Redline / Strikeout Version

Part III, Appendix III-D.5-2

Slope Stability Analyses

Reference 1, 2 and 5 are updated in entirety, no redline provided

APPENDIX III-D.5-2

SLOPE STABILITY ANALYSES

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Updates August 2017

Appendix III-D.5-2, Slope Stability Analyses

- Updated calculations to match new landfill geometry

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APTIM	Client Name:	Rancho Viejo Waste Management, LLC		
	Project Name:	Pescadito Environmental Resource Center	**Project No.:**	148866
	~~Prepared~~ Modified by:	O. Covert~~P. Thomas~~	**Date** ~~Prepared~~Modifie	8/2/2017~~2/24/2015~~
	Reviewed by:	~~Jesse P. Varsho, PE~~ P. Thomas	**Date Reviewed:**	~~3/2/2015~~ 8/7/17

TITLE: SLOPE STABILITY ANALYSES

Problem Statement

Determine the factor of safety against slope failure during the construction, operation and closure periods of the landfill under static loading conditions. A factor of safety of 1.5 for static conditions is deemed acceptable (note the site is not located within a seismic hazard zone).

References

The referenced literature cited below is provided in the attached pages. Referenced site specific information is provided within the Application as stated below, and referenced documents specific to this analysis are provided in the attached pages.

1. Computer model SLIDE - 2D Limit Equilibrium Slope Stability Analysis, version 6.0, developed by Rocscience, Inc. was used for the stability analyses (attached pages)
2. Figure No. 1 presents the locations of the critical cross section selected (attached pages).
3. Landfill design specifications for layer types and thicknesses provided in the Summary of Geotechnical Design Parameters (contained in **Appendix III-D.5-1**).
4. Details of landfill systems provided in the Design Drawing Set contained in this Application.
5. SLIDE output plot files (attached pages).

Assumptions

Critical Cross Section

Cross Section A-A' as shown on **Figure No. 1** (see attached pages, **Reference No. 2**) was determined to be the most critical cross section for the global mass stability of the proposed landfill design. Cross Section A-A' is an idealized cross section, is orientated from ~~north to south~~south to north (left to right), ~~through the South Unit landfill~~ and is characterized by the following features:

- Peak final landform elevation of approximately ~~843~~ 704 ft MSL;
- Final cover sideslopes are 4H:1V with a 6% slope across the plateau;
- Cell excavation slope of 3H:1V; and
- Maximum waste column thickness of ~~380~~ 241 ft.

Note, that both the north and south edges of Section A-A' were evaluated for stability, but results for only the most critical edge (i.e., that which yielded the lowest safety factors) — the ~~south~~ north edge for global stability is presented. The ~~and~~ interim stability stages ~~and the north edge for~~ and the cell excavation/development stages were analyzed on the north edge because it will be developed and have waste placed there first~~, are presented herein~~.

Landfill Stages Analyzed and Modes of Failure

Stability of the landfill was analyzed for essentially three different landfill stages: complete landfill build-out / final landform, landfill cell excavation / development, and operational at interim waste fill heights. The three landfill stages were analyzed using two modes of failure within the SLIDE model — translational (non-circular / block) failure and rotational (circular) failure. The translational failure mode was used to analyze the stability of the liner system along critical (weak) interfaces; and the rotational failure mode was used to analyze the stability of the waste mass and the foundation.

Stability of Liner System by Translational Failure Mode. The stability of the liner system was evaluated by constraining the failure surfaces (generated by the SLIDE model) to occur within the liner system at the most critical interface. The SLIDE model was used to perform a block search for translational failure surfaces (i.e., non-circular failure surfaces that follow along a weak plane or interface). A constraining boundary was applied through the liner system along the base liner and sideslope liner at approximately mid-height within the SLIDE model. Failure surfaces were then generated through the liner layer, and the most critical failure surface was determined (i.e., lowest factor of safety).

Stability of Waste Mass and Foundation by Rotational Failure Mode. The stability of the waste mass and foundation was evaluated within the SLIDE model using a grid search to find the most critical circular failure surfaces within the waste mass and foundation. The grid search was performed in an iterative manner by the SLIDE model user. Each time the user adjusted / fine-tuned the grid to the point where the model generated the absolute lowest factor of safety.

