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1998 Vegetation Monitoring for the 1100-EM-1, 1100-IU-1, 100-IU-3, 300-FF-1, and 200-ZP-1 Operable Units

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EXECUTIVE SUMMARY

This report documents the results of revegetation monitoring conducted in late May and early June of 1998. Third year monitoring was conducted at the Horseshoe Landfill, Nike Landfill, and Horn Rapids Landfill. Second year monitoring was conducted on the PSN 72/82, Bridge Overlook, PSN 12/14, and the North Slope Cheatgrass Area. First year monitoring was conducted at the 600-104 waste site (2,4-D cleanup site), 300-FF-1 sagebrush (*Artemisia tridentata*) and bitterbrush (*Purshia tridentata*) transplant areas, 216-A-25 emergency extension site, and the 200-ZP-1 pipeline.

The Horseshoe Landfill was revegetated with transplanted bunchgrasses and the Nike landfill sites were revegetated with sagebrush tubelings and transplanted bunchgrasses. The presence of numerous native bunchgrasses and the dense sagebrush cover on the Horseshoe Landfill shows that a good native plant diversity has developed and should continue into late seral conditions. The canopy cover of volunteer sagebrush plants on Horseshoe landfill has increased to 14.4% from 5.5% in 1997, and 2.8% in 1996. Non-native cheatgrass was the dominant grass species (25.5% cover versus 15.7% cover in the reference site). A total of four native grasses were found on the landfill and five on the reference site. A total of 29 species were found on the landfill (21 native) and 23 species were on the reference site (19 native).

The Horn Rapids Landfill was revegetated with crested wheatgrass (*Agropyron cristatum*) and Siberian wheatgrass (*Agropyron sibericum*) during the fall of 1995. The established wheatgrass component has increased its canopy coverage from 1997 measurements. The percent canopy cover of the wheatgrasses on all six plots ranged from 15.9 % to 26.7%. The two most abundant species for all plots were wheatgrass and cheatgrass (*Bromus tectorum*) in 1998. The Canopy

coverage of Russian thistle (*Salsola kali*) declined from 5.0% in 1997 to 0.5% in 1998. The wheatgrass appears to be progressing well towards a mature bunchgrass community.

The vegetation recovery at the Bridge Overlook and PSN 72/82 sites is promising. The 1995 revegetation effort used salvaged plants from the Environmental Restoration Disposal Facility. At Bridge Overlook, cheatgrass is still the most abundant plant (in frequency and cover); however, early to mid-seral shrubs have started to invade the waste site and native forbs continue to increase in canopy coverage. In addition, the cryptobiotic crust, which was absent last year, has started to develop.

On the PSN 72/82 Well Mound site, the shrub layer consists of sagebrush and gray rabbitbrush (*Chrysothamnus nauseosus*). While the frequency of occurrence for sagebrush remained the same since 1997, the canopy coverage has increased. Native grasses have also increased in canopy coverage and frequency. This is the first year of monitoring at the small staging area adjacent to the Well Mound site. All of the seeded species except for spring turpentine parsley (*Cymopteris terebinthinus*) were recorded. In addition, gray rabbitbrush, needle-and-thread grass (*Stipa comata*), six-weeks fescue (*Festuca octoflora*), and many native forbs have colonized at the site.

At PSN 12/14, seven plots were planted in 1995 with sagebrush tubelings and salvaged bunchgrasses while the access road was seeded with a mixture of sagebrush, bitterbrush, snow buckwheat (*Eriogonum niveum*), spring turpentine parsley, Carey's balsamroot (*Balsamorhiza careyana*), and Sandberg's bluegrass (*Poa sandbergii*) in 1996. The seeded species on the access road are starting to establish themselves with the exception of bitterbrush and spring turpentine parsley. The cryptobiotic crust is starting to colonize the waste sites, except for plot 5

and the access road. Sagebrush and bunchgrass survival was recorded for all seven plots, and sagebrush survival ranged from 43% to 69% while bunchgrass survival ranged from 61% to 88%.

Revegetation of waste site 600-104, 216-A-25 emergency extension, 300-FF-1, and the 200-ZP-1 pipeline was conducted in the early fall of 1997 and late winter of 1998. All seed and plants were derived from species on the Hanford Site. Seeding was conducted after bioremediation of 2,4-D contaminated soils and the site now has more native species than before remediation. Sagebrush planted at the 216-A-25 emergency extension had 74% survival. At the 300-FF-1 mitigation site two-year old sagebrush are surviving at 70% but the bitterbrush transplanting was not successful (100% dead). The planting of sagebrush tubelings at the 200-ZP-1 pipeline was only moderately successful with 54% survival but the surrounding area is very high quality habitat which should help initiate recovery at the site.

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In To Metric Units

If You Know	*Multiply By*	*To Get*
Length		
inches	25.4	millimeters
inches	2.54	centimeters
feet	0.3048	meters
yards	0.914	meters
miles	1.609	kilometers
Area		
sq. inches	6.452	sq. centimeters
sq. feet	0.093	sq. meters
sq. yards	.0836	sq. meters
sq. miles	2.6	sq. kilometers
acres	0.405	hectares
Mass (weight)		
ounces	28.35	grams
pounds	0.454	kilograms
ton	0.907	metric ton
Volume		
teaspoons	5	millimeters
tablespoons	15	millimeters
fluid ounces	30	millimeters
cups	0.24	liters
pints	0.47	liters
quarts	0.95	liters
gallons	3.8	liters
cubic feet	0.028	cubic meters
cubic yards	0.765	cubic meters
Temperature		
Fahrenheit	subtract 32, then multiply by 5/9	Celsius

Out of Metric Units

If You Know	*Multiply By*	*To Get*
Length		
millimeters	0.039	inches
centimeters	0.394	inches
meters	3.281	feet
meters	1.094	yards
kilometers	0.621	miles
Area		
sq. centimeters	0.155	sq. inches
sq. meters	10.76	sq. feet
sq. meters	1.196	sq. yards
sq. kilometers	0.4	sq. miles
hectares	2.47	acres
Mass (weight)		
grams	0.035	ounces
kilograms	2.205	pounds
metric ton	1.102	ton
Volume		
millimeters	0.033	fluid ounces
liters	2.1	pints
liters	1.057	quarts
liters	0.264	gallons
cubic meters	35.315	cubic feet
cubic meters	1.308	cubic yards
Temperature		
Celsius	multiply by 9/5, then add 32	Fahrenheit

1.0 INTRODUCTION

This report documents the results of revegetation monitoring conducted in late May and June of 1998. The monitoring sites included the Horseshoe and Nike Landfills on the Arid Lands Ecology Reserve; the Horn Rapids Landfill (HRL) near the City of Richland; waste sites on the Hanford North Slope at location number PSN 72/82, Bridge Overlook, location number PSN 12/14, and the 600-104 (2,4-D) cleanup site; the 300-FF-1 mitigation site; the 216-A-25 emergency extension site; and the 200-ZP-1 pipeline site. One other area, referred to as the North Slope Cheatgrass Area, was also monitored for survival of sagebrush (*Artemisia tridentata*) that was planted in 1996. Figure 1 shows the locations of these sites.

The extent of the revegetation effort conducted at each site varied depending upon the surrounding habitat, the future use of the site, and the existing conditions at the site. The purpose of the vegetation monitoring is to measure the progress of plant succession, and in most cases, compare it to the surrounding undisturbed plant community. Each site will be discussed separately along with a brief description of the revegetation effort and the results of the 1998 monitoring.

This report provides the third year measurements at the Horseshoe Landfill, Nike Landfill, and HRL. Results from the 1997 measurements were documented in Gano et al. (1997)and the 1996 measurements were provided in a letter report by Henckel (dated September 17, 1996). The measurement data from these two reports are provided in Appendices A and B of this report. A comparison of the vegetation changes over the three years is provided in this document. This is the second year that measurements have been taken at the PSN 72/82, Bridge Overlook, PSN 12/14, and the North Slope Cheatgrass Area. Revegetation at these sites, except for the Cheatgrass Area, began in the spring of 1995 with the salvage and transplanting of bunchgrasses from the Hanford Site. In 1996, supplemental plantings using locally collected seed was conducted at the PSN 12/14 access road and at the PSN 72/82 sites. The Cheatgrass Area was planted with salvaged sagebrush seedlings in August and October 1996. First year measurements are provided for the 600-104 (2,4-D) waste site, 216-A-25 emergency extension site, the 300-FF-1 remedial action site, and the 200-ZP-1 pipeline.

1.1 METHODS USED IN EVALUATING VEGETATION RECOVERY

The vegetation monitoring consisted of measuring the canopy cover of all plant species found at a site, the frequency of occurrence, and the survival of transplanted bunchgrasses and sagebrush. All values were then converted to percentages. Canopy cover and frequency measurements were conducted using the methods of Daubenmire (1970). Canopy coverage is defined as "the percentage of ground surface included in the vertical projection of a polygon drawn around the extremities of undisturbed foliage of a plant" (Daubenmire 1970). This is one method which can provided a measure of the amount of ground covered by each species. Since it is possible, in dense stands of vegetation, to have species overlapping each other, total measured vegetative cover can exceed 100%. Within each location, a series of plot-frames were analyzed for canopy coverage of each species present. Frequency is represented as the percentage of occurrences that

a species is observed in the number of plot-frames measured. For example, if a species was represented in 10 out of 25 plot-frames, its frequency would be 10/25 x 100 = 40%.

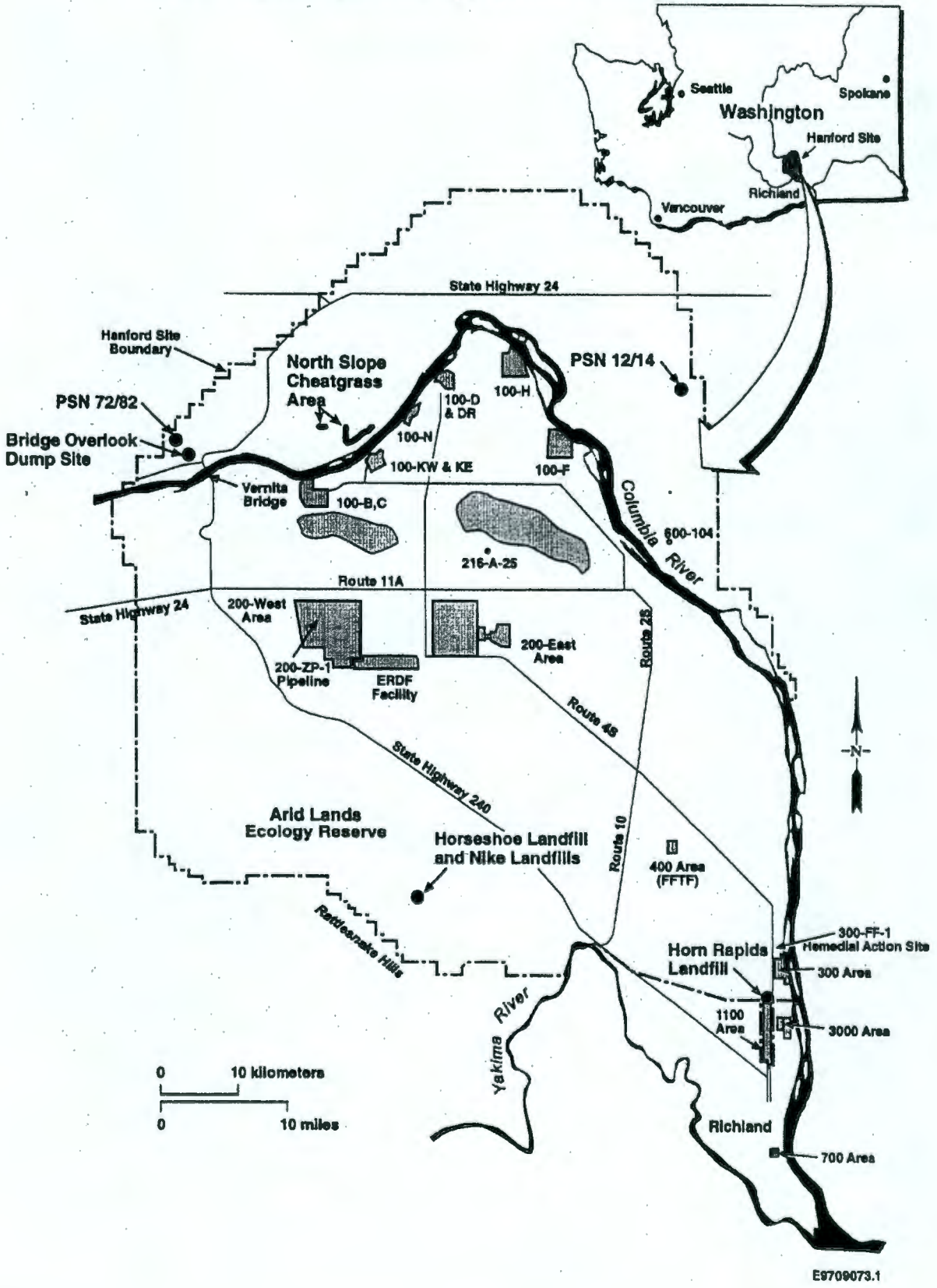
The relative magnitude of a frequency rating, when compared to a canopy coverage rating, provides an index of distribution of a species and its influence within a vegetative stand. At sites where bunchgrasses and/or sagebrush were transplanted, the survival (if it could still be determined in 1998) was measured by counting a representative number of plants at the site, determining if they were dead or alive, and calculating the percent alive. This report uses taxonomic nomenclature from Hitchcock and Cronquist (1973). Some plant taxonomic names have been updated and the revised names can be found in Appendix C.

The objective of all revegetation efforts is guided by the type of restoration that is conducted, as well as the criteria that is used to assess the success of the effort. At HRL, the objective was to stabilize the topsoil and protect the landfill cap, while at the Horseshoe and Nike landfills, the objective was to restore the areas with native bunchgrasses to suppress the growth of exotic plant species such as cheatgrass. All of the North Slope revegetation sites are surrounded by high quality habitat; thus, the objective was to restore those sites to reflect the nearby plant community. The objective of revegetating the North Slope Cheatgrass Area was to promote sagebrush re-establishment in an old burn area. At 600-104, 216-A-25, and ZP-1 pipeline sites the objective was to stabilize the soils and provide onsite rectification for lost sagebrush habitat. The objective at 300-FF-1 was to compensate for the loss of shrubs during remediation of the 618-4 burial ground.

