Facility and Engineering Plan

Johnston County C&D Landfill - Area 2
Smithfield, North Carolina

Prepared for:

Johnston County Department of Solid Waste Services
Smithfield, North Carolina

December 2013

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1.0 INTRODUCTION

The Johnston County Landfill facility is located on County Home Road off NC Highway 210 near Smithfield, North Carolina and is owned and operated by Johnston County (County) under NC Solid Waste Permit 51-03. The landfill facility includes an active 29.4 acre Subtitle D municipal solid waste (MSW) landfill (Phase 4A - Cells 1 - 3) and an active construction and demolition debris (C&D) landfill (Area 2 - Cell 1). The facility includes a scale and scale house facility, an office building, a maintenance building, a citizen's convenience center, and a yard waste processing area. The facility also has one (1) inactive MSW landfill unit (Phase 5 (lined)), three (3) closed MSW landfill units (Phases 1 and 2, Phase 3, and Phase 4 (each is unlined)), and one (1) closed C&D landfill unit (Area 1 (vertical expansion of Phase 4 MSW landfill unit)) which are maintained by the County.

Based on current projections, the active MSW landfill unit (Phase 4A - Cells 1 - 3) is expected to remain in operation until at least 2020. Likewise, the active C&D landfill unit (Area 2 - Cell 1) is expected to remain in operation until at least early 2015. As these units approach their capacity, the County will need to develop the subsequent disposal units. For the C&D landfill, it is the intent of Johnston County to proceed with the construction of Cell 2 in mid to late 2014 or early 2015.

The purpose of this Facility and Engineering Plan is to present the plans for the development of the landfill facility and the detailed design of the Area 2 C&D landfill unit. The design information for Area 2 updates the information contained in the following previously approved document:

> Facility and Engineering Plan
> Johnston County C&D Landfill - Area 2
> Prepared by G.N. Richardson & Associates, Inc.
> As Revised Through May 2006.

Additionally, the Facility Report (**Section 2**) has been updated from the version previously approved in 2009 which was contained in the following approved document:

> Facility and Engineering Plan
> Johnston County MSW Landfill - Phase 4A - Cell 3
> Prepared by Richardson Smith Gardner & Associates, Inc.
> As Revised Through December 2008.

This section gives a brief overview of this report and a description of the site. **Section 2** gives a description of the development of the Johnston County Landfill facility including the planned future MSW and C&D landfill units. **Sections 3 through 5** of this report focus on the detailed design of geosynthetics, the leachate management system, and the final cover system of the Area 2 C&D unit, respectively.

1.1 Site Description

Existing and proposed landfill units are located within the previously approved facility boundary, which consisted of approximately 500 acres. An expansion of the facility boundary is proposed as part of this application to include additional County-owned property. The expanded facility boundary consists of approximately 529 acres. The landfill facility is generally bounded to the north and west by Middle Creek and on the east and west by unnamed tributaries of Middle Creek. Adjacent properties include property owned by the County (including the site's active borrow area (Borrow Area E) located to the east of the facility boundary and a borrow area owned by the NC Department of Transportation (NC DOT) located to the southeast of the facility boundary. The topographic relief of the site is approximately 160 feet, ranging from elevation 120 feet along Middle Creek to elevation 280 feet on top of the closed Area 1 C&D landfill unit. Existing conditions are shown on **Figure 1** of **Attachment A** of this Permit Application. Access to the facility is from County Home Road.

The Area 2 C&D landfill unit will occupy approximately 15.8 acres (lined) including existing Cell 1 (11.9 acres) and yet to be constructed Cell 2 (3.9 acres). As described in **Section 2.0** (Facility Report), Area 2 (including the yet to be constructed Cell 2) is anticipated to have approximately 6.6 to 13.2 years of remaining capacity (from June 14, 2013) assuming annual disposal rates of 40,000 and 20,000 tons, respectively.

Additionally, Area 2 has been designed to meet current DWM setback and horizontal buffer requirements: 300 feet from property lines, 500 feet from residences or active water wells.

1.2 Site Development History

MSW Landfill Units

The Johnston County Landfill facility has three (3) existing unlined municipal solid waste (MSW) landfill units (Phases 1 & 2, 3, and 4). Operations in Phase 1 were initiated in 1973. The subsequent Phase 2 expansion was permitted in September 1974. Operations in subsequent Phases 3 and 4 began in approximately 1979 and 1984, respectively. NC Solid Waste Permit 51-01 was issued for the site in March 1984. The County ceased disposal in Phases 1 & 2 as well as a majority of Phase 4 prior to October 9, 1993 and these units were covered with 2 feet of soil cover in accordance with the then current regulations. The Phase 3 landfill unit and southern portion of the Phase 4 landfill unit were operated until the end of 1997.

Closure of Phases 3 and 4 as well as an enhancement of the closure of the top portion of Phases 1 & 2 was completed in 1999. The Phase 3 closure included a 24-inch thick soil cover over side slopes and a geosynthetic clay liner (GCL) and drainage composite overlain by 18-inches of soil cover on the top ridge of the unit. The south end of Phase 4

and the top of Phases 1 and 2 were closed with a 12-mil scrim reinforced geomembrane overlain by 18-inches of soil cover.

Phase 5 was the initial lined Subtitle D landfill unit developed at the site and was permitted under NC Permit 51-02. Construction of Phase 5 was completed in 1997 and operations began in October 1997. The liner system for Phase 5 includes the following components (listed top-down):

- a leachate collection system (LCS);
- a 60 mil HDPE geomembrane liner (textured on side slopes; smooth on base slopes); and
- a 24-inch thick soil liner ($k \leq 1 \times 10^{-7}$ cm/sec).

The currently active Phase 4A landfill unit was permitted in 2001 and is a double lined piggyback landfill unit between the Phase 3 and Phase 4 landfill units. At the time of permitting the Phase 4A landfill unit, the previous site solid waste permits (51-01 and 51-02) were combined as one permit (51-03). Construction of Cell 1 was completed in late 2002 and operations began in early 2003. Cells 2 and 3 were constructed in 2004 and 2008, respectively. The liner system for Phase 4A includes the following components (listed top-down):

- a leachate collection system (LCS);
- a 60-mil textured HDPE geomembrane liner;
- a geosynthetic clay liner (GCL);
- a leak detection system (LDS) (drainage geocomposite); and
- a 40-mil thick textured LLDPE geomembrane liner.

Additionally, on the base slopes of Cell 1, the above listed components were placed over a 12-inch thick soil liner ($k \leq 1 \times 10^{-7}$ cm/sec).

Construction and Demolition Debris (C&D) Landfill Units

The Johnston County Landfill facility has two (2) existing construction and demolition debris (C&D) landfill units (Areas 1 and 2). Prior to 1999, construction and demolition debris (C&D) waste was co-disposed with MSW. The unlined Area 1 landfill unit was permitted in 1999 and is a vertical expansion over the closed Phase 4 MSW landfill unit. Modifications of Area 1 were permitted in 2002 and 2006 which expanded the original footprint. Closure of the Area 1 C&D landfill unit was completed in 2011 and the final cover consists of the following components (listed top-down):

- a 24-inch thick vegetative soil layer;
- a drainage geocomposite;
- a 30-mil textured LLDPE geomembrane; and
- intermediate (soil) cover.

The lined Area 2 landfill unit was permitted in 2006 and the construction of Cell 1 was completed in 2007. Cell 1 is currently active. The liner system for Area 1 - Cell 1 includes the following components (listed top-down):

- a leachate collection system (LCS);
- a 40-mil textured LLDPE geomembrane liner; and
- a 12-inch thick soil liner ($k \leq 1 \times 10^{-5}$ cm/sec).

2.0 FACILITY REPORT

This section presents an updated plan for the development of the Johnston County Landfill facility. This report has been prepared in accordance with the requirements of Rule .0537 of the North Carolina Solid Waste Management Rules. Whereas some information is provided for MSW landfill units, emphasis is on the Area 2 C&D landfill unit.

2.1 Facility Services and Waste Stream

2.1.1 Facility Services

Currently, the following activities or services are provided at the Johnston County Landfill facility as shown on **Figure 1** of **Attachment A**):

- Scales and scale house
- Administrative offices
- Maintenance building
- Subtitle D MSW landfill
- C&D landfill
- White goods, scrap metal, and tire handling area
- Convenience center
- Yard waste processing area.

2.1.2 Types of Waste

The Johnston County Landfill facility accepts municipal solid waste (MSW) originating from residential, commercial, and industrial sources, construction and demolition debris (C&D) waste, and other wastes (i.e. white goods, tires, and yard waste). These wastes are segregated and directed to on-site facilities for disposal or processing/handling area as described below. Refer to the Operations Manual (**Attachment D**) for more information on wastes and materials accepted at the facility for processing and/or disposal.

2.1.3 Disposal Rates and Estimated Variances

Based on the FY 2012-2013 Solid Waste Management Annual Report information provided by the County, 92,085 tons of MSW and 20,142 tons of C&D waste were disposed of from 7/1/12 to 6/30/13 (average 7,674 tons per month and 307 tons per day of MSW and 1,679 tons per month and 67 tons per day of C&D waste based on 300 operating days per year). These are very similar figures from FY 2011-2012. However, disposal tonnages have been down in recent years due to the economy and changes in market conditions. As documented during the prior local government approval process, the County has set the following maximum disposal rates for the facility of which a maximum of 156,000 tons/year will be from outside the County:

2013-2015	350,000 tons/year
2016-2025	401,000 tons/year
2026-2035	452,000 tons/year
2036-2045	505,000 tons/year
2046-2055	568,000 tons/year.

For purposes of current facility life expectancy calculations, ranges of annual disposal rates were assumed as follows:

MSWLF:

Phase 4A & 6:	90,000 tons/year (Low); 120,000 tons/year (High)
Phases 7-10:	110,000 tons/year (Low): 160,000 tons/year (High)*

C&DLF:

Area 2:	20,000 tons/year (Low); 40,000 tons/year (High)

*The disposal rates for Phases 7-10 assume co-disposal of C&D waste.

2.1.4 Service Area

The landfill facility currently serves the State of North Carolina.

2.1.5 Procedures for Waste Segregation

A brief description of procedures for waste segregation at the landfill is as follows.

Wastes are segregated at the scale house. Operators at the scale house are trained to classify and segregate the waste stream. MSW and C&D wastes will directed to the active MSW or C&D landfill unit. Yard wastes will be directed toward the yard waste processing area. Tires and white goods will be directed to the appropriate processing/handling area where they will be temporarily stockpiled for collection by recycling contractors. Small loads and recyclables will be directed toward the citizen's convenience center.

Employees at the landfill are trained in the safety procedures for the handling and detection of illegal waste. The screening of unacceptable waste will be done through the random checking of incoming loads by a County employee at the scale house and at the tipping area. When unacceptable waste is detected at the scale house, the load will be rejected and not permitted into the facility. If hazardous waste is found at the tipping area, identification of the truck or persons will be made (if possible) and documented, then the hazardous waste will be identified and placed in a hazardous waste container by appropriately

trained personnel and taken to a designated hazardous waste staging area for proper disposal. If this occurs, the event will be reported to the appropriate authorities.

Refer also to the facility Operations Manual (**Attachment D**) for more information.

2.1.6 Equipment Requirements

The County will maintain on-site equipment required to perform the necessary landfill activities. Periodic maintenance of all landfilling equipment, and minor and major repair work will be performed at designated maintenance zones.

2.2 Landfill Capacity

2.2.1 Total Operating Capacity and Life Expectancy

Drawing S2 (Site Development Plan - Base Grades) and **Drawing S3** (Site Development Plan - Final Cover Grades), show conceptual subgrade and final cover grades, respectively, for the development of MSW Phases 4A and 6 through 10 and C&D Area 2. The final cover side slopes will be at a 4H to 1V slope, then transition at flatter slopes (5 to 8%) to the peak elevations.

The estimated gross and net operating capacities, life expectancies, and areas of existing and planned MSW and C&D landfill units are shown in **Table 2.1**. Note that the approximate total capacities and waste footprint areas for closed MSW and C&D landfill units are also shown in **Table 2.1**. The net capacity for waste and corresponding life expectancy of each landfill unit accounts for daily and intermediate cover and/or final cover. Life expectancies were calculated based on the disposal rates listed in **Section 2.1.3**.

2.2.2 In-Place Ratio of Waste to Soil and Compaction Factor

2.2.2.1 MSW Landfill Units

The capacities obtained above were based on a 15 percent periodic cover ratio and a compaction factor ranging from 1,200 to 1,400 pounds per cubic yard (pcy). The assumed periodic cover ratio is indicative of the County's current practices of using a tarp as an alternative to placing 6 inches of daily cover soil. The assumed compaction factor of 1,200 pcy is conservative for areas with lesser waste thicknesses (i.e. Phases 6, 7, and 8). The assumed compaction factor of 1,400 pcy is based on a recent analysis of waste density in Phase 4A and is assumed for areas with the greatest waste thicknesses (i.e. Phase 4A - Cell 3, Phase 9, and Phase 10).

2.2.2.2 C&D Landfill Unit

The capacities obtained above were based on a 10 percent periodic cover ratio and a compaction factor of 1,000 pounds per cubic yard (pcy). The assumed periodic cover ratio is indicative of the County's current practices. The assumed compaction factor of 1,000 pcy is based on a recent analysis of waste density in Area 2 and is conservative as waste thicknesses increase.

Note that changes in landfill operations (i.e. changes in the use of alternative daily cover and/or compaction equipment/methods) may affect the values assumed above and, thus, alter the life of the various landfill units.

2.3 Available Soil Resources and Required Soil Quantities

2.3.1 Earthwork Quantities

The soils required to construct and operate the existing and planned MSW and C&D landfill units will be removed from on-site borrow sources or will be imported from off-site. The soils removed during excavation of landfill units may be used for structural fill, soil liner, periodic cover, final cover, and general fill. These excavation (cut) and structural fill (fill) volumes are shown in **Table 2.2**.

2.3.2 Soil Liner

The soil required for the soil liner will be on-site or imported soils (A supply of 1 x 10^{-5} centimeters per second (cm/sec) or less soil is anticipated within Borrow Area E). The in-place volume required for each landfill unit is shown in **Table 2.3**.

2.3.3 Leachate Collection System (LCS) and Protective Cover

Overlying the liner system is the leachate collection system and protective cover. This layer is 24 inches thick on both the landfill base and side slopes. The required in-place volume of protective cover for each landfill unit is shown in **Table 2.4**. A portion of this volume will consist of aggregate, which will come from off-site sources.

2.3.4 Daily and Intermediate Cover

Assuming the previously mentioned periodic cover ratios, the required in-place volume for use as daily and intermediate cover during operations of each landfill unit is shown in **Table 2.5**.

2.3.5 Vegetative Soil Layer

On the basis of the 2 foot thick vegetative soil layer required for the landfill final cover, the in-place volume required for each landfill unit is shown in **Table 2.6**.

2.3.6 Soil Summary

The above on-site and off-site soil quantities are summarized in **Table 2.7**. Note that, based on the proposed base grades, long-term there is a soil deficit, which will be made up from the current and future borrow areas (adjacent County-owned properties).

2.4 Facility Design Criteria

Existing and proposed C&D landfill units were and will be constructed in accordance with Section .0540 of the North Carolina Administrative Code, Title 15A, Chapter 13, Subchapter 13B including the following requirements:

2.4.1 Horizontal Separation Requirements

The horizontal separation requirement between the disposal boundary (edge of waste) and the property lines is a minimum of 200 feet; the minimum buffer between private residences and wells and the disposal boundary is 500 feet; and the minimum buffer between any surface water (stream, river, creek) and the disposal boundary is 50 feet. The proposed design satisfies all buffer requirements.

2.4.2 Vertical Separation Requirements

The post-settlement bottom elevation of the liner system will meet the minimum requirement of four (4) feet above the seasonal high groundwater table and bedrock.

