# WEST VIRGINIA UNIVERISTY

FINAL EVALUATIOPN ON THE

# GEOTECHNICAL, HYDRAULIC AND LEACHING CHARACTERISTICS FLY ASH MIXTURES FOR FINAL COVER AND COMPLETE LINER APPLICATIONS

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CBRCW/O

# FINAL

# EVALUATION OF THE GEOTECHNICAL, HYDRAULIC AND LEACHING CHARACTERISTICS FLY ASH ADMIXTURES FOR FINAL COVER AND COMPOSITE LINER APPLICATIONS

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# ABSTRACT

The use of flyash as a construction material has been widely documented in the technical literature. However, the literature lacks substantial studies of a comprehensive nature that merge the Engineering, Geotechnical and Environmental aspects of flyash use in specific, practical settings.

This study addresses the practical aspects of using flyash and soil mixtures in landfill cover, landfill liner, and animal-waste lagoon liner applications. Initially, the optimum Geotechnical and Engineering properties of several mixtures were determined in the laboratory. Once the Geotechnical and Engineering parameters had been identified, the focus turned to a review of the chemical constituents observed in the leachate from the mixtures. Laboratory analyses of the leachate over time afforded valuable insight into the constituent-specific order of leaching, the chemical characteristics of the leachate from the individual mixtures, and the characteristics of nutrient leaching.

Percolation modeling was performed using EPA's HELP Model, and site-specific conditions found at the Sunflower Landfill. HELP modeling allowed projection of current and future percolation through the landfill unit, providing input for improved management practices. Conclusions derived from percolation modeling were merged into comprehensive recommendations that allowed Sunflower to seek operating improvements from the Kansas Department of Health and Environment.

# EXECUTIVE SUMMARY

This study examines the laboratory characteristics of fly ash and native soil materials, with the goal of demonstrating their potential use in landfill, lagoon liner and final vegetative cover applications. In the initial phase, the geotechnical and engineering qualities of several mixtures were studied and the performance of the more ideal blends documented. Following evaluation of the geotechnical and engineering aspects, the flyash/soil blends were subjected to leaching and the chemical characteristics of the leachate were determined through laboratory analyses. Performance of laboratory chemical analyses not only afforded insight into the leachate the associated constituents, but also allowed the research team to assess nutrient and animal waste transport and breakthrough characteristics. Concurrent with the leachate analyses, a chemical evaluation of initu soils and a screening of suitable plants was performed. During this phase plant samples which had established themselves on the landfill were collected and identified. This information was supplemented by a literature study of local plant species for potential re-establishment.

The 25/75 and 30/70 Flyash/Soil mixtures displayed engineering characteristics which indicate good potential for use in landfill and animal lagoon liner applications. Hydraulic conductivities in the order of 1 x $10^{-7}$ cm/sec range were consistently obtained in the laboratory experiments, making flyash/soil blends competitive with the liner criteria found in 40 CFR 258.40.

Leachate chemical analyses did not reveal the presence of mercury or arsenic above laboratory detection limits; the presence of selenium, chromium, sulfate, chloride, alkalinity and boron at various concentrations were, however, observed in some leachate samples. It is believed that the chemical concentrations of the leachate can effectively be managed in arid regions by placement of ash in increased thicknesses, as operationally practicable.

Modeling of leachate percolation was performed using the ash mixtures and the conditions found at the site. In the context of the Modeling and the recommended operational changes, percolation rates were found to be at or below those of clay lined landfills in more humid areas. In the context of this study the leachate chemical constituents in a landfill setting are viewed as nonsubstantial, this because the site and climate characteristics, combined with the low hydraulic conductivity of the ash/soil mixtures, will minimize percolation. In animal waste applications the hydraulic conductivity of the 25% ash mixture was reduced by one-order magnitude (3.1 x 10-8em/sec) using cattle waste as the influent. The mechanisms behind the reduction in hydraulic conductivity are thought to be a combination of physical, chemical and biological interaction of the waste within the mixture matrix creating a blockage effect.

# 1.0 INTRODUCTION AND BACKGROUND

The Holcomb landfill is a 110-acre facility located in Section 17, Township 24 South, Range 33 West of Finney County, Kansas The landfill is permitted to accept fly ash, bottom ash, and stabilized (dry) scrubber by-products. Baghouse filter bags, coal wastes, pyrites and other like-kind, low-volume wastes are managed in commingled-cells within the landfill unit.

The current fuel source for the 363 MW Holcomb facility is low sulfur sub-bituminous coal, which is mined in the Powder River Basin of Wyoming and transported by rail. Air pollution control equipment installed on the unit consists of a sulfur dioxide scrubber and twin-particulate control baghouses. Dry combustion ash by-products are removed from the production cycle at several locations, and collected at a common transfer station located within the unit. The type C fly ash is then transported to the landfill for disposal.

## 1.1 Study Parameters and Justification

This study examines the geotechnical and engineering characteristics of flyash admixtures for cover and liner applications, and assesses the hydraulic conductivity of several blends for potential composite liner applications. The chemical characteristics of leachate from several mixtures was evaluated and the efficiency of establishing vegetation was examined by KSU. Results from this study provides justification for revision to the Holcomb Landfill Operations Plan for final vegetative cover and the process for lining and development of new cells at the Holcomb Landfill site. Other objectives, including utilization of flyash admixtures in agricultural liner applications, were fulfilled as well.

The Holcomb Landfill is managed according to a 1982 Operations Plan prepared by GAI Consultants, of Monroeville, PA. The Operations Plan is part of the facility operating record for Kansas Department of Health and Environment (KDHE) Permit Number 420. Appendix B of the approved Operations Plan provides specifications for the closure of cells once filling is complete, and criteria for site preparation during development of new cells.

The Operations Plan calls for seed mixtures to be tilled in with a 2-foot-thick column of native soils and manure during closure. Because native soils at this site are almost exclusively comprised of infertile sands from the Tivoli Association, The resulting vegetative cover will be higher in permeability and less economically favorable than other potential solutions for the site. For new cell development, the Operations Plan calls for clearing and leveling of the native sandy soils, prior to placement of ash. Grading of the sand base, as required by the operations plan, provides little environmental benefit and can substantially increase the construction costs of new cells. This concern was the impetus for the development of optimum cover and new cell construction techniques, which are the focus of this study.

Sunflower contracted with Drs. Lakshmi Reddi and Mohan Bonala of Kansas State University (KSU) to perform an engineering and laboratory study of fly ash/soil blends for application at the Holcomb landfill site. The Final Report was prepared by James Carlson of Sunflower Electric Power Corporation and Drs. Reddi, and Bonala of KSU. A collaborative review was performed by Ken Ladwig of Electric Power Research Institute (EPRI).

## 1.2 Study Scope, Objective, and Goals

The objective of this study was to evaluate the engineering, geotechnical, and environmental characteristics of several fly ash/native soil mixtures that may be used for landfill cover and liner materials, and to optimize engineering and operational procedures for the landfill site. Conclusions and Recommendations of this study are designed for submittal to the KDHE, to be included as a revised Landfill Operations Plan. Specific objectives of this study include:

- Evaluate landfill operational procedures, taking advantage of the dry ash characteristics and semi-arid climate in minimizing potential for leachate percolation;
- Recommend engineering and technical criteria for alternative liner applications that minimize exfiltration and can be economically applied;
- Evaluate and recommend optimum fly ash/native soil blend(s) for final cover applications which sustain native plant species and minimize infiltration;
- Establish the chemical characteristics of the Holcomb landfill leachate;
- Model and document the site specific percolation rate from the landfill unit;
- Provide engineering and environmental data that supports utilization of fly ash/native soils in revegetation and lining of future cells.

Section 2 of this report describes the laboratory methods and procedures used to evaluate the physical and chemical characteristics of the flyash/native soil mixtures. Section 3 describes the infiltration modeling and its application toward revising ash placement procedures. The goal of the modeling effort was to reduce potential infiltration through the landfill unit, thus minimizing leachate percolation to near zero values.

# 2.0 RESULTS OF GEOTECHNICAL AND LEACHING EXPERIMENTS ON ASH/SOIL BLENDS

## 2.1 Sample Set and Mixture Blend Description

The engineering and geotechnical properties of multiple fly ash/sand blends with varying proportions of fly ash and sand were evaluated in the laboratory. One additional sample containing a fly ash, sand, and bentonite clay was also evaluated. Laboratory analyses were designed to establish the geotechnical, engineering, and environmental parameters of each admixture. Specific geotechnical and engineering testing included:

- Identification of Particle Size Distribution (PSD) of the native soils;
- Identification of the Atterberg Limits and compaction characteristics (optimum molding, percent moisture content and dry density) for the ash/native material admixtures;
- Qualitative determination of shrink-swell;
- Determination of hydraulic conductivity.

Two sample sets of the ash/sand mixtures were prepared. Sample Set 1 contained fly ash and sand mixtures that were compacted at the Optimum Moisture Content (OMC) for each blend of material. Samples in Set 1 are represented by the designation 20M, 25M, 30M, and 40M. Sample Set 2 contained blends compacted at 1% wet of OMC. These samples were assigned the designation 20W, 25W, 30W and 40W. The numeric designation preceding the letter (e.g. "20" in 20M) indicates the dry weight ash percentage in that mixture. The exception to this nomenclature is the sample mixture containing 5% bentonite, 30% fly ash, and 65% sand, which was labeled "5BW" for reporting purposes.

## 2.2 Sample PSD, Compaction Curves, Atterberg Limits and Shrink/Swell Characteristics - Results and Discussion

PSD curves for the native soils were determined by standard sieve methods (ASTM D422). The locally available Native Tivoli soils used in the mixtures were collected from three separate locations (SW1, SW5 and SW6) in the vicinity of the landfill site. Sample SW1 was obtained from a depth of 0.5 ft Visual inspection indicated that SW1 contained plant root material and other organic matter. Samples SW5 and SW6, obtained from a separate location but similar depths of 4 feet, displayed homogeneous sand particle-size distributions. The closeness in the shape of the PSD curves from the three locations indicates that the soils are homogeneous throughout the landfill site. Using the Unified Soil Classification System, the native Tivoli soils were classified as poorly graded sands (SP). No PSD curves were generated for the fly ash samples, which were observed to be 100% finer than the U.S. mesh #200 (opening = 0.075 mm). A literature review of other resources indicates that fly ash is typically silt-sized.[1] PSD curve data has been included in Attachment A.

Compaction curves (ASTM D698) were prepared following the laboratory evaluation of six sand/fly ash mixtures and the sand/fly ash/bentonite mixture (total of seven curves). The compaction curves have been included as Attachment B. The Maximum Dry Density (MDD) and the OMC values from these tests are presented in Table I.

**Table I**

**Maximum Dry Density and Optimum Moisture Content Values**

| Mixture | MDD (lb/ft$^{3)}$ | OMC (%) |
|---|---|---|
| 10% Fly ash + 90% SW6 Sand | 118 | 7.3 |
| 20% Fly ash + 80% SW6 Sand | 125.5 | 8.71 |
| 25% Fly ash + 75% SW6 Sand | 123 | 10.4 |
| 30% Fly ash + 70% SW6 Sand | 121.7 | 10.65 |
| 40% Fly ash + 60% SW6 Sand | 117.4 | 13 |
| 50% Fly ash + 50% SW6 Sand | 111.8 | 15.12 |
| 5% Bentonite + 30% Fly ash + 65% SW6 Sand | 118 | 11.86 |

Atterberg limit analyses were conducted on the fly ash and sand/fly ash mixtures. Fly ash was found to have 34 liquid limit (LL) and 24 plastic limit (PL), thus a plasticity index (PI) = 10 (LL-PL). The Activity [PI/(% finer than No. 200 sieve)] of fly ash is 0.1, which implies that the fly ash is inactive. Inactive soils are generally not prone to shrinkage or swelling when dried or saturated with water. LL and PL tests on 30% fly ash/sand mixtures indicated that those samples are non plastic (NP).

To observe the shrink/swell potential, the sample mixtures were compacted at varying moisture contents and air-dried at room temperature to observe shrinkage cracks. The samples did not exhibit noticeable cracking after several weeks of drying. This is further indication that these mixtures possess minimal shrink/swell characteristics.

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[1] EPRI, 1993 *Physical and Hydraulic Properties of Fly Ash and other By-Products from Coal Combustion* TR-101999

## 2.3 Shear Strength and Adhesion Evaluation of Fly Ash Mixtures and Synthetic Liner – Experiments, Results and Discussion

One study objective was to assess ways to improve the stability and adhesion between geotechnical liners and soil base materials. Since soil shear strength governs the ability to support external loading, including the soil's own weight, the shear strength parameters of cohesion ($c$) and angle of internal friction ($\phi$) were examined Knowing the parameters of cohesion and the angle of internal friction, the shear strength of any soil can be calculated using the Mohr-Coulomb failure criteria:

$$S = c + \boldsymbol{\sigma} \tan(\phi)$$

where, $\sigma$ is the normal stress acting on the plane under consideration. In general, higher shear strength parameters correspond to higher shear strengths of a given soil for normal stresses. In addition, for a given set of shear strength parameters, the shear strength increases as the normal stress increases.

Visual and laboratory testing of native tivoli soils indicated that these soils are "***P***oorly graded ***S***and (SP)." In the case of sands with virtually no cohesion, shear strength depends largely upon the angle of internal friction and the normal stresses acting upon the soil mass. Support and potential movement of hypalon depends upon adhesion and also on the effectiveness of the retaining warp along the perimeter of the pond.

Shear strength parameters can be determined in the laboratory by using either a drect shear test or a triaxial shear test. For the current study, a direct shear test was performed to determine the shear strength parameters. This test also measured the adhesion and angle of friction between the two dissimilar hypalon and soil materials.

### 2.3.1 Evaluation of Shear Strength Using Direct Shear Tests - Results

Shear strength was evaluated according to ASTM D3080 test procedure. The test apparatus consisted of a shear box in two halves. Materials undergoing testing were placed in the shear box with a known amount of normal stress applied to the upper half of the shear box. The shear stress at which the samples failed was obtained by plotting the horizontal strain versus shear stress. Testing was repeated using three different normal stresses, with the corresponding failure shear stresses being determined for each data set. These points were then plotted on the abscissa and ordinate, respectively. The intercept of the shear stress axis gives the soil cohesion ($c$) and the angle of the failure envelope with the horizontal gives the angle of internal friction ($\phi$). The graphs plotted for various soil and hypalon test conditions are plotted on Figures C-1 through C-7 in Attachment C.

### 2.3.2 Direct Shear Tests and Frictional-Adhesion Results

Seven types of direct shear tests were conducted on soil and flyash mixtures. The native soils were tested first for direct-shear and shear-strength parameters. The results of the shear tests are presented on Table II. Because the objective was to establish ways to improve the shear strength of native soils, the Tivoli sands were mixed with 20% flyash and retested for the shear-strength parameters. Due to the addition of flyash, cohesion of the soil mixture increased from 0 to 4.5 psi; however the angle of friction decreased from 41.9° to 26.8°. An increase in cohesion improves the stability of the soil mass and prevents the collapse of base materials, which was the concept under investigation.

To evaluate increases in the frictional adhesion between hypalon and base material, four tests were conducted. The results of the frictional adhesion test were outlined in Table II, test numbers 3 through 7. All possible scenarios were taken into account to find the best values for $c$ and $\phi$ Flyash slurry was prepared using a water content corresponding to 1.15 Liquid Limit (LL = 36%), i.e., 15% more water content than the Liquid Limit. This makes the flyash slurry neither too watery nor too plastic. Once the flyash paste was applied between 20% mixture and hypalon, the sample was subjected to normal stress and cured for 24-hour period. As can be seen from the results, the highest cohesion and friction angles were obtained when using a thin flyash layer between the hypalon and 20% flyash mixture. Using a 20% flyash mixture as base soil and adding a thin layer of flyash slurry between the base soil and hypalon will increase the stability significantly.

## Table II
## *c* and $\phi$ Values from Direct Shear Tests.

| Test # | Material / Combination of Materials | C, lb/in$^2$ | $\phi$° | Figure # |
|---|---|---|---|---|
| 1 | Sand only | 0 | 41.9 | Figure 2.2 |
| 2 | 20% flyash + 80% sand mixture only | 4.5 | 26.8 | Figure 2.3 |
| 3 | Sand and Hypalon | 0 | 28 8 | Figure 2.4 |
| 4 | 20% flyash + 80% sand and Hypalon | 0.8 | 26.6 | Figure 2.5 |
| 5 | "" "" (24h curing) | 0 | 38.7 | Figure 2.6 |
| 6 | "" "" (24h sat. curing) | 0 | 35.8 | Figure 2.7 |
| 7 | "" "" with a thin layer of flyash in between the Hypalon and 20% mixture (24hr cured). | 1.02 | 42.7 | Figure 2.8 |

The addition of 20% flyash to the native soils can stabilize the base soil matrix. Also, applying a thin layer of flyash between hypalon and base soil can increase adhesion between the soil and the hypalon liner system, promoting stability of the liner/soil interface.

### 2.4 Hydraulic Conductivity - Experiments, Results, and Discussion

To determine the hydraulic conductivity, each mixture was compacted in Plexiglas columns to a height of 1.5 inches, using standard Proctor compaction procedures (ASTM D698). Two samples were prepared for each of seven different ash/soil admixtures; the first at optimum moisture content (the "M" samples) and the second at 1% wet of the optimum moisture content (the "W" samples). Once prepared, all fly ash/soil samples were permeated with water at 30 inches of constant-head pressure. The two mixtures containing bentonite were subjected to an additional 3 psi pressure, to accelerate the infiltration and leaching process.

The minimum, maximum, and average hydraulic conductivities for the admixtures are summarized in Table III. The results in Table III indicate that the average hydraulic conductivity for the samples were reduced by more than one order of magnitude as sample ash content was increased from 20 to 40 percent. In addition, the hydraulic conductivity values for samples compacted wet of OMC were similar to or lower than for the samples compacted at OMC. The decreasing hydraulic conductivity with increasing ash content was expected given the favorable gradation of the ash-sand mixture and the pozzolanic (cementatious) nature of the Sunflower Class C fly ash. The average hydraulic conductivity for the 5/30/65 bentonite/ash/sand mixture was similar to the 30/70-ash/sand mixture, suggesting that at low percentages the bentonite provided little benefit to fluid movement.

**Table III**

**Hydraulic Conductivity of Fly ash, Sand, and Bentonite Mixtures**

| Mixture Percent: Fly Ash and Tivoli Sands | Hydraulic Conductivity, cm/s | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Last Reading | | Average | | Max | | Min | |
| | OMC | Wet of OMC | OMC | W/OMC | OMC | W/OMC | OMC | W/OMC |
| 10% F/A + 90% Sand | Too permeable to test | | | | | | | |
| 20% F/A + 80% Sand | 4.2E-07 | 1.0E-06 | 7.7E-06 | 1.9E-06 | 2.0E-05 | 3.0E-06 | 4.2E-07 | 5.1E-07 |
| 25% F/A + 75% Sand | 4.4E-07 | 9.1E-08 | 7.8E-07 | 6.8E-07 | 1.2E-06 | 1.1E-06 | 3.0E-07 | 9.1E-08 |
| 30% F/A + 70% Sand | 2.3E-07 | 1.8E-07 | 2.9E-07 | 2.1E-07 | 4.0E-07 | 3.1E-07 | 1.6E-07 | 9.7E-08 |
| 40% F/A + 60% Sand | 1.2E-07 | 1.0E-07 | 1.3E-07 | 1.5E-07 | 2.1E-07 | 2.6E-07 | 7.3E-08 | 5.6E-08 |
| 50% F/A + 50% Sand | Consistency is not workable in the field | | | | | | | |
| 5% Bentonite + 30% F/A + 65% Sand | 5.5E-07 | 5.0E-07 | 2.6E-07 | 2.7E-07 | 5.7E-07 | 5.5E-07 | 5.3E-08 | 5.0E-08 |

Note $5 \times 10^{-8}$ cm/s = 0.0017 in/day
$1 \times 10^{-7}$ cm/s = 0.0034 in/day
$2 \times 10^{-7}$ cm/s = 0.0068 in/day
$5 \times 10^{-7}$ cm/s = 0.0170 in/day

## 2.5 Leachate and Chemical Analyses – Experiments, Results, and Discussion

### 2.5.1 Nutrient Retention, Leachate Metals and Salts

Following permeation with tap water, samples from the "M" series were subjected to permeation by nutrient water. The primary objective was to evaluate the retention of nutrients in the soil/ash column and evaluate the chemical concentration in the leachate as a function of eluted pore volumes. The influent nutrient water was prepared by mixing 1 teaspoon of Miracle-Gro™ plant food per gallon of water and introduced as required during the study. Leachate samples were consistently submitted to an EPA-Certified laboratory for chemical analyses of selected metals, alkalinity, nutrients, and salts as leaching through the columns progressed. Laboratory analytical results are summarized in Tables 1-9 in Attachment D

Several elements were detected in the leachate samples submitted for laboratory analyses. Mercury (Hg) and arsenic (As) were not detected in any of the leachate samples, indicating minimal leachability of these compounds under the test conditions. Selenium (Se) was not detected in the effluent samples from the optimum moisture content (the "M") mixtures, or the bentonite mixture samples. However, Se was observed in the first round of leachate samples from the W (wet of OMC) mixtures. The low concentration of Se in the initial W leachate is indicative of limited leachablity following the initial leaching process. Iron was only detected sporadically, with no discernable trend.

Chromium (Cr) was detected in the initial leachate from all columns, and concentrations were observed to decrease as additional pore volumes were eluted from the columns. Sulfate concentrations also displayed a decreasing trend as the number of eluted pore volumes increased; barium (Ba) concentrations displayed a tendency to decrease between the initial and subsequent samples. Conversely, alkalinity and boron concentrations increased with increasing pore volumes indicating that the full range of leaching had not been reached when the experiment was terminated. Chloride (Cl) and potassium (K+) exhibited differing behavior in both the M and W samples. Chloride concentrations increased with increasing pore volumes for the M samples, yet exhibited no obvious trend for the W series samples. Potassium concentrations increased with increasing pore volumes in the M samples, but showed little trend, after an initial decrease, in the W series samples. This difference is attributed to the introduction of nutrient-laden water in the M samples but not in the W samples.

Phosphorus (P) was observed in two leachate samples only after multiple pore-volume exchanges, indicating the relatively low leachability of this nutrient through the soil column. Conversely, the nutrients' nitrogen (N) and potassium (K+) were observed in the initial leachate samples, and were observed to leach in concentrations increasing with pore-volume exchanges. The propensity for consistent leaching of nitrogen and phosphorus through the mixture column indicates that these nutrients can be readily mobilized and leached from the mixture columns. Because retention of the nutrients nitrogen, potassium and phosphorus is necessary for plant growth, the addition of inexpensive, nutrient-retaining soil amendments may be considered in cover applications. The potential exists to utilize locally available manure to retain nitrogen and phosphorus in the soil column; Sunflower will be conducting a field test in the Spring of 2002 which will demonstrate the potential for retention.

