A-Mehr Inc.

Professional Engineers and Scientists Specializing in Landfills

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October 26, 2021

Mr. Sage Kiyonaga, P.E.
Department of Environmental Management
Solid Waste Division
County of Maui
2200 Main Street, Suite 225
Wailuku, Hawaii 96793

SUBJECT: PHASES 5 AND 6 LINER EQUIVALENCY DEMONSTRATION
MOLOKAI INTEGRATED SOLID WASTE MANAGEMENT FACILITY
SOLID WASTE MANAGEMENT PERMIT LF-0070-09

Dear Mr. Kiyonaga:

On October 25, 2021, Mr. Glenn Haae of the Department of Health (DOH), Solid Waste Section made an enquiry regarding if an alternate liner equivalency demonstration would be submitted for the Phase 5 and 6 Disposal Area liner design. A-Mehr, Inc. has prepared this response to the enquiry.

The Phase 5 and 6 Disposal Area liner design, as presented in the Design Report portion of the SWMP application, consists of the following components (from bottom to top):

- A prepared subgrade consisting of native soil and rock, covered with a leveling layer of compacted soil as needed to provide a firm and smooth subgrade;
- A minimum 12-inch-thick layer of compacted low-permeability soil with a maximum hydraulic conductivity of 1.0 x 10^{-6} cm/sec; and
- A geomembrane liner of 80 mil high density polyethylene (HDPE).

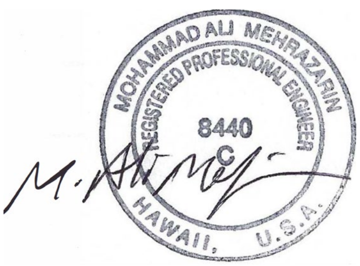
The use of this alternate liner design was addressed during the permitting process for the Phase 3 and Phase 4 Disposal areas, prior to its first use in the Phase 3 liner construction and its subsequent use in the Phase 4 liner construction. The Phase 3 and Phase 4 liner system design equivalency to prescriptive liner as defined in HAR 11-58.1-14(c) was presented for the proposed Phase 5 and Phase 6 liners as part of the current SWMP application since the liner design for Phase 5 and Phase 6 is identical to liners constructed for the existing Phases 3 and 4.

Attached response letter dated April 20, 2020 to DOH and their consultant Tetra Tech addressed the applicability of the Site-Specific Groundwater and Leachate Monitoring Plan presented in Appendix D of the Operations Plan portion of the SWMP application that includes the contaminant fate and transport modeling conducted to demonstrate the liner design used for Phases 3 and 4 and proposed Phases 5 and 6 provides protection of the underlying groundwater resources and satisfies the point of compliance criteria and is equivalent to the prescriptive liner as defined in HAR 11-58.1-14(c). Please see the highlighted comment and our response in the attached.

Appendix C of the Phase 3 Design Report included the attached Composite Liner Equivalency Demonstration, April 20, 2007, comparing the performance of this alternate liner design to the prescriptive liner as defined in HAR 11-58.1-14(c). This analysis and demonstration documents that the alternate liner design, under the site-specific conditions of arid location and steepened liner slope, provides performance that is effectively equivalent to the prescriptive liner. The equivalency demonstration is equally applicable to the Phase 5 and Phase 6 liner, and this letter is provided to certify this applicability.

Should you have any questions, please contact me at 949-206-0157.

Sincerely,



A-Mehr, Inc.
M. Ali Mehrazarin, P.E.
Principal Engineer

A-Mehr Inc.

Professional Engineers and Scientists Specializing in Landfills

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April 20, 2020

Mr. Sage Kiyonaga, P.E.
Department of Environmental Management
Solid Waste Division
County of Maui
2200 Main Street, Suite 225
Wailuku, Hawaii 96793

SUBJECT: RESPONSE TO COMMENTS, PHASE 5 & 6 SWFP APPLICATION
MOLOKAI INTEGRATED SOLID WASTE MANAGEMENT FACILITY
SOLID WASTE MANAGEMENT PERMIT LF-0070-09

Dear Mr. Kiyonaga:

A-Mehr, Inc., at the request of the County of Maui, has reviewed comments received via email on February 10, 2020 from Mr. Glenn Haae of the Department of Health (DOH), Solid Waste Section. The comments pertained to the Phase 5 & 6 SWFP Application and were a compilation of comments from DOH and their consultant Tetra Tech.

This letter and attachments are submitted in response to these comments. The responses reflect and follow the order of the comments as they were received in the February 10, 2020 DOH email.

<u>Tetra Tech Site Inspection/Design Review</u>

Tetra Tech performed a site inspection of the Molokai ISWMF on November 07, 2019, following are the observations from that inspection:

- Lysimeter is actually a leachate trench; therefore, the permit will indicate that the lysimeter is actually leachate trench.

  <u>Response:</u>
  It is our understanding the comment pertains to the existing Phase 2 lysimeter. Comment noted.

- Need plans on new leachate outfall as described in the field. Will new outfall be discharged to new sump or outside containment tank/sump. What will the protocols and/or control systems be to ensure that a maximum head of 30 cm will not occur over the liner if no automatic discharge equipment is installed?