2.5 Containment and Environmental Control Systems

The following systems and elements are the basic containment and environmental controls for the Area 2 C&D landfill unit. Technical specifications were provided in the following approved document:

Technical Specifications
Johnston County C&D Landfill - Area 2
Prepared by G.N. Richardson & Associates, Inc.
Dated October 2005.

Construction quality assurance requirements can be found in **Attachment C**.

2.5.1 Landfill Subgrade and Perimeter Berms

The landfill subgrade elevations are designed for minimum post-settlement slopes of two (2) percent. The subgrade elevations will be achieved by excavation or placement of compacted structural fill (embankment). During excavation, a determination of unsuitable soils (i.e. soils which are too soft, wet, or organic) will be made. Where unsuitable soils are found, the soils will be undercut and backfilled with structural fill.

In addition to providing the liner foundation in fill areas, structural fill will be used for berm and roadway construction. Structural fill will consist of on-site soils removed during excavation of the landfill units or imported borrow soils, except that no CH, OL, or OH soils will be allowed.

2.5.2 Liner and Leachate Collection Systems

The lined area for Area 2 is approximately 15.8 acres and is shown on **Drawing S5** (Area 2 - Composite Liner Grading and Leachate Collection System Plan). The components of the Area 2 liner and leachate collection systems will consist of the following components (top-down):

Type 1:

- a leachate collection system (LCS) consisting of:

  Base and Side Slopes:
  - a 24-inch thick layer of soil protective cover;
  - a series of perforated collection pipes placed within coarse aggregate columns; and
  - a drainage geocomposite.

- a 40-mil thick LLDPE geomembrane; and
- a 12-inch thick soil liner with a hydraulic conductivity of no more than 1×10^{-5} cm/sec ("compacted soil liner").

OR

Type 2:

- a LCS (components as listed above for the Type 1 liner system);
- a 40-mil LLDPE geomembrane;
- a geosynthetic clay liner (GCL); and

- a 12-inch thick layer of structural fill (no hydraulic conductivity criteria).

The detailed discussion of the design of the liner and leachate collection systems can be found in **Section 3.0** (Liner System Design) and **Section 4.0** (Leachate Management System Design), respectively.

Note that, for the purposes of this report and the calculations of volumes, the above listed Type1 liner has been assumed. Note also that the existing Area 2 - Cell 1 unit has the Type 1 liner system.

2.5.3 Stormwater/Leachate Separation System

In order to increase facility operating efficiency by reducing the leachate treatment quantities, stormwater/leachate separation is planned for each landfill unit. Leachate is considered to be any precipitation or fluid that comes in direct contact with the waste. This liquid will be collected by the LCS and pumped to the leachate storage tanks. Precipitation that falls in areas where it does not contact waste, such as within inactive areas, does not have to be treated as leachate. This fraction of the precipitation is treated as stormwater, which is treated for removal of sediment only.

For landfill units that have waste placed in them, precipitation infiltrates or runs-off into the LCS. For areas that have no waste, run-off is captured in one or more low points where a pump conducts the water to a perimeter drainage structure. This run-off does not contact waste or leachate. At their discretion, the County may also employ the use of geosynthetic rain cover (GRC) to further segregate leachate and stormwater. The GRC, if used, is removed and discarded as each portion of an area is placed into active operation. For additional discussion of the leachate-stormwater separation system, see the Operations Manual (**Attachment D**).

2.5.4 Final Cover System

The final cover system for Area 2 will consist of the following components (top-down):

- a 24-inch thick vegetative soil layer (including 6 inches of topsoil);
- a drainage geocomposite (with drainage breaks);
- a 30-mil textured LLDPE geomembrane; and
- a 12-inch thick intermediate cover layer.

A detailed discussion of the design of the final cover system can be found in **Section 5.0** (Final Cover System Design).

2.5.5 Erosion and Sedimentation Control

Erosion and sedimentation control devices/measures will be designed and maintained to manage the run-off generated by the 25-year 24-hour storm event and conform to the requirements of the North Carolina Sedimentation Pollution Control Law (15A, NCAC, 4).

Reference is made to the following document which has been approved by the NC Division of Energy, Mineral, and Land Resources:

Erosion and Sedimentation Control Plan
Johnston County C&D Landfill - Area 2
Prepared by G.N. Richardson & Associates, Inc.
As Revised Through August 2006.

2.5.6 Landfill Gas Control

The landfill gas (LFG) control system for Area 2 will consist of collection wells/vents placed within the waste to capture the gas and passively vent the gas. The collection wells/vents should be placed before any final cover geosynthetics are placed. The selected system will be designed to limit the gas pressures on the final cover geosynthetics. Also refer to the facility Operations Manual (**Attachment D**) for a discussion of LFG monitoring and record keeping requirements.

2.5.7 Access and Roadways

The facility is accessed from County Home Road. A scale and a scale house are located near this entrance. All-weather access to active areas as well as areas under intermediate cover will be provided. Access ramps into the landfill units will be provided where necessary.

2.6 Slope Stability, Settlement, and Bearing Capacity

An evaluation of the slope stability of the overall waste mass and perimeter berms, the LCS/protective cover veneer, and the final cover veneer, as well as evaluations of foundation settlement and bearing capacity were addressed in the following document which was part of the approved Area 2 Permit to Construct Application:

Slope Stability, Settlement, and Bearing Capacity Evaluation
Johnston County C&D Landfill - Area 2
Prepared by G.N. Richardson & Associates, Inc.
Dated October 2005.

Analyses contained therein indicated that the completed Area 2 landfill configuration will satisfy applicable regulatory criteria.

2.7 Leachate Management

The general leachate management system includes the collection, storage, treatment (if required), and disposal of the leachate generated. The collection and transmission of leachate to the on-site storage lagoon will be as described in **Section 4.0** (Leachate Management System Design). From the storage lagoon, which also serves as a wastewater equalization basin, the leachate is pumped via force main to a local wastewater treatment plant (WWTP) for disposal. Pretreatment, if required, will be employed on-site to meet the standards for disposal into the WWTP.

A detailed discussion of the leachate management system, including anticipated leachate volumes, can be found in **Section 4.0** (Leachate Management System Design).

2.8 Special Engineering Features

Special engineering features proposed for Area 2 include both liner and final cover systems which incorporate geosynthetics. These systems are as described in Sections 2.5.2 and 2.5.4, respectively.

Table 2.1 Total Operating Capacity and Life Expectancy - MSWLF Units

Landfill Unit	Area (Acres)	Gross Capacity (CY)	Net (Waste) Capacity (CY/Tons)	Life Expectancy (Years)[1]
Unlined Landfill Units				
Phase 1/2	22.1	732,363	459,790 CY 279,474 Tons	Closed
Phase 3	25.4	1,174,139	819,136 CY 491,482 Tons	Closed
Phase 4	37.3	1,631,731	1,133,533 CY 680,120 Tons	Closed
Total (Unlined):	84.8	3,538,233	2,448,459 CY 1,469,076 Tons	Closed
Lined (Subtitle D) Landfill Units				
Phase 5	19.2	1,087,199	884,625 CY 514,181 Tons	Inactive
Phase 4A - Used	29.4	1,932,768	1,642,853 CY 1,072,776 Tons	-----
Phase 4A - Remaining				
Fill Sequence 1		599,180	509,303 CY 356,512 Tons	3.0 to 4.0
Fill Sequence 2		785,112	586,711 CY 410,698 Tons	3.4 to 4.6
Phase 6	21.1	1,402,016	1,167,578 CY 700,547 Tons	5.8 to 7.8
Phase 7	19.8	1,758,991	1,462,230 CY 877,338 Tons	5.5 to 8.0
Phase 8	25.2	1,844,867	1,495,182 CY 897,109 Tons	5.6 to 8.2
Phase 9	22.5	6,684,914	5,611,690 CY 3,928,183 Tons	24.6 to 35.7
Phase 10	17.5	3,137,920	2,524,065 CY 1,766,846 Tons	11.0 to 16.1
Total (Lined):	154.7		CY Tons	58.9 to 84.4
Total (Overall):	239.5		CY Tons	58.9 to 84.4

Notes:

1. Life expectancy for the active Phase 4A unit shown above is from 6/14/13. Life expectancies are based on disposal rates of 120,000 tons/year and 90,000 tons/year (Phases 4A and 6) and 160,000 tons/year and 110,000 tons/year (Phases 6-10).

Table 2.2 Total Operating Capacity and Life Expectancy - C&DLF Units

Landfill Unit	Area (Acres)	Gross Capacity (CY)	Net (Waste) Capacity (CY/Tons)	Life Expectancy (Years)[1]
Area 1	16.2	614,472	515,563 CY 304,780 Tons	Closed
Area 2 Cell 1 Used	11.9	323,132	290,819 CY 151,988 Tons	-----
Cell 1 Remain.		87,544	62,237 CY 31,118 Tons	0.8 to 1.6
Cell 2 (See Note 2)	3.9	462,658	387,062 CY 232,237 Tons	5.8 to 11.6
Total:	32.0	1,487,806	1,255,681 CY 720,123 Tons	6.6 to 13.2

Notes:

1. Life expectancy for the active Area 2 unit shown above is from 6/14/13. Life expectancies are based on disposal rates of 40,000 tons/year and 20,000 tons/year.
2. A portion of the Cell 2 capacity is available within the footprint of Cell 1 (i.e. without need to construct Cell 2).

Table 2.3 General Earthwork Quantities

Landfill Unit	Cut (CY)	Fill (CY)
MSW Landfill Units		
Phase 6	279,493	55,613
Phase 7	222,037	85,202
Phase 8	242,630	105,976
Phase 9	68,999	178,758
Phase 10	151,736	21,326
C&D Landfill Units		
Area 2 - Cell 2	0	3,436

Table 2.4 Soil Liner Quantities

Landfill Unit	Required Volume (CY)
MSW Landfill Units	
Phase 6	51,062
Phase 7	47,916
Phase 8	60,984
Phase 9	54,450
Phase 10	42,350
C&D Landfill Units	
Area 2 - Cell 2[1]	6,292

Note:

1. Or structural fill layer.

Table 2.5 Leachate Collection System/Protective Cover Quantities

Landfill Unit	Required Volume (CY)
MSW Landfill Units	
Phase 6	68,083
Phase 7	63,888
Phase 8	81,312
Phase 9	72,600
Phase 10	56,467
C&D Landfill Units	
Area 2 - Cell 2	12,584

Note:

1. The quantity shown above is for a thickness of 24 inches.

Table 2.6 Daily and Intermediate Cover Quantities

Landfill Unit	Required Volume (CY)
MSW Landfill Units	
Phase 4A - Fill Seq. 1 Phase 4A - Fill Seq. 2	89,817 103,537
Phase 6	206,043
Phase 7	258,041
Phase 8	263,856
Phase 9	990,298
Phase 10	445,423
C&D Landfill Units	
Area 2 - Cell 1	6,915
Area 2 - Cell 2	43,007

Note:

1. Volumes shown above for Phase 4A and Area 2 are from 6/14/13.

Table 2.7 Vegetative Soil Layer Quantities

Landfill Unit	Required Volume (CY)
MSW Landfill Units	
Phase 4A	94,864
Phase 5	61,952
Phase 6	68,083
Phase 7	63,888
Phase 8	81,312
Phase 9	72,600
Phase 10	56,467
C&D Landfill Units	
Area 2	50,981

Note:

1. The quantity shown above is for a thickness of 24 inches.

Table 2.8 Soil Summary

Material	Quantity (CY)
Excavation	964,895
Structural Fill	(450,311)
Soil Liner	(263,054)
LCS/Protective Cover[1]	(354,933)
Daily/Intermediate Cover	(2,406,997)
Vegetative Soil Layer	(550,147)
Total[1]:	(3,060,547)

Notes:

1. A portion of the LCS/Protective Cover will be from off-site sources.
2. Soil deficit shown will be made up from existing and future borrow sources located on County-owned property adjacent to the site.

3.0 LINER SYSTEM DESIGN

This section addresses the design of the Area 2 liner system. Technical specifications for liner system components were provided in the following approved document:

Technical Specifications
Johnston County C&D Landfill - Area 2
Prepared by G.N. Richardson & Associates, Inc.
Dated October 2005.

Construction quality assurance requirements for liner system components can be found in **Attachment C**. Also refer to the Permit to Construct Drawings (**Attachment H**) for liner system details.

3.1 Liner System Components

As described in **Section 2.5.2**, the liner will consist of the following components (top-down):

Type 1:

- a leachate collection system (LCS) (see **Section 2.5.2**);
- a 40-mil thick LLDPE geomembrane; and
- a 12-inch thick soil liner with a hydraulic conductivity of no more than 1 x 10^{-5} cm/sec ("compacted soil liner").

OR

Type 2:

- a LCS (see **Section 2.5.2**);
- a 40-mil LLDPE geomembrane;
- a geosynthetic clay liner (GCL); and
- a 12-inch thick layer of structural fill (no hydraulic conductivity criteria).

The liner system will be placed on structurally sound, compacted, or adequately prepared native soil subgrades at a maximum slope of 3H:1V.

3.1.1 Geomembrane

The geomembrane component of the liner system will function as the primary barrier layer. The geomembrane will be a textured 40-mil thick Linear Low Density Polyethylene (LLDPE) synthetic liner. The geomembrane will be installed by a qualified contractor.

3.1.2 Geosynthetic Clay Liner (GCL)

The GCL will function as a secondary barrier layer in the Type 2 liner system. The selected material for the GCL will consist of a layer of sodium bentonite bonded between two (2) geotextiles. The selected GCL will provide a maximum hydraulic conductivity of 5×10^{-9} cm/sec when hydrated and will be reinforced to prevent potential shearing in the bentonite layer.

3.1.3 Soil Liner

The soil liner will function as a secondary barrier layer in the Type 1 liner system. The soil liner will consist of compacted on-site or imported borrow soils. The soil liner will be compacted in 6 inch lifts to achieve the required hydraulic conductivity and strength requirements.

3.2 Liner System Design

3.2.1 Slope Stability

An evaluation of the slope stability of the Area 2 landfill unit was provided in the following approved document:

Slope Stability, Settlement, and Bearing Capacity Evaluation
Johnston County C&D Landfill - Area 2
Prepared by G.N. Richardson & Associates, Inc.
Dated October 2005.

Even though the project site lies outside of a seismic impact zone, both static and seismic slope stability analyses were performed. The evaluation indicated that the liner system will be able to satisfy design criteria (FS_{static} = 1.5; $FS_{seismic}$ = 1.0) under both short-term (protective cover veneer stability) and long-term (waste mass) conditions if the minimum peak interface shear strength for the weakest interface is defined by the following values:

Normal Loads </= 1,000 psf (Based on Veneer Stability)*:

Cohesion = 0 psf
Phi = 26.5 degrees

* Also applies to internal shear strength of the protective cover. Note that the analysis was performed assuming no seepage force (i.e., no flowing water) in the protective cover. Therefore, it is recommended that geosynthetic rain cover (GRC) be installed over exposed drainage and protective cover soil on the steeper landfill side slopes to minimize the chance for seepage induced instability of this layer.

Normal Loads > 1,000 psf (Based on Global Stability):

Cohesion = 0 psf
Phi = 20 degrees*

* Note that, although 20.0 degrees was used in the evaluation, a value of 11.0 degrees is required to achieve the minimum required factors of safety.

Based on the slope stability analyses performed, a textured geomembrane and reinforced GCL (if used) are required on both the base and side slopes of the landfill. Interface shear strength testing of the materials representative of those to be used in construction should be conducted prior to installation to verify that the above minimum criteria are met.

3.2.2 Settlement

An evaluation of the settlement of the Area 2 landfill unit was provided in the following approved document:

Slope Stability, Settlement, and Bearing Capacity Evaluation
Johnston County C&D Landfill - Area 2
Prepared by G.N. Richardson & Associates, Inc.
Dated October 2005.

