SECTION VIII

CLOSURE / POST CLOSURE PLAN

Earth Tech

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CLOSURE / POST CLOSURE PLAN
WEST HAWAI`I SANITARY LANDFILL
NORTH KONA, HAWAI`I

Prepared for:

Waste Management of Hawai`i
92-460 Farrington Highway
Kapolei, Hawai`i 96707

Prepared by:

Earth Tech, Inc.
841 Bishop St., Suite 500
Honolulu, Hawai`i 96813

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CONTENTS

1.0 INTRODUCTION

This Closure & Post-Closure Plan (CPCP) has been prepared for the West Hawai`i Sanitary Landfill (WHSL) in Waikoloa, Hawai`i and is being submitted to the Hawai`i Department of Health (DOH) for review and approval. The CPCP has been prepared in accordance with Hawai`i Administrative Rules (HAR), Title 11 Department of Health, Chapter 58.1 Solid Waste Management Control, Section 17 (§11-58.1-17). The CPCP contains the following closure information required by HAR §11-58.1-17(a)(3):

- Description and design of the final cover system and methods and procedures for installation of the final cover system (See Section 3.1);
- Maximum potential closure area estimate (See Section 3.2);
- Estimate of the maximum potential inventory of wastes ever on-site (See Section 3.3); and,
- Closure schedule (Section 3.4);

The CPCP contains the following post-closure care information required by HAR §11-58.1-17(b)(3):

- Description of the post-closure monitoring and maintenance activities (See Section 4.2);
- Post-closure contact information (See Section 4.3); and,
- Post-closure land use (See Section 4.4).

Calculations, drawings and forms in support of the CPCP are provided within the Appendixes included with this Plan. Also, in accordance with HAR §11-58.1-18 Subsections (b)(1) & (c)(1), a detailed cost estimate for a third party to perform the closure and post-closure activities at the site has been prepared (See Section 5.0). The CPCP begins with a description of the site and its environmental monitoring & control systems (See Section 2.0).

2.0 SITE BACKGROUND

2.1 SITE LOCATION & LAYOUT

The WHSL is a permitted municipal solid waste (MSW) landfill for the disposal of non-hazardous solid wastes. It is owned by the County of Hawai`i and operated by Waste Management of Hawaii (WMH). The WHSL is located at 71-1111 Queen Kaahumanu Highway in North Kona on the northwest portion of the Island of Hawai`i. The facility is located between the Queen Ka`ahumanu and Mamalahoa Belt Highways, approximately 6,600 feet inland from Pueo and Keawaiki Bays (See Site Location Map in Appendix A).

The WHSL property covers approximately 300 acres. The permitted waste footprint, which covers 149 acres, is basically square and is divided into twenty (23) waste disposal cells (See Site Layout Map in Appendix A). Waste disposal operations began in 1993 under the original Permit No. LF0072-93 issued September 28, 1993 by the DOH. The original WHSL permit drawings prepared by Harding Lawson Associates (dated August 1993, revised June 1995) are included for reference purposes in Appendix B of this CPCP.

Waste disposal began in the northern portion of the permitted waste footprint (Cell 1) and has since extended eastward and southward. As of the date of this Plan, the status of the disposal cells is as follows:

- Cells 1 thru 7 (41 acres): Active;
- Cells 8 thru 9 (15 acres): Active / Under Construction; and,
- Cells 10 thru 23 (93 acres): Future Construction

Ancillary landfill facilities include the administration building, scale house, fueling area, maintenance shop, and water tank and pumping area, which are all shown on the Site Layout Map in Appendix A.

2.2 ENVIRONMENTAL MONITORING & CONTROL SYSTEMS

Existing environmental monitoring and control systems at the WHSL include the following:

- Liner System;
- Leachate Collection and Removal System;
- Groundwater Monitoring System;
- Interim Perimeter Gas Monitoring System; and,
- Surface Water Management System.

Descriptions of these systems are provided in the following subsections.

2.2.1 Liner System and Leachate Collection and Removal System

All disposal areas at the WHSL are equipped with a bottom and side slope composite liner system and leachate collection and removal system (LCRS) meeting Federal (Subtitle D equivalent) and State requirements (HAR §11-58.1-14). In general the landfill liner system at the WHSL consists of the following components, from top to bottom:

- 12-inch protective layer;
- 16 ounces per square yard (oz/yd^2) nonwoven geotextile separation layer between the drainage layer and the protective layer (on cell floor and 10 vertical feet up side slope only);
- 12-inch drainage layer (on cell floor and 10 vertical feet up side slope only);
- 16 oz/yd^2 nonwoven geotextile cushioning layer;

- 60 mil high density polyethylene (HDPE) single-sided textured geomembrane liner;
- Geosynthetic clay liner; and
- 6-inch soil cushion layer.

The LCRS consists of the following:

- A 12-inch gravel drainage layer on the cell floor to collect leachate that has percolated through the waste mass;
- Leachate collection trenches, which contain drainage gravel & perforated HDPE leachate collection trenches, that are graded to drain the leachate to an engineered low point (i.e. sump);
- Leachate side slope riser pipes trenches with automated sump pumps to extract leachate from the leachate collection sumps; and
- Leachate forcemain to convey leachate to the leachate storage tanks.

The current LCRS at the WHSL maintains the site's leachate levels in compliance with Federal (Subtitle D) and State regulations, which require that leachate not be allowed to accumulate on the landfill bottom liner to a depth of more than 1-foot, not including that contained in the collection sumps. When the leachate level in a sump reaches a pre-determined height, the pump will automatically start, and pump leachate out of the sump until the level has dropped to a set height. Currently, leachate is temporarily stored on-site in three individual 3,000-gallon tanks (one tank for each of the existing leachate sumps). The stored leachate is periodically pumped into a water truck and used as dust control on the lined MSW cells.

Leachate monitoring and sampling activities are conducted annually at the WHSL in conjunction with the site's groundwater monitoring program. Samples are taken from each of the leachate collection sumps. Sampling results and analysis are included with the semi-annual groundwater monitoring reports that are submitted to the DOH within 90 days of the sampling event.

2.2.2 Groundwater Monitoring System

The existing onsite groundwater well network consists of four (4) monitoring wells and one (1) production well. The production well is used as a water source for wash water and dust control. Two (2) upgradient monitoring wells are located along the eastern side of the property (WHW-01 & WHW-02) and two (2) downgradient monitoring wells are located along the western side of the property (WHW-03 & WHW-04). Historic groundwater level data for the monitoring wells shows a groundwater flow direction ranging from westerly to southwesterly in the immediate vicinity of the site.

Groundwater monitoring activities at the site are conducted pursuant to the WHSL Groundwater and Leachate Monitoring Plan, which complies with the Code of Federal Regulations (CFR) Solid Waste Disposal Facility Criteria (and its revisions) in 40 CFR §258 (Subtitle D), and HAR §11-58.1. Groundwater monitoring wells are inspected and monitored on a semiannual basis. Results of each groundwater and leachate monitoring events are presented in semiannual reports that are submitted to the DOH within 90 days of the sampling event.

2.2.3 Perimeter Gas Monitoring System

In accordance with the landfill gas monitoring requirements of the Federal Resource Conservation and Recovery Act (RCRA) Subtitle D regulations, HAR and the WHSL Solid Waste Permit (No. LF-0072-93), an interim perimeter gas monitoring system is installed at the WHSL to detect landfill gas migration from the WHSL. The gas probe network, which is monitored on a quarterly basis, is temporary until a permanent gas probe network is installed.

2.2.4 Surface Water Management System

The WHSL is located on the leeward side of the Island of Hawaii, a region that is relatively arid when compared to the windward side of the island. Average annual rainfall in the vicinity of the site for the previous ten (10) years (1998 – 2007) is 8.22 inches. This is based on data from the Waikoloa Beach Rt 95.9 National Weather Service Cooperative Station (COOP ID #519144) downloaded from NOAA's National Climatic Data Center (NCDC) website (http://www.ncdc.noaa.gov/oa/ncdc.html). Seven (7) of the previous ten (10) years have had annual rainfall amounts fewer than 10 inches. The minimum and maximum annual rainfall amounts in the past 10 years have been 2.08 inches in 1998 and 26.96 inches in 2004, respectively, with the Year 2004 amount being a severe outlier compared to the other years.

Due to the relatively low rainfall at the site, surface water runon and runoff has not been a significant issue during operation of the landfill. Surface water runon and runoff control, erosion control, and sediment control are accomplished through the grading of landfill slopes for positive drainage and by maintaining the design features of the WHSL surface water management system, which includes temporary ditches and berms to divert runon around, and control runoff from, the active disposal areas; the use of crushed rock spoils from the excavation of the disposal cells as an erosion layer; and the installation of an infiltration ditch around the landfill perimeter.

3.0 CLOSURE PLAN

3.1 FINAL COVER SYSTEM

3.1.1 Final Grading Plan

The final grading plan is shown on Permit Drawing C-4 prepared by Harding Lawson Associates (see Appendix B). The peak design height of the landfill is EL 262.0 ft MSL. The landfill plateau will have a maximum 5% grade and sideslopes will have a maximum 10% grade. A 32-ft wide access road with a maximum 10% slope will provide access to the landfill plateau. A perimeter access road will be maintained around the capped landfill.

3.1.2 HAR Design Requirements

The final cover design requirements per HAR 11-58.1-17(a), Subsections (1) and (2) are as follows:

(1) Owners or operators of all MSWLF units must install a final cover system that is designed to minimize infiltration and erosion. The final cover system must be comprised of an erosion layer underlain by an infiltration layer as follows:

(A) Have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present, or a permeability no greater than 1×10^{-5} cm/sec, whichever is less, and

(B) Minimize infiltration through the closed MSWLF by the use of an infiltration layer that contains a minimum eighteen inches of earthen material, and

(C) Minimize erosion of the final cover by the use of an erosion layer that contains a minimum six inches of earthen material that is capable of sustaining native plant growth.

(2) The director may·approve an alternative final cover design that includes:

(A) An infiltration layer that achieves an equivalent reduction in infiltration as the infiltration layer specified in paragraph (1)(A) and (1)(B); and

(B) An erosion layer that provides equivalent protection from wind and water erosion as the erosion layer specified in paragraph (1)(C).

3.1.3 Proposed Final Cover System Design

The proposed final cover system configuration for the WHSL consists of the following components from top to bottom:

- 18-inch erosion layer – This layer will be a ½" minus crushed aggregate/gravel.
- 16 oz/sy nonwoven cushion geotextile;
- 40 mil textured (both sides) linear low density polyethylene (LLDPE) liner;
- 6-inch cushioning layer – This layer will be a sandy or silty sand material similar to what is used as the 6-inch soil cushion layer placed below the WHSL base liner geosynthetics. It is expected that this material will be supplied from on-site sources; and,
- 12-inch intermediate cover – This layer will be a 2" minus crushed aggregate/gravel.

3.1.4 Final Cover System Evaluations

The proposed final cover system design is an alternate final cover design per HAR § 11-58.1-17(a)(2) (See Section 3.1.2). The following evaluations have been prepared to show that the proposed final cover system design meets the intent of the HAR requirements for the final cover system:

Final Cover Stability Analysis

The erosion layer above the geosynthetic cap was evaluated for erosion due to veneer cover soil failure under the following loading conditions (see Appendix C):

- Static condition w/o equipment loading;
- Static condition w/ equipment loading;
- Seismic condition; and
- Parallel seepage buildup.

Reference interface shear test data results show that the interfaces present in the proposed WHSL final cover system should provide the required interface shear strength to achieve the minimum factor of safety for each loading condition. However, it is recommended that this cover soil stability evaluation should be performed prior to final cover system construction using site-specific interface shear test results to verify that the interface shear strengths provide the required factor of safety for each loading condition.

Final Cover Geotextile Design

The proposed 16 oz/sy nonwoven cushion geotextile above the 40 mil LLDPE cap was designed for burst resistance, tensile strength, and puncture resistance (see Appendix D). The minimum required test value for each of the properties is as follows:

Property	Test Method	Minimum Required Test Value
Mullen Burst Resistance	ASTM D3786	41.9 psi
Grab Tensile Strength	ASTM D4632	4.5 lbs
Puncture	ASTM D4833	9.7 lbs

Product data sheets for several nonwoven geotextiles show that these requirements are met by currently available nonwoven geotextiles (see Appendix D). Minimum test values for the final cover geotextile should meet the manufacturer's specifications, which are significantly higher than what is required for this site-specific application.

Final Cover HELP Model Evaluation

A final cover evaluation using the HELP Model has been performed (see Appendix E) to show that the proposed 40 mil textured (both sides) LLDPE geomembrane cap has a rate of infiltration less than or equal to that of the WHSL bottom geomembrane liner in accordance with HAR § 11-58.1-17(a)(1)(A).

3.1.5 Final Cover System Installation

Final cover system construction will proceed in phases as areas of the landfill reach final grades. The process of a phased closure allows for a minimum amount of closure work either for the final closure event or in the event that premature closure becomes necessary. In the event that it becomes necessary to close the facility prematurely, placement of refuse will stop and the working face and other interim contours will be re-graded to a minimum 5% slope and maximum 10% slope per a revised final grading plan developed for the premature closure condition that prior to construction will be submitted to the DOH for their review and approval.

Areas that have reached maximum waste grades will be capped with the final cover system described in Section 3.1.3 and the installation procedures described as follows:

1. A twelve (12) inch intermediate cover soil will be placed over the compacted waste. A 2" minus crushed aggregate/gravel will be used for this purpose. The material may be processed and screened from on-site materials or provided from off-site sources. The intermediate cover shall be similar in gradation to Coarse Aggregate Modified Size 4 per Table 703.04-2, Section 703 – Aggregates, Hawaii DOT *2005 Standard Specifications for Road and Bridge Construction*. The intermediate cover surface shall be proof-rolled to achieve a smooth surface free of protrusions and debris in preparation for the installation of the cushioning layer.
2. A six (6) inch sand / silty sand cushioning layer will be placed over the intermediate cover. The cushioning layer surface shall be proof-rolled to achieve a smooth surface free of protrusions and debris in preparation for the installation of the LLDPE cap liner.
3. A 40 mil textured (both sides) linear low density polyethylene (LLDPE) cap liner. All LLDPE panels will be installed perpendicular to the slope. The geomembrane will be installed primarily using the fusion welding method on the main panels installed along the slope and on the plateau. Extrusion welding will be utilized for repairs and detailing.
4. A 16 oz/sy needle-punched nonwoven geotextile will be installed as a cushion layer over the LLDPE cap liner. The nonwoven geotextile panels will be overlapped a minimum of 6 inches. The geotextile will be sewn continuously throughout the slopes or continuously heat-bonded using the fusion welder. The geotextile may be continuously heat bonded on the plateau.
5. Finally, an eighteen (18) inch erosion layer will be placed over the nonwoven geotextile. A 1/2" minus crushed aggregate/gravel will be used for this purpose. The material may be processed and screened from on-site materials or provided from off-site sources. The erosion layer shall be similar in gradation to Filler Size 8 per Table 703.04-2, Section 703 – Aggregates, Hawaii DOT *2005 Standard Specifications for Road and Bridge Construction*. Low ground pressure (LGP) equipment will be used to place the erosion layer. The erosion layer will be placed from toe of slope to top of slope. Trucks unloading the crushed rock/gravel will operate on a minimum three (3) feet of cover over the LLDPE cap liner. Topsoil or material capable of supporting vegetation is not included in the final cover system profile due to the arid climate and the general lack of established vegetation in the vicinity of the site.

3.2 Maximum Closure Area Estimate

Due to the phasing of final cover system construction, it is expected that only a portion of the landfill will require capping for the final capping event at the site or in the event of premature closure of the site. Currently, the landfill has approximately fifty (50) acres of active area. Therefore, the worst-case closure area estimate is assumed to be fifty (50) acres of open area. Of the 50 acres, it is assumed that 25 acres will require all cap components (from the intermediate cover thru the erosion layer) and 25 acres will be at intermediate cover grades and will require all cap components above the intermediate cover. This maximum closure area was used for the closure cost estimate described in Section 5.0 of this CPCP.

3.3 Maximum Waste Inventory

Per Permit Drawing C-4 prepared by Harding Lawson Associates (See Appendix B), the net airspace of the WHSL is 11,744,000 cubic yards. Assuming a landfill density of 1200 lbs/cy (0.60 tons/cy), that equates to 7,046,400 tons of in-place waste.

3.4 Closure Schedule

Based on the WHSL 2007 Annual Operation Report, the estimated remaining site life as of the April 15, 2007 site survey is 48.8 years. This is based on a remaining airspace of 11,414,840 bank cubic yards, an in-place waste density of 0.60 tons/bcy, and an average gate rate of 380 tons/day. That projects to the WHSL reaching its full capacity in the Year 2056.

Per HAR requirements, capping/closure events must be completed in accordance with the closure plan within one hundred eighty (180) days following initiation of closure. Extensions of the closure period may be granted by the DOH if the owner or operator demonstrates to the DOH that the extension is necessary.

3.5 CLOSURE NOTIFICATIONS

Following each capping/closure event, the owner or operator must notify the DOH that a certification, signed by an independent registered professional engineer or approved by the DOH, verifying that closure has been completed in accordance with the closure plan, has been placed in the operating record.

Following the final capping/closure event, the owner or operator must record a notation on the deed to the landfill facility property, or some other instrument that is normally examined during title search, to identify any potential purchaser of the property that the land has been used as a landfill facility and its use is restricted under HAR § 11-58.1-17(b)(3)(c). The owner or operator must notify the DOH that the notation has been recorded and a copy has been placed in the operating record.