Direct correlation of leachate analyses between ash mixtures was not possible because the laboratory samples were obtained following differing numbers of pore volumes through the columns. Table IV shows leachate concentrations for the M and W samples that were closest to 20 pore volumes. These results indicate that alkalinity, sulfate, and potassium concentrations appear to increase with increasing ash content. Chloride concentrations increased with increasing ash content in the M samples only; Boron concentration increased with increasing ash content in the W samples only. No clear correlations could be drawn between the other parameters and ash percentage.

**Table IV**
**Leachate Concentrations in Samples Closest to 20 Pore Volumes**

| Sample | Pore Volumes | pH | Alk | Chloride | Sulfate | Nitrate | Potassium | Barium | Boron | Chromium | Iron |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 20M | 82 68 | 8 53 | 23 4 | 40 | 425 | ND | 7 31 | 0 403 | 0 234 | 0 0083 | ND |
| 25M | 27 78 | 9 09 | 75 | 144 | 1110 | 0 998 | 89 | 0 205 | 1 02 | 0 0219 | ND |
| 30M | 19 57 | 8 62 | 93 9 | 149 | 1590 | ND | 93 7 | 0 225 | 0 869 | 0 0133 | 0 0762 |
| 40M | 17 18 | 9 14 | 227 | 241 | 2360 | 2 35 | 136 | 0 232 | 0 723 | 0 0202 | ND |
| 20W | 35 69 | 7 64 | 40 8 | 50 2 | 722 | NA | 9 73 | 0 203 | 0 284 | 0 018 | ND |
| 25W | 24 22 | 6 82 | 65 7 | 50 6 | 1140 | NA | 12 9 | 0 188 | 0 358 | 0 0146 | 0 0805 |
| 30W | 17 62 | 8 28 | 73 | 43 6 | 1730 | NA | 25 7 | 0 26 | 0 414 | 0 0175 | ND |
| 40W | 17 85 | 8 09 | 125 | 54 6 | 1860 | NA | 35 2 | 0 276 | 0 591 | 0 0147 | ND |

1 phosphate, arsenic, mercury, and selenium not detected or not analyzed in selected samples
2 concentrations in mg/L, except pH in standard units
3 ND = not detected, NA = not analyzed

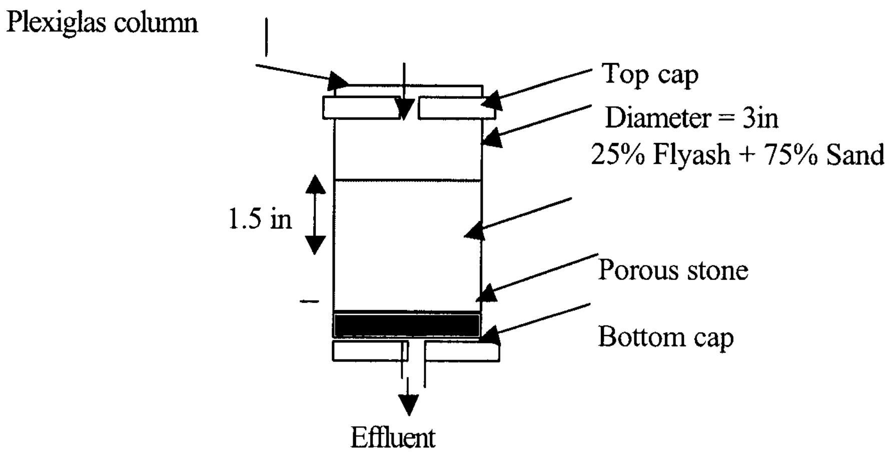
### 2.5.2 Permeability and Leachate Characteristics in Animal Waste Applications

Concentrated Animal Feeding Operations (CAFOs) produce significant quantities of waste that is rich in suspended solids, ammonium, nitrate, chloride, pathogens, and other constituents such as potassium, sodium, and sulfates. These wastes are usually stored in earthen lagoons lined either a clayey soil or with geosynthetic liner materials.

Many state regulatory agencies, including Kansas and North Carolina, are revisiting lagoon construction and maintenance rules to prevent ground water contamination. Lining of lagoons with low-permeability materials or with geosynthetic liners (or a combination) can inhibit seepage into the subsurface. Flyash produced from the combustion of coal has significant potential in lagoon-liner construction projects, as it is inexpensive and readily available. The inexpensive cost could also encourage farm owners to construct their lagoon liners with flyash. One task in the current study focused on the usefulness of flyash as a lagoon-liner material.

The 25% flyash and 75% sand mixture prepared wet of optimum water content mixture (W) was compacted to a height of 1.5-in in a Plexiglas column of 3-in diameter and 3-in in height, using standard Proctor techniques. The compacted sample was saturated with standing water and then connected to a 30-in constant head tank. Water was used as influent until about 17 pore volumes had been eluted, to make sure that the soil was fully saturated. Following saturation, cattle waste was introduced as the influent. To facilitate this process, the cattle waste was placed in an airtight jar and introduced into the 25W sample. In order to collect sufficient leachate, the sample was initially subjected to a 2 psi pressure, which was gradually increased to 5 psi. A schematic of the experimental setup is depicted in Figure 1.

**Figure 1:**
**Leaching Experiment**
**Schematic**



Effluent collected at regular intervals of time was measured to determine the hydraulic conductivity, ($k$) using Dracy's law:

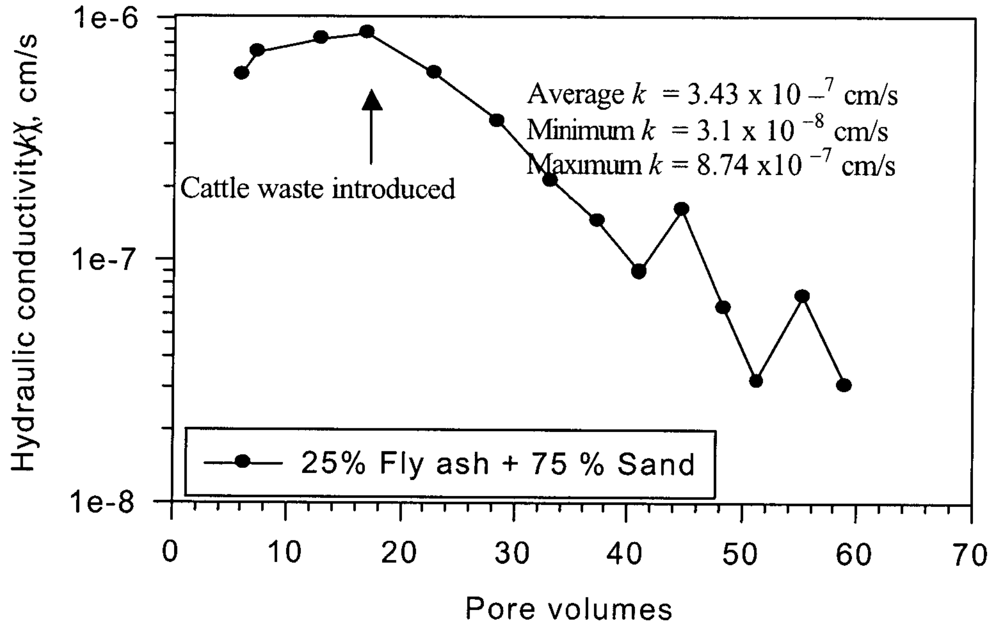
$$Q = kiAt$$

where,

$Q$ = quantity of leachate collected, ml
$k$ = hydraulic conductivity, cm/s
$i$ = hydraulic gradient,
$A$ = cross-sectional area of the sample, $\text{cm}^2$
$t$ = time (sec) to collect $Q$, quantity of leachate.

As the cattle waste experiment proceeded, a reduction of hydraulic conductivity with pore-volumes eluted was observed. This trend has been plotted on Figure 2. It can be observed from Figure 2 that the hydraulic conductivity decreased upon introduction of the cattle waste into the 25W sample. The reduction in hydraulic conductivity is thought to be a result of physical, chemical and biological interaction of the waste with the mixture matrix. Suspended solids in the waste could physically block (or seal) the soil pores. Growth of pathogens in the soil pores could also contribute to clogging of the pores. Chemical interaction between the soil particles and the animal waste also disperses the soil structure, causing a reduction in hydraulic conductivity. A combination of these mechanisms is likely responsible for reduction in the hydraulic conductivity observed on Figure 2.

**Figure 2**
**Variation of Hydraulic Conductivity with Pore Volumes**

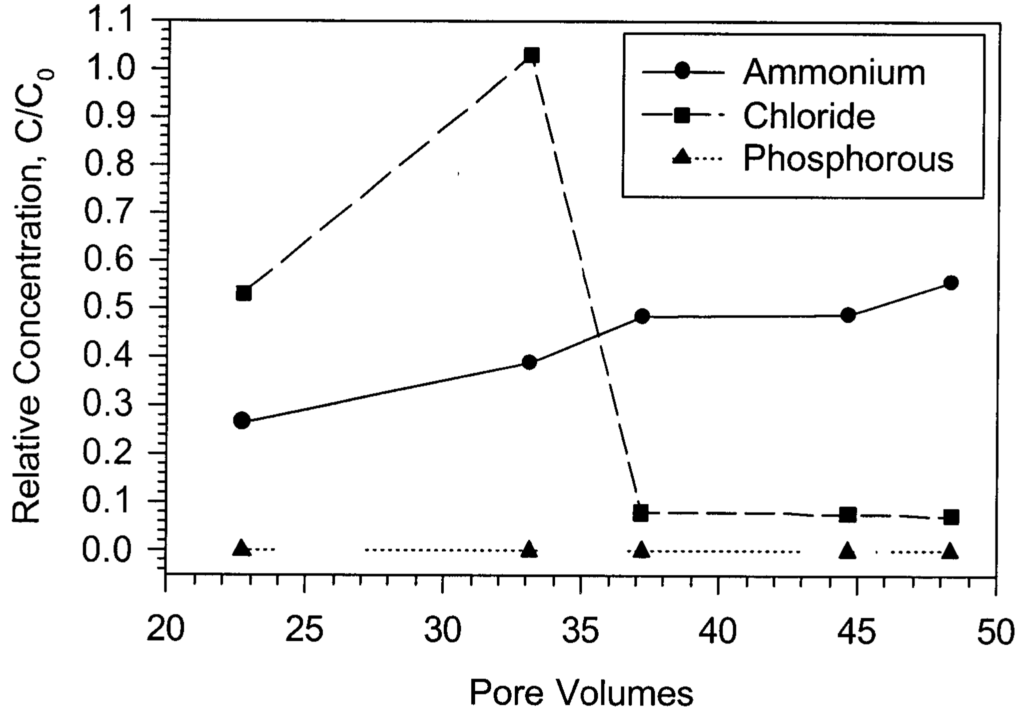


Leachate collected at regular time intervals was sent to Pace analytical laboratories for ammonium, chloride, and phosphorous determination Analytical results are presented in Table V. The corresponding breakthrough curves are shown on Figure 3

## Table V
## Influent and Effluent Characteristics.

| Influent/ Effluent pore volumes | Ammonium, mg/L | Chloride, mg/L | Phosphorous, mg/L |
|---|---|---|---|
| Influent | 229 | 1410 | 166 |
| 22.72 | 60.8 | 748 | ND |
| 33.1 | 89.1 | 1450 | ND |
| 37.19 | 111 | 114 | ND |
| 44.65 | 112 | 110 | ND |
| 48.34 | 127 | 104 | ND |

## Figure 3
## Breakthrough Curves of Ammonium, Chloride, and Phosphorous in 25W Mixture



## 2.6 Soil Mixture Chemical Analyses – Experiments, Results and Discussion

In order to observe nutrient retention, the ability to support plant growth and identify chemical constituents, two samples from the 20M and 25M mixtures and four field samples were submitted to the soil-testing laboratory at the KSU Department of Agronomy. The field samples were "discreet" samples collected from various parts of the landfill to demonstrate post-depositional waste characteristics, following weathering. Chemical analyses performed on the samples included pH, total phosphorous, potassium, total nitrogen, ammonia, nitrate, calcium, magnesium, iron, magnesium, sodium, nitrate, salt alkali, chloride, and organic matter. Laboratory analytical results on soil samples are summarized in Attachment E, and pH results are discussed below.

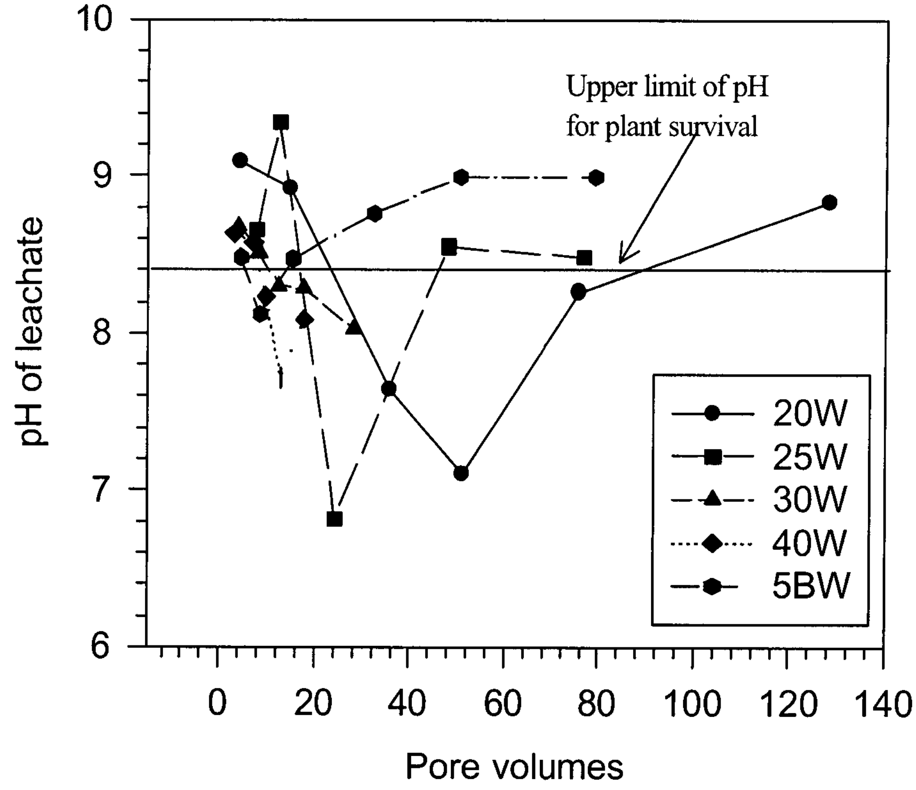
For optimum plant survival and growth, soils should be maintained at a pH of 8.5 or less. However, the pH for the 20M and 25M soil samples was measured at 9.1, which can be excessive for plant growth (Table E-1, Attachment E). By contrast, pH values in leachate samples fluctuated over time both above and below the PH threshold of 8.5 (Figure 4). All nine columns had initial leachate pH value of greater than 8.5; some exhibited decreases in pH to values lower than 8.5, with values fluctuating again to greater than 8.5 as additional elutions took place. Leachate samples from the 30W and 40W columns decreased to values less than 8.5 and did not increase; however these columns were sampled for a relatively low number of pore volumes (< 30), and pH increases in other columns (20W, 25W) were observed after more than 50 pore volumes.

As a further test of soil pH, the 20M soil sample was sacrificed for chemical analyses after leaching of approximately 310 pore volumes. These results, presented in Table E-3 of Attachment E, indicate pH values of 7.7 and 7.9, from the top and bottom soil halves (respectively). These values were considerably lower than the pre-leach soil pH of 9.1, suggesting possible decrease of pH as additional pore volumes were eluted from the samples.

Analyses on ash/sand samples taken from the vicinity of the landfill site revealed a pH between 7.4 and 8.7. These soils have been subjected to weathering processes, and some plant growth was observed to occur on the soil matrix. A discussion of the flora samples collected with the solids is found in Section 2.7. Because of the presence of the plants it is assumed that the pH range can be conducive to the growth of the native annuals observed at the site. Table E-2 of Attachment E presents results of soil analyses.

**Figure 4**

**pH Changes as a Function of Eluted Pore Volumes**



## 2.7 Native Flora Identification

Native flora samples and their associated soils were collected from seven locations on and around the existing landfill. The flora samples represent the establishment of plants in the area occupied by varying percentages of ash soils. The flora samples were identified with the help of K-State Extension Service, for assessment of flora survivability. The rationale for assessment of these plants was to establish baseline conditions of natural flora establishment, and to identify plant species that have the potential for use in constructed cover applications. Table VI outlines the location, species determination, and soil conditions from which samples were taken. Four species, Tumbleweed, Plains Sunflower, Wormwood, and Ragweed appear especially well suited to growth in this environment.

## Table VI
## Native Flora Samples and Locations

| Sample ID- Soil | Visual and qualitative description | Sample ID - Plant | Genus species | Common name | Annual/ perennial | Plant condition | Location |
|---|---|---|---|---|---|---|---|
| Flora-1-soil | Lot of fly ash | Flora 1 | Kochia scoparia | Fireweed | Annual | Dry leaves | North of Phase-I |
| Flora-2-soil | Lot of fly ash | Flora 2 | Salsola iberica | Tumbleweed | Annual | Green leaves and healthy plant | Top of Phase-I landfill |
| Flora-3-soil | Sandy | Flora 3 | Helianthus petiolaris | Plains sunflower | Annual | Green leaves and healthy plant | South of Phase-I |
| Flora-4-soil | Sandy | Flora 4 | Artemisia filifolia | Wormwood | Perennial | Green leaves and healthy | North of Phase-I |
| Flora-5-soil | Sandy | Flora 5 | Bouteloua gracilis | Grama | Perennial | Dry leaves | North of Phase-I |
| Flora-6-soil | Sandy | Flora 6 | Ambrosia psilostachya | Ragweed | Perennial | Green and healthy plant | North of Phase-I |
| Flora-7-soil | Moderate fly ash. | Flora 7 | Poaceae | *A grass type that is typical in Kansas. | Perennial | Dry leaves | North East of Phase-I |

* Identification became difficult because of dry leaves and plant condition.

# 3.0 MODEL ANALYESIS OF LEACHATE PERCOLATION RATES

### 3.1 Background

Fresh fly ash typically has a low moisture content (<13 percent). In fact, it is typically so dry that water is added to reduce dust and improve compactibility. Given the dry condition of the fly ash and the low rainfall conditions of western Kansas, the potential exists that fly ash can be managed such that precipitation falling on the landfill will evaporate or be retained within the ash matrix. Ash disposition can be conducted such to limit percolation and potential leaching. Construction of future cells in the Sandy Tivoli soils could be conducted by first establishing an ash/soil liner base on existing topography. This can be accomplished through the grubbing of vegetation and scarifying of the sandy soils, while stabilizing with a 25 – 30% ash mixture. Subsequent to the establishment of the low permeability base, the vertical height of the area being filled with ash would be maximized, while concurrently minimizing the horizontal area of the filled cell. Restated, each cell would be vertically filled as much as practically feasible before expanding laterally. This hypothesis was tested using EPA's Hydrologic Evaluation of Landfill Performance (HELP) model.[2]

The HELP model predicts one-dimensional vertical percolation through the landfill column based on daily precipitation, evapotranspiration, runoff, and the geometry/hydrogeologic properties of a layered soil and waste profile. The HELP program accounts for surface water storage, snowmelt, soil moisture storage, lateral subsurface drainage, and lateral subsurface inflows. Computations are linked in sequential order: 1) a surface water balance; 2) evapotranspiration; and 3) subsurface drainage and water routing.

HELP assumes that soils within any given layer are uniform with respect to hydrogeologic properties, and do not change over time. Vertical drainage is assumed to be by Darcian flow. The computations account for the effects of freezing conditions on infiltration, but not on soil hydraulic conductivity. Similarly, the effects of animal burrowing, desiccation and other similar conduits are not integrated into the model. Other simplifying assumptions in HELP are listed in Schroeder et al., 1994.

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[2] Schroeder, P R , T.S. Dozier, P.A. Zappi, B.M. McEnroe, J W Sjostrom, and R L. Peyton, 1994. *The Hydrologic Evaluation of Landfill Performance (HELP) Model. Engineering Documentation for Version 3*. EPA/600/R-94/168b, U S Environmental Protection Agency Office of Research and Development, Washington, D C

### 3.2 Model Setup

Percolation through the active Holcomb landfill was simulated while sequentially adding layers representing annual disposal of dry ash. As example, if an annual lift thickness was 10 feet, then the HELP simulation for the first year included two 5-foot layers with hydraulic characteristics representative of coal ash (model layer thickness was limited to 5 feet). Similarly the HELP simulation for the second year included two new 5-foot layers making a total of four 5-foot ash layers. The HELP model assumes that all simulations begin on January 1 and end on December 31; therefore each annual lift were assumed to be instantaneously placed in the landfill on January 1. Annual lifts were modeled until ash thickness was 60 feet. Then, the landfill was modeled with a native soil cap for a period of 20 years. Continuity between annual HELP simulations was achieved by recording moisture content values in each layer at the end of the previous years simulation and entering that value as the initial moisture content for that layer in the following year simulation. Tests were performed assuming annual ash lift thickness of 5, 10, 15 and 20 feet, and active landfilling simulations were respectively 12, 6, 4, and 3 years in length, after which the 20-year cap simulation was performed.

Input data for the HELP model are listed in Attachment F, Table 1, and key inputs are described below.

- Climate Data - Climate data were synthetically generated based on model defaults for Dodge City, Kansas. Precipitation and temperature calculations were refined using average monthly values from 1948 through 2000 at the Garden City, Kansas Experiment Station. The resulting annual precipitation totals are synthetically generated by HELP. Precipitation values ranged from 16 to 25 inches. Annual climate data were arranged so that average annual precipitation was between 19.2 and 19.5 inches/yr for all of the lift thickness scenarios. This arrangement assured that results were not biased by differing precipitation totals during the active landfilling period.

- Soil Parameters: Coal Ash - The initial soil parameters for coal ash were obtained from the HELP database. Hydraulic conductivity during active operation was set to the HELP default of $5x10^{-5}$ cm/s. Initial (first year) moisture content for each ash layer was set at 0.15 to represent dry ash after addition of water for material handling. Moisture content in subsequent years was set at the value for that layer as described above. Since the Class C ash disposed at this site is self-cementing when it is wetted, the hydraulic conductivity was assumed to decrease to 1x10$^{-7}$ following closure, which is consistent with laboratory analyses.

- Soil Parameters: Cap - Cap soils were assumed to be sandy. Soil property values used in the simulation were taken from the HELP database for a fine sandy loam and loamy fine sand.

- Runoff and Vegetation Parameters - No runoff and bare soil (no vegetation) were assumed during the active filling period, meaning that the only pathway for water to exit the model other than percolation was by evaporation from bare ground. The cap simulation assumed that runoff occurred over the entire area of the landfill based on a 2 degree slope and a slope length of 1200 feet.

