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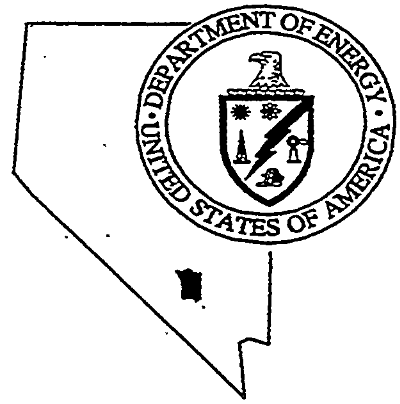

Clean Slate 2 Revegetation and Monitoring Plan

February 1998

Environmental Restoration
Division

U.S. Department of Energy
Nevada Operations Office

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CLEAN SLATE 2

REVEGETATION AND MONITORING PLAN

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CLEAN SLATE 2 REVEGETATION AND MONITORING PLAN

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ABBREVIATIONS AND ACRONYMS

a	Acre
Pu	Plutonium
cm	Centimeter(s)
COPPD	Cover-Point Optical Point Projection Device
DRI	Desert Research Institute
EC	Electrical Conductivity
ft	Foot (feet)
ft^2	Square Foot (feet)
gal	Gallon(s)
ha	Hectare
in	Inch
kg	Kilogram
km	Kilometer
lb	Pound(s)
l	Liter
m	Meter
m^2	Square Meter
mm	Millimeter
mmhos	Millimohs
mi	Mile

ABBREVIATIONS AND ACRONYMS (Continued)

NTS	Nevada Test Site
pCi/g	PicoCurie(s) per Gram (10^{-12})
PLS	Pure Live Seed
ppm	Part per Million
USDA	United States Department of Agriculture
SAR	Sodium Adsorption Ratio
TTR	Tonopah Test Range

1.0 INTRODUCTION

This document constitutes a revegetation plan for the short- and long-term stabilization of land disturbed by activities associated with the cleanup of radionuclide-contaminated surface soil at the Clean Slate 2 site. This document has been prepared to provide general revegetation practices and procedures that will be followed during restoration of the clean-up site. The results of reclamation trials at Area 11, Area 19, and more recently, the reclamation demonstration plots at the Double Tracks clean-up site, have been summarized and incorporated into this revegetation and monitoring plan. This plan also contains procedures for monitoring both the effectiveness and success of short- and long-term soil stabilization.

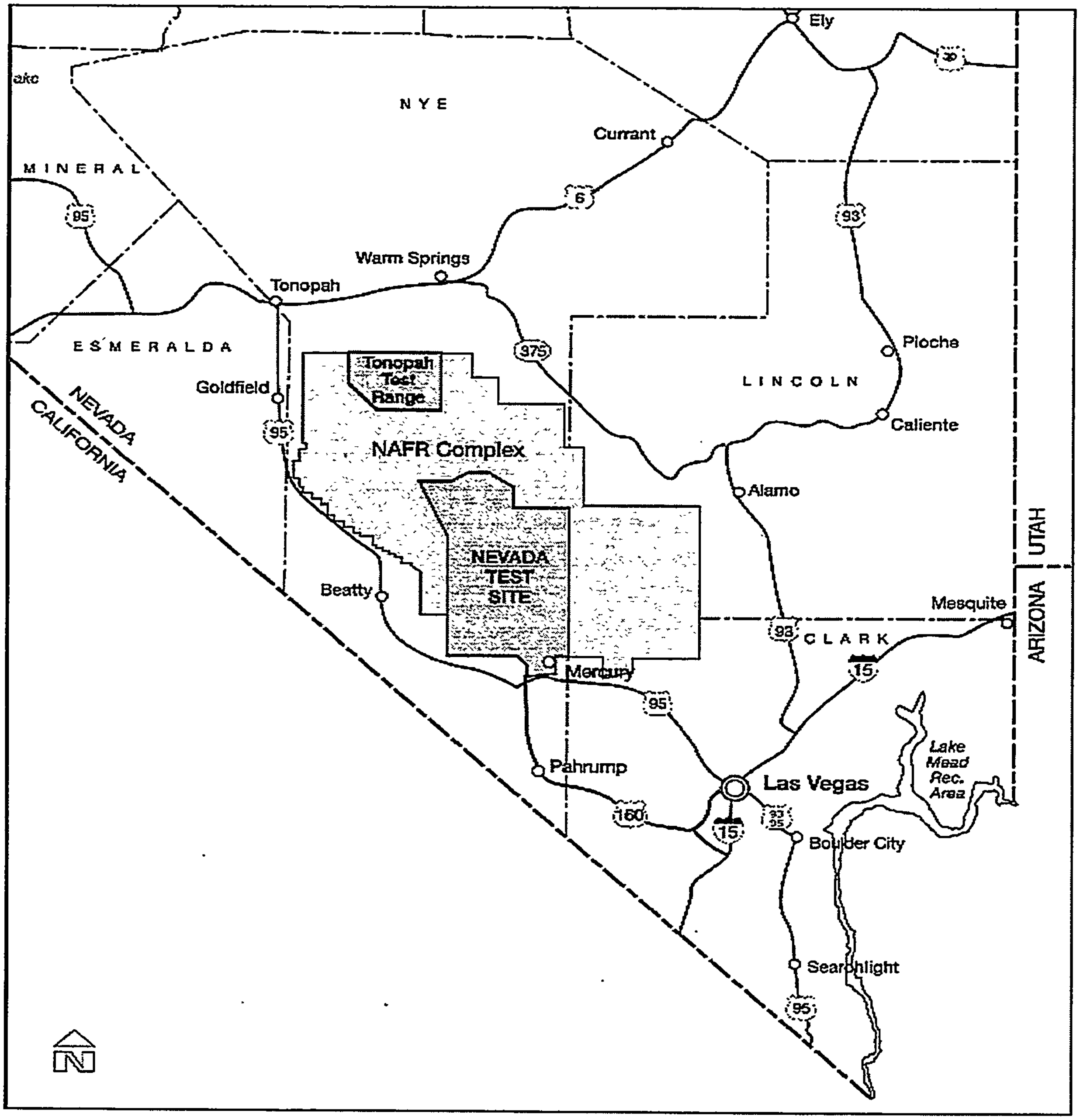
1.1 Physical Location and Setting of Clean-up Site

The Clean Slate 2 clean-up site is located on the Tonopah Test Range (TTR), which is approximately 64 kilometers (km) (40 miles [mi]) from Tonopah, Nevada (Figure 1). Typical access to the clean-up site is through the north entrance (main gate) to TTR, south on Main Road for approximately 13 km (8 mi), east on Bunker Road to Mellan Road, southeast on Mellan Road to Cedar Pass Road, approximately 5 km (3 mi), then east on Cedar Pass Road for approximately 1.6 km (1 mi). Clean Slate 2 is located approximately 0.5 km (0.3 mi) to the south of Cedar Pass Road (Figure 2).

