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To: UDEQ / DSHW
195 North 1950 West
Salt Lake City, UT 84114

From: David Waite – Project Manager
385.474.8560
David.Waite@ch2m.com

Attn: Roy Van Os

Date: March 28, 2016

Re: Request for Permit Modification – SLVSWMF Alternative Cover

We Are Sending You: Method of shipment: FedEx

Attached

Shop Drawings	Documents ☑	Tracings
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Quantity	Description
3	Binders containing the following: • Request for Permit Modification for Salt Lake Valley Solid Waste Management Facility, Solid Waste Permit #9429R1

If the material received is not as listed, please notify us at once.

David Waite, PE

Copy To:

Yianni Ioannou / Salt Lake Valley Solid Waste Management Facility
Tom Burrup / Salt Lake Valley Solid Waste Management Facility
Debbie Lyons / Salt Lake City Office of Sustainability

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Div of Waste Management
and Radiation Control

MAR 29 2016

DSHW-2016-008295

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Scott Anderson
Utah Department of Environmental Quality
Division of Waste Management and Radiation Control
195 North 1950 West
Salt Lake City, UT 84116

Subject: Request for Permit Modification for Salt Lake Valley Solid Waste Management Facility Solid Waste Permit #9429R1

Dear Mr. Anderson:

On behalf of the Salt Lake Valley Solid Waste Management Facility (SLVSWMF), and in accordance with Utah Administrative Code R315-311-2, the SLVSWMF is requesting a permit modification to replace the existing design for landfill final cover with an alternative final cover design. As described in Section 4 (Closure Plan) of the General Report in Support of Permit Application for the Salt Lake Valley Solid Waste Management Facility (Kleinfelder, 2005), existing Solid Waste Permit #9429R1 includes a final cover design consisting of the following:

- A low-permeability layer of 18 inches of soil with a hydraulic conductivity of <1 x 10-5 centimeters per second overlying the intermediate cover or a geosynthetic clay liner, overlying the intermediate cover.
- A geomembrane.
- A geonet.
- A minimum of 12 inches of soil suitable for plant growth.

This Request for Permit Modification seeks to change the permitted final cover system described above to an alternative final cover consisting of a four-foot thick soil cover system. This request is supported by Attachment A which was developed to demonstrate that the proposed alternative final cover design meets the requirements of Utah Administrative Code R315-303-3, including:

- UT Admin Code R315-303-3(4)(c)(i): the alternative final cover achieves an equivalent reduction in infiltration as achieved by the standard design in Subsection R315-303-3(4)(a)(i), which is as follows:
  - A layer to minimize infiltration, consisting of at least 18 inches of compacted soil, or equivalent, with a permeability of 1 x 10-5 cm/sec or less, or equivalent, shall be placed upon the final lifts.

- UT Admin Code R315-303-3(4)(c)(ii): the alternative final cover provides equivalent protection from wind and water erosion as achieved by the standard design in Subsection R315-303-3(4)(a)(ii), which is as follows:
    - A layer to minimize erosion consisting of (A) at least 6 inches of soil capable of sustaining vegetative growth placed over the compacted soil cover seeded with grass, other shallow rooted vegetation or other native vegetation; or (B) other suitable material, approved by the Director.
- UT Admin Code R315-303-3(4)(d): the expected performance of an alternative final cover design shall be documented by the use of an appropriate mathematical model.
- UT Admin Code R315-303-3(4)(d)(i): the input for the modeling shall include the climatic conditions at the specific landfill site and the soil types that will make up the final cover.
- UT Admin Code R315-303-3(4)(d)(ii): the model shall (A) be run to show the expected performance of the final cover at normal precipitation for a period of time until stability has been reached; and (B) shall be run to show the expected performance of the final cover during the five wettest years on record at the site or the nearest weather station.

The memorandum included as Attachment A provides model demonstration, as required by:

- UT Admin Code R315-303-3(4)(e)(ii): if the landfill has a liner composed in part of a synthetic material such as HDPE, the proposed alternative final cover meets the infiltration rate of no greater than 3 millimeters of water per year during any year of the model run.

Based upon soil sampling and model demonstration results included in the Attachment A memorandum, the alternative final cover system will consist of soils finer than a loam, as determined by the USDA soil textural classification system. The alternative final cover system will also include intermediate cover soils where they are determined to be acceptable (by the USDA soil textural classification system). Soils considered acceptable for the alternative final cover system are identified on the USDA soil triangle included as Attachment B.

Feel free to contact me at 385-468-6377 with any questions.

Sincerely,

David Waite, PE
Project Manager - CH2M

cc: Roy Van Os, Utah Department of Environmental Quality
Jeff Wolf, Acting Director Salt Lake Valley Landfill
Debbie Lyons, Salt Lake City Office of Sustainability
Tom Burrup, Salt Lake Valley Landfill

ATTACHMENT A

HYDRUS-1D Model Evaluations in Support of the Salt Lake Valley Landfill Alternative Cover Design

HYDRUS-1D Model Evaluations in Support of the Salt Lake Valley Landfill Alternative Cover Design

PREPARED FOR: Roy Van Os / DSHW

PREPARED BY: Darren Meadows/ CH2M HILL
David Waite/CH2M HILL

REVIEWED BY: Jim Jordahl/ CH2M HILL

DATE:

Introduction

This technical memorandum summarizes the results of hydrologic modeling performed to support the design of an evapotranspiration (ET) alternative cover for use at the Salt Lake Valley Landfill (SLVLF), Salt Lake City, Utah (Figure 1). The ET cover described in this memorandum will serve as an alternative for the currently-permitted landfill cap design. The primary goals of the ET cover are to reduce surface infiltration of precipitation and minimize percolation of soil water below the ET cover into the waste layer

Hydrologic modeling was performed to evaluate the potential effectiveness of several potential ET cover designs at the SLVLF. Performance of the modeled ET cover was evaluated based on the Solid Waste Permitting and Management Rules promulgated under the authority of the Solid and Hazardous Waste Act (Utah Administrative Code, Title R315, effective February 1, 2015). Under these rules, the modeled ET cover must show a rate of percolation below the cover of no greater than 3 millimeters per year (mm/yr) during any year of the simulation. Furthermore, this level of performance must be maintained throughout the five wettest consecutive years on record at the site.

The ET cover system will consist of several feet of fine-grained (most likely silty to clayey loam), vegetated soil to provide soil moisture storage above the waste material. The cover system is designed to limit infiltration of precipitation and to retain the water that does infiltrate into the cover material, so that it can be removed by transpiration through vegetation or soil evaporation before it percolates into the underlying waste material. The cover system uses the water storage capacity of the soil layers rather than lower permeability physical characteristics of traditional cover materials (for example, clays or synthetic liners) to minimize infiltration. ET covers can be a cost-effective and sustainable (long-term) way of minimizing infiltration as compared to more traditional engineered cover designs.