### 3.3 Model Results and Discussion

Model sensitivity analyses (Scenarios A1-A6 on Tables F-2c through F-2h, Attachment F) were performed to determine the influence of selected input parameters on model results. Results were compared to a control scenario that simulated percolation through native soils without coal ash. Percolation results simulating hydraulic conductivity during active closure, and hydraulic conductivity after filling, indicated decreases of greater than 90 percent compared to the lower of the two control scenarios. These results suggest that the model is insensitive to these parameters. The model was found to be sensitive to initial soil moisture content, suggesting that the degree of prior saturation of each ash lift plays a key role in the ability of the freshly disposed ash to retain moisture. Model results are summarized in Table VII and detailed in Table F-2 of Attachment F.

A comparison of annual lift thickness (Scenarios A1, B1, C1, and D1) indicates a generally decreasing percolation rate with increasing lift thickness. However, all scenarios indicated percolation rate reductions of 90 percent or more compared to the control scenarios.

These results suggest that disposal of nominally dry, Class C fly ash with a 15-percent (or lower) moisture content results in very low rates (less than 0 05 inches/year) of leachate percolation. During active operation, most of precipitation that falls on the ash surface will either be returned to the atmosphere (evaporation) or retained within the coal ash to compensate for soil-moisture deficits. Wetting of the ash will result in cementing reactions, further lowering the hydraulic conductivity of the ash column over time.

Predicted percolation rates averaging less than 0.05 inches/year are comparable to or <u>less</u> than values expected from clay-lined municipal landfills in more-humid areas of the United States. Operational recommendations observed from the modeling effort include:

- Placement of ash that is drier than its field capacity;
- Installation of a low hydraulic conductivity ash/sand liner at the cell base to minimize initial percolation of precipitation;
- Ensuring that the annual thickness of lifts is sufficient such that fresh ash is added before the existing lift reaches field capacity;
- Controlling runoff on active cells through the established physical controls;
- Establishment of vegetative cover on closed cells.
- Controlling runoff though physical controls, and establishing a viable vegetative cover on closed cells.

# Table VII
# HELP Model Summary

| Scenario Description | Percolation (in/yr) | | Change from Default 1 | | Parameters Changes |
|---|---|---|---|---|---|
| | Average | Max | Average | Max | (all parameters as in A1 except as noted) |
| Control 1, simulates fine sandy loam soil type | 0 301 | 1 187 | ----- | ------ | Soil K = 5 2E-4 cm/s |
| Control 2, simulates loamy fine sand soil type | 0 670 | 2 884 | ----- | ----- | Soil K = 1 0E-3 cm/s |
| A1 5-foot annual lifts | 0 013 | 0 101 | -96% | -92% | |
| A2 Assumes ash does not set-up | 0 020 | 0 101 | -93% | -92% | Ash K = 5 0E-5 cm/s after closure (1 0e-7 cm/s in A-1) |
| A3 Increased ash K for active landfilling period | 0 015 | 0 237 | -95% | -80% | Ash K =1 0E – while active (5 0E-5cm/s in A1) |
| A4 Decreased initial ash moisture content | 0 001 | 0 002 | -100% | -100% | Initial MC = 0 12 (0 15 in A1) |
| A5 Increased initial ash moisture content | 0 120 | 0 439 | -60% | -63% | Initial MC = 0 18 (0 015 in A1) |
| A6 Increased permeability of cap soils | 0 013 | 0 101 | -96% | -92% | Cap K = 1 0E-3 cm/s (5 2E-4 cm/s in A1) |
| B1 10 –foot annual lifts | 0 007 | 0 132 | -98% | -89% | |
| B2 Assumes ash does not set-up | 0 031 | 0 132 | -90% | -89% | Ash K = 5 0E-5cm/s after closure (1 0E-7 cm/s B1) |
| C1 15-foot annual lifts | 0 002 | 0 022 | -99% | -98% | |
| C2 Assumes ash does set up | 0 021 | 0 028 | -93% | -98% | Ash K = 5 0E-5cm/s after closure (1 0E-7 cm/s in C1) |
| D1 20-foot annual lifts | 0 002 | 0 024 | -99% | -98% | |
| D2 Assumes ash does not set-up | 0 019 | 0 025 | -94% | -98% | Ash K = 5 0E-5cm/s after closure (1 0E-7 cm/s in D1) |

# 4.0 CONCLUSIONS AND RECOMMENDATIONS

The fly ash/sand mixtures display good engineering characteristics (i.e., shrink-swell, plasticity index and Atterberg limits) making the mixtures a suitable material for landfill and lagoon liner applications. Hydraulic conductivity values of $1 \times 10^{-7}$ cm/sec and lower were observed in the 25/75 M and the 30/70 M mixtures. These results are on the order of the new MSWLF composite liner design criteria found in 40 CFR 258.40.

The laboratory data suggest that hydraulic conductivity values even lower than $3 \times 10^{-7}$ cm/sec can be attained by construction of new cells with a 25-30 percent fly ash/native soil mixture. This is orders of magnitude lower than sand or ash alone. Flyash/sand mixtures also display good engineering characteristics such as optimum shrink/swell and good compaction. Further, the addition of flyash slurry substantially increased the adhesion and friction in Geosynthetic/Flyash liner combinations.

Results indicate that the initial percolation rate from the landfill unit can be reduced over the current filling methods by construction on 30/70 ash liner, prior to filling cells. HELP modeling suggests that the volume of leachate generated from the landfill will be very low (0.05 inches/year) if the ash is deposited dry and in annual lift thicknesses of at least five feet, such that the moisture content of the landfilled material does not reach field capacity. This can be achieved by minimizing the horizontal expansion of the ash lifts as much as operationally necessary. Further, all cells should be sloped/drained toward the existing retention/evaporation basin located adjacent (east) of the landfill, and these controls should be adequate for future drainage applications. Drainage channels and sloping should be constructed at a minimum of 1.5 - 2%, as operationally feasible.

Laboratory analyses on leachate from the ash/sand mixtures did not yield mercury or arsenic above laboratory detection limits. Selenium was detected in the first analyses of the "W" samples, indicating limited leachability after soil pore volumes have been eluted. Chromium was detected in the initial leachate from all columns and concentrations were observed to decrease with additional pore volumes. Similarly, sulfate displayed decreasing concentration trends with eluted pore volumes. Alkalinity and Boron, on the other hand, displayed concentrations which increased with pore volumes eluted, indicating that the full range of leaching had not been reached when the experiments were terminated. In the context of this study and the associated recommendations, the leachate parameters are viewed as nonsubstantial, this because the site location and arid climate characteristics, combined with the liner recommendations, will minimize percolation from the landfill to well below the minimum RCRA Subtitle D Landfill Design Standards

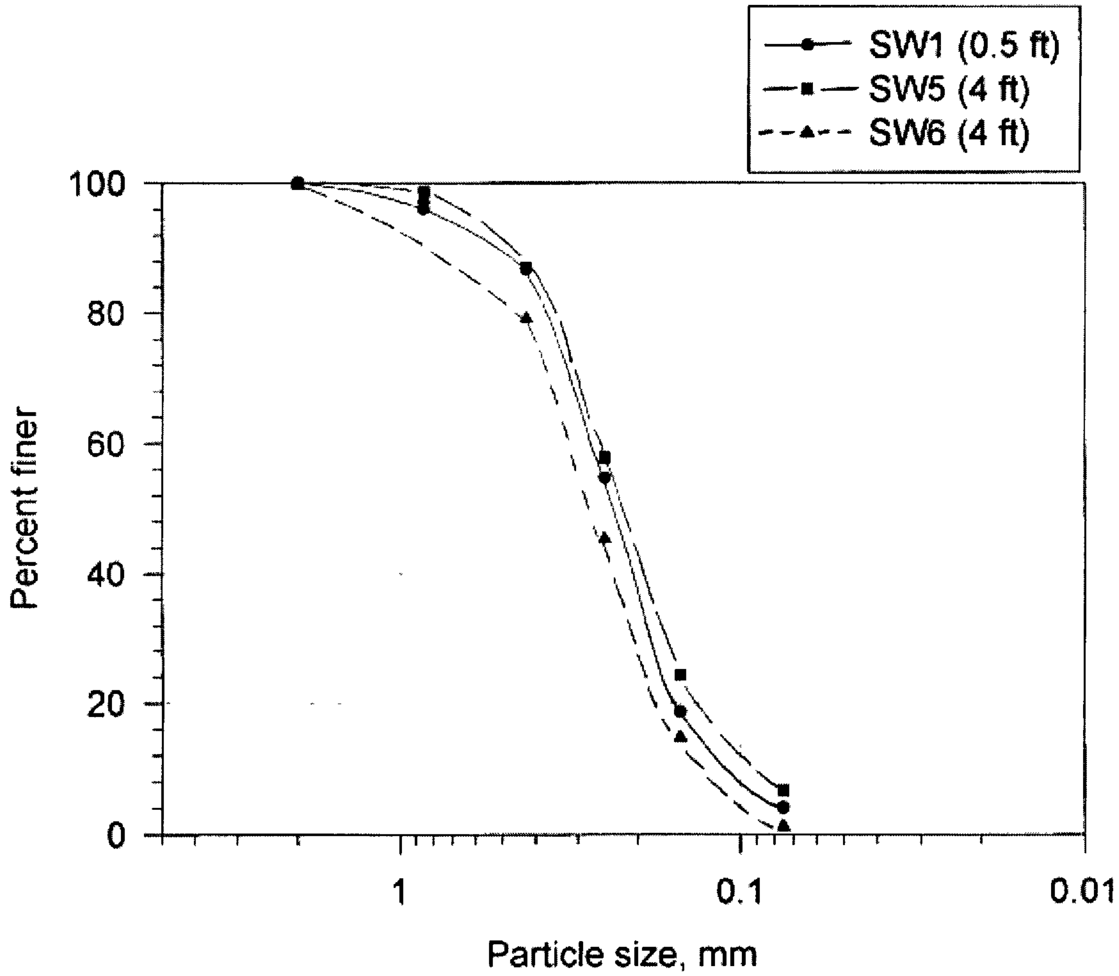
During the animal waste experiments, leaching tests were conducted on 25W mixture to evaluate the suitability of this mixture for lagoon liner construction. Results from animal waste leaching tests indicate that the hydraulic conductivity of the 25W mixture was reduced by one-order of magnitude after introducing cattle waste as influent. Ammonium transport parameters were obtained by fitting an analytical solution to the observed ammonium concentrations in the leachate tests. Modeling results indicate that ammonium retarded significantly in 25W mixture, and hence very less amount of ammonium was leached into the subsurface. Spray-injection technique did not work well due to very narrow pore openings of the native sands from the Tivoli soils.

Specific recommendations from this study are as follows:

- The 20% flyash and 80% sand mixture can be used to construct the lagoon liners. Cohesion of this mixture (c = 4.5 psi) will help maintain the soil shear strength, even in the absence of normal stresses.
- Adding a thin layer of flyash slurry prepared at 1.15 LL (=41% water content) increased the adhesion between hypalon and liner material.
- The hydraulic conductivity of 25W mixture was reduced to 3.1 x $10^{-8}$ cm/s following the introduction of cattle waste as influent.
- High transport parameters and reduced hydraulic conductivity retarded the ammonium transport significantly through the mixture columns. This is a good indication that 25W mixture can be used as lagoon liner material.
- Spray injection of flyash slurry onto coarse sands or gravels might work best to transport flyash into the soils mass; however, the soils at the Sunflower site are not coarse enough to allow this process.

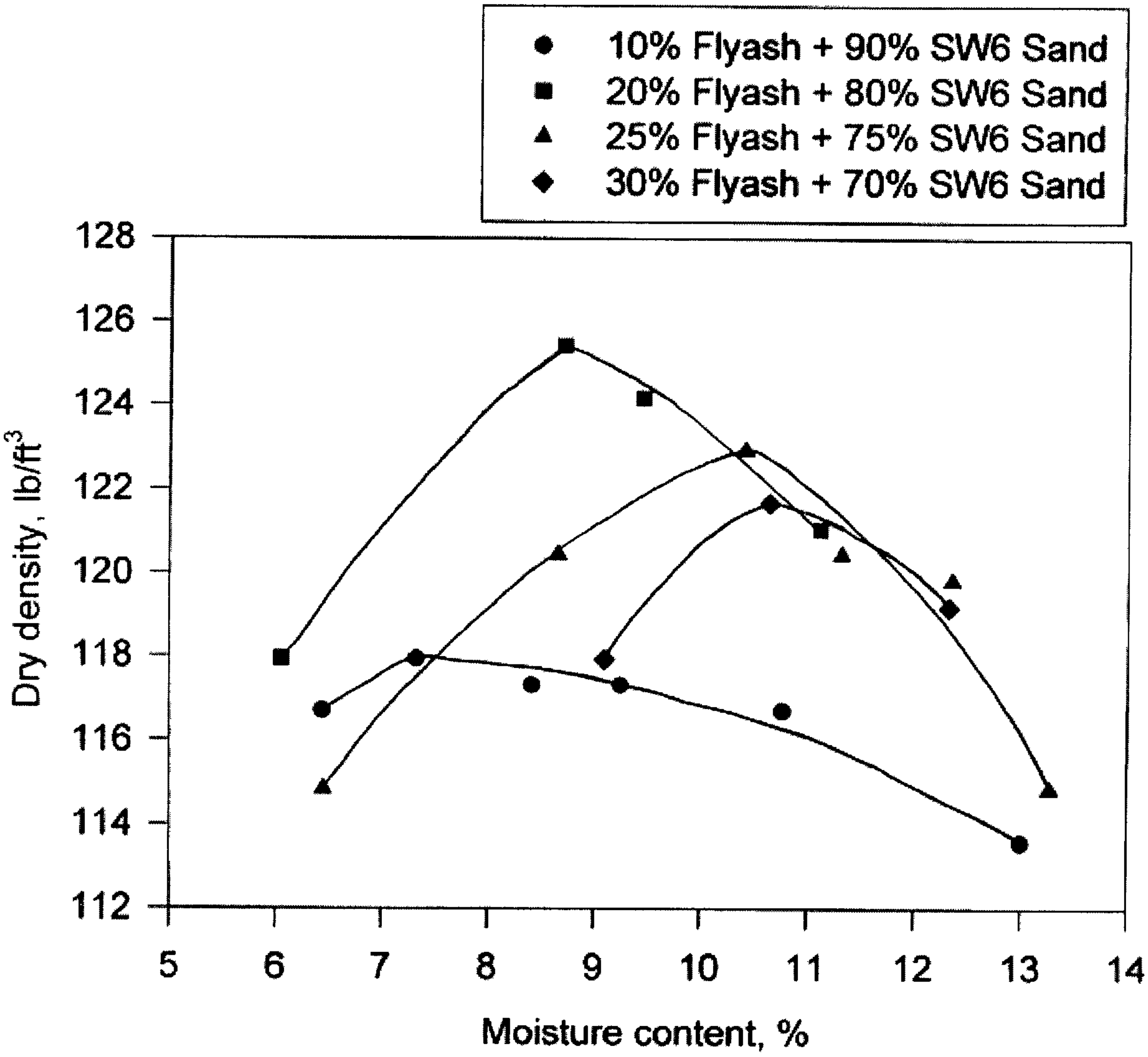
# ATTACHMENT A

# PSD Curves

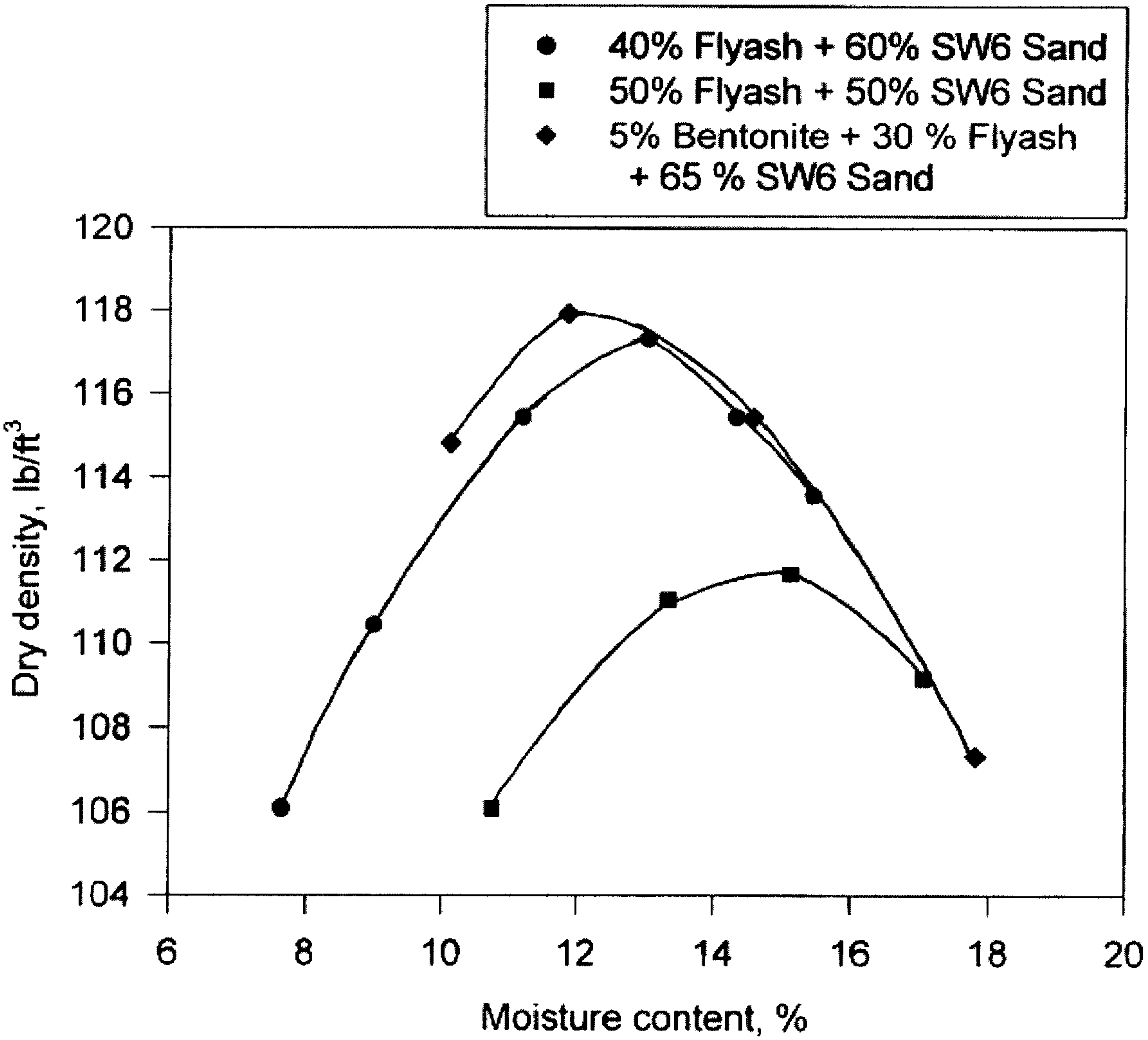

SW1 (0.5 ft)
SW5 (4 ft)
SW6 (4 ft)
100
80
60
40
20
0
Percent finer
1
0.1
0.01
Particle size, mm

# ATTACHMENT B

# Compaction Curves



Compaction characteristic curves for 10%, 20%, 25%, and 30% mixtures.



Compaction characteristic curves for 40%, 50%, and 5% bentonite mixtures.

# ATTACHMENT C

# Shear Strength Regression Curves

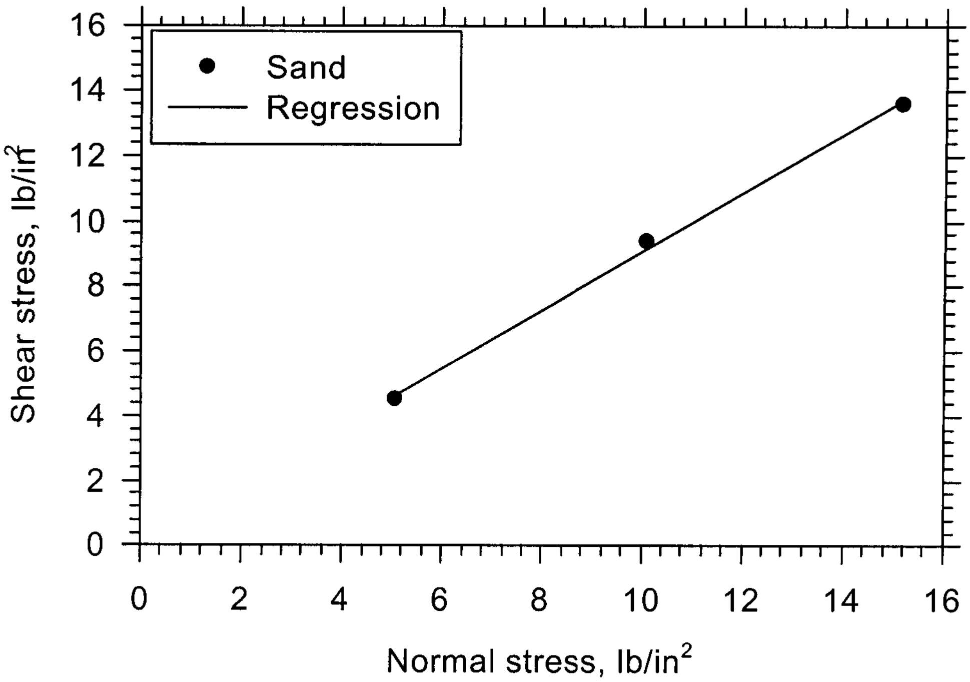


Figure C-1. Determination of shear strength parameters for sand using direct shear test results.

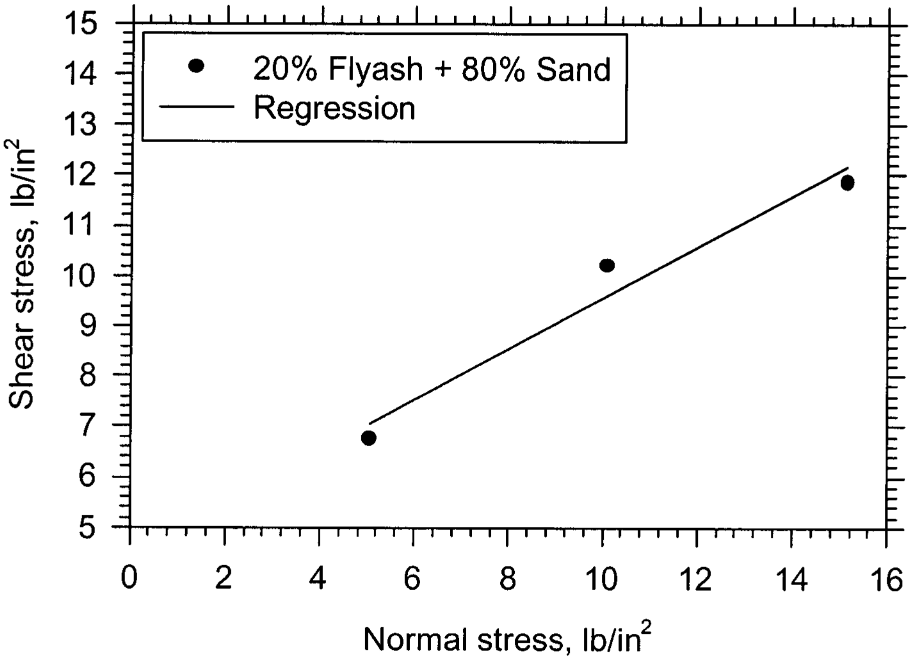


Figure C-2. Determination of shear strength parameters for 20% Flyash + 80% Sand mixture using direct shear test results.