Based on a worst case cross section, the evaluation indicated that the maximum total foundation settlement will be approximately 0.7 feet under maximum loads. Strains resulting from differential settlements are expected to be negligible meaning that no adverse impacts on the function of the liner or leachate collection systems are anticipated.

3.2.3 Bearing Capacity

An evaluation of the bearing capacity of the Area 2 landfill unit was provided in the following approved document:

Slope Stability, Settlement, and Bearing Capacity Evaluation
Johnston County C&D Landfill - Area 2
Prepared by G.N. Richardson & Associates, Inc.
Dated October 2005.

Both the bearing capacity of the landfill subgrade and the bearing capacity of the leachate collection system under anticipated construction and operations equipment loads were evaluated. Based on the anticipated conditions, the landfill subgrade and the leachate collection system have adequate bearing capacity. The evaluation of the equipment loads also determined the required

vertical separation between equipment and the underlying geomembrane (see **Sections 3.4.1 and 3.4.2**).

3.2.4 Anchor Trench Design

An anchor trench, 1.5-foot wide by 1.5-foot deep with a 3-foot setback from the crest of the slope, was evaluated to allow pullout of the geomembrane before the yield stress in the geomembrane is achieved (see **Appendix A**). In this configuration, the anchor trench provides sufficient resistance to prevent pullout during anticipated loading conditions. Large scale yielding or tearing of the geomembrane is, however, prevented under extreme loading conditions since the geomembrane is designed to pull out of the anchor trench rather than yield. It should be noted that the anchor trench calculations are very conservative, since the use of geosynthetics with the above listed minimum interface shear strength values (see **Section 3.2.1**) provide for an inherently stable system (see **Section 3.3.1**).

3.2.5 Protection of Geomembrane

Appendix A contains a cushion geotextile analysis which shows the minimum weight of nonwoven geotextile required to perform adequately as a cushion under long-term loads. Based on the analysis, the drainage geocomposite should have a minimum of 10.5 ounces per square yard (oz./SY) of nonwoven geotextile (conservatively not including any cushioning from the geonet drainage core) in order to protect the geomembrane from the gravel columns surrounding the leachate pipes. A 6 oz./SY nonwoven geotextile bonded to each side of the geonet drainage core will satisfy this requirement.

3.3 Anticipated Stresses

3.3.1 Installation Stresses

The most critical time for potential damage to the liner system occurs following installation of the geomembrane liner when the overlying components are placed. Installation stresses imposed on the geomembrane due to deployment are negligible under normal procedures. Due to the selection of textured LLDPE geomembrane on facility side slopes, interface friction angles for geosynthetics are expected to be greater than the maximum 3H:1V side slope angle (see **Section 3.2.1**). Thus, negligible stresses will be placed on geosynthetics and the system will be inherently stable.

Installation of the drainage geocomposite and aggregate/protective cover over the geomembrane (and other geosynthetics) will need to be performed with extreme care so as to minimize the potential for damage to these geosynthetics. The aggregate/protective cover will be placed on landfill side slopes by pushing

from the bottom up using low ground pressure (LGP) (< 6 pounds per square inch (psi)) dozers. This operation will be carefully observed such that the development of wrinkles and tension in the underlying geosynthetics is minimized. With the exception of properly operated ATVs used in deployment of the geosynthetics, no construction equipment should be allowed to drive down the landfill side slopes. Based on the bearing capacity analysis, it is recommended that non-LGP dozers (up to 12 psi contact stress), if used on the landfill base slopes, operate on at least 1 foot of aggregate/protective cover; also it is recommended that trucks used to haul material into the landfill have at least 3 feet of separation between the truck tires and the geomembrane.

3.3.2 Operational Stresses

Operational stresses are greatest during placement of the initial lift of waste. The facility Operations Manual (**Attachment D**) discusses the placement of an initial 4 to 5 foot (min.) lift of select waste (free of larger items) to minimize the potential for damage to the liner system. Based on the bearing capacity analysis, it is recommended that waste compactors have at least 3 feet of vertical separation to the liner system (when compacting the initial lift).

3.3.3 Long-Term Stresses

Settlement analyses performed for Area 2 demonstrate that the anticipated tensile stresses in the liner system due to settlement of underlying subgrade will be negligible.

4.0 LEACHATE MANAGEMENT SYSTEM DESIGN

This section addresses the design of the Area 2 leachate management system. The leachate management system for the landfill consists of the leachate collection system (LCS) and the leachate transmission and storage system. The LCS will consist of natural and/or geosynthetic drainage media on the base and side slopes of the landfill as well as a collection pipe network and sump. The leachate transmission and storage system will consist of pumps, piping, manholes, valves, and leachate storage lagoon. Technical specifications for leachate management system components were provided in the following approved document:

Technical Specifications
Johnston County C&D Landfill - Area 2
Prepared by G.N. Richardson & Associates, Inc.
Dated October 2005.

Construction quality assurance requirements for leachate management system components can be found in **Attachment C**. Also refer to the Permit to Construct Drawings (**Attachment H**) for leachate management system details.

4.1 Leachate Collection System (LCS) Components

The LCS will be constructed directly above the geomembrane on both the base and side slopes of the landfill. The LCS functions to collect leachate as quickly as is practical and to conduct the fluid out of the landfill via the sumps. The LCS also provides protection of the liner system. The goal of the LCS is to minimize the hydraulic head acting on the liner, thereby reducing the leak potential. As described in **Section 2.5.2**, the components of the leachate collection system (LCS) will consist of the following components (top-down):

Base and Side Slopes:

- a 24-inch thick layer of protective cover soil;
- a series of perforated collection pipes placed within coarse aggregate columns; and
- a drainage geocomposite.

Additionally, as noted in **Section 2.5.3**, the County may elect to install geosynthetic rain cover over the LCS to aid stormwater/leachate separation.

4.1.1 Drainage Aggregate

Drainage aggregate used in the LCS will consist of coarse aggregate (No. 57 or similar aggregate meeting required permeability and angularity criteria) which will provide primary leachate removal capacity and will be placed around collection piping and within the sump

4.1.2 Drainage Geocomposite

The drainage geocomposite will function as a blanket drain to conduct leachate to collection piping and the sump(s). The drainage geocomposite will consist of a polyethylene drainage net (geonet) bonded on both sides with a nonwoven, needle-punched geotextile. The minimum required transmissivity of the drainage geocomposite was determined in the leachate collection pipe spacing analysis (see **Section 4.3.1** and **Appendix A**). The minimum required properties of the drainage geocomposite to perform as a cushion were determined in the cushion geotextile analysis (see **Section 3.2.5** and **Appendix A**).

4.1.3 Separator (Type GT-S) Geotextile

A nonwoven separator (Type GT-S) geotextile will be used as a component of the drainage geocomposite. The Type GT-S geotextile will also be installed over gravel columns to keep the aggregate from fouling prior to waste placement. Due to long-term bio-clogging concerns, the geotextile should be cut and laid back or removed from gravel columns just ahead of waste placement so that the waste can be placed in direct contact with the aggregate. The minimum required properties of the Type GT-S geotextile to perform as a filter were determined in the filter geotextile analysis (see **Section 4.3.5** and **Appendix A**).

4.1.4 Collection Piping

The leachate collection piping will be high density polyethylene (HDPE) (DR 17) pipe. The required pipe dimension ratio (DR) (ratio of outside pipe diameter to wall thickness) was selected based upon the maximum static and dynamic loading conditions to be placed on the pipe (see **Section 4.3.4** and **Appendix A**).

Collection pipes have coarse aggregate placed over and around them and are referred to as "gravel columns". These gravel columns will provide a significant amount of storage, provide primary leachate removal capacity, and will be resistant to biological clogging. Since the gravel column aggregate extends through the protective cover and will be in direct contact with the waste (the Type GT-S geotextile placed initially will be removed prior to waste placement), the long-term clogging potential will be significantly reduced. Cleanout ports are designed, where possible, at the end of leachate collection piping along the perimeter berm to allow periodic hydro-washing of the piping when necessary. The collection piping of the LCS will conduct the leachate to the sump for the removal from the landfill by side riser pumps.

4.1.5 Leachate Sump

The leachate sump will function as the collection point for leachate within the landfill. The sump and side riser layout is shown on **Drawing LM2** (Leachate Management System Details - Sheet 2 of 3). As designed, the sump is filled with coarse aggregate and has a storage capacity of over 2,000 gallons (accounting for 30% porosity in the stone) for operation of the side riser pumps (see **Section 4.2.1** and **Appendix A**).

4.1.6 Geosynthetic Rain Cover (GRC)

The GRC will consist of a thin geomembrane. The GRC will be used at the option of the County to prevent stormwater infiltration through the protective cover and the gravel columns of the LCS in inactive cells. Where used, the GRC will be removed by operations personnel prior to activation of an individual disposal area or portion thereof.

4.2 Leachate Transmission and Storage System Components

Leachate from the Area 2 LCS will be collected in the leachate sump as shown on **Drawing S7** (Leachate Force Main Plan and Profile). The leachate collected in the sumps will be pumped to the leachate storage lagoon via a force main.

4.2.1 Pumps

Two side riser pumps will be used in each leachate sump. The pumps selected for this application will be Leachator or equal that are rated at a minimum flow of 75 to 100 gallons per minute (gpm). The pumps and control system will include alarms for power outage, high level, and no-flow conditions. A flow meter will be included to monitor leachate production. During normal operations, the pumps will alternate to reduce wear on one particular pump. Under high flow conditions, both pumps will operate in tandem to keep the head on the liner system to a minimum. Pump requirements were determined in the leachate pump and force main evaluation (see **Section 4.3.6** and **Appendix A**).

4.2.2 Transmission Piping

The leachate transmission piping will be HDPE pipe. The required pipe DR was selected as described above for collection piping (see **Section 4.1.5**) based upon the maximum static and dynamic loading conditions to be placed on the pipe (see **Section 4.3.4** and **Appendix A**).

4.2.3 Storage Lagoon/Wastewater Equalization Basin

Leachate from Area is routed to the existing leachate storage lagoon (pond) which has a capacity of approximately 4,200,000 gallons (not including 2 feet of freeboard). The pond is lined with a composite liner system consisting of 24 inches of compacted clay liner ($k \leq 1 \times 10^{-7}$ cm/sec) overlain by a 60 mil HDPE geomembrane and a 6 inch thick Fabri-Form concrete liner. The lagoon drains to an existing pump station. From this pump station, the leachate is pumped via a force main to a local wastewater treatment plant (WWTP) owned and operated by Johnston County.

Due to the large size of the pond relative to typical leachate generation at the site (between 1.26M and 3.05M gallons per year based on 2004 and 2005 data), the County previously modified the storage lagoon for use as an equalization basin for raw wastewater.

The maximum water level in the modified pond will be maintained at approximately elevation 151 to 152. With a top of pond elevation of approximately 155, this will provide a volume of at least 1 foot (approximately 650,000 gallons) below the required 2 feet of freeboard under typical conditions. This capacity is much greater than the anticipated surge volume from a newly operational landfill unit. Additionally, considering the very large pumping capacity (two 1,300 GPM pumps) of the existing raw sewage pump station which is connected to the pond, the ability to handle leachate generation at the site is very high.

The operation of the leachate storage lagoon as an equalization basin will not affect the County's ability to draw-down the basin in advance of predicted heavy rainfall (tropical storm, hurricane, etc.).

4.3 Leachate Management System Design

4.3.1 LCS Pipe Spacing Analysis

The spacing of the LCS collection pipes was evaluated to verify that the maximum hydraulic head on the geomembrane will be less than 1 foot (or within the thickness of the drainage geocomposite - where used) during normal operating conditions. The analysis (see **Appendix A**) was conducted using McEnroe's mounding equations and considered impingement rates corresponding to active conditions (1,200 gallons per acre per day (gpapd)) (See **Section 4.5**). The analysis conservatively included reduction factors (intrusion, creep deformation, chemical clogging, and biological clogging plus an overall factor of safety).

Based on the analysis, a minimum transmissivity of 7.5×10^{-4} cubic meters per meter per second ($m^3/m/sec$) was selected for the drainage geocomposite (where used). Transmissivity tests for the drainage geocomposite should be

conducted based on anticipated field conditions (maximum normal load, boundary conditions, and gradient).

4.3.2 LCS Pipe Sizing

The capacity of LCS piping was evaluated by comparing the maximum capacity of various pipe diameters with the peak daily leachate generation rate (14,000 gallons/acre/day) (see **Appendix A**). Based on this evaluation, a 6-inch diameter HDPE (DR 17) (I.D. = 5.8-inches) will handle a maximum drainage area of 17 acres with a factor of safety of 2.0. This maximum drainage area exceeds the maximum drainage area to be drained by any single pipe.

4.3.3 LCS Pipe Perforation Analysis

The maximum LCS pipe perforation size was evaluated based on the size of the pipe bedding. LCS pipe perforation calculations are presented in **Appendix A**. For No. 57 stone (or similarly graded) bedding, a maximum perforation size of 0.5 inches (diameter of circular holes or slot width) is acceptable.

The number of perforations required will depend on the quantity of leachate being handled by the pipe. However, 2 rows of 0.5-inch diameter circular holes or 0.125-inch wide by 1.0-inch long slots aligned 60 degrees from the bottom of the pipe with holes 4 to 6 inches apart will allow much greater inflow to the pipe than required to handle the peak leachate generation rates (Optionally, a third row of perforations can be added along the top of the pipe.). Likewise, for the perforated portion of side riser piping in the landfill sumps, 5 or 6 rows of 0.5-inch diameter circular holes evenly spaced around the circumference of the pipe with holes 6 inches apart should provide more than adequate capacity. With the larger number of holes in the side riser piping, the holes should be staggered or offset from one row of holes to the next.

4.3.4 Leachate Pipe Mechanical Properties

All leachate piping will be HDPE. For HDPE pipe, the required pipe dimension ratios (DR) for collection, side riser, and transmission piping were selected based upon anticipated static and dynamic loading conditions both during and after construction. Both the static and dynamic criteria are discussed briefly below. Pipe stress analyses for HDPE pipe are presented in **Appendix A**. All collection and side riser piping will be bedded in No. 57 (or similar) stone to ensure a safe load distribution on the piping under long-term conditions.

4.3.4.3 Static Load Requirement

The vertical stress applied by the fully constructed landfill, including (for collection and side riser piping) maximum waste and final cover loads,

was used to calculate the required DR. Calculations were performed for crushing, buckling, and pipe deflection.

For HDPE collection piping (also represents a worst case for side riser and transmission piping), the analysis for static loading was performed using a normal compressive stress greater than anticipated to account for potential future vertical expansion (approximately 73 psi assuming a maximum waste/cover thickness of ±150 feet and a density of 70 pcf). The analysis indicates that the selected DR of 17 will have factors of safety of 2.6 and 4.3 for crushing and buckling, respectively.

4.3.4.4 Equipment Loading (Dynamic Load Requirement)

During construction of the landfill, it may be necessary for certain construction equipment to operate over the pipe. Under this worst case condition, a dynamic impact factor of 1.5 was used to account for equipment loading. Under no circumstances should tracked vehicles be allowed to turn when operating over the pipe.

For analysis, typical construction and operations equipment were selected for calculation of dynamic crushing loads.

On the basis of the selected DR, the following equipment limitations will be employed:

- Placement of the leachate collection media/protective cover and No. 57 stone:
    - Low ground pressure (LGP) (< 6 psi) tracked equipment on 6H:1V and steeper slopes (12 inch minimum cover over geosynthetics and/or piping);
    - Tracked equipment with ground pressure of 12 psi or less on slopes flatter than 6H:1V (12 inch minimum cover over geosynthetics and/or piping); and
    - Wheeled equipment (hauling vehicles) (3 foot minimum cover over geosynthetics and/or piping).

- Placement of initial lift of waste:
    - Landfill compactors and hauling vehicles (3 foot minimum cover over geosynthetics and/or piping).