ET Cover System HYDRUS Modeling

The ET cover was evaluated using HYDRUS-1D version 4.15 (Šimůnek et al., 2008, 2009). HYDRUS-1D is a finite element numerical model designed for simulating saturated/unsaturated flow through porous media. The HYDRUS code has been used extensively to model ET covers at varied sites nationwide (Albright et al., 2002; Cadmus Group, 2011; CH2M HILL, 2013; USEPA, 2011; Zornberg and McCartney, 2005). The current modeling study was used to evaluate the performance of an ET cover base case scenario (Scenario 1), which implemented conservative input parameters. Additional model scenarios were run where key design parameters were varied to evaluate the sensitivity of the cover performance. The sensitivity analyses were performed considering variable soil hydraulic properties and ET cover thickness to evaluate the effect on modeled percolation rates through the bottom of the ET cover and are described in the *HYDRUS-1D Model Results* section.

Model Inputs

The following sections describe the key parameters used in the development of the ET cover models. Model inputs include site-specific climate data (recorded at the Salt Lake City International Airport, located about 2.5 miles from the site) and soil hydraulic property data collected from potential borrow materials currently stockpiled at the SLVLF (CH2M HILL, 2014). Additional model inputs include root water uptake and water stress parameters for grass species likely to be used to vegetate the ET cover. The modeling was conducted for a total simulation period of 20 years, using the 5 wettest years on record. Specific information for processes simulated in the HYDRUS-1D package is described in the HYDRUS-1D users' manual (Simunek et al., 2012).

Boundary Conditions

The following section describes the development of the boundary conditions and model parameters used in the base case scenario (Scenario 1).

Top Boundary Condition

The top boundary condition of the soil profile was defined by three processes: precipitation, potential evaporation (PE), and potential transpiration (PT). Transpiration is not, strictly speaking, a boundary condition, but is instead distributed throughout the root zone of the model. However, potential transpiration relates mainly to atmospheric conditions and leaf coverage of the surface, and therefore is discussed here along with potential evaporation as part of the climatological data that define the upper boundary condition of the HYDRUS-1D model.

Climate data from the weather station at the Salt Lake City International Airport (1948 through 2013) was used to define the wettest 5 year period on record, 1982 through 1986, with an average annual precipitation of 21.0 inches[1] (Figure 2). The assumed average annual precipitation used for modeling purposes (21.0 inches) is much larger (conservative) than the average annual precipitation value of 15.6 inches over the entire period of record. The 5 year series of daily precipitation values was used directly in the HYDRUS-1D model as the precipitation input for all model scenarios. This 5 year period of daily climate data was cycled through the model four times for a total simulation time of 20 years.

Daily potential evapotranspiration (PET) data calculated using the Hargreaves equation (Jensen et al., 1997) was also downloaded from the weather station at the Salt Lake City International Airport for the wettest 5 year period (Figure 2). However, HYDRUS-1D requires input of separate PE and PT values. The Ritchie-Burnett-Ankeny function was used to calculate PT from PET (Chadwick et al., 1999; Ogorzalek et al., 2008)

$$PT = 0.52 \times PET \times LAI^{0.5} \quad (1)$$

where LAI = leaf area index

The PE was then calculated as the remainder of the PET:

$$PE = PET - PT \quad (2)$$

Table 2 shows the average LAI values for western wheatgrass from a study conducted in Mandan, North Dakota (Frank, 2002). Western wheatgrass is a typical species used for revegetation in the Salt Lake Valley. Furthermore, using these values is likely conservative given the shorter growing season in North Dakota as compared to the Salt Lake Valley. To generate the input used in the model, the monthly LAI value was used in the calculation of daily PT values for each respective month.

TABLE 1
Leaf Area Index Values for Calculation of Potential Transpiration
HYDRUS-1D Model Evaluations in Support of the Salt Lake Valley Landfill Evapotranspiration Cover Design

Month	LAI
April	0.11

[1] https://climate.usurf.usu.edu/mapGUI/mapGUI.php - Accessed 11/25/2014

TABLE 1
Leaf Area Index Values for Calculation of Potential Transpiration
HYDRUS-1D Model Evaluations in Support of the Salt Lake Valley Landfill Evapotranspiration Cover Design

Month	LAI
May	0.36
June	0.45
July	0.43
August	0.35
September	0.22

LAI – Leaf Area Index
LAI values for months not shown equal 0

Bottom Boundary Condition

A free draining boundary condition was placed at the base of the simulated ET cover. Flow through this bottom boundary was counted as percolation which escaped ET and migrated below the cover system.

Soil Types

The soil hydraulic properties used in the HYDRUS-1D modeling for Scenario 1 (base case) were based on the results of laboratory analyses of soil samples collected from multiple stockpiles at the SLVLF. These stockpiles have been designated as potential borrow sources for the ET cover. Complete laboratory results are provided in Attachment 1.

Soil hydraulic parameters for Scenario 1 were taken from the sample collected at test pit 1 (TP-1) within the depth range of 15- to 18 feet. The results from this location were used as the base case because it represents the median value of saturated hydraulic conductivity (K_s) of the 10 samples that were analyzed. Additionally, this sample was one of the most coarse-grained of the samples analyzed. Thus, using this sample's hydraulic properties was a conservative choice. Table 2 summarizes the laboratory-determined soil hydraulic properties from the sample collected at TP-1 in the 15- to 18 foot depth range.

TABLE 2
Laboratory-Determined Soil Hydraulic Properties for Model Scenario 1
HYDRUS-1D Model Evaluations in Support of the Salt Lake Valley Landfill Evapotranspiration Cover Design

Sample	USDA Textural Classification	van Genuchten's α (cm^{-1})	van Genuchten's n (-)	θ_r (% vol)	θ_s (% vol)	K_s (cm/s)
TP-1 (15 to 18 ft bgs)	Sandy loam	0.0053	1.91	4.8	43.72	9.8×10^{-6}*

USDA – U.S. Department of Agriculture
θ_r – Residual moisture content
θ_s – Saturated moisture content
K_s – Saturated hydraulic conductivity
ft bgs – Feet below ground surface
% vol – percent by volume
cm/s – centimeters per second
* - at 84.6% of maximum dry density; remolded dry bulk density = 1.50 grams per cubic centimeter

Vegetation Parameters

The cover is assumed to be planted with mixed perennial grasses dominated by wheatgrass species. It was assumed that roots would be present throughout the thickness of the ET cover. Root density distributions for a revegetated ET cover were measured as part of the Alternative Cover Assessment Program on a test site near Helena, MT. The measured root density with depth was reported in Albright (2003) and is used in this modeling effort (Table 4). The use of this root density distribution is likely conservative because abnormally dry conditions following cover construction prevented the deeper rooted species from becoming well-established in the Albright (2003) study. Thus, the root density at the deeper depths (Table 4) is probably lower than that expected from a robust plant community. Table 5 shows the parameters that define the plant water stress response function (Feddes et al., 1978), which are representative of wheatgrass-dominated vegetation, used in the model.