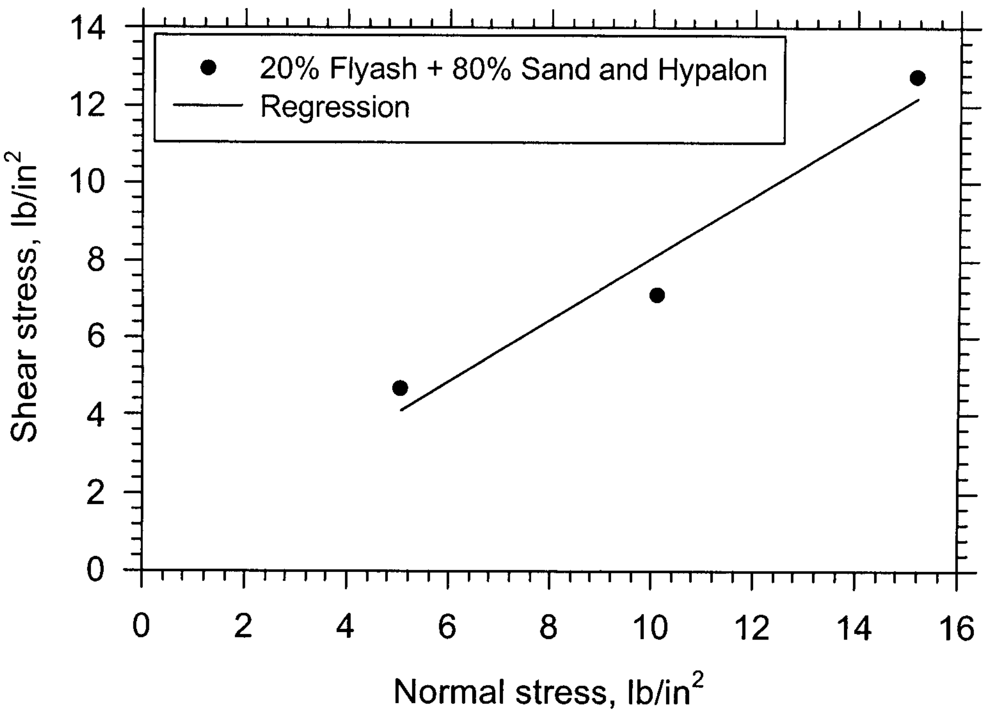


Figure C-3. Determination of adhesion and friction angle between 20% flyash mixture and hypalon using direct shear test results after curing for 24-hour period.

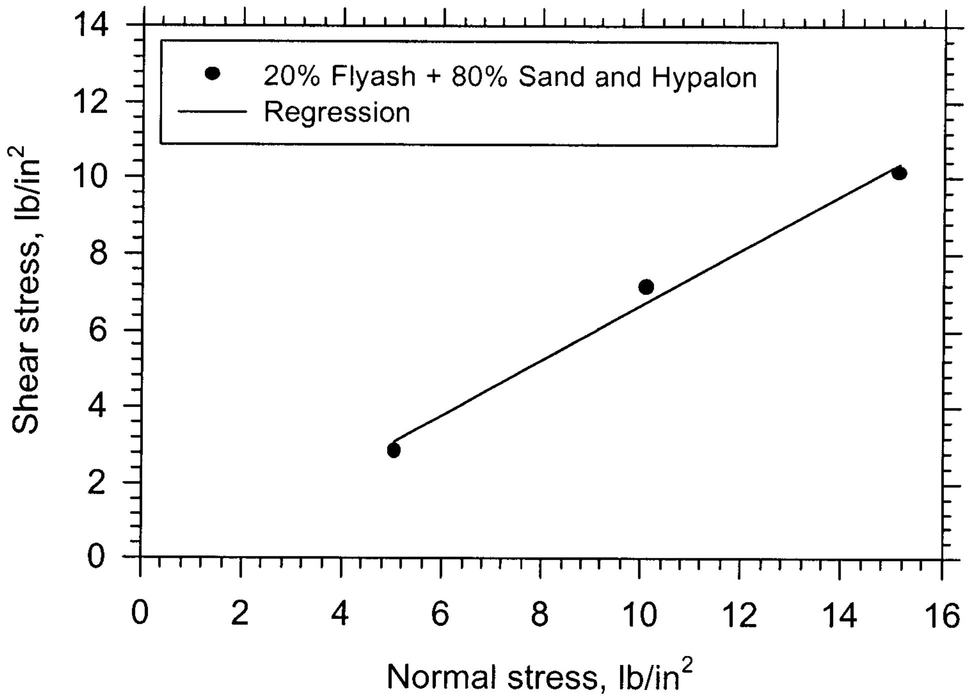


Figure C-4. Determination of adhesion and friction angle between 20% flyash mixture and hypalon using direct shear test results after curing for 24-hour period under saturated conditions.

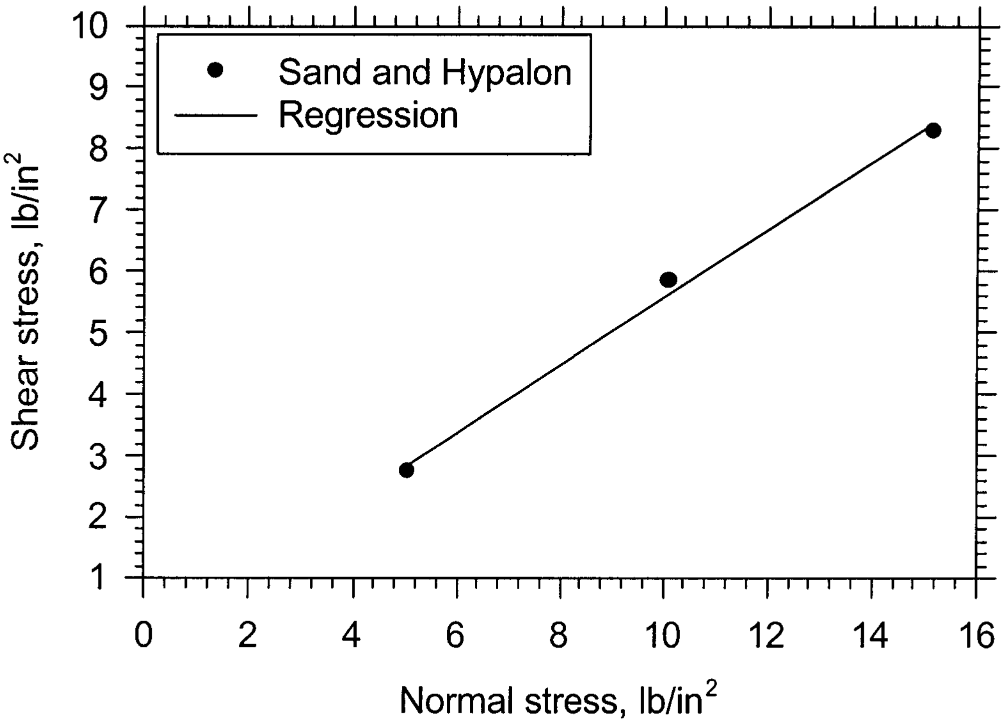


Figure C-5. Determination of adhesion and friction angle between sand and hypalon using direct shear test results. Figure C-6. Determination of adhesion and friction angle between 20% flyash mixture and hypalon using direct shear test results.

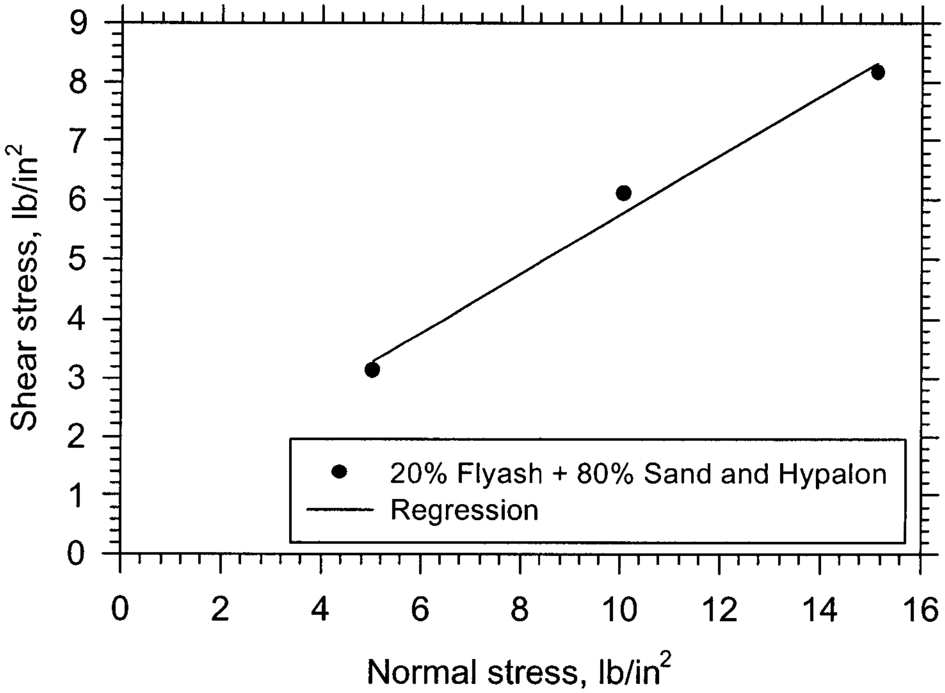


Figure C-6. Determination of adhesion and friction angle between 20% flyash mixture and hypalon using direct shear test results.

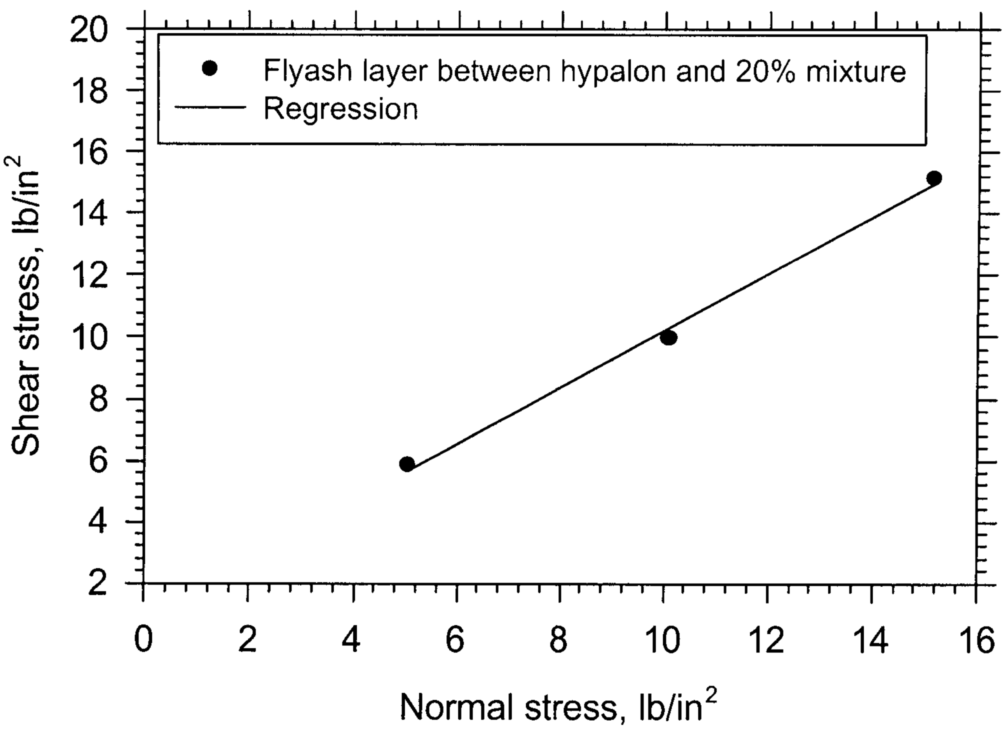


Figure C-7. Determination of adhesion and friction angle using a thin layer of flyash between 20% flyash mixture and hypalon after curing for 24-hour period.

# ATTACHMENT D

# Tables 1-9: Laboratory Analytical Results on Leachate

# Table D-1

## 20M Sample

## Leachate Chemical Analyses

## 20% Ash 80% Native Soils

| Pore Volumes Eluted[1] | pH | Total Alkalinity | Chloride | Sulfate | Nitrogen | Phos. | K | As | Ba | B | Cr | Hg | Fe | Se | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 82 68 | 8 53 | 23 4 mg/L | 40 mg/L | 425 mg/L | N/D | ND | 7 31 mg/L | ND | 0 403 mg/L | 0 234 mg/L | 0 0083 mg/L | ND | ND | ND | Before Introduction of Nutrient Water |
| 100 44 | 9 34 | 69 5 mg/L | 140 mg/L | 377 mg/L | 1 24 mg/L | ND | 86 8 mg/L | ND | 0 218 mg/L | 0 881 mg/L | 0 0167 mg/L | NS | 0 139 mg/L | ND | After Introduction of Nutrient Water |
| 153 62 | 8 64 | 153 mg/L | 140 mg/L | 398 mg/L | 1 57 mg/L | ND | 95 8 mg/L | ND | 0 112 mg/L | 1 08 mg/L | 0 0144 mg/L | NS | 0 426 mg/L | ND | After Introduction of Nutrient Water |
| 202 91 | 8 61 | 114 mg/L | 142 mg/L | 337 mg/L | 1 43 mg/L | ND | 124 mg/L | ND | 0 052 mg/L | 1 24 mg/L | 0 011 mg/L | NS | 0 057 mg/L | ND | After Introduction of Nutrient Water |
| 251 46 | 8 55 | 102 mg/L | 189 mg/L | 518 mg/L | 2.37 mg/L | 0 765 mg/L | 120 mg/L | ND | 0 081 mg/L | 1 4 mg/L | 0 015 mg/L | ND | 0 077 mg/L | ND | After Introduction of Nutrient Water |

**Notes**

N/D = Non Detect at Laboratory Detection Limit

(See Attachment 3 for Laboratory Detection Limits)

N/S = Not Sampled or Analyses not performed

[1] Pore Volumes (PV=V/$V_0$), V = Cumulative volume of sample leached, $V_0$ = Pore volume of the mixture

# Table D-2

## 25 M Sample

## Leachate Chemical Analyses

## 25% Ash 70% Native Soils

| Pore Volumes Eluted[1] | pH | Total Alkalinity | Chloride | Sulfate | Nitrogen | Phos. | K | As | Ba | B | Cr | Hg | Fe | Se | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15 13 | 9 31 | 65 3 mg/L | 50 6 mg/L | 1110 mg/L | N/D | ND | 15 2 mg/L | ND | 0.408 mg/L | 0 602 mg/L | 0 028 mg/L | ND | ND | ND | Before Introduction of Nutrient Water |
| 27 78 | 9 09 | 75 mg/L | 144 mg/L | 1110 mg/L | 0 998 mg/L | ND | 89 mg/L | ND | 0 205 mg/L | 1 02 mg/L | 0.0219 mg/L | NS | ND | ND | After Introduction of Nutrient Water |
| 48.78 | 8 76 | 83 2 mg/L | 162 mg/L | 959 mg/L | 1 33 mg/L | ND | 108 mg/L | ND | 0 187 mg/L | 1 49 mg/L | 0 0124 mg/L | NS | ND | ND | After Introduction of Nutrient Water |
| 77.55 | 9 09 | 106 mg/L | 159 mg/L | 845 mg/L | 1 55 mg/L | ND | 127 Mg/L | ND | 0 196 mg/L | 1 73 mg/L | .00936 mg/L | NS | ND | ND | After Introduction of Nutrient Water |
| 101 34 | 9 16 | 76 1 mg/L | 173 mg/L | 789 mg/L | 1 18 mg/L | 0 775 mg/L | 130 mg/L | ND | 0 209 mg/L | 1 86 mg/L | 0 0137 mg/L | ND | ND | ND | After Introduction of Nutrient Water |

**Notes**

N/D = Non Detect at Laboratory Detection Limit

(See Appendix X for Laboratory

Detection Limits)

N/S = Not Sampled or Analyses not performed

[1] Pore Volumes (PV=V/$V_0$), V = Cumulative volume of sample leached; $V_0$ = Pore volume of the mixture

# Table D-3

## 30M Sample

## Leachate Chemical Analyses

## 30% Ash 70% Native Soils

| Pore Volumes Eluted[1] | pH | Total Alkalinity | Chloride | Sulfate | Nitrogen | Phos. | K | As | Ba | B | Cr | Hg | Fe | Se | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.47 | 8.56 | NS | NS | 2940 mg/L | ND | ND | ND | ND | ND | ND | 0.011 mg/L | ND | ND | ND | Before Introduction of Nutrient Water |
| 19.57 | 8.62 | 93.9 mg/L | 149 mg/L | 1590 mg/L | ND | ND | 93.7 mg/L | ND | 0.225 mg/L | 0.869 mg/L | 0.0133 mg/L | NS | 0.0762 mg/L | ND | After Introduction of Nutrient Water |
| 30.67 | 9.12 | 93.1 mg/L | 170 mg/L | 1330 mg/L | 1.93 mg/L | ND | 124 mg/L | ND | 0.196 mg/L | 1.55 mg/L | 0.0177 mg/L | NS | ND | ND | After Introduction of Nutrient Water |
| 42.56 | 8.96 | 82.6 mg/L | 198 mg/L | 1320 mg/L | 2.07 mg/L | ND | 143 mg/L | ND | 0.236 mg/L | 1.93 mg/L | 0.0148 mg/L | ND | ND | ND | After Introduction of Nutrient Water |

**Notes**

N/D = Non Detect at Laboratory Detection Limit

(See Appendix X for Laboratory

Detection Limits)

N/S = Not Sampled or Analyses not performed

[1] Pore Volumes ($PV=V/V_0$), V = Cumulative volume of sample leached; $V_0$ = Pore volume of the mixture

# Table D-4

## 40M Sample

## Leachate Chemical Analyses

## 40% Ash 60% Native Soils

| Pore Volumes Eluted[1] | pH | Total Alkalinity | Chloride | Sulfate | Nitrogen | Phos. | K | As | Ba | B | Cr | Hg | Fe | Se | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 56 | 8 59 | NS | NS | 3420 mg/L | ND | ND | 54 3 mg/L | ND | 0.307 mg/L | 2 42 mg/L | 1 47 mg/L | ND | 0.143 mg/L | ND | Before Introduction of Nutrient Water |
| 11 73 | 7 73 | 92 mg/L | 107 mg/L | 1630 mg/L | 35 7 mg/L | ND | 56 3 mg/L | ND | 0 225 mg/L | 0.491 mg/L | 0 033 mg/L | NS | 0 138 mg/L | ND | After Introduction of Nutrient Water |
| 17 18 | 9 14 | 89.4 mg/L | 241 mg/L | 2360 mg/L | 2 35 mg/L | ND | 136 mg/L | ND | 0.232 mg/L | 0 723 mg/L | 0 0202 mg/L | ND | ND | ND | After Introduction of Nutrient Water |

**Notes**

N/D = Non Detect at Laboratory Detection Limit

(See Appendix X for Laboratory

Detection Limits)

N/S = Not Sampled or Analyses not performed

[1] Pore Volumes ($PV=V/V_0$), V = Cumulative volume of sample leached, $V_0$ = Pore volume of the mixture.

