselloides</i>		<i>Leucanthemum vulgare</i>	<i>Verbascum thapsus</i>

Table 10 con'd. Herbicide Impacts on Certain Native and Exotic Plants in Glacier NP.

Herbicide Negatively Impacts	Herbicide Positively Impact	Herbicide has Neutral Impact	Herbicide has Mixed Impact
Exotic forbs, con'd			
<i>Melilotus spp.</i>			
<i>Myosotis micrantha</i>			
<i>Thlaspi arvense</i>			
<i>Trifolium spp.</i>			
<i>Vicia villosa</i>			
Exotic grasses			
<i>Agrostis stolonifera</i>	<i>Bromus inermis</i>		
<i>Elymus repens</i>	<i>Bromus tectorum</i>		
<i>Poa compressa</i>	<i>Phleum pratense</i>		
	<i>Poa pratensis</i>		

Other studies are also beginning to gather data on the effects of herbicide on native species. In particular, Halsvedt et. al. (2010) have established field experiments to test the effects of Milestone on native forbs and shrubs at ten sites throughout Montana, North Dakota, Minnesota, and Colorado. Their report includes a list of plants and their tolerances to herbicide including tolerant (<15% plant injury in stand), moderately tolerant (15-50% plant injury), moderately susceptible (51-75% plant injury), and susceptible (>75% plant injury). Although our results did not use this same ranking system and our definition of susceptible was stricter in the sense that notable decreases in cover included the plant in the “herbicide negatively impacts” category, most of our conclusions about herbicide tolerances were similar (Table 11). Cells highlighted in red indicate notable differences in herbicide tolerance results between our study and Halsvedt et. al. It is important to note that results for these differences may be due to the differences in how each study determined “tolerant” versus “susceptible”. In addition, certain plants that were compared in Table 11 were similar but not always the same species.

Table 11. Herbicide Tolerance Rankings for Certain Native and Exotic Species in Glacier NP.

Species (Halsvedt species / GNP species)	Halsvedt et. al. ranking (year 1)	GNP ranking
<i>Lomatium triternatum</i>	Moderately tolerant	Positive Impact - tolerant
<i>Gaillardia aristata</i>	Moderately tolerant	Mixed Impact - tolerant
<i>Solidago canadensis</i>	Moderately susceptible	Negative Impact - susceptible
<i>Heterotheca villosa</i>	Moderately tolerant	Neutral impact - tolerant
<i>Solidago missouriensis</i> vs. <i>Solidago multiradiata</i>	Moderately tolerant	Mixed Impact - tolerant
<i>Arnica fulgens</i> vs. <i>Arnica sororia</i>	Susceptible	Negative Impact - susceptible
<i>Antennaria rosea</i>	Moderately tolerant	Mixed Impact - tolerant
<i>Erigeron pumilus</i> vs. <i>Erigeron caespitosus</i>	Moderately tolerant	Mixed Impact - tolerant
<i>Symphyotrichum laeve</i>	Moderately tolerant	Mixed Impact - tolerant
<i>Melilotus officinalis</i>	Susceptible	Negative Impact - susceptible
<i>Achillea millefolium</i>	Susceptible	Negative Impact - susceptible
<i>Lithospermum ruderae</i>	Moderately tolerant	Positive Impact - tolerant
<i>Arabis nuttallii</i>	Tolerant	Neutral impact - tolerant
<i>Cerastium arvense</i>	Moderately susceptible	Mixed Impact - susceptible
<i>Arenaria capillaris</i>	Susceptible	Negative Impact - susceptible
<i>Lupinus sericeus</i>	Tolerant	Mixed Impact - tolerant
<i>Astragalus miser</i> vs. <i>Astragalus</i> spp	Susceptible	Negative Impact - susceptible
<i>Zigadenus venenosus</i>	Tolerant	Mixed Impact - tolerant
<i>Monarda fistulosa</i>	Tolerant	Mixed Impact - tolerant
<i>Allium stellatum</i> vs. <i>Allium cernuum</i>	Tolerant	Neutral impact - tolerant
<i>Epilobium paniculatum</i> vs. <i>Epilobium brachycarpum</i>	Susceptible	Negative Impact - susceptible
<i>Collomia linearis</i>	Susceptible	Mixed Impact - tolerant
<i>Microsteris gracilis</i>	Tolerant	Mixed Impact - tolerant
<i>Androsace occidentalis</i> vs. <i>Androsace septentrionalis</i>	Moderately susceptible	Mixed Impact - tolerant
<i>Potentilla arguta</i> vs. <i>Potentilla glandulosa</i>	Susceptible	Positive Impact - tolerant
<i>Geum triflorum</i>	Moderately tolerant	Neutral impact - tolerant

Species (Halsvedt species / GNP species)	Halsvedt et. al. ranking (year 1)	GNP ranking
<i>Potentilla gracilis</i>	Susceptible	Positive Impact - tolerant
<i>Fragaria virginiana</i>	Tolerant	Mixed Impact - tolerant
<i>Collinsia parviflora</i>	Tolerant	Mixed Impact - tolerant
<i>Viola nuttallii</i> vs. <i>Viola adunca</i>	Moderately susceptible	Mixed Impact - tolerant
<i>Arctostaphylos uva-ursi</i>	Tolerant	Neutral impact - tolerant
<i>Prunus virginiana</i>	Moderately tolerant	Mixed Impact - tolerant
<i>Amelanchier alnifolia</i>	Susceptible	Mixed Impact - tolerant
<i>Rosa woodsii</i>	Susceptible	Mixed Impact - tolerant

If it is determined that additional seeding is desired or required at the St. Mary site, species should be chosen from the following species list (Table 12). This list is comprised of species that are present or near the site and have some tolerance of herbicide application. This is a comprehensive list so not all species need to be selected for seeding. The St. Mary site should continue to be monitored at years 5 (2013), 10 (2018), and 20 (2028) after revegetation. Additional years of monitoring could be added if additional seeding took place. This site should also be monitored for presence of weed populations so that continued control can take place. As stated above, the Camas Creek Overlook site is not scheduled for future monitoring due to time constraints and uncertainty about the value of the data being collected. The 2010 Revegetation Monitoring Report should be referenced for reviewing data for this site from 2008 to 2010.

Table 12. Recommended Revegetation Species for St. Mary Weed Revegetation Site

Species in *blue* were found within plots

Species in *black* were found in the macroplots or in the nearby area, but were not located within the microplots.

Dominant Grasses

Carex filifolia
Carex geyeri
Carex hoodii
Carex obtusata
Carex petasata
Carex rossii
Danthonia intermedia
Elymus trachycaulus ssp. *trachycaulus*
Festuca campestris
Festuca idahoensis
Koeleria macrantha
Pseudoroegneria spicata
Stipa nelsonii
Stipa richardsonii

Dominant Forbs

Antennaria rosea
Fragaria virginiana (plant)
Erigeron speciosus/caespitosus
Gaillardia aristata
Geranium viscosissimum
Geum triflorum
Hedysarum sulphurescens
Heterotheca villosa
Lupinus sericeus
Penstemon confertus
Potentilla gracilis
Symphytotrichum laeve

Shrubs to Plant

Arctostaphylos uva-ursi
Dasiphora floribunda
Mahonia repens

IV. GOING-TO-THE-SUN ROAD: PHASE VI MONITORING

A. BACKGROUND AND PURPOSE

In July 2007, an 8 to 10-year rehabilitation project for the Going to the Sun Road (GTSR) was initiated, funded by Federal Highway dollars. Phase VI of the project, including the roadside from West Tunnel to Haystack Creek, began in 2007 and continued into 2008. Construction during this phase included installation of retaining walls, culverts and drains, as well as base stabilization. Additionally, a day-use and vista area was created across from the “Road Camp” area on the south side of the road. Elevation for this phase of the GTSR Rehabilitation Project ranges from approximately 4,400 feet to 5,230 feet.

A species list was created for this segment of road in 2007 which directed seed collection. Disturbance created from construction of this phase was revegetated in June 2010. Five roadside sites or turnouts, estimated at 18,732 ft², in phase VI were planted, seeded, and provided with fencing to deter trampling. Several of these sites had significant plant material and were only lightly seeded with a forb, shrub, and grass mix (Table 14). Others had less planted material and were seeded more heavily with the same seed mix. In all turnout areas that were seeded, the soil was scarified and seeds were hand raked into the ground. All roadside edges that were disturbed throughout phase VI, totaling at 87,120 ft², were then hydroseeded with the same seed mix.

In 2012, plot MD-10-02 was planted with supplemental material (Table 15). The area was also seeded using the remaining seed mix from phase VI (Table 14). Turnouts had either guardrails or were fenced using sash-chain fencing.

B. METHODS

Monitoring plots were established in September 2010 at all five sites that were planted with nursery stock (Figure 7). At this time, seed was not yet germinating so no plots were created in areas that were seeded alone. Additional sites may be added in the future if deemed necessary. Plots are not permanently marked and size and shape of plots were determined by site parameters (Table 13). Most plots are located behind wood fencing and varied in width.

Plots were evaluated using Level II protocol. All plants within plots were identified to species and given ocular cover estimates. On August 22 and 30, 2012, all five monitoring plots were re-monitored, two years after planting.

Table 13. GTSR-Phase VI: Plot Dimensions and Locations

Plot Number	Plot dimensions	UTM N	UTM E
MD-10-01	24 m x 2 m	5403348	295945
MD-10-02	35 m x 3 m	5402887	296917
MD-10-03	50 m x 2 m	5402469	297398
MD-10-04	25 m x 4 m	5402249	297553
MD-10-05	18 m x 3 m	5402096	297673

C. RESULTS

By 2012, two years after planting, average vegetative cover in monitoring plots had increased by 7%, similar to the increase the first year after planting. This was solely due to increases in native cover. Native species cover rose by 8%, while exotic cover actually decreased by 1% (Figure 5). Some of the increase in native cover is due to supplemental planting in plot MD-10-02. Reduction in exotic species can be attributed to diligent weeding by the revegetation and monitoring crews, as well as a consistent regime of roadside herbicide application.

All native lifeforms increased in cover since 2011, while both exotic forbs and exotic grasses declined. As was seen last year, the largest increase in cover was observed in native forbs which rose 4% overall (Figure 6). Native forbs are now the dominant lifeform throughout the project, whereas shrubs were the dominant lifeform last year.

Shrub cover increased by 2% since 2011, while average cover of shrubs actually declined slightly the previous year. Seeded material had begun to establish by 2011 and continued to increase throughout the subsequent year. *Achillea millefolium*, *Symphotrichum laeve*, *Solidago canadensis* and *Geum macrophyllum* were the most successful seeded species. Exotic grasses had initially increased after the first year, threatening the success of the project, but with diligent weeding exotic grasses declined between years one and two.

Figure 5. GTSR-Phase VI: Percent Native vs. Exotic Cover for All Plots, 2010-2012

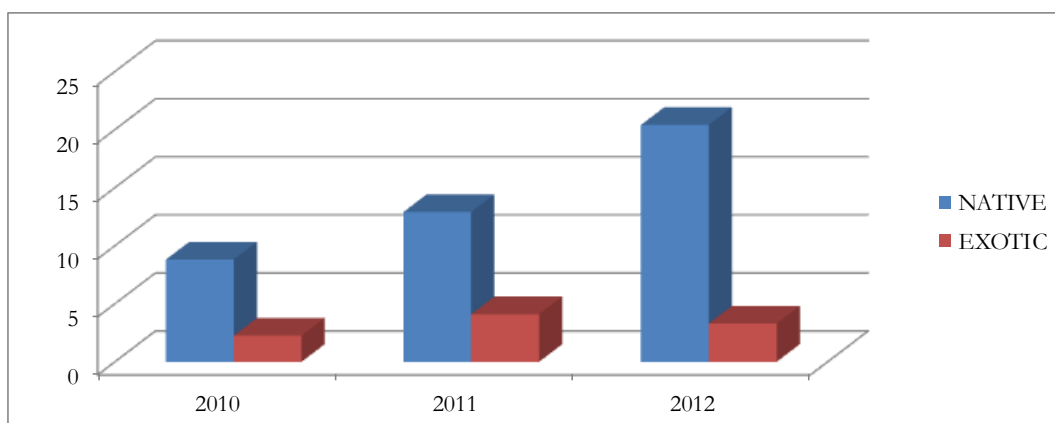
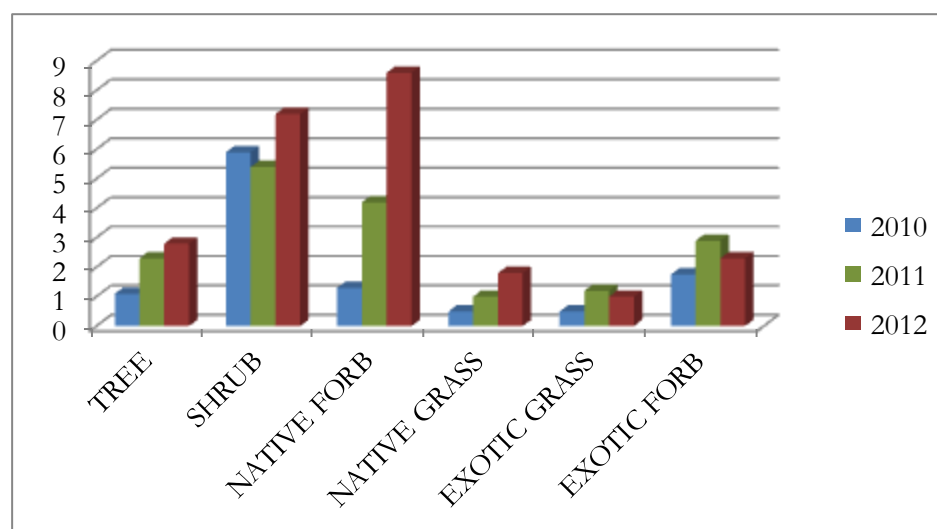


Figure 6. GTSR-Phase VI: Percent Ocular Cover of Life Forms for All Plots, 2010-2012



Trees: Tree cover increased slightly since 2011, mostly due to planted *Populus balsamifera*. This species increased in cover in three plots by 1% to 2%. It actually decreased in cover in plot MD-10-01, however. It is speculated that overstory was counted in overall cover in 2011, but was not in 2012. *Abies lasiocarpa*, *Betula papyrifera* and *Pseudotsuga menziesii* all remain with trace covers in the plots where they were planted. *Picea engelmannii* remained stable at 5% in plot MD-10-05 and was newly observed in plot MD-10-01.

Shrubs: Overall, shrub cover has increased by approximately 2% over the past year. Most plots saw an increase in shrub cover between 1% and 6% with the exception of plot MD-10-01, which decreased by 4%. Again, in plot MD-10-01, several non-planted species on the edge of the plot may have been included in cover estimates in 2011 but not in 2012. Shrubs also appeared less robust this year in this plot. No one species appears responsible for increases or declines but several species changed in cover by a fraction to 1%. Additionally, several shrub species

were new to plots, most notably in plot MD-10-02 where supplemental planting took place. Species showing the most success overall include *Acer glabrum*, *Cornus sericea* and *Rosa woodsii*.

Native forbs: An increase in native forb cover was seen in three of the five plots from 2011 to 2012, while native forb cover remained stable in the other two plots. *Achillea millefolium*, *Symphyotrichum laeve*, *Solidago canadensis* and *Geum macrophyllum* were responsible for much of this increase, each of which increased from between 1 and 4% in several plots. All of these species except for *S. laeve* were seeded. Given that this is near the upper limits for *S. laeve* and its abundance, it is likely that this species was included in the seed mix either inadvertently or was not noted. Other species that increased slightly in at least one plot include *Artemisia ludoviciana*, *Fragaria virginiana*, *Iliamna rivularis* and *Phacelia hastata*. Of these, only *Fragaria* was seeded. Most forb species continue to provide less than 1% cover, but diversity is high, contributing to relatively high overall native forb cover in the future. The highest cover observed for a single native forb species was 5% for *G. macrophyllum*, a seeded species. Across all plots, 27 incidents of new native forb species were recorded, as compared to 35 new native forb species in 2011. Since some of the same new species were found in more than one plot, this resulted in 15 native forb species newly found in at least one plot in 2012, as compared to 24 in 2011. Only three of these species were seeded, however. *Fragaria vesca* was new to three plots, while *Eurybia conspicua* and *Solidago canadensis* were each new to one plot. More germination of seeded species took place last year. Many of the newly recorded species this year are recruiting from adjacent communities and/or are disturbance-loving species. Only 7 native forb species, however, were lost from plots in the past year, while 13 were lost between 2010 and 2011. None of these were planted or seeded species.

Native grasses: Native grasses, on average, increased slightly in plots over the past year. Cover, however, remained stable in two of the five plots and actually decreased in one plot. Delayed germination appears to continue to occur in some cases with several seeded species establishing in plots for the first time in 2012. *Bromus carinatus* reappeared in one plot from which it disappeared last year. It also disappeared from one plot, increased in one plot and cover stayed the same in two plots, so there is no clear trend at this point for this species. *Elymus trachycaulus* established in one plot and cover stayed the same in three plots. *Carex* sp. was newly found in one plot after disappearing from that plot last year. *Elymus glaucus*, another seeded species, did not newly establish in any plots this year but increased in cover in two plots, although it disappeared from one plot since last year. This species provides the highest cover of any native grass species in the project with 1% to 3% cover in three plots. Three other naturally established native grass species were found in plots, all with only trace cover. No seeded grass species remains in plot MD-10-04.

Exotic grasses: Exotic species had begun to invade the project area by 2010, given that there was an abundance of open disturbed soil and seeded species had not yet germinated. While 2011 saw an upsurge in the number of exotic grass species, average cover actually decreased slightly in 2012 due to diligent weeding. Five species of exotic grass were eliminated from one plot alone since 2011. Annual bromes, likely brought in on construction equipment, are the highest threat to this area. *Bromus tectorum* was newly found in all five plots in 2011 but remains at trace cover in all plots in 2012. Another annual brome, *B. secalinus*, was present in one plot in 2011. It remains at trace cover in this plot but has recruited to two new plots this year. Both annual brome species are actively being pulled. While no exotic grass species are present with greater than trace cover, several new species have recruited into plots this year. *Agrostis stolonifera*, *Elymus repens* and *Poa pratensis* each were newly found in one plot in 2012 and *Poa annua* was observed for the first time in two plots this year. All of these species are highly invasive. Annual bromes have a high seed output and *A. stolonifera*, *E. repens* and *P. pratensis* spread by quickly growing rhizomes. Attempts should continue to be made to control all of these aggressive species.

Exotic forbs: Exotic forb cover has also decreased slightly since 2011. There were 17 incidents of new exotic forbs recruiting to plots with 13 species that were new to plots. This is a lower recruitment rate than in 2011 when 35 incidents of new exotic forb species occurred with 25 new species to individual plots. However, there were even more species lost from plots. Several of the species were pulled from plots in 2011 and did not reappear. Several noxious weed species also disappeared from plots. *Centaurea stoebe*, *Cynoglossum officinale* and *Leucanthemum vulgare* each vanished from one plot. Pulled weeds did return in some plots, however. Herbicide application in concert with pulling likely is keeping some of these species at bay.

New exotic forb species continue to recruit to plots, however, including *C. stoebe*, a noxious weed species, that was newly observed in one plot. No exotic forbs are proliferating rapidly. Only *Medicago lupulina* and *Trifolium pratense* were present with greater than trace cover in 2012, each with 1% cover in one plot. *Verbascum thapsus* declined in cover from 4% in one plot to trace cover due to ongoing pulling. This species appeared problematic in this area at the beginning of the project but now is present with only trace cover and has even disappeared in two plots. *Cirsium arvense* is increasing in cover slightly and should continue to be sprayed.

D. CONCLUSIONS AND RECOMMENDATIONS

Survival of planted material has continued to be good two years after planting. Most plots visually showed increased ground cover and many areas are quite aesthetically pleasing to visitors. Planted trees are surviving and most are showing growth. Shrubs, although not the dominant lifeform in monitoring plots this year, are showing high survival as well as some growth. The only planted shrub to disappear from a plot was *Mahonia repens*. Surviving species may be adjusting to transplantation since they are beginning to increase in cover. Planted native forbs are enduring, although they are not generally showing much growth yet. Only planted *Aster sp.* and *Antennaria howellii* have each disappeared from a single plot.

Many seeded species are beginning to increase in cover this year. Many seeded forb species germinated in 2010, survived into 2011 with low covers, and are beginning to show increases this year. While *Achillea millefolium* contributed the most consistent cover across plots, *Geum macrophyllum* showed the most prominent increase in one plot since last year, increasing from 1% to 5%. *Solidago canadensis* is also establishing well from seed. Several seeded species were planted as well as seeded within the same monitoring plot. *Fragaria sp.*, *Spiraea betulifolia* and *Penstemon confertus* are all surviving and increasing in cover in most cases. Some species are continuing to show delayed germination in some plots, including *Bromus carinatus*, *Carex* species and *Elymus trachycaulus*. A few seeded species germinated in 2010 but were lost in one or more plots in 2011, including *C. angustifolium*, *Fragaria vesca*, *B. carinatus* and *Carex sp.* Interestingly, most of these species re-established in plots from which they disappeared last year. One seeded species, *Eurybia conspicua*, germinated for the first time this year in one plot. Two species that were seeded still have not yet appeared in monitoring plots; these include *Carex rossii* and *Festuca occidentalis*.

Although exotic species cover is still not high at this time, it may become problematic over time if these areas are not consistently weeded and sprayed. New establishment of the weedy grasses *Bromus secalinus*, *Agrostis stolonifera*, *Poa pratensis*, and *Poa annua* has occurred in one or several plots in 2011. These grasses are known to overtake open areas with relatively low overall vegetative cover. Additionally, although not captured in monitoring plots, *Phalaris arundinacea* was observed growing on the roadside within the phase VI revegetation area. This extremely aggressive grass has not been historically present in many areas of the park but since the intensification of road rehabilitation in the last several years, it has been observed in several places. Some sites have high cover of this non-native grass species, such as the Packer's Roost Road. It is highly suggested to eradicate this grass when observed since it is known to rapidly overtake sensitive areas such as wetlands.

Montana Category 1 Noxious Weeds *Centaurea stoebe* (*Centaurea maculosa*), *Cirsium arvense*, *Cynoglossum officinale*, *Hypericum perforatum*, *Leucanthemum vulgare* and *Linnaea vulgaris* all were all found in at least one plot and several species were found in two to three plots. Many recruited to new areas. While none of these species have more than trace cover at this time, the spread of weeds across this project should be closely monitored. Herbicide application should continue in this area to reduce noxious weeds. Frequent weeding of exotic species is also recommended to enhance native species survival.

Plots should be read again in 2013 (year 3), 2015 (year 5) and 2020 (year 10).

Figure 7. GTSR-Phase VI: Location of Plots

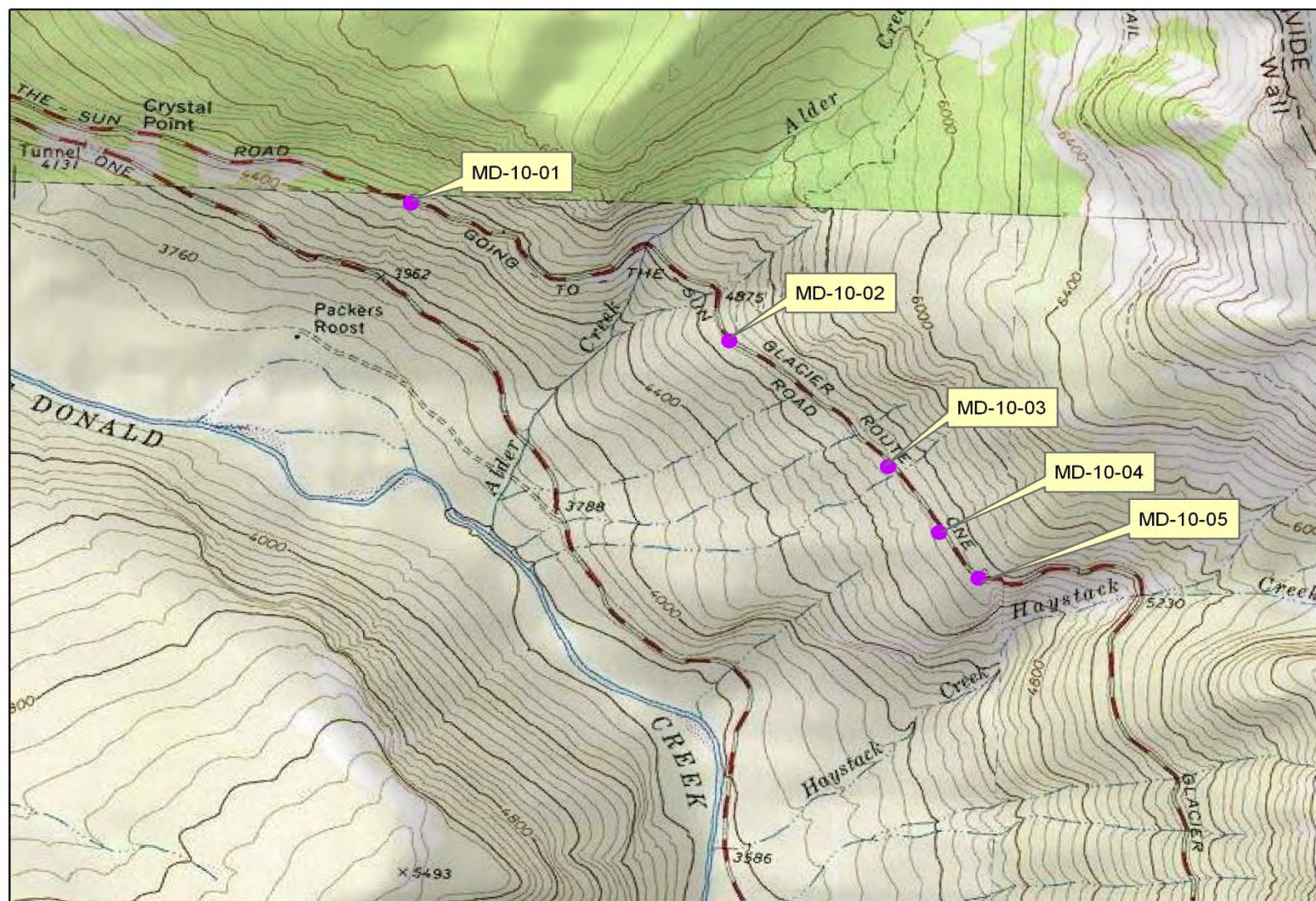


Table 14. GTSR-Phase VI: List of seeded species and their seed rates

Species	Grams of seeds	Seeds/ft ²	Acc. #
Forbs/Shrubs			
<i>Achillea millefolium</i>	73g	5 seeds/ft ²	9054522, 9054562, 9057899, 9076137
<i>Chamerion angustifolium</i>	28g	5 seeds/ft ²	9087363, 9082171
<i>Eurybia conspicua</i>	138g	5 seeds/ft ²	9081946, 9087433
<i>Fragaria spp.</i>	1.2g	trace/ft ²	09-002
<i>Geum macrophyllum</i>	261g	5 seeds/ft ²	9087654
<i>Monarda fistulosa</i>	6.11g	0.2 seeds/ft ²	9088010, 9088080
<i>Penstemon confertus</i>	39.0g	4 seeds/ft ²	9057993
<i>Penstemon hyallii</i>	29.78g	0.3 seeds/ft ²	9063300, 9057994
<i>Solidago canadensis</i>	32.5g	5 seeds/ft ²	9081611
<i>Spiraea betulifolia</i>	26.8g	0.8 seeds/ft ²	9078402
Grass/Sedge:			
<i>Carex pachystachya</i>	532g	seed weight estimated at 4900 seeds/g 30 seeds/ft ²	9078645
<i>Carex rossii</i>	119g	seed weight estimated at 2500 seeds/g 3.41 seeds/ft ²	9088095
<i>Elymus glaucus</i>	5866g	20 seeds/ft ²	9087927
<i>Elymus trachycaulus</i>	5462g	20 seeds/ft ²	cultivar Revenue
<i>Bromus carinatus</i>	9469g	20 seeds/ft ²	cultivar Garnet
<i>Festuca occidentalis</i>	1136g	10 seeds/ft ²	cultivar

Table 15. GTSR-Phase VI: Plants Added to Turnout Areas, 2012.

