WRANGELL MONOFILL PROJECT SUPPORT – HELP MODEL EVALUATION REPORT WRANGELL, ALASKA

Prepared For:

ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION
DIVISION OF SPILL PREVENTION AND RESPONSE

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LIST OF ACRONYMS

ADEC	Alaska Department of Environmental Conservation
Ahtna	Ahtna Engineering Services, LLC
cm	centimeters
cu.	cubic
E&E	Ecology and Environment, Inc.
EPA	United States Environmental Protection Agency
FML	flexible membrane layer
g	acceleration due to gravity
GCL	geosynthetic clay layer
Geosyntec	Geosyntec Consultants, Inc.
HDPE	high density polyethylene
HELP	Hydrologic Evaluation of Landfill Performance
K_s	saturated hydraulic conductivity
LLDPE	linear low-density polyethylene
mm	millimeter
n	total porosity
SCS	Soil Conservation Service
sec	second
ν	kinematic viscosity of water
vol/vol	volume by volume
Weston	Weston Solutions, Inc.

1.0 INTRODUCTION

Weston Solutions, Inc. (Weston) has been tasked by the Alaska Department of Environmental Conservation (ADEC) Division of Spill Prevention and Response to analyze the Hydrologic Evaluation of Landfill Performance (HELP) modeling results of two previously modeled landfill cover designs. These cover designs were prepared by Geosyntec Consultants, Inc. (Geosyntec) and Ecology and Environment, Inc. (E&E).

The Geosyntec report was completed in January 2017, on behalf of Ahtna Engineering Services, LLC (Ahtna), in order to present results from a geotechnical and hydrological investigation. The soil and groundwater data gathered by Ahtna was then used by Geosyntec to prepare a monofill cap design concept, as well as an infiltration evaluation using HELP software.

E&E created a Basis of Design Document in June 2017 that analyzes on-site soil and groundwater characteristics to assist in planning of the removal action. The E&E report also proposes a monofill cap design with corresponding infiltration modeling using HELP software.

The differences in the proposed cover designs and the HELP model results are discussed in this report.

2.0 GEOSYNTEC HELP MODEL

Geosyntec, on behalf of Ahtna, prepared *Proposed Wrangell Monofill Report of Findings, Wrangell, Alaska, 27 January 2017*, an infiltration study and HELP model analysis that allows for prediction of infiltration through the proposed Wrangell Monofill cap and eventually into the groundwater table (Ahtna and Geosyntec, 2017).

2.1 Input and Proposed Cap Configuration

Geosyntec assumed an engineered monofill cap consisting of (top to bottom): 2 feet of vegetative cover soil, a geocomposite drainage layer (non-woven geotextile heat bonded to both sides of a geonet), 60-mil high density polyethylene (HDPE) geomembrane textured on both sides, underlain by a geosynthetic clay liner (GCL). The waste layer is situated directly below the GCL, and gravel layer is modeled as the final layer below the waste.

Four different engineered monofill cap systems were analyzed by means of the HELP software. The maximum thickness of waste within the center of the Geosyntec conceptual monofill design was determined to be 40 feet above existing ground surface, with a 3% grade and a 130 foot slope length, whereas the thickness of waste within the side slopes was determined to be 20 feet. Therefore, a single liner system consisting of cover soil at the center of the monofill and a geocomposite drainage layer underlain by a geomembrane layer were analyzed with HELP software for both the 3% grade top deck and side slope configurations. Then, each of those two scenarios were also analyzed with the addition of the GCL beneath the geomembrane.

