Interim Reclamation Report Basalt Waste Isolation Project Boreholes 1989

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March 1990

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Richland, Washington 99352

SUMMARY

In 1968, a program was started to assess the feasibility of storing Hanford Site defense waste in deep caverns constructed in basalt. This program was expanded in 1976 to include investigations of the Hanford Site as a potential location for a mined commercial nuclear waste repository. An extensive site characterization program (the Basalt Waste Isolation Program - BWIP) was begun to determine the feasibility of using the basalts beneath the Hanford Site for the repository. Site research focused primarily on determining the direction and speed of ground-water movement, the uniformity of basalt layers, and tectonic stability. Some 98 boreholes were sited, drilled, deepened, or modified by BWIP between 1977 and 1988 to test the geologic properties of the Site. On December 22, 1987, President Reagan signed into law the Nuclear Waste Policy Amendments Act of 1987, which effectively stopped all repository-related activities except reclamation of disturbed lands at the Hanford Site.

This report describes the development of the reclamation program for the BWIP boreholes, its implementation, and preliminary estimates of its success. The goal of the reclamation program is to return sites disturbed by the repository program as nearly as practicable to their original conditions using native plant species.

Constraints on the reclamation program include climatic factors, edaphic (soil) characteristics, competition from native and non-native species, and seed germination and growth characteristics of the desired species. The Hanford Site experiences a net input to soil moisture between November and February and a severe moisture deficit from July to October. Summer storms occasionally drop large amounts of moisture, but these are very infrequent and cannot be relied on to sustain plant growth. Precipitation during any period is unreliable: droughts have occurred in 1 of 5 years. Temperatures during the winter months are usually not so low as to preclude some plant growth at that time: indeed most of the shrubs and grasses are physiologically very active during this period. However, arctic air masses occasionally push the temperatures down to -20°C or -30°C . At these temperatures, damage to unprotected growing plants may be severe. The transition period between March and June may be of primary importance to plant establishment. Temperatures ameliorate greatly from the winter lows, and moisture inputs usually increase. However, 15% of years since 1912 have failed to receive 2.5 cm of precipitation during this period. Thus, providing adequate moisture to revegetated plants will be a critical to their success, at least during the first growth year. The soils of the BWIP boreholes differ with location, ranging from sands where water holding capacity is low and susceptibility to erosion high, to silt loams, where conditions are much more conducive to reclamation.

Plant communities at the boreholes also vary with location. Plant communities were characterized by the predominant shrub and grass species present in assessment plots located near each borehole. Shrub components include big sagebrush (*Artemisia tridentata*), grey rabbitbrush (*Chrysothamnus nauseosus*), green rabbitbrush (*C. viscidiflorus*), bitterbrush (*Purshia tridentata*), and spiny hopsage (*Atriplex spinosa*). Grass components are dominated either by cheatgrass (*Bromus tectorum*) or Sandberg bluegrass (*Poa sandbergii*). Bottlebrush squirreltail (*Sitanion hystrix*) occurred at most locations, as did needle-and-thread grass (*Stipa comata*). Indian ricegrass (*Oryzopsis hymenoides*) was common in sandy locations.

Demolition and abandonment began in 1988 with the removal of aboveground facilities such as trailers and portable equipment. Aboveground utilities were removed and disposed of according to pertinent regulations. Where required, wells were decommissioned or converted to alternative uses. At sites where they were incompatible with seedbed preparation, surface materials were trucked to Hanford Pit 25. Where present, mud pit contents were pumped and disposed of according to pertinent regulations. Excess material was graded and blended to approximate surrounding contours.

Revegetation of boreholes was divided into two phases. Phase I included revegetation of boreholes where all construction and well modifications had been completed before October 1, 1988. Revegetation of Phase I sites occurred between October 1 and October 31, 1988. Phase II sites will be revegetated in 1989.

After construction and gravel removal was completed and sites had been restored to their original contours, all sites to be reseeded were machine ripped to a minimum depth of 30 cm and disked to a minimum depth of 15 cm.

An organic mulch of certified weed-free chopped straw was mechanically blown over the seedbed at a rate of 4500 kg/ha. Specific seeding mixes and depths of seeding were recommended for each revegetation site based on analysis of the surrounding plant community. Grasses were drilled using a John Deere/Van Brunt drill equipped with a furrowing device mounted ahead of the disk openers such that seeds were emplaced only in the bottom of the furrows. The furrowing device was set to provide a furrow no shallower than 7.5 cm and no deeper than 12.5 cm. Openers were spaced at 35 cm. After seeding grasses, 15-cm tubelings shrubs were planted at densities appropriate to each site.

To track the development of vegetation in the target habitats, data on percent cover and plant density were obtained from the 17 control plots located near 15 borehole sites representing 9 of the 10 shrub types. Cheatgrass was ubiquitous in all plots except the riparian habitat at borehole DC-14, ranging in cover from a low of 4% to a high of nearly 60% in the burned habitats. In most cases, cheatgrass cover was lower in 1989 than in 1988. Native grasses were present in all habitats except the riparian but predominated in only half. Sandberg bluegrass was the most prevalent native grass, occurring in 6 of the 10 habitat types. Bottlebrush squirreltail did not appear in the transect estimates, but was present in the majority of species tallies, consistent with a species that is common but sparsely distributed within habitats. The distribution of both the rabbitbrush species was highly patchy. Native forbs constitute a small portion of the total ground cover, but occur throughout the habitats. The predominant alien annual species found in the control plots were cheatgrass, bur ragweed (*Ambrosia acanthicarpa*), Russian thistle (*Salsola kali*), and spring whitlow-grass (*Draba verna*).

Vegetative growth on the revegetated areas was measured on March 21 to 31, 1989 (May 11 for DC-7/8) using a stratified random sampling scheme based on 1-m-length plots. Strata were distributed evenly over each site at the rate of 1 per 0.1 ha, with one plot located randomly within each stratum. In general, emergence rates of bluegrass were much higher than emergence of bottlebrush squirreltail, Indian ricegrass, or needle-and-thread. Grass failed to emerge on sites DC-7/8 and DH-26; there were fewer than 6.2 plants per m² at DB-12, DB-14, DC-15, and DC-23. The remaining sites had more than 25 plants per m². Emergence rates were lower in sandy areas than elsewhere. Seeding rate differences had little effect on the subsequent density of emergent bluegrass. Effects of seeding rate on bluegrass development were weak. Furrow orientation (north-south versus east-west) bore no significant relationship to the density of emergent bluegrass when the effects of seeding density are accounted for, nor were there significant relationships to plant development rates. Big sagebrush mortality averaged 43% over all sites.

As of March 1989, cover by Sandberg bluegrass was consistent with the reclamation objective (establishment of grass and shrub cover consistent with surrounding habitat) on all Phase I sites except DB-12, DB-14, DC-15, DC-23, DC-7/8, and DH-26. Emergence of bottlebrush squirreltail, needle-and-thread, and junegrass was less than necessary to meet the objective at all sites. The six sites exhibiting total or near-total failure of bluegrasses will require remediation in 1989. An extremely low-temperature arctic air mass entered the Pasco Basin early in February 1989, with temperatures below -25°C. Most of the grasses showed frost burns from this low-temperature event. Because of this damage, many plants deemed alive at the end of March were unlikely to survive another month. Whether or not sufficient grasses survive cannot be assessed until the fall 1989 growth period.

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1.0 INTRODUCTION

The restoration of areas disturbed by activities of the Basalt Waste Isolation Project (BWIP) constitutes a unique operation at the U.S. Department of Energy's (DOE) Hanford Site, both from the standpoint of restoration objectives and the time frame for accomplishing these objectives. The BWIP reclamation program comprises three separate projects: borehole reclamation, Near Surface Test Facility (NSTF) reclamation, and Exploratory Shaft Facility (ESF) Reclamation. This report describes the development of the reclamation program for the BWIP boreholes, its implementation, and preliminary estimates of its success.

1.1 BWIP HISTORY

In 1968, a program was started to assess the feasibility of storing Hanford Site defense waste in deep caverns constructed in basalt (Deju 1978). In 1976, the National Waste Terminal Storage Program, initiated by the DOE, expanded the studies of basalt to investigate the potential for a national commercial nuclear waste repository at Hanford. Eight other locations in a variety of host media (i.e., type of rocks) were also defined as possible commercial waste disposal locations by the initial studies (Babad 1985).

On January 7, 1983, President Reagan signed into law the Nuclear Waste Policy Act of 1982 (Public Law 97-425), which mandates the development of repositories in deep geologic formations as the primary disposal strategy for high-level commercial wastes (Babad 1985).

The Nuclear Waste Policy Act of 1982 required DOE to develop specific guidelines for establishing a repository site. In December 1984, the DOE published final guidelines for narrowing the nine sites under investigation by DOE to five. The five sites nominated were: Richton Dome, Mississippi; Yucca Mountain, Nevada; Deaf Smith County, Texas; Davis Canyon, Utah; and the Reference Repository Location on the Hanford Site in Washington State (Babad 1985). The Reference Repository Location was selected in 1981 after extensive geotechnical studies. This location is a 4660-ha site within the Hanford Site that met all of the initial DOE guidelines for safety that were required before site characterization.

Geologic and hydrologic field data were needed to determine if the Reference Repository Location on the Hanford Site could become one of the three candidate sites recommended to the President for final approval. An extensive site characterization program (BWIP) was begun to determine the feasibility of using the basalts beneath the Hanford Site for the repository. Site

research focused primarily on determining the direction and speed of ground-water movement, the uniformity of basalt layers, and tectonic stability.

Boreholes were necessary to test the geology of the Hanford Site. Approximately 2200 boreholes have been drilled on and adjacent to the Hanford Site since the early 1900s. These boreholes may be grouped into the following five categories: 1) water supply, including approximately 200 hand-dug wells along the Columbia River by turn-of-the-century homesteaders; 2) oil-gas exploration and production, including wells drilled into basalt between 1917 and 1931 in a small gas field located on the northern limb of Rattlesnake Mountain; 3) surveillance and waste management, including dry wells to characterize and monitor waste-disposal facilities and deeper boreholes to monitor potential ground-water contamination; 4) nuclear power plant siting, including boreholes drilled to support the siting and construction of nuclear power plants on the Site; and 5) repository feasibility and siting, including the 98 boreholes sited, drilled, deepened, or modified by BWIP between 1977 and 1988 to test the geologic properties of the Site (DOE 1988).

On December 22, 1987, President Reagan signed into law the Nuclear Waste Policy Amendments Act of 1987 that mandated, among other things, that DOE must 1) proceed with the orderly phase out of all site characterization activities (other than reclamation activities) at all candidate sites except Yucca Mountain and 2) suspend site characterization activities at all candidate sites, except for Yucca Mountain, within 90 days of the date of enactment of the Nuclear Waste Policy Amendments Act of 1987. This law effectively stopped all site characterization for BWIP at Hanford and established Yucca Mountain, Nevada, as the official site for the repository.

No specific standards and criteria were spelled out in the Nuclear Waste Policy Amendments Act that governed the reclamation of the Hanford Site;

therefore, other guidelines and commitments were applied. The Nuclear Waste Policy Act requires DOE to reclaim sites disturbed during civilian radioactive waste management activities. In Section 7.6 of the Nuclear Waste Policy Act document, Mission Plan for the Civilian Radioactive Waste Management Program (DOE 1985), the guidelines for decommissioning sites found unsuitable for repository development are presented. In general, the Mission Plan states that a site shall be returned as nearly as practicable to its original condition, which is the objective of the BWIP reclamation project. Although the Hanford Site was not determined to be unsuitable for licensing, for purposes of decommissioning, the provisions spelled out in the DOE Mission Plan were applied to BWIP closeout.

1.2 SITE HISTORY

The Hanford Site constitutes a significant preserve of natural resources in the state of Washington because of its unique history and location. This history is outlined in the following subsections.

1.2.1 Pre-Nuclear History

Lewis and Clark, who traveled the Columbia and Snake rivers during their 1803-1806 exploration of the Louisiana Territory, were the first Euro-Americans in the region. Fur trappers soon followed, passing through on their way to more productive lands to the west. In the 1860s, merchants established stores, a freight depot, and the White Bluffs Ferry on the Hanford reach of the Columbia River. Chinese miners began to work the gravel bars for gold. In the 1880s, cattle ranches and farms developed. In the early twentieth century, the small towns of Hanford, White Bluffs, and Ringold thrived. These towns were razed and the people relocated after the U.S. government acquired the land for nuclear materials production in the early 1940s (Cushing 1987).

1.2.2 Nuclear (Since 1943) History

The Hanford Site was chosen in 1943 as the location for the plutonium production facilities needed to produce an atomic bomb. Three reactors began producing plutonium in 1944-1945. Chemical separations facilities began operating in 1944, separating plutonium from the irradiated uranium fuel elements (Chatters 1989).

After World War II, the reactors continued to produce plutonium. In August 1947, a major expansion was announced, including construction of six additional reactors.

In 1964, a reduction of nuclear arms production began. By 1972 all reactors were shut down except the N Reactor, and all of the separation plants were shut down except the Plutonium-Uranium Extraction (PUREX) Plant (Chatters 1989).

In the 1970s, the Washington Public Power Supply System, a not-for-profit joint operating agency of public utilities in the Pacific Northwest, began constructing three nuclear power reactors in the southeastern portion of the Hanford Site. Reactor WNP-2 has been generating electricity for commercial use since 1984. Reactors WNP-1 and WNP-4 have been mothballed (an extended construction delay) (Chatters 1989).

Today the Hanford Site is managed by DOE. The Hanford Mission includes conducting research, developing new technology, managing the disposal of radioactive wastes, and conducting environmental, health, monitoring, and safety studies. The only large-scale DOE reactor operating on the Hanford Site is the Fast Flux Test Facility located in the 400 area. This sodium-cooled reactor began full-scale operations in April 1982 as a test reactor for testing reactor fuels and materials (Chatters 1989).

Because public access to the Hanford Site has been restricted since the 1940s, it is the only expanse of nearly-pristine shrub-steppe habitat in the state of Washington. Consequently, much of the Site is designated as wildlife refuges and ecological reserves.

1.3 SITE DESCRIPTION

The Hanford Site is located in southeastern Washington State, occupying an area of approximately 1450 km² (Figure 1). The Hanford Site lies within the Pasco Basin, the structural and topographic low part of the Columbia Plateau. The terrain of the basin is relatively flat with subtle topographical features formed by large, glacially related floods that occurred in the Pasco Basin more than 13,000 years ago. The semiarid land has a sparse covering of desert shrubs and drought-resistant grasses. The most broadly distributed vegetation type on the Site is the sagebrush/cheatgrass/bluegrass community.

Figure 1. Location of the Pacific Northwest coastal region and surrounding area.

2.0 RECLAMATION PROGRAM

The DOE determined on the basis of commitments made in several National Environmental Policy Act (NEPA) documents that sites disturbed by BWIP would be restored to conditions similar to natural plant communities adjacent to disturbed areas unless alternative land uses were to be implemented (DOE 1978, 1982, 1986). Primary goals were to establish self-sustaining vegetation and to produce cover conditions comparable to those existing prior to the disturbance. Restoration focused on re-establishment of native plant species and suppression of invading exotic species. Disturbed sites located entirely within plant communities dominated by exotic species would not be required to be reclaimed with native species.

For the purpose of reclamation, natural vegetation is defined as the pre-existing vegetation of sites prior to BWIP disturbance and can generally be determined by the plant communities surrounding a disturbed site. Native vegetation is defined as plants endemic to southeastern Washington as opposed to exotic vegetation. Exotic or alien vegetation is defined as plants that are not native to southeastern Washington (i.e., have been imported in historic times from outside this region).

The DOE has determined in its reclamation plan for the boreholes that recovery of natural vegetation on disturbed sites and eventual restoration success will be evaluated for 1 year after completion of the reclamation activities, and a determination will be made within that time relative to the need for additional reclamation work. Success will be based on how well the planted stands resemble nearby undisturbed plant communities.

2.1 STATUS OF BOREHOLES AT CLOSE OF SITE CHARACTERIZATION

The following paragraphs describe the numerous boreholes that were drilled or modified for use in the BWIP. The boreholes varied in diameter from 76 to 660 mm, and in depth from 6 m to nearly 1526 m. All were cased from the surface to appropriate testing levels.

Some borehole cleanup and/or site modification was conducted at six waste management and water supply boreholes (DB-4, DB-5, Benson Ranch, Ford, O'Brian, and Enyeart). Eight other existing waste management and reactor siting holes were extended into the Wanapum Basalt (BH-17, DB-1, DB-2, DB-11, DB-12, DB-14, DB-15, and DH-8B).

Between 1977 and 1982, eight deep core holes (DC-2, DC-4, DC-6, DC-8, DC-12, DC-14, DC-15, and DC-16A) and four rotary boreholes (DC-3, DC-5, DC-7, and DC-16C) were drilled into or through the Umtanum flow to evaluate geohydrologic properties of potential host rock and to support site identification. One existing water-supply borehole, the McGee well, was also deepened through the Umtanum flow.

Two shallow core holes (DC-10 and DC-11) were drilled on Gable Mountain during siting of the NSTF. A series of shallow core holes (CH-1 through CH-6)

were also drilled on Gable Mountain for potential use in borehole seal tests. Surface reclamation of these sites will be completed during reclamation of the NSTF. One core hole (DC-18) was drilled through the Wanapum Basalt between Gable Mountain and Gable Butte for tectonic and hydrochemical investigation.

Eighteen DH-series core holes were drilled or sited to develop the subsurface stratigraphy of the Ringold Formation and to assess tectonic deformation across geophysical anomalies.

Within the Reference Repository Location, several RRL series boreholes were drilled for site geohydrologic investigation and seismic monitoring purposes. The three deep core and rotary-core holes RRL-2A, RRL-6B, and RRL-14 and rotary hole RRL-2C were drilled through the Umtanum flow. Rotary-core hole RRL-17 was drilled through the Cohasset flow. One pump test hole (RRL-2B) was drilled into the Rocky Coulee flowtop. Four foundation test holes (FH-1 through FH-4) were within the Exploratory Shaft (ES) site pad. They were backfilled and abandoned prior to the reclamation program. Reclamation of the RRL-2-series borehole sites is covered as part of the ESF reclamation.

Seismic monitoring holes RRL-3, RRL-4, RRL-5, RRL-7, RRL-8, RRL-9, RRL-10, and RRL-16 were drilled to or through the first basalt flow. Holes RRL-11, RRL-12, RRL-13 were drilled as entry holes

only. RRL-13 was later extended as DC-19A. Borehole RRL-1 was abandoned and backfilled when a bit was lost in the hole at a depth of approximately 242 ft. One core hole (UC-1) was a shallow large diameter core hole in the Umatilla Member.