4.3.5 Filter Geotextile Analysis

A filter geotextile analysis was performed to determine the apparent opening size (AOS) and permittivity required for the proper performance of 1) the Type GT-S geotextile and 2) the upper geotextile component of the drainage

geocomposite as a filter. The analysis (see **Appendix A**) assumes that the protective cover will be silty and clayey sands (based on the typical grain size curves evaluated). Based on the filter geotextile analysis, recommended AOS and permittivity of the upper geotextile component are as follows:

AOS (upper geotextile) (ASTM D 4751):	70+ (U.S. Sieve)
Permittivity (upper geotextile) (ASTM D 4491):	1.0 sec-1

AOS and permittivity were determined based on typical values for a 6 oz./SY nonwoven geotextile.

The soils proposed for use as protective cover should be evaluated prior to construction to ensure compatibility with all the design assumptions stated herein.

4.3.6 Leachate Pump Calculations

Calculations (see **Appendix A**) were performed for each pump to determine the required pumping system parameters. On the basis of these calculations, the selected leachate side riser pumps will be capable of pumping at approximately 75 to 100 gpm under anticipated conditions.

4.4 Leachate Pretreatment

Pretreatment of the leachate may be required in order to discharge to the local WWTP. Experience with new lined landfills indicates that leachate pretreatment is generally not required during the initial three plus years of landfill operations. The majority of the leachate generated during this time comes from precipitation that has had little contact with waste.

As the landfill becomes mature, the concentrations of constituents in the leachate will increase - although the leachate volume may decrease with time. At this point, the County may add a pretreatment system if required by the WWTP.

It should be noted that as Federal and State mandated waste screening and prohibition is continued (e.g. for lead acid batteries, household hazardous waste, etc.) the impact on leachate quality is expected to reduce the future potential need for pretreatment.

4.5 Leachate Generation

The leachate management system for Area 2 has been designed to minimize head on the liner system and to maximize effective operations. The leachate generation rate for the landfill is heavily dependent on the following:

- Design storm event(s);

- Amount of waste in the cell; and
- Method of landfill operations.

An evaluation of leachate generation rates was performed to estimate flow rates during active, interim, and closed conditions (see **Appendix A**). The Hydrologic Evaluation of Landfill Performance (HELP) Model (Version 3.07) was used to confirm the volume of leachate anticipated during these three discrete conditions. It was found that the HELP Model values were approximately equal to or somewhat lower than empirical generation rates for these conditions which are based upon actual data. Thus, the empirical rates were applied to the proposed operational conditions to yield leachate generation rates for various stages of landfill development.

In order to determine typical leachate flow rates, empirical daily leachate generation values of 1,200 gallons per acre per day (gpapd) for active, 500 gpapd for interim, and 100 gpapd for final were applied to the proposed operational scenarios. Each operational scenario is basically a "snapshot" developed to depict the typical combination of areas which are being operated, under active, interim, and final cases.

In order to simulate a "surge" volume, a precipitation event of 3.2 inches for a 1-year 24-hour storm was applied over a maximum open area of the landfill corresponding to each newly opened cell and added to the leachate being produced under active, interim, and final conditions. The 1-year recurrence interval was selected since it is a conservative representation of the timeframe that an area will be open and only partially filled across the bottom. As shown in the calculations, the flow rate with the 1-year 24-hour storm event is estimated at approximately 300,000 gallons. This should be considered as a "worst case" scenario. Once covered by waste, the potential for a "surge" event in the landfill is essentially eliminated due to the ability of the waste to absorb and slowly release precipitation. The more typical flow rate for Area 2 operations is anticipated to be less than 50,000 gallons per day (includes flow from Phases 4A and 5).

The ability to prevent ponding in the landfill rests on the ability to hold leachate in the storage lagoon. As noted in **Section 4.2.3**, the capacity of the existing storage lagoon is approximately 4,200,000 gallons, which is greater than the total volume of leachate that can be generated by the "surge" event. This means that little to no ponding of leachate will occur in the landfill when the lagoon can handle the entire design storm.

In order to minimize the ponding potential in the landfill, the County will remove leachate from the storage lagoon at a rate to maintain water levels in the lagoon at or below elevation 152 on a typical basis, which will allow approximately 650,000 gallons of storage while maintaining 2 feet of freeboard.

5.0 FINAL COVER SYSTEM DESIGN

This section addresses the design of the final cover system for Area 2. Technical specifications for final cover system components were provided in the following approved document:

Technical Specifications
Johnston County C&D Landfill - Area 2
Prepared by G.N. Richardson & Associates, Inc.
Dated October 2005.

Construction quality assurance requirements for final cover system components can be found in **Attachment C**. A facility Closure and Post-Closure Plan, including cost analyses, is provided as **Attachment E**. Also refer to the Permit to Construct Drawings (**Attachment H**) for final cover system details.

5.1 Final Cover System Components

As described in **Section 2.5.4**, the final cover system for Area 2 will consist of the following components (top-down):

- a 24-inch thick vegetative soil layer (including 6 inches of topsoil);
- a drainage geocomposite (with drainage breaks);
- a 30-mil textured LLDPE geomembrane; and
- a 12-inch thick intermediate cover layer.

The final cover system will be placed on prepared intermediate cover at a maximum slope of 4H:1V. Landfill gas (LFG) wells/vents and surface water control devices will also be incorporated into the final cover. The final cover surface will be vegetated upon completion of the final cover installation according to the project seeding specifications.

5.1.1 Vegetative Soil Layer

The function of the vegetative soil layer will be to provide support for vegetation and protection of the underlying geosynthetics. The vegetative soil layer consists of on site or imported soil (the upper 6 inches of which will be capable of supporting the growth of vegetative cover).

5.1.2 Drainage Geocomposite

The drainage geocomposite will function as a blanket drain to conduct infiltration through the vegetative soil layer to the surface water drainage features (i.e. rain gutters, down pipes, and/or perimeter channels) and, thus, reduce the head on the underlying geomembrane.

The drainage geocomposite will consist of a polyethylene drainage net (geonet) bonded on both sides with a nonwoven, needle-punched geotextile. Alternatively, the drainage geocomposite may consist of a series of small diameter pipes bonded on both sides within two nonwoven geotextiles (Draintube or equal). The minimum required transmissivity of the drainage geocomposite was determined in the final cover drainage layer analysis (see **Section 5.2.2** and **Appendix A**).

5.1.3 Geomembrane

The geomembrane component of the final cover system will function as a barrier layer. The geomembrane will be a textured 30-mil thick Linear Low Density Polyethylene (LLDPE) synthetic liner. The geomembrane will be installed by a qualified contractor.

5.1.4 Intermediate Cover

The intermediate cover will separate the waste from and provide a foundation for the overlying geosynthetics. The intermediate cover will be placed by the landfill operator and will consist of on-site or imported soils. Additional intermediate cover may also be used for leveling or fine grading or for bridging of localized soft areas, as required.

5.1.5 Landfill Gas (LFG) Control System

The landfill gas (LFG) control system will consist of collection wells or vents placed within the waste to capture and passively vent the gas. The collection wells or vents should be placed before any final cover geosynthetics are placed. The selected system will be designed to limit the gas pressures on the final cover geosynthetics.

5.1.6 Surface Water Control Devices

Surface water run-off will be controlled in the final cover system by drainage breaks (rain gutters and/or diversion berms) that limit the distance the water flows and collects the water for conveyance (via down pipes and/or perimeter drainage structures) to one of the site sediment basins. The design of rain gutters and down pipes is discussed in **Section 5.2.3**.

5.2 Final Cover System Design

5.2.1 Slope Stability

An evaluation of the veneer stability of the Area 2 final cover system was provided in the following approved document:

Slope Stability, Settlement, and Bearing Capacity Evaluation
Johnston County C&D Landfill - Area 2
Prepared by G.N. Richardson & Associates, Inc.
Dated October 2005.

The evaluation indicates that the final cover system will satisfy design criteria if the minimum peak interface shear strength for the weakest interface is defined by the following values:

Normal Loads </= 1,000 psf (Based on Veneer Stability):

Cohesion = 0 psf
Phi = 24 degrees

Based on the slope stability analyses performed, a textured geomembrane is required. Interface shear strength testing of the materials representative of those to be used in construction should be conducted prior to installation to verify that the above minimum criteria are met.

5.2.2 Drainage Layer Analysis

The analysis of the final cover drainage layer (drainage geocomposite) is provided in **Appendix A**. This analysis focused on determining the required value of transmissivity to maintain peak heads within the drainage geocomposite.

The analysis was performed based on a worst case condition of 4H:1V (14.0 degrees) slopes and a maximum 140 foot flow length (horizontal projection) to drainage breaks in the drainage geocomposite (coincides with the maximum side slope length between rain gutters). This condition represents the worst case in that adequate transmissivity is required along the steeper side slopes to maintain flow within the geocomposite and, thus, minimize seepage forces in the vegetative soil layer which could affect stability. Calculations were carried out assuming the maximum permeability of the vegetative soil layer is 1×10^{-4} cm/sec (typical for on-site soils to be used). The calculations, which include an overall reduction factor of 6 (accounts for a factor of safety of 2 plus a combined reduction factor of 3 for long-term intrusion, creep, and clogging concerns), indicate that a minimum transmissivity of 1×10^{-3} m^3/m/sec is required for the drainage geocomposite. Transmissivity tests should be conducted based on

anticipated field conditions (maximum normal load, boundary conditions, and gradient).

The soils proposed for use as the vegetative soil layer should be evaluated prior to construction to ensure compatibility with all the design assumptions stated herein.

5.2.3 Rain Gutters and Down Pipes

Calculations for the design of rain gutters and down pipes are provided in **Appendix A**. These devices were conservatively designed based on the peak run-off from a 25-year storm.

5.3 Anticipated Stresses

The most critical time for potential damage to the final cover geomembrane occurs following installation of the geomembrane when the overlying components are placed. Installation stresses imposed on the geomembrane due to deployment are negligible under normal procedures. Due to the selection of textured LLDPE geomembrane, all interface friction angles for geosynthetics are expected to be greater than the maximum 4H:1V side slope angle (see **Section 5.2.2**). Thus, negligible stresses will be placed on geosynthetics and the system will be inherently stable.

Installation of the drainage geocomposite and the vegetative soil layer over the geomembrane (and other geosynthetics) will need to be performed with extreme care so as to minimize the potential for damage to these geosynthetics. The vegetative soil layer will be placed on landfill side slopes by pushing from the bottom up using low ground pressure (LGP) (< 6 psi) dozers. This operation will be carefully observed such that the development of wrinkles and tension in the underlying geosynthetics is minimized. With the exception of properly operated ATVs used in deployment of the geosynthetics, no construction equipment should be allowed to drive down the landfill side slopes.

In the construction of the final cover system, the hauling of materials down side slopes is not generally recommended. However, hauling down side slopes could be possible in certain situations should an analysis by a qualified engineer determine that there is an adequate factor of safety (>/= 1.5 for both static and dynamic loads) against sliding of the final cover veneer on the weakest interface. The analysis would have to evaluate the actual equipment to be used and use project specific interface shear strength values.

Appendix A

Landfill Design Calculations

Facility and Engineering Plan
Johnston County C&D Landfill - Area 2
Smithfield, North Carolina

Facility and Engineering Plan
Appendix A: Landfill Design Calculations

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1.0 Quantity Calculations *(Updated)*
- Capacity Evaluation (Density & Life Calcs.)
- Earthwork Quantities

2.0 Liner and LCS Geosynthetics Calculations*
- Anchor Trench Sizing
- Filter Geotextile Analysis
- Cushion Geotextile Analysis

3.0 Leachate Management System Calculations*
- Leachate Collection Pipe Spacing
- Leachate Collection Pipe Sizing
- HDPE Pipe Stress Analysis
- Evaluation of Leachate Generation Rates
- Leachate Pump Design Calculations

4.0 Final Cover System Calculations*
- Final Cover Drainage Layer Analysis
- Rain Gutter & Down Pipe Sizing

Except where updated calculations are noted, the attached calculations were included with the previously approved Permit to Construct application for Area 2.

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PROJECT **Johnston County Landfill** SHEET 1 OF 22 DATE 12/6/2013

COMPUTED BY PKS

SUBJECT **Capacity Evaluation (Density & Life)** JOB # JOHNSTON-13-4 CHECKED BY

OBJECTIVE:

To determine the capacity of landfill units. Also, to estimate the expected life of the landfill unit(s) given the proposed contours and the anticipated waste loading rate(s). As part of the evaluation, an evalution or estimate of waste density will be required based on the known or assumed percentage of periodic cover soil.

ANALYSIS:

The volume(s) will be calculated by using AutoCAD. Alternatively, the volume(s) will be calculated by taking cross sections of the landfill, using a planimeter to measure the area of the cross sections, and using the average end area method.

PROJECT	**Johnston County MSW Landfill - Phase 4A**	SHEET	2/22
		JOB #	JOHNSTON-13-4
SUBJECT	**Capacity Evaluation - Filling Rate & Density Calculations**	DATE	12/6/2013
		COMPUTED BY	PKS
		CHECKED BY	

Density and Filling Rate Calculations:

Start Date	Period of Interest End Date	Total Time (years)	Volume Filled (cy)	Quantity of Waste Disposed (tons)	Waste Filling Rate* (lbs/cy)	Periodic Cover Assumed %	Periodic Cover Volume (cy)	Waste Volume (cy)	Waste Density** (lbs/cy)	Cumulative Waste Density*** (lbs/cy)
1/9/2003	5/21/2004	1.36	312,843	139,098	**889**	15	46,926	265,917	**1,046**	**1,046**
5/22/2004	3/21/2005	0.83	200,019	89,280	**893**	15	30,003	170,016	**1,050**	**1,048**
3/22/2005	6/4/2006	1.20	287,402	131,910	**918**	15	43,110	244,292	**1,080**	**1,059**
6/5/2006	5/20/2007	0.96	209,118	110,112	**1,053**	15	31,368	177,750	**1,239**	**1,097**
5/21/2007	6/6/2008	1.05	192,780	121,693	**1,263**	15	28,917	163,863	**1,485**	**1,159**
6/7/2008	6/19/2009	1.03	191,213	108,036	**1,130**	15	28,682	162,531	**1,329**	**1,182**
6/20/2009	6/11/2010	0.98	142,560	96,845	**1,359**	15	21,384	121,176	**1,598**	**1,221**
6/12/2010	6/17/2011	1.01	150,437	96,994	**1,289**	15	22,566	127,871	**1,517**	**1,247**
6/18/2011	5/31/2012	0.95	128,242	83,621	**1,304**	15	19,236	109,006	**1,534**	**1,268**
6/1/2012	6/14/2013	1.04	143,970	95,187	**1,322**	15	21,596	122,375	**1,556**	**1,289**
	Totals:	**10.41**	**1,958,584**	**1,072,776**			**293,788**	**1,664,796**		

Current Cumulative Waste Density = 1,289 lbs/cy

Notes:

*Waste Filling Rate = (Tons of Waste Disposed)/(Volume Filled).