Below is a summary of the four HELP scenarios and corresponding annual infiltration:

1. 40-foot-high waste layer at center of monofill, GCL not included – 280.0 gallons/year/acre average annual infiltration into bedrock
2. 40-foot-high waste layer at center of monofill, GCL included, infiltration from top deck of monofill – 0.6 gallon/year/acre average annual infiltration into bedrock
3. 20-foot-high layer at side slope of monofill, GCL not included – 22.9 gallons/year/acre average annual infiltration into bedrock
4. 20-foot-high layer at side slopes of monofill, GCL included – 0.0 gallons/year/acre average annual infiltration into bedrock

Weston used the HELP data files provided as inputs into the program and re-ran those four scenarios listed above. The four scenarios used the same evaporative zone, evapotranspiration, solar radiation, and weather data. The HELP model references 30 years of built-in weather data.

2.2 Resulting Infiltration

Weston re-ran the original HELP model with data files provided from Geosyntec and obtained the same results. Therefore, according to the HELP model output and the recommendation of Geosyntec, the presence of a GCL as part of the monofill cap system is beneficial in minimizing infiltration rates. The HELP model shows infiltration rates of 0.6 gallon/year/acre with a GCL in place versus an infiltration rate of 280 gallons/year/acre without the addition of a GCL.

3.0 E&E HELP MODEL

E&E prepared *Volume I, Basis of Design; Wrangell Junkyard Repository Site Wrangell, Alaska; TDD:17-01-0015, 9 June 2017,* a basis of design document that includes a HELP model analysis prepared for the United States Environmental Protection Agency (EPA) Region 10 (E&E, 2017).

3.1 Input and Proposed Cap Configuration

The monofill soil layer configuration included in the E&E report consists of (from top to bottom): 6 inches of topsoil, 18 inches of clean vegetative fill, 12 inches of 1-inch minus aggregate, 6 inches of 3/8-inch minus aggregate, a 40 mil linear low-density polyethylene (LLDPE) flexible membrane liner (FML), a 4-inch layer of 3/8-inch minus aggregate, and 38 feet of waste material, all underlain by a non-woven geotextile fabric and a 2-foot base layer composed of on-site rock material. The maximum thickness of the landfill waste layer was assumed to be 38 feet with a surface slope of 3% and a slope length of 50 feet.

3.2 Resulting Infiltration

The HELP model was re-run by Weston using all eight layers as described in Section 3.1. The total average annual infiltration through the last layer of the landfill cap into the groundwater is estimated to be 72,243.4 gallons/year/acre. This is the only scenario proposed and analyzed by E&E and concludes with an infiltration rate much higher than that of the Geosyntec design.

4.0 MODEL COMPARISON

Tables 1 and 2 summarize the differences between input and output parameters of analyses completed in the HELP models provided by E&E and Geosyntec. This information is regarding the cap designs and corresponding infiltrations into the groundwater.

Table 1 Qualitative Differences Between HELP Models

Model Input and Output	Geosyntec	E&E
Soil Data Input		
1. Number of layers	6	8
2. Total thickness of soil analyzed	570.49 inches	526.04 inches
Evaporative Zone Data Input		
1. Soil Conservation Service (SCS) runoff curve number	45.60	50.50
2. Area project on horizontal plane	1.00 acre	0.76 acre
3. Initial water in evaporative zone	0.92 inch	2.21 Inches
4. Initial water in layer materials/total initial water	68.30 inches	72.30 inches

Table 1 Qualitative Differences Between HELP Models (Continued)