Six series of piezometric monitoring boreholes were drilled. Each borehole site contained one or more of the following borehole types: basal Ringold Formation-Rattlesnake Ridge interbed core holes (DC-19A, DC-20A, DC-22A); rotary pumping holes for the Mabton interbed-upper Wanapum Basalt (DC-16B, DC-20B, DC-22B); rotary holes through the Mabton interbed into the upper Wanapum Basalt (DC-19D, DC-20D, DC-22D); deep multiple zone rotary holes (DC-19C, DC-20C, DC-22C, DC-23GR, DC-24CX, and DC-25CX). Rotary borehole DC-23W was drilled into the Grande Ronde Basalt. Boreholes DC-24W and DC-32CX consisted of a site (drill pad) and entry hole. Borehole DC-33CX consisted of a site only; the borehole was never drilled.

Site-specific data regarding location, size of disturbed area, time since disturbance, surface condition as of October 1987, herbicide use history, and access road status are described in Appendix A.

2.2 ENVIRONMENTAL CONSTRAINTS

The definition of a successful reclamation program must account for a number of environmental constraints and processes that impinge on a site. The primary process involved is that of plant succession, which involves five stages: propagule migration, plant establishment, edaphic (soil) reaction, competition, and stabilization. Propagule migration can be enhanced by seeding or planting appropriate species; subsequent plant establishment may be influenced by manipulation of soil and microclimatic features of the site. Edaphic reaction follows, in which the biotic and abiotic characteristics of the soil are modified by growth and development of the resident plants. At some point, competition between plants will become important, changing the community structure on the site. Competition can be modified by manipulating species types, rates of interaction, and timing of interaction. Finally, succession is expected to produce a stable mix of species and edaphic characteristics.

Constraints that define the rates and endpoints of succession at any particular site include climatic

factors, edaphic (soil) characteristics, competition from native and non-native species, and seed germination and growth characteristics of the desired species. In arid areas, moisture availability and interspecific competition from alien annuals are the key constraints to reclamation.

2.2.1 Climate

Air temperature, precipitation, and wind are key influences that govern the geographic distribution of plants and animals on the Hanford Site. Climatological data for the Hanford Site have been gathered continuously since 1953 at the Hanford Meteorological Station (HMS), located near the 200-West Area. Although the HMS was established in 1944, data collection was not routinely established until 1953. Data for the years between 1912 and 1944 were recorded at the Hanford Townsite near the Columbia River.

High temperatures average in excess of 32°C during July and August, with a record high of 46°C in July 1939 (Figure 2). Winter (November to February) minimum temperatures average between -7 and -1°C, with a record low of -33°C (in December 1919).

Annual precipitation has exhibited a fairly broad range of variability since 1912 (Figure 3). The driest year on record was 1976, with a total precipitation of 7.5 cm, or 47% of normal. The wettest years were 1940 and 1950, with 28.2 and 28.6 cm, respectively. Annual precipitation may be expected to fall between 12.5 and 20 cm, though nearly 20% of the years between 1912 and 1987 experienced less than 12.5 cm (Figure 4).

Precipitation patterns over the Hanford Site generally increase with increasing elevation. Precipitation during the wet season is some 20% greater in and around the Rattlesnake Hills and Gable Mountain than in the surrounding lowlands and the 200-Area Plateau. Dry season precipitation more closely follows elevational changes (Thorp and Hinds 1977).

On average, some 52% of annual precipitation falls between the months of November and February (Figure 5). Monthly precipitation rates decline from the December high of 2.3 cm, but increase again from April to a secondary maximum in June of 1.3 cm. July is the driest month, with an average of only 0.4 cm of precipitation. The year may thus be subdivided into three phases, based upon temperature and precipitation regimes: 1) a dry, hot season from July through

Figure 2. Normal and Extreme Daily Temperatures at Hanford

October, 2) a relatively wetter cool season between November and February, and 3) a dry, warm season from March to June (Figure 6).

The November through February period is most important in terms of input to soil moisture. This 4-month period experiences an average of 8.5 cm of rainfall and a mean temperature of 1.4°C. At least

some rain has occurred during this period in every year since 1912 (Figure 7). Thirty-three percent of all years since 1912 had between 7.5 and 9.5 cm of rainfall in these months. Rainfall during this period ranged from a low of 2.2 cm to a high of 17.5 cm. Together with the low temperatures and high relative humidity (70 to 80%) during this period, evapotranspiration losses are minimal. Most of the precipitation remains in the

Figure 3. Annual Precipitation at Hanford Since 1912

Figure 4. Histogram of Annual Precipitation at Hanford, 1912 - 1987

topsoil, except when Chinook winds or warm rains occur after a period of sub-freezing temperatures. In such cases, much of the precipitation and melting snow may run off.

The period from March to June represents a transition from the relatively wet, cool winter to the hot, very dry summer and early fall. Temperatures during this transition period average 14°C, and precipitation averages 4.5 cm (Figures 6 and 7). Precipitation ranges from a low of 0.62 cm to a maximum of 11.2 cm, with most of this occurring in the month of June. Thirty-four percent of years received between 1.1 and 4.2 cm.

The dry season occurs from July through October, a period especially critical for plant survival. These

Figure 5. Average Monthly Precipitation at Hanford, 1912 - 1987

months include the hottest and driest of the year; only rarely are winter and spring moisture accumulations sufficient to provide a carry over of available soil moisture through this period (Hinds and Thorp 1972). Temperatures average 19.7°C, and rainfall averages 3.2 cm (Figures 6 and 7). Precipitation during this period ranges from a low of 0.17 cm to a high of 12.2 cm, most of which falls during summer thunderstorms (Stone et al. 1983). The extreme dryness of this period is reflected in the fact that 75% of all years since 1912 had less than 4.2 cm of rainfall during this 4-month period.

The key implications for revegetation are that the boreholes lie in an arid zone that experiences a net input to soil moisture between November and February and a severe moisture deficit from July to October.

Figure 6. Average Temperature (broken line) and Precipitation (solid line) for Three Periods of the Year

Summer storms occasionally drop large amounts of moisture, but these are very infrequent and cannot be relied on to sustain plant growth. Precipitation during any period is unreliable: droughts have occurred in 1 of 5 years. Temperatures during the winter months are usually not so low as to preclude some plant growth at that time: indeed most of the shrubs and grasses are physiologically very active during this period. However, arctic air masses occasionally push the temperatures down to -20°C or -30°C. At these temperatures, damage to unprotected growing plants may be severe. The transition period between March and June may be of primary importance to plant establishment. Temperatures ameliorate greatly from the winter lows, and moisture inputs usually increase. Again, however, 15% of years since 1912 have failed to receive 2.5 cm

Figure 7. Histograms of Precipitation During Three Periods of the Year, 1912 - 1987

of precipitation during this period. Thus, providing adequate moisture to revegetated plants will be critical to their success, at least during the first growth year. Options include irrigation and microtopographic modifications and planting schemes that will enhance snow harvesting and modify the soil moisture profile.

2.2.2 Wind Regimes

Wind data are routinely collected at the HMS. In addition to the surface 7-ft wind data, wind data are collected at the 50-, 100-, 200-, 300-, and 400-ft intervals of the 410-ft tower at the HMS. Telemetry stations distributed on and around the Hanford Site provide supplementary surface (30-ft) wind data for defining wind patterns.

Prevailing wind directions are from the northwest in all months (Figure 8). Southwesterly winds are of secondary importance. Wind direction summaries indicate that winds from the northwest quadrant occur

Figure 8. Monthly Wind Roses for the HMS Based on 50-ft Wind Data, 1955 - 1980

most often during the winter (December through February) and summer (June through August). During the spring and fall, the frequency of southwesterly winds increases with a corresponding decrease in northwesterly flow. Winds blowing from other directions (e.g., northeast) display minimal variation from month to month.

Monthly average wind speeds are lowest during the winter months, averaging 9 to 11 km per hour, and highest during the summer, averaging 14 to 16 km per hour. Wind speeds that are well above average are usually associated with southwesterly winds. In the summer, high-speed winds from the southwest are responsible for most of the dust storms experienced in the region.

The predominant wind direction varies also with location. The northwestern quadrant of the Hanford Site experiences predominantly northwesterly winds, while locations in the southeastern quadrant of the Site are

Figure 9. Wind Roses for the Hanford Telemetry Network, 1979 - 1982

subjected to more variable, but primarily northerly and southerly, flows (Figure 9).

Wind and precipitation regimes combine to make the summer months the critical period when erosion potential is at its highest. Winds at the boreholes during this period will generally be from the west to northwest, but winds along the Columbia River will come from more often from the north or south. Several of the boreholes had large disturbed areas, and the types of soils present (see next section) are very susceptible to wind erosion. Consequently, erosion

control measures are necessary to prevent disruption of the soil-root contact for seeded plants. Erosion control measures that could be employed at a site include the use of tacking agents, incorporating mulches such as straw into the soil, mechanical compaction of the soil surface, and irrigation.

2.2.3 Soils

Soils are classified according to general type, such as the Ritzville or Warden series, and subdivided according to texture. Soil series are named for towns or

other geographic features near the place where soils of that series were first described (Rasmussen 1971).

Further characterization of soils reflects differences in vegetative history, soil depth, parent material, and nature of deposition.

BWIP boreholes are located at different elevations and in a diversity of soil types, ranging from sands to silt loams (Table 1 and Figure 10). Generally, the boundaries of plant communities and soil types do not necessarily coincide (Daubenmire 1970). However, soil characteristics important to plants on the Hanford Site include water holding capacity, depth, and parent material. Water holding capacity is a function of texture and organic content: fine textured soils, such as silt loams, have higher water holding capacities than sands (Bradshaw and Chadwick 1980); thus, the water holding capacity of the soils is expected to vary widely. Sparse plant cover in areas adjacent to reclamation sites will increase the likelihood of wind erosion. Furthermore, some soils may require remedial treatments, such as fertilizers or organic amendments, to improve tilth and enhance mineral cycling. No problems with sodic soils are expected, but soil analyses are required to define appropriate treatments, if any.

2.2.4 Plant Communities

The Hanford Site lies within the shrub-steppe ecosystem, which is characterized by desert shrubs [e.g., sagebrush (*Artemisia* spp.), rabbitbrush (*Chrysothamnus* spp.), and bitterbrush (*Purshia tridentata*)] and bunchgrasses [e.g., bluegrasses (*Poa* spp.) and wheatgrasses (*Agropyron* spp.)] in roughly equal proportions, at least under pristine conditions (Daubenmire 1970).

Native plants on the non-riverine portions of the Hanford Site are comprised mainly of cool-season species (Rickard 1988). Vegetative growth occurs primarily during the late fall after the first rains and during spring before the extreme temperatures of summer (Rickard and Schuler 1988). The primary shrub species, big sagebrush (*Artemisia tridentata*), is capable of photosynthesis year-round, provided sufficient water is present in the soil and air temperatures are between 10°C and 20°C (DePuit and Caldwell 1973). Usually, however, growth is greatest in the cool season. Flowering and seed set occur in late November to early December. Germination of big sagebrush seeds is inhibited by continuous temperatures below 5°C and highest when warm period temperatures reach 15°C (Evans and Young 1986).

Table 1. Soil Type Groupings for BWIP Boreholes

Burbank Loamy Sand	Ephrata Sandy Loam	Esquatzel Silt Loam	Hezel Sand	Kiona Silt Loam	Koeler Sand	Pit Run	Ritzville Silt Loam	Rupert Sand	Warden Silt Loam
DB-12	BH-17	Benson	DC-12	CH-1-6	DB-14	DC-23	Obrian	DB-1	DB-11
DB-15	DB-5	DH-22	DC-16	DC-10	DH-20	DC-4/5		DB-2	DH-27
DB-4	DH-8B	RRL-1	DC-24	DC-11		DH-26		DC-15	DH-33
DC-14		RRL-10	DC-32	DH-19				DC-19	Enyeart
DC-18		RRL-11	DH-21	UC-1				DC-20	Ford
DC-3		RRL-5	DH-25					DC-22	McGee
DC-6		RRL-6	DH-32					DC-25	
DC-7/8		Laydown	RRL-12					DC-33	
DH-28		Yard	RRL-14					DH-18	
DH-29			RRL-2B					DH-30	
DH-34			RRL-2C					DH-31	
DH-35								RRL-16	
RRL-7								RRL-17	
								RRL-3	
								RRL-4	
								RRL-8	
								RRL-9	

Soil Types of the Hanford Site Based on Hajek (1966) and USGS (1978)

Figure 10. Soil Types of the Hanford Site

The most problematic shrub species as far as revegetation is concerned is spiny hopsage (*Atriplex spinosa*). Spiny hopsage drops its leaves at the onset of hot weather and remains dormant until late winter (Rickard and Schuler 1988). Its peak growth period is thus limited to the cool, moist conditions of the spring. Spiny hopsage flowers in early spring and sets seed just prior to leaf-drop. Germination of seeds under laboratory conditions reached optimum levels when exposed to 5°C nights and 10°C to 30°C days (Wood et al. 1976).

The principal native grasses important to borehole revegetation are Sandberg bluegrass (*Poa sandbergii*), bottlebrush squirreltail (*Sitanion hystrix*), and needle-and-thread grass (*Stipa comata*). All are cool season perennial species. Cheatgrass (*Bromus tectorum*) is an important non-native component of most habitats on the Hanford Site. Cheatgrass, an annual, is a highly competitive species, especially on disturbed areas. Both cheatgrass and Sandberg bluegrass germinate after the first significant rains in fall. Sandberg bluegrass sets seed during early spring, then becomes dormant until fall. Cheatgrass sets seed slightly later, then dies (Rickard and Schuler 1988). Sandberg bluegrass seeds have low germinability until 6 months after dehiscence (Evans et al. 1977).

Germination of Sandberg bluegrass seeds is highest at daytime temperatures of 15°C to 25°C and overnight temperatures of 5°C to 15°C (Evans et al. 1977). Needle-and-thread grass seeds germinate in early winter (Rickard and Schuler 1988); bottlebrush squirreltail germinates in late fall and early winter (Young and Evans 1977). Bottlebrush squirreltail seed germination is highest under conditions of warm days (10°C to 20°C) and cool nights (5°C), but, like all the grasses, may be inhibited by low soil moisture (Young and Evans 1977).

A number of alien annual species occur on the Hanford Site. Most of these are early successional varieties that rapidly colonize areas of soil disturbance. Such colonizers include prickly lettuce (*Lactuca serriola*), tansy mustard (*Descurainia pinnata*), tumble mustard (*Sisymbrium altissimum*), Russian thistle (*Salsola kali*), and cheatgrass (*Bromus tectorum*). The most aggressive and ubiquitous of these is

cheatgrass. Areas occupied by cheatgrass are resistant to invasion by native species (Rickard and Sauer 1982).

Cheatgrass is a Eurasian native that was introduced to Washington State in the 1890s (Klemmedson and Smith 1964; in Daubenmire 1970). The first plants to colonize a disrupted (e.g., plowed) area are usually Russian thistle and tumble mustard, though these are completely eliminated in a few years by cheatgrass without appropriate management (Daubenmire 1970). In arid areas such as the Hanford Site, cheatgrass occurs in nearly pure stands on formerly disturbed ground. Old fields abandoned on the Site in the early 1940s continue to be dominated by cheatgrass, to the exclusion of native species (Rickard and Vaughan 1989). Other areas outside the Hanford Site have remained as nearly pure stands of cheatgrass despite the elimination of man-caused disturbances at least as far back as 1911 (Daubenmire 1970). Establishment of native grasses early in the successional cycle is essential to their continued presence in the face of later invasion by cheatgrass (Daubenmire 1970).

Two considerations for reclamation derived from the above discussion are significant for revegetating the boreholes with native vegetation. First, the native grasses all germinate during the early fall period after the first significant rains, a period when soil temperatures are still high but occasional freezing air temperatures may be expected. Because native grasses are cool-season species, they perform most of their growth and nutrient storage during the winter before the ground freezes and in the spring between ground-thaw and summer heat (Chapin 1980). Grasses planted too close in time to ground freeze or in the spring may not have sufficient time to establish an adequate nutrient and moisture base to carry them successfully through summer dormancy. Irrigation may enhance the rate of survival should planting be performed late, but if dormancy is triggered by day length or temperature, such actions will be futile.

The second consideration for reclamation deals with competition from cheatgrass. As a component of nearly all communities on the Hanford Site, cheatgrass can be expected to invade the boreholes at some point. Establishment of native grasses early in the successional cycle prior to that invasion is essential to their continued presence at that site (Daubenmire 1970).

2.3 MAJOR CATEGORIES FOR BOREHOLE RECLAMATION

Reclamation activities for the 98 boreholes (located on 71 pads - see Figure 11) were divided into four major categories based on the types of activities that will be conducted at those sites:

- Category 1. 58 boreholes completely plugged and abandoned that may require site restoration.
- Category 2. 16 boreholes identified for future use by others (Westinghouse Hanford Company, Department of Waste Management and PNL) that require site restoration only.
- Category 3. 18 boreholes identified for future use by others Westinghouse Hanford Company and the Department of Waste Management that require reconfiguration and site restoration.
- Category 4. 6 pre-existing boreholes used by BWIP that will require site restoration only.

The boreholes are listed by category in Table 2.

The series of boreholes in Category 3 designated with the prefix DB were pre-existing boreholes that were deepened by BWIP. This series of boreholes, including the McGee well, were returned to the pre-BWIP configuration. Each remaining borehole in Category 3 is a piezometer facility. Reconfiguration of these boreholes consisted of one of the following: 1) addition of cement into the annular space surrounding the piezometer tubes from the top piezometer plug to the surface or 2) the addition of a piezometer(s) to the borehole and subsequent filling of the annular space with cement.

The decommissioning of boreholes included in Category 1 was completed in July of 1989 in accordance with the State of Washington Department of Ecology Minimum Standards for Construction and Maintenance of Water Wells (WAC 1973). Deeper boreholes were plugged in stages from the bottom of the hole to the surface using standard industry cementing practices. In general, all downhole equipment was removed from the boreholes and the boreholes were completely sealed.

Table 2. Preliminary Categorization of BWIP Boreholes For the Purposes of Site Reclamation (Some boreholes are covered in other reclamation reports (e.g., ESF Report).)

Category 1: Boreholes Completely Plugged and Abandoned and That Require Site Reclamation

RRL-1	DC-2	DH-30
RRL-3	DC-3	DH-31
RRL-4	DC-4	DH-32
RRL-5	DC-5	DH-33
RRL-6A & B	DC-7	DH-34
RRL-7	DC-8	DH-35
RRL-8	DC-10	CH-1 (NSTF)
RRL-9	DC-11	CH-2 (NSTF)
RRL-10	DC-12	CH-3 (NSTF)
RRL-11	DC-15	CH-4 (NSTF)
RRL-13	DC-16A	CH-5 (NSTF)
RRL-14	DC-20B	CH-6 (NSTF)
RRL-16	DC-22B	FH-1 (ESF)
RRL-17	DH-23	FH-2 (ESF)
UC-1	DH-27	FH-3 (ESF)
DC-32CX	DH-28	FH-4 (ESF)
DC-33CX	RRL-2 (ESF)	DH-29
DC-24W	RRL-2A (ESF)	
	RRL-2B (ESF)	

Category 2: Boreholes Identified for Use by others that May Require Site Reclamation Only

DC-16B & C	DH-19	DH-25
BH-17	DH-20	DH-26
DC-20A	DH-21	DH-8B
DC-22A	DH-22	DC-19A
DH-18	DH-24	DB-11
		DC-14

Category 3: Boreholes Identified for Use by Others that Require Reconfiguration and May Require Site Reclamation

DB-1	DC-6	DC-23GR
DB-2	DC-18	DC-23W
DB-12	DC-19C	DC-23W
DB-14	DC-19D	DC-24CX
DB-15	DC-20C	DC-25CX
McGee	DC-20D	DC-22C
RRL-2C (ESF)	DC-22D	

Category 4: Pre-existing Boreholes that May Require Site Reclamation Only

Ford	Enyeart	DB-4
O'Brian	Benson Ranch	DB-5

Figure 11. Locations of BWIP Borehole Sites

2.4 DERIVATION OF RECOMMENDATIONS FOR RECLAMATION

Specific reclamation objectives were formulated for each of the 71 borehole sites. Objectives were derived in two steps: the first step involved sorting sites into two groups: those sites that were to receive some sort of surface remediation and those that were consistent with the overall reclamation objective and, therefore, could be abandoned. The second phase identified the revegetation methods and materials to be used at each site receiving surface remediation.