Reference sites were established for the Horseshoe Landfill and the North Slope sites. The reference sites were chosen because they had similar physical and biological components to the pre-waste site disturbance of the area. For this monitoring effort, the reference sites served to identify the plant composition of the surrounding area which was then used to compare against the plant establishment of the revegetated area. In the case of 300-FF-1, reference sites were not used because sagebrush and bitterbrush were planted in a shrubless area with late successional perennial grass and forb understory.

Success criteria are often different for each waste site because of the different objectives of each revegetation planting. However, all sites will be evaluated based upon plant canopy cover, plant community composition, and the survival and growth of transplants. These criteria are detailed in the *Revegetation Manual for the Environmental Restoration Contractor* (McLendon and Redente 1997). The revegetation effort will be considered successful if the areas are stabilized to prevent erosion and dominated by recovering stands of native sagebrush and bunchgrasses.

Figure 1. Hanford Site Showing Locations of Revegetation Areas.



2.0 HORN RAPIDS LANDFILL

The Horn Rapids Landfill (HRL) is a 20 hectare area located in the 1100-EM-1 Operable Unit immediately north of Richland, Washington. The landfill was used primarily to dispose of office and construction waste, asbestos, sewage sludge, and fly ash. The remedial investigation/ feasibility study for this Operable Unit (DOE-RL 1992) identified about 230 m^3 of polychlorinated biphenyl (PCB) contaminated soil in the landfill. The remedial action, documented in the 1100 Area record of decision (EPA 1993) included excavation of the PCB-contaminated soil and capping 10.3 ha of the landfill. The landfill cap consisted of a 0.5-m layer of gravel covered with 15.2 cm of topsoil. The objective of this revegetation project was to stabilize the topsoil and protect the landfill cap. The site was revegetated with crested wheatgrass (*Agropyron cristatum*) and Siberian wheatgrass (*Agropyron sibericum)* in the fall of 1995 with guidance and concurrence from the Hanford Natural Resource Trustee Council.

A secondary goal of the revegetation effort was to compare planting techniques using a traditional rangeland seed drill and a planting device called an Imprinter. The Imprinter has been successfully used for planting in arid climates (St. John and Dixon 1995). A special imprinter was utilized at the HRL that had an added capability to inoculate the soil with mycorrhizal fungi. Mycorrhizal fungi form a beneficial symbiotic relationship with the roots of many late seral plants including bunchgrasses. The fungus absorbs nutrients from the soil and passes them to the plant in exchange for sugars from the plant. This relationship is not usually formed with the early seral stage weedy plant species.

2.1 REVEGETATION PLAN

Five different planting treatments were evaluated to determine the best technique and provide information that will be useful in planning future restoration projects. The area of the landfill that was revegetated was divided into six roughly equal plots for the purpose of establishing treatment areas (Figure 2). Two treatments using a rangeland seed drill were established. The first treatment included planting seed with a fertilizer application rate of 22.5 kg of nitrogen/hectare and mulching the area with wheat straw (plots 1 and 6). This method has been used many times on the Hanford Site and has proven successful with this seed mix. The second treatment using the rangeland drill (plot two) applied seed and straw mulch without fertilizer.

Three treatments were used to test the efficacy of the Imprinter under these conditions. The first was the application of seed, mycorrhizal fungi, and wheat straw mulch (plot 3). The second was the application of seed and mycorrhizal fungi with no mulch (plot 4) and the third was the application of seed alone (plot 5). The application of straw mulch was intended to reduce wind erosion and increase soil moisture retention. The mulch may also serve an added function to tie up excess available soil nitrogen which reduces competitiveness of early successional weedy species (Klein et al. 1996). Straw was spread over the appropriate treatment areas at a rate of 4.5 metric tons per hectare.

The target seeding rate was 16.8 kg/hectare pure live seed on all treatments with a 50% mix of both species. The actual seeding rate varied between the Imprinter and the range drill because of the difference in the metering systems on the two pieces of machinery. The three plots planted

with the range drill (plots 1, 2, and 6) and plots 3 and 5 planted with the Imprinter received similar rates of seed. Plot 4, however, was the first to be planted and received a higher seeding rate because the metering system was not initially calibrated to the proper rate.

2.2 MONITORING RESULTS

The vegetation on the HRL was measured on May 11, 1998 by estimating canopy coverage and frequency of occurrence. Twenty-five plot frames measuring 20 by 50 cm were analyzed for each treatment. This year, 28 species were recorded on the HRL, an increase of 8 from 1997 and 18 from 1996. The most abundant species this year were wheatgrasses, cheatgrass (*Bromus tectorum*), and jagged chickweed (*Holosteum umbellatum*). Jagged chickweed is a small (usually less than 15 cm) winter annual plant that is a very common early successional species. The wheatgrasses have at least doubled their canopy coverage on all plots this year and show very little difference between plots (Tables 1 and 2). Cheatgrass cover has also increased on all plots this year, however, it does not appear to have affected the development of the wheatgrasses. The canopy cover of Russian thistle (*Salsola kali*) has dropped this year to less than 1% on all plots except plot 4 where it was 1.1%. This reduction is caused by the increase in competition (canopy cover) of the grasses and other species that utilize the soil moisture during winter and spring before Russian thistle (a summer annual) can grow.

Several species were observed this year on the landfill that did not occur in the individual plot frames. Plot 6 had the most with 5 new species (Table 1). These are all species that occur in the surrounding area that are beginning to migrate into plot 6 because of the similar sandy soil. One plant of rush-skeletonweed (*Chondrilla juncea*) was found on plot 3 and was pulled up. This is a noxious weed that now occurs in several locations on the Hanford Site. An effort will be made to exclude this plant from the landfill.

The percent canopy cover of wheatgrasses is very similar on all plots this year. Plot 1 had 15.9% while the rest of the plots ranged from 21.6% on plot 4, to 26.7% on plot 6. It appears that regardless of the different planting techniques that were used, the canopy cover is leveling out across the plots and is now similar to a mature stand of wheatgrass. For a comparison, the canopy cover of a mature stand of Siberian wheatgrass/thickspike wheatgrass (*Agropyron dasytachyum*) that was planted on the 216-T-35 burial ground of the Hanford Site was measured at 18.3% after more than 10 years of growth (WHC 1994). The wheatgrass plants on the Horn Rapids Landfill are still smaller in stature with a higher density than plants within mature stands. The density and stature of the plants is expected to continue to change; however, since the soils are similar and all plots are exposed to the same weather conditions, the canopy cover and frequency of occurrence is expected to remain similar across the plots.

Figure 2. Horn Rapids Landfill Showing the Six Treatment Plants.

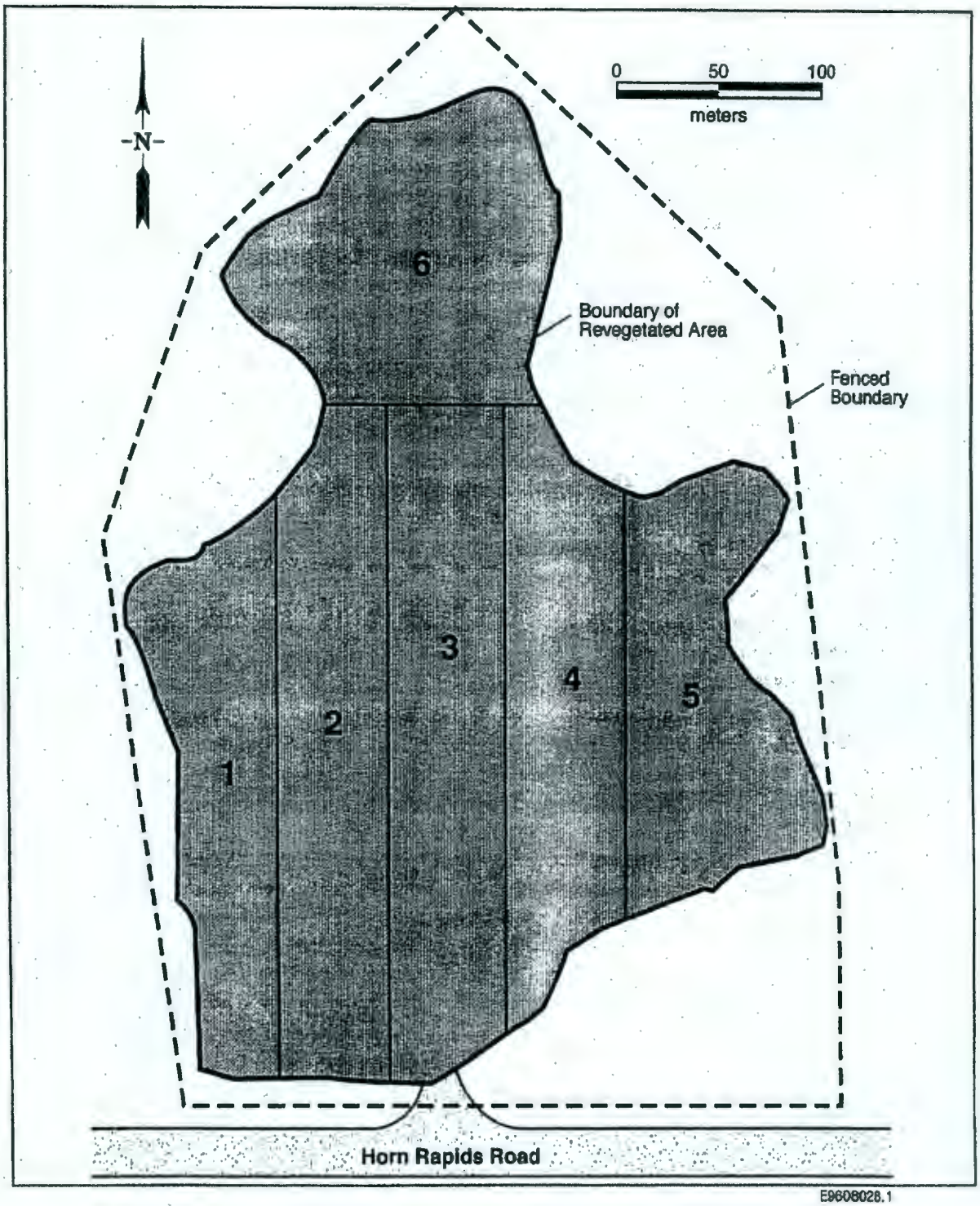


Table 1. Percent Canopy Cover on Horn Rapids Landfill for 1998.

Species	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6
Agropyron spp (wheatgrasses)	15.9	24	23.5	21.6	24.7	26.7
Salsola kali (Russian thistle)	0.2	0.3	0.6	1.1	0.9	0.1
Bromus tectorum (cheatgrass)	23.4	18.6	25.8	9.5	7	34.8
Amsinckia lycopsoides (tarweed)	0.3	0.1	2.2	--	--	0.7
Sisymbrium altissimum (tumblemustard)	--	0.3	0.1	0.3	0.2	--
Ambrosia acanthicarpa (bur ragweed)	0.2	0.5	--	0.2	0.3	0.4
Convolvulus arvensis (field bindweed)	--	--	--	0.1	--	--
Holosteum umbellatum (jagged chickweed)	10.1	25.9	16.4	20.8	10.6	8.3
Lactuca serriola (prickly lettuce)	--	--	0.5	0.1	--	--
Draba verna (spring whitlow)	2.1	9.7	3.8	24	8.8	4.2
Descurainia pinnata (tansymustard)	0.1	0.1	--	--	--	--
Epilobium paniculatum (tall willowherb)	--	0.4	0.2	0.6	0.4	--
Poa sandbergii (Sandberg's bluegrass)	--	--	0.6	--	X	0.1
Plantago patagonica (Indian wheat)	0.1	--	--	--	--	--
Erodium cicutarium (storksbill)	0.3	0.7	0.2	0.2	--	0.1
Tragopogon dubius (yellow salsify)	0.1	--	--	--	--	--
Agoseris grandiflora (mountain dandelion)	--	0.1	--	0.1	--	--
Stipa comata (needle and thread grass)	--	--	--	--	--	X
Chaenactis douglasii (hoary falseyarrow)	--	--	--	--	--	X
Phacelia hastata (whiteleaf scorpionweed)	--	--	--	--	--	X
Eriogonum niveum (snow buckwheat)	--	--	--	--	--	X
Astragalus caricinus (buckwheat milkvetch)	--	--	--	--	--	X
Machaeranthera canescens (hoary aster)	--	--	--	--	X	X
Achillea millefolium (yarrow)	--	--	X	--	--	--
*Medicago sativa** (alfalfa)	--	--	X	--	--	--
*Melilotus officinalis** (yellow sweet clover)	--	--	X	--	--	--
*Convolvulus arvensis** (field bindweed)	--	--	X	--	--	--
Chondrilla juncea * (skeletonweed)	--	--	X	--	--	--
*Cardaria draba** (whitetop)	--	--	--	--	X	--
Bare Soil	59.8	53.4	46	84.3	85.3	58.5
Litter	38.9	36.7	51.4	14.3	9.4	34.8
Crust	--	--	0.1	--	--	--
Total *	**52.8**	**80.7**	**73.9**	**78.6**	**52.9**	**75.4**

* Does not include bare soil, litter, or crust.
X = Present but not counted in plot frames.

Table 2. Percent Frequency of Occurrence on Horn Rapids Landfill for 1998.