  <u>Response:</u>
  The new Phase 5 LCRS sump located in the south corner of the Phase 5 lined area is described in Section 3.2, page 2, Design Report and the details of construction are illustrated in Design Drawings 4, 8, 12,

and 12A. This new sump will service the new lined areas of Phase 5 and Phase 6, and will also receive leachate flows from Phase 1 and Phase 2 as discussed on Section 3.2, page 3, Design Report.

Leachate levels are regularly monitored at each LCRS sump as discussed in Sections 8 and 14, Operations Plan. Monitoring of the leachate levels in the Phase 5 LCRS sump will be similar to the existing LCRS collection points, which has proved to be reliable in preventing leachate levels in excess of 30 cm on the liner, and is discussed in Section 8.1.4, Operations Plan.

Like the existing Phase 1 wet well and the Phase 3 sump, a submersible electric pump will be installed in the Phase 5 vertical riser and used to remove leachate periodically as needed to prevent leachate levels on the liner outside the limits of the LCRS sump from exceeding 30 cm. Leachate will be pumped from the sump into a tanker truck and transported to the County wastewater treatment plant for final disposal.

- How will the Phase 2 leachate (lysimeter) riser be abandoned?

  Response:
  Figure 7, Operations Plan illustrates the as-built condition of the Phase 2 lysimeter. When the Phase 6 liner is constructed, the lysimeter will be excavated to expose the edge of the Phase 2 compacted soil liner and the lysimeter riser pipe will be exposed and removed at this time. The remaining horizontal section of the lysimeter will be fitted with a temporary end cap with a drain line discharging to a temporary storage tank to prevent buildup or spillage of leachate. The Phase 6 compacted soil and geomembrane liners will be tied into the Phase 2 liners. A gravel filled LCRS trench equipped with a perforated 8-inch diameter HDPE pipe will be extended from the Phase 5 LCRS sump to the Phase 2 lysimeter. The perforated HDPE pipe will be connected to the end of the horizontal section of the Phase 2 lysimeter, and the drainage rock in the Phase 6 trench will be joined with the drainage rock in the Phase 2 lysimeter. Upon completion of the connection of the Phase 6 LCRS trench/pipe to the Phase 2 lysimeter trench/pipe, all leachate generated within Phase 2 will drain to the Phase 5 LCRS sump.

- Please submit information on the closure of the existing green waste operation; and of the proposed green waste operation, including design and operation.

  Response:
  The County, under a submittal independent of this application process, will submit a Closure Plan for the existing greenwaste operational area.

- How will assurance be provided that all organics will be removed such that remaining surface conditions are suitable for landfill construction. Will this be done during green waste closure or landfill construction?

  Response:
  The greenwaste operation has only received and processed clean greenwaste (yard trimmings, tree trimmings, etc.) and clean pallets. Composting has not been conducted at the facility. Therefore, soil contamination is not expected to be a significant concern.

  Construction of the Phase 5 and Phase 6 liner areas requires excavation of approximately 65,000 cy, which represents an average cut below the existing surface of approximately 6 feet. Approximately 500 cy of excavated soil will be utilized for structural fill in construction of the lined area. The balance of the excavated soils will be utilized for cover soil in the landfill operation.

During the initial excavation, the soil will be monitored for staining or discoloration and such soils will be transported to the active landfill area and stockpiled for use as daily cover. Only soils located below any staining or discoloration horizon will be utilized for structural fill.

Tetra Tech General Comments on HAR Requirements Checklist

- Current permit includes Molokai Metals (salvage yard) and the redemption center/recycling operation. The County has expressed a desire to obtain separate coverage for these operations and remove them from the permit, however, no documentation in the application is provided to request this removal.

  Response:
  The County has not made a final determination on the question of seeking separate permit coverage for the subject operations.

- 58.1-04, #1: Clean Air – no permit is noted in documentation. Is there a current permit?

  Response:
  HAR 11-60.1-62 exempts operating municipal waste landfills with a design capacity equal to or greater than 1,500,000 metric tons from the requirement to obtain an air permit. The volumetric design capacity of the MISWMF landfill is 837,200 cy (Section 5.1, Operations Plan). Density of landfilled waste at the MISWMF landfill has averaged approximately 583 lbs/cy for the period of April 16, 2013 through April 17, 2019 (Section 4.7, Operations Plan). Applying this average density to the landfill volumetric design capacity results in a design capacity of approximately 221,900 metric tons; which is substantially below the referenced threshold for requiring a permit.

- 58.1-14, #1: MSWLF Design Criteria, Information was not included in the Design Report for the liner design. Current proposed liner design for Phases 5 and 6 is same as Phases 3 and 4 which is not prescriptive as it includes a low-perm soil layer at $1x10^{-6}$ and prescriptive is $1x10^{-7}$. The landfill is currently exempt (small community landfill), however, if the County anticipates no longer meeting this exemption, justification for the alternative liner may be provided in the current application but is optional.

  Response:
  Comment noted. The Site-Specific Groundwater and Leachate Monitoring Plan, Appendix D, Operations Plan, discusses the contaminant fate and transport modeling conducted to demonstrate the liner design used for Phases 3 and 4, and proposed for Phase 5 and 6, provides protection of the underlying groundwater resources and satisfies the point of compliance criteria. The results of this evaluation indicate the liner design provides protections to the underlying groundwater in a manner that is equivalent to or exceeds that of the prescriptive liner as defined in HAR 11-58.1-3.