4.0 POST-CLOSURE PLAN

4.1 POST-CLOSURE REQUIREMENTS

Per HAR § 11-58.1-17(b)(1), post-closure care must be conducted for thirty (30) years and should consist of at least the following:

- Maintaining the integrity of the final cover system;
- Maintaining and operating the leachate collection system;
- Monitoring and maintaining the groundwater monitoring system; and,
- Maintaining and operating the gas monitoring system.

Per HAR § 11-58.1-17(b)(2), the length of the post-closure care period may be reduced by the DOH if the owner or operator demonstrates that the reduced period is sufficient to protect human health and the environment and this demonstration is approved by the DOH. The DOH may also lengthen the post-closure care period if it is deemed necessary to protect human health and the environment.

Per HAR § 11-58.1-17(b)(5), the owner or operator of a MSW landfill must notify the DOH that a certification, signed by an independent registered professional engineer or approved by the DOH, verifying that post-closure care has been completed in accordance with the post-closure plan, has been placed in the operating record.

4.2 MONITORING AND MAINTENANCE ACTIVITIES

Post-closure monitoring and maintenance will be necessary to ensure the long-term integrity of the closed landfill and its associated environmental control systems. The objective of post-closure care will be to maintain and monitor the following closure features at the WHSL:

- Final Cover System;
- Leachate Collection System;
- Groundwater Monitoring Wells; and,
- Perimeter Gas Monitoring Probes

The following sub-sections identify requirements for post-closure monitoring and maintenance at WHSL.

4.2.1 Site Inspections

On a monthly basis, WHSL will perform the following inspection and recordkeeping activities:

- Inspection of the leachate collection system components (i.e. pumps, piping, storage tanks, and automatic controls) to ensure that the system is operational and functioning properly;
- Recordkeeping of the leachate volume collected from each of the leachate collection sumps;
- Monitoring of the leachate levels in the leachate collection sumps to ensure that that the leachate head on primary liner is maintained below 1 foot;
- Recording the groundwater level in each of the site's groundwater monitoring wells; and,
- Inspection of the final cover system.

On an annual basis, WHSL will hire an independent licensed engineer to perform a site inspection and prepare an inspection report for WHSL. Semi-annual inspections will allow any defects (i.e., settlement, subsidence, erosion) in the landfill systems to be detected and repaired before they develop into major problems. The frequency of inspections may be changed during the 30-year post-closure care period. A summary report will be prepared by the inspector for WHSL.

Inspections will consist of the inspector walking throughout the site and documenting observations. Defects that are detected will be addressed at a minimum of annually or as necessary to prevent more significant problems from developing. The inspections will focus on the integrity and operability of the various landfill systems. Likewise, the condition, accessibility, and visibility of all monitoring wells and probes will be judged. The cover will be inspected for signs of erosion damage and any settlement, subsidence, or displacement.

- **Final Cover System:** All surveyed benchmarks will be evaluated as to their integrity and visibility. The cover will be inspected for signs of erosion damage and any settlement, subsidence, or displacement.
- **Leachate Collection System:** The system will be inspected to ensure it is operating efficiently. The inspection will include, but not be limited to: checking for sediment buildup within the leachate collection and transmission lines; testing level switches, control devices and flow meters; testing backup pumps and emergency systems; evaluating the integrity of the leachate storage tanks; and, inspecting the site's leachate flow records.
- **Groundwater Monitoring Wells:** The wells will be inspected to ensure that they are functional. Inspection will include judging the condition, accessibility, and visibility of all monitoring wells.
- **Perimeter Gas Monitoring Probes:** The gas monitoring probes will be inspected in the same fashion as the groundwater monitoring wells.

4.2.2 Site Monitoring

WHSL will conduct the following monitoring activities during the post-closure care period:

- **Leachate Collection System:** Leachate samples from each of the sumps will continue to be collected for analysis on an annual basis in accordance with the site's current Leachate Monitoring Plan. Results of each monitoring event will be presented in an annual report that will be submitted to the DOH within 90 days of the sampling event. The report may be combined with the groundwater monitoring report described below.
- **Groundwater Monitoring Wells:** The wells will continue to be sampled on a semi-annual basis in accordance with the site's current Groundwater Monitoring Plan. Results of each groundwater monitoring event will be presented in semiannual reports that will be submitted to the DOH within 90 days of the sampling event. During these monitoring events, the groundwater level in each of the wells will also be recorded.
- **Perimeter Gas Monitoring Probes:** The gas monitoring probes will be monitored on a quarterly basis in accordance with procedures listed in the site's Interim Perimeter Gas Monitoring Plan. A summary report for each monitoring event will be prepared and entered into the site's operating record.

4.2.3 Site Maintenance

Maintenance activities will be carried out as necessary on both a preventative and remedial basis based on observations and recommendations made during site inspections. Potential maintenance activities for the site are as follows:

- **Final Cover System:** Defects that may require corrective action include erosion, differential settlement resulting in ponding water, odor, cracks, slope failure and any other defects that will impair the performance of the final cover. Cracks greater than 1 inch wide or gullies 6 inches or deeper in the final cover will be repaired. Any erosion damage, which may occur as a result of extremely heavy rainfall, will be repaired. Repairs will be made in accordance with the type and extent of defect. Temporary berms, ditches, and/or other E&SC measures will be used as needed to prevent further erosion damage to areas of defect or repaired cover areas until site conditions permit repair. Recently filled and covered areas will require the most maintenance; however, the landfill will stabilize with time so that little, if any, maintenance will be required during the 30-year post-closure care period. Generally, a 3 to 5-year stabilization period is anticipated. Residual settlement of the closed landfill is anticipated, but it is expected to be minimal and confined to localized areas.

- **Leachate Collection System:** Maintenance of the leachate collection system during the 30-year post-closure care period will include repair and periodic replacement of leachate pumps, cleaning of leachate collection and transmission pipes, maintenance of the leachate storage tanks, and maintenance of the automated system to ensure continued operation of the leachate collection system. Leachate generation rates are expected to drop upon completion of landfill closure.
- **Groundwater Monitoring Wells:** Any required maintenance or repairs noted during inspection or monitoring will be carried out. Required maintenance may include repair and replacement of locks, pipes and other appurtenances. If monitoring wells are damaged beyond repair or are otherwise unable to be monitored, the wells may have to be decommissioned and redrilled.
- **Perimeter Gas Monitoring Probes:** Potential maintenance activities will be the same as those for the groundwater monitoring wells.
- **Other Site Maintenance Activities:** Repairs to site access roads, storage tanks, the water production well, fences, and the main gate will be carried out as necessary based upon observations and recommendations made during site inspections.

4.3 POST-CLOSURE CONTACT

The contacts during the post-closure period may be reached at the following addresses and phone numbers:

Site Owner:
County of Hawai`i
Department of Environmental Management
Solid Waste Division
25 Aupuni Street
Hilo, Hawai`i 96720
Phone: (808) 961-8339

Site Operator:
Waste Management of Hawaii, Inc.
92-460 Farrington Highway
Kapolei, Hawai`i 96707
Phone: (808) 668-2985

4.4 POST-CLOSURE LAND USE

Due to the rugged terrain surrounding the site and the need to maintain the integrity of the landfill's final cover system, it is not expected that the landfill will be used for any specific purpose during the post-closure period. Access to the landfill will be controlled by a six-foot chain link fence with a locking gate at the entrance of the WHSL with the rugged terrain making fence installation unnecessary in other portions of the landfill.

5.0 CLOSURE AND POST-CLOSURE ACTIVITIES COST ESTIMATE

5.1 FINANCIAL ASSURANCE REQUIREMENTS

Per HAR §11-58.1-18, the owner or operator of an MSW landfill must provide financial assurance for closure and post-closure care. The financial assurance for closure should be based on a detailed written estimate, in current dollars, of the cost of hiring a third party to close the largest area of the landfill ever requiring a final cover at any time during the active life of the landfill in accordance with the closure plan. The financial assurance for post-closure care should be based on a detailed written estimate, in current dollars, of the cost of hiring a third party to conduct post-closure care for the MSWLF unit in compliance with the post-closure plan developed for the site.

5.2 CLOSURE COST ESTIMATE

As discussed in Section 3.3, the worst-case closure area estimate is assumed to be fifty (50) acres of open area. Of the 50 acres, it is assumed that 25 acres will require all cap components (from the intermediate cover thru the erosion layer) and 25 acres will be at intermediate cover grades and will require all cap components above the intermediate cover. The closure cost estimate calculations are included in Appendix F of this CPCP Plan. Costs were developed using County of Hawaii prevailing wage rates, Means Cost Data, vendor pricing, previous bid estimates from similar projects, and engineer's cost estimates. The closure cost estimate includes, but is not limited to, the following items:

- Contractor mobilization, site cleanup, and demobilization;
- Closure design, surveying, and construction documents/drawings;
- Grading activities to achieve final grades;
- Supply and installation of all final cover soil materials;
- Supply and installation of all final cover geosynthetic materials;
- Supply and installation of passive gas vents through the final cover system into the waste mass;
- Supply and installation of perimeter gas monitoring probes;
- Supply and installation of leachate recirculation well; and,
- Construction quality assurance (CQA).

The closure cost estimate for the WHSL has been estimated at **$10,828,400**.

5.3 POST-CLOSURE CARE COST ESTIMATE

The post-closure care cost estimate calculations are included in Appendix F of this CPCP Plan. Costs were developed using County of Hawaii prevailing wage rates, Means Cost Data, vendor pricing, previous bid estimates from similar projects, and engineer's cost estimates. A 30-yr post-closure period was assumed for the cost estimate; however, costs for leachate management and management were assumed to be for a 10-year post-closure period, as it is expected that leachate generation will be negligible after ten (10) years of post-closure (see Appendix F for discussion). The post-closure care cost estimate includes, but is not limited to, the following items:

- Semi-annual groundwater monitoring;
- Quarterly perimeter gas probe monitoring;
- Leachate management;
- Annual leachate monitoring;
- Monthly and semi-annual site inspections;

- Final cover system maintenance; and
- Other site maintenance activities.

The post-closure care cost estimate for the WHSL has been estimated at **$1,731,000**.

Appendix A
Figures

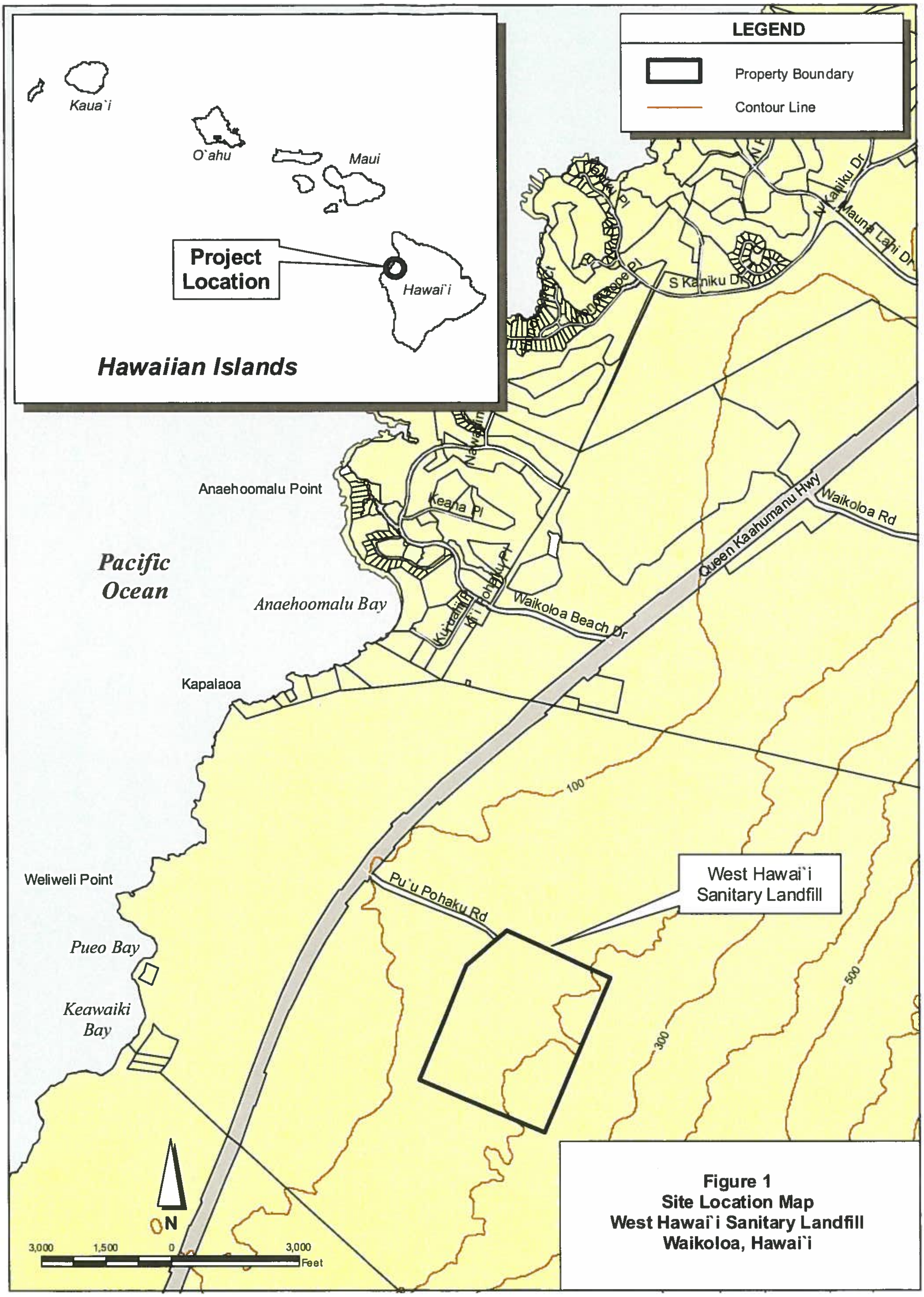

Figure 1
Site Location Map
West Hawai`i Sanitary Landfill
Waikoloa, Hawai`i

Map Document: (Q:\GIS\West_HI_Landfill\MXD\West_HI_Landfill.mxd)
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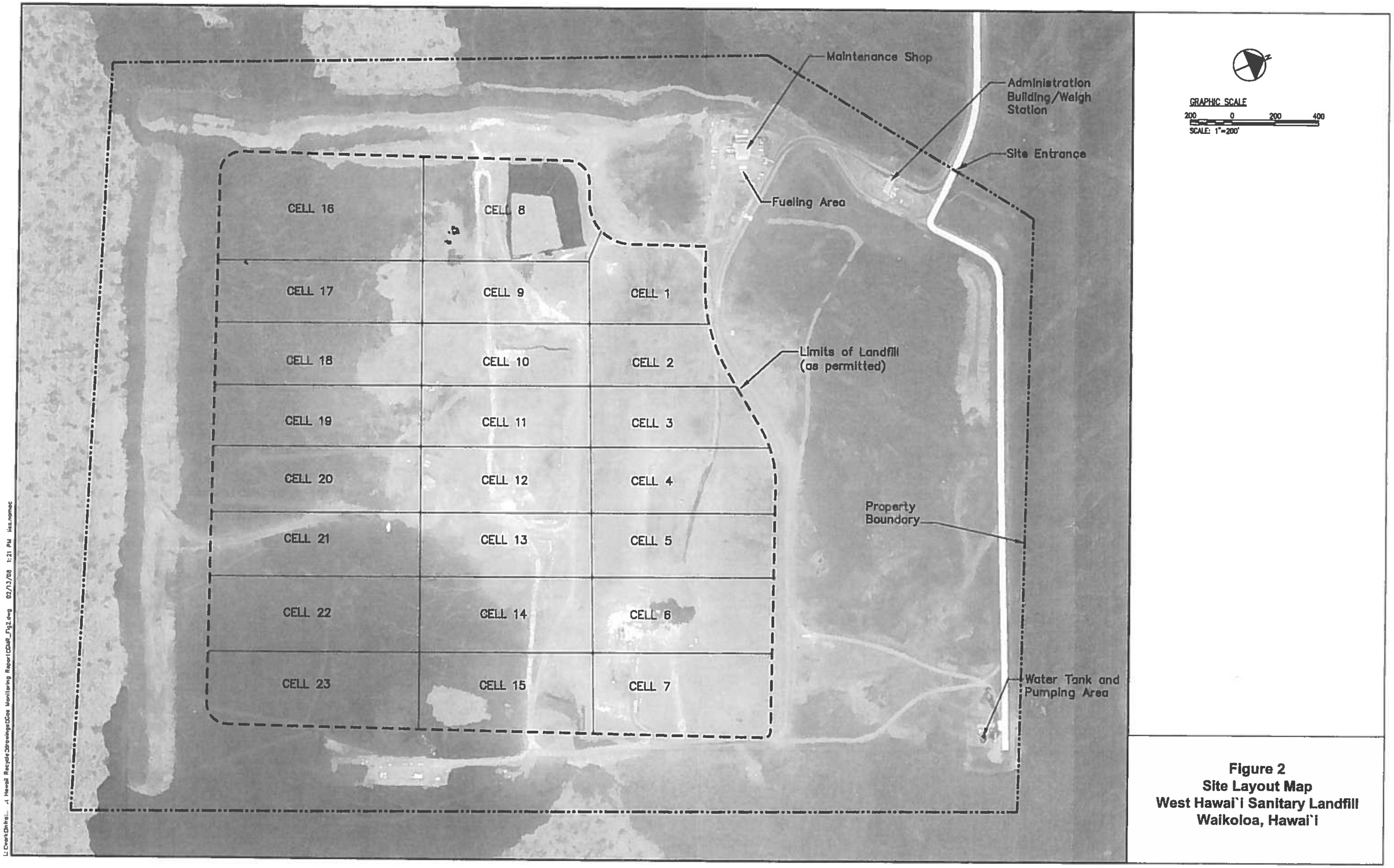
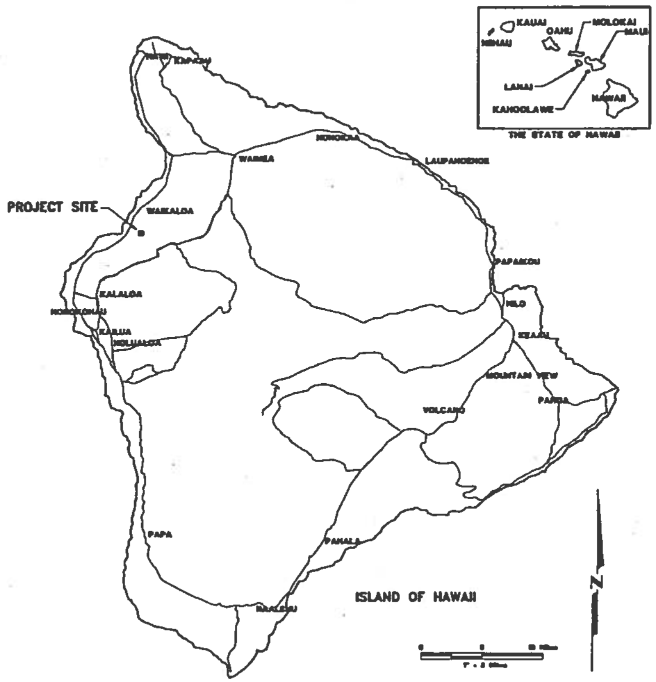