**Waste Density = (Tons of Waste Disposed)/(Volume Filled - Volume of Periodic Cover).

***Cumulative Waste Density = (Total Tons of Waste Disposed)/(Total Volume Filled - Total Volume of Periodic Cover).

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PROJECT	**Johnston County MSW Landfill**	SHEET	3/22
		JOB #	JOHNSTON-13-4
SUBJECT	**Capacity Evaluation - Phase 4A - Cells 1-3 (Fill Sequence 1)**	DATE	12/6/2013
		COMPUTED BY	PKS
		CHECKED BY	

Waste & Periodic Cover Parameters:

Waste Density (PCY) =	1,400	(From Filling Rate and Density Calcs.) (Conservative Based on Recent)
Waste Density (TCY) =	0.70	
Percentage of Periodic Cover =	15	

Volume Calculations:

Gross Capacity Used (Top of Protective Cover to Top of Final Cover):

Gross Capacity Used (CY) =	1,932,768	(Top of Protective Cover to June 14, 2013 Topo.)
		(Determined as Permitted Capacity - Gross Capacity Remaining)
Waste Disposed (Tons) =	1,072,776	(Per Site Records 1/9/2003 through 6/14/2013)

Gross Capacity Remaining (Top of Protective Cover to Top of Final Cover):

Volume From AutoCAD (CY) =	599,180	(Compared with June 14, 2013 Topo.)
		(Based on Top of Intermediate Cover)

Adjustment For Other Layers: (Add to Above)

	Area of Final Cover (Acres) =	0.0
2 feet	Vegetative Soil Layer (CY) =	0
	Sum (CY) =	0
	Gross Capacity Remaining (CY) =	599,180

Net (Waste) Capacity Remaining:

Adjustment For Other Layers: (Subtract from Above)

	Area of Final Cover (Ac.) =	0.0
2 feet	Vegetative Soil Layer (CY) =	0
	Sum (CY) =	0
	Volume of Waste and Periodic Cover (CY) =	599,180
	Volume of Periodic Cover (CY) =	(89,877)
	Net (Waste) Capacity Remaining (CY) =	509,303
	Net (Waste) Capacity Remaining (Tons) =	356,512

Life Expectancy Calculations:

Landfill Life Expectancy (Low Disposal Rate) (Years) =	4.0	Based on 90,000 Tons per Year
Landfill Life Expectancy (High Disposal Rate) (Years) =	3.0	Based on 120,000 Tons per Year

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PROJECT	**Johnston County MSW Landfill**	SHEET	4/22
		JOB #	JOHNSTON-13-4
SUBJECT	**Capacity Evaluation - Phase 4A - Cells 1-3 (Fill Sequence 2)**	DATE	12/6/2013
		COMPUTED BY	PKS
		CHECKED BY	

Waste & Periodic Cover Parameters:

Waste Density (PCY) =	1,400	(From Filling Rate and Density Calcs.) (Conservative Based on Recent)
Waste Density (TCY) =	0.70	
Percentage of Periodic Cover =	15	

Volume Calculations:

Gross Capacity (Fill Sequence 1 to Top of Final Cover):

Volume From AutoCAD (CY) =	690,248	(Compared with Fill Sequence 1)
		(Based on Top of Intermediate Cover)

Adjustment For Other Layers: (Add to Above)

	Area of Final Cover (Acres) =	29.4	(All Phase 4A Final Cover Included in FS2)
2 feet	Vegetative Soil Layer (CY) =	94,864	
	Sum (CY) =	94,864	
	Gross Capacity (CY) =	785,112	

Net (Waste) Capacity:

Adjustment For Other Layers: (Subtract from Above)

	Area of Final Cover (Ac.) =	29.4
2 feet	Vegetative Soil Layer (CY) =	(94,864)
	Sum (CY) =	(94,864)
	Volume of Waste and Periodic Cover (CY) =	690,248
	Volume of Periodic Cover (CY) =	(103,537)
	Net (Waste) Capacity (CY) =	586,711
	Net (Waste) Capacity (Tons) =	410,698

Life Expectancy Calculations:

Landfill Life Expectancy (Low Disposal Rate) (Years) =	4.6	Based on 90,000 Tons per Year
Landfill Life Expectancy (High Disposal Rate) (Years) =	3.4	Based on 120,000 Tons per Year

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PROJECT	**Johnston County MSW Landfill**	SHEET	5/22
		JOB #	JOHNSTON-13-4
SUBJECT	**Capacity Evaluation - Phase 6**	DATE	12/6/2013
		COMPUTED BY	PKS
		CHECKED BY	

Waste & Periodic Cover Parameters:

Waste Density (PCY) =	1,200	(Assumed)
Waste Density (TCY) =	0.60	
Percentage of Periodic Cover =	15	

Volume Calculations:

Gross Capacity (Top of Protective Cover to Top of Final Cover):

Volume From AutoCAD (CY) =	1,521,161	(Phase 6 Subgrade to Top of Phase 6 Fill)

Adjustment For Other Layers: (Subtract from Above)

	Area of Waste Footprint (Acres) =	21.1
1.5 feet	Soil Liner (CY) =	(51,062)
2 feet	LCS/Protective Cover (CY) =	(68,083)
	Sum (CY) =	(119,145)
	Gross Capacity (CY) =	1,402,016

Net (Waste) Capacity:

Adjustment For Other Layers: (Subtract from Above)

	Area of Final Cover (Ac.) =	8.8	(Partial Final Cover included in Gross Capacity)
2 feet	Vegetative Soil Layer (CY) =	(28,395)	
	Sum (CY) =	(28,395)	
	Volume of Waste and Periodic Cover (CY) =	1,373,622	
	Volume of Periodic Cover (CY) =	(206,043)	
	Net (Waste) Capacity (CY) =	1,167,578	
	Net (Waste) Capacity (Tons) =	700,547	

Life Expectancy Calculations:

Landfill Life Expectancy (Low Disposal Rate) (Years) =	7.8	Based on 90,000 Tons per Year
Landfill Life Expectancy (High Disposal Rate) (Years) =	5.8	Based on 120,000 Tons per Year

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PROJECT	**Johnston County MSW Landfill**	SHEET	6/22
		JOB #	JOHNSTON-13-4
SUBJECT	**Capacity Evaluation - Phase 7**	DATE	12/6/2013
		COMPUTED BY	PKS
		CHECKED BY	

Waste & Periodic Cover Parameters:

Waste Density (PCY) =	1,200	(Assumed)
Waste Density (TCY) =	0.60	
Percentage of Periodic Cover =	15	

Volume Calculations:

Gross Capacity (Top of Protective Cover to Top of Final Cover):

Volume From AutoCAD (CY) =	1,870,795	(Phase 7 Subgrade to Top of Phase 7 Fill)

Adjustment For Other Layers: (Subtract from Above)

	Area of Waste Footprint (Acres) =	19.8
1.5 feet	Soil Liner (CY) =	(47,916)
2 feet	LCS/Protective Cover (CY) =	(63,888)
	Sum (CY) =	(111,804)
	Gross Capacity (CY) =	1,758,991

Net (Waste) Capacity:

Adjustment For Other Layers: (Subtract from Above)

	Area of Final Cover (Ac.) =	12.0	(Partial Final Cover included in Gross Capacity)
2 feet	Vegetative Soil Layer (CY) =	(38,720)	
	Sum (CY) =	(38,720)	
	Volume of Waste and Periodic Cover (CY) =	1,720,271	
	Volume of Periodic Cover (CY) =	(258,041)	
	Net (Waste) Capacity (CY) =	1,462,230	
	Net (Waste) Capacity (Tons) =	877,338	

Life Expectancy Calculations:

Landfill Life Expectancy (Low Disposal Rate) (Years) =	8.0	Based on 110,000 Tons per Year
Landfill Life Expectancy (High Disposal Rate) (Years) =	5.5	Based on 160,000 Tons per Year

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PROJECT	**Johnston County MSW Landfill**	SHEET	7/22
		JOB #	JOHNSTON-13-4
SUBJECT	**Capacity Evaluation - Phase 8**	DATE	12/6/2013
		COMPUTED BY	PKS
		CHECKED BY	

Waste & Periodic Cover Parameters:

Waste Density (PCY) =	1,200	(Assumed)
Waste Density (TCY) =	0.60	
Percentage of Periodic Cover =	15	

Volume Calculations:

Gross Capacity (Top of Protective Cover to Top of Final Cover):

Volume From AutoCAD (CY) =	1,987,163	(Phase 8 Subgrade to Top of Phase 8 Fill)

Adjustment For Other Layers: (Subtract from Above)

	Area of Waste Footprint (Acres) =	25.2	
1.5 feet	Soil Liner (CY) =	(60,984)	
2 feet	LCS/Protective Cover (CY) =	(81,312)	
	Sum (CY) =	(142,296)	
	Gross Capacity (CY) =	1,844,867	

Net (Waste) Capacity:

Adjustment For Other Layers: (Subtract from Above)

	Area of Final Cover (Ac.) =	26.6	(Partial Final Cover included in Gross Capacity)
2 feet	Vegetative Soil Layer (CY) =	(85,829)	
	Sum (CY) =	(85,829)	
	Volume of Waste and Periodic Cover (CY) =	1,759,038	
	Volume of Periodic Cover (CY) =	(263,856)	
	Net (Waste) Capacity (CY) =	1,495,182	
	Net (Waste) Capacity (Tons) =	897,109	

Life Expectancy Calculations:

Landfill Life Expectancy (Low Disposal Rate) (Years) =	8.2	Based on 110,000 Tons per Year
Landfill Life Expectancy (High Disposal Rate) (Years) =	5.6	Based on 160,000 Tons per Year

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PROJECT	**Johnston County MSW Landfill**	SHEET	8/22
		JOB #	JOHNSTON-13-4
SUBJECT	**Capacity Evaluation - Phase 9**	DATE	12/6/2013
		COMPUTED BY	PKS
		CHECKED BY	

Waste & Periodic Cover Parameters:

Waste Density (PCY) =	1,400	(Assumed)
Waste Density (TCY) =	0.70	
Percentage of Periodic Cover =	15	

Volume Calculations:

Gross Capacity (Top of Protective Cover to Top of Final Cover):

Volume From AutoCAD (CY) =	6,811,964	(Phase 9 Subgrade to Top of Phase 9 Fill)

Adjustment For Other Layers: (Subtract from Above)

	Area of Waste Footprint (Acres) =	22.5
1.5 feet	Soil Liner (CY) =	(54,450)
2 feet	LCS/Protective Cover (CY) =	(72,600)
	Sum (CY) =	(127,050)
	Gross Capacity (CY) =	6,684,914

Net (Waste) Capacity:

Adjustment For Other Layers: (Subtract from Above)

	Area of Final Cover (Ac.) =	25.7	(Partial Final Cover included in Gross Capacity)
2 feet	Vegetative Soil Layer (CY) =	(82,925)	
	Sum (CY) =	(82,925)	
	Volume of Waste and Periodic Cover (CY) =	6,601,989	
	Volume of Periodic Cover (CY) =	(990,298)	
	Net (Waste) Capacity (CY) =	5,611,690	
	Net (Waste) Capacity (Tons) =	3,928,183	

Life Expectancy Calculations:

Landfill Life Expectancy (Low Disposal Rate) (Years) =	35.7	Based on 110,000 Tons per Year
Landfill Life Expectancy (High Disposal Rate) (Years) =	24.6	Based on 160,000 Tons per Year

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PROJECT	**Johnston County MSW Landfill**	SHEET	9/22
		JOB #	JOHNSTON-13-4
SUBJECT	**Capacity Evaluation - Phase 10**	DATE	12/6/2013
		COMPUTED BY	PKS
		CHECKED BY	

Waste & Periodic Cover Parameters:

Waste Density (PCY) =	1,400	(Assumed)
Waste Density (TCY) =	0.70	
Percentage of Periodic Cover =	15	

Volume Calculations:

Gross Capacity (Top of Protective Cover to Top of Final Cover):

Volume From AutoCAD (CY) =	3,174,785	(Phase 10 Subgrade to Top of Phase 10 Fill)

Adjustment For Other Layers: (Subtract from Above)

	Area of Waste Footprint (Acres) =	17.5	
1.5 feet	Soil Liner (CY) =	(42,350)	
2 feet	LCS/Protective Cover (CY) =	(56,467)	
	Sum (CY) =	(98,817)	

Adjustment For Other Layers: (Add to Above)

	Area of Final Cover (Ac.) =	19.2	(Phase 5 Area)
2 feet	Vegetative Soil Layer (CY) =	61,952	
	Sum (CY) =	61,952	
	Gross Capacity (CY) =	3,137,920	

Net (Waste) Capacity:

Adjustment For Other Layers: (Subtract from Above)

	Area of Final Cover (Ac.) =	52.2	(Partial Final Cover included in Gross Capacity) (Remaining Area of Ph. 5-10 not Accounted For)
2 feet	Vegetative Soil Layer (CY) =	(168,432)	
	Sum (CY) =	(168,432)	
	Volume of Waste and Periodic Cover (CY) =	2,969,488	
	Volume of Periodic Cover (CY) =	(445,423)	
	Net (Waste) Capacity (CY) =	2,524,065	
	Net (Waste) Capacity (Tons) =	1,766,846	

Life Expectancy Calculations:

Landfill Life Expectancy (Low Disposal Rate) (Years) =	16.1	Based on 110,000 Tons per Year
Landfill Life Expectancy (High Disposal Rate) (Years) =	11.0	Based on 160,000 Tons per Year

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PROJECT	**Johnston County C&D Landfill - Area 2**	SHEET	10/22
		JOB #	JOHNSTON-13-5
SUBJECT	**Capacity Evaluation - Filling Rate & Density Calculations**	DATE	12/6/2013
		COMPUTED BY	PKS
		CHECKED BY	

Density and Filling Rate Calculations:

Start Date	Period of Interest End Date	Total Time (years)	Volume Filled (cy)	Quantity of Waste Disposed (tons)	Waste Filling Rate* (lbs/cy)	Periodic Cover Assumed %	Periodic Cover Volume (cy)	Waste Volume (cy)	Waste Density** (lbs/cy)	Cumulative Waste Density*** (lbs/cy)
7/18/2007	6/6/2008	0.89	60,989	34,021	**1,116**	10	6,099	54,890	**1,240**	**1,240**
6/7/2008	6/19/2009	1.03	75,914	30,772	**811**	10	7,591	68,323	**901**	**1,052**
6/20/2009	6/11/2010	0.98	42,593	23,010	**1,080**	10	4,259	38,334	**1,201**	**1,087**
6/12/2010	6/17/2011	1.01	56,430	24,462	**867**	10	5,643	50,787	**963**	**1,057**
6/18/2011	5/31/2012	0.95	46,418	18,881	**814**	10	4,642	41,776	**904**	**1,032**
6/1/2012	6/14/2013	1.04	43,175	20,842	**965**	10	4,318	38,858	**1,073**	**1,038**
	Totals:	**5.90**	**325,519**	**151,988**			**32,552**	**292,967**		

Current Cumulative Waste Density = 1,038 lbs/cy

*Waste Filling Rate = (Tons of Waste Disposed)/(Volume Filled).
**Waste Density = (Tons of Waste Disposed)/(Volume Filled - Volume of Periodic Cover).
***Cumulative Waste Density = (Total Tons of Waste Disposed)/(Total Volume Filled - Total Volume of Periodic Cover).