Species	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6
Agropyron spp (wheatgrasses)	68	88	84	88	100	80
Salsola kali (Russian thistle)	8	12	24	24	36	4
Bromus tectorum (cheatgrass)	100	76	100	88	88	100
Amsinckia lycopsoides (tarweed)	12	4	12	--	--	8
Sisymbrium altissimum (tumblemustard)	--	12	4	12	8	--
Ambrosia acanthicarpa (bur ragweed)	8	20	--	8	12	16
Convolvulus arvensis (field bindweed)	--	--	--	4	--	--
Holosteum umbellatum (jagged chickweed)	96	96	96	100	100	84
Lactuca serriola (prickly lettuce)	--	--	20	4	--	--
Draba verna (spring whitlow)	68	92	92	100	100	48
Descurainia pinnata (tansymustard)	4	4	--	--	--	--
Epilobium paniculatum (tall willowherb)	--	16	8	24	16	--
Poa sandbergii (Sandberg's bluegrass)	--	--	4	--	--	4
Plantago patagonica (Indian wheat)	4	--	--	--	--	--
Erodium cicutarium (storksbill)	12	8	8	8	--	4
Tragopogon dubius (yellow salsify)	4	--	--	--	--	--
Agoseris grandiflora (mountain dandelion)	--	4	--	4	--	--
Bare Soil	100	100	96	100	100	96
Litter	100	100	100	100	100	100
Crust	--	--	4	--	--	--

3.0 HORSESHOE LANDFILL

The Horseshoe and the Nike Base landfills are located on the Fitzner-Eberhardt Arid Lands Ecology (ALE) Reserve and are included in the 1100-IU-1 Operable Unit (Figure 3). They were sampled and remediated as part of the remediation work outlined in the Record of Decision (ROD) for the 1100 Area National Priorities List site (EPA 1993). The completion of the remediation work was documented in the *Close-Out Report Fitzner-Eberhardt Arid Lands Ecology Reserve Remedial Action, Hanford, Washington* (DOE-RL 1996).

Survival of the planted bunchgrasses was measured on the Horseshoe Landfill and plot 1 of the 3 small sites of the Nike Landfill. This was done by examining the bunchgrasses for green plant material in the crown area. If there were any green leaves present, the plant was recorded as alive. On the Horseshoe Landfill, transects running across the width of the revegetated area were counted. On the three small Nike Landfill sites, all bunchgrasses and sagebrush were counted. The revegetated area of the Horseshoe landfill measures approximately 35 by 70 m. The revegetated area on the Nike Base landfill consists of three small sites measuring approximately 4 by 23 m (plot 1), 6 by 9 m (plot 2), and 4 by 9 m (plot 3). The disturbed soils on the surface of these sites were revegetated in the fall of 1995. Work began on November 29, 1995 and was completed on December 7, 1995.

The Horseshoe Landfill was revegetated with transplanted bunchgrasses. The landfill also had a large number of sagebrush seedlings growing on it that were inadvertently planted during the backfilling, i.e., the seeds were already in the soil used to cover the surface. The exceptionally wet winter of 1994/1995 allowed the seeds to grow and become established. Therefore, the prospects for this site returning to a sagebrush/bunchgrass dominated community in the near future are very good. The three small Nike Landfill sites varied in vegetative cover from nearly bare to having some small sagebrush, cheatgrass, and Sandberg's bluegrass (*Poa sandbergii*). These sites were planted with bunchgrasses with the addition of 12 to 15 sagebrush seedlings each.

The vegetation growing on the Horseshoe Landfill and a relatively undisturbed reference site adjacent to the waste site, was measured for canopy cover and frequency on May 20, 1997, using classical Daubenmire methods (1970). Within the Horseshoe Landfill and the reference site, 25 plot-frames measuring 50 x 100 cm were analyzed for canopy coverage and frequency of occurrence of each species present.

Survival of the planted bunchgrasses was measured on the Horseshoe Landfill and plot 1 of the 3 small sites of the Nike Landfill. This was done by examining the bunchgrasses for green plant material in the crown area. If there were any green leaves present, the plant was recorded as alive. On the Horseshoe Landfill, transects running across the width of the revegetated area were counted. On the three small Nike Landfill sites, all observed bunchgrasses and sagebrush were counted.

3.1 MONITORING RESULTS

Twenty-five species of plants were recorded in the plot frames on the Horseshoe Landfill in 1998, seventeen of which were native. Four additional native species were observed on the landfill that did not occur in the plot frames. The reference site had 22 species recorded in the plot frames and one additional species. Nineteen of the 23 species observed on the reference site were native (Tables 3 and 4). Cheatgrass still has the highest canopy cover on the waste site with 25.5%; however, the cover is lower than 1997's 36% (Appendix A). Sagebrush cover increased from 5.5% in 1997 to 14.4% in 1998. Bunchgrasses on the waste site are also increasing in dominance through recruitment of seedlings. Bluebunch wheatgrass (*Agropyron spicatum*) increased from 0.9% in 1997 to 3.4% in 1998, and Sandberg's bluegrass has increased from 2.4% to 9.8%. In addition, sweet clover increased from 1.6% cover in 1997 to 10.1% in 1998. This is because sweet clover is a biennial species and 1998 was the year these plants increased in biomass and flowered. The canopy cover of the other species has changed very little.

The reference site also saw a drop in cheatgrass cover this year of about the same proportion as the waste site. Sagebrush cover appears to have increased from 10.1% in 1997 to 30.3% in 1998 at the reference site. Since the plants on the reference site are old-growth shrubs, it is not likely the canopy cover has actually increased. The difference is more likely due to a difference in data collection technique. In 1997, there may have been an inadvertent avoidance of some of the very large shrubs because of the difficulty in maneuvering through them.

Sandberg's bluegrass is the dominant bunchgrass on the reference site with 36.2% cover and 100% frequency. Canopy cover of this species is declined by 15% in 1998 compared to 1997. This is consistent with the reduction in cheatgrass cover on both sites in 1998 and is likely the result of less precipitation during the 1998 growing season. Hanford climatological data show that the precipitation during the 1996/1997 growing season (October to May) was 26.2 cm compared to 14.7 cm during the 1997/1998 growing season (Hoitink and Burk 1998).

Cryptobiotic crust is an important component of the native shrub steppe community. It is made up of a mixture of lichens, mosses, and algae that bind the soil surface, thus helping to reduce erosion and facilitate percolation of water. A well-developed cryptobiotic crust is indicative of a mature native community, particularly in areas with fine soils. Ground coverage of biotic crust was measured at these sites. The amount of ground covered with biotic crust on the reference site was 49.1%, while on the Horseshoe landfill crust was measured for the first time with 2% cover. The crust is very thin on the landfill, but the frequency of occurrence was 40%. This is a good indication that the soils are beginning to recover from the disturbance.

The survival of the transplanted native bunchgrasses remains acceptable on all plots this year. On the Horseshoe landfill, 261 plants were examined and 183 were alive for a survival of 70% (Table 5). Survival of the bunchgrasses has not changed since 1997 when it was recorded at 68%. One note of interest on bunchgrass survival is that the down-slope half of the landfill had 48% survival while the up-slope half had 85% survival. This was not seen in 1997 because the transects were run the length of the landfill rather than the width. With the recruitment of seedlings occurring throughout the site, these survival counts appear to be sufficient to sustain the population.

On the three Nike Landfill sites, transplant survival was only counted on plot 1 because of the difficulty in locating dead plants among the cheatgrass and other dead leaf litter. Bunchgrass survival on plot 1 was 58%, down from 83% reported in 1997. Although survival of transplants is becoming impossible to count on these plots, recruitment of young plants is taking place. Counts were taken to get an indication of reproductive success of the bunchgrasses and sagebrush on these three plots. On plot 1, 40 sagebrush seedlings were counted in the south corner of the plot. Plot 2 contained 25 sagebrush and 45 bunchgrass plants. On plot 3, 51 sagebrush were counted, but only 1 bunchgrass was found. Plot 3 has a dense stand of cheatgrass making it difficult to see any other grasses. At least half of the sagebrush on this plot are seedlings.

Survival of transplanted bunchgrasses has remained about the same this year and recruitment is being seen for both bunchgrasses and sagebrush. This, combined with the increases seen in canopy cover for the bunchgrasses and sagebrush, indicate the health and development of the community is continuing to improve.

Figure 3. Horseshoe and Nike Landfills.

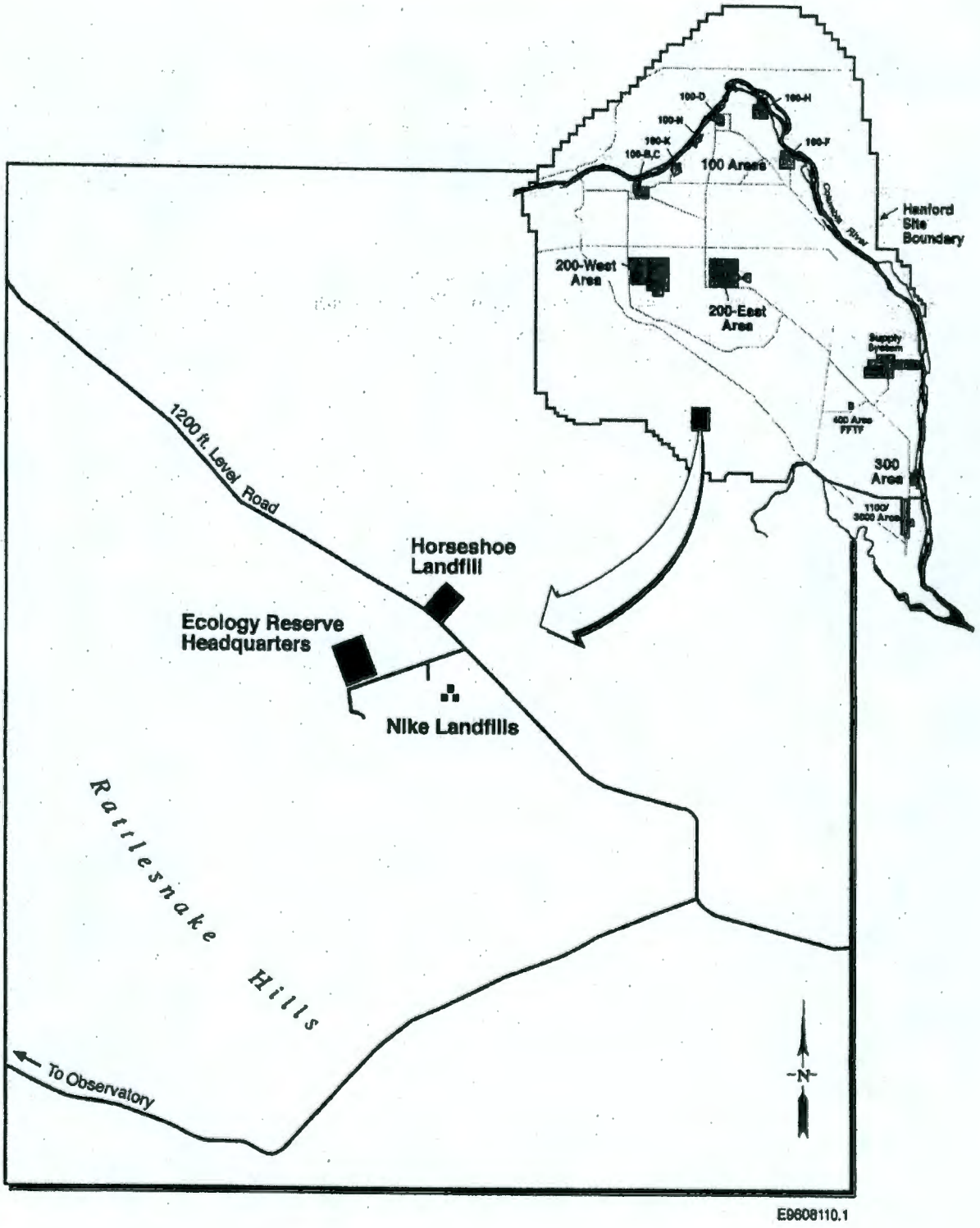


Table 3. Percent Canopy Cover on the Horseshoe Landfill in 1998.

Species	Waste Site	Reference Site
*Bromus tectorum** (cheatgrass)	25.5	15.7
Artemisia tridentata (big sagebrush)	14.4	30.3
Agropyron spicatum (bluebunch wheatgrass)	3.4	8.2
Poa sandbergii (Sandberg's bluegrass)	9.8	36.2
Sitanion hystrix (bottlebrush squirreltail)	1	0.2
*Poa bulbosa** (bulbous bluegrass)	0.2	--
Festuca octoflora (sixweeks fescue)	1.5	1.6
Oryzopsis hymenoides (Indian ricegrass)	X	2.8
*Sisymbrium altissimum** (tumblemustard)	0.3	--
*Melilotis officinalis** (sweet clover)	10.1	--
Epilobium paniculatum (tall willowherb)	0.6	0.6
*Lactuca serriola** (prickly lettuce)	1.1	0.2
Crepis atrabarba (slender hawksbeard)	1.9	3.7
Descurainia sp (tansymustard)	0.7	0.1
Amsinckia lycopsoides (tarweed fiddleneck)	0.1	--
Chaenactis douglassi (hoary falseyarrow)	0.1	--
Erigeron filifolius (threadleaf fleabane)	0.1	0.9
Linum perenne (wild blueflax)	0.3	0.1
*Lepidium perfoliatum** (clasping pepperweed)	1.6	--
Lupinus sulphurous (sulfur lupine)	0.6	8.8
*Tragopogon dubius** (yellow salsify)	0.2	0.3
Machaeranthera canescens (hoary aster)	0.8	0.1
Holosteum umbellatum (jagged chickweed)	2.4	0.4
Draba verna (spring whitlow)	--	3.2
Agoseris grandiflora (mountain dandelion)	0.1	--
Chrysothamnus nauseosus (gray rabbitbrush)	1.3	--
Chrysothamnus viscidiflorus (green rabbitbrush)	0.6	--
Achillea millefolium (yarrow)	X	--
Helianthus cusickii (Cusick's sunflower)	X	--
Lomatium macrocarpum (bigseed desertparsley)	X	--
Festuca idahoensis (Idaho fescue)	X	--
Bare soil	10.8	3.6
Biotic crust	2	49.1
Total	**78.7**	**113.4**

* Introduced species.

X = Present but not counted in plot frames.

Table 4. Percent Frequency on the Horseshoe Landfill in 1988.

