Appendix K

Vegetation

Appendix K-1

Sensitivity Analysis of Vegetated Class A, B, & C Cell Cover

To: Dan Shrum, Envirocare of Utah, Inc.

From: Susan Wyman

Date: **October 20, 2000**

Subject: ***Sensitivity Analysis Of Vegetated Class A,B,&C Cell Cover*** **4101O**

Sensitivity analyses were performed for the HELP infiltration model of the Class A, B, & C cell, to determine the effects of siltation and vegetation intrusion into the landfill cover.

The sensitivity analyses are listed in Table 1. The material properties of each layer were adjusted as the silt and roots penetrated each layer. Siltation would tend to decrease porosity, increase field capacity and increase the wilting point of the coarser layers. Hydraulic conductivity (K_s) of the rip rap and filter layers would decrease due to root penetration and siltation. The material properties in the base case model and in the vegetated models are shown in Table 2.

Vegetation was simulated using a leaf area index (LAI) of 0.5. A LAI of 1.0 represents a poor stand of grass, 2.0 a fair stand of grass, 3.5 a good stand of grass, and 5.0 for an excellent stand of grass.

The sensitivity analysis results are shown in Table 3 and Figure 1. The modeling indicates that siltation and root penetration of the rip rap, Type A filter, and sacrificial soil would result in a net decrease in infiltration, due to increased evaporation. Infiltration will also decrease if plants penetrate the entire thickness of the Type B filter layer.

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TABLE 1. VEGETATION / SILTATION SENSITIVITY ANALYSES

	DEPTH OF ROOT PENETRATION	MATERIAL	EZD	LEAF AREA INDEX	RIP RAP PROPERTY CHANGE	TYPE A FILTER PROPERTY CHANGE	TYPE B FILTER PROPERTY CHANGE	RADON BARRIER PROPERTY CHANGE
Base Case	0	rip rap	18	0	no	no	no	no
Veg18	18	rip rap	18	0.5	yes	no	no	no
Veg19	19	Type A Filter	19	0.5	yes	yes	no	no
Veg22	22	Type A Filter	22	0.5	yes	yes	no	no
Veg24	24	Type A Filter	24	0.5	yes	yes	no	no
Veg25	25	Sacrificial Soil	25	0.5	yes	yes	no	no
Veg28	28	Sacrificial Soil	28	0.5	yes	yes	no	no
Veg32	32	Sacrificial Soil	32	0.5	yes	yes	no	no
Veg34	34	Sacrificial Soil	34	0.5	yes	yes	no	no
Veg42	42	Type B Filter	42	0.5	yes	yes	yes	no

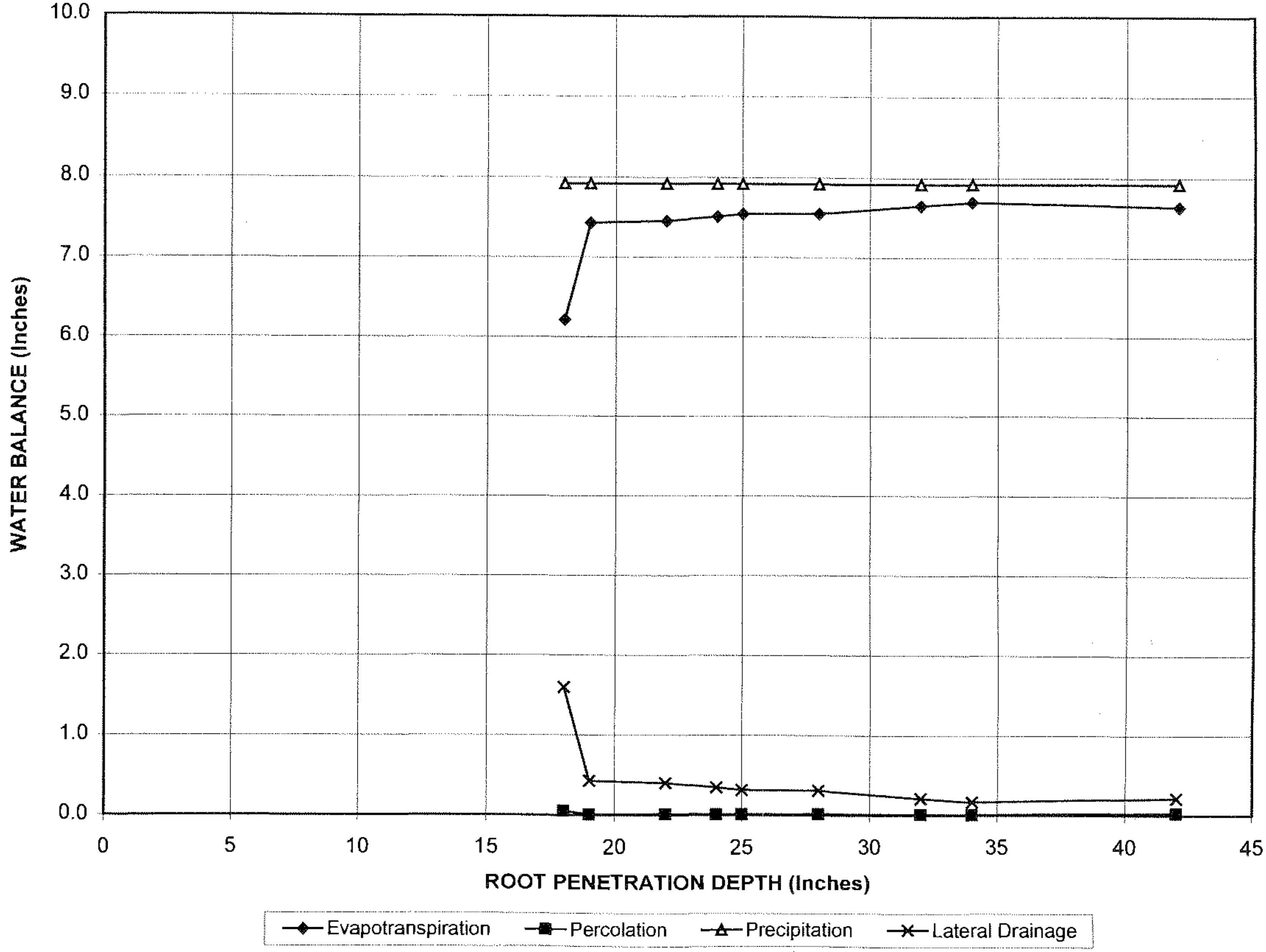
TABLE 2. CHANGES IN MATERIAL PROPERTIES DUE TO VEGETATION AND SILTATION CLASS A, B, + C CELL HELP MODEL SENSITIVITY ANALYSIS