- 58.1-15, #2: Cover Material, Alternative Daily Cover - Tarps are currently approved. The County is requesting use of green waste mulch as ADC, however, DOH recommends that materials that are compostable be recycled and reused rather than being placed in a landfill.

  Response:
  Comment noted. The County concurs with the DOH recommendation to recycle greenwaste to the maximum extent possible and avoid placing the material in the landfill. However, the supply of greenwaste mulch product oftentimes exceeds the demand for the product and results in an

accumulation of product on site. In addition to giving mulch away to residents free of charge, the County beneficially utilizes mulch as an erosion control blanket on the interim landfill slopes, but the County respectively maintains their request for authority to utilize greenwaste mulch as ADC.

- 58.1-15, #7: Run-on and run-off control systems: Ops Section 4.10, Design Report Section 5.2, Appendix D. Propose channels along the west side of proposed Phases 5 and 6. During construction of Phase 5 the existing basin will be enlarged by approx. 200% (Figure 3). There are calculations supporting channel capacity for peak flows in the channel. There are no calculations provided supporting the basin routing capacity. Please provide these calculations.

  Response:
  The new expanded stormwater basin capacity of 6,861 cy (approximately 4.25 acre-feet) represents approximately 2.09 times the total run-off from the design storm event and is adequately sized. Attachment A provides an addendum to the Hydrology Report, Appendix D, Design Report with a calculation supporting the capacity of the new stormwater basin improvements.

- 58.1-16, #4: Sampling and Analysis Requirements: Ops Section 4.11.2, Appendix D. Leachate monitoring at 5 locations. Plan should be updated to include monitoring for Phases 5 and 6 upon construction. The plan should include how background groundwater data will be collected; DOH prefers this data prior to waste placement.

  Response:
  Attachment B provides an edited page 4-10, Operations Plan noting the leachate monitoring locations will change over time as Phase 5 and Phase 6 are constructed.

  In regards to the collection of background groundwater data, the MISWMF is exempt from groundwater monitoring requirements as discussed in Section 4.11.1, Operations Plan. In the event that groundwater monitoring is required in the future, the County will install upgradient and downgradient wells consistent with applicable regulations and site-specific conditions.

  In the Site-Specific Groundwater and Leachate Monitoring Plan, Appendix D, Operations Plan it is documented that impacts to groundwater related to the landfill will most likely originate from the LCRS sumps. Therefore, the LCRS system design includes pan lysimeters under the sumps for early groundwater monitoring. If there are issues with the lysimeters then the County will install groundwater wells if required.

- 58.1-17, #2: Written Closure Plan: Closure and Post-Closure Plan Section 5.3.2 Appendix A. ET cover, 1' vegetative soil and 2' of compacted soil. A demonstration of equivalency will be provided in a future revision of this Closure Plan.

  Response:
  Comment noted. Equivalency demonstration will be submitted at a future date as noted.

- 58.1-18, #6: Financial Assurance for Corrective Action (CA): no discussion of CA financial assurance in any of the submittals. Please provide.

  Response:
  MISWMF is a publicly owned County landfill and financial assurance documentation is submitted annually. Attachment C contains the most recent financial assurance documentation.

Tetra Tech General Comments on Seismic Stability Analysis, Molokai Integrated Solid Waste Facility, May 2019, A-Mehr (Appendix C of the October 2019 Design Report)

Overall, the methodology, input data, and results of slope stability analyses are acceptable. The following comments are provided for the Consultant's consideration:

- Please clarify how the estimated peak ground acceleration of 0.31g was obtained for the design earthquake (i.e., an earthquake with a 2,475-year return period or 2% probability of exceedance in 50 years). The report referred to Figure 1 for the estimated design PGA. However, it appears Figure 1 shows the grading plan and cross-section locations for the facility. Note, the reviewer estimated the design PGA using the USGS Unified Hazard Tool and ASCE 7 Hazard Tool, and the adopted PGA of 0.31g is acceptable.

  Response:
  An update to the Appendix B, Operations Plan is attached (Attachment D) which incorporates and references Figure 1A and which was used to estimate the PGA for the project location.

- The Consultant used a seismic coefficient of 0.16g, which is about 50 percent of the design PGA, in accordance with the recommendations presented in EPA (1995). The current standard of practice for seismic slope stability evaluation is to estimate the seismic coefficient based on the seismic deformation design criteria (typically 6 to 12 inches for the landfill liner system) using the procedures outlined by Bray and Travasarou (2011).

  Response:
  Based on our slope stability analysis, the project will be stable during the design seismic event. Further, based on the EPA approved analyses procedures no seismic deformation is expected for this project, and therefore, the seismic deformation analysis procedures are not applicable for the project.

- A friction angle of 18 degrees was assigned to the base liner, which is conservative. Per the database by Koerner (2005), a peak shear strength with a friction angle of up to 25 degrees may be considered for the critical base liner interface between low permeability soil layer and 80 mil textured HDPE geomembrane.

  Response:
  During the design stage, we prefer to be more conservative with our analysis and use lower shear strength values.

- In Table 2, no cohesion value was assigned to the liner system. However, it appears that a cohesion of 50 psf was assigned to the base liner as shown in the computer output sheets for each cross-section. Please clarify.