Clean Slate 2 is located upslope from the dry lake beds of Cactus Flat valley. Elevations at the site range from 1,677 meters (m) (5,500 feet [ft]) to 1,689 m (5,540 ft). Common shrubs found on the reference site, which is located inside the fence and southwest of ground zero, include bud sagebrush (*Artemisia spinescens*), winterfat (*Krascheninnikovia lanata*), and shadscale saltbush (*Atriplex confertifolia*). Common grasses are galleta grass (*Pleuraphis jamesii*), Indian ricegrass (*Achnatherum hymenoides*) and bottlebrush squirreltail (*Elymus elymoides*). Big sagebrush (*Artemisia tridentata*) is found along the washes typcial of the eastern portion of Clean Slate 2. Soils are predominantly gravelly sandy loams (Leavitt, 1978). Average annual precipitation at Goldfield, located 30 miles to the west of the TTR, is 11.8 centimeters (cm) (5.22 inches [in]) (unpublished, Office of the Nevada State Climatologist).

1.2 Project Description

The Clean Slate 2 fenced area is approximately 160 m (525 ft) wide and 1,300 m (4,265 ft) long. The surface soils at Clean Slate 2 were contaminated as a result of the detonation of a device containing plutonium (Pu) and depleted uranium using chemical explosives (Church, 1969; Shreve, 1965). Excavation of contaminated soils at Clean Slate 2 will follow procedures similar to those used during the cleanup of the Double Tracks (Anderson and Hall, 1997a) and Clean Slate 1 (Anderson and Hall, 1997b) sites. A maximum of approximately 33 cm (12 in) of the surface soils will be excavated and removed from the site. Near ground zero, where contamination levels are highest, approximately 2 m (7 ft) of soil may be removed. The



LEGEND

Primary highway
State boundary
County boundary
City

Figure 1. Location of the Tonopah Test Range.

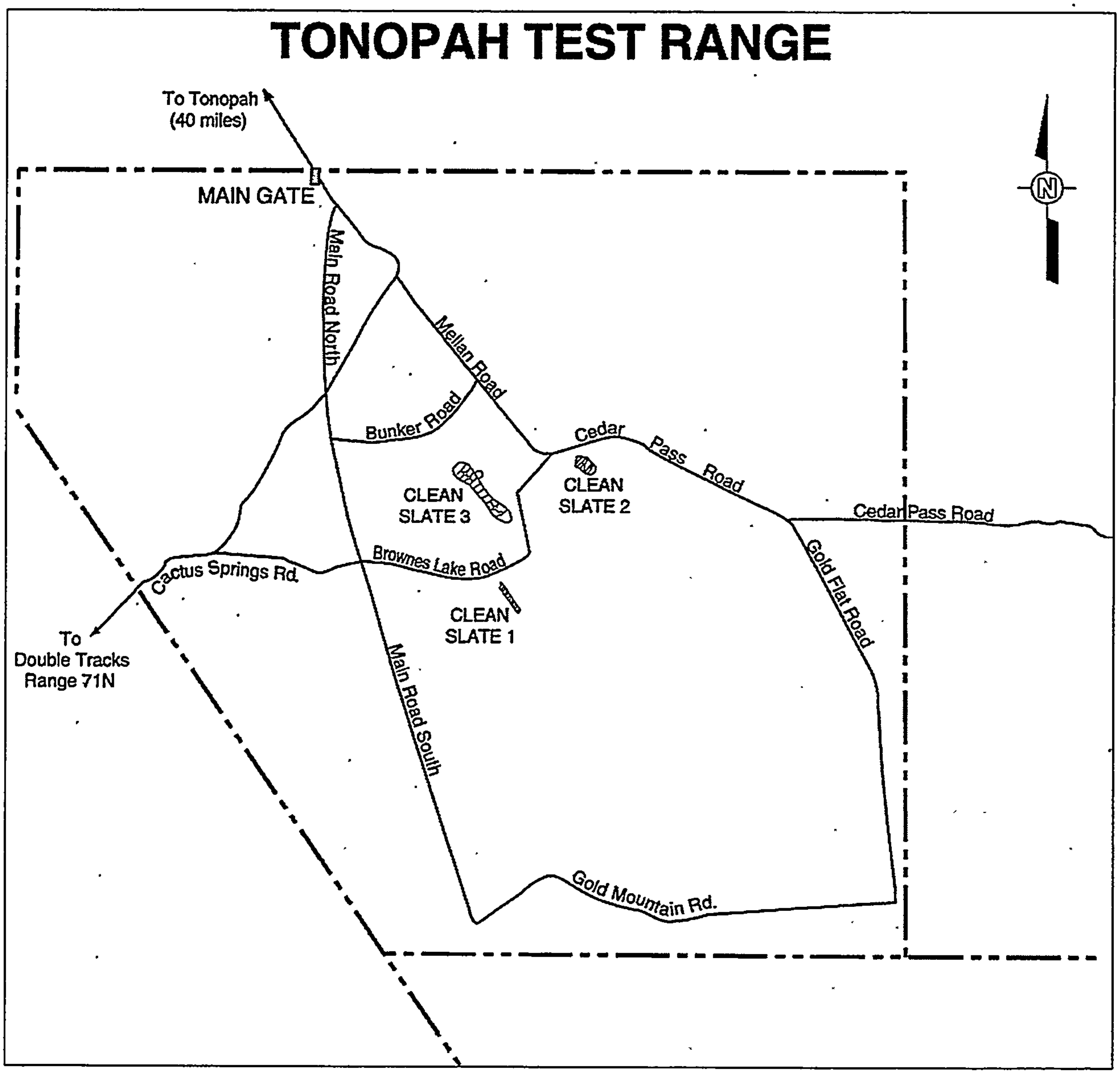


Figure 2. Location of Clean Slate 1, 2 and 3 on the Tonopah Test Range.

maximum area to be excavated is estimated to be 18.4 hectares(ha) (45.4 acres [a]). In addition to the disturbance associated with soil excavation, approximately 2.0 ha (5.0 a) will be disturbed by the construction of staging areas and placement of support facilities.

1.3 Objective

The primary objective of this document is to provide general procedures for short- and long-term stabilization of soils that will be disturbed during the cleanup of contaminated soils at Clean Slate 2. Stabilization is critical to prevent any resuspension of residual Pu and to reestablish wildlife habitat. Short-term or interim stabilization consists of the application of a chemical soil stabilizer that is applied immediately following excavation of the contaminated soils to minimize Pu resuspension, reducing health hazards for workers and the public. Long-term stabilization, which is accomplished by the establishment of a permanent vegetative cover, will also reduce Pu resuspension, and is critical in returning the site to predisturbance conditions, providing habitat for local wildlife and complementing the other actions being taken to release the site for future use.

A secondary objective is to establish procedures for monitoring the success of both short- and long-term stabilization. Contained in this document are the criteria and methodology for evaluating the effectiveness of the chemical soil stabilizer in reducing resuspension of soil particles, and the criteria for determining if revegetation has been successful.

2.0 CONSTRUCTION RECOMMENDATIONS

Removal of topsoil during the excavation process leaves a soil low in organic matter and soil nutrients. In addition, the pool of seeds from native plants commonly found in the surface soils is lost. These two factors result in a sterile soil and difficult conditions for reestablishing a viable plant community. The following actions are recommended to ameliorate the effects of the loss of the topsoil during the clean-up process.

- Salvage the topsoil from the staging areas and the equipment loading/unloading zone, and any other major disturbances

- Stockpile the salvaged topsoil on the up-slope side of the disturbed area, where possible; recommended locations are shown on Figure 3.