B&C/LLRW CELL TOP SLOPE LAYERS												
			BASE CASE CONDITION				VEGETATED CONDITION					
Layer	Material	Thickness (inches)	n (vol/vol)	θ_{fc} (vol/vol)	θ_{wp} (vol/vol)	K_s (cm/sec)	n (vol/vol)	θ_{fc} (vol/vol)	θ_{wp} (vol/vol)	K_s (cm/sec)	Size Range (inches)	Material Description n/a
Layer 1	Type-B Rip Rap	18	0.190	0.024	0.007	42	0.183	0.062	0.01175	0.042	0.75-4.5	1.25 inches
Layer 2	Type-A Filter (upper)	6	0.190	0.024	0.007	42	0.183	0.062	0.01175	0.042	0.08-6.0	Coarse Sand - Fine Cobble
Layer 3	Sacrificial Soil	12	0.31	0.2	0.025	4.00E-03	0.31	0.2	0.025	4.00E-03	<0.75	Silty Sand and Gravel
Layer 4	Type-B Filter (lower)	6	0.28	0.032	0.013	3.5	0.270	0.088	0.02	0.35	0.2-1.5	Coarse Sand -Fine Gravel
Layer 5	Upper Radon Barrier	12	0.430	0.390	0.28	5.00E-08	0.430	0.390	0.28	5.00E-08	n/a	Clay
Layer 6	Lower Radon Barrier	72	0.430	0.390	0.28	1.00E-06	0.430	0.390	0.28	1.00E-06	n/a	Clay
Layer 7	Waste	100	0.437	0.062	0.024	5.00E-04	0.437	0.062	0.024	5.00E-04	n/a	Sand
Layer 8	Clay Liner	24	0.430	0.390	0.28	1.00E-06	0.430	0.390	0.28	1.00E-06	n/a	Clay

TABLE 3. CLASS A, B, + C CELL HELP INFILTRATION MODEL VEGETATION SENSITIVITY ANLYSIS RESULTS

HELP Results (inches of water)	TS1	Veg18	Veg19	Veg22	Veg24	Veg25	Veg28	Veg32	Veg34	Veg42
Rooting Depth	0	18	19	22	24	25	28	32	34	42
Layer Penetrated	None	Rip Rap	Type A Filter	Type A Filter	Type A Filter	Sacrificial Soil	Sacrificial Soil	Sacrificial Soil	Sacrificial Soil	Type B Filter
Precipitation	7.92	7.920	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92
Runoff	0.007	0.061	0.059	0.057	0.055	0.054	0.053	0.051	0.05	0.049
Evapotranspiration	4.686	6.214	7.431	7.455	7.512	7.546	7.55	7.652	7.696	7.637
Lateral Drainage From Layer 4	3.1622	1.5942	0.4246	0.3987	0.3438	0.3115	0.3073	0.2086	0.1681	0.2107
Percolation/Leakage Through Layer 5	0.0664	0.0537	0.0077	0.0120	0.0115	0.0113	0.0126	0.0106	0.0087	0.0255
Average Head On Top of Layer 5	0.003	0.002	0	0	0	0	0	0	0	0.003
Percolation/Leakage Through Clay Liner	0.0664	0.0537	0.0078	0.0119	0.0113	0.0113	0.0135	0.0106	0.0087	0.0254
Average Head On Top Of Clay Liner	0	0	0	0	0	0	0	0	0	0
Change In Water Storage	0	0	0	0	0	0	-0.001	0	0	0
Percolation (in Centimeters)	0.169	0.136	0.020	0.030	0.029	0.029	0.034	0.027	0.022	0.065

FIGURE 1. VEGETATION SENSITIVTY ANALYSIS RESULTS



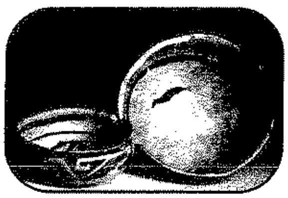
Appendix K-2

Assessment of Vegetative Impacts on LLRW

ASSESSMENT OF VEGETATIVE IMPACTS ON LLRW

Prepared for

ENVIROCARE OF UTAH, INC.



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Assessment of Vegetative Impacts on LLRW

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1.0 INTRODUCTION

SWCA was retained by Envirocare of Utah to evaluate the potential for root systems of native vegetation to penetrate and compromise the integrity of the cover of their Low Level Radioactive Waste (LLRW) cells in South Clive, Utah. In particular, black greasewood (*Sarcobatus vermiculatus*) was examined closely, since it has the ability to grow very deep tap roots and grows within the local plant community.

The cover of an LLRW cell consists of a 7-foot radon barrier composed of native soil material that is compacted to 1×10^{-6} cm / sec permeability for the lower 6 feet and 5×10^{-8} cm / sec permeability in the upper 1 foot. A series of layers of other materials are placed on top of the radon barrier to provided additional protection from frost and biointrusion from plants and animals. The uppermost layer of the radon barrier is 18 inches of rip rap. The design is engineered to allow precipitation to penetrate through the uppermost barriers and drain primarily in a horizontal direction off the embankment. However, some moisture will be absorbed and retained within the radon barrier, which is necessary for the transport and decay of radon gas. A study of vegetation growth patterns on the Vitro Chemical site in South Clive by the Uranium Mill Tailings Remedial Action Project (UMTRA 1992) reported a moist radon barrier when sampled for root penetration by halogeton (*Halogeton glomeratus*) and ironweed (*Bassia hyssopifolia*). Questions posed by Envirocare in response to discussions with the Division of Radiation Control are the following:

1) What is the potential for black greasewood to become established on the cover?

2) If established, what is the potential for black greasewood to compromise the cover system, particularly the low permeability clay layers?

SWCA conducted a site visit on October 26, 2000, to assess existing conditions of native vegetation and to investigate root depths and characteristics of black greasewood growing in the footprint of the LLRW cell. The following report describes findings of the site visit and addresses the issues raised by Envirocare as supported by the literature. The report also makes recommendations based on these findings.

2.0 VEGETATION ASSESSMENT

After meeting with Envirocare and reviewing the initial questions listed in the introduction, other questions arose that are specific to vegetation characteristics. These include:

1) Within the footprint of the LLRW cell, what is the percent cover of black greasewood in the established native vegetation?