The considerations used in defining appropriate revegetation criteria included pertinent regulations; documented commitments made by the DOE; considerations for the interests of Native Americans as interpreted by the DOE; technical issues regarding the climate, soil, and plant communities of the Hanford Site; specific details of the nature of the disturbances at the various BWIP sites; and information collected from onsite and elsewhere regarding revegetation practice in arid environments.

Reclamation sites were visited by PNL reclamation staff to determine the nature of the disturbance and the status of the surrounding habitat, to compare soil parameters in disturbed and undisturbed areas, and to identify the primary stumbling blocks for revegetation. Westinghouse Hanford Company personnel staff were consulted to identify the intended use of the various sites and their surroundings. Literature pertinent to reclamation was critically scrutinized, and interviews were conducted of key individuals involved in reclamation at the Hanford Site, eastern Washington, or arid lands in the western United States.

Additional considerations involved in determining reclamation goals and methods include:

- control of erosion
- restoration of pre-existing wildlife habitat
- planned use of the site or surrounding area (e.g., a number of BWIP borehole sites will not be reclaimed in toto because of their conversion for use in the Hanford Site Monitoring Network)
- the areas outside of the industrial zones on the Hanford Site constitute the only extensive areas

of ungrazed shrub-steppe habitat in Washington; as a consequence, the Hanford Site constitutes a preserve for a number of natural wildlife species whose populations are diminishing elsewhere in the Columbia Basin region of eastern Washington (Rickard and Poole 1989).

A decision framework was developed that identified the important considerations and provided resolution (Figures 12 and 13). Westinghouse Hanford Company was informed of the pad preparation requirements (e.g., No Action, Rip, Remove Gravel and Rip) for the borehole sites.

2.5 ASSESSMENT METHODS AND MATERIALS

All reclamation sites were revisited to identify 1) the status of the potential seedbed, 2) the relative proportions of native grasses in nearby communities, 3) the density of the various shrub species in nearby undisturbed communities, and 4) what, if any, residual toxicity remained in the soils from prior herbicide applications.

The vegetative community in relatively undisturbed habitats was characterized at all borehole sites undergoing restoration. Sites were then grouped into 10 habitat types (Table 3) on the basis of qualitative information collected in Phase 1 site visits (2.1.1). At least 20% of the sites within a habitat classification were selected for detailed study (total plots = 25). Selection was made by assigning each borehole a unique number and employing a random number generator to identify sites for analysis. Natural habitat types, in which few sites occurred, were sampled at a rate of 50% or 100% of the total number of such sites. The data generated from detailed studies of these plots were used to provide site-specific information regarding the species composition representing the pre-disturbance condition, which then served as standards for revegetating each site.

Appropriate habitat for sampling was identified at each site selected for quantitative analysis. Sampled habitats represented the least disturbed native community (if such existed) near the site. More than one sampling location was identified at sites where the disturbance covered more than one acre, or where two kinds of native communities were present.

Figure 12. Framework for Reclamation Decisions at the Boreholes

Figure 13. Logic for Deriving Site Preparation Recommendations at the Boreholes

Table 3. Preliminary Habitat Classification of BWIP Boreholes (Classified by dominant shrub and dominant grass. If shrubs absent, classified by grasses.)

Habitat Type	Borehole	Habitat Type	Borehole
Big sage/cheatgrass	RRL-2	Big sage/bluegrass	RRL-4
"	RRL-2A	"	RRL-7
"	RRL-2B	"	DB-12
"	RRL-2C	"	DB-14
"	RRL-6	"	DB-15
"	RRL-9	"	DC-3
"	RRL-16	"	DC-7/8
"	RRL-17	"	DC-18
"	DC-16	"	DC-20
"	DC-23	"	DC-22
"	DC-24	"	DH-19
"	DC-32	"	DH-34
"	DC-33	"	Benson
"	DH-26	"	McGee
"	O'Brian	"	Ford
"	Enyeart	Big sage/needle-and-thread	DB-1
Hopsage/bluegrass	RRL-10	"	DC-12
Cheatgrass	RRL-14	"	DH-30
Cheatgrass/bluegrass	RRL-5	"	DH-31
"	RRL-8	Bluegrass/cheatgrass	DH-27
"	DB-2	"	DH-28
"	DH-8B	"	DH-33
"	DH-32	"	DH-35
"	Laydown Yard	Bitterbrush/needle-and-thread	DC-19
Riparian	DC-14	Bitterbrush/ricegrass	DC-15
Needle-and-thread/ricegrass	DC-25		

Big sage: *Artemisia tridentata*; Hopsage: *Atriplex spinosa*; Bitterbrush: *Purshia tridentata*; Cheatgrass *Bromus tectorum*; Bluegrass: *Poa sandbergii*; Needle-and-thread: *Stipa comata*; Ricegrass: *Oryzopsis hymenoides*

Sampling locations consisted of 10- x 10-m plots located at least 10-m distant from the edge of the reclamation site. Plots were marked with wooden stakes bearing the site and location designations. Canopy cover of grasses and shrubs was measured along the side of the plot nearest the disturbed area. Plant cover was measured using the point-interception method (Goodall 1953) by means of an optical point bar (Viert 1985). The bar consists of 10 ocular scopes with crosshairs. Species were recorded whenever they intersected the view beyond the crosshairs. Sampling using the optical point bar was repeated at 1-m intervals starting 1 m from one corner of the plot. Percent cover for any species at any sampling location was, therefore, simply the sum of the point interceptions for that species at that location. Shrub density was determined by counting all shrubs, by species, within the plot. Sampling was conducted between 12 May and 17 May, 1988.

Habitat types for all sites were reassessed based on analysis of the quantitative data (Appendix B). Eleven habitat types were identified, based on 10 shrub groupings and 10 grass groupings (Table 4). No shrubs or grasses were present near DC-14 (Riparian) (Figure 14). No shrubs were found in the burned habitat surrounding RRL-14 (Cheatgrass-bluebunch wheatgrass). Sandberg bluegrass was found in all but four habitat types; big sage was found in all but five. Cheatgrass was present in all habitats except Riparian (DC-14). The big sage-cheatgrass habitat was the most widespread habitat type, occurring around 17 of the 46 reclamation sites (Table 4). It was composed of 30% cheatgrass cover and 22 sagebrush per 0.01 ha, on average. This habitat type also had a large proportion of rabbitbrush species. The big sage-Sandberg bluegrass habitat was the second most prevalent type, with no fewer big sage than the big sage-cheatgrass habitat, but with many fewer rabbitbrush and much greater

Figure 14. Species Composition in Undisturbed Habitat at Selected Borehole Sites, 1988 (see Table 14 for Site Locations)

(AGDA = downy wheatgrass, AGSP = bluebunch wheatgrass, ARTR = big sagebrush, ATSP = hopsage, BRTE = cheatgrass, CHNA = grey rabbitbrush, CHVI = green rabbitbrush, KOCR = June grass, ORHY = ricegrass, POSA = bluegrass, PUTR = bitterbrush, SIHY = bottlebrush, STCO = needle-and-thread)

Table 4. Habitat Reclassification for Boreholes Based on Quantitative Analysis of 30 Vegetation Plots at 25 Sites (data in Appendix B)

Habitat Type	Borehole	Habitat Type	Borehole
Big sage/cheatgrass	Benson	Big sage/bluegrass	DB-12
"	DC-12	"	DB-14
"	DC-16	"	DB-15
"	DC-22	"	DC-3
"	DC-24	"	DC-7/8
"	DC-32	"	DC-18
"	DC-33	"	DC-20
"	DH-26	"	DH-19
"	DH-35	"	DH-34
"	Ford	"	McGee
"	O'Brian	Hopsage/bluegrass	RRL-10
"	RRL-6	Grey rabbitbrush/needle-and-thread	DB-1
"	RRL-7	"	DH-30
"	RRL-8	"	DH-31
"	RRL-9	"	RRL-4
"	RRL-16	Cheatgrass/bluegrass (2)	DH-27
"	RRL-17	"	DH-28
Cheatgrass/bluegrass (1)	RRL-5	"	DH-33
"	DC-23	Grey rabbitbrush/nicegrass	DC-19
"	DB-2	Rabbitbrush/bluegrass	DC-15
"	DH-8B	Riparian	DC-14
"	DH-32	Downy wheatgrass/cheatgrass	DC-25
"	Laydown Yard	Cheatgrass/bluebunch wheatgrass	RRL-14

Grey rabbitbrush: *Chrysothamnus nauseosus*; Rabbitbrush: *Chrysothamnus* species; Downy wheatgrass: *Agropyron dasystachyum*; Bluebunch wheatgrass: *Agropyron spicatum*

bluegrass cover, suggesting that the habitat had undergone less disturbance. The spiny hopsage/Sandberg bluegrass type was represented by one site (RRL-10), though hopsage was a minor component of both the big sage habitat types.

Soil sampling was conducted between April 13 and May 5, 1988, to determine the physical and chemical

characteristics of undisturbed soils near the borehole sites. Samples were taken at 15 cm depth at the four cardinal compass points around the perimeter of each site. Parameters analyzed were texture (percent sand, silt, and clay), pH, phosphorus, potassium, total Kjeldahl nitrogen, organic carbon, and cation exchange capacity. Data are presented in Appendix C.

3.0 RECLAMATION METHODS

In formulating reclamation recommendations, our considerations were in order of priority:

- the objective stated in the reclamation plans: returning sites as near as practicable to conditions existing before disturbance
- the time frame available in which to accomplish that objective: 2 years
- the technical factors that would prevent obtaining that objective
- cost: how to approach the objective with the least amount of money.

Technical constraints and considerations for the borehole sites and the means selected to overcome or minimize each constraint are identified in Table 5.

3.1 DEMOLITION PHASE

Mud pit contents were examined to determine if any would require dispositioning according to the Resource Conservation and Recovery Act (RCRA), the Washington Solid Waste Management Act, or the Washington Hazardous Waste Management Act (Connelly and Chou 1989). No hazardous materials were identified.

Aboveground facilities such as trailers and portable equipment were removed and salvaged. Aboveground utilities were removed and disposed of according to pertinent regulations. Two wooden poles carrying power to RRL-6 were purchased by PNL from General Telephone and Electric and converted in place into raptor nesting platforms.

Where required, wells were decommissioned or converted to alternative uses. Decommissioned wells were cut off below grade level and backfilled.

At sites where they were incompatible with seedbed preparation, surface materials were transported to Hanford Pit 25. Where present, mud pit contents were pumped and disposed of according to pertinent regulations. Excess material was graded and blended to approximate surrounding contours. Those access roads scheduled for reclamation were also graded to match surrounding contours.

3.2 REVEGETATION PHASE

Numerous studies of succession in disturbed arid regions have shown that recovery after severe disturbance, such as topsoil removal or high-temperature wildfires, will be delayed by anywhere from 6 to 50 years or more, depending on the type and extent of the disturbance (e.g., Allen 1988). Often, especially in the presence of cheatgrass, the final community type may be much different than that present before the disturbance (Biondini et al. 1985). Intervention in the form of appropriate seedbed preparation and seeding or planting appropriate vegetation is the only way to ensure the development of the original native community (Figure 15).

The strategy employed at the borehole sites was to introduce the more robust native grasses from seed, using a furrowing drill to enhance moisture harvesting and stabilize soil moisture at the seed, and to establish the less robust shrub species by planting tubeling stock. Revegetation thus consisted of four steps: seedbed preparation, mulching the seedbed with straw, seeding of grasses using a furrowing drill, and planting shrubs using tubelings.

Revegetation of boreholes was divided into two phases. Phase I included revegetation of boreholes where all demolition and well modifications had been completed before October 1, 1988. Sites at which demolition work was completed between October 1 and 15 were prepared and fallowed. Phase I revegetation sites are listed in Table 6. Phase II will consist of

Table 5. Site-Specific Constraints and Considerations and Their Solutions to be Implemented in the Borehole Reclamation Program

Site Constraint	Site Solution
Sites occur in widely different vegetative conditions. Each site is unique in terms of surrounding vegetation.	Sites were grouped according to common habitat classification, and all sites within a given classification received the same revegetation treatment.
Constant soil moisture is critical to planting success.	Irrigation water was not available at the majority of sites; therefore, seeds were planted in the bottom of 7-cm furrows to maximize the time of seed contact with moisture.
Cheatgrass is a dominant element of the vegetation surrounding the site.	Where possible, sites were cleared after cheatgrass had set seed, and were seeded before growth of next generation of cheatgrass. Otherwise, sites were allowed to lie fallow for 1 year, during which they were subjected to chemical herbicide treatment.
Previous attempts at establishing big sage-brush from seed elsewhere on the Hanford Site had met with little success.	Shrubs will be established from containerized (tubeling) stock. Shrubs will be grown at a commercial nursery from seed collected on the Hanford Site. Potting media will be inoculated with Vesicular-Arbuscular Mycorrhizae to enhance resistance to drought and nutrient stress. Plants will be placed 3 cm below grade and in clumps of three to provide favorable microclimate. Plants will be watered at time of placement in ground.
Some sites will be cleared of top course materials several months before seeding.	Site surface will be held from wind erosion by application of an organic tacking agent.

seeding the remaining borehole sites with native grasses and planting all sites with native shrubs. The various steps for revegetating the boreholes sites are described below.

3.2.1 Seedbed Preparation

After demolition and gravel removal was completed and sites had been restored to their original contours, all sites to be reseeded were machine ripped to a minimum depth of 30 cm and disked to a minimum depth of 15 cm. Such scarification is recommended in compacted soils (e.g., Redente, et al. 1984), such as that expected to underlie the compacted top-course material at the borehole sites. Such treatment significantly enhances the likelihood of establishing appropriate vegetation (Biondini et al. 1985). Following diskings, the seedbed was surface-compacted using a cultipacker. This aids in the prevention of wind and water erosion (Toy and Shay 1987) and provides a

stable base for drilling seeds to the appropriate depths (Haferkamp et al. 1987).

3.2.2 Mulching

Mulches are commonly applied to soils to increase water retention and to decrease susceptibility to erosion (e.g., Scholl and Pase 1984). Organic mulches have the added benefit of stimulating mycorrhizal growth (Whitford 1988). Mycorrhizae are essential to the growth of many native plants in arid regions, buffering the plant against water and nutrient stress (Allen and Allen 1980).

An organic mulch of certified weed-free chopped straw was mechanically blown over the seedbed at a rate of 4500 kg/ha, which is the rate specified by the Washington State Department of Transportation. The use of certified weed-free straw limits the introduction of weeds to the seedbed that would otherwise lower

Figure 15. Schematic Diagram of Community Time-Transition Trajectories at the Boreholes (Width of transition arrows corresponds to the probability of continuing along a transition trajectory from one community type to another.)

Table 6. Boreholes Included in Phase I Revegetation (Seeded in 1988)

Benson	DB-12	DB-14	DC-15
DC-22	DC-23	DC-24	DC-32
DC-33	DC-7/8	DH-19	DH-26
DH-27	DH-28	DH-30	DH-31
DH-32	DH-33	DH-34	DH-35
Enyeart	Ford	O'Brian	

revegetation success (Evans et al. 1970). Lengths of straw as applied were in the range of 2.5 to 10 cm. Immediately following application, the mulch was crimped into the soil by a rotary hoe run in reverse. Chopped straw was used before drilling seed instead of after to increase the incorporation of soil with the straw. The resulting mixture greatly enhances the stability of the furrows and increases the decomposition rate of the introduced organic matter.

3.2.3 Fallow

Where delays of more than 1 month were anticipated between completion of seedbed preparation and seeding a given site, an erosion protection agent (Terra Tack AR) was applied within 1 week after cultivation at a rate of 90 kg/ha. Fallowed sites receiving this treatment are listed in Table 7.

Table 7. Boreholes With Seedbeds Prepared in 1988 and Left Fallow Before Seeding in 1989

DB-1	DC-19	DC-25
RRL-4	RRL-5	RRL-7
RRL-8	RRL-9	RRL-17

Fallowed areas were sprayed with a nonselective contact herbicide (glyphosate: Roundup™) to kill broad-leaf weeds and cheatgrass where such weeds had established on the seedbed. Spraying was done in May 1989.

3.2.4 Seeding

Table 8 lists the specific seeding mixes and depths of seeding recommended for each borehole site to be revegetated. Rates are given in terms of pounds Pure Live Seed (PLS) per acre. The percent PLS of a given batch of seed can be calculated as the product of the percent purity of the batch and the percent germination of the batch divided by 100. Seeding rates were based on information provided in Wasser and Shoemaker (1982). Seeding rates for Sandberg bluegrass and bottlebrush squirreltail were set relatively high to provide sufficient plants to compete effectively against cheatgrass and the shrub species (Hironaka and Tisdale 1963). Seeding depths were based on information in Fulbright et al. (1982) and Wasser and Shoemaker (1982).

Where two species were recommended, species were loaded into separate seed-hoppers on the drill, and seeding ports were covered with duct tape such that each species was seeded into alternate drill furrows. Where more than two species of grass were recommended, Sandberg bluegrass seeds were loaded into one hopper, and the remaining species were mixed in the other hopper. Separation of seed species will limit interspecific competition during the early phases of plant growth (Biondini et al. 1985).

Areas involved in Phase I revegetation were seeded between October 11 and October 31, 1988; Phase II seeding occurred in late 1989. Seed was placed with a John Deere/Van Brunt drill equipped with a furrowing device mounted ahead of the disk openers such that seeds were emplaced only in the bottom of the furrows. The drill was calibrated to deliver the amount of seed appropriate to the site. The furrowing device was set to provide a furrow no shallower than 7.5 cm and no deeper than 12.5 cm. Openers were spaced 35 cm. During drilling operations, a field assistant continuously stirred the seed in both seed boxes to keep seeds from bridging over the openers.

Seeding mixtures involving Indian rice grass (*Oryzopsis hymenoides*) entailed a modification to the above procedure. Indian rice grass was seeded first at the specified depth without using the furrowing attachment. The remaining grass species were seeded as per the above procedure; however, the drill was operated such that the seeding row was at 90° to the seeding rows done for Indian rice grass whenever possible.