TABLE 4
Relative Rooting Depth Distribution Used in HYDRUS-1D Models
HYDRUS-1D Model Evaluations in Support of the Salt Lake Valley Landfill Evapotranspiration Cover Design

Depth (cm)	Relative Root Density
0-10	0.284
10-20	0.213
20-30	0.159
30-40	0.119
40-50	0.089
50-60	0.067
60-70	0.05
70-80	0.037
80-90	0.028
90-100	0.021
100-110	0.016
110-120	0.012
120-130	0.009

cm – centimeters

TABLE 5
Plant Water Stress Parameters Used in HYDRUS-1D Models
HYDRUS-1D Model Evaluations in Support of the Salt Lake Valley Landfill Evapotranspiration Cover Design

Parameter	Description	Value
P0	Upper water content limit for root uptake to occur	-10 cm
Popt	Upper limit of optimum uptake range	-25 cm
P2H	Lower limit of optimum range	-5099 cm
P2L	Lower limit of optimum range	-5099 cm
P3	Lower water content limit for root uptake to occur-wilting point	-30591 cm
r2H	Potential transpiration rate at P2H	0.5 cm/d
r2L	Potential transpiration rate at P2L	0.1 cm/d

Parameters defining the water stress response function (Feddes et al., 1978)
Sources: Trlica and Biondini, 1990; Frank and Reis, 1990
cm – centimeters
cm/d – centimeters per day

Initial Conditions

The initial moisture content profile for each scenario was established by running the model for a twenty year period and using the final moisture content profile at the end of that period as the initial moisture profile. By running the model for a period of 20 years, the 5 year-period of climate data was repeated through 4 cycles. This process allows the soil hydraulic properties used in the model to come into a quasi-equilibrium with the climate inputs.

HYDRUS-1D Model Results

For this analysis, a total of 6 separate simulations were run. Two base simulations (Scenario 1) were run using the properties described above with assumed ET cover thicknesses of 3- and 4 feet. Four additional simulations were run using the same climatic and plant parameter inputs as Scenario 1, but different soil hydraulic properties. These additional simulations represent Scenarios 2 and 3, and were also run with cover thicknesses of 3- and 4 feet.

Scenario 2 represents a second set of onsite hydraulic properties taken from test pit 13 (TP-13). The hydraulic properties used in Scenario 2 are presented in Table 6. This set of properties was chosen because it represents a very different set of values from those used in Scenario 1. The K_s and *n* values are both significantly lower for the Scenario 2 parameters, which makes the soil more permeable than Scenario 1 under drier soil conditions. Thus, Scenarios 1 and 2 provide results from a wide range of site-specific hydraulic properties.

The purpose of Scenario 3 was to simulate moisture flux through a more mature ET cover representing potential long-term soil properties. Over time, the soil hydraulic properties of an ET cover change from the as-built parameters as soil structure develops and roots grow into deeper soil. Benson et al. (2011) summarized the findings of a survey of 12 different landfill sites across the United States where soil hydraulic properties of the landfill covers ranging in age from 5 to 10 years were compared to their as-built properties. Given the property changes that occurred in all of the covers in their study, they recommended the use of long-term properties as input to models used for ET cover performance assessment. This in most cases is a conservative approach, as the K_s for fine grained soils tends to increase over time due to desiccation and freeze-thaw cycles. Benson et al. (2011) found that, regardless of the initial soil conditions, the long-term soil properties for fine grained soils tended to coalesce around similar values. Table 6 presents soil hydraulic properties that are recommended by Benson et al. (2011) for use in modeling studies of long-term cover performance.

TABLE 6
Soil Hydraulic Properties for Model Scenarios 2 and 3
HYDRUS-1D Model Evaluations in Support of the Salt Lake Valley Landfill Evapotranspiration Cover Design

Scenario	USDA Textural Classification	van Genuchten's α (cm^{-1})	van Genuchten's n (-)	θ_r (% vol)	θ_s (% vol)	K_s (cm/s)
Scenario 2 (TP-13)	Sandy loam	0.0076	1.27	0	45.6	2.9×10^{-6}*
Scenario 3 (Benson et al., 2011)	-	0.0196	1.3	0**	40	5×10^{-5}

USDA – U.S. Department of Agriculture
θ_r – Residual moisture content
θ_s – Saturated moisture content
K_s – Saturated hydraulic conductivity
cm/s – centimeters per second
* - at 84.8% of maximum dry density; remolded dry bulk density = 1.47 grams per cubic centimeter
** - Value not provided in Benson et al. (2011). 0 assumed.

Figure 3 shows the simulated results for all modeled scenarios. The model results suggest that a three foot cover thickness may not be sufficient, assuming conservative final cover soil properties, to limit percolation through the ET cover to less than 3 mm/yr. In Scenarios 1 and 3, cumulative flux through the ET cover regularly exceeds 3 mm/yr for the 3 foot cover thickness case. Alternatively, none of the scenarios investigated shows cumulative flux through the ET cover exceeding 3 mm/yr when cover thickness is increased to 4 feet.

Figure 3 also shows that Scenario 3 (long-term hydraulic properties) allows less flux through the ET cover than Scenario 1; this difference in flux between the two simulations is significant for the case of a 4 foot cover thickness. Although K_s is greater for Scenario 3 as compared to Scenario 1 (5×10^{-5} cm/s versus 9.8×10^{-6} cm/s, respectively), the unsaturated parameter, *n*, is much higher for Scenario 1 than Scenario 3 (1.91 versus 1.3, respectively). Because the simulations forecast that the ET cover is never fully saturated, the unsaturated hydraulic properties significantly impact the overall permeability of the ET cover. Thus, K_s alone is not necessarily an indication of a cover's performance.

Conclusions

This analysis evaluated three sets of hydraulic properties for the final cover soil, and two different ET cover thicknesses to help in the design of the proposed ET cover at the SLVLF. Climate inputs for all evaluated scenarios were daily data representing the five consecutive wettest years on record. The hydraulic properties evaluated represent a wide range of site-specific values from onsite test pits that could potentially be used as borrow material for the ET cover, in addition to a set of properties that might be representative of longer term values for fine-grained soils. Model results show that across the wide range of hydraulic properties evaluated, the use of a four foot cover thickness limited the cumulative moisture flux through the bottom of the ET cover to less than 3 mm/yr. Furthermore, the use of the likely long-term hydraulic properties after weathering showed percolation rates of less than 3 mm/yr under both three and four foot cover thicknesses.