Figure 2
Site Layout Map
West Hawai`i Sanitary Landfill
Waikoloa, Hawai`i

Appendix B
WHSL Permit Drawings

WEST HAWAII SANITARY LANDFILL



AUGUST 1993

Tom Arizumi, Chief Environmental Management Division, State of Hawaii, Department of Health — Date 8-25-93

Donna Fay K. Kiyosaki, P.E., Chief Engineer, County of Hawaii, Department of Public Works — Date 8-23-93

Ray A. Rossetti, Division President & General Manager, Waste Management of Hawaii, Inc. — Date 8-18-93

Prepared By:

Harding Lawson Associates
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Phone: (808) 486-6009
Fax: (808) 486-7184

Prepared For:

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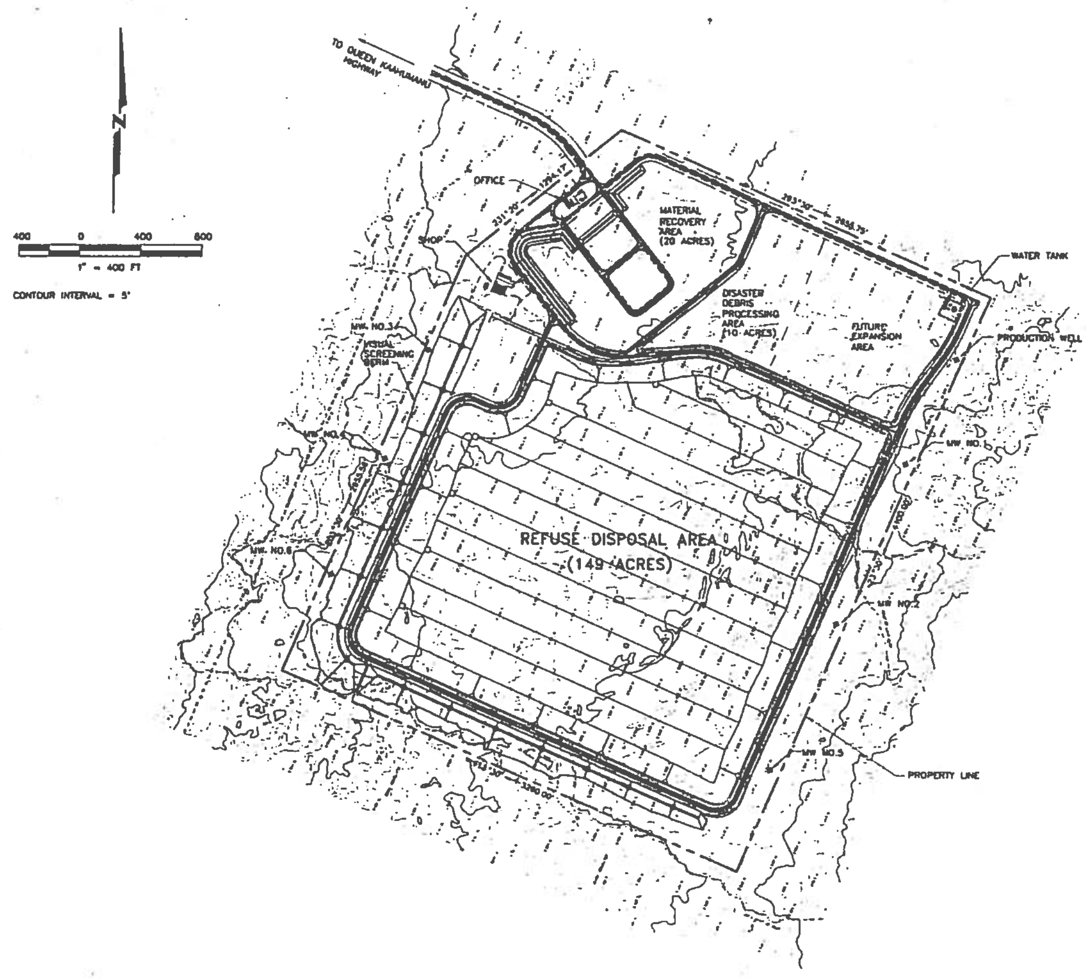
Fax: (808) 668-1366



SITE PLAN

DRAWING LIST

SHEET NO.	TITLE	DRAWING NO.
1	COVER SHEET	
2	SITE PLAN/DRAWING LIST/GENERAL NOTES	G-1
3	BASE GRADE PLAN	C-1
4	LEACHATE COLLECTION SYSTEM PLAN	C-2
5	LANDFILL PHASING PLAN	C-3
6	FINAL GRADING PLAN	C-4
7	LANDFILL CROSS-SECTIONS	C-5
8	PERIMETER ROAD PROFILE	C-6
9	LINER SECTIONS AND DETAILS	C-7
10	LEACHATE COLLECTION SYSTEM DETAILS	C-8
11	MISCELLANEOUS DETAILS	C-9

GENERAL NOTES:

1. DATA FOR THIS MAP OBTAINED FROM R.M.TOWILL CORP. PHOTOGRAMMETRY DEPARTMENT 6/28/93. COMPILED FROM PHOTOS TAKEN ON 4/23/84 AND 8/9/89
2. DEVELOPMENT OF FUTURE EXPANSION AREA, DISASTER DEBRIS PROCESSING AREA AND MATERIALS RECOVERY AREA ARE NOT INCLUDED IN WASTE MANAGEMENT OF HAWAII INC. CONTRACT WITH THE COUNTY OF HAWAII.
3. MONITORING WELLS SHOWN ARE FOR ILLUSTRATION PURPOSES ONLY. A SURVEY WILL BE PERFORMED AFTER INSTALLATION TO DETERMINE THEIR FINAL LOCATION.

GERALD A. FRIESEN LICENSED PROFESSIONAL ENGINEER No. 7477-C HAWAII, U.S.A.

THIS WORK WAS PREPARED BY ME OR UNDER MY SUPERVISION
[signature]
DATE 9/12/93

NO.	REVISION	BY	DATE

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DESIGNED MLK/JRL
DRAWN JRL
CHECKED GF

SUBMITTED [signature] DATE 9/12/93
APPROVED [signature] DATE 9-18-93
APPROVED ______ DATE ______

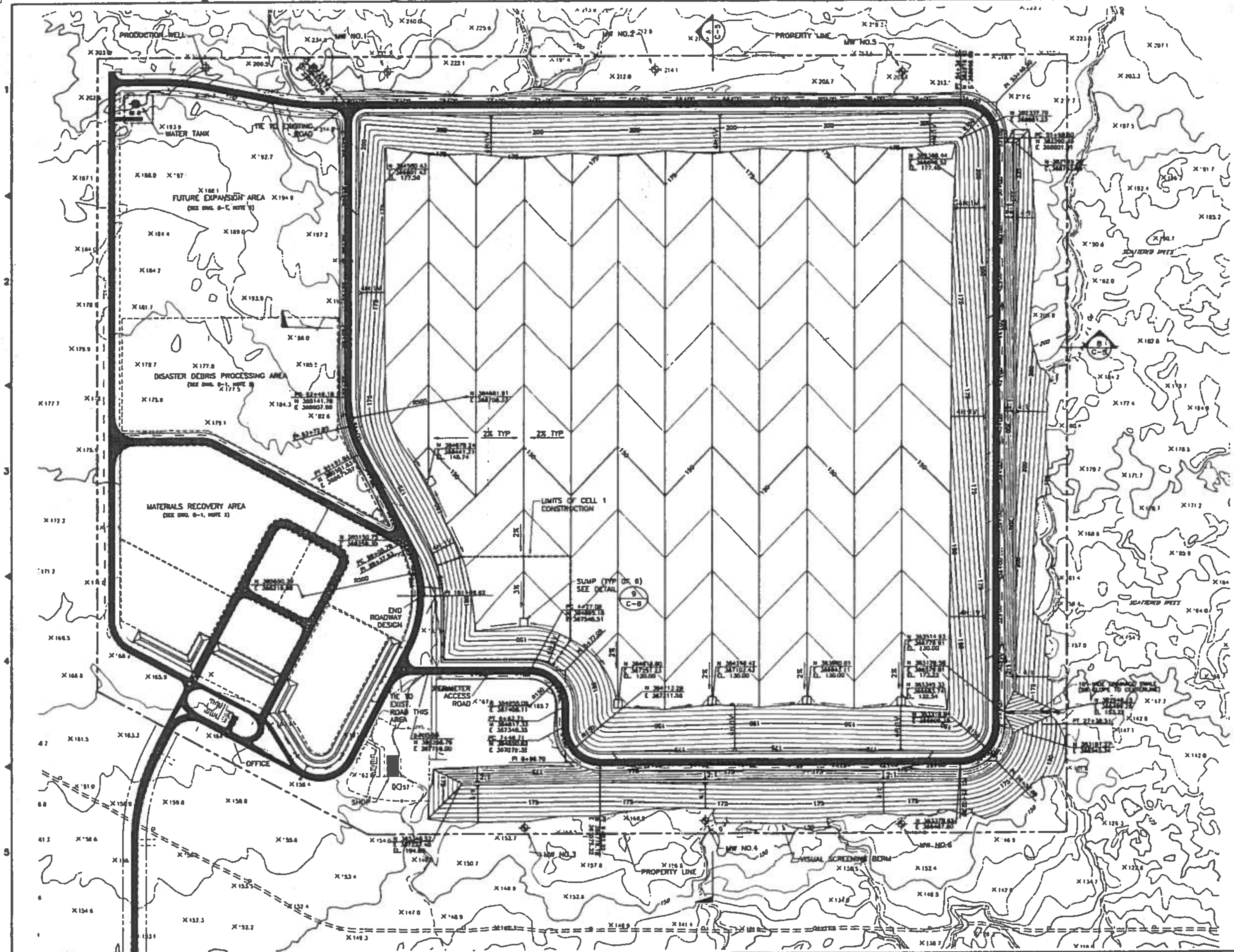
SCALE 1"=400'
DATE 08/12/93
JOB NO. 24789.204

ONE INCH AT FULL SCALE
IF NOT ONE INCH SCALE ACCORDINGLY

WEST HAWAII SANITARY LANDFILL
Puuanahulu, North Kona, Hawaii

SITE PLAN/DRAWING LIST/ GENERAL NOTES

DRAWING G-1
SHEET 2 OF 11



NOTES:

1. FOR VERTICAL ALIGNMENT OF PERIMETER ROAD, SEE DRAWING C-6.
2. SCREENING BERM SHALL BE CONSTRUCTED UTILIZING SURPLUS MATERIALS GENERATED DURING THE EXCAVATION FOR CELLS SUBSEQUENT TO CELL 1.

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DESIGNED MLK
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SUBMITTED DATE 8/12/93
APPROVED DATE 8-18-93
APPROVED DATE

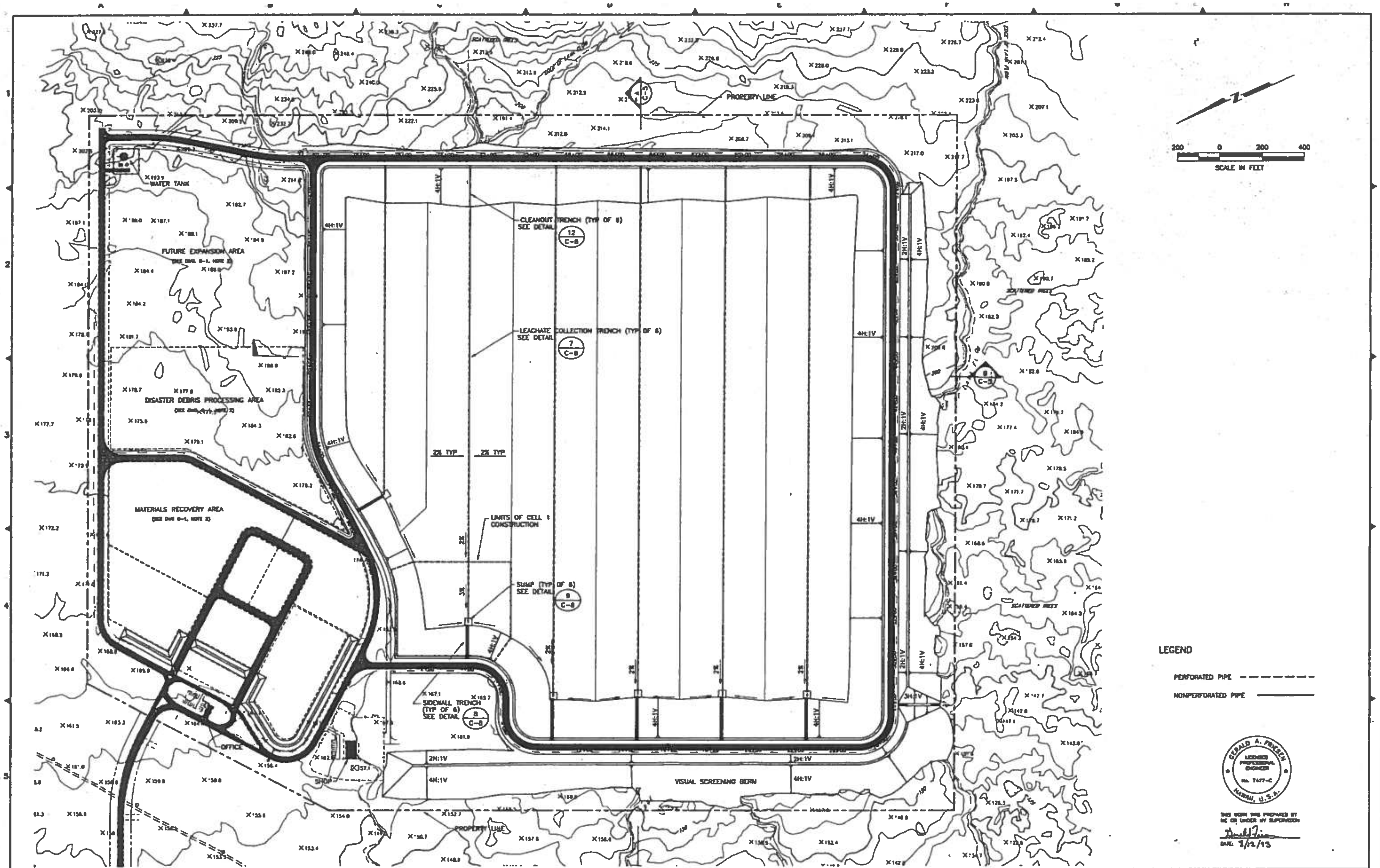
SCALE 1" = 200'
DATE 08/12/93
JOB NO. 24789.204

ONE INCH AT FULL SCALE
IF NOT ONE INCH SCALE ACCORDINGLY

WEST HAWAII SANITARY LANDFILL
Puuanahulu, North Kona, Hawaii

BASE GRADE PLAN

DRAWING C-1
SHEET 3 OF 11



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DESIGNED MLK
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SUBMITTED [signature] DATE 3/12/93
APPROVED [signature] DATE 8-18-93
APPROVED ____ DATE ____

