



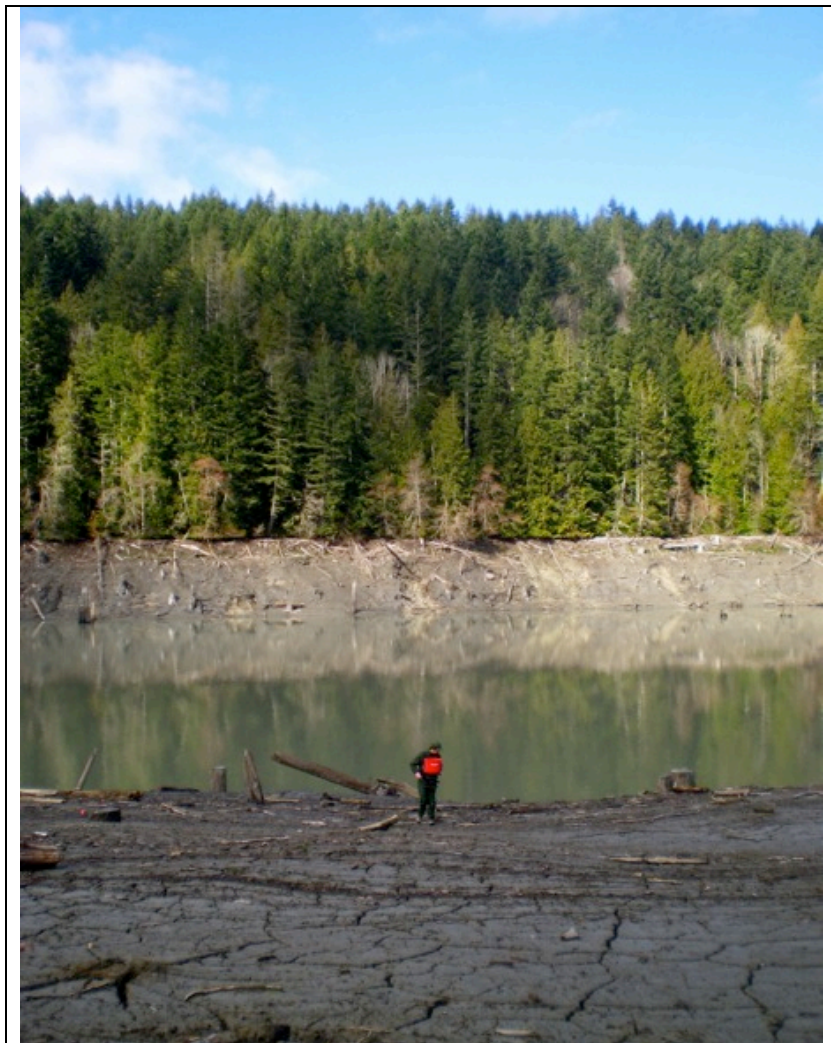
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and Forest Sciences

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# Elwha River Revegetation Project: 2012 Lake Aldwell Seeding Trials

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## Executive Summary

This Elwha River Ecosystem and Fisheries Restoration Act (1992) mandated the largest dam removal in US history. Over the past century much of the inundated valleys received accumulations of 34 million cubic yards of fine and coarse alluvial sediments 2-80 feet deep along and above the historic active channel floodplains (Hickey, 2013; Chenoweth *et al.*, 2011) leaving these newly exposed novel ecosystem to uncertain successional trajectories. Even with typical forest succession pathways of natural recruitment in areas reachable by native propagules, significant upland areas exist above floodplain and beyond the reach of substantial seed rain especially at former Lake Mills where the historic floodplain extends nearly ½-mile from surrounding forests. Invasions of exotic species are a concern to restoration particularly with significant populations of non-native pasture grasses and other weedy invaders in the immediate watershed (Woodward *et al.* 2011). Goals of the Elwha River Revegetation Project seek to 1) minimize invasive, exotic species; 2) restore ecosystem processes, and 3) accelerate the establishment of native forests within the Aldwell and Lake Mills reservoirs. To supplement planting efforts over the course of the revegetation project, portions of the former Lake Mills and Lake Aldwell reservoirs will be directly seeded with approximately 7,000 pounds of native grass and forbs. The primary goal of this study was to assist the Park in assessing their application methods of native seed using specific species compositions and sowing densities. A secondary goal in this study was to test the viability of a direct sowing method for conifers on exposed fine sediments.

In spring 2012, sites along the formerly inundated upper margins of Lake Aldwell were the first opportunities to experiment with seeding on fine sediments with relatively similar environmental conditions as those that would receive future seeding treatments. The Herbaceous seeded site chosen for this study was a 1.2-acre upland silt valley wall landform located at the northeast end of Lake Aldwell (Figure 2; Photos 1-2). Sediments at this site were several feet thick consisting of bare mineral silts and clays. Water availability in fine sediments is expected to be a major inhibitor of plant growth and survival due to the lack of pore spaces combined with summer drought periods (Chenoweth *et al.* 2011; Padilla and Pugnaire, 2007; Walker and Del Morel, 2003; van der Valk and Pederson 1989). Seed was locally collected within the Elwha watershed and then produced agriculturally at the NRCS Corvallis Plant Materials Center (CPMC). Eleven herbaceous forbs, grasses, and sedge species were selected by the Olympic National Park for seed application in the former reservoirs and combined into four distinct seed mixes. These mixes were tested at two sowing rates; low and high rates relative to each other (high = low x 2) for a total of eight treatments (Table 2). Sites were sown on March 6<sup>th</sup>, 2012 by hand-cranked belly grinder broadcast method and monitored throughout the first summer. The conifer seeding site was selected at a similar location in Lake Aldwell consisting of an approximately 0.6-acre valley wall landform with similar sediments. Two conifer species were sown using three treatments for a total of six prescriptions.

Seeded species germinated abundantly at the Herbs treatment site. Overall herbaceous seedling counts were significantly higher in seeded treatments than unseeded and cover (seeded and volunteer) increased between July and August for all treatments indicating successful establishment and sufficient conditions for first season plant growth (Figure 7). End of season counts of a combined weeds species group did not uniformly increase or decrease across all treatments depending on conditions specific to the treatment, particular species life histories, or relationships to other environmental factors such as access to seed sources, available seed bed, and sufficient

sediment moisture. Native woody colonizers increased consistently across all treatment areas although they were highest in the control where distance to shoreline trees was much closer than seeded treatment areas (Figures 8-9; 11). Germination of seeded conifers at the conifer treatment site was unsuccessful during this trial either due to cultural application methods or non-optimal germination conditions; however, high densities of *Tsuga heterophylla* were observed volunteering from proximal shoreline seed rain.

This seeding study occurred during a single, initial growing season immediately following draw-down where germinating vegetation received a longer period of sediment saturation (from capillary lake saturation and heavy spring/early summer precipitation) and may not reflect the typical moisture availability at this site in successive years nor reflect future germination and cover rates at different seed densities on different sediment types. Specific projected patterns of natural recruitment and spatial distribution of plants from this study represent Aldwell shoreline zones and should be used conservatively when making broad assumptions about particular species assemblages or abundances.

Early spring sowing of native herbaceous species on fine sediments is highly successful. If similar moisture conditions are present, preparation or post-treatment incorporation is unnecessary on the fine sediments. Hand broadcasting is an effective, low-cost, and highly accurate method for applying seed treatments to various sites throughout much of the Elwha reservoirs or other similarly exposed or disturbed sites. The abundance of identified invasive, exotic species of concern was lower in most seeded treatments than in the control indicating a potential initial suppression or exclusion effect of those species at these sowing densities. Seeded herbs appear to have established functional root systems on fine sediments and many treatments acquired lush biomass even in the first season. All seeded treatments reduced coverage of bare ground in the first season, capturing ambient moisture, and reducing formation of surface crusts. All herbs treatments supplied the system with at least some propagules for the next generation. *Achillea millefolium*, *Bromus* spp., *Deschampsia elongata*, and *Elymus glaucus* are clear first-year winners based on their rapid growth rates and successful seed production and *Artemisia suksdorfii* is likely a winner in coming years. Four coniferous and three or more deciduous tree species were observed recruiting in all treatment areas. The unseeded control showed the greatest end of season abundance and cover of native woody species but this seems just as likely a result of access to propagules with greater proximity to shoreline seed rain than any suppression effect from seeding.

Future assessment of typical seeded treatment sites in the former Lake Mills reservoir (away from the shoreline) will be critical for translating and building upon the results of this study in order to move the adaptive management strategies of the revegetation project forward and in desirable directions. Measuring and observing soil development at concurrent seeded and non-seeded sites should also be performed to better understand soil formation processes and how and to what extent they are enhanced by seeding.

Rapid site changes, seasonal timing, legacies, and seed application combined to create what was a novel and likely fleeting 2012 assemblage of plant species, and for many the first time ever to germinate and establish in that particular setting. It was an extraordinary ecological snapshot into the past, current, and future trajectories of the Lake Aldwell shoreline and potentially for the greater reservoirs.

## Background

A century after the first and largest dams on the North Olympic Peninsula were constructed, the United States Congress passed the Elwha River Ecosystem and Fisheries Restoration Act (1992) mandating their deconstruction for habitat and fish passage for listed salmonids. This project was the first time in US history such large reservoirs were fully and permanently drained exposing 28.8 million cubic yards of sediments on nearly 800 acres of former forestland (Chenoweth *et al.*, 2011). The Elwha River was expected to reform its historic riparian floodplain, carving and flushing large quantities of silt, sand, gravels, and woody debris downstream. Exposed reservoirs may act similarly to other post-disturbance, primary successional habitats (Walker and del Moral, 2003; Jumpponen *et al.*, 1999; Halpern, 1983) where seed rain, seed bank legacies, and floodwaters provide propagules for recruitment onto low-disturbance micro-sites (Chenoweth *et al.*, 2011; Michel, 2010; Hulce, 2009; Jumpponen *et al.*, 1999; Eriksson and Ehrlen, 1992; Cook, 1979).

Over the past century much of the inundated valleys received accumulations of 34 million cubic yards of fine and coarse alluvial sediments 2-80 feet deep along and above the historic active channel floodplains (Hickey, 2013; Chenoweth *et al.*, 2011) leaving these newly exposed novel ecosystem to uncertain successional trajectories. Lateral river migration began flushing large quantities of valley bottom sediments downstream during dam deconstruction but is not expected to reach all areas; some areas of reservoir sediments are expected to remain. Portions of the reservoirs reachable by floodwaters and with access to water table are anticipated to colonize quickly by riparian species primarily in the *Salicaceae* (Chenoweth *et al.* 2011; Stella *et al.*, 2006; Gurnell *et al.* 2005; Karrenberg *et al.*, 2002; Shafroth *et al.* 2002; Niyama, 1990). Surrounding forests are expected to provide native propagules to shoreline zones up to 160 feet (50 meters) into the newly exposed lands (Chenoweth *et al.*, 2011; Michel, 2010; Hulce, 2009). Even with these pathways of natural recruitment, significant upland areas exist above floodplain and beyond the reach of substantial seed rain especially above the upper dam at former Lake Mills where the historic floodplain extends nearly ½-mile from surrounding forests.

Invasions of exotic species are a concern to restoration particularly with significant populations of non-native pasture grasses and other weedy invaders in the immediate watershed (Woodward *et al.* 2011). A seed bank and extant vegetation study in the Lake Mills delta indicated the presence of 28 exotic species tolerant of an array of moisture regimes capable of rapid colonization of exposed sediments (Hulce, 2009). Prior to dam removal, National Park managers mapped and studied invasive plant populations in the watershed, specifically along trails, roads, and access points surrounding the reservoirs. Several invasive species with the ability to impede successional processes existed along the shoreline and in the vicinity of Lake Aldwell including *Phalaris arundinacea*, *Cirsium arvense*, *Polygonum sachalinense*, *Rubus discolor*, and *Hypericum perforatum* (Woodward *et al.*, 2011). Invasive species control efforts began in the watershed before dam removal to reduce the invasive potential of exotic species of concern into the newly exposed lands (Chenoweth *et al.* 2011).

Goals of the Elwha River Revegetation Project seek to 1) minimize invasive, exotic species; 2) restore ecosystem processes, and 3) accelerate the establishment of native forests within the Aldwell and Lake Mills reservoirs. Revegetation began immediately following reservoir draw down in late summer 2011 and is expected to continue until 2017. Primary efforts focus on planting native trees and shrubs from nursery-grown propagules. To supplement these efforts over the course of the

revegetation project, portions of the former Lake Mills and Lake Aldwell reservoirs will be directly seeded with approximately 7,000 pounds of native grass and forbs.

The direct application of seed in restoration is not a new technique but one growing in popularity as large-scale revegetation efforts are needed to improve or alter ecosystem trajectories as a result of extreme disturbance regimes and invasions by exotic species. Agencies and private industry are improving availability through collection, seed increase, processing and storage technologies (Native Seed Conference, 2013; Dumroese *et al.* 2009) making the use of seed versus nursery-grown propagules an incentive for large projects that can save on cost and time. Seed utilized in this project came from within-watershed collections and entered into the Natural Resources Conservation Service (NRCS) seed increase program at the Plant Material Center in Corvallis, OR.

## Seeding Trial Goals and Objectives

The primary goal of this study was to assist the Park in assessing the application of native seed in their revegetation efforts, specifically using practical application methods with specific species compositions and sowing densities. This was performed primarily through comparisons of end of season relative stand densities and cover as qualifiers and quantifiers of seeding success. The following study questions are evaluated in this report:

### Thesis Questions:

- Employing practical application methods, will native herbs germinate and survive summer seedling stage on lake bottom silt?
- How does seeding affect the abundance of desirable and non-desirable volunteer species?
- Will end of season relative stand density and cover differ between application rates and species assemblages?
- Will seeding the sites provide substantial cover of native vegetation relative to unseeded sites?

A secondary goal in this study was to test the viability of a direct sowing method for conifers on exposed silt sediments. In addition, two factors were tested for influence on conifer germination and survival - seed stratification to initiate germination and sheltering effect from large wood for summer seedling survival. Germination and end of season survival were measured within six treatments.

### Thesis Questions:

- Employing two stratification methods, will seeded conifers germinate on exposed silt and survive summer seedling stage and at what rates?
- Will large wood have a measurable effect on initial survival of seeded conifers?



## Methods

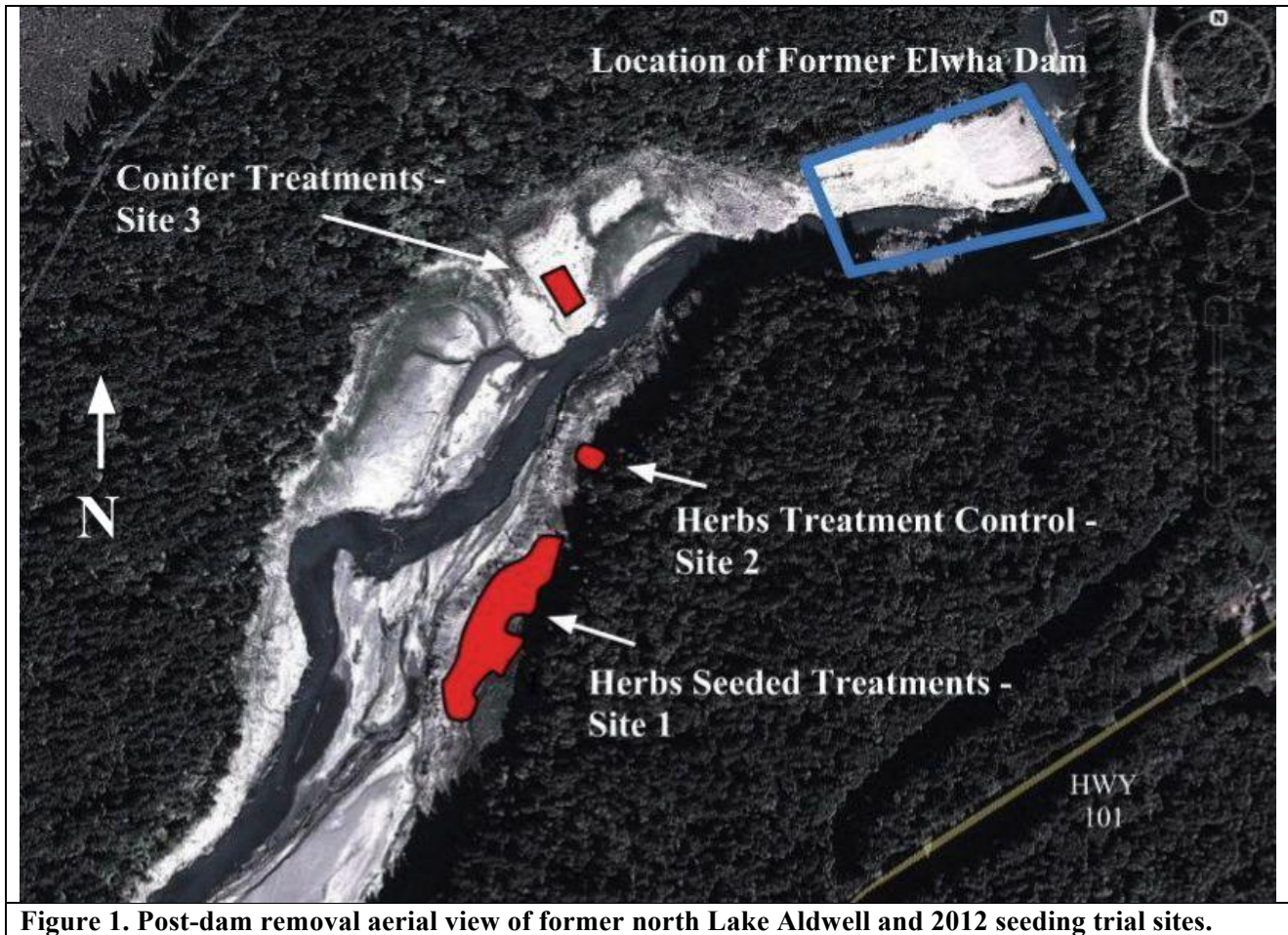
### Site Selection

Three sites were selected for 2012 seed trials (Figure 1):

**Site 1 – Herbaceous seed treatments (East shoreline);**

**Site 2 – Herbaceous Control; and**

**Site 3 – Conifer treatments (West shoreline).**



**Figure 1. Post-dam removal aerial view of former north Lake Aldwell and 2012 seeding trial sites.**

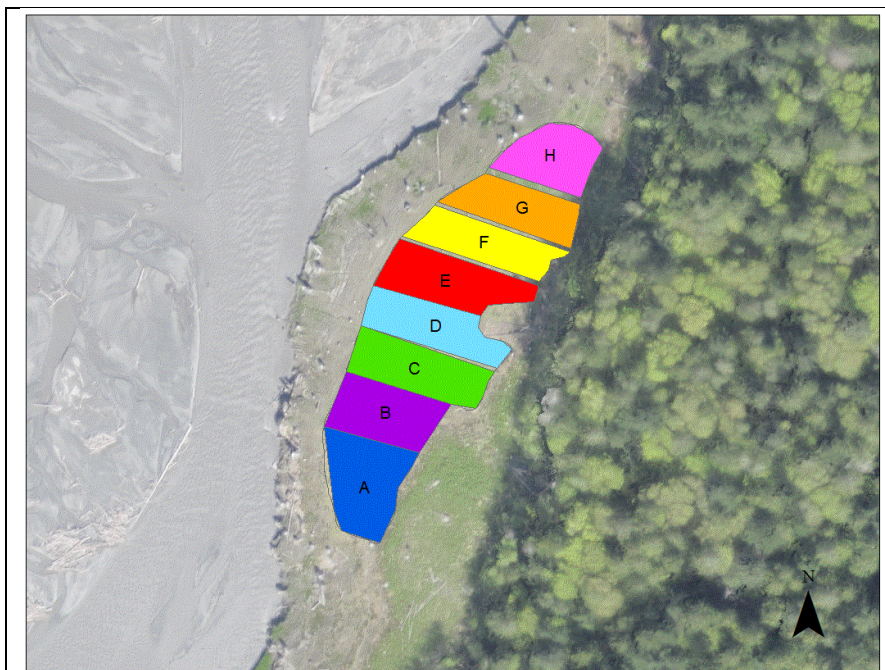
Reservoir drawdown and dam removal commenced on the lower Elwha Dam in late summer of 2011. Site selection criteria for this study were: a large enough area for practical application and study of multiple seed mixes, a relatively gentle slope and overall sediment stability, and a substrate of fine sediments composed of mostly silt with a small clay component, a substrate managers expect will be best restored by seeding with grasses and forbs. In spring 2012, sites along the formerly inundated upper margins of Lake Aldwell were the first opportunities to experiment with seeding on fine sediments with relatively similar environmental conditions as those that would receive future seeding treatments.