Species	Waste Site	Reference Site
*Bromus tectorum** (cheatgrass)	100	76
Artemisia tridentata (big sagebrush)	64	76
Agropyron spicatum (bluebunch wheatgrass)	36	24
Poa sandbergii (Sandberg's bluegrass)	64	100
Sitanion hystrix (bottlebrush squirreltail)	20	8
*Poa bulbosa** (bulbous bluegrass)	8	--
Festuca octoflora (sixweeks fescue)	40	44
Oryzopsis hymenoides (Indian ricegrass)	--	16
*Sisymbrium altissimum** (tumblemustard)	12	--
*Melilotis officinalis** (sweet clover)	56	--
Epilobium paniculatum (tall willowherb)	24	24
*Lactuca serriola** (prickly lettuce)	44	8
Crepis atrabarba (slender hawksbeard)	16	68
Descurainia sp (tansymustard)	28	4
Amsinckia lycopsoides (tarweed fiddleneck)	4	--
Chaenactis douglassi (hoary falseyarrow)	4	--
Erigeron filifolius (threadleaf fleabane)	4	16
Linum perenne (wild blueflax)	12	4
*Lepidium perfoliatum** (clasping pepperweed)	8	--
Lupinus sulphurous (sulfur lupine)	24	80
*Tragopogon dubius** (yellow salsify)	8	12
Machaeranthera canescens (hoary aster)	32	4
Holosteum umbellatum (jagged chickweed)	76	16
Draba verna (spring whitlow)	--	16
Agoseris grandiflora (mountain dandelion)	4	--
Chrysothamnus nauseosus (gray rabbitbrush)	12	--
Chrysothamnus viscidiflorus (green rabbitbrush)	4	--
Bare soil	80	48
Biotic crust	40	100

* Introduced species.

Table 5. Percent Survival of Transplanted Bunchgrasses and Sagebrush Plants in 1998.

Site Name	Sagebrush		Bunchgrass	
PSN 12/14	**1997**	**1998**	**1997**	**1998**
Plot 1	91.3	59	54	66
Plot 2	75	58	96.8	82
Plot 3	76.5	73	62.5	74
Plot 4	93.8	69	66.7	61
Plot 5	58.1	43	72	76
Plot 6	57.8	59	74.4	88
Plot 7	57.3	57	81.3	88
Bridge Overlook	N/A		94	
NS Cheatgrass Area				
Small Plots (Aug)	5.5		N/A	
Small Plots (Oct)	92.7		N/A	
Road Transect	85.7	81.8	N/A	
Horseshoe Landfill	N/A		68	
Nike Landfill				
Plot 1	N/A		83	
Plot 2	N/A		92	
Plot 3	N/A		86	

4.0 NORTH SLOPE SITES

There were 39 distinct waste sites identified within the 100-IU-3 Operable Unit of the 100 Area National Priority List site. The 100-IU-3 Operable Unit is located on the Hanford Site North Slope area. The cleanup of these waste sites was documented in the *Close-Out report North Slope (Wahluke Slope) Expedited Repose Action, Hanford Washington* (DOE/RL 1994a) to satisfy milestone No. M-16-82 of the *Hanford Federal Facility Agreement and Consent Order* (Ecology et al. 1989) and (Lerch 1998). The sites were remediated and cleanup activities took place in 1994 with the exception of waste site 600-104, which was remediated in 1997. A detailed description of the remediation activities is provided in *A Compendium of Field Reports for the North Slope (Wahluke Slope) Expedited Response Action* (DOE/RL 1994b) and *100-IU-3 Waste Site 600-104 Remediation Summary, January 1998*, BHI-01116. The Hanford North Slope was delisted in July 1998 by the EPA (Federal Register July 8, 1998, Volume 63, Number 130).

Most of the remediation efforts involved the removal of physical hazards associated with military and pre-World War II agricultural activities. Remediated sites included abandoned water wells, debris removal, excavation of landfills, and backfilling of open cisterns. In 1997, a remediation effort was conducted to remove tanks and bioremediate 2,4-D contaminated soils from a Bureau of Reclamation disposal site.

The restoration plan for the North Slope sites was based on the quality of the site and quality of the surrounding vegetation. The vegetation on and surrounding many of the sites prior to cleanup consisted primarily of cheatgrass, Russian thistle, tumblemustard (*Sisymbrium altissimum*), and other introduced species with some localized recolonization of big sagebrush and Sandberg's bluegrass. The soils at the revegetation areas are easily eroded by wind when exposed and are well drained and generally coarse soils.

Three sites (Bridge Overlook, PSN 72/82, and PSN 12/14) were revegetated in 1995 because of surrounding high quality habitat, project timing, and available resources (Hughes 1995). The revegetation efforts primarily used salvaged plant materials and sagebrush tubelings grown from seed collected on the Hanford Site. An additional area on the North Slope was selected for restoring the sagebrush component to a cheatgrass/Sandberg's bluegrass community after a previous burn (Figure 1). The planting of sagebrush at this site was conducted to compensate for not revegetating a number of very small waste sites on the Hanford Site North Slope that were in areas determined by the Hanford Site Natural Resources Trustee Council to have poor quality habitat. Also, these remaining sites were determined to be either too small or had the potential to be farmed in the future.

Waste site 600-104 (2,4-D waste site) was revegetated on September 29, 1997 after bioremediation of 2,4-D contaminated soils. The dominant species on the waste site were cheatgrass and tumblemustard before the site was exhumed and contaminated soils were bioremediated. After backfilling, the site was seeded with big sagebrush, snow buckwheat, Sandberg's bluegrass, Indian ricegrass, and balsamroot.

4.1 REVEGETATION PLAN BACKGROUND FOR 1995 AND 1996 REVEGETATION EFFORTS

Native bunchgrass species were salvaged from the Environmental Restoration Disposal Facility (ERDF) and were used for the initial planting on Bridge Overlook, PSN 72/82, and PSN 12/14. An estimated 9,000 (maximum) plants were salvaged from ERDF in February 1995. Of all the salvaged plants an estimated 90% were needle-and-thread grass (*Stipa comata*), and the remaining 10% were Indian ricegrass (*Oryzopsis hymenoides*) and Sandberg's bluegrass (*Poa sandbergii*). The 1998 and 1997 monitoring noted prairie junegrass (*Koeleria cristata*) as an additional bunchgrass species that was transplanted.

As part of the site preparation, soil samples were taken from each of the three revegetation sites and sent to a local laboratory for percent organic matter, nitrogenp, and potassium analysis. The results of the analysis indicated that the soils were deficient in phosphorus. A fertilizer with an analysis of 11-52-0 (11% N, 52% P_2O_5, and 0% K_2O) was recommended to correct the soil fertility deficiency (Hughes 1995). All plants at PSN 72/82 and Bridge Overlook along with an estimated 4,000 plants at three of the PSN 12/14 plots received fertilizer. Volunteer revegetation crews were directed to add 15 ml of fertilizer for plants in 3.8 L sized pots and 30 ml of fertilizer for plants in larger pots. Additionally, 30 native grass plants at both the Bridge Overlook (with fertilizer) and PSN 12/14 (without fertilizer) were planted in areas of undisturbed soil adjacent to the landfill areas (Hughes 1995). These reference areas were not permanently identified and could not be found in the 1997 or 1998 monitoring effort.

Hughes also noted that maintenance irrigation was applied to selected areas of PSN 72/82 and 12/14 throughout the growing season. The Bridge Overlook transplants were not to receive supplemental irrigation due to its remote location and another 886 plants at PSN 12/14 did not receive supplemental irrigation. The different irrigation regimes were done to test the effect of watering on transplant establishment. Unfortunately the selected areas and plants that were irrigated were not identified in the field by markings or on a map, therefore, monitoring of these treatments was not feasible.

4.2 BRIDGE OVERLOOK

The Bridge Overlook site is located approximately 1 mile northwest of the Vernita Bridge (Figures 1 and 4). The vegetation on the Bridge Overlook site was measured on May 21, 1997 and May 19, 1998. In 1998, a total of 13 plant species were identified on the waste site, 11 of which were native (Tables 6 and 7). Four new species were detected in the 1998 survey within the waste site plots, snow buckwheat, six-weeks fescue, annual phlox *(Microsteris gracilis),* and white-daisy tidytips (*Layia glandulosa).* Cheatgrass is still the most abundant plant (in frequency and cover) on the waste site. Cheatgrass cover has increased by 18.6% from 1997, with a similar percent cover increase in the reference plot (17.7%) (Table 6 and Appendix A). The cryptobiotic crust, which was absent at the waste site in 1997, has started to develop (1.5% cover). Native forbs such as great basin gilia (*Gilia leptomeria),* dune scurfpea (*Psoralea lanceolata),* and tansymustard *(Descurainia spp.)* have a much higher percent cover than 1997 (11.3% vs. 0.2%, 13.6% vs. 1.4%, and 7% vs. 1.7%, respectively). Shrubs have started to invade

the waste site including sagebrush, gray rabbitbrush, bitterbrush, and snow buckwheat, whereas last year, only spiny hopsage was identified.

The reference site, located just west of the waste site, had 16 plant species within the plots, 14 of which were native plants. The reference site had a cryptobiotic crust component (29.1% cover), and a dominant shrub overstory of primarily sagebrush (16.3% cover), spiny hopsage (7.4% cover), and bitterbrush (2.5% cover). A diverse forb and bunchgrass understory also exists at the reference site .

Survival of transplanted bunchgrasses is increasingly difficult to measure because the numbers originally planted and the planting pattern were not well documented. Also, as plants die and the plant material decomposes or is blown away, it becomes impossible to tell where the transplant occurred. The results of survival counts then become artificially high since only the survivors can be counted. Therefore, survival was not measured this year. Instead, the waste site was scouted to identify any dead bunchgrasses. Since none were found, no conclusions were drawn for the bunchgrass transplant survival, other than to suspect that survival has not changed much from last year's 94% survival. Bunchgrass seedlings are colonizing the waste site. Most of the seedlings are either needle-and-thread grass or Indian ricegrass, given that those two bunchgrasses are the most common in the waste site area.

4.3 PSN 72/82

The PSN 72/82 is located near the Bridge Overlook site (Figures 1 and 4). The areas that were revegetated included the PSN 72/82 Well Mound and a small staging area on the access road adjacent to the Well Mound. Sagebrush tubelings, and bunchgrasses salvaged from the ERDF were planted on the Well Mound in March 1995, with fertilized added to each planting hole. The 1998 vegetation analysis of the Well Mound site identified 25 plant species, 20 of which were native plants (Tables 8 and 9). Shrub cover on the site has increased from 1997 for sagebrush (7.3% vs. 3.6% cover), and gray rabbitbrush (3.0% vs. 0.1% cover). The four bunchgrass species initially transplanted onto the Well Mound Site were prairie junegrass, Indian ricegrass, Sandberg's bluegrass, and needle-and-thread grass. Percent canopy cover has increased from 1997 for needle-and-thread grass (5.1% vs. 0.5% cover), with a negligible increase for Sandberg's bluegrass (1.3% vs. 0.2% cover), and bottlebrush squirreltail (1.3% vs. 0.1% cover). In addition, cryptobiotic crust cover remained about the same as last year (0.6% vs. 0.1% cover). Bunchgrass and sagebrush survival was not counted this year because it was difficult to distinguish the transplants from recruitment that has occurred within the last three years.

On the reference site, a total of 18 plants were identified, 15 of which were native plants. Shrubs such as sagebrush (13.2% cover) and spiny hopsage (1.5% cover) are the dominant overstory species, while the grasses included cheatgrass (43.5% cover), Sandberg's bluegrass (3.2% cover), and six-weeks fescue (1.7% cover). The cryptobiotic crust cover and bare soil cover were 8.4% and 42.3%, respectively. The canopy coverage was similar to the 1997 data except for the canopy coverage of crust, which was 29.4% last year.

The small staging area (road) adjacent to the Well Mound site, was planted in the fall of 1996 with a seed mix of sagebrush, snow buckwheat, spring turpentine parsley (*Cymopteris terebinthinus*), Carey's balsamroot (*Balsamorhiza careyana*), and Sandberg's bluegrass. This year is the first monitoring effort for this site. A total of 24 species were identified, 18 of which were native species (Tables 8 and 9). All planted species except spring turpentine parsley were identified on the site. The percent canopy cover is still very small for these species; however, frequency of occurrence was good for both Carey's balsamroot and sagebrush relative to the reference site. Sagebrush frequency at the staging area was 28%, which is the same frequency as the Well Mound site where sagebrush tubelings were transplanted rather that direct seeded. In addition to the planted species, the site is being colonized by gray rabbitbrush, needle-and-thread grass, six-weeks fescue (*Festuca octoflora*), and many native forbs including hoary aster (*Machaeranthera canescens*), jagged chickweed (*Holosteum umbellatum*), and bur ragweed (*Ambrosia acanthicarpa*). To date, the cryptobiotic crust has not developed, and the amount of bare soil is still very high (81.3% cover).

4.4 PSN 12/14

The PSN 12/14 site is located in the northeast corner of the Hanford Site, approximately 6.4 kilometers east of the White Bluffs Landing (Figures 1 and 5). Both sagebrush tubelings and salvaged bunchgrasses from ERDF were planted on all seven PSN 12/14 plots from March 27 through April 1, 1995. For 1997 and 1998, sagebrush and bunchgrass survival was recorded for all seven plots; however, only plots 1, 2, 4, 5, and the access road were monitored for percent canopy cover and frequency of occurrence. The access road into the PSN 12/14 waste sites was revegetated with a seed mix consisting of sagebrush, bitterbrush, snow buckwheat, spring turpentine parsley, Carey's balsamroot, and Sandberg's bluegrass.

The access road is still dominated by cheatgrass. Nineteen plant species were identified within the plots, 14 of which were native plants (Tables 10 and 11). While none of the seeded species were detected in 1997, only bitterbrush and spring turpentine parsley were not detected on the access road in 1998. New native species to colonize the access road in 1998 include sagebrush, green and gray rabbitbrush, snow buckwheat, hoary aster, and Indian ricegrass. There is not much litter on the access road compared to the other PSN 12/14 sites, and a cryptobiotic crust has not developed yet.