2) Of the root systems sampled, what is the diameter of the roots?

3) What descriptive information exists on the life span of individual black greasewood and on succession of desert scrub communities?

2.1 Ecological Characteristics of Black Greasewood

The shrub, black greasewood (*Sarcobatus vermiculatus*) is indigenous to the cool deserts of the Western states (Robinson 1958, Brotherson et al. 1986.). Typically, black greasewood is1 to 2.5 meters tall, spiny, and erect (Stubbendieck 1992). It characteristically inhabits valley floors and playas as pure stands or in association with shadscale (*Atriplex* spp.), rabbitbrush (*Chrysothamnus nauseosus*), and sagebrush (*Artemisia tridentata*).

Black greasewood prefers cool deserts of the west, but it will also grow in the warm deserts above 5,000 feet (Robinson 1958). In the cool desert, the average precipitation is between 190 millimeters (mm) and 290 mm with over half of the moisture falling in the winter (Brotherson et al. 1986). The soils of the valleys and playas are usually alkali-sodic or saline, and heavy textured. More information about soil types associated with black greasewood are discussed in the Soil Assessment Section below.

To live in arid environments with saline soils, black greasewood has adaptations for conserving water. Some of the adaptations are long tap roots to utilize groundwater, thin leaves, and high salt tolerance (Robinson 1958, Groeneveld 1988). Black greasewood and other related species utilize water from the below groundwater tables to provide dependable water throughout the year. Studies indicate that black greasewood can use groundwater from water tables approximately 19 meters (m) below the surface (Robinson 1958). More information of water relations and physiological adaptations are discussed in the Growth Characteristics and Water Relationships of Black Greasewood Section below.

Black greasewood is a long-lived species and abundant seed producer. It flowers June through August, and the peak seed dispersal is in November and December. Seeds are dispersed via wind, rodents, and ants (Fort and Richards 1998). Establishment of black greasewood seeds can occur in a range of stressful environments, but it is typically gradual, due to low seed entrapment (Eddleman 1997, Fort and Richards 1998). Seedling establishment is also negatively affected by freeze-thaw action and insects, which have been shown to cause 58% embryo loss (Eddleman 1997).

2.2 Site Description of Cells B & C Footprint, South Clive, Utah

Envirocare of Utah operates a LLRW site operation near Clive, Utah. The site is about 2 miles south of exit 49 on Interstate 80 in Tooele County. Vegetation at the South Clive site was previously characterized in the 1984 Final Environmental Impact Statement (FEIS): Remedial Actions at the Former Vitro Chemical Company Site South Salt Lake, Salt Lake County, Utah Vol. I - Text (USDOE). The FEIS describes the site as a homogenous, semi-desert low shrubland composed primarily of shadscale (*Atriplex confertifolia*) with plant community associations of shadscale - gray molly (*Kochia americana* var. *vestita*), shadscale - gray molly - black greasewood (*Sarcobatus vermiculatus*), and black greasewood - Gardner saltbush (*Atriplex nuttallii*). A site visit on October 26, 2000, confirmed that the predominate vegetation is shadscale.

The purpose of the site visit was to assess existing vegetation and determine whether any of the species could pose a threat to the integrity of the embankment. Because black greasewood's ability to grow extensive tap roots is well documented in the literature, the primary concern of Envirocare is whether black greasewood will establish itself on top of the embankment and penetrate the radon barrier with its roots.

Black greasewood is one of the dominant species growing in the footprint of the LLRW cell and is growing in properties adjacent to Envirocare. The percent cover of dominant species within the footprint is 60% shadscale / Gardner saltbrush, 35% black greasewood, and 5% grasses and herbaceous species. Percent cover was determined in a qualitative manner for the entire site. A quantitative assessment may show slight differences in percent cover among the vegetative groups, including a lower percentage of black greasewood cover.

The soil is covered by a well-developed cryptobiotic crust, indicating that the community has developed to a late successional stage. The average canopy height of mature black greasewood is 0.96 m ± 0.07 se (n = 11), and the canopy of mature shadscale is 44.4 cm ± 4.08 se (n = 5). The Gardner saltbush canopy is 26.6 cm ± 2.12 se (n = 6). The Natural Resource Conservation Service (NRCS) Soil Survey (2000) describes the area of Clive as Alkali Flat and Desert Flat. Typically, black greasewood makes up 45% to 50% of the total species of an Alkali Flat, and shadscale can be up to 10% of the total vegetation. Alternatively, Desert Flat is composed of only 1% to 3% black greasewood and 50% to 60% shadscale. These characterizations are general and are used to set descriptive boundaries of species composition. However, it should be noted that the South Clive area probably falls somewhere between the Alkali Flat and Desert Flat descriptions, based on the soil composition of the site (described below) and the observed species composition.

2.3 Growth Characteristics and Water Relationships of Black Greasewood

Shadscale and black greasewood occur as dominant plant species throughout the Great Basin (Brotherson et al. 1986). Black greasewood is a halophytic or salt tolerant species that has adapted to living in arid climates and is known as a phreatophyte. Phreatophytes are defined as plants that derive supplementary water from shallow groundwater or from the overlying capillary fringe

(Robinson 1958, Groeneveld 1990). As such, these halophytic phreatophytes have ecophysiological adaptations, such as leaf shedding during severe water stress, depletion of water potential below -4.0 megapascals (Mpa), uptake and osmoregulation of sodium, and growth of deep tap root systems (Donovan et al. 1997, Trent et al. 1997, Groeneveld 1990).

The topography of South Clive is typical of alluvial basins in the Great Basin, which are relatively flat and interspersed with mounds and microplayas. The mounds are believed to be formed by eolian (windblown) depositions that are trapped by primary settlers, such as black greasewood and *Kochia* sp. These mounds are deposits of sands on top of alkaline, lacustrine clay deposits, which often have salinities too high for vegetation to thrive (Blank et al. 1998, Meinzer 1927). While scientists have suggested a cyclic progression of vegetation on some mounds (Blank et al. 1992), Blank and others (1998) now suggest that although some areas have mounds that show vegetative succession that ends in an unvegetated state, other systems show no evidence of plant succession on mounds. Mounds that exhibit no evidence of succession were inhabited by iodine bush *(Alenrolfea occidentalis)* and /or black greasewood. Both mound communities appear to succumb when soil salinities are excessively elevated by plant biogeochemical cycling and eolian dust depostition. Highly saline mounds can only be revegetated after salts are washed away from the mounds, onto the playa, during high precipitation years. Mounds have likely been a part of geomorphological processes since the late Pleistocene (Blank et al. 1998).