# Table D-5

## 20W Sample

## Leachate Chemical Analyses

## 20% Ash 80% Native Soils

| Pore Volumes Eluted[1] | pH | Total Alkalinity | Chloride | Sulfate | K | As | Ba | B | Cr | Hg | Fe | Se | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4.19 | 9.09 | NS | NS | 3100 mg/L | 26.9 mg/L | ND | 0.32 mg/L | NS | 1.23 mg/L | ND | NS | 0.145 mg/L | Before Introduction of Nutrient Water |
| 14.69 | 8.92 | NS | NS | 1100 mg/L | 8.38 mg/L | ND | 0.311 mg/L | NS | 0.0259 mg/L | NS | NS | ND | After Introduction of Nutrient Water |
| 35.69 | 7.64 | 40.8 mg/L | 50.2 mg/L | 722 mg/L | 9.73 mg/L | ND | 0.203 mg/L | 0.284 mg/L | 0.018 mg/L | NS | ND | ND | After Introduction of Nutrient Water |
| 50.99 | 7.1 | 50.4 mg/L | 54.9 mg/L | 599 mg/L | 9.11 mg/L | ND | 0.192 mg/L | 0.346 mg/L | 0.0109 mg/L | NS | ND | ND | After Introduction of Nutrient Water |
| 75.84 | 8.26 | 44.8 mg/L | 42.5 mg/L | 465 mg/L | 11 mg/L | ND | 0.213 mg/L | 0.444 mg/L | 0.012 mg/L | NS | ND | ND | After Introduction of Nutrient Water |
| 128.13 | 8.83 | 51 mg/L | 40.4 mg/L | 481 mg/L | 11.3 mg/L | ND | 0.243 mg/L | 0.607 mg/L | 0.0084 mg/L | ND | 0.069 mg/L | ND | After Introduction of Nutrient Water |

**Notes**

N/D = Non Detect at Laboratory Detection Limit

(See Appendix X for Laboratory

Detection Limits)

N/S = Not Sampled or Analyses not performed

[1] Pore Volumes ($PV=V/V_0$), V = Cumulative volume of sample leached, $V_0$ = Pore volume of the mixture

# Table D-6

## 25W Sample

## Leachate Chemical Analyses

## 25% Ash 75% Native Soils

| **Pore Volumes Eluted[1]** | **pH** | **Total Alkalinity** | **Chloride** | **Sulfate** | **K** | **As** | **Ba** | **B** | **Cr** | **Hg** | **Fe** | **Se** | **Notes** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.89 | 8.66 | NS | NS | 2680 mg/L | 24 mg/L | ND | 0.331 mg/L | NS | 0.818 mg/L | ND | NS | 0.102 mg/L | Before Introduction of Nutrient Water |
| 12.58 | 9.34 | NS | NS | 1480 mg/L | 10.8 mg/L | ND | 0.375 mg/L | NS | 0.00889 mg/L | NS | NS | ND | After Introduction of Nutrient Water |
| 24.22 | 6.82 | 65.7 mg/L | 50.6 mg/L | 1140 mg/L | 12.9 mg/L | ND | 0.188 mg/L | 0.358 mg/L | 0.0146 mg/L | NS | 0.0805 mg/L | ND | After Introduction of Nutrient Water |
| 48.09 | 8.55 | 51.4 mg/L | 53.8 mg/L | 705 mg/L | 11.5 mg/L | ND | 0.25 mg/L | 0.543 mg/L | 0.0133 mg/L | NS | ND | ND | After Introduction of Nutrient Water |
| 76.99 | 8.48 | 23.6 mg/L | 41.8 mg/L | 626 mg/L | 12.8 mg/L | ND | 0.229 mg/L | 0.609 mg/L | ND | ND | ND | ND | After Introduction of Nutrient Water |

**Notes**

N/D = Non Detect at Laboratory Detection Limit

(See Appendix X for Laboratory

Detection Limits)

N/S = Not Sampled or Analyses not performed

[1] Pore Volumes (PV=V/$V_0$), V = Cumulative volume of sample leached; $V_0$ = Pore volume of the mixture

# Table D-7

## 30W Sample

## Leachate Chemical Analyses

## 30% Ash 70% Native Soils

| Pore Volumes Eluted[1] | pH | Total Alkalinity | Chloride | Sulfate | K | As | Ba | B | Cr | Hg | Fe | Se | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 9 | 8 68 | NS | NS | 4200 mg/L | 41 6 mg/L | ND | 0 388 mg/L | NS | 1.68 mg/L | ND | NS | 0 204 mg/L | Before Introduction of Nutrient Water |
| 8 16 | 8 51 | NS | NS | 1830 mg/L | 22 2 mg/L | ND | 0 291 mg/L | NS | 0 0435 mg/L | NS | NS | ND | After Introduction of Nutrient Water |
| 12 5 | 8.3 | 77.8 mg/L | 54 9 mg/L | 1800 mg/L | 25 6 mg/L | ND | 0 217 mg/L | 0.349 mg/L | 0 0263 mg/L | NS | 0 0594 mg/L | ND | After Introduction of Nutrient Water |
| 17 62 | 8 28 | 73 mg/L | 43 6 mg/L | 1730 mg/L | 25 7 mg/L | ND | 0.26 mg/L | 0 414 mg/L | 0 0175 mg/L | NS | ND | ND | After Introduction of Nutrient Water |
| 28 25 | 8 03 | 55 6 mg/L | 69 4 mg/L | 1810 mg/l | 20 60 mg/L | ND | 0 259 mg/l | 0 546 mg/L | 0.0134 mg/L | ND | ND | ND | After Introduction of Nutrient Water |

**Notes**

N/D = Non Detect at Laboratory Detection Limit

(See Appendix X for Laboratory

Detection Limits)

N/S = Not Sampled or Analyses not performed

[1] Pore Volumes ($PV=V/V_0$); V = Cumulative volume of sample leached, $V_0$ = Pore volume of the mixture

# Table D-8

## 40W Sample

## Leachate Chemical Analyses

## 40% Ash 60% Native Soils

| Pore Volumes Eluted[1] | pH | Total Alkalinity | Chloride | Sulfate | K | As | Ba | B | Cr | Hg | Fe | Se | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.06 | 8.63 | NS | NS | 4940 mg/L | 54 mg/L | ND | 0.31 mg/L | NS | 2.18 mg/L | ND | NS | 0.272 mg/L | Before Introduction of Nutrient Water |
| 7.08 | 8.57 | NS | NS | 1920 mg/L | 30.9 mg/L | ND | 0.347 mg/L | NS | 0.0656 mg/L | NS | NS | ND | After Introduction of Nutrient Water |
| 9.7 | 8.23 | 81.2 mg/L | 44.4 mg/L | 2010 mg/L | 33.3 mg/L | ND | 0.204 mg/L | 0.442 mg/L | 0.0317 mg/L | NS | ND | ND | After Introduction of Nutrient Water |
| 12.77 | 7.72 | 76.5 mg/L | 46.5 mg/L | 1940 mg/L | 40.2 mg/L | ND | 0.290 mg/L | 0.528 mg/L | 0.0328 mg/L | NS | ND | ND | After Introduction of Nutrient Water |
| 17.85 | 8.09 | 68.8 mg/L | 54.6 mg/L | 1860 mg/L | 35.2 mg/L | ND | 0.276 mg/L | 0.591 mg/L | 0.0147 mg/L | ND | ND | ND | After Introduction of Nutrient Water |

**Notes**

N/D = Non Detect at Laboratory Detection Limit

(See Appendix X for Laboratory

Detection Limits)

N/S = Not Sampled or Analyses not performed

[1] Pore Volumes (PV=V/$V_0$), V = Cumulative volume of sample leached; $V_0$ = Pore volume of the mixture

# Table D-9

## 5BW Sample

## Leachate Chemical Analyses

## 5% Bentonite, 30% Ash, and 65% Native Soils

| Pore Volumes Eluted[1] | pH | Total Alkalinity | Chloride | Sulfate | K | As | Ba | B | Cr | Hg | Fe | Se | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4.52 | 8.48 | NS | NS | 3640 mg/L | 25.9 mg/L | ND | 0.209 mg/L | NS | 0.717 mg/L | ND | NS | ND | Before Introduction of Nutrient Water |
| 8.4 | 8.12 | NS | NS | 1880 mg/L | 15.9 mg/L | ND | 0.301 mg/L | NS | 0.0512 mg/L | ND | NS | ND | After Introduction of Nutrient Water |
| 15.39 | 8.47 | 62.1 mg/L | 43 mg/L | 1640 mg/L | 21.5 mg/L | ND | 0.329 mg/L | 0.275 mg/L | 0.00919 mg/L | NS | ND | ND | After Introduction of Nutrient Water |
| 32.45 | 8.76 | 44.3 mg/L | 53.5 mg/L | 1260 mg/L | 12.3 mg/L | ND | 0.294 mg/L | 0.375 mg/L | 0.011 mg/L | NS | ND | ND | After Introduction of Nutrient Water |
| 50.61 | 8.99 | 36.7 mg/L | 58.4 mg/L | 1390 mg/L | 10.8 mg/L | ND | 0.280 mg/L | 0.526 mg/L | 0.00717 mg/L | NS | 0.047 mg/L | ND | After Introduction of Nutrient Water |
| 79.06 | 8.99 | 26.8 mg/L | 59.3 mg/L | 724 mg/L | 8.79 mg/L | ND | 0.295 mg/L | 0.566 mg/L | ND | ND | 0.0496 mg/L | ND | After Introduction of Nutrient Water |

**Notes**

N/D = Non Detect at Laboratory Detection Limit

(See Appendix X for Laboratory

Detection Limits)

N/S = Not Sampled or Analyses not performed

[1] Pore Volumes (PV=V/$V_0$), V = Cumulative volume of sample leached, $V_0$ = Pore volume of the mixture

# ATTACHMENT E

## Tables 1-3: Laboratory Analytical Results on Soils

# Table E-1
## 20M, 25M Samples
## Soil Chemical Analyses
## (Sample Values)

| Soil type | pH | Bray 1 P, ppm | Ca, ppm | K, ppm | Mg, ppm | Na, ppm | $NH_4$-N, ppm | $NO_3N$, ppm | O.M. ppm | $SO_4$-S, ppm | Cu, ppm | Fe, ppm | Mn, ppm | Zn, ppm | Cl, ppm | Al, ppm | Total N ppm | Total P, ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20% Fly ash | 9 1 | 1 | 13655 | 51 | 235 | 2131 | 1.6 | 45 95 | 0.7 | 1170 | 47 5 | 1193 | 57 5 | 17 5 | 275 | 18.75 | 257 | 872 |
| 25% Fly ash | 9 1 | 1 | 17004 | 65 5 | 264 | 2920 | 2 45 | 56 | 0 75 | 1221 | 68 | 1157 | 57.5 | 23 5 | 350 | 16 6 | 300 | 1042 |

## Table E-1 Contd.
## Soil Saturated Paste/Salt Alkali Analyses

| Soil type | pH | Soluble Na Meq/100g | Extract. Na Meq/100g | Exch. Na Meq/100g | Est. CEC Meq/ 100g | Exch. Na % | Alkali* Ranking | Elec. Cond. MS/cm | Salinity** Ranking |
|---|---|---|---|---|---|---|---|---|---|
| 20% Fly ash | 10 05 | 2 16 | 9 27 | 7 11 | 7 | 101 6 | L | 10 45 | E |
| 25% Fly ash | 10 05 | 2 67 | 12 7 | 10 03 | 7 | 143.3 | L-E | 12 14 | E |

*Based upon Exch Na%, L = Low, E = Excessive

**Based upon Conductivity, L = Low, M = Moderate, H = High, E = Excessive, VE = Very Excessive

# Table E-2
## Native Flora Soils
## From Existing Landfill Unit

| Soil type | PH | Bray 1 P, ppm | Ca, ppm | K, ppm | Mg, ppm | Na, ppm | $NH_4$-N, ppm | $NO_3N$, ppm | O.M. ppm | $SO_4$-S, ppm | Cu, ppm | Fe, ppm | Mn, ppm | Zn, ppm | Cl, ppm | Al, ppm | Total N, ppm | Total P, ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Flora-2-soil | 8.45 | 0 | 21652 | 180 | 151 | 987.5 | 3.25 | 4.55 | 0.8 | 886 | 1.25 | 12.5 | 0.95 | 0.4 | 16 | 6.2 | 113 | 331.5 |
| Flora-3-soil | 8.5 | 13 | 2484 | 45 | 53 | 11 | 0.2 | 1.1 | 0.7 | 36.4 | 0.5 | 5.9 | 1.1 | 0.1 | 2 | 3.6 | 135 | 840 |
| Flora-6-soil | 8.7 | 21 | 3057 | 52 | 82 | 0 | 0.3 | 1.4 | 0.7 | 2 | 0.4 | 4.2 | 1.3 | 0.1 | 1 | 3.5 | 75 | 825 |
| Flora-7-soil | 8.4 | 1.5 | 4357 | 56.5 | 92 | 49 | 0.0 | 1 | 0.8 | 163.6 | 0.5 | 5.4 | 1 | 0.1 | 1 | 2.5 | 720.5 | 3026.5 |

## Table E-2 Contd.
## Soil Saturated Paste/Salt Alkali Analyses

| Soil type | pH | Soluble Na Meq/100g | Extract. Na Meq/100g | Exch. Na Meq/100 g | Est. CECMe q/100g | Exch. Na % | Alkali* Ranking | Elec. Cond. MS/cm | Salinity** Ranking |
|---|---|---|---|---|---|---|---|---|---|
| Flora-2-soil | 8 | 0.71 | 4.3 | 3.38 | 15 | 22.5 | E | 3.9 | M-H |
| Flora-3-soil | 7.4 | 0.02 | 0.05 | 0.03 | 9 | 0.3 | L | 2.02 | M |
| Flora-6-soil | 7.8 | 0.01 | 0.0 | 0.0 | 8 | 0.0 | L | 0.31 | L |
| Flora-7-soil | 7.75 | 0.03 | 0.22 | 0.19 | 7 | 2.6 | L | 1.72 | L-M |

*Based upon Exch Na%, L = Low, E = Excessive

**Based upon Conductivity, L = Low, M = Moderate, H = High, E = Excessive, VE = Very Excessive

## Table E-3
## Soil Chemical Analyses on 20M sample after leaching 310 pore volumes

| Soil section | PH | Olsen P, ppm | Ca, ppm | K, ppm | Mg, ppm | Na, ppm | $NH_4$-N, ppm | $NO_3N$, ppm | O.M. ppm | $SO_4$-S, ppm | Cu, ppm | Fe, ppm | Mn, ppm | Zn, ppm | Cl, ppm | Al, ppm | Total N, ppm | Total P, ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Top half | 7.7 | 900 | 639 | 393 | 273 | 53 | 134.2 | 5.4 | 0.5 | 148.3 | 2.5 | 14 | 3 | 2 | 31 | 4.2 | 285 | 6840 |
| Bottom half | 7.9 | 290 | 1184 | 224 | 132 | 55 | 23.4 | 7.9 | 0.7 | 560.7 | 2.8 | 15 | 2 | 1.1 | 21 | 68.5 | 203 | 2138 |

## Table E-3 Contd.
## Soil Saturated Paste/Salt Alkali Analyses

| Soil section | pH | Soluble Na Meq/100g | Extract. Na Meq/100g | Exch. Na Meq/100 g | Est. CEC Meq/100 g | Exch. Na % | Alkali* Ranking | Elec. Cond. MS/cm | Salinity** Ranking |
|---|---|---|---|---|---|---|---|---|---|
| Top half | 8 | 0.06 | 18.4 | 0.23 | 9 | 2.6 | L | 4.16 | H |
| Bottom half | 8.9 | 0.04 | 19.2 | 0.24 | 8 | 3 | L | 4.62 | H |

*Based upon Exch. Na%, L = Low, E = Excessive

**Based upon Conductivity, L = Low, M = Moderate, H = High, E = Excessive, VE = Very Excessive

# ATTACHMENT F

# Tables 1-2: HELP Model Input and Results

# Table F-1
# HELP Model Input Data

| Parameter | Unit | Default | Sensitivity | Notes |
|---|---|---|---|---|
| **Climate-General** | | | | |
| Simulation Period | years | varies | | to total thickness=60 ft + 20 years with cap |
| City | | Dodge City | | site is in Holcomb, nearest weather station is Garden City Exp Stn, 8 miles northeast |
| Latitude | degrees | 37.88 | | site specific latitude |
| Evap. zone depth | inches | 9, 20 | | bare ash, change to 20 for fair grass when cap added |
| Leaf Index | | 0, 2 | | bare ash, change to 2 for fair grass when cap added |
| Growing season | Julian d | 102-298 | | default for Dodge City |
| Average wind speed | mph | 13.9 | | default for Dodge City |
| Relative humidity (quarterly) | % | 57 to 64 | | default for Dodge City |
| Climate-precip/temp/ET | | | | |
| Precipitation (monthly) | inches | | | synthetically generated used Garden City Exp Stn 1948-2000 monthly means |
| Temperature (monthly) | F | | | |
| Solar radiation (monthly) | Lang | model calculated | | model-calculated based on latitude, precipitation, and defaults for nearest city |
| **Soils-General** | | | | |
| Area | acres | 1 | | not critical to calculations |
| % where runoff possible | % | 0, 100 | 100 (active) | assume no runoff during active operation, 100 percent after cap |
| Surface water/snow | inches | 0 | | assume no water on surface as of January 1 in first model year |
| **Soils-Layer Types** | | | | |
| 1 | | 1 | | assume vertical percolation layer for all ash and final cover |
| **Ash Parameters (active)** | | | | |
| Thickness | inches | 60 | | |
| Texture | | Ash | | |
| Porosity | % | 0.541 | | total volumetric porosity |
| Field capacity | % | 0.187 | | soil moisture content after prolonged gravity drainage. tension = 1/3 bar |
| Wilting point | % | 0.047 | | soil moisture when plants wilted. tension = 15 bars |
| Hydraulic conductivity | cm/s | 5.0E-05 | 1E-4, 1E-5 | |
| Moisture Content (initial) | % | 0.15 | 0.12, 0.18 | volumetric moisture content of dry ash when first placed in landfill |
| **Ash Parameters (capped)** | | | | |
| Hydraulic conductivity | cm/s | 1.0E-07 | 1E-6, 1E-8 | change for all ash layers when cap layer is added |
| **Soil Parameters for Cap** | | | | |
| Thickness | inches | 18 | | add cap when ash thickness = 60 feet |
| Texture | | 7 | 5 | local soils consist of fine sand |
| Porosity | % | Soil Default | | total volumetric porosity |
| Field capacity | % | Soil Default | | soil moisture content after prolonged gravity drainage. tension = 1/3 bar |
| Wilting point | % | Soil Default | | soil moisture when plants wilted. tension = 15 bars |
| Hydraulic conductivity | cm/s | Soil Default | | |
| **Soils--Runoff** | | | | |
| Slope | % | 0.51, 2 | | 0.51 while active, 2 after cap |
| Length | ft | 1200 | | distance from crest of landfill to stormwater collection point or line after cap is completed |

# Table F-2a
## HELP Model Results – Control Scenario 1, Fine Sandy Loam Soil

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Climate File | Ksdefaut | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Soil & Output File | KS_def7 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Runoff % | 100 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Runoff Slope | 0.51 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Soil Layer Thickness (in) | 60 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Soil Layer Type | 7 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Vegetation | 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Initial Moisture Content | default | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cap | no | no | no | no | no | no | no | no | no | no | no | no | no | <==soil texture 7 | | | | | | | | | | | | | | | | | | |
| Layer 1 | default | default | default | default | default | default | default | default | default | default | default | default | default | | | | | | | | | | | | | | | | | | | |
| Layer 2 | default | default | default | default | default | default | default | default | default | default | default | default | default | | | | | | | | | | | | | | | | | | | |
| Layer 3 | default | default | default | default | default | default | default | default | default | default | default | default | default | | | | | | | | | | | | | | | | | | | |
| Layer 4 | default | default | default | default | default | default | default | default | default | default | default | default | default | | | | | | | | | | | | | | | | | | | |
| Layer 5 | default | default | default | default | default | default | default | default | default | default | default | default | default | | | | | | | | | | | | | | | | | | | |
| Layer 6 | default | default | default | default | default | default | default | default | default | default | default | default | default | | | | | | | | | | | | | | | | | | | |
| Layer 7 | default | default | default | default | default | default | default | default | default | default | default | default | default | | | | | | | | | | | | | | | | | | | |
| Layer 8 | default | default | default | default | default | default | default | default | default | default | default | default | default | | | | | | | | | | | | | | | | | | | |
| Layer 9 | default | default | default | default | default | default | default | default | default | default | default | default | default | | | | | | | | | | | | | | | | | | | |
| Layer 10 | default | default | default | default | default | default | default | default | default | default | default | default | default | | | | | | | | | | | | | | | | | | | |
| Layer 11 | default | default | default | default | default | default | default | default | default | default | default | default | default | | | | | | | | | | | | | | | | | | | |
| Layer 12 | default | default | default | default | default | default | default | default | default | default | default | default | default | | | | | | | | | | | | | | | | | | | |
| Layer 13 | default | default | default | default | default | default | default | default | default | default | default | default | default | | | | | | | | | | | | | | | | | | | |
| Precipitation (in) | 16.31 | 25.44 | 16.72 | 18.17 | 17.76 | 21.24 | 16.07 | 16.94 | 22.70 | 19.73 | 20.11 | 20.93 | 21.84 | 17.89 | 25.2 | 18.53 | 17.40 | 15.61 | 20.02 | 21.21 | 23.76 | 19.97 | 17.38 | 22.93 | 17.40 | 16.21 | 16.58 | 20.60 | 18.08 | 19.97 | 18.32 | 17.38 |
| Runoff (in) | 0.000 | 0.004 | 0.000 | 0.082 | 0.029 | 0.126 | 0.000 | 0.003 | 0.031 | 0.004 | 0.000 | 0.044 | 0.000 | 0.081 | 0.000 | 0.000 | 0.000 | 0.000 | 0.011 | 0.129 | 0.036 | 0.051 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.137 | 0.000 | 0.063 | 0.004 | 0.000 |
| ET (in) | 16.308 | 24.746 | 16.742 | 17.368 | 17.224 | 20.518 | 17.116 | 16.86 | 21.948 | 18.007 | 21.58 | 18.711 | 21.698 | 17.925 | 24.626 | 18.473 | 15.468 | 17.572 | 18.042 | 20.477 | 23.044 | 18.224 | 19.317 | 21.808 | 16.689 | 17.545 | 15.969 | 19.507 | 17.867 | 17.028 | 20.502 | 17.071 |
| Percolation (in) | 0.0E+00 | 4.6E-03 | 3.2E-01 | 3.2E-01 | 3.3E-01 | 2.8E-01 | 7.3E-02 | 0.0E+00 | 1.2E-01 | 4.1E-01 | 3.0E-01 | 5.7E-02 | 2.4E-01 | 3.5E-01 | 2.4E-01 | 3.5E-01 | 6.6E-01 | 1.2E+00 | 5.4E-02 | 2.4E-01 | 3.9E-01 | 3.9E-01 | 4.4E-01 | 6.6E-01 | 8.5E-01 | 0.0E+00 | 0.0E+00 | 4.8E-02 | 2.0E-01 | 4.0E-01 | 3.6E-01 | 3.7E-01 |

All other input parameters as listed on Table 1

# Table F-2b
## HELP Model Results – Control Scenario 2, Loamy Fine Sand Soil

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Climate File | Ksdefaut | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Soil & Output File | KS_def5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Runoff % | 100 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Runoff Slope | 0 51 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Soil Layer Thickness (in) | 60 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Soil Layer Type | 5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Vegetation | 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Initial Moisture Content | default | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cap | no | no | no | no | no | no | no | no | no | no | no | no | no | <==soil texture 5 | | | | | | | | | | | | | | | | | | |
| Layer 1 | default | default | default | default | default | default | default | default | default | default | default | default | default | | | | | | | | | | | | | | | | | | | |
| Layer 2 | default | default | default | default | default | default | default | default | default | default | default | default | default | | | | | | | | | | | | | | | | | | | |
| Layer 3 | default | default | default | default | default | default | default | default | default | default | default | default | default | | | | | | | | | | | | | | | | | | | |
| Layer 4 | default | default | default | default | default | default | default | default | default | default | default | default | default | | | | | | | | | | | | | | | | | | | |
| Layer 5 | default | default | default | default | default | default | default | default | default | default | default | default | default | | | | | | | | | | | | | | | | | | | |
| Layer 6 | default | default | default | default | default | default | default | default | default | default | default | default | default | | | | | | | | | | | | | | | | | | | |
| Layer 7 | default | default | default | default | default | default | default | default | default | default | default | default | default | | | | | | | | | | | | | | | | | | | |
| Layer 8 | default | default | default | default | default | default | default | default | default | default | default | default | default | | | | | | | | | | | | | | | | | | | |
| Layer 9 | default | default | default | default | default | default | default | default | default | default | default | default | default | | | | | | | | | | | | | | | | | | | |
| Layer 10 | default | default | default | default | default | default | default | default | default | default | default | default | default | | | | | | | | | | | | | | | | | | | |
| Layer 11 | default | default | default | default | default | default | default | default | default | default | default | default | default | | | | | | | | | | | | | | | | | | | |
| Layer 12 | default | default | default | default | default | default | default | default | default | default | default | default | default | | | | | | | | | | | | | | | | | | | |
| Layer 13 | default | default | default | default | default | default | default | default | default | default | default | default | default | | | | | | | | | | | | | | | | | | | |
| Precipitation (in) | 16 31 | 25 44 | 16 72 | 18 17 | 17 76 | 21 24 | 16 07 | 16 94 | 22 70 | 19 73 | 20 11 | 20 93 | 21 84 | 17 89 | 25 20 | 18 53 | 17 40 | 15 61 | 20 02 | 21 21 | 23 76 | 19 97 | 17 38 | 22 93 | 17 40 | 16 21 | 16 58 | 20 60 | 18 08 | 19 97 | 18 32 | 17 38 |
| Runoff (in) | 0 000 | 0 004 | 0 000 | 0 000 | 0 034 | 0 132 | 0 000 | 0 000 | 0 028 | 0 000 | 0 000 | 0 022 | 0 000 | 0 081 | 0 000 | 0 000 | 0 000 | 0 000 | 0 000 | 0 129 | 0 038 | 0 052 | 0 002 | 0 000 | 0 000 | 0 000 | 0 000 | 0 118 | 0 000 | 0 065 | 0 003 | 0 000 |
| ET (in) | 16 074 | 23 698 | 16 46 | 16 162 | 17 058 | 20 351 | 16 803 | 16 609 | 21 463 | 17 404 | 21 041 | 18 406 | 21 508 | 17 721 | 23 991 | 18 346 | 14 810 | 17 513 | 16 761 | 20 609 | 22 809 | 18 084 | 18 836 | 21 417 | 16.288 | 17 816 | 15 586 | 19 739 | 17 498 | 17 446 | 19 842 | 16 648 |
| Percolation (in) | 1 1E-02 | 1 1E-01 | 1 0E+00 | 1 5E+00 | 7 0E-01 | 3 8E-01 | 2 7E-01 | 3 5E-01 | 3 9E-01 | 8 9E-01 | 9 1E-01 | 2 0E+00 | 1 1E+00 | 4 3E-01 | 2 8E-01 | 5 9E-01 | 6.2E-01 | 3 5E-01 | 2 9E+00 | 7 0E-01 | 3 8E-01 | 2 9E-01 | 5 4E-01 | 5 7E-01 | 3 6E-01 | 3 7E-01 | 2 8E-01 | 1 1E+00 | 6 7E-01 | 4 1E-01 | 4 2E-01 | 6 1E-01 |