Limitations

Mathematical models can only approximate processes of physical systems. Models are inherently inexact because the mathematical description of the physical system is imperfect and the understanding of interrelated physical processes is incomplete. However, the models described in this appendix are good tools that can provide useful insight into moisture dynamics within the physical system. Assumptions inherent in these models include the presence of a robust plant community with good spatial distribution across the landfill and an extensive root distribution. It is also assumed that the cover will be well-maintained to prevent the formation of significant surface cracks or other preferential flowpaths into the subsurface and to prevent significant ponding of water at the surface.

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Figures

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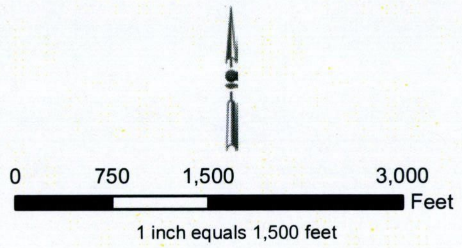


MAP INDEX

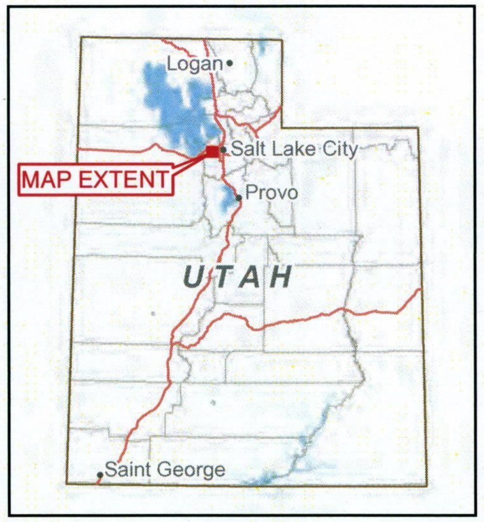
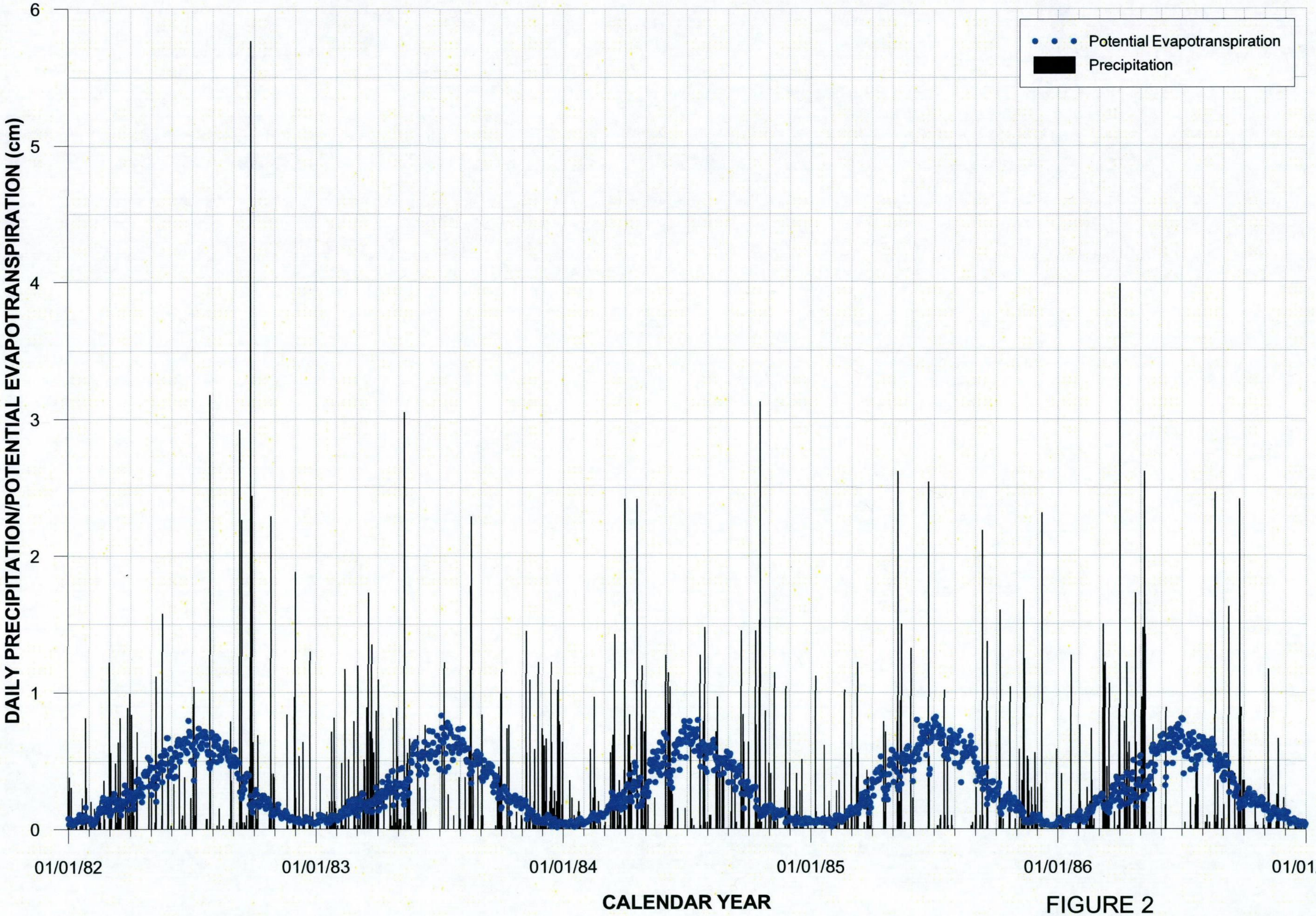