Although the literature infers that black greasewood communities have been in existence for the last 10,000 years, there is no published information of the lifespan of individual plants or their clones. Based on discussions with expert botanists, a conservative estimate of an average lifespan is suggested as 100 years. Annual growth rings of an individual *Sarcobatis baleyii*, a relative of *S. vermiculatus*, had 100 rings (James Young, Ph.D. , U.S.D.A. Agriculture Research Service, Conservation Biology of Rangelands, personal communication, 2000). The enumerated rings indicate an age of at least 100 years of growth but do not indicate the number of years that little or no growth occurred during years of low precipitation. Black greasewood periodically replaces its above ground tissue, or columns, every 45 to 50 years and could persist for several hundred years (Jack Brotherson, Ph.D., Department of Botany and Range Science, Brigham Young University, personal communication, 2000).

2.4 Limiting Factors

Black greasewood is well suited to surviving severe environmental conditions, which could explain its distribution throughout the Great Basin. It is known to overcome extreme water potential differences, however, it likely relies on consecutive years of high precipitation for recruitment (Romney et al. 1980). The deep tap roots are adaptations to low precipitation, and each individual may have several tap roots, as demonstrated by Groenvelld (1990). Shadscale may also develop tap roots. However, their tap roots were never observed growing below 0.5 m, where they discontinued downward growth and initiated lateral growth (Groenvelld 1990). Groenveld (1990) also observed that plants growing in uncrowded conditions developed few, but far-reaching branches, while plants that grew in crowded conditions grew many “finger roots”. The morphology of black greasewood roots consists of dense fibrous secondary roots near the surface of the soil and less-dense secondary rooting deeper in the soil. Groenveld (1990) suggests that the exponential decrease of root density with depth is due to an exponential decrease in nitrogen. However, nitrogen limitation does not appear to keep tap roots of this species from extending as much as 19 m below the surface (Robinson 1958, Meinzer 1927). Groenveld (1990) reports that, although roots have been found at extreme depths under special circumstances, the probable maximum effective depth of rooting is about 3.6 m or 11.8 feet.

Black greasewood has been shown to survive and grow in highly saline sites, suggesting that salinity alone is not a limiting factor (Donovan and Richards 2000, Donovan et al. 1997). In fact, black greasewood is an osmoregulator and relies on uptake of sodium for carrying out metabolic and physiological processes (Donovan et al. 1997). Black greasewood uses sodium to maintain water uptake, cell turgor, and growth, and actually takes up more sodium than is required for these processes (Donovan et al. 1997). It is hypothesized that sodium concentrations are kept high within the plant tissue so that uptake of essential micronutrients, which would otherwise be unavailable in alkaline and saline soils, is possible. This is an important physiological adaptation for soil salinities, which vary between wet and dry years (Trent et al. 1997).

Another limiting factor of prolonged black greasewood growth and establishment is its lack of tolerance to inundation by water. Although black greasewood is more tolerant of flooding than big sagebrush (*Artemisia tridentata wyomingensis*) and green rabbitbrush (*Chrysothamnus viscidiflorus*), greasewood was not able to survive prolonged exposure (of 6 months) (Groeneveld and Crowley 1988, Ganskopp 1986). Black greasewood does not develop aerenchyma cells in its roots in response to flooding, unlike the desert shrubs rubber rabbitbrush *(Chrysothamnus nauseosus* ssp. *viridulus)* and Torrey's saltbush *(Atriplex torreyi)*.

2.5 Future Conditions

Limiting factors discussed above show that black greasewood is highly tolerant of saline soils and low precipitation, and is able to extract enough water and nutrients to survive conditions that are limiting to other plant species. Another adaptation that enables its establishment in harsh environments is its high productivity of viable seeds, which are dispersed by the wind (Fort and Richards 1998). Fort and Richards recorded black greasewood seed dispersal of up to 700 m in the ancient lakebed playa system of Mono Lake, California. Black greasewood was shown to colonize eolian sediments and further trap sediments that accreted as mounds. Although black greasewood displays prolific seed dispersal, Fort and Richards (1998) noted that the only recruitment within the last 40 years started during a flood cycle of Mono Lake (between 1984 and 1986) and continued into1997. This suggests that flooding resets the environmental conditions so that they are more suitable for recruitment.

Thus, the factor that appears to be most limiting for black greasewood is precipitation, which over the course of 500 years could change as climatic conditions change. However, unfavorable dry and wet periods over the next 500 years may not be enough to permanently exclude black greasewood from establishing on the cover of the LLRW cell. In fact, eolian processes, which are likely to prevail during dry years, may lead to the infilling of voids in the top rip rap layer of the cover, providing sediment for germination once precipitation levels rise. Prolonged wet periods may result in flood events of the Great Basin, which would recharge the underlying water table and promote more favorable conditions for vegetation establishment in the vicinity of the embankments.

3.0 SOIL ASSESSMENT

After meeting with Envirocare and reviewing the initial questions listed in the introduction, other questions arose that are more specific to soil characteristics. These include:

1) What are the soil conditions where black greasewood is growing?

2) What soil types have range sites dominated by black greasewood in Tooele County?

3) What soil type may the LLRW cover resemble, if the voids between cobbles and stones become filled with eolian fines?

4) Which range site might become established on the LLRW eolian soil cover?

5) What possible alterations to the LLRW cover would possibly restrict plant rooting depth more than the present cover design?

The purpose of this evaluation is to determine if there is a potential for deep rooting plants to penetrate the disposal cell cover and grow down into the LLRW. If roots are able to grow through the cover and into the LLRW, then the possibility of radon gas seeping upward through root channels to the outside atmosphere may exist.

Three directions were taken to evaluate the possibility of plant roots reaching the LLRW. First, a literature review was undertaken to determine the rooting characteristics of deep rooting plants that can be found in Utah's West Desert. Black greasewood was determined to be the plant most likely to have deep tap roots in western Tooele County. Second, the *Soil Survey of Tooele Area, Utah* (NRCS 2000) was reviewed to determine: 1) what types of soils black greasewood grows in naturally; 2) what soil and range types occur at Envirocare's LLRW site; 3) and which range is most likely to develop on the LLRW cover after the voids have become filled with eolian fines. Third, a field evaluation was conducted at the Envirocare site to determine existing soil and vegetation conditions.