On the waste sites, all plots are still dominated by cheatgrass. Russian thistle coverage did not change much from the 1997 data, remaining consistently low on all plots. Tumble mustard coverage was highest on plots 1(16.5%) and 4 (21.3%), where coverage in 1997 was only high on plot 4 (16%). Plot 2 had the highest coverage and frequency of native grasses as well as a fairly high coverage of dune scurfpea (20%), a leguminous dune stabilizer. Plot 1 had the highest cover of sagebrush (8.5%) of all the waste sites, as well as the highest cover of the winter annual, jagged chickweed. Of the four waste sites, only plot 5 lacked a cryptobiotic crust layer, whereas in 1997, only plot 1 had a crust layer.

Survivorship of sagebrush tubelings and transplanted bunchgrasses were also monitored on all plots (1-7). Sagebrush survivorship was reduced in 1998 on plots 1, 2, 3, 4, and 5 compared to 1997 data (Table 5). Survivorship declined the most on plot 1 from 91.3% in 1997 to 59% in

1998. Survivorship slightly increased from 57.8% to 59% on plot 6, and remained the same for plot 7. Bunchgrass survival was greater for plots 1, 3, 5, 6, and 7 in 1998 compared to 1997, but it declined on plots 2 and 4. The increase in sagebrush and bunchgrass survivorship is either due to the inability to locate dead transplants or that new recruits were included in the count.

On the reference site, a total of 19 plants were identified, 16 of which were native plants. The bare soil component and the cryptobiotic crust had about the same canopy coverage (40.3% vs. 36.3%, respectively). Cheatgrass had the highest frequency and coverage of any plant followed by the winter annuals, jagged chickweed and spring whitlow grass. The shrub overstory included sagebrush, bitterbrush, green rabbitbrush, and snow buckwheat. Sandberg's bluegrass and Indian ricegrass comprised the bunchgrass understory, while dominant forbs included spring turpentine parsley, longleaf phlox, and annual phlox.

4.5 NORTH SLOPE CHEATGRASS AREA

Sagebrush seedlings were planted in August and October, 1996 in a burned area on the Saddle Mountain Wildlife Refuge (Figures 1 and 6). These burned areas have had the sagebrush component removed due to repeated wildfires. The objective of this planting was to provide a seed source in the area to promote sagebrush regeneration.

Approximately 3,000 sagebrush were planted in groups of three along an access road in August 1996. These sagebrush were salvaged as seedlings from gravel pits at the junction of the access road and Highway Route 24. A few different planting methods were used during the August transplanting. All of the sagebrush were planted directly in the ground and watered. A few sagebrush were surrounded by black plastic to help control weed competition. A few other sagebrush were also planted with Dri-Water™[1] which is a commercial product composed of a vegetable gel that slowly releases water into soil over an extended period of time.

Approximately 2,700 sagebrush were planted in October, 1996. These sagebrush were salvaged from an area just south of the Hanford Site 300-Area. The plantings were done in groups of three along the access road (Road Transect) and in small transect plots that were established perpendicular to the access road. The sagebrush transplants along the road transect area and small plots were monitored for survival in June, 1998, and had 81.8% survival (Table 5). This compares with measured survivorship of 85.9% in 1997. The small transect plots were not monitored in 1998.

The dramatic improvement in survivorship of sagebrush planting in October versus August shows that successful late summer planting under the conditions described here is not a successful approach. The average daily maximum temperature during August 1996 was 92.6° F (Hoitink and Burk, 1997). Also the sagebrush were salvaged from very gravelly soils, thereby, making it difficult to extract the plants without injuring the root systems. These two conditions were the primary factors of the a very low survivorship in 1997 for the August planting.

[1] Dri-Water is a trademark of Dri-water, Inc., Petaluma, California.

4.6 WASTE SITE 600-104

Waste site 600-104 (2,4-D site) is located approximately 9.7 km south of PSN 12/14 and approximately 1 km east of the Columbia River (see Figure 1). The 1 hectare site was used by the Bureau of Reclamation to dispose of 11 tanks and soil contaminated with 2,4-D. The site in 1997 was dominated primarily by cheatgrass and tumblemustard. In August 1997 the tanks were exhumed and bio-remediation of 2,4-D contaminated soils took place. On September 28, 1998, the site was seeded by hand with 1 kg/ha of uncleaned big sagebrush seed, 0.75 kg/ha snow buckwheat, 5 kg/ha Sandberg's bluegrass, 1 kg/ha Indian ricegrass, and 20 mg/ha balsamroot. After hand broadcasting the seed using a fertilizer spreader, the planted area was watered with 5 cm of water (approximately 100,000 liters of water over the entire site).

In May 1998, cheatgrass and Russian thistle were the dominant species with 34.7% and 6.2% canopy cover respectively (Table 12). Sandberg's bluegrass was found throughout the plot and two incidental counts of balsamroot were recorded. Sagebrush, snow buckwheat, and Indian ricegrass were not observed. A total of 14 species had colonized the site in May 1998, of which 10 were native species.

Figure 4. PSN 72/82 and Bridge Overlook Revegetation Sites.

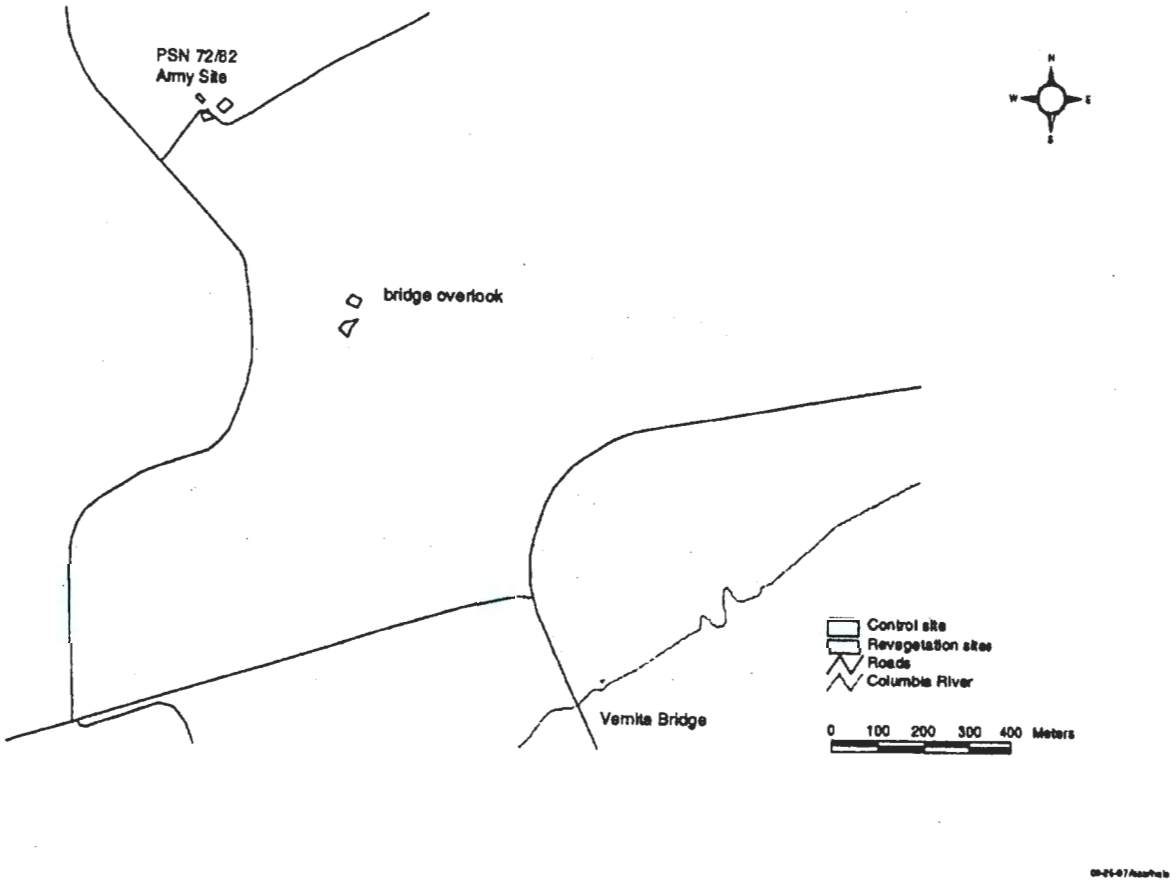


Figure 5. PSN 12/14 Revegetation Sites.

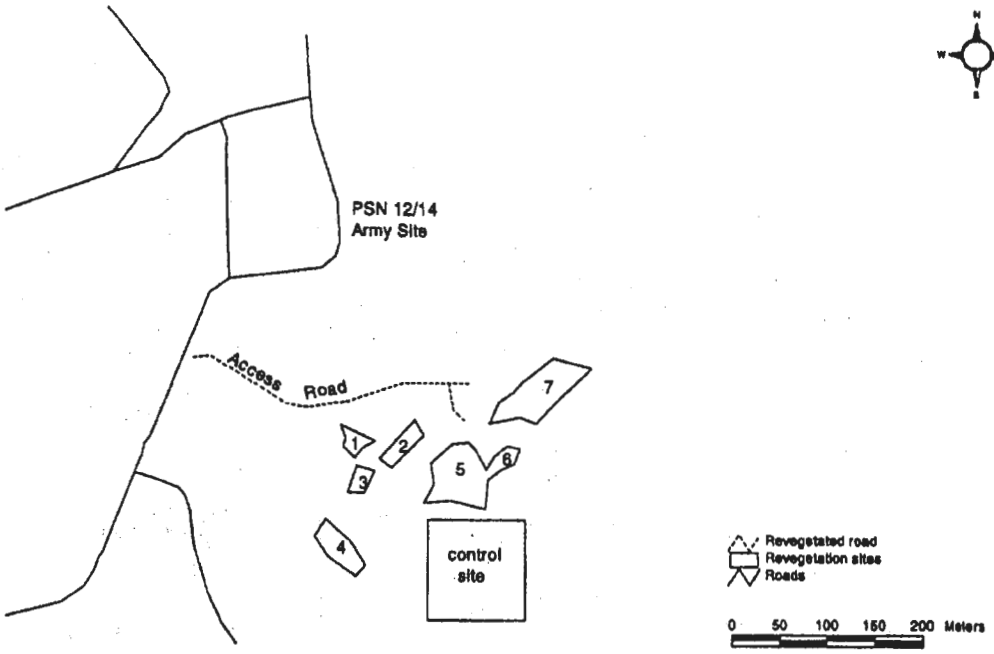


Figure 6. Sagebrush Transplant Sites on the North slope Cheatgrass Area.

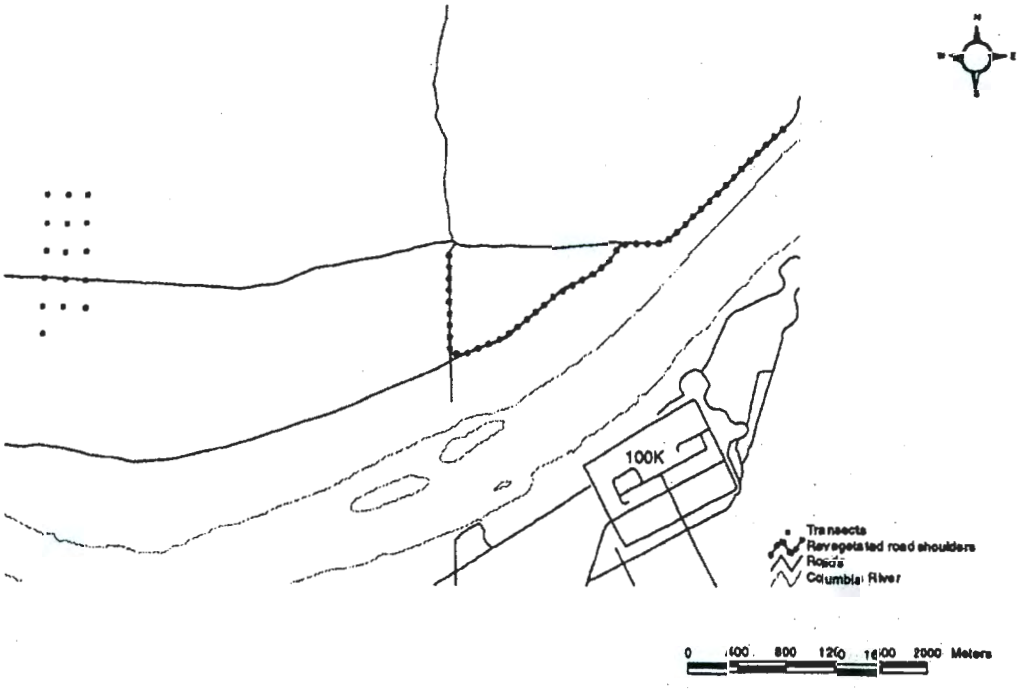


Table 6. Percent Canopy Cover on Bridge Overlook Sites in 1998.

Species	Waste Site	Control Site
*Bromus tectorum** (cheatgrass)	24.4	50.1
*Salsola kali** (Russian thistle)	2.5	0.7
Ambrosia acanthicarpa (bur ragweed)	0.5	0.1
Psoralea lanceolata (dune scurfpea)	13.6	0.6
Stipa comata (needle-and-thread grass)	0.5	X
Gilia leptomeria (great basin gilia)	11.3	8.5
Mentzelia albicaulis (whitestem stickleaf)	0.1	--
Oenothera pallida (pale evening primrose)	X	1.2
Descurainia sp. (tansymustard)	7	3.4
Cryptantha circumscissa (matted cryptantha)	0.6	0.4
Eriogonum niveum (snow buckwheat)	0.6	3.9
Artemisia tridentata (big sagebrush)	X	16.3
Purshia tridentata (antelope bitterbrush)	X	2.5
Chrysothamnus viscidiflorus (green rabbitbrush)	--	X
Grayia spinosa (spiny hopsage)	--	7.4
Oryzopsis hymenoides (Indian ricegrass)	X	X
Festuca octoflora (six-weeks fescue)	0.4	0.5
Cymopterus terebinthinus (turpentine parsley)	X	2.5
Layia glandulosa (white-daisy tidytips)	0.1	0.1
Comandra umbellata (bastard toadflax)	--	2.9
Amsinckia lycopsoides (tarweed fiddleneck)	X	X
Microsteris gracilis (annual phlox)	0.1	--
Poa scabrella (pine bluegrass)	X	X
Sitanion hystrix (bottlebrush squirreltail)	X	--
Chrysothamnus nauseosus (gray rabbitbrush)	X	--
Abronia mellifera (white sandverbena)	X	--
Balsamorhiza careyana (Carey's balsamroot)	--	X
Erysimum asperum (rough wallflower)	--	X
Tragopogon dubius (yellow salsify)		X
Poa sandbergii (Sandberg's bluegrass)	--	X
Biotic crust	1.5	29.1
Bare soil	58.4	31.4
Total (does not include crust or soil)	61.7	101.1

* Introduced species.