  Response:
  Table 2 of the updated Appendix B, Operations Plan (Attachment D) is revised to include the cohesion of 50 psf assigned to the liner system as shown in the computer output sheets.

- Please verify/confirm that the Spencer's Method was used to calculate the critical static and pseudostatic Factor of Safety for cross-section 1-1. The "Modified Bishop Method" was labelled in the computer output sheets for the static FS = 2.39 and pseudostatic FS = 1.35.

Response:

The lowest safety factor using Spencer's Method resulted in static FS= 2.38 and pseudostatic FS= 1.32 for cross-section 1-1. The summary of analysis results presented in the attached Appendix B, Operations Plan (Attachment D) is updated to include the method of slope stability analyses and these results.

- Please verify/confirm the yield acceleration of 0.16g as indicated in the Table for Final Analysis – Spencer's method of slices. It appears that the 0.16g is the seismic coefficient used for pseudostatic analyses, and it is not the calculated yield acceleration. Please include the calculated yield acceleration for each cross-section as appropriate.

Response:

The slope stability analyses presented in Appendix B, Operations Plan (Attachment D) meets the industry standards and the regulatory requirements. The slope stability analyses indicate that Molokai Landfill meets and exceeds the State and Federal regulations. The 0.16g is the seismic coefficient used for pseudostatic analyses. As requested we calculated yield acceleration for the critical failure surfaces for the cross sections 1-1, 2-2, and 3-3 to be 0.26g, 0.27g, and 0.18g respectively (see Attachment E) and these values inherently should be and are higher than the required design seismic coefficient of 0.16g.

- Please clarify the groundwater conditions in the report text or in the computer output sheets in Appendix B. In the output sheets, the piezometer surface is designated as "W1". However, the surface "W1" was not presented in the cross-sections.

Response:

Groundwater below the landfill is estimated to be at least 175 feet below the liner grades and in the hard bedrock. The output file default print out includes this generic information

Should you have any questions, please contact me at 949-206-0157.

Sincerely,

M. Ali Meh

A-Mehr, Inc.
M. Ali Mehrazarin, P.E.
Principal Engineer

Phase 3 Design Report

Appendix C

HELP Model Results and

Composite Liner Equivalency Demonstration

COMPOSITE LINER EQUIVALENCY DEMONSTRATION
Molokai Integrated Solid Waste Facility
Phase 3 Disposal Cell
April 20, 2007

Objective

Determine whether the performance of the alternative liner and leachate collection system proposed for Phase 3 of the Molokai Integrated Solid Waste Facility is effectively equivalent to the prescriptive liner system as defined in HAR 11-58.1-14.

Proposed Design

The proposed Phase 3 liner system consists of the following components, listed from bottom to top:

- Prepared subgrade;
- Barrier layer consisting of one (1) foot of compacted native soil, maximum permeability 1.0 x 10^{-6} cm/sec;
- 80-mil HDPE geomembrane;
- 16-ounce / square yard non-woven geotextile;
- Drainage layer consisting of one (1) foot of LCRS gravel; and
- Two (2) feet of protective cover soil.

The prescriptive liner system would consist of:

- Prepared subgrade;
- Barrier layer consisting of one (2) feet of compacted native soil, maximum permeability 1.0 x 10^{-7} cm/sec;
- 60-mil HDPE geomembrane;
- 16-ounce / square yard non-woven geotextile;
- Drainage layer capable of achieving a maximum of 30 cm (12 inches) of hydraulic head on the liner; and
- Two (2) feet of protective cover soil.

Analytical Method

The proposed design has liner grades sloping at 5 percent. The maximum hydraulic head on the liner system has been evaluated using the HELP model, based on a 5-year simulation assuming 5 feet of refuse in the landfill, representing the worst-case conditions for leachate generation. To determine equivalency with the prescriptive liner, the leakage rate through the liner system will be computed using the same assumed properties of the geomembrane, combined with the maximum allowable hydraulic head on the liner (30 cm) allowed under HAR 11-58.1-14. If the computed leakage through the proposed alternative liner is equal to or less than that computed for the prescriptive liner, then the alternative will be deemed equivalent to the prescriptive.

Analysis

The HELP model analysis of Phase 3 with the proposed liner system (Attachment A) computed the maximum head on the liner system to be 0.004 inches. To be conservative, assume a head of 1.0 inch for the proposed design (factor of safety of 250).

An accepted equation for estimating leakage or percolation through a composite liner system (Giroud et. al., 1998)[1] is:

$Q = 0.21\ H^{0.9} A^{0.1} K^{0.74}$ where:

Q = flow rate (m^3/s)
H = hydraulic head on liner (m)
A = area of hole in liner (m)
K = hydraulic conductivity of soil liner (m/s)

For the prescriptive liner with the maximum allowable head (30 cm)::

$H = 30\ cm = 0.30\ m$
$A = 1.0\ cm^2 = 1.0 \times 10\text{-}^4\ m^2$
$K = 1.0 \times 10^{-7}\ cm/sec = 1.0 \times 10^{-9}\ m/sec$

$Q = 0.21\ (0.30)^{0.9} (1.0 \times 10\text{-}^4)^{0.1} (1.0 \times 10^{-9})^{0.74}$
$Q = .21\ (0.338)\ (0.398)\ (2.18 \times 10^{-7})$
$Q = 6.16 \times 10^{-9}\ m^3/s$