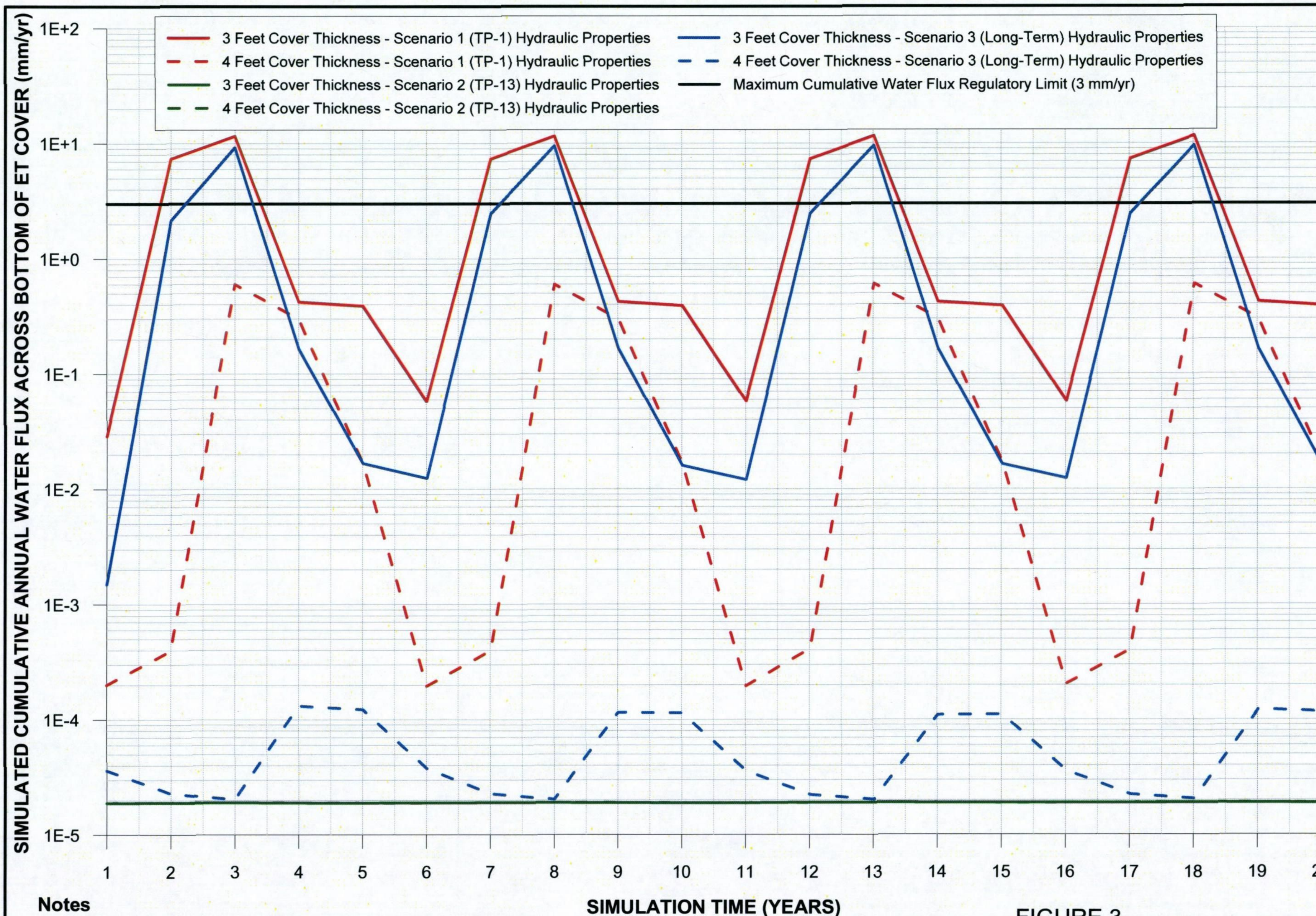
FIGURE 1
SALT LAKE VALLEY LANDFILL LOCATION MAP
SALT LAKE VALLEY LANDFILL
SALT LAKE CITY, UTAH



Note
1. cm - centimeters
2. Data measured at Salt Lake City International Airport.

FIGURE 2
Meteorologic Data from Wettest 5 Year Period on Record
Salt Lake Valley Landfill
Salt Lake City, Utah

CH2MHILL



Notes

1. Results for Scenario 2 simulations overlay each other.
2. Long-term hydraulic properties from Benson et al. (2011).
3. mm/yr - millimeters per year
4. ET - evapotranspiration
5. TP - test pit

FIGURE 3
Simulated Cumulative Annual Water Flux Across Bottom of ET Cover
Salt Lake Valley Landfill
Salt Lake City, Utah

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Attachment 1
Analytical Testing Results for Potential Borrow Materials

Table 1

Soil Classification

Salt Lake Valley Landfill Stockpile Characterization

Stockpile	Test Pit Location	Excavation Depth (ft bgs)	Sample Depth (ft bgs)	Group Symbol	Group Name	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Gravel (%)	Sand (%)	Fines (%)
1	TP-1	18	0-15	CL	Lean CLAY with sand	35	17	18	1.7	21.2	77.1
	TP-1		15-18	CL	Sandy lean CLAY	32	17	15	0.7	35.7	63.6
	TP-2	20	0-10	CL	Sandy lean CLAY	28	18	10	1.1	32	66.9
	TP-2		10-20	CL	Lean CLAY with sand	38	19	19	0.8	17.5	81.7
	TP-3	21	0-10	CL	Lean CLAY with sand	37	18	19	0.2	15.5	84.3
	TP-3		10-21	CL	Lean CLAY	31	19	12	0.2	8	91.8
	TP-4	20	0-10	CL	Lean CLAY with sand	37	19	18	4.5	16.8	78.7
	TP-4		10-20	CL	Lean CLAY with sand	41	19	22	0.4	18.7	80.8
	TP-5	17	0-10	CL	Lean CLAY with sand	32	18	14	0.1	21.1	78.7
	TP-5		10-17	ML	Sandy SILT	22	19	3	0.1	44.4	55.5
2a	TP-6	22	0-10	SC	Clayey SAND with gravel	77	32	45	18.3	33.6	48.1
	TP-6		10-22	SC	Clayey SAND with gravel	59	30	29	17.4	51.6	31
	TP-7	22	0-10	SM	Silty SAND with gravel	72	36	36	20	56.2	23.8
	TP-7		10-22	SC	Clayey SAND	68	31	37	14.3	55.4	30.3
	TP-8	19	0-10	SC	Clayey SAND	62	30	32	13.9	57.6	28.5
	TP-8		10-19	SC	Clayey SAND with gravel	54	29	25	16.3	44.5	39.2
	TP-9	10	0-10	SC	Clayey SAND	45	25	20	6.6	46.2	47.2
	TP-10	21	0-10	CL	Lean CLAY with sand	36	19	17	0.3	15.3	84.5
	TP-10		10-21	CL	Lean CLAY with sand	35	19	16	2.4	16.2	81.4
2b	TP-11	11	0-11	CL	Lean CLAY with sand	32	17	15	0.5	19.1	80.4
	TP-12	11	0-11	CL	Lean CLAY	35	19	16	0.4	11.4	88.2
	TP-13	12	0-12	CL	Lean CLAY with sand	35	18	17	0.1	27.6	72.3
3	TP-14	18	0-10	SC	Clayey SAND	53	27	26	9.7	49.2	41.2
	TP-14		10-18	SC	Clayey SAND	60	30	30	11.4	48.9	39.7
	TP-15	21	0-10	SM	Silty SAND	51	29	22	8.8	51.5	39.7
	TP-15		10-21	SC	Clayey SAND	59	29	30	14	52.7	33.2
	TP-16	20	0-10	SC	Clayey SAND with gravel	66	30	36	32.2	46.3	21.5
	TP-16		10-20	SC	Clayey SAND	57	30	27	7.4	54.3	38.3
					Side Slope Final Cover Grab Samples						
	GS-1		0-1.5	SM	Silty SAND	54	31	23	8	58.7	33.2
	GS-2		0-1.5	SC	Clayey SAND with gravel	54	29	25	16.6	45.5	37.8
	GS-3		0-1.5	CL	Sandy lean CLAY	36	19	17	10.9	24.8	64.3
	GS-4		0-1.5	CL	Lean CLAY with sand	41	21	20	0.5	21.6	77.9