Model Input and Output	Geosyntec	E&E
Evapotranspiration and Weather Data[1] Input		
5. Evapotranspiration data obtained from	Wrangell, Alaska	Annette, Alaska
6. Station latitude	56.35 degrees	56.47 degrees
Average Annual Totals for Years 1 through 30 Output		
1. Runoff	14.93 inches; 54,197.98 cubic (cu.) feet	28.33 inches; 78,153.47 cu. feet
2. Evapotranspiration	14.10 inches; 51,198.07 cu. feet	18.45 inches; 50,892.48 cu. feet
3. Lateral drainage collected from inferred cap drainage layer	Layer 2 (Geocomposite Drainage Layer): 59.08 inches; 214,443.89 cu. feet	Layer 4: 38.58 inches; 106,436.29 cu. feet
4. Percolation/leakage through FML	Layer 4 (GCL): 0.00002 inch; 0.078 cu. feet	Layer 5 (LLDPE Liner): 2.78 inches; 7,663.06 cu. feet Layer 8 (On-Site Crushed Rock): 2.66 inches; 7,340.18 cu. feet
5. Percolation/leakage through base layer	Layer: 6 (Crushed Rock): 0.00002 inch; 0.080 cu. feet	Layer 8 (On-Site Crushed Rock): 2.66 inches; 7,340.18 cu. feet
6. Average head on top of	Layer 3 (HDPE Liner): 0.099 inch	Layer 5 (LLDPE Liner): 0.47 inch
7. Change in water storage	0.056 inch; 204.96 cu. feet	0.15 inch; 411.77 cu. feet
Peak Daily Values for Years 1 through 30 (Output)		
1. Precipitation	8.90 inches; 32,307.0 cu. feet	8.90 inches; 24,553.32 cu. feet
2. Drainage collect from	Layer 2 (Geocomposite Drainage Layer): 5.12 inches; 18,591.45 cu. feet	Layer 4 (Drainage Layer): 0.72 inch; 1,988.97 cu. feet
3. Percolation leakage through	Layer 4 (GCL): 0.000016 inch; 0.057 cu. feet	Layer 5 (LLDPE Liner): 0.04 inch; 106.09 cu. feet
4. Avg. head on top of	Layer 3 (HDPE Liner): 19.02 inches	Layer 5 (LLDPE Liner): 3.21 inches
5. Max. head on top of	Layer 3 (HDPE Liner): 23.29 inches	Layer 5 (LLDPE Liner): 4.44 inches
6. Location of max. head in (distance from drain)	Layer 2 (Geocomposite Drainage Layer): 56.5 feet	Layer 4 (Drainage Layer): 15.4 feet

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[1] Although the evapotranspiration data were obtained from different cities, the input was the same; precipitation data were taken from Olympia, Washington, for both models.

Table 1 Qualitative Differences Between HELP Models (Continued)

Model Input and Output	Geosyntec	E&E
7. Percolation/leakage through	Layer 6 (Crushed Gravel): 0.000043 inch; 0.157 cu. feet	Layer 8 (On-Site Crushed Rock): 0.03 inch; 77.97 cu. feet
8. Snow water	13.33 inches; 48,399.14 cu. feet	8.54 inches; 23,564.36 cu. feet
9. Max. veg. soil water	0.4159 volume by volume (vol/vol)	0.4170 vol/vol
Final water storage at end of year 30 (per layer) Output		
1. Per layer	1. Cover Soil: 2.90 inches 2. Geocomposite Drainage Layer: 0.01 inch 3. HDPE Liner: 0.00 inch 4. GCL: 0.17 inch 5. Waste Layer: 62.88 inches 6. Crushed Gravel: 2.11 inches	1. Topsoil: 1.88 inches 2. Clean Fill: 6.02 inches 3. Top of Drainage Layer: 1.16 inches 4. Drainage Layer: 0.42 inch 5. LLDPE Liner: 0.00 inch 6. Drainage Layer: 0.22 inch 7. Waste Layer: 64.92 inches 8. On-Site Crushed Rock: 1.35 inches
Final Infiltration (gallons/acre/year)		
Infiltration through final layer of system	0.6	72,243.4

