ENGINEERING DESIGN REPORT

FOR THE

CUBA LANDFILL SITE

Prepared for:

NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION

Prepared by:

DVIRKA AND BARTILUCCI CONSULTING ENGINEERS

WOODBURY, NEW YORK

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ENGINEERING DESIGN REPORT
CUBA LANDFILL SITE

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1.0 INTRODUCTION

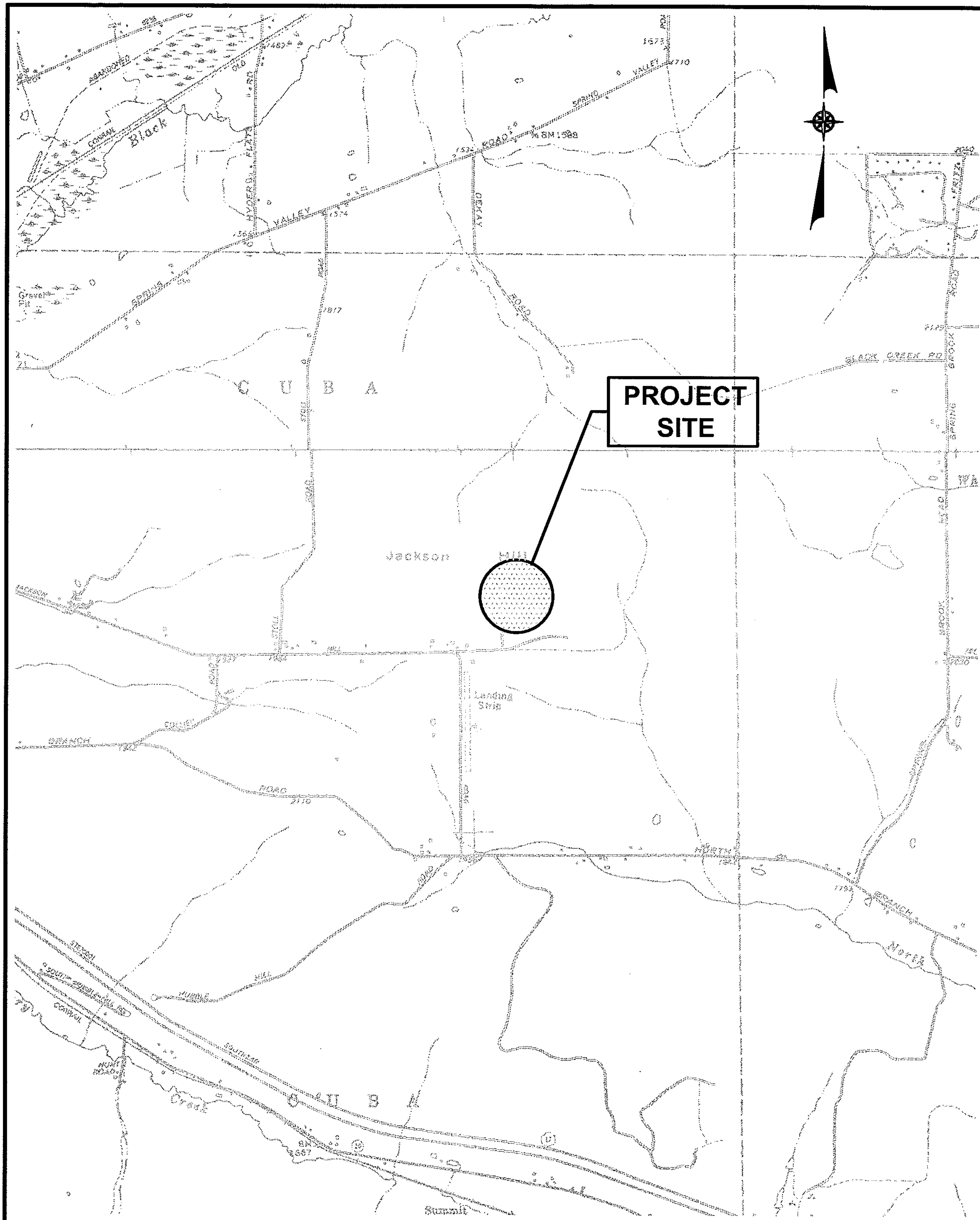
1.1 General

As part of the New York State's program to investigate and remediate hazardous waste sites, the New York State Department of Environmental Conservation (NYSDEC) issued a Work Assignment to Dvirka and Bartilucci Consulting Engineers (D&B) of Woodbury, New York. The Work Assignment was issued to D&B under its State Superfund Standby Contract with NYSDEC to conduct a remedial design for the Cuba Municipal Waste Site, located in the Village of Cuba, Allegany County, New York (see Figure 1-1). The site is listed in the New York State Registry of Inactive Hazardous Waste Sites. The registry number for this New York State Superfund site is 9-02-012. The design for this site is being performed with funds allocated under the New York State Superfund Program.

1.2 Site Description and History

The Cuba Landfill site is composed of two contiguous parcels of property totaling approximately 40 acres. The Village of Cuba currently owns both parcels. The site is bordered on the west and the north by Deep Snow Road (Figure 1-2). An unnamed intermittent tributary of the North Branch of Van Campen Creek closely parallels the eastern border, and forested private property borders the south side of the site. The site slopes steeply from north to south and consists mainly of tall grasses and brush. Several dozen partially settled disposal trenches are evident running both east-west and north-south across the site. Access to the site is from Jackson Hill Road and unpaved Deep Snow Road off Jackson Hill Road.

From the early 1950s until 1981, the Cuba Municipal Waste Disposal Site accepted household, commercial and industrial waste, including industrial waste from the Acme Electric Corporation. Acme Electric has identified several listed hazardous wastes generated by the facility and disposed at the landfill between 1952 and 1981. These wastes included spent halogenated solvents used in degreasing operations, plating bath sludges and cleaning bath from



SOURCE: USGS BLACK CREEK AND FRIENDSHIP QUADRANGLES

N.T.S.

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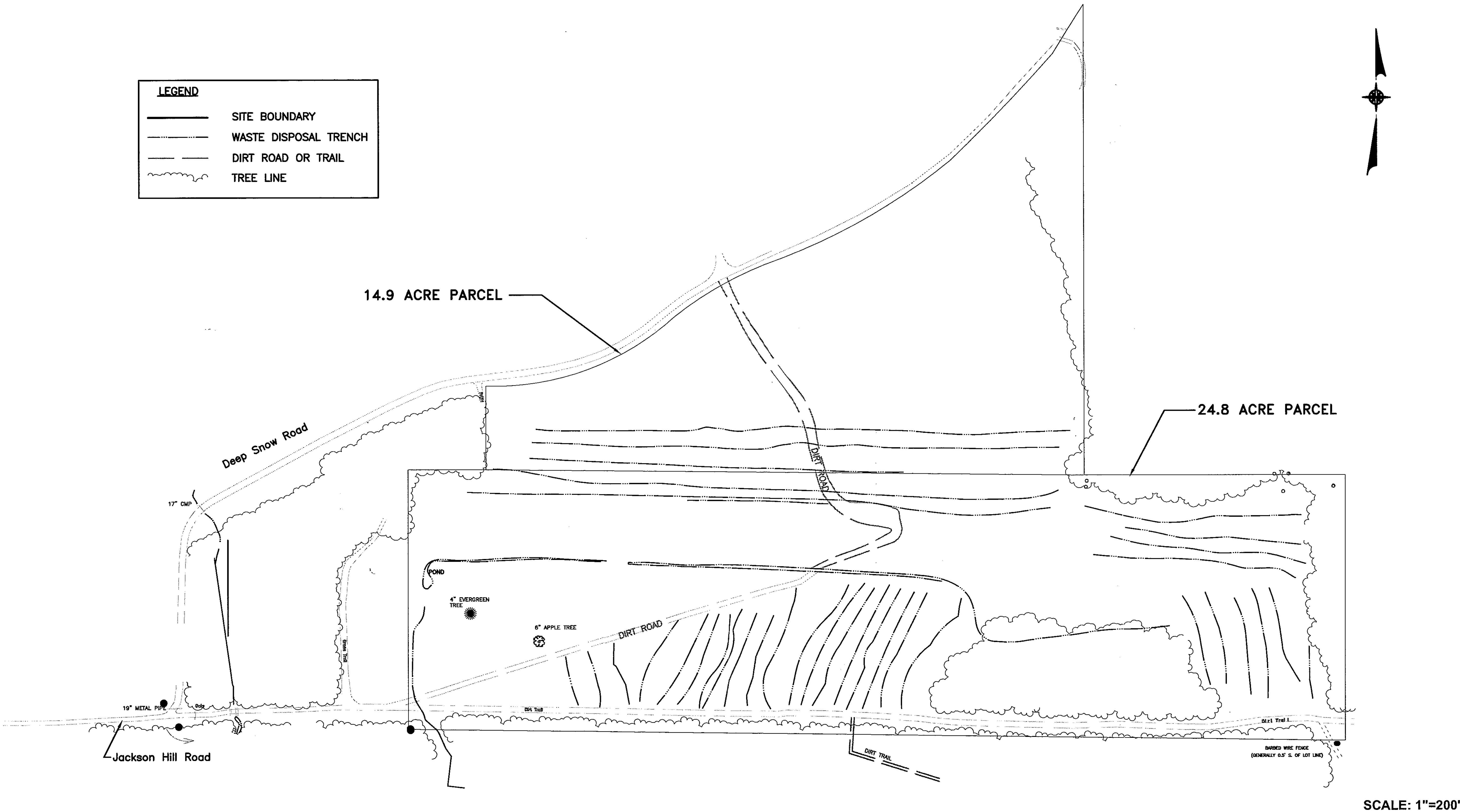
CUBA LANDFILL SITE
VILLAGE OF CUBA, NEW YORK

SITE LOCATION MAP

FIGURE 1-1

F:\2600\dwg\2600-C-COV.dwg, FIG1, 11/13/2007 11:11:29 AM, LGlubiak



CUBA LANDFILL SITE
VILLAGE OF CUBA, NEW YORK

SITE PLAN

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FIGURE 1-2

F:\2600\dwg\2600-C-PL03.dwg, Layout1, 11/13/2007 11:01:44 AM, LGlubiak electroplating operations PCB capacitors and paint sludges. No records of the quantities of the wastes disposed by Acme Electric are available.

The Village of Cuba has owned the property since November 1967. Prior to 1967, the property was leased by the Village from Ida Barber. The facility was issued a sanitary landfill permit in 1979 by the NYSDEC and was inspected on a regular basis by NYSDEC until the Village completed an approved closure plan in 1987.

Site Geology and Hydrology

Overburden thickness at the site is variable. Generally, the thickness of the soil is thin and ranges from 2 to 10 feet. Unconsolidated soil consists of silt with little gravel and trace sand. Soil thickness increases down-slope and south of the site. Borings into the bedrock beneath the site show that the bedrock is highly fractured, thinly bedded brown, gray and green-gray shale with less common siltstone. Most fractures are horizontal and parallel to the bedrock bedding planes. Groundwater flow is generally to the south; however, groundwater flow is dominated by bedrock fractures and precipitation/recharge events and is therefore complex.

1.3 Remediation Objectives

As described in the Record of Decision (ROD), the goals selected for this site are:

- Eliminate, to the extent practicable, direct human or animal exposure to waste in the landfill;
- Eliminate, to the extent practicable, the migration of contaminants from the landfill to groundwater;
- Reduce, control or eliminate, to the extent practicable, the generation of leachate within the landfill mass;
- Eliminate, to the extent practicable, ingestion of groundwater affected by the site that does not attain NYSDEC Class GA Ambient Water Quality Criteria; and

- Eliminate, to the extent practicable, off-site migration of groundwater that does not attain NYSDEC Class GA Ambient Water Quality Criteria.

Based on the results of the Remedial Investigation/Feasibility Study (RI/FS) for the Cuba Landfill Site and the criteria identified for evaluation of alternatives, the NYSDEC selected containment as the remedy for the site in accordance with NYSDEC TAGM No. 4044 - Accelerated Remedial Actions at Non-RCRA Regulated Landfills and 6 NYCRR Part 360. The components of the remedy, as defined in the ROD, are as follows:

- A remedial design program to verify the components of the conceptual design and provide details necessary for constructing the selected remedy;
- Construction of a new landfill cap to comply with 6 NYCRR Part 360 consisting of a gas venting system, geomembrane, geocomposite drainage layer, barrier protection layer and vegetative cover;
- Construction of a diversion trench on the north side of the landfill;
- Installation of a phytoremediation leachate control system on the southern toe of the landfill; and
- A long-term groundwater monitoring program to verify the effectiveness of the selected remedy.

2.0 PRE-DESIGN INVESTIGATIONS

Several environmental investigations were performed at the Cuba Landfill Site. Information from these investigations were used to prepare the remedial design for the site. The following summarizes the results of these investigations.

2.1 Summary of Site Assessments and Remedial Investigation

In October 1990, URS Consultants, Inc. prepared a Phase 1 – Preliminary Site Assessment (PSA) for the New York State Department of Environmental Conservation (NYSDEC) to determine if the site qualified for the New York State Registry of Inactive Hazardous Waste Disposal Sites. The report recommended additional sampling be conducted to determine if the site should be classified as a Class 2. In January 1994, Engineering Science, Inc. prepared a Phase II PSA report for NYSDEC. The Phase II PSA included installation and sampling of four groundwater monitoring wells, and sampling of surface water, leachate and surface soils. The results indicated the presence of volatile organic compounds (VOCs) in on-site groundwater and leachate. Based on the results from the Phase II PSA and the confirmed disposal of hazardous waste, including solvents, plating wastes, PCB capacitors and paint sludges, the site was reclassified from Class 2a to Class 2 in 1994. A Class 2 site is defined by the NYSDEC as posing a significant threat to human health and/or the environment.

A Remedial Investigation (RI) Report was completed for the Cuba Landfill Site in July 1999. The purpose of the RI was to define the nature and extent of contamination resulting from previous waste disposal activities at the site. The RI was conducted in two phases. Phase I was conducted during the summer and fall of 1997, and Phase II of the investigation was conducted during spring 1998 under high groundwater conditions. The RI included the following activities:

- Installation of soil borings and monitoring wells for analysis of soil and groundwater, as well as determination of physical properties of soil and hydrogeologic conditions;
- Excavation of test pits to observe subsurface conditions and collect landfill leachate for analysis;

- Surface soil sampling, groundwater seep sampling and sediment sampling from two nearby streams;

- Residential well sampling conducted by the New York State Department of Health (NYSDOH) to ensure that existing water supply wells have not been impacted by the site;

- Fish and wildlife impact analysis; and

- Qualitative health risk assessment to evaluate potential risks to human health.

Based on the RI results, in comparison to the standards, criteria and guidance values (SCGs) and potential public health and environmental exposure routes, areas and media of the site required remediation as summarized below.

<u>Groundwater</u>

Two rounds of groundwater samples were collected from ten monitoring wells. All wells were screened in the upper weathered bedrock due to the thin non-water bearing overburden at the site. Groundwater samples were analyzed for VOCs, semivolatile organic compounds (SVOCs), PCBs, pesticides, metals and cyanide. Ten VOCs were detected in the groundwater above NYSDEC Class GA standards. Monitoring wells with the highest total VOCs were MW-3 (723 ppb), MW-4 (164 ppb) and MW-6 (353 ppb). The highest individual concentration for a single VOC was 290 ppb for trichloroethene. MW-3 and MW-4 are located at the downgradient edge of the landfill property, and MW-6 is located within the interior of the landfill.

PCBs were found above SCGs (0.09 ppb) at MW-6 and MW-7. MW-7 is a deeper bedrock well located downgradient (south) of the site. Aroclor 1016 was found in MW-6 at 0.42 ppb, and Aroclor 1242 at 0.46 ppb and Aroclor 1254 at 0.27 ppb were identified in samples from MW-7. No SVOCs or pesticides were detected in groundwater above SCGs.

Among the results for total inorganic constituents for groundwater samples, SCGs were exceeded for antimony, arsenic, barium, beryllium, chromium, iron, lead, manganese, sodium and zinc.

Leachate

Twenty test pits were excavated to accumulate leachate for sampling and 12 leachate samples were collected during the RI. Leachate samples were identified as liquid exhibiting orange staining. Samples consisting of relatively clear, unstained surface water collected off-site and downgradient of the landfill, were reported as groundwater springs.

The leachate samples were collected from the downgradient/south side of the landfill (toe of slope). VOCs were detected in exceedance of SCGs in five of the 12 samples. Total VOC concentrations in leachate ranged from 10 to 100 ppb. The highest individual concentration for a single VOC was 63 ppb for 1,1,1-trichloroethane. No SVOCs and only one pesticide compound, endrin at 14 ppb, was detected above SCGs. PCBs were detected above SCGs in four of the 12 leachate samples. The maximum PCB concentration for a leachate sample was Aroclor 1260 at 19 ppb. The results of the inorganic analysis for the leachate samples demonstrated exceedances for iron, lead and manganese.

Groundwater Springs

Ten groundwater springs were sampled downgradient of the landfill during the RI. The springs are wet areas of bedrock outcropping, are generally low flow (<1 gpm) and are somewhat isolated by the heavily wooded area south of the site. The springs are not used as a source of potable water. Analysis of samples collected from springs SP-1 and SP-2, located 200 feet southeast of the landfill, exhibited concentrations for several compounds above SCGs. Total VOCs detected were 228 ppb at SP-1 and 368 ppb at SP-2. The highest individual concentration for a single VOC was 180 ppb for trichloroethene. The pesticide endrin (SCG of nondetect) at a concentration of 0.021 ppb was detected at SP-1 and the PCB Aroclor-1260 was detected above the SCG of 0.09 ppb at a concentration of 0.93 ppb at both SP-1 and SP-2. This was the only PCB compound detected at either location and no PCBs were detected at the remaining spring sampling locations. Inorganic analyses of the spring samples exhibited exceedance of SCGs for iron and manganese at most sampling locations.

Surface Water Sediment

Surface water sediment samples were collected at five locations in nearby creeks. Both upgradient and downgradient sampling results did not exhibit contamination by any contaminant above SCGs.

Surface Soils

Twelve surface soil samples were collected during the RI. VOCs were not detected at any of the soil sampling locations. Only one SVOC and one PCB compound were detected slightly above SCGs at one sampling location. No other SVOCs and PCBs were detected at any of the other surface soil sampling locations. Inorganic analyses of the surface soil samples detected concentrations of metals that are generally comparable to background soil samples.

Subsurface Soil

Subsurface soil samples were collected from the interior of the site from borings at MW-5 and MW-6. These samples were selected because they are located outside of or between landfill trenches and are representative of unsaturated overburden from the interior of the landfill. No VOCs, SVOCs, PCBs or pesticides were detected above SCGs. Metals and cyanide were found to be consistent with site background concentrations. Each subsurface sampling location, including the subsurface borings and the test pits, was screened for organic vapors with a photoionization detector and a combustible gas indicator. The results indicate that methane gas was not detected in elevated levels during the RI.

Residential Wells

One residential water supply well was sampled in 1998 during the RI. In August 1999, the NYSDOH collected samples from the five nearest private drinking water wells located downgradient of the site. The nearest well is located over 1,000 feet southwest of the landfill and over 800 feet from the nearest spring exhibiting site contamination. Based on the results of the well samples, the NYSDOH determined that all of the private wells are suitable for all domestic purposes.

Based on an assessment of human exposure pathways, the RI sampling has confirmed that the concentrations of landfill contaminants are of concern in groundwater springs, leachate and groundwater only in close proximity to the landfill. Although the potential for human exposure to these contaminants exists, it is not expected that they present a significant health risk under current conditions. However, should conditions change or new private groundwater wells be installed near the landfill, exposures could become a concern under current conditions.

2.2 Pre-Design Investigation

Test Pits and Test Trenches

In June of 2001, 36 test pits and trenches were excavated to define the limits of buried waste at the site. Additionally, several test pits were extended to the bedrock surface to determine the depth of overburden in selected areas of the site. Test trenches were excavated near the center of the property to profile waste disposal trenches. In October 2001, twelve (TP-40 through TP-51) test pits were constructed along the northern limits of waste to determine the depth of bedrock in this area and two test pits (TP-52 and TP-53) were constructed in the wooded area in the southeastern part of the site to evaluate the thickness and type of overburden in this area. The information obtained from the test pit excavations was used to estimate the limits of waste.

The test pits and test trenches were identified using the labeling convention TP- followed by a number. Test pits excavated during the Pre-Design Investigation were labeled TP-4 through TP-51 (Test pits TP-1, TP-2 and TP-3 were excavated during the Remedial Investigation). Test pits TP-5, TP-6, TP-7, TP-8, TP-9, TP-12, TP-13, TP-14, TP-15, TP-18, TP-19, TP-20, TP-21, TP-22, TP-23, TP-24, TP-25, TP-32, TP-33, TP-34, TP-35, TP-36, TP-37, TP-38 and TP-39 were excavated for the purpose of determining the limits of waste on the site. In addition to defining the limits of waste, the two test pits (TP-10 and TP-17) in the northernmost portion of the site and six test pits (TP-26, TP-27, TP-28, TP-29, TP-30 and TP-31) within the tree line in the southeastern portion of the site were excavated to determine the thickness of overburden soils. Test pits TP-40 through TP-51 were excavated to determine the thickness of overburden soils in the northern portion of the site.

Three test trenches (TP-11, TP-16 and TP-17) were excavated perpendicular to and through waste disposal trenches. The purpose of these test trenches, oriented north-south on the central part of the property, was to determine depth and width of waste and amount of soil cover since the waste in this region of the site is being considered for excavation and consolidation.

One test pit (TP-4) was excavated off-site, west of the western perimeter of the property to determine if a ridge-like feature in this area contains waste.

Test pits TP-52 and TP-53 were constructed in the wooded portion of the site to determine if this area would be suitable for on-site borrow material.

In general, based on the information obtained from test trenches TP-11 and TP-16, the average thicknesses of waste and soil cover in the waste disposal trenches in the northwestern portion of the site are 3 feet and 10 feet, respectively. The width of the waste disposal trenches was found to vary from approximately 16 feet to 21 feet. The average depth to bedrock in the northern portion of the site, based on TP-10, TP-17 and TP-40 through TP-51 is 9 feet; and within the tree line near the southeastern corner of the site, based on TP-26 through TP-31, the average depth to bedrock is 10 feet.

Leachate Sampling

Leachate samples were collected from areas of the site previously reported to contain contaminated leachate in order to confirm the Remedial Investigation (RI) results and to determine if changes in water quality have occurred since the RI. Leachate samples were collected from RI sample locations L-5, L-6 and L-21. A leachate sample was also collected at location L-26, a previously unobserved seep, located north of the east-west runoff diversion ditch in the central portion of the site. Another leachate sample was collected at L-27 to evaluate stained water that originates at a point off-site to the west of the southwest corner of the site. Each leachate sample was collected by digging a small pit with a shovel and allowing it to fill with leachate. The sample containers were submersed in the leachate to collect the samples. The leachate samples were analyzed for Target Compound List (TCL) +30 organic compounds, Target Analyte List (TAL) metals and cyanide.

Volatile organic compounds (VOCs) were detected in exceedance of SCGs at locations L-5, L-6 and L-21, all located in the southwest portion of the landfill. Analytes exhibiting exceedances of SCGs are vinyl chloride, 1,1-dichloroethane and 1,2-dichloroethene (total). Total VOCs were generally low (L-5 [29 μg/l], L-6 [81 μg/l] and L-21 [89 μg/l]). The highest individual concentration for a single VOC is 43 μg/l for 1,2-dichloroethene (total) at L-21. Samples L-26 and L-27 contained no VOC exceedances.

There were no SVOCs or pesticides detected above SCGs in any of the five leachate samples. One polychlorinated biphenyl (PCB) compound was detected above SCGs in one of the leachate samples. Aroclor-1260 (SCG 0.09 μg/l) was detected in sample L-6 at a concentration of 1.8 μg/l.

The results of the metals analyses for the leachate samples demonstrate exceedances of SCGs for antimony, cadmium, iron, lead, manganese and selenium. Iron exceeded the SCG of 300 μg/l in all of the five samples analyzed, at concentrations ranging from 4,910 to 87,900 μg/l. Manganese also exceeded the SCG of 300 μg/l in all five samples and ranged in concentration from 1980 to 3,720 μg/l. Antimony was detected above the SCG of 3 μg/l in two of five samples at L-6 (3.4 μg/l) along the southern site boundary and L-27 (3.6 μg/l) at the southwest corner of the site. Lead was detected above the SCG of 25 μg/l in one of five samples at L-27 (27.1 μg/l) in the southwestern corner of the site. Cadmium was detected above the SCG (5 μg/l) in one sample, L-6, at 5.9 μg/l. Selenium was also detected above the SCG (10 μg/l) in L-6, at 11.1 μg/l.

Cyanide was not detected above SCGs in any of the five leachate samples.

The results of leachate sampling were consistent with those reported in the RI. There were no significant trends or variations between the RI results and the Pre-Design Investigation results.

Surface Water Sampling

One surface water sample was collected from location SW-6, in the small pond located in the west-central portion of the site. The sample was collected near the influent of the west flowing runoff diversion ditch by submersing the sample containers below the water surface. The surface water sample was analyzed for TCL +30 organic compounds, TAL metals and cyanide. Table 2 presents the complete results for the surface water sample.

The surface water results are compared to the TOGS 1.1.1 Class GA groundwater standards and guidance values since groundwater is the principal source of surface water on-site.

There were no VOCs, SVOCs, pesticides or PCBs detected above SCGs in the surface water sample.

Five metals were detected above SCGs in the surface water sample SW-6. Arsenic (SCG of 25 µg/l) was present at a concentration of 51.9 µg/l, iron (SCG of 300 µg/l) was found at a concentration of 75,200 µg/l, lead (SCG of 25 µg/l) was detected at a concentration of 44.7 µg/l, manganese (SCG of 300 µg/l) was detected at a concentration of 4,530 µg/l and sodium (SCG of 20,000 µg/l) was detected at a concentration of 20,700 µg/l.

Cyanide was not detected above the SCG in the surface water sample.

Groundwater Sampling

Groundwater samples were collected for analysis from monitoring wells MW-1S, MW-1D, MW-2, MW-3, MW-4, MW-5S, MW-5D, MW-6, MW-7, MW-8 and MW-9 in June 2001. All monitoring wells with sufficient quantities of groundwater were analyzed for TCL +30 organic parameters (VOCs and SVOCs), and TAL metals and cyanide. Insufficient water quantity in monitoring well MW-2 prevented the analyses for SVOCs and cyanide at that location. Similarly, cyanide was not analyzed at monitoring wells MW-5S and MW-8.

A total of six VOCs were detected above SCGs in the groundwater samples. Monitoring wells with the greatest total concentrations of VOCs were MW-3 (700 μg/l), MW-4 (517 μg/l) and MW-6 (146 μg/l). Monitoring wells MW-3 and MW-4 are located on the downgradient edge of the landfill property and MW-6 is located on the interior of the site. Monitoring wells MW-5D, MW-7, MW-8 and MW-9 exhibited less than 35 μg/l total VOCs. VOCs were not detected in wells MW-1D, MW-1S, MW-2 and MW-5S.

1,1-Dichloroethane was detected above the SCG of 5 μg/l in five monitoring wells with concentrations ranging from 6 μg/l to 280 μg/l; 1,1,1-trichloroethane was also found above the SCG of 5 μg/l in five monitoring wells with concentrations ranging from 9 μg/l to 180 μg/l; trichloroethene was found above the SCG of 5 μg/l in two monitoring wells, with concentrations of 360 μg/l at MW-3 and 11 μg/l at MW-8; 1,1-dichloroethene was detected above the SCG of 5 μg/l in two monitoring wells, with concentrations of 15 μg/l at MW-3 and 7 μg/l at MW-4; chloroethane was detected above the SCG of 5 μg/l in two monitoring wells, with concentrations of 160 μg/l at MW-4 and 28 μg/l at MW-6; and 1,2-dichloroethene (total) was also detected above the SCG of 5 μg/l in two monitoring wells, with concentrations of 100 μg/l at MW-3 and 6 μg/l at MW-4.

There were no SVOCs detected above SCGs in any of the groundwater samples; however, the sample collected from monitoring well MW-2 was not analyzed for SVOCs due to an insufficient quantity of groundwater. Additionally, there were no pesticide or PCB compounds detected above SCGs in any of the groundwater samples.

Six metals were detected above SCGs in the groundwater samples. Iron was detected above the SCG of 300 µg/l in six of the eleven samples, with concentrations ranging from 452 µg/l to 23,300 µg/l; manganese was also detected above the SCG of 300 µg/l in six of eleven samples, with concentrations ranging from 807 µg/l to 8,380 µg/l; thallium was found above the SCG of 0.5 µg/l in five of the samples, with concentrations ranging from 10.1 µg/l to 42.9 µg/l; lead was identified above the SCG of 25 µg/l in three samples, with concentrations ranging from 56.8 µg/l to 313 µg/l; sodium (SCG of 20,000 µg/l) and arsenic (SCG of 25 µg/l) were detected above SCGs in wells MW-2 and MW-6 at concentrations of 35,000 µg/l and 43.4 µg/l, respectively.

Cyanide was not detected above the SCG in any of the groundwater samples; however, the samples collected from wells MW-2, MW-5S and MW-8 were not analyzed for cyanide due to an insufficient quantity of groundwater.

The results of groundwater sampling were consistent with those reported in the RI. There were no significant trends or variations between the RI results and the Pre-Design Investigation results.

2.3 2007 Test Trench Investigation

In August 2007, a field program was performed to evaluate the characteristics of the waste being considered for excavation and relandfilling and to develop an estimate of the quantity of waste to be consolidated from these areas. Twelve test trenches were excavated from the southeastern and southwestern portion of the landfill. One test trench was excavated in the northern portion of the site. In addition to these test trenches, four test pits were excavated in the central portion of the site to evaluate the soil in this area for use as borrow soil. The approximate locations of the test trenches, test pits and waste trenches are shown on Figure 2-1.

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CUBA LANDFILL SITE
VILLAGE OF CUBA, NEW YORK

ALLEGANY COUNTY — NEW YORK

NEW YORK STATE
DEPARTMENT OF ENVIRONMENTAL CONSERVATION

APPROXIMATE LOCATIONS OF TEST TRENCHES AND TEST PITS

PROJECT NO.: 2600
DATE: JUNE 2007
SCALE: 1"=80'
DRAWING NO.: 2-1

Of the thirteen test trenches excavated, eight were located in the southeastern portion of the site and four were located in the southwestern portion of the site. One test trench was excavated in the northern portion of the site to evaluate depth to bedrock and groundwater. The following describes each of the areas investigated:

Southeastern Portion of the Site

This approximately 4-acre area is under evaluation for consolidation. The results of the test trenching in this area indicated that the average depth of the waste below ground surface is approximately 11 feet, with the depth of waste ranging from 7 feet to 14 feet below ground surface (see Table 2-1). Waste encountered in the trenches included household waste, rubble, glass, tires, newspaper, scrap metal and wood fragments. Due to the presence of significant vegetation, TT-9 was advanced in three segments. Waste trenches in this area were apparent at ground surface and, therefore, in an effort to limit clearing, no excavation was performed between trenches. Four of the test trenches constructed in this area uncovered drums and/or drum remnants (TT-4, TT-5, TT-9 and TT-11). The two drums that were encountered in TT-4 contained a black sludge like material with strong solvent odor. Elevated readings on the photoionization detector (PID) were noted both in the headspace of the drum and the breathing zone. One drum containing a brown viscous liquid was noted in TT-5. Elevated PID readings were also noted within the drum headspace. Multiple drums were found in both TT-9 and TT-11 although elevated PID readings from the drum headspace were not noted in either excavation.
Of note is that the drums that were encountered were not localized. The test trenches in which drums were uncovered were found in the northern, southern, eastern and western portions of the area being considered for consolidation. Therefore, it is likely that drums may have been buried throughout this area and could routinely be encountered during any consolidation efforts.

In general, waste was found primarily within the original waste trenches excavated in the landfill. The width of the waste trenches in this area was noted to be between 6 and 32 feet. The distance between waste trenches in the area varied from approximately 3 feet to 33 feet with the

Table 2-1
Cuba Landfill
Summary of Test Trench Observations

Test Pit Location	Depth to Waste (feet below ground surface)	Depth to Water (feet below ground surface)	Depth to Bedrock (feet below ground surface)	Drums Encountered?
Southwestern Portion of Site				
TT-1	NE	NE	NE	No
TT-2	<1-3'	NE	8'	No
TT-3	1-3'	5-6' *	7'	Yes
TT-12	1'	5'**	5'	No
Southeastern Portion of Site				
TT-4	4.5-5'	NE	10-12'	Yes
TT-5	1-6'	9***	9.5-12'	Yes
TT-6	1-6'	NE	13-14'	No
TT-7	2.5-3'	NE	10-13'	No
TT-8	2.5-5'	NE	10-12'	No
TT-9	4-5'	NE	9-12'	Yes
TT-10	1-2'	NE	8-9.5'	No
TT-11	1.5-2'	NE	7-8'	Yes
Northern Portion of Site				
TT-13	NE	NE	4.5'	No

NE: Not encountered.