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PROJECT	**Johnston County C&D Landfill**	SHEET	11/22
		JOB #	JOHNSTON-13-4
SUBJECT	**Capacity Evaluation - Area 2 - Cell 1**	DATE	12/6/2013
		COMPUTED BY	PKS
		CHECKED BY	

Waste & Periodic Cover Parameters:

Waste Density (PCY) =	1,000	(From Filling Rate and Density Calcs.) (Based on Recent)
Waste Density (TCY) =	0.50	
Percentage of Periodic Cover =	10	

Volume Calculations:

Gross Capacity Used (Top of Protective Cover to Top of Final Cover):

Gross Capacity Used (CY) =	323,132	(Top of Protective Cover to June 14, 2013 Topo.)
		(Determined as Permitted Capacity - Gross Capacity Remaining)
Waste Disposed (Tons) =	151,988	(Per Site Records 7/18/2007 through 6/14/2013)

Gross Capacity Remaining (Top of Protective Cover to Top of Final Cover):

Volume From AutoCAD (CY) =	87,544	(Compared with June 14, 2013 Topo.)
	(= Gross Capacity Remaining)	

Net (Waste) Capacity Remaining:

Adjustment For Other Layers: (Subtract from Above)

Area of Final Cover (Ac.) =	5.7	(Partial Final Cover included in Gross Capacity)
2 feet Vegetative Soil Layer (CY) =	(18,392)	
Sum (CY) =	(18,392)	
Volume of Waste and Periodic Cover (CY) =	69,152	
Volume of Periodic Cover (CY) =	(6,915)	
Net (Waste) Capacity Remaining (CY) =	62,237	
Net (Waste) Capacity Remaining (Tons) =	31,118	

Life Expectancy Calculations:

Landfill Life Expectancy (Low Disposal Rate) (Years) =	1.6	Based on 20,000 Tons per Year
Landfill Life Expectancy (High Disposal Rate) (Years) =	0.8	Based on 40,000 Tons per Year

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PROJECT	**Johnston County C&D Landfill**	SHEET	12/22
		JOB #	JOHNSTON-13-4
SUBJECT	**Capacity Evaluation - Area 2 - Cell 2**	DATE	12/6/2013
		COMPUTED BY	PKS
		CHECKED BY	

Waste & Periodic Cover Parameters:

Waste Density (PCY) =	1,200	(Assumed)
Waste Density (TCY) =	0.60	
Percentage of Periodic Cover =	10	

Volume Calculations:

Gross Capacity (Cell 1/Cell 2 Protective Cover to Top of Final Cover):

Volume From AutoCAD (CY) =	462,658	(Compared with Cell 1 Fill Grades)
	(= Gross Capacity)	

Net (Waste) Capacity:

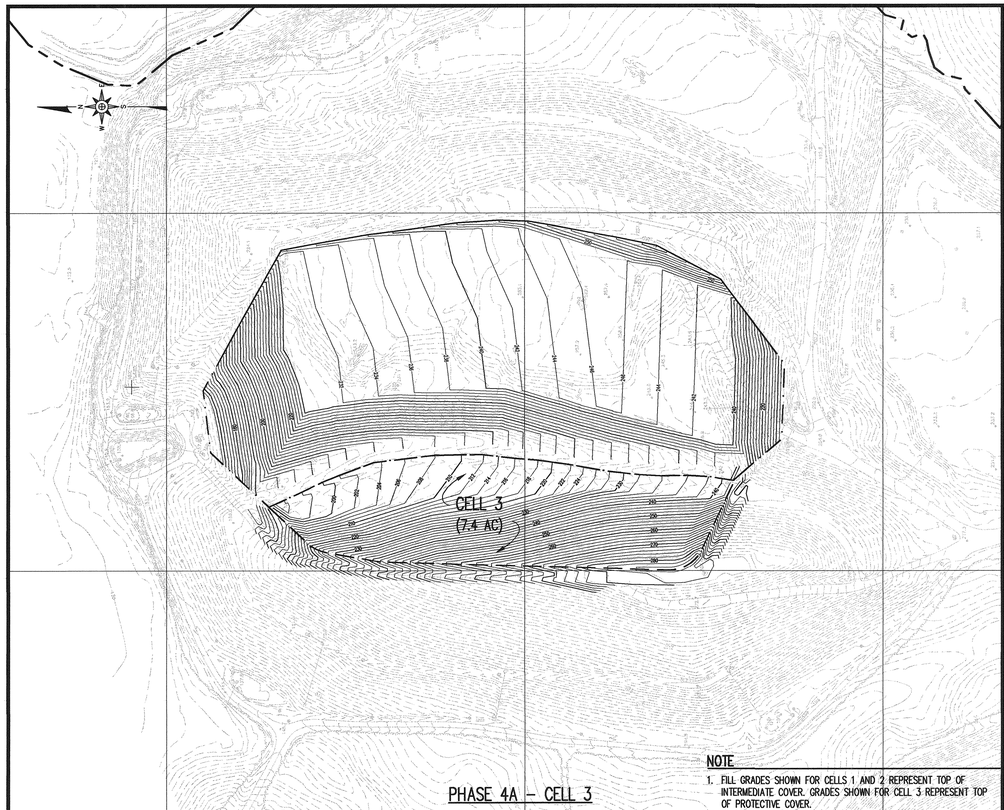
Adjustment For Other Layers: (Subtract from Above)

	Area of Final Cover (Ac.) =	10.1	(Partial Final Cover included in Gross Capacity)
2 feet	Vegetative Soil Layer (CY) =	(32,589)	
	Sum (CY) =	(32,589)	
	Volume of Waste and Periodic Cover (CY) =	430,069	
	Volume of Periodic Cover (CY) =	(43,007)	
	Net (Waste) Capacity (CY) =	387,062	
	Net (Waste) Capacity (Tons) =	232,237	

Life Expectancy Calculations:

Landfill Life Expectancy (Low Disposal Rate) (Years) =	11.6	Based on 20,000 Tons per Year
Landfill Life Expectancy (High Disposal Rate) (Years) =	5.8	Based on 40,000 Tons per Year

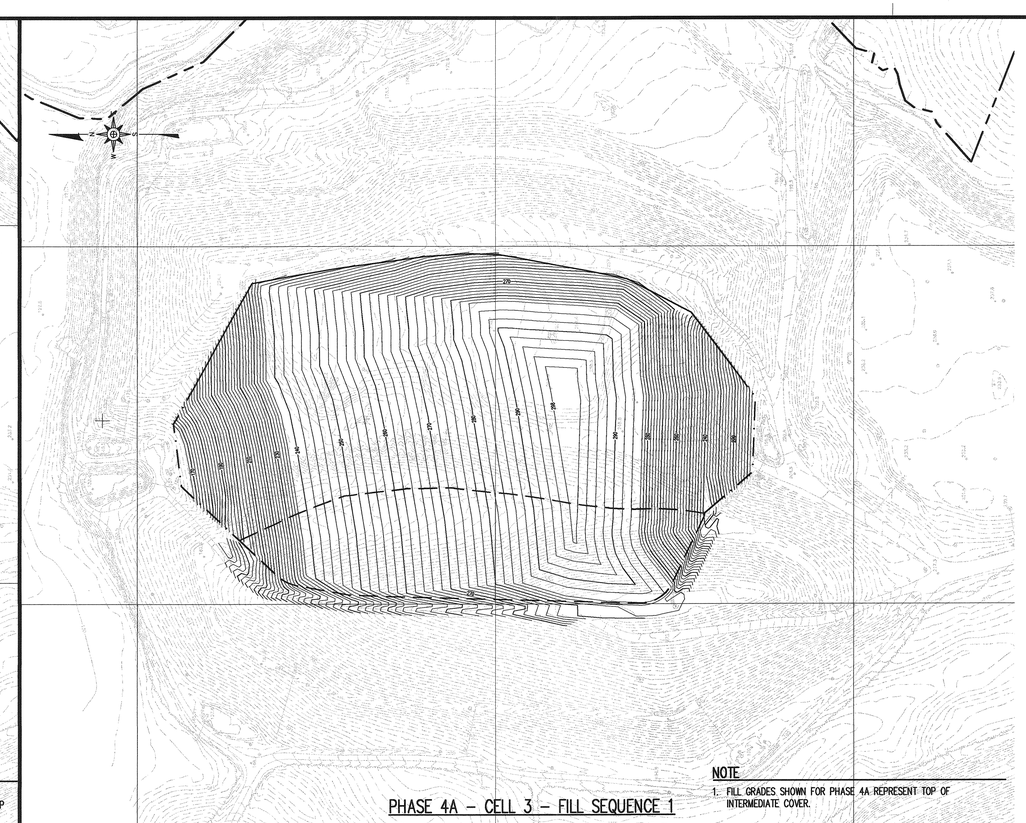
SMITH+GARDNER



PHASE 4A – CELL 3

NOTE

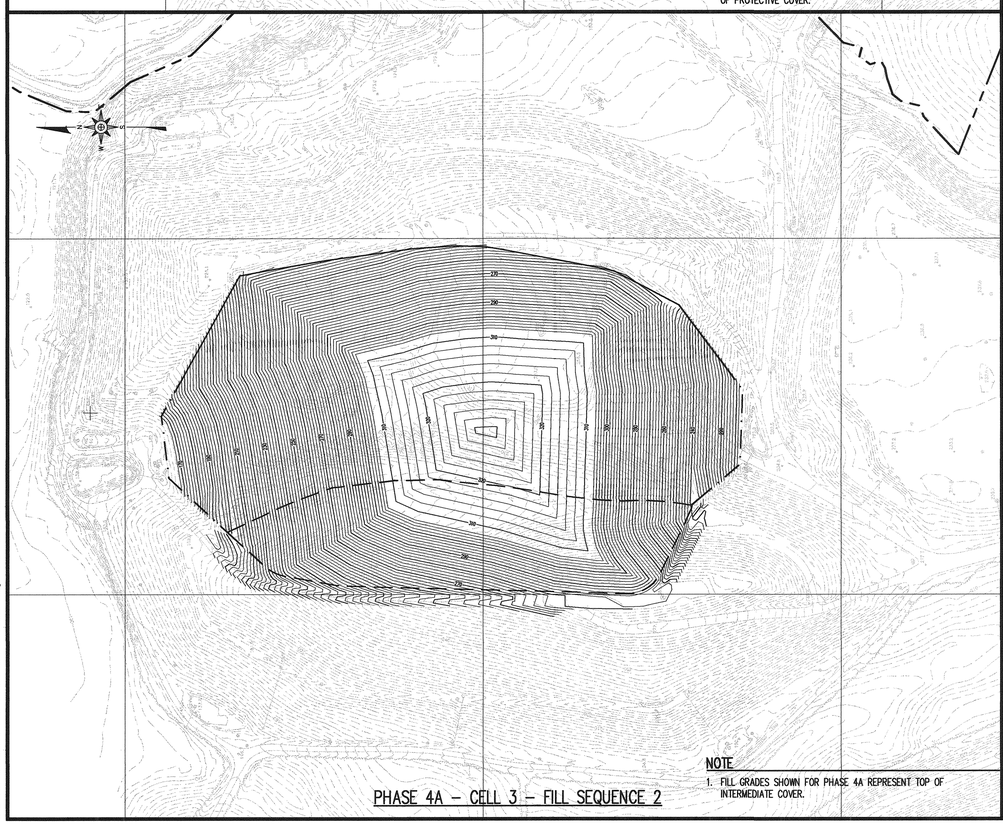
1. FILL GRADES SHOWN FOR CELLS 1 AND 2 REPRESENT TOP OF INTERMEDIATE COVER. GRADES SHOWN FOR CELL 3 REPRESENT TOP OF PROTECTIVE COVER.



PHASE 4A – CELL 3 – FILL SEQUENCE 1

NOTE

1. FILL GRADES SHOWN FOR PHASE 4A REPRESENT TOP OF INTERMEDIATE COVER.



PHASE 4A – CELL 3 – FILL SEQUENCE 2

NOTE

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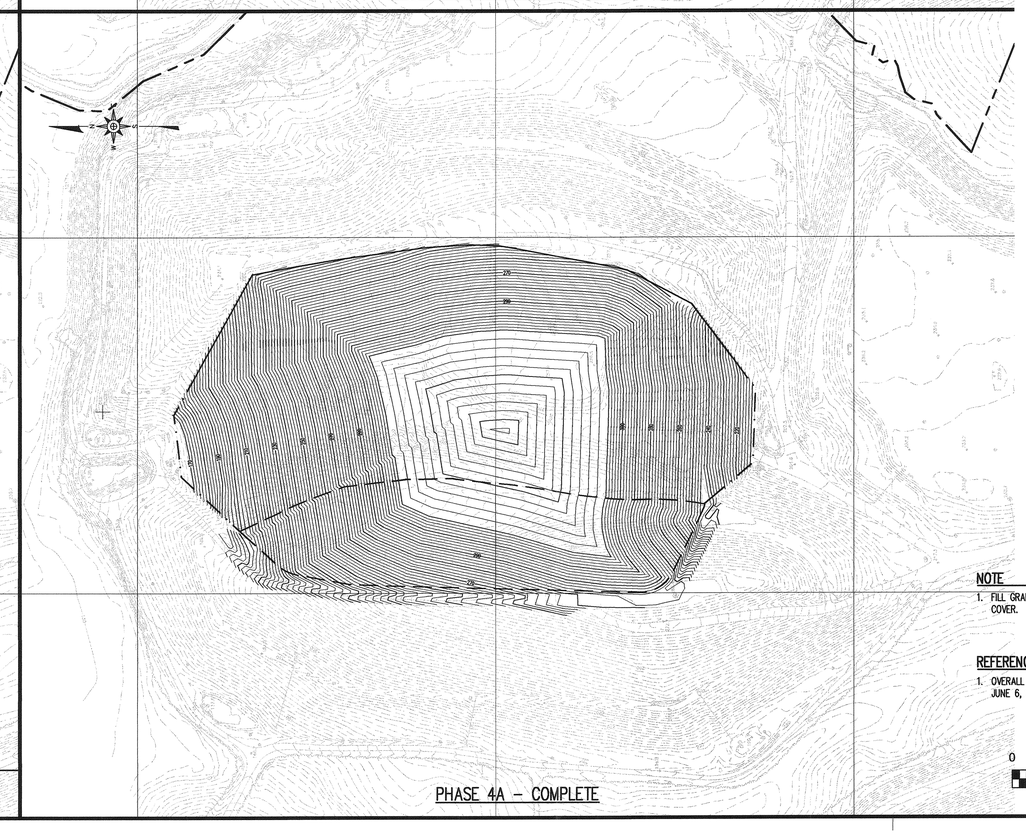

PHASE 4A – COMPLETE

NOTE

1. FILL GRADES SHOWN FOR PHASE 4A REPRESENT TOP OF FINAL COVER.

REFERENCE

1. OVERALL SITE TOPOGRAPHY PROVIDED BY GEODATA CORP., BASED ON JUNE 6, 2008 AERIAL PHOTOGRAPHY.

0 200' 400' 600'

NO.	DATE	REVISION
1	11/08	RESPONSE TO NCDENR COMMENTS AND ADDITIONAL CHANGES

RICHARDSON SMITH GARDNER & ASSOCIATES
Engineering and Geological Services
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Raleigh, N.C. 27603
www.rsgengineers.com
ph: 919-828-0577
fax: 919-828-3899

SEAL

SEAL

PROJECT TITLE:
JOHNSTON COUNTY MSW LANDFILL
PHASE 4A - CELL 3
PERMIT AMENDMENT DRAWINGS

DRAWING TITLE:
MSW LANDFILL PHASING PLAN
(SHEET 1 OF 3)

DESIGNED BY: P.K.S.	DRAWN BY: J.A.L.
CHECKED BY:	PROJECT NO.: JOHN 07-2
SCALE: AS SHOWN	DATE: JUNE 2007
FILE NAME: JOHN-D0503A	
SHEET NO. 22	DRAWING NO. P1