Failure Conditions

The stability analyses were performed for both short-term and long-term shear strength / static conditions. Long-term shear strength conditions will most likely occur following the complete build-out of the landfill.

Material Properties

The geotechnical parameters used in the slope stability analyses have been discussed in detail in the Summary of the Geotechnical Design Parameters **(Appendix III-D.5-1)**. ~~**Reference No. 2.**~~ A summary of the material properties and shear strength parameters used in the stability analyses are presented on the following page on **Table 1**.

Water Table

The water table was conservatively assumed to be at ground surface for the stability calculations and was assumed as follows for the different stability scenarios:

- *Cell Excavation / Development Scenarios* - the water surface is at the bottom of the compacted low permeable soil liner layer along the base liner and sideslope liner; and
- *Complete Build-Out / Final Landform and Interim Waste Scenarios* - the water surface is at the top of the leachate collection system drainage geocomposite, or approximately 1 inch above the compacted low permeable soil liner layer along sideslopes and base.

Table 1
Summary of Material Unit Weights and Shear Strength

Layer Description	Moist Unit Weight γ_{moist}	Saturated Unit Weight γ_{sat}	Short-Term Shear Strength		Long-Term Shear Strength	
			Cohesion c	Friction Angle φ	Cohesion c'	Friction Angle φ'
Soil Stratum I:						
Beneath Landfill Liner Sideslopes, and outside of Landfill footprint	125 pcf	126 pcf	1,000 psf	0°	250 psf	10°
Soil Stratum II-III- IV:						
Beneath Landfill Base Liner, Sideslope Liner, and areas outside Landfill footprint	129 pcf	132 pcf	2,500 psf	5°	720 psf	13.5°
Landfill Layers:						
Final Cover	129 pcf	132 pcf	720 psf	13.5°	720 psf	13.5°
Waste	65 pcf	65 pcf	0 psf	30°	0 psf	30°
Protective Soil Cover Layer (2-ft) on Base Liner and Sideslope Liner	129 pcf	132 pcf	720 psf	13.5°	720 psf	13.5°
Compacted Low Permeable Soil Liner (3-ft)	129 pcf	132 pcf	720 psf	13.5°	720 psf	13.5°
Critical Geosynthetic Interface along Sideslope Liner	129 pcf	132 pcf	0 psf	8°	0 psf	8°
Critical Geosynthetic Interface along Base Liner	129 pcf	132 pcf	0 psf	14°	0 psf	14°

Analyses

The stability analyses were performed for the following modeled scenarios:

- Global Stability of Complete Build-Out / Final Landform
  - *Stability of Liner System* - evaluated stability of the liner system under short-term and long-term shear strength / static conditions. *(Note that because the liner shear strength parameters are the same for both short- and long-term conditions, the resulting critical failure surface and safety factor are identical for both short- and long-term analyses. The SLIDE output plot file is therefore only presented for the short-term analysis in the attached pages.)*
  - *Stability of Waste and Foundation* - evaluated stability of the waste mass and foundation under short-term and long-term shear strength / static conditions.
- Stability at Interim Waste Fill Height
  - *Stability of Liner System* -- evaluated the stability of the liner system under short-term shear strength / static conditions. Landfill filling is intended to progress from North to South (Cell NE-1 through NE-3). Therefore the stability of the interim waste was modeled from the maximum waste thickness with 100-foot benches every 60 vertical feet with 3H:1V sideslopes with complete buildout in cell NE-1 and partial buildout in cells NE-2 and NE-3 . *(Note that because the liner shear strength parameters are the same for both short- and long-term conditions, the resulting critical failure surface and safety factor for the long-term conditions would be identical to that of the short-term conditions analysis.)*
  - *Stability of Waste and Foundation* -- evaluated the stability of the waste mass and foundation for short-term shear strength / static conditions.
- Stability of Cell Excavation / Development
  - *Stability of Liner System* -- evaluated the stability of the liner system under short-term shear strength / static conditions. Landfill cell development is intended to progress from North to South (Cell NE-1 through NE-3). Therefore the stability of the initial cell excavation/development was modeled in cell NE-1 along section A-A' from North to South. *(Note that because the liner shear strength parameters are the same for both short- and long-term conditions, the resulting critical failure surface and safety factor for the long-term conditions would be identical to that of the short-term conditions analysis.)*
  - *Stability of Foundation* -- evaluated the stability of the foundation under short-term shear strength / static conditions.