3.1 LLRW Disposal Cell Cover

The cover under construction at the LLRW cover consists of layers of rock, gravel, and sandy soil over compacted clay that has very slow permeability rates (Table 1). The LLRW waste material consists of contaminated metal debris and soil material. The LLRW is formed to approximate the shape of the containment cover. The first layer to cover the LLRW is a compacted clay layer 6 feet deep with a permeability of $1x10^{-6}$ cm/sec. A 12 inch layer of more densely compacted clay, with a maximum permeability of $5x10^{-8}$ cm/sec is on top of the first layer. Above the densely compacted clay layer is a 6 inch layer of 0.75 inch gravel for filtration, topped by a 12 inch layer of sandy soil for frost protection. The sandy frost protection layer is covered by a 6 inch layer of 0.75 inch gravel for additional filtration. The 18 inch surface layer consists of cobbles and stones with an average diameter (D50) of approximately 12 inches. The total thickness of the cover, from surface cobble/stone surface layer to the bottom of the compacted clay layer, is 10.5 feet. The coarse fragment layers provide a means of draining precipitation off the LLRW disposal cell. Over time, voids in the cobble and stone surface layer may become filled with eolian silts and sands.

Table 1. Low Level Radioactive Waste (LLRW) disposal cell cover profile.

Depth		Material
Total Depth = 10.5 feet	1.5 feet	Cobble and stone rip rap layer with D50 of approximately 12 inches.
	0.5 feet	0.75 inch crushed gravel filter zone
	1.0 feet	Sacrificial sandy soil frost protection layer
	0.5 feet	0.75 inch crushed gravel filter zone
	1.0 feet	Radon barrier - densely compacted native clay layer with maximum permeability of 5 X 10^{-8} cm/sec
	6.0 feet	Radon barrier - compacted native clay layer with maximum permeability of 1 X 10^{-6} cm/sec
LLRW		

3.2 Soils Literature Review

The Envirocare of Utah site is in Section 32 of Township 1 South and Range 11 West of the Salt Lake City Base Meridian. This section is mapped as Unit 56 in the *Soil Survey of Tooele Area, Utah*. Map Unit 56 is Skumpah silt loam with 0% to 2% slopes. Skumpah soils are classified as typic natragids, fine-silty, mixed, mesic in the *Keys to Soil Taxonomy* (NRCS 1998). The Skumpah soils are over 60 inches deep, well drained, moderately slowly permeable (1 x 10^{-4} to 4 x 10^{-4} cm/sec). They formed in alluvium derived from shale, limestone, and sandstone on an alluvial flat (NRCS 2000).

Skumpah soils have an elluvial (E) horizon on the surface, underlain by a natric agillic (Btn) horizon, and a gypsic (Cy) horizon at the bottom of the profile. The sodium adsorption ratio (SAR) ranges from 3 to 30 in the E horizon, 13 to 90 in the Btn horizon, and from 13 to 90 in the Cy horizon. Salinity ranges from moderate to strong throughout the soil profile. Textures in the Skumpah soil range from clay loam to silty clay loam with clay percentages of 27% to 35%.

The dominant range site on Skumpah soils is Desert Flat with an average annual precipitation of 5 to 8 inches. Shadscale is the dominant vegetation (average 30% of the total vegetation) with other shrubs making up another 5% of the total vegetation.

Black greasewood dominates the Alkali Flat range site in the *Soil Survey of Tooele Area, Utah*. Timpie and Tooele soils are listed as part of the Alkali Flat range site. These soils may be similar to the LLRW eolian cover soil in texture, but neither of these soils contain coarse fragments in the soil profile. Dynal soils can be found in a Desert Oolitic Dunes range site, which is also dominated by black greasewood. However, the Dynal soil type is not similar to the eolian cover soil (NRCS 2000).

The potential eolian cover soil (formed by filling the surface voids with eolian fines) may have a loamy-skeletal texture underlain by the compacted clay. Cliffdown and Izamatch are loamy-skeletal soils (medium-textured soils that contain coarse fragments) that may be similar to the LLRW eolian cover soil. Cliffdown soils can be found in either a desert gravelly loam (shadscale) or Desert Alkali Bench (bud sage) range site. Izamatch soils are part of a Desert Gravelly Sandy Loam (Indian ricegrass) range site. Neither of these range sites is dominated by black greasewood (NRCS 2000).

An alternative for restricting plant root depth is to build a hardpan beneath the lower gravel filter zone. Shallow soils (Theriot soils) near the project area have a hardpan, and are found in a Desert Shallow Loam range site that is dominated by shadscale. Because of the prevalence of shadscale and other shallow-rooted vegetation that are common in these types of soils, the cover is unlikely to be compromised by greasewood tap roots.

3.3 Existing Native Soil Conditions

A field evaluation of soils and plant rooting depths at the Envirocare of Utah site was conducted on October 26, 2000. Three soil pits were dug adjacent to patches of black greasewood by an excavator provided by Envirocare. Soil horizons in all three pits were similar (Table 2). The soils in these pits had finer textures (silty clay loams and silty clays) than the Skumpah soil listed in the *Soil Survey of Tooele Area, Utah* (NRCS 2000). The range site was Desert Flat (shadscale) with patches of black greasewood.

The majority of the plant roots were in the upper 12 to 16 inches of the soil profile (Table 2). Black greasewood tap roots were followed in the second and third pits to depths of 11 and 11.5 feet, respectively, before growing laterally from the excavation side wall. (Soil pit examinations were limited to the listed depths, due to safety concerns.) The tap roots' diameters ranged from 0.7 to 1.5 centimeters (cm). A few very fine and fine roots were observed starting at a depth of 16 inches, extending to a maximum depth of 13 feet.

Pores were not observed in the clay horizon (3.5 to 8.5 feet). Old root channels were observed in the clay horizon, but appeared to have been closed by clay films and the shrink-swell potential of the silty clay.

Table 2. Average soil characteristics observed during field examination of three soil profiles conducted at the Envirocare of Utah site near Clive, Utah on October 26, 2000.