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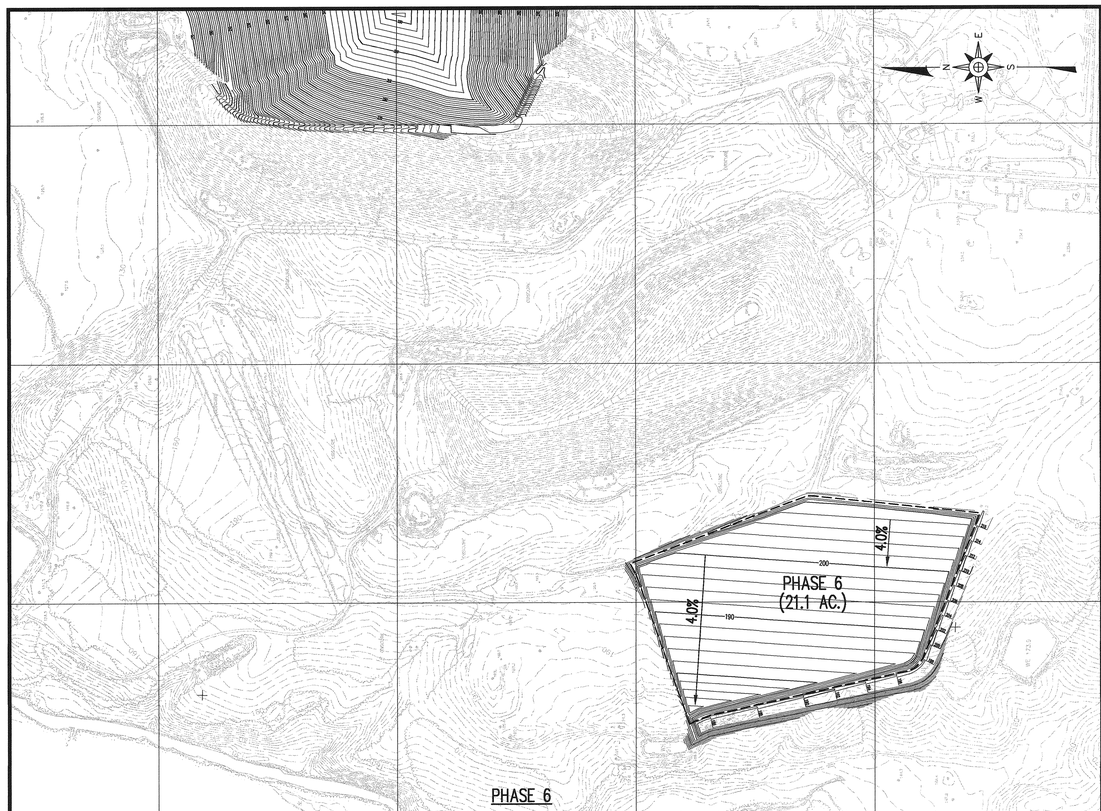

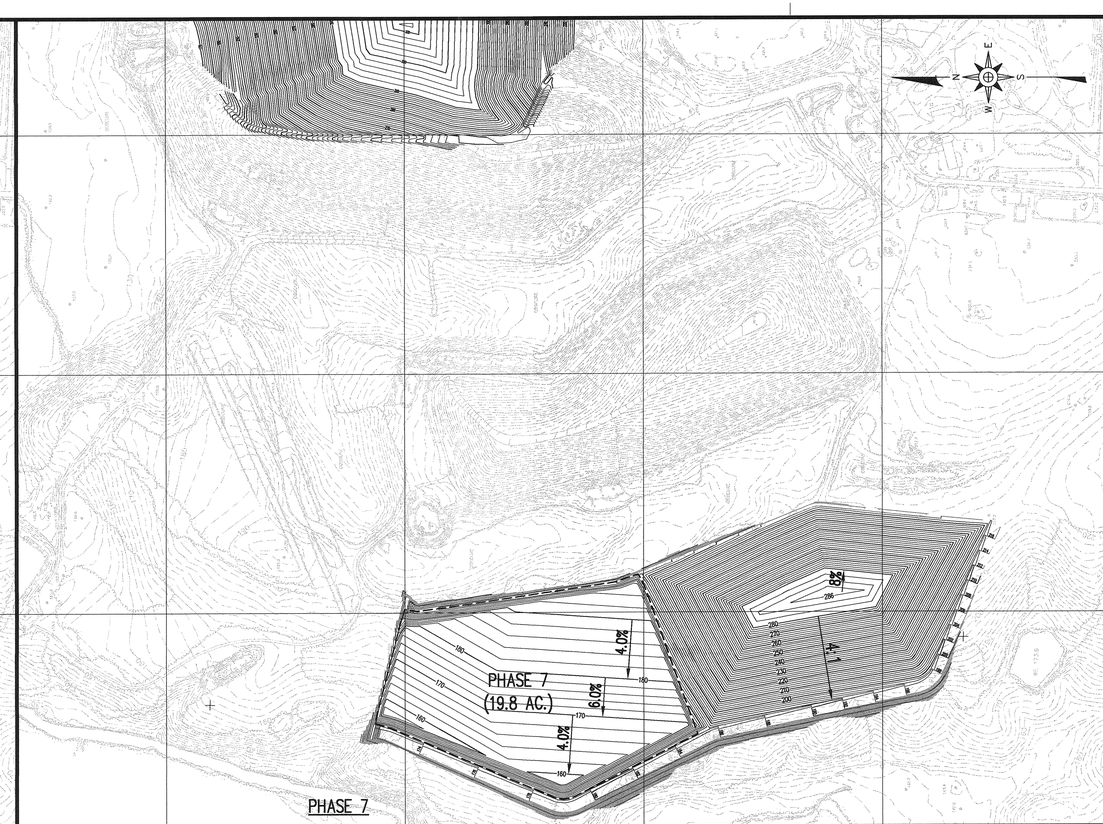

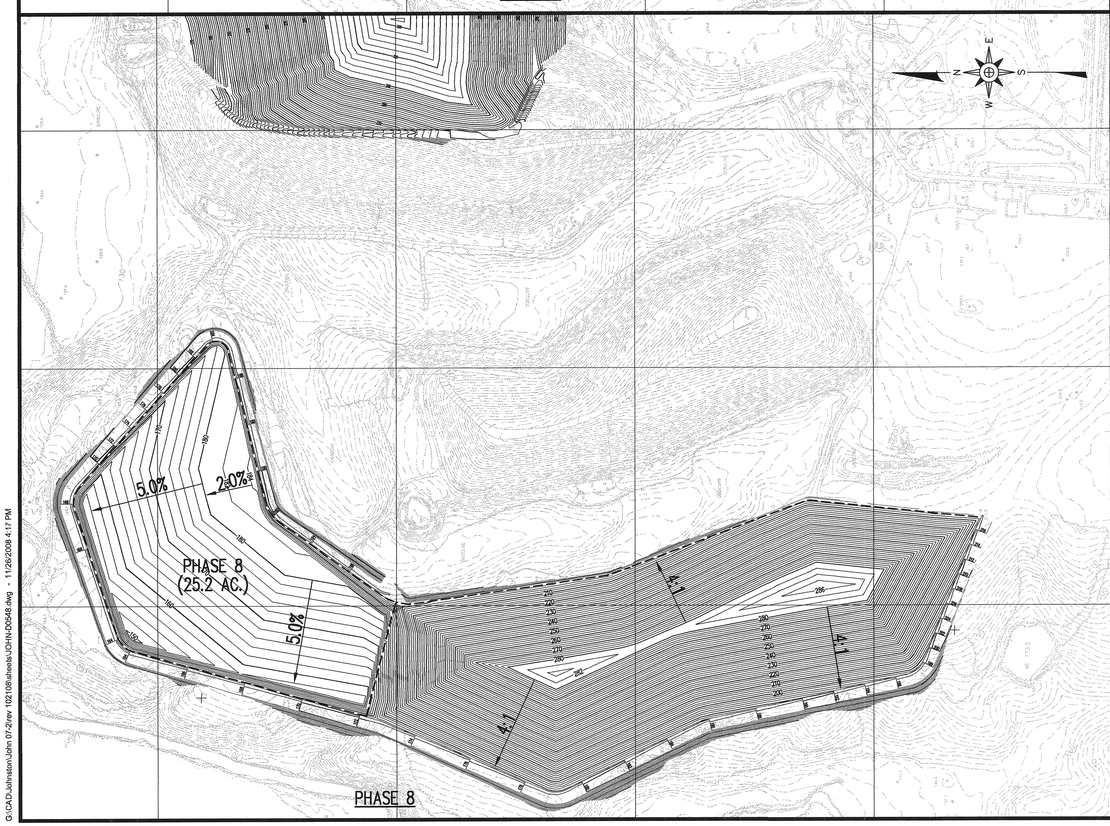

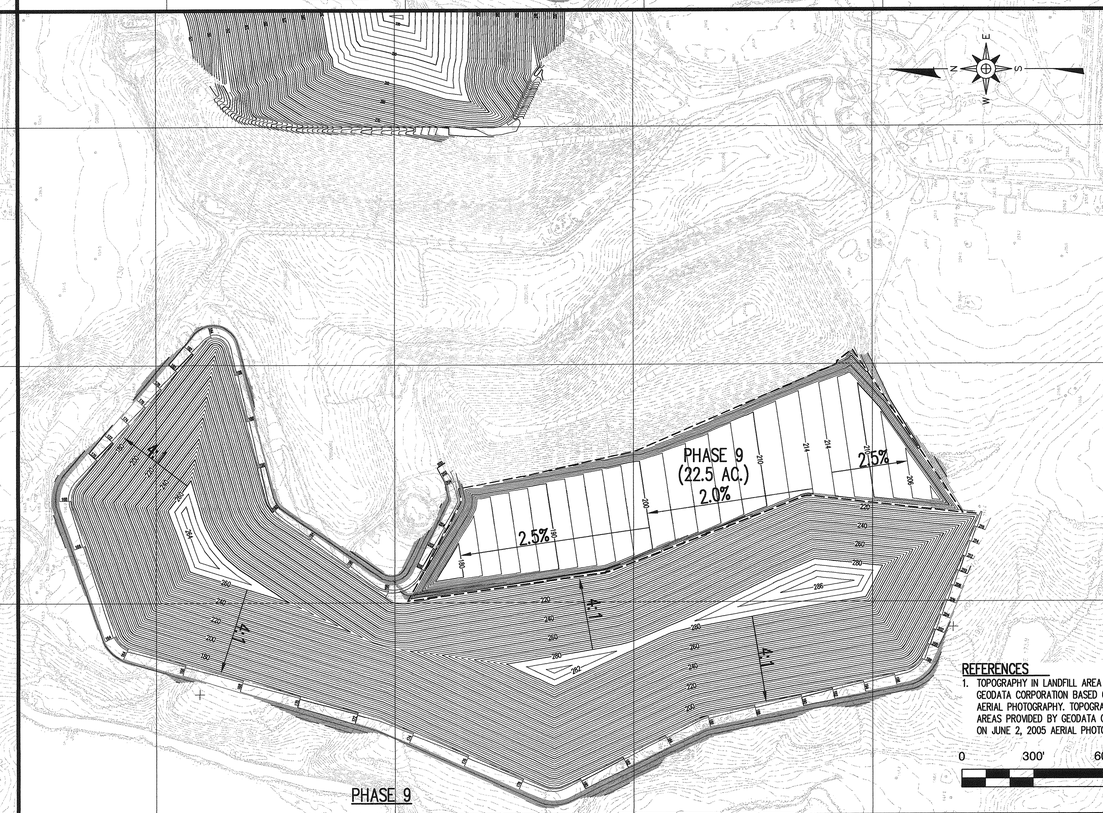

REFERENCES

1. TOPOGRAPHY IN LANDFILL AREA PROVIDED BY GEODATA CORPORATION BASED ON JUNE 6, 2008 AERIAL PHOTOGRAPHY. TOPOGRAPHY IN OTHER AREAS PROVIDED BY GEODATA CORPORATION BASED ON JUNE 2, 2005 AERIAL PHOTOGRAPHY.

0 300' 600' 900'

DATE	NO.	REVISION
11/08	1	RESPONSE TO NCDENR COMMENTS AND ADDITIONAL CHANGES

RICHARDSON SMITH GARDNER & ASSOCIATES
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www.rsgengineers.com

SEAL

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PROJECT TITLE:
JOHNSTON COUNTY MSW LANDFILL
PHASE 4A - CELL 3
PERMIT AMENDMENT DRAWINGS

DRAWING TITLE:
MSW LANDFILL PHASING PLAN
(SHEET 2 OF 3)

DESIGNED BY: P.K.S.	DRAWN BY: J.A.L.
CHECKED BY:	PROJECT NO.: JOHN 07-2
SCALE: AS SHOWN	DATE: JUNE 2007
FILE NAME: JOHN-D0548	
SHEET NO. 23	DRAWING NO. P2

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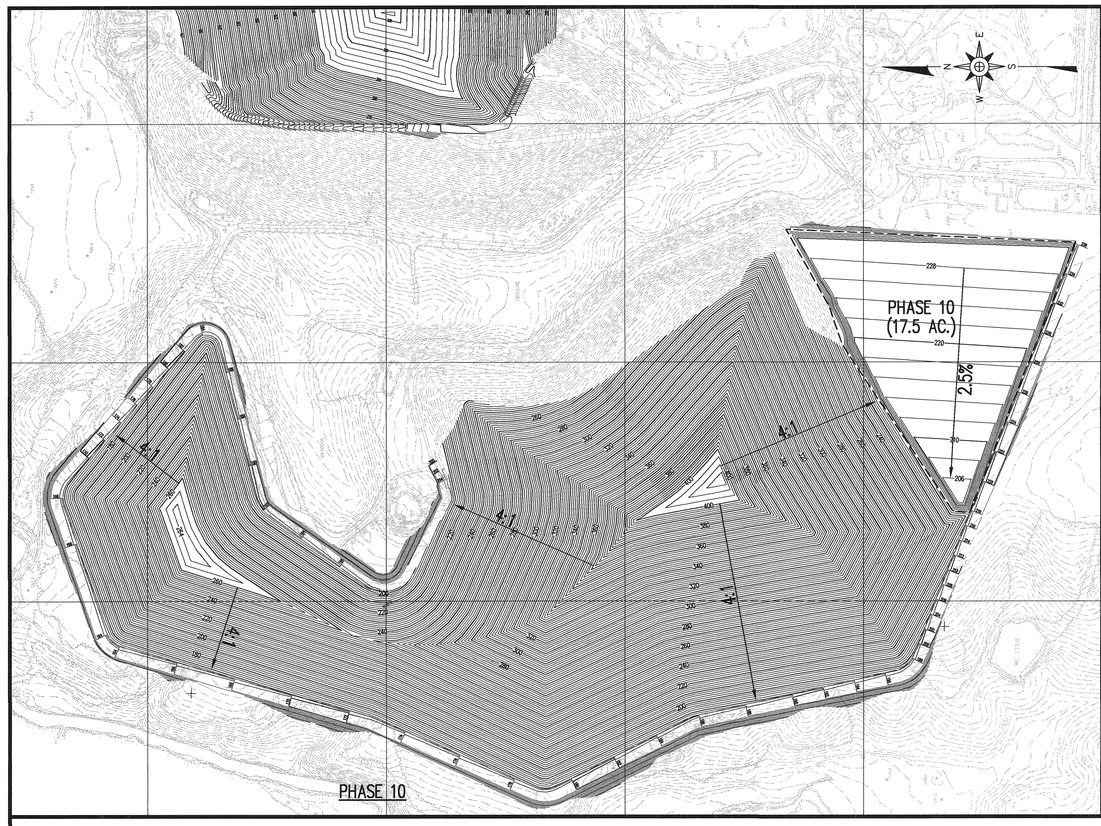
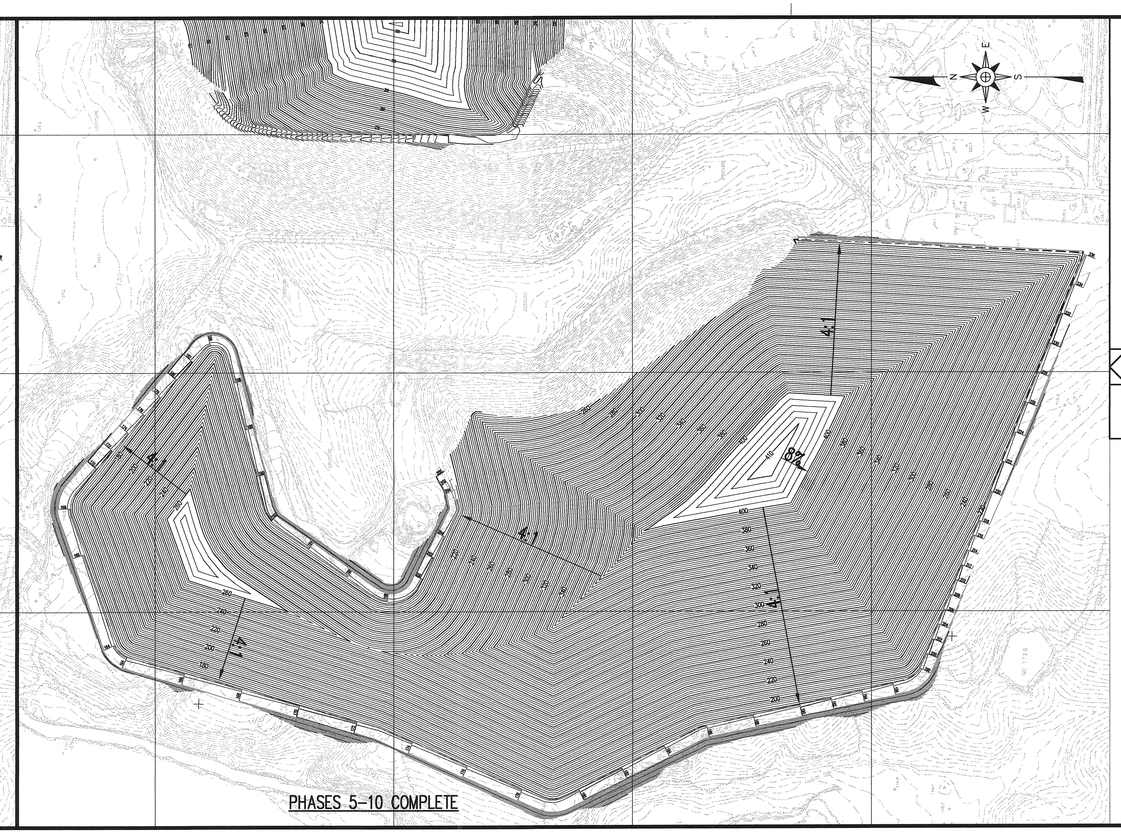


PHASE 10



PHASES 5–10 COMPLETE

REFERENCES

1. TOPOGRAPHY IN LANDFILL AREA PROVIDED BY GEODATA CORPORATION BASED ON JUNE 6, 2008 AERIAL PHOTOGRAPHY. TOPOGRAPHY IN OTHER AREAS PROVIDED BY GEODATA CORPORATION BASED ON JUNE 2, 2005 AERIAL PHOTOGRAPHY.