## Site 1 – Herbs

### Study Area and Site Analysis

The site chosen for this study was a 1.2-acre upland silt valley wall landform located at the northeast end of Lake Aldwell (Figure 2; Photos 1-2). The site is west facing and contains some large woody debris, standing cut stumps, and small snags at variable densities. Slopes on this landform ranged from 8.1° to 12.7° with an average of 10.4°. Distance from the study area to the forest edge varied from 137 feet at the south end to 34 feet at its northern extent. An additional area identified as a control was located on the valley wall approximately 100 meters to the north. Slope at the control site averaged 10.1 and distance to the forest edge was 5 feet. This area was selected as a control based on available exposed landforms at time of seeding with similar aspect, sediment conditions, and slope.

Sediments at this site were several feet thick consisting of bare mineral silts and clays. Seed bed surfaces varied with micro-topography, cracks in the sediment, large stumps, small woody debris, and variable deposits of undecomposed forest litter such as needles, bark, and leaves (Photos 1-4). These environmental factors are known to benefit plant recruitment by providing ‘safe site’ opportunities for seed establishment and seedling growth (Jumpponen *et al.* 1999; Harper *et al.* 1965). Fine textured reservoir sediments are saturated at the surface in winter and when exposed to the effects of extreme summer albedo (Chenoweth *et al.*, 2011), insulation, and drying with the absence of significant vegetative cover they form hypo-hydric surface crusts. Soil analysis of the fine sediments from Lake Aldwell revealed generally poor conditions for plant growth with low primary and micro-nutrient availability and low organic matter, with the exception of high levels of phosphorous (Chenoweth *et al.*, 2011). Water availability in fine sediments is expected to be a major inhibitor of plant growth and survival due to the lack of pore spaces combined with summer drought periods (Chenoweth *et al.* 2011; Padilla and Pugnaire, 2007; Walker and Del Morel, 2003; van der Valk and Pederson 1989).



**Figure 2. Eight herbaceous seed treatments at Site 1 (Treatment Areas A-H).**

The site was divided into a 4 x 2 factorial design for a total of 8 approximately equal portions of the terrace (~0.125 acre per treatment) (Figure 2). Areas A-H were assigned from south to north and the eight treatments were randomly assigned to an area. No seed was applied at the control site (Treatment I).

### Species and Treatment Selection

Seed for the revegetation of the former reservoirs was locally collected within the Elwha watershed and then produced agriculturally at the NRCS Corvallis Plant Materials Center (CPMC). Park staff selected species for seeding based on several criteria including seed availability from wild populations within the watershed, plant physiologies most capable of penetrating fine sediment, tolerances to extreme edaphic and micro-climate conditions, and species capable of agricultural production at CPMC. Table 1 lists species selected for this trial in their specific seed mixes.

**Table 1. Species mixes seeded at Site 1.**

| Latin Name                           | Common Name         |
|--------------------------------------|---------------------|
| <b>Slow Graminoids Mix:</b>          |                     |
| <i>Carex deweyana</i> (CARDEW)       | Dewey's sedge       |
| <i>Carex pachystachya</i> (CARPAC)   | Big-head sedge      |
| <i>Agrostis exarata</i> (AGREXA)     | Spike bentgrass     |
| <i>Deschampsia elongata</i> (DESELO) | Slender hairgrass   |
| <b>Aggressive Grasses Mix:</b>       |                     |
| <i>Bromus carinatus</i> (BROCAR)     | California brome    |
| <i>Bromus pacificus</i> (BROPAC)     | Pacific brome       |
| <i>Elymus glaucus</i> (ELYGLA)       | Blue wildrye        |
| <b>Forbs Mix:</b>                    |                     |
| <i>Achillea millefolium</i> (ACHMIL) | Common yarrow       |
| <i>Artemisia suksdorfii</i> (ARTSUK) | Suksdorf's wormwood |
| <i>Eriophyllum lanatum</i> (ERILAN)  | Oregon sunshine     |
| <i>Achillea millefolium</i> (ACHMIL) | Common yarrow       |
| <b>All Species Mix:</b>              |                     |
| <i>Agrostis exarata</i> (AGREXA)     | Spike bentgrass     |
| <i>Artemisia suksdorfii</i> (ARTSUK) | Suksdorf's wormwood |
| <i>Bromus carinatus</i> (BROCAR)     | California brome    |
| <i>Bromus pacificus</i> (BROPAC)     | Pacific brome       |
| <i>Carex deweyana</i> (CARDEW)       | Dewey's sedge       |
| <i>Carex pachystachya</i> (CARPAC)   | Big-head sedge      |
| <i>Deschampsia elongata</i> (DESELO) | Slender hairgrass   |
| <i>Elymus glaucus</i> (ELYGLA)       | Blue wildrye        |
| <i>Eriophyllum lanatum</i> (ERILAN)  | Oregon sunshine     |

These mixes were tested at two sowing rates; low and high rates relative to each other (high = low x 2) (Table 2). These approximated rates are within the range of those previously tested and recommended on disturbed revegetation sites (Burton *et al.*, 2006) but much higher than those typically used on rangeland conservation lands (NRCS 2009b). Pounds of Pure Live Seed (PLS) applied per treatment are approximated based on seed mix specifications provided by the CPMC and summarized in Appendix A.

**Table 2. Approximated sowing rates for Site 1 Treatment Areas from south to north (A-I).**

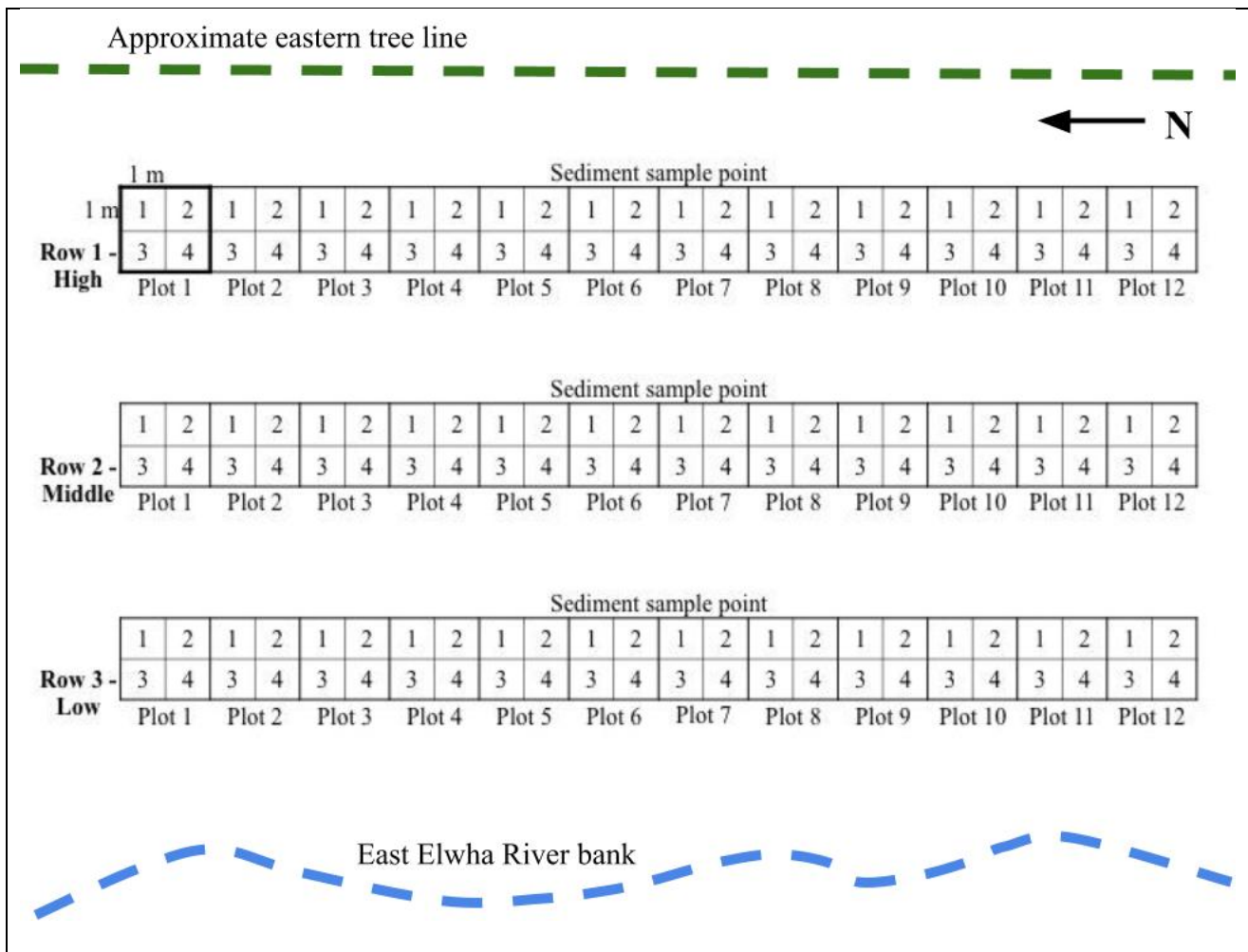
| Treatment Area | Treatment Type            | Approximate Sowing Rate (ft <sup>2</sup> ) | Approximate Sowing Rate (m <sup>2</sup> ) |
|----------------|---------------------------|--|---|
| A              | Slow Graminoids - Low     | 478  | 5148                                      |
| B              | Forbs - Low               | 176  | 1905                                      |
| C              | All Species - High        | 319  | 3444                                      |
| D              | Slow Graminoids - High    | 956  | 10296                                     |
| E              | Aggressive Grasses - High | 170  | 1830                                      |
| F              | Aggressive Grasses - Low  | 85   | 915                                       |
| G              | Forbs - High              | 353  | 3810                                      |
| H              | All Species - Low         | 160  | 1722                                      |

### **Seeding Method**

Sites were sown on March 6<sup>th</sup>, 2012 by hand-cranked belly grinder broadcast method. The seeder made passes up and down the slope from east to west for each treatment. One half the total seed applied per treatment was broadcast in an initial sweep. The second half was then spread over areas with low or inconsistent ground coverage in order to increase likelihood of even coverage throughout the treatment areas. Recommended seed bed prep and seed incorporation such as raking or light tilling (Levy-Boyd, 2012), and protection techniques like mulching or erosion control fabrics (NRCS, 2009; Dumroese *et al.*, 2009; Darris, 2005) were not practical at the scale of expected reservoir applications; therefore, seeds were spread at the surface and left to the elements.

### **Monitoring Plot Design**

In mid- to late-May, three rows of blocked plots were installed in each treatment area in a high, middle, and low location along the slope at equal distances relative to each other based determined by length of treatment area in order to capture any response variables resulting from gradient (Figure 3). Blocks of plots were never less than 10 feet from treatment edges so as to avoid edge effect from seed drift.



**Figure 3. General blocked plot layout and sediment sample locations at the Herbs Study Area (Site 1).**

After determining length and width of treatment area, block edges were marked at even intervals down the slope and 12 total 2-m<sup>2</sup> plots were installed within the blocks using brightly colored pin flags. The 2-m<sup>2</sup> plots were then broken into four 1-m<sup>2</sup> subplots. Treatment area shapes were not uniform; therefore, some blocked plots were arranged in 1 x 12 layout (Figure 3); in the narrowest treatment areas blocks were placed in a 2 x 6 or 3 x 4 arrangement. Random selection of 1 m<sup>2</sup> subplots (1-4) from which to monitor was determined and then marked at all four corners with different colored pin flags during the first round of monitoring so as to accurately relocate plots during following monitoring visits.

### **Vegetation Monitoring**

Three rounds of data collection were performed in the summer of 2012; the first period from May 24<sup>th</sup> to June 19<sup>th</sup>; the second period from July 9<sup>th</sup> to July 20<sup>th</sup>; and the third from August 13<sup>th</sup> to September 5<sup>th</sup>. Using a 1 m<sup>2</sup> PVC plot frame divided by 100-decimeter strings, data were collected within a subsampling of the 1 m<sup>2</sup> area consisting of two corners (upper right and lower left corners) in-set from the perimeter (Photo 5). Data in Treatment Areas A, C, and G were collected within two corners consisting of 2 x 2 square decimeters for a total of 8 square decimeters. Data in Treatment Areas B, D, E, F, H, and I were collected within two corners consisting of 4 x 4 square decimeters for a total of 32 square decimeters. Sampling area size was determined by seedling density. High seedling densities are difficult to accurately count in a 1m<sup>2</sup> plot, so the sampling area

was scaled down relative to the seedling densities observed on site to make seedling counts practical. The sampling size was kept consistent through the entire summer data collection. Individual seedling counts by species were performed in June of all those seeded and naturally recruiting. Existing micro-site conditions were recorded in June within the entire 1 m<sup>2</sup> plot from a (bird-eye perspective) consisting of:

- Visual estimated aerial cover of large woody debris (wood >10 cm diameter and >10 cm length) overhanging or touching the surface within the plot;
- Visual estimated aerial cover of small woody debris (wood <10 cm diameter and <10 cm length)
- Visual estimated aerial cover of litter (undecomposed forest litter, needles, cones, pieces of bark, humus);
- Visual estimated ground surface cover of cracks within the sediment in order to determine how much growing space was actually present within the sampling plot area.

Percent aerial cover was estimated in July and August once seedlings had grown substantial enough to measure. Cover estimates of seedlings for each observed species (seeded and natural regeneration) were performed on the portions of subsampled areas where the counts were performed (not the entire 1 m<sup>2</sup> area) and estimated from bird's eye perspective using the decimeter squares as references. For example in a subplot where 32 square decimeters were observed, if *Agrostis exarata* biomass (basal portions, leaves, and flowering structures) obscured the ground within 3.5 cumulative square decimeters then the number 3.5 was recorded for cover. A cumulative cover value was recorded in the field by adding up all individual species cover values. A second overall cover value was then estimated looking at all cover within the sub-plot area (regardless of species) to provide a better cover value accounting for any overlapping vegetation (cumulative percent cover has the potential to go above 100 percent). Calculated ratios for estimated percent aerial cover were performed later following data entry.

### **ONP Park Staff and Volunteer Assistance**

Four Park staff and 3 volunteers assisted with various aspects of plot setup and initial data collection in June. Additional volunteers were deemed necessary following June seedling counts in order to prevent continuous data collection and because Park staff were no longer available. Five consistent volunteers were recruited and utilized for July and August rounds of monitoring. In order to reduce the variability between multiple data collectors, certain volunteers were designated counters and recorders and positions kept consistent during these rounds of monitoring.

### **Sediment Moisture Monitoring**

Sediment was sampled for gravimetric water content once during each round of data collection at approximately the same location at a designated mid point of the top of each blocked row (Figure 3).

### **Grab Sample Field Method**

Soil samples were gathered using the grab sample method (Ewing, 2012). A core of the top 10 cm was collected using a section of ~1.5-inch diameter aluminum piping. The edge of one end of the pipe end was filed inward to provide enough holding force when extracting a sample. The pipe was pushed straight down into the ground until a marked point on the pipe (at 10 cm depth). One hand was then placed over the exposed pipe end to form a vacuum and firmly pulled out. A wooden dowel was used to push the sample out of the pipe and into jars or tins correctly labeled to specific locations (block A1, A2, A3, etc.) and placed into sealed ziplock bags.

Samples were then taken to a University of Washington lab for drying and weighing for moisture content within 48-72 hours of extraction.

### **Grab Sample Lab Method**

Wet sediment samples and their containers were weighed (in grams) with a digital scale prior to drying. Wet samples were then placed in a 90° C lab oven for 24 hours or until dry. Dry weights were then recorded and sediment discarded. Paired containers and lids were kept together. In the final step clean tin/jar and associated lid weights were then recorded as the tare.

### **Calculating Gravimetric Water Content**

The standard formula below was used to calculate gravimetric moisture content (Black, 1965) in surface sediments:

$$\theta_d = \frac{(\text{wt of wet soil} + \text{tare}) - (\text{wt of dry soil} + \text{tare})}{(\text{wt of dry soil} + \text{tare}) - (\text{tare})}$$

### **Data Analysis Methods**

Data sheets were reviewed for errors and entered into an Excel database in fall/winter 2012. In order to standardize count estimates between treatment areas, all individual subplot data (the variable 8 to 32 square decimeters measured) were scaled to 1 m<sup>2</sup> for consistency and comparison. Treatment Area A, C, and G data were multiplied by 12.5 and Treatment Area B, D, E, F, H, and I data were multiplied by 3.125.

All species present in plots were recorded; however, a few species groups were targeted for specific interest and efficiency of analysis. Counts and coverage averages for the following target groups were lumped: seeded species, weeds, and native woody colonizers. Seeded species are those selected for the experiment. Weeds are grouped by all identified non-native species as defined by USDA Plants Database. Some non-priority exotic species were observed in great numbers (*Poa annua*, *Myosotis* spp., *Sisymbrium* sp. and therefore lumped into the weedy species group for a broader view analysis of summer plant growth patterns. The weeds group includes those listed as invasive, exotic species of concern in the Revegetation and Restoration Plan for Lake Mills and Lake Aldwell (Chenoweth *et al.*, 2011) and are also presented in their own summary table. Native woody colonizers are defined as all native woody trees and shrubs.