Horizon	Depth (ft.)	USDA Texture	Munsell Color (moist)	Salinity (mmhos /cm)	$CaCO_3$ (effervesc.)	Roots	Mottles	Soil Moisture
E	0 - 1.0	clay loam	10YR 5/3	24	moderate	common fine, medium and coarse	none	slightly moist
Btn1	1.0 - 3.5	clay	10YR 6/4	30	violent	common fine, medium and coarse	none	slightly moist
Btn2	3.5 - 8.33	silty clay	5Y 6/4	30	non-eff. / strong (alternat-ing)	few fine and very fine very few medium	none	moist
C	8.33 - 15.0	sandy loam to loam	7.5YR 6/4	ND	moderate	very few fine to medium (deepest observed at 13.0 ft.)	many / distinct 5YR 6/8	dry

4.0 CONCLUSIONS

Field observations in the soil pits verified that black greasewood tap roots do have the potential of reaching depths in excess of 11.5 feet. This depth exceeds the thickness of the LLRW cover by at least 1 foot. Except for the tap roots, there was only a limited amount of very fine and fine roots below16 inches. Old root channels were filled by clay films and the shrink-swell characteristics of the silty clay, but the time necessary for dead roots to decay is unknown. If greasewood becomes established on the cover, the diameter of the tap roots may range from 0.7 to1.5 cm.

The eolian soil that could potentially fill voids in the LLRW cover may resemble either Cliffdown or Izamatch loamy-skeletal soils, which have range sites dominated by shadscale and Indian ricegrass, respectively, which are relatively shallow-rooted plants. However, we cannot definitively conclude that the soil type that would fill the voids over time will exclude greasewood establishment.

The most critical limiting factor of greasewood appears to be precipitation, as opposed to depth to groundwater. The native soils used to construct the LLRW were observed to retain moisture throughout the entire depth of the excavation pits. Although the soil is dried and compacted during the construction of an embankment, the LLRW cover system will most likely remain moist after construction. Moisture in the system could allow the LLRW cover to support plant life, just as the moist radon barrier of the adjacent Vitro chemical site does (UMTRA 1992).

Densely compacted clays in the Vitro cover do not restrict root growth (UMTRA 1992). Penetration of the dense clay by very fine and fine roots occurs in the native soil profiles. Envirocare staff stated that the in situ density of the undisturbed native clay is approximately 85% Proctor, while the upper foot of the clay cover is compacted to 95% Proctor. This increase in clay density may provide some increased restriction to root penetration of the clay cover, but the exact amount of restriction cannot be quantified at this time.

The age structure of black greasewood populations is not understood well. However, based on experience of expert botanists, it is suggested that black greasewood could live for an average of 100 years as a conservative estimate.

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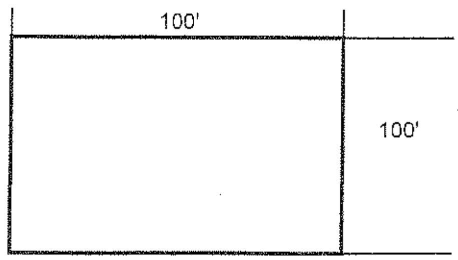
Appendix K-3

Vegetation Impact Calculation

Vegetation Impact Calculation Sheet

The long-term vegetation analysis considers the abnormal condition that deep-rooted greasewood is establisheed on the LLRW cover.



A typical 100' x 100' area of the cover has been used for this analysis.

The following evaluation was performed to conservatively estimate potential impacts on embankment performance of a significant black greasewood population on the LLRW cover.

1 Consider that a complete black greasewood population is fully established on year 101 (first year after the end of the maintenance period). That is, within one year after institutional controls end, the vegetation on the cover reaches the late successional stage currently present in undisturbed vegetation within the LLRW cell footprint.

2 Late successional vegetation coverage and species distribution was developed as follows. The native vegetation at the site has a 10% ground cover (Vitro Embankment Final Environmental Impact Statement - FEIS). Of the native vegetation, 35% of the plants are black greasewood. (Appendix K, Section 2.2). Each black greasewood plant is assumed to have two tap roots. Appendix K, Section 2.4 discusses the possibility of "several" tap roots per plant; however, excavations at the site discussed in Section 3.3 do not report multiple tap roots. Each black greasewood tap root has a diameter of 1.5 cm (Appendix K, Section 3.3 reports mature tap roots observed in field pits ranged from .7 to 1.5 cm in diameter). Assuming that each plant has a diameter equal to the height of the plant. Therefore, the diameter of each plant is 7.79 ft^2. Finally, the average life of each black greasewood population is assumed to 100 years (Appendix K, Section 2.3). With the first population instantaneously present at year 101 after final closure, a total of four populations of black greasewood plants on the final cover are evaluated.

3 For a typical area of the LLRW cover, 10% of that area is assumed to be covered by vegetated ground cover. Of the vegetated area, 35% represent black greasewood plants and the number of black greasewood plants was determined within that area. Each plant was assumed to have two tap roots, each with a diameter of 1.5 cm. That area was multiplied by four to conservatively account for multiple populations. Finally, the affected area was divided by the typical area under evaluation and converted to %. This results in a calculated impact to .00683% of the typical area evaluated due to black greasewood tap roots.

<u>Calculations for the Number of Black Greasewood Plants per a Typical 10,000 ft^2 Area.</u>

Area = 100' x 100' = 10000 ft^2
Area vegetated by greasewood = 10,000 ft^2 x .1 x .35 = 350 ft^2
Number of greasewood plants per 10,000 ft^2 = 350 ft^2/7.79 plants/ft^2 = 44.93
Rounding up to the nearest whole plant = 45 plants per 10,000 ft^2 area.

<u>Abnormal Area of Roots and % Area Degraded in Typical 10,000 ft^2 Area</u>

Using 2 tap roots per plant, a root diameter of 1.5 cm (1-root area = 1.9E-3 ft^2) and assuming four cycles of greasewood on the cover:
Total area of roots = 45 plants x 2 roots x 1.9E-3ft^2 per root x 4 cycles = .683 ft^2.
% area degraded = .683 ft^2/10,000 ft^2 x 100 = .00683%.

4 The % area degraded was then applied as a sensitivity evaluation in the HELP model to evaluate effect on infiltration through the LLRW cover.