- Topsoil stockpile should not exceed 2 m (6 ft) in depth to maintain soil microbiological viability.

- During construction of new roads, any topsoil that is removed should be salvaged and stockpiled along side the road in berms not exceeding 2 m (6 ft) in depth.

- During construction of topsoil stockpiles, traffic of earth moving equipment on top of the topsoil stockpile should be minimized.

- Topsoil stockpiles will be stabilized with a chemical stabilizer immediately following construction and maintained as needed thereafter until soils are returned to the site from which they were removed.

- Reclamation scientist(s) should be on-site during construction activities to assist in locating topsoil stockpiles and minimizing impacts to the environment.

- Construction equipment and all other vehicles on-site should travel on existing roads; no off-road travel should occur.

The reclamation scientist(s) will coordinate with the construction superintendant or his designee to ensure that these recommendations are implemented.

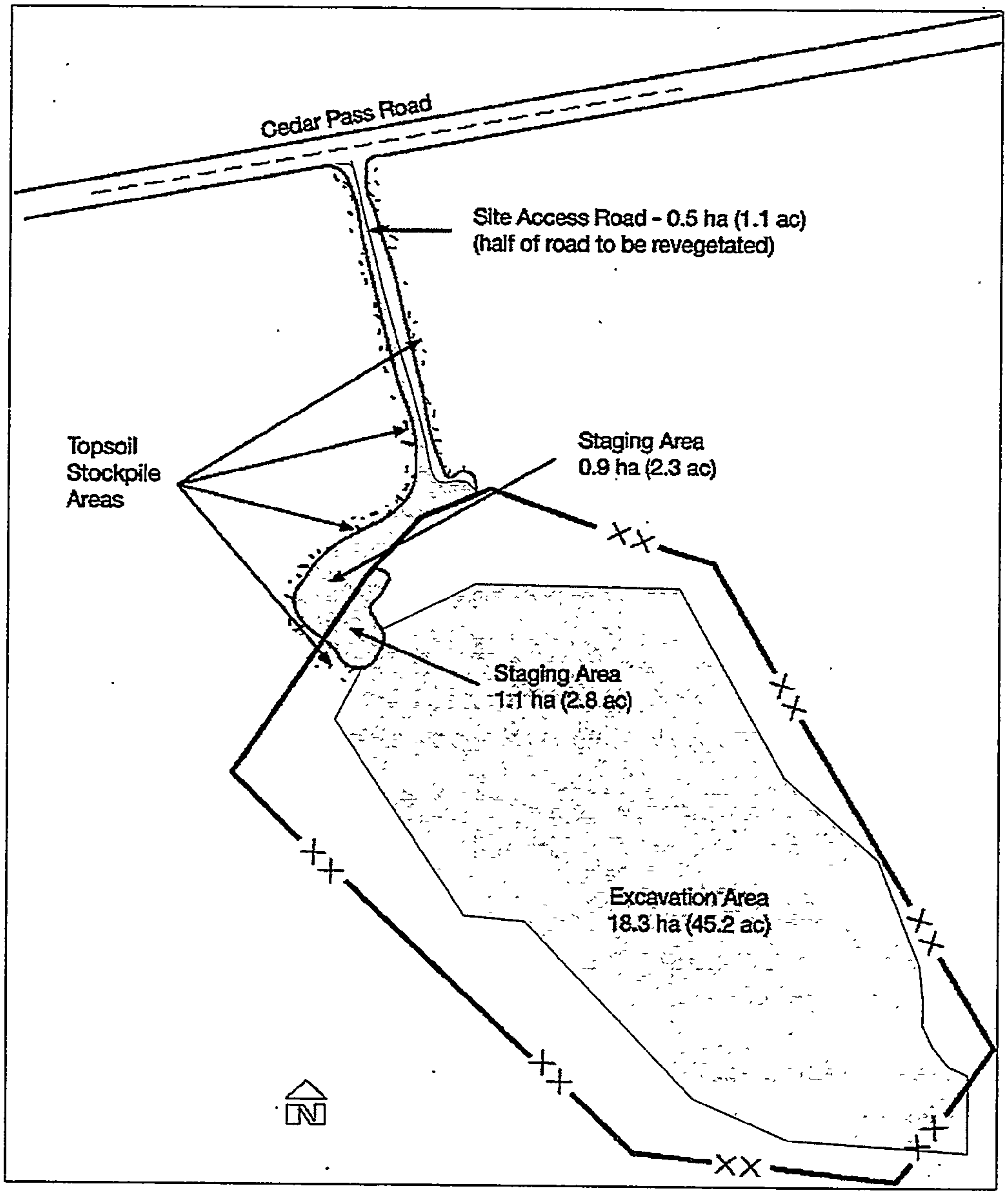


Figure 3. Potential locations for topsoil stockpiles. Areas to be revegetated at Clean Slate 2 clean-up site are shaded.

3.0 SHORT-TERM STABILIZATION

Short-term (interim) stabilization will be conducted after contaminated soils are excavated and verified to be within the established clean-up concentration levels of Pu. The duration of this phase will be as long as the excavation and verification processes may take. Short-term stabilization must remain effective until long-term stabilization occurs. To maintain effectiveness, reapplication of the soil stabilizer may continue until revegetation of the site occurs. The window for long-term stabilization (revegetation) is between October 1 and November 30. If excavation is completed outside this window, then short-term stabilization must continue until the site is revegetated.

3.1 Areas to be Stabilized

The highest priority for short-term soil stabilization are contaminated soils that through exposure to the wind could become airborne and thus pose a risk to the health of workers. These high-priority sites include subsurface soils exposed during excavation; i.e., the plume and ground zero, and the stockpile of contaminated soil awaiting packaging and shipment to NTS for disposal. The plume will be stabilized after each segment has been cleaned up to predetermined levels (200 picoCuries/gram). Once all contaminated soils have been picked up and stockpiled, ground zero and the stockpile will be stabilized. Stabilization will occur as soon after disturbance as possible, depending on the availability of personnel to perform the work.

The next priority for stabilization are those soils that have been disturbed during the cleanup process, but are considered non-contaminated. Stockpiles of these non-contaminated soils will be created during construction of staging areas both inside and outside the fenced area. The surface soils are scraped typically up-slope and to the edge of the staging area. These soils will be used later in final revegetation (Section 4.0). Disturbed soils around the soil-packaging operation, loading zone, and roadways (both entrance roadways and site peripheral roads) may also be stabilized to minimize fugitive dust and potential hazardous working conditions. Some soils may become stabilized by natural soil crusting in which case application of a chemical soil stabilizer may not be necessary. These miscellaneous disturbances of non-contaminated soils will be stabilized with AGRI-LOCK as may be requested by the project manager and/or construction superintendant or his designee.

After demobilization of excavation and soil-handling equipment, the soil surfaces in the staging areas inside and outside the fence will be ripped to alleviate the compaction of the soil (Section 4.6, Site Preparation) and disked to break up larger soil clods. Following ripping and disking, the soils may be stabilized again using AGRI-LOCK. Interim stabilization may be necessary at this point if revegetation is not scheduled to occur in the near future (within 30 to 60 days).