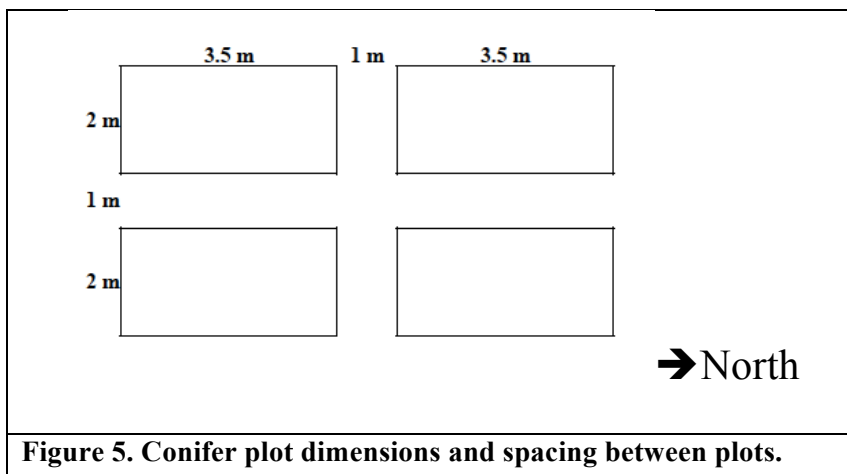
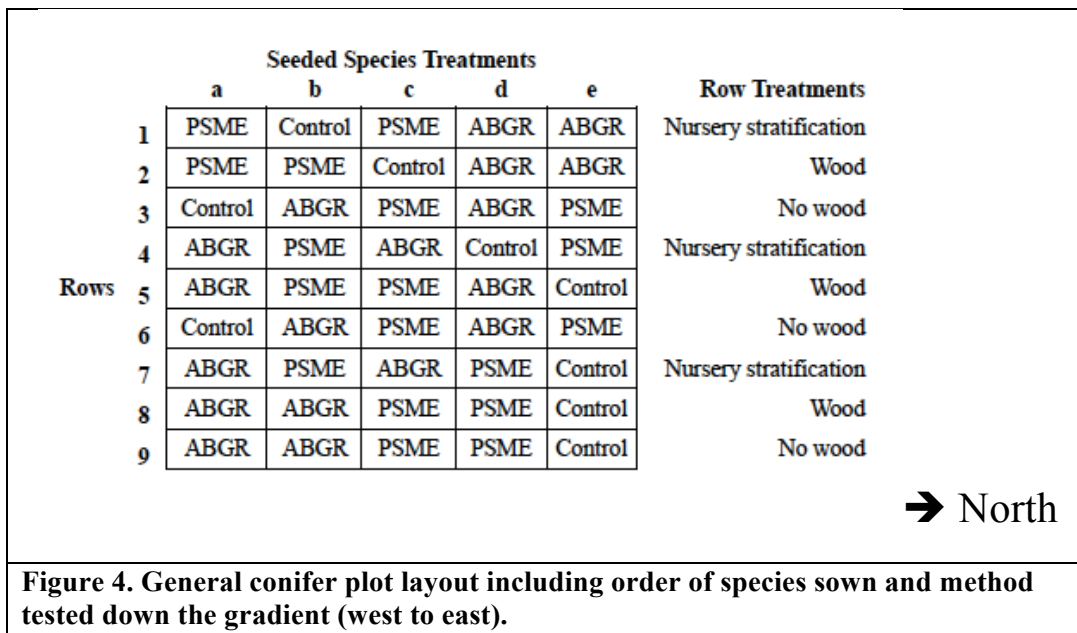
## **Site 2 – Conifers**

### **Study Area**

Site 2 is an approximately 0.6-acre valley wall landform covered in lacustrine silt and clay in the northwest corner of the former Lake Aldwell reservoir (Figure 1). The site has a southeast aspect with similar gentle slopes as Site 1 but with significantly fewer snags and downed dead wood than Site 1. The study area chosen for the experiment encompassed approximately 600 ft<sup>2</sup>.

### **Treatment Plot Design**

3.5 meter x 2 meter (7 m<sup>2</sup>) plots were established in nine rows and five columns. Each row consists of two plots per species plus one control. Species/control plot order within rows was randomly selected (Figures 4 and 5).



### Conifer Seeding Methods and Treatments

Two species were sown using three methods for a total of six prescriptions:

*Pseudotsuga menziesii*

1. Large woody debris.
2. No wood.
3. Nursery stratification.

*Abies grandis*

4. Large woody debris.
5. No wood.
6. Nursery stratification.

A shelter treatment in the form of on-site woody debris was applied to each plot of rows 2, 5, and 8 (the largest possible pieces that two people could lift were selected from within the site). Wood was situated perpendicular to the shoreline at a northwest/southeast orientation.

Douglas fir (*Pseudotsuga menziesii*) and grand fir (*Abies grandis*) were hand sown in double rows of 100 (200 total seeds per plot) at ~1/4-1/2 inch depth at 1 inch spacing (Figure 3). Rows of seed were sown 0.5 m from plot edges and 1 m from each other; row ends were then marked with small diameter sticks located on site. 1,200 seeds of each species were sown for each of three methods (presence of woody debris, no wood, and nursery stratified seed) for a total of 3,600 total seeds per species. 7,200 total seeds were sown at Site 2.

Two-thirds of the seed was sown on April 2<sup>nd</sup>, 2012 for on-site stratification. One third was reserved and placed in cold/moist stratification at the Matt Albright Native Plant Center on the same day. Nursery stratified seeds were poured into mesh cloth bags and then placed into another mesh bag packed with perlite. Bags were wetted thoroughly and excess water was squeezed and shaken off. Bags were then placed in steady 40° F refrigeration for 35 days (28 days minimum recommended by Fourth Corner nursery and USDA Woody plant manual). Nursery stratified seeds were sown on-site on May 7<sup>th</sup> 2012.

### **Vegetation Monitoring Schedule**

Late spring monitoring at Site 2 began following completion of monitoring at Herbaceous Sites 1 and 3 in late June 2012. Summer monitoring occurred in late July and early September 2012. Data collection began from West to East (top to bottom) at Site 2. In order to reduce impacts from foot traffic, perimeter areas between plots were utilized for moving across the site.

### **Data Collection Method**

Seedling emergence in seeded rows was observed and counted during each visit. In addition to seeded conifers, all native tree seedlings within plots were counted.

### **Sediment Moisture Monitoring**

Sediment samples were taken monthly (June-September) at a similar point on the uphill side of the central plot of each row in order to capture difference in soil moisture along the gradient. Samples were gathered using the grab sample method described previously (Ewing, 2012). Sediment moisture was measured in a lab using the same method as described previously.



## Results

### Site 1 – Herbs

Approximated sowing rates (seeds/m<sup>2</sup>) varied between treatments due to high and low sowing treatments, actual pounds applied per treatment, and individual seed weights (see seed mix specifications in Appendix A). Seeded species counts in June varied between 11-58 percent of those estimated to have been sown (Table 3).

**Table 3. Comparison of the approximate sowing rate and June seedling count.**

| Treatment Area | Treatment Type      | Approximate Sowing Rate (ft <sup>2</sup> ) | Approximate Sowing Rate (m <sup>2</sup> ) | Estimated June seeded count (m <sup>2</sup> ) | % Difference (counted vs. sown) |
|----------------|---------------------|--|---|---|---------------------------------|
| A              | Slow Gram - Low     | 478  | 5148                                      | 795   | 15%                             |
| B              | Forbs - Low         | 176  | 1905                                      | 1100  | 58%                             |
| C              | All Species - High  | 319  | 3444                                      | 926   | 27%                             |
| D              | Slow Gram - High    | 956  | 10296                                     | 1117  | 11%                             |
| E              | Agg. Grasses - High | 170  | 1830                                      | 647   | 35%                             |
| F              | Agg. Grasses - Low  | 85   | 915                                       | 235   | 26%                             |
| G              | Forbs - High        | 353  | 3810                                      | 1859  | 49%                             |
| H              | All Species - Low   | 160  | 1722                                      | 415   | 24%                             |

Change in count estimates of all species are depicted from the beginning to the end of summer growing season in Figure 6. Seeded treatment area counts were greater than control for all monitored months. Temporal declines in seedling counts were generally observed for all treatments except for control, which increased in its seedling count from June to August. Treatment Area G was the highest of all other treatments for all months (1899/m<sup>2</sup> in June; 1293 in July; 1873 in August). The control treatment area total counts increased over time but were still lowest of all treatment areas (54/m<sup>2</sup> in June; 66 in July; 98 in August). End of season total counts in high seeded treatments were not always greater than in low seeded treatments. Exceptions were A (slow graminoids/low) that appears comparable to its paired high treatment in D (slow graminoids/high) by end of season; B (forbs/low) is similar to C (all species/high). Total species count values are summarized in Table 5.

**Average Treatment Area Seedling Counts from June to August**  
(estimated based on direct count)

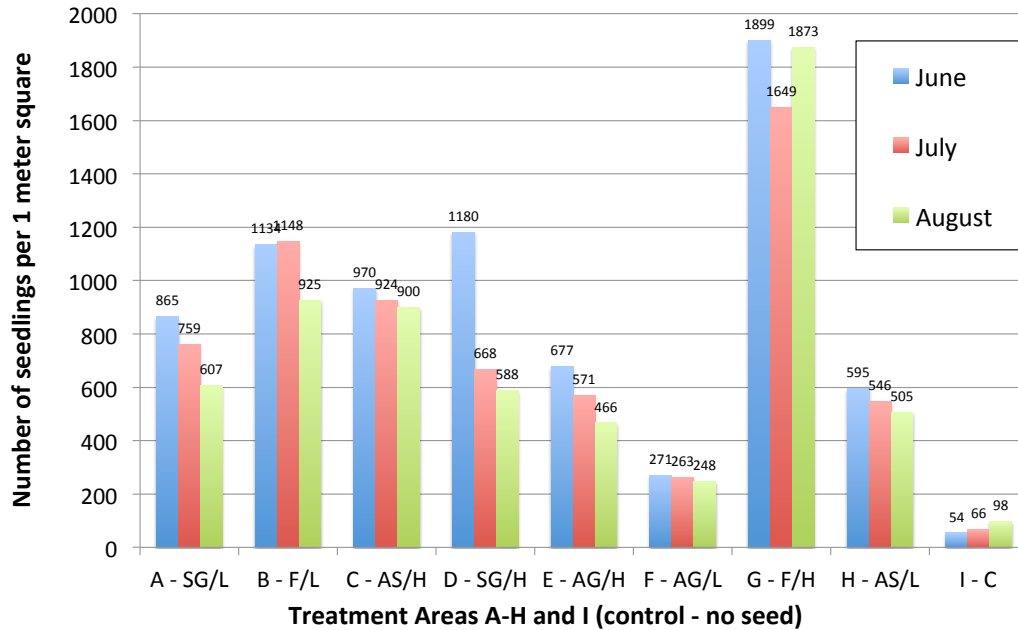


Figure 6. June, July, and August count for all species seedlings observed within plots (seeded and volunteer) in treatment areas A-I. (A – slow graminoids/low sowing; B – forbs/low; C – all species/high; D – slow graminoids/high; E – aggressive grasses/high; F – aggressive grasses/low; G – forbs/high; H – all species/low; I – control/no seed)

**Table 5. Seedling counts for all species estimated per m<sup>2</sup> in Treatment Areas A-I during the monitoring period.**

| Treatment Area | June | July | August |
|----------------|------|------|--------|
| A - SG/L       | 865  | 759  | 607    |
| B - F/L        | 1134 | 987  | 925    |
| C - AS/H       | 970  | 924  | 900    |
| D - SG/H       | 1180 | 668  | 588    |
| E - AG/H       | 677  | 571  | 466    |
| F - AG/L       | 271  | 263  | 248    |
| G - F/H        | 1899 | 1293 | 1873   |
| H - AS/L       | 595  | 458  | 505    |
| I - C          | 54   | 66   | 98     |

Overall seedling cover (seeded and volunteer) increased between July and August for all treatments (Figure 7). Highest estimated end of season percent cover was observed in treatment areas D (56.9 percent), C (49.2), and G (38.5). Lowest percent cover estimates were observed in I (9.2 percent), F (13.6), and H (19.1). Greatest rates of increase were observed in D, C, A, and G where cover

increased by 200, 161, 159, and 146 percent respectively. Tables 6 and 7 summarize average seedling cover estimates per treatment area.

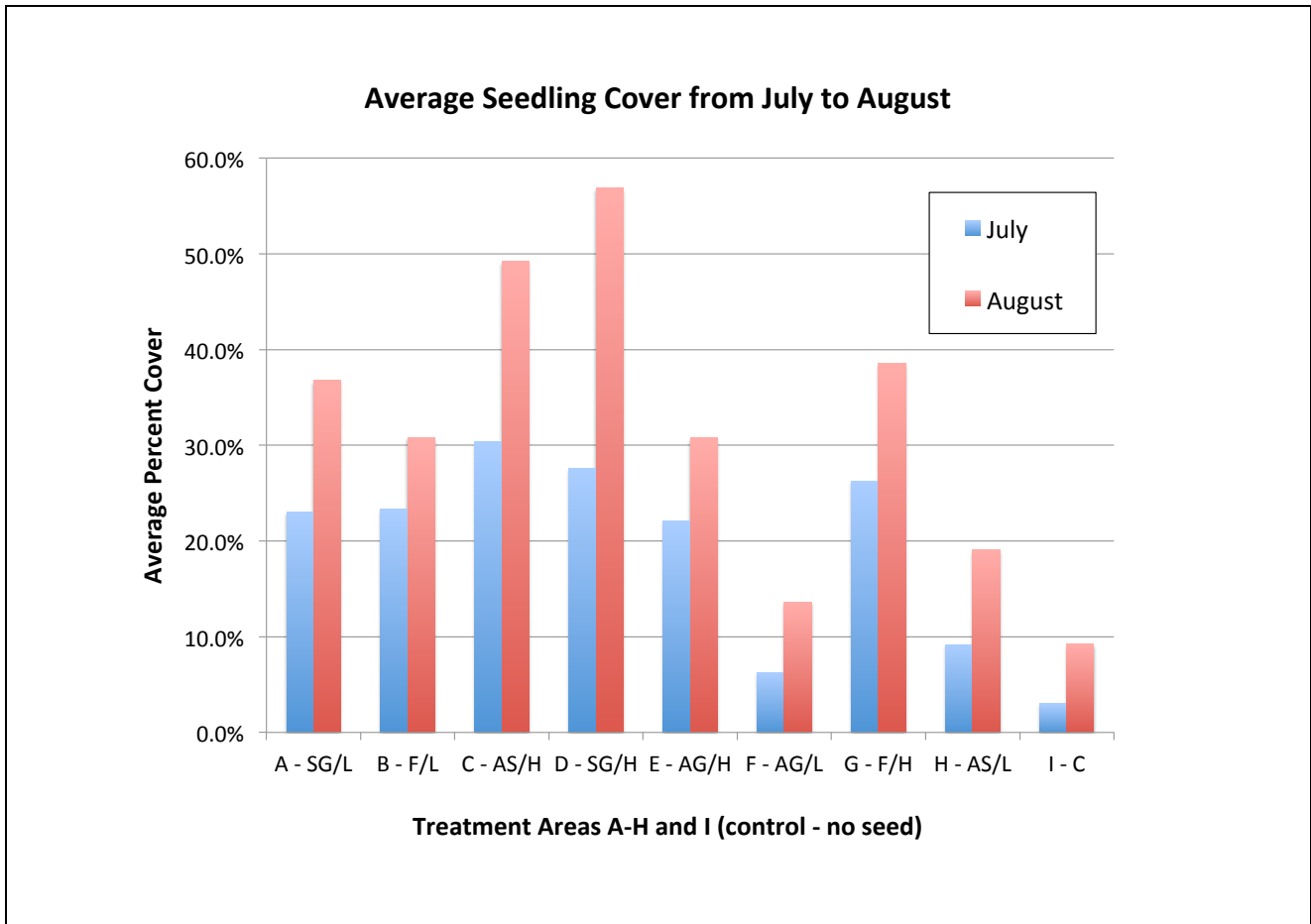


Figure 7. Average July and August cover estimates of all species across treatment areas A-I.

**Table 6. July and August average species cover of all seedlings for Treatment Areas A-I.**

| Treatment Area | July  | August |
|----------------|-------|--------|
| A - SG/L       | 23.1% | 36.8%  |
| B - F/L        | 23.3% | 30.8%  |
| C - AS/H       | 30.4% | 49.2%  |
| D - SG/H       | 27.6% | 56.9%  |
| E - AG/H       | 22.1% | 30.8%  |
| F - AG/L       | 6.3%  | 13.6%  |
| G - F/H        | 26.3% | 38.5%  |
| H - AS/L       | 9.1%  | 19.1%  |
| I - C          | 3.0%  | 9.2%   |

**Table 7. August average cover of all seedlings for Treatment Areas broken down by blocked plot rows.**

| Average Cover of All Observed Species Per Row in August |              |              |
|---|--------------|--------------|
| Slow Graminoids/Low                                     |              |              |
| A--1  | A--2         | A--3         |
| <b>33.0%</b>  | <b>37.8%</b> | <b>39.6%</b> |
| Forbs/Low   |              |              |
| B--1  | B--2         | B--3         |
| <b>29.9%</b>  | <b>41.2%</b> | <b>21.4%</b> |
| All Species/High  |              |              |
| C--1  | C--2         | C--3         |
| <b>53.9%</b>  | <b>61.5%</b> | <b>32.3%</b> |
| Slow Graminoids/High                                    |              |              |
| D--1  | D--2         | D--3         |
| <b>48.8%</b>  | <b>71.7%</b> | <b>50.1%</b> |
| Aggressive Grasses/High                                 |              |              |
| E--1  | E--2         | E--3         |
| <b>29.4%</b>  | <b>31.6%</b> | <b>31.3%</b> |
| Aggressive Grasses/Low                                  |              |              |
| F--1  | F--2         | F--3         |
| <b>15.8%</b>  | <b>13.1%</b> | <b>12.0%</b> |
| Forbs/High  |              |              |
| G--1  | G--2         | G--3         |
| <b>30.5%</b>  | <b>49.2%</b> | <b>35.9%</b> |
| All Species/Low   |              |              |
| H--1  | H--2         | H--3         |
| <b>16.0%</b>  | <b>17.6%</b> | <b>23.6%</b> |
| Control/No Seed   |              |              |
| I--1  | I--2         | I--3         |
| <b>11.1%</b>  | <b>10.1%</b> | <b>6.4%</b>  |

Weeds and native woody colonizer counts in June are summarized below (Figure 8; Table 8). June counts of these two species groups were not uniform across treatment areas. Plots in treatments A and D had significantly higher weed counts (39 and 46) while weeds in all other treatment area plots ranged from 2/m<sup>2</sup> (H-all species/low) to 14/m<sup>2</sup> (C-all species/high). Weed counts in treatments A, C, and D were higher than control (I); B, E, F, G, and H all contained fewer weeds in plots than control. June plot counts of native woody colonizers generally increased from south to north in

seeded Treatment Areas A-H, ranging from 6-18/m<sup>2</sup>. The highest June count for this species group was observed in the control (24/m<sup>2</sup>).