X = Present but not counted in plot frames.

Table 7. Percent Frequency of Occurrence on Bridge Overlook Sites in 1998.

Species	Waste Site	Control Site
*Bromus tectorum** (cheatgrass)	80	92
*Salsola kali** (Russian thistle)	80	28
Ambrosia acanthicarpa (bur ragweed)	20	4
Psoralea lanceolata (dune scurfpea)	52	4
Stipa comata (needle-and-thread grass)	20	--
Gilia leptomeria (great basin gilia)	72	52
Mentzelia albicaulis (whitestem stickleaf)	4	--
Oenothera pallida (pale evening primrose)	--	8
Descurainia sp. (tansymustard)	48	40
Cryptantha circumscissa (matted cryptantha)	4	16
Eriogonum niveum (snow buckwheat)	4	20
Artemisia tridentata (big sagebrush)	--	24
Purshia tridentata (antelope bitterbrush)	--	4
Grayia spinosa (spiny hopsage)	--	12
Festuca octoflora (six-weeks fescue)	16	20
Cymopterus terebinthinus (turpentine parsley)	--	4
Layia glandulosa (white-daisy tidytips)	4	4
Comandra umbellata (bastard toadflax)	--	20
Microsteris gracilis (annual phlox)	4	--
Biotic crust	4	88
Bare soil	100	80

* Introduced species.

Table 8. Percent Canopy Cover at PSN 72/82 Well Mound Sites in 1998.

Species	Waste Site	Road	Control Site
*Bromus tectorum** (cheatgrass)	29.5	26.7	43.5
*Salsola kali** (Russian thistle)	0.6	0.2	0.1
Ambrosia acanthicarpa (bur ragweed)	1.4	2.9	0.3
Oenothera pallida (pale evening primrose)	1.5	0.6	0.2
Artemisia tridentata (big sagebrush)	7.3	3.2	13.2
Chrysothamnus nauseosus (gray rabbitbrush)	3.0	0.1	--
Grayia spinosa (spiny hopsage)	0.1	--	1.5
Koeleria cristata (prairie junegrass)	0.1	--	--
Poa sandbergii (Sandberg's bluegrass)	1.3	0.1	3.2
*Poa bulbosa** (bulbous bluegrass)	0.1	0.3	--
Poa scabrella (pine bluegrass)	0.1	--	--
Sitanion hystrix (bottlebrush squirreltail)	1.3	--	--
Stipa comata (needle-and-thread grass)	5.1	0.1	--
Festuca octoflora (six-weeks fescue)	5.6	6.6	1.7
Microsteris gracilis (annual phlox)	1.3	1.4	0.3
Holosteum umbellatum (jagged chickweed)	4.5	3.8	1.9
Draba verna (spring whitlow)	2.4	7	3.5
Rumex venosus (winged dock)	--	--	0.7
*Lactuca serriola** (prickly lettuce)	--	--	0.1
Amsinckia tessellata (devil's lettuce)	0.4	0.2	0.3
Amsinckia lycopsoides (tarweed fiddleneck)	0.3	0.3	0.3
*Sisymbrium altissimum** (tumblemustard)	0.5	0.3	--
Descurainia spp (tansymustard)	1.5	0.2	0.9
*Erodium cicutarium** (storksbill)	4.5	3.2	--
Balsamorhiza careyana (Carey's balsamroot)	0.7	0.3	3.6
Comandra umbellata (bastard toadflax)	0.2	--	--
Machaeranthera canescens (hoary aster)	3.8	6.4	1
Cryptantha circumscissa (matted cryptantha)	--	1.1	--
Eriogonum niveum (snow buckwheat)	--	0.8	--
*Tragopogon dubius** (yellow salsify)	--	0.1	--
Plantago patagonica (Indian wheat)	--	0.8	--
Biotic crust	0.6	--	8.4
Bare soil	90.3	81.3	42.3
Litter	7.8	9.6	35.7
Total (does not include crust , soil, or litter)	**168**	**148**	**127**

* Introduced species.

X = Present but not counted in plot frames.

Table 9. Percent Frequency of Occurrence at PSN 72/82 Well Mound Sites in 1998.

Species	Waste Site	Road	Control Site
*Bromus tectorum** (cheatgrass)	96	96	84
*Salsola kali** (Russian thistle)	24	8	4
Ambrosia acanthicarpa (bur ragweed)	56	56	12
Oenothera pallida (pale evening primrose)	20	4	8
Artemisia tridentata (big sagebrush)	28	28	36
Chrysothamnus nauseosus (gray rabbitbrush)	8	4	--
Grayia spinosa (spiny hopsage)	4	--	4
Koeleria cristata (prairie junegrass)	4	--	--
Poa sandbergii (Sandberg's bluegrass)	12	4	28
*Poa bulbosa** (bulbous bluegrass)	4	12	--
Poa scabrella (pine bluegrass)	4	--	--
Sitanion hystrix (bottlebrush squirreltail)	12	--	--
Stipa comata (needle-and-thread grass)	48	4	--
Festuca octoflora (six-weeks fescue)	32	68	28
Microsteris gracilis (annual phlox)	52	36	12
Holosteum umbellatum (jagged chickweed)	84	72	36
Draba verna (spring whitlow)	76	68	24
Rumex venosus (winged dock)	--	--	8
*Lactuca serriola** (prickly lettuce)	--	--	4
Amsinckia tessellata (devil's lettuce)	16	8	12
Amsinckia lycopsoides (tarweed fiddleneck)	12	12	12
*Sisymbrium altissimum** (tumblemustard)	20	12	--
Descurainia sp (tansymustard)	40	8	36
*Erodium cicutarium** (storksbill)	64	48	--
Balsamorhiza careyana (Carey's balsamroot)	8	12	12
Comandra umbellata (bastard toadflax)	8	--	--
Machaeranthera canescens (hoary aster)	36	44	20
Cryptantha circumscissa (matted cryptantha)	--	24	--
Eriogonum niveum (snow buckwheat)	--	12	--
*Tragopogon dubius** (yellow salsify)	--	4	--
Plantago patagonica (Indian wheat)	--	32	--
Biotic crust	4	--	52
Bare soil	100	96	80
Litter	100	72	96

* Introduced species.

Table 10. Percent Canopy Cover for PSN 12/14 in 1998.

Species	Control	Plot 5	Plot 4	Plot 2	Plot 1	Road
*Bromus tectorum** (cheatgrass)	46.6	21.6	26.8	42.5	28.5	45.2
Ambrosia acanthicarpa (bur ragweed)	0.6	0.4	7.6	2.0	4.0	3.5
*Sisymbrium altissimum** (tumblemustard)	0.7	0.4	21.3	0.5	16.5	0.3
*Salsola kali** (Russian thistle)	0.3	1.9	4.4	0.5	2.0	1.2
Artemisia tridentata (big sagebrush)	9.4	0.6	3.9	X	8.5	1.6
Purshia tridentata (antelope bitterbrush)	3.9	--	--	--	--	--
Chrysothamnus viscidiflorus (green rabbitbrush)	1.7	--	--	--	--	0.1
Chrysothamnus nauseosus (gray rabbitbrush)	--	--	--	--	--	0.2
Poa sandbergii (Sandberg's bluegrass)	7.7	--	16	11	0.5	0.2
*Poa bulbosa** (bulbous bluegrass)	--	--	--	--	--	0.2
Stipa comata (needle-and-thread grass)	--	7.6	7.5	30.5	3.5	--
Oryzopsis hymenoides (Indian ricegrass)	0.1	5.4	--	--	--	X
Agropyron dasytachyum (thickspike wheatgrass)	--	5.0	--	--	--	--
Amsinckia lycopsoides (tarweed fiddleneck)	--	--	--	0.5	--	0.1
Cymopterus terebinthinus (turpentine parsley)	4.8	--	--	--	--	--
Descurainia pinnata (tansymustard)	--	0.1	--	--	--	--
Epilobium paniculatum (tall willowherb)	--	0.2	0.9	--	1.5	1.3
Eriogonum niveum (snow buckwheat)	1.6	--	0.1	--	--	0.9
Festuca octoflora (six weeks fescue)	--	--	--	--	--	0.9
Holosteum umbellatum (jagged chickweed)	16.3	0.6	6.3	15.5	26.5	3.3
Draba verna (spring whitlow)	13.5	--	--	--	--	0.7
*Lactuca serriola** (prickly lettuce)	--	--	2.3	--	2.5	0.4
Machaeranthera canescens (hoary aster)	0.2	--	0.3	0.5	--	0.1
Microsteris gracilis (annual phlox)	1.6	--	--	6.5	--	2.6
Oenothera pallida (pale evening primrose)	0.9	3.0	0.1	3.0	0.5	X
Phlox longifolia (longleaf phlox)	1.3	--	--	--	--	--
Comandra umbellatum (bastard toadflax)	0.8	--	--	--	--	--
Achillea millefolium (yarrow)	0.7	0.1	0.3	--	--	X
*Tragopogon dubius** (yellow salsify)	--	--	0.1	--	--	X
Psoralea lanceolata (dune scurfpea)	--	--	--	20	--	--
Balsamorhiza careyana (Carey's balsamroot)	--	--	--	--	--	0.1
Lappula redowskii (Western stickseed)	--	--	--	--	--	X
Plantago patagonica (Indian wheat)	--	--	--	--	--	X
Poa scabrella (pine bluegrass)	--	X	--	--	--	--
Koeleria cristata (prairie junegrass)	--	X	--	--	--	--
Phacelia linearis (threadleaf scorpionweed)	--	--	--	--	--	X
Brodiaea douglasii (Douglas' clusterlily)	--	--	--	--	--	X
biotic crust	36.3	--	8.5	0.5	7.5	--
bare soil	40.3	78.8	32.5	40.5	54	60.9
Litter	37.6	14.1	58.1	57.5	59.5	5.4
Total cover (not including crust, bare soil, or litter)	**112.7**	**46.9**	**97.9**	**133**	**94.5**	**62.9**

* Introduced species.

X = Present but not counted in plot frames.

Table 11. Percent Frequency of Occurrence on PSN 12/14 Sites in 1998.

Species	Control	Plot 5	Plot 4	Plot 2	Plot 1	Road
*Bromus tectorum** (cheatgrass)	100	100	95	100	100	100
Ambrosia acanthicarpa (bur ragweed)	24	16	70	80	60	60
*Sisymbrium altissimum** (tumblemustard)	28	16	70	20	80	12
*Salsola kali** (Russian thistle)	12	76	30	20	80	48
Artemisia tridentata (big sagebrush)	16	4	10	--	60	8
Purshia tridentata (antelope bitterbrush)	4	--	--	--	--	--
Chrysothamnus viscidiflorus (green rabbitbrush)	12	--	--	--	--	4
Chrysothamnus nauseosus (gray rabbitbrush)	--	--	--	--	--	8
Poa sandbergii (Sandberg's bluegrass)	60	--	45	60	20	8
*Poa bulbosa** (bulbous bluegrass)	--	--	--	--	--	8
Stipa comata (needle-and-thread grass)	--	56	40	80	40	--
Oryzopsis hymenoides (Indian ricegrass)	4	28	--	--	--	--
Agropyron dasytachyum (thickspike wheatgrass)	--	8	--	--	--	--
Amsinckia lycopsoides (tarweed fiddleneck)	--	--	--	20	--	4
Cymopterus terebinthinus (turpentine parsley)	36	--	--	--	--	--
Descurainia pinnata (tansymustard)	--	4	--	--	--	--
Epilobium paniculatum (tall willowherb)	--	8	35	--	60	32
Eriogonum niveum (snow buckwheat)	8	--	5	--	--	16
Festuca octoflora (six weeks fescue)	--	--	--	--	--	16
Holosteum umbellatum (jagged chickweed)	96	24	55	60	100	72
Draba verna (spring whitlow)	76	--	--	--	--	28
*Lactuca serriola** (prickly lettuce)	--	--	65	--	100	16
Machaeranthera canescens (hoary aster)	8	--	10	20	--	4
Microsteris gracilis (annual phlox)	44	--	--	60	--	44
Oenothera pallida (pale evening primrose)	16	40	5	20	20	--
Phlox longifolia (longleaf phlox)	8	--	--	--	--	--
Comandra umbellatum (bastard toadflax)	12	--	--	--	--	--
Achillea millefolium (yarrow)	8	4	10	--	--	--
*Tragopogon dubius** (yellow salsify)	--	--	5	--	--	--
Psoralea lanceolata (dune scurfpea)	--	--	--	40	--	--
Balsamorhiza careyana (Carey's balsamroot)	--	--	--	--	--	4
biotic crust	84	--	35	20	20	--
bare soil	92	100	95	100	80	96
litter	100	96	100	100	100	8

* Introduced species.

Table 12. Percent Canopy Cover and Frequency of Occurrence on 2,4-D Site.