3.2 Product Selection

AGRI-LOCK, a synthetic chemical soil stabilizer, was selected to be used for interim stabilization. Over the past several years, numerous organic mulches, inorganic mulches, chemical stabilizers, soil surface manipulation treatments and windbreaks were evaluated. Each product or treatment was evaluated for its ability to (a) control wind erosion, (b) remain effective for at least five months, (c) be compatible with eventual revegetation of the site, (d) not introduce hazardous materials to the environment, (e) not pose a risk to workers, (f) show resistance to traffic, (g) not impede the verification process, (h) be compatible with the excavation process, (i) show compatibility with different soil types, and finally (j) be cost effective. Of the numerous products available in each of the aforementioned groups, eight representative products were field tested for erosion control capabilities, longevity of effectiveness, and effect on the emergence of seedlings. Based on the results of the original screening and the field trials, AGRI-LOCK was selected to be used for short-term stabilization.

Interim stabilization does not include active roads. AGRI-LOCK may not be the appropriate product for stabilization of disturbances that receive vehicular traffic. Examples of traffic resistant products include: petroleum byproducts, wood byproducts, and salts. These products should be applied to a compacted soil surface. Most require a pre-wetting treatment, although some products must be incorporated into the soil. This would reduce costs associated with hauling water for dust suppression. These products require much less water than a water-only, soil-stabilization treatment and have an effective longevity of one to several months.

3.3 Product Application

AGRI-LOCK will be applied with a hydromulcher at a minimum rate of approximately 84 liters (l)/ha (55 gallons [gal]/a). The product will be diluted at a ratio of from 1:18 to 1:12 parts product to water. The ratio selected will be based on the crust strength desired. A ratio of 1:12 (314 l [83 gal] of product to 3,785 l [1,000 gal] of water) would be appropriate for areas where additional light traffic might be expected. A ratio of 1:18 (84 l [55 gal] of product to 3,785 l [1,000 gal] of water) would be used on the stockpiles and on areas where excavation activities are completed and are unlikely to be disturbed.

Application of AGRI-LOCK, like most chemical stabilizers, requires a pre-wetting of the soil. If soils exposed after excavation are not adequately wet, they should be wetted prior to application of AGRI-LOCK. After application, a curing time of one to three hours is required. The duration of the drying time is dependent on the wetness of the soil, air temperature and wind. After curing, the soil surface should be resistant to some light traffic. Repeated vehicular traffic may require reapplication. A wood fiber treated with a chemical dye may be used to act as a tracer or indicator of areas treated. The wood fiber should be applied at a rate of approximately 23 kg (50 pounds [lbs]) of product to 3,785 l (1,000 gal) of water.

4.0 LONG-TERM STABILIZATION: REVEGETATION

The primary objective of long-term stabilization is to establish a stable plant cover that will reduce wind and water erosion, and reestablish wildlife habitat. Long-term stabilization is critical for minimizing fugitive dust and Pu resuspension, restoring the site to predisturbance conditions, and reestablishing habitat for wildlife. The potential for successful revegetation is enhanced by identifying soil plant growth potential; selecting appropriate plant species; using appropriate site preparation techniques; amending the soil, if needed; and implementing a tested arid-land revegetation strategy. The following sections outline the areas to be revegetated and the procedures to be used for revegetation at the Clean Slate 2 clean-up site.

4.1 Areas to be Revegetated

The following areas are to be revegetated during the revegetation window.

Table 1. List of areas to be revegetated at the Clean Slate 2 clean-up site (See also Figure 3).

Description	Number of Hectares (Acres)
Inside Fenced Area: Area to be excavated: Ground Zero and Plume Area	18.4 ha (45.4 a)
Staging/Loading Area	1.1 ha (2.8 a)
Outside Fenced Area: Staging Area	0.7 ha (1.7 a)
Loading/Unloading	0.2 ha (0.6 a)
Portion of Road from Staging Area to Cedar Pass Road	0.5 ha (1.1 a)
TOTAL AREA TO BE REVEGETATED	20.9 ha (51.6 a)

Some roads may also be revegetated, as determined by the project manager, or they may be revegetated at a future date when monitoring activities are completed. A portion of the road from the staging area outside the fence to Cedar Pass Road will be revegetated.

4.2 Plant Growth Potential of Soils

The layer of exposed soil on the excavated areas at Clean Slate 2 has physical and chemical characteristics that will support plant growth. The uppermost layer (30 cm [12 in]) of soil after excavation will have parameters consistent with those in the good suitability class (USDA, Forest Service, 1979; USDA, Soil Conservation Service, 1978). The results of soil analyses conducted by EG&G (1995) and Leavitt (1978) on soils at Clean Slate 2 were used to assess soil suitability. Overall the soils are slightly alkaline (pH 8.1 to 8.2), and organic matter is low (< 1%). However, the plants in the area have adapted to such conditions and soil amendments to ameliorate the higher pH would change conditions such that native species may not reestablish.

Soils in the Mojave and Great Basin Deserts are generally low in organic matter. Soils collected near the Clean Slate 2 clean-up site contain about 0.3 percent organic matter in the interspace between plants and about 0.6 percent in soils collected underneath plants. The desired amount of organic matter is between 0.5 and 1.5 percent. Since the top portion of the soil at Clean Slate 2 will be removed, most or all of the organic matter will be lost. The low percentage of organic matter results in a reduction in nutrients available to plants and reduction of soil water-holding capacity. To improve soil conditions several actions will be taken. First, a polyacrylamide gel will be applied, which improves the water-holding capacity in the upper layer of the soil (Section 4.7.1). Second, to increase the organic matter in the soil, a straw mulch will be used following seeding (Section 4.7.3). The mulch will be crimped into the soil. Although some may blow from the site, much of the straw will become incorporated into the soil, improving the amount of organic matter in the soil. Finally, the topsoil that is salvaged during construction of the staging areas will be returned to the site, when clean-up activities are completed (Section 4.6). This action will return to the site needed nutrients and seeds, which are important elements of the restoration process.

4.3 Plant Species Selection

Vascular plant species native to the Clean Slate 2 area will be used to revegetate the clean-up area. To determine naturally occurring plants at the Clean Slate 2 site, vascular plant density and cover data were collected in July 1995 from 15 permanent, 50-m (164-ft) transects located in the southwestern corner of Clean Slate 2, immediately south of ground zero. Density (absolute) was determined by averaging the number of plants occurring in five random 2 x 2-m quadrats on each of the 15 transects (Table 2). Relative percent density was calculated for each species by dividing the absolute percent density for a particular species by the total absolute percent density for all species combined. Relative density can be used to identify the proportion of an individual species' density in the total plant density of a site.

Plant cover was determined using a point-intercept method. Cover (absolute), defined as the percentage of ground surface area covered by the canopy of a particular species, was recorded for each perennial species encountered along the transects (Table 2). Relative percent cover was calculated for each species by dividing the absolute percent cover for a particular species by the total absolute percent cover for all species (Table 2).

Density and cover data are used in determining the species and proportion of each species to be included in the seed mix, and/or transplants used in revegetation of the Clean Slate 2 site. Annual plant species are not included because they do not provide constant vegetative cover. Other criteria used to select species for revegetation include (a) previous success in establishing the species either by seeding or transplanting, (b) the ability to collect seed from native species in environments similar to the Clean Slate 2 site, and (c) the commercial availability of seed from species adapted to the Clean Slate 2 environs.