Species	Number of plants
<i>Betula papyifera</i>	10
<i>Populus balsamifera</i>	10
<i>Arctostaphylos uva-ursi</i>	10
<i>Cornus sericea</i>	9
<i>Cornus sericea</i>	6
<i>Holodiscus discolor</i>	7
<i>Paxistima myrsinites</i>	7
<i>Rubus parviflorus</i>	10
<i>Salix scouleriana</i>	14
<i>Spiraea betulifolia</i>	7
<i>Symphoricarpos albus</i>	10
<i>Anaphalis margaritacea</i>	7
<i>Eurybia conspicua</i>	21
<i>Fragaria virginiana</i>	1
<i>Maianthemum stellatum</i>	10
<i>Penstemon confertus</i>	35
<i>Solidago canadensis</i>	21
<i>Symphyotrichum laeve</i>	10
<i>Carex pachystachya</i>	21
Total plants	226

Table 16: GTSR-Phase VI: Ocular Canopy Cover of all Species by Plot, 2010-2012.

Species:	MD-10-01				MD-10-02				MD-10-03				MD-10-04				MD-10-05			
	source	2010	2011	2012	source	2010	2011	2012	source	2010	2011	2012	source	2010	2011	2012	source	2010	2011	2012
TREE	planted?	T	3	1	planted?	0	0	1-	planted?	T	T	2	planted?	2+	3	5	planted?	2	5	5
<i>Abies lasiocarpa</i>	p													T	T	T				
<i>Betula papyrifera</i>					p					T	T	T								
<i>Picea engelmannii</i>				T														2	5	5
<i>Populus balsamifera</i>	p	T	3	1	p			1-		T	T	1+		2	3	5			T	T
<i>Pseudotsuga menziesii</i>	p		T	T										T	T	T				
SHRUB	planted?	14	15	11	planted?	T	1	5	planted?	9	5	11	planted?	4	3	4	planted?	2	3	5
<i>Acer glabrum</i>		T+	1+	1									p		T	T		T	T	1
<i>Alnus viridis</i>								T+		T										
<i>Amelanchier alnifolia</i>		T	1	0.5									p							
<i>Arctostaphylos uva-ursi</i>	p	2-	1+	1	p	T	T	T	p	3-	1	T+	p						T	T
<i>Cornus sericea</i>	p	5	4	3	p			1+		3	T	1.5	p	1	1	1	p	1	1	1+
<i>Dasiphora floribunda</i>				T												T				T
<i>Holodiscus discolor</i>			T	T				T												
<i>Mahonia repens</i>	p				p	T	T		p	T	T	1-						T	T	T+
<i>Paxistima myrsinites</i>	p				p			T		T	T	T						T	T	T+
<i>Prunus virginiana</i>	p				p					T	T	1-								
<i>Ribes viscosissimum</i>		T	T			T			p				p							
<i>Rosa woodsii</i>	p				p					2 (other Rosa sp?)	3	5					p	T+	1	2
<i>Rosa sp.</i>				T																
<i>Rubus idaeus</i>		T+	1	1		T	T	1		T	T	T	p	T		T				
<i>Rubus parviflorus</i>		T+	T+	0.5	p					T	1	0.5	p	T		T				
<i>Salix sp.</i>	p	5											p	2-						
<i>Salix boothii</i> (?)	p												p		1	2+				
<i>Salix commutata</i> (?)	p		3	1				T					p							
<i>Salix scouleriana</i>	p		T	T				T					p							
<i>Salix sitchensis</i>	p		T	T									p							
<i>Sambucus racemosa</i>						T (regen)	1	2										T		
<i>Sorbus scopulina</i> (on edge, not reveg.)															T	T				
<i>Spiraea betulifolia</i>	p/s	T	2	1	p/s	T	T	T	p/s	T+	T	1-	p/s	T	T	T	p/s	T	T	T+
<i>Symphoricarpos albus</i>		1	1	1	p			T						T+	1	T		T	T	T
NATIVE FORB		T	1	1		1	3	3		1	5	10		2	5	9		2	7	20
<i>Achillea millefolium</i>	s	T	T	T	s	T	T	T	s	T	4	4+	s	T+	3	5	s	1-	5	6
<i>Actaea rubra</i>																			T	T
<i>Anaphalis margaritacea</i>			T	T		T	T	T				T				T			T	T
<i>Angelica arguta</i>												T			T	T				
<i>Antennaria bonellii</i>	p				p	T	T	T	p	T		T					p	T	T	T
<i>Antennaria rosea</i>							T	T			T	T							T	T
<i>Aquilegia flavescens</i>																T		T	T	T
<i>Arabis drummondii</i>											T	T				T				
<i>Arabis hirsuta</i>			T																	
<i>Arabis bolboellii</i>							T													
<i>Artemisia ludoviciana</i>				T		T	1	1			T	T		T	T	1-				T

Table 16 cont'd: GTSR-Phase VI: Ocular Canopy Cover of all Species by Plot, 2010-2012.

Species:	MD-10-01				MD-10-02				MD-10-03				MD-10-04				MD-10-05			
	source	2010	2011	2012	source	2010	2011	2012	source	2010	2011	2012	source	2010	2011	2012	source	2010	2011	2012
NATIVE FORB cont'd	planted?																			
<i>Aster sp.</i>	p	T																		
<i>Brickellia grandiflora</i>												T								T
<i>Campanula rotundifolia</i>															T	T				
<i>Cardamine pensylvanica</i>						T				T				T						
<i>Castilleja miniata</i>		T		T											T	T				T
<i>Chamerion angustifolium</i>	s	T		T	s				s	T		T	s			T	s	T	T	T+
<i>Cirsium hookerianum</i>												T		T	T	T				
<i>Conyza canadensis</i>																			T	T
<i>Convolvulus arvensis</i>																T				
<i>Cryptantha (?) - annual</i>																			T	
<i>Draba nemerosa</i>																			T	
<i>Epilobium brachycarpum</i>				T				T				T				T				
<i>Epilobium brachycarpum (wide leaves)</i>			T				T				T	T		T	T	T			T	T
<i>Epilobium sp.</i>						T								T						
<i>Erigeron strigosus</i>																				T
<i>Eurybia conspicua (Aster conspicuus)</i>																				T
<i>Fragaria vesca</i>	s			T	s	T		T	p/s	T	T	T	p/s	T	T	T	s			T
<i>Fragaria virginiana</i>	p/s	T	T	T	s	T	T	T	p/s	T	T	T	p/s	1	T	T	s	T	T	1+
<i>Galium triternatum</i>												T								
<i>Geranium bicknellii</i>						T														
<i>Geum macrophyllum</i>	s	T	T	T	s	T	T	T	s	T	T	T+	s	T	T	T+	s		1	5
<i>Gnaphalium macounii</i>						T														
<i>Heracleum sphondylium</i>												T								
<i>Illiciopsis rivularis</i>	p			T	p	T	T	T	p			T	p	T	T	T	p	T	T	1
<i>Maianthemum stellatum</i>		T	T	T			T	T					p							
<i>Minuartia sp.</i>															T					
<i>Monarda fistulosa</i>	s		T		s	T	T	T+	s		T	T	s		T	T	s		T	T
<i>Oxyria digyna</i>																			T	T
<i>Penstemon albertinus</i>						T														
<i>Penstemon confertus</i>	p/s	T	T	T	p/s	T	T	T	p/s	T	T	T	p/s	T	T	T	p/s	T	T	3
<i>Penstemon ellipticus</i>						T														
<i>Penstemon hyalii</i>	p/s	T	T	T	s			T	p/s	T	T	T	p/s	T	T	T	s		T	T
<i>Phacelia hastata</i>						T		T		T				T		T				1
<i>Phacelia sericea</i>															T				T	T
<i>Plagiobothrys snyderi</i>		T																		T
<i>Polygonum achoreum</i>							T	T												
<i>Polygonum douglasii</i>											T	T				T				
<i>Potentilla glandulosa/arguta</i>												T				T				
<i>Solidago canadensis</i>	p/s	T	T	T	p/s	T	T	T+	s	T	T	2-	s	T	T	1-	p/s			T
<i>Solidago multiradiata</i>			T																	
<i>Symphotrichum laeve (Aster laevis)</i>	p	T	T+	T	p	T	T	T	p	T	T	1+		T	T	T+		T		1
<i>Urtica dioica</i>										T	T	T			T	T		T	T	T
<i>Viola spp.</i>														T						

Table 16 cont'd: GTSR Phase VI: Ocular Canopy Cover of all Species by Plot, 2010-2012.

Species:	MD-10-01				MD-10-02				MD-10-03				MD-10-04				MD-10-05			
	seeded?	2010	2011	2012	seeded?	2010	2011	2012	seeded?	2010	2011	2012	seeded?	2010	2011	2012	seeded?	2010	2011	2012
NATIVE GRASS		T	T	T		T	1	1		T	1	3		T	2-	T		T	T	4
<i>Agrostis scabra</i>			T								T	T				T				
<i>Bromus carinatus</i>	s	T		T	s	T	T	T	s	T	T	T	s	T	T		s		T	1
<i>Carex sp.*</i>	s				s	T		T	s				s	T			s	T		T
<i>Carex atbrostachya</i>							T				T	T								
<i>Carex deweyana</i>															T					
<i>Carex pachystachya</i>	s				s				s		T	T	s		T		s			
<i>Deschampsia elongata</i>																				T
<i>Elymus glaucus</i>	s		T	T	s		T	T	s		T	2	s		1		s		T	3
<i>Elymus trachycaulus</i> v. <i>trachycaulus</i>	s	T	T	T	s		T	T	s			T	s				s		T	T
<i>Hordeum jubatum</i>											T	T								
<i>Poa alpina</i>															T					
<i>Trisetum cernuum</i> (?)		T								T				T				T	T	
EXOTIC GRASS		T	1	T		T	1	1		T	1	2		T	2	T		T	1	1
<i>Agrostis stolonifera</i>			T	T			T	T			T	T+			T					T+
<i>Bromus secalinus</i> (?)			T	T												T (P)				
<i>Bromus tectorum</i>			T	T			T	T			T	T			T	T (P)			T	T
<i>Elymus repens</i>							T	T		T		T								
<i>Lolium perenne</i>															T					
<i>Panicum capillare</i>						T (P)														
<i>Phleum pratense</i>							T	T			T	T		T	T				T	
<i>Poa annua</i>				T (P)				T		T		T						T		T
<i>Poa compressa</i>		T	1	T		T	T	T			T				T				T	T
<i>Poa pratensis</i>			T	T			T	T				T		T	T				T	T
<i>unknown grass</i>								T				T			T			T		
EXOTIC FORB		1	T	T		3	8	4		T+	2	3		1	3	3		3	1	1
<i>Achillea nobilis</i>							T								T	T				T
<i>Amaranthus graecizans</i>														T (P)						
<i>Arenaria serpyllifolia</i>						T		T (P)							T	T (P)		T (P)		
<i>Artemisia absinthium</i>																T (P)				
<i>Cardamine oligosperma</i>											T									
<i>Capsella bursa-pastoris</i>		T		T		T (P)	T	T (P)		T	T	T		T (P)	T	T (P)		2-	T	T
<i>Centaurea stoebe</i> (<i>Centaurea maculosa</i>)				T (P)		T	T	T (P)							T					
<i>Ceratium fontanum</i>				T			T					T			T	T				
<i>Chaenorrhinum minus</i>						T		T			T	T								
<i>Chenopodium album</i>								T (P)		T (P)	T	T		T (P)	T			T (P)	T	T
<i>Chenopodium sp.</i>						T				T (P)										
<i>Cirsium arvense</i>						T	T	T		T	T	T+						T (P)		T
<i>Cirsium vulgare</i>						T	T											T		T
<i>Cynoglossum officinale</i>						T	T			T	T	T		T (P)	T	T (P)		T (P)	T	T (P)
<i>Descurainia sophia</i>														T (P)				T (P)		
<i>Erodium cicutarium</i>						T	T	T		T (P)										
<i>Filago arvensis</i>															T			T (P)		
<i>Gnaphalium palustre</i>														T						
<i>Hypericum perforatum</i>		T (P)	T	T (P)		T (P)	T	T (P)							T	T (P)				
<i>Lactuca serriola</i>											T			T (P)	T	T		T (P)		
<i>Lamium amplexicaule</i>														T (P)				T (P)		T
<i>Leucanthemum vulgare</i>			T	T (P)										T (P)		T (P)			T	
<i>Linaria vulgaris</i>											T	T								

Table 16 cont'd: GTSR Phase VI: Ocular Canopy Cover of all Species by Plot, 2010-2012.

Species:	MD-10-01			MD-10-02			MD-10-03			MD-10-04			MD-10-05		
	2010	2011	2012	2010	2011	2012	2010	2011	2012	2010	2011	2012	2010	2011	2012
EXOTIC FORB cont'd															
<i>Matricaria matricarioides</i>						T (P)								T	
<i>Medicago lupulina</i>	T (P)	T	T	T (P)	T	T (P)			T	T (P)	1	1	T (P)	T	T
<i>Melilotus officinalis</i>	T+ (P)		T		T	T (P)					T	T		T	
<i>Melilotus sp.</i>				T (P)											
<i>Mustard sp.</i>					T										
<i>Myosotis arvensis</i>				T											
<i>Myosotis stricta</i>														T	T
<i>Plantago major</i>					T	T		T	T	T	T	T+			T
<i>Polygonum aviculare</i>				T (P)		T (P)	T (P)			T (P)		T	T (P)		
<i>Polygonum convolvulus</i>				T (P)	T	T (P)				T (P)		T	T (P)		
<i>Potentilla argentea</i>								T							
<i>Potentilla norvegica</i>				T	T	T (P)									T (P)
<i>Prunella vulgaris</i>					T			T		T	T	T			
<i>Rumex acetosella</i>					T	T			T						
<i>Rumex crispus</i>							T	T	T		T	T	T (P)	T	T+
<i>Rumex sp.</i>				T	T										
<i>Silene latifolia</i>										T	T	T		T	T
<i>Sisymbrium altissimum</i>				T (P)	T	T		T		T (P)	T		T+ (P)		
<i>Spergularia rubra</i>			T						T			T			
<i>Taraxacum officinale</i>	T (P)		T				T	T	T		T	T	T (P)		T
<i>Thlaspi arvense</i>				T		T (P)				T (P)	T	T	T (P)	T	T
<i>Tragopogon dubius</i>				T										T	
<i>Trifolium agrarium</i>	T (P)	T		T	T										
<i>Trifolium hybridum</i>										T	T	T			T
<i>Trifolium pratense</i>		T	T		T				T		T	1			T
<i>Verbascum thapsus</i>	T (P)	T	T	2	4	T (P)	T			T (P)	T		T (P)	T	
<i>Veronica arvensis</i>							T							T	T
<i>Veronica peregrina</i>								T							
<i>Veronica serpyllifolia</i>				T	T	T		T	T	T	T				

(P) = Pulled some or all

red text = noxious weed species

p = planted s = seeded

*CARPHA & CARPRA are in plot 2

V. WHITEBARK AND LIMBER PINE RESTORATION PROJECTS

A. INTRODUCTION

Whitebark pine (*Pinus albicaulis*), is a long-lived, slow-growing mid to high-elevation five-needled pine tree. In Glacier National Park, this species is found on the east and west sides of the Continental Divide, although it is more abundant on the east side. Whitebark pine is considered a keystone species because of the important role it plays in the ecosystem. It is a hardy subalpine conifer that tolerates poor soils, steep slopes, windy exposures, and tree-line environments (Arno and Hoff 1990). This species provides valuable cover, shelter and nesting opportunities for many wildlife species. The grizzly bear and Clark's nutcracker rely on their seed for food. These trees also influence vegetation patterns by pioneering dry, exposed sites where no other tree species can grow. Because they establish on windy ridges and have broad crowns, they accumulate and retain snow which lengthens the snow melt period.

Another five-needled pine, limber pine (*Pinus flexilis*), is also considered to be a keystone species. This tree is found only on the east side of the Continental Divide in the park. Small to medium in size, it often grows on rocky ridges and its form is frequently irregular. At the lower tree line it mixes with other conifers. Being relatively shade-intolerant, it is mostly a pioneer species and maintains its presence only on somewhat severe sites. Like whitebark pine, this species also provides valuable cover, shelter and nesting opportunities. The large seeds are a nutritious food source for birds, rodents, and bears.

Whitebark and limber pine populations have declined dramatically in Glacier National Park, largely due to the introduction of a non-native fungus, white pine blister rust (*Cronartium ribicola*). White pine blister rust is a disease of five-needled pines and has been linked to the decline of all five-needled pines in the Park. Severe climatic events, mistletoe, fire exclusion, and/or mountain pine beetles may have also contributed to the poor health of these trees. Whitebark pine mortality has been estimated at 44% within the park with approximately 78% of the remaining live trees infected (Kendall and Keane 2001). Kendall and Keane (2001) have also estimated limber pine mortality in Glacier National Park at 39% with 78% of the remaining live trees infected. Recent anecdotal evidence regarding limber pine stands indicates that current mortality and infection rates for this species have increased since 2001 and may be comparable to those observed in whitebark pine populations.

Some mature whitebark and limber pines have shown phenotypic genetic resistance to blister rust including few to no blister rust cankers, healthy needles, and cone production. These 'plus' trees continue to be identified in the park. Restoration efforts for these two species began in 1997 when seeds were collected from trees that showed phenotypic genetic resistance. In 1998, Glacier National Park received funding from the Intermountain Region Natural Resource Fund to continue collection efforts, grow seedlings from collected seeds, and plant seedlings at specific sites around the park. These seedlings have been planted in an effort to restore the ecosystem with disease-resistant trees. Limber pine seedlings have been planted at select sites on the east-side of the Park and whitebark pine seedlings have been planted at eight sites, six on the east-side and two on the west-side. Sites were selected based on accessibility for planting, appropriate habitat characteristics, and recent burn activity. Planting years are chosen based on the availability of seedlings.

Due to the mortality and expense associated with growing and planting seedlings, another restoration approach was initiated in 2006 and continued in 2007. To date, seeds from potentially resistant whitebark pine trees were directly planted at three sites, two of which have burned in recent years. Seeds were cached in groups, mimicking planting schemes of Clark's nutcrackers. The idea behind this strategy is not only to minimize expense, but also to provide a more natural scenario whereby seed can germinate when environmental conditions are favorable. Seedlings were also planted at two of the sites for comparison.

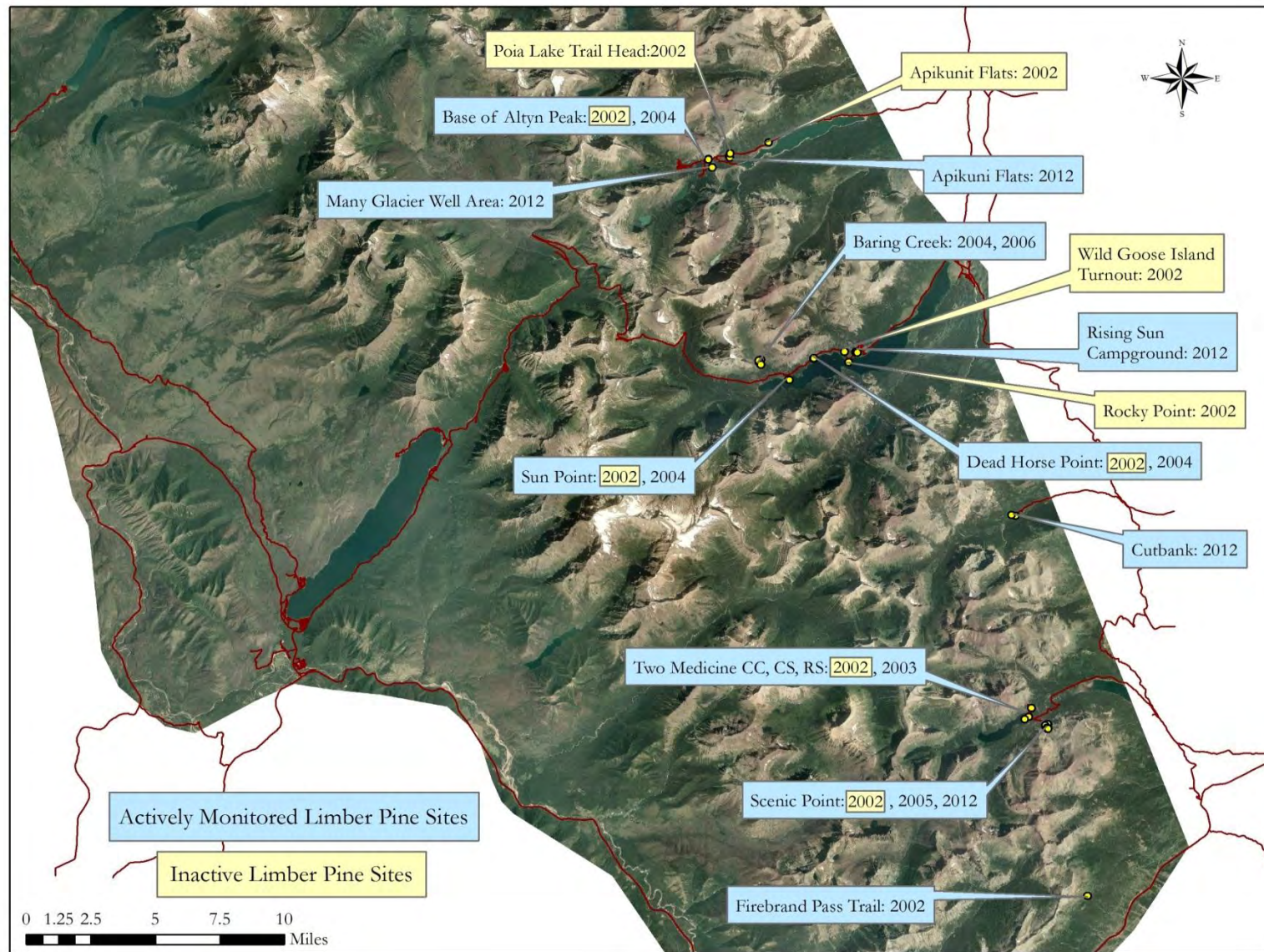
1. Limber Pine

Limber pine seedlings have been planted on sixteen sites, eleven of which continue to have live trees in monitoring plots (Table 17 & Figure 8). A total of 7,756 seedlings have been planted in the park between 2002 and 2012. Plantings typically occurred in the fall but a few plantings occurred in the spring. Planting sites and the total number of seedlings planted varied between years. Monitoring plots captured 23% of total planted seedlings (Table 17).

Table 17. Limber Pine Monitoring Plot Establishment

<i>Site</i>	<i>Year</i>	<i># of Plots Established</i>	<i># of Trees Planted Overall</i>	<i>Total # Trees Captured</i>	<i>% Trees Monitored</i>
Apikuni Flats	2002	2	160	25	16%
	2012	2	662	123	19%
Total		2	822	148	18%
Baring Creek	2004	5	450	91	20%
	2006	3	250	71	28%
Total		8	700	162	23%
Base Altyn Peak	2002	1	160	27	17%
	2004	2	200	40	20%
Total		3	360	67	19%
Cutbank	2012	2	286	82	29%
Total		5	286	82	29%
Dead Horse Point	2002	5	800	188	24%
	2004	2	250	53	21%
	2006	1	262	20	8%
Total		8	1312	261	20%
Firebrand Pass	2002	2	140	38	27%
Total		2	140	38	27%
Many Glacier Well Area	2012	1	196	64	65%
Total		1	196	64	33%
Poia Lake TH	2002	2	160	41	26%
Total		2	160	41	26%
Rising Sun	2012	2	570	130	23%
Total		2	570	130	23%
Rocky Point	2002	2	150	37	25%
Total		2	150	37	25%
Scenic Point	2002	4	200	74	37%
	2005	6	700	149	21%
	2012	4	1264	326	26%
Total		14	2164	549	25%
Sun Point	2002	2	220	53	24%
	2004	2	250	54	22%
Total		4	470	107	23%
Two Medicine CG	2002	2	160	35	22%
Total		2	160	35	22%
Two Medicine CS	2003	1	26	26	100%
Total		1	26	26	100%
Two Medicine RS	2002	2	140	38	27%
Total		2	140	38	27%
Wild Goose Island TO	2002	1	100	29	29%
Total		1	100	29	29%
Overall Total		58	7,756	1,814	23%

Figure 8. Limber Pine Seedling Monitoring Sites



In 2012, 2,978 limber pine seedlings were planted, the most limber pine trees that have been planted in Glacier National Park since the restoration program began. The second largest planting took place in 2002 with 2,390 trees planted. Due to lack of suitable limber pine habitat that has burned, no seedlings from any year have been planted in burn areas. Additionally, limber pine has not been utilized in the Montana State ectomycorrhizal inoculation study, so no limber pine seedlings have been inoculated. Recently, most seedlings have been grown with several trees in one container. Multiple trees, therefore, are often planted in one hole during restoration plantings.