For the proposed alternative liner with a 5 percent slope:

$H = 1\ inch = 2.54\ cm = 0.0254\ m$
$A = 1.0\ cm^2 = 1.0 \times 10\text{-}^4\ m^2$
$K = 1.0 \times 10^{-6}\ cm/sec = 1.0 \times 10^{-8}\ m/sec$

$Q = 0.21\ (0.0254)^{0.9} (1.0 \times 10\text{-}^4)^{0.1} (1.0 \times 10^{-8})^{0.74}$
$Q = .21\ (0.0367)\ (0.398)\ (1.20 \times 10^{-6})$
$Q = 3.68 \times 10^{-9}\ m^3/s$

For heads greater than 1 inch, this result may be multiplied by the factor $H^{0.9}$, where H is the head in inches. For heads of 1, 2, 6 and 12 inches this results in the following estimated leakage rate and rate relative to leakage from the prescriptive liner:

Head (in.)	$H^{0.9}$	Leak Rate, m^3/s	$Q_{alt}/Q_{prescriptive}$
1	1	3.68×10^{-9}	0.60
2	1.86	6.84×10^{-9}	1.11
6	5.02	18.5×10^{-9}	3.00
12	9.36	34.4×10^{-9}	5.60

[1] Giroud, J.P., Khatami, A., and K. Badu-Tweneboah (1989), "Evaluation of the Rate of Leakage through Composite Liners," Geotextiles and Geomembranes, Vol. 8, pp. 337-340.

Based on this conservative analysis, the alternative design constructed on cell floor with a 5 percent slope has a lower potential for leakage than the prescriptive liner with the allowable 30 cm head on the liner. In addition, the order of magnitude of leakage is within an order of magnitude of the prescriptive liner, for up to 12 inches of head.

Given the extremely low leak rates projected in the relative comparison presented above, it is appropriate to consider the actual magnitude of leakage the equation would project from a cell the size of Phase 3. For this analysis, the area of the pinhole is assumed to be 1.0 cm^2, the value used in the HELP model[2], with a pinhole density of one per acre for a liner installed with a high level of quality control. The resulting estimates of leakage from the 2-acre Phase 3 area are:

Prescriptive Liner, 12 inches head

$$Q = 6.16 \times 10^{-9}\ m^3/s/acre \times 2\ acres = 1.23 \times 10^{-8}\ m^3/s$$
$$Q = 1.23 \times 10^{-8}\ m^3/s \times 2.28 \times 10^{7}\ gal/day / m^3/s = 0.28\ gal/day$$

Alternative Liner, 12 inches head

$$Q = 34.4 \times 10^{-9}\ m^3/s/acre \times 2\ acres = 6.88 \times 10^{-8}\ m^3/s$$
$$Q = 6.88 \times 10^{-8}\ m^3/s \times 2.28 \times 10^{7}\ gal/day / m^3/s = 1.56\ gal/day$$

Either of these values are exceptionally low for a 2-acre area, equivalent to .0000051 inches/day and 0.000029 inches/day, respectively, of leakage spread across the cell area. In addition, the likelihood of the Phase 3 cell experiencing a 12-inch head is extremely small, due to the semi-arid climate of Molokai, the 5 percent slope on the floor of the cell, and regular monitoring and pumping of leachate from the sump. For comparison, the HELP model simulation of Phase 3 predicted a maximum daily average head of 0.002 inches in a 5-year simulation with 5 feet of waste in the cell.

Based on these results, it is concluded that the alternative liner system is effectively equivalent to the prescriptive liner.

To further verify and demonstrate the suitability of the proposed liner system in practice, A-Mehr, Inc. recommends construction of a lysimeter to monitor for potential leakage below the most sensitive area of the liner. The lysimeter would cover two specific areas:

- The leachate collection sump, which will be constructed with additional layers of liner in order to hold up to five (5) feet of liquid before being pumped; and
- The area of single-lined cell immediately upgradient and adjacent to the sump.

Monitoring of the lysimeter would detect any leakage from the liner and provide a basis for reducing the allowable head on the liner.

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[2] The Hydrologic Evaluation of Landfill Performance (HELP) Model, Engineering Documentation for Version 3. Schroeder, Paul R et. al. U.S. Army Corps of Engineers, September 1994.

Project : Molokai Landfill Phase 3

Open Cell

Model : HELP
A US EPA model for predicting landfill hydrologic processes and testing of effectiveness of landfill designs

Author : Ali Mehrazarin, P.E.

Client : County of Maui

Location : Molokai Landfill

Description:

Estimates of leachate generation, head on the liner system and percolation through the liner system are computed using:

- Five (5) feet of municipal solid waste covered by six inches of cover soil;
- Proposed liner and leachate collection system for Molokai Landfill Phase 3
- 5-year synthetic climate data base generated using monthly average rainfall and temperature data for Molokai Airport in combination with other default parameters for Honolulu.

Results are presented in units of inches.