All other input parameters as listed on Table 1

# Table F-2c

## HELP Model Results – Scenario A1, 5-Foot Annual Lifts (default)

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Climate File | KS1 | KS2 | KS3 | KS4 | KS5 | KS6 | KS7 | KS8 | KS9 | KS10 | KS11 | KS12 | KSCAP | | | | | | | | | | | | | | | | | | | |
| Soil & Output File | KS1A1 | KS2A1 | KS3A1 | KS4A1 | KS5A1 | KS6A1 | KS7A1 | KS8A1 | KS9A1 | KS10A1 | KS11A1 | KS12A1 | KSCAPA1 | | | | | | | | | | | | | | | | | | | |
| Runoff % | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | | | | | | | | | | | | | | | | | | | |
| Runoff Slope | 0 51 | 0 51 | 0 51 | 0 51 | 0 51 | 0 51 | 0 51 | 0 51 | 0 51 | 0 51 | 0 51 | 0 51 | 2 | | | | | | | | | | | | | | | | | | | |
| Ash Layer Thickness (in) | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | -- | | | | | | | | | | | | | | | | | | | |
| Ash Layer K | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 1E-07 | | | | | | | | | | | | | | | | | | | |
| Vegetation | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | | | | | | | | | | | | | | | | | | | |
| Initial Moisture Content | 0 15 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cap | no | no | no | no | no | no | no | no | no | no | no | no | yes | <==soil texture 7 | | | | | | | | | | | | | | | | | | |
| Layer 1 | 0 15 | 0 15 | 0 15 | 0 15 | 0 15 | 0 15 | 0 15 | 0 15 | 0 15 | 0 15 | 0 15 | 0 15 | 0 222 | <==set equal to cap soil field capacity | | | | | | | | | | | | | | | | | | |
| Layer 2 | x | 0 1520 | 0 1931 | 0 1714 | 0 1768 | 0 1564 | 0 1701 | 0 1511 | 0 1616 | 0.2162 | 0 1666 | 0 1550 | 0 1858 | <== | | | | | | | | | | | | | | | | | | |
| Layer 3 | x | x | 0 1520 | 0 1866 | 0 1740 | 0 1755 | 0 1560 | 0 1680 | 0 1511 | 0 1605 | 0.2014 | 0 1666 | 0 1550 | | | | | | | | | | | | | | | | | | | |
| Layer 4 | x | x | x | 0.1584 | 0.1828 | 0 1755 | 0 1760 | 0 1580 | 0.1661 | 0 1525 | 0 1738 | 0 1932 | 0 1666 | | | | | | | | | | | | | | | | | | | |
| Layer 5 | x | x | x | x | 0 1620 | 0 1795 | 0 1760 | 0 1754 | 0 1599 | 0 1644 | 0 1540 | 0 1795 | 0 1870 | | | | | | | | | | | | | | | | | | | |
| Layer 6 | x | x | x | x | x | 0 1653 | 0 1769 | 0 1754 | 0 1746 | 0 1616 | 0 1630 | 0 1565 | 0 1825 | | | | | | | | | | | | | | | | | | | |
| Layer 7 | x | x | x | x | x | x | 0 1678 | 0 1754 | 0 1746 | 0 1738 | 0 1630 | 0 1630 | 0 1597 | | | | | | | | | | | | | | | | | | | |
| Layer 8 | x | x | x | x | x | x | x | 0 1697 | 0 1746 | 0 1738 | 0 1730 | 0 1630 | 0 1630 | | | | | | | | | | | | | | | | | | | |
| Layer 9 | x | x | x | x | x | x | x | x | 0 1711 | 0 1738 | 0 1730 | 0 1726 | 0 1630 | | | | | | | | | | | | | | | | | | | |
| Layer 10 | x | x | x | x | x | x | x | x | x | 0 1717 | 0 1730 | 0 1726 | 0 1726 | | | | | | | | | | | | | | | | | | | |
| Layer 11 | x | x | x | x | x | x | x | x | x | x | 0 1723 | 0 1726 | 0 1726 | | | | | | | | | | | | | | | | | | | |
| Layer 12 | x | x | x | x | x | x | x | x | x | x | x | 0 1726 | 0 1726 | | | | | | | | | | | | | | | | | | | |
| Layer 13 | x | x | x | x | x | x | x | x | x | x | x | x | 0 1726 | | | | | | | | | | | | | | | | | | | |
| Precipitation (in) | 16 31 | 25 44 | 16 72 | 18 17 | 17 76 | 21 24 | 16 07 | 16 94 | 22 7 | 19 73 | 20 11 | 20 93 | 21 84 | 17 89 | 25 2 | 18 53 | 17 4 | 15 61 | 20 02 | 21 21 | 23 76 | 19 97 | 17 38 | 22 93 | 17 4 | 16 21 | 16 58 | 20 6 | 18 08 | 19 97 | 18 32 | 17 38 |
| Runoff (in) | 0 000 | 0 000 | 0 000 | 0 000 | 0 000 | 0 000 | 0 000 | 0 000 | 0 000 | 0 000 | 0 000 | 0 000 | 0 000 | 0 084 | 0 000 | 0 000 | 0 000 | 0 000 | 0 026 | 0 129 | 0 037 | 0 052 | 0 002 | 0 000 | 0 000 | 0 000 | 0 000 | 0 148 | 0 000 | 0 063 | 0 005 | 0 000 |
| ET (in) | 16 196 | 22 854 | 15 436 | 16 562 | 17 378 | 20 035 | 16 002 | 16.244 | 18 707 | 18 733 | 19 808 | 18 781 | 24 055 | 17 779 | 25 187 | 18.269 | 16 060 | 17 008 | 19 747 | 20 718 | 23 152 | 18 151 | 19 574 | 21 787 | 16 690 | 17 522 | 16 017 | 21.259 | 18 036 | 17 010 | 20 839 | 16 988 |
| Percolation (in) | 3 6E-04 | 0 0E+00 | 2 8E-03 | 1.2E-02 | 1 7E-02 | 2 0E-02 | 5 8E-02 | 8 4E-02 | 9 3E-02 | 1 0E-01 | 4 4E-02 | 3 0E-04 | 0 0E+00 | 0 0E+00 | 0 0E+00 | 0 0E+00 | 0 0E+00 | 0 0E+00 | 0 0E+00 | 0 0E+00 | 0 0E+00 | 0 0E+00 | 0 0E+00 | 0 0E+00 | 0 0E+00 | 0 0E+00 | 0 0E+00 | 0 0E+00 | 0 0E+00 | 0 0E+00 | 0 0E+00 | 0 0E+00 |

initial soil moisture content is the final soil moisture content of the layer above during the preceding year simulation. (e.g., the final moisture content for Layer 1 at the end of year 1 is the initial moisture content for Layer 2 at the beginning of year 2)

All other input parameters as listed on Table 1

# Table F-2d

# HELP Model Results – Scenario A2, 5-Foot Annual Lifts (assumes ash does not set up)

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Climate File | KS1 | KS2 | KS3 | KS4 | KS5 | KS6 | KS7 | KS8 | KS9 | KS10 | KS11 | KS12 | KSCAP | | | | | | | | | | | | | | | | | | | |
| Soil & Output File | KS1A1 | KS2A1 | KS3A1 | KS4A1 | KS5A1 | KS6A1 | KS7A1 | KS8A1 | KS9A1 | KS10A1 | KS11A1 | KS12A1 | KSCAPA2 | | | | | | | | | | | | | | | | | | | |
| Runoff % | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | | | | | | | | | | | | | | | | | | | |
| Runoff Slope | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 2 | | | | | | | | | | | | | | | | | | | |
| Ash Layer Thickness (in) | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | – | | | | | | | | | | | | | | | | | | | |
| Ash Layer K | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | | | | | | | | | | | | | | | | | | | |
| Vegetation | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | | | | | | | | | | | | | | | | | | | |
| Initial Moisture Content | 0.15 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cap | no | no | no | no | no | no | no | no | no | no | no | no | yes | <==soil texture 7 | | | | | | | | | | | | | | | | | | |
| Layer 1 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.222 | <==set equal to cap soil field capacity | | | | | | | | | | | | | | | | | | |
| Layer 2 | x | 0.1520 | 0.1931 | 0.1714 | 0.1768 | 0.1564 | 0.1701 | 0.1511 | 0.1616 | 0.2162 | 0.1666 | 0.1550 | 0.1858 | <== | | | | | | | | | | | | | | | | | | |
| Layer 3 | x | x | 0.1520 | 0.1866 | 0.1740 | 0.1755 | 0.1560 | 0.1680 | 0.1511 | 0.1605 | 0.2014 | 0.1666 | 0.1550 | | | | | | | | | | | | | | | | | | | |
| Layer 4 | x | x | x | 0.1584 | 0.1828 | 0.1755 | 0.1760 | 0.1580 | 0.1661 | 0.1525 | 0.1738 | 0.1932 | 0.1666 | | | | | | | | | | | | | | | | | | | |
| Layer 5 | x | x | x | x | 0.1620 | 0.1795 | 0.1760 | 0.1754 | 0.1599 | 0.1644 | 0.1540 | 0.1795 | 0.1870 | | | | | | | | | | | | | | | | | | | |
| Layer 6 | x | x | x | x | x | 0.1653 | 0.1769 | 0.1754 | 0.1746 | 0.1616 | 0.1630 | 0.1565 | 0.1825 | | | | | | | | | | | | | | | | | | | |
| Layer 7 | x | x | x | x | x | x | 0.1678 | 0.1754 | 0.1746 | 0.1738 | 0.1630 | 0.1630 | 0.1597 | | | | | | | | | | | | | | | | | | | |
| Layer 8 | x | x | x | x | x | x | x | 0.1697 | 0.1746 | 0.1738 | 0.1730 | 0.1630 | 0.1630 | | | | | | | | | | | | | | | | | | | |
| Layer 9 | x | x | x | x | x | x | x | x | 0.1711 | 0.1738 | 0.1730 | 0.1726 | 0.1630 | | | | | | | | | | | | | | | | | | | |
| Layer 10 | x | x | x | x | x | x | x | x | x | 0.1717 | 0.1730 | 0.1726 | 0.1726 | | | | | | | | | | | | | | | | | | | |
| Layer 11 | x | x | x | x | x | x | x | x | x | x | 0.1723 | 0.1726 | 0.1726 | | | | | | | | | | | | | | | | | | | |
| Layer 12 | x | x | x | x | x | x | x | x | x | x | x | 0.1726 | 0.1726 | | | | | | | | | | | | | | | | | | | |
| Layer 13 | x | x | x | x | x | x | x | x | x | x | x | x | 0.1726 | | | | | | | | | | | | | | | | | | | |
| Precipitation (in) | 16.31 | 25.44 | 16.72 | 18.17 | 17.76 | 21.24 | 16.07 | 16.94 | 22.7 | 19.73 | 20.11 | 20.93 | 21.84 | 17.89 | 25.2 | 18.53 | 17.4 | 15.61 | 20.02 | 21.21 | 23.76 | 19.97 | 17.38 | 22.93 | 17.4 | 16.21 | 16.58 | 20.6 | 18.08 | 19.97 | 18.32 | 17.38 |
| Runoff (in) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.084 | 0.000 | 0.000 | 0.000 | 0.000 | 0.022 | 0.129 | 0.037 | 0.052 | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | 0.148 | 0.000 | 0.063 | 0.004 | 0.000 |
| ET (in) | 16.196 | 22.854 | 15.436 | 16.562 | 17.378 | 20.035 | 16.002 | 16.244 | 18.707 | 18.733 | 19.808 | 18.781 | 23.565 | 17.778 | 25.16 | 18.086 | 15.979 | 17.089 | 17.916 | 20.265 | 23.137 | 18.151 | 19.414 | 21.783 | 16.664 | 17.532 | 16.007 | 19.497 | 17.915 | 16.998 | 20.586 | 17.034 |
| Percolation (in) | 3.6E-04 | 0.0E+00 | 2.8E-03 | 1.2E-02 | 1.7E-02 | 2.0E-02 | 5.8E-02 | 8.4E-02 | 9.3E-02 | 1.0E-01 | 4.4E-02 | 3.0E-04 | 3.0E-04 | 0.0E+00 | 0.0E+00 | 0.0E+00 | 0.0E+00 | 0.0E+00 | 0.0E+00 | 0.0E+00 | 0.0E+00 | 0.0E+00 | 0.0E+00 | 0.0E+00 | 0.0E+00 | 0.0E+00 | 0.0E+00 | 0.0E+00 | 4.6E-02 | 3.7E-02 | 5.7E-02 | 6.4E-02 |

initial soil moisture content is the final soil moisture content of the layer above during the preceding year simulation (e.g., the final moisture content for Layer 1 at the end of year 1 is the initial moisture content for Layer 2 at the beginning of year 2)

**All other input parameters as listed on Table 1**

# Table F-2e
## HELP Model Results – Scenario A3, 5-Foot Annual Lifts (increased K during active landfill period)

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Climate File | KS1 | KS2 | KS3 | KS4 | KS5 | KS6 | KS7 | KS8 | KS9 | KS10 | KS11 | KS12 | KSCAP | | | | | | | | | | | | | | | | | | | |
| Soil & Output File | KS1A3 | KS2A3 | KS3A3 | KS4A3 | KS5A3 | KS6A3 | KS7A3 | KS8A3 | KS9A3 | KS10A3 | KS11A3 | KS12A3 | KSCAPA3 | | | | | | | | | | | | | | | | | | | |
| Runoff % | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | | | | | | | | | | | | | | | | | | | |
| Runoff Slope | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 2 | | | | | | | | | | | | | | | | | | | |
| Ash Layer Thickness (in) | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | – | | | | | | | | | | | | | | | | | | | |
| Ash Layer K | 1E-04 | 1E-04 | 1E-04 | 1E-04 | 1E-04 | 1E-04 | 1E-04 | 1E-04 | 1E-04 | 1E-04 | 1E-04 | 1E-04 | 1E-07 | | | | | | | | | | | | | | | | | | | |
| Vegetation | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | | | | | | | | | | | | | | | | | | | |
| Initial Moisture Content | 0.15 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cap | no | no | no | no | no | no | no | no | no | no | no | no | yes | <==soil texture 7 | | | | | | | | | | | | | | | | | | |
| Layer 1 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.222 | <==set equal to cap soil field capacity | | | | | | | | | | | | | | | | | | |
| Layer 2 | x | 0.1596 | 0.1757 | 0.1680 | 0.1667 | 0.1574 | 0.1696 | 0.1537 | 0.1603 | 0.1766 | 0.1699 | 0.1667 | 0.1718 | <== | | | | | | | | | | | | | | | | | | |
| Layer 3 | x | x | 0.1753 | 0.1808 | 0.1797 | 0.1758 | 0.1665 | 0.1705 | 0.1633 | 0.2100 | 0.1806 | 0.1780 | 0.2003 | | | | | | | | | | | | | | | | | | | |
| Layer 4 | x | x | x | 0.1789 | 0.1797 | 0.1797 | 0.1758 | 0.1705 | 0.1705 | 0.1723 | 0.1806 | 0.1798 | 0.1780 | | | | | | | | | | | | | | | | | | | |
| Layer 5 | x | x | x | x | 0.1798 | 0.1797 | 0.1797 | 0.1758 | 0.1705 | 0.1705 | 0.1806 | 0.1798 | 0.1798 | | | | | | | | | | | | | | | | | | | |
| Layer 6 | x | x | x | x | x | 0.1798 | 0.1797 | 0.1797 | 0.1758 | 0.1705 | 0.1806 | 0.1798 | 0.1798 | | | | | | | | | | | | | | | | | | | |
| Layer 7 | x | x | x | x | x | x | 0.1798 | 0.1797 | 0.1797 | 0.1758 | 0.1791 | 0.1799 | 0.1798 | | | | | | | | | | | | | | | | | | | |
| Layer 8 | x | x | x | x | x | x | x | 0.1798 | 0.1797 | 0.1797 | 0.1787 | 0.1799 | 0.1799 | | | | | | | | | | | | | | | | | | | |
| Layer 9 | x | x | x | x | x | x | x | x | 0.1798 | 0.1797 | 0.1797 | 0.1799 | 0.1799 | | | | | | | | | | | | | | | | | | | |
| Layer 10 | x | x | x | x | x | x | x | x | x | 0.1798 | 0.1797 | 0.1799 | 0.1799 | | | | | | | | | | | | | | | | | | | |
| Layer 11 | x | x | x | x | x | x | x | x | x | x | 0.1798 | 0.1799 | 0.1799 | | | | | | | | | | | | | | | | | | | |
| Layer 12 | x | x | x | x | x | x | x | x | x | x | x | 0.1799 | 0.1799 | | | | | | | | | | | | | | | | | | | |
| Layer 13 | x | x | x | x | x | x | x | x | x | x | x | x | 0.1799 | | | | | | | | | | | | | | | | | | | |
| Precipitation (in) | 16.31 | 25.44 | 16.72 | 18.17 | 17.76 | 21.24 | 16.07 | 16.94 | 22.7 | 19.73 | 20.11 | 20.93 | 21.84 | 17.89 | 25.2 | 18.53 | 17.4 | 15.61 | 20.02 | 21.21 | 23.76 | 19.97 | 17.38 | 22.93 | 17.4 | 16.21 | 16.58 | 20.6 | 18.08 | 19.97 | 18.32 | 17.38 |
| Runoff (in) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.084 | 0.000 | 0.000 | 0.000 | 0.000 | 0.026 | 0.129 | 0.037 | 0.052 | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | 0.148 | 0.000 | 0.063 | 0.005 | 0.000 |
| ET (in) | 15.708 | 22.874 | 14.882 | 16.393 | 16.789 | 19.516 | 15.553 | 15.747 | 17.586 | 18.268 | 18.621 | 17.608 | 24.038 | 17.779 | 25.19 | 18.264 | 16.061 | 17.007 | 19.746 | 20.717 | 23.156 | 18.15 | 19.574 | 21.789 | 16.69 | 17.526 | 16.013 | 21.26 | 18.036 | 17.009 | 20.839 | 16.990 |
| Percolation (in) | 2.6E-02 | 7.8E-02 | 2.4E-01 | 8.3E-02 | 2.0E-03 | 2.0E-03 | 2.0E-03 | 2.0E-03 | 2.0E-03 | 2.0E-03 | 3.8E-02 | 0.0E+00 | 0.0E+00 | 0.0E+00 | 0.0E+00 | 0.0E+00 | 0.0E+00 | 0.0E+00 | 0.0E+00 | 0.0E+00 | 0.0E+00 | 0.0E+00 | 0.0E+00 | 0.0E+00 | 0.0E+00 | 0.0E+00 | 0.0E+00 | 0.0E+00 | 0.0E+00 | 0.0E+00 | 0.0E+00 | 0.0E+00 |

initial soil moisture content is the final soil moisture content of the layer above during the preceding year simulation. (e.g., the final moisture content for Layer 1 at the end of year 1 is the initial moisture content for Layer 2 at the beginning of year 2)