Table 2 Analysis of HELP Model Layers and Input Data

Summary of Input Parameters	Geosyntec	E&E
Cover Soil	Geosyntec uses the HELP model database and default values for a Type 1 material, or silty sand as the 2-foot thick cover material. (Layer 1)	E&E models the 2-foot cover soil similarly using parameters appropriate for a topsoil and clean fill cover system. (Layers 1 and 2)
Drainage Layer	A 0.2-inch geocomposite material is used to model the monofilament drainage layer. Default drainage layer soil values are used. These values appear to appropriately represent a drainage layer. The effective saturated hydraulic conductivity is much higher than that of the soil drainage layer modeled by E&E. This shows that the water is able to infiltrate more quickly and is shed through a lateral drain, thus decreasing the amount of head on the layer below. (Layer 2)	An 18-inch drainage system is modeled by a 12-inch-thick layer of 1-inch minus aggregate underlain by a 6-inch-thick layer of 3/8-inch minus aggregate. The drainage material is modeled after typical gravel parameters. (Layers 3 and 4)

Table 2 Analysis of HELP Model Layers and Input Data (Continued)

Summary of Input Parameters	Geosyntec	E&E
FML	The FML is modeled using HELP model provided input parameters for a HDPE 60-mil liner. The liner is modeled to be nearly impervious with exception to pinhole density, installation defects, and placement quality. The HELP user manual (Vol. 3) recommends a pinhole density of 0.5 to 1 holes per acre. The model output shows a higher value, but would most likely have negligible effects to the results. (Layer 3)	The FML is modeled using HELP model provided input parameters for an LLDPE 40-mil liner. The liner is modeled to be nearly impervious with exception to pinhole density, installation defects, and placement quality. The inputs are typical parameters used to represent material and construction errors. (Layer 5)
GCL	Modeled as a 0.23-inch barrier soil liner with very low permeability. The model shows infiltration through the combination of the HDPE and GCL system to be nearly 0. Minimal infiltration with the HDPE and GCL combination is feasible. (Layer 4)	Not included in model.
Aggregate Layer	Not included in model.	Additional 4-inch aggregate layer separating the LLDPE liner from the waste soils. Typical input parameters for 3/8-inch minus aggregate used. (Layer 6)
Waste Layer	The 40-foot waste layer was modeled by using HELP database parameters for a silty sand type material with relatively high permeability. (Layer 5)	The 38-foot waste layer was modeled using similar soil values to those of Geosyntec with the exception of a lower permeability value representative of a material with a larger fines content. (Layer 7)
Rock Layer	The final rock layer is modeled using typical gravel soil parameters provided by the HELP database. The soil parameters are identical to the E&E rock layer, with exception to thickness. However, the thickness of the rock layer has no bearing on the amount of infiltration that percolates through the liner system above. (Layer 6)	The final rock layer is modeled using typical gravel soil parameters provided by the HELP database. The soil parameters are identical to the Geosyntec rock layer, with exception to thickness. However, the thickness of the rock layer has no bearing on the amount of infiltration that percolates through the liner system above. (Layer 8)
Precipitation Data	Generated from HELP database, identical to E&E input	Generated from HELP database, identical to Geosyntec input
Temperature Data	Generated from HELP database, similar to E&E input, slight but negligible variation in project area latitudes.	Generated from HELP database, similar to Geosyntec input, slight but negligible variation in project area latitudes.
Solar Radiation Data	Typical model generated parameters.	Typical model generated parameters.
Evapotranspiration Data	Generated from HELP database, identical to E&E input	Generated from HELP database, identical to Geosyntec input
General Design Data	Modeled with steady state flow through the cap, typical curve number and grade.	Modeled with steady state flow through the cap, typical curve number and grade.
Infiltration Results	0.6 gallon/acre/year	72,243 gallons/acre/year

4.1 Hand Calculations

Hand calculations were performed by Weston to validate the HELP models. Weston contacted EPA HELP model representatives to determine the best method to manually check the HELP computer program to validate model computations. The EPA HELP representatives relayed that there is not a simplified way to check the entirety of the model. Therefore, a representative suggested checking other various input parameters.