Limit Equilibrium Analysis Methods

The limit equilibrium analysis methods used in the SLIDE model analyses included the following three methods:

- Bishop Simplified - the Bishop Simplified method uses the method of slices to determine the stability of the slide mass. It satisfies vertical force equilibrium for each slice as well as overall horizontal force equilibrium for the entire slide mass (i.e., all slices). It assumes zero interslice shear forces.
- Janbu Corrected - the Janbu Corrected method uses the method of slices to determine the stability of the slide mass, satisfying vertical force equilibrium for each slice and horizontal force equilibrium for the entire slide mass (i.e., all slices). It also accounts for interslice shear forces in the analysis.

- GLE / Morgenstern-Price - the GLE (Generalized Limit Equilibrium) / Morgenstern-Price method uses the method of slices to determine the stability of the slide mass. It satisfies vertical force equilibrium for each slice as well as overall horizontal force equilibrium for the entire slide mass (i.e., all slices). It also accounts for interslice shear forces in the analysis.

The lowest factor of safety from the three methods used (i.e., Bishop, Janbu, GLE / Morgenstern-Price) is reported on the SLIDE plot for each modeled scenario (attached pages) and on the summary table on the following page. All of the modeled scenarios are graphically presented on the SLIDE plots provided in the attached pages.

Results

Results of the stability analyses are summarized on **Table 2** below. The following results demonstrate that the proposed landfill development meets and/or exceeds the recommended safety factor of 1.5, and complies with the regulatory requirements of Title 30 Texas Administrative Code (TAC) §330.337. SLIDE output plot files are provided in the attached pages.

Table 2
Slope Stability Summary
Stability Section A-A'

Scenario	**Safety Factor**	
	Short-Term Conditions	**Long-Term Conditions**
Complete Build- Out / Final Landform:		
Global Stability of Liner System - **Block** *(orientation ~~North~~ South to North~~to South~~ / left to right)*	~~2.041~~2.005 (~~B~~bishop)	~~2.041~~2.005 (~~B~~bishop)
Global Stability of Waste & Foundation - **Circular** *(orientation South to North~~North to South~~ / left to right)*	~~2.008~~ 2.453 (~~janbu~~GLE/M-P)	~~2.382~~2.091 (~~janbu~~GLE/M-P)
Excavated / Partially Lined Cell w/ 100-ft Length of Sideslope Liner Installed, Complete Base Liner Installed, and 35-ft High Lift of Waste Fill Placed at 3H:1V Slope:		
Stability of Liner System - **Block** *(orientation ~~North to South~~South to North / left to right)*	~~1.767~~1.711 (~~B~~bishop)	*same*
Stability of Waste & Foundation - **Circular** *(orientation ~~North to South~~South to North / left to right)*	~~1.536~~ 1.518 (~~J~~janbu)	*n/a*
Excavated / Developed Cell w/ Complete Liner System Installed, & 100-ft High Waste Fill Lift Placed (at 3H:1V Slope with ~~75~~100-ft Wide Benching):		
Stability of Liner System - **Block** *(orientation ~~North to South~~South to North / left to right)*	~~1.605~~1.551 (~~B~~bishop)	*same*
Stability of Waste & Foundation - **Circular** *(orientation ~~North to South~~South to North / left to right)*	~~1.959~~1.733 (~~janbu~~Bishop)	*n/a*
Interim Waste Fill Height ~~of 2 Cells~~ with 3H:1V Waste Slope and ~~75~~100-ft Wide Benching (Maximum Elevation - ~~824~~ 704 ft MSL):		
Stability of Liner System - **Block** *(orientation ~~North to South~~South to North / left to right)*	~~1.535~~1.512 (~~b~~Bishop)	*same*
Stability of Waste & Foundation - **Circular** *(orientation South to North / left to right)*	1.688 (Janbu)	n/a

This entire section has been updated and redline not possible

Reference No. 1

SLIDE - 2D Limit Equilibrium
Slope Stability Program