Species	Percent Cover	Percent Frequency
*Bromus tectorum** (Cheatgrass)	34.7	96
*Salsola kali** (Russian thistle)	6.2	56
*Sisymbrium altissimum** (tumblemustard)	1.0	20
Ambrosia acanthicarpa (bur ragweed	0.5	20
Descurainia spp (tansymustard)	0.2	8
Poa sandbergii (Sandberg's Bluegrass)	2.0	40
*Poa bulbosa** (bulbous bluegrass)	0.1	4
Festuca octoflora (six weeks fescue)	0.1	4
Rumex venosus (winged dock)	0.1	4
Lappula redowskii (stickseed)	0.1	4
Amsinckia lycopsoides (tarweed fiddleneck)	0.3	12
Holosteum umbellatum (jagged chickweed)	0.2	8
Draba verna (spring whitlow)	0.3	12
Plantago patagonica (Indian wheat)	0.1	4
Bare soil	81	96
Total Cover	**45.9**	

* Introduced species.

5.0 SAGEBRUSH PLANTINGS IN THE 200 AND 300 AREAS

5.1 216-A-25 EMERGENCY EXTENSION SITE

On February 11, 1998, a total of 1,000 sagebrush tubelings were planted in groups of three to mitigate for interim stabilization of the 216-A-25 emergency extension site. The sagebrush were planted by using a small straight crowbar to create a hole for planting the tubelings. Then the soil was gently pushed in to fill any void spaces around the roots. The soil moisture during planting conditions was ideal. A count of tubeling survival on August 18, 1998 showed an 84% survival for the 100 tubelings counted in the planted area.

5.2 300-FF-1

On October 16 – 17, 1998, a total of 24 antelope bitterbrush (*Purshia tridentata*) were salvaged from the perimeter of the 618-4 burial ground and moved 200 m. east. The salvaging effort was conducted to mitigate for the loss of mature shrubs on the 618-4 burial ground during grubbing and remediation of the site. The salvaged plants averaged 0.25 to 0.5 m in height and were replanted in groups of three over a 500 m^2 area. The plants were removed with a "1/4 yard backhoe" and moved directly to the planting hole with a minimum of handling.

The soil around the burial ground where the shrubs were salvaged had a thin veneer of fine soil covering a coarse sandy gravel. Using extreme care, the shrubs were lifted from the ground, taking as much soil as possible to reduce damage to the root systems. However, because the soil was so coarse, most of it fell apart during the extraction, breaking most of the fine roots. Before planting, the hole in which the salvaged plant was to be placed was filled with water and allowed to drain.

On August 31, 1998, the transplanted bitterbrush were examined for survival and all 24 plants had died. The loss of the fine roots during excavation of the plants is likely the major cause of the failure. A contributing factor may also have been the dry sandy soil at the transplant sites, even though water was provided during transplanting.

On December 2, 1998, a total of 293 two-year old sagebrush plants were planted over an area of 3,100 m^2 just north of the bitterbrush planting area. This planting was additional mitigation for the loss of shrubs on the 618-4 burial ground. Five rows of plants were placed in clusters of 3, spaced 0.5 to 1.0 meter apart, with each cluster 4.6 m apart.

On August 31, 1998, this planting was examined to determine survivorship. In row 1 the plants were placed with the root ball broken up to simulate a bare-root planting. Using this planting method, 14 out of 59 plants survived (69.5% survival). In rows 3 and 4, the root ball was moderately loosened and 78 out of 120 plants survived (65% survival). In rows 2 and 5, the planting was done with the root ball intact, producing 86 out of 114 surviving plants (75.4% survival). Keeping the root ball intact seems to be the most successful technique for planting 2-year old potted sagebrush plants. The overall survivorship for this planting was 70%.

5.3 200-ZP-1 PIPELINE

The 200-ZP-1 Injection well Pipeline is located on the western edge of the 200-West Area (Figure 1) On September 28, 1997, a total of 600 sagebrush tubelings were planted in the 200-ZP-1 pipeline corridor to replace habitat that was lost during construction of the 200-ZP-1 injection well system. After planting, the tubelings were watered because of dry soil conditions. In addition, Sandberg's bluegrass was planted at a seeding rate of 5 kg/ha along with snow buckwheat at 1.5 kg/ha.

On August 18, 1998, a total of 100 sagebrush were counted and 54% had survived. The early planting and dry soil conditions are probably contributing factors to the reduced survival counts. The revegetated area is relatively narrow (20 m wide) and bordered on both sides by mature stands of sagebrush. Although the survival count of the tubelings is lower than expected, a healthy seed supply exists along the perimeter of the site that should continue to increase the number of shrubs on the site. In fiscal year 1999, canopy cover measurements will be added to the vegetation monitoring on this site to document the establishment of understory species.

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APPENDIX A

1997 MONITORING RESULTS

Table A-1. Percent Canopy Cover on Horn Rapids Landfill for 1997.

Species	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6
Agropyron spp (wheatgrasses)	7.5	9.5	10.1	6.4	11.5	11.1
Salsola kali (Russian thistle)	2.2	2.6	1.6	8.6	13.3	1.5
Bromus tectorum (cheatgrass)	6	7.8	5.5	1.6	1.2	22.9
Amsinckia lycopsoides (tarweed)	--	--	--	--	--	0.6
Sisymbrium altissimum (tumblemustard)	0.2	0.1	0.4	0.5	0.9	0.1
Ambrosia acanthicarpa (bur ragweed)	0.2	1.4		0.3	0.4	1.8
Chenopodium sp (lambsquarter)	0.2	0.1	0.3	1.0	1.1	--
Convolvulus arvensis (field bindweed)	--	--	--	0.2	--	--
Holosteum umbellatum (jagged chickweed)	4.0	4.8	2.3	0.9	0.3	0.4
Lactuca serriola (prickly lettuce)	0.2	0.3	0.3	--	--	--
Draba verna (spring whitlow)	0.2	2.9	2.1	0.6	1.1	0.2
Medicago sativa (alfalfa)	--	0.1	--	--	--	--
Descurainia pinnata (tansymustard)	0.1	0.3	0.2	--	--	--
Epilobium paniculatum (tall willowherb)	--	--	0.2	0.2	--	--
Poa sandbergii (Sandberg's bluegrass)	--	--	0.1	--	--	--
Plantago patagonica (Indian wheat)	--	--	--	0.2	--	--
Erodium cicutarium (storksbill)	--	--	--	0.2	0.1	0.2
Agastache occidentalis (western horsemint)	--	--	--	0.2	--	--
Tragopogon dubius (yellow salsify)	0.8	0.1	--	--	--	--
Cardaria draba * (whitetop)	--	--	--	--	3 plants	--
Total	**21.6**	**30**	**23.1**	**20.9**	**29.9**	**38.8**

* Not counted in plot frames.

Table A-2. Percent Frequency of Occurrence on Horn Rapids Landfill for 1997.

Species	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6
Agropyron spp (wheatgrasses)	80	92	84	100	92	80
Salsola kali (Russian thistle)	68	84	64	96	96	40
Bromus tectorum (cheatgrass)	84	80	80	64	48	96
Amsinckia lycopsoides (tarweed)	--	--	--	--	--	4
Sisymbrium altissimum (tumblemustard)	8	4	16	20	36	4
Ambrosia acanthicarpa (bur ragweed)	8	36	--	12	16	52
Chenopodium sp (lambsquarter)	8	4	12	40	44	--
Convolvulus arvensis (field bindweed)	--	--	--	8	--	--
Holosteum umbellatum (jagged chickweed)	80	72	52	16	12	16
Lactuca serriola (prickly lettuce)	8	12	12	--	--	--
Draba verna (spring whitlow)	8	40	44	24	44	8
Medicago sativa (alfalfa)	--	4	--	--	--	--
Descurainia pinnata (tansymustard)	4	12	8	--	--	--
Epilobium paniculatum (tall willowherb)	--	--	8	8	--	--
Poa sandbergii (Sandberg's bluegrass)	--	--	4	--	--	--
Plantago patagonica (Indian wheat)	--	--	--	8	--	--
Erodium cicutarium (storksbill)	--	--	--	8	4	8
Agastache occidentalis (western horsemint)	--	--	--	8	--	--
Tragopogon dubius (yellow salsify)	12	4	--	--	--	--

Table A-3. Percent Canopy Cover on the Horseshoe Landfill in 1997.

Species	Waste Site	Reference Site
*Bromus tectorum** (cheatgrass)	36.1	25
Artemisia tridentata (big sagebrush)	5.5	10.1
Agropyron spicatum (bluebunch wheatgrass)	0.9	2.5
Poa sandbergii (Sandberg's bluegrass)	2.4	51.4
Sitanion hystrix (bottlebrush squirreltail)	1.1	--
Stipa comata (needle-and-thread grass)	--	0.1
*Poa bulbosa** (bulbous bluegrass)	0.1	--
Festuca octoflora (sixweeks fescue)	0.2	--
Oryzopsis hymenoides (Indian ricegrass)	0.1	0.1
*Sisymbrium altissimum** (tumblemustard)	2.2	0.1
*Melilotis officinalis** (sweet clover)	1.6	--
Epilobium paniculatum (tall willowherb)	1.6	0.1
*Lactuca serriola** (prickly lettuce)	1.8	--
Crepis atrabarba (slender hawksbeard)	0.7	4.7
*Kochia scoparia** (red belvedere)	0.1	--
*Salsola kali** (Russian thistle)	0.1	--
Descurainia sp (tansymustard)	0.2	--
Amsinckia lycopsoides (tarweed fiddleneck)	--	0.1
Chaenactis douglasii (hoary falseyarrow)	0.1	0.2
Erigeron filifolius (threadleaf fleabane)	0.8	1.2
Linum perenne (wild blueflax)	--	0.1
*Lepidium perfoliatum** (clasping pepperweed)	0.1	--
Lupinus sulphurous (sulfur lupine)	0.3	13.5
*Tragopogon dubius** (yellow salsify	--	0.5
Balsamorhiza careyana (Carey's balsamroot)	--	0.1
Machaeranthera canescens (hoary aster)	2.0	--
Biotic crust	--	88.3
Total (biotic crust not included)	**58**	**109.8**

* Introduced species.

Table A-4. Percent Frequency of Occurrence on the Horseshoe Landfill in 1997.

Species	Waste Site	Reference Site
*Bromus tectorum** (cheatgrass)	88	84
Artemisia tridentata (big sagebrush)	64	60
Agropyron spicatum (bluebunch wheatgrass)	36	4
Poa sandbergii (Sandberg's bluegrass)	56	92
Sitanion hystrix (bottlebrush squirreltail)	24	--
Stipa comata (needle-and-thread grass)	--	4
*Poa bulbosa** (bulbous bluegrass)	4	--
Festuca octoflora (sixweeks fescue)	8	--
Oryzopsis hymenoides (Indian ricegrass)	4	4
*Sisymbrium altissimum** (tumblemustard)	48	4
*Melilotis officinalis** (sweet clover)	64	--
Epilobium paniculatum (tall willowherb)	64	4
*Lactuca serriola** (prickly lettuce)	52	--
Crepis atrabarba (slender hawksbeard)	8	68
*Kochia scoparia** (red belvedere)	4	--
*Salsola kali** (Russian thistle)	4	--
Descurainia sp (tansymustard)	8	--
Amsinckia lycopsoides (tarweed fiddleneck)	--	4
Chaenactis douglasii (hoary falseyarrow)	4	8
Erigeron filifolius (threadleaf fleabane)	12	28
Linum perenne (wild blueflax)	--	4
*Lepidium perfoliatum** (clasping pepperweed)	4	--
Lupinus sulphurous (sulfur lupine)	12	76
*Tragopogon dubius** (yellow salsify	--	20
Balsamorhiza careyana (Carey's balsamroot)	--	4
Machaeranthera canescens (hoary aster)	40	--
Biotic crust	--	96

* Introduced species.

Table A-5. Percent Canopy Cover on Bridge Overlook Sites in 1997.

Species	Waste Site	Reference Site
*Bromus tectorum** (cheatgrass)	5.8	32.4
*Salsola kali** (Russian thistle)	1.4	0.2
Ambrosia acanthicarpa (bur ragweed)	1.8	0.6
Psoralea lanceolata (dune scurfpea)	1.4	1.2
Koeleria cristata (prairie junegrass)	0.1	--
Stipa comata (needle-and-thread grass)	0.7	--
Gilia leptomeria (great basin gilia)	0.2	0.2
Mentzelia albicaulis (whitestem stickleaf)	0.2	--
Oenothera pallida (pale evening primrose)	0.1	0.1
Descurainia sp. (tansymustard)	1.7	--
Cryptantha circumscissa (matted cryptantha)	0.1	0.2
Eriogonum niveum (snow buckwheat)	--	12.1
Artemisia tridentata (big sagebrush)	--	4.2
Purshia tridentata (antelope bitterbrush)	--	6.5
Chrysothamnus viscidiflorus (gray rabbitbrush)	--	1.5
Grayia spinosa (spiny hopsage)	X	3.5
Oryzopsis hymenoides (Indian ricegrass)	X	1.5
Festuca octoflora (six-weeks fescue)	--	0.1
Cymopterus terebinthinus (spring turpentine parsley)	X	0.6
Layia glandulosa (white-daisy tidytips)	--	0.1
Comandra umbellata (bastard toadflax)	--	0.9
Amsinckia lycopsoides (tarweed fiddleneck)	X	0.1
Biotic crust	--	21.8
Total (biotic crust not included)	**13.5**	**66**

* Introduced species.

X = Present but not counted in plot frames.

Table A-6. Percent Frequency of Occurrence on Bridge Overlook Sites in 1997.

Species	Waste Site	Reference Site
*Bromus tectorum** (cheatgrass)	60	84
*Salsola kali** (Russian thistle)	36	8
Ambrosia acanthicarpa (bur ragweed)	32	24
Psoralea lanceolata (dune scurfpea)	16	8
Koeleria cristata (prairie junegrass)	4	--
Stipa comata (needle-and-thread grass)	8	--
Gilia leptomeria (great basin gilia)	8	8
Mentzelia albicaulis (whitestem stickleaf)	8	--
Oenothera pallida (pale evening primrose)	4	4
Descurainia sp. (tansymustard)	12	--
Cryptantha circumscissa (matted cryptantha)	4	8
Eriogonum niveum (snow buckwheat)	--	28
Artemisia tridentata (big sagebrush)	--	16
Purshia tridentata (antelope bitterbrush)	--	12
Chrysothamnus viscidiflorus (gray rabbitbrush)	--	4
Grayia spinosa (spiny hopsage)	--	8
Oryzopsis hymenoides (Indian ricegrass)	--	4
Festuca octoflora (six-weeks fescue)	--	4
Cymopterus terebinthinus (turpentine parsley)	--	4
Layia glandulosa (white-daisy tidytips)	--	4
Comandra umbellata (bastard toadflax)	--	16
Amsinckia lycopsoides (tarweed fiddleneck)	--	4
Biotic crust	--	56

* Introduced species.