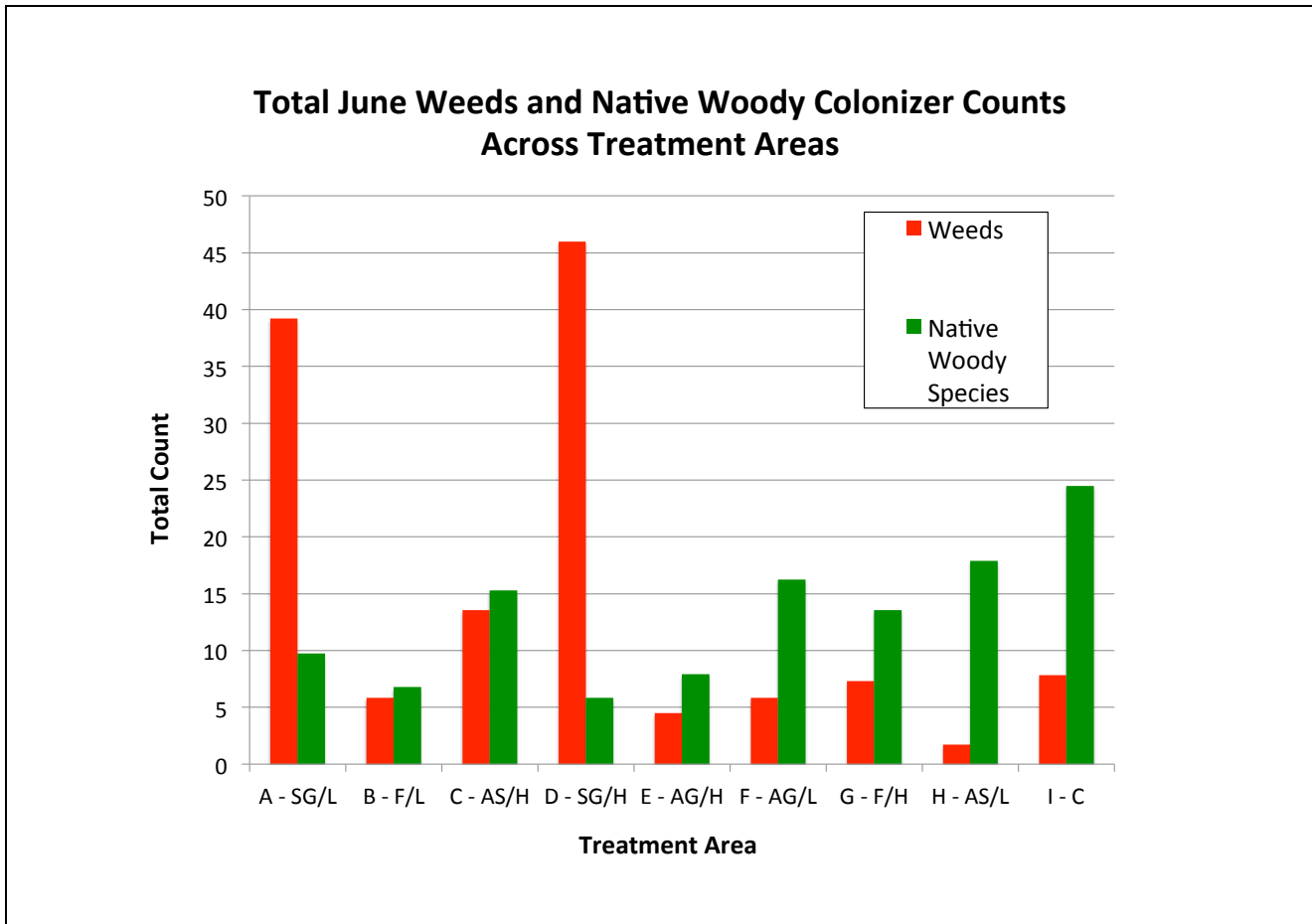


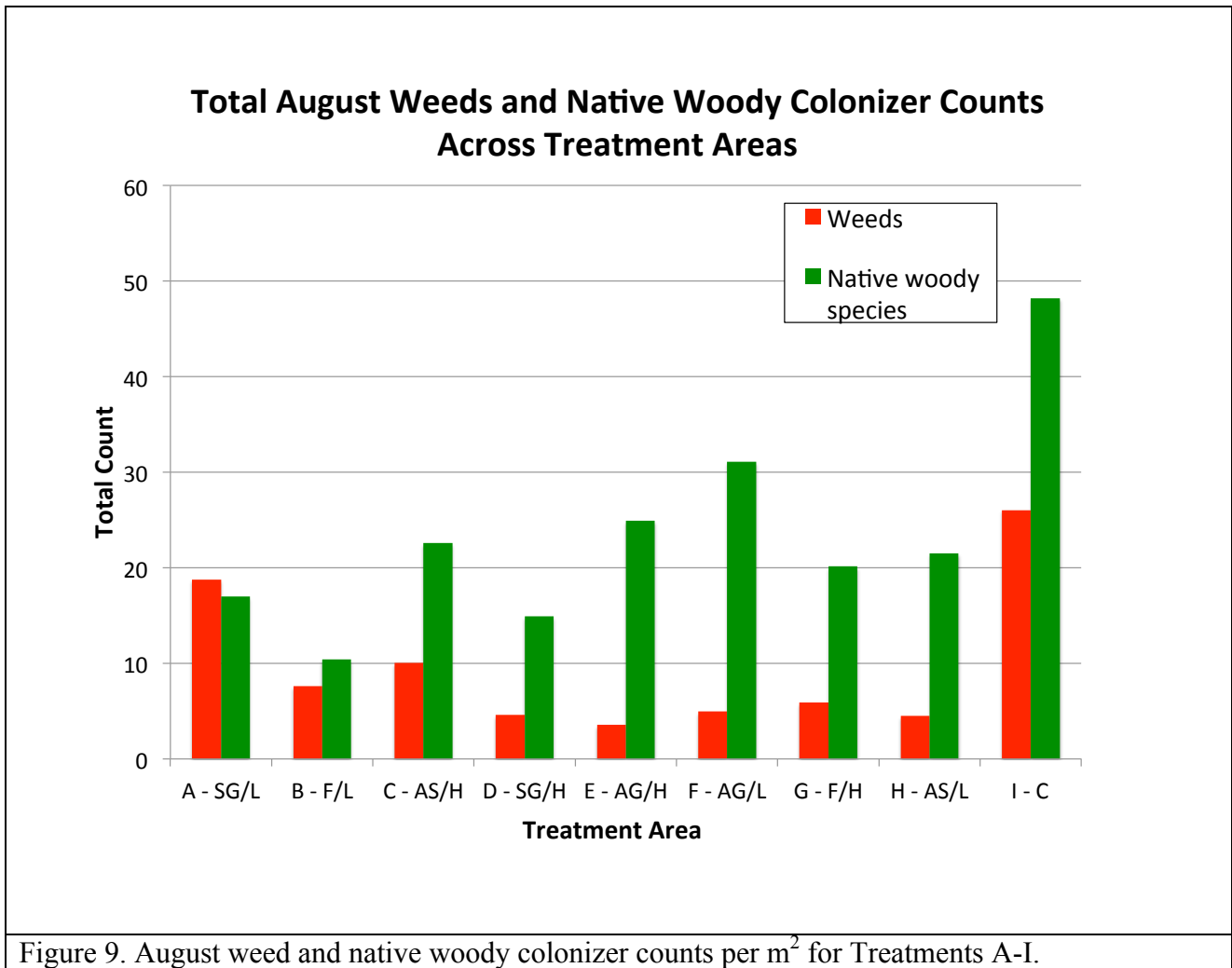
Figure 8. June weed and native woody colonizer counts per m<sup>2</sup> for Treatments A-I.

Table 8. June count totals for seeded species, weeds, and native woody colonizers (estimated) per treatment.

| Treatment | Total Seeded Count (m <sup>2</sup> ) | Total Weed Count (m <sup>2</sup> ) | Total Native Woody Count (m <sup>2</sup> ) |
|-----------|--------------------------------------|------------------------------------|--|
| A - SG/L  | 795                                  | 39                                 | 10   |
| B - F/L   | 1100                                 | 6                                  | 7  |
| C - AS/H  | 926                                  | 14                                 | 15   |
| D - SG/H  | 1117                                 | 46                                 | 6  |
| E - AG/H  | 647                                  | 5                                  | 8  |
| F - AG/L  | 235                                  | 6                                  | 16   |
| G - F/H   | 1859                                 | 7                                  | 14   |
| H - AS/L  | 415                                  | 2                                  | 18   |
| I - C     | 0                                    | 8                                  | 24   |

In August, weed counts decreased from June by 20 in treatment area A and 41 in treatment area D; representing 53- and 89-percent declines, respectively. Weed counts increased slightly in B, E, F,

G, and H. End of season weed counts were lower in all seeded treatment plots compared to control, where the overall weed count nearly tripled from June. Treatment A was the only treatment in August that contained a greater number of weeds than native woody colonizers in plots. Similarly to June counts of the native woody species group, August counts generally increased south to north from A to I. Counts of this species group more than doubled in August in treatments D (slow graminoids/high), E (aggressive grasses/high), F (aggressive grasses/low), and I (control) (Figure 9; Table 9).



**Table 9. August count totals for seeded species, weeds, and native woody colonizers (estimated per meter square) for treatments A-I.**

| Treatment | Total Seeded Count (m <sup>2</sup> ) | Total Weed Count (m <sup>2</sup> ) | Total Native Woody Count (m <sup>2</sup> ) |
|-----------|--------------------------------------|------------------------------------|--|
| A - SG/L  | 540                                  | 19                                 | 17   |
| B - F/L   | 884                                  | 8                                  | 10   |
| C - AS/H  | 831                                  | 10                                 | 23   |
| D - SG/H  | 543                                  | 5                                  | 15   |
| E - AG/H  | 422                                  | 4                                  | 25   |
| F - AG/L  | 173                                  | 5                                  | 31   |
| G - F/H   | 1831                                 | 6                                  | 20   |
| H - AS/L  | 446                                  | 5                                  | 22   |
| I - C     | 1                                    | 26                                 | 48   |

Average cover of different species groups varied somewhat between treatments by end of season (Figure 10; Table 10). Weeds cover appears higher in the most southern treatments A-C. Average weed cover in plots ranged from a low of 1.2 (E – aggressive grasses/high) to a high of 3.6 percent (B – forbs/low). Cover of weeds in control plots averaged 2.7 percent. In August, the lowest average cover of native woody colonizers was 0.8 percent (B – forbs/low); the highest was 5.1 percent (I – control) where cover of native woody colonizers is nearly twice that of weeds. A slightly trending increase in native woody colonizers is observable from south to north treatments (A-I).

### Average August Cover of Weeds and Native Woody Colonizers across Treatments Areas

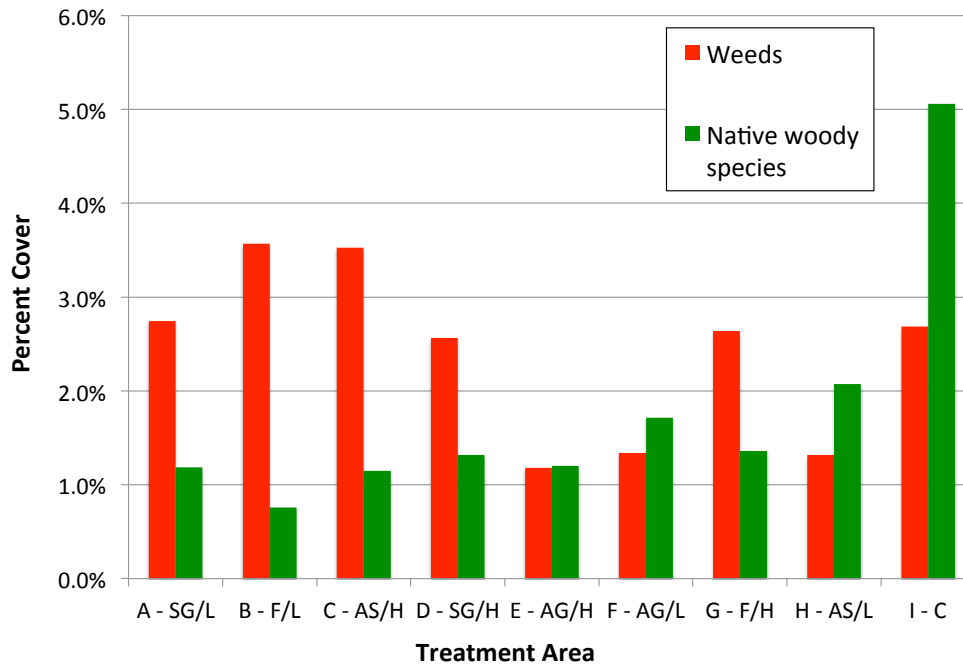


Figure 10. Estimated August/September cover of weeds and native woody colonizers across all treatment areas.

Table 10. August cover estimates for seeded species, weeds, and native woody colonizers per m<sup>2</sup> for treatments A-I.

| Treatment | Average Seeded Cover (m <sup>2</sup> ) | Average Weed Cover (m <sup>2</sup> ) | Average Native Woody Cover (m <sup>2</sup> ) |
|-----------|--|--------------------------------------|--|
| A - SG/L  | 32.6%                                  | 2.7%                                 | 1.2%   |
| B - F/L   | 28.1%                                  | 3.6%                                 | 0.8%   |
| C - AS/H  | 48.2%                                  | 3.5%                                 | 1.1%   |
| D - SG/H  | 60.0%                                  | 2.6%                                 | 1.3%   |
| E - AG/H  | 28.4%                                  | 1.2%                                 | 1.2%   |
| F - AG/L  | 9.7%                                   | 1.3%                                 | 1.7%   |
| G - F/H   | 39.4%                                  | 2.6%                                 | 1.4%   |
| H - AS/L  | 18.8%                                  | 1.3%                                 | 2.1%   |
| I - C     | 0.2%                                   | 2.7%                                 | 5.1%   |

Decreasing native woody counts are compared to increasing distance from the east tree line in Figure 11. A potential linear relationship between native woody species recruitment and tree line is depicted.

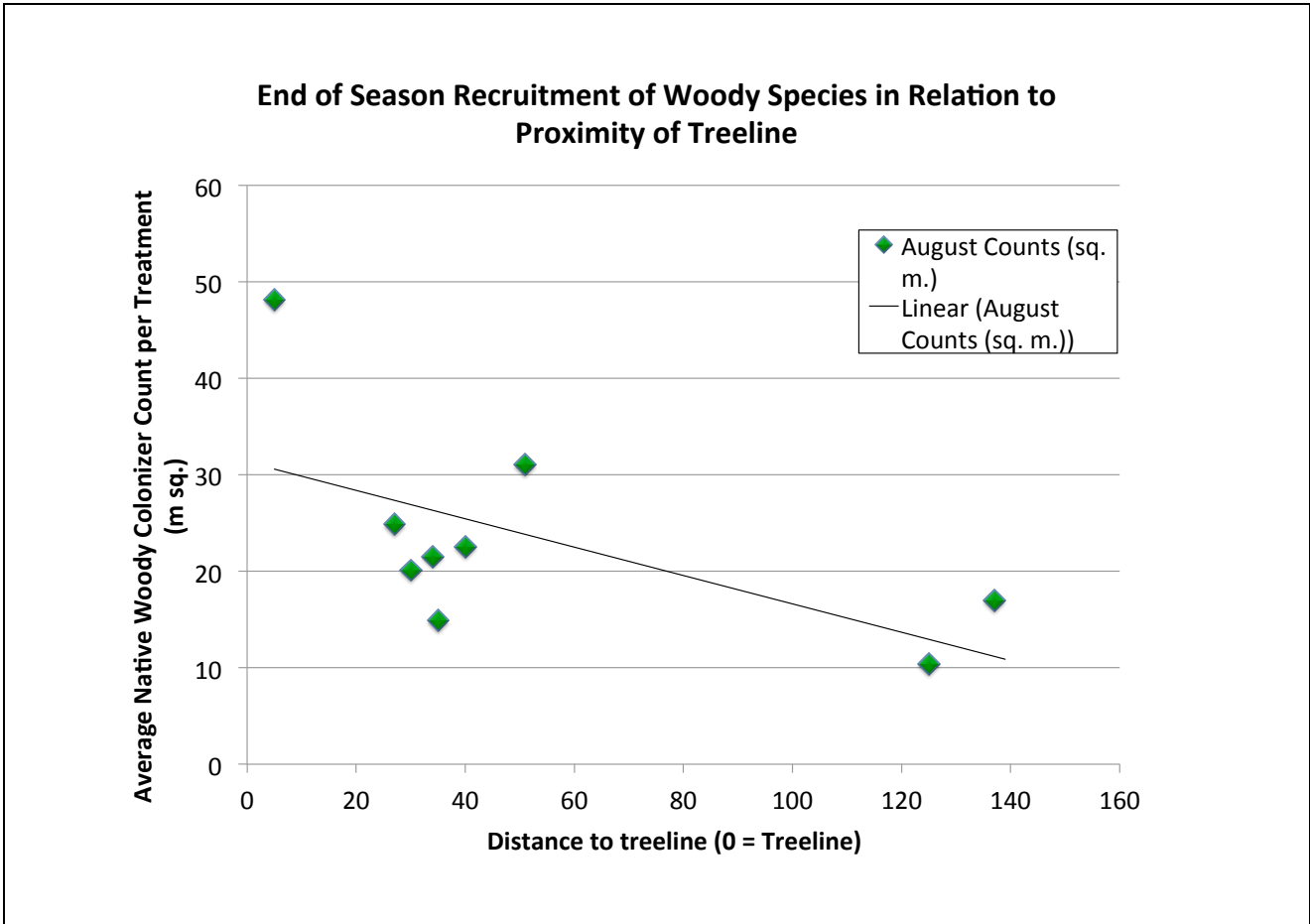


Figure 11. Average native woody colonizer counts (per m<sup>2</sup>) in treatments relative to edge of tree line.

Average August cover between species groups (seeded, weeds, and native woody colonizers) is displayed in Figure 12 and compares cover between high and low sowing rates. As expected, seeded species cover in low sowing treatments (22.3 percent) is half that of high sowing treatments (44.0 percent). Average percent cover of weeds and native woody colonizers are comparable between sowing rate treatments - 2.2 and 1.4 percent, respectively for the low rates; 2.5 and 1.3 percent for the high rates. A full summary of target species group counts and cover estimates between sowing rates are available in Tables 11-13.