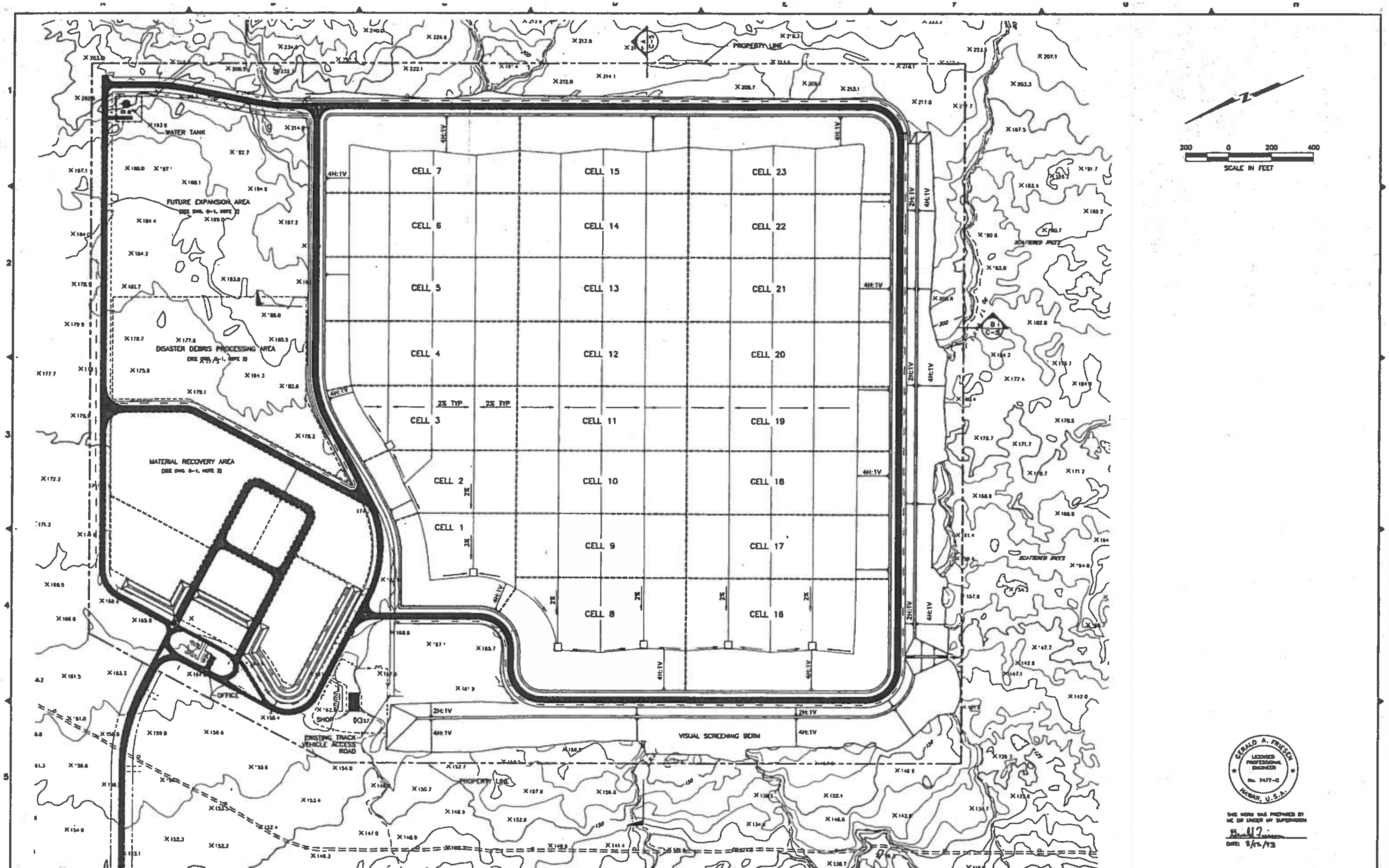
SCALE 1"=200'
DATE 08/12/93
JOB NO. 24789.204

ONE INCH AT FULL SCALE
IF NOT ONE INCH SCALE ACCORDINGLY

WEST HAWAII SANITARY LANDFILL
Puuanahulu, North Kona, Hawaii

LEACHATE COLLECTION SYSTEM PLAN

DRAWING C-2
SHEET 4 OF 11



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APPROVED [signature] DATE 8-18-93
APPROVED DATE

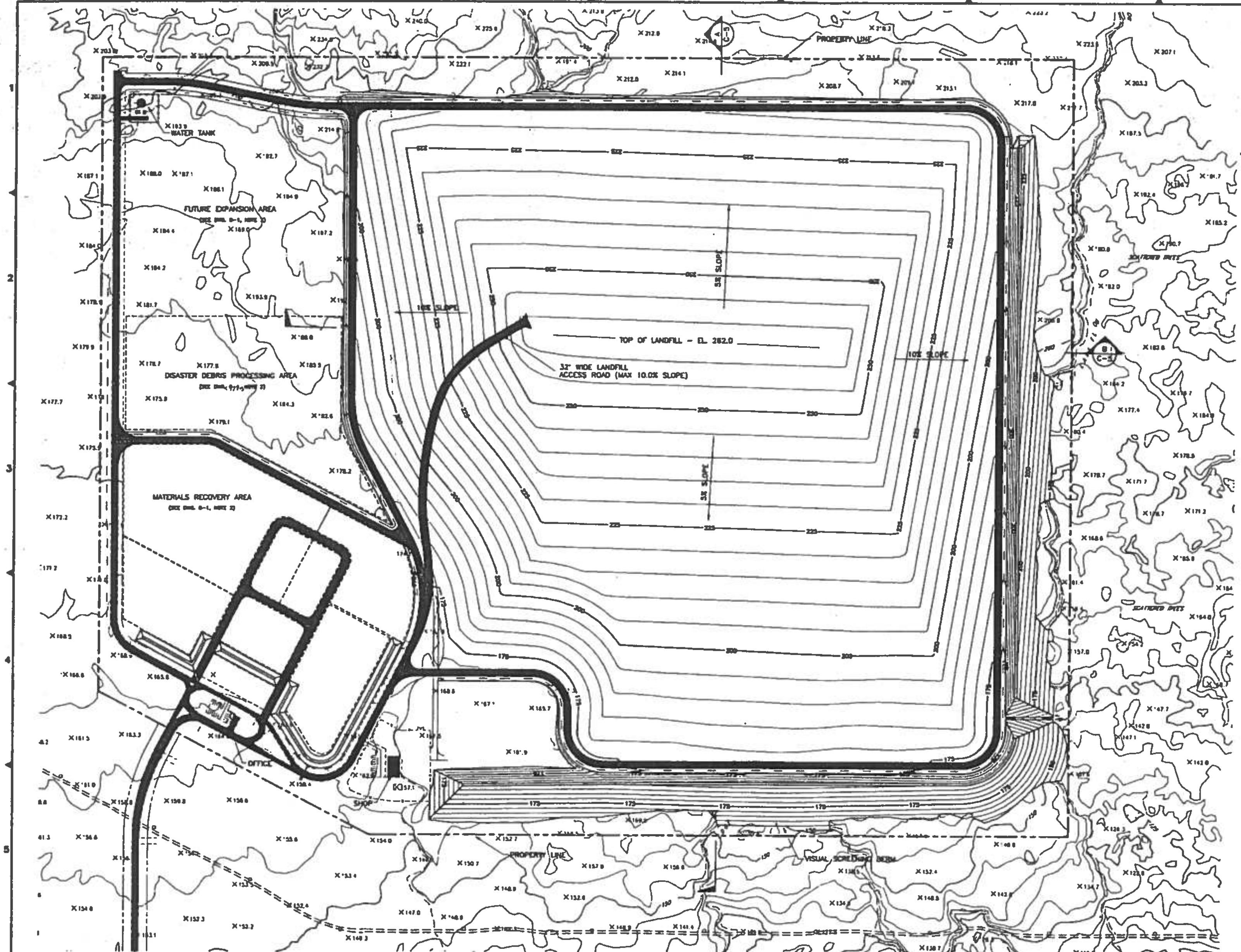
SCALE 1"=200'
DATE 08/12/93
JOB NO. 24789,204

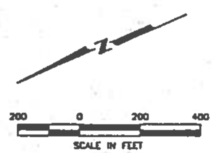
ONE INCH AT FULL SCALE
IF NOT ONE INCH SCALE ACCORDINGLY

WEST HAWAII SANITARY LANDFILL
Puuanahulu, North Kona, Hawaii

LANDFILL PHASING PLAN

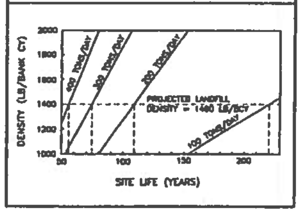
DRAWING C-3
SHEET 3 OF 11





VOLUME CALCULATIONS	
LANDFILL EXCAVATION	7,678,000 CY CUT
SCREENING BERM & ROADS	49,000 CY CUT
	576,000 CY FILL
EARTHWORK TOTAL	7,727,000 CY CUT
	576,000 CY FILL
12" CUSHION LAYER	247,000 CY
12" DRAINAGE LAYER	240,000 CY
12" PROTECTIVE LAYER	239,000 CY
LINER SYSTEM TOTAL	726,000 CY
12" EROSION LAYER	252,000 CY
12" CUSHIONING LAYER	248,000 CY
18" INFILTRATION LAYER	406,000 CY
FINAL COVER SYSTEM TOTAL	906,000 CY
GROSS AIRSPACE	14,093,000 CY
DAILY AND INTERMEDIATE COVER	2,349,000 CY
NET AIRSPACE (REFUSE BANK YARDS)	11,744,000 CY

SITE LIFE ESTIMATES



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APPROVED — DATE 8-18-93
APPROVED — DATE

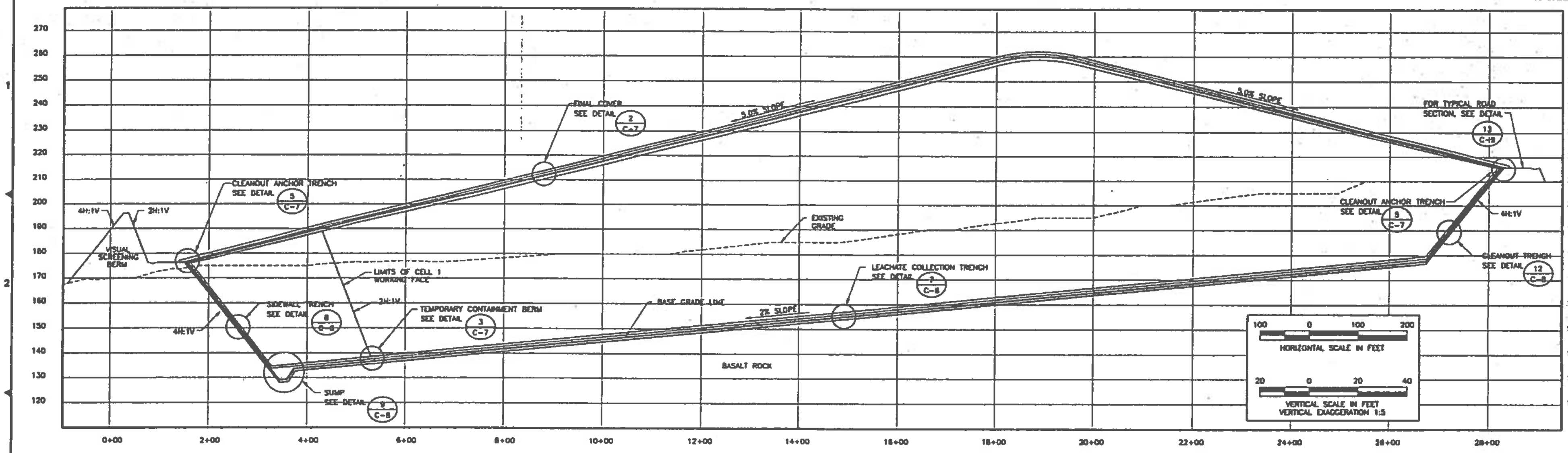
SCALE 1"=200'
DATE 08/12/93
JOB NO. 24789 204

ONE INCH AT FULL SCALE
IF NOT ONE INCH SCALE ACCORDINGLY

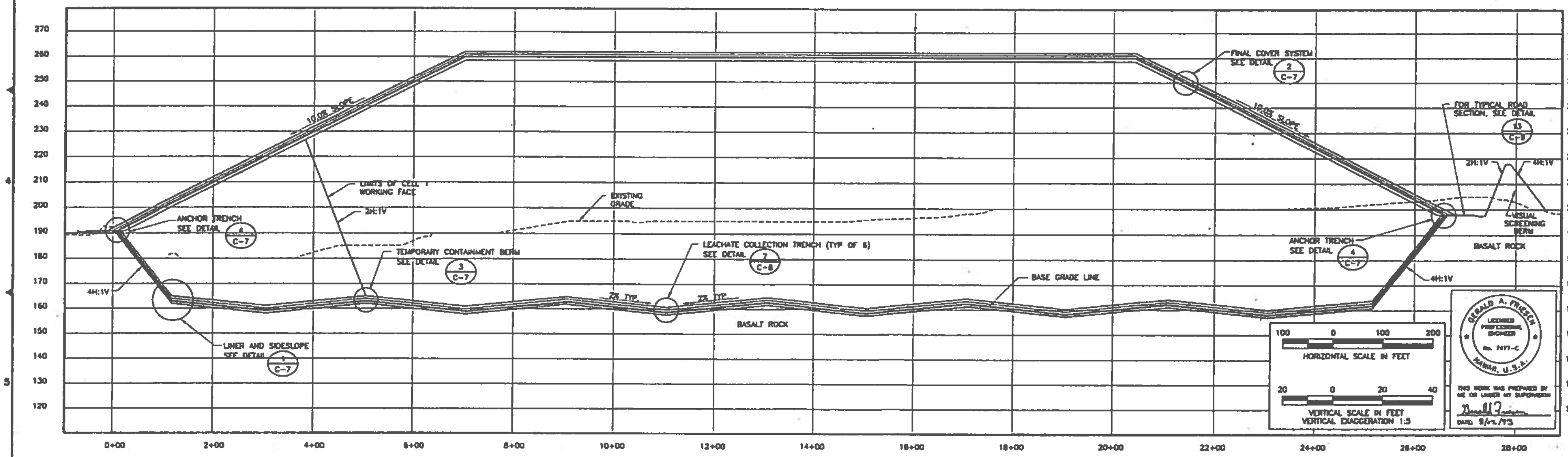
WEST HAWAII SANITARY LANDFILL
Puuanahulu, North Kona, Hawaii

FINAL GRADING PLAN

DRAWING C-4
SHEET 6 OF 11



LANDFILL SECTION A-A (1)



LANDFILL SECTION B-B (2)

NO.	REVISION	BY	DATE

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SUBMITTED — DATE 8/12/93
APPROVED — DATE 8/17/93
APPROVED — DATE

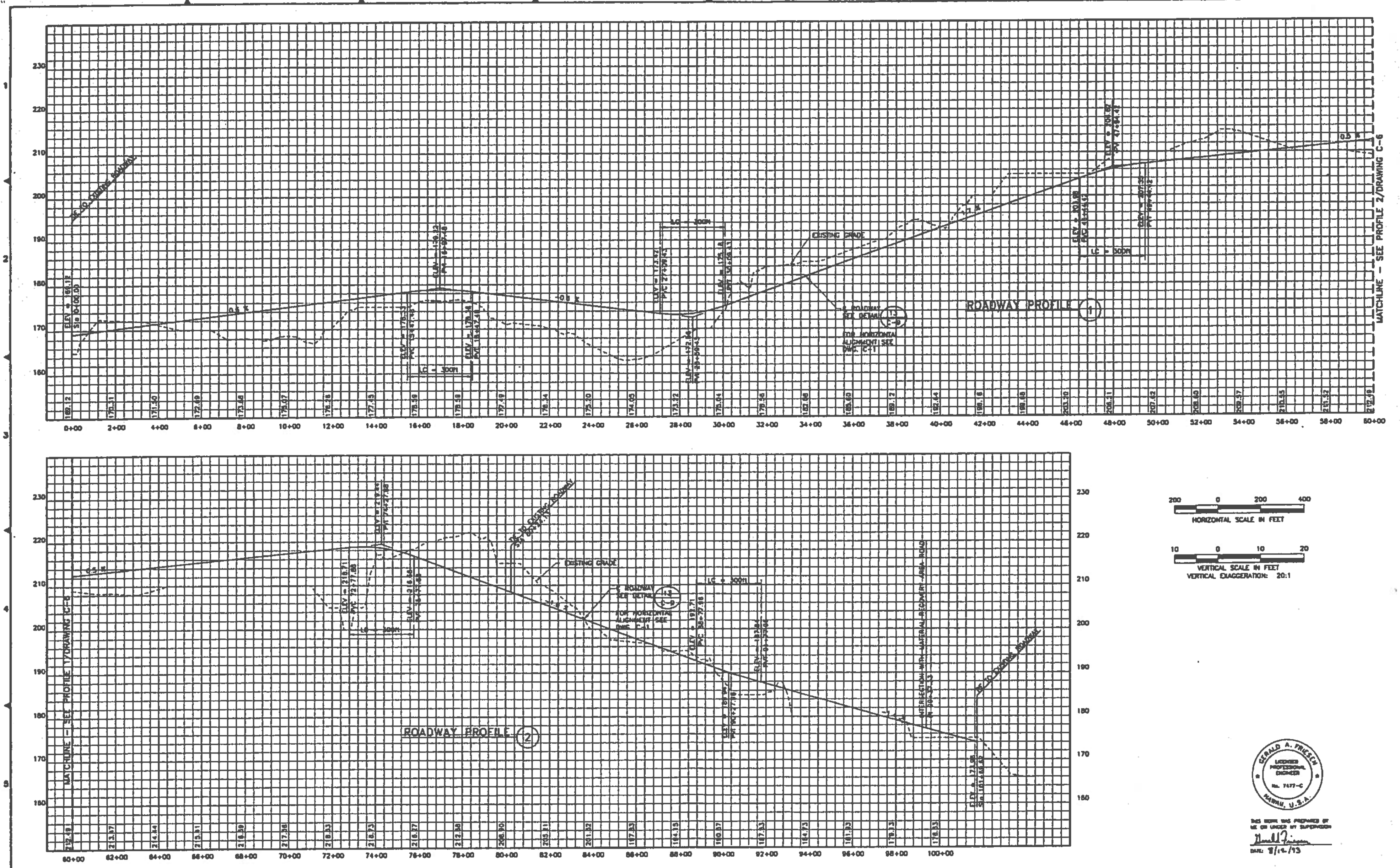
SCALE AS NOTED
DATE 08/12/93
JOB NO. 24789,204