Table 2. List of perennial plants found in the reference area established in the southwest corner of the Clean Slate 2 fenced area on the TTR. Percent density and cover values are given for species encountered on fifteen transects established in the reference area.

Scientific Name	Common Name	Density		Cover (%)		Seed Commercially Available	Seed Collection Feasible
		Absolute (plants/m^2)	Relative (%)	Absolute	Relative		
Perennial species							
Artemisia spinescens	Bud sagebrush	1.0	6.4	3.1	20.8	no	yes
Atriplex confertifolia	Shadscale saltbush	0.2	1.1	0.3	2.3	yes	yes
Krascheninnikovia lanata	Winterfat	1.6	10.3	4.3	29.4	yes	yes
Opuntia pulchella	Sagebrush cholla	<0.1	<0.1	0.0	0.0	no	no
Pleuraphis jamesii	Galleta grass	12.3	78.3	4.5	30.8	yes	yes
Achnatherum hymenoides	Indian ricegrass	0.6	3.8	2.5	16.7	yes	yes
Elymus elymoides	Bottlebrush squirreltail	<0.1	<0.1	0.0	0.0	yes	yes
Sphaeralcea ambigua	Desert globemallow	<0.1	0.2	0.0	0.0	yes	yes
	Totals	15.7		14.7			

The seed mix for the Clean Slate 2 clean-up site will contain a minimum of three species of shrubs, three grasses, and one forb (Table 3). The ratio of the different life forms in the seed mix is similar to that found on the reference sites. Big sagebrush and rubber rabbitbrush may also be added to the seedmix used on the eastern portion of the site along the drainages.

Seed collected from within the same geographical region is usually available from commerical seed-collecting companies for all species except bud sagebrush and galleta grass. If growing conditions are favorable and seed is produced, bud sagebrush seed will be collected from within a 32-km (20-mi) radius of the Clean Slate 2 clean-up site. Seed purity and viability will be determined for bud sagebrush after it is cleaned. Seed from other species may also be collected depending on the availability of the seed commerically and abundance of seed in the vicinity of Clean Slate 2.

Seed purchased from native seed companies will be on a pure live seed (PLS) basis. Specifications for the purchase of native seeds will require collection from the Mojave and/or Great Basin Desert environments and recent (within six months) certification of seed purity and viability.

4.4 Site Access Requirements

The Clean Slate 2 site should have an access with a width of at least 5 m (16 ft). Equipment that will be required at the site includes a tractor, road graders, water tankers, irrigation equipment, disks, a harrow, flat bed truck, four wheel drive trucks, a seed drill, a hydromulcher, and a straw blower.

4.5 Timing of Revegetation

Revegetation will occur between October 1 and November 30. During this period, conditions are more favorable for meeting germination requirements of the seeded species. Seeding may occur later depending on climatic conditions, but seeding earlier is not recommended.

Table 3. Composition of seed mix to be used for revegetation of the Clean Slate 2 clean-up site.

Life Form	Scientific Name	Common Name	Seeds/m^2 (Seeds/ft^2)	PLS kg/ha (lbs/ac)
Shrub	*Artemisia spinescens*	Bud sagebrush	296 (28)	0.3 (0.3)
	Artemisia tridentata	Big sagebrush	99 (9)	0.1 (0.1)
	Atriplex confertifolia	Shadscale saltbush	80 (7)	5.6 (5.0)
	Krascheninnikovia lanata	Winterfat	210 (20)	16.8 (15.0)
	Ericameria nauseosa	Rubber rabbitbrush	99 (9)	1.1 (1.0)
Grasses	*Pleuraphis jamesii*	Galleta grass	236 (22)	6.7 (6.0)
	Achnatherum hymenoides	Indian ricegrass	139 (13)	4.5 (4.0)
	Elymus elymoides	Bottlebrush squirreltail	47 (4)	1.1 (1.0)
Forbs	*Sphaeralcea ambigua*	Desert globemallow	37 (3)	0.3 (0.3)
Total			1,243 (115)	36.5 (32.7)

4.6 Site Preparation

Site preparation will be completed prior to the October 1 to November 30 revegetation window. It is assumed that the soils will be compacted, which will require alleviation for good plant establishment. Heavily compacted (e.g., staging areas) soils will be ripped using a grader equipped with 40-cm (16-in) ripper teeth. Depth of ripping will be below the compacted soil layers, usually from between 30 and 40 cm (12 and 16 in). Less compacted areas will be ripped using a chisel-tooth plow, again to a depth below compaction. Disking and/or harrowing may follow ripping or it may be delayed until just before planting. The delay will allow a natural breakdown of the soil clods and may negate the need for disking. Ripping and disking, if necessary, increase water infiltration, and provide a firm seedbed for good soil-to-seed contact (Munshower, 1994). After ripping and disking the staging areas, the area will be recontoured to approximately pre-disturbance conditions. Working the soil will be minimized so soil structure may be maintained.

Any non-remediated topsoils that were removed and stockpiled during construction or clean-up activities will be returned to the site prior to recontouring. The topsoil will be evenly distributed over the site not to exceed 10 to 15 cm (4 to 6 in) deep.

4.7 Revegetation

The revegetation strategy implemented at the Clean Slate 2 site will include a combination of seeding and supplemental irrigation to increase the potential for the establishment of a native plant community during the first few years. The possibility of establishment occurring without seeding is remote because the native seed source in the native soils has been removed. Leaving the excavation area to reseed naturally would only promote an influx of weedy annual species, thereby decreasing the potential for perennial plant establishment due to competition. The abundance of weedy annual species often gives the appearance of restoration success, but their effectiveness in controlling erosion is short lived and undependable. Those species are dependent on good growing conditions. Based on climatic conditions experienced during the past decade, several years may pass in this region without good growing conditions and consequently the absence of annual plant species.

The overall objective of artificially seeding disturbed sites is to accelerate the natural restoration process by establishing a viable, native, perennial plant community. The establishment of perennial species will provide a more permanent means of controlling wind and water erosion throughout the growing season. Additionally, wildlife should adapt to the newly revegetated area because species native to the area will be used in revegetation efforts.

4.7.1 Soil Amendments

The only soil amendment that will be used is a polyacrylamide gel. Polyacrylamide gels (cross-linked polymer gels) can absorb 40 to 500 times their weight in water. At the NTS, polyacrylamide applications have been successful in increasing the numbers of germinating perennial species over areas not receiving the polyacrylamide application (EG&G/EM 1994; EG&G/EM 1995). The gel will be applied at a rate of 24 kg/ha (20 lbs/a) using a drill seeder. Application will be concurrent with the seeding process (Section 4.7.2).

4.7.2 Seeding

The Clean Slate 2 site will be seeded during the revegetation window, which is between October 1 and November 30. Seeding at this time ensures that dormancy-breaking requirements for germination of most seeded species would be met. Additionally, seed would be in the ground prior to winter precipitation and freezing temperatures.