Notes:

bgs = below ground surface

ft = feet

Table 2

Summary of Standard Proctor Results and Organic Matter

Salt Lake Valley Landfill Stockpile Characterization

Stockpile	Test Pit Location	Sample Depth (ft bgs)	Group Symbol	Group Name	Optimum Water Content (%)	Maximum Dry Unit Weight (pcf)	Organic Matter (%)
1	TP-1	0-15	CL	Lean CLAY with sand	17.1	111.3	3.4
	TP-1	15-18	CL	Sandy lean CLAY	15.8	110.6	2.3
	TP-3	10-21	CL	Lean CLAY	18.8	107.6	2.8
	TP-4	10-20	CL	Lean CLAY with sand	17.2	109.8	4.0
2a	TP-7	0-10	SM	Silty SAND with gravel	29.9	83.6	12.7
	TP-9	0-10	SC	Clayey SAND	20.5	95.8	9.2
	TP-10	10-21	CL	Lean CLAY with sand	17.7	108.7	4.1
2b	TP-13	0-12	CL	Lean CLAY with sand	18.2	108.5	3.2
3	TP-15	10-21	SC	Clayey SAND	26.0	90.0	9.4
	TP-16	0-10	SC	Clayey SAND with gravel	25.5	90.5	9.1

Notes:

bgs = below ground surface

ft = feet

pcf = pounds per cubic foot

Table 3
Summary of Sample Preparation/Volume Changes
Salt Lake Valley Landfill Stockpile Characterization

	Proctor Data		Target Remold Parameters[1]			Actual Remold Data			Volume Change Post Saturation[2]			Volume Change Post Drying Curve[3]		
Sample Number	Opt. Moist. Cont. (%, g/g)	Max. Dry Density (g/cm³)	Moist. Cont. (%, g/g)	Dry Bulk Density (g/cm³)	% of Max. Density (%)	Moist. Cont. (%, g/g)	Dry Bulk Density (g/cm³)	% of Max. Density (%)	Dry Bulk Density (g/cm³)	% Volume Change (%)	% of Max. Density (%)	Dry Bulk Density (g/cm³)	% Volume Change (%)	% of Max. Density (%)
TP-1 0'-15' (85%, 1.51)	17.1	1.78	15.1	1.52	85%	15.8	1.51	84.8%	1.47	+2.9%	82.4%	1.51	---	84.8%
TP-1 15'-18' (85%, 1.50)	15.8	1.77	13.8	1.51	85%	14.6	1.50	84.6%	1.50	---	84.6%	1.70	-11.9%	96.0%
TP-3 10'-21' (85%, 1.46)	18.8	1.72	16.8	1.47	85%	17.3	1.46	84.9%	1.44	+1.9%	83.3%	1.46	---	84.9%
TP-4 10'-20' (85%, 1.49)	17.2	1.76	15.2	1.50	85%	16.1	1.49	84.6%	1.44	+3.3%	81.9%	1.44	+3.0%	82.1%
TP-7 0'-10' (84%, 1.13)	29.9	1.34	27.9	1.14	85%	29.7	1.13	84.2%	1.10	+2.5%	82.1%	1.13	---	84.2%
TP-9 0'-10' (84%, 1.28)	20.5	1.53	18.5	1.30	85%	20.5	1.28	83.5%	1.24	+3.1%	80.9%	1.28	---	83.5%
TP-10 10'-21' (85%, 1.48)	17.7	1.74	15.7	1.48	85%	16.0	1.48	84.8%	1.48	---	84.8%	1.48	---	84.8%
TP-13 0'-12' (85%, 1.47)	18.2	1.74	16.2	1.48	85%	16.8	1.47	84.8%	1.45	+1.3%	83.7%	1.47	---	84.8%
TP-15 10'-21' (84%, 1.21)	26.0	1.44	24.0	1.23	85%	26.3	1.21	83.8%	1.18	+2.4%	81.9%	1.21	---	83.8%
TP-16 0'-10' (84%, 1.21)	25.5	1.45	23.5	1.23	85%	25.3	1.21	83.7%	1.16	+4.5%	80.1%	1.21	---	83.7%

[1]Target Remold Parameters: Provided by the client: 85% of maximum dry density at 2% below optimum moisture content.

[2]Volume Change Post Saturation: Volume change measurements were obtained after saturated hydraulic conductivity testing.

[3]Volume Change Post Drying Curve: Volume change measurements were obtained throughout hanging column and pressure plate testing. The 'Volume Change Post Drying Curve' values represent the final sample dimensions after the last pressure plate point.

Notes:

"+" indicates sample swelling, "-" indicates sample settling, and "---" indicates no volume change occurred.

g/cm^3 = gram per cubic centimeter

g/g = gram per gram

Table 4

Summary of Initial Moisture Content, Dry Bulk Density

Salt Lake Valley Landfill Stockpile Characterization

Sample Number	Moisture Content: As Received Gravimetric (%, g/g)	Moisture Content: As Received Volumetric (%, cm^3/cm^3)	Moisture Content: Remolded Gravimetric (%, g/g)	Moisture Content: Remolded Volumetric (%, cm^3/cm^3)	Dry Bulk Density (g/cm^3)	Wet Bulk Density (g/cm^3)	Calculated Porosity (%)
TP-1 0'-15' (85%, 1.51)	NA	NA	15.8	23.9	1.51	1.75	44.4
TP-1 15'-18' (85%, 1.50)	NA	NA	14.6	21.9	1.50	1.72	44.0
TP-3 10'-21' (85%, 1.46)	NA	NA	17.3	25.4	1.46	1.72	46.0
TP-4 10'-20' (85%, 1.49)	NA	NA	16.1	23.9	1.49	1.73	44.9
TP-7 0'-10' (84%, 1.13)	NA	NA	29.7	33.5	1.13	1.46	54.7
TP-9 0'-10' (84%, 1.28)	NA	NA	20.5	26.2	1.28	1.54	50.2
TP-10 10'-21' (85%, 1.48)	NA	NA	16.0	23.7	1.48	1.71	44.9
TP-13 0'-12' (85%, 1.47)	NA	NA	16.8	24.8	1.47	1.72	45.3
TP-15 10'-21' (84%, 1.21)	NA	NA	26.3	31.8	1.21	1.53	53.1
TP-16 0'-10' (84%, 1.21)	NA	NA	25.3	30.6	1.21	1.52	53.1