**Average August Cover Between Sowing Rates**

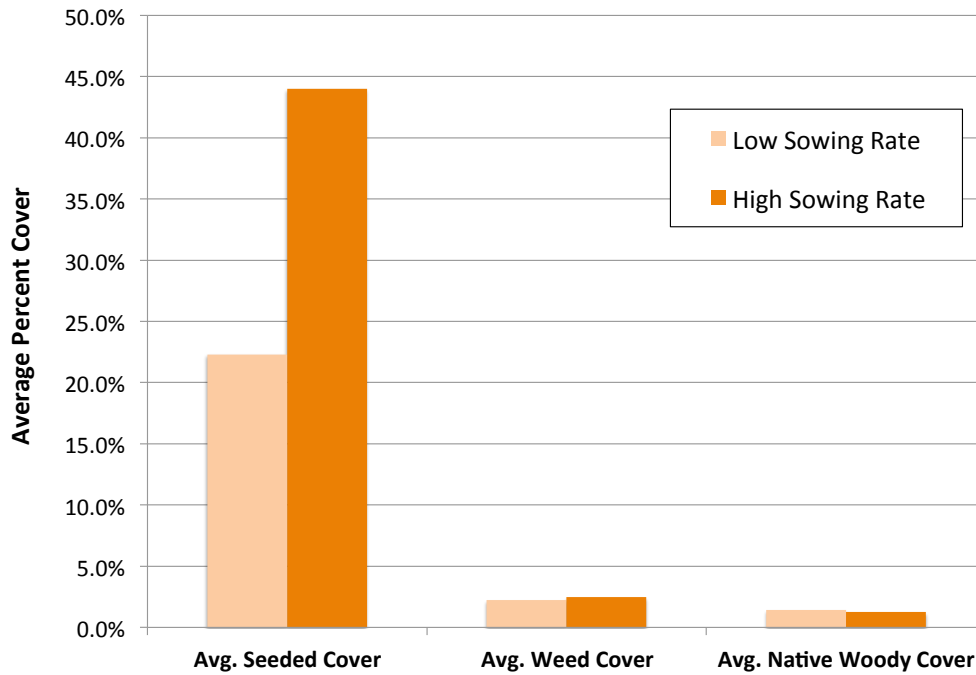


Figure 12. Average August cover of seeded, weeds, and native woody colonizers between low versus high sowing rates.

**Table 11. June count totals for low and high seeding rates.**

| Treatment | Seeded Count Sum | Weed Count | Native Woody Count |
|-----------|------------------|------------|--------------------|
| Low Rate  | 2545             | 53         | 51                 |
| High Rate | 4549             | 71         | 43                 |

**Table 12. August count totals for low and high seeding rates.**

| Treatment | Seeded Count Sum | Weed Count | Native Woody Count |
|-----------|------------------|------------|--------------------|
| Low Rate  | 2043             | 36         | 80                 |
| High Rate | 3627             | 24         | 83                 |

**Table 13. August cover averages between low and high seeding rate treatments.**

| Treatment        | Avg. Seeded Cover | Avg. Weed Cover | Avg. Native Woody Cover |
|------------------|-------------------|-----------------|-------------------------|
| Low Sowing Rate  | 22.3%             | 2.2%            | 1.4%                    |
| High Sowing Rate | 44.0%             | 2.5%            | 1.3%                    |

### Herbaceous Treatment Site Sediment Moisture

Overall sediment moisture losses were measured in all gradients (Rows 1-3) over the course of the summer (Figure 13; Tables 14 and 15). Measurements in late May revealed silts from the study site ranged between 50-59 percent water content by mass. By the end of the season, water content ranged between 26-49 percent.

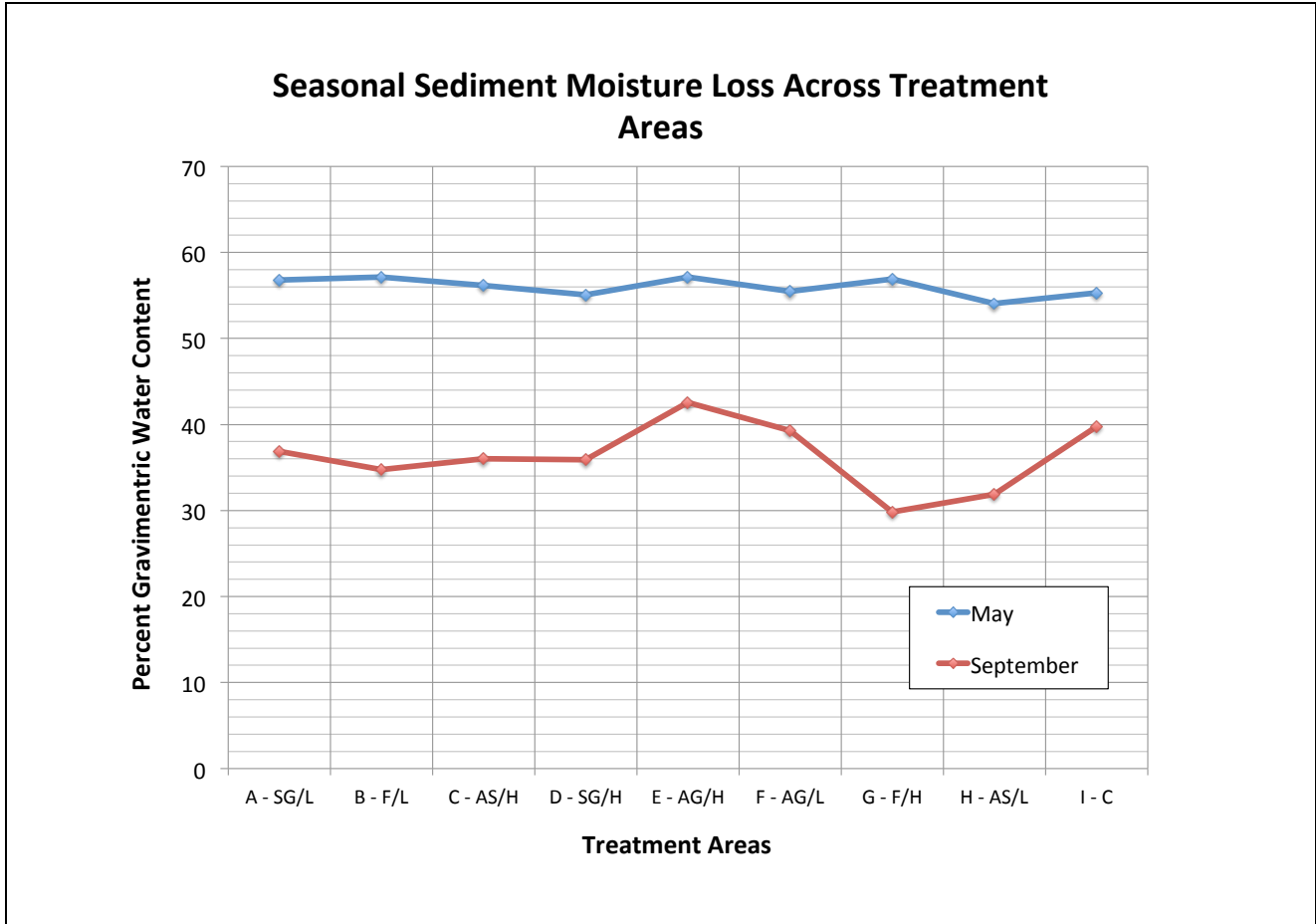


Figure 13. Average sediment moisture loss in each treatment area from late May to early-September.

Treatment area G samples showed the greatest average sediment moisture loss by end of the summer (-48%); treatment area E had the least loss in average sediment moisture (-26.2%). The most extreme losses were generally observed in middle (Treatment G - 55.6%) and low (Treatment G - 49.4%) treatment rows with the highest average loss (-40.8%) across all treatments in the lowest gradient plots (Row 3). The highest gradient area (Row 1) showed the least moisture loss of all rows and all treatments (-14.3%). Summary sediment moisture data are available in Tables 14-15.

**Table 14. Sampled Sediment Moisture in May, June, July, and August**

| <b>% Gravimetric Water Content per Block Sample</b> |              |              |              |                       |              |              |              |
|---|--------------|--------------|--------------|-----------------------|--------------|--------------|--------------|
| <b>5/25/12</b>                                      |              |              |              | <b>7/27/12</b>        |              |              |              |
| <b>Treatment Area</b>                               | <b>Row 1</b> | <b>Row 2</b> | <b>Row 3</b> | <b>Treatment Area</b> | <b>Row 1</b> | <b>Row 2</b> | <b>Row 3</b> |
| A   | 53.9         | 57.7         | 58.8         | A                     | 45.5         | 50.8         | 49.3         |
| B   | 57.1         | 57.7         | 56.7         | B                     | 49.4         | 48.1         | 48.1         |
| C   | 57           | 57.1         | 54.4         | C                     | 50.9         | 60           | 48           |
| D   | 49.5         | 58.1         | 57.6         | D                     | 43.1         | 53           | 47.7         |
| E   | 58.4         | 57.5         | 55.5         | E                     | 54.7         | 51.8         | 45.1         |
| F   | 56.4         | 52.5         | 57.5         | F                     | 52.5         | 46.7         | 49.4         |
| G   | 56.2         | 58.3         | 56.3         | G                     | 47.6         | 47.7         | 45.9         |
| H   | 55.6         | 52.6         | 54           | H                     | 48.2         | 48.6         | 45           |
| I   | 56.1         | 52.5         | 57.4         | I                     | 50.1         | 46.8         | 47.7         |
| <b>6/27/12</b>                                      |              |              |              | <b>9/5/12</b>         |              |              |              |
| <b>Treatment Area</b>                               | <b>Row 1</b> | <b>Row 2</b> | <b>Row 3</b> | <b>Treatment Area</b> | <b>Row 1</b> | <b>Row 2</b> | <b>Row 3</b> |
| A   | 36.3         | 35.5         | 33.7         | A                     | 37.1         | 39.1         | 34.5         |
| B   | 25.8         | 28.9         | 57.9         | B                     | 35.6         | 35.9         | 32.7         |
| C   | 26.9         | 29.2         | 51.9         | C                     | 35           | 39.6         | 33.5         |
| D   | 27.7         | 51.2         | 55.4         | D                     | 27.5         | 45.7         | 34.5         |
| E   | 38.9         | 55.5         | 51.4         | E                     | 46.1         | 44.3         | 37.3         |
| F   | 51.7         | 51.1         | 53.9         | F                     | 47.3         | 33           | 37.5         |
| G   | 52.5         | 50.3         | 36.7         | G                     | 35.1         | 25.9         | 28.5         |
| H   | 55.1         | 49.8         | 45.9         | H                     | 32.2         | 35.8         | 27.7         |
| I   | 44.3         | 52.8         | 50.2         | I                     | 48.4         | 35.9         | 34.9         |

**Table 15. Gravimetric sediment moisture loss along the project site gradient (high, middle, and low plots) from June to September.**

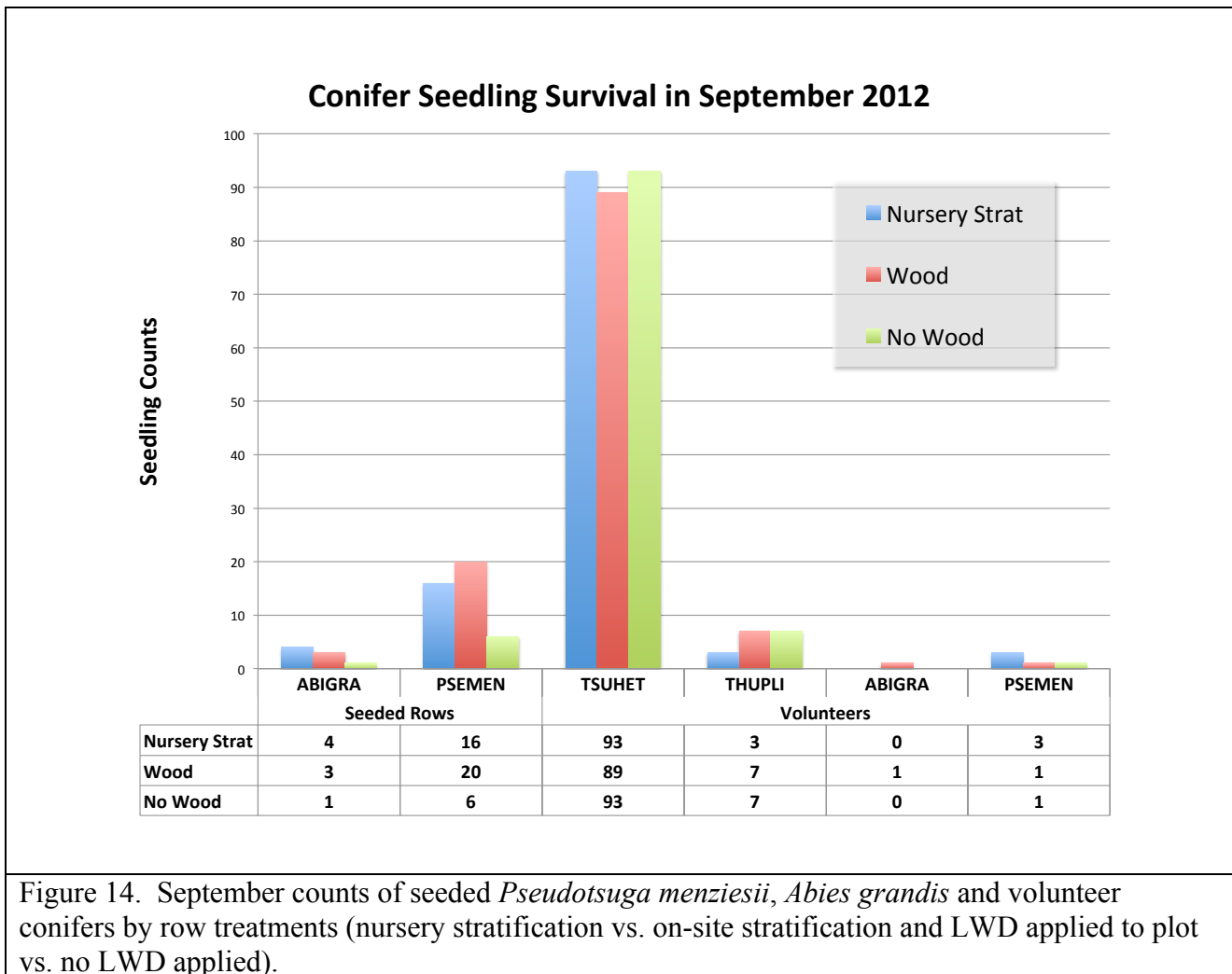
| <b>Percent Soil Moisture Change in Blocked Plots (from June to September)</b> |                     |                       |                    |                          |
|---|---------------------|-----------------------|--------------------|--------------------------|
| <b>Treatment Area</b>   | <b>Row 1 (High)</b> | <b>Row 2 (Middle)</b> | <b>Row 3 (Low)</b> | <b>Treatment Average</b> |
| A   | -31.2%              | -32.2%                | -41.3%             | -34.9%                   |
| B   | -39.9%              | -37.8%                | -42.3%             | -40.0%                   |
| C   | -40.8%              | -30.6%                | -38.4%             | -36.6%                   |
| D   | -40.8%              | -21.3%                | -40.1%             | -34.1%                   |
| E   | -22.8%              | -23.0%                | -32.8%             | <b>-26.2%</b>            |
| F   | -16.9%              | -37.1%                | -34.8%             | -29.6%                   |
| G   | -39.1%              | <b>-55.6%</b>         | -49.4%             | <b>-48.0%</b>            |
| H   | -43.4%              | -31.9%                | -48.7%             | -41.4%                   |
| I   | <b>-14.3%</b>       | -31.6%                | -39.2%             | -28.4%                   |
| <b>Row Averages</b>   | <b>-32.1%</b>       | <b>-33.5%</b>         | <b>-40.8%</b>      | --                       |

### Other Environmental Variables Measured

Percent cover estimates of woody debris, forest litter, and cracks in the sediment surface were estimated and averaged for entire rows and are summarized in Appendix B.

### Site 2 - Conifers

Nine seeded *Abies grandis* were counted June; of those, eight survived until September (Figures 14 and 15). This represents a 0.22% germination rate by the end of the growing season. A total of 36 *Pseudotsuga menziesii* were counted in June; by August 42 *P. menziesii* seedlings were counted representing a 1.17% germination rate by season end. In contrast, successful propagation using the same seed lot was performed at the Matt Albright Native Plant Materials Center indicating approximately 80 percent seed viability for both species (Allen, pers. comm., 2012). June and August conifer counts are summarized in Tables 15-18.



**September Conifer Counts vs. Plot Treatment**

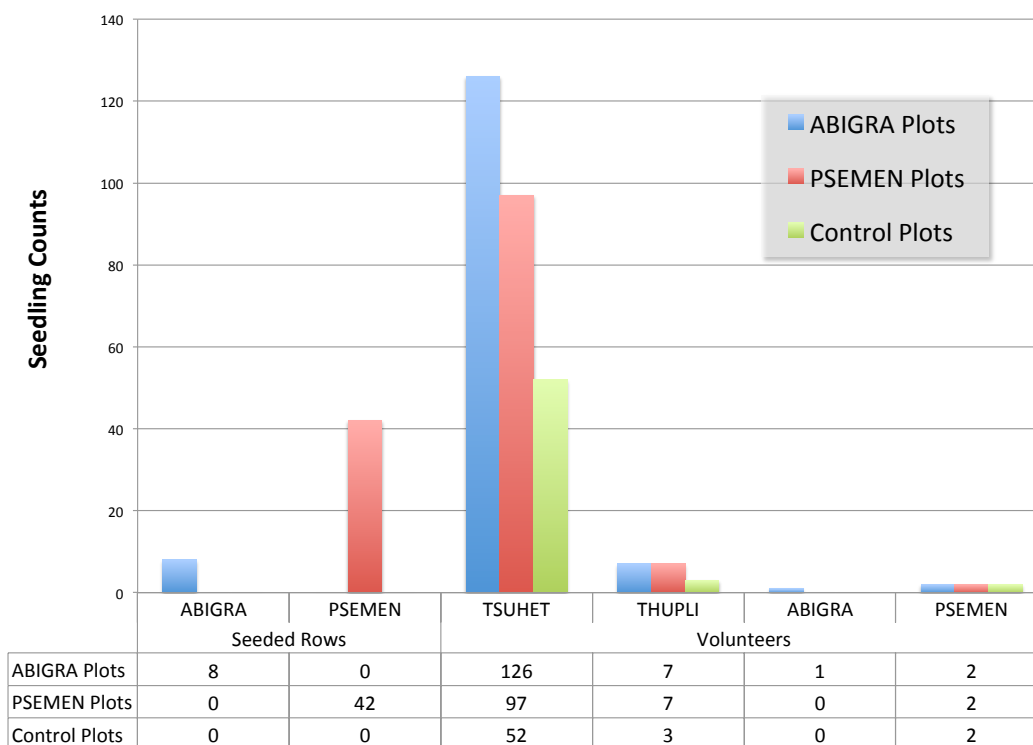


Figure 15. September counts of seeded *Pseudotsuga menziesii*, *Abies grandis* and volunteer conifers by species plot treatment (seeded *Abies*, seeded *Pseudotsuga* vs. no seed applied).