The seed will be broadcast-seeded at a rate of 36.5 PLS kg/ha (32.7 lbs/a) (Table 3). The area will be seeded with a tractor-drawn seed drill having seedboxes that accommodate intermediate and fluffy seeds. The seed tubes will be disconnected from the disk openers, thus allowing the seed to be broadcast over the soil surface. A drag bar with ten 75-cm (30-in) chains attached, will be fitted onto the walkboard at the rear of the seeder. The length of the chain that is allowed to drag will be adjusted according to the soil structure to ensure propoer coverage of seeds. In coarser soils the chain should drag 20 to 25 cm (8 to 10 in) on the ground in order to adequately cover the seed. However, in finer soils, which is the case at Clean Slate 2, the length of chain should be shortened, so seed is not buried too deep. This process improves soil-seed contact and places the seed in the surface few centimeters of soil. Seeding will be perpendicular to the slope or at an angle to the slope to avoid gullying or rilling in the event of excessive runoff that may occur during intense precipitation events.

4.7.3 Mulching

Immediately after seeding, the site will be mulched with a grain (wheat or barley) straw. The mulch is secured to the soil surface by crimping, which creates a vertical barrier to both wind and water erosion. The incorporation of the mulch into the soil also increases the percentage of organic matter in the soil, thus creating a more favorable micro-environment for seedling establishment and plant growth.

The straw is applied evenly to the soil surface with a straw blower at a minimum rate of 4,500 kg/ha (4,000 lbs/ac). The exposed soil surface should be less than 5 percent and the thickness of the straw mulch should not exceed 7.5 cm (3 in). Straw stem length should be 15 to 25 cm (6 to 10 in). This is accomplished by adjusting the number of chains attached to the hammermill.

A tractor drawn disk-crimper will be used to punch the straw into the soil. Weights are added to the disk-crimper so that disk and straw penetration into the soil is 10-15 cm (4-6 in). The direction of crimping will be perpendicular to the slope of the site.

4.7.4 Transplants

Transplants are not planned to be used during initial revegetation. Transplanting may occur in subsequent years to increase species diversity on the site, if certain dominant species such as bud sagebrush are not reestablishing on the site. The number of transplants per hectare for bud sagebrush and other species that may be identified, would be determined from: (a) relative cover and density (Table 2) of the species in the native plant community, (b) desired percentage of a species density as transplants, (c) past success in establishment of the species from seeding or transplanting, and (d) the availability of transplants from either commercial nurseries or contract growers. Bud sagebrush is not available from plant nurseries, and it is unlikely that any of the other species are available either. If transplants are to be used it would be necessary to collect local seed and contract with a nursery to grow the desired number of plants. The decision to use transplants will be made the third or fifth growing season following initial revegetation.

4.8 Irrigation

One of the most limiting factors for successful seed germination and plant establishment is the availability of water. Precipitation amounts fluctuate from year to year at the Clean Slate 2 site, and extended periods of drought conditions could result in the complete failure of long-term soil stabilization attempts. Preliminary results from reclamation field study plots established at Double Tracks and at other sites on the NTS suggest that irrigation improves seedling densities, which eventually results in the establishment of a stable perennial plant community. Results from these studies also suggest that irrigation during the late spring and early summer months improves survival of seeded species over the summer months. Approximately 98 percent of the seedlings on study plots that were irrigated with 25 millimeters (mm) (1in) of water seven different times at intervals of 2 to 3 weeks during the late spring and early summer, survived the hot, dry summer months of 1995. About 95 percent of the seedlings on plots irrigated with 50 mm (2 in), instead of 25 mm (1 in) of water, survived, indicating that 25 mm (1 in) is just as effective as 50 mm (2 in). Seedling survival on the two irrigated treatments was higher than on the plots that were not irrigated: 84 percent survival on non-irrigated plots as opposed to 95 percent on irrigated plots. Although the non-irrigated plots did not receive any supplemental irrigation, natural precipitation during the late spring and early summer was 83.6 mm (3.3 in), which created optimal growing conditions. In addition, temperatures during the summer of 1995 were moderate, and high temperatures did not occur until late in the summer. Under below-normal precipitation and poor growing conditions, irrigation would have had a more dramatic effect on seedling survival over the dry summer months.

Another study was conducted during the fall of 1995 and spring of 1996 to evaluate different irrigation strategies. One strategy tested was to irrigate in the fall to recharge the soil water levels, thus providing an environment more conducive to seed germination requirements. Another strategy was to irrigate just prior to seed germination in the spring of the year to provide an immediate source of water to ensure seed germination. A third strategy was a combination of the two. Results of the study suggest that seedling emergence is enhanced by fall or spring irrigations, as well as the combination of the two. In fact, seedling densities on non-irrigated plots were near zero. It was not possible to determine if different levels or intensities of irrigation were better than others. The study does, however, suggest that during years of poor growing conditions, irrigation is essential for establishing native plant species on disturbed sites.

Results of monitoring efforts at the Double Tracks clean-up site also indicate the positive effect of irrigation on the germination of native seeds. At the Double Tracks site all areas revegetated inside the fenced area were irrigated in the fall and spring following reseeding. The staging area outside the fenced area was only irrigated in the spring. Two abandoned areas north of the site and the loading area southeast of the site were reseeded but not irrigated. All sites were monitored in the spring, approximately eight months after reseeding. On the sites inside the fence that were irrigated in the fall and spring there were 7.9 seedlings/m^2. On the area outside the fence that was irrigated only in the spring there were 10.6 seedlings/m^2. There were 1.7 seedlings/m^2 on the three sites that were not irrigated. For successful revegetation to occur it is projected that after the first growing season the number of seedlings/m^2 should be close to ten (Angerer et al. 1995).

4.8.1 Irrigation Water Quality

The quality of the available water must be adequate for use in irrigation. To ensure this, a sample of water from the water source will be tested to determine the quality of the water. If the water quality is poor, actions must be taken to amend the water to improve the quality, or seek an alternative source. Ludwig et al. (1976) lists four basic criteria for evaluating water quality for irrigation purposes:

1) total soluble salt content (salinity hazard),
2) relative proportion of sodium cations to other cations (sodium hazard),
3) bicarbonate anion concentration as related to calcium plus magnesium cations, and
4) the concentration of elements that may be toxic.

Total soluble salt is measured by electrical conductivity (EC). For irrigation water, the EC should not exceed 1.5 millimhos(mmhos)/cm (Ludwig et al., 1976). However, soil solutions should not have an EC greater than 4 mmhos/cm (Ries and Day, 1978).

The relative proportion of sodium cations is measured by the sodium adsorption ratio (SAR). Ludwig et al. (1976) recommend that the SAR for irrigation water not exceed 10. Water high in bicarbonate will tend to precipitate calcium carbonate and magnesium carbonate when the soil solution concentrates through evapotranspiration. This increases the SAR, which in turn, will increase the sodium hazard of the water to a level greater than that indicated by the SAR value.

Devitt (1989) lists boron as one micronutrient that is essential for plant growth, but it becomes toxic to plant growth at levels exceeding 1 part per million (ppm). Fluoride is another element that limits plant growth when levels exceed 1 ppm (U.S. Environmental Protection Agency, 1983).