*: TT-3 is located at a topographically and hydraulically low end of the site and adjacent to a surface water drainage ditch. The noted groundwater depth may be attributed to these factors.
** TT-12 is located at a topographically and hydraulically low end of the site and is situated in an area where surface water collects.
***Groundwater observed in TT-5 is likely attributed to localized surface water infiltration along waste trench I causing a localized perched water condition. Waste trench I surface features consist of a elongated depression with a low soil embankment on the downgradient side. These surface features serve to intercept and retain surface water runoff.

larger distances between trenches found in the very southern portion of the eastern side of the site (TT-10 and TT-11). The widths of the waste in the trenches were estimated based on the measurements taken from the top section of the trenches.

Depth of soil cover in this area ranges from 1 to 6 feet in thickness. The soil cover is described as fill containing tan-light brown fine medium silty sand and pebble sized angular shale fragments.

Southwestern Portion of the Site

This approximately 1-acre area is also under evaluation for consolidation. Four test trenches were excavated in this area. No waste was encountered in TT-1. The remaining three test trenches encountered waste at depths down to 5 to 8 feet below ground surface, with an average depth of 7 feet. The waste encountered in this area is similar to the waste encountered in the southeastern portion of the landfill and included household waste, bottles, cans, scrap metal and paper. Drums were encountered in TT-3. The drums encountered appeared similar to the drums encountered in TT-4, with strong solvent odor and elevated PID readings in the drum headspace. Groundwater was encountered in TT-3 and TT-12 and was noted to seep into the bottom of the trench. The width of the waste trenches in this area ranged from 14 to 28 feet in width. Distance between the two waste trenches excavated as part of TT-3 was 28 feet. Depth of soil cover ranged from less than 1 foot to 3 feet. The soil cover encountered was described as a light brown to gray silty/clayey fine to medium sand with some cobble to pebble-sized angular shale fragments.

In general, waste buried in this area appears to be more sporadic than and not as extensive as the southeastern portion of the site. However, similar to the southeastern portion of the site, if waste consolidation is pursued in this area, drums will likely be encountered.

Borrow Soil Area

Four test pits (TP-52 through TP-55) were constructed in the central portion of the site to evaluate this area for use of the soil as cover/capping material. This area is approximately 1 acre in size. The test pits were excavated at approximately 150-foot intervals through this area. Soil samples were collected from depths of 3 to 4 feet below ground surface by NYSDEC on-site representative from each of the test pits. Each sample was analyzed for grain size analysis by ASTM D-422; standard proctor compaction by ASTM D-698; and liquid limit/plastic limit/plasticity index by ASTM D-4318, as well as target compound list (TCL) organic and target analyte list (TAL) inorganic parameters. The results of the geotechnical analysis are provided in Table 2-2 and the results of the chemical analysis are provided in Table 2-3.

Bedrock was encountered at depths ranging between 3 and 12 feet. The material above bedrock is described as silt with little fine coarse sand and angular coarse gravel to cobbles. Damp soils were noted in the test pits ranging from depths between 2.5 to 13 feet below ground surface. The information obtained from these test pits have been combined with information from five other test pits (TP-7, 12, 13A, 15 and 35) previously excavated in this area. This information is presented on Table 2-4.

TABLE 2-2
CUBA LANDFILL
TEST PIT PROGRAM
SUMMARY OF GEOTECHNICAL PARAMETERS

			Sieve Size - Percent Passing Sieve													Component Percent			
Lab I.D. #	Sample ID	Depth (feet)	3"	2"	1 1/2"	1"	3/4"	1/2"	1/4"	#4	#10	#20	#40	#100	#200	Gravel	Sand	Silt	Clay
07-982	TP-52	5.0	100.0	97.5	88.2	82.8	79.2	73.2	62.7	57.6	52.3	47.3	45.1	42.8	40.3	42.4	17.3	23.1	17.2
07-983	TP-53	5.0	100.0	93.8	92.3	91.0	88.9	84.0	69.7	63.3	56.6	50.3	46.6	42.8	40.5	36.7	22.8	21.9	18.6
07-984	TP-54	5.0	100.0	95.3	90.6	83.9	79.0	71.3	60.7	57.6	48.8	43.9	41.5	39.2	37.1	42.4	20.5	28.6	8.5
07-985	TP-55	3.0	100.0	96.4	87.0	79.3	73.1	63.1	48.5	43.7	35.0	30.2	27.8	25.7	24.4	56.3	19.3	13.6	10.8

Lab I.D. #	Sample ID	Depth (feet)	Moisture Content (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Maximum Dry Density (pcf)	Optimum Moisture (%)	Unified Soil Classification System
07-982	TP-52	5.0	10.8	33	16	17	123.4	10.0	GC- Clayey gravel with sand
07-983	TP-53	5.0	12.2	34	19	15	124.5	9.1	GC- Clayey gravel with sand
07-984	TP-54	5.0	11.0	28	20	8	120.0	9.6	GC- Clayey gravel with sand
07-985	TP-55	3.0	10.0	37	19	18	127.1	10.1	GC- Clayey gravel with sand

TABLE 2-3
CUBA LANDFILL
TEST PIT PROGRAM
SOIL ANALYTICAL RESULTS
TARGET COMPOUND LIST VOLATILE ORGANIC COMPOUNDS

SAMPLE ID	TP-52	TP-53	TP-54	TP-55	NYSDEC 6 NYCRR SUBPART 375-6 UNRESTRICTED USE SOIL CLEANUP OBJECTIVES
SAMPLE DATE	8/7/2007	8/7/2007	8/7/2007	8/7/2007	
SAMPLE DEPTH (FEET)	5.0	5.0	5.0	3.0	
Units	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg
1,1,1-Trichloroethane	U	U	U	U	680
1,1,2,2-Tetrachloroethane	U	U	U	U	--
1,1,2-Trichloro-1,2,2-Trifluoroethane	U	J	U	U	--
1,1,2-Trichloroethane	U	U	U	U	--
1,1-Dichloroethane	U	U	U	U	270
1,1-Dichloroethene	U	U	U	U	330
1,2,4-Trichlorobenzene	U	U	U	U	--
1,2-Dibromo-3-Chloropropane	U	U	U	U	--
1,2-Dibromoethane	U	U	U	U	--
1,2-Dichlorobenzene	U	U	U	U	1,100
1,2-Dichloroethane	U	U	U	U	20
1,2-Dichloropropane	U	U	U	U	--
1,3-Dichlorobenzene	U	U	U	U	2,400
1,4-Dichlorobenzene	U	U	U	U	1,800
2-Butanone	U	U	U	U	120
2-Hexanone	U	U	U	U	--
4-Methyl-2-Pentanone	U	U	U	U	--
Acetone	9 J	U	U	6 J	50
Benzene	U	U	U	U	60
Bromodichloromethane	U	U	U	U	--
Bromoform	U	U	U	U	--
Bromomethane	U	U	U	U	--
Carbon Disulfide	U	U	U	U	--
Carbon Tetrachloride	U	U	U	U	760
Chlorobenzene	U	J	U	U	1,100
Chloroethane	U	J	U	U	--
Chloroform	U	U	U	U	370
Chloromethane	U	U	U	U	--
cis-1,2-Dichloroethene	U	U	U	U	250
cis-1,3-Dichloropropene	U	U	U	U	--
Cyclohexane	U	U	U	U	--
Dibromochloromethane	U	J	U	U	--
Dichlorodifluoromethane	U	U	U	U	--
Ethylbenzene	U	U	U	U	1,000
Isopropylbenzene	U	U	U	U	--
Methyl Acetate	U	U	U	U	--
Methyl tert-butyl Ether	U	U	U	U	930
Methylcyclohexane	U	U	U	U	--
Methylene Chloride	44	26	44	30	50
Styrene	U	U	U	U	--
t-1,3-Dichloropropene	U	U	U	U	--
Tetrachloroethene	U	U	U	U	1,300
Toluene	1 J	U	U	U	700
trans-1,2-Dichloroethene	U	U	U	U	190
Trichloroethene	U	U	U	U	470
Trichlorofluoromethane	U	U	U	U	--
Vinyl Chloride	U	U	U	U	20
Xylenes (total)	U	U	U	U	260
Total VOA	54	26	44	36	--

NOTES:
--: Not established

QUALIFIERS:
U: Compound analyzed for but not detected
J: Compound greater than or equal to the instrument detection limit, but less than the CRDL

TABLE 2-3 (continued)
CUBA LANDFILL
TEST PIT PROGRAM
SOIL ANALYTICAL RESULTS
TARGET COMPOUND LIST SEMIVOLATILE ORGANIC COMPOUNDS

SAMPLE ID SAMPLE DATE SAMPLE DEPTH (FEET) Units	TP-52 8/7/2007 5.0 ug/kg	TP-53 8/7/2007 5.0 ug/kg	TP-54 8/7/2007 5.0 ug/kg	TP-55 8/7/2007 3.0 ug/kg	NYSDEC 6 NYCRR SUBPART 375-6 UNRESTRICTED USE SOIL CLEANUP OBJECTIVES ug/kg
Phenol	U	U	U	U	330
bis(2-Chloroethyl)ether	U	U	U	U	--
2-Chlorophenol	U	U	U	U	--
2-Methylphenol	U	U	U	U	--
2,2-oxybis(1-Chloropropane)	U	U	U	U	--
4-Methylphenol	U	U	U	U	--
N-Nitroso-di-n-propylamine	U	U	U	U	--
Hexachloroethane	U	U	U	U	--
Nitrobenzene	U	U	U	U	--
Isophorone	U	U	U	U	--
2-Nitrophenol	U	U	U	U	--
2,4-Dimethylphenol	U	U	U	U	--
2,4-Dichlorophenol	U	U	U	U	--
1,2,4-Trichlorobenzene	U	U	U	U	--
Naphthalene	U	U	U	U	12,000
4-Chloroaniline	U	U	U	U	--
bis(2-Chloroethoxy)methane	U	U	U	U	--
Hexachlorobutadiene	U	U	U	U	--
4-Chloro-3-methylphenol	U	U	U	U	--
2-Methylnaphthalene	U	U	U	U	--
Hexachlorocyclopentadiene	U	U	U	U	--
2,4,6-Trichlorophenol	U	U	U	U	--
2,4,5-Trichlorophenol	U	U	U	U	--
2-Chloronaphthalene	U	U	U	U	--
2-Nitroaniline	U	U	U	U	--
Dimethylphthalate	U	U	U	U	--
Acenaphthylene	U	U	U	U	100,000
2,6-Dinitrotoluene	U	U	U	U	--
3-Nitroaniline	U	U	U	U	--
Acenaphthene	U	U	U	U	20,000
2,4-Dinitrophenol	U	U	U	U	--
4-Nitrophenol	U	U	U	U	--
Dibenzofuran	U	U	U	U	--
2,4-Dinitrotoluene	U	U	U	U	--
Diethylphthalate	U	U	U	U	--
4-Chlorophenyl-phenylether	U	U	U	U	--
Fluorene	U	U	U	U	30,000
4-Nitroaniline	U	U	U	U	--
4,6-Dinitro-2-methylphenol	U	U	U	U	--
N-Nitrosodiphenylamine	U	U	U	U	--
4-Bromophenyl-phenylether	U	U	U	U	--
Hexachlorobenzene	U	U	U	U	--
Pentachlorophenol	U	U	U	U	800
Phenanthrene	U	U	U	U	100,000
Anthracene	U	U	U	U	100,000
Carbazole	U	U	U	U	--
Di-n-butylphthalate	U	U	U	U	--
Fluoranthene	U	10 J	U	U	100,000
Pyrene	U	8 J	U	U	100,000
Butylbenzylphthalate	U	U	69 J	U	--
3,3-Dichlorobenzidine	U	U	U	U	--
Benzo(a)anthracene	U	8 J	U	U	1,000
Chrysene	U	U	U	U	1,000
bis(2-Ethylhexyl)phthalate	370	410	190	290	--
Di-n-octyl phthalate	U	8 J	U	U	--
Benzo(b)fluoranthene	U	8 J	U	U	1,000
Benzo(k)fluoranthene	U	U	U	U	800
Benzo(a)pyrene	U	U	U	U	1,000
Indeno(1,2,3-cd)pyrene	U	U	U	U	500
Dibenzo(a,h)anthracene	U	U	U	U	330
Benzo(g,h,i)perylene	U	U	U	U	--
1,1'-Biphenyl	U	U	U	U	--
Acetophenone	U	U	U	U	--
Atrazine	U	U	U	U	--
Benzaldehyde	U	U	U	U	--
Caprolactam	U	U	U	U	--
					0
Total PAHs	0	34	0	0	--
Total CaPAHs	0	16	0	0	--
Total SVOCs	370	452	259	290	--

NOTES:
--: Not established

QUALIFIERS:
U: Compound analyzed for but not detected
J: Compound greater than or equal to the instrument detection limit, but less than the CRDL

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TABLE 2-3 (continued)
CUBA LANDFILL
TEST PIT PROGRAM
SOIL ANALYTICAL RESULTS
TARGET COMPOUND LIST PCBS

SAMPLE ID SAMPLE DATE SAMPLE DEPTH (FEET) Units	TP-52 8/7/2007 5.0 ug/kg	TP-53 8/7/2007 5.0 ug/kg	TP-54 8/7/2007 5.0 ug/kg	TP-55 8/7/2007 3.0 ug/kg	NYSDEC 6 NYCRR SUBPART 375-6 UNRESTRICTED USE SOIL CLEANUP OBJECTIVES ug/kg
Aroclor-1016	U	U	U	U	100
Aroclor-1221	U	U	U	U	100
Aroclor-1232	U	U	U	U	100
Aroclor-1242	U	U	U	U	100
Aroclor-1248	U	U	U	U	100
Aroclor-1254	U	U	U	11 J	100
Aroclor-1260	U	4.2 J	U	U	100
Total PCBs	0	4.2	0	11	100

QUALIFIERS:
U: Compound analyzed for but not detected
J: Compound greater than or equal to the instrument detection limit, but less than the CRDL

TABLE 2-3 (continued)
CUBA LANDFILL
TEST PIT PROGRAM
SOIL ANALYTICAL RESULTS
TARGET COMPOUND LIST PESTICIDES

SAMPLE ID	TP-52		TP-53		TP-54		TP-55		NYSDEC 6 NYCRR SUBPART 375-6 UNRESTRICTED USE SOIL CLEANUP OBJECTIVES
SAMPLE DATE	8/7/2007		8/7/2007		8/7/2007		8/7/2007		
SAMPLE DEPTH (FEET)	5.0		5.0		5.0		3.0		
Units	ug/kg		ug/kg		ug/kg		ug/kg		ug/kg
4,4'-DDD		U		U		U		U	3.3
4,4'-DDE	1.3	J		U		U	0.92	J	3.3
4,4'-DDT		U	2.2			U	2.1		3.3
Aldrin		U		U		U		U	5
alpha-BHC		U		U		U		U	20
beta-BHC		U		U		U		U	36
Chlordane		U		U		U		U	94
delta-BHC		U		U		U		U	40
Dieldrin		U		U		U	0.52	J	5
Endosulfan I		U		U		U		U	2,400
Endosulfan II		U		U		U		U	2,400
Endosulfan sulfate		U	0.68	J		U		U	2,400
Endrin		U		U		U		U	14
Endrin aldehyde		U		U		U		U	--
Endrin ketone		U		U		U		U	--
gamma-BHC (Lindane)		U		U		U		U	100
Heptachlor		U		U		U		U	42
Heptachlor epoxide		U		U		U		U	--
Methoxychlor		U		U		U		U	--
Toxaphene		U		U		U		U	--
Total Pesticides	1.3		2.9		0.0		3.5		--

NOTES:
--: Not established

QUALIFIERS:
U: Compound analyzed for but not detected
J: Compound greater than or equal to the instrument detection limit, but less than the CRDL

TABLE 2-3 (continued)
CUBA LANDFILL
TEST PIT PROGRAM
SOIL ANALYTICAL RESULTS
TARGET COMPOUND LIST PCBS

SAMPLE ID SAMPLE DATE SAMPLE DEPTH (FEET) Units	TP-52 8/7/2007 5.0 ug/kg	TP-53 8/7/2007 5.0 ug/kg	TP-54 8/7/2007 5.0 ug/kg	TP-55 8/7/2007 3.0 ug/kg	NYSDEC 6 NYCRR SUBPART 375-6 UNRESTRICTED USE SOIL CLEANUP OBJECTIVES ug/kg
Aroclor-1016	U	U	U	U	100
Aroclor-1221	U	U	U	U	100
Aroclor-1232	U	U	U	U	100
Aroclor-1242	U	U	U	U	100
Aroclor-1248	U	U	U	U	100
Aroclor-1254	U	U	U	11 J	100
Aroclor-1260	U	4.2 J	U	U	100
Total PCBs	0	4.2	0	11	100

QUALIFIERS:
U: Compound analyzed for but not detected
J: Compound greater than or equal to the instrument detection limit, but less than the CRDL

TABLE 2-3 (continued)
CUBA LANDFILL
TEST PIT PROGRAM
SOIL ANALYTICAL RESULTS
TARGET ANALYTE LIST METALS

SAMPLE ID	TP-52	TP-53	TP-54	TP-55	NYSDEC 6 NYCRR SUBPART 375-6 UNRESTRICTED USE SOIL CLEANUP
SAMPLE DATE	8/7/2007	8/7/2007	8/7/2007	8/7/2007	
SAMPLE DEPTH (FEET)	5.0	5.0	5.0	3.0	
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Aluminum	15,900	17,300	16,400	17,400	--
Antimony	U	U	U	U	--
Arsenic	16.7	13.1	7.6	18.2	13
Barium	107	81	91.8	176	350
Beryllium	0.89	0.73	0.76	0.95	7.2
Cadmium	U	0.39	0.25	0.41	2.5
Calcium	1,350	792	403	239	--
Chromium	20.3	19.2	21.2	22.2	30
Cobalt	16.6	13.6	14.2	17.1	--
Copper	24.3	18.2	28.5	25.8	50
Iron	33,600	33,200	36,300	38,200	--
Lead	16.3	18.2	10	24.0	63
Magnesium	4,760	3,340	4,920	4,550	--
Manganese	798	698	487	997	1,600
Mercury	U	0.044	U	U	0.18
Nickel	32.4	24.5	35.2	33.9	30
Potassium	1,470	924	1,160	1,470	--
Selenium	U	U	U	U	3.9
Silver	U	U	U	U	2
Sodium	U	U	U	U	--
Thallium	U	U	U	U	--
Vanadium	18.2	22.1	17.1	20.6	--
Zinc	74.7	76.7	77.4	78.3	109

NOTES:
SB: Site Background
--: Not established
Concentration exceeds the NYSDEC 6 NYCRR Subpart 375-6 Unrestricted Use Soil Cleanup Objectives

QUALIFIERS:
U: Compound analyzed for but not detected
J: Compound greater than or equal to the instrument detection limit, but less than the CRDL

Table 2- 4
Cuba Landfill
Summary of Test Pit Observations

Test Pit Location	Depth to Damp Soils (feet below ground surface)	Depth to Bedrock (feet below ground surface)
TP-7**	6	6-9
TP-12**	4	11
TP-13A**	NE	8
TP-15**	2.5	8
TP-35**	*	10
TP-52	13	NE
TP-53	9	12
TP-54	5	11
TP-55	NE	3

NE: Not encountered.
*Moist soil noted from surface to base of test pit.
**Test pits constructed as part of the Pre-Design Investigation in 2003.

3.0 REMEDIAL DESIGN

3.1 General

The closure system for the capping of the Cuba Landfill Site will consist of a layered system of soil and geosynthetic material to provide a cost-effective, low permeability hydraulic barrier which will mitigate the vertical percolation of precipitation into the underlying waste mass. The primary functions of the layered capping system are as follows:

- Reduce the vertical percolation of precipitation into the underlying waste mass;
- Reduce the generation of leachate resulting from contact between precipitation and the waste mass;
- Reduce the transport of leachate to the groundwater system by inhibiting the generation of leachate;
- Control the accumulation of landfill gas below the capping system and mitigate the potential for lateral migration;
- Eliminate the potential for direct contact with waste;
- Provide control of surface runoff and subsurface drainage to promote the efficiency of the hydraulic barrier;
- Resist the erosional forces of storm events;
- Provide physical protection to the hydraulic barrier layer of the capping system; and
- Provide for an aesthetically acceptable appearance of the completed system, suitable for its intended purpose.

The capping system is intended to provide general conformance to the regulations and performance criteria of 6 NYCRR Part 360 Solid Waste Management Facilities. The capping system, described from bottom to top, will be as follows:

- Existing waste;
- General fill, thickness varies, minimum thickness of 6 inches;

- Gas venting layer (geocomposite);
- 40-mil textured linear low density polyethylene (LLDPE) geomembrane;
- Geocomposite drainage layer;
- Barrier protection layer of 18 inches;
- Topsoil layer of 6 inches;
- Vegetation;
- Erosion control blanket.

A graphic presentation of the proposed capping system is presented on Sheet 9 of the Contract Drawings.

3.2 Site Preparation

As previously discussed, a Remedial Investigation and a pre-design investigation were conducted on-site to establish the horizontal and vertical extent of the waste in order to establish the area of the property which requires capping. The findings of these investigations indicate that the waste mass is concentrated in trenches across the site.

3.2.1 Clearing and Grubbing

The first step in preparing the site for construction will be to clear the existing vegetation. Woody vegetation such as trees will be cut down, chipped and used on-site in the perimeter areas not being capped. Tree stumps, will be excavated and reduced in size on-site for placement on-site in the areas adjacent to the capping system. They can be used on-site as general fill materials or erosion controls outside the cap.

Brush and ground cover will be cleared by thoroughly and completely tracking the areas with a bulldozer to grind up the vegetation and incorporate it into the loosened soil. The existing vegetation will be cleared prior to proceeding with any other aspects of the cap construction.

After clearing, waste consolidation will commence and cutting, grading and filling will be performed as required to achieve prepared subgrade elevations.

3.2.2 Monitoring Well/Piezometer Abandonment

Existing monitoring wells within the Limits of Cap, as well as within the limits of consolidation, will be abandoned. Monitoring wells MW-5S, MW-5D, and MW-6, and piezometers PZ-1, PZ-2, PZ-3 and PZ-4 will be abandoned. The monitoring well/ piezometer abandonment procedures will follow NYSDEC protocols and comprise the following:

- Removal of surface protective casing and concrete slabs, as appropriate;
- Overboring and removal of the casing, if present, to the greatest extent possible (minimum 5 feet);
- Perforation of any casing remaining in the borehole;
- Pressure grouting of the borehole from the base of the borehole with cement-bentonite grout to a depth of 5 feet below the ground surface using the tremie method;
- Backfilling the remaining 5 feet with native soil and compacting to avoid settlement;
- Grouted area will be periodically inspected for possible settlement; and
- If subsequent settlement occurs, soil will be placed into the depression and repacked to grade level. If severe settlement occurs, the settled portion will be regrouted and backfilled with soil.

3.2.3 Access Roads

A service/maintenance roadway will be constructed around the landfill in order to provide access to the landfill during construction for cap installation. The roadway will remain after construction for cap maintenance to facilitate any post-construction maintenance. The roadway will be approximately 12 feet wide. A geotextile will first be placed at the bottom of the service/maintenance roadway and 6 inches of road paving material will be placed over the geotextile for construction of the road.

3.3 Waste Consolidation and Grading

3.3.1 Consolidation

Test trenches excavated in the southwestern and southeastern portions of the site during an August 2007 pre-design investigation identified the type of waste that was buried at the site, as well as the method by which it was buried. The results of this investigation are summarized in Section 2.3. Since the waste appears to be limited to the on-site trenches, consolidation will be performed by excavation of the waste trenches only allowing soil between the trenches to remain in place or to be used as cover material or general fill.

Approximately 56,000 cubic yards of fill/waste material shall be excavated from the southeastern and southwestern portions of the site and consolidated within the limits of the cap. A portion of the site within the limits of cap, identified as the Borrow Area, will be excavated prior to initiation of the consolidation. Clean fill from this area will be stockpiled for use as grading material or preparation of the subgrade layer for the landfill cap. Excavation in this area is expected to proceed to approximately 7.5 feet below ground surface. A minimum of 2 feet of clean material will remain in this area overlying bedrock. Waste excavated from the areas outside the limits of cap will be placed in this area.

3.3.2 Grading Plan

The Cuba Landfill site is situated on the steep south-facing slope of Jackson Hill at elevation 2,220 feet above mean sea level (msl), which is one of the most prominent hills in the region. The upper portion of the site is 2,212 feet in elevation and the southern boundary is over 100 feet lower, with an elevation approximately 2,095 feet.

The landfill site is extensively covered with landfill trenches. Landfilling was performed by digging trenches into the side of the hill. In the early stages of use, trenches were dug in a north-south orientation near the bottom of the hill. Later, trenches were constructed in an east-west orientation perpendicular to the slope of the hill. Surface runoff water generally flows south over the site. Grasslands and emergent scrub growth dominate the site.

The grading plan attempts to make use of the existing terrain to the greatest extent practical in order to minimize the need for gross reshaping and filling of the site. This approach proposes to make use of the existing slope. The maximum slope is approximately 17 percent which is less than the requirements of 6 NYCRR Part 360 allowing for a maximum slope of 33 percent. The grading plan is presented on Sheet 5 of the Contract Drawings.

The overall height of the landfill will increase by approximately 4 to 5 feet from the existing grade due to the placement of consolidation waste and the thickness of the landfill cap. The grading of the landfill will allow for drainage from the landfill to be collected in drainage swales and downchutes and directed to the detention basin. Further discussion of site drainage is provided in Section 3.5.

Excavated materials resulting from cuts or excavations in the landfill footprint will be relandfilled within the limits of the cap in areas requiring fill. Relandfilled materials will be spread in lifts up to 2 feet in thickness and compacted using a bulldozer or a vibratory compactor. Intermediate cover material will be placed if conditions necessitate its use. Open excavations will be graded and protected from the accumulation of surface runoff.

Areas requiring fill to attain the proposed prepared subgrade elevations will be constructed with controlled lifts of compacted general fill. The fill will be placed and spread in lifts of uniform thickness then compacted with a minimum of six passes with a vibratory drum compactor. The moisture content of the fill material will be controlled to facilitate compaction and the maximum compacted lift thickness will be limited to 6 inches.

3.4 Cap Design

3.4.1 Subgrade Layer

At a minimum, 6 inches of compacted general fill will be placed over the entire surface of the landfill to be capped. Existing ground surfaces which coincide with proposed prepared subgrade elevations and exhibit waste at the surface will be scraped to a depth of 6 inches to allow for placement of the general fill. In areas where the existing surface presents itself as being suitable for establishment of the prepared subgrade surface, scraping of the surface will be eliminated and the existing surface will be accepted as the prepared subgrade surface.

The subgrade surface will be proofrolled with a smooth drum vibratory roller to provide a smooth, uniformly sloping, unyielding surface. Depressions, soft spots and yielding areas detected by proofrolling will be remedied by recompaction or excavation and replacement as appropriate. The prepared subgrade surface will be free from protruding rocks, litter, debris and disturbance due to erosion which may inhibit intimate contact with the overlying geocomposite.

The 6" layer of general fill will be obtained from on-site sources and will serve as the prepared subgrade for the overlying capping system. This layer will be constructed with general fill obtained from on-site sources with a maximum particle size of 3 inches. Approval from NYSDEC will be required prior to the use of any alternative material. The prepared subgrade surface will be surveyed for as-built conditions.

3.4.2 Geocomposite Gas Venting Layer

The gas venting layer will consist of a geocomposite that will allow for the lateral transmission of landfill gas, which may accumulate below the geomembrane, to the landfill gas vents. The gas venting layer serves several purposes in the function of the capping system, including the following:

- The gas venting layer provides for a smooth, uniformly sloped surface for the installation of the overlying geomembrane.
- The gas venting layer will allow for the lateral movement of landfill gas below the geomembrane. The gas venting layer, in combination with the gas vents, will allow for the dissipation of landfill gas which vertically migrates to the underside of the geomembrane. The evacuation of landfill gas via the gas venting layer will inhibit the formation of positive gas pressures below the geomembrane. In turn, the relief of these pressures will minimize vertical uplift forces on the geomembrane and reduce the potential for lateral migration of the landfill gas to areas beyond the cap and the property boundaries.

The geocomposite gas venting layer will consist of a tri-axial geosynthetic layer (geonet) core with a 6-ounce per square yard geotextile heat fused to both the upper and lower surfaces. The lower geotextile will serve as a separation/filter layer to the underlying general fill. The upper geotextile will serve to secure the geocomposite to the textured geomembrane through interface friction. The geocomposite gas venting layer will have the physical properties detailed in Tables 3-1 and 3-2.

The geocomposite gas venting layer will be installed directly on top of general fill layer, after the prepared surface of the general fill has been inspected, tested and accepted. Deployment of the geocomposite gas venting layer will be coordinated with the placement of the overlying geomembrane to ensure that the geotextiles will not be exposed to the elements for more than 14 calendar days.

The geocomposite gas venting layer will be deployed in the direction of the slope. The lower geotextiles of adjacent panels will be overlapped. The drainage net cores will be overlapped and secured by tying with nylon cable ties. The upper geotextiles will be seamed by sewing using a double-thread lockstitch Type 401 or equivalent. The seam will be a "flat" or "prayer" seam. All terminal ends or edges of the geocomposite will be finished by seaming the upper and lower geotextiles by sewing as described above or wrapping the terminal end of the geocomposite with a supplemental piece of geotextile. The exposed end of the geotextile will be heat seamed to the top geotextile surface of the geocomposite.

Table 3-1

CUBA LANDFILL SITE
ENGINEERING DESIGN REPORT
GEOCOMPOSITE GAS VENTING LAYER PROPERTY VALUES

Fabric Property	Test Method	Unit	Specified Value	Qualifier[(2)]
Geonet Component:				
Polymer Composition	--	%	95 polyethylene by weight	Min
Polymer Specific Gravity	ASTM D1505	gm/cm^3	0.94	Min
Polymer Melt Index	ASTM D1238	g/10 min	1.0	Max
Creep Reduction Factor @ 1,000 psf, 20°C	GR1-GC8		1.1	
Carbon Black Content	ASTM D4218	%	2-3	MARV
Tensile Strength (machine direction)	ASTM D4595	lbs/ft	425	MARV
Air Transmissivity[(1)] Load @1,000 psf Gradient: 3 33	ASTM D4716 GRI-GC8	 M^2/sec M^2/sec	 7.0×10^{-4} 3.0×10^{-4}	 MAV MAV
Geotextile Component:	See Table 3-2			
Geocomposite:				
Ply Adhesion	ASTM D7005	lb/in	0.5	MAV

Note:

1. The geocomposite shall be sandwiched as follows:

   Steel plate/Ottawa sand/geocomposite/40 mil LLDPE geomembrane/steel plate. The minimum sealing period shall be 100 hours and the report for the test results shall include measurements at intervals over the entire test duration.

2. MAV – Minimum Average Value.
   Min – Minimum Value
   Max – Maximum Value
   MARV – Minimum Average Roll Value

Table 3-2

CUBA LANDFILL SITE
ENGINEERING DESIGN REPORT
GEOCOMPOSITE GAS VENTING LAYER PROPERTY VALUES - GEOTEXTILE

Fabric Property	Test Method	Unit	Specified Value	Qualifier[1]
Fabric Weight	ASTM D5261	oz/sq yd	6	MARV
Grab Strength[2]	ASTM D4632	lbs	160	MARV
Grab Elongation	ASTM D4632	%	50	MARV
Trapezoid Tear Strength	ASTM D4533	lbs	60	MARV
Puncture Resistance	ASTM D4833	lbs	85	MARV
Permittivity	ASTM D4491	sec^{-1}	1.1	MARV
Apparent Opening Size (AOS)	ASTM D4751	sieve size	70	MaxARV
UV Resistance (500 hours)	ASTM D4355 or ASTM G154	% strength retained	70	Min

Notes:

1. MARV - Minimum average roll value.
   MAV – Minimum average value.
   MaxARV – Maximum Average roll value.
   Min - Minimum
2. Values in the weakest principal direction.

3.4.3 Geomembrane

The proposed geomembrane to serve as the hydraulic barrier layer in the capping system will be a 40-mil, textured linear low density polyethylene (LLDPE) sheet or equivalent. The LLDPE geomembrane will conform to the physical properties listed in Table 3-3 and in accordance with the requirements of Geosynthetic Research Institute (GRI) GM-17.

The geomembrane will be in contact with the underlying geocomposite gas venting layer and the overlying geocomposite drainage layer. The geomembrane will not be in direct contact with the waste or leachate generated by the waste. Therefore, the chemical compatibility of the geomembrane materials and the waste materials should not be at issue. Nonetheless, LLDPE geomembrane is well documented for its use in landfill capping systems. For the purpose of this project, site-specific chemical compatibility of the proposed geomembrane is not warranted.

The geomembrane will be furnished in standard roll widths and standard roll lengths. There will be no special requirements for extra long or custom roll lengths. Geomembrane panels will be deployed in the direction of the slope. Adjacent panels will be seamed by either the fusion weld or extrusion weld process. All seams will be nondestructively tested in total and destructively tested at a frequency no less than once per 500 feet of seam length.