The following is a hand calculation checking the effective saturated hydraulic conductivity of a gravel layer using equations (A-6) of the HELP User's Guide, Vol 3 (EPA, 1994a). The soil parameter inputs are shown on Table 1, Default: Low Density Soil Characteristics of HELP User's Guide Vol for Sandy Soils (Soil Texture Class 1).

$$K_s = \left(\frac{g}{\nu}\right)\left[\frac{n^3}{(1-n)^2}\right]\left(\frac{d_g^2}{1.80\times10^4}\right) \qquad \text{(A-6)}$$

Where K_s= saturated hydraulic conductivity in centimeters per second (cm/sec) and K_s=0.01 cm/sec (for SP)

g= acceleration due to gravity = 981 cm/sec^2

ν= kinematic viscosity of water $1.14\text{x}10^{-2}$ cm^2/sec at 15 degrees Celsius

n= total porosity (0.417) (given value for SP)

Solving for d_g (geometric mean soil particle diameter in millimeters [mm]) using equation A-6, $d_{g=}1$ mm, which is defined as a sand on the Unified Soil Classification System classification chart. The calculation shows a correct relationship between total porosity, grain size and saturated hydraulic conductivity.

5.0 CONCLUSIONS

Weston re-computed and analyzed the two HELP models as provided by Geosyntec and E&E. The two models show different monofill cap designs as well as highly variable infiltration rates through the proposed caps and into the groundwater. Weston found no errors after re-computing the given HELP parameters in the models because the output remained the same. Cost and construction feasibility differences were not analyzed in this report.

Geosyntec provides a cap design that includes 2 feet of vegetative cover, an efficient geocomposite drainage layer, and a 60-mil HDPE liner underlain by a GCL. The soil parameter model input was primarily based on the HELP database, which represents typical material property values.

E&E provides a monofill cap design that includes 2 feet of vegetative cover or clean fill, a drainage layer consisting of gravel, and a 40-mil LLDPE liner. The soil parameter model input varied slightly from the HELP database material properties, but were still within typical industry material values. The LLDPE liner is designed to be bedded in gravel. This technique is not typical because the gravel can cause pressure points and possibly rupture the liner. Sand bedding or a protective layer of fabric may be more appropriate and provide better protection of the LLDPE liner.

The E&E report mentions that the monofill material be compacted in 6- to 12-inch lifts (E&E, 2017). Compaction can be addressed in the HELP model by decreasing the porosity of the material identified to be compacted. The E&E model shows the waste characteristics to be a silty sand material with a porosity of 0.4570 vol/vol. This value is typical for a silty sand, but slightly conservative for a compacted material. The increase in porosity may result in a greater amount of infiltrate transferred into the lateral drains in the modeled drainage layer. Geosyntec models the waste layer with the same porosity, but most of the infiltrate is captured through the drainage layer before it percolates through the waste layer, which is discussed below.

The precipitation data for both models were identical; therefore, the major differences between the two models lie in the material properties of the drainage layers, drainage layer length, and the addition of a GCL in the Geosyntec model. A larger amount of infiltrate was collected and transferred off the landfill in the Geosyntec lateral drainage system (59.08 inches/year) than in the E&E design (38.58 inches/year). If the infiltrate is not transferred off the landfill, it builds up on top of the FML. The corresponding head build up is a major driving force of infiltration through a FML, such as the HDPE or LLPDE liners. Because a smaller amount of drainage was collected through the E&E lateral drainage system, a larger amount of head (average of 0.471 inch/year) is shown to build up on the LLDPE layer, which subsequently leads to infiltration through the liner and into the waste layer.

However, the smaller amount of head build up (average of 0.099 inch/year) coupled with two nearly impervious layers (HDPE and GCL) in the Geosyntec model results in minimal infiltration through the base layer. Even without the addition of the GCL in the Geosyntec design, only a small amount of infiltrate would seep through the base layer because of the efficiency of the drainage system. Similarly, the addition of the geocomposite drainage system to the E&E model would significantly decrease the amount of infiltration into the groundwater.

6.0 REFERENCES

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