Specifications and sources for seeds are listed in Table 9. Calibration tables used to set the John-Deere drill are given in Table 10. Calibration was performed by jacking up one drive wheel of the drill, placing a container over the drop tube from the seed box, and rotating the drive wheel 1, 2, or 3 revolutions. Seeds dropped into the container during the revolution of the wheel were counted and compared to the amount listed in Table 10. The setting on the seed feed gear was opened or closed according the deviation of the count from that listed in the table and the process repeated.

Sandberg bluegrass often formed bridges over the feed gears, so an operator was stationed on the drill rig during operation to prod the seed with a screwdriver to limit bridging. Another problem with the bottlebrush/needle-and-thread grass mixes was that the awns of both seeds were becoming enmeshed with each

Table 8. Seeding Mixtures and Seed Specifications for Reseeding Boreholes

Borehole	Species to be Seeded	Rate (kg PLS/ha)	Depth of Seeding (cm)
Enyeart	<i>Poa sandbergii</i>	3.3	0.6 - 1.25
O'Brian	<i>Sitanion hystrix</i>	2.2	0.6 - 1.25
RRL-6	"	"	"
RRL-7	"	"	"
RRL-8	"	"	"
RRL-9	"	"	"
RRL-16	"	"	"
RRL-17	"	"	"
DC-12	"	"	"
DC-16	"	"	"
DC-20	"	"	"
DC-22	"	"	"
DC-24	"	"	"
DC-32	"	"	"
DC-33	"	"	"
DH-26	"	"	"
DH-35	"	"	"
Benson	"	"	"
Ford	"	"	"
DB-12	<i>Poa sandbergii</i>	3.3	0.6 - 1.25
DB-14	<i>Stipa comata</i>	1.1	0.6 - 1.25
DB-15	<i>Sitanion hystrix</i>	1.1	0.6 - 1.25
DC-7	"	"	"
DC-8	"	"	"
DC-18	"	"	"
DH-19	"	"	"
DH-34	"	"	"
McGee	"	"	"
DB-1	<i>Poa sandbergii</i>	2.2	0.6 - 1.25
DH-30	<i>Stipa comata</i>	2.2	0.6 - 1.25
DH-31	<i>Oryzopsis hymenoides</i>	2.2	5 - 7.5
RRL-4	<i>Koeleria cristata</i>	0.6	0.6 - 1.25
RRL-10	<i>Poa sandbergii</i>	4.5	0.6 - 1.25
DC-15	"	"	"
RRL-14	<i>Agropyron spicatum</i>	4.5	1.25 - 1.9
RRL-5	<i>Poa sandbergii</i>	3.3	0.6 - 1.25
DB-2	"	"	"
DC-23	"	"	"
DH-32	"	"	"
Laydown Yard	"	"	"
DH-27	<i>Poa sandbergii</i>	3.3	0.6 - 1.25
DH-28	<i>Sitanion hystrix</i>	1.1	0.6 - 1.25
DH-33	"	"	"
DC-19	<i>Oryzopsis hymenoides</i>	9	7.5 - 11.25
DC-25	<i>Agropyron dasystachyum</i>	6.7	1.25 - 1.9
	<i>Oryzopsis hymenoides</i>	2.2	7.5 - 11.25

Table 9. Specifications for Seed Used in Phase I of Borehole Reclamation

Species	Origin	Percent			
		Pure Seed	Weed	Inert	Germ
<i>Poa sandbergii</i>	CO	91.37	0.11	8.52	71
<i>Sitanion hystrix</i>	UT	84.81	0.12	12.85	80
<i>Stipa comata</i>	UT	97.74	0.26	1.66	91
<i>Koeleria cristata</i>	Unk	78.00	Unk	Unk	92
<i>Oryzopsis hymenoides</i>	MT	99.48	0.01	0.45	98

successful than the seeding shrubs on other sites (Cook 1988). Shrubs will be planted in clumps of three at or 2.5 cm below grade. Clumps consist of three tubelings of the same species planted in a triangular configuration with approximately 35 cm between plants. Clumped plants have higher survival and growth rates than plants set out in a more even pattern (MacMahon 1988) because of microclimatic changes and water harvesting by snow drifting caused by the clumped plants. After planting each clump, each tubeling will be

Table 10. Calibration Rates for Various Pure Live Seeding Rates for Species Seeded at BWIP Boreholes

Species	# seeds/lb	lb/acre	14 in furrow spacing		28 in furrow spacing	
			# seeds/22 ft	gram seed/22 ft	# seeds/22 ft	gram seed/22 ft
<i>Agropyron dasystachyum</i>	186,000	6	658	1.54	1315	3.08
<i>Agropyron spicatum</i>	117,000	4	330	1.03	660	2.05
<i>Koeleria cristata</i>	2,315,000	0.5	950	0.18	1900	0.36
<i>Oryzopsis hymenoides</i>	188,000	8	682	2.11	1365	4.22
		2	171	0.53	341	1.05
<i>Poa sandbergii</i>	925,000	4	3375	1.59	6750	3.18
		3	2531	1.19	5062	2.38
		2	1687	0.79	3375	1.59
<i>Sitanion hystrix</i>	192,000	2	334	0.76	667	1.51
		1	167	0.38	334	0.76
<i>Stipa comata</i>	115,000	2	152	0.58	305	1.15
		1	76	0.29	152	0.58

other such that seeds were delivered to the openers in boluses rather than in a continuous stream. To help correct this problem, cracked corn was introduced into the mix at a rate of 2 parts corn to 1 part seed, by weight.

Because of the tedium of performing the calibration and the variation over time in seed delivery rate, calibration was neither very precise nor accurate. Furthermore, the fact that only half the total openers were delivering a given species into the ground was not taken into account in planting sites DH-30, DH-31, DB-14, DC-24, DH-26, DC-32, DC-33, and Benson Ranch. Consequently, the actual seeding rate on these sites was approximately half that specified. Actual seeding rates based on calibration data are given for the first 13 sites seeded in Table 11. Actual rates were not obtained for the remainder of the sites.

3.2.5 Planting

After seeding grasses, 15-cm tubeling shrubs are to be planted at the rates and densities given in Table 12. The use of tubeling stock has proved much more

Table 11. Actual Seeding Rates of Grasses Seeded at Phase I Boreholes as Measured at the Drill

Site	Species	Seeding Rate (kg PLS/ha)	
		Actual	Specified
DH-30	<i>Koeleria cristata</i>	0.3	0.6
	<i>Oryzopsis hymenoides</i>	2.5	2.2
	<i>Poa sandbergii</i>	1.0	2.2
	<i>Stipa comata</i>	1.3	2.2
DH-31	<i>Koeleria cristata</i>	0.7	0.6
	<i>Oryzopsis hymenoides</i>	2.5	2.2
	<i>Poa sandbergii</i>	0.9	2.2
	<i>Stipa comata</i>	1.9	2.2
Benson	<i>Poa sandbergii</i>	1.6	3.3
	<i>Sitanion hystrix</i>	0.4	2.2
DB-14	<i>Poa sandbergii</i>	1.6	3.3
	<i>Sitanion hystrix</i>	0.4	1.1
	<i>Stipa comata</i>	0.6	1.1
DC-24	"		
DC-32	"		
DC-33	"		
DH-26	"		
DH-27	<i>Poa sandbergii</i>	2.2	3.3
	<i>Sitanion hystrix</i>	0.6	1.1
DH-28	"		
DH-33	"		
DH-35	"		
DH-32	<i>Poa sandbergii</i>	3.1	3.3

Table 12. Shrub Species and Densities to be Planted at Borehole Reclamation Sites

Borehole	Species	Clump Density (clumps/ha)
Enyeart	<i>Artemisia tridentata tridentata</i>	939
Benson	<i>Chrysothamnus nauseosus</i>	198
Ford	<i>Chrysothamnus viscidiflorus</i>	198
O'Brian	<i>Atriplex (Grayia) spinosa</i>	89
RRL-6	"	"
RRL-7	"	"
RRL-8	"	"
RRL-9	"	"
RRL-16	"	"
RRL-17	"	"
DC-12	"	"
DC-16	"	"
DC-20	"	"
DC-22	"	"
DC-24	"	"
DC-32	"	"
DC-33	"	"
DH-26	"	"
DH-35	"	"
DB-12	<i>Artemisia tridentata tridentata</i>	840
DB-14	<i>Chrysothamnus nauseosus</i>	99
DB-15	<i>Chrysothamnus viscidiflorus</i>	74
DC-7	<i>Atriplex (Grayia) spinosa</i>	30
DC-8	"	"
DC-18	"	"
DH-19	"	"
DH-34	"	"
McGee	"	"
DB-1	<i>Chrysothamnus nauseosus</i>	914
DH-30	<i>Chrysothamnus viscidiflorus</i>	395
DH-31	"	"
RRL-4	"	"
DC-15	<i>Chrysothamnus nauseosus</i>	198
	<i>Purshia tridentata</i>	49
RRL-10	<i>Atriplex (Grayia) spinosa</i>	741
RRL-5	<i>Artemisia tridentata tridentata</i>	49
DB-2	"	"
DC-23	"	"
DH-32	"	"
Laydown Yard	"	"
DH-27	<i>Artemisia tridentata tridentata</i>	25
DH-28	"	"
DH-33	"	"
DC-19	<i>Artemisia tridentata tridentata</i>	25
	<i>Chrysothamnus nauseosus</i>	395
	<i>Chrysothamnus viscidiflorus</i>	99

surrounded with a hand-made soil berm between 2.5 and 5.0 cm high with a radius of approximately 17 cm. Two liters of water will be applied by hand to each tubeling within 1 h of planting (but after berming). Plants are to be kept in cool storage until ready to be moved to the site. At the site, plants are to be kept in a cool-box until removed for planting.

Clumps will be distributed over each site in a spatially random pattern. Planting densities given in Table 12 are given as the number of clumps to be planted per hectare.

Big sagebrush was planted on three sites (DC-22, DC-24, DC-32) in Phase I between March 1 and March 29, 1989. Planting under Phase II was done between November 1 and December 15, 1989.

Planting configurations were derived for Phase I sites by employing a computer-generated Poisson sampling distribution with a mean set at the average number of clumps per 58 m² necessary to produce the planting density given in Table 12. Each value generated was located in one and only one 58 m² square on a rough site map. In the field, squares were laid out

using ropes and clumps. Planting occurred at the rate specified on the figure at haphazard locations within the outlined square.

Actual field operations deviated somewhat from specifications, in that many plants were not planted below grade, but instead were planted atop a mound of soil pulled together from the surrounding surface. Approximately one-third of the plants set in DC-24 and half the plants at DC-22 were placed in this fashion. Otherwise, plants were set and treated according to specifications.

Revegetation of DC-14 will be limited to the planting of five white poplar trees (*Populus alba*) at least 3 m in height. These are to be planted during dormancy either in October or March. Trees are to be supported by padded guy wires and protected from browsing by a 1.8-m-high circle of hogwire (or similar stiff wire). Berms 1.8 m in diameter will be formed around each plant and 380 L of water applied at seeding. Watering will continue once a month during the months of April through August of 1990, with 380 L per tree being applied at each watering. This borehole was transferred to PNL for research purposes and will be revegetated by PNL at an unspecified future date.

4.0 RECLAMATION SUCCESS

The progress of the reclamation program at the boreholes was tracked by periodic checks as demolition and revegetation advanced. A quantitative examination of the germination and growth of plants on the seeded areas was conducted in the spring of 1989 before the summer dormancy period of the native grasses. Surveys of control plots established near borehole sites were conducted to serve as a basis for estimations of revegetation success and identification of community trends.

4.1 DEMOLITION

Demolition was completed in early September 1989. By that date, all man-made materials had been removed from all the borehole sites and the original ground surface had been re-exposed at those sites where gravel removal had been recommended. Where wells were to be retained as part of the Hanford Site monitoring network or were to be used for research purposes, a small portion of the gravel pad was retained to provide access to the well head.

During gravel removal at DC-23, it was discovered that the natural soil layer had been removed during pad construction. The site was found to be underlain by deep gravels without any soil. To provide a suitable soil surface, material was imported from Pit 25 and spread to a depth of 15 cm over the site, up to the level of surrounding contours. This material was made up of gravel and sand screened from top course material removed from other boreholes and the ESF. This material is low in nutrients and organic matter, and consequently has poor water retention characteristics, but was the only material available for use.

4.2 VEGETATION

To track the development of vegetation in the target habitats, data on percent cover and plant density were obtained from the 17 control plots located near 15 borehole sites representing 9 of the 10 shrub types. Because DC-14 was not scheduled for any treatment other than the planting of trees, no control plots were established in the riparian habitat. Vegetative cover and density in the control plots were assessed using the same methods described previously (Section 2.5). Plant cover was measured in April and again in June 1989 (Figure 16b), as were species tallies. Shrub density was measured only in June (Figure 16a). Full data are presented in Appendix D.

Cheatgrass was ubiquitous in all plots except the riparian habitat at DC-14, ranging in cover from a low of 4% to a high of nearly 60% in the burned habitats (those with few or no shrubs). No grass or shrub species occurred in the neighborhood of DC-14. In most cases, cheatgrass cover was lower in 1989 than in 1988. Native grasses were present in all habitats except the riparian but predominated in only half. Sandberg bluegrass was the most prevalent native grass, occurring in 6 of the 10 habitat types. Bottlebrush squirreltail did not appear in the transect estimates, but was present in the majority of species tallies, consistent with a species that is common but sparsely distributed within habitats.

Although shrub density is likely to change little within plots between years, several differences were noted between the 1988 design basis and 1989 plot data. These differences are due to differences in the selection of plots making up the data set for each habitat type. For example, the 1989 density of green rabbitbrush in the big sage-cheatgrass habitat was sixfold that in the 1988 design basis measurements. The density of grey rabbitbrush in the 1988 measurements in the grey rabbitbrush/needle-and-thread habitat were three times greater than the measurements in the same habitat in 1989. Such differences point out the highly patchy nature of the distribution of both the rabbitbrush species. Values in 1989 for the other species showed little change from 1988.

Native forbs constitute a small portion of the total ground cover, but occur throughout the habitats. Common native forbs found on the plots included hoary aster (*Machaeranthera canescens*), winged cryptantha (*Cryptantha pterocarya*), various species of buckwheat (*Eriogonum* spp.), white-stemmed globe-mallow (*Sphaeralcea munroana*), pale evening primrose (*Oenothera pallida*), threadleaf phacelia (*Phacelia linearis*), lance-leaf scurf pea (*Psoralea lanceolata*), large-flowered desert parsley,

Figure 16. Shrub Density (A) and Plant Cover (B) in Undisturbed Plots at BWIP Boreholes, Spring 1989 (AGDA = downy wheatgrass, AGSP = bluebunch wheatgrass, ARTR = big sagebrush, ATSP = spiny hopsage, BRTE = cheatgrass, CHNA = grey rabbitbrush, CHVI = green rabbitbrush, KOCR = junegrass, ORHY = indian ricegrass, POSA = bluegrass, PUTR = bitterbrush, SIHY = bottlebrush, STCO = needle-and-thread)

(*Lomatium macrocarpum*), turpentine cymopterus (*Cymopterus terebinthinus*), Cary's balsamroot (*Balsamorhiza careyana*), yarrow (*Achillea millefolium*), and yellow salsify (*Tragopogon dubius*).

The predominant alien annual species found in the control plots were cheatgrass, bur ragweed (*Ambrosia acanthicarpa*), Russian thistle (*Salsola kali*), and spring whitlow-grass (*Draba verna*). Whitlow-grass is a small member of the mustard family (Cruciferae), seldom reaching more than 5 CM in height, constituting only a small fraction of plant communities on the

Hanford Site. Native to Eurasia, spring whitlow-grass flowers in May on the Hanford Site. Cheatgrass flowers in April and sets seed in May and June. Ragweed and Russian thistle set seed later in the summer.

All the alien species in the control plots are early-succession colonizers, and so are expected to invade the revegetated areas at some time. Because of their late seed-set, ragweed and Russian thistle are likely to be present before the other invasive species and in greater number during the first year. Because of the large amount of cheatgrass in the surrounding habitat,

however, cheatgrass is expected to overtake the other annuals on the revegetated site within several years.

Vegetative growth on the revegetated areas was measured on March 21 to 31, 1989 (May 11 for DC-7/8) using a stratified random sampling scheme based on 1-m-length plots. Strata were distributed evenly over each site at the rate of 1 per 0.1 ha, with one plot located randomly within each stratum. Plots were located parallel to the drill furrow. Plots were located by tossing a stake within a stratum, directions for locating the plot frames were determined by the direction the stake was pointing when it landed. All plants growing within 2 adjacent furrows along the meter plot frame were counted by species and by the number of leaves present. Average height of each species was recorded. Because the plants were quite immature, it was seldom possible to differentiate *Sitanion* and *Koeleria* from *Stipa*, so observations of these species were lumped as a single category. Data summaries are presented in Table 13.

In general, emergence rates of bluegrass was much higher than emergence of bottlebrush squirreltail, Indian ricegrass, or needle-and-thread (Figure 17). However, because ricegrass was planted 5 to 7.5 cm below the surface (vs 1 to 1.5 cm for the other species) little emergence was expected in March. Bottlebrush squirreltail showed particularly poor emergence, indicating that the actual germination rate of the seed was much lower than that stated in the seed specification. Because of the relative scarcity of the species other than bluegrass, further analysis of revegetation success is confined to comparisons based on bluegrass emergence and development.

Seeded sites showed significant differences in bluegrass plant density ($F_{22,146} = 2.911$, $p = 0.0001$). Grass failed to emerge on sites DC-7/8 and DH-26; there were fewer than 5 plants per m (6.2 plants per m²) at DB-12, DB-14, DC-15, and DC-23. These six sites were significantly lower in bluegrass seedling count than any of the other sites (Fisher's PLSD, $p < 0.05$). The remaining sites had more than 20 plants per m (25 plants per m²); Benson Ranch, DH-28, and Enyeart had over 80 plants per m (100 plants per m²) on average (Figure 17). Most sites where grasses were present showed extremely high variability in plant density: for example, 68% of plots at DH-32 range in density from 0 to nearly 275 plants per m²! However, most sites with average densities of bluegrass over 75 per m² showed less variability than did sites with lower average densities.