Conformance samples will be obtained at a frequency of once per 100,000 square feet of geomembrane. Testing of the conformance samples will be performed, at the discretion of the certifying engineer based upon field observation, as well as the geomembrane fabrication quality control data.

Textured geomembrane will be used throughout the project. Use of textured geomembrane in contact with the overlying geocomposite drainage layer will provide an interface between the geomembrane and the geocomposite which exhibits interface friction less susceptible to sliding or displacement during construction. The textured geomembrane also provides for enhanced interface friction with the underlying geocomposite gas venting layer when compared to a smooth geomembrane.

Table 3-3

CUBA LANDFILL SITE
ENGINEERING DESIGN REPORT
40-MIL TEXTURED LLDPE GEOMEMBRANE

Properties	Test Method	Test Value	Testing Frequency (Minimum)
Thickness mils (min. avg.) • lowest individual for 8 out of 10 values • lowest individual for any of the 10 values	D 5994	40 mil. nom. (-5%) -10% -15%	per roll
Asperity Height mm (min. avg.) (1)	GM 12	10	Every 2nd roll (2)
Density g/ml (max.)	D 1505/D 792	0.939	200,000 lb
Tensile Properties (3) (min. avg.) • break strength – lb/inch • break elongation – %	D 6693 Type IV	60 250	20,000 lb
2% Modulus – lb/inch (max.)	D 5323	2,400	per formulation
Tear Resistance – lb (min. avg.)	D 1004	22	45,000 lb
Puncture Resistance – lb (min. avg.)	D 4833	44	45,000 lb
Axi-Symmetric Break Resistance Strain - % (min.)	D 5617	30	per formulation
Carbon Black Content – %	D 1603 (4)	2.0 – 3.0	45,000 lb
Carbon Black Dispersion	D 5596	note (5)	45,000 lb
Oxidative Induction Time (OIT) (min. avg.) (6) (a) Standard OIT - or - (b) High Pressure OIT	D 3895 D 5885	100 400	200,000 lb
Oven Aging at 85°C (7) (a) Standard OIT (min. avg.) - % retained after 90 days - or - (b) High Pressure OIT (min. avg.) - % retained after 90 days	D 5721 D 3895 D 5885	35 60	per formulation
UV Resistance (8) High Pressure OIT (min. avg.) - % retained after 1,600 hours (9)	D 5885	35	per formulation

(1) Of 10 readings, 8 out of 10 must be ≥7 mils, and lowest individual reading must be ≥ 5 mils.
(2) Alternate the measurement side for double-sided texture sheet.
(3) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
- Break elongation is calculated using a gage length of 2.0 inches at 2.0 inches/minute.

(4) Other methods, such as D 4218 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D 1603 (tube furnace) can be established.
(5) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
- 9 in Categories 1 or 2, and 1 in Category 3

(6) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.
(7) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.
(8) The condition of the test should be 20 hr. UV cycle at 75°C, followed by a 4 hr. condensation at 60°C.
(9) UV resistance is based on percent retained value, regardless of the original HP-OIT value.

Penetrations of the liner material for the construction of landfill gas vents will be sealed with a fabricated pipe boot. The flange of the pipe boot will be welded to the geomembrane. The barrel of the pipe boot will be secured with stainless steel band clamps or batten strips as appropriate and sealed with a neoprene strip. The boot detail also provides for closure of the cut edges of the geocomposite drainage layer to minimize the intrusion of fines into the geocomposite.

All geomembrane panels will be uniquely identified with a panel number which is correlated to the roll number and fabrication (production) quality control test data. Quality control test data will be reviewed prior to deployment and any material with questionable or unacceptable test data or documentation will not be utilized. Upon completion, an as-built panel layout will be prepared identifying, as a minimum, panel numbers (correlated to roll numbers), seam numbers, destructive sample numbers and locations, repairs, patches, etc.

3.4.4 Geocomposite Drainage Layer

A geocomposite drainage layer will be installed immediately above the textured geomembrane. The geocomposite drainage layer will serve as a lateral or horizontal drainage medium to relieve the potential for developing a significant hydraulic head of water above the geomembrane. The geocomposite drainage layer will also serve as a means to mitigate the potential for the barrier protection layer and the topsoil layer from becoming saturated and compromising the stability and effectiveness of the overall capping system. Geocomposite will also be installed above the geomembrane in the drainage swales.

The selection of the geocomposite drainage layer includes the determination of the transmissivity of the geonet/geocomposite, the filtration characteristics of the upper geotextile relative to the soil retained and the interface friction with adjacent soil and geomembrane. Determination of the required transmissivity for the geocomposite was completed using the Unit Gradient Method – Design Calculator as described on Landfilldesign.com. The design calculation with drainage geocomposite was performed for slopes of 14%, 17% and 20% with horizontal lengths ranging from 140 feet to 180 feet. Since cover soil permeability typically exhibits a great level of variation several cover soil permeability values were selected for use in the calculation ranging between a maximum of 7.5 x 10^{-5} and a minimum of 1 x 10^{-5} cm/sec. A minimum drainage safety factor of 2.0 was used. Soil permeabilities in excess of 1.0 x 10^{-4} cm/sec were found to promote subsurface drainage conditions which could overwhelm the hydraulic capacity of the geocomposite drainage layer. The long-term hydraulic performance of drainage geocomposite is affected by geonet creep, geotextile intrusion, biological clogging and chemical clogging. The following reduction factors are used in the calculation: RCR = 1.1 (creep), RIN = 1.2 (intrusion), RCC = 1.1 (chemical clogging), and RBC = 3 (biological clogging). The results of the calculations are provided in Appendix A.

The corresponding slope geometry and the required geocomposite ultimate transmissivity values (typically tested under 1000 psf normal pressure, 100-hour, in soil, according to GRI GC8) for these cases are provided in Appendix B. In order to accommodate the variation of the cover soil permeability and meet the slope drainage requirement, high flow geocomposite is required.

The selected geocomposite drainage layer will consist of a tri-axial geosynthetic drainage layer (geonet) core with a 6-ounce per square yard geotextile heat fused to both the upper and lower surfaces. The upper geotextile will serve as separation/filter layer to the overlying barrier protection layer. The lower geotextile will serve to secure the geocomposite to the textured geomemberane through interface friction. The geocomposite drainage layer will have the physical properties detailed in Tables 3-4 and 3-5.

The geocomposite drainage layer will be installed directly on top of the geomembrane after the prepared surface of the geomembrane has been inspected, tested and accepted. Deployment of the geocomposite drainage layer will be coordinated with the placement of the overlying barrier protection layer to ensure that the geotextiles will not be exposed to the elements for more than 14 calendar days.

Table 3-4

CUBA LANDFILL SITE
ENGINEERING DESIGN REPORT
GEOCOMPOSITE DRAINAGE LAYER PROPERTY VALUES

Fabric Property	Test Method	Unit	Specified Value	Qualifier[1]
Geonet Component:				
Polymer Composition	--	%	95 polyethylene by weight	Minimum
Polymer Specific Gravity	ASTM D1505	gm/cm^3	0.94	Min
Polymer Melt Index	ASTM D1238	g/10 min	1.0	Max
Creep Reduction Factor @ 1,000 psf, 20°C	GR1-GC8		1.1	
Carbon Black Content	ASTM D4218	%	2-3	MARV
Tensile Strength (machine direction)	ASTM D4595 modified	lbs/ft	425	MAV
Transmissivity – Machine Direction; Load @ 1,000 psf Gradient: 0.33 0.10	ASTM D4716 GRI-GC8	 m^2/sec M^2/sec	 4×10^{-3} 7.0×10^{-3}	 MAV MAV
Geotextile Component:	See Table 3-2			
Geocomposite:				
Ply Adhesion	ASTM D7005	lb/in	0.5	MAV

Note:

1. MAV – Minimum Average Value.
   MARV – Minimum Average Roll Value
   Max – Maximum Value

Table 3-5

CUBA LANDFILL SITE
ENGINEERING DESIGN REPORT
GEOCOMPOSITE DRAINAGE LAYER PROPERTY VALUES - GEOTEXTILE

Fabric Property	Test Method	Unit	Specified Value	Qualifier(1)
Fabric Weiht	ASTM 5261	02/sq. yd	6	MARV
Grab Strength(2)	ASTM D4632	lbs	160	MARV
Grab Elongation	ASTM D4632	%	50	MARV
Trapezoid Tear	ASTM D4533	lbs	60	MARV
Puncture Resistance	ASTM D4833	lbs	85	MARV
Permittivity	ASTM D4491	sec^{-1}	1.1	MARV
Apparent Opening Size (AOS)	ASTM D4751	sieve size	70	MAxARV
UV Resistance @ 500 hours	ASTM D4355 or ASTM G154	% strength retained	70	Min
pH Resistance			2-13	Range

Notes:

1. MARV - Minimum average roll value.
   MAV - Minimum average value.
   Min – Minimum
   MaxARV – Maximum Average Roll Value
2. Values in the weakest principal direction.

The geocomposite drainage layer will be deployed in the direction of the slope. The lower geotextiles of adjacent panels will be overlapped. The drainage net cores will be overlapped and secured by tying with nylon cable ties. The upper geotextiles will be seamed by sewing using a double-thread lockstitch Type 401 or equivalent. The seam will be a "flat" or "prayer" seam. All terminal ends or edges of the geocomposite will be finished by seaming the upper and lower geotextiles by sewing as described above or by wrapping the terminal end with a supplemental piece of geotextile heat seamed to the top geotextile of the geocomposite.

The geocomposite drainage layer will convey subsurface flow resulting from precipitation which has infiltrated the topsoil and barrier protection layers. The direction of flow will follow the direction of the slope and convey the water to drainage swales.

3.4.5 Barrier Protection Layer

The barrier protection layer will be installed directly above the geocomposite drainage layer over the entire area to be capped. The barrier protection layer will be installed as two compacted lifts.

The barrier protection layer is intended to provide physical protection to the hydraulic barrier (geomembrane) against the effects of frost penetration, roots, erosion, burrowing animals and the elements. The barrier protection layer material will be imported to the site from approved off-site sources. Each proposed source will be subject to prequalification testing and acceptance.

The barrier protection layer material will be clean, inert, well graded granular material free from any organic materials, roots, stumps, chunks of earth or clay, shale or other soft, poor durability particles, waste or other foreign material and shall conform to the following gradation:

Sieve Size	Percent Passing By Weight
1 inch	100
No. 40	0-70

Sieve Size	Percent Passing By Weight
No. 200	0-40

The minimum coefficient of permeability of the soil will be 1 x 10^{-5} cm/sec and the maximum coefficient of the soil will be 7.5 x 10^{-5} as measured in accordance with ASTM D2434 - Permeability of Granular Soils (Constant Head).

A silty sand soil has been selected for the barrier protection layer to provide a stable, non-yielding surface. Fine grained soil containing substantial quantities of silt and/or clay would be prone to moisture retention, capillary action and ultimately, pumping or displacement under load. Shifting of the barrier protection layer under load could then result in damage or stresses imposed on the underlying geosynthetics.

The first lift of barrier protection soil will be placed as a loose lift of 12 inches in thickness. The material will be placed by low ground pressure machines. Construction equipment will not be permitted to travel directly on the geocomposite drainage layer. Rubber tired vehicles will only be permitted to operate on a layer of soil at least 3 feet in thickness over the liner as a temporary access way. The first lift of material will be compacted by making several passes with the low ground pressure spreading/placing equipment. The moisture content of the soil will be controlled to facilitate compaction; however, a minimum degree of compaction will not be specified for the lift.

The second 6-inch lift will be placed with low ground pressure equipment and compacted in-place to achieve a minimum of 95 percent maximum dry density (ASTM D698 – Standard Proctor) as measured by nuclear means. The moisture content of the placed material will be controlled to facilitate compaction. The compactive effort imposed on the second lift will also serve to improve the compaction of the first lift to some degree.

Prior to placement of the barrier protection layer, the exposed surface of the geocomposite drainage layer will be inspected to ensure that it is clean, free of defects and flat. Placement of the barrier protection layer will only be permitted to progress upslope (pushing up the side slopes) to prevent undo stress from being imposed on the geocomposite.

Grade control for placement of the barrier protection layer will utilize non-intrusive means such as laser, stanchions, traffic cones, etc. to prevent damage to or penetration of the underlying geosynthetics.

Testing of the barrier protection layer material during construction will be performed at a frequency of once per 1,000 cubic yards for gradation analysis (ASTM D422) and once per 2,500 cubic yards for permeability (ASTM D2434) and once per 5,000 cubic yards for moisture/density relationship (ASTM D698 – Standard Proctor). In-place moisture/density measurements of the second lift will be performed at a frequency of nine tests per acre per lift utilizing nuclear methods (ASTM D3017 and D2922, respectively).

The finished surface of the barrier protection layer will be surveyed for "as-built" conditions. The in-place thickness of the barrier protection layer will be confirmed by hand excavating a test hole on a 100-foot grid pattern. A board or straight edge will be used to reference grade and three measurements of the in-place depth will be made. The average of the three readings will be considered the depth of the material. The average thickness of the compacted barrier protection layer will be no less than 18 inches.

3.4.6 Topsoil and Vegetation

The topsoil layer will be the uppermost layer of soil in the capping system and will be suitable for establishing and growing surface vegetation. The topsoil layer will be 6 inches in thickness and will be placed over the entire area to be capped.

A review of existing site conditions suggests that there is no appreciable or salvageable quantities of topsoil on-site which would serve to satisfy the need for cap construction. Therefore, all topsoil requirements for the site must be satisfied by the import of topsoil from approved off-site sources.

Natural topsoil will be defined as fertile, friable, topsoil of loamy character, without admixtures of subsoil and shall be uniform in quality. Topsoil will be free from debris and waste of any kind, clay, hard pan, rocks, pebbles larger than 2 inches in diameter, plants, sod, noxious weeds, roots, sticks, brush and other rubbish. Muck soils will not be considered natural topsoil.

Natural topsoil will have an organic content of no less than 5 percent nor more than 20 percent as determined by loss on ignition of oven-dried samples tested in accordance with ASTM D2974. The pH of the topsoil will not be less than 5.5 and not more than 6.8. The topsoil will have a gradation which conforms to the following:

Sieve Size	Percent Passing By Weight
2 inch	100
1 inch	85-100
1/4 inch	65-100
No. 200	20-80

The topsoil layer will be placed as one lift 6 inches in depth over the exposed surface of the barrier protection layer (or general fill). The topsoil layer will be raked and cleaned and rolled with a roller weighing between 40 and 65 pounds per foot of width. During rolling, all depressions caused by settlement will be filled with topsoil and the surface shall be regraded and rolled until a smooth, even finished grade is achieved.

The placement and spreading of topsoil will be coordinated with the planting and seeding operation to allow for planting and seeding within 7 days of placement. Soil amendments such as fertilizer, lime, etc., will be applied as required based upon test data.

Testing of the topsoil material during construction will be performed at a frequency of once per 1,000 cubic yards for particle size (sieve and hydrometer analysis), pH and organic content.

The proposed vegetation for the capped area of the site will be a mixture of turf grasses which will provide for rapid establishment to minimize erosion, as well as slower growing species to minimize long-term maintenance. The seed mixture will include:

- Birdsfoot Trefoil;
- Palmer Perennial Ryegrass;
- Creeping Red Fescue;
- Kentucky 31 Tall Fescue;
- Orchard Grass (Pennlate);
- Annual Rye Grass;
- or equivalent species.

The seed mixture will be applied by hydroseeding onto the loosened surface of the topsoil layer. The hydroseeding operation will include the application of a hydromulch and hydromulch adhesive to secure and protect the seeding sufficiently to allow for the placement of the overlying erosion control fabric.

The closure construction specifications will require establishment of vegetative cover of 85% (i.e., areal coverage) within 2 years. The specifications will also require that contiguous unvegetated areas do not exceed one square foot in size.

All areas of exposed soil beyond the cap limits which become exposed as a result of construction activities will be seeded with a mixture of Smooth Brome Grass, Perennial Rye and Birdsfoot Trefoil at the rate of 30 pounds per acre.

The in-place depth of the topsoil on the landfill cap will be confirmed using the procedures for test pits discussed for the barrier protection layer soils. The in-place depth of topsoil shall be no less than six inches. The finished surface of the topsoil layer will be surveyed for as-built conditions.

3.4.7 Passive Gas Vents

Passive gas vents will be constructed in the capping system to provide for passive relief of landfill gas which may accumulate below the geomembrane in the void space of the geocomposite gas venting layer. The gas vents will be located at a frequency of one per acre in the landfill cap in accordance with the requirements of 6 NYCRR Part 360. Twelve gas vents will be installed in the landfill cap. The details of the gas vents are shown on Sheet 10 of the Contract Drawings.

The passive relief vents will function based upon differential pressure between the underside of the geomembrane where positive gas pressures may accumulate and atmospheric pressure at the exposed open end of the vent. By necessity, the open end of the vent (above grade gooseneck fitting) is constructed above grade with at least 3 feet of clearance to the ground surface to promote unobstructed conditions at all times.

The gas vents will include a 10-foot length horizontal "cross arm" of 6-inch diameter Schedule 80 slotted PVC (slot size 0.080 inch) embedded in washed, rounded gravel which is in contact with the gas venting layer. The vertical slotted riser pipe will extend downwards a minimum of 5 feet into the waste mass. Immediately surrounding the horizontal cross arm and vertical screen will be washed rounded gravel as noted above.

3.4.8 Site Restoration

As mentioned in previous sections, the uppermost layer of the landfill capping system shall be restored with a six-inch layer of topsoil and seed. Areas surrounding the capping system, which may be disturbed as a result of the work performed, will also be restored in the same fashion.

A perimeter access roadway will also be constructed as an integral part of the landfill capping system to facilitate construction, as well as any required post-construction maintenance. The perimeter access roadway will consist of a 12-foot-wide roadway.

A final grading plan depicting final topography and site-related features (e.g., roadways) is presented in Sheet 6 of the Contract Drawings.

3.4.9 Slope Stability

A critical element in the design of a landfill capping system is the assessment of the lining system to remain stable and to not impose undue stresses to the components of the system. These stresses may be imparted through the sliding action of one surface against another. Typically, the focus of concern is addressed to the interface or contact plane between the soil components of the systems against the geosynthetic components of the system and also the interface between two contacting geosynthetics.

The design requirements prescribed by 6 NYCRR Part 360 place restrictions on the maximum slope angle permitted. The maximum prescribed slope angle may be considered to be 1 vertical to 3 horizontal (1V:3H), 33 percent or 18.4 degrees. In instances where the interface friction angle (resistance) is not sufficiently large to counteract the tendency of the lining materials to progress downslope (driving force) the difference in forces must be assumed by the tensile properties of the lining components. In instances where the resistive forces of friction exceed the driving forces, the forces acting across the interface are considered to be neutral and no tensile contribution is required of the geosynthetics.

The typical landfill capping system is constructed in a succession of layers, each of a generally uniform and definable cross section. Each layer may be equated to a thin veneer separated from underlying and overlying layers or veneers by identifiable boundaries or interfaces. An examination of the forces acting at the critical interfaces is referred to as a Veneer Stability Analysis.

For landfills which project upwards as a mound above surrounding grades and impart unbalanced loads through the waste and/or underlying and adjacent soils, the issue of global or slope stability is an area of concern. In these instances, failure through the waste as a rotating wedge is a possibility. In the case of the Cuba Landfill Site, it is clear that the waste mass is essentially below grade in trenches and the upper surfaces are consistent with the surrounding natural grades. On this basis, an analysis of the global stability of the site is not warranted.

Given that the proposed grading plan for the Cuba Landfill Site generally includes mildly sloping terrain with minimal areas of appreciable slope inclination or length, an examination of the seismic stability of the proposed capping system is also not warranted.

3.4.9.1 – Veneer Stability Analysis

The veneer stability of the proposed capping system for the Cuba Landfill Site was analyzed to assess the potential for a sliding failure of the cap components and to confirm the capacity to achieve the required factors of safety. 6 NYCRR Part 360, dated October 9, 1993, prescribes a factor of safety of 1.5 for capping systems.

The calculations for the veneer stability analysis were performed using the Cover Slope Stability calculator from Landfilldesign.com and can be found in Appendix B.

The analysis is predicated on the work of R.M. Koerner and T-Y Soong in a paper entitled "Analysis and Design of Veneer Cover Soils," dated July 2003. The calculations involve a series of steps which consider the effects of the active wedge, the passive wedge at the toe of the slope, the interface friction between the veneers of the proposed capping system and the destabilizing effects of pore water pressure.

The Landfilldesign.com calculator provides an algorithym of mathematical calculations to allow for a resultant factor of safety. Site specific information regarding the site make-up and conditions are input as well as values associated with select components of the capping system. The input parameters are as follows:

- Slope length (see discussion below).
- Slope angle (see discussion below).

- Height of cover soil – taken as 24 inches (600 mm) (18 inches of barrier protection layer soils plus 6 inches of topsoil).

- Height of drainage layer – taken as 8.6 mm for the thickness of the specified geocomposite drainage layer.

- Permeability of the cover soil – taken as 7.5 x 10^{-5} cm/sec. The specified permeability of the barrier protection layer is in the range of 1.0 x 10^{-5} cm/sec to 7.5 x 10^{-5} cm/sec. Using a permeability of 7.5 x 10^{-5} cm/sec for calculation purposes presents a worst case analysis.

- Design permeability of the drainage layer-calculated as the product transmissivity of the specified geocomposite drainage layer divided by the thickness of the geocomposite. The transmissivity of the specified product was selected for a gradient of 0.33 and a normal load of 1,000 pounds per square foot. Site slopes are in the range of 14 to 20 percent and are therefore well below the gradient of 0.33 or 33 percent.

- Precipitation/rain intensity – for the purpose of analysis, the rainfall intensity for a 25 year, 24-hour duration storm was analyzed for the peak hour of precipitation. The peak hour of precipitation, was identified to be at the rate of 1.94 inches in one hour or 49.3 mm/hour.

- Run-off coefficient – value taken as 0.4 to represent steep lawn areas with heavy soils.

- Dry unit weight of cover soils – taken as 115 pounds per cubic foot (18 KN/m^3) to be representative of cover soils.

- Saturated unit weight of cover soils – taken as 134 pounds per cubic foot (21 KN/m^3).

- Friction angle of the cover soil – taken as 30 degrees to be representative of the internal shear strength of the cover soils. The soils are assumed to be cohesionless.

- Friction angle of the cover soil to the underlying interface – taken 22 degrees to be representative of soil to geocomposite and geocomposite to textured geomembrane interfaces. The actual interface friction angles will be determined through laboratory testing as a prerequisite for approval of the proposed materials.

Given the above defined inputs, the two remaining variables which will define the factor of safety are the slope angle and the slope length. In general, the overall slope angle is approximately 17 percent. However, the capped slope will be broken up into discrete sections as defined by the drainage swales which traverse the slope from east to west. Consequently, the discrete slope areas present moderately steep slope inclinations of approximately 14, 17 and 20 percent with flatter slopes at the northern, top slope area. Slope lengths vary for each of the representative slope angles.

For the purpose of this discussion, the longest slope length for each representative slope angle was used to calculate a worst case factor of safety.

The results for each calculator run provides three outputs: factor of safety, unitless measure of the drainage layer capacity and a parallel submergence ratio. The factor of safety for veneer stability must always be greater than 1.0 in order for the cap system to be stable and must be greater than or equal to 1.5 to comply with the requirements of 6NYCRR Part 360. The drainage layer capacity is the ratio of the carrying capacity of the specified drainage layer compared to the flow capacity required for the prevailing conditions. The drainage layer capacity value must always exceed 1.0 in order to avoid surcharging the drainage layer and the resultant formation of seepage forces in the cover soils.

The parallel submergence ratio is calculated as a comparison of the height of water parallel to the slope angle divided by the height of the cover soils. A lower ratio value represents less water accumulated at the drainage layer/cover soil interface and, therefore, the lower the occurrence of destabilizing forces due to saturation and seepage forces.

Table 3-6 presents the results of these calculations. Copies of the printouts from Landfilldesign.com are included in Appendix B. Clearly, these results support that the proposed capping system is stable and compliant with the requirements of 6 NYCRR Part 360. In each case, the drainage layer capacity is shown to be more than adequate to minimize the potential for pore water to accumulate to produce destabilizing seepage forces. This is reinforced by the calculated parallel submergence ratio, which in each case, suggests that the cover soils will not become saturated due to the hydraulic design of the cover system.

Table 3-6

CUBA LANDFILL SITE
ENGINEERING DESIGN REPORT
FACTORS OF SAFETY

Slope		Slope Length		Factor of Safety		Drainage Layer Capacity		Parallel Submergence Ratio
%	Degrees	Feet	Meters		Test ≥ 1.5		Test ≥ 1.0	
14	8.0	180	55	2.99	YES	13.63	YES	0.001
17	9.7	160	49	2.46	YES	18.60	YES	0.001
20	11.3	160	49	2.09	YES	21.75	YES	0.001

The required interface friction angles should be readily attainable using construction materials routinely utilized for the landfill caps. A review of the literature, as well as site specific test data from other sites, support that these conditions can be readily met. On this basis, site specific testing of the capping components for the design phase of the Cuba Landfill is not warranted. The interface friction angles described above will be confirmed by the Contractor using the proposed products.

Clearly, the results of the veneer stability analysis support that the proposed capping system will provide a stable and durable cap capable of being maintained for the post closure monitoring and maintenance period.

3.5 Drainage and Erosion Control

3.5.1 Erosion Control

Erosion control will be implemented during construction and incorporated as part of the final capping system. During construction, the contractor will be required to install and maintain erosion control measures which will include, but not necessarily be limited to, silt fences, hay bales, grade and excavation control, stockpile maintenance, and control measures and surface runoff controls. Construction-related erosion control measures will be initiated prior to disturbance of the affected area and shall be maintained through the course of the construction. Stabilized construction entrances will be constructed at all exits from the construction site to minimize the carryover of construction soil from the site to surrounding roads by way of vehicle tires. Surface runoff from the site will not be permitted to run off onto adjacent roads or properties.

A detailed construction erosion control plan will be prepared as a submittal by the Contractor. Typical details to be used in formulating the erosion control plan are presented on the Contract Drawings.

The final capping system will provide for erosion control through the inclusion of erosion control materials on the exposed finished surfaces. Erosion control blankets will be installed on the seeded landfill surfaces to provide temporary soil erosion resistance. Erosion control fabrics will be installed in the seeded swales to provide permanent soil erosion resistance and vegetation reinforcement. Each product will assist in establishing the permanent vegetation by shielding the seeded areas from direct impact by precipitation, direct exposure to sunlight and surface runoff, as well as improving the moisture conditions of the seed bed which are necessary for proper germination.

Given the remote nature of the site, there are no other sources of water in close proximity to the landfill. All water for establishment and maintenance of the vegetation will have to be delivered to the site and applied by a water truck. This situation promotes the likelihood that the seeded surfaces will not be watered as frequently, or to the extent generally necessary, to promote germination and growth of the grasses. The use of erosion control blankets and fabrics will aid in the germination and growth of the grasses under these conditions and lessen the impacts of erosive forces prior to establishment.

A distinction is made between the erosion control blanket and the erosion control fabric based upon its materials, construction, durability and permanence.

The erosion control blanket will be a fabricated machine-produced mat consisting of 70 percent agricultural straw and 30 percent coconut fiber. The upper surface of the mat will be covered with UV stabilized black polypropylene netting having approximately a 5/8-inch by 5/8-inch mesh size. The bottom surface of the mat will be a lightweight, photodegradable netting with approximately 1/2-inch by 1/2-inch mesh size. The components of the blanket will be factory sewn together using biodegradable thread.

The erosion control blanket will be installed directly over the prepared seed bed and secured in place using heavy duty staples. Anchor trenches and check slots will be installed, as appropriate, to anchor the material and minimize erosion from occurring below the blanket. The erosion control blankets will be installed in the direction of the slope. The erosion control blanket will remain viable for two to three growing seasons.

The erosion control fabric will be a fabricated machine-produced mat suitable as a permanent channel lining and turf reinforcement mat. The mat will be fabricated from 100 percent UV stabilized polypropylene. The fiber matrix core will have a minimum of 0.70 lb./sq. yd. of high denier UV stabilized polypropylene fiber. The top netting and bottom netting will be UV stabilized polypropylene netting with approximately 1/2-inch by 1/2-inch and 5/8-inch by 5/8-inch mesh, respectively. The netting and core will be secured in relative position by sewing using UV stabilized polypropylene thread.

The erosion control fabric will be installed in the drainage swales on top of the prepared seed bed and will be positioned longitudinally with the channel. The fabric will be secured in place using anchor slots, check slots and heavy duty staples. Adjacent panels will overlap a minimum of 6 inches. The fabric will be installed to ensure intimate contact with the ground surface. Trampolining of the material above the ground surface will not be permitted.

The erosion control materials will serve to protect the site, promote the establishment of the vegetation layer and minimize the loss of topsoil due to the erosional forces of surface runoff. During construction, a bare, exposed topsoil surface presents the most susceptible condition for erosion prior to establishment of the vegetation. During the period of establishing the vegetation from seed, erosion of the topsoil surface will disturb the prepared seedbed and transport the seeds from their intended location. Repair efforts requiring heavy equipment will typically disturb additional areas while accessing the area of concern, thereby further setting back the overall establishment of vegetation. In addition, landfill capping construction projects typically near completion toward the latter part of the construction season, considered late fall to early winter. Typically, it is unlikely that seeding of the topsoil surface will occur during the normal windows of the growing season, suggesting that the topsoil surface may lay bare and exposed for an extended period.

The Universal Soil Loss Equation (USLE) provides an opportunity to assess the impacts of erosion to the topsoil surface, as well as gauge the apparent effectiveness of an included erosion control material. The USLE is used to calculate the loss of topsoil in terms of tons per acre per year. The loss of surface soil is most directly dependent on the texture and erodability of the surface soil, the geographic location of the site in terms of rainfall events, the slope angle or gradient, and the unbroken length of slope. The USLE integrates these factors in the following equation:

$$A = (R)(K)(LS)$$

where:

A = Soil loss in tons/acre/year

R = Rainfall intensity factor. For the Cuba Landfill Site, the R value is taken as 100. See Figure 3-1.

K = Soil erodability factor. For this project, the K value is taken as 0.20 representing a silty loam.

LS = Slope length – slope gradient factor. As an example, a 17 percent slope with slope length of 200 feet exhibits an LS factor of 4.53.

Substituting the above values into the equation yields the following

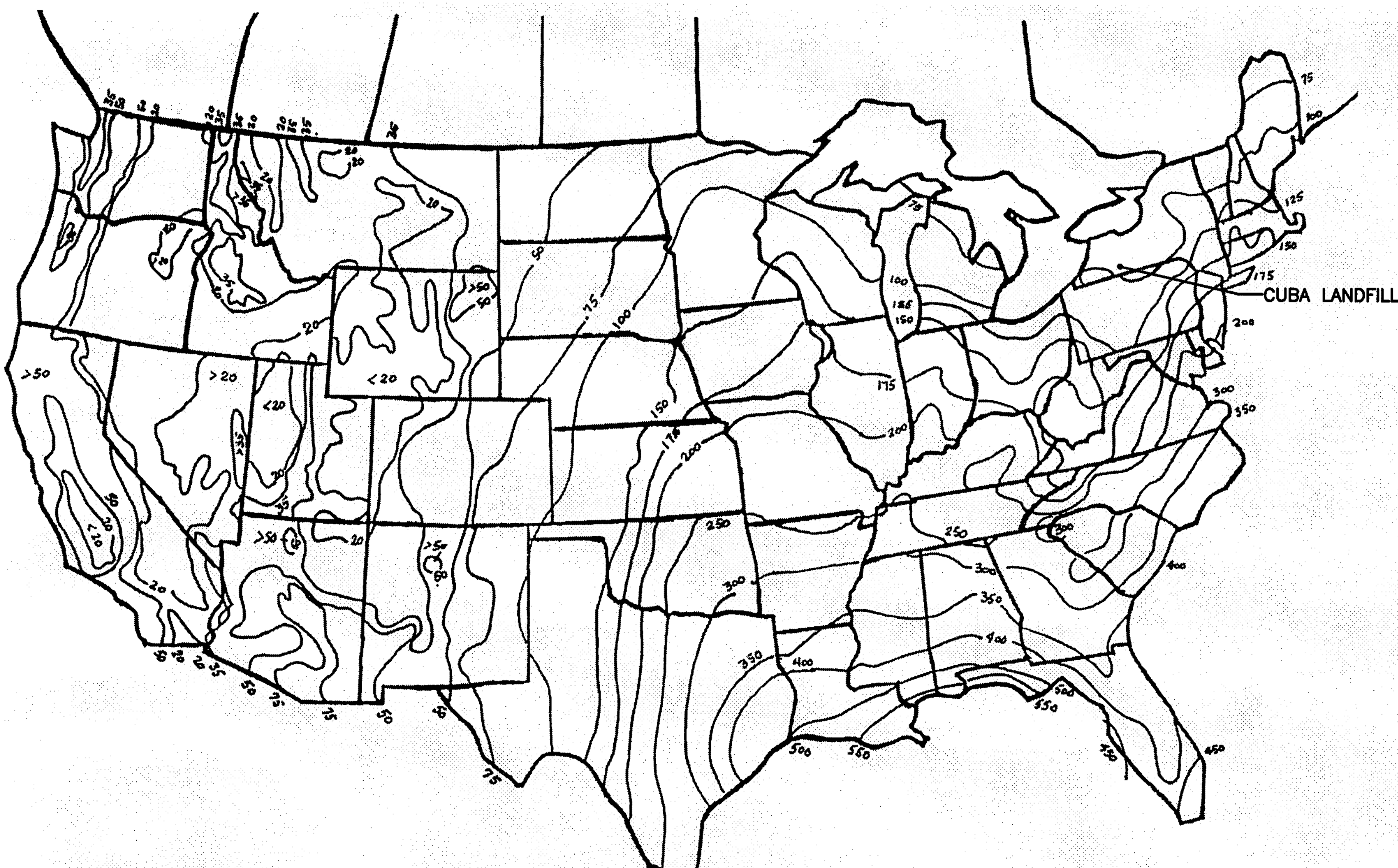
A = 90.6 tons/acre/year

This value represents the potential loss of soil from the slopes on the project at a point in time where the slopes have been constructed but the vegetation has not become established (i.e., bare ground). The addition of the erosion control materials allows for the equation to be expanded to include a C factor for cover management as follows:

$$A = (R)(K)(LS)(C)$$

where:

C = Cover management factor. For the proposed erosion control blanket (coconut/straw), the C factor is 0.015, based upon information provided by North American Green.