The three areas that were planted in 2012 had also been previously planted in 2002, including Apikuni Flats, Rising Sun Campground, and Scenic Point. No trees survived in plots in these areas from 2002, a drought year, although no monitoring plots were installed at Rising Sun Campground to monitor 2002 trees. Additionally, two new sites were selected in 2012; Cutbank campground area and the Many Glacier water supply area.

The largest number of seedlings this year was planted at the Scenic Point area, a site that had also been planted with limber pine in 2002 and 2004. It harbored one of the park's largest limber pine stands, most of which are no longer living. However, some mature trees and seedlings do persist in this area. Although the soil is rocky in this area, microsites and natural shade were utilized as much as possible to prevent desiccation of seedlings. Rocks, logs, stumps and snags were utilized as microsites. Planting elevations range from 5,575 to 5,735. Altogether, 1,264 seedlings were planted in this area in 2012; 284 in the spring and 980 in the fall. A total of 26% of seedlings are being monitored at Scenic Point from 2012.

Apikuni Flats is located near the confluence of Apikuni Creek and Lake Sherburne in a very gently sloped area of the Many Glacier Valley. Limber pine have historically been scattered in this area and a few mature limber pine trees survive in this area today. Plot elevations range from 4,904 to 4,927 feet. Vegetative cover is high at this site, particularly with grasses, so some scalping of vegetation at planting sites occurred to reduce competition. Natural microsites were limited in this area as well, so rocks, logs and branches were re-located for use as planting microsites. A total of 662 seedlings were planted at Apikuni Flats in 2012; 270 in the spring and 392 in the fall with 19% of the seedlings being captured in monitoring plots.

Additionally, 196 seedlings were planted on a ridge near the Many Glacier water supply area. All of these trees were planted in the fall, 33% of which were captured in monitoring plots. This area is also highly vegetated with grasses and forbs so scalping of planting sites also occurred at this site. This is a more naturally rocky area, bordering a small cliff band, and rocks were primarily utilized as microsites. Elevation is 5,125 feet.

Rising Sun Campground is located in a relatively flat area at the confluence of Rose Creek and St. Mary Lake, ranging from 4,525 to 4,540 feet in elevation. Limber pine have historically been scattered in this area. Seedlings were planted in an open meadow area and in wooded areas of the campground with low understory cover. Logs were mostly utilized as planting microsites. A total of 570 limber pine seedlings were planted at this site; 286 in the spring and 284 in the fall. Only spring plantings were monitored at this site, capturing 23% of seedlings.

A new planting area was established in the Cutbank Campground area in 2012. One site lies within the campground itself and a second site is located about 220 meters west of the campground in a small opening just above the Triple Divide trail. Elevations range from 5,185 to 5,240 feet. Limber pine are not historically present in this area but have grown nearby. The campground area offers shade from a mature canopy and little groundcover competition. The site above the trail, however, is highly vegetated and provides ample vegetative competition for seedlings. Microsites were provided here when possible, using small logs or branches when possible. Microsites were more prevalent in the campground area in the form of stumps and snags. This site was only planted in the spring; 286 seedlings were planted with 29% seedlings captured in monitoring plots.

2. *Whitebark Pine*

Whitebark pine seedlings have been planted at nine sites between 2000 and 2012, all of which continue to support live trees (Table 18 & Figure 9). A total of 11,030 seedlings have been planted in the park between 2002 and 2012. Most sites were planted in the fall, although some areas at Flattop Mountain were planted in the spring and two sites, specifically Cobalt Lake and Grinnell Glacier Picnic Area, were planted in late summer. Monitoring plots have captured 22% of total planted seedlings (Table 18). The number of plots created at each site was dependent on planting densities and number of seedlings planted at the site. Data on the survival and health of individuals were collected during each monitoring event.

Table 18. Whitebark Pine Seedling Monitoring Plot Establishment

<i>Site</i>	<i>Year Established</i>	<i># of Plots Established</i>	<i># of Trees Planted</i>	<i># of Trees Monitored</i>	<i>% Trees Monitored</i>
Flattop Mtn.	2001(spring)	16	1,500	285	19%
	2001(fall)	11	1,438	350	24%
	2002 (fall)	11	2,222	292	13%
Total		38	5,160	927	18%
Grinnell Point	2000 (fall)	7	96	96	100%
Caper Peak	2006 (fall)	2	139	139	100%
Red Eagle	2007 (fall)	9	2,000	422	21%
Divide Creek	2010 (fall)	5	1,126	263	23%
Hole-in-the-Wall	2010 (fall)	5	830	159	19%
Grinnell Glacier Picnic	2011 (summer)	2	146	98	67%
Cobalt Lake	2011 (summer)	3	250	108	43%
Divide Mountain	2012 (fall)	4	1,283	216	17%
Overall Total		75	11,030	2,428	22%

In the fall of 2000, 96 seedlings were planted at Grinnell Point after the Grinnell Point Fire passed through the site earlier in the season. Plantings in this area range in elevation from 6,560 – 7,320 feet. All seedlings planted at this site were incorporated into monitoring plots. Due to the difficulty of accessing this site, these plots have not been visited by Glacier National Park Staff since planting.

Almost half of the whitebark pine seedlings have been planted at Flattop Mountain, another site that has experienced recent fire. Seedlings were planted at this location, which burned in the McDonald Creek Fire of 1998, at elevations between 6,300 and 6,800 feet. A total of 5,160 trees were planted on Flattop Mountain between 2001 and 2002 with 927 trees incorporated in monitoring plots, capturing 18% of planted seedlings (Table 18). Plantings occurred in early summer and fall with various numbers of seedlings planted during each planting event.

In fall of 2006, 139 seedlings were planted at Caper Peak above Lake Isabel. This site is located at 6,520 feet and burned in the Rampage Fire of 2003. All seedlings planted at this site were included in monitoring plots. Due to the remote location of these sites, they were not monitored until 2008. In addition, whitebark pine seeds have been directly planted in the ground at this site (Table 19). A total of 423 whitebark pine seeds were planted in the fall of 2006 in caches of 4 to 13 seeds. All seeds planted at this site were placed in monitoring plots. Germination rates and survival results of direct seeding may take several years to determine.

In 2007, 2,000 whitebark pine seedlings were planted along the eastern flank of Red Eagle Mountain and near the Red Eagle Campground that burned in the 2006 Red Eagle Fire. A total of 422 seedlings, 21% of the planted trees, were captured in nine monitoring plots; 359 seedlings are being monitored on the midslope of Red Eagle Mountain at elevations between 5,700 and 5,900 feet, while 63 seedlings were monitored on an open knoll near the campground at 4,800 feet in elevation. A new methodology was used to install two transects to monitor whitebark pine seed directly planted into the ground (see Methods section). A total of 102 whitebark pine seeds were planted in caches along a 25m transect on the midslope of Red Eagle Mountain, while 98 whitebark pine seeds were planted in caches along a 20m transect on the same open knoll near the Red Eagle Campground (Table 19).

Using the same methodology, three additional transects were installed in 2007 at Siyeh Bend along the Going-To-The-Sun Road to monitor whitebark pine seed germination and tree growth in a more natural setting (Figure 9). Thirty-one seeds were planted along one 20m transect that was installed on a flatter section of slope, while 70 seeds were planted within two transects that were installed on flat benches near Siyeh Bend (Table 19).

Figure 9. Whitebark Pine Seedling and Seed Monitoring Sites

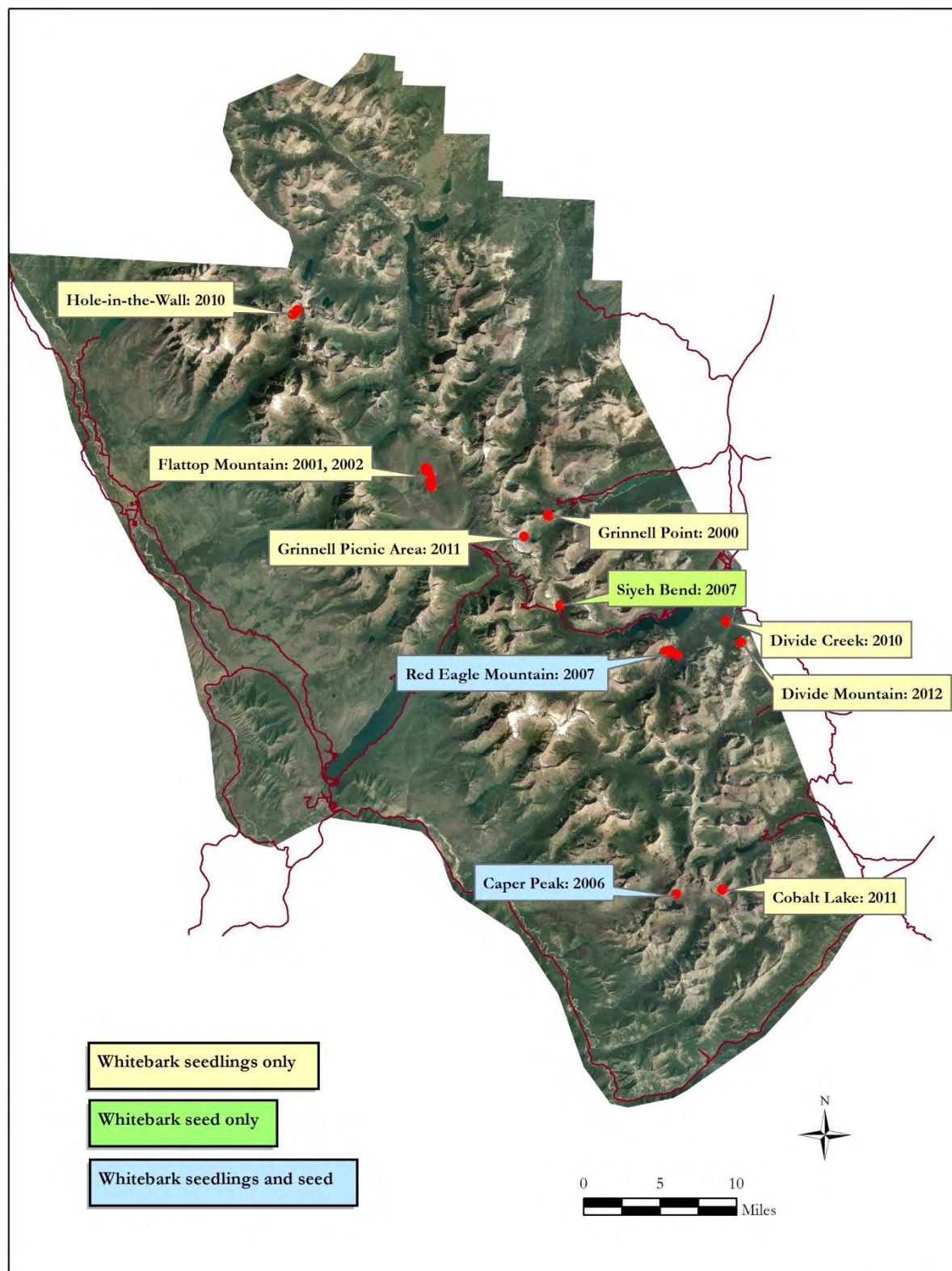


Table 19. Whitebark Pine Seed Plot Establishment

<i>Site</i>	<i>Year Established</i>	<i># of Plots Established</i>	<i># of Seeds Monitored</i>	<i>Source of Seed</i>
Caper Peak	2006 (fall)	2	423	unkown
Siyeh Bend	2007 (summer)	3	101	Preston Park, 2005 (#155)
Red Eagle Mtn.	2007 (fall)	1	102	Preston Park, 2005 (#155)
Red Eagle CG	2007 (fall)	1	98	Preston Park, 2005 (#155)
Total		7	724	

In the fall of 2010, two sites were planted with whitebark pine seedlings. The Hole-in-the-Wall Campground area was the first site where whitebark pine seedlings were planted in a non-burned area. Whitebark pine, however, currently grows in this area and historic whitebark pine stands also existed in the area. Divide Creek was the second planting site established in 2010. This site burned in the 2006 Red Eagle Fire with moderate severity. Whitebark pine has not historically grown at this site but the area is located within potential whitebark pine habitat.

In August 2010, a total of 830 whitebark pine seedlings were planted in the Hole-in-the-Wall campground area and in the cirque area above the campground. Elevations of planting sites ranged from 6,349 to 6,922 feet. Since this site has not been burned, an area of vegetation was “scalped” surrounding planting sites to reduce competition. Additionally, special attention was given to planting in sites with minimal surrounding vegetation, especially *Xerophyllum tenax*. Seedlings were preferentially planted near *Vaccinium scoparium*, *Luzula hitchcockii*, *Carex geyeri* and *Carex rossii*, since whitebark pine is disproportionately associated with these species (Izlar 2007). Microsites were utilized or provided for seedlings when possible. Five monitoring plots were established containing 159 seedlings, monitoring 19% of planted trees.

In September 2010, a total of 1,126 whitebark pine seedlings were planted on a ridge above Divide Creek. The elevation of this area ranged from 5,720 to 5,760 feet. Existing burned stumps and logs were used as planting microsites. As part of the planting, 300 of the seedlings planted at Divide Creek had been previously inoculated at Montana State University with a slurry made from ectomycorrhizal (ECM) mushroom species. Pines require ECM fungi for normal growth and survival and studies have confirmed whitebark pine to be ectomycorrhizal (Cripps and Mohatt 2005). These seedlings were planted together in groupings of 3 trees per hole throughout the revegetation site. Five monitoring plots were installed, encompassing 261 seedlings or 21% of the total trees planted. Forty of the monitored seedlings were inoculated, 13% of the total inoculated seedlings.

Two sites were planted in 2011 with a small number of trees. In August 2011, 250 whitebark pine seedlings were planted near the campground at Cobalt Lake. The elevation near this planting area is approximately 6,600 feet. This area is not within a burn and, similar to the Hole-In-The-Wall site, vegetation was ‘scalped’ around the planted whitebark seedling to reduce competition. Seedlings were planted in forest openings nearby to existing whitebark pine trees. There were few natural microsites here so rocks and logs were placed near planting sites to create small microsites. Three monitoring plots were established that captured 108, or 43%, of planted seedlings.

Also in August 2011, 146 whitebark pine seedlings were planted at the Grinnell Glacier Picnic Area. The elevation near this planting area is approximately 6,240 feet. This area was also not within a burn but had both sparsely vegetated, open areas and denuded soil areas (from social trails) under trees. Both areas were used as planting sites and are nearby to existing whitebark pine trees. Similar to the Cobalt Lake site, there were few natural microsites, particularly in the open areas, so rocks and logs were placed near planting sites to create small microsites. Two monitoring plots were established that captured 98, or 67%, of planted seedlings.

This year, one whitebark pine planting site was added. On September 19, 2012, 1,283 whitebark pine seedlings were planted on the northwest flank of Divide Mountain. Plantings occurred on the edge of the 2006 Red Eagle Fire, spanning from 7,070 to 7,150 feet in elevation. On occasion, plots spanned both burned and non-burned areas, although the majority of seedlings were planted in burned areas. Location within or outside of the burn was

recorded for each tree. This site is located at the edge of treeline among a standing dead forest of subalpine fir with a small whitebark pine component. Natural regeneration of whitebark pine seedlings is high here. This site is located at the base of a boulder field with abundant boulders, rocks, stumps and snags for use as planting microsites. Four plots were installed, containing 216 seedlings and representing 17% of seedlings planted. Almost half (47%) of seedlings planted had been inoculated with ectomycorrhizal fungi; 54% of monitored seedlings were inoculated. It is important to note that most of the seedlings planted at Divide Mountain were grown in the USFS Coeur d'Alene Nursery and were in good health at the time of planting. A smaller amount of planted trees at this site had been grown in the Glacier National Park Nursery and were not in as good of health due to the fact that they had been held over in cones to the point of being root-bound. While some of these trees may be within monitoring plots, the majority of the monitored trees appeared healthy and were likely trees from the Coeur d'Alene nursery.

B. METHODS

1. *Seedling Monitoring Plots*

Shortly after seedlings are planted, monitoring plots are installed. Plot locations are chosen based on areas that are representative of the planting site and that contain a relatively high concentration of newly planted trees. UTM coordinates are taken at plot center and directions to the plot are recorded. To further assist with center stake location, a photo is taken of each stake and its associated location and azimuth are recorded.

Plot center is permanently marked with a large nail, often painted florescent orange for visibility, and tagged with the plot number. Plot numbers are either engraved on brass tags or hand pressed on aluminum tags. Plot center is chosen in order to capture as many trees in all directions as possible. Descriptive data are recorded for the plot, including slope, aspect, elevation, light availability, landform, moisture regime, dominant lifeform cover, potential animal disturbance, and soil type. Special attention is given to describing the location of the center nail.

Each planted seedling within the plot is located and assigned a number. For each seedling, the distance from plot center, in meters, and azimuth from plot center are recorded. The health of each tree is assessed and recorded, using the following scale: 1=dead, 2=missing (not found), 3=almost dead, 4=fair, 5=good (healthy). Comments that further describe the tree's health or may have a bearing on its ability to survive (e.g. growth, dead needles, presence and type of microsite, and whether or not a seedling was inoculated with ectomycorrhizal fungi) are recorded as well.

Plots are distributed throughout the entire planting site to avoid over sampling any given area. Monitoring plots attempt to capture 20% to 25% of the total seedlings planted at each site. The number of seedlings captured per plot and plot radius varies between plots but ideally plots contain 15 to 50 trees with a radius not much larger than 10 meters. It is difficult to obtain accurate distances or see all seedlings in plots with radii greater than 10 meters.

Subsequent monitoring events entail locating each plot and each seedling within the plot and utilizing the 5 point scale of health and survival assessment with comments as deemed necessary. Trees assigned a "2" (missing) were either previously dead and subsequently had disintegrated or were not found. Many times a tree can be given a "2" one year and then be found alive the next year. Additionally beginning in 2006, height and width of whitebark pine seedlings began to be measured (in cm). Size measurements are being recorded for trees at the Flattop Mountain, Caper Peak, Red Eagle, Hole-in-the-Wall, Divide Creek, Cobalt Lake, Grinnell Glacier Picnic Area and Divide Mountain sites. Plots should be monitored at years 1, 2, 3, 5, 10, 15 and 20 years after planting as logistics permit.

2. *Whitebark Pine Seed Monitoring Transects*

There have been two methodologies used to install plots that monitor whitebark pine seed that is planted directly into the ground. On Caper Peak, two plots were installed in 2006 that resembled the whitebark and limber pine seedling plots. A center nail was installed, tagged, and documented with a GPS. Azimuth and distance from plot center measurements were then recorded for each seed cache, similar to the seedling plots described above. Multiple plantings occurred at each azimuth but with different distances from the center point. In this case, seed caches were interspersed with planted seedlings so that these two plots contain both seedlings and seed in the same plot. Plots ranged in size from 18 to 19 foot radius. Thirty eight and twenty nine caches of seed were installed in these respective plots with each cache containing 4 to 13 seeds (Table 20). Due to their remote location, these plots were not monitored in 2007 but were monitored in 2009, three years after seeding.

As stated above, a new methodology was used in 2007 near Siyeh Bend and Red Eagle Campground to monitor whitebark pine seed. In both locations, transects ranging from 20 to 30m were installed along relatively flat benches or mild slopes. These locations were chosen for their stability and the fact that large-scale snow movement that could take out both seedlings and monitoring stakes did not seem likely. Transects generally ran parallel to any slope that existed and were staked at the start and end of the transect line. GPS locations were recorded for these start and end points. A tape was laid out between these two points and then planting sites were haphazardly located at different distances either upslope or downslope originating from different lengths along the center line. Eight to thirteen caches of seed were then planted along the transect with 3 to 5 seeds per cache at Siyeh Bend and 6 to 10 seeds per cache at Red Eagle (Table 20). The location of each cache was staked with a tagged nail and the distance along the transect line and direction and distance up or down from the transect line was recorded. Attempts were made to plant the seed caches in appropriate microsites for shade or to prevent erosion and snow damage. Attempts were also made to plant the seed caches within relatively open areas to reduce competition from other vegetation. Associated species, microsite slope, and description of the microsite were recorded for each cache site.

Table 20. Whitebark Pine Seed Transect Data

<i>Location</i>	<i>Plot Number</i>	<i>Length of Transect</i>	<i># Seeds Planted</i>	<i># Caches Planted</i>	<i># of Seeds Per Cache</i>	<i>Average Seed # Per Cache</i>
Caper Peak	1	18 ft.	227	38	4 to 10	6.0
	2	19 ft.	196	29	5 to 13	6.8
Siyeh Bend	1	20m	31	8	3 to 5	3.9
	2	30m	39	10	3 to 5	3.9
	3	20m	31	8	3 to 5	3.9
Red Eagle	1	25m	102	13	6 to 10	7.8
	2	20m	98	12	6 to 10	8.2

C. RESULTS

1. *Limber Pine Seedling Results*

a. *2002 Plantings*

2012 was the ten year mark for monitoring limber pine seedlings planted in 2002. Unfortunately, only one seedling out of 585 seedlings monitored from 2002 plantings had survived to be monitored ten years after planting. Eleven sites were originally planted with limber pine seedlings in 2002, a period plagued by drought. One plot along the Firebrand Pass Trail was monitored on September 25, 2012. The lone surviving tree continues to thrive and increased 19 cm in height (from 11 to 30 cm) since 2008. It grew 35 cm in width (from 30 to 65 cm). No evidence of blister rust was observed.

b. *2003 Plantings*

Although seedlings from 2003 were not due to be monitored until next year, convenience allowed for monitoring of the only site planted in 2003. Only one tree was found to be surviving at the Two Medicine Camp Store site that was monitored on September 17, 2012. However, this was not a formal survey and a seedling rated “almost dead” at the last monitoring event in 2008 was not searched for. The located tree was thriving, however, and measured 30 cm tall by 38 cm side. It had not been previously measured.

c. *2012 Plantings*

Seedlings were planted at Many Glacier (Apikuni Flats and the Many Glacier Well Area), Cutbank, Rising Sun and Scenic Point in 2012. Monitoring plots were established at the time of planting for all sites. Plots for spring plantings were established by the revegetation crew. Plots for fall plantings were established by the monitoring crew

at all sites except for Rising Sun, which was planted in the spring and fall but not monitored in the fall. Spring plantings were monitored again in the fall at Scenic Point, Cutbank and Apikuni Flats to determine survival over the summer. Survival was determined based on all trees that were rated a 5 (good), 4 (fair), or 3 (almost dead).

1. *Apikuni Flats*

One plot was established at this site after planting in the spring and an additional plot was installed at this site after planting in the fall. All trees were alive and in good health at the time of planting in the spring (Table 21). After a summer of being planted out, 93% of these trees survived with 83% in good health. Three trees (7%) were dead or missing. Seedlings grew slightly in height (0.55 cm on average) but grew substantially in width (2.91 cm on average) over the course of the summer. Almost all trees were alive and in good health at the time of planting in the fall with only one tree in poor health. Seedlings planted in the fall were larger than initial measurements of seedlings planted in the spring at this site (0.22 cm taller and 2.32 cm wider). However, these spring-planted seedlings grew over the summer, resulting in larger trees than those planted in the fall (0.33 cm taller and 0.59 cm wider).

2. *Cutbank*

Two plots were established in the spring near the Cutbank Campground. Additional seedlings were not planted at this site in fall. All trees were alive and most were in good condition at the time of planting in the spring. Three trees (4%) were considered in fair condition at the time of planting and the rest were in good health. By fall, survival was 93%. Most trees, 78%, continued to be in good condition, while 12% were in fair condition and 4% were almost dead. Seedlings grew an average of 0.54 cm in height and 1.82 cm in width during the summer.

3. *Many Glacier Well Area*

One plot was installed at this new planting site in fall. All trees were in good health. Average height was 10.61 cm and average width was 7.69 cm.

4. *Rising Sun*

Seedlings were planted at this site in both spring and fall but were only monitored in the spring. At the time of planting, 96% of seedlings were rated in good health, while 3% were rated fair and 0.7% (one tree) was considered “almost dead”. Average height of trees was 7.43 cm and average width was 8.48 cm.

5. *Scenic Point*

Due to the high number of seedlings planted here in 2012, two monitoring plots were established in the spring and two monitoring plots were installed in the fall at this site. All trees were in at least fair condition at the time of planting with 97% considered in good health and 3% rated “fair”. By fall, 91% of the seedlings had survived, although only 52% were rated as “good”. Three percent were rated in “fair” condition and 36% were considered “almost dead”. Nine percent of seedlings were dead or missing at this more exposed site. Most of the seedlings that were in poor health were from plot LP12-06, the most exposed and rocky site. Seedlings grew 1.19 cm in height and 0.91 cm in width on average from spring to fall.

Seedlings planted in the fall had a 99% survival rate with 96% rated in “good” health. About 2% of trees were rated in “fair” condition, 2% were considered “almost dead” and 0.5% (one tree) was dead. Seedlings planted in the fall were taller than trees that were planted in the spring at the time of fall monitoring by an average of 1.65 cm, but trees planted in the spring were slightly wider by an average of 0.28 cm.

Table 21. Health and Survival of Limber Pine Planted in 2012

Site	Season Planted	Season Monitored	Dead/ Missing	Almost Dead	Fair	Good	# Survived	# of Trees Monitored	% Survival	Height (cm)	Width (cm)
Apikuni Flats	Spring	Spring	0	0	0	41	41	41	100	8.24	5.66
Apikuni Flats	Spring	Fall	3	1	3	34	38	41	93	8.79	8.57
Apikuni Flats	Fall	Fall	0	1	0	45	46	46	100	8.46	7.98
Cutbank	Spring	Spring	0	0	3	79	82	82	100	7.89	6.22
Cutbank	Spring	Fall	6	2	10	64	76	82	93	8.43	8.04
Many Glacier Well Area	Fall	Fall	0	0	0	64	64	64	100	10.61	7.69
Rising Sun	Spring	Spring	0	1	4	125	130	130	100	7.43	8.48
Scenic Point	Spring	Spring	0	0	5	158	163	163	100	7.76	7.59
Scenic Point	Spring	Fall	15	58	5	85	148	163	91	8.98	8.50
Scenic Point	Fall	Fall	1	4	3	172	179	180	99	10.63	8.22

Tables 22 to 25 recap survival over time of limber pine seedling monitoring sites that were planted from 2002 to 2006. For these planting years only, overall survival of limber pine trees at all sites over all years in monitoring plots is 6%. Thirty four percent of the remaining live trees have been rated 'fair' and 65% of the trees have been rated 'good'. Overall, 94% of all planted limber pine trees have died, the same mortality rate since 2009 (Table 22).