Figure 17. Grass Density at Phase I Revegetated Boreholes, March 1989

The probable cause of much of the variation lies with the seeding method itself. Emergence of Sandberg bluegrass is highly sensitive to planting depth: seed planted over 3 cm seldom emerges even under controlled experimental conditions (Evans et al. 1977). The furrowing mechanism used in the Phase I

Table 13. Summary of Plant Emergence on Phase I BWIP Boreholes, March 1989

Location	Sampling Date	Species	No. 1-m Transects	Avg. # Plants per Transect
Benson	3/24/89	<i>Poa sandbergii</i>	2	82.5
		<i>Sitanion hystrix</i>	2	0.0
DB-12	3/31/89	<i>Poa sandbergii</i>	2	4.5
		<i>Sitanion hystrix/Stipa comata</i>	2	0.0
DB-14	3/28/89	<i>Poa sandbergii</i>	2	4.5
		<i>Sitanion hystrix/Stipa comata</i>	2	0.0
DC-15	3/27/89	<i>Poa sandbergii</i>	6	4.8
		<i>Sitanion hystrix</i>	6	0.0
DC-23	3/31/89	<i>Poa sandbergii</i>	9	3.8
DC-24	3/28/89	<i>Poa sandbergii</i>	25	38.0
		<i>Sitanion hystrix</i>	25	1.9
DC-32	3/29/89	<i>Poa sandbergii</i>	26	22.0
		<i>Sitanion hystrix</i>	26	0.5
DC-33	3/29/89	<i>Poa sandbergii</i>	30	43.3
		<i>Sitanion hystrix</i>	30	0.5
DC-7/8	5/11/89	<i>Poa sandbergii</i>	5	0.0
		<i>Sitanion hystrix/Stipa comata</i>	5	0.0
DH-19	3/31/89	<i>Poa sandbergii</i>	2	33.0
		<i>Sitanion hystrix/Stipa comata</i>	2	0.0
DH-26	3/28/89	<i>Poa sandbergii</i>	2	0.0
		<i>Sitanion hystrix</i>	2	0.0
DH-27	3/31/89	<i>Poa sandbergii</i>	4	49.3
		<i>Sitanion hystrix</i>	4	0.3
DH-28	3/22/89	<i>Poa sandbergii</i>	2	82.5
		<i>Sitanion hystrix</i>	2	0.0
DH-30	3/29/89	<i>Oryzopsis hymenoides</i>	6	0.8
		<i>Poa sandbergii</i>	6	21.0
		<i>Sitanion hystrix/Koeleria cristata</i>	6	2.0
DH-31	3/28/89	<i>Oryzopsis hymenoides</i>	5	1.4
		<i>Poa sandbergii</i>	5	28.8
		<i>Sitanion hystrix/Koeleria cristata</i>	5	3.8
DH-32	3/24/89	<i>Poa sandbergii</i>	6	47.5
DH-33	3/24/89	<i>Poa sandbergii</i>	4	36.5
		<i>Sitanion hystrix</i>	4	0.0
DH-34	3/31/89	<i>Poa sandbergii</i>	6	48.8
		<i>Sitanion hystrix/Stipa comata</i>	6	0.0
DH-35	3/22/89	<i>Poa sandbergii</i>	5	56.6
		<i>Sitanion hystrix</i>	5	0.0
Enyeart	3/21/89	<i>Poa sandbergii</i>	4	86.5
	3/22/89	<i>Sitanion hystrix</i>	4	0.0
Ford	3/31/89	<i>Poa sandbergii</i>	4	19.3
	3/22/89	<i>Sitanion hystrix</i>	4	0.0
Obrian	3/31/89	<i>Sitanion hystrix</i>	4	42.3
		<i>Sitanion hystrix</i>	4	0.8

seeding did not provide a furrow of consistent depth, and often dragged wads of mulch causing severe distortion of the furrow. The drill openers also were inconsistent in the depth at which they delivered seed: some dribbled seed onto the surface of the furrow, others pushed the seed well down into the furrow. Finally, after planting, winds deposited sediments in the bottom of furrows, further burying the seed. Such deposition would tend to increase the variation of emergence, as well as lowering the average. Effects of winds are likely to be more severe in sandy sites because of the greater deposition in such areas.

Analysis of bluegrass emergence in different soil types supports this prediction: emergence rates were lower in sandy areas than elsewhere (square-root-transformed data: $F_{8,152} = 3.398, p = 0.0013$) (Figure 18). Emergence rates were particularly poor

Figure 18. Effect of Soil Type on Seeded Bluegrass Density at Phase I Revegetated Boreholes, March 1989

in top-course material (pit run: DC-23 and DH-26) and Koehler Sands (DC-15). Furrows in these areas were nearly filled with wind-deposited sand by March. Deposition at DC-15 was especially heavy. Deposition was not as severe in Hezel Sands or Rupert Sands, though average emergence rates were lower than in finer-grain sites. Part of the difference in emergence rates is also likely to be due to differences in water capacity: water capacity of sands is some 3.6 times less than that of silt loams (Bradshaw and Chadwick 1980). Plants in soils with low water capacity experience greater variation in available water than do plants in finer-grain soils, or soils with high organic content. Such variation will increase mortality and may affect plant development, especially in early growth stages.

Soil type had only minimal effects on plant growth after emergence. Height of bluegrass on Koehler sand and Esquatzel silt loam soils were lower than in other soils, but only two plots on the Esquatzel silt loam and one plot on the Koehler sand had any plants growing at all. Consequently no differences were statistically significant (square-root-transformed data: $F_{8,125} = 1.506, p = 0.1615$) (Figure 19). Effects of soil type on the number of leaves produced per bluegrass plant were limited to a significant difference between Rupert Sand and Hezel Sand, Warden Silt Loam, and Burbank Loamy Sands (square-root-transformed data: $F_{8,152} = 2.464, p = 0.0163$) (Figure 20). The primary difference in plant development among soil types was therefore limited to effects on emergence: once bluegrass was established, soil type had little further effect on growth.

Figure 19. Effect of Soil Type on Seeded Bluegrass Height at Phase I Revegetated Boreholes, March 1989

Figure 20. Effect of Soil Type on Seeded Bluegrass Leaf Number at Phase I Revegetated Boreholes, March 1989

Seeding rate differences had little effect on the subsequent density of emergent bluegrass. The relationship between the actual number of seeds planted per meter of furrow versus the resulting number of plants emerging per meter of furrow was best fit by a positive second-order polynomial regression (Figure 21) indicating that an intermediate seeding rate produced the greatest number of emergent plants; however, the regression was not statistically significant ($F_{2,158} = 0.389, p = 0.678$). The lack of significance is primarily a consequence of the wide variation in emergence rates seen at any given seeding rate. For example, emergence rates ranged over 2 orders of magnitude for the seeding rate of 275 seeds/m. Effects of seeding rate on bluegrass development were weak. All relationships were best-fit by linear regression. Excluding plots with no plants, there was no significant effect of seeding density on plant height ($F_{1,132} = 0.354, p = 0.553$) (Figure 22), and a weakly negative effect on leaf number $F_{1,132} = 03.802, p = 0.053$) (Figure 23). Thus, the greater the number of plants per meter of furrow, the slower those plants were to add leaves. This effect occurred prior to or shortly after emergence and was not a consequence of stand density as measured in March, since the regression of plant density on average leaf number was positive and significantly different from zero ($F_{1,132} = 7.436, p = 0.0073$) (Figure 24), as

was the regression of density on plant height ($F_{1,132} = 15.024, p = 0.0002$) (Figure 25).

Furrow orientation (north-south versus east-west) bore no significant relationship to the density of emergent bluegrass when the effects of seeding density are accounted for, nor were there significant relationships to plant development rates (Table 14).

Survival of planted shrubs on DC-22, DC-24, and DC-32 was assessed by means of transects radiating from the center of each site. Transects were walked on June 23, 1989 (DC-24: 7 transects) and July 7, 1989 (DC-22: 8 transects; DC-32: 4 transects) noting the number of shrubs within 10 meters of each transect according to whether the shrub appeared alive or dead. Transects were noted as to whether they lay in the north or south quadrant. Tallies were subdivided according to whether the observation was within the central third of the site (NEAR), middle third (MIDDLE), or the outer third (FAR). Observations on DC-32 were divided into NEAR and FAR halves only.

Big sagebrush mortality averaged 43% over all sites. Sites differed significantly in mortality rates: DC-24 averaged 52.5% mortality and DC-22 averaged 45.5% mortality, while DC-32 averaged only

Figure 21. Effect of Seeding Rate on Bluegrass Emergence at Phase I Revegetated Boreholes, March 1989

Figure 22. Effect of Seeding Rate on Bluegrass Height on Phase I Revegetated Boreholes, March 1989

Figure 23. Effect of Seeding Rate on Bluegrass Leaf Number at Phase I Revegetated Boreholes, March 1989

Figure 24. Relationship Between Plant Density and Leaf Number of Bluegrass Seeded During Phase I Revegetation of Boreholes

Figure 25. Relationship Between Plant Density and Height of Bluegrass Seeded During Phase I Revegetation of Boreholes

3.4% mortality ($F_{2,47} = 6.599, p = 0.003$, mortality data transformed to arcsine square roots) (Figure 26). Edges and centers of the sites had slightly lower mortality rates than did the more exposed territory in between, but the differences were not significant statistically ($F_{2,47} = 1.154, p = 0.324$, mortality data transformed to arcsine square roots) (Figure 27).

Table 14. Multiple Regression Analysis of Furrow Orientation and Sandberg Bluegrass Seeding Density Effects on Bluegrass Emergence and Growth on Phase I BWIP Boreholes (Dependent variables transformed to arcsine square roots)

Source	DF	Sum of Squares	Mean Square	F	p
Dependent Variable: Plant Count					
REGRESSION	2	1887.273	943.636	0.782	0.460
Seeds per meter	1			0.412	0.522
Furrow	1			1.116	0.292
RESIDUAL	158	190763.932	1207.367		
TOTAL	160	192651.205			
Dependent Variable: Plant Height					
REGRESSION	2	0.122	0.061	1.278	0.282
Seeds per meter	1			0.578	0.448
Furrow	1			2.199	0.140
RESIDUAL	131	6.262	0.048		
TOTAL	133	6.384			
Dependent Variable: Leaf #					
REGRESSION	2	0.131	0.066	1.900	0.154
Seeds per meter	1			3.656	0.058
Furrow	1			0.025	0.874
RESIDUAL	131	4.529	0.035		
TOTAL	133	4.661			

Figure 26. Differences Among Sites in Mean Mortality of Big Sagebrush Tubelings Planted During Phase I Revegetation of Boreholes

Figure 27. Effect of Distance From Site Center on Mean Mortality of Big Sagebrush Tubelings Planted During Phase I Revegetation of Boreholes

5.0 CONCLUSION AND ASSESSMENT OF SUCCESS

Revegetation of the boreholes is in its early stages. Seeding has been completed on 21.8 ha, but seeded grasses failed to establish on 2.8 ha. A further 17.9 ha remains to be seeded in Phase II in the fall of 1989. Insufficient time has elapsed to allow meaningful determination of the success of the Phase I work, since plants seeded in 1988 have yet to complete a full year of growth. All species of grasses that were seeded are cold season grasses, that is, they are photosynthetically active during the colder, wetter months between late October and early May. During the remainder of the year they are dormant, with little evidence of photosynthetic activity. To remain viable, plants must stockpile sufficient stores of nutrients, water, and energy during the growing season to carry them through the rest of the year. Consequently, the dry, hot summer months constitute the most rigorous period in the early life of these plants. An assessment of plant mortality at the beginning of the second growing season will provide a much better indication of the success of the revegetation effort than that currently available.

That caveat aside, some general assessments and predictions may be made regarding first year success and the expected course of succession on the boreholes. As of March, 1989, cover by Sandberg bluegrass was consistent with the reclamation objective (establishment of grass and shrub cover consistent with surrounding habitat) on all Phase I sites except DB-12, DB-14, DC-15, DC-23, DC-7/8, and DH-26. Emergence of bottlebrush squirreltail, needle-and-thread, and junegrass was less than necessary to meet the objective at all sites. Indeed, most sites failed to produce any bottlebrush squirreltail or needle-and-thread. This failure can probably be attributed to the seed itself, i.e., the actual germination rate was much less than that obtained when the seed was certified. Should these species fail to appear on the sites within the next year, it may be necessary to broadcast seeds of these species in September of 1990.

The six sites exhibiting total or near-total failure of bluegrasses will require remediation in the current year. Causes of failure vary at each site: plants emerged at DC-23 and DC-7/8 but died shortly thereafter. Volunteer winter wheat introduced to the sites in the straw mulch was stunted and chlorotic, suggesting stress due to residual soil herbicide. The

seedbed at DC-23 was composed of salvaged top course material from other boreholes; soils from a number of such sites had exhibited significant residual phytotoxicity in laboratory tests conducted in summer 1988. No plants grew on DB-12 and DH-26. No surficial material had been removed from these sites prior to seeding, and both had received herbicide treatment with Arsenal in May 1987 (Appendix A). Because of the lack of growth of any kind, including Russian thistle, on these sites, some phytotoxicity from residual herbicide is implicated. Although gravels were removed from DC-7/8, some phytotoxicity could still have been present there as well. DC-15 lies in a dune area of Rupert Sand. The soils were very low in organic content and were subject to severe wind erosion, such that furrows were completely filled with sand by March 1989. As noted earlier, Sandberg bluegrass does not emerge when planted 3 cm or deeper (Evans et al. 1977).

The six sites currently below reclamation standard will be reseeded in Phase II. The causes of their failure (herbicide and erosion) can be ameliorated by heavy irrigation (to wash out herbicide and stabilize the sands) or by the addition of a biologically active organic mulch, such as dewatered municipal sludge. Sludge amendments can improve a number of adverse soil conditions such as pH, water supply capacity, cation exchange capacity, organic carbon content, and carbon:nitrogen ratios (Schneider et al. 1981). Sludge applications also increase the rate of degradation of some synthetic hydrocarbons in soils (Overcash and Weber 1986). Sludge composted with refractory mulches such as wood bark or fiber have the additional benefit of significantly enhancing VA mycorrhizal infection rates (beneficial for most plants native to arid areas) and mineral cycling (Whitford 1988). Municipal sludge that had been composted for one year with wood fiber (GroCo™) was applied to DB-12, DH-26, DC-15, and DC-23 in August 1989 at the rate of 7% composted sludge on a weight basis. This material was incorporated into the surface using a disc. Sites DH-26, DB-12, and DB-14 will not receive additional mulching; otherwise, all sites to be reseeded will otherwise be treated as if they were being seeded for the first time.

Bluegrass emergence at the remaining "successful" Phase I sites was spotty, with many assessment plots

showing no grasses at all. Bluegrass growth after emergence was less variable both within and between revegetation sites. Much of the variation in emergence can be attributed to any variation in depth of seed placement and to bridging within the seeder box during seed drilling. Future drilling of bluegrass should be done using depth bands on the soil openers to limit the range of seed depths and employ a furrowing device that cuts a more uniform furrow than that produced by the modified John Deere/Van Brunt drill used in Phase I. Furthermore, more careful attention must be paid to keeping seeds flowing evenly and continuously from the seed box. The use of pearlized low-nitrogen fertilizer in a mixture with the seed may benefit uniformity of seed delivery.

Several weeks prior to the assessment of revegetation success in March 1989, an extremely low-temperature arctic air mass entered the Pasco Basin. Temperatures were below -25°C for several days, and did not return to normal for several weeks. Many of the seeded grasses showed frost burns from this low temperature. Damage appeared sufficiently severe that some plants deemed alive at the end of March were unlikely to survive another month. Whether or not sufficient grasses have survived cannot be assessed until the fall 1989 growth period. However, the furrow seemed to have protected most plants from more severe damage: frost damage was much more widespread and severe at the Exploratory Shaft Facility where no furrowing was employed.

Two aspects of the Phase I reclamation program will require less attention in Phase II. First, furrow orientation had no significant effect on bluegrass emergence rates or on plant growth, thus whatever orientation may be implemented most easily at a given site can be used without fear of adverse consequence. Second, bluegrass seeding rates over the ranges used in Phase I bore no significant relationship to the number of plants emerging or their growth rates through March. Drill calibration is a tedious procedure that dramatically slows the rate of reclamation where a number of seed mixes are employed. Data from Phase I reclamation indicate that less attention need be paid to accuracy of seeding rates in the future.

Mortality of big sagebrush plantings was higher than that anticipated in the design phase (50% versus 30% as the design basis). The primary cause behind this mortality can be traced to deviations from the planting directions given. Plants were to be set 3 cm below the ground surface such that they would lie in a

depression, thereby increasing their contact with soil moisture. However, the planting contractor set most plants on DC-24 and DC-22 in mounds well above the surrounding grade, thereby increasing the rate of water drainage away from the plants. This deviation in planting method was corrected partway through planting of DC-22, such that plants on DC-32 were set according to specifications. As the data in Figure 26 show, shrub mortality on DC-32 was an order of magnitude less than on the other sites. Further monitoring will be needed before conclusions can be made regarding attaining the reclamation objective for these sites, or the need for remedial action.

In the future, a great deal of care must be exercised during shrub planting. Depredation by jackrabbits can be expected to deplete the numbers of shrubs growing on the site over the next several years. Depredation control measures, such as the use of wire cages over young shrubs, may be warranted. The need for such treatment will become evident within the first several years of growth.

By July of 1989, most of the Phase I and fallowed sites supported a large number of alien forbs, including Russian thistle, ragweed, and tumble mustard. Control of these annuals is essential prior to seeding native species. Herbicide treatment with glyphosate (Roundup^{TM}) was instigated in May to curb this growth on the fallowed sites. Otherwise, colonization of Phase I sites was not unexpected and is not entirely unwelcome. Extensive data have been gathered on plant succession at coal mine reclamation sites in Montana and Wyoming by DePuit and Redente (1988). Their results indicate three distinct phases in succession at revegetation sites: First, the site is heavily invaded by alien annual forbs such as Russian thistle, tumble mustard, and ragweed. On sites with sufficient nutrients available in the soil, this colonization peaks within the first several years at something on the order of 50 to 60% alien annuals. Within 6 years, the number of alien annual forbs declines to very low levels (Figure 28). Second, seeded grasses increase in numbers to compose up to 40% of species after 3 to 4 years. Cheatgrass can also be expected to show a similar increase at all sites where it is a significant portion of the surrounding community. Third, planted shrubs begin to increase in numbers after 4 to 5 years, but remain at intermediate levels thereafter. Native forbs, such as Carey's balsamroot, invade the area within the same period, but never reach significant proportions.

Cheatgrass remains the primary potential spoiler at the borehole reclamation sites. In terms of the reclamation goal set for each site, the presence of cheatgrass would not be inappropriate, however, dense stands of cheatgrass will impede the development of native cover. This may be especially likely in areas experiencing limited growth of native species. Without careful management, including remediation where necessary, these areas may revert to pure stands of cheatgrass (Figure 11). Whether or not such an event will occur may not become evident for several more growing seasons.

Figure 28. Successional Profiles Expected at BWIP Reclamation Sites (modified from DePuit and Redente 1988)

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APPENDIX A

**BWIP BOREHOLE DATA:
STATUS AT CLOSE OF BWIP SITE CHARACTERIZATION, OCTOBER 1987**

Table A.1. BWIP Borehole Data: Status at Close of BWIP Site Characterization, October 1987

<u>Borehole</u>	<u>Map Coordinates</u>	<u>Construction Date</u>	<u>Disturbed Area (acres)</u>	<u>Access Road Length (ft)</u>	<u>Date of Last Herbicide</u>	<u>Site Condition on October 1987</u>
Benson	R25E, T12N, S26	1980	0.5	62.0		Thick gravel layer with pad at two levels. Backfilled mud pit.
BH-17	R26E, T14N, S26	1982	0.0	620.0	5/20/87	Thin, sparse gravel with open mud pit drained onto surrounding vegetation.
CH-1-6	R26E, T13N, S22	1980	0.0	0.0		Bare ground with exposed casing.
DB-1	R20E, T11N, S14	1973	0.7	0.0	5/21/87	Thin gravel pad with wellhouse. Shallow mud pit is open beside pad
DB-11	R25E, T13N, S32	1977	0.0	0.0	5/13/87	Thin gravel pad without buildings. Shallow trench (2 ft deep) on pad.
DB-12	R25E, T13N, S16	1978	0.4	0.0	5/19/87	Thin compacted gravel without buildings. No open mud pit. Misc. equipment on pad.
DB-14	R25E, T12N, S23	1979	0.7	5,280.0	5/13/87	Pad composed of disturbed soil. Mudpit was filled. Misc. equipment on pad.
DB-15	R27E, T13N, S31	1979	0.6	2,640.0	5/20/87	Thick gravel pad with closed mud pit.