SOURCE: NORTH AMERICAN GREEN

Dvirka and Bartilucci
CONSULTING ENGINEERS
A DIVISION OF WILLIAM F. COSULICH ASSOCIATES, P.C.

CUBA LANDFILL SITE
VILLAGE OF CUBA, NEW YORK

RAINFALL INTENSITY "R" FACTORS

FIGURE 3-1

F:\2600\dwg\2600-FIG-3-2.dwg, FIG 3-2, 3/3/2008 9:43:41 AM, PMartorano

Recalculating:

A = 1.36 tons/acre/year

The above value represents less than 25.5 cubic feet per year per acre. This quantity of soil is negligible given that a 6-inch layer of soil over 1 acre equals 21,780 cubic feet. The proposed erosion control blanket should provide 2 to 3 years of surface protection before it naturally decomposes. This period should be more than ample to allow the ultimate vegetation to establish. The proposed erosion control fabric for the drainage swales is considered a permanent material and should provide long-term utility.

The finished surface of the topsoil layer will be surveyed for as-built conditions.

3.5.2 Drainage Controls

At the present time, site drainage for the Cuba Landfill is managed through surface runoff and infiltration and percolation of precipitation into and through the waste mass. Existing grading patterns suggest that storm water runoff leaves the site to the south. The existing site is not connected or tributary to any local or regional storm water management system.

In order to develop a basic storm water management approach for the landfill area, an examination of the property and its surroundings must be considered. The first step involves a determination of the potential for existing facilities to accommodate, with or without modifications, flow from a source which is not currently tributary to it. Absent any existing facilities, consideration is then given to developing new facilities specifically to satisfy the need.

With the construction of the proposed capping system, the opportunity for infiltration to occur over the capped area will be mitigated as a basic function of the cap. The landfill cap, which will reduce infiltration of storm water, will have the effect of increasing the volume and peak rate of discharge of storm water generated by the landfill. This increase in volume and peak rate of discharge can have a detrimental impact on the downstream lands and rivers that receive the storm water runoff. Excessive storm water runoff can cause erosion, transportation of silt and sedimentation and declining water quality and flooding.

In order to preserve the existing hydraulic characteristics of the watershed south of the landfill and the receiving bodies of water, the post-development runoff rates will be mitigated to be equal to or less than the existing storm water runoff rates. Therefore, management of storm water runoff after cap construction will require use of facilities which do not presently exist.

The landfill area is remote and isolated from developed areas and does not afford a ready opportunity to convey storm water to existing management facilities. The construction of an on-site detention basin will serve to address the storm water management needs of the capped landfill area, as well as immediately adjacent non-landfill areas in the watershed. A second benefit of constructing an on-site detention basin is that the soil generated by the excavation of a basin may be incorporated into the cap construction, thereby eliminating the need to import general fill to the site.

The area of the site which offers an opportunity for the construction of a small detention basin is to the southwest of the landfill footprint. This location will allow for storm water to be conveyed from the landfill area and also receive existing overland flow from other tributary areas not disturbed by the cap construction.

In order to establish the needed capacity for an on-site detention basin and outlet structure configuration, a hydraulic analysis of the site was conducted in its existing and proposed conditions. In accordance with 6 NYCRR Part 360, the storm water management system must be sufficient to accommodate a 25-year storm event with a 24-hour duration. For the Cuba area, this storm event is equivalent to 4.3 inches of rainfall. In addition, the New York State Department of Environmental Conservation (NYSDEC) requirements for Stream Channel Protection, Overbank Flood Control, and Extreme Flood Control will be met by the proposed storm water management basin.

In order to evaluate the pre- and post-development conditions, a design point was chosen for the purpose of analyzing and quantifying the pre- and post-runoff conditions. The existing and proposed conditions of the area contributing storm water runoff to the design point were modeled using HydroCAD 7.0. HydroCAD is a software package that uses the Soil Conservation Service's (SCS) TR-20 and TR-55 methods to develop linked hydrographs for the drainage areas, conveyance systems and impoundments. Several of the parameters which are input for each sub-area include: rainfall amount, storm duration, rainfall intensity distribution, plan area of the sub-area, time of concentration, quality and nature of vegetative cover, and a soil group to reflect the nature of the ground cover. The HydroCAD outputs for the existing and proposed site conditions can be found in Appendix C.

The output from the model provides data on the total quantity of runoff from each area as well as the time distribution and peak flow rate for each subarea. Conveyance systems are analyzed for their capacity to transmit the flow and impoundments are analyzed for their capacity to receive, contain and release the discharge over time.

As discussed previously, the opportunities for on-site management of storm water are limited by the topography of the site, beyond the consolidated limits of waste. In order to provide on-site storage capacity, one detention basin has been proposed. The proposed detention basin and outlet structure area are sized to meet the 6 NYCRR Part 360 and NYSDEC requirements.

As shown on Sheet 6 of the Contract Drawings, the landfill will be serviced by seven swales which traverse the landfill footprint from the northeast to the southwest. Refer to Sheet 8 of the Contract Drawings for a cross section of the proposed swale construction. The swales will intercept overland flow and convey it to the downchutes. The swales will also intercept subsurface flow from the geocomposite drainage layer by allowing the geocomposite to drain into the swales and perimeter toe drains. The subsurface flow is generated by precipitation which has infiltrated the topsoil layer and percolated down through the barrier protection layer to the geocomposite drainage layer. The geocomposite serves as a lateral drainage layer to convey the flow to the swales and reduce the generation of hydrostatic head on the geomembrane hydraulic barrier. By reducing the head on the geomembrane, the quantity of percolated precipitation which can pass through any defects in the geomembrane, should any exist, is minimized.

The geocomposite drainage layer also serves to minimize the occurrence of saturated conditions in the overlying barrier protection layer and topsoil layer soil. Under saturated conditions, these overlying soil layers would become less stable, more susceptible to erosion and more likely to fail.

3.6 Phytoremediation

Phytoremediation was selected in the ROD for the site to address leachate seeps at the toe of the slope of the landfill in the southwest corner of the site. Planting of trees in this area will attempt to address the leachate seeps through a combination of plant uptake and enhanced biodegradation by root-associated microorganisms. Although planting of hybrid poplar trees was discussed in the ROD, due to the presence of very saturated conditions in the southwest portion of the site, it was determined to use willow trees in lieu of hybrid poplar trees. The willow trees were selected due to their superior tolerance to saturated conditions.

As shown on the Contract Drawings, willow trees will be planted with 8-foot spacing on center with 10 feet between each row. The trees will be oriented to maximize the number of trees planted in this area.

4.0 COST EVALUATION

4.1 Purpose

The purpose of this cost estimate is to provide a budgetary value for funding the proposed remedial construction at the Cuba Landfill Site.

4.2 Cost Estimate

This cost estimate presents capital costs based on the conceptual design developed and presented in this report. The unit costs are based on values contained in RS Means, quotes received from contractors and suppliers, as well as data from recently completed projects. Table 4-1 summarizes the costs of the proposed remedial construction at the Cuba Landfill Site. As can be seen in Table 4-1, the estimated cost of the proposed remedial construction is approximately $6,200,000.

Table 4-1

CUBA LANDFILL
CONSTRUCTION COST ESTIMATE

Payment Item No.	Description	Unit	Estimated Quantity	Unit or Lump Sum Price		Total Amount
				Words	Figures	
1	Mobilization and Demobilization	L.S.	1	Three Hundred Thirty Three Thousand Dollars	$333,000	$333,000
2	Site Services	Day	220	Three Hundred Dollars	$300	$66,000
3	Health and Safety	Day	60	Eight Hundred Dollars	$800	$48,000
4	Winter Shutdown	L.S.	1	One Hundred Sixteen Thousand Dollars	$116,000	$116,000
5	Site Improvements	L.S.	1	Three Hundred Nine Thousand Dollars	$309,000	$309,000
6	Clearing and Grubbing	L.S.	1	Two Hundred Nineteen Thousand Dollars	$219,000	$219,000
7	Unclassified Excavation and Relandfilling	C.Y.	56,000	Fifteen Dollars	$15	$840,000
8	Drum Handling, Staging, Characterization, Transportation and Disposal	Drums	20	Six Hundred Dollars	$600	$12,000
9	Bulk Hazardous Waste, Excavation, Handling, Staging, Characterization Transportation and Disposal	Tons	300	Three Hundred Dollars	$300	$90,000
10	Screened General Fill Using On-site Borrow	C.Y.	27,000	Twenty Two Dollars	$22	$594,000
11	General Fill Using On-site Borrow	C.Y.	27,000	Thirteen Dollars	$13	$351,000
12	Geocomposite/Gas Venting Layer	S.Y.	55,000	Nine Dollars	$9	$495,000

Table 4-1 (continued)

CUBA LANDFILL
CONSTRUCTION COST ESTIMATE

Payment Item No.	Description	Unit	Estimated Quantity	Unit or Lump Sum Price		Total Amount
				Words	Figures	
13	40 mil Textured LLDPE Geomembrane	S.Y.	55,000	Nine Dollars	$9	$495,000
14	Landfill Gas Vents	Vent	12	Five Thousand Dollars	$5,000	$60,000
15	Geocomposite Drainage Layer	S.Y.	55,000	Ten Dollars	$10	$550,000
16	Barrier Protection layer	S.Y.	55,000	Nine Dollars	$9	$495,000
17	Topsoil	S.Y.	55,000	Six Dollars	$6	$330,000
18	Erosion Control Blanket	S.Y.	75,000	Three Dollars	$3	$225,000
19	Erosion Control Fabric	S.Y.	9,600	Eight Dollars	$8	$76,800
20	Hydroseeding	S.Y.	119,000	Two Dollars	$2	$238,000
21	Maintenance Road	S.Y.	6,300	Thirteen Dollars	$13	$81,900
22	Fencing	L.F.	1,100	Twenty Nine Dollars	$29	$31,900
23	Installation of New Groundwater Monitoring Wells	L.F.	220	Three Hundred Dollars	$300	$66,000
24	Confirmation Tests	Test	25	Five Hundred Dollars	$500	$12,500

Table 4-1 (continued)

CUBA LANDFILL
CONSTRUCTION COST ESTIMATE

Payment Item No.	Description	Unit	Estimated Quantity	Unit or Lump Sum Price		Total Amount
				Words	Figures	
13	40 mil Textured LLDPE Geomembrane	S.Y.	55,000	Nine Dollars	$9	$495,000
14	Landfill Gas Vents	Vent	12	Five Thousand Dollars	$5,000	$60,000
15	Geocomposite Drainage Layer	S.Y.	55,000	Ten Dollars	$10	$550,000
16	Barrier Protection layer	S.Y.	55,000	Nine Dollars	$9	$495,000
17	Topsoil	S.Y.	55,000	Six Dollars	$6	$330,000
18	Erosion Control Blanket	S.Y.	75,000	Three Dollars	$3	$225,000
19	Erosion Control Fabric	S.Y.	9,600	Eight Dollars	$8	$76,800
20	Hydroseeding	S.Y.	119,000	Two Dollars	$2	$238,000
21	Maintenance Road	S.Y.	6,300	Thirteen Dollars	$13	$81,900
22	Fencing	L.F.	1,100	Twenty Nine Dollars	$29	$31,900
23	Installation of New Groundwater Monitoring Wells	L.F.	220	Three Hundred Dollars	$300	$66,000
24	Confirmation Tests	Test	25	Five Hundred Dollars	$500	$12,500
TOTAL: *$6,130,300*						

APPENDIX A

GEOCOMPOSITE DESIGN CALUCATIONS

CUBA LANDFILL
GEOCOMPOSITE DESIGN

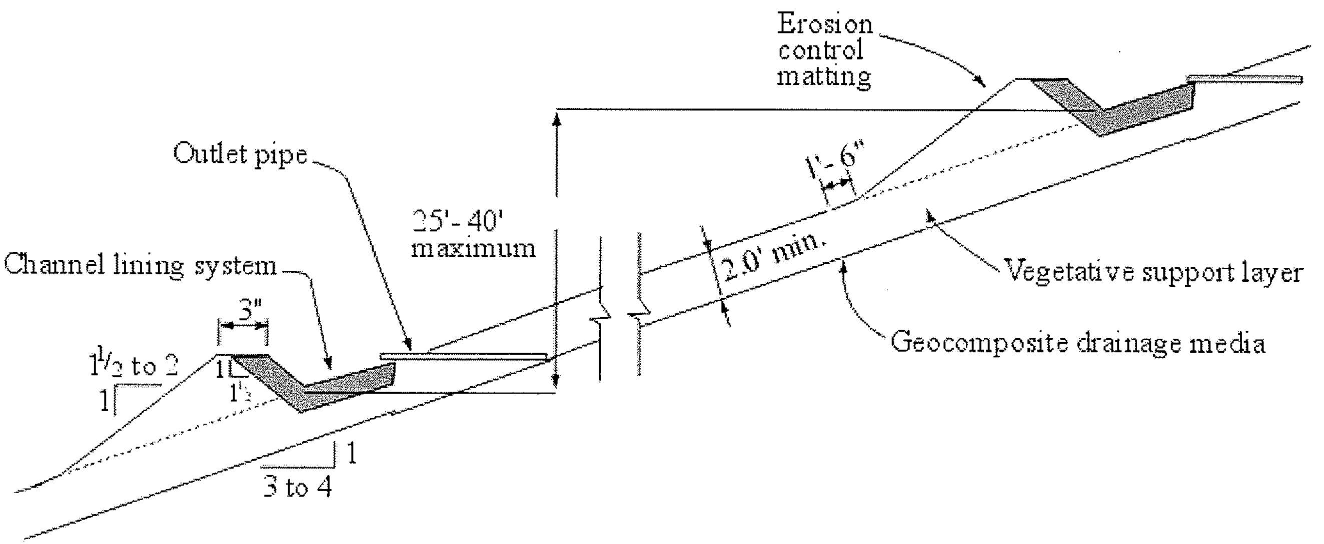
Slope (%)	Slope (degrees)	Slope Length (m)	Permeability of Soil (cm/sec)	Factor of Safety	Red Factor - Intrusion (Rf_{in})	Red Factor - Creep (RF_{cr})	Red Factor - Chem Clog (RF_{cc})	Red Factor - Biol Clog (RF_{bc})	Factor of Safety - Drainage (FS_d)	Gradient	Transmissivity - Ultimate θ_{ult} (m^2/sec)	Interface Friction Req'd δ_{reqd}
14	7.97	54.9	1.00E-05	1.5	1.2	1.1	1.1	3	2	0.14	3.45E-04	11.86
14	7.97	54.9	5.00E-05	1.5	1.2	1.1	1.1	3	2	0.14	1.72E-03	11.86
14	7.97	54.9	7.50E-05	1.5	1.2	1.1	1.1	3	2	0.14	2.59E-03	11.86
14	7.97	54.9	1.00E-04	1.5	1.2	1.1	1.1	3	2	0.14	3.45E-03	11.86
14	7.97	54.9	5.00E-04	1.5	1.2	1.1	1.1	3	2	0.14	1.72E-02	11.86
20	11.31	48.8	1.00E-05	1.5	1.2	1.1	1.1	3	2	0.20	2.17E-04	16.70
20	11.31	48.8	5.00E-05	1.5	1.2	1.1	1.1	3	2	0.20	1.08E-03	16.70
20	11.31	48.8	7.50E-05	1.5	1.2	1.1	1.1	3	2	0.20	1.63E-03	16.70
20	11.31	48.8	1.00E-04	1.5	1.2	1.1	1.1	3	2	0.20	2.17E-03	16.70
20	11.31	48.8	5.00E-04	1.5	1.2	1.1	1.1	3	2	0.20	1.08E-02	16.70
17	9.65	48.8	1.00E-05	1.5	1.2	1.1	1.1	3	2	0.17	2.54E-04	14.31
17	9.65	48.8	5.00E-05	1.5	1.2	1.1	1.1	3	2	0.17	1.27E-03	14.31
17	9.65	48.8	7.50E-05	1.5	1.2	1.1	1.1	3	2	0.17	1.90E-03	14.31
17	9.65	48.8	1.00E-04	1.5	1.2	1.1	1.1	3	2	0.17	2.54E-03	14.31
17	9.65	48.8	5.00E-04	1.5	1.2	1.1	1.1	3	2	0.17	1.27E-02	14.31
20	11.31	44.2	1.00E-05	1.5	1.2	1.1	1.1	3	2	0.20	1.96E-04	16.70
20	11.31	44.2	5.00E-05	1.5	1.2	1.1	1.1	3	2	0.20	9.82E-04	16.70
20	11.31	44.2	7.50E-05	1.5	1.2	1.1	1.1	3	2	0.20	1.47E-03	16.70
20	11.31	44.2	1.00E-04	1.5	1.2	1.1	1.1	3	2	0.20	1.96E-03	16.70
20	11.31	44.2	5.00E-04	1.5	1.2	1.1	1.1	3	2	0.20	9.82E-03	16.70
14	7.97	42.7	1.00E-05	1.5	1.2	1.1	1.1	3	2	0.14	2.68E-04	11.86
14	7.97	42.7	5.00E-05	1.5	1.2	1.1	1.1	3	2	0.14	1.34E-03	11.86
14	7.97	42.7	7.50E-05	1.5	1.2	1.1	1.1	3	2	0.14	2.01E-03	11.86
14	7.97	42.7	1.00E-04	1.5	1.2	1.1	1.1	3	2	0.14	2.68E-03	11.86
14	7.97	42.7	5.00E-04	1.5	1.2	1.1	1.1	3	2	0.14	1.34E-02	11.86

go to problem statement input values solution contact help references

landfilldesign.com

Unit Gradient Method - Design Calculator

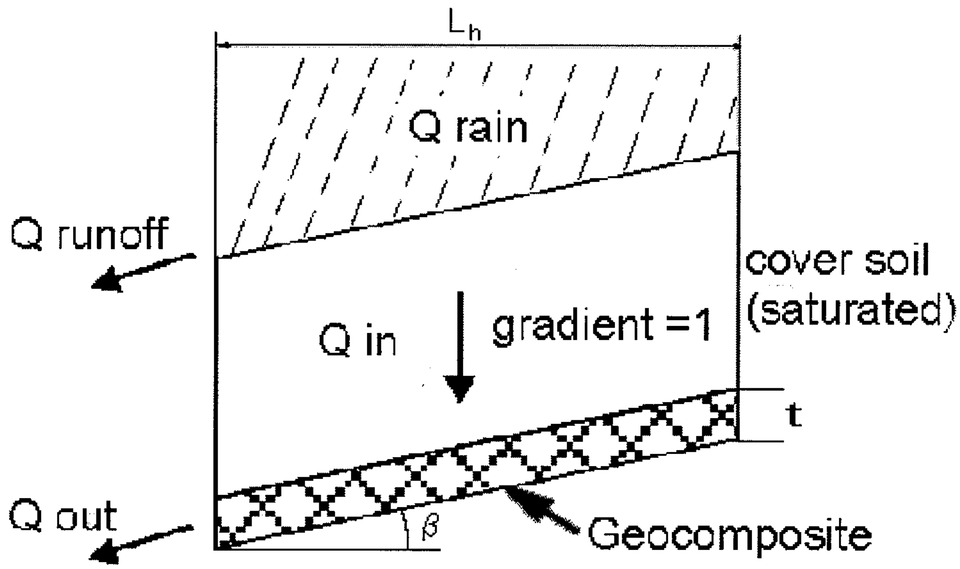
Problem Statement



The transmissivity of a drainage geocomposite must be great enough to carry all of the infiltrating flow from the soil layer(s) above. If the drainage geocomposite can not carry all the infiltrating water (very long slope, or very permeable cover soil,...); swales can be placed as shown in the above figure. The three conditions for stability are:

1. The interface shear strength of all interfaces is adequate
2. Pore water pressures do not build up and reduce the contact stress between the geomembrane and the soil. The Seepage Force Stability Calculator can be used to determine the factor of safety of a landfill cover with consideration of seepage forces
3. Landfill gas pressures beneath the liner are vented properly.The Landfill Gas Pressure Relief Calculator can be used to determine the gas transmissivity of the relief layer. The Landfill Gas Stability Calculator can be used to verify the factor of safety of a landfill cover subject to landfill gas pressure underneath a geomembrane liner.

This webpage determines the ultimate transmissivity sufficient to transmit all incoming flow within the thickness of the geocomposite; i.e. maximum head < geonet thickness; therefore seepage forces in the cover soil will be zero.



With Darcy's law:

$$Q = k * i * A$$

Inflow of water in the geocomposite

$$Q_{in} = k_{veg} * i * A = k_{veg} * 1 * L_h * 1$$

Outflow of water from the geocomposite at the toe of the slope

$$Q_{out} = k_{comp} * i * A = k_{comp} * i * t * 1 = \theta_{required} * \sin\beta$$

Inflow equals outflow (Factor of Safety = 1)

$$Q_{in} = Q_{out}$$

This results in a required transmissivity of the geocomposite of:

$$\theta_{required} = \frac{k_{veg} * L_h}{\sin\beta}$$

Which results in the ultimate transmissivity after multiplying by the Total Serviceability Factor (TSF)

$$\theta_{ultimate} = \theta_{required} * FS_d * RF_{in} * RF_{cr} * RF_{cc} * RF_{bc}$$

Required Data

Symbol	Name	Dimensions

L_h	Drainage pipe spacing or length of slope measured horizontally	Length
k_{veg}	Permeability of the vegetative supporting soil	Length/Time
S	The liner's slope, **S** = tan **b**	-
FS_{slope}	Minimum factor of safety against sliding, for soil/geocomposite or geocomposite/geomembrane interfaces	-

FS_d	Overall factor of safety for drainage
RF_{in}	Intrusion Reduction Factor
RF_{cr}	Creep Reduction Factor
RF_{cc}	Chemical Clogging Reduction Factor
RF_{bc}	Biological Clogging Reduction Factor

Input Values

Note: If you do not wish to perform calculations for 3 cases, please leave default data as is.

	Case 1	Case 2	Case 3
S	14 %	14 %	14 %
L_h	54.9 m	54.9 m	54.9 m
k_{veg}	1E-5 cm/sec	5E-5 cm/sec	1E-4 cm/sec
FS_{slope}	1.5	1.5	1.5

Reduction Factors and Safety Factor

	Case 1	Case 2	Case 3		Surface Water Drains
RF_{in}	1.2	1.2	1.2	[1]	1.0 - 1.2
RF_{cr}	1.1	1.1	1.1	[2]	Calculate RF_{CR}
RF_{cc}	1.1	1.1	1.1	[3]	1.0 - 1.2
RF_{bc}	3	3	3	[3]	1.2 - 3.5
FS_d	2	2	2	[4]	2.0 - 10.0

Calculate Transmissivity

[1] Intrusion reduction factor from 100 hour to design life. Giroud et. al (2000)
[2] Creep reduction factor from 100 hour to design life (for instance, 30 years). RF_{CR} is determined from 10,000 hour compressive creep test, extrapolated to design life, GRI-GC8 (2001). RF_{CR} is product and normal load specific.
[3] GRI-GC8
[4] FS value = 2-3. Giroud, et. al (2000)
FS value > 10 for filtration and drainage. Koerner (2001)
[5] Note: The calculated transmissivity is corresponding to the case where the seating time is 100 hours and the boundary conditions due to adjacent materials are simulated in the hydraulic transmissivity test.

Solution

Symbol	Name	Dimensions
gradient	Gradient	
$\theta_{ultimate}$	Ultimate Transmissivity	$Length^2/Time$
$\delta_{req'd}$	Minimum interface friction angle	degrees

	Case 1		Case 2		Case 3	
gradient	0.14		0.14		0.14	
$\theta_{ultimate}$	3.45E-004	m^2/s	1.72E-003	m^2/s	3.45E-003	m^2/s
$\delta_{req'd}$	11.86	degrees	11.86	degrees	11.86	degrees

Additional Assistance

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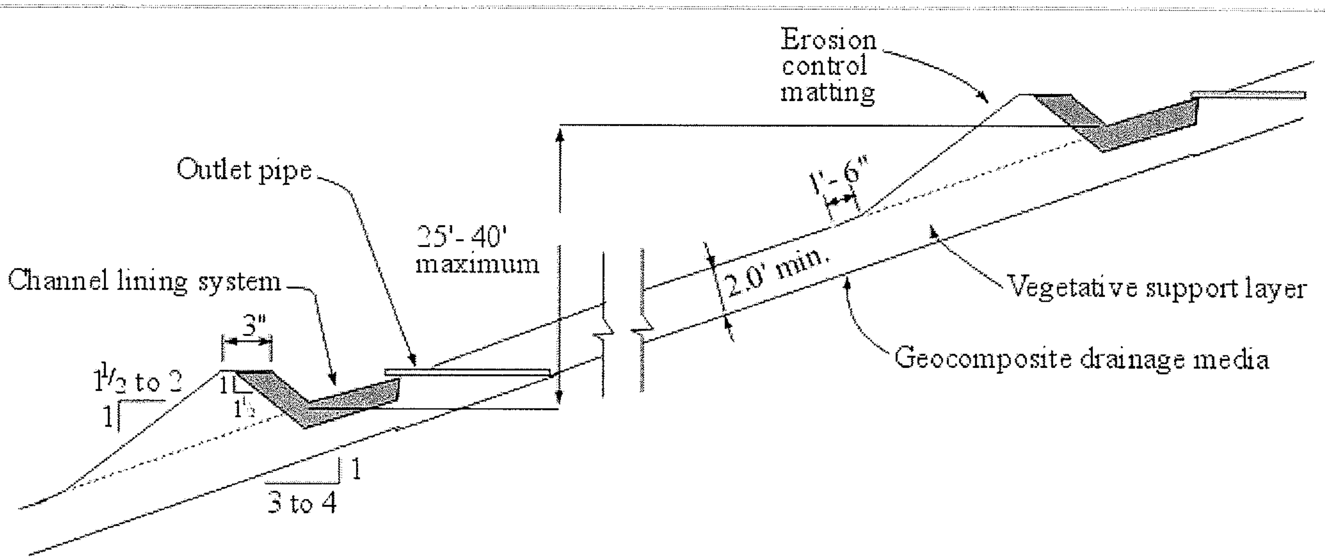
Unit Gradient Method - Design Calculator

Problem Statement



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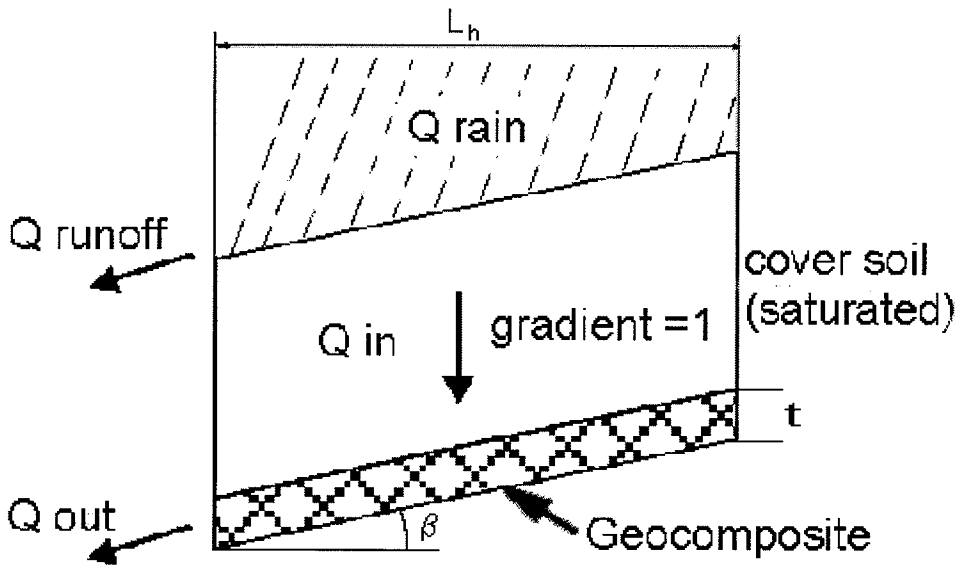
This webpage determines the ultimate transmissivity sufficient to transmit all incoming flow within the thickness of the geocomposite; i.e. maximum head < geonet thickness; therefore seepage forces in the cover soil will be zero.



With Darcy's law:

$Q = k * i * A$

Inflow of water in the geocomposite

$Q_{in} = k_{veg} * i * A = k_{veg} * 1 * L_h * 1$

Outflow of water from the geocomposite at the toe of the slope

$Q_{out} = k_{comp} * i * A = k_{comp} * i * t * 1 = \theta_{required} * \sin \beta$

Inflow equals outflow (Factor of Safety = 1)

$Q_{in} = Q_{out}$

This results in a required transmissivity of the geocomposite of:

$$\theta_{required} = \frac{k_{veg} * L_h}{\sin \beta}$$

Which results in the ultimate transmissivity after multiplying by the Total Serviceability Factor (TSF)

$$\theta_{ultimate} = \theta_{required} * FS_d * RF_{in} * RF_{cr} * RF_{cc} * RF_{bc}$$

Required Data

Symbol	Name	Dimensions

L_h	Drainage pipe spacing or length of slope measured horizontally	Length
k_{veg}	Permeability of the vegetative supporting soil	Length/Time
S	The liner's slope, **S** = tan **b**	-
FS_{slope}	Minimum factor of safety against sliding, for soil/geocomposite or geocomposite/geomembrane interfaces	-

FS_d	Overall factor of safety for drainage
RF_{in}	Intrusion Reduction Factor
RF_{cr}	Creep Reduction Factor
RF_{cc}	Chemical Clogging Reduction Factor
RF_{bc}	Biological Clogging Reduction Factor

Input Values

Note: If you do not wish to perform calculations for 3 cases, please leave default data as is.