Table 22. Health and Survival of Remaining Live Limber Pine Seedlings Planted in 2002 - 2006

Site	Year Planted	Last Year Monitored	Dead / Missing	Almost Dead	Fair	Good	Unk.	# Survived	# of Trees Monitored	% Survival
Firebrand Pass	2002	2012	37	0	0	1	0	1	38	3%
Total 2002			584	0	0	1	0	1	585	0.2%
Two Med Camp Store	2003	2012	25	0	0	1	0	1	26	4%
Total 2003			25	0	0	1	0	1	26	4%
Baring Creek	2004	2009	71	0	7	13	1	20	91	22%
Base of Altyn Peak	2004	2009	28	0	7	5	0	12	40	30%
Sun Point	2004	2009	51	0	1	3	0	4	55	7%
Total 2004			150	0	15	21	1	36	186	19%
Scenic Point	2005	2010	128	1	5	15	0	21	149	14%
Total 2005			128	1	5	15	0	21	149	14%
Baring Creek	2006	2011	68	0	1	2	0	3	71	4%
Total 2006			68	0	1	2	0	3	71	4%
Subtotal			955	1	21	40	1	62	1017	6%
Percentage of Surviving Trees				2%	34%	65%	2%			
Percentage of Monitored Trees			94%	0.1%	2%	4%	0%	6%		6%

Table 23. Survival of Limber Pine Seedlings by Site, Planted in 2002

<i>Site</i>	<i>Monitoring Year</i>	<i>Total # Trees Monitored</i>	<i># Trees Survived</i>	<i>% of Trees Survived</i>
Apikuni Flats	2003	25	18	72%
	2004	25	0	0%
Base of Altyn Peak	2003	27	7	26%
(slope above Many	2004	27	1	4%
Glacier Hotel)	2006	27	1	4%
	2007	27	1	4%
	2009	27	0	0%
Dead Horse Point	2003	188	67	36%
	2004	188	0	0%
Firebrand Pass Trail	2003	38	27	71%
	2004	38	1	3%
	2006	38	1	3%
	2008	38	1	3%
	2012	38	1	3%
Poia Lake Trail Head	2003	41	21	51%
	2004	41	0	0%
Rocky Point	2003	37	10	27%
	2004	37	0	0%
Scenic Point	2003	74	56	76%
	2004	74	0	0%
Sun Point	2003	53	24	45%
	2004	53	1	2%
	2006	53	1	2%
	2007	53	1	2%
	2009	53	0	0%
Two Medicine CG	2003	35	14	40%
	2004	35	0	0%
Two Medicine RS	2003	38	24	63%
	2004	38	0	0%
Wild Goose Island	2003	29	18	62%
Turnout	2004	29	0	0%
Total One Year Survival	2003	585	286	49%
Total Two Year Survival	2004	585	3	0.5%
Total Four Year Survival	2006	585	3	0.5%
Total Five Year Survival	2007	585	3	0.5%
Total Six Year Survival	2008	585	3	0.5%
Total Seven Year Survival	2009	585	1	0.2%

*Cells highlighted in red have 0% survival. These are no longer being monitored

Table 24. Survival of Limber Pine Seedlings by Site, Planted in 2004

<i>Site</i>	<i>Monitoring Year</i>	<i>Total # Trees Monitored</i>	<i># Trees Survived</i>	<i>% of Trees Survived</i>
Baring Creek	2005	90	47	52%
	2006	90	39	43%
	2007	90	28	31%
	2008	90	20	22%
	2009	90	20	22%
Base of Altyn Peak	2005	40	23	58%
(slope above MG Hotel)	2006	40	13	33%
	2007	40	13	33%
	2009	40	12	30%
Dead Horse Point	2005	53	11	21%
	2006	53	4	8%
	2007	53	3	6%
	2009	53	0	0%
Sun Point	2005	55	28	51%
	2006	55	26	47%
	2007	55	16	29%
	2009	55	4	7%
Total One Year Survival	2005	238	109	46%
Total Two Year Survival	2006	238	82	34%
Total Three Year Survival	2007	238	60	25%
Total Five Year Survival	2009	238	36	15%

Table 25. Survival of Limber Pine Seedlings by Site, Planted in 2006

<i>Site</i>	<i>Monitoring Year</i>	<i>Total # Trees Monitored</i>	<i># Trees Survived</i>	<i>% of Trees Survived</i>
Baring Creek (2006)	2007	71	12	17%
	2008	71	3	4%
	2009	71	3	4%
	2011	71	3	4%
Dead Horse Point	2007	20	0	0%
Total One Year Survival	2007	91	12	13%
Total Two Year Survival	2008	91	3	3%
Total Three Year Survival	2009	91	3	3%
Total Five Year Survival	2011	91	3	3%

2. *Whitebark Pine Seedling Results*

Five whitebark pine seedling sites, Red Eagle, Hole-in-the-Wall, Divide Creek, Grinnell Glacier Picnic Area and Cobalt Lake Campground were monitored in 2012. One new planting site was established this year at Divide Mountain.

a. *Red Eagle*

1. *Seedling Plots*

The Red Eagle site was monitored in 2012 at year five after planting. Seven plots at Red Eagle were read this year, monitoring the success of seedlings planted in 2007. These 7 plots are located on the flanks of Red Eagle Mountain (Figure 10). Two plots that were located near Red Eagle Campground (Figure 10) were abandoned after 2010 monitoring since all seedlings within these plots had been dead or missing for at least two years. Four hundred

Figure 10. Location of Whitebark Pine Seedling and Seed Plots Established at Red Eagle Campground, 2007



and twenty seedlings, or 21% of the planted material, were originally captured in all nine monitoring plots. The seed source of the seedlings was primarily Preston Park, however, some seedlings came from seed collected at Cobalt Lake and Scenic Point. Monitoring plots captured 1,690 seedlings (84.5%) from seed collected at Preston Park, 250 seedlings (12.5%) from seed collected at Cobalt Lake, and 60 seedlings (3%) from seed collected at Scenic Point. Due to their low numbers, no seedlings grown from Scenic Point seed were captured in monitoring plots (Table 26). In addition, several planting amendments are being evaluated at Red Eagle. To test their impact on tree survival and growth, four planting treatments were tested: (1) Osmocote 13-13-13 fertilizer and watered in when planted; (2) Soil Moist¹ water polymer and watered in when planted; (3) both fertilizer and water polymer amendments as well as watered in; and (4) a few trees were solely watered in to serve as a control. While this is not a controlled experiment with equal numbers of trees under each treatment, it may be possible to make educated decisions concerning their effectiveness with monitoring data. The percent of trees monitored by site and treatment are presented in Table 26. Treatments by plot are presented with survival, heights and widths in Table 28.

Table 26. Red Eagle Whitebark Pine Seedlings: Percent of Trees Monitored by Seed Source and Treatment

Seed Source	% of trees monitored
Preston Park	61%
Cobalt Lake	39%
Treatment	% of trees monitored
Fertilizer + watered in	22.50%
Water polymer + watered in	22.70%
Fertilizer, water polymer + watered in	30.20%
Watered in only (control)	24.60%

Survival of trees within plots on the flanks of Red Eagle Mountain (Figure 10), specifically plots WB07-01 through WB07-07, has remained relatively stable since the last monitoring event two years ago. Average five-year survival was 55%, decreasing 2% since the previous monitoring event (Table 27). Since 2010, percent survival has stayed the same in three plots (plots WB07-05, WB07-06 and WB07-07) and decreased by 1% in three plots (plots WB07-02, WB07-03 and WB07-04). Seedling survival dropped by 9%, however, in plot WB07-01.

Between years one and two, soil sliding and subsequent seedling burial on the steeper slopes caused high mortality in several plots. Plot WB07-01 had the largest decline in survival between years one and two, declining from 96% to 31% (Table 28). This was due primarily to soil slides that buried many of the seedlings. This plot also had fewer microsites than other plots in flatter areas. Seedling survival stabilized and remained the same for this plot between years two and three, but again declined by 9% by year five with several seedlings again being buried. Plots WB07-04, WB07-05, and WB07-06 were also affected early on by slides with several seedlings in each area buried by soil, but have since stabilized. Survival for the rest of the Red Eagle Mountain plots that were located in flatter areas with deeper soils and more microsites averaged 83% in 2010 and 82% in 2012.

Average height of seedlings in the Red Eagle Mountain plots was 27.8 cm and average width was 26.9 cm (Table 27). Similar to other projects, seedling height decreased slightly the first year after planting as seedlings shed their long leader needles. While width was not measured at planting at the Red Eagle site, seedlings often have grown in width the first year as snow has caused these smaller seedlings to sprawl or lay sideways. Typical of other planting sites as well, this initial height decline was followed by an increase in growth of about 3.5 cm a year between years 1 to 2 and years 2 to 3. From years 3 to 5, height increased an average of 6 cm a year. The rate of growth in width changed less over time. From years 1 to 2, seedlings grew faster in width than in height. After year 2, trees begin to put on more height than width.

¹ Soil Moist is a synthetic acrylic polyacrylamide with a potassium salt base. It allows initial rapid intake of water by a portion of the polymer followed by a slower absorption of water by a balance of the polymer. It contains a 5-5-5 fertilizer made from ammonium phosphate, sulfate, and muriate of potash.

It appears that certain planting amendments may be more successful than others, although many environmental variables may also be affecting growth and survival at each site making conclusions difficult. Preston Park seed that has been fertilized and watered in continues to have the highest survival rate, height, and width of all other treatments (Table 28). However, this trend does not hold for seed from Cobalt Lake. Seed from this source had the highest survival, height, and width when watered in without additional soil amendments. Currently, amending soil with water polymer at the time of planting does not appear to offer any measurable advantage to seedlings. A similar result was found in a southern Rocky Mountain study for limber pine with no positive impacts to seedlings using hydrogels (Casper, 2011). Survival rates are somewhat deceiving, since plot WB07-01 lost many seedlings between years one and two due to soil slides and thus it is difficult to assess the effect of soil amendment on seedling survival.

Table 27. Average Height and Width of Whitebark Pine Seedlings of upper plots at Red Eagle, 2008-2012.

Year	Survival	Height (cm)	Width (cm)
2007	100%	9.12	not taken
2008	74%	8.92	9.57
2009	58%	12.29	14
2010	57%	15.87	17.55
2012	55%	27.81	26.94

Table 28. Red Eagle Campground: Percent Survival and Dimensions of Whitebark Pine Seedlings

Plot #	Seed Source	# Trees Planted	# Live Trees	2008 Survival	2009 Survival	2010 Survival	2012 Survival	Planting Treatment	Avg Height 2012 (cm)	Avg Width 2012 (cm)
WB-07-01	Preston Park	49	10	96%	31%	31%	20%	Water polymer + watered in	26.1	27.4
WB-07-07	Preston Park	44	32	89%	77%	73%	73%	Water polymer + watered in	28.3	25.1
WB-07-02	Cobalt Lake	77	62	88%	83%	82%	81%	Watered in only (control)	26.1	27.4
WB-07-03	Preston Park	55	51	98%	98%	94%	93%	Fertilizer + watered in	32.3	30.1
WB-07-04	Cobalt Lake	40	17	53%	43%	44%	43%	Fert, water polymer + watered in	21.4	22.1
WB-07-06	Cobalt Lake	46	13	64%	27%	28%	28%	Fertilizer + watered in	27.2	24.4
WB-07-08	Preston Park	26	0	81%	0%	0%	0%	Watered in only (control)	All Dead or Missing	
WB-07-05	Preston Park	48	11	40%	25%	23%	23%	Fert, water polymer + watered in	27.6	25.2
WB-07-09	Preston Park	37	0	97%	0%	0%	0%	Fert, water polymer + watered in	All Dead or Missing	

Finally, as stated above, Red Eagle plots WB07-08 and WB07-09 are located 85 to 150 meters northeast of the Red Eagle Campground (Figure 10). They are located in a very different habitat from the Red Eagle Mountain sites and thus survival is reported separately. First year survival for these plots was high, at 91%, where 86% of the surviving plants were in good condition (Table 28). By 2009, year two after planting, all of the trees in both plots were either dead or missing. These plots were abandoned after the 2010 reading since all seedlings were confirmed as either dead or missing. Center stakes for these plots were removed. Overall, this rocky site with little soil and few microsites may not have been a good choice for planting whitebark pine. Additionally, some competition from regenerating herbaceous plants was also a potential factor. This site is also susceptible to more human disturbance. The rocky substrate, lack of good planting medium, lack of good microsites, human use, low elevation and competing vegetation likely all contributed to the failure of whitebark seedlings in this area.

Overall first year survival for all plots in the Red Eagle area was 71% with 64% of the surviving trees in good health. Second year overall survival was 49% with all of the surviving trees rated as fair or good. By 2010, year three overall survival was 49%. Five years after planting, in 2012, overall survival was 47%.

Table 29. Red Eagle: Health and Survival of Whitebark Pine Seedlings Monitored in 2012

<i>Plot</i>	<i>Dead/ Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>
WB-07-01	39	0	1	9	10	49	20%
WB-07-02	15	0	3	59	62	77	81%
WB-07-03	4	0	1	50	51	55	93%
WB-07-04	23	0	1	16	17	40	43%
WB-07-05	37	0	0	11	11	47	23%
WB-07-06	33	0	1	12	13	46	28%
WB-07-07	12	0	4	28	32	44	73%
		Total Flank of Red Eagle:			196	358	55%
WB07-08	26	0	0	0	0	26	
WB07-09	37	0	0	0	0	37	
		Total Red Eagle Campground:			0	63	0%
		Total Red Eagle Entire Site:			196	421	47%

2. Seed Plots

A few seedlings have been observed in seed plots since 2009. In 2009, one seedling was found in plot WBS07-05, the lower elevation plot, but appeared to already be dead. No other seedlings have been observed in this plot since. Strong evidence of cache predation existed at this plot suggesting that many of the seeds were likely eaten. At the higher elevation, two seedlings were found in plot WBS07-04 for the first time in 2009, two years after seeding. At that time, seedlings averaged 3.5 cm tall and 3 cm wide (Table 30). These seedlings continued to grow and by 2012, they averaged 11 cm tall by 11.5 cm wide. While these seedlings continue to thrive, beargrass encroachment threatens one of them. Also in 2012, four additional seedlings were found in this plot but it was uncertain whether these were whitebark pine seedlings or not. One of these was very fragile and they were much smaller than the older seedlings, averaging 1.75 cm tall and 1.75 cm wide. Clearly at this site under these conditions and seeding techniques, planting seedlings rather than directly planting seed is more successful.

Table 30. Red Eagle: Survival, Height and Width of Whitebark Pine Seeds Monitored in 2012

Year	Number of Seedlings	Height (cm)	Width (cm)
2009	2	3.5	3
2010	2	5	5
2012	6*	4.8*	5*

*includes 4 seedlings of uncertain identification

b. Hole-in-the-Wall

A total of 830 whitebark pine seedlings were planted in the Hole-in-the-Wall campground area and in the cirque area above the campground. This is the first whitebark pine site that has not been burned and results from this experimental planting could direct planting site selection in the future. Areas of vegetation were “scalped” surrounding planting sites to reduce competition. Seedlings were preferentially planted near *Vaccinium scoparium*, *Luzula hitchcockii*, *Carex geyeri* and *Carex rossii*, since whitebark pine is disproportionately associated with these species (Izlar 2007). Microsites were utilized or provided for seedlings when possible.

Five monitoring plots were established near the Hole-in-the-Wall Campground between August 23 and 25, 2010 (Figure 11). Plots contained 172 seedlings, monitoring 21% of planted trees. Overall survival was 46% five years after planting. Of the monitored seedlings, 43 (25%) were given a “5” or “healthy” rating, 32 (19%) were assigned a “4” or “fair” rating, 4 (2%) were considered “almost dead”, 21 (12%) were missing and 72 (42%) were dead. However, these trends did not hold true across all plots. Survival was highest in the meadows north of the campground, near the trail to Boulder Pass, with 61% survival in plot 3 and 58% survival in plot 4. Survival was lowest in the herbaceous meadow west of the campground with only 7% of trees alive in this plot in 2012. Plots 1 and 5, the plots near the old food cable site and in the campground, had average survival at 48% and 47%, respectively (Table 31).

Interestingly, seedlings were smaller in 2012 than they were at the time of planting in 2010. Average height of seedlings shrunk by 2.37 cm and average width decreased slightly by 0.18 cm (Table 32).

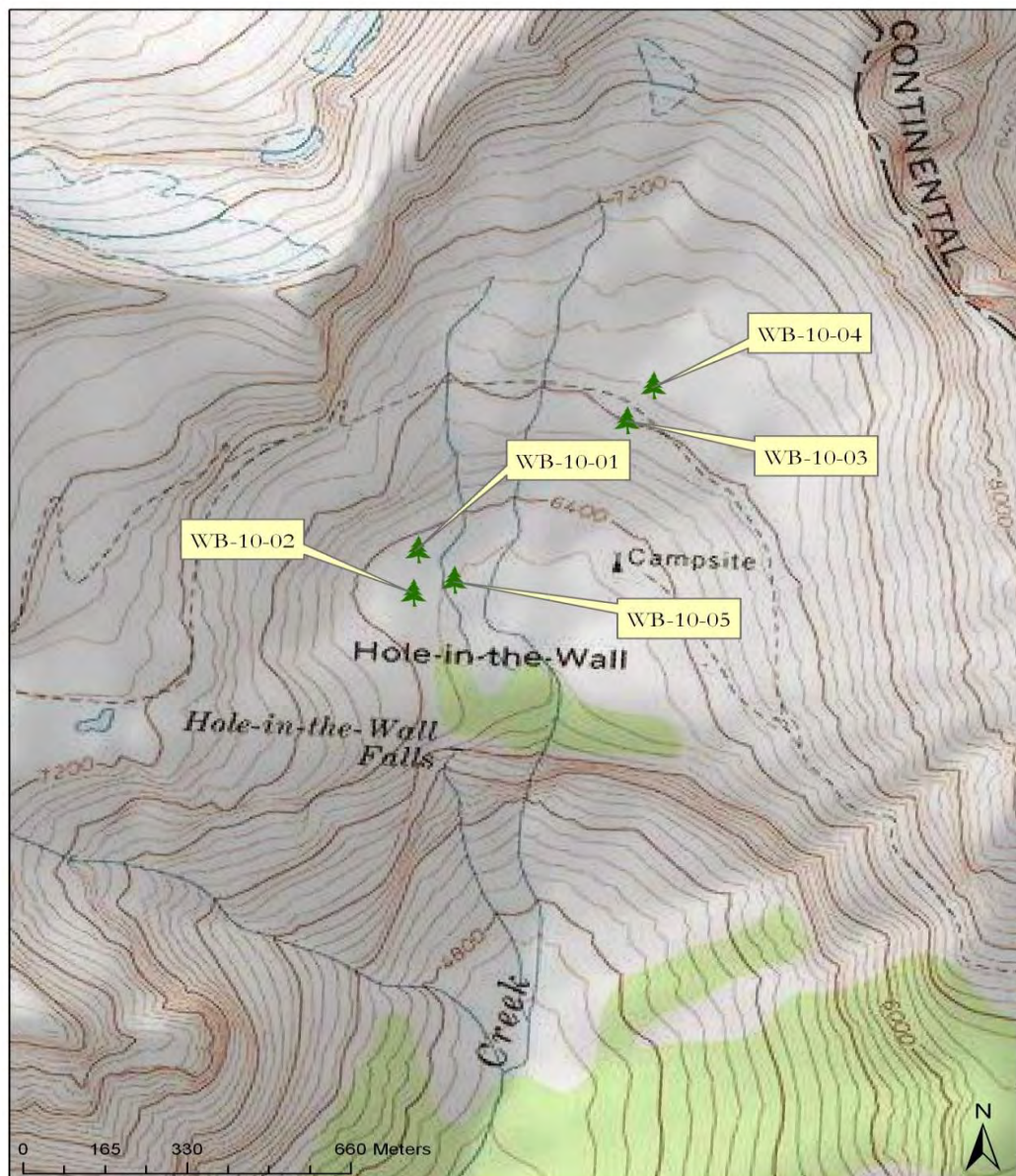
Table 31. Hole in the Wall: Health and Survival of Whitebark Pine Seedlings Monitored in 2012

<i>Plot</i>	<i>Dead/ Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>
WB-10-01	21	1	11	7	19	40	48%
WB-10-02	25	0	2	0	2	27	7%
WB-10-03	11	2	3	12	17	28	61%
WB-10-04	19	1	10	15	26	45	58%
WB-10-15	17	0	6	9	15	32	47%
Total	93	4	32	43	79	172	46%

Table 32. Overall Survival and Average Height and Width of Whitebark Pine Seedlings at Hole in the Wall, 2010-2012.

Year	Survival	Average Height (cm)	Average Width (cm)
2010	100%	10.94	9.42
2012	46%	8.57	9.24

Figure 11. Location of Whitebark Pine Seedling Monitoring Plots Established at Hole-in-the-Wall Campground, 2010.



c. Divide Creek

On September 20-22, 2010, a total of 1,126 whitebark pine seedlings were planted on a ridge above Divide Creek (Figure 12). This area burned in the Red Eagle fire of 2006 with moderate severity. An experimental planting occurred at this site where 300 of the planted seedlings had been inoculated by Cathy Cripps' lab from Montana State University. Inoculum was prepared from mushroom species known to have ectomycorrhizal relationships with whitebark pine. These were planted together, usually in groupings of 3 seedlings per hole, throughout the revegetation site.

Five monitoring plots were installed in 2010 tracking 263 seedlings, 40 of which were inoculated. This captured 21% of planted seedlings. At year two after planting, 96% of the planted seedlings survived (Table 34), the highest year two survival rate of planted whitebark pine that the park has had to date and only a 1% decrease since last year. Of the monitored seedlings, 158 (60%) were given a "5" or "healthy" rating and 87 (33%) were assigned a "4" or "fair" rating in 2012 (Table 34). A total of 10 seedlings (4%) were dead or missing and 8 seedlings (3%) were observed to be almost dead.

Table 33. Overall Survival and Average Height and Width of Whitebark Pine Seedlings at Divide Creek, 2010-2012.

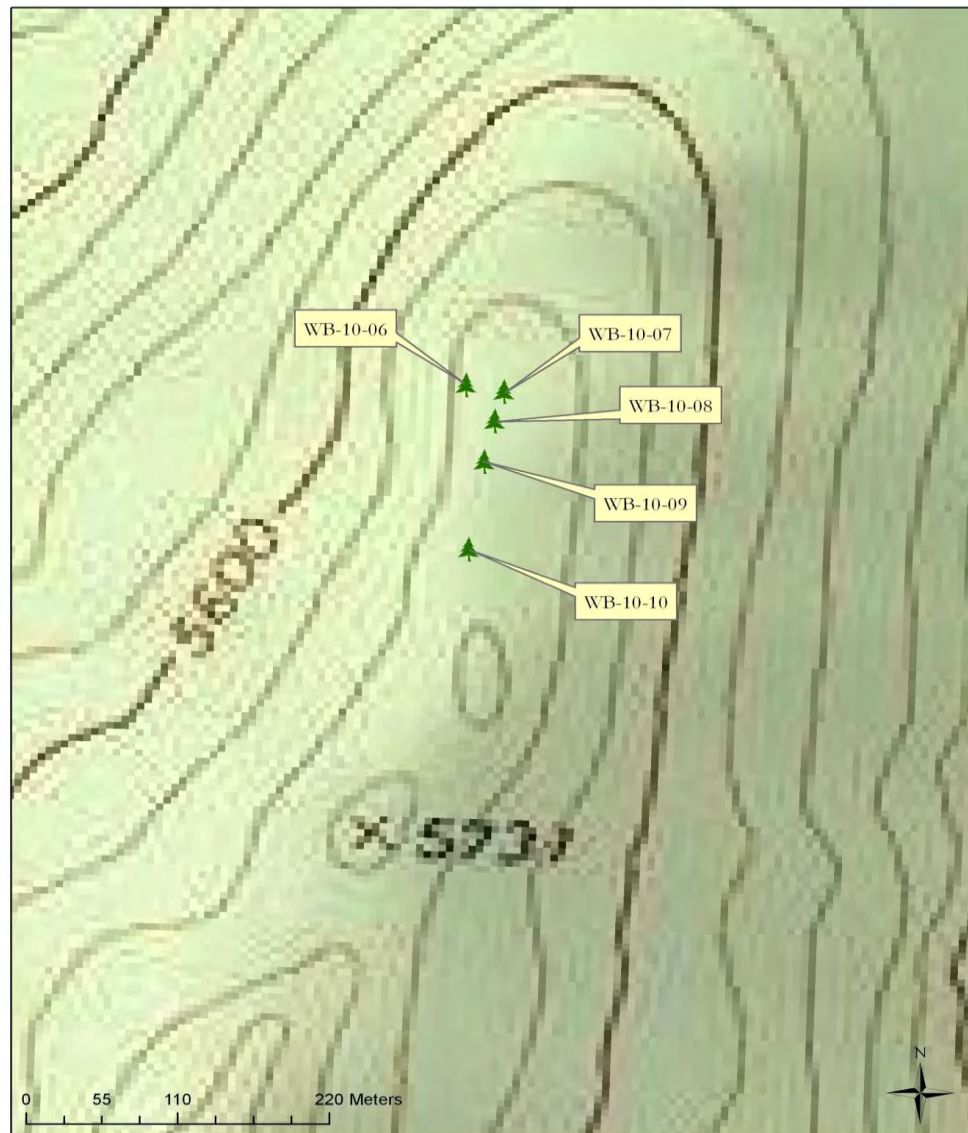
Year	Survival	Average Height (cm)	Average Width (cm)
2010	100%	10.62	10.22
2011	97%	9.87	10.96
2012	96%	10.27	10.59

Table 34. Divide Creek: Health and Survival of Whitebark Pine Seedlings Monitored in 2012

<i>Plot</i>	<i>Dead/ Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>
WB-10-06	1	0	34	17	51	52	98%
WB-10-07	1	0	7	45	52	53	98%
WB-10-08	6	1	26	32	59	65	91%
WB-10-09	2	7	13	45	65	67	97%
WB-10-10	0	0	7	19	26	26	100%
Total	10 (3.8%)	8 (3.0%)	87 (33.1%)	158 (60.1%)	253	263	96%

As has been the trend with whitebark pine plantings, the average height of seedlings decreased the first year after planting, followed by a slight increase the second year (Table 33). Average height decreased slightly from 2010 to 2011 while average width increased slightly over the same time frame. The initial small changes in size are due mostly to the fact that long needles that often grow on nursery-raised seedlings shed after the first year and are replaced by dense, short new growth needles. This often results in a slightly smaller seedling after the first year of planting. Data from other projects has shown that it often takes four to five years before whitebark pine seedlings will grow significantly in both height and width. Seedlings are using energy to establish root systems and new growth after initial needle shed.