All other input parameters as listed on Table 1

# Table F-2f

## HELP Model Results – Scenario A4, 5-Foot Annual Lifts (decreased initial ash moisture content)

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Climate File | KS1 | KS2 | KS3 | KS4 | KS5 | KS6 | KS7 | KS8 | KS9 | KS10 | KS11 | KS12 | KSCAP | | | | | | | | | | | | | | | | | | | |
| Soil & Output File | KS1A4 | KS2A4 | KS3A4 | KS4A4 | KS5A4 | KS6A4 | KS7A4 | KS8A4 | KS9A4 | KS10A4 | KS11A4 | KS12A4 | KSCAPA4 | | | | | | | | | | | | | | | | | | | |
| Runoff % | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | | | | | | | | | | | | | | | | | | | |
| Runoff Slope | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 2 | | | | | | | | | | | | | | | | | | | |
| Ash Layer Thickness (in) | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | – | | | | | | | | | | | | | | | | | | | |
| Ash Layer K | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 1E-07 | | | | | | | | | | | | | | | | | | | |
| Vegetation | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | | | | | | | | | | | | | | | | | | | |
| Initial Moisture Content | 0.12 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cap | no | no | no | no | no | no | no | no | no | no | no | no | yes | <==soil texture 7 | | | | | | | | | | | | | | | | | | |
| Layer 1 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.222 | <==set equal to cap soil field capacity | | | | | | | | | | | | | | | | | | |
| Layer 2 | x | 0.1219 | 0.1626 | 0.1411 | 0.1465 | 0.1263 | 0.1404 | 0.1220 | 0.1329 | 0.1861 | 0.1400 | 0.1255 | 0.1561 | <== | | | | | | | | | | | | | | | | | | |
| Layer 3 | x | x | 0.1219 | 0.1614 | 0.1411 | 0.1459 | 0.1263 | 0.1400 | 0.1220 | 0.1326 | 0.1821 | 0.1400 | 0.1255 | | | | | | | | | | | | | | | | | | | |
| Layer 4 | x | x | x | 0.1233 | 0.1600 | 0.1417 | 0.1453 | 0.1267 | 0.1396 | 0.1223 | 0.1363 | 0.1787 | 0.1400 | | | | | | | | | | | | | | | | | | | |
| Layer 5 | x | x | x | x | 0.1246 | 0.1587 | 0.1423 | 0.1447 | 0.1271 | 0.1392 | 0.1225 | 0.1394 | 0.1757 | | | | | | | | | | | | | | | | | | | |
| Layer 6 | x | x | x | x | x | 0.1258 | 0.1575 | 0.1429 | 0.1441 | 0.1275 | 0.1388 | 0.1228 | 0.1420 | | | | | | | | | | | | | | | | | | | |
| Layer 7 | x | x | x | x | x | x | 0.1270 | 0.1564 | 0.1435 | 0.1438 | 0.1279 | 0.1384 | 0.1232 | | | | | | | | | | | | | | | | | | | |
| Layer 8 | x | x | x | x | x | x | x | 0.1281 | 0.1553 | 0.1438 | 0.1438 | 0.1283 | 0.1380 | | | | | | | | | | | | | | | | | | | |
| Layer 9 | x | x | x | x | x | x | x | x | 0.1291 | 0.1543 | 0.1438 | 0.1438 | 0.1287 | | | | | | | | | | | | | | | | | | | |
| Layer 10 | x | x | x | x | x | x | x | x | x | 0.1301 | 0.1533 | 0.1438 | 0.1438 | | | | | | | | | | | | | | | | | | | |
| Layer 11 | x | x | x | x | x | x | x | x | x | x | 0.1310 | 0.1524 | 0.1438 | | | | | | | | | | | | | | | | | | | |
| Layer 12 | x | x | x | x | x | x | x | x | x | x | x | 0.1319 | 0.1515 | | | | | | | | | | | | | | | | | | | |
| Layer 13 | x | x | x | x | x | x | x | x | x | x | x | x | 0.1327 | | | | | | | | | | | | | | | | | | | |
| Precipitation (in) | 16.31 | 25.44 | 16.72 | 18.17 | 17.76 | 21.24 | 16.07 | 16.94 | 22.7 | 19.73 | 20.11 | 20.93 | 21.84 | 17.89 | 25.2 | 18.53 | 17.4 | 15.61 | 20.02 | 21.21 | 23.76 | 19.97 | 17.38 | 22.93 | 17.4 | 16.21 | 16.58 | 20.6 | 18.08 | 19.97 | 18.32 | 17.38 |
| Runoff (in) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.084 | 0.000 | 0.000 | 0.000 | 0.000 | 0.026 | 0.129 | 0.037 | 0.052 | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | 0.148 | 0.000 | 0.063 | 0.005 | 0.000 |
| ET (in) | 16.193 | 22.883 | 15.451 | 16.578 | 17.38 | 20.014 | 15.948 | 16.168 | 18.734 | 18.53 | 19.783 | 18.766 | 24.002 | 17.779 | 25.185 | 18.270 | 16.059 | 17.011 | 19.745 | 20.711 | 23.162 | 18.151 | 19.573 | 21.786 | 16.691 | 17.528 | 16.012 | 21.261 | 18.037 | 17.010 | 20.838 | 16.986 |
| Percolation (in) | 1.3E-05 | 0.0E+00 | 1.1E-03 | 9.5E-04 | 1.3E-03 | 1.4E-03 | 1.6E-03 | 1.6E-03 | 2.1E-03 | 2.0E-03 | 2.3E-03 | 2.4E-03 | 3.0E-06 | 3.0E-06 | 5.0E-06 | 3.0E-06 | 3.0E-06 | 3.0E-06 | 4.0E-06 | 4.0E-06 | 4.0E-06 | 5.0E-06 | 3.0E-06 | 3.0E-06 | 4.0E-06 | 4.0E-06 | 3.0E-06 | 3.0E-06 | 4.0E-06 | 4.0E-06 | 3.0E-06 | 2.0E-06 |

initial soil moisture content is the final soil moisture content of the layer above during the preceding year simulation. (e.g., the final moisture content for Layer 1 at the end of year 1 is the initial moisture content for Layer 2 at the beginning of year 2)

All other input parameters as listed on Table 1

# Table F-2g

## HELP Model Results – Scenario A5, 5-Foot Annual Lifts (increased initial ash moisture content)

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Climate File | KS1 | KS2 | KS3 | KS4 | KS5 | KS6 | KS7 | KS8 | KS9 | KS10 | KS11 | KS12 | KSCAP | | | | | | | | | | | | | | | | | | | |
| Soil & Output File | KS1A5 | KS2A5 | KS3A5 | KS4A5 | KS5A5 | KS6A5 | KS7A5 | KS8A5 | KS9A5 | KS10A5 | KS11A5 | KS12A5 | KSCAPA5 | | | | | | | | | | | | | | | | | | | |
| Runoff % | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | | | | | | | | | | | | | | | | | | | |
| Runoff Slope | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 2 | | | | | | | | | | | | | | | | | | | |
| Ash Layer Thickness (in) | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | — | | | | | | | | | | | | | | | | | | | |
| Ash Layer K | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 1E-07 | | | | | | | | | | | | | | | | | | | |
| Vegetation | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | | | | | | | | | | | | | | | | | | | |
| Initial Moisture Content | 0.18 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cap | no | no | no | no | no | no | no | no | no | no | no | no | yes | <==soil texture 7 | | | | | | | | | | | | | | | | | | |
| Layer 1 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.222 | <==set equal to cap soil field capacity | | | | | | | | | | | | | | | | | | |
| Layer 2 | x | 0.1809 | 0.2222 | 0.2005 | 0.2042 | 0.1858 | 0.2005 | 0.1814 | 0.1913 | 0.2342 | 0.1963 | 0.1850 | 0.2159 | <== | initial soil moisture content is the final soil moisture content of the layer above during the preceding year simulation (e.g., the final moisture content for Layer 1 at the end of year 1 is the initial moisture content for Layer 2 at the beginning of year 2) | | | | | | | | | | | | | | | | | |
| Layer 3 | x | x | 0.1813 | 0.2039 | 0.1948 | 0.1953 | 0.1858 | 0.1926 | 0.1816 | 0.1990 | 0.2077 | 0.1890 | 0.1850 | | | | | | | | | | | | | | | | | | | |
| Layer 4 | x | x | x | 0.1986 | 0.2035 | 0.1979 | 0.1881 | 0.1916 | 0.1870 | 0.1861 | 0.2203 | 0.2054 | 0.1807 | | | | | | | | | | | | | | | | | | | |
| Layer 5 | x | x | x | x | 0.2007 | 0.2020 | 0.1987 | 0.1878 | 0.1917 | 0.1870 | 0.1908 | 0.2144 | 0.1989 | | | | | | | | | | | | | | | | | | | |
| Layer 6 | x | x | x | x | x | 0.2015 | 0.2015 | 0.1947 | 0.1895 | 0.1870 | 0.1870 | 0.2031 | 0.2108 | | | | | | | | | | | | | | | | | | | |
| Layer 7 | x | x | x | x | x | x | 0.2014 | 0.2010 | 0.1932 | 0.1896 | 0.1870 | 0.1885 | 0.2074 | | | | | | | | | | | | | | | | | | | |
| Layer 8 | x | x | x | x | x | x | x | 0.2016 | 0.1995 | 0.1915 | 0.1870 | 0.1872 | 0.1929 | | | | | | | | | | | | | | | | | | | |
| Layer 9 | x | x | x | x | x | x | x | x | 0.2010 | 0.1984 | 0.1901 | 0.1870 | 0.1876 | | | | | | | | | | | | | | | | | | | |
| Layer 10 | x | x | x | x | x | x | x | x | x | 0.2000 | 0.1966 | 0.1870 | 0.1879 | | | | | | | | | | | | | | | | | | | |
| Layer 11 | x | x | x | x | x | x | x | x | x | x | 0.1994 | 0.1949 | 0.1870 | | | | | | | | | | | | | | | | | | | |
| Layer 12 | x | x | x | x | x | x | x | x | x | x | x | 0.1993 | 0.1913 | | | | | | | | | | | | | | | | | | | |
| Layer 13 | x | x | x | x | x | x | x | x | x | x | x | x | 0.1983 | | | | | | | | | | | | | | | | | | | |
| Precipitation (in) | 16.31 | 25.44 | 16.72 | 18.17 | 17.76 | 21.24 | 16.07 | 16.94 | 22.7 | 19.73 | 20.11 | 20.93 | 21.84 | 17.89 | 25.2 | 18.53 | 17.4 | 15.61 | 20.02 | 21.21 | 23.76 | 19.97 | 17.38 | 22.93 | 17.4 | 16.21 | 16.58 | 20.6 | 18.08 | 19.97 | 18.32 | 17.38 |
| Runoff (in) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.084 | 0.000 | 0.000 | 0.000 | 0.000 | 0.027 | 0.129 | 0.037 | 0.052 | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | 0.148 | 0.000 | 0.063 | 0.005 | 0.000 |
| ET (in) | 16.198 | 22.877 | 15.484 | 16.582 | 17.393 | 20.01 | 15.976 | 16.247 | 18.715 | 18.75 | 19.811 | 18.777 | 24.062 | 17.779 | 25.189 | 18.270 | 16.012 | 17.059 | 19.742 | 20.698 | 23.179 | 18.146 | 19.570 | 21.787 | 16.691 | 17.542 | 16.002 | 21.262 | 18.037 | 17.015 | 20.834 | 16.987 |
| Percolation (in) | 6.0E-02 | 8.2E-03 | 6.6E-02 | 3.8E-01 | 4.0E-01 | 4.2E-01 | 4.1E-01 | 4.4E-01 | 4.3E-01 | 4.2E-01 | 3.9E-01 | 3.9E-01 | 4.1E-04 | 4.7E-04 | 5.4E-04 | 6.1E-04 | 6.7E-04 | 7.2E-04 | 7.7E-04 | 8.2E-04 | 8.5E-04 | 8.8E-04 | 9.1E-04 | 9.4E-04 | 7.6E-04 | 7.6E-04 | 7.9E-04 | 8.1E-04 | 8.3E-04 | 8.5E-04 | 8.7E-04 | 8.8E-04 |

All other input parameters as listed on Table 1

# Table F-2h

## HELP Model Results – Scenario A6, 5-Foot Annual Lifts (increased K for cap soils)

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Climate File | KS1 | KS2 | KS3 | KS4 | KS5 | KS6 | KS7 | KS8 | KS9 | KS10 | KS11 | KS12 | KSCAP | | | | | | | | | | | | | | | | | | | |
| Soil & Output File | KS1A6 | KS2A6 | KS3A6 | KS4A6 | KS5A6 | KS6A6 | KS7A6 | KS8A6 | KS9A6 | KS10A6 | KS11A6 | KS12A6 | KSCAPA6 | | | | | | | | | | | | | | | | | | | |
| Runoff % | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | | | | | | | | | | | | | | | | | | | |
| Runoff Slope | 0 51 | 0 51 | 0 51 | 0 51 | 0 51 | 0 51 | 0 51 | 0 51 | 0 51 | 0 51 | 0 51 | 0 51 | 2 | | | | | | | | | | | | | | | | | | | |
| Ash Layer Thickness (in) | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | — | | | | | | | | | | | | | | | | | | | |
| Ash Layer K | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 1E-07 | | | | | | | | | | | | | | | | | | | |
| Vegetation | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | | | | | | | | | | | | | | | | | | | |
| Initial Moisture Content | 0 15 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cap | no | no | no | no | no | no | no | no | no | no | no | no | yes | <==soil texture 5 | | | | | | | | | | | | | | | | | | |
| Layer 1 | 0 15 | 0 15 | 0 15 | 0 15 | 0 15 | 0 15 | 0 15 | 0 15 | 0 15 | 0 15 | 0 15 | 0 15 | 0 131 | <==set equal to cap soil field capacity | | | | | | | | | | | | | | | | | | |
| Layer 2 | x | 0 1520 | 0 1931 | 0 1714 | 0 1768 | 0 1564 | 0 1701 | 0 1511 | 0 1616 | 0.2162 | 0 1666 | 0 1550 | 0 1858 | <== | | | | | | | | | | | | | | | | | | |
| Layer 3 | x | x | 0 1520 | 0 1866 | 0 1740 | 0 1755 | 0 1560 | 0 1680 | 0 1511 | 0 1605 | 0.2014 | 0 1666 | 0 1550 | | | | | | | | | | | | | | | | | | | |
| Layer 4 | x | x | x | 0 1584 | 0.1828 | 0 1755 | 0 1760 | 0 1580 | 0 1661 | 0 1525 | 0 1738 | 0 1932 | 0 1666 | | | | | | | | | | | | | | | | | | | |
| Layer 5 | x | x | x | x | 0 1620 | 0 1795 | 0 1760 | 0 1754 | 0 1599 | 0 1644 | 0 1540 | 0 1795 | 0 1870 | | | | | | | | | | | | | | | | | | | |
| Layer 6 | x | x | x | x | x | 0 1653 | 0 1769 | 0 1754 | 0 1746 | 0 1616 | 0 1630 | 0 1565 | 0 1825 | | | | | | | | | | | | | | | | | | | |
| Layer 7 | x | x | x | x | x | x | 0 1678 | 0 1754 | 0 1746 | 0 1738 | 0 1630 | 0 1630 | 0 1597 | | | | | | | | | | | | | | | | | | | |
| Layer 8 | x | x | x | x | x | x | x | 0 1697 | 0 1746 | 0 1738 | 0 1730 | 0 1630 | 0 1630 | | | | | | | | | | | | | | | | | | | |
| Layer 9 | x | x | x | x | x | x | x | x | 0 1711 | 0 1738 | 0 1730 | 0 1726 | 0 1630 | | | | | | | | | | | | | | | | | | | |
| Layer 10 | x | x | x | x | x | x | x | x | x | 0 1717 | 0 1730 | 0 1726 | 0 1726 | | | | | | | | | | | | | | | | | | | |
| Layer 11 | x | x | x | x | x | x | x | x | x | x | 0 1723 | 0 1726 | 0 1726 | | | | | | | | | | | | | | | | | | | |
| Layer 12 | x | x | x | x | x | x | x | x | x | x | x | 0 1726 | 0 1726 | | | | | | | | | | | | | | | | | | | |
| Layer 13 | x | x | x | x | x | x | x | x | x | x | x | x | 0 1726 | | | | | | | | | | | | | | | | | | | |
| Precipitation (in) | 16 31 | 25 44 | 16 72 | 18 17 | 17 76 | 21 24 | 16 07 | 16 94 | 22 7 | 19 73 | 20 11 | 20 93 | 21 84 | 17 89 | 25 2 | 18 53 | 17 4 | 15 61 | 20 02 | 21 21 | 23 76 | 19 97 | 17 38 | 22 93 | 17 4 | 16 21 | 16 58 | 20 6 | 18 08 | 19 97 | 18 32 | 17 38 |
| Runoff (in) | 0 000 | 0 000 | 0 000 | 0 000 | 0 000 | 0 000 | 0 000 | 0 000 | 0 000 | 0 000 | 0 000 | 0 000 | 0 000 | 0 081 | 0 000 | 0 000 | 0 000 | 0 000 | 0 000 | 0 129 | 0 041 | 0 055 | 0 002 | 0 000 | 0 000 | 0 000 | 0 000 | 0 118 | 0 000 | 0 064 | 0 003 | 0 000 |
| ET (in) | 16 196 | 22 854 | 15 436 | 16 562 | 17 378 | 20 035 | 16 002 | 16 244 | 18 707 | 18 733 | 19 808 | 18 781 | 23 357 | 17 754 | 25 130 | 18 521 | 15.240 | 17 645 | 19 742 | 20 779 | 23 100 | 18 356 | 19 177 | 21 701 | 16 825 | 17 835 | 15 797 | 21.274 | 17 869 | 17.236 | 20 521 | 16.817 |
| Percolation (in) | 3 6E-04 | 0 0E+00 | 2 8E-03 | 1.2E-02 | 1 7E-02 | 2 0E-02 | 5 8E-02 | 8 4E-02 | 9 3E-02 | 1 0E-01 | 4 4E-02 | 3 0E-04 | 0 0E+00 | 0 0E+00 | 0 0E+00 | 0 0E+00 | 0 0E+00 | 0 0E+00 | 0 0E+00 | 0 0E+00 | 0 0E+00 | 0 0E+00 | 0 0E+00 | 0 0E+00 | 0 0E+00 | 0 0E+00 | 0 0E+00 | 0 0E+00 | 0 0E+00 | 0 0E+00 | 0 0E+00 | 0 0E+00 |

initial soil moisture content is the final soil moisture content of the layer above during the preceding year simulation. (e.g., the final moisture content for Layer 1 at the end of year 1 is the initial moisture content for Layer 2 at the beginning of year 2)

All other input parameters as listed on Table 1

# Table F-2i
## HELP Model Results – Scenario B1, 10-Foot Annual Lifts (default)

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Climate File | KS1 | KS2 | KS3 | KS4 | KS5 | KS6 | KSCAP | | | | | | | | | | | | | | | | | | | |
| Soil & Output File | KS1B1 | KS2B1 | KS3B1 | KS4B1 | KS5B1 | KS6B1 | KSCAPB1 | | | | | | | | | | | | | | | | | | | |
| Runoff % | 0 | 0 | 0 | 0 | 0 | 0 | 100 | | | | | | | | | | | | | | | | | | | |
| Runoff Slope | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 | 2 | | | | | | | | | | | | | | | | | | | |
| Ash Layer Thickness (in) | 120 | 120 | 120 | 120 | 120 | 120 | – | | | | | | | | | | | | | | | | | | | |
| Ash Layer K | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 1E-07 | | | | | | | | | | | | | | | | | | | |
| Vegetation | 1 | 1 | 1 | 1 | 1 | 1 | 3 | | | | | | | | | | | | | | | | | | | |
| Initial Moisture Content | 0.15 | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cap | no | no | no | no | no | no | yes | <==soil texture 7 | | | | | | | | | | | | | | | | | | |
| Layer 1 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.222 | <==set equal to cap soil field capacity | | | | | | | | | | | | | | | | | | |
| Layer 2 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.1702 | <== | | | | | | | | | | | | | | | | | | |
| Layer 3 | x | 0.1518 | 0.1930 | 0.1713 | 0.1768 | 0.1559 | 0.1502 | | | | | | | | | | | | | | | | | | | |
| Layer 4 | x | 0.1501 | 0.1501 | 0.1501 | 0.1500 | 0.1502 | 0.1549 | | | | | | | | | | | | | | | | | | | |
| Layer 5 | x | x | 0.1510 | 0.1866 | 0.1691 | 0.1741 | 0.1512 | | | | | | | | | | | | | | | | | | | |
| Layer 6 | x | x | 0.1507 | 0.1565 | 0.1523 | 0.1527 | 0.1717 | | | | | | | | | | | | | | | | | | | |
| Layer 7 | x | x | x | 0.1508 | 0.1825 | 0.1671 | 0.1551 | | | | | | | | | | | | | | | | | | | |
| Layer 8 | x | x | x | 0.1508 | 0.1596 | 0.1542 | 0.1653 | | | | | | | | | | | | | | | | | | | |
| Layer 9 | x | x | x | x | 0.1512 | 0.1790 | 0.1560 | | | | | | | | | | | | | | | | | | | |
| Layer 10 | x | x | x | x | 0.1510 | 0.1619 | 0.1760 | | | | | | | | | | | | | | | | | | | |
| Layer 11 | x | x | x | x | x | 0.1517 | 0.1636 | | | | | | | | | | | | | | | | | | | |
| Layer 12 | x | x | x | x | x | 0.1513 | 0.1523 | | | | | | | | | | | | | | | | | | | |
| Layer 13 | x | x | x | x | x | x | 0.1518 | | | | | | | | | | | | | | | | | | | |
| Precipitation (in) | 16.31 | 25.44 | 16.72 | 18.17 | 17.76 | 21.24 | 21.84 | 17.89 | 25.20 | 18.53 | 17.40 | 15.61 | 20.02 | 21.21 | 23.76 | 19.97 | 17.38 | 22.93 | 17.40 | 16.21 | 16.58 | 20.60 | 18.08 | 19.97 | 18.32 | 17.38 |
| Runoff (in) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.084 | 0.000 | 0.000 | 0.000 | 0.000 | 0.026 | 0.129 | 0.037 | 0.052 | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | 0.148 | 0.000 | 0.063 | 0.005 | 0.000 |
| ET (in) | 16.196 | 22.854 | 15.436 | 16.562 | 17.395 | 20.014 | 24.035 | 17.779 | 25.189 | 18.270 | 16.054 | 17.015 | 19.746 | 20.709 | 23.163 | 18.149 | 19.574 | 21.788 | 16.69 | 17.535 | 16.006 | 21.261 | 18.036 | 17.012 | 20.837 | 16.984 |
| Percolation (in) | 1.5E-03 | 1.3E-01 | 3.7E-03 | 2.1E-02 | 1.8E-02 | 1.7E-02 | 4.1E-05 | 3.5E-05 | 4.0E-05 | 3.4E-05 | 4.0E-05 | 3.5E-05 | 4.2E-05 | 3.9E-05 | 4.1E-05 | 4.0E-05 | 3.4E-05 | 3.6E-05 | 3.5E-05 | 3.2E-05 | 3.7E-05 | 3.7E-05 | 3.7E-05 | 3.1E-05 | 3.7E-05 | 3.9E-05 |

initial soil moisture content is the final soil moisture content of the layer above during the preceding year simulation. (e.g., the final moisture content for Layer 1 at the end of year 1 is the initial moisture content for Layer 2 at the beginning of year 2)