Table A.1. (Cont.)

<u>Borehole</u>	<u>Map Coordinates</u>	<u>Construction Date</u>	<u>Disturbed Area (acres)</u>	<u>Access Road Length (ft)</u>	<u>Date of Last Herbicide</u>	<u>Site Condition on October 1987</u>
DB-2	R28E, T12N, S34	1974	0.6	0.0	5/21/87	Compacted soil with some gravel. Mud pit open, shallow, beside pad.
DB-4	R27E, T12N, S8	1975	0.0	0.0		
DB-5	R26E, T13N, S22	1975	0.0	0.0		
DC-10	R26E, T13N, S15	1977	0.0			Unknown, located on or near NSTF
DC-11	R26E, T13N, S15	1978	0.0			Unknown
DC-12	R26E, T11N, S3	1982	0.7	0.0	5/19/87	Thick gravel pad near ground-water monitoring well pad #1054. Mudpit is shallow, open, and on pad.
DC-14	R27E, T14N, S29	1981	0.5	0.0	5/20/87	Thick compacted cobble pad with open trench (3 ft x50 ft) off pad toward river. Wellhouse on pad.
DC-15	R28E, T11N, S35	1981	2.0	1,343.0	5/19/87	Thick gravel pad with open (3 ft) mudpit off pad.

Table A.1. (Cont.)

<u>Borehole</u>	<u>Map Coordinates</u>	<u>Construction Date</u>	<u>Disturbed Area (acres)</u>	<u>Access Road Length (ft)</u>	<u>Date of Last Herbicide</u>	<u>Site Condition on October 1987</u>
DC-16	R25E, T12N, S20	1981	3.8	0.0	5/13/87	Thick gravel pad with wellhouse, equipment, trailer, open shallow mudpit.
DC-18	R26E, T13N, S21	1986	2.6	200.0	5/20/87	Thick gravel pad with open mudpit off pad. Drill rig and equipment on pad.
DC-19	R26E, T12N, S19	1984	3.4	0.0	5/19/87	Thick gravel layer on half of pad with solid compaction. Wellhouses (3) on pad. Backfilled mud pits
DC-20	R25E, T13N, S35	1983	3.8	0.0	5/19/87	Thick gravel pad with long wide ditch (4 ft x2500 ft) located off pad. Mud pit contents on pad. Wellhouses (4) on pad.
DC-22	R25E, T12N, S4	1983	4.5	1,320.0	5/13/87	Thick gravel pad, wire and debris at the site, open shallow mud pit off pad. Wellhouses (4) on pad.
DC-23	R25E, T13N, S23	1984	3.4	1,584.0	5/19/87	Thick gravel pad with open mud pit (6 ft) on pad. Misc. equipment on pad.
DC-24	R25E, T12N, S23	1987	6.6	0.0	5/19/87	Thick gravel pad with open mudpit on pad. Trailer and equipment on pad.
DC-25	R27E, T12N, S30	1987	5.2	1,320.0	5/13/87	Thick compacted gravel on pad with open mud pit, water in pit, berm piled on pit edge. Trailer and equipment on pad.

Table A.1. (Cont.)

<u>Borehole</u>	<u>Map Coordinates</u>	<u>Construction Date</u>	<u>Disturbed Area (acres)</u>	<u>Access Road Length (ft)</u>	<u>Date of Last Herbicide</u>	<u>Site Condition on October 1987</u>
DC-3	R26E, T12N, S6	1977	0.0	528.0	5/21/87	Thick gravel pad with backfilled mudpit. Drilling muds exposed on surface. Misc. equipment on pad.
DC-32	R25E, T12N, S10	1987	6.5	800.0		Thick gravel pad with open mud pit
DC-33	R25E, T12N, S11	1987	6.5	1,310.0		Thick gravel pad with open mud pit.
DC-4/5	R25E, T13N, S34	1979	0.0	0.0	5/13/87	Thick gravel pad located within boundaries of gravel Pit 25. Mud pit open with misc. equipment present.
DC-6	R27E, T13N, S26	1978	0.0	0.0	5/21/87	Thick gravel pad with some asphalt and an open mudpit just off pad. Wellhouse on pad.
DC-7/8	R27E, T12N, S35	1978	1.2	1,320.0	5/19/87	Thick compacted gravel pad with rock-backfilled mud pit. Trailer on pad.
DH-18	R27E, T12N, S24	1980	0.0	0.0		Mixed-thickness gravel pad with open mud pit located off pad.
DH-19	R27E, T13N, S11	1980	0.4	0.0		Scattered thin gravel and concrete foundation fragments on pad. Open trench (5 x 60 ft) with trash and equipment in trench.

Table A.1. (Cont.)

<u>Borehole</u>	<u>Map Coordinates</u>	<u>Construction Date</u>	<u>Disturbed Area (acres)</u>	<u>Access Road Length (ft)</u>	<u>Date of Last Herbicide</u>	<u>Site Condition on October 1987</u>
DH-20	R25E, T13N, S11	1981	0.0	0.0		Thin gravel layer with light compaction. Mud pit closed.
DH-21	R25E, T12N, S10	1981	0.0	0.0		Thin gravel pad with light compaction. Mud pit back filled.
DH-22	R25E, T12N, S9	1981	0.0	2,600.0		Thin gravel with light compaction. Mud pit back filled.
DH-23	T13N, R25E, S35	1981	0.0	0.0		Thin gravel pad without exposed mud pit.
DH-24	R25E, T12N, S3	1982	0.0	0.0		Medium gravel thickness with back filled mud pit.
DH-25	R25E, T12N, S3	1982	0.0	0.0		Medium gravel layer with solid compaction. Mud pit filled and muds spread outside pad.
DH-26	R25E, T12N, S22	1982	0.1	0.0		Thin gravel with light compaction and back filled mud pit.
DH-27	R25E, T13N, S29	1985	0.5	0.0	5/13/87	Thick gravel with backfilled mud pit.

Table A.1. (Cont.)

<u>Borehole</u>	<u>Map Coordinates</u>	<u>Construction Date</u>	<u>Disturbed Area (acres)</u>	<u>Access Road Length (ft)</u>	<u>Date of Last Herbicide</u>	<u>Site Condition on October 1987</u>
DH-28	R25E, T13N, S29	1985	0.4	0.0	5/13/87	Thin gravel pad with backfilled mud pit.
DH-29	R25E, T13N, S29	1981	0.0	0.0		Thin gravel layer with light compaction. Small mound of gravel on pad. No mud pit.
DH-30	R25E, T12N, S13	1986	1.6	765.0	5/14/87	Thick gravel with solid compaction. No mud pit.
DH-31	R25E, T12N, S24	1986	1.4	327.0	5/13/87	Thick gravel pad with solid compaction and filled mud pit.
DH-32	R25E, T12N, S16	1986	1.8	1,775.0		Thick gravel without mudpit.
DH-33	R25E, T12N, S17	1986	1.0	480.0		Thick compacted gravel with shallow open mudpit on pad.
DH-34	R25E, T13N, S29	1986	1.2	0.0	5/13/87	Medium gravel layer with solid compaction. Open mud pit (8 ft - 10 ft) located on pad.
DH-35	R25E, T13N, S29	1986	1.2	0.0	5/13/87	Medium gravel layer, solid compaction, with open mud pit (8 ft -10 ft) on pad.

Table A.1. (Cont.)

<u>Borehole</u>	<u>Map Coordinates</u>	<u>Construction Date</u>	<u>Disturbed Area (acres)</u>	<u>Access Road Length (ft)</u>	<u>Date of Last Herbicide</u>	<u>Site Condition on October 1987</u>
DH-8B	R26E, T13N, S15	1976	0.0	0.0		Thin gravel on site atop small hillock on edge of gravel pit.
Enyeart	R24E, T13N, S36	1980	1.4	0.0	5/13/87	Thick gravel on part of pad, with 300 ft channel leading from pad.
Ford	R25E, T13N, S25	1980	1.0	0.0	5/13/87	Thick gravel pad solidly compacted. No mud pit.
Laydown Yard	R25E, T12N, S3	1985	4.8	528.0	5/20/87	Thick gravel pad and bare soil. Trailers and equipment on pad.
Mcgee	R25E, T13N, S30	1980	1.0	0.0	5/13/87	Thick gravel pad, solid compaction, trash, concrete foundations, wellhouse, and equipment on pad. No mud pit.
Obrian	R24E, T13N, S26	1980	1.0	0.0	5/13/87	Thin gravel layer with medium compaction. Trash on pad. No mud pit.
RRL-1	R25E, T12N, S15	1980	0.0	0.0		Light soil compaction with back filled mud pit.
RRL-10	R25E, T12N, S10	1982	0.5	0.0	3/31/89	Medium gravel with back-filled mud pit.

Table A.1. (Cont.)

<u>Borehole</u>	<u>Map Coordinates</u>	<u>Construction Date</u>	<u>Disturbed Area (acres)</u>	<u>Access Road Length (ft)</u>	<u>Date of Last Herbicide</u>	<u>Site Condition on October 1987</u>
RRL-11	R25E, T12N, S28	1982	0.0	0.0		Thin gravel pad with open U-shaped trenches on pad.
RRL-12	R25E, T12N, S18	1982	0.0	0.0		Thin gravel pad without mudpit.
RRL-14	R25E, T12N, S4	1982	3.1	1,584.0	5/13/87	Medium gravel layer with solid compaction. Gas tank and wellhouse on pad. Mud pit is open and located off pad.
RRL-16	R25E, T12N, S11	1983	0.8	1,056.0	3/26/86	Thick gravel pad with solid compaction, backfilled mud pit.
RRL-17	R25E, T12N, S2	1986	6.1	2,410.0	5/21/87	Thick gravel pad with solid compaction. Gravel up to 30 ft deep in downslope areas. Open mud pit (10 ft) on pad. Misc. equipment on pad.
RRL-2B	R25E, T12N, S10	1985	4.6		5/13/87	Thick gravel pad with bermed pump test pit offsite. Access road to pit. Open mud pit present. Sucker pump on pad.
RRL-2C	R25E, T12N, S2	1985	3.8	0.0	5/13/87	Thick gravel pad with open mud pit (6 ft -8 ft) on pad. Wellhouse on pad.
RRL-3	R25E, T13N, S36	1981	0.0	0.0	11/27/84	Thin gravel pad with backfilled mud pit.

Table A.1. (Cont.)

<u>Borehole</u>	<u>Map Coordinates</u>	<u>Construction Date</u>	<u>Disturbed Area (acres)</u>	<u>Access Road Length (ft)</u>	<u>Date of Last Herbicide</u>	<u>Site Condition on October 1987</u>
RRL-4	R25E, T12N, S12	1981	0.5	0.0	3/31/86	Thin gravel pad with backfilled mud pit.
RRL-5	R25E, T12N, S3	1981	0.3	0.0	3/27/86	Thin gravel pad with backfilled mud pit.
RRL-6	R25E, T13N, S15	1981	2.2	3,300.0	5/13/87	Thick gravel pad with backfilled mud pit and wellhouse on pad.
RRL-7	R25E, T13N, S34	1982	0.7	33.0	3/31/86	Thin gravel pad with partially backfilled trench (1 ft -2 ft deep) on pad.
RRL-8	R25E, T13N, S33	1981	2.0	1,680.0	3/31/86	Thin gravel pad with backfilled mud pit.
RRL-9	R25E, T12N, S2	1982	0.5	0.0	3/31/86	Medium gravel pad with backfilled mud pit.
UC-1	R25E, T13N, S17	1981	0.0	220.0		No gravel, light compaction, cracked concrete in small piles on pad. Open, shallow mud pit.

APPENDIX B

VEGETATION DATA ON UNDISTURBED PLOTS ASSOCIATED WITH BWIP BOREHOLE RECLAMATION, SPRING 1988

Table B.1. Shrub Data for Undisturbed Control Plots at BWIP Borehole Reclamation Sites, Spring 1988

Location	Date	Habitat Type	Species	no. plants/10 X 10 m plot					Total
				<10 cm	10- 30 cm	30- 70 cm	70- 100 cm	>100 cm	
DB-1	5/12/88	CHNA/STCO	<i>Chrysothamnus viscidiflorus</i>	0	9	6	0	0	15
DB-14	5/12/88	ARTR/POSA	<i>Artemisia tridentata</i>	0	0	7	4	10	21
DB-2	5/12/88	BRTE/POSA(2)	<i>Artemisia tridentata</i>	0	0	0	0	0	0
DC-15	5/12/88	PUTR/POSA	<i>Chrysothamnus nauseosus</i>	0	0	3	1	0	4
			<i>Purshia tridentata</i>	0	0	0	1	0	1
			<i>Chrysothamnus nauseosus</i>	0	0	3	1	0	4
			<i>Purshia tridentata</i>	0	0	0	1	0	1
DC-19 #1	5/12/88	CHNA/ORHY	<i>Artemisia tridentata</i>	0	0	1	0	0	1
			<i>Chrysothamnus nauseosus</i>	0	1	9	0	0	10
			<i>Artemisia tridentata</i>	0	0	1	0	0	1
			<i>Chrysothamnus nauseosus</i>	0	1	8	1	0	10
DC-19 #2	5/12/88	CHNA/ORHY	<i>Chrysothamnus nauseosus</i>	0	3	2	1	0	6
			<i>Chrysothamnus viscidiflorus</i>	0	2	2	0	0	4
			<i>Chrysothamnus nauseosus</i>	0	3	5	2	0	10
			<i>Chrysothamnus viscidiflorus</i>	0	6	3	0	0	9
DC-20 #1	5/13/88	ARTR/BRTE	<i>Artemisia tridentata</i>	1	6	1	1	6	15
			<i>Atriplex spinosa</i>	0	0	0	0	1	1
			<i>Chrysothamnus viscidiflorus</i>	0	0	2	0	0	2
DC-20 #2	5/13/88	ARTR/BRTE	<i>Artemisia tridentata</i>	10	16	9	2	8	45
			<i>Chrysothamnus viscidiflorus</i>	0	1	0	0	0	1
DC-20 Control	6/24/88	ARTR/BRTE	<i>Artemisia tridentata</i>	0	7	3	1	8	19
			<i>Atriplex spinosa</i>	0	0	0	0	1	1
			<i>Chrysothamnus viscidiflorus</i>	0	0	2	0	0	2
			<i>Artemisia tridentata</i>	0	3	17	7	4	31
DC-25 #1	5/12/88	AGDA/BRTE	<i>Artemisia tridentata</i>	0	0	0	0	0	0
			<i>Artemisia tridentata</i>	0	0	0	0	0	0
DC-25 #2	5/12/88	AGDA/BRTE	<i>Artemisia tridentata</i>	0	0	0	0	0	0
			<i>Artemisia tridentata</i>	0	0	0	0	0	0
DC-3	5/13/88	ARTR/POSA	<i>Artemisia tridentata</i>	0	0	2	1	7	10
			<i>Chrysothamnus viscidiflorus</i>	0	1	0	0	0	1
			<i>Artemisia tridentata</i>	0	5	4	2	2	13
			<i>Chrysothamnus viscidiflorus</i>	0	1	4	2	0	7
DC-7/8	5/12/88	ARTR/POSA	<i>Artemisia tridentata</i>	0	0	1	6	3	10
			<i>Chrysothamnus nauseosus</i>	0	0	3	2	0	5
			<i>Artemisia tridentata</i>	0	4	13	16	10	43
DH-19	7/8/88	ARTR/POSA	<i>Atriplex spinosa</i>	0	0	4	1	0	5
			<i>Artemisia tridentata</i>	0	1	14	3	0	18
DH-26	5/12/88	ARTR/BRTE	<i>Atriplex spinosa</i>	0	0	13	1	0	14
			<i>Chrysothamnus nauseosus</i>	0	27	63	3	0	93
			<i>Artemisia tridentata</i>	0	1	10	5	2	18
			<i>Atriplex spinosa</i>	0	0	8	1	0	9
			<i>Chrysothamnus nauseosus</i>	0	30	52	5	0	87
			<i>Artemisia tridentata</i>	0	0	0	0	0	0
DH-27	5/13/88	BRTE/POSA(2)	<i>Artemisia tridentata</i>	0	0	0	0	0	0
DH-30	6/24/88	CHNA/STCO	<i>Artemisia tridentata</i>	0	0	0	2	5	7
			<i>Chrysothamnus nauseosus</i>	0	1	4	2	0	7
DH-31	5/12/88	CHNA/STCO	<i>Chrysothamnus nauseosus</i>	0	3	32	2	0	37
			<i>Chrysothamnus viscidiflorus</i>	0	0	1	0	0	1

Table B.1. (Cont.)