Figure 12. Location of Whitebark Pine Seedling Monitoring Plots Established at Divide Creek, 2010



The effect of inoculating whitebark pine seedlings with an ectomycorrhizal slurry is not yet evident two years after planting. Differences between the inoculated and non-inoculated seedlings are minor (Tables 35 and 36) and are currently difficult to attribute solely to the impact of inoculation. On average, inoculated seedlings are a bit shorter and wider than non-inoculated seedlings. Seedlings under both treatments did increase in height, however, with inoculated seedlings increasing at a slightly greater rate this year (Table 35). Seedlings under both treatments also decreased slightly in width with inoculated trees shrinking slightly more. Survival of inoculated seedlings continues to be approximately 1% higher than non-inoculated seedlings, although this difference is not significant and, again, may not be attributed to the effect of inoculation.

Table 35. Treatment Survival and Average Height and Width of Whitebark Pine Seedlings at Divide Creek, 2010-2012.

Year	Survival		Average Height (cm)		Average Width (cm)	
	Inoculated	Not inoculated	Inoculated	Not inoculated	Inoculated	Not inoculated
2010	100%	100%	10.85	10.58	9.88	10.29
2011	97.6%	96.8%	9.70	9.90	11.55	10.85
2012	97.6%	96.4%	10.18	10.24	11.00	10.43

Table 36. Treatment Health Ratings of Whitebark Pine Seedlings at Divide Creek, 2010-2012.

Year	5 (Good)		4 (Fair)		3 (Almost Dead)		2 or 1 (Dead or Missing)	
	Inoculated	Not inoculated	Inoculated	Not inoculated	Inoculated	Not inoculated	Inoculated	Not inoculated
2010	41 (100%)	216 (97.3%)		6 (2.7%)				
2011	34 (82.9%)	197 (88.7%)	6 (14.7%)	17 (7.7%)			1 (2.4%)	8 (3.6%)
2012	24 (58.6%)	134 (60.3%)	15 (36.6%)	72 (32.4%)	1 (2.4%)	7 (3.2%)	1 (2.4%)	9 (4.1%)

d. Grinnell Glacier Picnic Area

In August, 2011, a total of 146 whitebark pine seedlings were planted in relatively flat areas near the Grinnell Glacier Picnic Area (Figure 13). This area was not within a burn but does contain sparsely vegetated, open areas and denuded soil areas (from social trails) under trees. Seedlings were typically planted together in groupings of 2 or 3 trees per hole throughout the revegetation site.

Two monitoring plots were installed in 2011 tracking 98 seedlings. In 2012, supplemental planting took place in this area and 5 seedlings were added to plots. This captured 67% of planted seedlings. Although overall survival one month after planting in 2011 was 94%, a substantial percentage (28%) of seedlings was considered “almost dead” at this time (Table 37). The decline in survival to 49% in 2012 reflects the death of these “almost dead” trees in addition to a number of others that failed to survive the ensuing winter and summer. For the surviving seedlings, average height was 10.52 cm, an increase of 1.11 cm, and average width was 11.84 cm, an increase of 1.81 cm from last year (Table 38). This illustrates a different trend than is commonly seen in newly planted whitebark pine seedlings. Typically, seedlings decrease in size, or at least in height, the first year after planting, as they shed long, nursery-grown needles and replace them with shorter needles.

High early mortality at this site has been attributed to early season planting, transplantation in the nursery and inadequate microsites. These seedlings were planted at the end of August when temperatures remained high and rainfall was low (Appendix A). Although seedlings were well watered in when planted, the results of this project may again indicate how important climate is to surviving whitebark pine seedlings. This time of year appears to be too hot and dry for prime survival rates. Later planting dates should be targeted for cooler temperatures and more reliable precipitation. Additionally, these seedlings came as bare root plants from the Coeur d’Alene nursery and needed to be put back into containers prior to planting. This is a high amount of handling for tree seedlings and many of them did not look healthy upon planting. Finally, the Grinnell Glacier Picnic Area did not provide many microsites. Small microsites were improvised but, in general, these microsites are not providing the protection and shade that these seedlings often require. Most of the mortality seen in the first year of planting is likely attributable to death or near-death within the first season.

Figure 13. Location of Whitebark Pine Seedling Monitoring Plots Established at Grinnell Glacier Picnic Area, 2011.

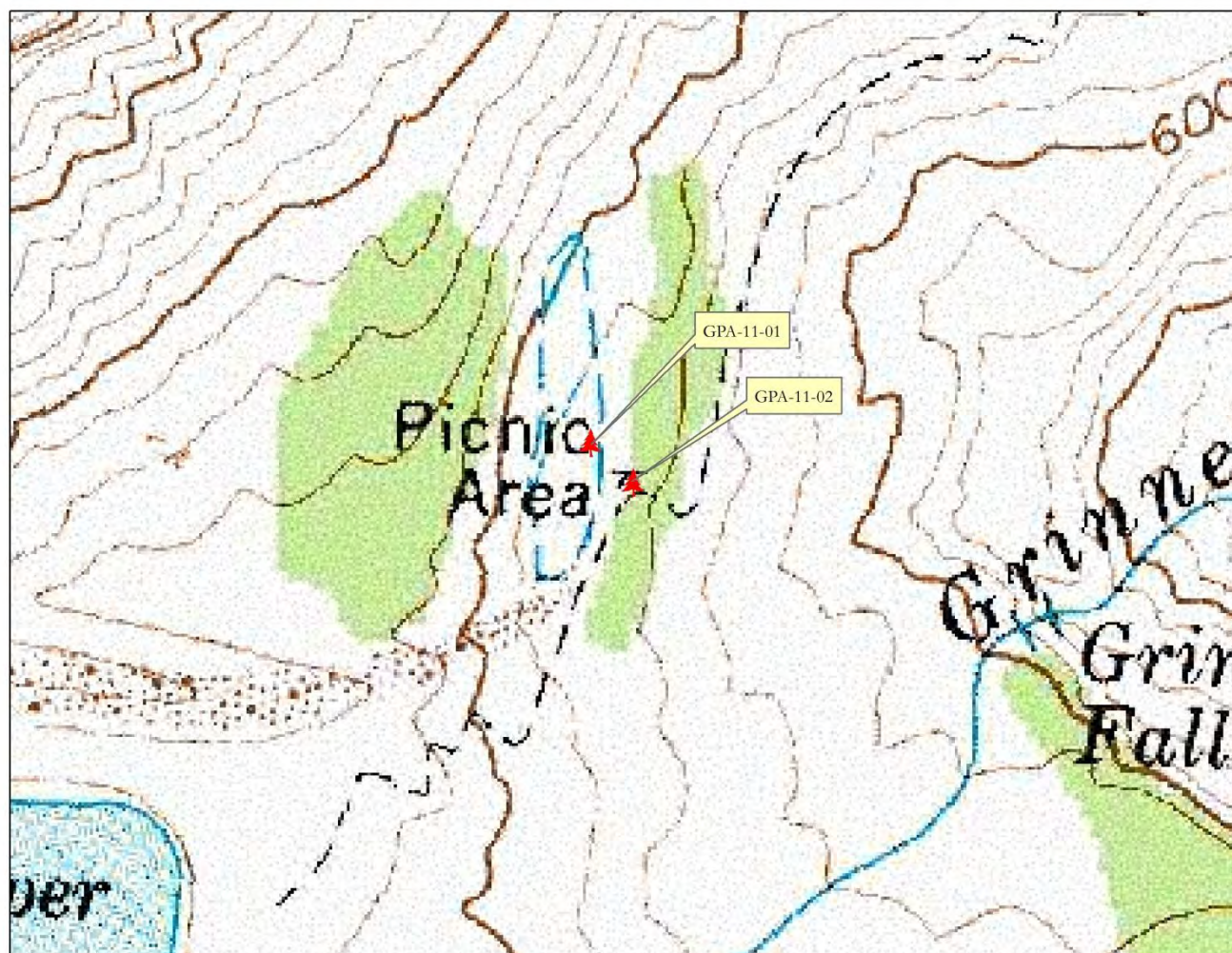


Table 37. Grinnell Picnic Area: Health and Survival of Whitebark Pine Seedlings Monitored in 2011 - 2012

<i>Plot</i>	<i>Dead/ Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>
GPA-WB-11-01	5	17	2	41	60	65	92%
GPA-WB-11-02	1	10	11	11	32	33	97%
Total 2011	6	27	13	52	92	98	94%
GPA-WB-11-01	28	2	2	35	39	67	58%
GPA-WB-11-02	25	1	2	8	11	36	31%
Total 2012	53	3	4	43	50	103	49%

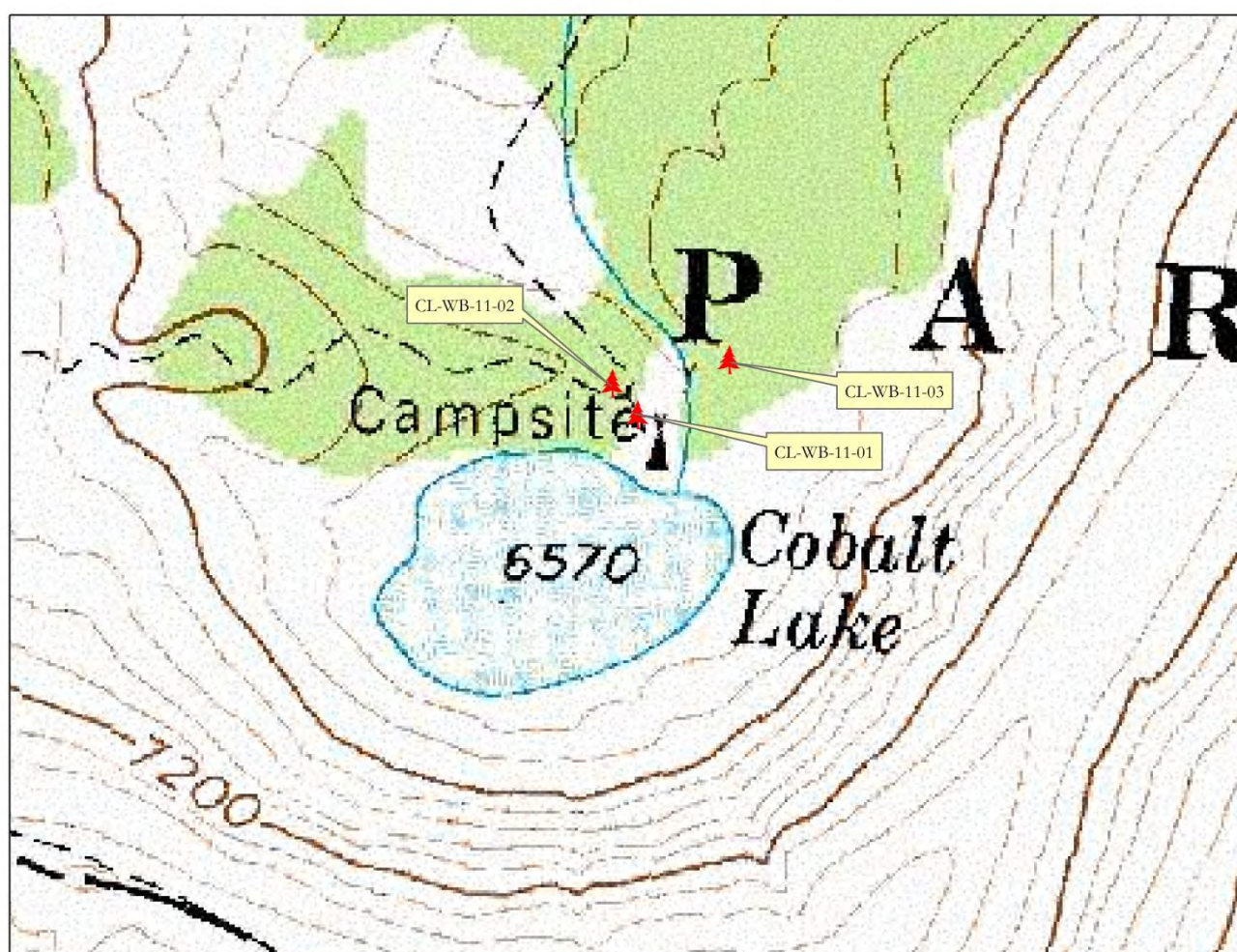
Table 38. Overall Survival and Average Height and Width of Whitebark Pine Seedlings at Grinnell Picnic Area, 2011-2012.

Year	Survival	Average Height (cm)	Average Width (cm)
2011	94%	9.41	10.03
2012	49%	10.52	11.84

e. Cobalt Lake Campground

In August, 2011, a total of 250 whitebark pine seedlings were planted in open, flat areas to the north of the Cobalt Lake Campground (Figure 14). Similar to the Grinnell Glacier Picnic Area site, this area is not within a burn requiring that vegetation was ‘scalped’ around the planted whitebark seedling to reduce competition. Seedlings were planted in forest openings nearby to existing whitebark pine trees and typically planted together in groupings of 2 to 3 trees per planting hole.

Figure 14. Location of Whitebark Pine Seedling Monitoring Plots Established at Cobalt Lake, 2011.



Three monitoring plots were installed in 2011 tracking 108 seedlings. This captured 43% of planted seedlings. Survival decreased from 99% in 2011 to 31% in 2012 (Table 39). Almost half (49%) of seedlings were in fair condition or worse a month after planting. It is likely that all of these trees died in the course of the following year, in addition to many trees that were deemed healthy following planting. Of the remaining surviving trees, only 18 trees, or 16%, are still considered healthy. Ten trees were almost dead and 5 trees were rated in “fair” condition.

Similar to results at Grinnell Glacier Picnic Area, the same three reasons are likely responsible for the early mortality at this site. First, these seedlings were planted at the end of August when temperatures remained high and rainfall was low. This time of year appears to be too hot and dry for prime survival rates. Second, these seedlings came as bare root plants from the Coeur d’Alene nursery and needed to be put back into containers prior to planting. This is a high amount of handling for tree seedlings and many of them did not look healthy upon planting. Finally, the Cobalt Lake Campground area did not provide many microsites. Small microsites were improvised but, in general, these microsites are not providing the protection and shade that these seedlings often require.

Surviving seedlings have grown over the course of the last year, however. Average height of seedlings was 10.15 cm, a 0.61 cm increase since 2011, and average width was 12.0 cm, a 1.45 cm increase. Similarly to Grinnell Glacier Picnic Area, this is an atypical pattern for the first year after planting. Perhaps the advantage of being planted in late summer is to enable a growth spurt the first year, while later plantings likely go dormant soon after planting.

Table 39. Cobalt Lake: Health and Survival of Whitebark Pine Seedlings Monitored in 2011 - 2012

<i>Plot</i>	<i>Dead/ Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>
CL-WB-11-01	0	9	9	14	32	32	100%
CL-WB-11-02	1	7	10	20	37	38	97%
CL-WB-11-03	0	0	17	21	38	38	100%
Total 2011	1	16	36	55	107	108	99%
CL-WB-11-01	23	2	3	4	9	32	28%
CL-WB-11-02	24	6	2	6	14	38	37%
CL-WB-11-03	28	2	0	8	10	38	26%
Total 2012	75	10	5	18	33	108	31%

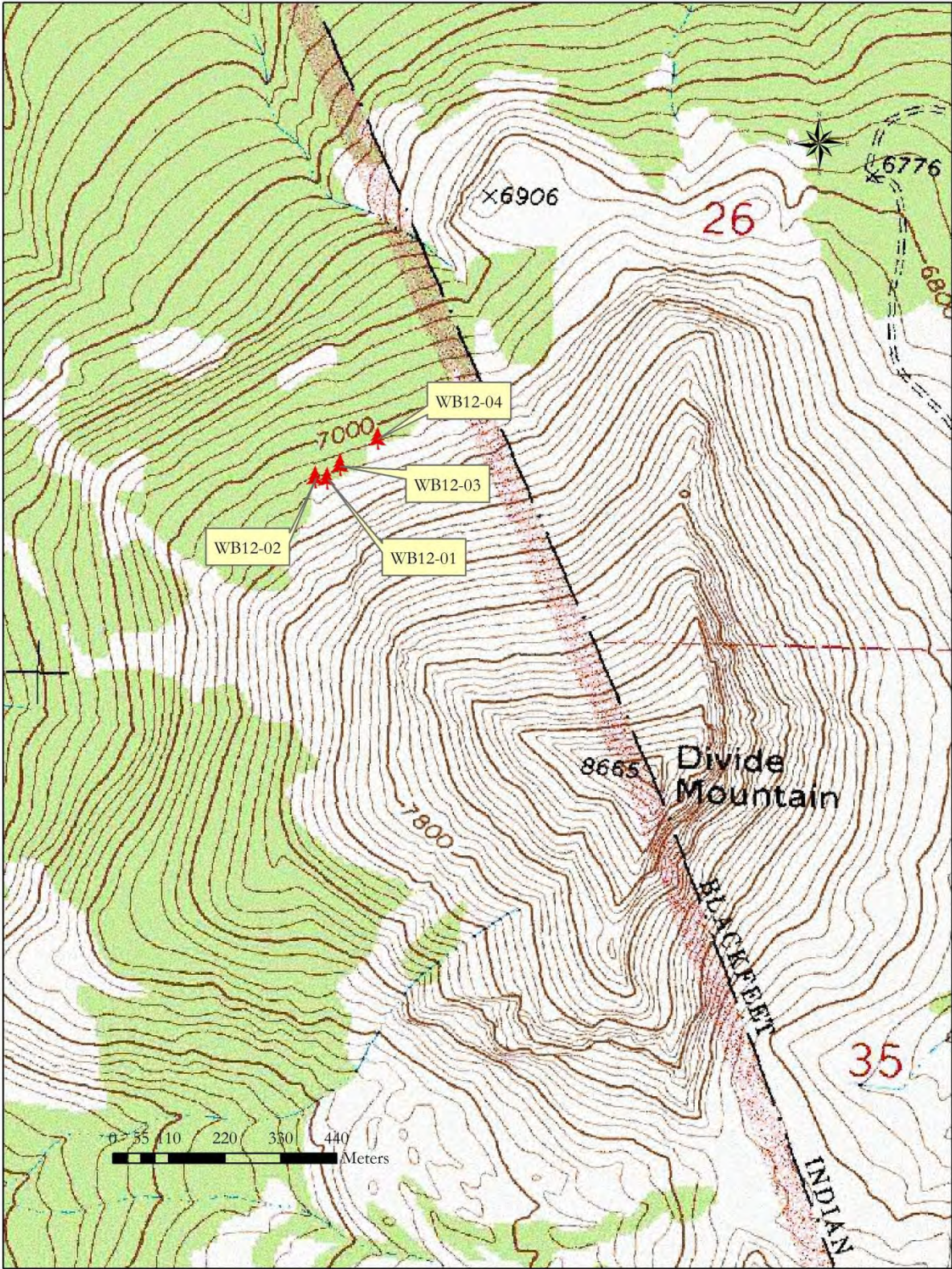
Table 40. Overall Survival and Average Height and Width of Whitebark Pine Seedlings at Cobalt Lake, 2011-2012.

Year	Survival	Average Height (cm)	Average Width (cm)
2011	99%	9.54	10.55
2012	31%	10.15	12.00

f. Divide Mountain

One new site was planted with whitebark pine seedlings in 2012. In September, 2012, a total of 1,283 whitebark pine seedlings were planted at tree line on a bench and a gentle slope on the northwest flank of Divide Mountain (Figure 15). The total number of trees planted is an estimate based on an average of two seedlings per cone. Cone numbers are known but individual seedlings were not counted in each cone. This planting site is on the edge of the Red Eagle Fire which burned the area in 2006. Seedlings were planted among standing snags of subalpine fir and some whitebark pine. Naturally regenerating whitebark pine seedlings are abundant at this site. A variety of environmental conditions were included within planting sites. Some planting areas contained fairly thick mats of mountain avens or kinnikinnick and required some scalping. One plot (plot 4) is located in a swale that likely holds late snow melt, as indicated by typical plants of those areas growing there, which may aid in holding soil moisture for seedlings. Another plot (plot 3) is located on a slope with more open scree on the lower half. Most, but not all,

Figure 15. Location of Whitebark Pine Seedling Monitoring Plots Established at Divide Mountain, 2012.



seedlings were planted in the burned area; location inside or outside of the burn was noted. Being as the site was situated just below a boulder field, ample rocks and existing boulders were available for planting microsites. Seedlings were typically planted together in groupings of 2 to 3 trees per planting hole with some single trees and some planted in groupings of 4. Herbivory on newly planted trees had already been noted during the days in which seedlings were planted; in some cases trees had been totally removed. Pikas and chipmunks were observed in the area and are thought to be the culprits.

Divide Mountain is the second site in the park to utilize seedlings that have been inoculated by Cathy Cripps' lab from Montana State University. Divide Creek, planted in 2010, was the first site where experimental seedlings were planted. Inoculum was prepared from mushroom species known to have ectomycorrhizal relationships with whitebark pine. Just over half of the seedlings planted at Divide Mountain had been inoculated (608 trees; 51%).

Four monitoring plots were installed in 2012 tracking 216 seedlings. This captured 17% of planted seedlings. All of the monitored seedlings were given a "5" or "healthy" rating. Average height of seedlings was 9.10 cm and average width was 8.95 cm.

g. Siyeh Bend Seed Plots

After five years, seed plots at Siyeh Bend showed no signs of any seedling germination from any of the 21 caches containing a total of 101 whitebark pine seeds. This site is extremely rocky and suffers from avalanche activity, as evidenced by missing and bent nails and rebar. Additionally, herbivory appears to be a problem, since abundant small holes were observed at or near planted caches. Since it appears that no germination will occur at this site, these plots have been abandoned. All nails and rebar was removed from these plots.

D. CONCLUSIONS AND RECOMMENDATIONS

1. Limber Pine

Summer survival was over 90% for limber pine planted in June or early July of 2012. This likely reflects good site selection, good planting techniques, and healthy plant material, as well as adequate rainfall. Most sites provided some shade and wind protection and planting crews utilized existing microsites or brought in microsite material. Limber pine seedlings planted in 2012 were also the first limber pine seedlings that were grown in short cones, preventing the j-rooting that occurred in the past in the often rocky planting terrain in Glacier. Although June was a record-setting wet month in West Glacier, rainfall was just above the 31-year average in St. Mary (Appendix A). St. Mary received 3.9 inches of rain in June, providing excellent moisture to seedlings planted in the spring on the east side of the park.

Even with ample precipitation, however, rocky soil and other environmental parameters may prevent high survival at certain sites, particularly for those trees planted in the spring. Seedlings planted in the spring at Scenic Point, for example, may show a significant decline in survival by next year. This may be especially true in plot LP12-06 where trees were planted in a more open, rocky habitat. By fall, 52% of the seedlings in this plot were rated as "almost dead". These seedlings are currently counted as surviving. In the second plot planted in the spring at Scenic Point, plot LP12-07, 18% of the seedlings were considered "almost dead". If those seedlings are not counted in the overall survival, the overall survival rate at Scenic Point from spring to fall was 55%. In general, most other limber pine spring planting sites had much better soil, less exposure, and thus very few trees were rated as "almost dead". While there is only one year of monitoring data, spring planting of limber pine appears to be feasible in protected sites with deeper soils. Planning planting events around predicted rainfall also appears critical to the success of these seedlings when planted at this time of year.

Regardless of the potentially declining survival next year, this year's early success is particularly encouraging, since previous limber pine plantings have not been very promising. Of the 1,089 trees planted from 2002 to 2006 that were monitored in 13 different locations, only 62 trees, or 6%, remain in 2012. Of the remaining 62 trees, 61 trees are in good condition with a rating of fair or good and only 1 is rated as almost dead. Most of this overall low survival rate was due to a large planting event in 2002, preceding an extremely hot, dry summer in 2003, resulting in 0.5% survival by year two and 0.2% for year seven. Since then, survival rates of the limber pine trees planted in subsequent years improved slightly. Average survival for trees planted from 2003 to 2006 was 13%. The revegetation crew is

utilizing what we have learned from previous plantings as well as information from other parks and national forests to provide better planting sites.

Results from a smaller planting of limber pine seedlings at Waterton Lakes National Park (WLNP) may shed some light on our results. It is interesting to note that the one cohort of planted limber pine trees (which came from the same source of seed as GNP limber pine seedlings) in WLNP that were planted in 2003 had an 85% survival rate at year one after planting, 76% survival rate at year two after planting, and 72% survival rate at year three after planting (Smith et al., 2007). While the number of monitored trees is lower than GNP's data set and only looked at one planting location, survival rates of this one trial in WLNP are significantly higher than results we have seen in GNP. In their study, they began to see three trends that may explain our lower survival rates and confirm some of our observations over the past few years. First, they found limber pine seedling survival was marginally better in seedlings planted near cover (Smith et al., 2007). Supporting our theory that seedlings may need some shade and some protection from wind to prevent desiccation, cover from microsites appears to increase survival of limber pine seedlings. As stated above, our planting technique has changed to incorporate microsites that offer cover that did not occur during 2002 and in the 2006 Baring Creek planting when we had high mortality.