Appendix K-4

Infiltration Through Lower Radon Barrier, Class A, B, & C Cell Cover

Whetstone Associates

Technical Memorandum

To:	Dan Shrum, Envirocare of Utah, Inc.
From:	Susan Wyman
Date:	**November 7, 2000**
Subject:	***Infiltration Through Lower Radon Barrier, Class A,B,&C Cell Cover*** 4101O

A sensitivity analyses was performed for the HELP infiltration model of the Class A, B, & C cell, to determine the effects of vegetation intrusion through the upper and lower radon barrier of the cover. The extent of potential vegetation intrusion into the upper radon barrier was investigated by vegetation specialists, who identified that greasewood would be the only plant species to potentially invade the upper radon barrier. The density of root penetration was estimated at $6.8\text{x}10^{-3}\%$, which represents the percent of area occupied by greasewood tap roots at depth. Although the vegetation study did not indicate that the greasewood would penetrate the lower radon barrier, a sensitivity analysis was performed to evaluate the potential effects of such an occurrence.

The greasewood tap root penetration into the upper radon barrier was modeled by setting the upper radon barrier to geomembrane (Layer Type 4). The tap roots were modeled as pinholes in the geomembrane. Since HELP assumes that a pinhole is 1 mm in diameter, the pinhole density (in holes per acre) was calculated as follows:

$$A_{hole} = \pi\frac{D^2}{4} = \frac{\pi}{4}(1\text{ mm})^2 = \frac{\pi}{4}(0.00328\text{ ft})^2 = 8.4539\text{x}10^{-6}\text{ ft}^2$$

$$\text{Pinhole Density} = \left(\frac{6.8\text{x}10^{-5}\text{ ft}^2\text{ holes}}{\text{ft}^2\text{ liner}}\right)\left(\frac{1\text{ hole}}{8.4539\text{x}10^{-6}\text{ ft}^2}\right)\left(\frac{43560\text{ ft}^2}{\text{acre}}\right) = 350{,}378\text{ pinholes/acre}$$

The transmissivity of the geomembrane was calculated as the saturated hydraulic conductivity times the layer thickness, in accordance with the HELP documentation:

$$T = K_{sat} \times d = (5\text{x}10^{-8}\text{ cm/sec})(30.48\text{ cm}) = 1.524\text{x}10^{-6}\text{ cm}^2\text{/sec}$$

The greasewood tap root penetration into the lower radon barrier was modeled by increasing the lower radon barrier permeability by two orders of magnitude, from $1\text{x}10^{-6}$ cm/sec to $1\text{x}10^{-4}$ cm/sec.

The evaporative zone depth was set at 42 inches, that is, to the base of the Type B filter. This approach is somewhat conservative because any taproots which penetrated the upper radon barrier would have the ability to extract some moisture. Transpiration from the upper radon barrier is conservatively neglected.

As with the previous vegetation sensivity analysis modeling, the material properties of each layer were adjusted as the silt and roots penetrated each layer. Siltation would tend to decrease porosity, increase field capacity and increase the wilting point of the coarser layers. Hydraulic conductivity (K_s) of the rip rap and filter layers would decrease due to root penetration and siltation. The material properties in the base case model and in the vegetated models are shown in Table 2.

The sensitivity analysis results are shown in Table 3 and Figure 1. The modeling indicates that siltation and root penetration of the rip rap, Type A filter, and sacrificial soil would result in a net decrease in infiltration, due to increased evaporation. If the greasewood taproots penetrate the upper radon barrier, the infiltration rate would be 0.028 inches/yr (0.071 cm/yr). If the greasewood taproots penetrate 126 inches (through the lower radon barrier) and cause a 100-fold increase in the permeability of the lower radon barrier, the infiltration rate would be 0.036 inches/yr (0.091 cm/yr).

TABLE 1. VEGETATION / SILTATION SENSITIVITY ANALYSES

	DEPTH OF ROOT PENETRATION	MATERIAL	EZD	LEAF AREA INDEX	RIP RAP PROPERTY CHANGE	TYPE A FILTER PROPERTY CHANGE	TYPE B FILTER PROPERTY CHANGE	U. RADON BARRIER PROPERTY CHANGE	L. RADON BARRIER PROPERTY CHANGE
Base Case	0	rip rap	18	0	no	no	no	no	no
Veg18	18	rip rap	18	0.5	yes	no	no	no	no
Veg19	19	Type A Filter	19	0.5	yes	yes	no	no	no
Veg22	22	Type A Filter	22	0.5	yes	yes	no	no	no
Veg24	24	Type A Filter	24	0.5	yes	yes	no	no	no
Veg25	25	Sacrificial Soil	25	0.5	yes	yes	no	no	no
Veg28	28	Sacrificial Soil	28	0.5	yes	yes	no	no	no
Veg32	32	Sacrificial Soil	32	0.5	yes	yes	no	no	no
Veg34	34	Sacrificial Soil	34	0.5	yes	yes	no	no	no
Veg42	42	Type B Filter	42	0.5	yes	yes	yes	no	no
VegL	54	Upper Radon Barrier	42	0.5	yes	yes	yes	yes	no
VegLRBE-4	126	Lower Radon Barrier	42	0.5	yes	yes	yes	yes	yes

TABLE 2. CHANGES IN MATERIAL PROPERTIES DUE TO VEGETATION AND SILTATION
CLASS A, B, + C CELL HELP MODEL SENSITIVITY ANALYSIS

B&C/LLRW CELL TOP SLOPE LAYERS													
			BASE CASE CONDITION				VEGETATED CONDITION						
Layer	Material	Thickness (inches)	n (vol/vol)	θ_{fc} (vol/vol)	θ_{wp} (vol/vol)	K_s (cm/sec)	n (vol/vol)	θ_{fc} (vol/vol)	θ_{wp} (vol/vol)	K_s (cm/sec)	Size Range (inches)	Material Description n/a
Layer 1	Type-B Rip Rap	18	0.190	0.024	0.007	42	0.183	0.062	0.01175	0.042	0.75-4.5	1.25 inches
Layer 2	Type-A Filter (upper)	6	0.190	0.024	0.007	42	0.183	0.062	0.01175	0.042	0.08-6.0	Coarse Sand - Fine Cobble
Layer 3	Sacrificial Soil	12	0.31	0.2	0.025	4.00E-03	0.31	0.2	0.025	4.00E-03	<0.75	Silty Sand and Gravel
Layer 4	Type-B Filter (lower)	6	0.28	0.032	0.013	3.5	0.270	0.088	0.02	0.35	0.2-1.5	Coarse Sand -Fine Gravel
Layer 5	Upper Radon Barrier	12	0.430	0.390	0.28	5.00E-08	---	---	---	See notes	n/a	HDPE with holes
Layer 6	Lower Radon Barrier	72	0.430	0.390	0.28	1.00E-06	0.430	0.390	0.28	1.00E-04	n/a	Clay
Layer 7	Waste	100	0.437	0.062	0.024	5.00E-04	0.437	0.062	0.024	5.00E-04	n/a	Sand
Layer 8	Clay Liner	24	0.430	0.390	0.28	1.00E-06	0.430	0.390	0.28	1.00E-06	n/a	Clay