**Table 15. June conifer seedling counts (seeded and volunteer) per row treatments.**

| Row Treatment          | Seeded Rows |           | Volunteers    |          |          |
|------------------------|-------------|-----------|---------------|----------|----------|
|                        | ABIGRA      | PSEMEN    | TSUHET/THUPLI | ABIGRA   | PSEMEN   |
| Nursery Stratification | 4           | 15        | 102           | 0        | 1        |
| Wood                   | 2           | 18        | 97            | 0        | 0        |
| No Wood                | 3           | 3         | 94            | 0        | 0        |
| <b>TOTALS</b>          | <b>9</b>    | <b>36</b> | <b>293</b>    | <b>0</b> | <b>1</b> |

**Table 16. June conifer seedling counts (seeded and volunteer) per plot treatments.**

| Plot Treatment | Seeded Rows |           | Volunteers    |          |          |
|----------------|-------------|-----------|---------------|----------|----------|
|                | ABIGRA      | PSEMEN    | TSUHET/THUPLI | ABIGRA   | PSEMEN   |
| ABIGRA Plots   | 8           | 1         | 124           | 0        | 0        |
| PSEMEN Plots   | 1           | 35        | 103           | 0        | 0        |
| Control Plots  | 0           | 0         | 66            | 0        | 1        |
| <b>TOTALS</b>  | <b>9</b>    | <b>36</b> | <b>293</b>    | <b>0</b> | <b>1</b> |

**Table 17. August conifer seedling counts (seeded and volunteer) per row treatments.**

| Row Treatment          | Seeded Rows |           | Volunteers |           |          |          |
|------------------------|-------------|-----------|------------|-----------|----------|----------|
|                        | ABIGRA      | PSEMEN    | TSUHET     | THUPLI    | ABIGRA   | PSEMEN   |
| Nursery Stratification | 4           | 16        | 93         | 3         | 0        | 3        |
| Wood                   | 3           | 20        | 89         | 7         | 1        | 1        |
| No Wood                | 1           | 6         | 93         | 7         | 0        | 1        |
| <b>TOTALS</b>          | <b>8</b>    | <b>42</b> | <b>275</b> | <b>17</b> | <b>1</b> | <b>5</b> |

**Table 18. August conifer seedling counts (seeded and volunteer) per plot treatments.**

| Plot Treatment | Seeded Rows |           | Volunteers |           |          |          |
|----------------|-------------|-----------|------------|-----------|----------|----------|
|                | ABIGRA      | PSEMEN    | TSUHET     | THUPLI    | ABIGRA   | PSEMEN   |
| ABIGRA Plots   | 8           | 0         | 126        | 7         | 1        | 2        |
| PSEMEN Plots   | 0           | 42        | 97         | 7         | 0        | 2        |
| Control Plots  | 0           | 0         | 52         | 3         | 0        | 2        |
| <b>Totals</b>  | <b>8</b>    | <b>42</b> | <b>275</b> | <b>17</b> | <b>1</b> | <b>6</b> |



## Discussion

### Seeding Methods

Exploring feasibility of practical seeding methods was a key concern for park managers. The majority of the reservoir areas are inaccessible to mechanized seeding equipment (hydroseeders or seed drills). Broadcasting (mechanized and by hand) is also considered the best low cost option for seeding large areas. Broadcasting seed by hand is often performed in access-limited sites but may result in poorer stand densities and even distributions that are often compensated by higher sowing rates (NRCS, 2009). For this trial, broadcast seeding by hand-cranked belly grinders was effective at getting seed onto the site quickly to allow flexibility in application timing (cool, low-wind days without precipitation), and relative precision and extent at fine scales with different species mixes.

Spring herbaceous sowing windows are likely to have greater success than fall sowings as the majority of high precipitation events that may cause seed loss due to washout (Cook, 1979; Watkinson, 1978; Sharitz and McCormick, 1973) primarily occur in winter months (October to March) (US Climate Data, no date). Sowing seed on fine sediments in spring appears to provide adequate moisture for germination and root establishment.

### Initial Seed Establishment

The stage following seedling emergence is the most crucial as seedlings switch from internal energy resources to external sources (Roach and Marchand, 1984; Harper, 1965), presenting a challenge in the nutrient poor, low porosity sediments of the Elwha River reservoirs. Major causes of seedling mortality are attributed to lack of soil moisture (Moles and Westoby, 2004; del Moral and Wood 1993; Cook, 1979; Mack, 1976; Sharitz and McCormick, 1973), competition from neighboring vegetation (Putwain and Harper, 1970), herbivory (Moles and Westoby, 2004; Meiners and Handel, 2000; Christiensen and Muller, 1975), fungal attack (Moles and Westoby, 2004), and physical disturbance caused by wind and erosion following heavy rains (Cook, 1979; Watkinson, 1978; Sharitz and McCormick, 1973). The last of these certainly an issue in the exposed reservoirs with greater than 10° slopes on valley walls. Physical disturbance may also occur in the former reservoirs when surface cracks in the fine sediments widen and erode into large rills.

An accurate evaluation of germination rates between treatments could not be achieved for this study; a qualitative comparison between roughly estimated sowing rates and estimated June seeded counts indicates some variability in how seed was spread, remained in place and germinated on the site (Table 3). Regardless of actual germination rates it appears there was an adequate moisture-rich seed-bed on the fine sediments where seeds stuck in place, successfully germinated, and rooted in all treatment areas. It should be noted that germination and seedling survival discussed below in further detail was occurring on the fine sediments during a very wet, cool June (204% of average precipitation on record) and in spite of an exceptionally dry August/September warm period (6% of average precipitation on record) (Elwha Ranger Station climate data, 2012). And although actual sediment moisture measurements indicate high moisture content by mass, little of the soil water reservoir may have been available to plants (especially later in the season) in the fine sediments due to high surface area and tight binding with fine sediment particles (Figure 13; Tables 14-15).

## Herbaceous Treatment Performance

### Sowing Densities

Observations of natural seedling populations rarely indicate that seedling-seedling competition is a direct cause of mortality; this outcome more likely resulting from artificially high densities achieved through application of seed (Moles and Westoby, 2004). Optimal seeding rates have been established for conservation stand densities at around 20-60 pure live seeds (PLS) per square foot (NRCS, 2009b). Other sources recommend back calculating the seeding rate from the desired density of the species or mix (Dorner, 2002). A restoration sowing density study using a mix of four graminoids and forbs in northern British Columbia determined 50 percent cover could be achieved in Year 1 at a sowing rate of 4,690 PLS/m<sup>2</sup> (435 PLS/ft<sup>2</sup>). Even a low sowing density of 375 PLS/m<sup>2</sup> (34 PLS/ft<sup>2</sup>) achieved equivalent densities up to 3,000 PLS/m<sup>2</sup> after Year 2 (Burton *et al.*, 2006). Sowing densities for this study fall within the ranges tested by Burton *et al.* (2006) as the goals of this project application are similar and intended to achieve short-term rapid cover. Testing the two (low and high) sowing rates was an attempt to discern whether similar cover could be achieved with less seed.

In terms of this trial study, an unknown amount of seed loss was expected from reservoir winds, gravity, and storm-mediated erosion. It was further unknown whether seeds would germinate on fine sediments without incorporation. These unknown factors further justify the high sowing rates applied in this study. Ultimately, the National Park's end goal in seeding is not to create functioning grasslands but to reduce initial erosion and jump-start ecosystem processes that will aid succession without interference. It is generally accepted that more seed does not necessarily equal more growth or establishment as suitable micro-sites and resources are limiting factors for plants on any given site (Jumpponen *et al.*, 1999; Harper *et al.* 1965). Too little seed may lead to other issues like available space for the establishment of weeds (NRCS, 2009b).

This study does not seek to quantify appropriate seeding rates or seed saturation thresholds for these seed mixes but does indicate what should be expected of resulting stand density and approximate rates of cover in these mixes at these two sowing rates on fine sediments. Interestingly, similar end of season cover were reached for certain seed mixes at low sowing rates as were reached by certain mixes at high rates. The slow graminoids/low treatment resulted in similar coverage in August (36.8%) to the forbs/high treatment (38.5%). Cover estimates in August plots for the forbs/low and aggressive grasses/high treatments were the same (30.8%) and not dramatically different (low – 28.1% and high – 39.4%) even with the approximated double quantity of seed sown. This measurement in addition to observed growth rates indicate that similar first year coverage can be achieved with the forbs mix even at lower sowing densities (Figure 7).

Twice as much cover (on average across all seed mix types) was achieved in high sowing rates (44.0%) as was achieved in low sowing rate (22.3%) treatments further confirming that ample safe-sites and seed bed were present for seed establishment (Jumpponen *et al.* 1999) at this study location and seed saturation thresholds (NRCS, 2009a; NRCS, 2009b; Darris, 2005; Harper *et al.* 1965) may not have been reached in general with these treatments (Figure 12). Neighboring factors associated with high densities can mean high root competition for moisture and nutrients, sunlight, and increased rates of mortality (NRCS, 2009a; NRCS, 2009b; Mack and Harper, 1977; Harper, 1961) but may not occur until at least the second growth season (Burton *et al.* 2006). Anecdotally, treatments with higher stand densities appeared to shade surface sediments and prevent the formation of soil crusts in contrast to the exposed, steeper-sloped sediments immediately below the

study area. Even in July and August, morning dew had collected on any available biomass potentially mediating ambient surface temperatures and sediment moisture that reduced overall plant stress.

Resulting cover of weeds and native woody colonizers was nearly the same between low and high sowing rates within treatments that received seed, indicating that weeds may have been effectively controlled by seeding regardless of density. Potential exclusion of native woody species, if any, from seeded plants is not likely explained by sowing rate (Figure 11; Table 12). The highest average loss in sediment moisture occurred in the two forb only treatments which could indicate increased evapotranspiration rates, increased competition for moisture, and perhaps a relatively less optimal seed bed for native woody species in these two tested forb stand densities than others. The lowest average count of native woody colonizers occurred in the forb/low treatment and was less in the forb/high treatment than four other treatments bordering it. The all species mix showed the greatest cover increase between sowing rates (18.8 – low; 48.2% – high) suggesting that seed saturation was not at all an issue during the monitoring period for this mix.

### **Seed Mixes**

All seeded treatments resulted in greater abundance of native species and seeding clearly increased cover of bare sediments in the first season when compared to the unseeded site (Figure 7). To evaluate naturally recruiting species, stem counts were used since many species remained too small to influence cover estimates. Summary counts and cover are presented as averages across three gradient positions and it should be noted that seedling establishment was visibly lower in third row monitoring blocks (placed at the lower treatment area limits). This may explain lower than expected cover estimates when compared to photo point observations located at middle rows. That said, some unique and important differences between seeded treatments were observed.

### ***Slow Graminoids***

Individual counts were difficult to assess in August for the slow graminoids treatment due to high densities of the densely-tufting annual, *Deschampsia elongata*, with often no visible bare ground in some plots. This may explain why the August count for the high and low sowing densities is nearly the same (Table 9). Highest resulting cover of all vegetation was observed in the Slow Graminoids/high sowing treatment (60%)(Figure 7; Table 10). Much of that cover is explained by the rapid growth rate and densely tufting habit of *Deschampsia elongata*. This short-lived species thrived on the fine sediments, effectively covered bare ground, and went to seed abundantly in August (see photo points). This “fast” species was included with slower growing species (*Carex* species) in order to provide immediate cover with the idea that the plants would die back and give way to the slow growing species over time. *Carex deweyana* and *Carex pachystachya* germinants were not observed in plots until July and never became a measurable presence in this study; the long-term effects of these species in seeded treatments is not yet known. It has been suggested that *Carex* species may not reach their mature size even after two seasons especially on degraded or low productivity sites (Burton *et al.*, 2006). It is also unknown whether adequate moisture will remain on this site in order to sustain these two facultative wetland species.

In June approximately three to 27 times more weeds were counted in this treatment when compared to other treatments including the control. The weedy annual *Poa annua* was observed in high levels in this mix; it flowered early in the season and many of the plants senesced prior to the August count explaining the dramatic decrease in weeds for these two treatments (Figures 8 and 9). The most likely explanation for the high weed presence in this mix in June is a contaminated seed lot;

however, analysis for the presence of specific weeds in the *D. elongata* seed lot was not performed and cannot be independently confirmed (OSU, 2011). For all seeded treatments, the August weed count was highest in the slow graminoids/low (Treatment A) and comparable to the Control; the most dominant perennial in the weedy species group here were *Agrostis* spp., which may have included species of concern (see Appendix E additional information about abundances of invasive, exotic species of concern). Continued weed recruitment in Treatment A may have occurred due to its relative geographic location; the furthest from sheltering forest edges and southeastern-most exposure could have captured the most airborne seeds from reservoir winds or somehow received the most lake deposit during draw-down. Counts of native woody species increased over the growing season in both high and low sowing treatments for this mix indicating initial recruitment of these species was not suppressed by applied sowing rates at least during this first growing season. Cover of native woody species was similar in these treatments although interestingly ~4 times less than that of the control. Other limiting factors may better explain fewer native woody species colonizing Treatments A and D such as distance to existing seed sources.

### ***All Species***

The all species/high treatment had the second highest resulting cover (48.2%) with *D. elongata*, *Elymus glaucus*, *Bromus* spp., and *Achillea millefolium* all blooming and producing seed in the first season. All species/high received approximately twice the seed as that applied to the all species/low treatment yet resulted in more than 2.5 times the average observed coverage of the low sowing (18.8%) (Figure 7). Fewer weeds were counted in this mix in August in comparison to the Control (Figure 9). Resulting cover of weeds in the high sowing of this mix (Treatment C) was one of the highest and even greater than control although cover differences between them (3.5% Treatment C and 2.7% Control) are unlikely to be significant (Figure 10). Counts and cover of native woody colonizers were similar between both treatments of this mix indicating no suppression effect from treatment. On average the end of season counts of native woody species in the all species treatment was two times lower than control suggesting similar effects as the slow graminoids mix or that distance to seed sources again played a role.

### ***Aggressive Grasses***

The aggressive grass mix consisting of *E. glaucus*, *Bromus carinatus*, and *B. pacificus* performed low to moderately well over the course of the season in terms of cover of bare ground and resulted in 9.7%(low sowing) – 28.4%(high sowing) observed cover (Figure 7). Lack of dense basal leaves on these species in their first growing season explains these low cover values; however, it should be noted that these species grew up to 3 feet tall, erect flowering stems producing seed in late July/early August (see Herbs Photopoints in Appendix C). Treatments with this mix also experienced the least losses in sediment moisture over the season (-26.2% and -29.6 on average). Perhaps at these rates *Elymus* and *Bromus* are either not in as much competition for moisture as other species in the study or they were somehow reducing net moisture loss possibly by trapping more nightly moisture from dew with their tall erect stems (Table 4). Weed count and cover was lowest in this seed mix in August (Figures 9 and 10; Tables 9 and 10), although this is likely as much due to less contamination in the seed lot as it is to a suppression effect on weeds. Of all seeded treatments, native woody species counts were highest in the aggressive grasses mix but still much lower than control (Figure 9; Table 8). And in spite of this relatively higher count, cover of native woody species remained low in this mix similarly to other treatment areas. This is probably explained by the ongoing later season recruitment of seedlings that were too small for cover measurements. Higher abundance of native woody colonizers may be explained by both greater plant heights capturing more late season seed rain from wind (*Salicaceae* species) in addition to

higher relative sediment moisture that may have provided a more optimal seed bed than other seeded treatments. Other factors not measured in this study may also explain this difference.

### **Forbs**

The highest seedling counts were recorded in the high Forbs mix (Treatment G) for all monitoring months (Figure 6; Table 5). Treatment G had more than twice the individual seedlings counted in August as any other treatment. Even the low forbs treatment performed equally as well in relative seedling abundance as the high All Species treatment. In spite of this head start in individuals, cover was not highest in the forbs treatments. The high Slow Graminoids and All Species performed better; the high Forbs treatment was third in overall resulting estimated cover (39.4%) (Figure 7; Table 9). This may be explained by several factors related to variable growth rates of the species in this mix. Additionally, seed saturation limits may have been reached creating greater root competition for available moisture. Moisture loss was greatest in the high sowing (-48%) and comparably high in the low sowing (-40%) further accounting for cover resulting from lowered growth rates in spite of the high density of individuals. Based on visual observation, individuals of all three forbs appeared larger at the end of season in the low density sowing than the high sowing further supporting a theory of increased competition for available resources in the high sowing treatment. It appears that similar cover can be reached with less seed of this mix as the establishing individual plants put on more growth.

*Achillea millefolium* performed the best in this mix. Not all *Achillea* matured in the first season but some scattered individuals grew rapidly enough to flower and produce seed either from the ability to take advantage of optimal micro-sites, phenotypic plasticity, individual genetic fitness, or by some combination of these factors. Although *Eriophyllum lanatum* germinated abundantly in these treatments most individuals appeared to grow slowly in August or stop growing altogether with dieback. Many were lost to desiccation during the dry months. The first seeded *E. lanatum* to flower was observed in the second season (March 2013). *Artemisia suksdorfii* is the species to watch in the second season as it established well on the silts and should accrue significant biomass (50-200 cm tall and spreading) in second and third growing seasons (Flora of North America, 2012).

End of season weedy species counts in Forbs treatments were far less than control, were among the lowest counted for all treatments ( $\sim 7/m^2$ ) from June to August indicating little weed recruitment over the season (Figures 8 and 9; Tables 8 and 9). Treatment Areas B and G were also positioned somewhat centrally with a potential buffering effect from Treatment Area A to the south that may have captured more weedy seed rain from prevailing winds. Some of this pattern is likely contributed to high seed purity as well. Contrasting with low weed counts, cover in these treatments was either the same or greater than control indicating that the weedy individuals present were acquiring greater rates of biomass (although this was not directly measured). August native woody colonizer counts and cover were lowest of all treatments in the forb/low treatment which might indicate a suppression effect if this were not contradicted by a doubling count of native woody species in the forbs/high treatment (Figure 9; Table 8). Greater relative sediment moisture loss in these treatments may explain lower recruitment and end of season cover of native woody species; however, native woody cover in Forbs treatments appears similar to other seeded treatments (Figure 10).

### **Control**

Control plots showed consistent increases of total seedling counts and cover over the growing season indicating consistent recruitment of species without major die-offs like those observed in seeded treatments. The greatest abundance of native woody colonizers was observed in June (24) in the control with a doubling by August (48). Recruitment of native woody species in the control was far greater than treatments receiving seed (24/m<sup>2</sup> in June) with a doubling count in August (48/m<sup>2</sup>) by where distance to tree line was only 1.5 meters (5 feet) (Figures 8 and 9; Tables 8 and 9).