Notes:

NA = Not analyzed

--- = This sample was not remolded

cm^3/cm^3 = cubic centimeter per cubic centimeter

g/cm^3 = gram per cubic centimeter

g/g = gram per gram

Table 5

Summary of Saturated Hydraulic Conductivity Tests - Falling Head Flexible Wall Analysis

Salt Lake Valley Landfill Stockpile Characterization

Sample Number	K_{sat} (cm/sec)	Oversize Corrected K_{sat} (cm/sec)
TP-1 0'-15' (85%, 1.51)	1.5E-06	---
TP-1 15'-18' (85%, 1.50)	9.8E-06	---
TP-3 10'-21' (85%, 1.46)	8.4E-07	---
TP-4 10'-20' (85%, 1.49)	3.1E-06	---
TP-7 0'-10' (84%, 1.13)	5.48E-05	4.87E-05
TP-9 0'-10' (84%, 1.28)	4.64E-05	---
TP-10 10'-21' (85%, 1.48)	3.78E-04	---
TP-13 0'-12' (85%, 1.47)	2.9E-06	---
TP-15 10'-21' (84%, 1.21)	7.6E-06	6.8E-06
TP-16 0'-10' (84%, 1.21)	1.7E-04	1.3E-04

Notes:

cm/sec = centimeter per second

NR = Not requested

NA = Not applicable

--- = Oversize correction is unnecessary since coarse fraction < 5% of composite mass

Table 6
Summary of Moisture Characteristics of the Initial Drainage Curve
Salt Lake Valley Landfill Stockpile Characterization

Sample Number	Pressure Head (-cm water)	Moisture Content (%, cm^3/cm^3)	Sample Number	Pressure Head (-cm water)	Moisture Content (%, cm^3/cm^3)
TP-1 0'-15' (85%, 1.51)	0	43.1 ‡‡	TP-9 0'-10' (84%, 1.28)	0	51.2 ‡‡
	21	43.1 ‡‡		16	50.9 ‡‡
	68	40.3 ‡‡		47	48.5 ‡‡
	147	38.1 ‡‡		121	40.7 ‡‡
	337	35.3		337	35.1
	848426	6.1		848426	4.3
TP-1 15'-18' (85%, 1.50)	0	44.1	TP-10 10'-21' (85%, 1.48)	0	44.2
	16	43.4 ‡‡		6	42.5
	49	42.0 ‡‡		20	35.8
	120	37.9 ‡‡		66	31.3
	337	24.9 ‡‡		337	22.4
	848426	4.8 ‡‡		848426	3.5
TP-3 10'-21' (85%, 1.46)	0	46.3 ‡‡	TP-13 0'-12' (85%, 1.47)	0	45.2 ‡‡
	21	46.1 ‡‡		16	44.7 ‡‡
	67	42.7 ‡‡		47	44.0 ‡‡
	146	38.6 ‡‡		121	39.9
	337	34.7		337	33.0
	848426	5.2		848426	4.4
TP-4 10'-20' (85%, 1.49)	0	45.3 ‡‡	TP-15 10'-21' (84%, 1.21)	0	52.8 ‡‡
	21	45.6 ‡‡		16	52.7 ‡‡
	67	45.3 ‡‡		49	52.0 ‡‡
	146	43.1 ‡‡		120	47.1 ‡‡
	337	38.6 ‡‡		337	32.7
	848426	7.1 ‡‡		848426	4.2
TP-7 0'-10' (84%, 1.13)	0	55.1 ‡‡	TP-16 0'-10' (84%, 1.21)	0	53.2 ‡‡
	11	55.1 ‡‡		11	53.5 ‡‡
	32	52.4 ‡‡		32	53.4 ‡‡
	95	44.4 ‡‡		95	45.6 ‡‡
	337	38.3		337	40.4
	848426	3.7		848426	3.0

Notes:
‡‡ Volume adjustments are applicable at this matric potential (see data sheet for this sample).
cm = centimeter
cm^3/cm^3 = cubic centimeter per cubic centimeter

Table 7

Summary of Calculated Unsaturated Hydraulic Properties

Salt Lake Valley Landfill Stockpile Characterization

					Oversize Corrected	
Sample Number	a (cm^{-1})	N (dimensionless)	q_r (% vol)	q_s (% vol)	q_r (% vol)	q_s (% vol)
TP-1 0'-15' (85%, 1.51)	0.0057	1.2269	0.00	43.08	---	---
TP-1 15'-18' (85%, 1.50)	0.0053	1.9056	4.82	43.72	---	---
TP-3 10'-21' (85%, 1.46)	0.0089	1.2422	0.00	46.54	---	---
TP-4 10'-20' (85%, 1.49)	0.0038	1.2336	0.00	45.98	---	---
TP-7 0'-10' (84%, 1.13)	0.0128	1.2632	0.00	55.32	0.00	52.41
TP-9 0'-10' (84%, 1.28)	0.0124	1.2647	0.00	51.76	---	---
TP-10 10'-21' (85%, 1.48)	0.0783	1.2125	0.00	44.34	---	---
TP-13 0'-12' (85%, 1.47)	0.0076	1.2717	0.00	45.55	---	---
TP-15 10'-21' (84%, 1.21)	0.0044	1.8824	4.20	52.92	4.00	50.45
TP-16 0'-10' (84%, 1.21)	0.0065	1.3090	0.00	53.44	0.00	46.47

Notes:

cm = centimeter

vol = volume

Table 8

Summary of Specific Gravity Tests

Salt Lake Valley Landfill Stockpile Characterization

	Test Sample			Oversize Material			Bulk Sample
Sample Number	Specific Gravity	Particle Size	% of Bulk Sample	Specific Gravity	Particle Size	% of Bulk Sample	Specific Gravity[1]
TP-1 0'-15'	2.72	<4.75mm	98.3%	---	>4.75mm	1.7%	2.72
TP-1 15'-18'	2.68	<4.75mm	99.3%	---	>4.75mm	0.7%	2.68
TP-3 10'-21'	2.72	<4.75mm	99.8%	---	>4.75mm	0.2%	2.72
TP-4 10'-20'	2.71	<4.75mm	99.6%	---	>4.75mm	0.4%	2.71
TP-7 0'-10'	2.49	<4.75mm	80.0%	NR	>4.75mm	20.0%	2.49
TP-9 0'-10'	2.58	<4.75mm	93.4%	NR	>4.75mm	6.6%	2.58
TP-10 10'-21'	2.69	<4.75mm	97.6%	---	>4.75mm	2.4%	2.69
TP-13 0'-12'	2.70	<4.75mm	99.9%	---	>4.75mm	0.1%	2.70
TP-15 10'-21'	2.58	<4.75mm	86.0%	NR	>4.75mm	14.0%	2.58
TP-16 0'-10'	2.59	<4.75mm	67.8%	NR	>4.75mm	32.2%	2.59