ONE INCH AT FULL SCALE
IF NOT ONE INCH SCALE ACCORDINGLY

WEST HAWAII SANITARY LANDFILL
Puuanahulu, North Kona, Hawaii

LANDFILL CROSS-SECTIONS

DRAWING C-5
SHEET 7 OF 11

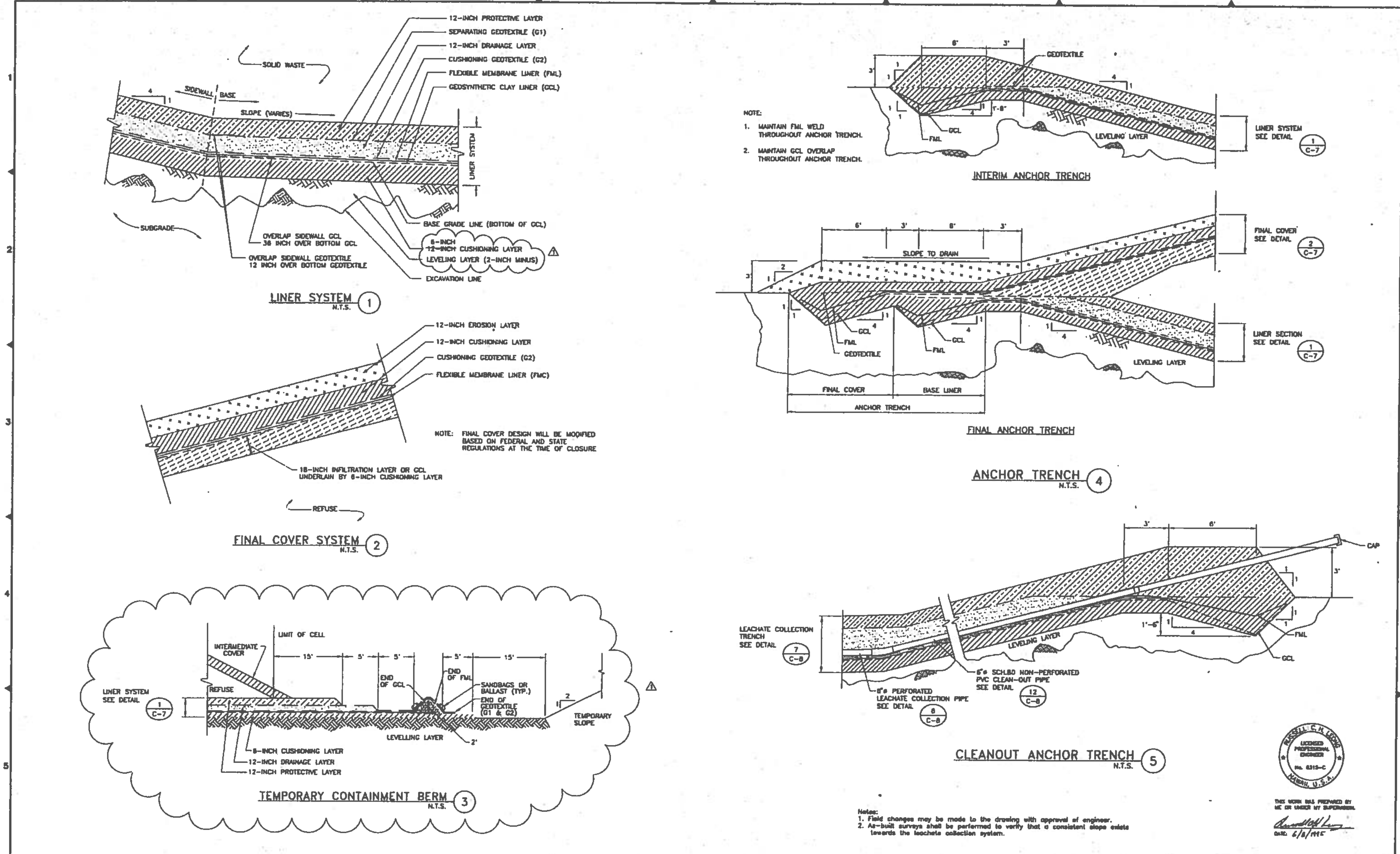


Harding Lawson Associates 233 Pearlridge Center, Phase 1 98-1005 Moanalua Road Aiea, Hawaii 96701 Phone: 808/486-6009 Fax: 808/486-7184	DESIGNED MLK DRAWN MLK CHECKED CF	SUBMITTED [signature] DATE 8/12/93 APPROVED Roy A. [signature] DATE 8-12-93 APPROVED ____ DATE ____	SCALE AS SHOWN DATE 08/12/93 JOB NO. 24789 204	ONE INCH AT FULL SCALE IF NOT ONE INCH SCALE ACCORDINGLY	WEST HAWAII SANITARY LANDFILL Puuanahulu, North Kona, Hawaii

PERIMETER ROAD PROFILE

DRAWING C-6

SHEET 8 OF 11



Notes:
1. Field changes may be made to the drawing with approval of engineer.
2. As-built surveys shall be performed to verify that a consistent slope exists towards the leachate collection system.

NO.	REVISION	BY	DATE
1	REVISED DETAIL 1 AND 3	RCHL	6/8/95

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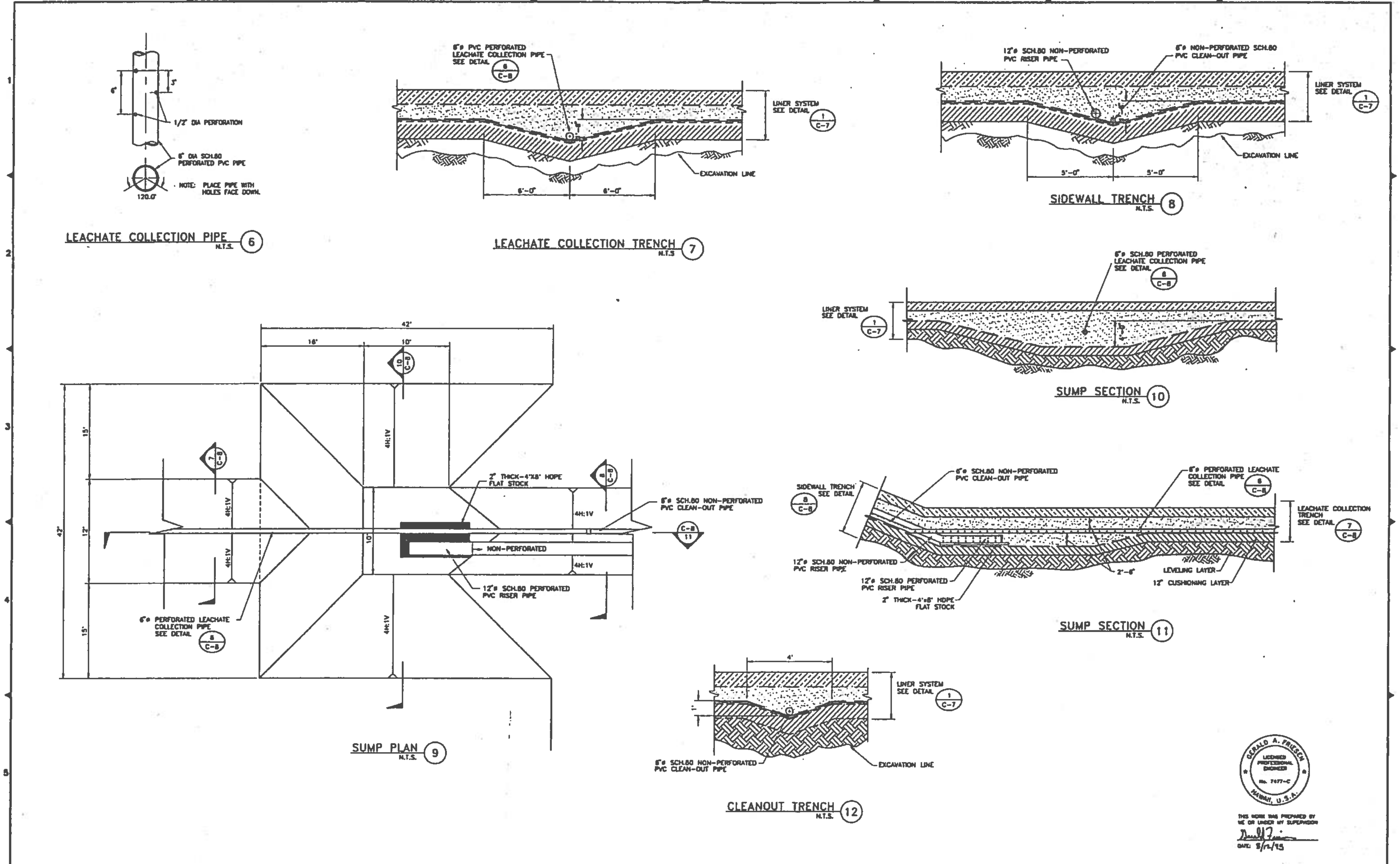
APPROVED ____ DATE ____
APPROVED ____ DATE ____

SCALE AS SHOWN
DATE 08/12/93
JOB NO. 24789,204
ONE INCH AT FULL SCALE
IF NOT ONE INCH SCALE ACCORDINGLY

WEST HAWAII SANITARY LANDFILL
Puuanahulu, North Kona, Hawaii

LINER SECTIONS AND DETAILS

DRAWING C-7
SHEET 9 OF 11



NO.	REVISION	BY	DATE

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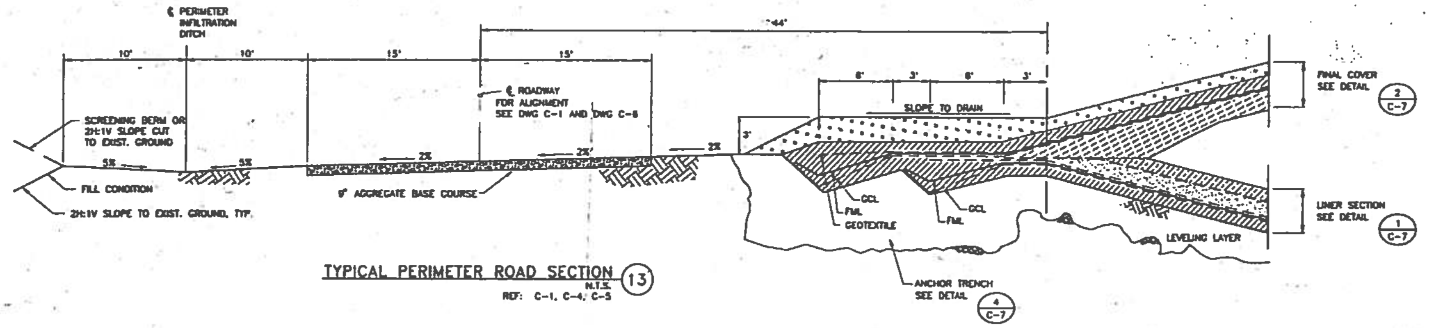
DESIGNED: MLK	SUBMITTED: [signature]	DATE: 8/12/93	SCALE: AS NOTED
DRAWN: MLK/JBL	APPROVED: [signature]	DATE: 8-12-93	DATE: 08/12/93
CHECKED: CF	APPROVED:	DATE:	JOB NO. 24789.204

ONE INCH AT FULL SCALE
IF NOT ONE INCH SCALE ACCORDINGLY

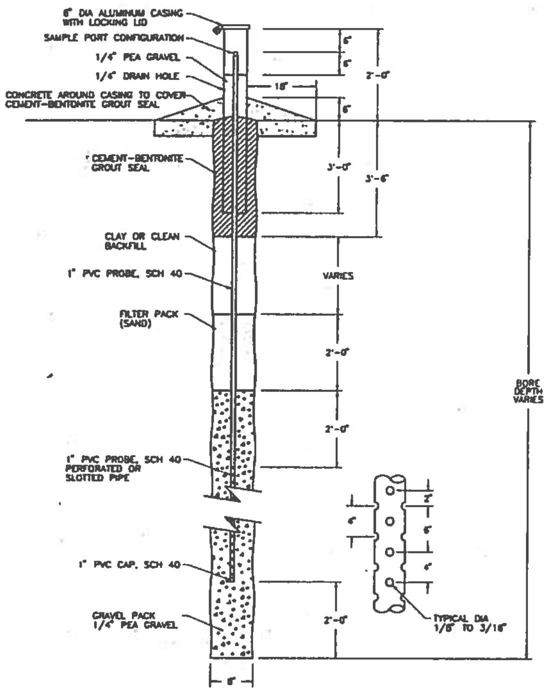
WEST HAWAII SANITARY LANDFILL
Puuanahulu, North Kona, Hawaii

LEACHATE COLLECTION SYSTEM DETAILS

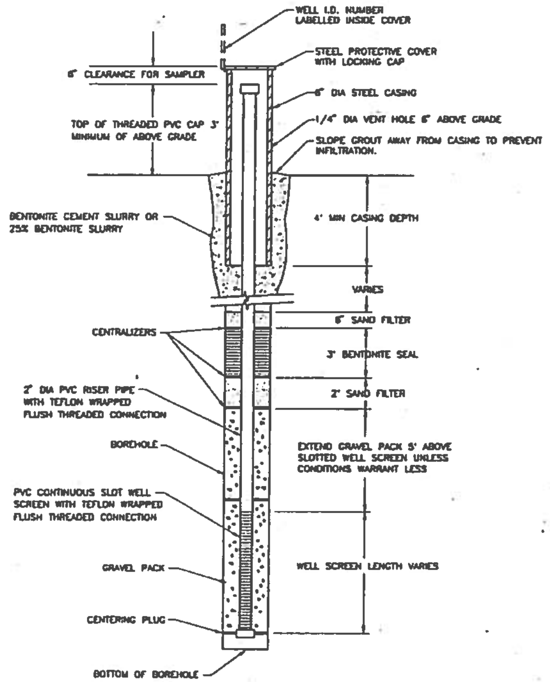
DRAWING C-8
SHEET 10 OF 11



TYPICAL PERIMETER ROAD SECTION (13)
N.T.S.
REF: C-1, C-4, C-5



GAS PROBE DETAIL (14)
N.T.S.



MONITORING WELL DETAIL (15)
N.T.S.

GERALD A. FRIESEN
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No. 7477-C
HAWAII, U.S.A.

THIS WORK WAS PREPARED BY ME OR UNDER MY SUPERVISION
DATE: 8/12/93

NO. / REVISION / BY / DATE	HLA Harding Lawson Associates, 235 Pearlridge Center, Phase 1, 98-1005 Moanalua Road, Aiea, Hawaii 96701, Phone: 808/486-6009, Fax: 808/486-7184	DESIGNED MLK DRAWN MLK CHECKED CF	SUBMITTED [signature] DATE 8/12/93 APPROVED Ray A. [signature] DATE 8-18-93 APPROVED DATE	SCALE AS NOTED DATE 08/12/93 JOB NO. 24789,204	ONE INCH AT FULL SCALE IF NOT ONE INCH SCALE ACCORDINGLY	WEST HAWAII SANITARY LANDFILL Puuanahulu, North Kona, Hawaii	MISCELLANEOUS DETAILS	DRAWING C-9 SHEET 11 OF 11

Appendix C
Final Cover Stability Analysis

CLIENT: Waste Management of Hawaii
PROJECT: West Hawaii Sanitary Landfill
SUBJECT: Final Cover Stability Analysis

Prepared By TW Date 04/08/08
Reviewed By JFG Date 04/09/08
Approved By ____ Date ____

TASK

Evaluate the cover soil stability of the proposed final cover system at West Hawaii Sanitary Landfill (WHSL) for the following conditions:

1) Static condition w/o equipment loading;
2) Static condition w/ equipment loading;
3) Seismic condition; and
4) Parallel seepage buildup.

REFERENCES

1. Koerner, R. M. and Soong, T.-Y., "Analysis of Design Veneer Cover Soils," Proc. 6th Intl. Conf. on Geosynthetics, IFAI Publ., St. Paul, MN, 1998, pp. 1-23.
2. Soong, Te-Yang and Koerner, R. M., "The Design of Drainage Systems over Geosynthetically Lined Slopes", GRI Report #19, June 17, 1997.
3. West Hawaii Sanitary Landfill Permit Drawings, prepared by Harding Lawson Associates, dated August 1993 and revised June 1995.
4. Caterpillar Performance Handbook, 22nd edition, 1991.
5. USEPA RCRA Subtitle D (259) Seismic Design Guidance for Municipal Solid Waste Landfill Facilities, April 1995, EPA/600/R-95/051.
6. USGS Seismic Hazard Map for Hawaii – Horizontal Ground Acceleration (%g) with 2% Probability of Exceedance in 50 Years, Retrieved April 8, 2008 from http://earthquake.usgs.gov/research/hazmaps/products_data/Hawaii/his/HIpga250r.pdf.
7. Technical Paper 43, "Rainfall-Frequency Atlas of the Hawaiian Islands for Areas to 200 Square Miles, Durations to 24 Hours, and Return Periods from 1 to 100 Years", U.S. Department of Commerce Weather Bureau, 1962.
8. Storm Drainage Standard, Department of Public Works, County of Hawaii, October 1970.
9. Geosynthetic Research Institute Report 30, "Direct Shear Database of Geosynthetic-to-Geosynthetic and Geosynthetic-to-Soil Interfaces", 14 June 2005.