### **Conifer Treatment Performance**

Shelter-mediated protection from winds, temperature, albedo effect, and moisture loss have been observed to increase rates of *Pseudotsuga menziesii* establishment (Dunne and Parker, 1999). Any effects from germination and shelter treatments could not be measured because recorded germination rates were very low (0.22% for *Abies grandis* and 1.17% for *Pseudotsuga menziesii*). Greenhouse germination trials at Matt Albright Native Plant Materials Center indicated relatively good seed viability of both species seed lots (D. Allen, pers. comm., July 2012); therefore, cultural factors such as planting method, seasonality of planting, and seed loss resulting from inadequate protection are likely explanations for such low seedling emergence. All seed received a minimum of 35 days cool-moist stratification (~40° F/2-5° C). Seeds sown directly in early April for on-site stratification would have experienced diurnal temperature fluctuations with most nights in the 40° F range. Fall sowings that provide consistent and longer stratification periods may have resulted in greater conifer germination (Levy-Boyd, pers. comm., March 2012; Bonner, 2008; Edwards, 2008).

Although seed planting depths (1/4-1/2 inch) were typical for normal soil conditions (Levy-Boyd, 2012) this could have resulted in lack of oxygen and gas exchange in the fine sediments especially if seed bed rows were buried by eroding silts. Poor oxygen exchange and presence of a seed coat inhibitor may be a reason for poor *Abies grandis* germination (Edwards, 2008). Piercing of this seed coat and planting at shallower depths might also have increased germination rates in both species. Planting at typical depths was a dual consideration in also preventing seed loss from wash out; however, this may have played a role in seed loss or suppression, as seeded rows were not protected by any barriers or coverings. Any future work to direct sow conifers on reservoir sediments should attempt to incorporate lessons learned from this study. Similarly to the herbs treatment site, conifer seed rain deposited at the sediment surface resulted in far greater numbers of natural recruitment (Figures 12 and 13).

### **Natural Regeneration**

Over the monitoring period (May-September) 87 total species were identified in the herbs study (Site 1 and 2) plots (see full list of identified species in Appendix C). Seventy-nine of these were volunteer species from a range of natural and introduced plant communities including wetland obligates, early seral natives, invading non-native grasses from the watershed, weeds introduced from the seed mix (discussed earlier), and a host of colonizing native woody species of trees and shrubs.

Obligate and Facultative wetland species (such as *Juncus* spp., *Impatiens* sp., *Typha* sp., *Glyceria* sp., *Eleocharus ovata*, and *Ranunculus aquatilis*) were recorded in nearly every plot in every treatment having been either deposited on this terrace during reservoir drawdown or persisted in the shoreline sediment seed bank. Seeds of some emergent wetland species remain viable for up to 400 years (Leck, 1989). The fine sediments at this study site were moist enough to allow these species

to persist and tolerate the first full season of exposure. Long-term presence by these obligate emergent species is not expected here as upland soil development occurs and other colonizers shift successional trajectories.

Several aggressive native herb species showed up at the herbs study site that may play an important role in accumulation of organic matter and soil development as they all mature to significant size with some having the ability to tolerate variable environmental conditions. *Chamerion angustifolium*, *Aruncus dioicus*, *Stachys cooleyae*, *Equisetum* sp., and *Epilobium ciliatum* were all observed in the study area in varying densities. *Equisetum* spores germinated in June and July in high numbers but did not achieve enough growth to be measurable in end of season cover estimates. Where adequate moisture is available this species may become a dominant herb on fine sediments. *Epilobium* colonized in obvious water line patterns likely deposited during the 2011 reservoir drawdown.

Many recruiting species in the control were also weeds (highest abundance of all treatment areas) as their numbers were nearly four times greater in August than in June. End of season weed count and cover measurements in the control site were more than twice measurements in other treatments (except Treatment A) perhaps supporting a theory of weed suppression. The most abundant weeds in the control were *Agrostis* spp., *Holcus lanatus*, *Myosotis laxa* and *M. scorpioides*, *Phalaris arundinacea*, *Ranunculus repens* and *Sagina* sp. Those listed as invasive, exotic species of concern are provided in detail in Appendix E.

Twenty-four non-native species were identified in plots during this study (Table 21). Five of these are listed as species of concern by the Revegetation and Restoration Plan for Lake Mills and Lake Aldwell (Chenoweth *et al.*, 2011) and provided in both direct counts in all treatment area monitoring plots and as estimated counts per m<sup>2</sup> in Appendix E. Control plot weed abundance averaged 48/m<sup>2</sup> and 5.1%/m<sup>2</sup> of all weeds. The estimated abundance of invasive exotic species of concern was greatest in treatment areas A (8.03/m<sup>2</sup>) and I (8.1/m<sup>2</sup>) (see Table 22 in Appendix E). This high abundance in the control may justify some concern over exotic invasion issues in these reservoirs, especially in the former Lake Aldwell reservoir considering its disturbed matrix and phosphorous-rich sediments (Chenoweth, *et al.* 2011). The colonizing weedy species community was dominated by several species of concern – *Phalaris arundinacea*, *Holcus lanatus*, *Agrostis tenuis*, and *Dactylis glomerata*. Where native succession is slow to respond and exotic seeds have access, rapid unperturbed colonization by exotic, invasive grasses appears possible given first year observations of successful weedy species germination and rapid growth and should be addressed per the management strategies outlined by the Restoration and Revegetation Plan. *Ranunculus repens* was common in plots in every treatment; its long-term dominance as upland soils develop and experience consistent seasonal drought is unknown. Other non-dominant secondary species of concern identified in the treatment areas (although not necessarily in plots) were *Digitalis purpurea* and *Rumex* spp. *Rumex* spp. were scattered across the site and appeared to germinate early with other colonizers indicating these may have been in the seed bank or deposited during reservoir drawdown. *Cirsium arvense* showed up later in the season and was recorded in small quantities in Treatment Areas B, F, G, H, and I. This species was actually observed in greater numbers in the most southern treatment areas but outside of plots and many of them along the upper edges of treatment areas A and B. This species produces air-borne seeds that can travel several kilometers (USDA Forest Service, no date) and may have blown onto this terrace from the south in late summer/fall 2011.

No *Rubus armeniacus* and *Cytisus scoparius* were positively identified in plots; however, a few unidentified *Rubus* spp. were recorded in plots and observed outside of plots that may have been *R. armeniacus*. Many *Rubus* species present at this site were difficult to differentiate as first year seedlings. Further monitoring for both these invasive, exotic species of concern is necessary as dispersal from birds, mammals, wind and gravity is likely to occur (USDA Forest Service, undated; Astley, 2010; Caplan and Yeakley, 2006; Hoshovsky *et al.*, 2000).

Native woody recruitment at seeded treatments (Site 1) show a clear increase in abundance and cover from south to north along the terrace. Native woody colonizer counts in August varied some across seeded treatments with the highest measured in E (25/m<sup>2</sup>) where distance to tree line was 10.3 meters (34 feet) and lowest in B (10/m<sup>2</sup>) where distance to tree line increased to 38.1 meters (125 feet) (Figures 8 and 9; Tables 7 and 8). An apparent linear relationship between these two factors is further depicted in Figure 11. This is probably best explained by a decrease in propagule access with distance to seed rain from existing tree line. End of season cover of native woody colonizers was similar throughout seeded treatments suggesting that treatment was not the most significant factor controlling growth of native woody colonizers.

*Acer macrophyllum* germinated in early spring at time of seeding; however, growth rates for this species slowed and many *Acer* seedlings failed later in the season. The most abundantly germinating native woody species at the beginning and end of the monitoring period was *Alnus rubra*. Seed rain from shoreline trees played a significant role here as the control was within 5 feet of overhanging mature trees including *Alnus rubra*. The next most abundant species were also tree species: *Populus balsamifera*, *Salix* spp., and *Tsuga heterophylla*. A late season flush of *Salicaceae* germination was observed in June and July; and identified to *Populus balsamifera* and *Salix* sp. *Salicaceae* species produce wind born seeds in late spring and early summer capable of travelling considerable distance and germinating on exposed uplands above floodplains if adequate seed bed moisture is present (Stella *et al.*, 2006; Karrenberg *et al.*, 2002; Niyama, 1990). By August these species had true leaves and were confirmed by comparison to similar germinants along the banks of the river. Of shrub species observed in Site 1 herbaceous study plots, *Rubus* spp. (likely *Rubus spectabilis* and *Rubus ursinus*) and *Holodiscus discolor* were most dominant at the herbs site.

*Tsuga heterophylla* was the most successfully germinating (similar abundance to that of *Salix*) and surviving conifer, even putting on true leaves in the first season, on the fine sediments here (see Appendix D for more detailed abundance information). This is most likely due to close propagule access from nearby trees and adequate first season moisture in the fine sediments. It remains to be seen how tree growth rates will continue into the future given the undeveloped sediments, lack of primary nutrients and likely lack of mycorrhizal communities. The high germination and end of first-season presence of the nitrogen-fixing *Alnus* is certainly a positive trend for forest trajectories. In addition, the ability of shade tolerant conifers to successfully co-germinate on the fine sediments leads to even greater support for successful natural regeneration in these proximal shoreline areas. At the end of the 2012 growing season 275 *Tsuga heterophylla* and 17 *Thuja plicata* seedlings were counted in conifer treatment plots at Site 2 (Seeded Conifer site). This represents on average approximately one *T. plicata* seedling for every 1.15 m<sup>2</sup> (~12 ft<sup>2</sup>) and one *T. plicata* for every 18.53 m<sup>2</sup> (~200 ft<sup>2</sup>). Average volunteer conifer densities at this site reflect access to propagules with proximity to tree line (within 200 feet), low slope surfaces relative to the reservoir, and local climate conditions particular to the 2012-growing season. Numerous *Holodiscus discolor* and

*Spiraea douglasii* seedlings were observed at the conifer site although not measured as part of this study.

Rapid site changes, seasonal timing, legacies, and seed application combined to create what was a novel and likely fleeting 2012 assemblage of plant species, and for many the first time ever to germinate and establish in that particular setting. It was an extraordinary ecological snapshot into the past, current, and future trajectories of the Lake Aldwell shoreline and potentially for the greater reservoirs. Further analysis of natural recruitment is beyond the scope of this project and currently under assessment by Olympic National Park staff with the Elwha River Revegetation Project.



## Project Limitations

This seeding study occurred during a single, initial growing season immediately following draw-down where germinating vegetation received a longer period of soil saturation (from capillary lake saturation and heavy spring/early summer precipitation) and may not reflect the moisture availability at this site in successive years nor reflect future germination and cover rates at different seed densities on different sediment types. The project site was selected from the best available area at the time of the study. Specific projected patterns of natural recruitment and spatial distribution of plants from this study represent Aldwell shoreline zones and should be used conservatively when making broad assumptions about particular species assemblages or abundances. In reality similar treatments at micro-sites throughout the reservoirs may not result in the same stand densities observed here due to variable sediment types, slopes, aspects, moisture availability, seasonality factors, and a host of other variables and growth-limiting environmental factors.

A measurement of individuals producing seed in the first year for each treatment type would have added to our understanding of treatment success enhancing the presence of productive, self-sowing native propagules. And although rates of first season seed production are greatly determined by species life cycles (semi-annual and aggressive grass species produced seed in the first year) knowing at what rates these were occurring within their populations (within treatments) would have been useful.

Some additional species were present in the study area that could not be identified due to time constraints and in plots that could not be distinguished from other species (stoloniferous grasses or grass seedlings without sufficient identifying characteristics) and were therefore lumped into the *Agrostis* species or unknown grass categories. Although a small number of species were never fully identified, all individual plants were included in counts and cover estimates as a whole.

The park is actually using lower sowing densities on the fine sediments based on the first season success of this trial. Based on poor results observed from spring sowings on coarse sediment types, the park will likely use a dual seeding strategy between the sediment types (fall sowing with higher sowing rates on coarse sediment). In summer 2012 the park received and is storing the majority of seed that will be used for the entire project – changes to species or dramatic shifts in quantities are an unlikely option. Seed mix compositions don't necessarily reflect actual treatments that will be used – *Artemisia suksdorfii* was not successfully increased at CPMC so small-scale seed increase of this species and others are occurring at the Matt Albright Native Plant Materials Center to allow some flexibility and supplementation in plant materials beyond the initial seed increase and scope of these seeded treatments.



# Implications for the Elwha River Revegetation Project

## Seed Application Methods

- Early spring sowing on fine sediments is highly successful.
- If similar moisture conditions are present seed bed preparation or post-treatment incorporation is unnecessary on the fine sediments.
- Hand broadcasting is an effective, low-cost, and highly accurate method for applying seed treatments to various sites throughout much of the Elwha reservoirs.

## Minimizing invasive, exotic species

- The abundance of identified invasive, exotic species of concern was lower in most seeded treatments than in the control indicating a potential initial suppression or exclusion effect of those species at these sowing densities;
- August counts of species of concern in Treatments B (aggressive grasses/high), C (all species/high), D (slow graminoids/high), E (aggressive grasses/high), F (aggressive grasses/low), G (forbs/high), and H (All Species/low) were notably lower than control;

## Restoring ecosystem processes

- Seeded herbs appear to have established functional root systems on fine sediments, many treatments acquired lush biomass in the first season;
- All seeded treatments reduced coverage of bare ground in the first season;
- All treatments appeared to capture ambient moisture and reduce formation of surface crusts;
- All herbs treatments supplied the system with at least some propagules for the next generation;

## Establishing native forests

- Four coniferous and three or more deciduous tree species were observed recruiting in all treatment areas;
- Slow Graminoids, All Species, and Aggressive grasses appeared to perform the best at allowing the recruitment and growth of native woody species;
- The unseeded control showed the greatest end of season abundance and cover of native woody species but this seems just as likely a result of access to propagules with greater proximity to shoreline seed rain than any suppression effect from seeding;

## Seed Winners

- *Achillea millefolium*, *Bromus* spp., *Deschampsia elongata*, and *Elymus glaucus* are clear first-year winners based on their rapid growth rates and successful seed production; and
- *Artemisia suksdorfii* is likely a winner in successive years.

## Further Recommendations for Seed Treatments

As plants achieve mature sizes, measuring cover and seedling growth rates in the second and third growing seasons at this site will provide better indication of effects from seeding at these rates on natural recruitment of both desirable and undesirable species. Future assessment of typical seeded treatment sites in the former Lake Mills reservoir (away from the shoreline) will be critical for translating and building upon the results of this study in order to move the adaptive management strategies of the revegetation project forward and in desirable directions. Measuring and observing

soil development at concurrent seeded and non-seeded sites should also be performed to better understand soil formation processes and how and to what extent they are enhanced by seeding.

Seed inoculation by ectomycorrhizal fungi can increase water and nutrient availability (Plamboeck *et al.* 2007) and might be an appropriate treatment for direct sown seeds (conifer or herb species). Ectomycorrhizal fungi-plant associations are often species specific and could add expense and reduce practicality with diverse seed mixes. Continued monitoring of native forest succession should be performed at these sites (and those receiving lower densities in the Lake Mills reservoir) for a more accurate understanding of the effects of seeding.

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# Photos

## Site Photos



Photo 1. View of seeding trial site prior to seeding looking north (3/6/12).



Photo 2. View of Lake Aldwell trial site being seeded looking south (3/6/12).



Photo 3. View of treatment site plots (marked by pin flagging) looking west and down gradient at the Elwha River (May/June 2012).





























Photo 4. View of litter and small woody debris microsites on sediment surface.



Photo 5. View of 1 m<sup>2</sup> plot frames with sub-sampled areas marked by pink flagging.

## Herbs Photopoints

|   |   |  |
|---|---|--|
|    |    |    |
| <p>Treatment Area A (Slow Graminoids/Low Rate) in June</p>                          | <p>A - July</p>   | <p>A - August</p>  |
|    |    |    |
| <p>Treatment Area B (Forbs/Low) - June</p>  | <p>B - July</p>   | <p>B - August</p>  |
|   |   |   |
| <p>Treatment Area C (All/High) - June</p>   | <p>C - July</p>   | <p>C - August</p>  |
|  |  |  |
| <p>Treatment Area D (Slow Graminoids/High) - June</p>                               | <p>D - July</p>   | <p>D - August</p>  |

|   |   |  |
|---|---|--|
|    |    |    |
| Treatment Area E (Aggressive Grasses/High) – June                                   | E – July  | E – August   |
|    |    |    |
| Treatment Area F (Aggressive Grasses/Low) – June                                    | F – July  | F – August   |
|   |   |   |
| Treatment Area G (Forbs/High) – June  | G – July  | G – August   |
|  |  |  |
| Treatment Area H (All Species/Low) – June   | H – July  | H – August   |
|  | No Photo  |  |
| Treatment Area I (Control/No  | I – July  | I – August   |

|              |  |  |
|--------------|--|--|
| seed) – June |  |  |
|--------------|--|--|