Smith et al. also found that survival and seedling health was improved when more seedlings were planted together in a clump. Singly-planted seedlings had the lowest survival rate at the end of three monitoring seasons while three- and five-clumped seedlings had higher survival rates. They argue that once emerged, seedling growth and survivorship are enhanced by the presence of other vegetation or seedlings (Powell 1996; Feldman et al. 1999) that may alleviate the abiotic effects of the surrounding environment, thus making the microclimate more suitable. The presence of other vegetation may promote growth since soil nutrients, density and moisture are retained, due to an established root system from the other plants. On the whole, a significant majority of limber pine trees planted in GNP prior to 2012 were planted as single trees, possibly putting them at a disadvantage to retain soil moisture and nutrients, as well as to obtain protection from nearby vegetation. There is also conjecture that the survival benefit of being in a larger clump may not be a long-term effect. It is conceivable that the increased competition from being surrounded by more seedlings may result in lower survival once the seedlings are large enough to compete with one another (Smith et al., 2007). This year, trees were most often planted in clumps, which consisted of between 2 to 6 trees per clump.

Additionally, the WLNP study showed that seedling health was marginally better in burned areas than unburned areas within the experimental area. In general, burned soils carry a higher mineral load and more nutrients than unburned soils, thus having a positive effect on the growth of seedlings. To date, no limber pine seedlings have been planted in burned areas in GNP. Instead, they have been planted in unburned areas where limber pine is either present or has been present in the past. Some of those areas appear to be more amenable to limber pine survival, perhaps because they offer more soil nutrients and moisture, as well as appropriate microsites. These areas include the shadier areas of Baring Creek and Sun Point with moderate to low vegetation cover. Perhaps a site such as Scenic Point that is hot and exposed with little top soil or vegetation development offers too little protection, moisture, and nutrients. Until suitable limber pine habitat burns in GNP, we will have to utilize protected planting sites as well as possible.

Now that other agencies and researchers are beginning to study five-needled pines, more studies throughout the west are continuing to find similar results and suggest new planting techniques for limber pine. Not only have they also documented the importance of microsites for successful seedling survival, one study in the southern Rocky Mountains found higher survival of limber pine seedlings when planted under a dense canopy (Casper 2011). They found 80% of planted limber pines survived under a dense canopy compared to a 60% survival rate for limber pines planted in open canopy, indicating that overstory vegetation may be beneficial. They also documented higher limber pine survival when the seedlings were planted on the north or west side of microsites. Finally, they documented that spring plantings in moist soils can be highly successful. Overall limber pine survival was 76% after 3 years when trees were planted during a time of good precipitation. From this research, spring plantings of limber pine were experimented with in Glacier in 2012 at four locations and seedlings are being planted on cooler aspects of microsites at all planting locations in the park. In addition, experimental plantings under a denser canopy were also established in 2012 at Scenic Point and Apikuni Flats to test the theory of higher survival under a tree canopy.

Continued monitoring is critical as results become even more complicated with impacts from annual changes in precipitation and temperature. On the east side of GNP, where all of the limber pine sites are located, there was considerably low precipitation and in both 2002 and 2003 and higher temperatures in 2003. Increased rain

and cooler temperatures since 2004 may be contributing to higher survival rates (Appendix A). Climate change research on five-needled pines is still in its infancy but early results from these studies have documented the importance of soil moisture for the survival of limber pine (Kueppers, in press). Research has shown that limber pine seedlings shut down if there is no moisture due to zero stomatal conductance during this time. This study showed that watering clearly aids in survival across the study's entire elevation gradient. While seedlings are watered in at the time of planting in Glacier, perhaps supplemental watering should occur during the first year when possible.

In recent years, we have been more critical about choosing sites that are appropriate for limber pine planting in GNP. We have also taken greater care in planting techniques for each seedling. The following recommendations have recently been and should continue to be considered when choosing a site and when planting seedlings:

- Plant in areas with good microsite availability that provides some shade and wind protection. Consider planting under tree canopy, when available, for additional shade.
- Plant on the north and west sides of microsites to the extent that is possible.
- Try to plant in areas that have decent to good soil moisture and soil nutrients, including low to moderate vegetation and/or an area that has burned. Consider supplemental watering in areas that are accessible during the first year of planting.
- Do not plant in areas that have on-going disturbance that would cause soil movement or trampling. Do not plant in avalanche-prone areas.
- Continue to grow limber pine seedlings in short pots to prevent the need for j-rooting in shallow soils.
- Continue to plant seedlings in groups of 3 to 5 seedlings as this appears to increase survival.
- Assess the health of the seedlings prior to planting to assure that the healthiest material is being planted.
- Plant in appropriate habitat to prevent competition.
- Continue to consider spring plantings when precipitation is high at or near the time of planting so that soil moisture can remain high. Again, consider supplemental watering in areas that are accessible during the first year of planting if precipitation levels are not as expected during the spring.
- For fall plantings, plant only in later September and October when precipitation is more reliable.
- Do not use netting on limber pine trees, as it does not appear to be increasing their survival from our observations. If netting is still of interest, a more controlled experiment should be conducted to determine the benefits if its use to prevent seedling damage.
- Do not use water polymers or hydrogels with seedlings when planted. If these amendments are still of interest, a more controlled experiment should be conducted to determine the benefits of its use.
- Continue to research the effectiveness of fertilizer amendments on the success of planted limber pine.

Limber pine monitoring scheduled for 2013 includes the one remaining limber pine tree planted in 2003 at the Two Medicine Campground, as well as first year survival monitoring at Cutbank Campground, Scenic Point, Many Glacier and Rising Sun Campground (Table 41). Additionally, 700 new limber pine seedlings are scheduled to be planted in the fall of 2013. Monitoring plots will be established at these sites.

2. *Whitebark Pine*

Traditionally, revegetation of whitebark pine seedlings has shown better progress than planted limber pine seedlings. Whitebark pine survival rates are higher than at all of the limber pine sites for years two through seven after planting. It is hopeful that limber pine seedlings planted in 2012 will begin to see equal success.

This year's results continue to track recent trends. Year five survival was 47% at Red Eagle (55% for upper plots), year two survival at Hole-in-the-Wall was 46%, year two survival at Divide Creek was 96%, year one survival at Grinnell Picnic Area was 49%, and year one survival at Cobalt Lake was 31%.

Seedlings were not monitored this year at these sites, but year ten survival was 31% at Flattop Mountain, year six survival was 41% at Grinnell Point and year two survival was 46% at Caper Peak. Most sites were planted using some of the recommendations learned from limber pine plantings, including planting in burned areas, planting in microsites, and not using shade netting. However, due to lack of vast burned whitebark pine habitat in the park, some

recent planting sites currently occur in non-burned areas. Additionally, several sites lacked adequate natural shelter or available microsite materials.

These results are much more in keeping with results from other whitebark pine planting projects. Izlar (2007) compiled data from 37 whitebark planting events over the last 15 years in Montana, Wyoming, and Idaho. That summary reported that typical year one survival of planted whitebark seedlings is 74% (59-92% range), typical year three survival is 38% (31-47% range), and typical year five survival is 30% (19-42% range). Considering only the upper plots at Red Eagle, where planting sites were much more suitable, year one survival was 74%; exactly the average calculated by Izlar. Year three survival was 57%, much higher than the average and exceeded the highest end of the range. Year five survival was 55%, remaining much higher than average. If soil slides hadn't occurred in the area, survival would have even been even higher. Overall seedling survival, including the lower campground sites where all seedlings were dead, year five at Red Eagle is 47%. This is higher than average and also exceeds the high end of the range for Izlar's study.

Divide Creek remains the most successful planting site to date. Two years after planting, 96% of seedlings continue to thrive. These seedlings were planted late in the season with ample moisture, which appears to be very important. Also two years after planting, average survival across plots at Hole-in-the-Wall was 46%, ranging from 7% to 61%. Izlar's study did not include statistics for year two but we have seen that survival rates do not often change substantially between years two and three. Given this assumption, overall survival at Divide Creek is well above the three-year average of 38% and at Hole-in-the-Wall survival is above average as well. Again, plots with low survival seemed to have little protection from the elements for individual seedlings.

Unfortunately, year one survival is quite a bit lower than average at Grinnell Picnic Area and Cobalt Lake. Both of these sites were planted in late summer, just prior to a period of fairly unseasonably warm weather for early fall. Given the number of seedlings in poor condition one month prior to planting, it is likely that it was simply too hot for newly transplanted seedlings to survive. Additionally, fewer microsites were available, especially at Cobalt Lake, to help shelter seedlings. These sites also have not burned, so perhaps reduced available soil nutrients also affected survival.

As with limber pine plantings, we may need to be more critical about assessing a site as an appropriate whitebark pine planting site in GNP. The planting recommendations listed above for limber pine should also continue to be applied to whitebark pine plantings. In addition, there should be assessments made concerning the influence of slopes within planting areas, the possibility of falling bark of dead trees, and the impacts of competition from regenerating vegetation. All plantings should occur in the fall when temperatures are lower and precipitation is more reliable. Burned areas should be utilized when possible.

Direct seeding of whitebark pine seed has not been very successful so far at Glacier National Park. Only two of the five seed plots saw any germination and only one plot continues to support a few seedlings. Site selection was likely at least part of the problem at Siyeh Bend, which experiences frequent avalanches or snow slides and where seed predation by small mammals appeared high. If seed plots are to be experimented with again in the future, sites should be carefully selected and small screens should be installed to protect the seeds from herbivory. Seeds were not scarified or treated in any way prior to planting, which may also play a role. Additionally, seed was not extremely fresh or stored perfectly, which should also be taken into consideration in the future.

In 2013, seedling plots at Divide Creek (year 3) and Divide Mountain (year 1) should be monitored. Hole-in-the-Wall is also scheduled for year three monitoring, but due to distance, will be skipped next year. These plots should be monitored again in 2015, five years after planting. Seedling plots at Cobalt Lake and Grinnell Glacier Picnic Area would typically be due for monitoring next year, for second year after planting data, but time and money constraints have caused us to re-evaluate monitoring frequency. It has been decided to skip year two monitoring events and retain years 1, 3, 5 and 10 monitoring. In 2013, 2,900 whitebark pine seedlings are scheduled to be delivered in the fall for planting. Monitoring plots will be installed at planting areas to capture a targeted 20% of seedlings.

Table 41. Whitebark and Limber Pine Monitoring Schedule

black text = completed

red text = notes about trees in plots with high mortality

orange text = scheduled but not completed

blue text = scheduled for future

Plot(s)	Species	Location	Year Planted	Year Monitored: 2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
None installed	Whitebark pine	Dutch Creek	2000?											X (year 10)		
GP00 -01 to -07	Whitebark pine	Ginnell Point	2000	X (year 0)						X (year 6)				X (year 10)		
FT01 -01 to -27	Whitebark pine	Flattop	2001		X (year 0)	X (year 1)			X (year 4)	X (year 5)			X (year 8)		X (year 10)	
FT02 -01 to -11	Whitebark pine	Flattop	2002			X (year 0)			X (year 3)	X (year 4)			X (year 7)			
LP02 -01 to -25	Limber pine	Various	2002			X (year 0)	X (year 1)	X (year 2) ALL DEAD								
LP02-05	Limber pine	Many Glacier Hotel Slope	2002			X (year 0)	X (year 1)	X (year 2)		X (year 4) 1 TREE LEFT	X (year 5) 1 TREE LEFT		X (year 7) ALL DEAD			
LP02-22	Limber pine	Sun Point	2002			X (year 0)	X (year 1)	X (year 2)		X (year 4) 1 TREE LEFT	X (year 5) 1 TREE LEFT		X (year 7) ALL DEAD			
LP02-24	Limber pine	Firebrand Pass	2002			X (year 0)	X (year 1)	X (year 2)		X (year 4) 1 TREE LEFT						X (year 10)
LP03-01	Limber pine	Two Med Camp Store	2003				X (year 0)	X (year 1)		X (year 3)		X (year 6)				
LP04 -01 to -05	Limber pine	Baring Creek	2004					X (year 0)	X (year 1)	X (year 2)	X (year 3)	X (year 4)	X (year 5)			
LP04 -06 to -07	Limber pine	Many Glacier Hotel Slope	2004					X (year 0)	X (year 1)	X (year 2)	X (year 3)		X (year 5)			
LP04 -08	Limber pine	Sun Point	2004					X (year 0)	X (year 1)	X (year 2)	X (year 3)		X (year 5) ALL DEAD			
LP04 -09	Limber pine	Sun Point	2004					X (year 0)	X (year 1)	X (year 2)	X (year 3)		X (year 5)			
LP04 -10	Limber pine	Dead Horse Point	2004					X (year 0)	X (year 1)	X (year 2)	X (year 3)		X (year 5) 1 TREE LEFT			
LP04 -11	Limber pine	Dead Horse Point	2004					X (year 0)	X (year 1)	X (year 2)	X (year 3)		X (year 5) ALL DEAD			
LP05 -01 to -06	Limber pine	Scenic Point	2005						X (year 0)	X (year 1)	X (year 2)	X (year 3)		X (year 5)		
LP06 -02	Limber pine	Baring Creek	2006							X (year 0)	X (year 1)		X (year 3)		X (year 5)	
LP06 -01 & -03	Limber pine	Baring Creek	2006							X (year 0)	X (year 1)	X (year 2) ALL DEAD				
LP06 -04	Limber pine	Dead Horse Point	2006							X (year 0)	X (year 1)	Not done: all dead but 1 missing	X (year 3) ALL DEAD			
CP06 -01 to -02	Whitebark pine	Caper Peak (seeds + trees)	2006							X (year 0)		X (year 2)			X (year 5)	
WB07 -01 to -09	Whitebark pine	Red Eagle (seedlings)	2007								X (year 0)		X (year 2)	X (year 3)		X (year 5)
WBS07 -04 to -05	Whitebark pine	Red Eagle (seeds)	2007									X (year 1)	X (year 2)	X (year 3)		X (year 5)
WBS07 -01 to -03	Whitebark pine	Sneh Bend (seeds)	2007									X (year 1)	X (year 2)	X (year 3)		X (year 5)
WB10-01-05	Whitebark pine	Hole-in-the-Wall	2010								X (year 0)	X (year 1)	X (year 2)	X (year 3)	X (year 5)	NOTHING COMING UP
WB10-06-10	Whitebark pine	Divide Creek	2010											X (year 0)	X (year 1)	X (year 2)
GPA-WB-11-01 to -02	Whitebark pine	Ginnell Picnic Area	2011											X (year 0)	X (year 1)	X (year 2)
CL-WB-11-01 to -03	Whitebark pine	Gobalt Lake	2011											X (year 0)	X (year 1)	X (year 2)
WB12-01 to -04	Whitebark pine	Divide Mountain	2012													X (year 0)
LP12-01 to -02	Limber pine	Cutbank	2012													X (year 0)
LP12-03; 11	Limber pine	Apikuni Flats	2012													X (year 0)
LP12-04 to -05	Limber pine	Rising Sun CG	2012													X (year 0)
LP12-06 to -07	Limber pine	Scenic Point	2012													X (year 0)
LP12-10	Limber pine	Many Glacier Well Area	2012													X (year 0)

Plot(s)	Species	Location	Year Planted	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
None installed	Whitebark pine	Dutch Creek	2000?			X (year 15)					X (year 20)					X (year 25)					X (year 30)
GP00 -01 to -07	Whitebark pine	Ginnell Point	2000			X (year 15)					X (year 20)					X (year 25)					X (year 30)
FT01 -01 to -27	Whitebark pine	Flattop	2001			X (year 15)						X (year 20)					X (year 25)				
FT02 -01 to -11	Whitebark pine	Flattop	2002			X (year 14)						X (year 19)					X (year 24)				
LP02 -01 to -25	Limber pine	Various	2002																		
LP02-05	Limber pine	Many Glacier Hotel Slope	2002																		
LP02-22	Limber pine	Sun Point	2002																		
LP02-24	Limber pine	Firebrand Pass	2002				X (year 15) 1 TREE LEFT					X (year 20) 1 TREE LEFT						X (year 25) 1 TREE LEFT			
LP03-01	Limber pine	Two Med Camp Store	2003	X (year 10)				X (year 15)						X (year 20)					X (year 25)		
LP04 -01 to -05	Limber pine	Baring Creek	2004		X (year 10)					X (year 15)					X (year 20)					X (year 25)	
LP04 -06 to -07	Limber pine	Many Glacier Hotel Slope	2004							X (year 15)					X (year 20)					X (year 25)	
LP04 -08	Limber pine	Sun Point	2004																		
LP04 -09	Limber pine	Sun Point	2004			X (year 10)				X (year 15)					X (year 20)					X (year 25)	
LP04 -10	Limber pine	Dead Horse Point	2004		X (year 10) 1 TREE LEFT					X (year 15) 1 TREE LEFT					X (year 20) 1 TREE LEFT					X (year 25) 1 TREE LEFT	
LP04 -11	Limber pine	Dead Horse Point	2004																		
LP05 -01 to -06	Limber pine	Scenic Point	2005			X (year 10)					X (year 15)					X (year 20)					X (year 25)
LP06-02	Limber pine	Baring Creek	2006				X (year 10)					X (year 15)					X (year 20)				
LP06 -01 & -03	Limber pine	Baring Creek	2006					X (year 10)													
LP06 -04	Limber pine	Dead Horse Point	2006																		
CP06 -01 to -02	Whitebark pine	Caper Peak (seeds + trees)	2006				X (year 10)					X (year 15)					X (year 20)				
WB07 -01 to -09	Whitebark pine	Red Eagle (seeds + trees)	2007					X (year 10)						X (year 15)				X (year 20)			
WBS07 -04 to -05	Whitebark pine	Red Eagle (seeds)	2007					X (year 10)						X (year 15)				X (year 20)			
WBS07 -01 to -03	Whitebark pine	Sneh Bend (seeds)	2007															X (year 20)			
WB10-01-05	Whitebark pine	Hole-in-the-Wall	2010	X (year 3)		X (year 5)					X (year 10)					X (year 15)					X (year 20)
WB10-06-10	Whitebark pine	Divide Creek	2010	X (year 3)		X (year 5)					X (year 10)					X (year 15)					X (year 20)
GPA-WB-11-01 to -02	Whitebark pine	Ginnell Picnic Area	2011		X (year 3)		X (year 5)					X (year 10)					X (year 15)				
CL-WB-11-01 to -03	Whitebark pine	Gobalt Lake	2011		X (year 3)		X (year 5)					X (year 10)					X (year 15)				
WB12-01 to -04	Whitebark pine	Divide Mountain	2012	X (year 1)		X (year 3)		X (year 5)					X (year 10)					X (year 15)			
LP12-01 to -02	Limber pine	Cutbank	2012	X (year 1)		X (year 3)		X (year 5)					X (year 10)					X (year 15)			
LP12-03; 10 to 11	Limber pine	Apikuni Flats	2012	X (year 1)		X (year 3)		X (year 5)					X (year 10)					X (year 15)			
LP12-04 to -05	Limber pine	Rising Sun CG	2012	X (year 1)		X (year 3)		X (year 5)					X (year 10)					X (year 15)			
LP12-06 to -09	Limber pine	Scenic Point	2012	X (year 1)		X (year 3)		X (year 5)										X (year 15)			
LP12-10	Limber pine	Many Glacier Well Area	2012	X (year 1)		X (year 3)		X (year 5)					X (year 10)					X (year 15)			

VI. WHITEBARK AND LIMBER PINE PLUS TREE MONITORING

A. INTRODUCTION

Whitebark pine (*Pinus albicaulis*) and limber pine (*Pinus flexilis*) populations have declined dramatically in Glacier National Park, largely due to the introduction of a non-native fungus, white pine blister rust (*Cronartium ribicola*). White pine blister rust is a disease of five-needled pines and has been linked to the decline of all five-needled pines in the park. Spores from a secondary host infect trees through the needles and the fungus subsequently grows into the stem, producing fusiform cankers, almost always eventually killing the tree (Hoff 1992). Glacier National Park not only has a high mortality rate associated with blister rust, but it also has an extremely high blister rust infection rate of remaining live trees. Infection is estimated at 78% for both whitebark and limber pine trees that remain in the Park (Kendall and Keane 2001). A massive effort at removing secondary hosts for white pine blister rust in the Park was attempted between 1930 and 1970. Enormous numbers of *Ribes* species were removed by hand pulling and chemical control with no success at curtailing the disease (USGS 2003). Additionally, climate change may favor conditions that enhance distribution of blister rust spores. Recent climatic conditions produce frequent “wave years” that promote massive numbers of infections (Koteen 2002). Therefore, it does not appear that preventing the spread of blister rust is an effective strategy for preservation of whitebark or limber pine.

Taking advantage of natural blister rust resistance may be a more effective strategy for restoration of whitebark and limber pine. Natural genetic resistance has been found in several species of five-needled pines and there is preliminary evidence that whitebark pine may also exhibit natural resistance (Schwandt 2006). A protocol has been implemented by U.S. Forest Service nurseries whereby potential rust-resistant seedlings are tested for resistance. Preliminary tests have revealed resistance in some whitebark pine seedlings (Maholovich et al. 2006).

Glacier National Park has been attempting to utilize naturally resistant trees in its restoration program for the past 14 years. Cones have been collected from phenotypic-resistant whitebark pine trees since 1997. Phenotypic indicators of blister rust resistance include no or very few active blister rust cankers, no or very few inactive blister rust cankers, no to little impact to canopy cover of tree (no flags, dead branches, etc.), and the presence of cones. Wire cages are placed around cones during seed production for protection from predators with seed then collected later in the season. It is important to note that there has been no testing to date of blister rust resistance for any tree in Glacier National Park, so it is unknown whether or not the cone trees were truly resistant. In addition, despite best intentions, seed was combined so that it is now impossible to tell which seedlings were grown from which potential rust resistant cone tree. Beginning in 2007, seedlings were able to be tracked to a parent tree in a particular location in the park (i.e., Preston Park) but surviving seedlings have not been traceable with their seed source tree. Caging of trees in 2008 began a large scale collection for genetic testing, whereby all seed will be directly traceable to a specific tree.

Occasionally, trees were inadvertently caged that were infected with blister rust, and over time some of the potentially rust resistant trees have become infected. This influenced the decision to expand upon the initial purpose for monitoring potential plus trees purely as a seed source. Previously, cone trees have not been monitored over time for long-term health and resistance. Initially the purpose of this study was to identify and build baseline data for potential phenotypically rust resistant whitebark pine trees (“plus trees”) for field monitoring over time, as well as to identify potential cone collection trees for the future. Since whitebark pine often grow in very remote and isolated areas, this survey was also designed to reduce the amount of time and effort required when searching for cone trees to cage. Information is now being gathered concerning the trees’ ability to resist infection, how quickly the infection spreads and how long a tree may survive with infection. Additionally, more is now known about multiple forms of blister rust resistance in whitebark pine. Varying degrees of resistance exist, from showing no symptoms when exposed to spores to active cankers on trees that never die (Maholovich, pers. comm.). While this information may aid in future cone collection, it may also help answer questions about resistance of specific trees in Glacier’s populations that are highly infected with blister rust, as well as the fate of trees that have mild blister rust infection.

In 2009, Glacier National Park had the opportunity to join the U.S. Forest Service’s study on genetic resistance in whitebark pine plus trees. Since then, collection efforts have centered on caging from trees that meet requirements for the study. In order to be accepted into this experiment, seed must be collected from 25 individual trees, with no more than three trees per stand and individual trees being at least 300 feet apart. Protocol requires

1,800 seeds per tree to be donated to the program. One-third of the seeds will be grown into seedlings for exposure to blister rust and resistance testing, one-third will go into a seed bank and one-third will be grown into seedlings for an off-site seed orchard, if Glacier decides to participate in this. Glacier met the seed requirements for all 25 trees in 2012 and genetic testing began. Once the seedlings are inoculated with blister rust for the screening, they are outplanted and monitored for rust for 5 years.

In addition to blister rust, whitebark pine is also susceptible to attack from mountain pine beetle (*Dendroctonus ponderosae*), a native bark beetle. While alpine environments in Glacier have not experienced much pine beetle exposure, it has caused extensive damage to whitebark pine forests in other areas in the state in recent years. Pine beetle infestation has been moderate in the middle fork region of Glacier over the last few years, and potentially could reach some plus tree sites. Additionally troublesome is that there seems to be an inverse relationship between blister rust resistance and mountain pine beetle resistant, meaning that plus trees are more at risk from pine beetle attack (Maholovich, pers. comm.). Beginning in 2011, verbenone patches have been applied to plus trees in an attempt to ward off pine beetle attack. Verbenone is an antiaggregation pheromone, thought to trick beetles into thinking the tree is already infected and that they need to look elsewhere for a suitable host tree.

B. METHODS

Beginning in 2007, whitebark pine tree populations were scouted for potential plus trees. Limber pine was also targeted in a few sites. For each population, trees were assessed for the presence of blister rust as well as overall health. Mostly blister rust canker-free trees were chosen for inclusion in the monitoring pool. Occasionally, trees that looked healthy but were mildly infected were also selected for monitoring to document the impacts of mild infestation on whitebark pines trees. Resistant trees can suppress cankers by a defense reaction whereby the tree builds a periderm around the infection (Hoff 1992). As cone production is variable by year, the presence of cones was not initially a determining factor for including a tree in the monitoring pool. Monitoring these plus trees on an annual to biannual basis should also provide information on cone production trends over time.

Potential plus trees were each numbered and their locations were recorded using a GPS unit. In 2007 and 2008, identification numbers were written on each tree bole with a waterproof marker to reduce impacts to the tree. By 2009, after realizing that this marking does not persist over time, some of the plus trees were marked with nails and flagging in the ground at the base of the tree to further assist with re-location. This method is working well for tree identification and will be continued for all plus trees in the future. Trees were assessed for percent live canopy and measured for DBH and height. Presence and number of cones was noted. A digital photograph was taken of each tree with the distance and azimuth from the tree recorded. Evidence of blister rust on the bole or branches of the tree was recorded and categorized as active or inactive canker. Additional information about the site, such as the canopy cover of the surrounding forest, state of surrounding whitebark pine trees, whitebark regeneration in the area, and general site characteristics, was documented. Also noted were associated species, particularly any known or potential secondary hosts to blister rust, such as *Ribes* or *Castilleja* species. Presence of Clark's nutcrackers, whitebark pine seed dispersers, was also recorded.