METHODOLOGY

The cover soil stability of the proposed final cover system was evaluated using the methodologies presented in References 1 and 2. The authors used limit equilibrium and a finite slope model to analyze the stability of veneer cover soils over geosynthetic-lined slopes for several loading conditions. The development of the free body diagram shows that two zones are present for the finite slope analysis: (1) a small passive wedge at the toe of slope resisting (2) a long thin active wedge extending the length of the slope. The free body diagrams for each of the conditions evaluated are provided on the calculations in Attachment 2 of this calculation brief. By setting the forces on the passive wedge equal to the forces on the active wedge, a quadratic equation is developed to solve for the factor of safety (FS):

$$FS = \frac{-b + \sqrt{b^2 - 4ac}}{2a}$$

The equations for each of the conditions based on References 1 and 2 are as follows:

1. **Static Condition without Equipment Loading**

$$a = (W_A - N_A \cos\beta)\cos\beta$$
$$b = -\{[(W_A - N_A \cos\beta)\sin\beta \tan\phi + (N_A \tan\delta + C_a)\sin\beta\cos\beta + \sin\beta(C + W_P \tan\phi)\}$$
$$c = (N_A \tan\delta + C_a)\sin^2\beta \tan\phi$$

Where:

W_A = total weight of the active wedge

$$W_A = \gamma h^2\left(\frac{L}{h} - \frac{1}{\sin\beta} - \frac{\tan\beta}{2}\right)$$

W_P = total weight of the passive wedge

$$W_P = \frac{\gamma h^2}{\sin 2\beta}$$

N_A = effective force normal to the failure plane of the active wedge

$$N_A = W_A \cos\beta$$

γ = unit weight of the cover soil
h = height of cover soil
L = length of slope
β = slope angle
Φ = friction angle of the cover soil
δ = interface friction angle between the cover soil and geosynthetic component
C_a = adhesive force between cover soil of the active wedge and the geosynthetics

$$C_A = c_a\left(L - \frac{h}{\sin\beta}\right)$$

c_a = adhesion between cover soil of the active wedge and the geosynthetics
C = cohesive force along the failure plane of the passive wedge

$$C = \frac{(c)(h)}{\sin\beta}$$

c = cohesion of the cover soil (kN/m^2)

2. **Static Condition with Equipment Loading**

$$a = [(W_A + W_E)\sin\beta + F_e)\cos\beta$$
$$b = -\{[(N_E + N_A)\tan\delta + C_a]\cos\beta + [(W_A + W_E)\sin\beta + F_E]\sin\beta\tan\phi + (C + W_P \tan\phi)\}$$
$$c = [(N_E + N_A)\tan\delta + C_a]\sin\beta\tan\phi$$

CLIENT: Waste Management of Hawaii SUBJECT: Final Cover Stability Analysis
PROJECT: West Hawaii Sanitary Landfill

Prepared By TW Date 04/08/08
Reviewed By JFG Date 04/09/08
Approved By ____ Date ____

Where:

W_A	=	same as above
W_P	=	same as above
N_A	=	same as above
W_e	=	equipment force per unit length
	=	q w I
q	=	W_b / (2wb)
W_b	=	actual weight of equipment
w	=	length of equipment track
b	=	width of equipment track
I	=	influence factor at the geosynthetic interface (see Table on calculation sheet in Attachment 2)

3. Seismic Condition

$$a = (C_S W_A + N_A \sin\beta)\cos\beta + C_S W_P \cos\beta$$

$$b = -\{[(C_S W_A + N_A \sin\beta)\sin\beta\tan\phi + (N_A \tan\delta + C_a)\cos^2\beta + (C + W_P \tan\phi)\cos\beta\}$$

$$c = (N_A \tan\delta + C_a)\cos\beta\sin\beta\tan\phi$$

Where:

W_A	=	same as above
W_P	=	same as above
N_A	=	same as above
C_s	=	seismic coefficient

4. Parallel to Slope Seepage Condition

a	=	$W_A (\sin\beta)(\cos\beta) - U_h(\cos^2\beta) + U_h$
b	=	$-W_A(\sin^2\beta)(\tan\Phi) + U_h(\sin\beta)(\cos\beta)(\tan\Phi) - N_A(\cos\beta)(\tan\delta) - (W_P - U_V)(\tan\Phi)$
c	=	$N_A(\sin\beta)(\tan\delta)(\tan\Phi)$

Where:

$$W_A = \frac{\gamma_{dry}(h-h_w)[2H\cos\beta - (h+h_w)] + \gamma_{sat}(h_w)(2H\cos\beta - h_w)}{\sin 2\beta}$$

$$U_h = \frac{\gamma_w (h_w)^2}{2}$$

$$N_A = W_A(\cos\beta) + U_h(\sin\beta) - U_n$$

$$U_n = \frac{\gamma_w (h_w)(\cos\beta)(2H\cos\beta - h_w)}{\sin 2\beta}$$

$$W_P = \frac{\gamma_{dry}(h^2 - h_w^{\ 2}) + \gamma_{sat}(h_w^{\ 2})}{\sin 2\beta}$$

$$U_V = U_h / \tan\beta$$

γ_{dry}	=	dry unit weight of cover soil
γ_{sat}	=	saturated unit weight of cover soil
γ_w	=	unit weight of water
h_w	=	height of saturated cover soil
	=	PSR x h
PSR	=	parallel submergence ratio (based on cover soil drainage capacity)

ASSUMPTIONS

1. Soil and Slope Parameters

γ	=	105 pcf = 16.51 kN/m^3 (assumed for 2" minus crushed rock erosion layer)
γ_{dry}	=	95 pcf = 14.93 kN/m^3
γ_{sat}	=	115 pcf = 18.08 kN/m^3
γ_w	=	62.4 pcf = 9.81 kN/m^3
h	=	18 inches = 457.2 mm ≈ 0.46 m
L	=	650 ft = 198.1 m (max. slope length for 10% slope per Permit Drawing C-4 - Reference 3)
	=	1750 ft = 533.4 m (max. slope length for 5% slope per Permit Drawing C-4 - Reference 3)
β	=	5.71° (10% slope)
	=	2.86° (5% slope)
Φ	=	32°
c	=	0
c_a	=	0

2. Vehicle Loading
It is assumed that a Caterpillar D6H LGP (low ground pressure) Series II dozer will be used to place the erosion layer (see Attachment 1):

w	=	3.27 m
b	=	0.915 m
W_b	=	19,989 kg x 9.81 m/s^2 x (1 kN/1000 N)
	=	196.1 kN
q	=	W_b / 2wb
	=	(196.1 kN) / (2 x 3.27 m x 0.915 m)
	=	32.77 kN/m^2
I	=	0.97 (wide width, cover soil > 300 mm and < 1000 mm)
a	=	0.20g (assumed)

3. Seismic Coefficient (C_s)
Per Reference 5, in their 1984 Report titled "Rationalizing the Seismic Coefficient Method", Hynes and Franklin concluded that slopes and embankments with a yield acceleration equal to half the peak ground acceleration would

experience permanent seismic deformations of less than 1 meter (3 feet) in any earthquake, even for embankments where amplification of acceleration by a factor of three occurs.

The peak ground acceleration would be the "Maximum horizontal acceleration in lithified earth material" as defined in HAR § §11-58.1-03:

> *"Maximum horizontal acceleration in lithified earth material means the maximum expected horizontal acceleration depicted on a seismic hazard map with a ninety per cent or greater probability that the acceleration will not be exceeded in two hundred fifty years, or the maximum expected horizontal acceleration based on a site-specific seismic risk assessment."*

The peak ground acceleration (PGA) with a 10% probability of exceeedance (PE) in 250 years is not available on the USGS Earthquake Hazards Program website; however, the PGA with a 2% PE in 50 years is (see Reference 6 in Attachment 1). Per the site's FAQ (retrieved 4/8/08 from http://earthquake.usgs.gov/research/hazmaps/haz101/faq/parm08.php), the PGA with 10% PE in 250 years is basically equivalent to the PGA with 2% PE in 50 years. Therefore,

PGA with 2% PE in 50 years = 0.70g

And,

$C_s = 0.50 \times 0.70g = 0.35g$

4. Parallel to Slope Seepage Analysis
   In order to calculate the drainage layer capacity (DLC) and the parallel submergence ratio, the following parameters were input:

k_{cs}	=	permeability of cover soil
	=	0.5 cm/sec (assumed permeability for 2" minus erosion layer)
P	=	precipitation rate for design storm event (Assume 25-yr, 24-hr storm)
	=	2.5 in/hr = 63.5 mm/hr (Assume maximum precipitation rate during storm is equal to 50% of the design storm rainfall → 24-yr, 24-hr rainfall ≈ 5 inches per Reference 7 – See Attachment 1)
RC	=	runoff coefficient (per Rational Method)
	=	0.43 (using Table 1 of Reference 8 – See Attachment 1)

5. Factor of Safety
   The minimum factor of safety to be targeted for each of the evaluations is as follows:

   1) Static condition w/o equipment loading = 1.5 (long-term condition)
   2) Static condition w/ equipment loading = 1.2 (short-tern condition)
   3) Seismic condition = 1.0
   4) Parallel seepage buildup = 1.2 (short-term condition)

RESULTS

Spreadsheets have been developed to analyze the cover soil stability for each of the design conditions. Both the maximum 10% slope length and the maximum 5% slope length were evaluated to determine the critical slope section. The minimum interface friction angle of the final cover system was varied until the minimum factor of safety for each condition (Assumption 5) was met. The results are shown in Table 1 and the calculation spreadsheets are provided as Attachment 2.

Table 1. Cover Soil Stability Results

Condition	Slope	Minimum Factor of Safety (FS_{min})	Minimum Interface Friction Angle to Achieve FS_{min} [1] (degrees)
Static w/o Equipment	5%	1.5	4.0
	10%		8.1
Static w/ Equipment	5%	1.2	3.5
	10%		7.3
Seismic	5%	1.0	21.7
	10%		24.2
Parallel to Slope Seepage	5%	1.2	7.4
	10%		14.6

[1] Assumes zero adhesion

As shown in Table 1, the critical condition is the seismic condition for the maximum 10% slope length (24.2° interface friction angle needed to achieve FS = 1.0).

Interface shear test data results from Reference 9 provided below show that the interfaces present in the proposed WHSL final cover system should provide the required interface shear strength:

From Reference 9:

- Granular soil to needle-punched nonwoven geotextile: $\Phi = 33°$, $c_a = 0$
- Needle-punched nonwoven geotextile to textured LLDPE: $\Phi = 26°$, $c_a = 8.1$ kPa
- Textured LLDPE to granular soil: $\Phi = 26°$, $c_a = 7.7$ kPa

This cover soil stability evaluation should be performed prior to final cover system construction using site-specific interface shear test results to verify that the interface shear strengths provide the required factor of safety for each loading condition.

Please note that adhesion was neglected for this evaluation, and thus, the combination of an adhesive force with an interface friction angle lower than the minimum required friction angle reported in Table 1 could still provide the minimum factor of safety for the design condition.

Attachment 1

References

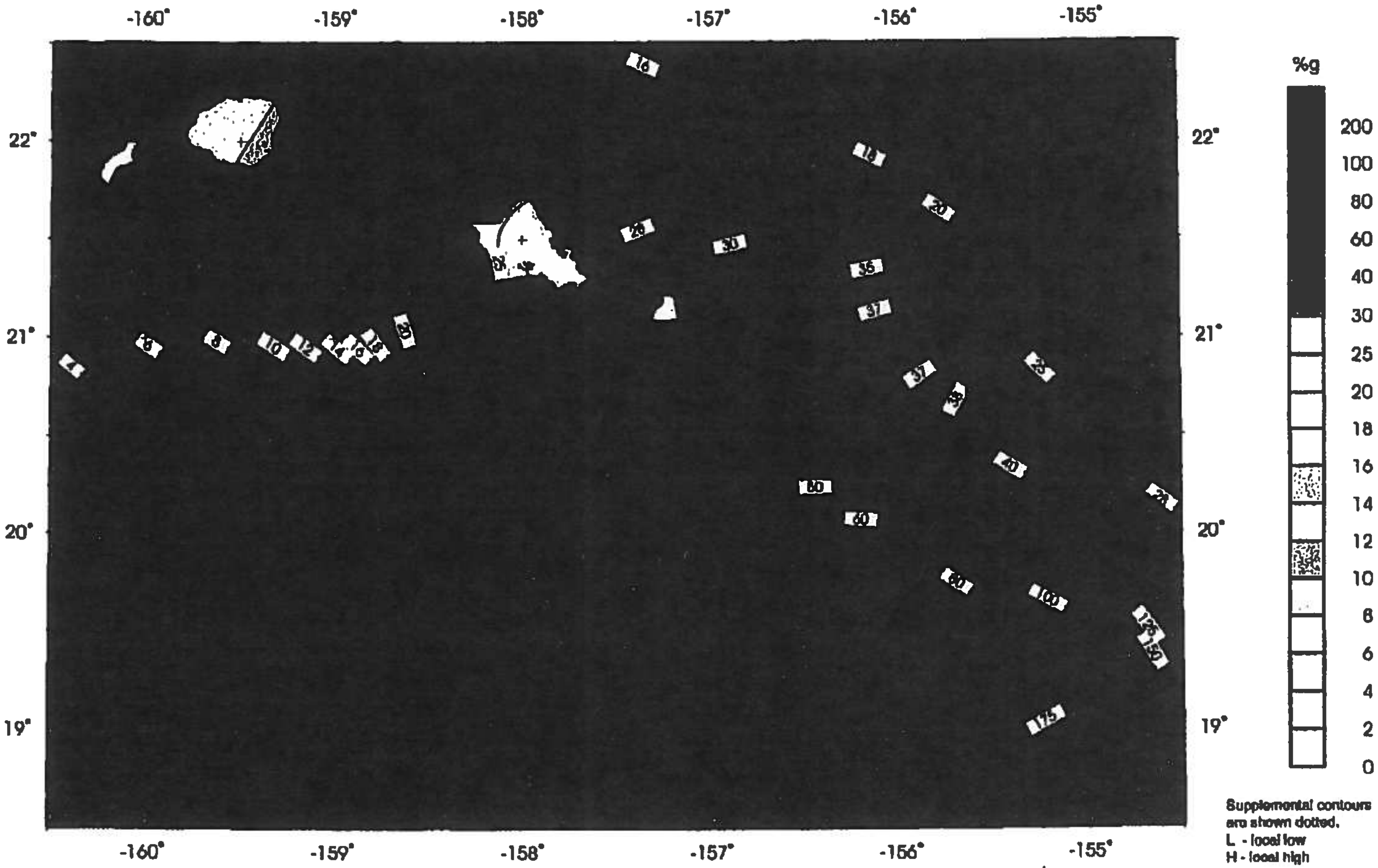
Reference 4

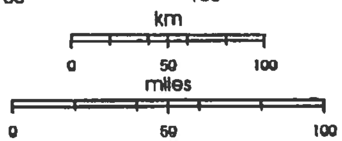
MODEL	D5H LGP Series II		D6H LGP Series II		D7H LGP Series II	
Flywheel Power	93.3 kW	125 HP	127 kW	170 HP	160 kW	215 HP
Operating Weight*						
(Power Shift)	15 810 kg	34,782 lb	19 814 kg	43,590 lb	25 886 kg	57,645 lb
(Direct Drive)	15 892 kg	34,961 lb	19 989 kg	43,976 lb	26 040 kg	57,903 lb
(Power Shift Differential Steer)	—		20 060 kg	44,131 lb	26 087 kg	58,248 lb
Engine Model	3304		3306		3306	
Rated Engine RPM	2200		1800		2100	
No. of Cylinders	4		6		6	
Bore	121 mm	4.75"	121 mm	4.75"	121 mm	4.75"
Stroke	152 mm	6"	152 mm	6"	152 mm	6"
Displacement	7 L	425 in³	10.5 L	638 in³	10.5 L	638 in³
Track Rollers (Each Side)	8		8		7	
Width of Standard Track Shoe	860 mm	34"	915 mm	36"	915 mm	36"
Length of Track on Ground	3.12 m	10'3"	3.27 m	10'8.5"	3.17 m	10'5.4"
Ground Contact Area (W/Std. Shoe)	5.37 m²	8320 in²	5.97 m²	9254 in²	5.83 m²	9029 in²
Track Gauge	2.16 m	7'1"	2.23 m	7'3"	2.23 m	7'3"
GENERAL DIMENSIONS:						
Height (Stripped Top)**	2.30 m	7'6.5"	2.32 m	7'7"	2.55 m	8'4"
Height (To Top of ROPS Canopy)	3.12 m	10'3"	3.16 m	10'5"	3.42 m	11'2.6"
Height (To Top of Cab ROPS)	3.18 m	10'5"	—		3.50 m	11'6"
Overall Length (With P Blade)	5.30 m	17'6.3"	5.18 m	17'0"	5.54 m	18'2"
(Without Blade)	4.13 m	13'7"	4.49 m	14'9"	4.62 m	15'2"
Width (Over Trunnion)	3.26 m	10'8.4"	3.43 m	11'3"	3.37 m	11'1"
Width (W/O Trunnion — Std. Shoe)	3.02 m	9'11"	3.14 m	10'3.6"	3.15 m	10'4"
Ground Clearance	444 mm	17.5"	382 mm	15"	490 mm	19.3"
Blade Types and Widths:						
Straight	3.65 m	12'0"	3.99 m	13'1"	4.40 m	14'5"
Angle	—		—		—	
Universal	—		—		—	
Semi-U	—		—		—	
Power Angle & Tilt	3.98 m	13'0.1"	—		—	
Angled	3.66 m	11'11.9"	—		—	
Fuel Tank Refill Capacity	246 L	65 U.S. gal	337 L	89 U.S. gal	488 L	129 U.S. gal

*Operating Weight includes lubricants, coolant, full fuel tank, straight bulldozer, hydraulic controls and fluid, ROPS canopy and operator and rigid drawbar. D5H Series II with P-blade.
**Height (stripped top) — without ROPS canopy, exhaust, seat back or other easily removed encumbrances.