	Case 1	Case 2	Case 3
S	14 %	20 %	20 %
L_h	54.9 m	48.8 m	48.8 m
k_{veg}	5E-4 cm/sec	1E-5 cm/sec	5E-5 cm/sec
FS_{slope}	1.5	1.5	1.5

Reduction Factors and Safety Factor

	Case 1	Case 2	Case 3		Surface Water Drains
RF_{in}	1.2	1.2	1.2	[1]	1.0 - 1.2
RF_{cr}	1.1	1.1	1.1	[2]	Calculate RF_{CR}
RF_{cc}	1.1	1.1	1.1	[3]	1.0 - 1.2
RF_{bc}	3	3	3	[3]	1.2 - 3.5
FS_d	2	2	2	[4]	2.0 - 10.0

Calculate Transmissivity

[1] Intrusion reduction factor from 100 hour to design life. Giroud et. al (2000)
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Solution

Symbol	Name	Dimensions
gradient	Gradient	
$\theta_{ultimate}$	Ultimate Transmissivity	$Length^2/Time$
$\delta_{req'd}$	Minimum interface friction angle	degrees

	Case 1		Case 2		Case 3	
gradient	0.14		0.20		0.20	
$\theta_{ultimate}$	1.72E-002	**m^2/s**	2.17E-004	**m^2/s**	1.08E-003	**m^2/s**
$\delta_{req'd}$	11.86	**degrees**	16.70	**degrees**	16.70	**degrees**

Additional Assistance

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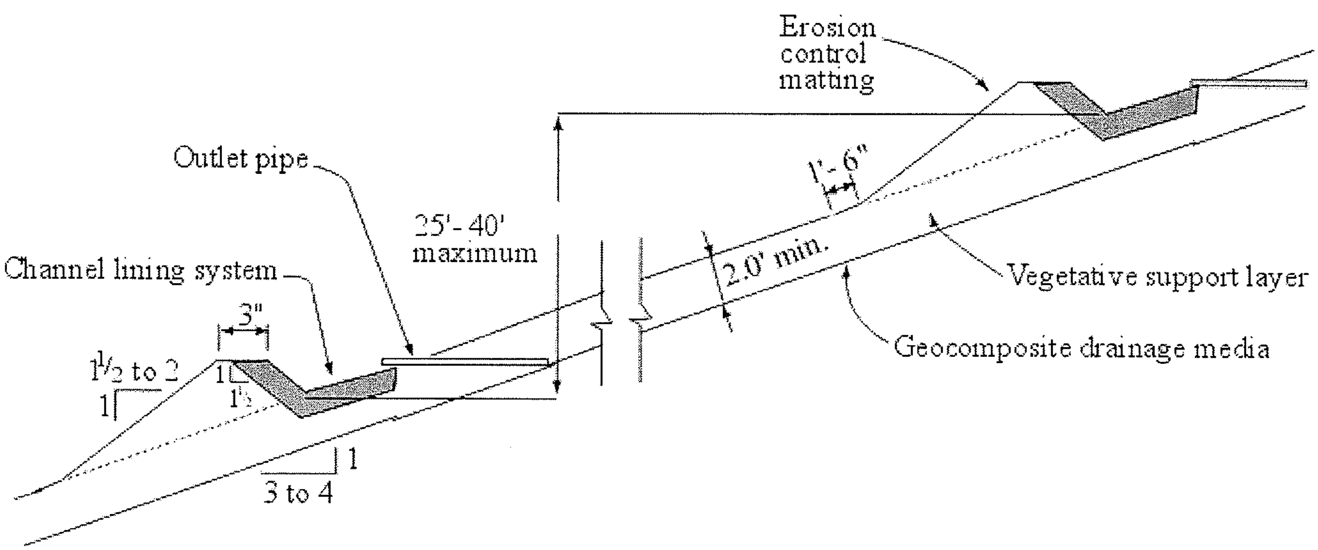
Unit Gradient Method - Design Calculator

Problem Statement



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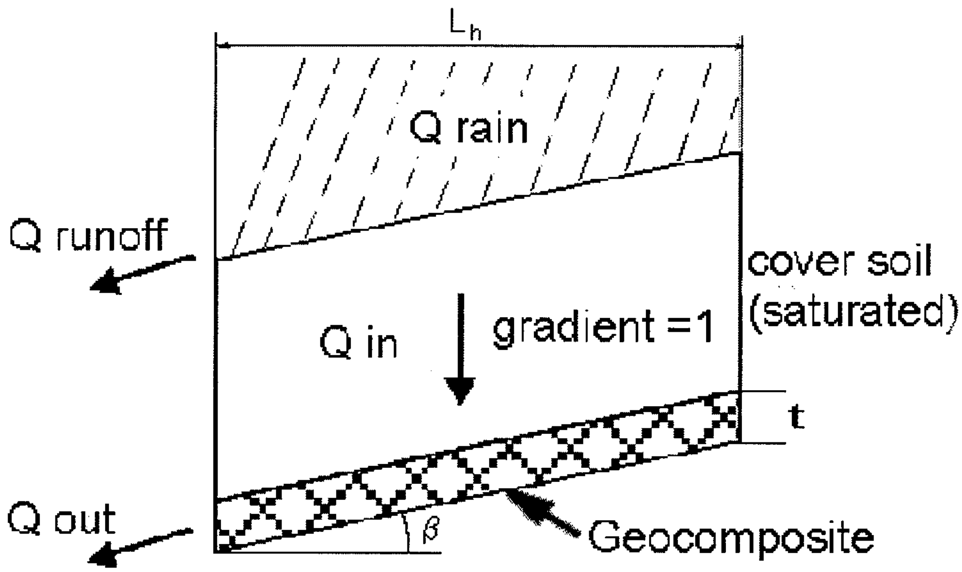

With Darcy's law:

$$Q = k * i * A$$

Inflow of water in the geocomposite

$$Q_{in} = k_{veg} * i * A = k_{veg} * 1 * L_h * 1$$

Outflow of water from the geocomposite at the toe of the slope

$$Q_{out} = k_{comp} * i * A = k_{comp} * i * t * 1 = \theta_{required} * \sin\ \beta$$

Inflow equals outflow (Factor of Safety = 1)

$$Q_{in} = Q_{out}$$

This results in a required transmissivity of the geocomposite of:

$$\theta_{required} = \frac{k_{veg} * L_h}{\sin\ \beta}$$

Which results in the ultimate transmissivity after multiplying by the Total Serviceability Factor (TSF)

$$\theta_{ultimate} = \theta_{required} * FS_d * RF_{in} * RF_{cr} * RF_{cc} * RF_{bc}$$

Required Data

Symbol	Name	Dimensions

FS_d	Overall factor of safety for drainage
RF_{in}	Intrusion Reduction Factor
RF_{cr}	Creep Reduction Factor
RF_{cc}	Chemical Clogging Reduction Factor
RF_{bc}	Biological Clogging Reduction Factor

Input Values

Note: If you do not wish to perform calculations for 3 cases, please leave default data as is.

	Case 1	Case 2	Case 3
S	20 %	20 %	17 %
L_h	48.8 m	48.8 m	48.8 m
k_{veg}	1E-4 cm/sec	5E-4 cm/sec	1E-5 cm/sec
FS_{slope}	1.5	1.5	1.5

Reduction Factors and Safety Factor

	Case 1	Case 2	Case 3		Surface Water Drains
RF_{in}	1.2	1.2	1.2	[1]	1.0 - 1.2
RF_{cr}	1.1	1.1	1.1	[2]	Calculate RF_{CR}
RF_{cc}	1.1	1.1	1.1	[3]	1.0 - 1.2
RF_{bc}	3	3	3	[3]	1.2 - 3.5
FS_d	2	2	2	[4]	2.0 - 10.0

Calculate Transmissivity

[1] Intrusion reduction factor from 100 hour to design life. Giroud et. al (2000)
[2] Creep reduction factor from 100 hour to design life (for instance, 30 years). RF_{CR} is determined from 10,000 hour compressive creep test, extrapolated to design life, GRI-GC8 (2001). RF_{CR} is product and normal load specific.
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Solution

Symbol	Name	Dimensions

gradient	Gradient	
$\theta_{ultimate}$	Ultimate Transmissivity	Length²/Time
$\delta_{req'd}$	Minimum interface friction angle	degrees

	Case 1		Case 2		Case 3	
gradient	0.20		0.20		0.17	
$\theta_{ultimate}$	2.17E-003	**m^2/s**	1.08E-002	**m^2/s**	2.54E-004	**m^2/s**
$\delta_{req'd}$	16.70	**degrees**	16.70	**degrees**	14.31	**degrees**

Additional Assistance

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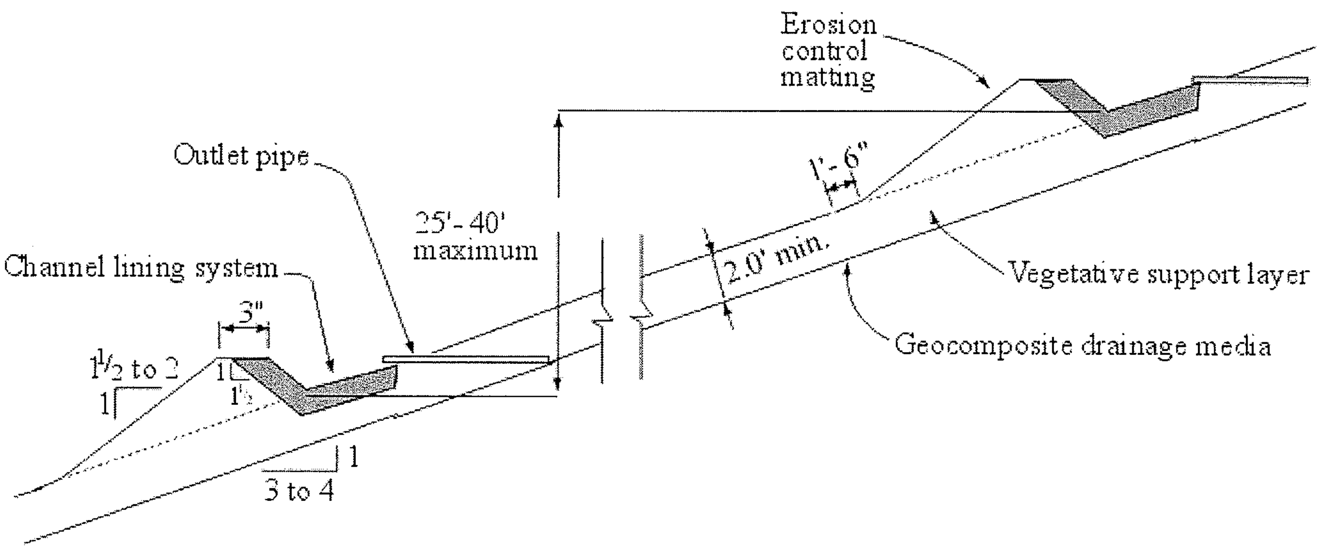
Unit Gradient Method - Design Calculator

Problem Statement



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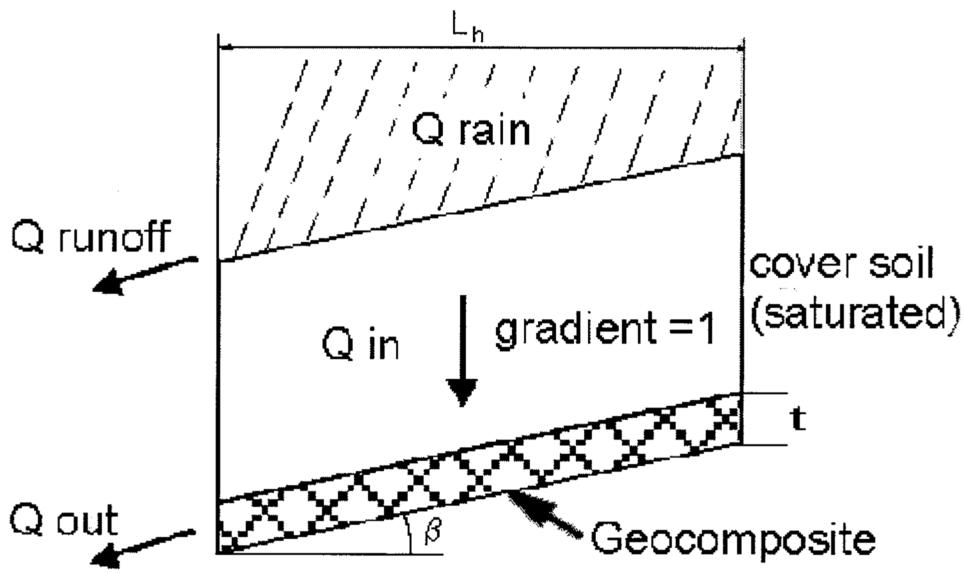

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Inflow of water in the geocomposite

$Q_{in} = k_{veg} * i * A = k_{veg} * 1 * L_h * 1$

Outflow of water from the geocomposite at the toe of the slope

$Q_{out} = k_{comp} * i * A = k_{comp} * i * t * 1 = \theta_{required} * \sin \beta$

Inflow equals outflow (Factor of Safety = 1)

$Q_{in} = Q_{out}$

This results in a required transmissivity of the geocomposite of:

$$\theta_{required} = \frac{k_{veg} * L_h}{\sin \beta}$$

Which results in the ultimate transmissivity after multiplying by the Total Serviceability Factor (TSF)

$\theta_{ultimate} = \theta_{required} * FS_d * RF_{in} * RF_{cr} * RF_{cc} * RF_{bc}$

Required Data

Symbol	Name	Dimensions

FS_d	Overall factor of safety for drainage
RF_{in}	Intrusion Reduction Factor
RF_{cr}	Creep Reduction Factor
RF_{cc}	Chemical Clogging Reduction Factor
RF_{bc}	Biological Clogging Reduction Factor

Input Values

Note: If you do not wish to perform calculations for 3 cases, please leave default data as is.

	Case 1	Case 2	Case 3
S	17 %	17 %	17 %
L_h	48.8 m	48.8 m	48.8 m
k_{veg}	5E-5 cm/sec	1E-4 cm/sec	5E-4 cm/sec
FS_{slope}	1.5	1.5	1.5

Reduction Factors and Safety Factor

	Case 1	Case 2	Case 3		Surface Water Drains
RF_{in}	1.2	1.2	1.2	[1]	1.0 - 1.2
RF_{cr}	1.1	1.1	1.1	[2]	Calculate RF_{CR}
RF_{cc}	1.1	1.1	1.1	[3]	1.0 - 1.2
RF_{bc}	3	3	3	[3]	1.2 - 3.5
FS_d	2	2	2	[4]	2.0 - 10.0

Calculate Transmissivity

[1] Intrusion reduction factor from 100 hour to design life. Giroud et. al (2000)
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Solution

Symbol	Name	Dimensions

gradient	Gradient	
$\theta_{ultimate}$	Ultimate Transmissivity	Length^2/Time
$\delta_{req'd}$	Minimum interface friction angle	degrees

	Case 1		Case 2		Case 3	
gradient	0.17		0.17		0.17	
$\theta_{ultimate}$	1.27E-003	**m^2/s**	2.54E-003	**m^2/s**	1.27E-002	**m^2/s**
$\delta_{req'd}$	14.31	**degrees**	14.31	**degrees**	14.31	**degrees**

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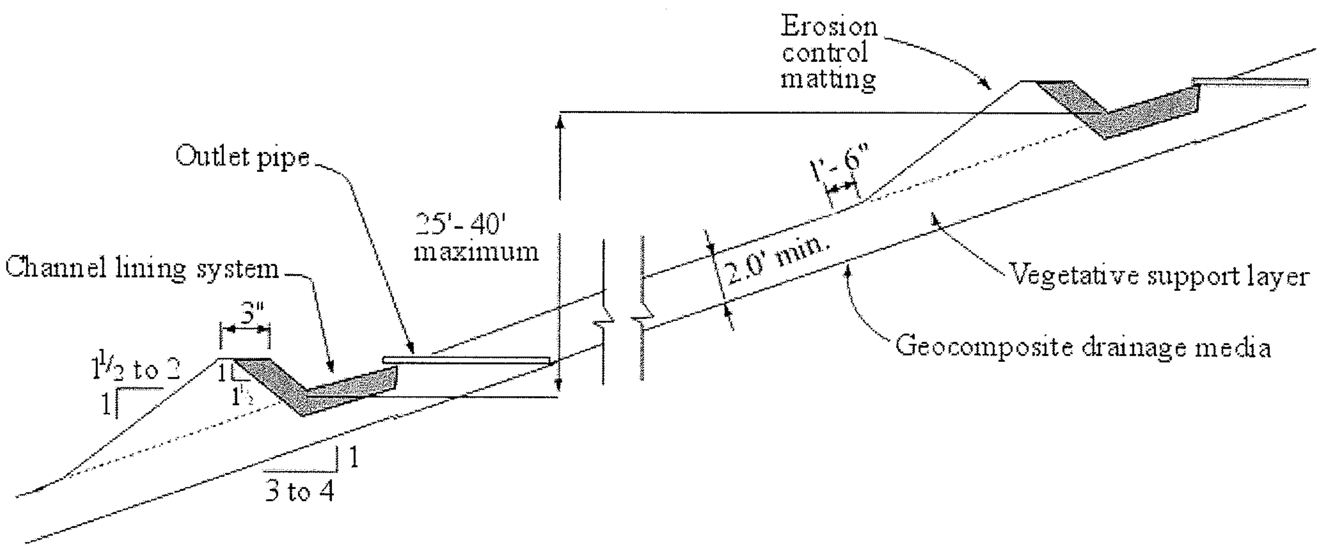
Unit Gradient Method - Design Calculator

Problem Statement



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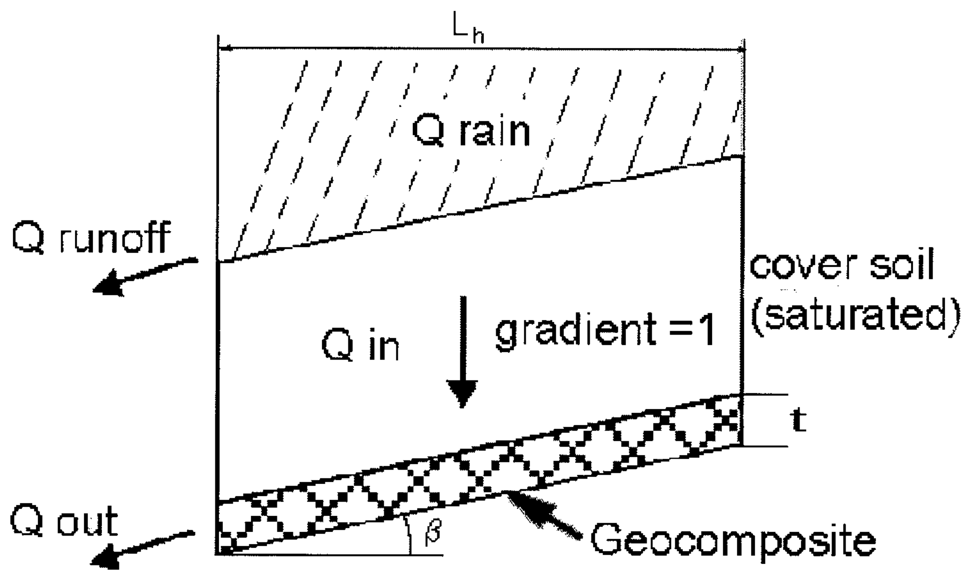

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This results in a required transmissivity of the geocomposite of:

$$\theta_{required} = \frac{k_{veg} * L_h}{\sin \beta}$$

Which results in the ultimate transmissivity after multiplying by the Total Serviceability Factor (TSF)

$$\theta_{ultimate} = \theta_{required} * FS_d * RF_{in} * RF_{cr} * RF_{cc} * RF_{bc}$$

Required Data

Symbol	Name	Dimensions

FS_d	Overall factor of safety for drainage
RF_{in}	Intrusion Reduction Factor
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Input Values

Note: If you do not wish to perform calculations for 3 cases, please leave default data as is.

	Case 1	Case 2	Case 3
S	20 %	20 %	20 %
L_h	44.2 m	44.2 m	44.2 m
k_{veg}	1E-5 cm/sec	5E-5 cm/sec	1E-4 cm/sec
FS_{slope}	1.5	1.5	1.5

Reduction Factors and Safety Factor

	Case 1	Case 2	Case 3		Surface Water Drains
RF_{in}	1.2	1.2	1.2	[1]	1.0 - 1.2
RF_{cr}	1.1	1.1	1.1	[2]	Calculate RF_{CR}
RF_{cc}	1.1	1.1	1.1	[3]	1.0 - 1.2
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Solution

Symbol	Name	Dimensions

gradient	Gradient	
$\theta_{ultimate}$	Ultimate Transmissivity	Length^2/Time
$\delta_{req'd}$	Minimum interface friction angle	degrees

	Case 1		**Case 2**		**Case 3**	
gradient	0.20		0.20		0.20	
$\theta_{ultimate}$	1.96E-004	**m^2/s**	9.82E-004	**m^2/s**	1.96E-003	**m^2/s**
$\delta_{req'd}$	16.70	**degrees**	16.70	**degrees**	16.70	**degrees**

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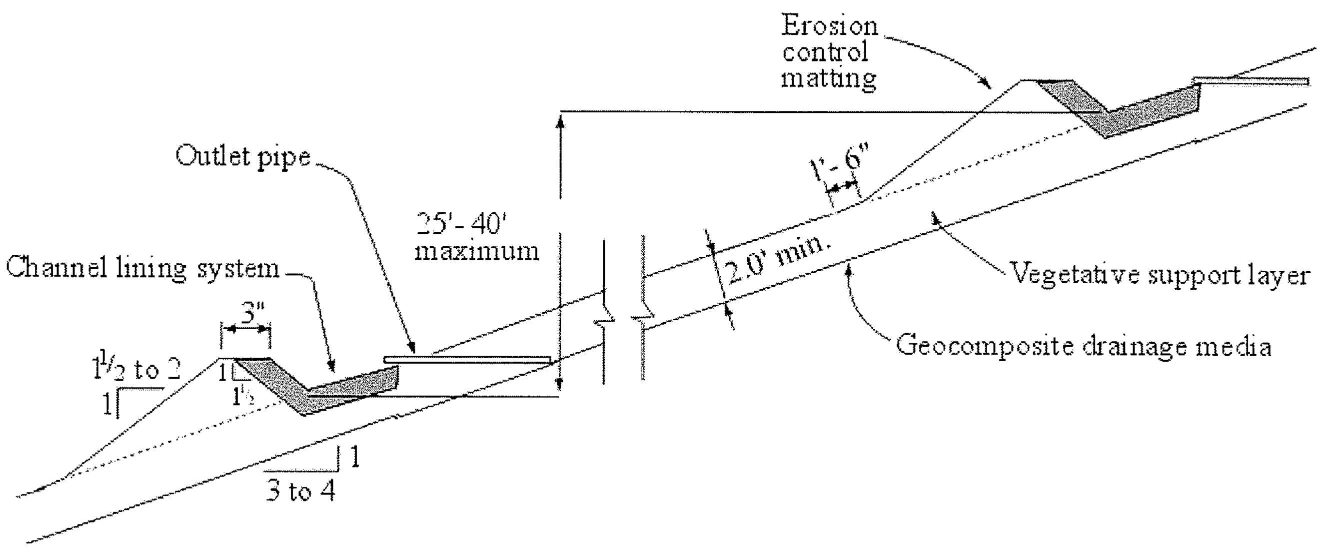
Unit Gradient Method - Design Calculator

Problem Statement



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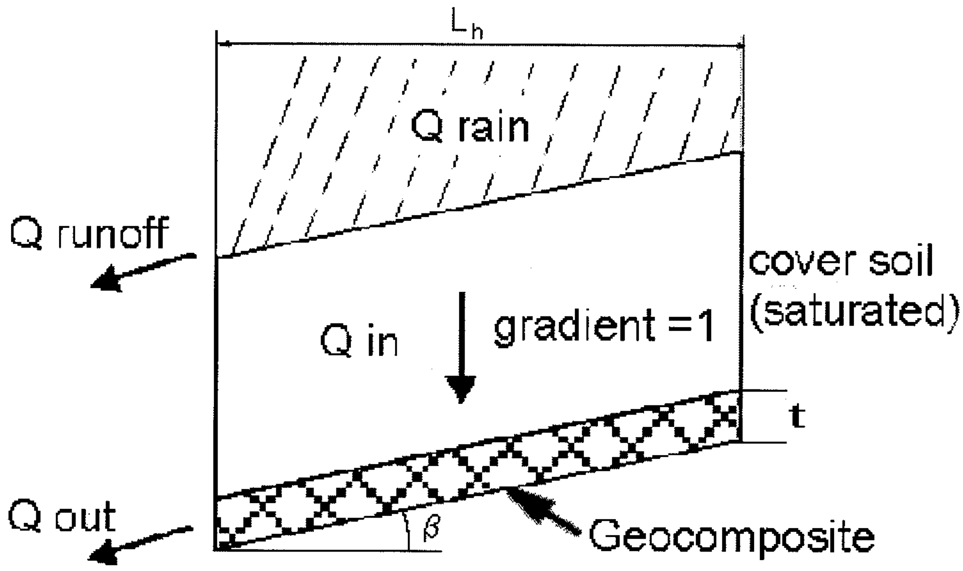

With Darcy's law:

$Q = k * i * A$

Inflow of water in the geocomposite

$Q_{in} = k_{veg} * i * A = k_{veg} * 1 * L_h * 1$

Outflow of water from the geocomposite at the toe of the slope

$Q_{out} = k_{comp} * i * A = k_{comp} * i * t * 1 = \theta_{required} * \sin\ \beta$

Inflow equals outflow (Factor of Safety = 1)

$Q_{in} = Q_{out}$

This results in a required transmissivity of the geocomposite of:

$$\theta_{required} = \frac{k_{veg} * L_h}{\sin\ \beta}$$

Which results in the ultimate transmissivity after multiplying by the Total Serviceability Factor (TSF)

$\theta_{ultimate} = \theta_{required} * FS_d * RF_{in} * RF_{cr} * RF_{cc} * RF_{bc}$

Required Data

Symbol	Name	Dimensions

FS_d	Overall factor of safety for drainage
RF_{in}	Intrusion Reduction Factor
RF_{cr}	Creep Reduction Factor
RF_{cc}	Chemical Clogging Reduction Factor
RF_{bc}	Biological Clogging Reduction Factor

Input Values

Note: If you do not wish to perform calculations for 3 cases, please leave default data as is.

	Case 1	Case 2	Case 3
S	20 %	14 %	14 %
L_h	44.2 m	42.7 m	42.7 m
k_{veg}	5E-4 cm/sec	1E-5 cm/sec	5E-5 cm/sec
FS_{slope}	1.5	1.5	1.5

Reduction Factors and Safety Factor

	Case 1	Case 2	Case 3		Surface Water Drains
RF_{in}	1.2	1.2	1.2	[1]	1.0 - 1.2
RF_{cr}	1.1	1.1	1.1	[2]	Calculate RF_{CR}
RF_{cc}	1.1	1.1	1.1	[3]	1.0 - 1.2
RF_{bc}	3	3	3	[3]	1.2 - 3.5
FS_d	2	2	2	[4]	2.0 - 10.0

Calculate Transmissivity

[1] Intrusion reduction factor from 100 hour to design life. Giroud et. al (2000)
[2] Creep reduction factor from 100 hour to design life (for instance, 30 years). RF_{CR} is determined from 10,000 hour compressive creep test, extrapolated to design life, GRI-GC8 (2001). RF_{CR} is product and normal load specific.
[3] GRI-GC8
[4] FS value = 2-3. Giroud, et. al (2000)
FS value > 10 for filtration and drainage. Koerner (2001)
[5] Note: The calculated transmissivity is corresponding to the case where the seating time is 100 hours and the boundary conditions due to adjacent materials are simulated in the hydraulic transmissivity test.

Solution

Symbol	Name	Dimensions

gradient	Gradient	
$\theta_{ultimate}$	Ultimate Transmissivity	Length^2/Time
$\delta_{req'd}$	Minimum interface friction angle	degrees

	Case 1		**Case 2**		**Case 3**	
gradient	0.20		0.14		0.14	
$\theta_{ultimate}$	9.82E-003	**m^2/s**	2.68E-004	**m^2/s**	1.34E-003	**m^2/s**
$\delta_{req'd}$	16.70	**degrees**	11.86	**degrees**	11.86	**degrees**

Additional Assistance

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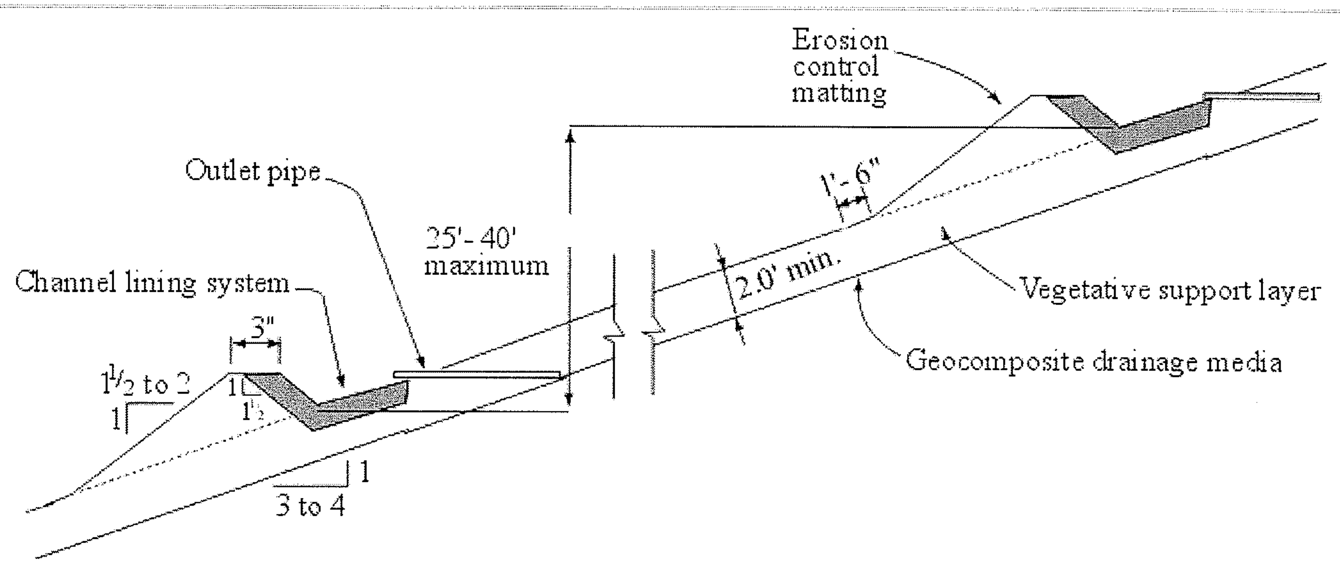
Unit Gradient Method - Design Calculator

Problem Statement



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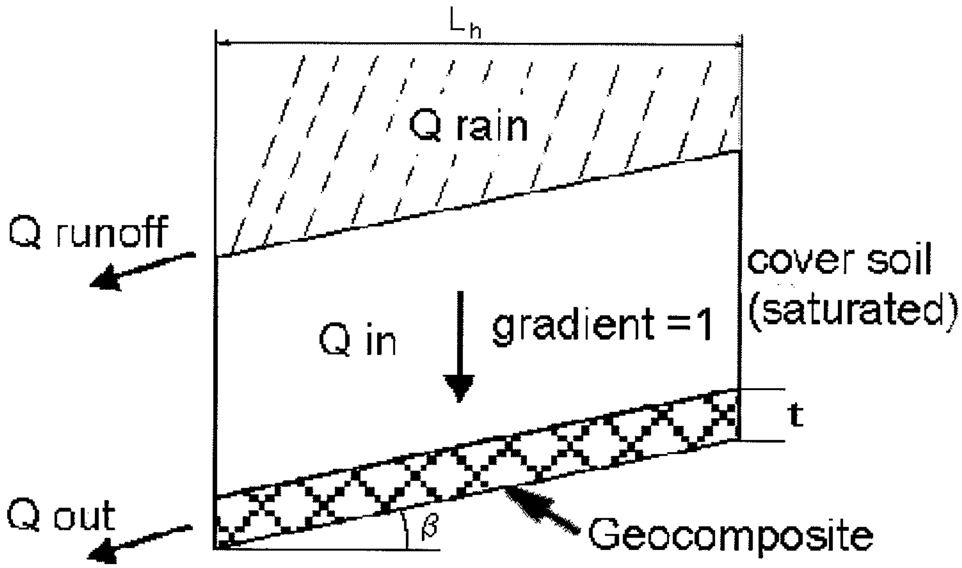

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Outflow of water from the geocomposite at the toe of the slope

$Q_{out} = k_{comp} * i * A = k_{comp} * i * t * 1 = \theta_{required} * \sin\ \beta$

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This results in a required transmissivity of the geocomposite of:

$$\theta_{required} = \frac{k_{veg} * L_h}{\sin\ \beta}$$

Which results in the ultimate transmissivity after multiplying by the Total Serviceability Factor (TSF)

$\theta_{ultimate} = \theta_{required} * FS_d * RF_{in} * RF_{cr} * RF_{cc} * RF_{bc}$

Required Data

Symbol	Name	Dimensions

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RF_{in}	Intrusion Reduction Factor
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Input Values

Note: If you do not wish to perform calculations for 3 cases, please leave default data as is.