All other input parameters as listed on Table 1

# Table F-2j

# HELP Model Results – Scenario B2, 10-Foot Annual Lifts (assumes ash does not set up)

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Climate File | KS1 | KS2 | KS3 | KS4 | KS5 | KS6 | KSCAP | | | | | | | | | | | | | | | | | | | |
| Soil & Output File | KS1B1 | KS2B1 | KS3B1 | KS4B1 | KS5B1 | KS6B1 | KSCAPB2 | | | | | | | | | | | | | | | | | | | |
| Runoff % | 0 | 0 | 0 | 0 | 0 | 0 | 100 | | | | | | | | | | | | | | | | | | | |
| Runoff Slope | 0 51 | 0 51 | 0 51 | 0 51 | 0 51 | 0 51 | 2 | | | | | | | | | | | | | | | | | | | |
| Ash Layer Thickness (in) | 120 | 120 | 120 | 120 | 120 | 120 | – | | | | | | | | | | | | | | | | | | | |
| Ash Layer K | 5 E-05 | 5 E-05 | 5 E-05 | 5 E-05 | 5 E-05 | 5 E-05 | 5E-05 | | | | | | | | | | | | | | | | | | | |
| Vegetation | 1 | 1 | 1 | 1 | 1 | 1 | 3 | | | | | | | | | | | | | | | | | | | |
| Initial Moisture Content | 0 15 | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cap | no | no | no | no | no | no | yes | <==soil texture 7 | | | | | | | | | | | | | | | | | | |
| Layer 1 | 0 15 | 0 15 | 0 15 | 0 15 | 0 15 | 0 15 | 0 222 | <==set equal to cap soil field capacity | | | | | | | | | | | | | | | | | | |
| Layer 2 | 0 15 | 0 15 | 0 15 | 0 15 | 0 15 | 0 15 | 0 1702 | <== | | | | | | | | | | | | | | | | | | |
| Layer 3 | x | 0 1518 | 0 1930 | 0 1713 | 0 1768 | 0 1559 | 0 1502 | | | | | | | | | | | | | | | | | | | |
| Layer 4 | x | 0 1501 | 0 1501 | 0 1501 | 0 1500 | 0 1502 | 0 1549 | | | | | | | | | | | | | | | | | | | |
| Layer 5 | x | x | 0 1510 | 0 1866 | 0 1691 | 0 1741 | 0 1512 | | | | | | | | | | | | | | | | | | | |
| Layer 6 | x | x | 0 1507 | 0 1565 | 0 1523 | 0 1527 | 0 1717 | | | | | | | | | | | | | | | | | | | |
| Layer 7 | x | x | x | 0 1508 | 0 1825 | 0 1671 | 0 1551 | | | | | | | | | | | | | | | | | | | |
| Layer 8 | x | x | x | 0 1508 | 0 1596 | 0 1542 | 0 1653 | | | | | | | | | | | | | | | | | | | |
| Layer 9 | x | x | x | x | 0 1512 | 0 1790 | 0 1560 | | | | | | | | | | | | | | | | | | | |
| Layer 10 | x | x | x | x | 0 1510 | 0 1619 | 0 1760 | | | | | | | | | | | | | | | | | | | |
| Layer 11 | x | x | x | x | x | 0 1517 | 0 1636 | | | | | | | | | | | | | | | | | | | |
| Layer 12 | x | x | x | x | x | 0 1513 | 0 1523 | | | | | | | | | | | | | | | | | | | |
| Layer 13 | x | x | x | x | x | x | 0 1518 | | | | | | | | | | | | | | | | | | | |
| Precipitation (in) | 16 31 | 25 44 | 16 72 | 18 17 | 17 76 | 21 24 | 21 84 | 17 89 | 25 20 | 18 53 | 17 40 | 15 61 | 20 02 | 21 21 | 23 76 | 19 97 | 17 38 | 22 93 | 17 40 | 16 21 | 16 58 | 20 60 | 18 08 | 19 97 | 18 32 | 17 38 |
| Runoff (in) | 0 000 | 0 000 | 0 000 | 0 000 | 0 000 | 0 000 | 0 000 | 0 084 | 0 000 | 0 000 | 0 000 | 0 000 | 0 022 | 0 129 | 0 037 | 0 052 | 0 002 | 0 000 | 0 000 | 0 000 | 0 000 | 0 148 | 0 000 | 0 063 | 0 004 | 0 000 |
| ET (in) | 16 196 | 22 854 | 15 436 | 16 562 | 17 395 | 20 014 | 23 545 | 17 779 | 25 178 | 18 085 | 15 990 | 17 081 | 17 964 | 20 221 | 23 112 | 18 156 | 19 416 | 21 788 | 16 668 | 17 531 | 16 011 | 19 521 | 17 900 | 16 996 | 20 589 | 17 036 |
| Percolation (in) | 1 5E-03 | 1 3E-01 | 3 7E-03 | 2 1E-02 | 1 8E-02 | 1 7E-02 | 1 5E-02 | 2 2E-02 | 2 3E-02 | 2 3E-02 | 2 3E-02 | 2.2E-02 | 2 3E-02 | 2 3E-02 | 2 8E-02 | 2 8E-02 | 2 8E-02 | 3 8E-02 | 4 0E-02 | 3 7E-02 | 3 6E-02 | 3 8E-02 | 4 0E-02 | 5 4E-02 | 4 3E-02 | 4 2E-02 |

initial soil moisture content is the final soil moisture content of the layer above during the preceding year simulation.
(e g., the final moisture content for Layer 1 at the end of year 1 is the initial moisture content for Layer 2 at the beginning of year 2)

All other input parameters as listed on Table 1

# Table F-2k

## HELP Model Results – Scenario C1, 15-Foot Annual Lifts (default)

| Year | 1 | 2 | 3 | 4 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Climate File | KS1 | KS2 | KS3 | KS4 | KSCAP | | | | | | | | | | | | | | | | | | | |
| Soil & Output File | KS1C1 | KS2C1 | KS3C1 | KS4C1 | KSCAPC1 | | | | | | | | | | | | | | | | | | | |
| Runoff % | 0 | 0 | 0 | 0 | 100 | | | | | | | | | | | | | | | | | | | |
| Runoff Slope | 0.51 | 0.51 | 0.51 | 0.51 | 2 | | | | | | | | | | | | | | | | | | | |
| Ash Layer Thickness (in) | 180 | 180 | 180 | 180 | — | | | | | | | | | | | | | | | | | | | |
| Ash Layer K | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 1E-07 | | | | | | | | | | | | | | | | | | | |
| Vegetation | 1 | 1 | 1 | 1 | 3 | | | | | | | | | | | | | | | | | | | |
| Initial Moisture Content | 0.15 | | | | | | | | | | | | | | | | | | | | | | | |
| Cap | no | no | no | no | yes | <==soil texture 7 | | | | | | | | | | | | | | | | | | |
| Layer 1 | 0.15 | 0.15 | 0.15 | 0.15 | 0.222 | <==set equal to cap soil field capacity | | | | | | | | | | | | | | | | | | |
| Layer 2 | 0.15 | 0.15 | 0.15 | 0.15 | 0.1768 | <== | | | | | | | | | | | | | | | | | | |
| Layer 3 | 0.15 | 0.15 | 0.15 | 0.15 | 0.150 | | | | | | | | | | | | | | | | | | | |
| Layer 4 | x | 0.1517 | 0.1930 | 0.1713 | 0.150 | | | | | | | | | | | | | | | | | | | |
| Layer 5 | x | 0.1501 | 0.1501 | 0.1501 | 0.1691 | | | | | | | | | | | | | | | | | | | |
| Layer 6 | x | 0.1500 | 0.1501 | 0.1501 | 0.1519 | | | | | | | | | | | | | | | | | | | |
| Layer 7 | x | x | 0.1509 | 0.1866 | 0.1505 | | | | | | | | | | | | | | | | | | | |
| Layer 8 | x | x | 0.1504 | 0.1564 | 0.1825 | | | | | | | | | | | | | | | | | | | |
| Layer 9 | x | x | 0.1502 | 0.1503 | 0.1595 | | | | | | | | | | | | | | | | | | | |
| Layer 10 | x | x | x | 0.1504 | 0.1507 | | | | | | | | | | | | | | | | | | | |
| Layer 11 | x | x | x | 0.1504 | 0.1505 | | | | | | | | | | | | | | | | | | | |
| Layer 12 | x | x | x | 0.1504 | 0.1505 | | | | | | | | | | | | | | | | | | | |
| Layer 13 | x | x | x | x | 0.1505 | | | | | | | | | | | | | | | | | | | |
| Precipitation (in) | 16.31 | 25.44 | 16.72 | 18.17 | 21.84 | 17.89 | 25.20 | 18.53 | 17.40 | 15.61 | 20.02 | 21.21 | 23.76 | 19.97 | 17.38 | 22.93 | 17.40 | 16.21 | 16.58 | 20.60 | 18.08 | 19.97 | 18.32 | 17.38 |
| Runoff (in) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.084 | 0.000 | 0.000 | 0.000 | 0.000 | 0.026 | 0.129 | 0.037 | 0.052 | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | 0.148 | 0.000 | 0.063 | 0.005 | 0.000 |
| ET (in) | 16.196 | 22.854 | 15.436 | 16.562 | 24.045 | 17.779 | 25.189 | 18.270 | 16.056 | 17.016 | 19.746 | 20.712 | 23.159 | 18.150 | 19.573 | 21.789 | 16.690 | 17.523 | 16.017 | 21.261 | 18.036 | 17.009 | 20.839 | 16.988 |
| Percolation (in) | 1.8E-03 | 2.2E-02 | 1.4E-02 | 1.5E-02 | 6.4E-05 | 6.0E-05 | 6.2E-05 | 6.1E-05 | 6.0E-05 | 6.2E-05 | 5.6E-05 | 5.7E-05 | 6.6E-05 | 5.9E-05 | 6.4E-05 | 6.1E-05 | 5.9E-05 | 6.3E-05 | 6.2E-05 | 5.8E-05 | 6.3E-05 | 6.4E-05 | 5.7E-05 | 6.5E-05 |

initial soil moisture content is the final soil moisture content of the layer above during the preceding year simulation.
(e.g., the final moisture content for Layer 1 at the end of year 1 is the initial moisture content for Layer 2 at the beginning of year 2)

All other input parameters as listed on Table 1

# Table F-21
# HELP Model Results – Scenario C2, 15-Foot Annual Lifts (assumes ash does not set up)

| Year | 1 | 2 | 3 | 4 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Climate File | KS1 | KS2 | KS3 | KS4 | KSCAP | | | | | | | | | | | | | | | | | | | |
| Soil & Output File | KS1C1 | KS2C1 | KS3C1 | KS4C1 | KSCAPC2 | | | | | | | | | | | | | | | | | | | |
| Runoff % | 0 | 0 | 0 | 0 | 100 | | | | | | | | | | | | | | | | | | | |
| Runoff Slope | 0 51 | 0 51 | 0 51 | 0 51 | 2 | | | | | | | | | | | | | | | | | | | |
| Ash Layer Thickness (in) | 180 | 180 | 180 | 180 | – | | | | | | | | | | | | | | | | | | | |
| Ash Layer K | 5 E-05 | 5 E-05 | 5 E-05 | 5 E-05 | 5E-05 | | | | | | | | | | | | | | | | | | | |
| Vegetation | 1 | 1 | 1 | 1 | 3 | | | | | | | | | | | | | | | | | | | |
| Initial Moisture Content | 0 15 | | | | | | | | | | | | | | | | | | | | | | | |
| Cap | no | no | no | no | yes | <==soil texture 7 | | | | | | | | | | | | | | | | | | |
| Layer 1 | 0 15 | 0 15 | 0 15 | 0 15 | 0 222 | <==set equal to cap soil field capacity | | | | | | | | | | | | | | | | | | |
| Layer 2 | 0 15 | 0 15 | 0 15 | 0 15 | 0 1768 | <== | | | | | | | | | | | | | | | | | | |
| Layer 3 | 0 15 | 0 15 | 0 15 | 0 15 | 0 150 | | | | | | | | | | | | | | | | | | | |
| Layer 4 | x | 0 1517 | 0 1930 | 0 1713 | 0 150 | | | | | | | | | | | | | | | | | | | |
| Layer 5 | x | 0 1501 | 0 1501 | 0 1501 | 0 1691 | | | | | | | | | | | | | | | | | | | |
| Layer 6 | x | 0 1500 | 0 1501 | 0 1501 | 0 1519 | | | | | | | | | | | | | | | | | | | |
| Layer 7 | x | x | 0 1509 | 0 1866 | 0 1505 | | | | | | | | | | | | | | | | | | | |
| Layer 8 | x | x | 0 1504 | 0 1564 | 0 1825 | | | | | | | | | | | | | | | | | | | |
| Layer 9 | x | x | 0 1502 | 0 1503 | 0 1595 | | | | | | | | | | | | | | | | | | | |
| Layer 10 | x | x | x | 0 1504 | 0 1507 | | | | | | | | | | | | | | | | | | | |
| Layer 11 | x | x | x | 0 1504 | 0 1505 | | | | | | | | | | | | | | | | | | | |
| Layer 12 | x | x | x | 0 1504 | 0 1505 | | | | | | | | | | | | | | | | | | | |
| Layer 13 | x | x | x | x | 0 1505 | | | | | | | | | | | | | | | | | | | |
| Precipitation (in) | 16 31 | 25 44 | 16 72 | 18 17 | 21 84 | 17 89 | 25 2 | 18 53 | 17 4 | 15 61 | 20 02 | 21 21 | 23 76 | 19 97 | 17 38 | 22 93 | 17 4 | 16 21 | 16 58 | 20 6 | 18 08 | 19 97 | 18 32 | 17 38 |
| Runoff (in) | 0 000 | 0 000 | 0 000 | 0 000 | 0 000 | 0 084 | 0 000 | 0 000 | 0 000 | 0 000 | 0 022 | 0 129 | 0 037 | 0 051 | 0 002 | 0 000 | 0 000 | 0 000 | 0 000 | 0 148 | 0 000 | 0 063 | 0 004 | 0 000 |
| ET (in) | 16 196 | 22 854 | 15 436 | 16 562 | 23 535 | 17 775 | 25 183 | 18 1 | 15 961 | 17 08 | 17 935 | 20.273 | 23 096 | 18 164 | 19 416 | 21 797 | 16 659 | 17 532 | 15 991 | 19 549 | 17 899 | 17 | 20 587 | 17 039 |
| Percolation (in) | 1 8E-03 | 2.2E-02 | 1 4E-02 | 1 5E-02 | 2 2E-02 | 2.2E-02 | 1 7E-02 | 2 0E-02 | 1 9E-02 | 2 5E-02 | 1 8E-02 | 2 1E-02 | 2 3E-02 | 2 2E-02 | 2 4E-02 | 2 4E-02 | 2 5E-02 | 2 4E-02 | 2 3E-02 | 2 5E-02 | 2 6E-02 | 2 8E-02 | 2 5E-02 | 2 6E-02 |

initial soil moisture content is the final soil moisture content of the layer above during the preceding year simulation (e g., the final moisture content for Layer 1 at the end of year 1 is the initial moisture content for Layer 2 at the beginning of year 2)

All other input parameters as listed on Table 1

# Table F-2m

## HELP Model Results – Scenario D1, 20-Foot Annual Lifts (default)

| Year | 1 | 2 | 3 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Climate File | KS1 | KS2 | KS3 | KSCAP | | | | | | | | | | | | | | | | | | | |
| Soil & Output File | KS1D1 | KS2D1 | KS3D1 | KSCAPD1 | | | | | | | | | | | | | | | | | | | |
| Runoff % | 0 | 0 | 0 | 100 | | | | | | | | | | | | | | | | | | | |
| Runoff Slope | 0.51 | 0.51 | 0.51 | 2 | | | | | | | | | | | | | | | | | | | |
| Ash Layer Thickness (in) | 240 | 240 | 240 | – | | | | | | | | | | | | | | | | | | | |
| Ash Layer K | 5E-05 | 5E-05 | 5E-05 | 1E-07 | | | | | | | | | | | | | | | | | | | |
| Vegetation | 1 | 1 | 1 | 3 | | | | | | | | | | | | | | | | | | | |
| Initial Moisture Content | 0.15 | | | | | | | | | | | | | | | | | | | | | | |
| Cap | no | no | no | yes | <==soil texture 7 | | | | | | | | | | | | | | | | | | |
| Layer 1 | 0.15 | 0.15 | 0.15 | 0.2220 | <==set equal to cap soil field capacity | | | | | | | | | | | | | | | | | | |
| Layer 2 | 0.15 | 0.15 | 0.15 | 0.1712 | <== | | | | | | | | | | | | | | | | | | |
| Layer 3 | 0.15 | 0.15 | 0.15 | 0.1500 | | | | | | | | | | | | | | | | | | | |
| Layer 4 | 0.15 | 0.15 | 0.15 | 0.1500 | | | | | | | | | | | | | | | | | | | |
| Layer 5 | x | 0.1517 | 0.1930 | 0.1500 | | | | | | | | | | | | | | | | | | | |
| Layer 6 | x | 0.1501 | 0.1500 | 0.1866 | | | | | | | | | | | | | | | | | | | |
| Layer 7 | x | 0.1500 | 0.1500 | 0.1562 | | | | | | | | | | | | | | | | | | | |
| Layer 8 | x | 0.1500 | 0.1500 | 0.1501 | | | | | | | | | | | | | | | | | | | |
| Layer 9 | x | x | 0.1509 | 0.1501 | | | | | | | | | | | | | | | | | | | |
| Layer 10 | x | x | 0.1503 | 0.1503 | | | | | | | | | | | | | | | | | | | |
| Layer 11 | x | x | 0.1501 | 0.1503 | | | | | | | | | | | | | | | | | | | |
| Layer 12 | x | x | 0.1501 | 0.1502 | | | | | | | | | | | | | | | | | | | |
| Layer 13 | x | x | x | 0.1502 | | | | | | | | | | | | | | | | | | | |
| Precipitation (in) | 16.3 | 25.44 | 16.72 | 21.84 | 17.89 | 25.2 | 18.53 | 17.4 | 15.61 | 20.02 | 21.21 | 23.76 | 19.97 | 17.38 | 22.93 | 17.4 | 16.21 | 16.58 | 20.6 | 18.08 | 19.97 | 18.32 | 17.38 |
| Runoff (in) | 0.000 | 0.000 | 0.000 | 0.000 | 0.084 | 0.000 | 0.000 | 0.000 | 0.000 | 0.026 | 0.129 | 0.037 | 0.052 | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | 0.148 | 0.000 | 0.063 | 0.005 | 0.000 |
| ET (in) | 16.196 | 22.854 | 15.436 | 24.037 | 17.779 | 25.184 | 18.271 | 16.062 | 17.008 | 19.747 | 20.719 | 23.153 | 18.150 | 19.573 | 21.787 | 16.689 | 17.534 | 16.008 | 21.260 | 18.036 | 17.011 | 20.838 | 16.990 |
| Percolation (in) | 1.7E-03 | 2.1E-02 | 2.4E-02 | 8.0E-05 | 7.8E-05 | 8.0E-05 | 8.1E-05 | 8.0E-05 | 8.0E-05 | 8.0E-05 | 8.1E-05 | 8.0E-05 | 8.1E-05 | 8.0E-05 | 8.1E-05 | 7.6E-05 | 7.9E-05 | 7.6E-05 | 8.1E-05 | 7.8E-05 | 7.6E-05 | 8.1E-05 | 7.9E-05 |

initial soil moisture content is the final soil moisture content of the layer above during the preceding year simulation. (e.g., the final moisture content for Layer 1 at the end of year 1 is the initial moisture content for Layer 2 at the beginning of year 2)

All other input parameters as listed on Table 1

# Table F-2n
## HELP Model Results – Scenario D2, 20-Foot Annual Lifts (assumes ash does not set up)

| Year | 1 | 2 | 3 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Climate File | KS1 | KS2 | KS3 | KSCAP | | | | | | | | | | | | | | | | | | | |
| Soil & Output File | KS1D1 | KS2D1 | KS3D1 | KSCAPD2 | | | | | | | | | | | | | | | | | | | |
| Runoff % | 0 | 0 | 0 | 100 | | | | | | | | | | | | | | | | | | | |
| Runoff Slope | 0 51 | 0 51 | 0 51 | 2 | | | | | | | | | | | | | | | | | | | |
| Ash Layer Thickness (in) | 240 | 240 | 240 | – | | | | | | | | | | | | | | | | | | | |
| Ash Layer K | 5 E-05 | 5 E-05 | 5 E-05 | 5E-05 | | | | | | | | | | | | | | | | | | | |
| Vegetation | 1 | 1 | 1 | 3 | | | | | | | | | | | | | | | | | | | |
| Initial Moisture Content | 0 15 | | | | | | | | | | | | | | | | | | | | | | |
| Cap | no | no | no | yes | <==soil texture 7 | | | | | | | | | | | | | | | | | | |
| Layer 1 | 0 15 | 0 15 | 0 15 | 0 2220 | <==set equal to cap soil field capacity | | | | | | | | | | | | | | | | | | |
| Layer 2 | 0 15 | 0 15 | 0 15 | 0 1712 | <== | | | | | | | | | | | | | | | | | | |
| Layer 3 | 0 15 | 0 15 | 0 15 | 0 1500 | | | | | | | | | | | | | | | | | | | |
| Layer 4 | 0 15 | 0 15 | 0 15 | 0 1500 | | | | | | | | | | | | | | | | | | | |
| Layer 5 | x | 0 1517 | 0 1930 | 0 1500 | | | | | | | | | | | | | | | | | | | |
| Layer 6 | x | 0 1501 | 0 1500 | 0 1866 | | | | | | | | | | | | | | | | | | | |
| Layer 7 | x | 0 1500 | 0 1500 | 0 1562 | | | | | | | | | | | | | | | | | | | |
| Layer 8 | x | 0 1500 | 0 1500 | 0 1501 | | | | | | | | | | | | | | | | | | | |
| Layer 9 | x | x | 0 1509 | 0 1501 | | | | | | | | | | | | | | | | | | | |
| Layer 10 | x | x | 0 1503 | 0 1503 | | | | | | | | | | | | | | | | | | | |
| Layer 11 | x | x | 0 1501 | 0 1503 | | | | | | | | | | | | | | | | | | | |
| Layer 12 | x | x | 0 1501 | 0 1502 | | | | | | | | | | | | | | | | | | | |
| Layer 13 | x | x | x | 0 1502 | | | | | | | | | | | | | | | | | | | |
| Precipitation (in) | 16 3 | 25 44 | 16 72 | 21 84 | 17 89 | 25 2 | 18 53 | 17 4 | 15 61 | 20 02 | 21 21 | 23 76 | 19 97 | 17 38 | 22 93 | 17 4 | 16 21 | 16 58 | 20 6 | 18 08 | 19 97 | 18 32 | 17 38 |
| Runoff (in) | 0 000 | 0 000 | 0 000 | 0 000 | 0 084 | 0 000 | 0 000 | 0 000 | 0 000 | 0 022 | 0 129 | 0 037 | 0 052 | 0 002 | 0 000 | 0 000 | 0 000 | 0 000 | 0 148 | 0 000 | 0 063 | 0 004 | 0 000 |
| ET (in) | 16 196 | 22 854 | 15 436 | 23 54 | 17 778 | 25 158 | 18 091 | 15 978 | 17 092 | 17 92 | 20 265 | 23 125 | 18 153 | 19 416 | 21 787 | 16 69 | 17 537 | 16 008 | 19 528 | 17 89 | 16 998 | 20 589 | 17 035 |
| Percolation (in) | 1 7E-03 | 2 1E-02 | 2 4E-02 | 1 4E-02 | 2 4E-02 | 1 2E-02 | 2 0E-02 | 2 1E-02 | 1 8E-02 | 2 0E-02 | 1 4E-02 | 2.2E-02 | 2 1E-02 | 1 8E-02 | 2 2E-02 | 1 8E-02 | 2 1E-02 | 1 7E-02 | 2 4E-02 | 2 0E-02 | 2 5E-02 | 2 5E-02 | 1 9E-02 |

initial soil moisture content is the final soil moisture content of the layer above during the preceding year simulation.
(e g , the final moisture content for Layer 1 at the end of year 1 is the initial moisture content for Layer 2 at the beginning of year 2)

All other input parameters as listed on Table 1

# ATTACHMENT G

# References

## 6 References

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