Table A-7. Percent Canopy Cover at PSN 72/82 Well Mound Sites in 1997.

Species	Waste Site	Reference Site
*Bromus tectorum** (cheatgrass)	23.1	40.8
*Salsola kali** (Russian thistle)	2.5	6.4
Ambrosia acanthicarpa (bur ragweed)	2.0	0.1
Oenothera pallida (pale evening primrose)	0.5	0.1
Artemisia tridentata (big sagebrush)	3.6	16
Chrysothamnus nauseosus (gray rabbitbrush)	0.1	0.6
Grayia spinosa (spiny hopsage)	--	1.5
Koeleria cristata (prairie junegrass)	0.1	--
Oryzopsis hymenoides (Indian ricegrass)	0.3	--
Poa sandbergii (Sandberg's bluegrass)	0.2	--
Sitanion hystrix (bottlebrush squirreltail)	0.1	--
Stipa comata (needle-and-thread grass)	0.5	--
Amsinckia tessellata (devil's lettuce)	0.2	0.1
*Sisymbrium altissimum** (tumblemustard)	0.5	0.1
Descurainia pinnata (tansymustard)	0.3	1.4
Fritillaria pudica (yellowbell)	0.1	0.8
Erodium cicutarium (storksbill)	0.1	0.2
Balsamorhiza careyana (Carey's balsamroot)	--	0.8
Comandra umbellata (bastard toadflax)	--	0.6
Machaeranthera canescens (hoary aster)	--	0.1
Biotic crust	0.1	29.4
Total cover (biotic crust not included)	**34.2**	**69.6**

* Introduced species.

Table A-8. Percent Frequency of Occurrence at PSN 72/82 Well Mound Sites in 1997.

Species	Waste Site	Reference Site
*Bromus tectorum** (cheatgrass)	88	96
*Salsola kali** (Russian thistle)	80	28
Ambrosia acanthicarpa (bur ragweed)	80	4
Oenothera pallida (pale evening primrose)	20	4
Artemisia tridentata (big sagebrush)	28	52
Chrysothamnus nauseosus (gray rabbitbrush)	4	4
Grayia spinosa (spiny hopsage)	--	4
Koeleria cristata (prairie junegrass)	4	--
Oryzopsis hymenoides (Indian ricegrass)	12	--
Poa sandbergii (Sandberg's bluegrass)	8	--
Sitanion hystrix (bottlebrush squirreltail)	4	--
Stipa comata (needle-and-thread grass)	20	--
Amsinckia tessellata (devil's lettuce)	8	4
*Sisymbrium altissimum** (tumblemustard)	20	4
Descurainia pinnata (tansymustard)	12	36
Fritillaria pudica (yellowbell)	4	32
Erodium cicutarium (storksbill)	4	8
Balsamorhiza careyana (Carey's balsamroot)	--	12
Comandra umbellata (bastard toadflax)	--	4
Machaeranthera canescens (hoary aster)	--	4
Biotic crust	4	72

* Introduced species.

Table A-9. Percent Canopy Cover for PSN 12/14 in 1997.

Species	Reference	Plot 5	Plot 4	Plot 2	Plot 1	Road
*Bromus tectorum** (cheatgrass)	52.3	13.7	42.9	14.5	56.5	32.3
Ambrosia acanthicarpa (bur ragweed)	0.4	3.2	6.0	4.5	0.5	3.4
*Sisymbrium altissimum** (tumblemustard)	0.4	--	16	1.0	1.5	1.1
*Salsola kali** (Russian thistle)	--	0.9	4.0	1.5	2.0	0.7
Artemisia tridentata (big sagebrush)	15.6	--	1.5	0.5	--	--
Purshia tridentata (antelope bitterbrush)	2.1	--	--	--	--	--
Poa sandbergii (Sandberg's bluegrass)	14.6	0.1	0.3	--	--	--
Stipa comata (needle-and-thread grass)	--	6.8	3.0	3.5	3.0	--
Koeleria cristata (prairie junegrass)	--	0.1	--	--	--	--
Amsinckia tessellata (devil's lettuce)	--	--	0.1	--	--	--
Cymopterus terebinthinus (turpentine parsley)	0.7	--	--	--	--	--
Descurainia pinnata (tansymustard)	0.1	0.9	--	--	--	--
Draba verna (spring whitlow)	2.5	--	--	--	--	--
Epilobium paniculatum (tall willowherb)	--	--	0.3	0.5	1.5	0.1
Eriogonum niveum (snow buckwheat)	--	0.6	--	--	--	--
Festuca octoflora (six weeks fescue)	--	--	--	--	--	0.5
Holosteum umbellatum (jagged chickweed)	0.8	--	--	--	--	0.3
*Lactuca serriola** (prickly lettuce)	--	--	0.8	--	1.0	0.2
Machaeranthera canescens (hoary aster)	--	--	0.3	--	--	--
Microsteris gracilis (annual phlox)	1.1	--	--	--	--	0.3
Oenothera pallida (pale evening primrose)	--	0.2	0.3	3.5	--	--
Phlox longifolia (longleaf phlox)	0.1	--	0.1	--	--	--
Rumex venosus (winged dock)	--	--	--	0.5	--	--
Biotic crust	52.5	--	38.5	--	0.5	--
Bare soil	20.2	86.3	20.9	80.5	30	--
Total cover (not including crust or bare soil)	**90.7**	**26.5**	**75.6**	**30**	**66**	**38.9**

* Introduced species.

Table A-10. Percent Frequency of Occurrence on PSN 12/14 Sites in 1997.

Species	Reference	Plot 5	Plot 4	Plot 2	Plot 1	Road
*Bromus tectorum** (cheatgrass)	100	96	95	100	80	96
Ambrosia acanthicarpa (bur ragweed)	16	88	45	80	20	56
*Sisymbrium altissimum** (tumblemustard)	16	--	70	40	60	24
*Salsola kali** (Russian thistle)	--	36	65	60	80	28
Artemisia tridentata (big sagebrush)	32	--	10	20	--	--
Purshia tridentata (antelope bitterbrush)	8	--	--	--	--	--
Poa sandbergii (Sandberg's bluegrass)	48	4	10	--	--	--
Stipa comata (needle-and-thread grass)	--	56	20	40	20	--
Koeleria cristata (prairie junegrass)	--	4	--	--	--	--
Amsinckia tessellata (devil's lettuce)	--	--	5	--	--	--
Cymopterus terebinthinus (turpentine parsley)	8	--	--	--	--	--
Descurainia pinnata (tansymustard)	4	36	--	--	--	--
Draba verna (spring whitlow)	60	--	--	--	--	--
Epilobium paniculatum (tall willowherb)	--	--	10	20	60	4
Eriogonum niveum (snow buckwheat)	--	4	--	--	--	--
Festuca octoflora (six weeks fescue)	--	--	--	--	--	20
Holosteum umbellatum (jagged chickweed)	12	--	--	--	--	12
*Lactuca serriola** (prickly lettuce)	--	--	30	--	40	8
Machaeranthera canescens (hoary aster)	--	--	10	--	--	--
Microsteris gracilis (annual phlox)	44	--	--	--	--	12
Oenothera pallida (pale evening primrose)	--	8	10	40	--	--
Phlox longifolia (longleaf phlox)	4	--	5	--	--	--
Rumex venosus (winged dock)	--	--	--	20	--	--
Biotic crust	72	--	70	--	20	--
Bare soil	64	100	70	100	60	--

* Introduced species.

APPENDIX B

1996 MONITORING RESULTS FOR HORN RAPIDS LANDFILL AND HORSESHOE LANDFILL

Table B-1. Percent Canopy Cover on Horn Rapids Landfill in 1996.

Plant Name	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6
Agropyron spp (wheatgrasses)	11	5.2	9.3	25.9	12.8	12
Salsola kali (Russian thistle)	22.7	9.8	12.2	6.0	8.4	14.7
Bromus tectorum (cheatgrass)	1.8	1.1	1.7	0.3	0.1	2.8
Amsinckia lycopsoides (tarweed)	0.3	0.6	0.1	0.1	0.3	0.4
Sisymbrium altissimum (tumblemustard)	1.3	0.4	0.1	0.2	0.3	0.4
Triticum sp (wheat)	2.6	0.3	0.7	0	0	5.6
Ambrosia acanthicarpa (bur ragweed)	1.2	0.7	0.1	0.8	0.9	2.0
Chenopodium sp (lambsquarter)	1.0	4.8	2.4	1.7	1.2	0.1
Lactuca serriola (prickly lettuce)	0.1	0.2	0	0.1	0.1	0
Erodium cicutarium (storksbill)	0.2	0	0	0.1	0	0
Total	**41.9**	**23.2**	**26.8**	**35**	**24.2**	**38.1**

Table B-2. Percent Frequency of Occurrence on Horn Rapids Landfill in 1996.

Plant Name	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6
Agropyron spp (wheatgrasses)	92	88	100	100	100	92
Salsola kali (Russian thistle)	100	100	100	100	100	100
Bromus tectorum (cheatgrass)	16	24	12	12	4	36
Amsinckia lycopsoides (tarweed)	12	4	4	4	12	16
Sisymbrium altissimum (tumblemustard)	32	16	4	8	12	16
Triticum sp (wheat)	44	12	28	0	0	32
Ambrosia acanthicarpa (bur ragweed)	28	8	4	12	36	60
Chenopodium sp (lambsquarter)	20	76	76	48	28	4
Lactuca serriola (prickly lettuce)	0	4	8	4	4	4
Erodium cicutarium (storksbill)	0	8	0	0	4	0

Table B-3. Percent Canopy Cover on the Horseshoe Landfill in 1996.

Plant Name	Percent Cover
*Melilotis officinalis** (sweet clover)	7.8
*Bromus tectorum** (cheatgrass)	7.2
Artemisia tridentata (big sagebrush)	2.8
Descurainia sp (tansymustard)	2.7
*Sisymbrium altissimum** (tumblemustard)	2.1
Epilobium paniculatum (tall willowherb)	1.2
Agropyron spicatum (bluebunch wheatgrass)	1.1
Crepis atrabarba (slender hawksbeard)	1.0
Lupinus sulphurous (sulfur lupine)	0.7
Erigeron filifolius (threadleaf fleabane)	0.7
Linum perenne (wild blueflax)	0.7
*Lactuca serriola** (prickly lettuce)	0.6
*Salsola kali** (Russian thistle)	0.5
*Kochia scoparia** (red belvedere)	0.5
Poa sandbergii (Sandberg's bluegrass)	0.3
Sitanion hystrix (bottlebrush squirreltail)	0.3
*Lepidium perfoliatum** (clasping pepperweed)	0.2
Chenopodium leptophyllum (slimleaf goosefoot)	0.2
Amsinckia lycopsoides (tarweed fiddleneck)	0.2
Chaenactis douglasii (hoary falseyarrow)	0.2
Machaeranthera canescens (hoary aster)	0.2
Ambrosia acanthicarpa (bur ragweed)	0.1
Chrysothamnus nauseosus (gray rabbitbrush)	0.1
Total	**31.4**

* Introduced species.

Table B-4. Percent Frequency of Occurrence on the Horseshoe Landfill in 1996.

Plant Name	Percent Frequency
*Bromus tectorum** (cheatgrass)	92
Artemisia tridentata (big sagebrush)	52
Agropyron spicatum (bluebunch wheatgrass)	44
*Sisymbrium altissimum** (tumblemustard)	44
*Melilotis officinalis** (sweet clover)	40
Epilobium paniculatum (tall willowherb)	28
*Lactuca serriola** (prickly lettuce)	24
Crepis atrabarba (slender hawksbeard)	20
*Kochia scoparia** (red belvedere)	20
*Salsola kali** (Russian thistle)	20
Descurainia sp (tansymustard)	12
Poa sandbergii (Sandberg's bluegrass)	12
Sitanion hystrix (bottlebrush squirrel)	12
Amsinckia lycopsoides (tarweed fiddleneck)	8
Chaenactis douglasii (hoary falseyarrow)	8
Chenopodium leptophyllum (slimleaf goosefoot)	8
Erigeron filifolius (threadleaf fleabane)	8
*Lepidium perfoliatum** (clasping pepperweed)	8
Linum perenne (wild blueflax)	8
Lupinus sulphurous (sulfur lupine)	8
Machaeranthera canescens (hoary aster)	8
Ambrosia acanthicarpa (bur ragweed)	4
Chrysothamnus nauseosus (gray rabbitbrush)	4

* Introduced species.

APPENDIX C

NAME CHANGES INCLUDED IN INTEGRATED TAXONOMIC INFORMATION SYSTEM

Name changes included in Integrated Taxonomic Information System (ITIS 1997).

Recent name changes for species mentioned in this report. The first name is that used in Hitchcock and Cronquist (1973) and the second is the more recent version.

Chrysothamnus nauseosus = *Ericameria nauseosa* ssp. *nauseosa* var. *nauseosa*
Cymopteris terebinthinus = *Pteryxia terebinthina* var. *terebinthina*
Epilobium paniculatum = *Epilobium brachycarpum*
Festuca octoflora = *Vulpia octoflora* var. *octoflora*
Koeleria cristata = *Koeleria macrantha*
Microsteris gracilis = *Phlox gracilis* ssp. *gracilis*
Oryzopsis hymenoides = *Achnatherum hymenoides*
Poa sandbergii = *Poa secunda*
Psoralea lanceolata = *Psoralidium lanceolatum*
Sitanion hystrix = *Elymus elymoides* ssp. *elymoides*
Stipa comata = *Hesperostipa comata* ssp. *comata*

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