4.8.2 Irrigation System Design and Implementation

It is assumed that water will be available at the Clean Slate 2 site to irrigate the revegetated areas. The irrigation system used at the Clean Slate 2 site will be designed to produce an even distribution of water across the entire revegetated area. Sprinkler heads will be selected so as to apply water at the optimal rate and spray pattern. The sprinkler heads chosen will have a droplet size that maximizes distribution of water to the soil, minimizes runoff, and reduces wind drift.

Irrigation typically includes three implementation periods: pre-germination irrigation, germination irrigation, and establishment irrigation. Pre-germination irrigation is the application of water to recharge the soil profile prior to germination of the seeded species. This recharge will encourage deep rooting and establishment of the seeded plants. Pregermination irrigation also aids in meeting dormancy-breaking requirements for some plants. Pre-germination irrigation will be implemented during late fall or winter after seeding. The maximum amount that would be applied is 50 percent of the average amount of rainfall for this period (October to January), which would be 50 percent of 80 mm (3.15 in) or 40 mm (1.58 in). This will be applied over a two- to three-week period. Based on the results of the revegetation efforts at the Double Tracks clean-up site, if sufficient precipitation is received on-site after seeding occurs, no pre-germination irrigation will be necessary.

Germination irrigation is defined as supplemental irrigation applied to initiate germination and seedling emergence. Germination irrigation can be adjusted by changing the amount applied during an irrigation event, the frequency of the events, and the duration of an irrigation event. Soil moisture cells will be placed in the upper 5 cm (2 in) of soil to determine optimal application levels. Germination irrigation would begin in March and continue through May. Approximately 40 mm (1.6 in) of water would be applied over a four-day period during each of the three months. The amount will be adjusted based on the amount of natural rainfall that is received during the same period.

Establishment irrigation is the application of supplemental water following germination and seedling emergence. Establishment irrigation is used to supplement pre-germination irrigation by recharging the soil profile to encourage deep-rooting and survival of seedlings. As with germination irrigation, optimal application levels for establishment irrigation are dependent upon soil and climatic parameters. Typically, establishment irrigation would be initiated soon after seedling emergence and consist of the application of approximately 25 mm (1 in) of water every two weeks until July. Establishment irrigation will not be used unless determined necessary because of severe negative climatic conditions.

Irrigation is not scheduled to continue past the first growing season. The objective of irrigation is to create optimum conditions for the establishment of perennial species during the first growing season. After the first growing season perennial plants should be well enough established to adapt to and survive growing conditions that may follow.

4.8.3 Soil Moisture

Soil moisture data provides a means to monitor amounts and frequency of germination and establishment irrigation, and to determine possible causes of revegetation failure. Soil moisture cells (resistance blocks) will be used to measure soil moisture in the surface soils (2.5 cm [1 in]) and at a depth of 25 cm (10 in). Soil moisture data will be recorded daily and downloaded as necessary, approximately every three months.

4.9 Fencing

The fence currently surrounding the contaminated area at Clean Slate 2 should be left in place to reduce the effects of herbivores on plant establishment. This fence would primarily exclude horses and burros, but would not exclude rabbits and small rodents. The fence should remain in place for a minimum of five years, which should be sufficient time for plants to become established and able to withstand the effects of herbivory. Fencing may also be necessary around the staging area located outside the fenced area.

The effects of herbivores on new seedlings at the excavation area will be subjectively monitored during the growing season for the first two years. If herbivory is detected and is determined to be severe; i.e., may lead to the mortality of the majority of the plants, corrective action may be taken. If rabbits are noted to be the dominant herbivore, then a 1.2-m (4-ft) tall wire netting fence would be installed at the base of the existing fence.

5.0 SOIL STABILIZATION AND REVEGETATION SUCCESS MONITORING

The objectives of monitoring both short- and long-term (revegetation) soil stabilization are to document the effectiveness of measures taken to control erosion, track the successful establishment of a stable vascular plant community on the disturbed site, and document the use of the site by wildlife. The success of revegetation will be determined by comparing plant and animal communities on the revegetated area with those on adjacent reference or undisturbed areas.

5.1 Short-Term (Interim) Soil Stabilization

The effectiveness of short-term or interim soil stabilization will be monitored monthly. A staff scientist will conduct a meandering survey of the excavation area every four weeks following the initial application of AGRI-LOCK. The excavation area will be surveyed for signs of soil erosion, occurrence of loose soil particles on the soil surface, major soil cracking thus exposing subsurface soil layers, and active rodent burrows, which usually result in subsurface soils being moved to the surface. The scientist will determine whether reapplication of AGRI-LOCK is necessary for the entire site, or for specific areas, such as areas of recent rodent activity. AGRI-LOCK will be reapplied as soon after completion of the survey as possible. The time frame will depend on the availability of required personnel and the preparation of work documents. The same methods of application will be used. The rate of application may or may not be altered depending on the recommendation of the scientist conducting the survey.

A second evaluation of the effectiveness of interim soil stabilization may be made by the Desert Research Institute (DRI). The resuspension of soil particles will be measured using a wind tunnel. Measurements will be taken prior to interim soil stabilization and at different intervals after stabilization. DRI scientists will evaluate the results of the wind tunnel. If resuspension of soil particles reaches a level considered to be excessive by DRI scientists, reapplication of AGRI-LOCK may occur or some other form of corrective action will be taken.

5.2 Long-Term Soil Stabilization: Revegetation Success

Revegetation success will be evaluated by comparing conditions on the clean-up site with predetermined success criteria or standards, developed specifically for Clean Slate 2. Revegetation will be considered successful if, after ten years, plant density and cover on the revegetated area, are 60 percent of that measured on the reference areas during the same year. This percentage is based on the fact that complete restoration of the site would naturally take several decades (Angerer et al., 1996) and that after one decade, if the site is within 60 percent of the native undisturbed reference area, it would appear to be on track for successful restoration.

To determine revegetation success, vascular plant cover and density will be measured on both the revegetated area and the reference area over the next ten years. Success for density will only consider those species that were seeded or native to the plant community surrounding the Clean Slate 2 site (Table 2).

During the first growing season after revegetation, 15 permanent, 50-m transects, similar to those in the reference area at Clean Slate 2 (Section 4.3), will be randomly located within the revegetated area. Vascular plant density and cover data on key perennial species will be measured along each of these transects and used for statistical comparisons with similar data collected from the reference area. These comparisons will be the basis for determining revegetation success.

The number of transects sampled will provide a level of precision that will allow the detection of a 10 percent change in the mean with 90 percent confidence. The formula is:

$$N_{min} = (t_{.05})^2\, 2(S^2) \div [(10\%)(\bar{x})]^2$$

where t = the two-tailed t value at .10 significance with infinite degrees of freedom; S^2 = the variance; and $\bar{x}$ = the mean. Density estimates will be used to determine the minimum number of transects to sample. The total number of transects sampled will not exceed 15. If 15 are sampled, the confidence intervals will be determined and reported.

5.2.1 Vascular Plant Density

Plant density will be measured to determine numbers of established plants, seedling emergence and plant survival. Density will be determined by recording the number of individual plants of each species occurring within each of five 4-m^2 (43.1-ft^2) quadrats randomly located along each permanent transect. Plant density will be sampled after each growing season during the first, third, fifth, and tenth years following revegetation.