Location	Date	Habitat Type	Species	no. plants/10 X 10 m plot					Total
				≤10 cm	10- 30 cm	30- 70 cm	70- 100 cm	≥100 cm	
DH-32	5/13/88	BRTE/POSA(1)	<i>Artemisia tridentata</i>	0	1	2	0	0	3
	6/22/88		<i>Artemisia tridentata</i>	0	1	2	0	0	3
DH-33	5/17/88	BRTE/POSA(2)	<i>Artemisia tridentata</i>	0	0	1	0	0	1
	6/22/88		<i>Artemisia tridentata</i>	0	1	0	0	0	1
DH-8B	5/17/88	ARTR/POSA	<i>Artemisia tridentata</i>	0	0	0	0	0	0
Otrian	5/17/88	ARTR/BRTE	<i>Artemisia tridentata</i>	0	15	37	17	0	69
			<i>Chrysothamnus nauseosus</i>	0	3	4	1	0	8
RRL-10	5/12/88	ATSP/POSA	<i>Atriplex spinosa</i>	0	0	9	6	0	15
	6/24/88		<i>Atriplex spinosa</i>	0	0	6	7	0	13
RRL-14	5/13/88	BRTE/AGSP	<i>Artemisia tridentata</i>	0	0	0	0	0	0
RRL-16	6/24/88	ARTR/BRTE	<i>Artemisia tridentata</i>	0	0	0	5	10	15
			<i>Chrysothamnus viscidiflorus</i>	0	0	5	0	0	5
				0	0	0	0	0	0
RRL-5	7/8/88	BRTE/POSA(1)	<i>Artemisia tridentata</i>	0	0	0	0	0	0
RRL-6	5/13/88	ARTR/BRTE	<i>Artemisia tridentata</i>	0	0	0	0	7	7
			<i>Chrysothamnus viscidiflorus</i>	0	1	0	0	0	1
				0	0	0	0	0	0
RRL-9	6/28/88	ARTR/BRTE	<i>Artemisia tridentata</i>	0	0	0	1	2	3
			<i>Chrysothamnus nauseosus</i>	0	0	7	6	0	13
			<i>Chrysothamnus viscidiflorus</i>	0	2	3	1	0	6

Table B.2. Percent Cover Data for Undisturbed Control Plots at BWIP Borehole Reclamation Sites, Spring 1988

<u>Location</u>	<u>Habitat Type</u>	<u>Sample Date</u>	<u>Species</u>	<u>% Cover</u>
DB-1	CHNA/STCO	5/12/88	<i>Bromus tectorum</i>	18%
			<i>Poa sandbergii</i>	21%
			<i>Stipa comata</i>	4%
			<i>Chrysothamnus viscidiflorus</i>	6%
			<i>Eriogonum sp</i>	5%
DB-14	ARTR/POSA	5/12/88	<i>Bromus tectorum</i>	23%
			<i>Poa sandbergii</i>	17%
			<i>Artemisia tridentata</i>	6%
DB-2	BRTE/POSA(2)	5/12/88	<i>Bromus tectorum</i>	35%
			<i>Poa sandbergii</i>	2%
DC-15	PUTR/POSA	5/12/88	<i>Bromus tectorum</i>	17%
			<i>Poa sandbergii</i>	48%
			<i>Chrysothamnus nauseosus</i>	6%
		6/21/88	<i>Eriogonum sp</i>	8%
			<i>Bromus tectorum</i>	19%
			<i>Poa sandbergii</i>	39%
DC-19 #1	CHNA/ORHY	5/12/88	<i>Chrysothamnus nauseosus</i>	7%
			<i>Bromus tectorum</i>	12%
		6/22/88	<i>Oryzopsis hymenoides</i>	21%
			<i>Bromus tectorum</i>	12%
			<i>Stipa comata</i>	6%
			<i>Oryzopsis hymenoides</i>	19%
			<i>Penstemon acuminatus</i>	1%
DC-19 #2	CHNA/ORHY	5/12/88	<i>Hymenopappus filifolius</i>	4%
			<i>Bromus tectorum</i>	9%
			<i>Oryzopsis hymenoides</i>	19%
		6/22/88	<i>Chrysothamnus nauseosus</i>	7%
			<i>Bromus tectorum</i>	13%
			<i>Stipa comata</i>	9%
			<i>Oryzopsis hymenoides</i>	8%
			<i>Koeleria cristata</i>	7%
			<i>Chrysothamnus nauseosus</i>	12%
DC-20 #1	ARTR/BRTE	5/13/88	<i>Comandra umbellata</i>	3%
			<i>Bromus tectorum</i>	26%
			<i>Artemisia tridentata</i>	16%
			<i>Atriplex spinosa</i>	11%
DC-20 #2	ARTR/BRTE	5/13/88	<i>Bromus tectorum</i>	34%
			<i>Poa sandbergii</i>	1%

Table B.2. (Cont.)

<u>Location</u>	<u>Habitat Type</u>	<u>Sample Date</u>	<u>Species</u>	<u>% Cover</u>
DC-20 Control	ARTR/BRTE	6/24/88	<i>Agropyron spicatum</i>	1%
			<i>Artemisia tridentata</i>	30%
			<i>Bromus tectorum</i>	29%
			<i>Artemisia tridentata</i>	13%
			<i>Atriplex spinosa</i>	11%
DC-22	ARTR/BRTE	6/24/88	<i>Cymopterus terebinthinus</i>	1%
			<i>Bromus tectorum</i>	9%
			<i>Poa sandbergii</i>	1%
			<i>Artemisia tridentata</i>	19%
			<i>Astragalus speirocarpus</i>	1%
DC-25 #1	AGDA/BRTE	5/12/88	<i>Bromus tectorum</i>	6%
			<i>Agropyron dasytachyum</i>	59%
		6/22/88	<i>Bromus tectorum</i>	5%
DC-25 #2	AGDA/BRTE	5/12/88	<i>Agropyron dasytachyum</i>	60%
			<i>Bromus tectorum</i>	16%
		6/22/88	<i>Oryzopsis hymenoides</i>	5%
			<i>Bromus tectorum</i>	11%
			<i>Stipa comata</i>	1%
			<i>Oryzopsis hymenoides</i>	2%
			<i>Rumex venosus</i>	8%
			<i>Salsola kali</i>	3%
			<i>Descurainia pinnata</i>	1%
			<i>Cymopterus terebinthinus</i>	9%
DC-3	ARTR/POSA	5/13/88	<i>Bromus tectorum</i>	32%
			<i>Poa sandbergii</i>	6%
			<i>Artemisia tridentata</i>	21%
		6/28/88	<i>Bromus tectorum</i>	27%
			<i>Artemisia tridentata</i>	15%
			<i>Chrysothamnus viscidiflorus</i>	14%
			<i>Balsamorhiza hirsuta</i>	3%
DC-7/8	ARTR/POSA	5/12/88	<i>Bromus tectorum</i>	13%
			<i>Poa sandbergii</i>	23%
			<i>Stipa comata</i>	5%
			<i>Artemisia tridentata</i>	7%
			<i>Chrysothamnus nauseosus</i>	9%
DH-19	ARTR/POSA	7/8/88	<i>Bromus tectorum</i>	34%
			<i>Poa sandbergii</i>	13%
			<i>Agropyron spicatum</i>	2%

Table B.2. (Cont.)

<u>Location</u>	<u>Habitat Type</u>	<u>Sample Date</u>	<u>Species</u>	<u>% Cover</u>
DH-26	ARTR/BRTE	5/12/88	<i>Artemisia tridentata</i>	10%
			<i>Bromus tectorum</i>	36%
			<i>Artemisia tridentata</i>	22%
		6/22/88	<i>Atriplex spinosa</i>	18%
			<i>Bromus tectorum</i>	32%
			<i>Artemisia tridentata</i>	19%
DH-27	BRTE/POSA(2)	5/13/88	<i>Chrysothamnus nauseosus</i>	2%
			<i>Atriplex spinosa</i>	9%
			<i>Bromus tectorum</i>	17%
DH-30	CHNA/STCO	6/24/88	<i>Poa sandbergii</i>	29%
			<i>Bromus tectorum</i>	12%
			<i>Stipa comata</i>	4%
			<i>Oryzopsis hymenoides</i>	7%
DH-31	CHNA/STCO	5/12/88	<i>Artemisia tridentata</i>	34%
			<i>Cymopterus terebinthinus</i>	2%
			<i>Bromus tectorum</i>	1%
			<i>Stipa comata</i>	18%
			<i>Oryzopsis hymenoides</i>	4%
			<i>Koeleria cristata</i>	9%
DH-32	BRTE/POSA(1)	5/13/88	<i>Chrysothamnus nauseosus</i>	9%
			<i>Bromus tectorum</i>	43%
			<i>Bromus tectorum</i>	51%
DH-33	BRTE/POSA(2)	5/17/88	<i>Sitanion hystrix</i>	4%
			<i>Bromus tectorum</i>	50%
			<i>Poa sandbergii</i>	18%
DH-33 Control	BRTE/POSA(2)	6/22/88	<i>Sitanion hystrix</i>	1%
			<i>Bromus tectorum</i>	64%
			<i>Poa sandbergii</i>	7%
DH-8B	ARTR/POSA	5/17/88	<i>Amsinckia lycopsoides</i>	6%
			<i>Bromus tectorum</i>	49%
			<i>Poa sandbergii</i>	21%
Obrian	ARTR/BRTE	5/17/88	<i>Bromus tectorum</i>	41%
			<i>Poa sandbergii</i>	2%
			<i>Artemisia tridentata</i>	13%
			<i>Chrysothamnus nauseosus</i>	2%
RRL-10	ATSP/POSA	5/12/88	<i>Bromus tectorum</i>	16%
			<i>Poa sandbergii</i>	41%
			<i>Atriplex spinosa</i>	19%

Table B.2. (Cont.)

<u>Location</u>	<u>Habitat Type</u>	<u>Sample Date</u>	<u>Species</u>	<u>% Cover</u>
RRL-14	BRTE/AGSP	6/24/88	<i>Bromus tectorum</i>	14%
			<i>Poa sandbergii</i>	30%
			<i>Atriplex spinosa</i>	24%
		5/13/88	<i>Bromus tectorum</i>	59%
			<i>Agropyron spicatum</i>	3%
RRL-16	ARTR/BRTE	6/24/88	<i>Bromus tectorum</i>	29%
			<i>Artemisia tridentata</i>	23%
RRL-5	BRTE/POSA(1)	7/8/88	<i>Bromus tectorum</i>	10%
			<i>Poa sandbergii</i>	56%
RRL-6	ARTR/BRTE	5/13/88	<i>Bromus tectorum</i>	43%
			<i>Poa sandbergii</i>	1%
			<i>Artemisia tridentata</i>	31%
RRL-9	ARTR/BRTE	6/28/88	<i>Bromus tectorum</i>	20%
			<i>Artemisia tridentata</i>	4%
			<i>Chrysothamnus nauseosus</i>	9%
			<i>Deschampsia pinnata</i>	1%

APPENDIX C

**SOIL DATA FOR UNDISTURBED SITES ASSOCIATED WITH BWIP
BOREHOLE RECLAMATION, SPRING 1988**

Table C.1. Soil Data for Undisturbed Sites Associated With BWIP Borehole Reclamation, Spring 1988

Location	Soil Type	pH	P	K	N	Organic Carbon	CEC	Texture Class	% Sand	% Silt	% Clay
Benson	Esquatzel Silt Loam	8.2	14	472	0.05	0.53	13.9	Sandy Loam	59.8%	32.6%	7.6%
DB-15	Burbank Loamy Sand	7.5	6	254	0.02	0.13	5.0	Sand	91.3%	5.7%	3.0%
DC-12	Hezel Sand	8.4	17	1326	0.04	0.57	13.8	Sandy Loam	64.7%	27.0%	8.3%
DC-14	Burbank Loamy Sand	8.0	25	624	0.12	1.34	11.9	Sandy Loam	69.3%	24.4%	6.4%
DC-16	Hezel Sand	8.4	8	386	0.02	0.20	6.9	Sand	89.2%	7.5%	3.2%
DC-18	Burbank Sandy Loam	8.0	19	1045	0.07	0.63	13.0	Silt Loam	36.4%	55.4%	8.2%
DC-19	Rupert Sand	8.6	5	281	0.01	0.13	6.1	Sand	93.9%	3.2%	2.9%
DC-20	Rupert Sand	7.2	6	234	0.02	0.13	5.6	Sand	87.2%	9.1%	3.7%
DC-22	Rupert Sand	8.3	5	234	0.02	0.19	5.7	Loamy Sand	84.4%	11.1%	4.5%
DC-23		7.4	12	343	0.03	0.28	5.3	Loamy Sand	82.3%	15.4%	2.3%
DC-24	Hezel Sand	7.8	7	226	0.02	0.16	6.1	Sand	88.5%	8.4%	3.1%
DC-25	Rupert Sand	7.8	3	246	0.01	0.13	7.8	Sand	87.4%	7.6%	5.0%
DC-3	Burbank Loamy Sand	8.2	13	464	0.03	0.22	6.7	Loamy Sand	79.1%	16.3%	4.6%
DC-32	Hezel Sand	7.1	11	203	0.02	0.28	5.2	Loamy Sand	87.7%	8.8%	3.5%
DC-33	Rupert Sand	7.3	10	300	0.02	0.19	4.5	Sand	88.2%	8.5%	3.2%
DC-7/8	Burbank Loamy Sand	8.1	4	300	0.02	0.32	6.1	Loamy Sand	83.6%	10.1%	6.3%
DH-19	Kiona Silt Loam	8.4	4	168	0.04	0.64	9.0	Silt	10.8%	88.3%	0.9%
DH-30	Rupert Sand	7.2	9	222	0.02	0.23	4.4	Sand	91.8%	5.6%	2.6%
DH-31	Rupert Sand	8.3	4	140	0.02	0.19	6.7	Sand	88.7%	8.7%	2.6%
DH-32	Hezel Sand	8.0	8	339	0.03	0.32	7.9	Loamy Sand	85.2%	11.0%	3.7%
DH-33	Warden Silt Loam	8.2	9	421	0.04	0.41	9.0	Sandy Loam	63.7%	28.1%	8.2%
DH-34	Burbank Loamy Sand	7.2	5	269	0.02	0.60	7.2	Loamy Sand	78.2%	18.8%	3.0%
DH-35	Burbank Loamy Sand	8.0	8	222	0.02	0.25	5.9	Loamy Sand	83.4%	9.8%	6.8%
DH-4B	Ephrata Sandy Loam	7.5	7	511	0.02	0.22	6.7	Sand	87.4%	8.4%	4.1%
Emyeart	Warden Silt Loam	8.3	27	1404	0.07	0.63	14.2	Silt Loam	30.9%	61.5%	7.6%
Ford	Warden Silt Loam	8.4	16	1018	0.05	0.41	11.5	Silt Loam	41.9%	50.3%	7.8%
Laydown Yard	Esquatzel Silt Loam										
O'Brien	Ritzville Silt Loam	7.3	11	460	0.03	0.25	6.0	Loamy Sand	69.6%	24.9%	5.5%
RRL-10	Esquatzel Silt Loam	8.0	12	956	0.04	0.45	14.5	Loam	50.6%	38.0%	11.4%

Table C.1. (Cont.)

<u>Location</u>	<u>Soil Type</u>	<u>pH</u>	<u>P</u>	<u>K</u>	<u>N</u>	<u>Organic Carbon</u>	<u>CEC</u>	<u>Texture Class</u>	<u>% Sand</u>	<u>% Silt</u>	<u>% Clay</u>
RRL-14	Hazel Sand	7.6	9	569	0.03	0.28	10.3	Sandy Loam	67.8%	27.8%	4.4%
RRL-16	Rupert Sand	7.6	5	211	0.02	0.13	5.9	Loamy Sand	82.4%	13.0%	4.6%
RRL-17	Rupert Sand	7.4	10	335	0.03	0.16	6.3	Loamy Sand	80.0%	15.9%	4.1%
RRL-4	Rupert Sand	7.3	8	234	0.02	0.13	5.4	Loamy Sand	85.4%	11.7%	2.8%
RRL-6	Esquatzel Silt Loam	8.3	6	168	0.02	0.16	6.0	Loamy Sand	85.7%	9.4%	4.9%
RRL-8	Rupert Sand	7.1	13	312	0.03	0.22	6.7	Loamy Sand	74.2%	21.2%	4.5%

APPENDIX D

**VEGETATION DATA FOR UNDISTURBED CONTROL PLOTS AT BWIP
BOREHOLE RECLAMATION SITES, SPRING 1989**

Table D.1. Shrub Data for Undisturbed Control Plots at BWIP Borehole Reclamation Sites, Spring 1989

Location	Date	Habitat Type	Species	no. plants/10 X 10 m plot					Total
				<10 cm	10- 30 cm	30- 70 cm	70- 100 cm	>100 cm	
DC-15	6/14/89	PUTR/POSA	<i>Chrysothamnus nauseosus</i>	0	1	4	0	0	5
			<i>Eriogonum nivium</i>	8	86	58	0	0	152
			<i>Purshia tridentata</i>	0	0	0	1	0	1
DC-19 #1	6/13/89	CHNA/ORHY	<i>Artemisia tridentata</i>	0	0	1	0	0	1
			<i>Chrysothamnus nauseosus</i>	0	1	6	3	0	10
DC-19 #2	6/13/89	CHNA/ORHY	<i>Chrysothamnus nauseosus</i>	0	3	5	2	0	10
			<i>Chrysothamnus viscidiflorus</i>	0	2	5	0	0	7
DC-20 #1	6/12/89	ARTR/BRTE	<i>Artemisia tridentata</i>	1	5	2	2	6	16
DC-22	6/13/89	ARTR/BRTE	<i>Artemisia tridentata</i>	0	2	16	7	3	28
DC-25 #1	6/13/89	AGDA/BRTE	<i>Artemisia tridentata</i>	0	0	0	0	0	0
DC-25 #2	6/13/89	AGDA/BRTE	<i>Artemisia tridentata</i>	0	0	0	0	0	0
DC-3	6/14/89	ARTR/POSA	<i>Artemisia tridentata</i>	0	5	7	1	2	15
			<i>Chrysothamnus viscidiflorus</i>	0	0	6	1	0	7
DH-19	6/15/89	ARTR/POSA	<i>Artemisia tridentata</i>	0	4	15	12	10	41
DH-26	6/13/89	ARTR/BRTE	<i>Artemisia tridentata</i>	0	1	7	5	2	15
			<i>Atriplex spinosa</i>	0	0	12	0	0	12
			<i>Chrysothamnus viscidiflorus</i>	0	31	56	2	0	89
DH-30	6/13/89	CHNA/STCO	<i>Artemisia tridentata</i>	1	0	0	2	5	8
			<i>Chrysothamnus nauseosus</i>	0	1	6	0	0	7
DH-32	6/13/89	BRTE/POSA(1)	<i>Artemisia tridentata</i>	0	0	1	0	0	1
DH-33	6/13/89	BRTE/POSA(2)	<i>Artemisia tridentata</i>	0	0	0	0	0	0
RRL-10	6/12/89	ATSP/POSA	<i>Atriplex spinosa</i>	0	0	10	6	0	16

Table D.2. Percent Cover Data for Undisturbed Control Plots at BWIP Borehole Reclamation Sites, Spring 1989

<u>Location</u>	<u>Habitat Type</u>	<u>Sample Date</u>	<u>Species</u>	<u>% Cover</u>
DC-15	PUTR/POSA	4/10/89	<i>Bromus tectorum</i>	11%
			<i>Poa sandbergii</i>	40%
			<i>Draba verna</i>	3%
			<i>Chrysothamnus nauseosus</i>	4%
			<i>Eriogonum niveum</i>	5%
		6/14/89	<i>Bromus tectorum</i>	10%
			<i>Poa sandbergii</i>	31%
			<i>Eriogonum niveum</i>	10%
DC-19 #1	CHNA/ORHY	4/13/89	<i>Chrysothamnus nauseosus</i>	9%
			<i>Bromus tectorum</i>	17%
			<i>Oryzopsis hymenoides</i>	15%
			<i>Compositae</i>	2%
		6/13/89	<i>Bromus tectorum</i>	19%
			<i>Stipa comata</i>	10%
			<i>Oryzopsis hymenoides</i>	23%
DC-19 #2	CHNA/ORHY	4/18/89	<i>Hymenopappus filifolius</i>	4%
			<i>Bromus tectorum</i>	20%
			<i>Stipa comata</i>	5%
			<i>Oryzopsis hymenoides</i>	5%
			<i>Koeleria cristata</i>	4%
			<i>Comandra umbellata</i>	2%
		6/13/89	<i>Comandra umbellata</i>	2%
			<i>Bromus tectorum</i>	21%
			<i>Stipa comata</i>	9%
			<i>Oryzopsis hymenoides</i>	2%
			<i>Chrysothamnus nauseosus</i>	9%
			<i>Koeleria cristata</i>	3%
DC-20 #1	ARTR/BRTE	4/12/89	<i>Bromus tectorum</i>	26%
			<i>Cryptantha pterocarya</i>	1%
			<i>Artemisia tridentata</i>	17%
			<i>Atriplex spinosa</i>	14%
			<i>Descurainia pinnata</i>	1%
			<i>Cymopterus terebinthinus</i>	4%
			<i>Balsamorhiza canyana</i>	1%
		6/12/89	<i>Bromus tectorum</i>	27%
			<i>Artemisia tridentata</i>	14%
			<i>Atriplex spinosa</i>	2%
DC-22	ARTR/BRTE	4/12/89	<i>Bromus tectorum</i>	10%

Table D.2. (Cont.)