	Case 1	Case 2	Case 3 NOT USED
S	14 %	14 %	33 %
L_h	42.7 m	42.7 m	90 m
k_{veg}	1E-4 cm/sec	5E-5 cm/sec	1E-4 cm/sec
FS_{slope}	1.5	1.5	1.5

Reduction Factors and Safety Factor

	Case 1	Case 2	Case 3		Surface Water Drains
RF_{in}	1.2	1.2	1.2	[1]	1.0 - 1.2
RF_{cr}	1.1	1.1	1.4	[2]	Calculate RF_{CR}
RF_{cc}	1.1	1.1	1.2	[3]	1.0 - 1.2
RF_{bc}	3.0	3.0	3.5	[3]	1.2 - 3.5
FS_d	2	2	3	[4]	2.0 - 10.0

Calculate Transmissivity

[1] Intrusion reduction factor from 100 hour to design life. Giroud et. al (2000)
[2] Creep reduction factor from 100 hour to design life (for instance, 30 years). RF_{CR} is determined from 10,000 hour compressive creep test, extrapolated to design life, GRI-GC8 (2001). RF_{CR} is product and normal load specific.
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Solution

Symbol	Name	Dimensions

gradient	Gradient	
$\theta_{ultimate}$	Ultimate Transmissivity	$Length^2/Time$
$\delta_{req'd}$	Minimum interface friction angle	degrees

	Case 1		Case 2		Case 3	
gradient	0.14		0.14		0.31	
$\theta_{ultimate}$	2.68E-003	**m^2/s**	1.34E-003	**m^2/s**	6.08E-003	**m^2/s**
$\delta_{req'd}$	11.86	**degrees**	11.86	**degrees**	26.34	**degrees**

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Unit Gradient Method - Design Calculator

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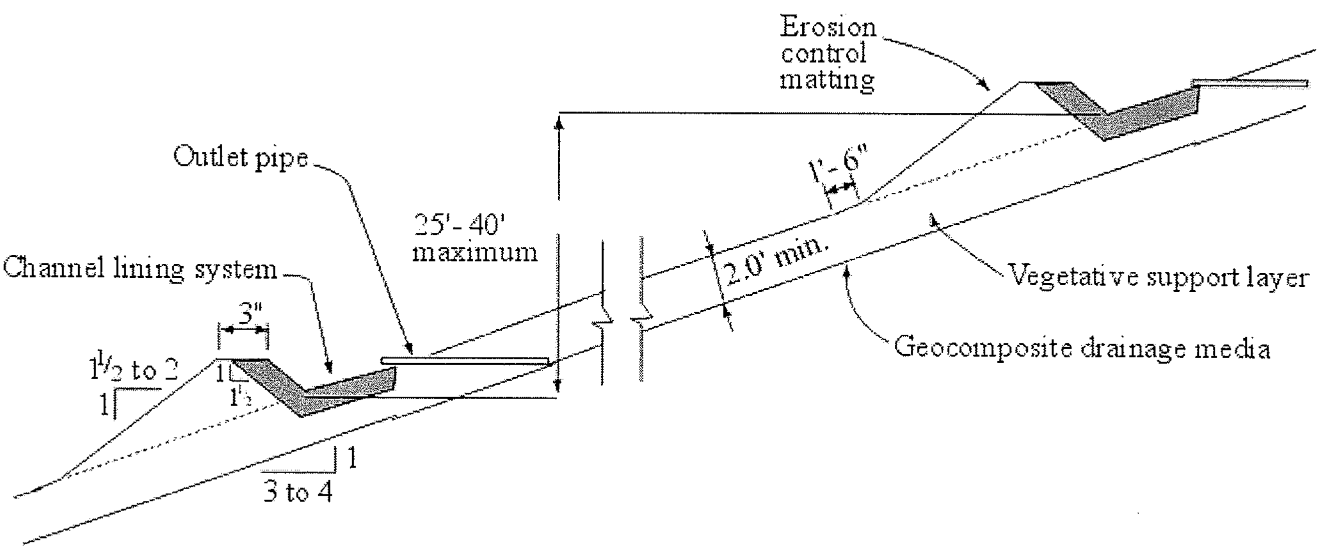

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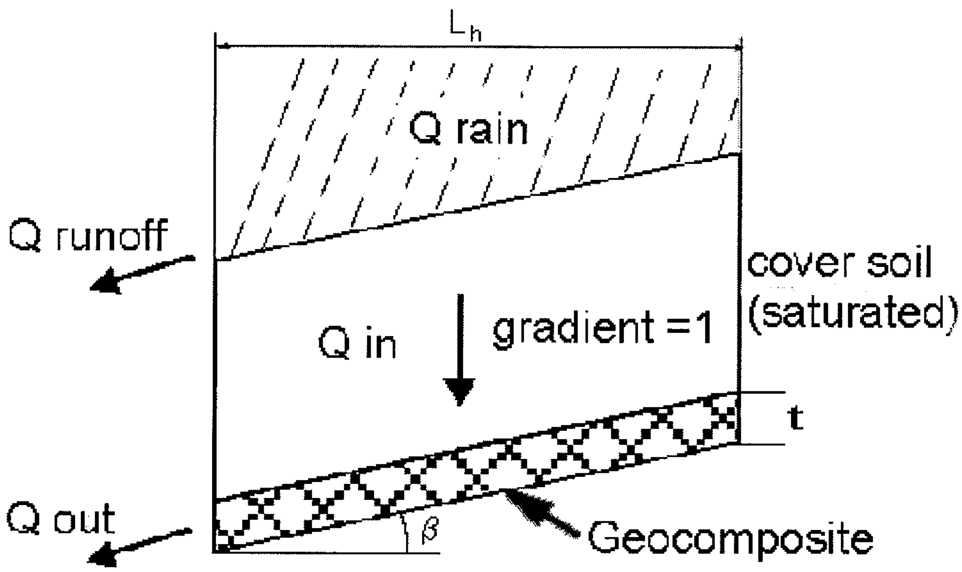

With Darcy's law:

$$Q = k * i * A$$

Inflow of water in the geocomposite

$$Q_{in} = k_{veg} * i * A = k_{veg} * 1 * L_h * 1$$

Outflow of water from the geocomposite at the toe of the slope

$$Q_{out} = k_{comp} * i * A = k_{comp} * i * t * 1 = \theta_{required} * \sin \beta$$

Inflow equals outflow (Factor of Safety = 1)

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$$\theta_{ultimate} = \theta_{required} * FS_d * RF_{in} * RF_{cr} * RF_{cc} * RF_{bc}$$

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RF_{bc}	Biological Clogging Reduction Factor

Input Values

Note: If you do not wish to perform calculations for 3 cases, please leave default data as is.

	Case 1	Case 2	Case 3
S	14 %	20 %	17 %
L_h	54.9 m	48.8 m	48.8 m
k_{veg}	7.5E-5 cm/sec	7.5E-5 cm/sec	7.5E-5 cm/sec
FS_{slope}	1.5	1.5	1.5

Reduction Factors and Safety Factor

	Case 1	Case 2	Case 3		Surface Water Drains
RF_{in}	1.2	1.2	1.2	[1]	1.0 - 1.2
RF_{cr}	1.1	1.1	1.1	[2]	Calculate RF_{CR}
RF_{cc}	1.1	1.1	1.1	[3]	1.0 - 1.2
RF_{bc}	3	3	3	[3]	1.2 - 3.5
FS_d	2	2	2	[4]	2.0 - 10.0

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$\delta_{req'd}$	11.86	**degrees**	16.70	**degrees**	14.31	**degrees**

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Unit Gradient Method - Design Calculator

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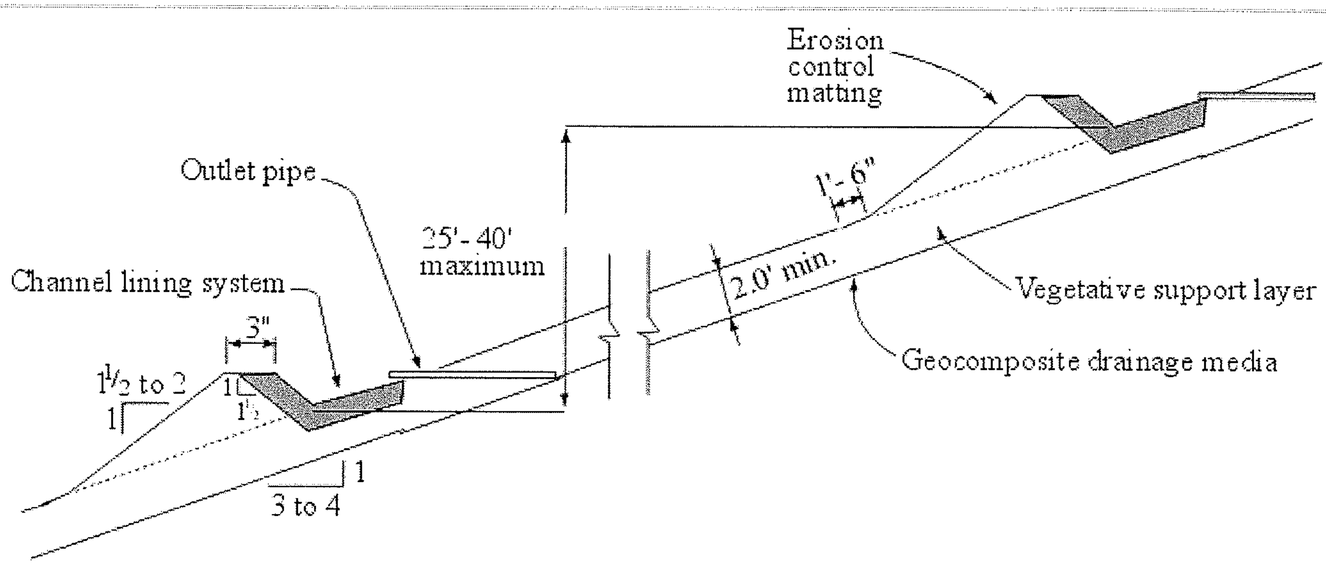

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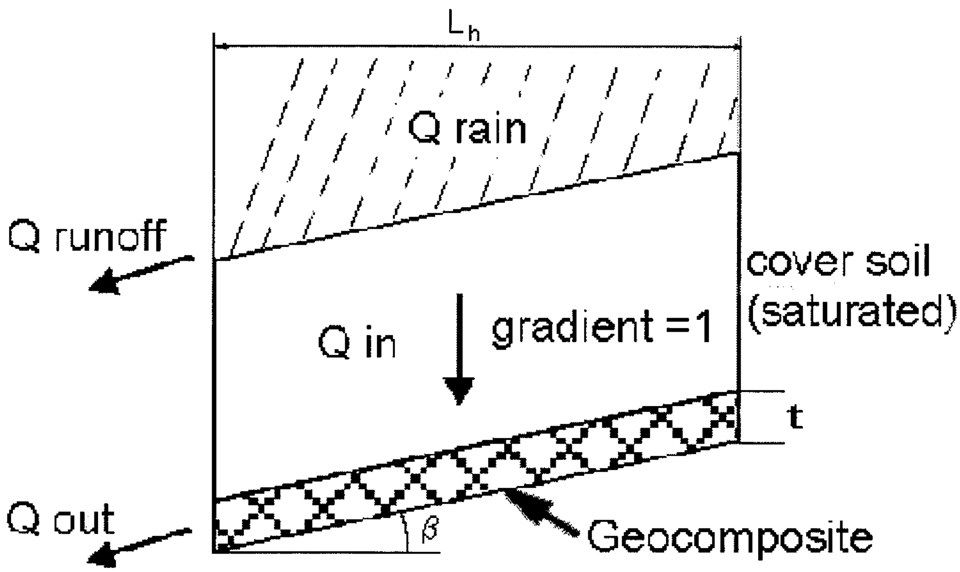

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Reduction Factors and Safety Factor

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RF_{cr}	1.1	1.1	1.4	[2]	Calculate RF_{CR}
RF_{cc}	1.1	1.1	1.2	[3]	1.0 - 1.2
RF_{bc}	3.0	3.0	3.5	[3]	1.2 - 3.5
FS_d	2	2	3	[4]	2.0 - 10.0

Calculate Transmissivity

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Solution

Symbol	Name	Dimensions

gradient	Gradient	
$\theta_{ultimate}$	Ultimate Transmissivity	Length²/Time
$\delta_{req'd}$	Minimum interface friction angle	degrees

	Case 1		**Case 2**		**Case 3**	
gradient	0.20		0.14		0.31	
$\theta_{ultimate}$	1.47E-003	**m^2/s**	2.01E-003	**m^2/s**	6.08E-003	**m^2/s**
$\delta_{req'd}$	16.70	**degrees**	11.86	**degrees**	26.34	**degrees**

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APPENDIX B

VENEER STABILITY ANALYSIS

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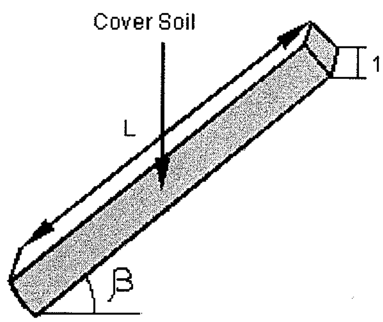
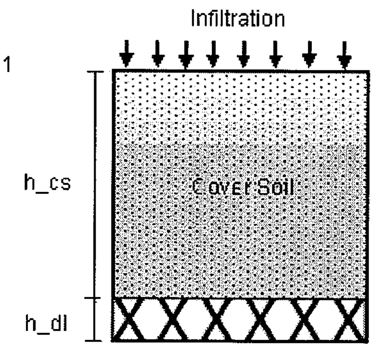
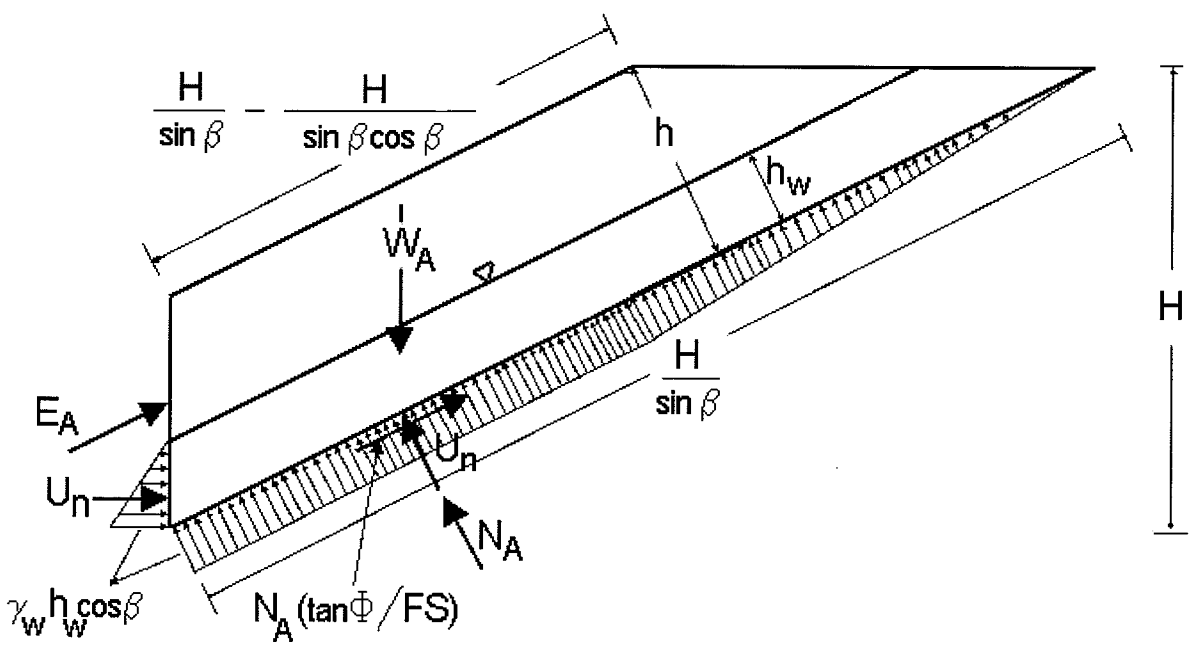
Cover Slope Stability - Design Calculator

SLOPE ANGLE: 14%/8.0°
SLOPE LENGTH: 55 m

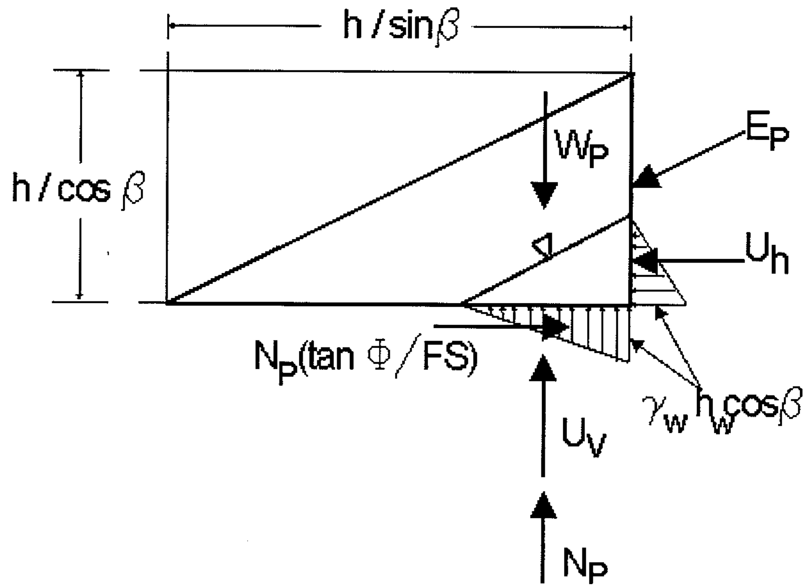
Problem Statement







Active Wedge



Passive Wedge

Input Values

Design Input		
Slope characteristics		
Length of the slope (L)	55	m
Slope angle (ß)	8.0	degrees
Height of soil layers		
Height of cover soil (h_cs)	600	mm
Height of drainage layer (h_dl)	8.62	mm
Permeability of the soil layers		
Permeability of cover soil	.000075	cm/s
Design permeability of drainage layer	46.4	cm/s
Rain intensity parameters		
Precipitation	49.3	mm/hr
Run-off coefficient	0.4	
Soil characteristics		
Dry unit weight of cover soil	18	kN/m^3
Saturated unit weight of the cover soil	21	kN/m^3
Friction angles		
Friction angle of the cover soil	30	degrees
Friction angle of the cover soil / underlying interface	22	degrees

Stability Calculation

Solution

I. Normalized Input data

Gradient	0.139
Horizontal length	54.465 m
Height cover soil and drainage layer	0.60862 m
Permeability of cover soil in m/s	7.50E-007 m/s
Design permeability of the drainage layer in m/s	0.464 m/s

II. Calculation of the Drainage Capacity

Precipitation from input	49.3 mm/hr
Actual runoff	46.6 mm/hr
Actual percolation	2.7 mm/hr
Actual flux	0.147 m^3/hr
Allowable flux	2.004 m^3/hr
Drainage Layer Capacity (DLC) (needs to be >1.0 to avoid saturation)	**13.627**

III. Parallel Submergence Ratio (PSR)

Average height water table	6.33E-004 m
Parallel Submergence Ratio (PSR)	**0.001**

Stability Factor of Safety (FS) **2.999**

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Company
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Project Reference
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References

R. M. Koerner, and T-Y. Soong, 1998. "Analysis and Design of Veneer Cover Soils". Proceedings of 6th International Conference on Geosynthetics, Vol. 1, pp. 1-23, Atlanta, Georgia, USA.

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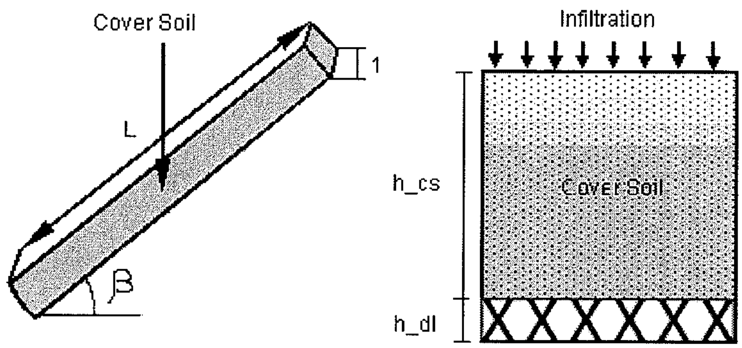
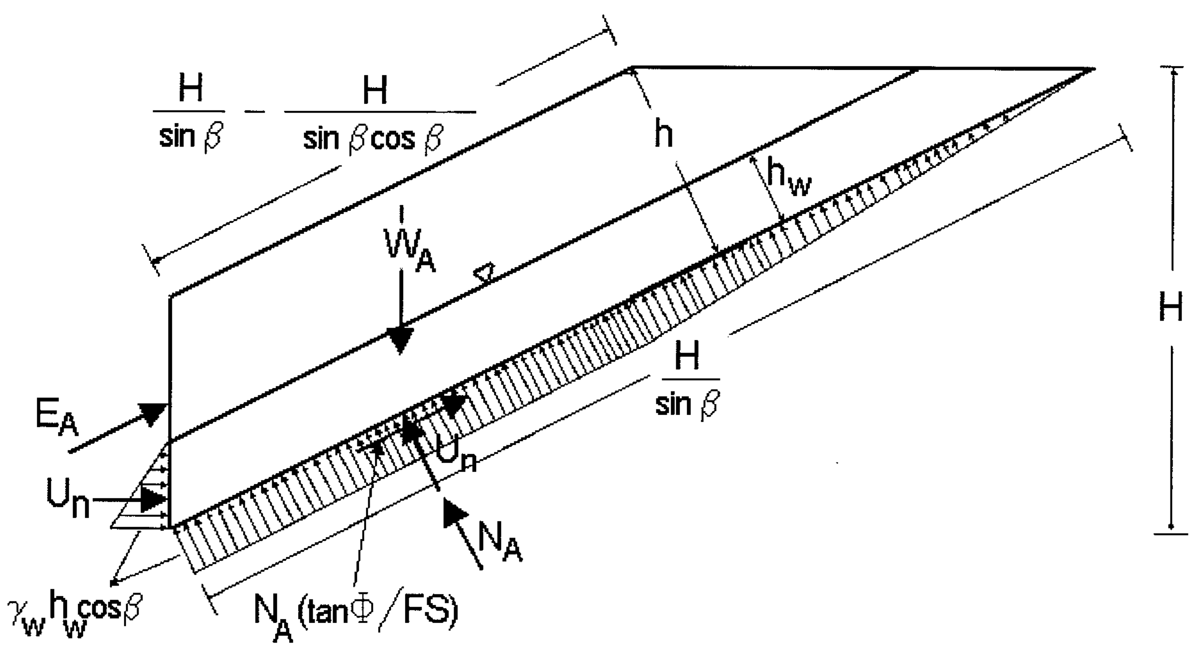
Cover Slope Stability - Design Calculator

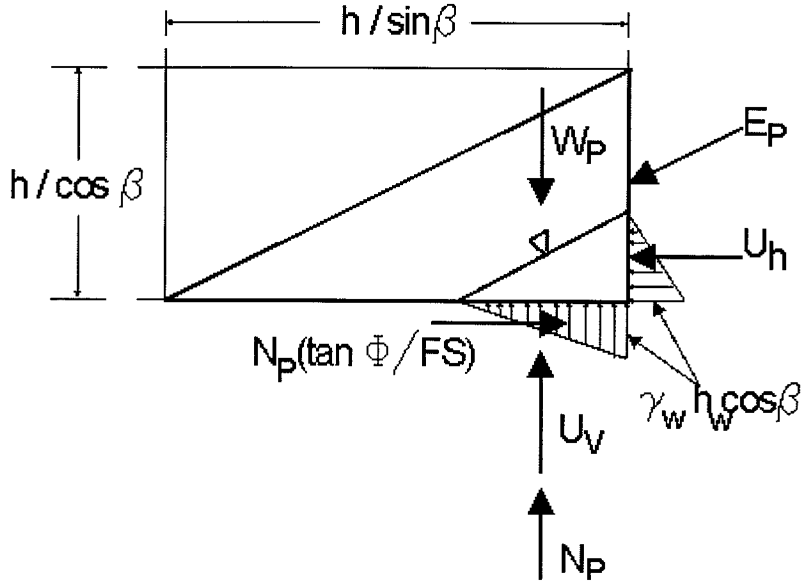
SLOPE ANGLE: 17% / 9.7°
SLOPE LENGTH: 49 m

Problem Statement





Active Wedge



Passive Wedge

Input Values

Design Input		
Slope characteristics		
Length of the slope (L)	49	m
Slope angle (ß)	9.7	degrees
Height of soil layers		
Height of cover soil (h_cs)	600	mm
Height of drainage layer (h_dl)	8.62	mm
Permeability of the soil layers		
Permeability of cover soil	.000075	cm/s
Design permeability of drainage layer	46.4	cm/s
Rain intensity parameters		
Precipitation	49.3	mm/hr
Run-off coefficient	0.4	
Soil characteristics		
Dry unit weight of cover soil	18	kN/m^3
Saturated unit weight of the cover soil	21	kN/m^3
Friction angles		
Friction angle of the cover soil	30	degrees
Friction angle of the cover soil / underlying interface	22	degrees

Stability Calculation

Solution

I. Normalized Input data

Gradient	0.168
Horizontal length	48.299 m
Height cover soil and drainage layer	0.60862 m
Permeability of cover soil in m/s	7.50E-007 m/s
Design permeability of the drainage layer in m/s	0.464 m/s

II. Calculation of the Drainage Capacity

Precipitation from input	49.3 mm/hr
Actual runoff	46.6 mm/hr
Actual percolation	2.7 mm/hr
Actual flux	0.130 m^3/hr
Allowable flux	2.426 m^3/hr
Drainage Layer Capacity (DLC) (needs to be >1.0 to avoid saturation)	**18.603**

III. Parallel Submergence Ratio (PSR)

Average height water table	4.63E-004 m
Parallel Submergence Ratio (PSR)	**0.001**

Stability Factor of Safety (FS) **2.461**

Additional Assistance

If you would like to have Advanced Geotech Systems provide material specifications that meet your performance criteria, please fill in the following fields and click the submit button. All information is kept strictly confidential.

Name * ______ Comments ______

Company ______

Email Address * ______

Phone ______

Project Reference ______

*required fields

Submit Design Results

References

R. M. Koerner, and T-Y. Soong, 1998. "Analysis and Design of Veneer Cover Soils". Proceedings of 6th International Conference on Geosynthetics, Vol. 1, pp. 1-23, Atlanta, Georgia, USA.

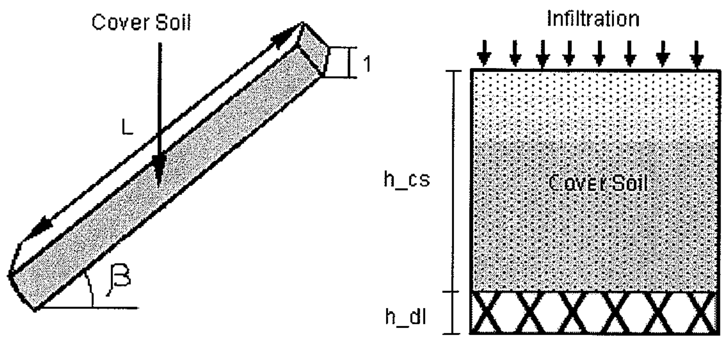
go to problem statement input values solution contact help references

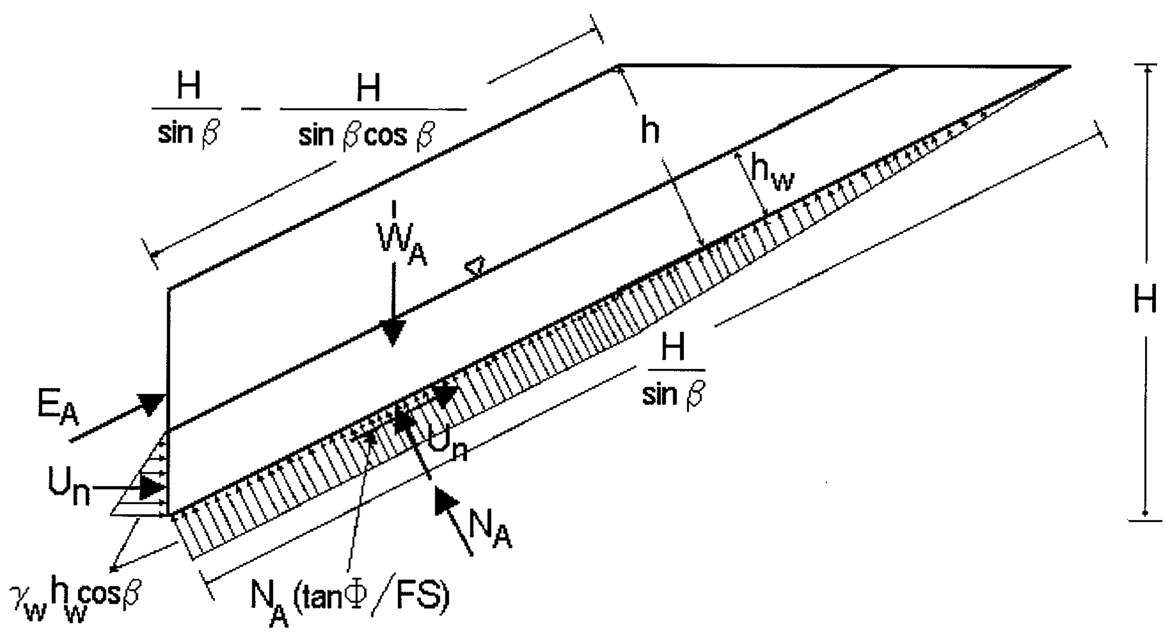
landfilldesign.com

Cover Slope Stability - Design Calculator

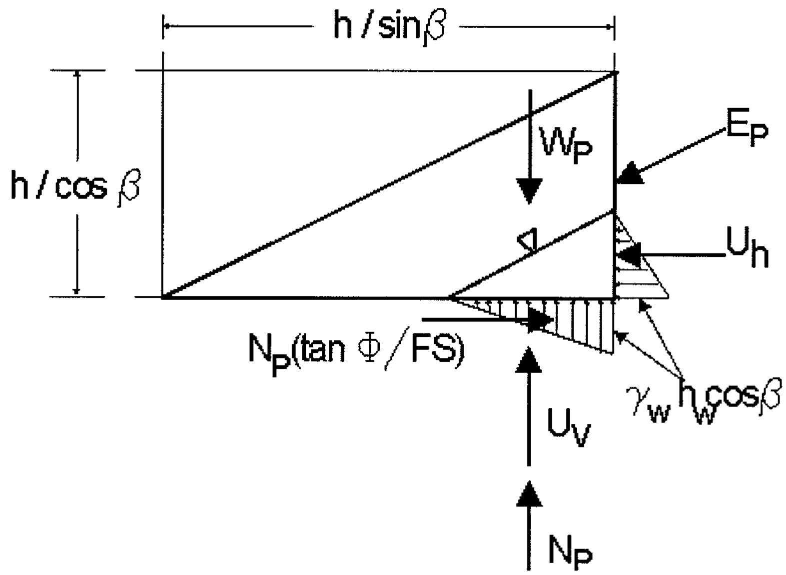
SLOPE ANGLE: 20% / 11.3°
SLOPE LENGTH: 49 m

Problem Statement





Active Wedge



Passive Wedge

Input Values

Design Input		
Slope characteristics		
Length of the slope (L)	49	m
Slope angle (ß)	11.3	degrees
Height of soil layers		
Height of cover soil (h_cs)	600	mm
Height of drainage layer (h_dl)	8.62	mm
Permeability of the soil layers		
Permeability of cover soil	.000075	cm/s
Design permeability of drainage layer	46.4	cm/s
Rain intensity parameters		
Precipitation	49.3	mm/hr
Run-off coefficient	0.4	
Soil characteristics		
Dry unit weight of cover soil	18	kN/m^3
Saturated unit weight of the cover soil	21	kN/m^3
Friction angles		
Friction angle of the cover soil	30	degrees
Friction angle of the cover soil / underlying interface	22	degrees

Stability Calculation

Solution

I. Normalized Input data

Gradient	0.196
Horizontal length	48.050 m
Height cover soil and drainage layer	0.60862 m
Permeability of cover soil in m/s	7.50E-007 m/s
Design permeability of the drainage layer in m/s	0.464 m/s

II. Calculation of the Drainage Capacity

Precipitation from input	49.3 mm/hr
Actual runoff	46.6 mm/hr
Actual percolation	2.7 mm/hr
Actual flux	0.130 m^3/hr
Allowable flux	2.821 m^3/hr
Drainage Layer Capacity (DLC) (needs to be >1.0 to avoid saturation)	**21.747**

III. Parallel Submergence Ratio (PSR)

Average height water table	3.96E-004 m
Parallel Submergence Ratio (PSR)	**0.001**

Stability Factor of Safety (FS) **2.095**

Additional Assistance

If you would like to have Advanced Geotech Systems provide material specifications that meet your performance criteria, please fill in the following fields and click the submit button. All information is kept strictly confidential.