5.2.2 Vascular Plant Cover

Ground cover is determined from the proportion of the ground surface covered by each of three categories: (a) living, above ground vegetation, (b) dead vegetative material (litter), and (c) bare ground. Each of these cover parameters is expressed as a percentage of the total area of measurement (Chambers and Brown, 1983). Ground cover data will be collected at peak production during the third, fifth, and tenth growing seasons.

Cover is determined using a cover-point optical point projection device (COPPD) (Buchner, 1985). The COPPD is positioned approximately 1 m (3.3 feet) above the ground and the plant species, litter, or bare ground that is intercepted by the theoretical vertical line is recorded. Cover parameters will be determined from four line intercepts or points recorded at 2-meter intervals along each 50-m (163-ft) transect, or 100 points along each transect (4 points at 25 locations).

5.3 Reestablishment of Wildlife Habitat

One of the objectives of revegetating the Clean Slate 2 site is to restore wildlife habitat. To document that the site is being used by wildlife, the presence of wildlife and/or their sign will be recorded during vegetation sampling. Wildlife observed on-site will be noted as will the presence of any wildlife sign, such as scat, burrows, and browsed vegetation. These passive animal indicators will serve as a means to monitor use of the revegetated site by wildlife.

5.4 Remediation Criteria

Remediation, which involves some site preparation, reseeding, and remulching, will only be considered if revegetation of the site is not on track to meet the success criteria. Both vascular plant density and cover will be considered in determining the need for remedial reclamation.

5.4.1 Vascular Plant Density

Plant density for the area surrounding the Clean Slate 2 site is approximately 15.7 plants/m^2 (1.46 plants/ft^2). There were 2.8 shrubs/m^2 (0.26/ft^2) and 12.9 grasses/m^2 (1.20/ft^2). To attain this density by the fifth growing season, a density of at least 10 shrub seedlings/m^2 (0.93 seedlings/ft^2) and approximately 20 grass seedlings/m^2 (1.86/ft^2) of seeded or native species is necessary after the first growing season (Angerer, et al., 1995; Anderson and Hall, 1997a; Anderson and Hall, 1997b). If seedling density is significantly less than this after the first growing season, or less than 15.7 plants/m^2 (1.46 plants/ft^2) after the third or fifth growing season, some form of remediation may be necessary to ensure successful revegetation of the site.

5.4.2 Vascular Plant Cover

Vascular plant cover will be measured in the third, fifth, and tenth years after revegetation. Data collected in year five will be used to evaluate the need for remedial reclamation. If vascular plant cover is below approximately 50 percent of the amount of cover on the reference area, remedial action may be necessary to ensure that revegetation success criteria are met.

5.4.3 Soil Properties

Soil on the revegetated area may change over time as plants become established, soil amendments are added, or as salts build up from irrigation waters and rainfall. Soils from the revegetated area will be monitored for conditions that may cause poor vascular plant establishment and/or growth. If such conditions are observed, soil samples may be retrieved from the top 30 cm (12 in) of soil and analyzed for key physical and chemical properties. The soil analyses will be used to identify the cause of poor growing conditions and to assist in developing remedial action(s).

6.0 LITERATURE CITED

Angerer, J.P., V.K. Winkel, D.C. Anderson, K.W. Blomquist, and D.B. Hall. 1995. Integrated Closure Program: Revegetation and Ecological Monitoring Plan. EG&G/EM Final Report to Reynolds Electrical and Engineering Co., Inc.

Angerer, J.P., W.K. Ostler, W.D. Gabbert, and B.W. Schultz. 1996. Secondary Succession on Disturbed Sites at Yucca Mountain, Nevada. EG&G/EM Topical Report, EGG-11265-1118, Las Vegas, Nevada.

Anderson, D.C. and D.B. Hall. 1997a. Double Tracks Revegetation and Monitoring Plan. Bechtel Nevada Report DOE/NV 1178-104, UC-708, Las Vegas, Nevada.

Anderson, D.C. and D.B. Hall. 1997b. Clean Slate 1 Revegetation and Monitoring Plan. Bechtel Nevada Report DOE/NV 1178-062, UC-708, Las Vegas, Nevada.

Buchner, D.L. 1985. Point Intercept Sampling in Revegetation Studies: Maximizing Objectivity and Repeatability, *in* Proceedings of the American Society for Surface Mining and Reclamation Meeting, October 1985, pp. 110-113.

Chambers, J.C., and R.W. Brown. 1983. Methods for Vegetation Sampling and Analysis on Revegetated Mined Lands. USDA Forest Service Intermountain Forest and Range Experiment Station General Technical Report, INT-151, Ogden, Utah, 57 pp.

Church, H.W. 1969. Cloud Rise From High-Explosives Detonations. Sandia National Laboratories Report, SC-RR-68-903, Albuquerque, New Mexico.

Devitt, D.A. 1989. Supplemental Irrigation in the Reclamation of Soils, *in* Reclamation of Mining-Disturbed Lands in the Great Basin. Nevada Cooperative Extension Shortcourse, October 3-4, 1989, Reno, Nevada.

EG&G/Energy Measurements. 1994. Yucca Mountain Biological Resources Monitoring Program, Progress Report Oct. 1992 - Dec. 1993. EG&G/EM Las Vegas Area Operations Report, EGG-11265-1073, Las Vegas, Nevada, 69 pp.

EG&G/Energy Measurements. 1995. Yucca Mountain Biological Resources Monitoring Program, Progress Report Jan. 1994 - Dec. 1994. EG&G/EM Las Vegas Area Operations Report, EGG-11265-1136, Las Vegas, Nevada, 79 pp.

Leavitt, V.D. 1978. Soil Surveys and Profile Descriptions of Plutonium-Contaminated Areas on the Test Range Complex in Nevada, 1970-1977, *in* Selected Environmental Plutonium Research Reports of the NAEG, M.G. White and P.B. Dunaway, Eds. U.S. Department of Energy Nevada Operations Office Report, NVO-192, Las Vegas, Nevada.

Ludwig, A.E., G.W. Hergert, and W.T. Franklin. 1976. Irrigation Water Quality Criteria. Colorado State University Extension Service, Service in Action Sheet no. 506, 2 pp.

Munshower, F.F. 1994. Practical Handbook of Disturbed Land Revegetation. Lewis Publishers, Boca Raton, Florida, 265 pp.

Ries, R.E. and A.D. Day. 1978. Use of Irrigation in Reclamation in Dry Regions, *in* Reclamation Of Drastically Disturbed Lands, F.W. Schaller and P. Sutton, Eds. American Society of Agronomy, Madison, Wisconsin.

Shreve, Jr., J.D. 1965. Operation Roller Coaster, Scientific Director's Summary Report. Sandia National Laboratories Report, DASA-1644, Albuquerque, New Mexico.

U.S. Department of Agriculture, Soil Conservation Service. 1978. National Soils Handbook, Notice 24.

U.S. Department of Agriculture, Forest Service. 1979. User Guide to Soils. USDA Forest Service Intermountain Forest and Range Experiment Station General Technical Report, INT-68, Ogden, Utah, 80 pp.

U.S. Environmental Protection Agency. 1983. Hazardous Waste Land Treatment. Office of Solid Waste and Emergency Response Report, SW-874, Washington, D.C.

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