Notes:

[1]Based on the <4.75mm material

mm = millimeter

NA = Not analyzed

NR = Not requested

--- = Unnecessary since specified fraction < 5% of composite mass

Table 9

Agronomic Properties

Salt Lake Valley Landfill Stockpile Characterization

Stockpile	Test Pit Location	Sample Depth (ft bgs)	Texture	pH	Salinity (dS/m)[1]	Phosphorus (mg/kg)	Potassium (mg/kg)	Nitrate-Nitrogen (mg/kg)	Zinc (mg/kg)	Iron (mg/kg)	Copper (mg/kg)	Manganese (mg/kg)	Sulfate-Sulfur (mg/kg)	Organic Matter (%)
1	TP-1	0-15	Silty Clay Loam	8.2	6.38	4.90	407	4.40	1.41	9.46	2.79	9.99	255	0.7
	TP-1	15-18	Sandy Loam	8.1	6.22	3.50	274	4.55	1.50	15.7	2.80	8.25	200	0.7
	TP-3	10-21	Silty Clay Loam	8.7	7.56	4.80	566	5.42	0.95	10.7	2.14	11.1	239	0.6
	TP-4	10-20	Silty Clay Loam	8.1	8.14	16.8	321	22.1	2.85	28.9	3.03	14.8	229	0.8
2a	TP-7	0-10	Clay Loam	7.9	6.41	274	899	0.17	101	150	23.9	54.7	1101	6.4
	TP-9	0-10	Clay Loam	8.0	6.13	221	678	70.1	47.5	96.3	17.3	19.7	858	5.9
	TP-10	10-21	Silty Clay Loam	8.0	4.56	56	253	15.4	7.16	38.2	5.27	10.5	275	1.5
2b	TP-13	0-12	Sandy Loam	8.2	8.29	10.4	246	2.77	1.99	21.1	2.31	7.78	221	0.8
3	TP-15	10-21	Clay Loam	7.9	7.36	250	814	0.25	77.3	167	23.1	32.3	1781	6.0
	TP-16	0-10	Clay Loam	7.9	7.66	195	810	4.02	61.3	202	10.7	32.4	1820	5.9

Notes:

[1]Salinity results from Daniel B Stephens & Associates. Salinity results from Utah State University Analytical Laboratory determined to be erroneous.

bgs = below ground surface

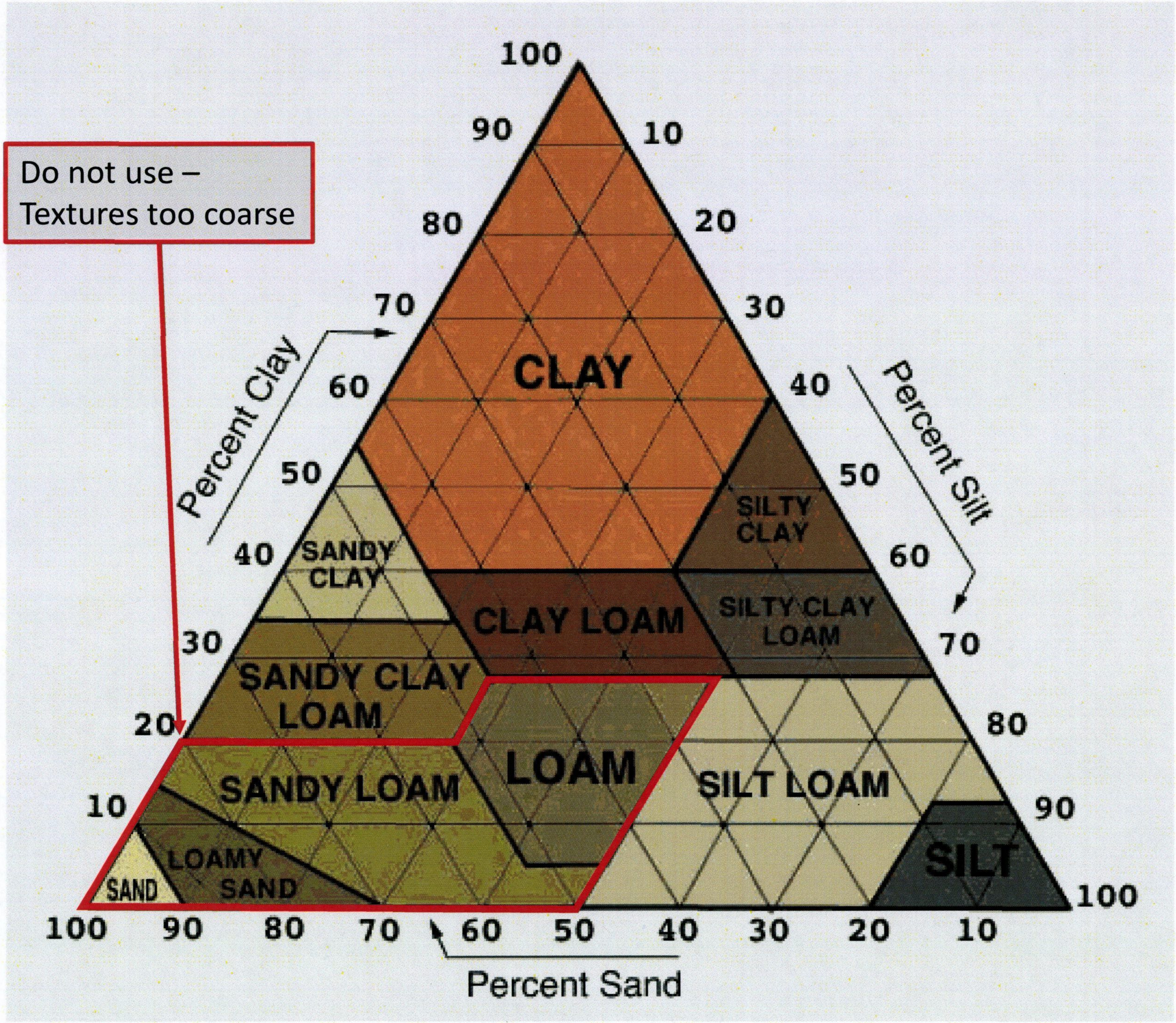
dS/m = decisiemens per meter

ft = feet

mg/kg = milligrams per kilogram

ATTACHMENT B

Soil Textural Triangle


Do not use –
Textures too coarse
CLAY
SILTY CLAY
SANDY CLAY
CLAY LOAM
SILTY CLAY LOAM
SANDY CLAY LOAM
LOAM
SILT LOAM
SANDY LOAM
LOAMY SAND
SAND
SILT
Percent Clay
Percent Silt
Percent Sand