Name *

Company

Email Address *

Phone

Project Reference

Comments

*required fields

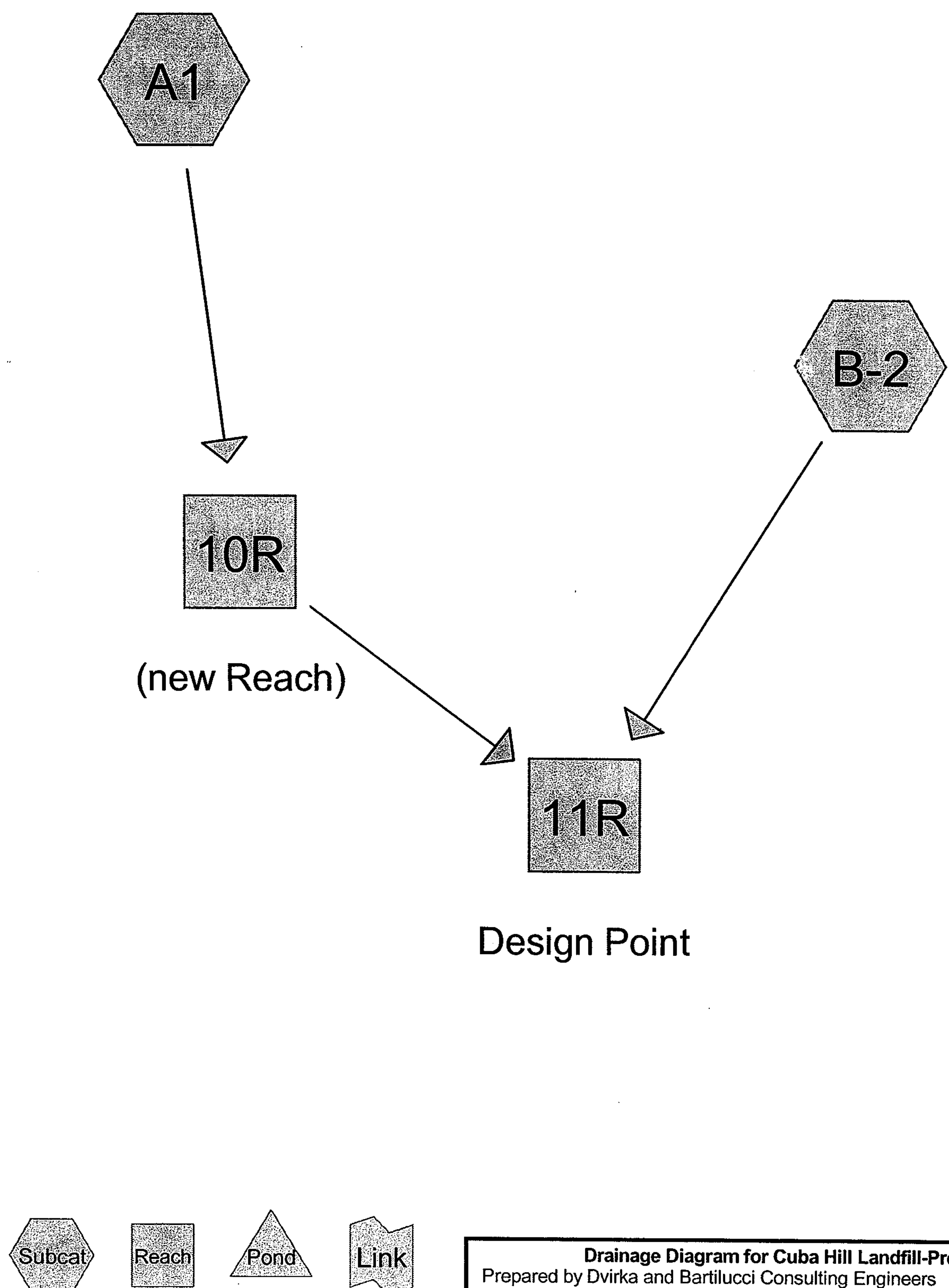
Submit Design Results

References

R. M. Koerner, and T-Y. Soong, 1998. "Analysis and Design of Veneer Cover Soils". Proceedings of 6th International Conference on Geosynthetics, Vol. 1, pp. 1-23, Atlanta, Georgia, USA.

APPENDIX C

HYDROCAD RESULTS



Drainage Diagram for Cuba Hill Landfill-Pre
Prepared by Dvirka and Bartilucci Consulting Engineers 12/7/2007
HydroCAD® 7.00 s/n 000636 © 1986-2003 Applied Microcomputer Systems

Time span=5.00-20.00 hrs, dt=0.05 hrs, 301 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment A1: Runoff Area=8.020 ac Runoff Depth=0.85"
Tc=29.4 min CN=61 Runoff=5.65 cfs 0.566 af

Subcatchment B-2: Runoff Area=132.750 ac Runoff Depth=0.69"
Flow Length=2,000' Tc=44.3 min CN=58 Runoff=53.07 cfs 7.627 af

Reach 10R: (new Reach) Peak Depth=0.58' Max Vel=2.9 fps Inflow=5.65 cfs 0.566 af
n=0.043 L=1,000.0' S=0.0240 '/' Capacity=341.21 cfs Outflow=5.30 cfs 0.559 af

Reach 11R: Design Point Peak Depth=0.99' Max Vel=8.2 fps Inflow=58.24 cfs 8.186 af
n=0.034 L=3,000.0' S=0.0530 '/' Capacity=904.21 cfs Outflow=56.43 cfs 8.067 af

Total Runoff Area = 140.770 ac Runoff Volume = 8.194 af Average Runoff Depth = 0.70"

Subcatchment A1:

Runoff = 5.65 cfs @ 12.28 hrs, Volume= 0.566 af, Depth= 0.85"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 25-Year Storm Rainfall=4.30"

Area (ac)	CN	Description
8.020	61	>75% Grass cover, Good, HSG B

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
29.4					**Direct Entry,**

Subcatchment B-2:

Runoff = 53.07 cfs @ 12.51 hrs, Volume= 7.627 af, Depth= 0.69"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 25-Year Storm Rainfall=4.30"

Area (ac)	CN	Description
132.750	58	Woods/grass comb., Good, HSG B

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
27.9	300	0.0300	0.2		**Sheet Flow,** Grass: Dense n= 0.240 P2= 3.50"
16.4	1,700	0.1200	1.7		**Shallow Concentrated Flow,** Woodland Kv= 5.0 fps
44.3	2,000	Total			

Reach 10R: (new Reach)

Inflow Area = 8.020 ac, Inflow Depth = 0.85" for 25-Year Storm event
Inflow = 5.65 cfs @ 12.28 hrs, Volume= 0.566 af
Outflow = 5.30 cfs @ 12.45 hrs, Volume= 0.559 af, Atten= 6%, Lag= 10.6 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.9 fps, Min. Travel Time= 5.7 min
Avg. Velocity = 1.5 fps, Avg. Travel Time= 11.3 min

Peak Depth= 0.58' @ 12.36 hrs
Capacity at bank full= 341.21 cfs
Inlet Invert= 2,120.00', Outlet Invert= 2,096.00'
2.00' x 4.00' deep channel, n= 0.043 Length= 1,000.0' Slope= 0.0240 '/'
Side Slope Z-value= 2.0 '/'

Reach 11R: Design Point

[61] Hint: Submerged 4% of Reach 10R bottom

Inflow Area = 140.770 ac, Inflow Depth = 0.70" for 25-Year Storm event
Inflow = 58.24 cfs @ 12.50 hrs, Volume= 8.186 af
Outflow = 56.43 cfs @ 12.69 hrs, Volume= 8.067 af, Atten= 3%, Lag= 11.2 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Max. Velocity= 8.2 fps, Min. Travel Time= 6.1 min
Avg. Velocity = 4.5 fps, Avg. Travel Time= 11.1 min

Peak Depth= 0.99' @ 12.58 hrs
Capacity at bank full= 904.21 cfs
Inlet Invert= 2,096.00', Outlet Invert= 1,937.00'
5.00' x 4.00' deep channel, n= 0.034 Length= 3,000.0' Slope= 0.0530 '/'
Side Slope Z-value= 2.0 '/'

Time span=5.00-20.00 hrs, dt=0.05 hrs, 301 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment A1: Runoff Area=8.020 ac Runoff Depth=1.38"
Tc=29.4 min CN=61 Runoff=9.92 cfs 0.921 af

Subcatchment B-2: Runoff Area=132.750 ac Runoff Depth=1.17"
Flow Length=2,000' Tc=44.3 min CN=58 Runoff=100.39 cfs 12.909 af

Reach 10R: (new Reach) Peak Depth=0.78' Max Vel=3.4 fps Inflow=9.92 cfs 0.921 af
n=0.043 L=1,000.0' S=0.0240 '/' Capacity=341.21 cfs Outflow=9.41 cfs 0.912 af

Reach 11R: Design Point Peak Depth=1.39' Max Vel=9.8 fps Inflow=109.51 cfs 13.821 af
n=0.034 L=3,000.0' S=0.0530 '/' Capacity=904.21 cfs Outflow=106.60 cfs 13.669 af

Total Runoff Area = 140.770 ac Runoff Volume = 13.830 af Average Runoff Depth = 1.18"

Subcatchment A1:

Runoff = 9.92 cfs @ 12.26 hrs, Volume= 0.921 af, Depth= 1.38"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 100 Year Storm Rainfall=5.30"

Area (ac)	CN	Description
8.020	61	>75% Grass cover, Good, HSG B

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
29.4					**Direct Entry,**

Subcatchment B-2:

Runoff = 100.39 cfs @ 12.47 hrs, Volume= 12.909 af, Depth= 1.17"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 100 Year Storm Rainfall=5.30"

Area (ac)	CN	Description
132.750	58	Woods/grass comb., Good, HSG B

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
27.9	300	0.0300	0.2		**Sheet Flow,** Grass: Dense n= 0.240 P2= 3.50"
16.4	1,700	0.1200	1.7		**Shallow Concentrated Flow,** Woodland Kv= 5.0 fps
44.3	2,000	Total			

Reach 10R: (new Reach)

Inflow Area = 8.020 ac, Inflow Depth = 1.38" for 100 Year Storm event
Inflow = 9.92 cfs @ 12.26 hrs, Volume= 0.921 af
Outflow = 9.41 cfs @ 12.41 hrs, Volume= 0.912 af, Atten= 5%, Lag= 9.0 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.4 fps, Min. Travel Time= 4.9 min
Avg. Velocity = 1.6 fps, Avg. Travel Time= 10.2 min

Peak Depth= 0.78' @ 12.33 hrs
Capacity at bank full= 341.21 cfs
Inlet Invert= 2,120.00', Outlet Invert= 2,096.00'
2.00' x 4.00' deep channel, n= 0.043 Length= 1,000.0' Slope= 0.0240 '/'
Side Slope Z-value= 2.0 '/'

Reach 11R: Design Point

[61] Hint: Submerged 6% of Reach 10R bottom

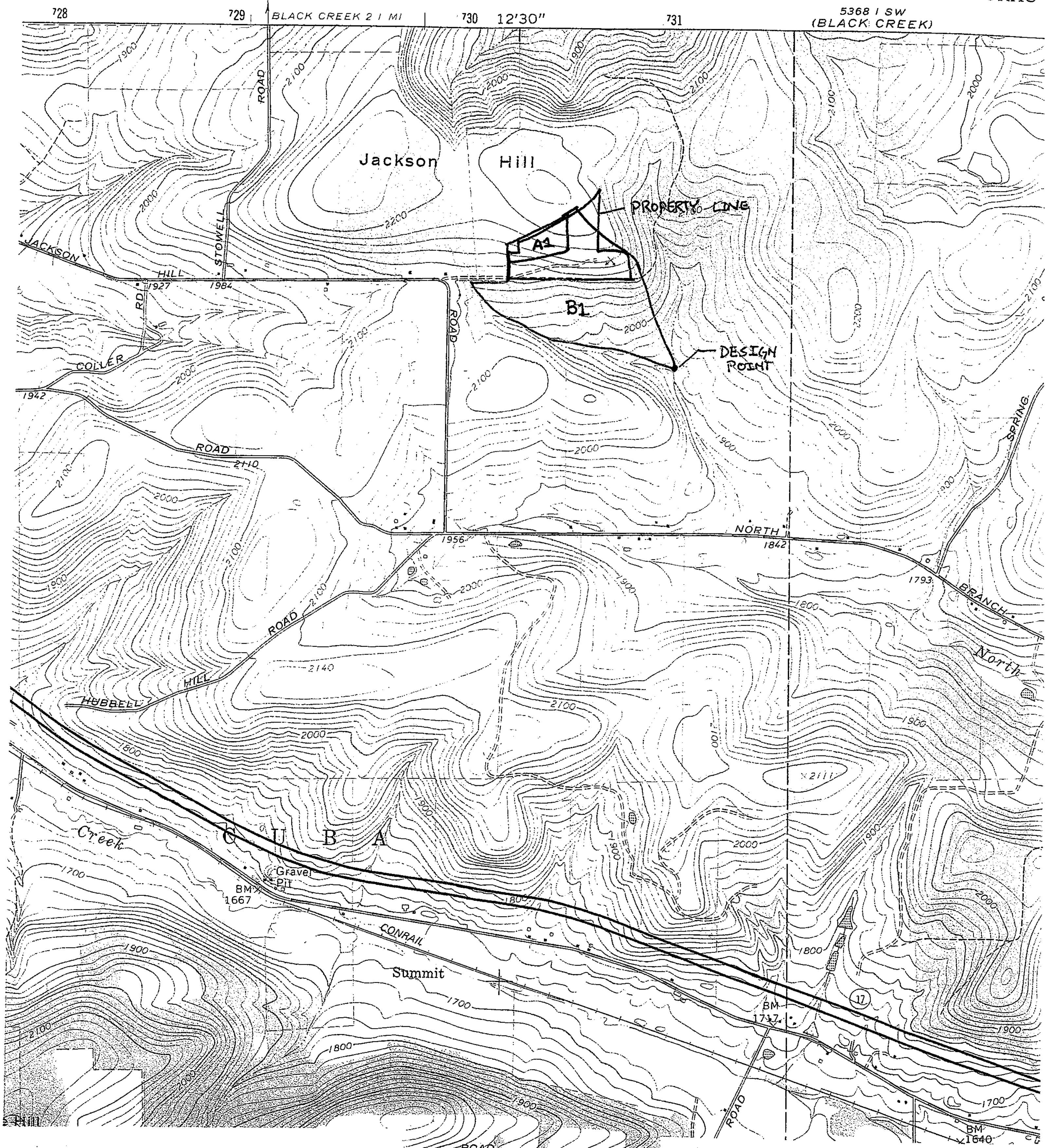
Inflow Area = 140.770 ac, Inflow Depth = 1.18" for 100 Year Storm event
Inflow = 109.51 cfs @ 12.46 hrs, Volume= 13.821 af
Outflow = 106.60 cfs @ 12.62 hrs, Volume= 13.669 af, Atten= 3%, Lag= 9.4 min

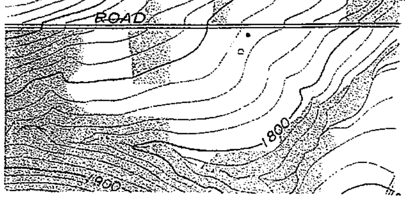
Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Max. Velocity= 9.8 fps, Min. Travel Time= 5.1 min
Avg. Velocity = 5.2 fps, Avg. Travel Time= 9.7 min

Peak Depth= 1.39' @ 12.54 hrs
Capacity at bank full= 904.21 cfs
Inlet Invert= 2,096.00', Outlet Invert= 1,937.00'
5.00' x 4.00' deep channel, n= 0.034 Length= 3,000.0' Slope= 0.0530 '/'
Side Slope Z-value= 2.0 '/'

TATES
THE INTERIOR
SURVEY

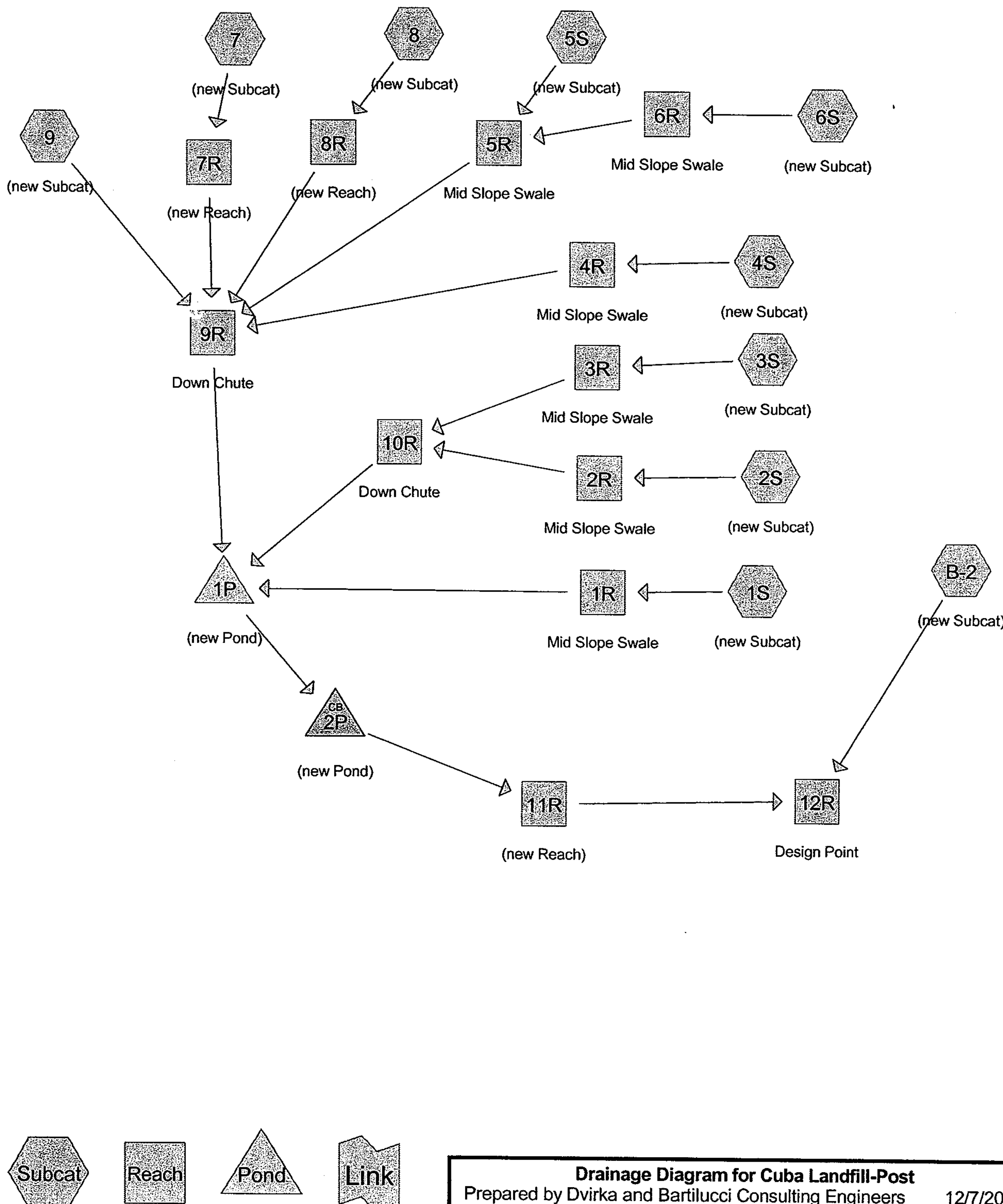
STATE OF NEW YORK
DEPARTMENT OF PUBLIC WORKS





CUBA LANDFILL
EXISTING CONDITIONS
1" = 2000

FRIENDSHIP QUADRANGLE
NEW YORK-ALLEGANY CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)



Drainage Diagram for Cuba Landfill-Post
Prepared by Dvirka and Bartilucci Consulting Engineers 12/7/2007
HydroCAD® 7.00 s/n 000636 © 1986-2003 Applied Microcomputer Systems

Time span=1.00-60.00 hrs, dt=0.01 hrs, 5901 points x 9
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment 1S: (new Subcat) Runoff Area=75,155 sf Runoff Depth=2.82"
Tc=15.0 min CN=86 Runoff=6.23 cfs 0.405 af

Subcatchment 2S: (new Subcat) Runoff Area=134,880 sf Runoff Depth=2.82"
Tc=15.0 min CN=86 Runoff=11.19 cfs 0.728 af

Subcatchment 3S: (new Subcat) Runoff Area=100,225 sf Runoff Depth=2.82"
Tc=15.0 min CN=86 Runoff=8.31 cfs 0.541 af

Subcatchment 4S: (new Subcat) Runoff Area=54,533 sf Runoff Depth=2.82"
Tc=15.0 min CN=86 Runoff=4.52 cfs 0.294 af

Subcatchment 5S: (new Subcat) Runoff Area=94,745 sf Runoff Depth=2.82"
Tc=15.0 min CN=86 Runoff=7.86 cfs 0.511 af

Subcatchment 6S: (new Subcat) Runoff Area=94,584 sf Runoff Depth=2.82"
Tc=15.0 min CN=86 Runoff=7.84 cfs 0.510 af

Subcatchment 7: (new Subcat) Runoff Area=29,537 sf Runoff Depth=2.82"
Tc=15.0 min CN=86 Runoff=2.45 cfs 0.159 af

Subcatchment 8: (new Subcat) Runoff Area=26,182 sf Runoff Depth=2.82"
Tc=15.0 min CN=86 Runoff=2.17 cfs 0.141 af

Subcatchment 9: (new Subcat) Runoff Area=107,820 sf Runoff Depth=2.82"
Tc=15.0 min CN=86 Runoff=8.94 cfs 0.582 af

Subcatchment B-2: (new Subcat) Runoff Area=124.300 ac Runoff Depth=0.81"
Flow Length=2,000' Tc=44.3 min CN=58 Runoff=49.75 cfs 8.346 af

Reach 1R: Mid Slope Swale Peak Depth=0.30' Max Vel=3.8 fps Inflow=6.23 cfs 0.405 af
n=0.035 L=550.0' S=0.0509 '/' Capacity=354.74 cfs Outflow=6.09 cfs 0.405 af

Reach 2R: Mid Slope Swale Peak Depth=0.38' Max Vel=5.2 fps Inflow=11.19 cfs 0.728 af
n=0.035 L=860.0' S=0.0698 '/' Capacity=415.28 cfs Outflow=10.84 cfs 0.728 af

Reach 3R: Mid Slope Swale Peak Depth=0.33' Max Vel=4.4 fps Inflow=8.31 cfs 0.541 af
n=0.035 L=850.0' S=0.0588 '/' Capacity=381.32 cfs Outflow=7.98 cfs 0.541 af

Reach 4R: Mid Slope Swale Peak Depth=0.26' Max Vel=3.2 fps Inflow=4.52 cfs 0.294 af
n=0.035 L=560.0' S=0.0411 '/' Capacity=318.63 cfs Outflow=4.38 cfs 0.294 af

Reach 5R: Mid Slope Swale Peak Depth=0.64' Max Vel=3.7 fps Inflow=15.34 cfs 1.021 af
n=0.035 L=600.0' S=0.0200 '/' Capacity=222.35 cfs Outflow=14.86 cfs 1.021 af

Reach 6R: Mid Slope Swale Peak Depth=0.51' Max Vel=2.5 fps Inflow=7.84 cfs 0.510 af
n=0.035 L=420.0' S=0.0119 '/' Capacity=171.55 cfs Outflow=7.59 cfs 0.510 af

Reach 7R: (new Reach) Peak Depth=0.16' Max Vel=3.0 fps Inflow=2.45 cfs 0.159 af
n=0.035 L=240.0' S=0.0625 '/' Capacity=393.06 cfs Outflow=2.43 cfs 0.159 af

Reach 8R: (new Reach) Peak Depth=0.17' Max Vel=2.5 fps Inflow=2.17 cfs 0.141 af
n=0.035 L=240.0' S=0.0417 '/' Capacity=320.93 cfs Outflow=2.15 cfs 0.141 af

Reach 9R: Down Chute Peak Depth=0.58' Max Vel=9.5 fps Inflow=32.36 cfs 2.198 af
n=0.035 L=410.0' S=0.1463 '/' Capacity=567.63 cfs Outflow=32.28 cfs 2.198 af

Reach 10R: Down Chute Peak Depth=0.38' Max Vel=9.5 fps Inflow=18.82 cfs 1.268 af
n=0.035 L=220.0' S=0.2273 '/' Capacity=634.01 cfs Outflow=18.81 cfs 1.268 af

Reach 11R: (new Reach) Peak Depth=0.76' Max Vel=1.7 fps Inflow=4.51 cfs 3.778 af
n=0.043 L=1,000.0' S=0.0060 '/' Capacity=170.60 cfs Outflow=4.44 cfs 3.775 af

Reach 12R: Design Point Peak Depth=0.93' Max Vel=7.8 fps Inflow=51.21 cfs 12.121 af
n=0.034 L=3,000.0' S=0.0510 '/' Capacity=886.99 cfs Outflow=49.78 cfs 12.117 af

Pond 1P: (new Pond) Peak Elev=2,108.26' Storage=99,437 cf Inflow=57.16 cfs 3.871 af
Outflow=4.51 cfs 3.778 af

Pond 2P: (new Pond) Peak Elev=2,097.10' Inflow=4.51 cfs 3.778 af
24.0" x 400.0' Culvert Outflow=4.51 cfs 3.778 af

Total Runoff Area = 140.775 ac Runoff Volume = 12.217 af Average Runoff Depth = 1.04"

Subcatchment 1S: (new Subcat)

Runoff = 6.23 cfs @ 12.07 hrs, Volume= 0.405 af, Depth= 2.82"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs
Type II 24-hr 25 Year Storm Rainfall=4.30"

Area (sf)	CN	Description
75,155	86	Landfill Cap

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry,**

Subcatchment 2S: (new Subcat)

Runoff = 11.19 cfs @ 12.07 hrs, Volume= 0.728 af, Depth= 2.82"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs
Type II 24-hr 25 Year Storm Rainfall=4.30"

Area (sf)	CN	Description
134,880	86	Landfill Cap

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry,**

Subcatchment 3S: (new Subcat)

Runoff = 8.31 cfs @ 12.07 hrs, Volume= 0.541 af, Depth= 2.82"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs
Type II 24-hr 25 Year Storm Rainfall=4.30"

Area (sf)	CN	Description
100,225	86	Landfill Cap

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry,**

Subcatchment 4S: (new Subcat)

Runoff = 4.52 cfs @ 12.07 hrs, Volume= 0.294 af, Depth= 2.82"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs
Type II 24-hr 25 Year Storm Rainfall=4.30"

Area (sf)	CN	Description
54,533	86	Landfill Cap

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry,**

Subcatchment 5S: (new Subcat)

Runoff = 7.86 cfs @ 12.07 hrs, Volume= 0.511 af, Depth= 2.82"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs
Type II 24-hr 25 Year Storm Rainfall=4.30"

Area (sf)	CN	Description
94,745	86	Landfill Cap

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry,**

Subcatchment 6S: (new Subcat)

Runoff = 7.84 cfs @ 12.07 hrs, Volume= 0.510 af, Depth= 2.82"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs
Type II 24-hr 25 Year Storm Rainfall=4.30"

Area (sf)	CN	Description
94,584	86	Landfill Cap

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry,**

Subcatchment 7: (new Subcat)

Runoff = 2.45 cfs @ 12.07 hrs, Volume= 0.159 af, Depth= 2.82"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs
Type II 24-hr 25 Year Storm Rainfall=4.30"

Area (sf)	CN	Description
29,537	86	Landfill Cap

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry,**

Subcatchment 8: (new Subcat)

Runoff = 2.17 cfs @ 12.07 hrs, Volume= 0.141 af, Depth= 2.82"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs
Type II 24-hr 25 Year Storm Rainfall=4.30"

Area (sf)	CN	Description
26,182	86	Landfill Cap

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry,**

Subcatchment 9: (new Subcat)

Runoff = 8.94 cfs @ 12.07 hrs, Volume= 0.582 af, Depth= 2.82"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs
Type II 24-hr 25 Year Storm Rainfall=4.30"

Area (sf)	CN	Description
107,820	86	Landfill Cap

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry,**

Subcatchment B-2: (new Subcat)

Runoff = 49.75 cfs @ 12.50 hrs, Volume= 8.346 af, Depth= 0.81"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs
Type II 24-hr 25 Year Storm Rainfall=4.30"

Area (ac)	CN	Description
117.000	58	Woods/grass comb., Good, HSG B
5.700	61	>75% Grass cover, Good, HSG B
1.600	86	Landfill Cap
124.300	58	Weighted Average

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
27.9	300	0.0300	0.2		**Sheet Flow,** Grass: Dense n= 0.240 P2= 3.50"
16.4	1,700	0.1200	1.7		**Shallow Concentrated Flow,** Woodland Kv= 5.0 fps
44.3	2,000	Total			

Reach 1R: Mid Slope Swale

Inflow Area = 1.725 ac, Inflow Depth = 2.82" for 25 Year Storm event
Inflow = 6.23 cfs @ 12.07 hrs, Volume= 0.405 af
Outflow = 6.09 cfs @ 12.09 hrs, Volume= 0.405 af, Atten= 2%, Lag= 1.5 min

Routing by Dyn-Stor-Ind method, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs / 9
Max. Velocity= 3.8 fps, Min. Travel Time= 2.4 min
Avg. Velocity = 1.0 fps, Avg. Travel Time= 8.8 min

Peak Depth= 0.30' @ 12.09 hrs
Capacity at bank full= 354.74 cfs
Inlet Invert= 2,138.00', Outlet Invert= 2,110.00'
4.50' x 2.50' deep channel, n= 0.035 Length= 550.0' Slope= 0.0509 '/'
Side Slope Z-value= 3.0 2.5 '/'

Reach 2R: Mid Slope Swale

Inflow Area = 3.096 ac, Inflow Depth = 2.82" for 25 Year Storm event
Inflow = 11.19 cfs @ 12.07 hrs, Volume= 0.728 af
Outflow = 10.84 cfs @ 12.10 hrs, Volume= 0.728 af, Atten= 3%, Lag= 1.7 min

Routing by Dyn-Stor-Ind method, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs / 9
Max. Velocity= 5.2 fps, Min. Travel Time= 2.8 min
Avg. Velocity = 1.4 fps, Avg. Travel Time= 10.5 min

Peak Depth= 0.38' @ 12.10 hrs
Capacity at bank full= 415.28 cfs
Inlet Invert= 2,170.00', Outlet Invert= 2,110.00'
4.50' x 2.50' deep channel, n= 0.035 Length= 860.0' Slope= 0.0698 '/'
Side Slope Z-value= 3.0 2.5 '/'

Reach 3R: Mid Slope Swale

Inflow Area = 2.301 ac, Inflow Depth = 2.82" for 25 Year Storm event
Inflow = 8.31 cfs @ 12.07 hrs, Volume= 0.541 af
Outflow = 7.98 cfs @ 12.10 hrs, Volume= 0.541 af, Atten= 4%, Lag= 2.0 min

Routing by Dyn-Stor-Ind method, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs / 9
Max. Velocity= 4.4 fps, Min. Travel Time= 3.2 min
Avg. Velocity = 1.2 fps, Avg. Travel Time= 12.0 min

Peak Depth= 0.33' @ 12.10 hrs
Capacity at bank full= 381.32 cfs
Inlet Invert= 2,185.00', Outlet Invert= 2,135.00'
4.50' x 2.50' deep channel, n= 0.035 Length= 850.0' Slope= 0.0588 '/'
Side Slope Z-value= 3.0 2.5 '/'

Reach 4R: Mid Slope Swale

Inflow Area = 1.252 ac, Inflow Depth = 2.82" for 25 Year Storm event
Inflow = 4.52 cfs @ 12.07 hrs, Volume= 0.294 af
Outflow = 4.38 cfs @ 12.10 hrs, Volume= 0.294 af, Atten= 3%, Lag= 1.8 min

Routing by Dyn-Stor-Ind method, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs / 9
Max. Velocity= 3.2 fps, Min. Travel Time= 2.9 min
Avg. Velocity = 0.9 fps, Avg. Travel Time= 10.5 min

Peak Depth= 0.26' @ 12.10 hrs
Capacity at bank full= 318.63 cfs
Inlet Invert= 2,193.00', Outlet Invert= 2,170.00'
4.50' x 2.50' deep channel, n= 0.035 Length= 560.0' Slope= 0.0411 '/'
Side Slope Z-value= 3.0 2.5 '/'

Reach 5R: Mid Slope Swale

Inflow Area = 4.346 ac, Inflow Depth = 2.82" for 25 Year Storm event
Inflow = 15.34 cfs @ 12.08 hrs, Volume= 1.021 af
Outflow = 14.86 cfs @ 12.11 hrs, Volume= 1.021 af, Atten= 3%, Lag= 1.8 min

Routing by Dyn-Stor-Ind method, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs / 9
Max. Velocity= 3.7 fps, Min. Travel Time= 2.7 min
Avg. Velocity = 1.0 fps, Avg. Travel Time= 10.3 min

Peak Depth= 0.64' @ 12.11 hrs
Capacity at bank full= 222.35 cfs
Inlet Invert= 2,192.00', Outlet Invert= 2,180.00'
4.50' x 2.50' deep channel, n= 0.035 Length= 600.0' Slope= 0.0200 '/'
Side Slope Z-value= 3.0 2.5 '/'

Reach 6R: Mid Slope Swale

Inflow Area = 2.171 ac, Inflow Depth = 2.82" for 25 Year Storm event
Inflow = 7.84 cfs @ 12.07 hrs, Volume= 0.510 af
Outflow = 7.59 cfs @ 12.10 hrs, Volume= 0.510 af, Atten= 3%, Lag= 1.8 min

Routing by Dyn-Stor-Ind method, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs / 9
Max. Velocity= 2.5 fps, Min. Travel Time= 2.8 min
Avg. Velocity = 0.7 fps, Avg. Travel Time= 10.6 min

Peak Depth= 0.51' @ 12.10 hrs
Capacity at bank full= 171.55 cfs
Inlet Invert= 2,200.00', Outlet Invert= 2,195.00'
4.50' x 2.50' deep channel, n= 0.035 Length= 420.0' Slope= 0.0119 '/'
Side Slope Z-value= 3.0 2.5 '/'

Reach 7R: (new Reach)

Inflow Area = 0.678 ac, Inflow Depth = 2.82" for 25 Year Storm event
Inflow = 2.45 cfs @ 12.07 hrs, Volume= 0.159 af
Outflow = 2.43 cfs @ 12.08 hrs, Volume= 0.159 af, Atten= 1%, Lag= 0.8 min