Blister rust was identified in trees by the presence of active cankers, inactive cankers, or by old dead cankers evidenced by bark cracking or spindle-shaped branches (Hoff 1992). Signs of active (sporulating) cankers were orange-colored spore casings emerging from small cracks in the branches. Inactive cankers were identified by empty white fruiting bodies leftover from sporulation from the current year or spindle-shaped limbs characterized by extensive bark cracking. Early infections, prior to fruiting, were more difficult to identify but were recorded when recognized. Heavy sap flow and discoloration on the outside of the bark can be an early sign of blister rust (Hagle et al. 2003) and was also recorded when sighted. Yellow-orange patches on the stem and the beginnings of spindle-shaped stems may also be one of the only signs of blister rust infection for the first 4-5 years. Additionally, "bark stripping" was noted as possible evidence of cankers. High amounts of sugars are produced in cankers and animals such as rodents, ants and grasshoppers feed on them (Hoff, 1992) causing areas where bark has been scraped or chewed off. "Flagging", or ends of branches where needles have died that leave a red-needled branch tip, was also recorded as a potential sign of blister rust infection. Whenever signs were encountered that were most likely the early signs of blister rust, but could not be definitively called so, it was recorded as "probable".

To date, there are 100 whitebark pine trees that are monitored as part of the plus tree pool; 56 trees were identified in 2007, 4 trees were identified in 2008, 13 were identified in 2009, and 9 were identified in 2010. In 2011,

18 trees were added to the plus tree pool (Figure 16 and Table 42). Monitoring sites for whitebark pine established in 2007 include Numa Lookout (7 trees), Old Man Lake Trail (7 trees), Otokomi Lake (6 trees), Preston Park (20 trees), Rising Wolf (6 trees), Scenic Point (7 trees) and Siyeh Bend (3 trees). In 2008, only one site was added at Triple Divide with 4 trees. In 2009, 5 additional trees were added at Scenic Point, 5 additional trees were added at Numa Lookout and 3 additional trees were added at Preston Park. In 2010, one additional tree was added at Preston Park, one additional tree was added at Scenic Point, and 7 additional trees were added at White Calf, a new site for plus tree monitoring. In 2011, 4 new plus trees were added to the pool at White Calf, 2 new trees were added at Triple Divide Trail and 3 new trees were added at Fire Brand Trail, which is a new monitoring site. Additionally, 9 new trees were added to the pool from Old Man Lake Trail, although 4 of these trees had been monitored since 2010 as potential plus trees. Four limber pine trees are present in the plus tree monitoring pool. Two trees, one at Dead Horse Point and one at Scenic Point, were identified in 2007, while two additional trees were identified in 2010, one at White Calf and a second tree at Dead Horse Point (Figure 16 and Table 45).

In 2012, due to time and money constraints, only cone counts were performed on whitebark and limber pine plus trees. This was done at the time that the revegetation crew applied verbenone patches to plus trees in the spring as well as while climbing trees for cone caging and collection.

C. RESULTS

All whitebark and limber pine plus tree sites were monitored for cone production in 2012. Health of individual plus trees was not assessed this year. Cones were collected from only two trees in 2012 in order to complete the seed requirement for the rust-resistance genetics testing program with the USFS. Cone counts were performed on these trees again at this time. Since cones are much more visible when climbing a tree, cone counts increased in these trees from initial assessment in the spring. At Numa Lookout, tree WB09-08 was estimated to have 22 cones in the spring, increasing to 67 cones when climbing the tree later in the season. At Otokomi Lake, tree WB07-46 was estimated to have 45 cones in the spring but 127 cones were counted when climbing. It should be noted, therefore, that cone estimates from previous years are probably about three times lower than the true number. For the most part, cone numbers listed in the tables below were estimated from the ground unless the tree was climbed for cone collection.

After a banner cone year in 2011, cone production has dropped this year to levels more similar to 2009-2010 (Tables 42 and 44; Figure 17). This year, 57% of monitored trees produced cones, as compared to 89% last year. The average number of cones per tree was 12 compared to 66 average cones in 2011. This is not as low as our lowest monitoring year in 2008 when the average number of cones per tree was 5 and only 52% of trees produced cones. Very little is known about the frequency of mast years in whitebark pine, although it has been found that healthy stands of whitebark pine in the Greater Yellowstone area had moderate or large conecrop years 2 or 3 times from 1980-1990 (Morgan and Bunting 1990). It appears that we may be on about a 5-year cycle (Figure 17), although too little data is available to make any predictions. It should be noted that the healthiest whitebark pine trees, now that they have been identified, are currently being targeted for cone collection. The actual cone production rate for the overall stand could indeed be much lower. A total of 194 cones were collected by the revegetation crew this year from two trees (Table 43). This was to fulfill our seed requirement for the USFS genetic study. No seed was collected for operational purposes.

Figure 16. Location of Whitebark and Limber Pine Plus Trees for Monitoring

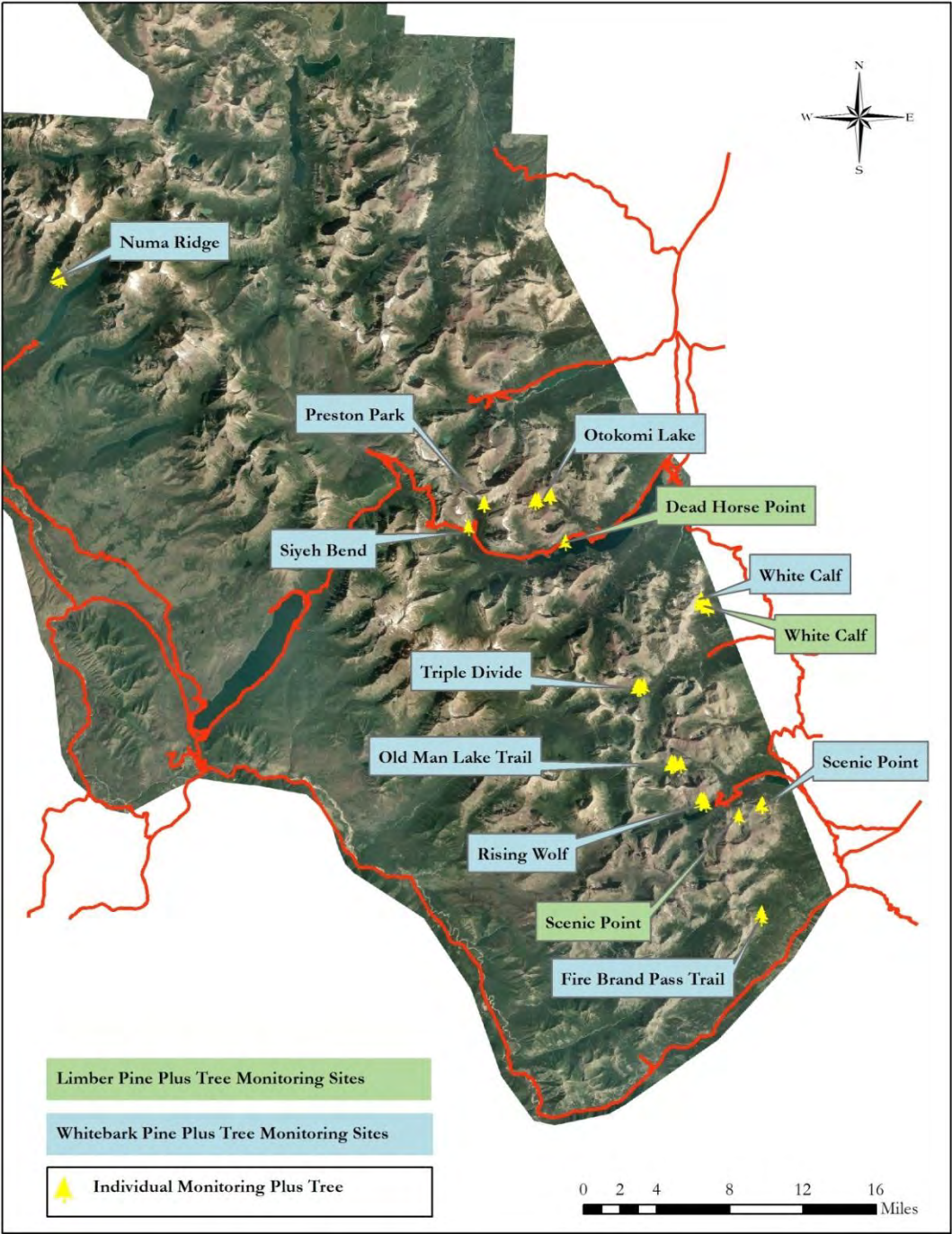


Table 42. Whitebark Pine Plus Trees: Comparison of Health and Cone Production, 2007-2012.

<i>Site</i>	<i>Date</i>	<i># of Trees Monitored</i>	<i># of Healthy Trees¹</i>	<i># with Active Cankers</i>	<i># with Inactive Cankers</i>	<i># with Possible Cankers</i>	<i># With Cones</i>
Numa Lookout	2007	7	5	1	0	2	7
Numa Lookout	2008	7	4	3	2	1	1
Numa Lookout	2009	12	6	5	4	1	6
Numa Lookout	2011	12	3	8	5	1	11
Numa Lookout	2012	12	n/a	n/a	n/a	n/a	8
Old Man Lake Trail	2007	7	5	1	2	0	2
Old Man Lake Trail	2010	7	4	3	3	2	2
Old Man Lake Trail	2011	16	7	7	6	5	16
Old Man Lake Trail	2012	10	n/a	n/a	n/a	n/a	8
Otokomi Lake	2007	6	4	0	0	2	4
Otokomi Lake	2010	6	3	2	3	4	3
Otokomi Lake	2012	6	n/a	n/a	n/a	n/a	5
Preston Park	2007	20	13	5	4	1	20
Preston Park	2008	20	13	7	3	1	13
Preston Park	2009	23	12	4	8	3	18
Preston Park	2010	24	13	9	7	8	21
Preston Park	2011	24	n/a	n/a	n/a	n/a	19
Preston Park	2012	24	n/a	n/a	n/a	n/a	21
Rising Wolf	2007	6	5	0	0	1	2
Rising Wolf	2009	6	2	3	4	1	3
Rising Wolf	09 & '11	6	1	3	4	0	6
Rising Wolf	2012	6	n/a	n/a	n/a	n/a	3
Scenic Point	2007	7	4	1	1	2	7
Scenic Point	2008	7	2	1	3	2	5
Scenic Point	2009	12	3	6	6	2	8
Scenic Point	2010	13	2	8	8	3	13
Scenic Point	2011	13	5	6	7	2	13
Scenic Point	2012	13	n/a	n/a	n/a	n/a	12
Siyeh Bend	2007	3	1	2	2	0	0
Siyeh Bend	2008	3	0	3	3	0	1
Siyeh Bend	2012	3	n/a	n/a	n/a	n/a	0
Triple Divide	2008	4	3	1	0	0	3
Triple Divide	2010	4	3	0	1	0	1
Triple Divide	2011	6	4	1	2	1	6
Triple Divide	2012	6	n/a	n/a	n/a	n/a	5
White Calf	2010	7	2	4	4	0	7
White Calf	2011	11	5	5	6	3	11
White Calf	2012	11	n/a	n/a	n/a	n/a	11
Firebrand Pass Trail	2011	3	0	1	2	2	3
Firebrand Pass Trail	2012	3	n/a	n/a	n/a	n/a	0
TOTAL 2007		56	37	10	9	8	42
TOTAL 2008		60	36	16	13	7	31
TOTAL 2009		73	35	23	27	9	45
TOTAL 2010		82	35	37	37	19	57
TOTAL 2011		100	41	45	45	26	89
TOTAL 2012		94	n/a	n/a	n/a	n/a	54
% 2007			66%	18%	16%	14%	75%
% 2008			60%	27%	22%	12%	52%
% 2009			48%	32%	37%	12%	62%
% 2010			43%	45%	45%	23%	70%
% 2011			41%	45%	45%	26%	89%
% 2012			n/a	n/a	n/a	n/a	57%

* Some of these trees have active, inactive and/or probable cankers on the same tree.

Table 43. Caged Whitebark Pine Trees and Cones Collected, 2012.

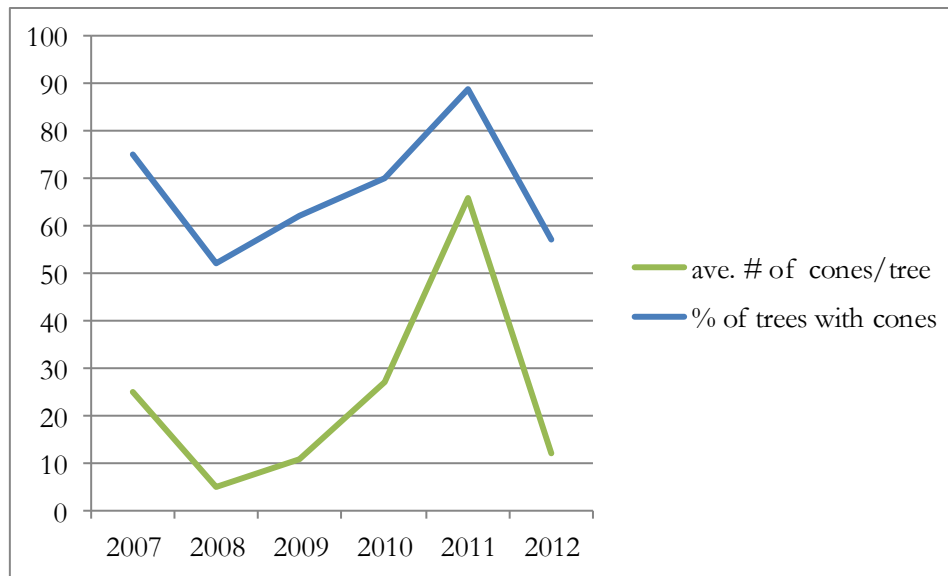
<i>Site</i>	<i>Trees Caged</i>	<i>Cones Collected</i>
Numa	1	67
Otokomi	1	107
Total	2	174

Table 44. Whitebark Pine Plus Trees: Cone Frequency, 2007 – 2012.

<i>Site</i>	<i>2007</i>			<i>2008</i>			<i>2009</i>		
	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Ave. # of Cones/Tree</i>	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Ave. # of Cones/Tree</i>	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Ave. # of Cones/Tree</i>
Fire Brand Pass Tr.	0	n/a	n/a	0	n/a	n/a	0	n/a	n/a
Numa Lookout	7	165	24	7	5	1	6	52	9
Old Man Trail	7	38	5	0	n/a	n/a	0	n/a	n/a
Otokomi Lake	6	14	2	0	n/a	n/a	0	n/a	n/a
Preston Park	20	925	46	20	176	9	23	267	12
Rising Wolf	6	16	3	0	n/a	n/a	6	89	15
Scenic Point	7	237	34	7	10	1	10	109	11
Siyeh Bend	3	4	1	3	10	3	0	n/a	n/a
Triple Divide	0	n/a	n/a	4	4	1	0	n/a	n/a
White Calf	0	n/a	n/a	0	n/a	n/a	0	n/a	n/a
TOTAL	56	1395	25	41	195	5	45	517	11

<i>Site</i>	<i>2010</i>			<i>2011</i>			<i>2012</i>		
	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Ave. # of Cones/Tree</i>	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Ave. # of Cones/Tree</i>	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Ave. # of Cones/Tree</i>
Fire Brand Pass Tr.	0	n/a	n/a	3	246	82	3	0	0
Numa Lookout	0	n/a	n/a	12	305	25	12	193	16
Old Man Trail	7	9	1	15	1399	103	10	95	10
Otokomi Lake	6	25	4	0	n/a	n/a	6	171	29
Preston Park	24	718	30	21	219	10	24	189	8
Rising Wolf	0	n/a	n/a	3	500	167	6	31	5
Scenic Point	11	599	54	13	631	56	13	152	12
Siyeh Bend	0	n/a	n/a	0	n/a	n/a	3	0	0
Triple Divide	4	1	0	6	723	121	6	44	7
White Calf	7	232	33	11	1484	135	11	269	24
TOTAL	59	1584	27	84	5507	66	94	1144	12

Figure 17. Trends in Whitebark Pine Cone Production 2007-2012.



Four limber pine trees were monitored this year; one at Dead Horse Point, one at Scenic Point and two at White Calf. Each tree is healthy and producing abundant cones (Tables 45 and 46). Average numbers of cones is slightly higher this year than last year, although it is difficult to assess with such a small sample size. It should be noted that only one tree was monitored at Whitecalf last year, while two trees were monitored this year. The tree monitored both years had about half the number of cones as last year (49 vs. 100). The additional tree monitored at Whitecalf this year had an exceptional number of cones (200), which may have skewed the data.

Table 45. Limber Pine Plus Trees: Health and Cone Production, 2012.

<i>Site</i>	<i>Date</i>	<i># of Trees Monitored</i>	<i># of Healthy Trees¹</i>	<i># with Active Cankers</i>	<i># with Inactive Cankers</i>	<i># with Possible Cankers</i>	<i># With Cones</i>
Dead Horse Point	7/2/2012	1	n/a	n/a	n/a	n/a	1
Scenic Point	6/18/12	1	n/a	n/a	n/a	n/a	1
White Calf	7/9/12	2	n/a	n/a	n/a	n/a	2
	TOTAL	4	n/a	n/a	n/a	n/a	4
	2007 PERCENT		100%	0%	0%	0%	100%
	2008 PERCENT		100%	0%	0%	0%	100%
	2009 PERCENT		100%	0%	0%	0%	50%
	2010 PERCENT		75%	0%	25%	0%	100%
	2011 PERCENT		100%	0%	0%	0%	100%
	2012 PERCENT		n/a	n/a	n/a	n/a	100%

Table 46. Limber Pine Plus Trees: Cone Frequency, 2007 – 2012.

<i>Site</i>	<i># of Trees Monitored</i>	<i># of Cones in 2007</i>	<i>Avg Cones per Tree 07</i>	<i># of Cones in 2008</i>	<i>Avg Cones per tree 08</i>	<i># of Cones in 2009</i>	<i>Avg Cones per tree 09</i>
Dead Horse Point	1/2	100	100	50	50	200	200
Scenic Point	1	10	10	20	20	0	0
Whitecalf	0						
TOTAL	2/4	110	55	70	35	200	100

<i>Site</i>	<i># of Trees Monitored 10</i>	<i># of Cones in 2010</i>	<i>Avg Cones per tree 10</i>	<i># of Trees Monitored 11</i>	<i># of Cones in 2011</i>	<i>Avg Cones per tree 11</i>	<i># of Trees Monitored 12</i>	<i># of Cones in 2012</i>	<i>Avg Cones per tree 12</i>
Dead Horse Point	1	46	23	0	n/a	n/a	1	40	40
Scenic Point	1	15	15	1	55	55	1	40	40
Whitecalf	1	75	75	1	100	100	2	249	125
TOTAL	3	136	34	2	155	78	4	329	82

D. CONCLUSIONS AND RECOMMENDATIONS

Monitoring data is beginning to document the cyclic nature of cone production in whitebark pine trees. While 2008 and 2009 showed a decline in whitebark pine cone production throughout the park, cone production was higher in 2010 at 70% and much higher in 2011 with 89% of plus trees having cones. This year's data showed a decline in cone production again, similar to 2009 and 2010 levels. In addition, the number of cones per tree also decreased this year. Once again, it is important to note that the overall park-wide cone production was likely lower, given that the healthiest trees were targeted for cone collection and thus monitoring. Future monitoring over the next several years will begin to document the local trends of cone production in the park, as well track the impacts of increasing blister rust on cone production of the plus tree pool.

Since the future of healthy whitebark pine trees is unknown, a larger pool of trees is imperative for seed collection and genetic integrity of our seedling stock. Three new collection sites were added in 2011, along the Old Man Lake Trail, Triple Divide Trail and Firebrand Pass Trail, furthering this goal. Old Man and Triple Divide have had established plus trees that have been monitored since 2007 and 2008. There continue to be areas within known whitebark stands that could be scouted for additional plus trees, particularly at White Calf, which appears to be the largest and healthiest whitebark population in the park. Numerous other healthy-looking trees with cones have been observed in that area. Preston Park also offers potential for adding new plus trees, since it is a large stand and the entire area has not been scouted for healthy whitebark pine. Preston Park has the highest number of plus trees and has a fairly reliable cone crop. Other possible sites to search for healthy whitebark pine in 2013 include the trails in the Many Glacier subdistrict, the Morning Star Lake trail, Bighorn Basin and the flanks of Spot Mountain.

Additionally, care of currently identified plus trees continues to be a goal. Since 2008, limbs with active cankers have been removed or cut off, a recent practice that may prolong the life of certain whitebark pine plus trees in the monitoring pool. Since 2011, verbenone patches have been applied to plus trees for the in an effort to protect them from mountain pine beetle attacks. A Whitebark Pine Management Plan needs to be written to address the continued care of these trees, including protection from encroaching subalpine fire and from wildfire.

No data on the health of plus trees was taken this year. As time and money permit, health data should continue to be collected to learn more about the potential resistance of these trees. Now that more is known about varying levels of resistance to blister rust in whitebark pine trees, it is more encouraging that some infected trees may be able to remain functional for some time. The highest level of resistance is obtained when a tree contains two recessive "no spot genes"; there is no evidence these trees have been infested even after exposure. Needle shed resistance, from a single recessive gene, is another form of defense whereby blister rust spores penetrate stomates and grow down needles, but the tree is able to shed infected needles and not become further infected. A third form of

defense, fascicle shed resistance, is observed when the entire 5-needled fascicle is shed after infection. A fourth form of resistance, bark reactive resistance is a polygenetic form. The bark forms a callus or “scab” and walls off the disease. This can even happen at the bole; so contrary to popular belief, bole cankers can still be present on a resistant tree. Finally, trees can still have a form of resistance while harboring active cankers that never die. As long as cankers do not girdle the tree, some trees are able to survive with one or more persistent active cankers (Maholovich pers. comm.).

As mentioned in the introduction, Glacier is participating in a genetic resistance program with the U.S. Forest Service to test the resistance of whitebark pine plus trees to blister rust. This year’s cone collection should have fulfilled our requirements to enter 25 plus trees into the testing program. Information from this study will provide us with guidance for whitebark seed collection in the future and protection of our plus tree pool. In order to target our most potentially resistant trees, our current strategy for collecting whitebark and limber pine seed is to collect seed from trees that either show no or very little sign of blister rust. With the amount of energy, time and money it takes to restore whitebark and limber pine trees in the park, it seems prudent to begin the process with seed that has the best chance of restoring healthy trees to the area. Gathering long-term data on these plus trees will help to ensure that the healthiest trees in the park are being used for seed collection.

As monitoring continues, data may help to answer whether some trees that exhibit mild blister rust infection can fend off lethal infection and remain healthy. It may also help us determine a timeline for survival of trees that succumb to infection. Data may also determine whether trees that appear healthy in the midst of dead and dying trees can remain blister rust free. Monitoring plus trees should also provide data on cone production cycles that could help plan future seed collection efforts.

Whitebark and limber pine plus trees should be monitored each year if funding and time exists. Plus trees should, at a minimum, be monitored on a bi-annual basis to collect information on cone production and tree health. Additionally, it is recommended that verbenone continue to be applied to trees annually to protect against mountain pine beetle attack, which exists as a threat in the southern and northwestern edges of the park.

VII. OVERALL RECOMMENDATIONS FOR REVEGETATION AND REVEGETATION MONITORING

The revegetation and revegetation monitoring programs are making positive strides in restoring disturbed communities in Glacier National Park. One area in which we have made improvements is assessing appropriate species to use in specific revegetation areas. Listed below are recommendations for general plant species that are typically found in common forest, grassland, and subalpine meadow types. While these lists should not override the use of specific information found in site analysis data, these general lists should help to guide the nursery and restoration planners in common plants that we consistently see across the park in common habitats. Due to the complexity and site specific nature of wetland, shrubland, and alpine types, there are no general lists for these areas. A few additional recommendations are also listed that address communication and sampling design.

SPECIES SELECTION:

Certain plant species in Glacier National Park have a wide amplitude of habitats in which they grown and are quite common in the Park. From our observations, the following species are often present in these common plant communities. As a result, we have found that we recommend them frequently for revegetating areas. Adding to the complexity of the restoration process, many of these listed species are generally difficult to grow in the nursery. Species listed with a * are species that have been difficult to grow in the past and are species that are currently being experimented with in the nursery. Given their common presence in a number of plant communities, however, these species should be salvaged whenever possible.