<u>Location</u>	<u>Habitat Type</u>	<u>Sample Date</u>	<u>Species</u>	<u>% Cover</u>
DC-25 #1	AGDA/BRTE	6/13/89	<i>Poa sandbergii</i>	2%
			<i>Salicola kali</i>	1%
			<i>Artemisia tridentata</i>	23%
			<i>Astragalus speirocarpus</i>	1%
			<i>Bromus tectorum</i>	13%
			<i>Poa sandbergii</i>	6%
			<i>Artemisia tridentata</i>	24%
			<i>Astragalus sp</i>	4%
		6/13/89	<i>Sphaeralcea munroana</i>	1%
			<i>Agropyron dasystachyum</i>	37%
			<i>Penstemon acuminatus</i>	1%
			<i>Gilia miniiflora</i>	1%
			<i>Bromus tectorum</i>	11%
			<i>Bromus tectorum</i>	13%
DC-25 #2	AGDA/BRTE	6/13/89	<i>Stipa comata</i>	2%
			<i>Oryzopsis hymenoides</i>	1%
			<i>Cymopterus terebinthinus</i>	8%
			<i>Salicola kali</i>	13%
			<i>Astragalus sp</i>	1%
			<i>Bromus tectorum</i>	27%
			<i>Poa sandbergii</i>	3%
			<i>Artemisia tridentata</i>	17%
			<i>Chrysothamnus viscidiflorus</i>	7%
			<i>Descurainia pinnata</i>	1%
DC-3	ARTR/POSA	4/13/89	<i>Poa sandbergii</i>	3%
			<i>Artemisia tridentata</i>	17%
			<i>Chrysothamnus viscidiflorus</i>	7%
			<i>Descurainia pinnata</i>	1%
			<i>Poa sandbergii</i>	3%
		6/14/89	<i>Bromus tectorum</i>	25%
			<i>Artemisia tridentata</i>	6%
			<i>Balsamorhiza hanceana</i>	2%
			<i>Chrysothamnus viscidiflorus</i>	10%
			<i>Bromus tectorum</i>	4%
DH-19	ARTR/POSA	4/13/89	<i>Poa sandbergii</i>	17%
			<i>Agropyron spicatum</i>	6%
			<i>Lomatium macrocarpum</i>	1%
			<i>Helianthus cusickii</i>	1%
			<i>Artemisia tridentata</i>	17%
			<i>Descurainia pinnata</i>	4%
			<i>Bromus tectorum</i>	33%
			<i>Poa sandbergii</i>	1%
DH-26	ARTR/BRTE	4/6/89		

Table D.2. (Cont.)

<u>Location</u>	<u>Habitat Type</u>	<u>Sample Date</u>	<u>Species</u>	<u>% Cover</u>
DH-30	CHNA/STCO	4/18/89	<i>Artemisia tridentata</i>	21%
			<i>Chrysothamnus viscidiflorus</i>	3%
			<i>Atriplex spinosa</i>	8%
			<i>Bromus tectorum</i>	30%
			<i>Poa sandbergii</i>	1%
			<i>Artemisia tridentata</i>	22%
		6/13/89	<i>Descurainia pinnata</i>	1%
			<i>Chrysothamnus viscidiflorus</i>	2%
			<i>Bromus tectorum</i>	37%
			<i>Artemisia tridentata</i>	21%
			<i>Atriplex spinosa</i>	5%
			<i>Chrysothamnus viscidiflorus</i>	2%
		4/18/89	<i>Bromus tectorum</i>	13%
			<i>Stipa comata</i>	8%
			<i>Artemisia tridentata</i>	34%
			<i>Bromus tectorum</i>	5%
DH-32	BRTE/POSA(1)	6/13/89	<i>Stipa comata</i>	11%
			<i>Artemisia tridentata</i>	43%
			<i>Bromus tectorum</i>	58%
			<i>Poa sandbergii</i>	3%
			<i>Cymopterus serebinthinus</i>	2%
			<i>Ambrosia acanthicarpa</i>	4%
DH-33	BRTE/POSA(2)	6/13/89	<i>Salsola kali</i>	1%
			<i>Bromus tectorum</i>	56%
			<i>Poa sandbergii</i>	8%
RRL-10	ATSP/POSA	4/12/89	<i>Ambrosia acanthicarpa</i>	2%
			<i>Bromus tectorum</i>	9%
			<i>Poa sandbergii</i>	30%
		6/12/89	<i>Descurainia pinnata</i>	2%
			<i>Polemonium micranthum</i>	2%
			<i>Atriplex spinosa</i>	18%
RRL-5	BRTE/POSA(1)	4/12/89	<i>Bromus tectorum</i>	14%
			<i>Poa sandbergii</i>	35%
			<i>Atriplex spinosa</i>	15%
			<i>Bromus tectorum</i>	6%
			<i>Poa sandbergii</i>	41%
			<i>Salsola kali</i>	2%
			<i>Descurainia pinnata</i>	1%

Table D.2. (Cont.)

<u>Location</u>	<u>Habitat Type</u>	<u>Sample Date</u>	<u>Species</u>	<u>% Cover</u>
RRL-9	ARTR/BRTE	4/18/89	<i>Bromus tectorum</i>	20%
			<i>Chrysothamnus nauseosus</i>	8%

Table D.3. Species Occurrences in Control Plots at BWIP Borehole Reclamation Sites, Spring 1989

<u>Location</u>	<u>Habitat Type</u>	<u>Date</u>	<u>Species Name</u>
DC-15	PUTR/POSA	4/10/89	<i>Bromus tectorum</i>
			<i>Chrysothamnus nauseosus</i>
			<i>Descurainia pinnata</i>
			<i>Draba verna</i>
			<i>Eriogonum nivium</i>
			<i>Halostemum umbellatum</i>
			<i>Machaeranthera canescens</i>
			<i>Microseris gracilis</i>
			<i>Opuntia polyacantha</i>
			<i>Phlox longifolia</i>
			<i>Plantago macrocarpa</i>
			<i>Poa sandbergii</i>
			<i>Purshia tridentata</i>
		6/14/89	<i>Artemisia tridentata</i>
			<i>Bromus tectorum</i>
			<i>Chrysothamnus nauseosus</i>
			<i>Eriogonum nivium</i>
			<i>Opuntia polyacantha</i>
			<i>Phlox longifolia</i>
			<i>Plantago patagonica</i>
			<i>Poa sandbergii</i>
			<i>Purshia tridentata</i>
			<i>Tragopogon dubius</i>
DC-19 #1	CHNA/PORHY	4/13/89	<i>Ambrosia sp.</i>
			<i>Bromus tectorum</i>
			<i>Chrysothamnus nauseosus</i>
			<i>Composite sp.</i>
			<i>Descurainia pinnata</i>
			<i>Oxyopsis hymenoides</i>
			<i>Pentstemon acuminatus</i>
			<i>Phacelia linearis</i>
			<i>Stipa comata</i>
		6/13/89	<i>Ambrosia sp.</i>
			<i>Artemisia tridentata</i>
			<i>Bromus tectorum</i>
			<i>Chrysothamnus nauseosus</i>
			<i>Cryptantha sp.</i>
			<i>Hymenopappus filifolius</i>
			<i>Oxyopsis hymenoides</i>
			<i>Pentstemon acuminatus</i>
			<i>Phacelia linearis</i>
			<i>Salvia kali</i>
			<i>Stipa comata</i>

Table D.3. (Cont.)

<u>Location</u>	<u>Habitat Type</u>	<u>Date</u>	<u>Species Name</u>
DC-19 #2	CHNA/ORHY	4/18/89	<i>Ambrosia acanthicarpa</i>
			<i>Astragalus</i> sp.
			<i>Bromus tectorum</i>
			<i>Chrysanthemum nauseosus</i>
			<i>Chrysanthemum viscidiflorum</i>
			<i>Comandra umbellata</i>
			<i>Cymopterus terebinthinus</i>
			<i>Desmodium pinnata</i>
			<i>Festuca octoflora</i>
			<i>Fritillaria pudica</i>
			<i>Koeleria cristata</i>
			<i>Lupinus</i> spp.
			<i>Microsteris gracilis</i>
			<i>Oenothera pallida</i>
			<i>Oryopsis hymenoides</i>
			<i>Phacelia linearis</i>
			<i>Salvia kali</i>
			<i>Stipa comata</i>
		6/13/89	<i>Ambrosia</i> sp.
			<i>Astragalus</i> sp.
			<i>Bromus tectorum</i>
			<i>Chrysanthemum nauseosus</i>
			<i>Chrysanthemum viscidiflorum</i>
			<i>Cymopterus terebinthinus</i>
			<i>Hymenopappus filifolius</i>
			<i>Koeleria cristata</i>
			<i>Oenothera pallida</i>
			<i>Oryopsis hymenoides</i>
			<i>Pseudomonas acuminatus</i>
			<i>Phacelia linearis</i>
			<i>Poa sandbergii</i>
			<i>Salvia kali</i>
			<i>Stipa comata</i>
DC-20 #1	ARTR/BRTE	6/12/89	<i>Artemisia tridentata</i>
			<i>Atriplex spinesa</i>
			<i>Balsamorhiza hanceana</i>
			<i>Bromus tectorum</i>
			<i>Chrysanthemum viscidiflorum</i>
			<i>Cymopterus terebinthinus</i>
			<i>Poa sandbergii</i>
			<i>Sitanion hystrix</i>
DC-22	ARTR/BRTE	4/12/89	<i>Artemisia tridentata</i>
			<i>Astragalus spirocarpus</i>

Table D.3. (Cont.)

<u>Location</u>	<u>Habitat Type</u>	<u>Date</u>	<u>Species Name</u>
DC-25 #1	AGDA/BRTE	6/13/89	<i>Bromus tectorum</i>
			<i>Deschampsia pinnata</i>
			<i>Festuca octoflora</i>
			<i>Fritillaria pudica</i>
			<i>Poa sandbergii</i>
			<i>Salzola kali</i>
			<i>Sitanion hystrix</i>
			<i>Sphaeralcea macrocarpa</i>
			<i>Artemisia tridentata</i>
			<i>Astragalus</i> sp.
			<i>Bromus tectorum</i>
			<i>Machaeranthera canescens</i>
		6/13/89	<i>Poa sandbergii</i>
			<i>Salzola kali</i>
			<i>Sitanion hystrix</i>
			<i>Sphaeralcea macrocarpa</i>
			<i>Abronia umbellata</i>
			<i>Agropyron dasystachyum</i>
			<i>Ambrosia acanthicarpa</i>
			<i>Amsinckia</i> sp.
			<i>Astragalus</i> sp.
			<i>Bromus tectorum</i>
			<i>Cryptantha circumscrips</i>
			<i>Cymopterus terebinthinus</i>
DC-25 #2	AGDA/BRTE	6/13/89	<i>Gilia multiflora</i>
			<i>Machaeranthera canescens</i>
			<i>Oenothera pallida</i>
			<i>Oryopsis hymenoides</i>
			<i>Penstemon acuminatus</i>
			<i>Poa sandbergii</i>
			<i>Rumex venosus</i>
			<i>Salzola kali</i>
			<i>Achillea millefolium</i>
			<i>Ambrosia acanthicarpa</i>
			<i>Astragalus</i> sp.
			<i>Balsamorhiza coreana</i>
			<i>Bromus tectorum</i>
			<i>Cymopterus terebinthinus</i>
			<i>Mentzelia albicaulis</i>
			<i>Oenothera pallida</i>
			<i>Oryopsis hymenoides</i>
			<i>Penstemon acuminatus</i>
			<i>Phacelia hastata</i>

Table D.3. (Cont.)

<u>Location</u>	<u>Habitat Type</u>	<u>Date</u>	<u>Species Name</u>
DC-3	ARTR/POSA	4/13/89	<i>Rumex venosus</i>
			<i>Salzola kali</i>
			<i>Sitanion hystrix</i>
			<i>Stipa comata</i>
			<i>Artemisia tridentata</i>
			<i>Astragalus</i> sp.
			<i>Balsamorhiza carneyana</i>
			<i>Bromus tectorum</i>
			<i>Chrysothamnus viscidiflorus</i>
			<i>Descurainia pinnata</i>
			<i>Festuca octoflora</i>
			<i>Machaeranthera canescens</i>
			<i>Microsteris gracilis</i>
			<i>Poa sandbergii</i>
		6/14/89	<i>Artemisia tridentata</i>
			<i>Balsamorhiza carneyana</i>
			<i>Bromus tectorum</i>
DH-19	ARTR/POSA	4/13/89	<i>Chrysothamnus viscidiflorus</i>
			<i>Poa sandbergii</i>
			<i>Agropyron spicatum</i>
			<i>Artemisia tridentata</i>
			<i>Astragalus</i> sp.
			<i>Atriplex spinosa</i>
			<i>Balsamorhiza carneyana</i>
			<i>Bromus tectorum</i>
			<i>Calochortus macrocarpus</i>
			<i>Cryptantha pterocarya</i>
			<i>Descurainia pinnata</i>
			<i>Draba verna</i>
			<i>Erigeron</i> sp.
			<i>Fritillaria pudica</i>
			<i>Helianthus cusickii</i>
			<i>Hymenopappus filifolius</i>
			<i>Lomatium macrocarpum</i>
			<i>Phlox longifolia</i>
			<i>Poa sandbergii</i>
			<i>Sisymbrium olissimum</i>
			<i>Sitanion hystrix</i>
		6/15/89	<i>Agropyron spicatum</i>
			<i>Artemisia tridentata</i>
			<i>Astragalus</i> sp.
			<i>Atriplex spinosa</i>
			<i>Balsamorhiza carneyana</i>

Table D.3. (Cont.)

<u>Location</u>	<u>Habitat Type</u>	<u>Date</u>	<u>Species Name</u>
DH-26	ARTR/BRTE	4/6/89	<i>Bromus tectorum</i>
			<i>Descurainia pinnata</i>
			<i>Erigeron</i> sp.
			<i>Helianthus cusickii</i>
			<i>Lomatium</i> sp.
			<i>Oryopsis hymenoides</i>
			<i>Phlox longifolia</i>
			<i>Plantago patagonica</i>
			<i>Poa sandbergii</i>
			<i>Sitanion hystrix</i>
		4/18/89	<i>Artemisia tridentata</i>
			<i>Atriplex spinosa</i>
			<i>Bromus tectorum</i>
			<i>Chrysothamnus viscidiflorus</i>
			<i>Poa sandbergii</i>
			<i>Artemisia tridentata</i>
			<i>Atriplex spinosa</i>
			<i>Bromus tectorum</i>
			<i>Calochortus macrocarpus</i>
			<i>Chrysothamnus viscidiflorus</i>
		6/13/89	<i>Descurainia pinnata</i>
			<i>Poa sandbergii</i>
			<i>Sisymbrium altissimum</i>
			<i>Ambrosia</i> sp.
			<i>Artemisia tridentata</i>
			<i>Atriplex spinosa</i>
			<i>Bromus tectorum</i>
			<i>Chrysothamnus viscidiflorus</i>
			<i>Salsola kali</i>
			<i>Sisymbrium altissimum</i>
DH-30	CHNA/STCO	4/18/89	<i>Sitanion hystrix</i>
			<i>Achillea millefolium</i>
			<i>Artemisia tridentata</i>
			<i>Astragalus</i> sp.
			<i>Bromus tectorum</i>
			<i>Chrysothamnus nauseosus</i>
			<i>Comandra umbellata</i>
			<i>Cymopterus serebinthinus</i>
			<i>Descurainia pinnata</i>
			<i>Oryopsis hymenoides</i>
			<i>Poa sandbergii</i>
			<i>Sitanion hystrix</i>
			<i>Stipa comata</i>

Table D.3. (Cont.)

<u>Location</u>	<u>Habitat Type</u>	<u>Date</u>	<u>Species Name</u>
		6/13/89	<i>Achillea millefolium</i> <i>Artemisia tridentata</i> <i>Astragalus</i> sp <i>Bromus tectorum</i> <i>Chrysothamnus nauseosus</i> <i>Comandra umbellata</i> <i>Oxytropis hymenoides</i> <i>Sitanion hystrix</i> <i>Stipa comata</i>
DH-32	BRTE/POSA(1)	6/13/89	<i>Ambrosia</i> sp. <i>Artemisia tridentata</i> <i>Astragalus</i> sp <i>Bromus tectorum</i> <i>Cymopterus serebinthinus</i> <i>Epilobium paniculatum</i> <i>Lomatium</i> sp <i>Poa sandbergii</i> <i>Salvia kali</i> <i>Sisymbrium altissimum</i> <i>Sitanion hystrix</i> <i>Sphaeralcea muwona</i> <i>Tragopogon dubius</i>
DH-33	BRTE/POSA(2)	6/13/89	<i>Amsinckia</i> sp. <i>Bromus tectorum</i> <i>Holosteum umbellatum</i> <i>Poa sandbergii</i> <i>Salvia kali</i> <i>Tragopogon dubius</i>
RRL-10	ATSP/POSA	4/12/89	<i>Atriplex spinosa</i> <i>Bromus tectorum</i> <i>Descurainia pinnata</i> <i>Holosteum umbellatum</i> <i>Microstis gracilis</i> <i>Polemonium micranthum</i> <i>Poa sandbergii</i> <i>Salvia kali</i> <i>Sitanion hystrix</i> <i>Sphaeralcea muwona</i> <i>Tragopogon dubius</i>
RRL-5	BRTE/POSA(1)	4/12/89	<i>Bromus tectorum</i> <i>Descurainia pinnata</i> <i>Lomatium triseriatum</i> <i>Poa sandbergii</i>

Table D.3. (Cont.)

<u>Location</u>	<u>Habitat Type</u>	<u>Date</u>	<u>Species Name</u>
RRL-9	ARTR/B RTE	4/18/89	<i>Salsola kali</i>
			<i>Amsinckia</i> sp
			<i>Artemisia tridentata</i>
			<i>Astragalus</i> sp
			<i>Bromus tectorum</i>
			<i>Calochortus macrocarpus</i>
			<i>Chaenactis douglasii</i>
			<i>Chrysothamnus nauseosus</i>
			<i>Chrysothamnus viscidiflorus</i>
			<i>Cryptantha leucophaea</i>
			<i>Deschampsia pinnata</i>
			<i>Festuca octoflora</i>
			<i>Sitanion hystrix</i>

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