Reference 6



U.S. Geological Survey
National Seismic Hazard Mapping Project
Based on:
1. USGS Open-File Report - in progress
2. USGS Open-File Report - in progress



Scale - 1:3750000
Albers Equal-Area Conic Projection
Standard Parallels 8.0°N and 18.0°N

Horizontal Ground Acceleration (%g)
With 2% Probability of Exceedance in 50 Years
Firm Rock - 760 m/sec shear wave velocity

Reference 7

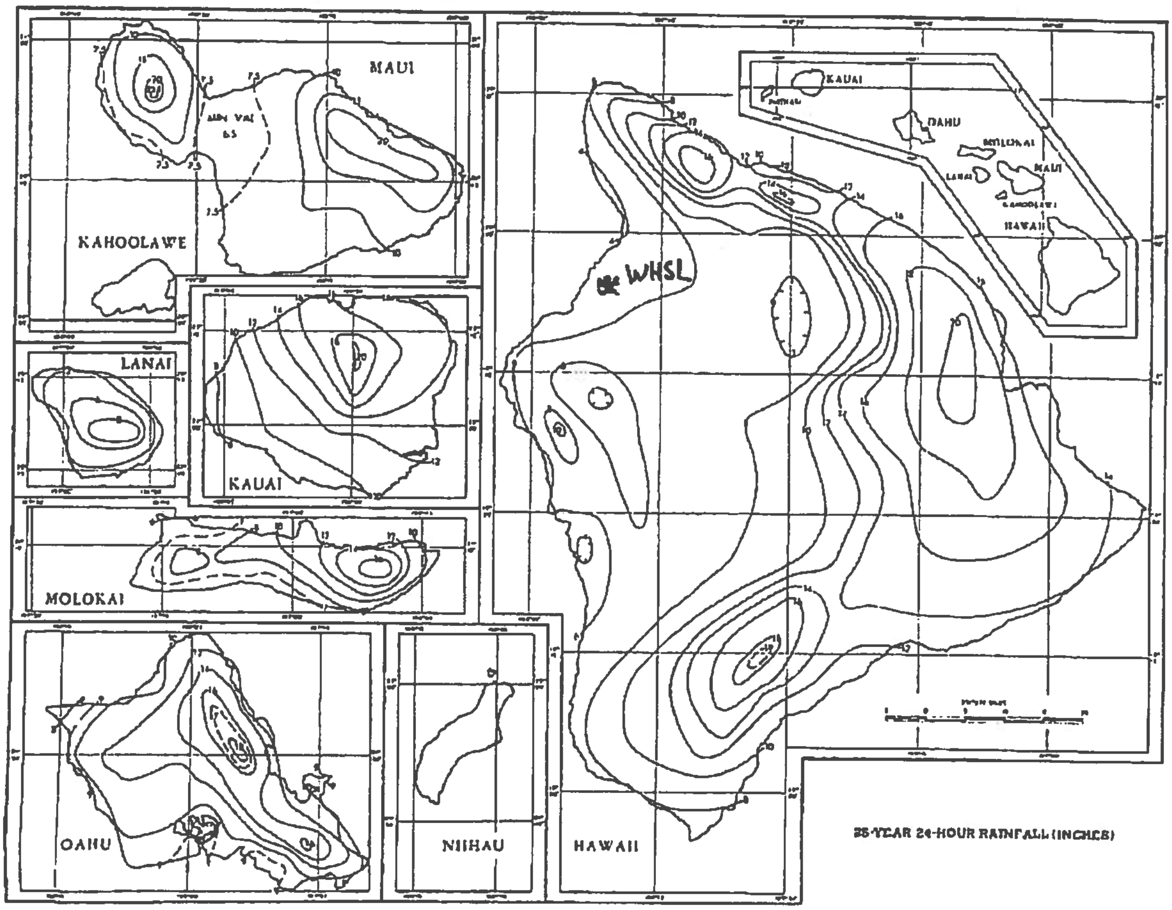


FIGURE 54.—25-yr. 24-hr. rainfall (in.)

Reference 8

Table 1

GUIDE FOR THE DETERMINATION OF RUNOFF COEFFICIENTS FOR BUILT-UP AREAS*

WATERSHED CHARACTERISTICS	EXTREME	HIGH	MODERATE	LOW	
INFILTRATION	NEGLIGIBLE 0.20	SLOW 0.14	MEDIUM 0.07	HIGH 0.0	→ 0.20
RELIEF	STEEP (> 25%) 0.08	HILLY (15-25%) 0.06	ROLLING (5-15%) 0.03	FLAT (0-5%) 0.0	→ 0.03
VEGETAL COVER	NONE 0.07	POOR (< 10%) 0.05	GOOD (10-50%) 0.03	HIGH (50-90%) 0.0	→ 0.05
DEVELOPMENT TYPE	INDUSTRIAL & BUSINESS 0.55	HOTEL-APARTMENT 0.45	RESIDENTIAL 0.40	AGRICULTURAL 0.15	→ 0.15
					RC = 0.43

NOTE: The design coefficient "c" must result from a total of the values for all four watershed characteristics of the site.

Table 2

APPROXIMATE AVERAGE VELOCITIES OF RUNOFF FOR CALCULATING TIME OF CONCENTRATION

TYPE OF FLOW	VELOCITY IN FPS FOR SLOPES (in percent) INDICATED			
OVERLAND FLOW:	0-3%	4-7%	8-11%	12-15%
Woodlands	1.0	2.0	3.0	3.5
Pastures	1.5	3.0	4.0	4.5
Cultivated	2.0	4.0	5.0	6.0
Pavements	5.0	12.0	15.0	18.0
OPEN CHANNEL FLOW:				
Improved Channels	Determine Velocity by Manning's Formula			
Natural Channel* (not well defined)	1.0	3.0	5.0	8.0

These values vary with the channel size and other conditions so that the ones given are the averages of a wide range. Wherever possible, more accurate determinations should be made for particular conditions by Manning's formula.

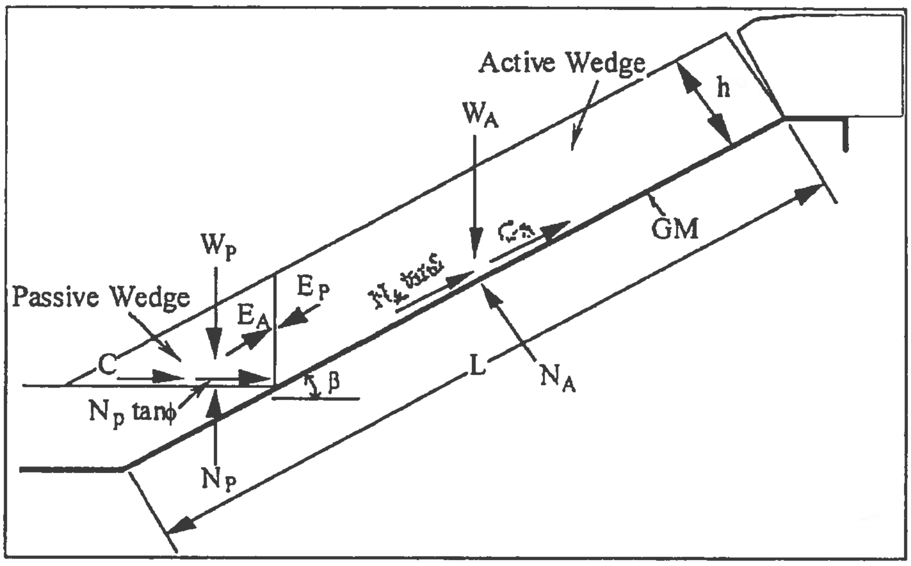
Attachment 2

Final Cover Stability Analyses

For GSI/GRI members only

WHSL Final Cover Stability Analysis

Static Condition w/o Equipment - Uniform Cover Soil Thickness - 5% slope



Calculation of FS

Active Wedge:

Wa= 3980.9 kN

Na= 3975.9 kN

Passive Wedge:

Wp= 35.1 kN

$$FS = \frac{-b + \sqrt{b^2 - 4ac}}{2a}$$

a= 9.898

b= -15

c= 0.4

FS= 1.51

thickness of cover soil = h =	0.46	m			
soil slope angle beneath the geomembrane = β =	2.86	°	*= 0.05 (rad.)*		
length of slope measured along the geomembrane = L =	533.4	m			
unit weight of the cover soil = γ =	16.51	kN/m^3			
friction angle of the cover soil = φ =	32.0	°	*= 0.56 (rad.)*		
cohesion of the cover soil = c =	0.0	kN/m^2		*C= 0*	*kN*
interface friction angle between cover soil and geomembrane = δ =	4.0	°	*= 0.07 (rad.)*		
adhesion between cover soil and geomembrane = ca =	0.0	kN/m^2		*Ca= 0*	*kN*

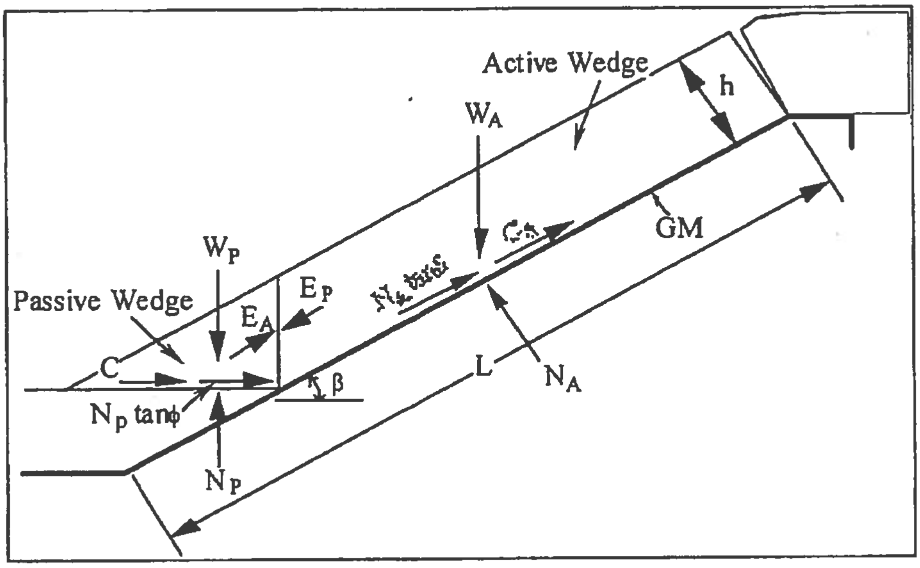
Note: numbers in boxes are input values

numbers in Italics are calculated values

For GSI/GRI members only

WHSL Final Cover Stability Analysis

Static Condition w/o Equipment - Uniform Cover Soil Thickness - 10% slope



Calculation of FS

Active Wedge:

Wa= 1469.2 kN

Na= 1461.9 kN

Passive Wedge:

Wp= 17.6 kN

$$FS = \frac{-b + \sqrt{b^2 - 4ac}}{2a}$$

a= 14.5

b= -23

c= 1.3

FS= 1.50

thickness of cover soil = h =	0.46	m			
soil slope angle beneath the geomembrane = β =	5.7	°	*= 0.10 (rad.)*		
length of slope measured along the geomembrane = L =	198.1	m			
unit weight of the cover soil = γ =	16.51	kN/m^3			
friction angle of the cover soil = φ =	32.0	°	*= 0.56 (rad.)*		
cohesion of the cover soil = c =	0.0	kN/m^2		*C= 0*	*kN*
interface friction angle between cover soil and geomembrane = δ =	8.1	°	*= 0.14 (rad.)*		
adhesion between cover soil and geomembrane = ca =	0.0	kN/m^2		*Ca= 0*	*kN*

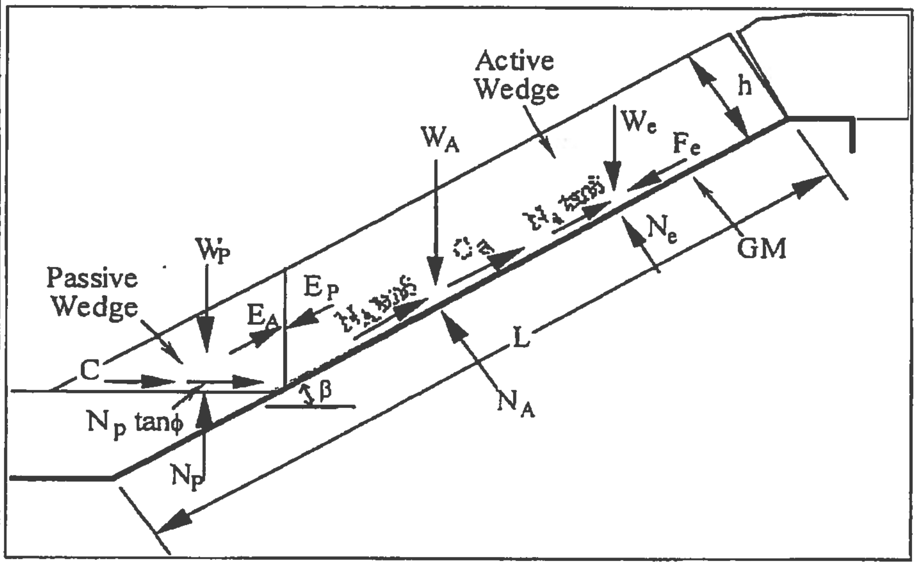
Note: numbers in boxes are input values

numbers in Italics are calculated values

For GSI/GRI members only

WHSL Final Cover Stability Analysis

Static Condition w/ Equipment Loading - 5% slope



Calculation of FS

Active Wedge:

Wa= 3980.9 kN

Na= 3975.9 kN

Passive Wedge:

Wp= 35.1 kN

$$FS = \frac{-b + \sqrt{b^2 - 4ac}}{2a}$$

a= 224.3

b= -278

c= 7.8

FS= 1.21

thickness of cover soil = h =	0.46	m			
soil slope angle beneath the geomembrane = β =	2.86	°	*= 0.05 (rad.)*		
finished cover soil slope angle = ω =	2.86	°	*= 0.05 (rad.)*		
length of slope measured along the geomembrane = L =	533.4	m			
unit weight of the cover soil = γ =	16.51	kN/m^3			
friction angle of the cover soil = ϕ =	32.0	°	*= 0.56 (rad.)*		
cohesion of the cover soil = c =	0.0	kN/m^2		*C= 0*	*kN*
interface friction angle between cover soil and geomembrane = δ =	3.5	°	*= 0.06 (rad.)*		
adhesion between cover soil and geomembrane = ca =	0.0	kN/m^2		*Ca= 0*	*kN*

thickness of cover soil = h =	0.46	m	*b/h=*	*2.0*
equipment ground pressure (= wt. of equipment/(2wb)) = q =	32.77	kN/m^2	*We=q w I=*	*103.9*
length of each equipment track = w =	3.27	m	*Ne=Wecos β=*	*103.8*
width of each equipment track = b =	0.915	m	*Fe=We (a/g) =*	*20.8*
influence factor* at geomembrane interface = I =	0.97			
acceleration/deceleration of the bulldozer = a =	0.20	g		

*Influence Factor Default Values

Cover Soil Thickness	Equipment Track Width		
	Very Wide	Wide	Standard
²300 mm	1.00	0.97	0.94
300-1000 mm	0.97	0.92	0.70
³1000 mm	0.95	0.75	0.30

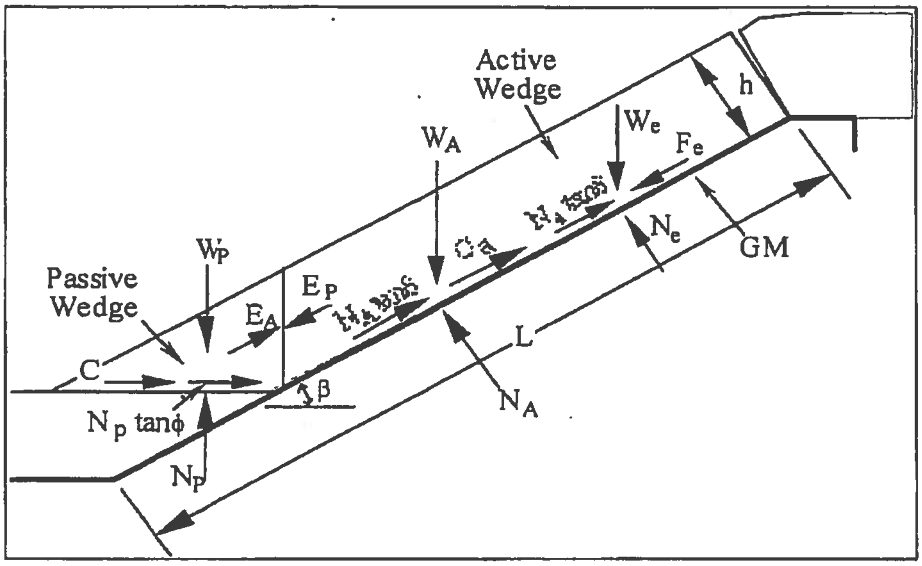
Note: numbers in boxes are input values

numbers in Italics are calculated values

For GSI/GRI members only

WHSL Final Cover Stability Analysis

Static Condition w/ Equipment Loading - 10% slope



Calculation of FS

Active Wedge:

Wa= 1469.2 kN

Na= 1461.9 kN

Passive Wedge:

Wp= 17.6 kN

$$FS = \frac{-b + \sqrt{b^2 - 4ac}}{2a}$$

a= 176.4

b= -222

c= 12.5

FS= 1.20

thickness of cover soil = h =	0.46	m			
soil slope angle beneath the geomembrane = β =	5.71	°	*= 0.10*	*(rad.)*	
finished cover soil slope angle = ω =	5.71	°	*= 0.10*	*(rad.)*	
length of slope measured along the geomembrane = L =	198.1	m			
unit weight of the cover soil = γ =	16.51	kN/m^3			
friction angle of the cover soil = φ =	32.0	°	*= 0.56*	*(rad.)*	
cohesion of the cover soil = c =	0.0	kN/m^2			*C= 0 kN*
interface friction angle between cover soil and geomembrane = δ =	7.3	°	*= 0.13*	*(rad.)*	
adhesion between cover soil and geomembrane = ca =	0.0	kN/m^2			*Ca= 0 kN*

thickness of cover soil = h =	0.46	m	*b/h= 2.0*
equipment ground pressure (= wt. of equipment/(2wb)) = q =	32.77	kN/m^2	*We=q w I= 103.9*
length of each equipment track = w =	3.27	m	*Ne=Wecos β= 103.4*
width of each equipment track = b =	0.915	m	*Fe=We (a/g) = 20.8*
influence factor* at geomembrane interface = I =	0.97		
acceleration/deceleration of the bulldozer = a =	0.20	g	

*Influence Factor Default Values

Cover Soil Thickness	Equipment Track Width		
	Very Wide	Wide	Standard
² 300 mm	1.00	0.97	0.94
300-1000 mm	0.97	0.92	0.70
³ 1000 mm	0.95	0.75	0.30

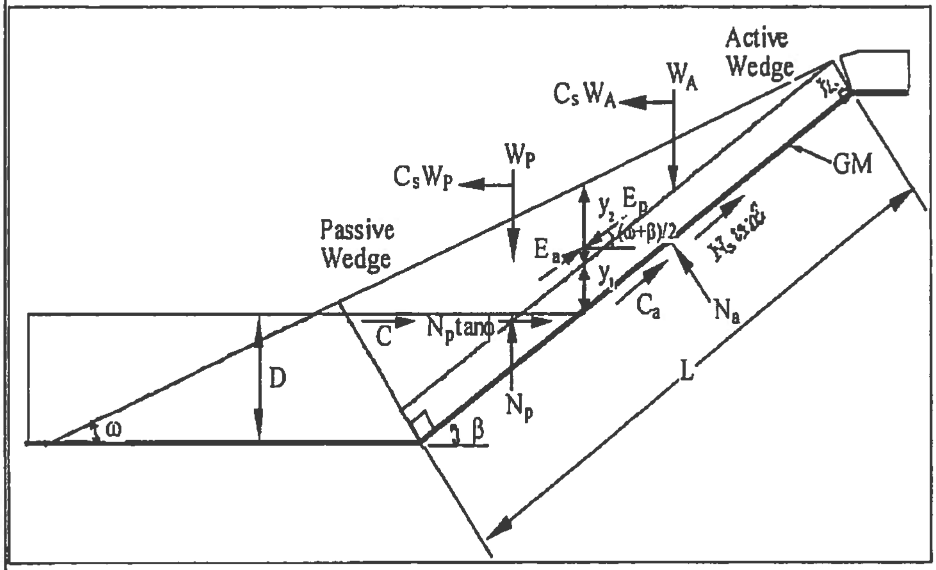
Note: numbers in boxes are input values

numbers in Italics are calculated values

For GSI/GRI members only

WHSL Final Cover Stability Analysis

Seismic Condition - 5% slope



Calculation of FS

Active Wedge:

Wa=	*3980.9*	*kN*
Na=	*3975.9*	*kN*
Ca=	*0.0*	*kN*

Passive Wedge:

Wp=	*35.1*	*kN*
C=	*0.0*	*kN*

$$FS = \frac{-b + \sqrt{b^2 - 4ac}}{2a}$$

a=	*1601.9*
b=	*-1650*
c=	*49.3*

FS= 1.00

(Note: for uniform cover soil thickness the input value of ω = β)

thickness of cover soil at top (crest) of the slope = hc =	0.46	m		
thickness of cover soil along the bottom of the site = D =	0.46	m		
soil slope angle beneath the geomembrane = β =	2.86	°	*= 0.05*	*(rad.)*
finished cover soil slope angle = ω =	2.86	°	*= 0.05*	*(rad.)*
length of slope measured along the geomembrane = L =	533.4	m		

y2=	*0.00*	*(m)*
y1=	*0.46*	*(m)*
(ω+β)/2=	*0.050*	*(rad.)*
(=	*2.9*	*°)*

unit weight of the cover soil = γ =	16.51	kN/m^3		
friction angle of the cover soil = φ =	32.0	°	*= 0.56*	*(rad.)*
cohesion of the cover soil = c =	0.0	kN/m^2		
interface friction angle between cover soil and geomembrane = δ =	21.7	°	*= 0.38*	*(rad.)*
adhesion between cover soil and geomembrane = ca =	0.0	kN/m^2		

seismic coefficient = Cs = 0.35 g

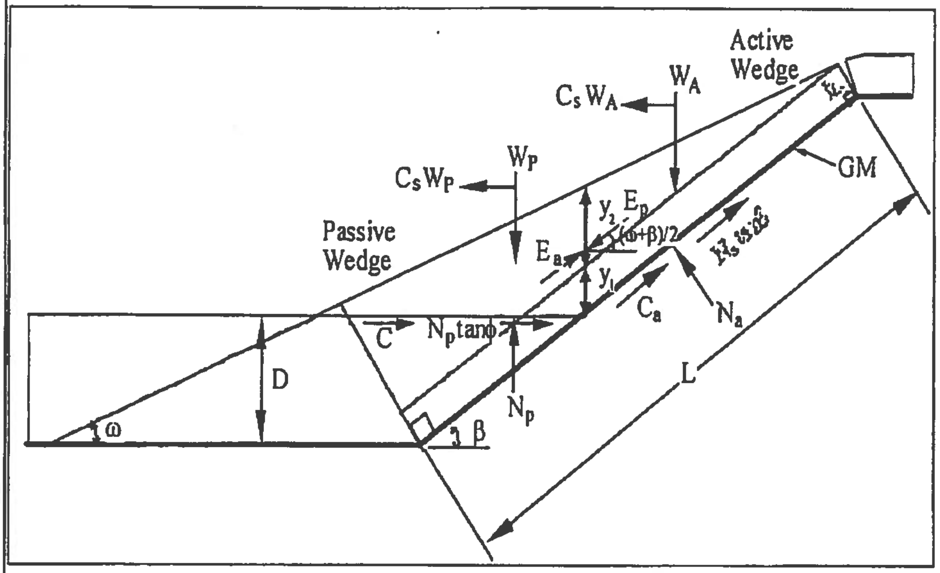
Note: numbers in boxes are input values

numbers in Italics are calculated values

For GSI/GRI members only

WHSL Final Cover Stability Analysis

Seismic Condition - 10% slope



Calculation of FS

Active Wedge:

Wa= 1469.2 kN

Na= 1461.9 kN

Ca= 0.0 kN

Passive Wedge:

Wp= 17.6 kN

C= 0.0 kN

$$FS = \frac{-b + \sqrt{b^2 - 4ac}}{2a}$$

a= 662.5

b= -702

c= 40.6

FS= 1.00

(Note: for uniform cover soil thickness the input value of ω = β)

thickness of cover soil at top (crest) of the slope = hc =	0.46	m		
thickness of cover soil along the bottom of the site = D =	0.46	m		
soil slope angle beneath the geomembrane = β =	5.71	°	*= 0.10*	*(rad.)*
finished cover soil slope angle = ω =	5.71	°	*= 0.10*	*(rad.)*
length of slope measured along the geomembrane = L =	198.1	m		

y2= 0.00 (m)

y1= 0.46 (m)

(ω+β)/2= 0.100 (rad.)

(= 5.7 °)

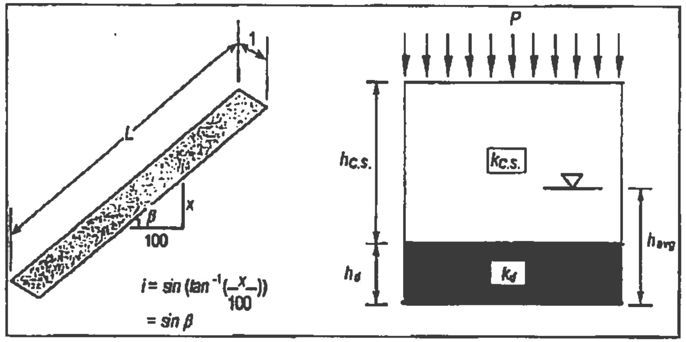
unit weight of the cover soil = γ =	16.51	kN/m^3		
friction angle of the cover soil = φ =	32.0	°	*= 0.56*	*(rad.)*
cohesion of the cover soil = c =	0.0	kN/m^2		
interface friction angle between cover soil and geomembrane = δ =	24.2	°	*= 0.42*	*(rad.)*
adhesion between cover soil and geomembrane = ca =	0.0	kN/m^2		
seismic coefficient = Cs =	0.35	g		

Note: numbers in boxes are input values

numbers in Italics are calculated values

WHSL Final Cover Stability Analysis

Parallel to Slope Seepage Condition - 5% slope



L = 533.4 m
β = 2.86 °

$h_{c.s.}$ = [blank] mm
h_d or t_{GS} = 457.2 mm

$k_{c.s.}$ = [blank] cm/s
k_d or k_{GS} = 5.0E-01 cm/s

P = 63.50 mm/hr
RC = 0.43

* Note: If only one soil layer above GM, treat it as the drainage layer.

i = 0.0499
$L(\cos\beta)$ = *532.74* m
x = *26.61* m
$h_{c.s.}$ = *0.0* m
h_d or t_{GS} = *0.46* m
$h_{c.s.} + h_d$ = *0.46* m

$k_{c.s.}$ = *0.0E+00* m/s
k_d or k_{GS} = *5.0E-03* m/s

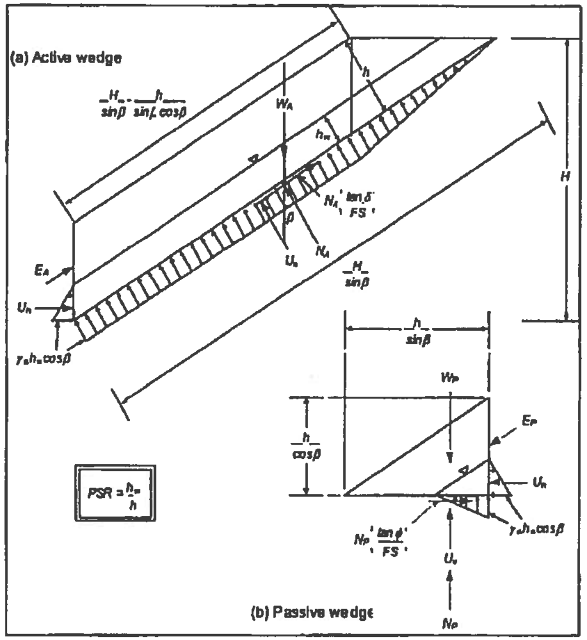
P (RC) = *27.3* mm/hr
Actual runoff = *27.31* mm/hr
PERC = *36.20* mm/hı
$FLUX_{actual}$ = *19.282* m³/hr
$FLUX_{allow}$ = *0.411* m³/hr *DLC = 0.0213*

q = 5.4E-03 m³/sec

h_{avg} = *0.46* m

PSR = 1.000

DLC	*0.021*
PSR	*1.000*
FS	*1.200*



thickness of cover soil = h = *0.46* m
length of slope measured along the geomembrane = L = *533* m
soil slope angle beneath the geomembrane = β = *2.9* ° = *0.05* (rad.)
vertical height of the slope measured from the toe = H = *26.6* m
parallel submergence ratio = *PSR* = *1.00*
depth of the water surface measured from the geomembrane = h_w = *0.46* m

dry unit weight of the cover soil = γ_{dry} = 14.93 kN/m³
saturated unit weight of the cover soil = γ_{satd} = 18.08 kN/m³
unit weight of water = γ_w = 9.81 kN/m³
friction angle of the cover soil = ϕ = 30.0 ° = *0.52* (rad.)
interface friction angle between cover soil and geomembrane = δ = 7.4 ° = *0.13* (rad.)

Calculation of FS

Active Wedge:
W_A = *4371.3* kN
U_n = *2368.8* kN
U_h = *1.0253* kN
N_A = *1996.9* kN

Passive Wedge:
W_P = *37.919* kN
U_V = *20.523* kN

$$FS = \frac{-b + \sqrt{b^2 - 4ac}}{2a}$$

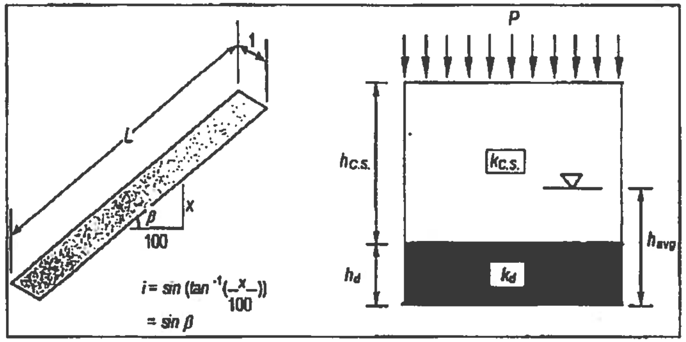
where a = *217.8*
b = *-267.5*
c = *7.5*

FS = 1.200

Note: numbers in boxes are input values
numbers in italics are calculated values

WHSL Final Cover Stability Analysis

Parallel to Slope Seepage Condition - 10% slope



L = 198.1 m
β = 5.71 °

$h_{C.S.}$ = [ ] mm
h_d or t_{GS} = 457.2 mm

$k_{C.S.}$ = [ ] cm/s
k_d or k_{GS} = 5.0E-01 cm/s

P = 63.50 mm/hr
RC = 0.43

* Note: if only one soil layer above GM treat it as the drainage layer.

i = *0.0995*
$L(\cos\beta)$ = *197.12* m
x = *19.71* m
$h_{C.S.}$ = *0.0* m
h_d or t_{GS} = *0.46* m
$h_{C.S.} + h_d$ = *0.46* m

$k_{C.S.}$ = *0.0E+00* m/s
k_d or k_{GS} = *5.0E-03* m/s

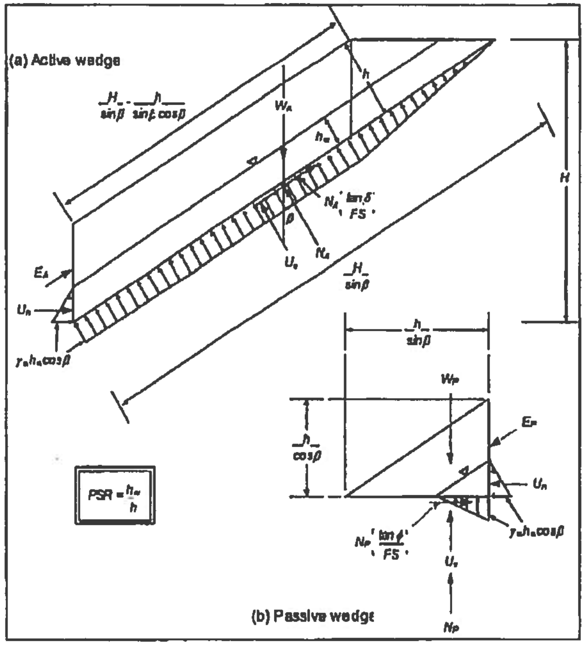
P (RC) = *27.3* mm/hr
Actual runoff = *27.31* mm/hr
PERC = *36.20* mm/hr
$FLUX_{actual}$ = *7.135* m^3/hr
$FLUX_{allow}$ = *0.819* m^3/hr *DLC = 0.1148*

q = *2.0E-03* m^3/sec

h_{avg} = *0.46* m

PSR = 1.000

DLC	0.115
PSR	1.000
FS	1.206



thickness of cover soil = h = *0.46* m
length of slope measured along the geomembrane = L = *198* m
soil slope angle beneath the geomembrane = β = *5.7* ° = *0.10* (rad.)
vertical height of the slope measured from the toe = H = *19.7* m
parallel submergence ratio = PSR = *1.00*
depth of the water surface measured from the geomembrane = h_w = *0.46* m

dry unit weight of the cover soil = γ_{dry} = 14.93 kN/m³
saturated unit weight of the cover soil = γ_{satd} = 18.08 kN/m³
unit weight of water = γ_w = 9.81 kN/m³
friction angle of the cover soil = ϕ = 30.0 ° = *0.52* (rad.)
interface friction angle between cover soil and geomembrane = δ = 14.6 ° = *0.25* (rad.)

Calculation of FS

Active Wedge:

W_A = *1618.4* kN
U_n = *873.79* kN
U_h = *1.0253* kN
N_A = *736.52* kN

Passive Wedge:

W_P = *19.087* kN
U_V = *10.254* kN

$$FS = \frac{-b + \sqrt{b^2 - 4ac}}{2a}$$

where a = *160.2*
b = *-202.4*
c = *11.0*

FS= 1.206

Note: numbers in boxes are input values
numbers in italics are calculated values