Summary of Results:

Parameter	Average, Years 1-5 (inches)	Peak Daily Value, Years 1-5 (inches)
Precipitation	35.9	4.02
Runoff	3.50	2.21
Evapotranspiration	32.4	n/a
Leachate Collected	0.101	0.00096
Average Head on Liner	0.001	0.002
Maximum Head on Liner	n/a	0.004
Percolation/Leakage through Liner System	$< 1.0 \times 10^{-5}$	$< 1.0 \times 10^{-6}$

2/23/2007

1. Profile. Molokai Phase 3 Cell

Model Settings

[HELP] Case Settings

Parameter	Value	Units
Runoff Method	Model calculated	(-)
Initial Moisture Settings	Model calculated	(-)

[HELP] Surface Water Settings

Parameter	Value	Units
Runoff Area	100	(%%)
Vegetation Class	Bare soil	(-)

Profile Structure

Layer	Top (ft)	Bottom (ft)	Thickness (ft)
Silty Loam	29.5028	29.0028	0.5000
Municipal Waste (312 kg/cub.m)	29.0028	24.0028	5.0000
Loamy Sand1	24.0028	22.0028	2.0000
Gravel	22.0028	21.0028	1.0000
High Density Polyethylene (HDPE)	21.0028	20.9995	0.0033
Barrier Soil	21.0000	20.0000	1.0000
Loamy Sand	20.0000	10.0000	10.0000

1.1. Layer. Silty Loam

Top Slope Length: 200.0000
Bottom Slope Length: 0.0000
Top Slope: 3.0000
Bottom Slope : 0.0000

[HELP] Vertical Perc. Layer Parameters

Parameter	Value	Units
total porosity	0.501	(vol/vol)
field capacity	0.284	(vol/vol)
wilting point	0.135	(vol/vol)
sat.hydr.conductivity	1.0E-03	(cm/sec)
subsurface inflow	0	(mm/year)

1.2. Layer. Municipal Waste (312 kg/cub.m)

Top Slope Length: 0.0000
Bottom Slope Length: 0.0000
Top Slope: 0.0000
Bottom Slope : 0.0000

[HELP] Vertical Perc. Layer Parameters

Parameter	Value	Units
total porosity	0.671	(vol/vol)
field capacity	0.292	(vol/vol)
wilting point	0.077	(vol/vol)
sat.hydr.conductivity	0.001	(cm/sec)
subsurface inflow	0	(mm/year)

1.3. Layer. Loamy Sand1

Top Slope Length: 0.0000
Bottom Slope Length: 0.0000
Top Slope: 0.0000
Bottom Slope : 0.0000

[HELP] Vertical Perc. Layer Parameters

Parameter	Value	Units
total porosity	0.437	(vol/vol)
field capacity	0.105	(vol/vol)
wilting point	0.047	(vol/vol)
sat.hydr.conductivity	0.0017	(cm/sec)
subsurface inflow	0	(mm/year)

1.4. Layer. Gravel

Top Slope Length: 0.0000
Bottom Slope Length: 600.0000
Top Slope: 0.0000
Bottom Slope : 5.0000

[HELP] Lateral Drainage Layer Parameters

Parameter	Value	Units
total porosity	0.397	(vol/vol)
field capacity	0.032	(vol/vol)
wilting point	0.013	(vol/vol)
sat.hydr.conductivity	1	(cm/sec)
subsurface inflow	0	(mm/year)

1.5. Layer. High Density Polyethylene (HDPE)

Top Slope Length: 600.0000
Bottom Slope Length: 600.0000
Top Slope: 5.0000
Bottom Slope : 5.0000

[HELP] Geomembrane Liner Parameters

Parameter	Value	Units
sat.hydr.conductivity	2E-13	(cm/sec)
pinhole density	1	(#/ha)
installation defects	1	(#/ha)
placement quality	2	(-)
geotextile transmissivity	0	(cm2/sec)

1.6. Layer. Barrier Soil

Top Slope Length: 600.0000
Bottom Slope Length: 0.0000
Top Slope: 5.0000
Bottom Slope : 0.0000

[HELP] Barrier Soil Liner Parameters

Parameter	Value	Units
total porosity	0.427	(vol/vol)
field capacity	0.418	(vol/vol)
wilting point	0.367	(vol/vol)
sat.hydr.conductivity	0.000001	(cm/sec)
subsurface inflow	0	(mm/year)

1.7. Layer. Loamy Sand

Top Slope Length: 600.0000
Bottom Slope Length: 0.0000
Top Slope: 0.5000
Bottom Slope : 0.0000

[HELP] Vertical Perc. Layer Parameters

Parameter	Value	Units
total porosity	0.437	(vol/vol)
field capacity	0.105	(vol/vol)
wilting point	0.047	(vol/vol)
sat.hydr.conductivity	0.00001	(cm/sec)
subsurface inflow	0	(mm/year)

Results

Annual Totals rate (inch)

	Year-1	Year-2	Year-3	Year-4
Precipitation (inch)	2.8590E+01	3.9640E+01	3.8700E+01	3.1490E+01
Runoff (inch)	8.3466E-01	5.3420E+00	5.9218E+00	1.5544E+00
Evapotranspiration (inch)	2.7656E+01	3.6502E+01	3.2302E+01	2.8953E+01
Change in water storage (inch)	9.4792E-02	-2.2178E+00	3.2928E-01	7.6485E-01
Water budget balance (inch)	-4.2938E-07	-5.9533E-07	-5.8122E-07	-4.7293E-07
Soil water (inch)	3.8910E+01	3.6692E+01	3.7022E+01	3.7787E+01
Snow water (inch)	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
Lateral drainage collected from Layer 4 (inch)	4.3513E-03	1.3997E-02	1.4709E-01	2.1776E-01
Percolation or leakance through Layer 6 (inch)	1.6693E-06	2.4950E-06	1.9607E-06	2.6738E-06
Average head on top of Layer 5 (inch)	2.5122E-05	8.1017E-05	8.5065E-04	1.2636E-03
Percolation or leakance through Layer 7 (inch)	1.7027E-06	2.4309E-06	2.4824E-06	3.4014E-06