Routing by Dyn-Stor-Ind method, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs / 9
Max. Velocity= 3.0 fps, Min. Travel Time= 1.3 min
Avg. Velocity = 1.0 fps, Avg. Travel Time= 4.1 min

Peak Depth= 0.16' @ 12.08 hrs
Capacity at bank full= 393.06 cfs
Inlet Invert= 2,160.00', Outlet Invert= 2,145.00'
4.50' x 2.50' deep channel, n= 0.035 Length= 240.0' Slope= 0.0625 '/'
Side Slope Z-value= 3.0 2.5 '/'

Reach 8R: (new Reach)

Inflow Area = 0.601 ac, Inflow Depth = 2.82" for 25 Year Storm event
Inflow = 2.17 cfs @ 12.07 hrs, Volume= 0.141 af
Outflow = 2.15 cfs @ 12.09 hrs, Volume= 0.141 af, Atten= 1%, Lag= 1.0 min

Routing by Dyn-Stor-Ind method, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs / 9
Max. Velocity= 2.5 fps, Min. Travel Time= 1.6 min
Avg. Velocity = 0.8 fps, Avg. Travel Time= 5.0 min

Peak Depth= 0.17' @ 12.09 hrs
Capacity at bank full= 320.93 cfs
Inlet Invert= 2,130.00', Outlet Invert= 2,120.00'
4.50' x 2.50' deep channel, n= 0.035 Length= 240.0' Slope= 0.0417 '/'
Side Slope Z-value= 3.0 2.5 '/'

Reach 9R: Down Chute

[61] Hint: Submerged 3% of Reach 4R bottom
[63] Warning: Exceeded Reach 7R inflow depth by 10.41' @ 12.11 hrs
[63] Warning: Exceeded Reach 8R inflow depth by 40.41' @ 12.11 hrs

Inflow Area = 9.353 ac, Inflow Depth = 2.82" for 25 Year Storm event
Inflow = 32.36 cfs @ 12.09 hrs, Volume= 2.198 af
Outflow = 32.28 cfs @ 12.10 hrs, Volume= 2.198 af, Atten= 0%, Lag= 0.5 min

Routing by Dyn-Stor-Ind method, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs / 9
Max. Velocity= 9.5 fps, Min. Travel Time= 0.7 min
Avg. Velocity = 2.5 fps, Avg. Travel Time= 2.8 min

Peak Depth= 0.58' @ 12.10 hrs
Capacity at bank full= 567.63 cfs
Inlet Invert= 2,170.00', Outlet Invert= 2,110.00'
4.45' x 2.50' deep channel, n= 0.035 Length= 410.0' Slope= 0.1463 '/'
Side Slope Z-value= 2.5 '/'

Reach 10R: Down Chute

[61] Hint: Submerged 84% of Reach 2R bottom
[61] Hint: Submerged 51% of Reach 3R bottom

Inflow Area = 5.397 ac, Inflow Depth = 2.82" for 25 Year Storm event
Inflow = 18.82 cfs @ 12.10 hrs, Volume= 1.268 af
Outflow = 18.81 cfs @ 12.10 hrs, Volume= 1.268 af, Atten= 0%, Lag= 0.3 min

Routing by Dyn-Stor-Ind method, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs / 9
Max. Velocity= 9.5 fps, Min. Travel Time= 0.4 min
Avg. Velocity = 2.5 fps, Avg. Travel Time= 1.5 min

Peak Depth= 0.38' @ 12.10 hrs
Capacity at bank full= 634.01 cfs
Inlet Invert= 2,160.00', Outlet Invert= 2,110.00'
4.50' x 2.50' deep channel, n= 0.035 Length= 220.0' Slope= 0.2273 '/'
Side Slope Z-value= 2.0 '/'

Reach 11R: (new Reach)

Inflow Area = 16.475 ac, Inflow Depth = 2.75" for 25 Year Storm event
Inflow = 4.51 cfs @ 13.10 hrs, Volume= 3.778 af
Outflow = 4.44 cfs @ 13.26 hrs, Volume= 3.775 af, Atten= 2%, Lag= 9.5 min

Routing by Dyn-Stor-Ind method, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs / 9
Max. Velocity= 1.7 fps, Min. Travel Time= 10.0 min
Avg. Velocity = 0.9 fps, Avg. Travel Time= 18.3 min

Peak Depth= 0.76' @ 13.26 hrs
Capacity at bank full= 170.60 cfs
Inlet Invert= 2,096.00', Outlet Invert= 2,090.00'
2.00' x 4.00' deep channel, n= 0.043 Length= 1,000.0' Slope= 0.0060 '/'
Side Slope Z-value= 2.0 '/'

Reach 12R: Design Point

[61] Hint: Submerged 16% of Reach 11R bottom

Inflow Area = 140.775 ac, Inflow Depth = 1.03" for 25 Year Storm event
Inflow = 51.21 cfs @ 12.51 hrs, Volume= 12.121 af
Outflow = 49.78 cfs @ 12.60 hrs, Volume= 12.117 af, Atten= 3%, Lag= 5.6 min

Routing by Dyn-Stor-Ind method, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs / 9
Max. Velocity= 7.8 fps, Min. Travel Time= 6.4 min
Avg. Velocity = 2.2 fps, Avg. Travel Time= 22.4 min

Peak Depth= 0.93' @ 12.60 hrs
Capacity at bank full= 886.99 cfs
Inlet Invert= 2,090.00', Outlet Invert= 1,937.00'
5.00' x 4.00' deep channel, n= 0.034 Length= 3,000.0' Slope= 0.0510 '/'
Side Slope Z-value= 2.0 '/'

Pond 1P: (new Pond)

Inflow Area =	16.475 ac,	Inflow Depth = 2.82"	for 25 Year Storm event
Inflow =	57.16 cfs @	12.10 hrs, Volume=	3.871 af
Outflow =	4.51 cfs @	13.10 hrs, Volume=	3.778 af, Atten= 92%, Lag= 60.1 min
Primary =	4.51 cfs @	13.10 hrs, Volume=	3.778 af

Routing by Dyn-Stor-Ind method, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs / 9
Peak Elev= 2,108.26' @ 13.10 hrs Surf.Area= 35,021 sf Storage= 99,437 cf
Plug-Flow detention time= 675.3 min calculated for 3.777 af (98% of inflow)
Center-of-Mass det. time= 660.7 min (1,483.6 - 823.0)

#	Invert	Avail.Storage	Storage Description
1	2,105.00'	152,488 cf	**Custom Stage Data (Prismatic)** Listed below

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
2,105.00	15,626	0	0
2,110.00	45,369	152,488	152,488

#	Routing	Invert	Outlet Devices
1	Device 3	2,105.00'	**6.0" Vert. Orifice/Grate** C= 0.600
2	Device 3	2,108.00'	**4.0' long x 1.0' breadth Broad-Crested Rectangular Weir X 2.00** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 Coef. (English) 2.69 2.72 2.75 2.85 2.98 3.08 3.20 3.28 3.31 3.30 3.31 3.32
3	Primary	2,102.00'	**18.0" x 160.0' long Culvert** CPP, square edge headwall, Ke= 0.500 Outlet Invert= 2,096.00' S= 0.0375 '/' n= 0.012 Cc= 0.900

Primary OutFlow Max=4.51 cfs @ 13.10 hrs HW=2,108.26' TW=2,097.10' (Dynamic Tailwater)
└─**3=Culvert** (Passes 4.51 cfs of 19.97 cfs potential flow)
  ├─**1=Orifice/Grate** (Orifice Controls 1.64 cfs @ 8.4 fps)
  └─**2=Broad-Crested Rectangular Weir** (Weir Controls 2.87 cfs @ 1.4 fps)

Pond 2P: (new Pond)

[57] Hint: Peaked at 2,097.10' (Flood elevation advised)

Inflow Area =	16.475 ac,	Inflow Depth = 2.75"	for 25 Year Storm event
Inflow =	4.51 cfs @	13.10 hrs, Volume=	3.778 af
Outflow =	4.51 cfs @	13.10 hrs, Volume=	3.778 af, Atten= 0%, Lag= 0.0 min
Primary =	4.51 cfs @	13.10 hrs, Volume=	3.778 af

Routing by Dyn-Stor-Ind method, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs / 9

Peak Elev= 2,097.10' @ 13.17 hrs
Plug-Flow detention time= (not calculated: outflow precedes inflow)
Center-of-Mass det. time= (not calculated)

#	Routing	Invert	Outlet Devices
1	Primary	2,096.00'	**24.0" x 400.0' long Culvert X 2.00** CPP, square edge headwall, Ke= 0.500 Outlet Invert= 2,095.50' S= 0.0013 '/' n= 0.012 Cc= 0.900

Primary OutFlow Max=4.51 cfs @ 13.10 hrs HW=2,097.10' TW=2,096.75' (Dynamic Tailwater)
└─**1=Culvert** (Barrel Controls 4.51 cfs @ 1.9 fps)

Time span=1.00-60.00 hrs, dt=0.01 hrs, 5901 points x 9
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment 1S: (new Subcat) Runoff Area=75,155 sf Runoff Depth=3.75"
Tc=15.0 min CN=86 Runoff=8.20 cfs 0.539 af

Subcatchment 2S: (new Subcat) Runoff Area=134,880 sf Runoff Depth=3.75"
Tc=15.0 min CN=86 Runoff=14.71 cfs 0.967 af

Subcatchment 3S: (new Subcat) Runoff Area=100,225 sf Runoff Depth=3.75"
Tc=15.0 min CN=86 Runoff=10.93 cfs 0.719 af

Subcatchment 4S: (new Subcat) Runoff Area=54,533 sf Runoff Depth=3.75"
Tc=15.0 min CN=86 Runoff=5.95 cfs 0.391 af

Subcatchment 5S: (new Subcat) Runoff Area=94,745 sf Runoff Depth=3.75"
Tc=15.0 min CN=86 Runoff=10.34 cfs 0.679 af

Subcatchment 6S: (new Subcat) Runoff Area=94,584 sf Runoff Depth=3.75"
Tc=15.0 min CN=86 Runoff=10.32 cfs 0.678 af

Subcatchment 7: (new Subcat) Runoff Area=29,537 sf Runoff Depth=3.75"
Tc=15.0 min CN=86 Runoff=3.22 cfs 0.212 af

Subcatchment 8: (new Subcat) Runoff Area=26,182 sf Runoff Depth=3.75"
Tc=15.0 min CN=86 Runoff=2.86 cfs 0.188 af

Subcatchment 9: (new Subcat) Runoff Area=107,820 sf Runoff Depth=3.75"
Tc=15.0 min CN=86 Runoff=11.76 cfs 0.773 af

Subcatchment B-2: (new Subcat) Runoff Area=124.300 ac Runoff Depth=1.34"
Flow Length=2,000' Tc=44.3 min CN=58 Runoff=94.14 cfs 13.853 af

Reach 1R: Mid Slope Swale Peak Depth=0.35' Max Vel=4.2 fps Inflow=8.20 cfs 0.539 af
n=0.035 L=550.0' S=0.0509 '/' Capacity=354.74 cfs Outflow=8.04 cfs 0.539 af

Reach 2R: Mid Slope Swale Peak Depth=0.44' Max Vel=5.6 fps Inflow=14.71 cfs 0.967 af
n=0.035 L=860.0' S=0.0698 '/' Capacity=415.28 cfs Outflow=14.33 cfs 0.967 af

Reach 3R: Mid Slope Swale Peak Depth=0.39' Max Vel=4.8 fps Inflow=10.93 cfs 0.719 af
n=0.035 L=850.0' S=0.0588 '/' Capacity=381.32 cfs Outflow=10.56 cfs 0.719 af

Reach 4R: Mid Slope Swale Peak Depth=0.31' Max Vel=3.5 fps Inflow=5.95 cfs 0.391 af
n=0.035 L=560.0' S=0.0411 '/' Capacity=318.63 cfs Outflow=5.79 cfs 0.391 af

Reach 5R: Mid Slope Swale Peak Depth=0.75' Max Vel=4.0 fps Inflow=20.25 cfs 1.357 af
n=0.035 L=600.0' S=0.0200 '/' Capacity=222.35 cfs Outflow=19.70 cfs 1.357 af

Reach 6R: Mid Slope Swale Peak Depth=0.59' Max Vel=2.7 fps Inflow=10.32 cfs 0.678 af
n=0.035 L=420.0' S=0.0119 '/' Capacity=171.55 cfs Outflow=10.04 cfs 0.678 af

Reach 7R: (new Reach) Peak Depth=0.19' Max Vel=3.3 fps Inflow=3.22 cfs 0.212 af
n=0.035 L=240.0' S=0.0625 '/' Capacity=393.06 cfs Outflow=3.20 cfs 0.212 af

Reach 8R: (new Reach) Peak Depth=0.20' Max Vel=2.8 fps Inflow=2.86 cfs 0.188 af
n=0.035 L=240.0' S=0.0417 '/' Capacity=320.93 cfs Outflow=2.83 cfs 0.188 af

Reach 9R: Down Chute Peak Depth=0.67' Max Vel=10.4 fps Inflow=42.83 cfs 2.921 af
n=0.035 L=410.0' S=0.1463 '/' Capacity=567.63 cfs Outflow=42.74 cfs 2.921 af

Reach 10R: Down Chute Peak Depth=0.44' Max Vel=10.4 fps Inflow=24.89 cfs 1.686 af
n=0.035 L=220.0' S=0.2273 '/' Capacity=634.01 cfs Outflow=24.88 cfs 1.686 af

Reach 11R: (new Reach) Peak Depth=1.40' Max Vel=2.3 fps Inflow=16.86 cfs 5.047 af
n=0.043 L=1,000.0' S=0.0060 '/' Capacity=170.60 cfs Outflow=15.74 cfs 5.044 af

Reach 12R: Design Point Peak Depth=1.40' Max Vel=9.7 fps Inflow=108.57 cfs 18.897 af
n=0.034 L=3,000.0' S=0.0510 '/' Capacity=886.99 cfs Outflow=106.14 cfs 18.893 af

Pond 1P: (new Pond) Peak Elev=2,108.76' Storage=114,750 cf Inflow=75.64 cfs 5.146 af
Outflow=16.86 cfs 5.047 af

Pond 2P: (new Pond) Peak Elev=2,098.10' Inflow=16.86 cfs 5.047 af
24.0" x 400.0' Culvert Outflow=16.86 cfs 5.047 af

Total Runoff Area = 140.775 ac Runoff Volume = 18.999 af Average Runoff Depth = 1.62"

Subcatchment 1S: (new Subcat)

Runoff = 8.20 cfs @ 12.07 hrs, Volume= 0.539 af, Depth= 3.75"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs
Type II 24-hr 100- Year Storm Rainfall=5.30"

Area (sf)	CN	Description
75,155	86	Landfill Cap

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry,**

Subcatchment 2S: (new Subcat)

Runoff = 14.71 cfs @ 12.07 hrs, Volume= 0.967 af, Depth= 3.75"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs
Type II 24-hr 100- Year Storm Rainfall=5.30"

Area (sf)	CN	Description
134,880	86	Landfill Cap

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry,**

Subcatchment 3S: (new Subcat)

Runoff = 10.93 cfs @ 12.07 hrs, Volume= 0.719 af, Depth= 3.75"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs
Type II 24-hr 100- Year Storm Rainfall=5.30"

Area (sf)	CN	Description
100,225	86	Landfill Cap

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry,**

Subcatchment 4S: (new Subcat)

Runoff = 5.95 cfs @ 12.07 hrs, Volume= 0.391 af, Depth= 3.75"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs
Type II 24-hr 100- Year Storm Rainfall=5.30"

Area (sf)	CN	Description
54,533	86	Landfill Cap

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry,**

Subcatchment 5S: (new Subcat)

Runoff = 10.34 cfs @ 12.07 hrs, Volume= 0.679 af, Depth= 3.75"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs
Type II 24-hr 100- Year Storm Rainfall=5.30"

Area (sf)	CN	Description
94,745	86	Landfill Cap

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry,**

Subcatchment 6S: (new Subcat)

Runoff = 10.32 cfs @ 12.07 hrs, Volume= 0.678 af, Depth= 3.75"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs
Type II 24-hr 100- Year Storm Rainfall=5.30"

Area (sf)	CN	Description
94,584	86	Landfill Cap

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry,**

Subcatchment 7: (new Subcat)

Runoff = 3.22 cfs @ 12.07 hrs, Volume= 0.212 af, Depth= 3.75"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs
Type II 24-hr 100- Year Storm Rainfall=5.30"

Area (sf)	CN	Description
29,537	86	Landfill Cap

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry,**

Subcatchment 8: (new Subcat)

Runoff = 2.86 cfs @ 12.07 hrs, Volume= 0.188 af, Depth= 3.75"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs
Type II 24-hr 100- Year Storm Rainfall=5.30"

Area (sf)	CN	Description
26,182	86	Landfill Cap

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry,**

Subcatchment 9: (new Subcat)

Runoff = 11.76 cfs @ 12.07 hrs, Volume= 0.773 af, Depth= 3.75"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs
Type II 24-hr 100- Year Storm Rainfall=5.30"

Area (sf)	CN	Description
107,820	86	Landfill Cap

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry,**

Subcatchment B-2: (new Subcat)

Runoff = 94.14 cfs @ 12.46 hrs, Volume= 13.853 af, Depth= 1.34"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs
Type II 24-hr 100- Year Storm Rainfall=5.30"

Area (ac)	CN	Description
117.000	58	Woods/grass comb., Good, HSG B
5.700	61	>75% Grass cover, Good, HSG B
1.600	86	Landfill Cap
124.300	58	Weighted Average

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
27.9	300	0.0300	0.2		**Sheet Flow,** Grass: Dense n= 0.240 P2= 3.50"
16.4	1,700	0.1200	1.7		**Shallow Concentrated Flow,** Woodland Kv= 5.0 fps
44.3	2,000	Total			

Reach 1R: Mid Slope Swale

Inflow Area = 1.725 ac, Inflow Depth = 3.75" for 100- Year Storm event
Inflow = 8.20 cfs @ 12.07 hrs, Volume= 0.539 af
Outflow = 8.04 cfs @ 12.09 hrs, Volume= 0.539 af, Atten= 2%, Lag= 1.4 min

Routing by Dyn-Stor-Ind method, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs / 9
Max. Velocity= 4.2 fps, Min. Travel Time= 2.2 min
Avg. Velocity = 1.1 fps, Avg. Travel Time= 8.3 min

Peak Depth= 0.35' @ 12.09 hrs
Capacity at bank full= 354.74 cfs
Inlet Invert= 2,138.00', Outlet Invert= 2,110.00'
4.50' x 2.50' deep channel, n= 0.035 Length= 550.0' Slope= 0.0509 '/'
Side Slope Z-value= 3.0 2.5 '/'

Reach 2R: Mid Slope Swale

Inflow Area = 3.096 ac, Inflow Depth = 3.75" for 100- Year Storm event
Inflow = 14.71 cfs @ 12.07 hrs, Volume= 0.967 af
Outflow = 14.33 cfs @ 12.09 hrs, Volume= 0.967 af, Atten= 3%, Lag= 1.6 min

Routing by Dyn-Stor-Ind method, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs / 9
Max. Velocity= 5.6 fps, Min. Travel Time= 2.5 min
Avg. Velocity = 1.5 fps, Avg. Travel Time= 9.7 min

Peak Depth= 0.44' @ 12.09 hrs
Capacity at bank full= 415.28 cfs
Inlet Invert= 2,170.00', Outlet Invert= 2,110.00'
4.50' x 2.50' deep channel, n= 0.035 Length= 860.0' Slope= 0.0698 '/'
Side Slope Z-value= 3.0 2.5 '/'

Reach 3R: Mid Slope Swale

Inflow Area = 2.301 ac, Inflow Depth = 3.75" for 100- Year Storm event
Inflow = 10.93 cfs @ 12.07 hrs, Volume= 0.719 af
Outflow = 10.56 cfs @ 12.10 hrs, Volume= 0.719 af, Atten= 3%, Lag= 1.8 min

Routing by Dyn-Stor-Ind method, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs / 9
Max. Velocity= 4.8 fps, Min. Travel Time= 2.9 min
Avg. Velocity = 1.3 fps, Avg. Travel Time= 11.2 min

Peak Depth= 0.39' @ 12.10 hrs
Capacity at bank full= 381.32 cfs
Inlet Invert= 2,185.00', Outlet Invert= 2,135.00'
4.50' x 2.50' deep channel, n= 0.035 Length= 850.0' Slope= 0.0588 '/'
Side Slope Z-value= 3.0 2.5 '/'

Reach 4R: Mid Slope Swale

Inflow Area = 1.252 ac, Inflow Depth = 3.75" for 100- Year Storm event
Inflow = 5.95 cfs @ 12.07 hrs, Volume= 0.391 af
Outflow = 5.79 cfs @ 12.09 hrs, Volume= 0.391 af, Atten= 3%, Lag= 1.6 min

Routing by Dyn-Stor-Ind method, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs / 9
Max. Velocity= 3.5 fps, Min. Travel Time= 2.7 min
Avg. Velocity = 0.9 fps, Avg. Travel Time= 10.0 min

Peak Depth= 0.31' @ 12.09 hrs
Capacity at bank full= 318.63 cfs
Inlet Invert= 2,193.00', Outlet Invert= 2,170.00'
4.50' x 2.50' deep channel, n= 0.035 Length= 560.0' Slope= 0.0411 '/'
Side Slope Z-value= 3.0 2.5 '/'

Reach 5R: Mid Slope Swale

Inflow Area = 4.346 ac, Inflow Depth = 3.75" for 100- Year Storm event
Inflow = 20.25 cfs @ 12.08 hrs, Volume= 1.357 af
Outflow = 19.70 cfs @ 12.11 hrs, Volume= 1.357 af, Atten= 3%, Lag= 1.7 min

Routing by Dyn-Stor-Ind method, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs / 9
Max. Velocity= 4.0 fps, Min. Travel Time= 2.5 min
Avg. Velocity = 1.0 fps, Avg. Travel Time= 9.6 min

Peak Depth= 0.75' @ 12.11 hrs
Capacity at bank full= 222.35 cfs
Inlet Invert= 2,192.00', Outlet Invert= 2,180.00'
4.50' x 2.50' deep channel, n= 0.035 Length= 600.0' Slope= 0.0200 '/'
Side Slope Z-value= 3.0 2.5 '/'

Reach 6R: Mid Slope Swale

Inflow Area = 2.171 ac, Inflow Depth = 3.75" for 100- Year Storm event
Inflow = 10.32 cfs @ 12.07 hrs, Volume= 0.678 af
Outflow = 10.04 cfs @ 12.09 hrs, Volume= 0.678 af, Atten= 3%, Lag= 1.6 min

Routing by Dyn-Stor-Ind method, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs / 9
Max. Velocity= 2.7 fps, Min. Travel Time= 2.5 min
Avg. Velocity = 0.7 fps, Avg. Travel Time= 9.8 min

Peak Depth= 0.59' @ 12.09 hrs
Capacity at bank full= 171.55 cfs
Inlet Invert= 2,200.00', Outlet Invert= 2,195.00'
4.50' x 2.50' deep channel, n= 0.035 Length= 420.0' Slope= 0.0119 '/'
Side Slope Z-value= 3.0 2.5 '/'

Reach 7R: (new Reach)

Inflow Area = 0.678 ac, Inflow Depth = 3.75" for 100- Year Storm event
Inflow = 3.22 cfs @ 12.07 hrs, Volume= 0.212 af
Outflow = 3.20 cfs @ 12.08 hrs, Volume= 0.212 af, Atten= 1%, Lag= 0.8 min

Routing by Dyn-Stor-Ind method, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs / 9
Max. Velocity= 3.3 fps, Min. Travel Time= 1.2 min
Avg. Velocity = 1.0 fps, Avg. Travel Time= 4.0 min

Peak Depth= 0.19' @ 12.08 hrs
Capacity at bank full= 393.06 cfs
Inlet Invert= 2,160.00', Outlet Invert= 2,145.00'
4.50' x 2.50' deep channel, n= 0.035 Length= 240.0' Slope= 0.0625 '/'
Side Slope Z-value= 3.0 2.5 '/'

Reach 8R: (new Reach)

Inflow Area = 0.601 ac, Inflow Depth = 3.75" for 100- Year Storm event
Inflow = 2.86 cfs @ 12.07 hrs, Volume= 0.188 af
Outflow = 2.83 cfs @ 12.08 hrs, Volume= 0.188 af, Atten= 1%, Lag= 0.9 min

Routing by Dyn-Stor-Ind method, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs / 9
Max. Velocity= 2.8 fps, Min. Travel Time= 1.4 min
Avg. Velocity = 0.8 fps, Avg. Travel Time= 4.8 min

Peak Depth= 0.20' @ 12.08 hrs
Capacity at bank full= 320.93 cfs
Inlet Invert= 2,130.00', Outlet Invert= 2,120.00'
4.50' x 2.50' deep channel, n= 0.035 Length= 240.0' Slope= 0.0417 '/'
Side Slope Z-value= 3.0 2.5 '/'

Reach 9R: Down Chute

[61] Hint: Submerged 3% of Reach 4R bottom
[63] Warning: Exceeded Reach 7R inflow depth by 10.48' @ 12.11 hrs
[63] Warning: Exceeded Reach 8R inflow depth by 40.47' @ 12.11 hrs

Inflow Area = 9.353 ac, Inflow Depth = 3.75" for 100- Year Storm event
Inflow = 42.83 cfs @ 12.09 hrs, Volume= 2.921 af
Outflow = 42.74 cfs @ 12.10 hrs, Volume= 2.921 af, Atten= 0%, Lag= 0.5 min

Routing by Dyn-Stor-Ind method, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs / 9
Max. Velocity= 10.4 fps, Min. Travel Time= 0.7 min
Avg. Velocity = 2.7 fps, Avg. Travel Time= 2.6 min

Peak Depth= 0.67' @ 12.10 hrs
Capacity at bank full= 567.63 cfs
Inlet Invert= 2,170.00', Outlet Invert= 2,110.00'
4.45' x 2.50' deep channel, n= 0.035 Length= 410.0' Slope= 0.1463 '/'
Side Slope Z-value= 2.5 '/'

Reach 10R: Down Chute

[61] Hint: Submerged 84% of Reach 2R bottom
[61] Hint: Submerged 51% of Reach 3R bottom

Inflow Area = 5.397 ac, Inflow Depth = 3.75" for 100- Year Storm event
Inflow = 24.89 cfs @ 12.10 hrs, Volume= 1.686 af
Outflow = 24.88 cfs @ 12.10 hrs, Volume= 1.686 af, Atten= 0%, Lag= 0.2 min

Routing by Dyn-Stor-Ind method, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs / 9
Max. Velocity= 10.4 fps, Min. Travel Time= 0.4 min
Avg. Velocity = 2.6 fps, Avg. Travel Time= 1.4 min

Peak Depth= 0.44' @ 12.10 hrs
Capacity at bank full= 634.01 cfs
Inlet Invert= 2,160.00', Outlet Invert= 2,110.00'
4.50' x 2.50' deep channel, n= 0.035 Length= 220.0' Slope= 0.2273 '/'
Side Slope Z-value= 2.0 '/'

Reach 11R: (new Reach)

Inflow Area = 16.475 ac, Inflow Depth = 3.68" for 100- Year Storm event
Inflow = 16.86 cfs @ 12.46 hrs, Volume= 5.047 af
Outflow = 15.74 cfs @ 12.59 hrs, Volume= 5.044 af, Atten= 7%, Lag= 7.6 min

Routing by Dyn-Stor-Ind method, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs / 9
Max. Velocity= 2.3 fps, Min. Travel Time= 7.1 min
Avg. Velocity = 1.0 fps, Avg. Travel Time= 17.5 min

Peak Depth= 1.40' @ 12.59 hrs
Capacity at bank full= 170.60 cfs
Inlet Invert= 2,096.00', Outlet Invert= 2,090.00'
2.00' x 4.00' deep channel, n= 0.043 Length= 1,000.0' Slope= 0.0060 '/'
Side Slope Z-value= 2.0 '/'

Reach 12R: Design Point

[61] Hint: Submerged 23% of Reach 11R bottom

Inflow Area = 140.775 ac, Inflow Depth = 1.61" for 100- Year Storm event
Inflow = 108.57 cfs @ 12.50 hrs, Volume= 18.897 af
Outflow = 106.14 cfs @ 12.57 hrs, Volume= 18.893 af, Atten= 2%, Lag= 4.1 min

Routing by Dyn-Stor-Ind method, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs / 9
Max. Velocity= 9.7 fps, Min. Travel Time= 5.2 min
Avg. Velocity = 2.4 fps, Avg. Travel Time= 20.9 min

Peak Depth= 1.40' @ 12.57 hrs
Capacity at bank full= 886.99 cfs
Inlet Invert= 2,090.00', Outlet Invert= 1,937.00'
5.00' x 4.00' deep channel, n= 0.034 Length= 3,000.0' Slope= 0.0510 '/'
Side Slope Z-value= 2.0 '/'

Pond 1P: (new Pond)

Inflow Area =	16.475 ac, Inflow Depth = 3.75"	for 100- Year Storm event	
Inflow =	75.64 cfs @ 12.10 hrs, Volume=	5.146 af	
Outflow =	16.86 cfs @ 12.46 hrs, Volume=	5.047 af,	Atten= 78%, Lag= 21.9 min
Primary =	16.86 cfs @ 12.46 hrs, Volume=	5.047 af	

Routing by Dyn-Stor-Ind method, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs / 9
Peak Elev= 2,108.76' @ 12.46 hrs Surf.Area= 38,008 sf Storage= 114,750 cf
Plug-Flow detention time= 545.0 min calculated for 5.046 af (98% of inflow)
Center-of-Mass det. time= 533.3 min (1,347.5 - 814.3)

#	Invert	Avail.Storage	Storage Description
1	2,105.00'	152,488 cf	**Custom Stage Data (Prismatic)** Listed below

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
2,105.00	15,626	0	0
2,110.00	45,369	152,488	152,488

#	Routing	Invert	Outlet Devices
1	Device 3	2,105.00'	**6.0" Vert. Orifice/Grate** C= 0.600
2	Device 3	2,108.00'	**4.0' long x 1.0' breadth Broad-Crested Rectangular Weir X 2.00** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 Coef. (English) 2.69 2.72 2.75 2.85 2.98 3.08 3.20 3.28 3.31 3.30 3.31 3.32
3	Primary	2,102.00'	**18.0" x 160.0' long Culvert** CPP, square edge headwall, Ke= 0.500 Outlet Invert= 2,096.00' S= 0.0375 '/' n= 0.012 Cc= 0.900

Primary OutFlow Max=16.85 cfs @ 12.46 hrs HW=2,108.76' TW=2,098.08' (Dynamic Tailwater)
└─**3=Culvert** (Passes 16.85 cfs of 20.86 cfs potential flow)
  ├─**1=Orifice/Grate** (Orifice Controls 1.77 cfs @ 9.0 fps)
  └─**2=Broad-Crested Rectangular Weir** (Weir Controls 15.08 cfs @ 2.5 fps)

Pond 2P: (new Pond)

[57] Hint: Peaked at 2,098.10' (Flood elevation advised)

Inflow Area =	16.475 ac, Inflow Depth = 3.68"	for 100- Year Storm event	
Inflow =	16.86 cfs @ 12.46 hrs, Volume=	5.047 af	
Outflow =	16.86 cfs @ 12.46 hrs, Volume=	5.047 af,	Atten= 0%, Lag= 0.0 min
Primary =	16.86 cfs @ 12.46 hrs, Volume=	5.047 af	

Routing by Dyn-Stor-Ind method, Time Span= 1.00-60.00 hrs, dt= 0.01 hrs / 9

Peak Elev= 2,098.10' @ 12.51 hrs
Plug-Flow detention time= (not calculated: outflow precedes inflow)
Center-of-Mass det. time= (not calculated)

#	Routing	Invert	Outlet Devices
1	Primary	2,096.00'	**24.0" x 400.0' long Culvert X 2.00** CPP, square edge headwall, Ke= 0.500 Outlet Invert= 2,095.50' S= 0.0013 '/' n= 0.012 Cc= 0.900

Primary OutFlow Max=16.85 cfs @ 12.46 hrs HW=2,098.08' TW=2,097.33' (Dynamic Tailwater)
↑—**1=Culvert** (Barrel Controls 16.85 cfs @ 3.2 fps)

NO.	DATE	REVISION	INT.

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PROJECT ENGINEER: MW	DRAWN BY: JEZ
DESIGNED BY: EJR	CHECKED BY: NJB

Dvirka and Bartilucci
CONSULTING ENGINEERS
A DIVISION OF WILLIAM F. COSULICH ASSOCIATES, P.C.

CUBA LANDFILL SITE
VILLAGE OF CUBA, NEW YORK

ALLEGANY COUNTY NEW YORK

NEW YORK STATE
DEPARTMENT OF ENVIRONMENTAL CONSERVATION

POST RUNOFF CONDITIONS

PROJECT NO.	2600
DATE:	DECEMBER 2007
SCALE:	1"=60'
DRAWING NO.	1