## Appendix A – Seed Mix Specifications

**Table 19. NRCS Corvallis Plant Materials Center herbaceous seed mix specification estimates for Site 1 treatment areas.**

| Species  | Lbs/0.15 ac    | PLS lbs used | Bulk lbs used | Seeds per ft <sup>2</sup> | Seeds per m <sup>2</sup> | Seeds per 0.15 ac    |
|--|----------------|--------------|---------------|---------------------------|--------------------------|----------------------|
| <b>Treatment Area A: Slow Graminoids - Low</b>     |                |              |               |                           |                          |                      |
| CADE   | 0.5            | 0.25         | 0.365         | 28                        | 305                      | 185103               |
| CAPA   | 1              | 0.5          | 0.655         | 60                        | 646                      | 391982               |
| DEEL   | 1              | 0.5          | 0.69          | 200                       | 2153                     | 1306607              |
| AGEX   | 0.5            | 0.25         | 0.26          | 190                       | 2045                     | 1241276              |
| <b>Total</b>                                       | <b>3</b>       | <b>1.5</b>   | <b>1.97</b>   | <b>478</b>                | <b>5148</b>              | <b>3124968</b>       |
| <b>Treatment Area B: Forbs - Low</b>               |                |              |               |                           |                          |                      |
| ACMI   | 0.5            | 0.25         | 0.35          | 115                       | 1238                     | 751299               |
| ERLA   | 2              | 1            | 2             | 110                       | 1184                     | 718634               |
| ARSU   | 0.25           | 0.125        | 0.25          | 70                        | 753                      | 457312               |
| <b>Total</b>                                       | <b>2.75</b>    | <b>1.375</b> | <b>2.6</b>    | <b>295</b>                | <b>3175</b>              | <b>1927245</b>       |
| <b>Treatment Area C: All Species - High</b>        |                |              |               |                           |                          |                      |
| ACMI   | 0.14           | 0.07         | 0.09          | 33                        | 359                      | 217768               |
| ERLA   | 1              | 0.5          | 0.98          | 47                        | 502                      | 304875               |
| ARSU   | 0.1            | 0.05         | 0.2           | 40                        | 431                      | 261321               |
| Species  | Lbs/0.125 acre | PLS lbs used | Bulk lbs used | Seeds per ft <sup>2</sup> | Seeds per m <sup>2</sup> | Seeds per 0.125 acre |
| Brome  | 5              | 2.5          | 2.74          | 33                        | 359                      | 217768               |
| ELGL   | 5              | 2.5          | 2.63          | 53                        | 574                      | 348428               |
| CADE   | 0.25           | 0.13         | 0.19          | 13                        | 144                      | 87107                |
| CAPA   | 0.5            | 0.25         | 0.33          | 33                        | 359                      | 217768               |
| DEEL   | 0.14           | 0.07         | 0.09          | 33                        | 359                      | 217768               |
| AGEX   | 0.1            | 0.05         | 0.52          | 33                        | 359                      | 217768               |
| <b>Total</b>                                       | <b>12.23</b>   | <b>6.12</b>  | <b>7.77</b>   | <b>320</b>                | <b>3444</b>              | <b>2090571</b>       |
| <b>Treatment Area D: Slow Graminoids - High</b>    |                |              |               |                           |                          |                      |
| CADE   | 1              | 0.5          | 0.73          | 57                        | 610                      | 370205               |
| CAPA   | 2              | 1            | 1.31          | 120                       | 1292                     | 783964               |
| DEEL   | 2              | 1            | 1.38          | 400                       | 4305                     | 2613214              |
| AGEX   | 1              | 0.5          | 0.52          | 380                       | 4090                     | 2482553              |
| <b>Total</b>                                       | <b>6</b>       | <b>3</b>     | <b>3.94</b>   | <b>957</b>                | <b>10296</b>             | <b>6249936</b>       |
| <b>Treatment Area E: Aggressive grasses - High</b> |                |              |               |                           |                          |                      |
| Brome  | 8              | 4            | 4.3           | 50                        | 538                      | 326652               |
| ELGL   | 12             | 6            | 6.3           | 120                       | 1292                     | 783964               |
| <b>Total</b>                                       | <b>20</b>      | <b>10</b>    | <b>10.6</b>   | <b>170</b>                | <b>1830</b>              | <b>1110616</b>       |

| <b>Treatment Area F: Aggressive grasses - Low</b> |              |               |              |            |             |                |
|---|--------------|---------------|--------------|------------|-------------|----------------|
| Brome   | 4            | 2             | 2.15         | 25         | 269         | 163326         |
| ELGL  | 6            | 3             | 3.15         | 60         | 646         | 391982         |
| <b>Total</b>                                      | <b>10</b>    | <b>5</b>      | <b>5.3</b>   | <b>85</b>  | <b>915</b>  | <b>555308</b>  |
| <b>Treatment Area G: Forbs - High</b>             |              |               |              |            |             |                |
| ACMI  | 1            | 0.5           | 0.7          | 230        | 2475        | 1502598        |
| ERLA  | 2            | 2             | 4            | 220        | 2368        | 1437267        |
| ARSU  | 0.25         | 0.25          | 0.5          | 140        | 1507        | 914625         |
| <b>Total</b>                                      | <b>3.25</b>  | <b>2.75</b>   | <b>5.2</b>   | <b>590</b> | <b>6350</b> | <b>3854490</b> |
| <b>Treatment Area H: All species - Low</b>        |              |               |              |            |             |                |
| ACMI  | 0.07         | 0.035         | 0.045        | 17         | 179         | 108884         |
| ERLA  | 0.5          | 0.25          | 0.49         | 23         | 251         | 152437         |
| ARSU  | 0.05         | 0.025         | 0.1          | 20         | 215         | 130661         |
| Brome   | 2.5          | 1.25          | 1.37         | 17         | 179         | 108884         |
| ELGL  | 2.5          | 1.25          | 1.315        | 27         | 287         | 174214         |
| CADE  | 0.125        | 0.0625        | 0.095        | 7          | 72          | 43554          |
| CAPA  | 0.25         | 0.125         | 0.165        | 17         | 179         | 108884         |
| DEEL  | 0.07         | 0.035         | 0.045        | 17         | 179         | 108884         |
| AGEX  | 0.05         | 0.025         | 0.26         | 17         | 179         | 108884         |
| <b>Total</b>                                      | <b>6.115</b> | <b>3.0575</b> | <b>3.885</b> | <b>160</b> | <b>1722</b> | <b>1045285</b> |

## Appendix B – Plot Micro-Site Conditions

Table 20. Average estimated cover of woody debris, litter, and surface cracks in June 2012 per blocked plot rows.

| Row  | % Woody Debris | % Litter | % Surface Cracks |
|------|----------------|----------|------------------|
| A--1 | 6.0%           | 1.4%     | 2.6%             |
| A--2 | 5.1%           | 11.3%    | 12.6%            |
| A--3 | 4.7%           | 5.3%     | 3.9%             |
|      |                |          |                  |
| B--1 | 0.5%           | 1.0%     | 7.5%             |
| B--2 | 1.5%           | 2.2%     | 40.7%            |
| B--3 | 5.0%           | 3.8%     | 4.0%             |
|      |                |          |                  |
| C--1 | 0.7%           | 0.5%     | 3.9%             |
| C--2 | 2.5%           | 3.5%     | 10.3%            |
| C--3 | 5.9%           | 2.6%     | 4.8%             |
|      |                |          |                  |
| D--1 | 0.6%           | 1.4%     | 1.7%             |
| D--2 | 2.3%           | 4.8%     | 15.8%            |
| D--3 | 5.2%           | 3.8%     | 4.7%             |
|      |                |          |                  |
| E--1 | 1.2%           | 0.6%     | 1.8%             |
| E--2 | 2.5%           | 2.0%     | 12.9%            |
| E--3 | 4.3%           | 3.2%     | 7.3%             |
|      |                |          |                  |
| F--1 | 0.8%           | 1.4%     | 2.8%             |
| F--2 | 3.9%           | 1.2%     | 7.4%             |
| F--3 | 4.0%           | 4.2%     | 7.4%             |
|      |                |          |                  |
| G--1 | 0.7%           | 0.6%     | 3.7%             |
| G--2 | 2.9%           | 3.9%     | 9.3%             |
| G--3 | 5.8%           | 3.2%     | 3.8%             |
|      |                |          |                  |
| H--1 | 1.7%           | 0.5%     | 3.6%             |
| H--2 | 5.8%           | 3.1%     | 2.5%             |
| H--3 | 7.9%           | 4.8%     | 6.8%             |
|      |                |          |                  |
| I--1 | 10.1%          | 7.3%     | 5.8%             |
| I--2 | 42.5%          | 5.9%     | 15.8%            |
| I--3 | 8.6%           | 7.8%     | 4.9%             |



## Appendix C – All Species Identified in Monitoring Plots

Table 21. All species identified (seeded and naturally recruiting) in herb and conifer treatment areas from May-September 2012.

| Latin Name                       | Common Name                |
|----------------------------------|----------------------------|
| <b>Trees</b>                     |                            |
| <i>Abies grandis</i>             | grand fir                  |
| <i>Acer macrophyllum</i>         | big-leaf maple             |
| <i>Alnus rubra</i>               | red alder                  |
| <i>Populus balsamifera</i>       | black cottonwood           |
| <i>Pseudotsuga menziesii</i>     | Douglas fir                |
| <i>Salix</i> spp.                | willow                     |
| <i>Thuja plicata</i>             | western red cedar          |
| <i>Tsuga heterophylla</i>        | western hemlock            |
| <b>Shrubs</b>                    |                            |
| <i>Holodiscus discolor</i>       | oceanspray                 |
| <i>Rubus parviflorus</i>         | thimbleberry               |
| <i>Rubus spectabilis</i>         | salmonberry                |
| <i>Rubus ursinus</i>             | trailing blackberry        |
| <i>Rubus</i> spp.                | unidentified Rubus         |
| <i>Spiraea douglasii</i>         | Douglas spirea             |
| <b>Forbs</b>                     |                            |
| <i>Achillea millefolium</i>      | common yarrow              |
| <i>Agrostis exarata</i>          | spike bentgrass            |
| <i>Agrostis tenuis</i> *         | colonial bentgrass         |
| <i>Agrostis</i> spp.             | unidentified bentgrass     |
| <i>Alopecurus</i> sp.            | unidentified foxtail grass |
| <i>Artemisia suksdorfii</i>      | Suksdorf's wormwood        |
| <i>Aruncus dioicus</i>           | goat's beard               |
| <i>Bromus</i> spp.               | brome species              |
| <i>Carex</i> spp.                | sedge species              |
| <i>Deschampsia elongata</i>      | slender hairgrass          |
| <i>Elymus glaucus</i>            | blue wildrye               |
| <i>Eriophyllum lanatum</i>       | Oregon sunshine            |
| <i>Capsella bursa-pastoris</i> * | shepherd's purse           |
| <i>Cardamine</i> sp.             | unidentified bittercress   |
| <i>Chamerion angustifolium</i>   | fireweed                   |
| <i>Cirsium arvense</i> *         | Canada thistle             |
| <i>Cirsium</i> sp.               | unidentified thistle       |
| <i>Claytonia</i> sp.             | unidentified purslane      |
| <i>Digitalis purpurea</i> *      | foxglove                   |
| <i>Equisetum</i> spp.            | unidentified horsetail     |
| <i>Eleocharis ovata</i>          | Ovate spikerush            |
| <i>Epilobium ciliatum</i>        | fringed willowherb         |
| <i>Epilobium brachycarpum</i>    | tall annual willowherb     |
| <i>Gallium</i> sp.               | unidentified bedstraw      |
| <i>Geranium molle</i> *          | dove foot geranium         |
| <i>Glyceria</i> sp.              | unidentified mannagrass    |
| <i>Gnaphalium uliginosum</i> *   | marsh cudweed              |

|  |                            |
|--|----------------------------|
| <i>Hypochaeris radicata</i> *                      | hairy cat's ear            |
| <i>Holcus lanatus</i>                              | common velvetgrass         |
| <i>Impatiens</i> spp.                              | unknown jewelweed          |
| <i>Iris pseudocharis</i>                           | yellow-flag iris           |
| <i>Juncus bolanderi</i>                            | Bolander's rush            |
| <i>Juncus bufonius</i>                             | toad rush                  |
| <i>Juncus effusus</i>                              | common rush                |
| <i>Juncus ensifolius</i>                           | swordleaf rush             |
| <i>Juncus</i> sp.                                  | unidentified rush          |
| <i>Lactuca communis</i> *                          | prickly lettuce            |
| <i>Lolium perenne</i> *                            | perennial ryegrass         |
| <i>Luzula</i> sp.                                  | unidentified wood rush     |
| <i>Medicago</i> sp.*                               | unidentified medic         |
| <i>Mimulus guttatus</i>                            | yellow monkey flower       |
| <i>Mimulus</i> sp.                                 | unidentified monkey flower |
| <i>Myosotis laxa</i> *                             | bay forget-me-not          |
| <i>Myosotis scorpioides</i> *                      | true forget-me-not         |
| <i>Oenanthe sarmentosa</i>                         | water parsley              |
| <i>Phalaris arundinacea</i> *                      | reed canarygrass           |
| <i>Plantago lanceolata</i> *                       | narrowleaf plantain        |
| <i>Poa annua</i> *                                 | annual bluegrass           |
| <i>Polygonum</i> sp.                               | unidentified smartweed     |
| <i>Prunella</i> sp.                                | unidentified selfheal      |
| <i>Ranunculus aquatilis</i>                        | white water crowfoot       |
| <i>Ranunculus repens</i> *                         | creeping buttercup         |
| <i>Rumex acetosella</i> *                          | common sheep sorrel        |
| <i>Rumex obtusifolius</i> *                        | bitter dock                |
| <i>Sagina</i> sp.*                                 | unidentified pearlwort     |
| <i>Sonchus</i> sp.*                                | unidentified sowthistle    |
| <i>Sisymbrium</i> sp.*                             | unidentified tumbledustard |
| <i>Senecio sylvaticus</i> *                        | woodland ragwort           |
| <i>Stachys cooleyae</i>                            | Cooley's hedgenettle       |
| <i>Stellaria</i> spp.                              | unidentified chickweed     |
| <i>Taraxicum officinale</i> *                      | common dandelion           |
| <i>Tolmeia menziesii</i>                           | youth-on-age               |
| <i>Torreyochloa pallida</i> var. <i>pauciflora</i> | weak mannagrass            |
| <i>Trifolium repens</i> *                          | white clover               |
| <i>Typha</i> sp.                                   | unidentified cattail       |
| <i>Veronica americana</i>                          | American speedwell         |
| <i>Urtica dioica</i>                               | stinging nettle            |

\* Denotes identified exotic species.

## Appendix D – Natural Native Regeneration Abundance in the Control

**Table 22. Total June Count of Native Woody Colonizers in Unseeded Control across all 36 measured plots.**

| <b>Latin Name</b>        | <b>Total Count From 36 Plots</b> |
|--------------------------|----------------------------------|
| <i>Acer macrophyllum</i> | 86                               |
| <i>Alnus rubra</i>       | 173                              |
| <i>Rubus</i> spp.        | 1                                |
| Unknown conifer          | 94                               |

**Table 23. Total August Count of Native Woody Colonizers in Unseeded Control across all 36 measured plots.**

| <b>Latin Name</b>          | <b>Total Count From 36 Plots</b> |
|----------------------------|----------------------------------|
| <i>Acer macrophyllum</i>   | 74                               |
| <i>Alnus rubra</i>         | 232                              |
| <i>Holodiscus discolor</i> | 2                                |
| <i>Populus balsamifera</i> | 127                              |
| <i>Rubus parviflorus</i>   | 1                                |
| <i>Rubus spectabilis</i>   | 1                                |
| <i>Salix</i> spp.          | 56                               |
| <i>Thuja plicata</i>       | 7                                |
| <i>Tsuga heterophylla</i>  | 53                               |



## Appendix E – Actual and Standardized Plot Counts of Invasive Exotic Species of Concern

Table 24. Total August counts of of invasive, exotic species of concern per treatment area.

| Latin Name                     | Actual Count in 36 Plots | Standardized Count/m <sup>2</sup> |
|--------------------------------|--------------------------|-----------------------------------|
| <b>Treatment Area A</b>        |                          |                                   |
| <i>Agrostis</i> spp.+          | 11                       | 4                                 |
| <i>Phalaris arundinacea</i> *  | 7                        | 2                                 |
| <i>Ranunculus repens</i> **    | 6                        | 2                                 |
| <i>Rubus</i> spp.+             | 1                        | 0.03                              |
| <b>Total</b>                   | <b>25</b>                | <b>8.03</b>                       |
| <b>Treatment Area B</b>        |                          |                                   |
| <i>Agrostis</i> spp.+          | 39                       | 1                                 |
| <i>Agrostis tenuis</i> +       | 3                        | 0.25                              |
| <i>Cirsium arvense</i> *       | 3                        | 0.25                              |
| <i>Phalaris arundinacea</i> *  | 2                        | 0.2                               |
| <b>Total</b>                   | <b>47</b>                | <b>1.7</b>                        |
| <b>Treatment Area C</b>        |                          |                                   |
| <i>Agrostis</i> spp.+          | 5                        | 2                                 |
| <i>Dactylis glomerata</i> **   | 2                        | 0.05                              |
| <i>Holcus lanatus</i> **       | 1                        | 0.03                              |
| <i>Phalaris arundinacea</i> *  | 1                        | 0.03                              |
| <i>Ranunculus repens</i> **    | 5                        | 1.7                               |
| <i>Rubus</i> spp.+             | 1                        | 0.03                              |
| <i>Rumex obtusifolius</i> ++   | 1                        | 0.03                              |
| <b>Total</b>                   | <b>16</b>                | <b>3.87</b>                       |
| <b>Treatment Area D</b>        |                          |                                   |
| <i>Agrostis</i> spp.+          | 10                       | 0.9                               |
| <i>Dactylis glomerata</i> **   | 1                        | 0.08                              |
| <i>Holcus lanatus</i> **       | 3                        | 0.25                              |
| <i>Phalaris arundinacea</i> *  | 8                        | 0.7                               |
| <i>Ranunculus repens</i> **    | 6                        | 0.5                               |
| <b>Total</b>                   | <b>28</b>                | <b>2.43</b>                       |
| <b>Treatment Area E</b>        |                          |                                   |
| <i>Agrostis</i> spp.+          | 14                       | 1.2                               |
| <i>Dactylis glomerata</i> **   | 1                        | 0.08                              |
| <i>Phalaris arundinacea</i> *  | 5                        | 0.2                               |
| <i>Ranunculus repens</i> **    | 1                        | 0.08                              |
| <b>Total</b>                   | <b>21</b>                | <b>1.56</b>                       |
| <b>Treatment Area F</b>        |                          |                                   |
| <i>Agrostis</i> spp.+          | 21                       | 1.8                               |
| <i>Cirsium arvense</i> *       | 1                        | 0.08                              |
| <i>Dactylis glomerata</i> **   | 2                        | 0.2                               |
| <i>Phalaris arundinacea</i> ** | 7                        | 0.6                               |
| <i>Ranunculus repens</i> **    | 3                        | 0.25                              |
| <b>Total</b>                   | <b>34</b>                | <b>2.93</b>                       |

| Treatment Area G              |           |            |
|-------------------------------|-----------|------------|
| <i>Agrostis</i> spp.+         | 4         | 1.4        |
| <i>Circium arvense</i> *      | 1         | 0.3        |
| <i>Dactylis glomerata</i> **  | 1         | 0.3        |
| <i>Holcus lanatus</i> **      | 1         | 0.3        |
| <i>Phalaris arundinacea</i> * | 5         | 1.7        |
| <b>Total</b>                  | <b>12</b> | <b>4</b>   |
| Treatment Area H              |           |            |
| <i>Agrostis</i> spp.+         | 19        | 0.6        |
| <i>Circium arvense</i> *      | 1         | 0.3        |
| <i>Dactylis glomerata</i> **  | 3         | 1          |
| <i>Holcus lanatus</i> **      | 2         | 0.7        |
| <i>Phalaris arundinacea</i> * | 3         | 1          |
| <b>Total</b>                  | <b>28</b> | <b>3.6</b> |
| Treatment Area I              |           |            |
| <i>Agrostis</i> spp.+         | 24        | 2.1        |
| <i>Circium arvense</i> *      | 1         | 0.3        |
| <i>Holcus lanatus</i> **      | 4         | 1.4        |
| <i>Phalaris arundinacea</i> * | 9         | 3.1        |
| <i>Ranunculus repens</i> **   | 10        | 0.9        |
| <i>Rumex obtusifolius</i> ++  | 1         | 0.3        |
| <b>Total</b>                  | <b>49</b> | <b>8.1</b> |

\*Positively identified primary species of concern as identified in the Revegetation and Restoration Plan for Lake Mills and Lake Aldwell (Chenoweth *et al.*, 2011).

\*\*Positively identified secondary species of concern.

+Combined grouping of unidentified species that may contain counts of *Agrostis gigantea*, *Agrostis stolonifera*, or *Rubus armeniacus*.

++Not identified as an invasive exotic species of concern in the Revegetation Plan but may be of weed management interest.