(continued)

	Year-5	Total
Precipitation (inch)	4.1290E+01	1.7971E+02
Runoff (inch)	3.8761E+00	1.7529E+01
Evapotranspiration (inch)	3.6844E+01	1.6226E+02
Change in water storage (inch)	4.4660E-01	-5.8232E-01
Water budget balance (inch)	-6.2011E-07	-2.6990E-06
Soil water (inch)	3.8233E+01	1.8864E+02
Snow water (inch)	0.0000E+00	0.0000E+00
Lateral drainage collected from Layer 4 (inch)	1.2292E-01	5.0612E-01
Percolation or leakance through Layer 6 (inch)	2.5870E-06	1.1386E-05
Average head on top of Layer 5 (inch)	7.1541E-04	2.9358E-03
Percolation or leakance through Layer 7 (inch)	3.2145E-06	1.3232E-05

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07 (1 November 1997)                 **
**                DEVELOPED BY ENVIRONMENTAL LABORATORY                     **
**                  USAE WATERWAYS EXPERIMENT STATION                       **
**            FOR USEPA RISK REDUCTION ENGINEERING LABORATORY               **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE: C:\Documents and Settings\Ali M\Desktop\VHELP22\data\P7254.VHP_weather1.dat
TEMPERATURE DATA FILE: C:\Documents and Settings\Ali M\Desktop\VHELP22\data\P7254.VHP_weather2.dat
SOLAR RADIATION DATA FILE: C:\Documents and Settings\Ali M\Desktop\VHELP22\data\P7254.VHP_weather3.dat
EVAPOTRANSPIRATION DATA: C:\Documents and Settings\Ali M\Desktop\VHELP22\data\P7254.VHP_weather4.dat
SOIL AND DESIGN DATA FILE: C:\Documents and Settings\Ali M\Desktop\VHELP22\data\P7254.VHP\I_390673.inp
OUTPUT DATA FILE: C:\Documents and Settings\Ali M\Desktop\VHELP22\data\P7254.VHP\O_390673.prt

TIME: 16: 8 DATE: 3/20/2007

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TITLE: Molokai Phase 3 Cell

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NOTE: INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

LAYER 1

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 9
THICKNESS = 15.24 CM

POROSITY = 0.5010 VOL/VOL
FIELD CAPACITY = 0.2840 VOL/VOL
WILTING POINT = 0.1350 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.2138 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.100000000000E-02 CM/SEC
NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 5.00
FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 18
THICKNESS = 152.40 CM
POROSITY = 0.6710 VOL/VOL
FIELD CAPACITY = 0.2920 VOL/VOL
WILTING POINT = 0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.2797 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.100000000000E-02 CM/SEC

LAYER 3

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 4
THICKNESS = 60.96 CM
POROSITY = 0.4370 VOL/VOL
FIELD CAPACITY = 0.1050 VOL/VOL
WILTING POINT = 0.0470 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.1100 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.170000000000E-02 CM/SEC

LAYER 4

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 21
THICKNESS = 30.48 CM
POROSITY = 0.3970 VOL/VOL
FIELD CAPACITY = 0.0320 VOL/VOL
WILTING POINT = 0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.0320 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 1.00000000000 CM/SEC
SLOPE = 5.00 PERCENT
DRAINAGE LENGTH = 182.9 METERS

LAYER 5

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS = 0.10 CM
POROSITY = 0.0000 VOL/VOL
FIELD CAPACITY = 0.0000 VOL/VOL
WILTING POINT = 0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.200000000000E-12 CM/SEC
FML PINHOLE DENSITY = 1.00 HOLES/HECTARE
FML INSTALLATION DEFECTS = 1.00 HOLES/HECTARE
FML PLACEMENT QUALITY = 2 - EXCELLENT

LAYER 6

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 16

THICKNESS = 30.48 CM
POROSITY = 0.4270 VOL/VOL
FIELD CAPACITY = 0.4180 VOL/VOL
WILTING POINT = 0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.100000000000E-05 CM/SEC

LAYER 7

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 4

THICKNESS = 304.80 CM
POROSITY = 0.4370 VOL/VOL
FIELD CAPACITY = 0.1050 VOL/VOL
WILTING POINT = 0.0470 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.1050 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.100000000000E-04 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
SOIL DATA BASE USING SOIL TEXTURE # 9 WITH BARE

GROUND CONDITIONS, A SURFACE SLOPE OF 3.% AND
A SLOPE LENGTH OF 61. METERS.