FIGURE 1. VEGETATION SENSITIVTY ANALYSIS RESULTS

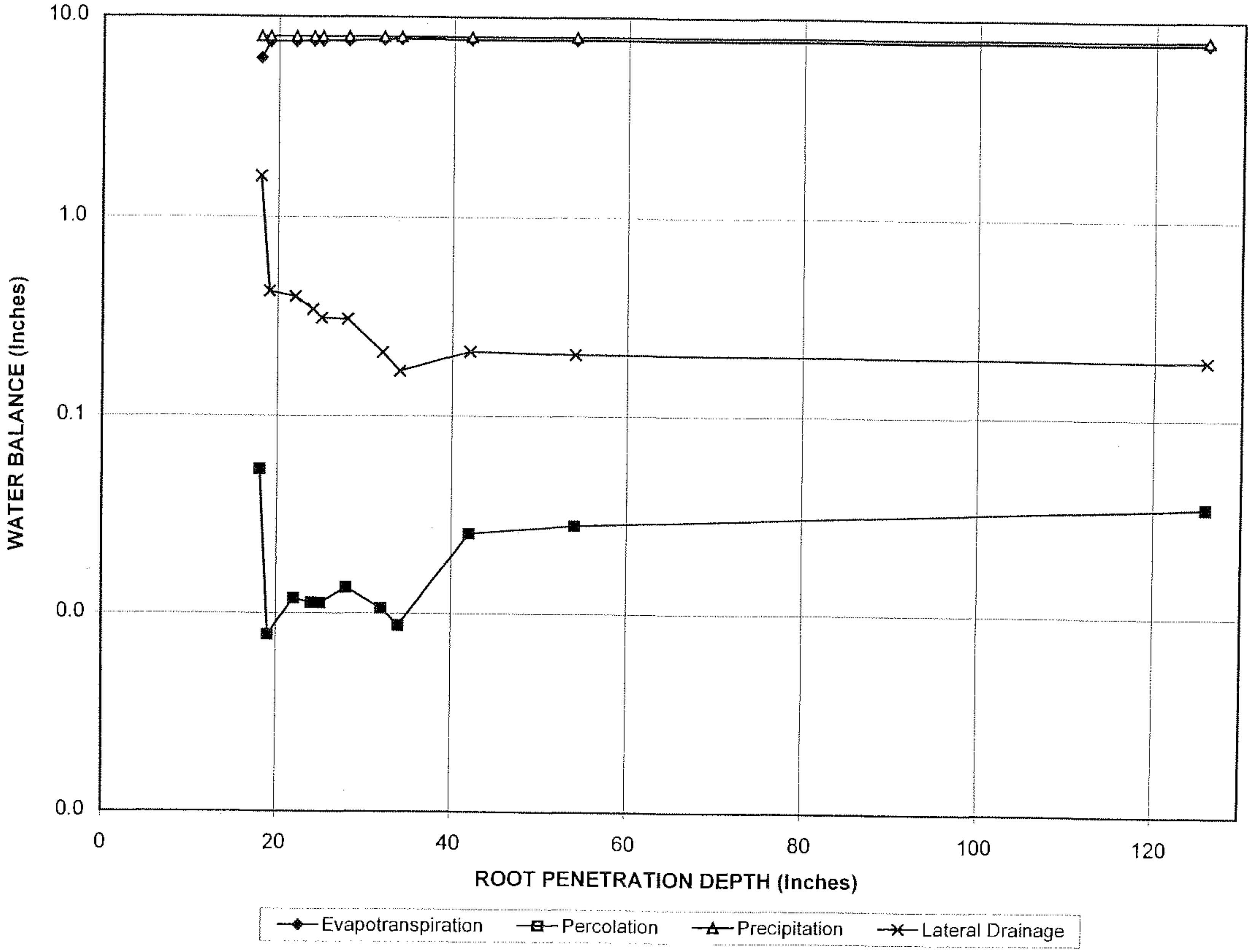


TABLE 3. CLASS A, B, + C CELL HELP INFILTRATION MODEL VEGETATION SENSITIVITY ANLYSIS RESULTS

HELP Results (inches of water)	TS1	Veg18	Veg19	Veg22	Veg24	Veg25	Veg28	Veg32	Veg34	Veg42	VegL	VegRBE-4
Rooting Depth	0	18	19	22	24	25	28	32	34	42	54	126
Layer Penetrated	None	Rip Rap	Type A Filter	Type A Filter	Type A Filter	Sacrificial Soil	Sacrificial Soil	Sacrificial Soil	Sacrificial Soil	Type B Filter	U. Radon Barrier	L. Radon Barrier
Precipitation	7.92	7.920	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92
Runoff	0.007	0.061	0.059	0.057	0.055	0.054	0.053	0.051	0.05	0.049	0.049	0.049
Evapotranspiration	4.686	6.214	7.431	7.455	7.512	7.546	7.55	7.652	7.696	7.637	7.641	7.643
Lateral Drainage From Layer 4	3.1622	1.5942	0.4246	0.3987	0.3438	0.3115	0.3073	0.2086	0.1681	0.2107	0.2047	0.1950
Percolation/Leakage Through Layer 5	0.0664	0.0537	0.0077	0.0120	0.0115	0.0113	0.0126	0.0106	0.0087	0.0255	0.0281	0.0354
Average Head On Top of Layer 5	0.003	0.002	0	0	0	0	0	0	0	0.003	0.003	0.002
Percolation/Leakage Through Clay Liner	0.0664	0.0537	0.0078	0.0119	0.0113	0.0113	0.0135	0.0106	0.0087	0.0254	0.0280	0.0359
Average Head On Top Of Clay Liner	0	0	0	0	0	0	0	0	0	0	0	0
Change In Water Storage	0	0	0	0	0	0	-0.001	0	0	0	0	0
Percolation (in Centimeters)	0.169	0.136	0.020	0.030	0.029	0.029	0.034	0.027	0.022	0.065	0.071	0.091