Moist cedar-hemlock forest (montane - west side):

<u>Trees</u>	<u>Shrubs</u>	<u>Forbs/Ferns</u>	<u>Grasses</u>
<i>Betula papyrifera</i>	<i>Acer glabrum</i>	<i>Adenocaulon bicolor</i> *	<i>Bromus vulgaris</i>
<i>Larix occidentalis</i>	<i>Amelanchier alnifolia</i>	<i>Aralia nudicaulis</i> *	<i>Calamagrostis rubescens</i>
<i>Picea engelmannii</i>	<i>Linnaea borealis</i> *	<i>Athyrium filix-femina</i>	<i>Carex concinnoides</i>
<i>Pinus monticola</i>	<i>Lonicera utahensis</i>	<i>Chimaphila umbellata</i> *	<i>Carex rossii</i>
<i>Pseudotsuga menziesii</i>	<i>Menziesia ferruginea</i>	<i>Clintonia uniflora</i> *	<i>Elymus glaucus</i>
<i>Thuja plicata</i>	<i>Paxistima myrsinites</i>	<i>Cornus canadensis</i>	
<i>Tsuga heterophylla</i>	<i>Rosa acicularis</i>	<i>Disporum hookeri/ trachycarpum</i> *	
	<i>Rubus parviflorus</i>	<i>Dryopteris expansa</i>	
	<i>Spiraea betulifolia</i>	<i>Goodyera oblongifolia</i> *	
	<i>Vaccinium membranaceum</i> *	<i>Gymnocarpium dryopteris</i>	
		<i>Maianthemum stellatum</i> *	
		<i>Orthilia secunda</i> *	
		<i>Osmorhiza berteroi</i> *	
		<i>Thalictrum occidentale</i> *	
		<i>Tiarella trifoliata</i> *	
		<i>Viola orbiculata</i> *	
		<i>Xerophyllum tenax</i> *	

Engelmann spruce-subalpine fir forest (montane – east and west):

<u>Trees</u>	<u>Shrubs</u>	<u>Forbs/Ferns</u>	<u>Grasses</u>
<i>Abies lasiocarpa</i>	<i>Acer glabrum</i>	<i>Arnica cordifolia</i>	<i>Bromus vulgaris</i>
<i>Larix occidentalis</i>	<i>Amelanchier alnifolia</i>	<i>Clintonia uniflora</i> *	<i>Calamagrostis rubescens</i>
<i>Picea engelmannii</i>	<i>Linnaea borealis</i> *	<i>Disporum hookeri</i> *	<i>Elymus glaucus</i>
<i>Pinus contorta</i>	<i>Mahonia repens</i>	<i>Disporum trachycarpum</i> *	<i>Festuca occidentalis</i>
	<i>Paxistima myrsinites</i>	<i>Eurybia conspicua</i>	<i>Festuca subulata</i>
	<i>Salix scouleriana</i>	<i>Maianthemum racemosum</i> *	
	<i>Sorbus scopulina</i>	<i>Oryzopsis asperifolia</i>	
	<i>Spiraea betulifolia</i>	<i>Osmorhiza berteroi</i> *	
	<i>Symphoricarpos albus</i>	<i>Thalictrum occidentale</i> *	
	<i>Vaccinium caespitosum</i> *	<i>Viola orbiculata</i> *	
	<i>Vaccinium membranaceum</i> *	<i>Xerophyllum tenax</i> *	
	<i>Vaccinium myrtillus</i> *		

Engelmann spruce-subalpine fir forest (subalpine – east and west):Trees

Abies lasiocarpa
Picea engelmannii
Pinus contorta

Shrubs

Alnus viridis
Arctostaphylos uva-ursi
Menziesia ferruginea
Paxistima myrsinites
Ribes lacustre
Rubus parviflorus
Sorbus scopulina
Spiraea betulifolia
*Vaccinium membranaceum**
*Vaccinium myrtillus**
*Vaccinium scoparium**

Forbs/Ferns

Arnica cordifolia/ latifolia
Erigeron peregrinus
*Erythronium grandiflorum**
Eucephalus engelmannii
Luzula glabrata var. hitchcockii
*Mitella breweri**
Pedicularis bracteosa
*Thalictrum occidentale**
Valeriana sitchensis
Veratrum viride
*Viola orbiculata**
*Xerophyllum tenax**

Grasses

Calamagrostis rubescens
Carex geyeri

Douglas fir forest (mesic montane – east and west):Trees

Abies lasiocarpa
Larix occidentalis
Pinus contorta
Pseudotsuga menziesii

Shrubs

Acer glabrum
Amelanchier alnifolia
*Linnaea borealis**
Lonicera utahensis
Mahonia repens
Menziesia ferruginea (higher)
Paxistima myrsinites
Rosa woodsii
Rubus parviflorus
Shepherdia canadensis

Forbs/Ferns

Achillea millefolium
Arnica cordifolia
*Clintonia uniflora**
Eurybia conspicua
*Goodyera oblongifolia**
*Orthilia secunda**
*Thalictrum occidentale**
*Xerophyllum tenax**

Grasses

Calamagrostis rubescens
Carex geyeri
Carex rossii
Festuca occidentalis

Douglas fir and/or ponderosa pine forest (drier montane – mostly west): species listed in Douglas fir forest above plus these additional speciesTrees

Pinus ponderosa

Shrubs

Arctostaphylos uva-ursi
Dasiphora floribunda
Juniperus communis
*Vaccinium caespitosum**

Forbs/Ferns

Antennaria rosea
Heuchera cylindrica
Penstemon confertus
Potentilla gracilis

Grasses

Festuca campestris
Danthonia intermedia
Pseudoroegneria spicata

Lodgepole pine and/or western larch forests (montane – mostly west):Trees

Larix occidentalis
Pinus contorta
Pseudotsuga menziesii

Subcanopy:

Abies lasiocarpa
Pseudotsuga menziesii
Thuja plicata
Tsuga heterophylla

Shrubs

Acer glabrum
Amelanchier alnifolia
*Linnaea borealis**
Mahonia repens
Rosa woodsii
Rubus parviflorus
Spiraea betulifolia
Symphoricarpos albus
*Vaccinium caespitosum**
*Vaccinium membranaceum**
*Vaccinium myrtillus**

Forbs/Ferns

Arnica cordifolia
Chamerion angustifolium
*Chimaphila umbellata**
*Clintonia uniflora**
Eurybia conspicua
Symphyotrichum laeve var. laeve
*Xerophyllum tenax**

Grasses

Calamagrostis rubescens
Carex concinnoides
Carex geyeri
Oryzopsis asperifolia

Quaking aspen (montane – east and west):Trees

Abies lasiocarpa
Picea engelmannii
Pinus contorta
Populus tremuloides

Shrubs

Acer glabrum
Amelanchier alnifolia
Mahonia repens
Prunus virginiana
Rosa acicularis
Rubus parviflorus
Salix scouleriana
Spiraea betulifolia
Symphoricarpos albus

Forbs/Ferns

Aster conspicuus
*Castilleja miniata**
Chamerion angustifolium
Equisetum arvense
Fragaria virginiana
Heracleum sphondylium
*Maianthemum racemosum**
*Maianthemum stellatum**
*Osmorhiza occidentalis**
*Thalictrum occidentale**
Veratrum viride
*Viola canadensis**

Grasses

Bromus carinatus
Calamagrostis canadensis
Calamagrostis rubescens
Carex geyeri
Elymus glaucus

Quaking aspen/black cottonwood/conifer (montane – east and west):Trees

Abies lasiocarpa
Betula papyrifera
Picea engelmannii
Pinus contorta
Populus tremuloides
Populus balsamifera

Shrubs

Alnus viridis
Amelanchier alnifolia
Cornus sericea
Lonicera utahensis
Ribes inerme
Rubus parviflorus
Spiraea betulifolia
Symphoricarpos albus/occidentalis

Forbs/Ferns

Actaea rubra
*Angelica arguta**
Chamerion angustifolium
*Disporum trachycarpum**
*Equisetum arvense**
Eurybia conspicuus
Fragaria virginiana
Geranium viscosissimum
Heracleum sphondylium
*Maianthemum stellatum**
*Osmorhiza occidentalis**
Pteridium aquilinum
*Thalictrum occidentale**
*Viola canadensis**

Grasses

Calamagrostis canadensis
Carex geyeri
Elymus glaucus
Melica smithii

Idaho Fescue/rough fescue (montane – east and west):Shrubs

Arctostaphylos uva-ursi
Dasiphora floribunda

Forbs/Ferns

Achillea millefolium
Agoseris glauca
Anemone multifida
Antennaria rosea
Antennaria umbrinella
Cerastium arvense
Eriogonum umbellatum
Fragaria virginiana
Gaillardia aristata
Galium boreale
Geranium viscosissimum
Geum triflorum
Hedysarum sulphurescens
Heuchera cylindrica
Lithospermum ruderales
Lomatium triternatum
Lupinus sericeus
Penstemon confertus
Potentilla glandulosa
Potentilla gracilis
Sedum lanceolatum

Grasses

Achnatherum occidentale
Achnatherum richardsonii
Carex obtusata
Carex petasata
Carex rossii
Danthonia intermedia
Elymus trachycaulus var. subsecundus
Elymus trachycaulus var. trachycaulus
Festuca campestris
Festuca idahoensis
Koeleria macrantha
Pseudoroegneria spicata

Subalpine meadow (subalpine – east and west):

Trees

Abies lasiocarpa

Shrubs

Dasiphora floribunda

Salix arctica

*Vaccinium caespitosum**

*Vaccinium scoparium**

Forbs/Ferns

Achillea millefolium

Agoseris glauca

Anemone occidentalis

Antennaria alpina/umbrinella

Arenaria capillaris

Arnica diversifolia/mollis

Castilleja spp.*

Chamerion angustifolium

Epilobium anagallidifolium

Erigeron compositus

Erigeron peregrinus

Eriogonum flavum

Galium boreale

Hedysarum sulphurescens

Heracleum sphondylium

Hypericum scouleri

Oxyria digyna

Pedicularis bracteosa

Phacelia hastata

Polygonum bistortoides

Potentilla diversifolia

Senecio cymbalarioides

Sibbaldia procumbens

Solidago multiradiata

Symphyotrichum foliaceum var. *foliaceum*

Symphyotrichum laeve var. *laeve*

Valeriana sitchensis

Veratrum viride

Veronica wormskejoldii

*Xerophyllum tenax**

Zigadenus elegans

Grasses

Agrostis variabilis

Carex haydeniana

Carex nigricans

Carex paysonis

Carex phaeocephala

Carex spectabilis

Deschampsia atropurpurea

Juncus drummondii

Juncus mertensianus

Juncus parryi

Luzula glabrata / *spicata*

Phleum alpinum

Poa alpina

Poa secunda

Trisetum spicatum

See 2008 Revegetation Monitoring Report to see suggestions about which species should be seeded or grown in containers, or both.

Road sides (montane – east and west):

Trees

various by site

Shrubs

Arctostaphylos uva-ursi

Juniperus communis

*Linnaea borealis**

Mabonia repens

Rosa woodsii

Spiraea betulifolia

Symphoricarpos albus

Forbs/Ferns

Achillea millefolium

Anaphalis margaritacea

Antennaria howellii

Antennaria rosea

*Aralia nudicaulis**

Arnica cordifolia/latifolia

Chamerion angustifolium

Eurybia conspicua

Fragaria virginiana/vesca

Geranium viscosissimum

Geum macrophyllum

Heracleum sphondylium

*Maianthemum stellatum**

*Osmorhiza berteroi**

Solidago canadensis

Symphyotrichum laeve var. *laeve*

*Xerophyllum tenax**

Grasses

Bromus carinatus

Bromus vulgaris

Calamagrostis rubescens

Carex concinnoides

Carex geyeri

Carex microptera

Carex rossii

Deschampsia elongata

Elymus glaucus

Elymus trachycaulus v.

trachycaulus

Festuca occidentalis

Festuca subulata

Oryzopsis asperifolia

Other generally good revegetation species to use that have wide ecological amplitude:

Achillea millefolium
Anaphalis margaritacea
Antennaria howellii
Fragaria virginiana/vesca
Symphotrichum laeve var. *laeve*

Species to continue experimenting with in the nursery:

<i>Adenocaulon bicolor</i> *	<i>Maianthemum stellatum</i> *
<i>Angelica arguta</i> *	<i>Orthilia secunda</i> *
<i>Aralia nudicaulis</i> *	<i>Osmorhiza berteroi</i> *
<i>Castilleja</i> spp.*	<i>Osmorhiza occidentalis</i> *
<i>Chimaphila umbellata</i> *	<i>Thalictrum occidentale</i> *
<i>Clintonia uniflora</i> *	<i>Tiarella trifoliata</i> *
<i>Disporum bookeri</i> *	<i>Vaccinium</i> spp.*
<i>Disporum trachycarpum</i> *	<i>Viola canadensis</i> *
<i>Hieracium albiflorum</i> *	<i>Viola orbiculata</i> *
<i>Linnaea borealis</i> *	<i>Xerophyllum tenax</i> *
<i>Maianthemum racemosum</i> *	

COMMUNICATION:

- (1) Continue to conduct revegetation monitoring meetings for discussion about the monitoring data and evaluation of revegetation program. It may be more useful to hold several meetings that focus on certain revegetation issues. These issues could include: (1) use of fertilizers; (2) road shoulder revegetation strategies; (3) setting goals and objectives; (4) evaluation of monitoring techniques; (5) seed bank analysis and its impact on revegetation; and (6) research ideas for the field and for the nursery.

SAMPLING DESIGN:

- (1) Monitoring staff should consult with a statistician for assessment on monitoring design and appropriate statistical methods for past and future projects.
- (2) The types of monitoring methods that other parks/natural areas use should be investigated for comparison to our program. In particular, methods should be investigated as alternatives to ocular estimates used in Level II and in the site analysis.

VIII. MONITORING SCHEDULE: 1992 - 2016

1992

- 303-B - Level III (year 1)

1993

- 303-B - Level III, photomonitor (year 2)
- 303-B road shoulders - Level II (year 1)
- 303-C - Level II, photomonitor (year 1)
- Rob Tyser's Two Dog Flats plots - Level IV (year 1)
- 303-D - site analysis, photomonitor
- 303-E - site analysis, photomonitor
- Polebridge Developed Area - Level II, photomonitor
- Polebridge Bridge - Level II, photomonitor
- Bowman Creek Campground - Level II, photomonitor
- River Campground - Level II, photomonitor
- Swiftcurrent Apartments - Level II
- Three Bears Lake - Level II
- St. Mary Housing - Level II

1994

- 303-B - Level III, photomonitor (year 3)
- 303-B road shoulders - Level II, photomonitor (year 2)
- 303-C - Level II, photomonitor (year 2)
- 303-C road shoulders - Level II, photomonitor (year 1)
- 303-D - set up first series of shrub plots and established monitoring plots for Level IV experiment
- 303-F - site analysis along road corridor
- Granite Park Chalet - site analysis, photomonitor
- Two Medicine Housing Area - site analysis, photomonitor
- Camas Road - site analysis (2 sites)

1995

- 303-B road shoulders - Level II, photomonitor (year 3)
- 303-C - Level II, photomonitor (year 3)
- 303-C road shoulders - Level II, photomonitor (year 2)
- Rob Tyser's Two Dog Flats plots - Level IV (year 3)
- 303-D - Level IV, photomonitor (year 1)
- 303-E - photomonitor, wrote preliminary monitoring plans
- 303-F - continued site analysis along road corridor
- Camas Road - site analysis (10 sites)

1996

- 303-B - Level III, photomonitor (year 5)
- 303-D - Level IV, photomonitor (year 2)
- 303-D road shoulders - Level II, photomonitor (year 1)
- 303-E - photomonitor, set up Level IV experiments
- 303-F - Avalanche campground site analysis

1997

- Rob Tyser's Two Dog Flats plots - Level IV (year 5)
- 303-D - Level IV, photomonitor (year 3)
- 303-D road shoulders - Level II, photomonitor (year 2)
- 303-E - Level IV (year 1), photomonitor, set up additional experiments
- 303-F (Avalanche Picnic Area) - photomonitor (pre-disturbance)
- Camas Road - photomonitor (pre-disturbance)

1998

- 303-B road shoulders - Level II, photomonitor (year 6)
- 303-C - Level II, photomonitor (year 6)
- 303-C road shoulders - Level II, photomonitor (year 5)
- 303-E - Level IV, photomonitor (year 1 and 2)
- Polebridge Developed Area - Level II, photomonitor
- Polebridge Bridge - Level II, photomonitor
- Bowman Creek Campground - Level II, photomonitor
- River Campground - Level II, photomonitor

1999

- 303-D - Level IV, photomonitor (year 5)
- 303-E - Level IV, photomonitor (year 2 and 3)
- Camas Road - photomonitor (year 1)

2000

- 303-F - Level II, photomonitor (year 1)
- Logan Pass Unit D: seed vs. seed & plant experimental plots (year 4)
- Camas Road - Level II, photomonitor (year 2)
- Three Bears Lake - Level II
- Oberlin Bend / Jones Flat Social Trail Assessment
- Logan Pass Visitor's Center Handicapped Access Trail Assessment
- Lunch Creek Social Trail Assessment

2001

- 303-B - Level III, photomonitor (year 10)
- 303-E - Level IV, photomonitor (year 4 and 5)
- 303-F - Level II, photomonitor (year 2)

2002

- Camas Road - Level II, photomonitor (year 4)
- Rob Tyser's Two Dog Flats plots - Level IV (year 10)
- 303-F – Level II, photomonitor (year 3)

2003

- 303-C - Level II, photomonitor (year 10)
- Camas Road - Level II, photomonitor (year 5)
- Hidden Lake – Level II (year 3)

2004

- 303-D – Level III, photomonitor (year 10)
- 303-F - Level II, photomonitor (year 5)
- GTSR Phase VII Site Analysis

2005

- 303D Shrub Monitoring – Level IV (year 11)
- Apgar-Headquarters Bike Path – Level II (year 1)
- Camas Road Hydromulch – Level II (year 1)
- Hidden Lake Social Trails – Level II (year 5)

2006

- 303-E - Level IV, photomonitor (year 10)
- Apgar Transit Center Site Analysis

2007

- Apgar-Headquarters Bike Path – Level II (year 3)
- Camas Road Hydromulch – Level II (year 3)
- Apgar Transit Center – Level II (year they were planted)
- Apgar Transit Center Experimental Plots - Level IV (year they were planted)
- GTSR Phase VI Site Analysis

2008

- Camas Road - Level II, photomonitor (year 10)
- Apgar Transit Center – Level II (year 1)
- Apgar Transit Center Experimental Plots - Level IV (year 1)
- Logan Pass Unit D: seed vs. seed & plant experimental plots (year 12)
- Above St. Mary Campground Weed/Reveg. (site analysis)
- Camas Creek Overlook Weed/Reveg. (site analysis)
- West Entrance (site analysis)

2009

- 303-F - Level II, photomonitor (year 10)
- Apgar-Headquarters Bike Path – Level II (year 5)
- Camas Road Hydromulch – Level II (year 5)
- Apgar Transit Center – Level II (year 2)
- Apgar Transit Center Experimental Plots - Level IV (year 2)
- Above St. Mary Campground Weed Rev. (year 1)
- Camas Creek Overlook Weed Rev. (year 1)
- West Entrance (year 1)
- Lake McDonald Dorms (site analysis)

2010

- Hidden Lake Social Trails – Level II (year 10)
- Apgar Transit Center – Level II (year 3)
- Apgar Transit Center Experimental Plots - Level IV (year 3)
- Above St. Mary Campground Weed Rev. (year 2)

- Camas Creek Overlook Weed Reveg. (year 2)
- West Entrance (repeat site analysis when construction is completed)
- Lake McDonald Dorms (year 1)
- GTSR – Phase 6 (year of planting)

2011

- 303-B - Level III, photomonitor (year 20)
- 303-E – Level IV, photomonitor (year 15)
- West Entrance (year 3)
- Lake McDonald Dorm (year 2)
- GTSR – Phase 6 (year 1)
- St. Mary Visitor Center (year 1)

2012

- Rob Tyser's Two-Dog Flats (year 20) – did not do
- Apgar Transit Center – Level II (year 5) – did not do
- Apgar Transit Center Experimental Plots - Level IV (year 5)
- Lake McDonald Dorm (year 3) – did not do
- GTSR – Phase 6 (year 2)
- Above St. Mary Campground Weed Reveg. (year 1 after seeding)
- Camas Creek Overlook Weed Reveg. (year 1 after seeding) – did not do

2013

- 303-C - Level II, photomonitor (year 20)
- West Entrance (year 5)
- GTSR – Phase 6 (year 3)
- St. Mary Visitor Center (year 3)

2014

- 303-D – Level III, photomonitor (year 20)
- Apgar-Headquarters Bike Path – Level II (year 10)
- Camas Road Hydromulch – Level II (year 10)
- Above St. Mary Campground Weed Reveg. (year 6)
- Lake McDonald Dorm (year 5)
- GTSR – Phase VII (???)

2015

- GTSR – Phase 6 (year 5)
- St. Mary Visitor Center (year 5)
- Hidden Lake Social Trails – Level II (year 15)

2016

- Logan Pass Unit D: seed vs. seed & plant experimental plots (year 20)

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APPENDIX A. TEMPERATURE AND PRECIPITATION DATA *

WEST GLACIER

	April	May	June	July	August	September	October	November
Mean Temperature (degrees F) **								
1949-2012	41.4	50.6	57.5	63.7	62.5	53.2	42.3	31.3
1993	43.2	55.7	56.1	56.3	59.0	51.2	43.7	24.0
1994	43.8	53.4	56.8	65.7	65.4	55.5	42.5	28.4
1995	41.1	51.4	56.2	63.1	58.5	54.0	40.2	32.6
1996	42.0	46.3	58.5	65.0	61.5	51.0	40.2	26.4
1997	36.0	51.5	57.4	63.1	63.5	54.5	42.5	31.8
1998	44.0	54.9	56.4	68.4	64.5	59.4	42.3	36.0
1999	41.5	49.3	55.2	60.5	65.7	51.8	42.8	37.7
2000	43.0	50.2	56.7	63.4	63.0	51.0	42.8	28.3
2001	40.0	52.4	55.4	62.8	64.8	57.6	42.7	35.5
2002	39.7	47.8	57.4	67.0	60.3	54.1	37.5	33.2
2003	43.1	50.9	59.7	68.7	67.9	56.8	46.0	26.6
2004	45.8	51.5	58.5	66.7	64.9	52.4	43.2	33.7
2005	43.9	52.7	57.1	65.9	63.3	52.8	44.4	32.6
2006	44.4	53.7	61.8	68.5	64.2	55.3	43.3	30.7
2007	44.0	53.4	60.0	72.3	63.8	54.2	43.5	33.4
2008	37.4	51.3	56.6	65.4	64.2	52.9	43.4	36.4
2009	40.9	51.8	58.2	66.2	63.3	57.9	37.6	34.2
2010	42.2	47.3	56.5	62.7	60.3	53.4	45.1	28.7
2011	37.4	48.8	54.1	62.1	64.9	57.0	44.2	31.8
2012	45.7	49.1	56.7	67.1	63.7	56.2	44.3	#
Precipitation (inches)								
1949-2010	1.9	2.6	3.5	1.7	1.6	2.1	2.4	3.1
1993	3.2	1.9	4.5	5.1	2.2	2.3	1.0	0.7
1994	1.2	2.2	3.1	0.6	0.2	0.5	4.2	2.7
1995	1.7	1.2	6.9	3.4	2.1	1.4	5.2	7.5
1996	3.0	6.1	1.9	1.2	1.9	3.1	4.1	4.4
1997	2.0	1.8	3.0	1.5	1.4	3.0	3.0	1.6
1998	2.0	4.6	4.9	2.6	1.2	1.7	1.0	3.3
1999	0.9	1.2	3.1	1.8	1.1	0.5	3.8	3.2
2000	1.8	1.6	3.0	1.0	0.4	3.2	0.9	0.7
2001	3.0	1.3	4.0	0.6	0.1	1.2	3.8	2.3
2002	2.4	2.7	3.0	1.5	0.7	1.7	0.5	2.5
2003	1.4	1.9	1.8	0.04	0.1	2.0	2.7	4.1
2004	2.2	2.4	2.2	2.5	4.4	3.7	4.3	3.2
2005	1.7	2.1	7.5	0.5	1.1	4.4	4.6	3.0
2006	1.4	2.3	4.2	0.6	0.8	1.4	1.9	6.2
2007	1.4	2.6	2.4	0.6	0.2	2.1	2.5	0.6
2008	1.2	3.0	3.2	0.9	1.9	1.5	1.4	3.2
2009	1.0	4.0	1.4	2.7	1.6	0.3	3.3	1.4
2010	2.6	3.5	6.6	1.3	1.9	3.9	2.4	3.7
2011	4.7	3.3	4.4	1.7	0.2	1.7	3.9	1.5
2012	3.6	2.5	7.9	2.8	0.5	0.3	3.9	#

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	April	May	June	July	August	September	October	November
Mean Temperature (degrees F) **								
1981-2012	39.9	48.2	55.4	62.5	62.1	53.0	43.5	31.5
1993	42.5	53.8	54.1	54.9	57.6	52.4	44.1	27.7
1994	42.1	52.0	56.9	62.8	63.1	58.9	43.0	27.6
1995	38.8	46.4	54.3	61.9	59.8	53.9	40.4	32.5
1996	43.2	45.0	56.6	64.7	64.0	50.2	42.0	21.0
1997	35.8	47.9	56.2	62.5	62.6	58.3	45.1	34.8
1998	42.1	53.8	53.0	67.8	62.3	58.5	45.8	33.1
1999	39.7	46.9	53.7	59.2	65.7	52.1	43.0	40.1
2000	43.7	50.1	65.3	65.7	65.5	52.6	43.9	28.0
2001	38.2	53.1	56.3	64.7	67.7	59.1	43.5	38.5
2002	34.4	43.9	52.7	63.8	56.6	50.3	36.1	38.2
2003	39.9	52.9	55.7	66.5	66.6	54.5	46.0	26.9
2004	42.5	43.5	52.7	62.6	59.3	49.8	41.1	35.8
2005	38.3	46.9	51.6	63.0	57.2	49.3	42.4	33.6
2006	40.5	48.7	55.8	65.8	59.2	52.5	39.0	26.4
2007	39.1	49.4	56.9	69.0	60.2	52.1	44.5	32.5
2008	35.4	46.5	53.0	#	#	#	44.4	37.2
2009	34.8	47.2	52.2	62.0	58.8	57.2	34.7	35.0
2010	36.0	38.7	48.3	56.6	53.0	#	45.8	15.4
2011	29.6	42.2	52.3	60.0	61.1	54.9	41.4	28.6
2012	40.6	44.3	52.7	62.3	#	#	#	#
Precipitation (inches)								
1981 - 2012	1.9	3.0	3.6	1.8	1.7	2.0	2.2	2.4
1993	0.8	1.9	3.1	6.3	3.6	3.1	0.9	2.0
1994	2.7	2.8	1.4	2.2	0.5	0.2	4.4	1.9
1995	1.9	5.5	7.2	3.3	1.2	3.2	4.2	5.1
1996	1.8	5.0	4.1	0.8	0.4	2.2	1.3	3.6
1997	1.4	3.6	4.1	0.9	2.6	1.1	1.6	0.8
1998	2.2	3.7	5.1	1.7	0.3	1.0	0.2	4.9
1999	1.5	1.5	1.8	0.9	2.2	1.7	3.1	4.1
2000	2.0	1.5	3.8	0.3	0.7	2.2	0.6	0.5
2001	3.8	1.2	3.9	0.7	0.03	0.8	2.3	0.5
2002	1.1	2.0	5.1	0.6	1.5	2.3	1.0	0.2
2003	1.5	1.2	1.6	0.1	0.0	1.0	1.0	2.2
2004	1.6	2.6	3.2	0.7	1.8	1.1	0.8	2.4
2005	1.6	1.3	7.4	0.2	2.0	3.8	2.0	2.0
2006	2.3	2.4	4.3	0.5	0.8	1.9	1.3	5.7
2007	1.5	2.7	1.1	0.4	0.7	2.8	2.0	1.8
2008	0.6	6.7	3.9	#	#	#	0.6	1.6
2009	2.9	1.2	1.4	4.9	1.8	0.1	2.7	1.5
2010	2.0	4.4	4.7	1.3	1.9	#	0.1	2.1
2011	4.0	3.1	2.5	0.6	0.7	0.9	3.1	2.5
2012	1.1	1.0	3.9	0.7	#	#	#	#

* This data was obtained from U.S./NOAA weather stations operated by Glacier National Park, and from the Western Regional Climate Center.

** Mean temperature calculated by summing the daily maximum temperature and daily minimum temperature and dividing by two.

Missing data