SCS RUNOFF CURVE NUMBER = 91.97
FRACTION OF AREA ALLOWING RUNOFF = 100.0 PERCENT
AREA PROJECTED ON HORIZONTAL PLANE = 2.0234 HECTARES
EVAPORATIVE ZONE DEPTH = 45.7 CM
INITIAL WATER IN EVAPORATIVE ZONE = 10.290 CM
UPPER LIMIT OF EVAPORATIVE STORAGE = 28.087 CM
LOWER LIMIT OF EVAPORATIVE STORAGE = 4.404 CM
INITIAL SNOW WATER = 0.000 CM
INITIAL WATER IN LAYER MATERIALS = 98.591 CM
TOTAL INITIAL WATER = 98.591 CM
TOTAL SUBSURFACE INFLOW = 0.00 MM/YR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
Honolulu HI

STATION LATITUDE = 21.32 DEGREES
MAXIMUM LEAF AREA INDEX = 5.00
START OF GROWING SEASON (JULIAN DATE) = 0
END OF GROWING SEASON (JULIAN DATE) = 367
EVAPORATIVE ZONE DEPTH = 18.0 INCHES
AVERAGE ANNUAL WIND SPEED = 11.70 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY = 72.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY = 66.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY = 66.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY = 70.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR Honolulu HI

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.00	3.00	3.00	3.00	3.00	3.00
3.00	3.00	3.00	3.00	3.00	3.00

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR Honolulu HI

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC

72.60	72.90	74.40	75.70	77.50	79.10
80.10	81.00	80.60	79.50	76.60	74.00

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR Honolulu HI
AND STATION LATITUDE = 21.15 DEGREES

HEAD #1: AVERAGE HEAD ON TOP OF LAYER 5
DRAIN #1: LATERAL DRAINAGE FROM LAYER 4 (RECIRCULATION AND COLLECTION)
LEAK #1: PERCOLATION OR LEAKAGE THROUGH LAYER 6
LEAK #2: PERCOLATION OR LEAKAGE THROUGH LAYER 7

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 5

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	1.94	2.87	2.36	1.93	3.97	2.43
	4.57	2.33	3.87	2.84	3.52	3.33
STD. DEVIATIONS	0.68	3.03	0.90	1.47	3.04	1.27
	2.07	1.30	1.58	1.51	0.98	1.70
RUNOFF						
TOTALS	0.082	0.258	0.173	0.137	0.499	0.269
	0.508	0.231	0.729	0.151	0.305	0.164
STD. DEVIATIONS	0.074	0.426	0.230	0.286	0.513	0.452
	0.467	0.226	0.922	0.175	0.328	0.223
EVAPOTRANSPIRATION						
TOTALS	1.745	3.056	2.865	1.659	3.097	2.585
	3.906	2.194	3.194	2.548	3.275	2.327
STD. DEVIATIONS	0.596	1.520	1.281	0.906	1.976	1.531
	1.413	1.214	0.801	1.216	0.828	0.589
LATERAL DRAINAGE COLLECTED FROM LAYER 4						
TOTALS	0.0082	0.0072	0.0070	0.0064	0.0063	0.0062
	0.0085	0.0101	0.0104	0.0107	0.0102	0.0101
STD. DEVIATIONS	0.0106	0.0094	0.0098	0.0090	0.0088	0.0078
	0.0075	0.0095	0.0104	0.0109	0.0103	0.0101
PERCOLATION/LEAKAGE THROUGH LAYER 6						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 7						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 5

AVERAGES	0.0006	0.0005	0.0005	0.0005	0.0004	0.0004
	0.0006	0.0007	0.0007	0.0007	0.0007	0.0007
STD. DEVIATIONS	0.0007	0.0007	0.0007	0.0006	0.0006	0.0006
	0.0005	0.0007	0.0007	0.0007	0.0007	0.0007

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 5

	INCHES	CU. FEET	PERCENT
PRECIPITATION	35.94 (5.562)	652333.1	100.00
RUNOFF	3.506 (2.2521)	63628.50	9.754
EVAPOTRANSPIRATION	32.451 (4.2119)	588981.16	90.288
LATERAL DRAINAGE COLLECTED FROM LAYER 4	0.10122 (0.09103)	1837.170	0.28163
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00000 (0.00000)	0.041	0.00001
AVERAGE HEAD ON TOP OF LAYER 5	0.001 (0.001)		
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.00000 (0.00000)	0.048	0.00001
CHANGE IN WATER STORAGE	-0.116 (1.1993)	-2113.79	-0.324

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 5 and their dates (DDDYYYY)

	(INCHES)	(CU. FT.)	
PRECIPITATION	4.02	72961.40971	2600003
RUNOFF	2.209	40085.51176	2600003
DRAINAGE COLLECTED FROM LAYER 4	0.00096	17.51335	2920003
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000000	0.00014	2920003
AVERAGE HEAD ON TOP OF LAYER 5	0.002		
MAXIMUM HEAD ON TOP OF LAYER 5	0.004		
LOCATION OF MAXIMUM HEAD IN LAYER 4 (DISTANCE FROM DRAIN)	0.0 FEET		
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.000000	0.00660	2440001
SNOW WATER	0.00	0.0000	0
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3074		
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0963		

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 5

LAYER	(INCHES)	(VOL/VOL)
1	1.0988	0.1831
2	16.1972	0.2700
3	2.8289	0.1179
4	0.3842	0.0320
5	0.0000	0.0000
6	5.1240	0.4270
7	12.6000	0.1050

SNOW WATER 0.000

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