0 300' 600' 900'

DATE	NO.	REVISION
11/08	1	RESPONSE TO NCDENR COMMENTS AND ADDITIONAL CHANGES

RICHARDSON SMITH GARDNER & ASSOCIATES
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www.rsgengineers.com

SEAL:

SEAL: PETER K. SMITH, REGISTERED PROFESSIONAL ENGINEER, SEAL 010600, NORTH CAROLINA, 10/14/08

PROJECT TITLE:
JOHNSTON COUNTY MSW LANDFILL
PHASE 4A - CELL 3
PERMIT AMENDMENT DRAWINGS

DRAWING TITLE:
MSW LANDFILL PHASING PLAN
(SHEET 3 OF 3)

DESIGNED BY: P.K.S.	DRAWN BY: J.A.L.
CHECKED BY:	PROJECT NO.: JOHN 07-2
SCALE: AS SHOWN	DATE: JUNE 2007
FILE NAME: JOHN-D0549	
SHEET NO. 24	DRAWING NO. P3

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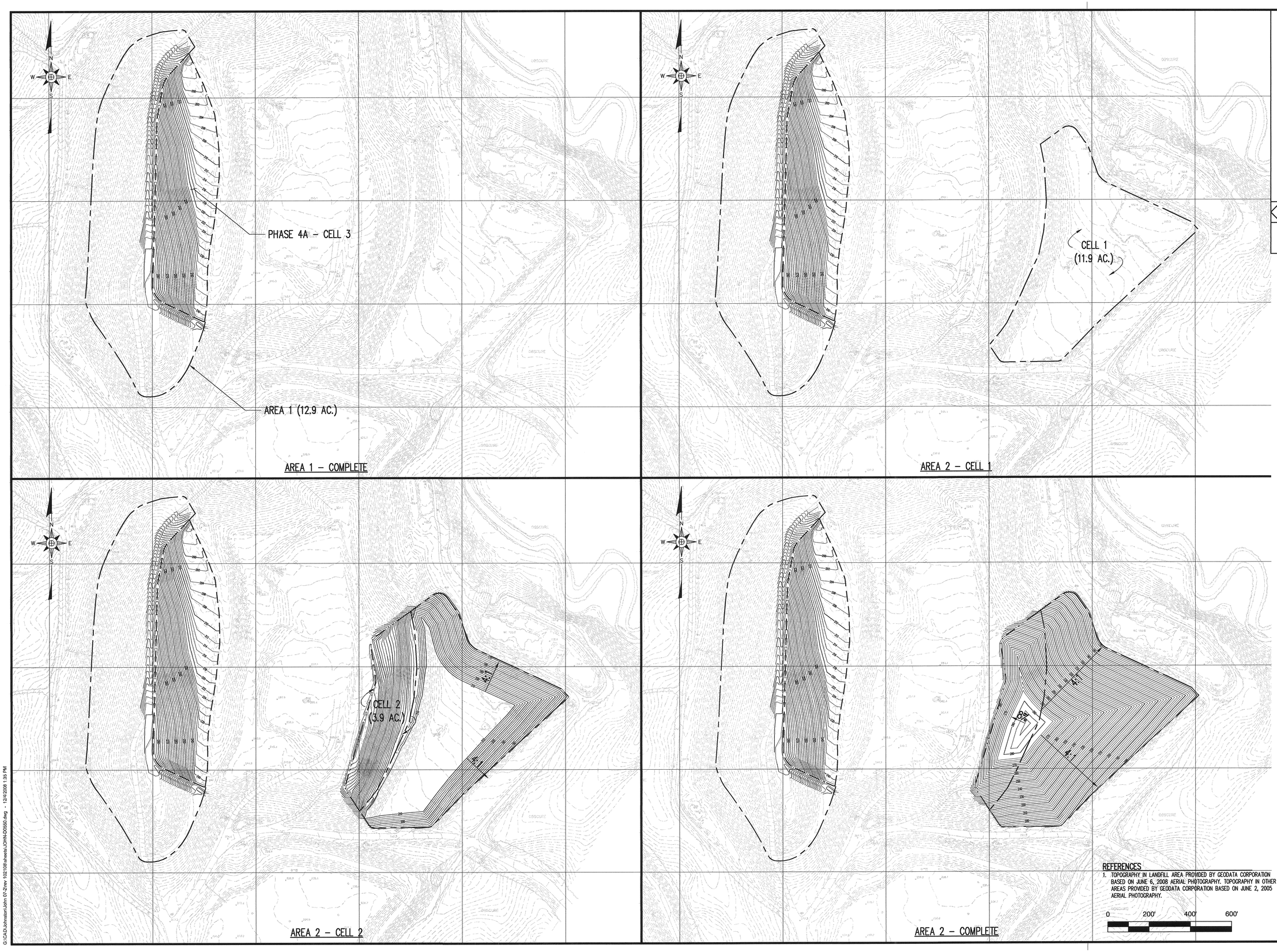

REFERENCES

1. TOPOGRAPHY IN LANDFILL AREA PROVIDED BY GEODATA CORPORATION BASED ON JUNE 6, 2008 AERIAL PHOTOGRAPHY. TOPOGRAPHY IN OTHER AREAS PROVIDED BY GEODATA CORPORATION BASED ON JUNE 2, 2005 AERIAL PHOTOGRAPHY.

0 200' 400' 600'

NO.	REVISION	DATE
1	RESPONSE TO NCDENR COMMENTS AND ADDITIONAL CHANGES	11/08

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fax: 919-828-3899
www.rsgengineers.com

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PROJECT TITLE:
JOHNSTON COUNTY MSW LANDFILL
PHASE 4A - CELL 3
PERMIT AMENDMENT DRAWINGS

DRAWING TITLE:
C&D LANDFILL PHASING PLAN

DESIGNED BY: P.K.S.	DRAWN BY: J.A.L.
CHECKED BY:	PROJECT NO.: JOHN 07-2
SCALE: AS SHOWN	DATE: JUNE 2007
FILE NAME: JOHN-D0550	
SHEET NO. 25	DRAWING NO. P4

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Volume

Base Surface	TOPO 061413
Comparison Surface	FILL_SEQ1

Cut volume (unadjusted)	9,803.81 Cu. Yd.
Fill volume (unadjusted)	608,983.85 Cu. Yd.
Net volume (unadjusted)	599,180.03 Cu. Yd.<Fill>

Richardson Smith Gardner & Associates 12/1/2008

Client
Project
Date

version	date	time	surfBase	surfCompare	volCut	volFill	volNet
1	11/21/2008	17-37-18	TOPO 060608_PASTE-ICVR+PCVR	FILL_SEQ1	533.66	1,421,099.85	1,420,566.19
1	11/21/2008	17-37-18	FILL_SEQ1	FILL_SEQ2	8.55	690,256.14	690,247.59
1	11/21/2008	17-37-18	FILL_SEQ2	FCVR_112108	298.30	56,531.88	56,233.58

12/19

volume report 092905.txt

Site Volume Table: Unadjusted

	Cut yards	Fill yards	Net yards	Method
Site: SITE2				
PH6 Stratum: sgrd-cell-6-10 to fcvr-cell-6 sgrd-cell6-10 fcvr-cell6	491	1,521,652	1,521,161	(F) Composite
~~Stratum: sgrd-cell-6-10 to fcvr-cell-7 sgrd-cell6-10 fcvr-cell7~~	~~1,037~~	~~3392987~~	~~3,391,950~~	~~(F) Composite~~
PH8 Stratum: paste-sgrd-ph7-to-fcvr-6-8 paste-sgrd-cell6-10-to-fcvr-7 fcvr-cell6-8	100	1,987,263	1,987,163	(F) Composite
PH.7 Stratum: paste-sgrd-fcvr-ph6 to fcvr-cell7 paste-sgrd-cell6-10-to-fcvr-6 fcvr-cell7	547	1,871,341	1,870,795	(F) Composite
Stratum: topo 032105 to sgrd cell 6 topo-032105 sgrd-cell-6	279,493	55,613	223,879	(C) Composite
Stratum: topo 032105 to sgrd cell 7 topo-032105 sgrd-cell7	222,037	85,202	136,834	(C) Composite
Stratum: topo 032105 to sgrd cell 8 topo-032105 sgrd-cell8	242,630	105,976	136,654	(C) Composite
Stratum: topo 032105 to sgrd cell 9 topo-032105 sgrd-cell9	68,999	178,758	109,759	(F) Composite
Stratum: topo 032105 to sgrd cell 10 topo-032105 sgrd-cell10	151,736	21,326	130,410	(C) Composite

volume report 090905.txt

```
Project: land projects                              Fri September 09 16:53:05 2005
                     Site Volume Table: Unadjusted
                 Cut              Fill              Net
                yards           yards           yards      Method
=====================================================================

Site: CELL 6-10

  Stratum: cell 6-10 fcvr airspace  sgrd-cell6-10  fcvr-cell6-10
                       30         15,374,052         15,374,022 (F) Composite

  Stratum: cell 6-10 sgrd cut-fill  topo-032105  sgrd-cell6-10
                  962,425            431,448            530,977 (C) Composite


  Stratum: cell 6-8 fcvr airspace  sgrd-cell6-10  fcvr-cell6-8
                        1          5,386,536          5,386,535 (F) Composite

  Stratum: cell 9 fcvr airspace  sgrd-cell6-10-fcvr8-paste  fcvr-cell9
                       82          6,812,047          6,811,964 (F) Composite

  Stratum: cell 10 fcvr airspace  sgrd-cell6-10-fcvr9-paste  fcvr-cell10
                        0          3,174,786          3,174,785 (F) Composite
```

Volume

Base Surface	TOPO 061413
Comparison Surface	CD AREA 2_FCVR CELL 2
Cut volume (unadjusted)	19,534.63 Cu. Yd.
Fill volume (unadjusted)	107,078.96 Cu. Yd.
Net volume (unadjusted)	87,544.33 Cu. Yd.<Fill>

Index	Surface Pair		Volume			
	Base Surface	Comparison Surface	Cut	Fill	Net	Net Graph
1	TOPO-060205	SGRD	44610.31 Cu. Yd.	77951.65 Cu. Yd.	33341.34 Cu. Yd. <Fill>	
2	PCVR	PCVR CELL 1	302.14 Cu. Yd.	451912.78 Cu. Yd.	451610.63 Cu. Yd. <F...	
3	PCVR CELL 1 PASTE	PCVR	67.90 Cu. Yd.	462726.08 Cu. Yd.	462658.18 Cu. Yd. <F...	

SMITH+GARDNER	ADDRESS	TEL	WEB
	14 N. Boylan Avenue, Raleigh, NC 27603	919.828.0577	www.smithgardnerinc.com

PROJECT Johnston County Landfill SHEET 1 OF 4 DATE 12/1/2013

COMPUTED BY PKS

SUBJECT Earthwork Quantities JOB # JOHNSTON-13-4 CHECKED BY

OBJECTIVE: To determine the earthwork and related material quantities associated with the construction and operation of the landfill.

ANALYSIS: The volumes of each material were calculated by taking design thicknesses and/or cross sections and multiplying by design areas and/or lengths. Areas and lengths were determined using AutoCAD, a planimeter, and/or direct measurement.

PROJECT Johnston County Landfill

SUBJECT Earthwork Quantities - Summary

SHEET 2/4
JOB # JOHNSTON-13-4
DATE 12/1/2013
COMPUTED BY PKS
CHECKED BY

Landfill Unit	Area (Acres)	General Earthwork		Soil Liner (CY)	LCS/Pro. Cover (CY)	Periodic Cover (CY)	Vegetative Soil Layer (CY)
		Cut (CY)	Fill (CY)				
MSW Phase 4A F.S. 1 Remaining	29.4	-----	-----	-----	-----	89,877	-----
MSW Phase 4A F.S. 2		-----	-----	-----	-----	103,537	94,864
MSW Phase 5	19.2	-----	-----	-----	-----	-----	61,952
MSW Phase 6	21.1	279,493	55,613	51,062	68,083	206,043	68,083
MSW Phase 7	19.8	222,037	85,202	47,916	63,888	258,041	63,888
MSW Phase 8	25.2	242,630	105,976	60,984	81,312	263,856	81,312
MSW Phase 9	22.5	68,999	178,758	54,450	72,600	990,298	72,600
MSW Phase 10	17.5	151,736	21,326	42,350	56,467	445,423	56,467
C&D Area 2 - Cell 1 Remaining	11.9	-----	-----	-----	-----	6,915	-----
C&D Area 2 - Cell 2	3.9	0	3,436	6,292	12,584	43,007	50,981
Totals (CY) =	**170.5**	**964,895**	**450,311**	**263,054**	**354,933**	**2,406,997**	**550,147**
Location (On-Site/Off-Site):		On-Site	On-Site	On/Off-Site	On-Site	On-Site	On-Site
						On-Site Soil Balance (CY) =	**(3,060,547)**

SMITH+GARDNER

volume report 092905.txt

Site Volume Table: Unadjusted

	Cut yards	Fill yards	Net yards	Method
Site: SITE2				
PH6 Stratum: sgrd-cell-6-10 to fcvr-cell-6 sgrd-cell6-10 fcvr-cell6	491	1,521,652	1,521,161	(F) Composite
~~Stratum: sgrd-cell-6-10 to fcvr-cell-7 sgrd-cell6-10 fcvr-cell7~~	~~1,037~~	~~3392987~~	~~3,391,950~~	~~(F) Composite~~
PH8 Stratum: paste-sgrd-ph7-to-fcvr-6-8 paste-sgrd-cell6-10-to-fcvr-7 fcvr-cell6-8	100	1,987,263	1,987,163	(F) Composite
PH.7 Stratum: paste-sgrd-fcvr-ph6 to fcvr-cell7 paste-sgrd-cell6-10-to-fcvr-6 fcvr-cell7	547	1,871,341	1,870,795	(F) Composite
Stratum: topo 032105 to sgrd cell 6 topo-032105 sgrd-cell-6	279,493	55,613	223,879	(C) Composite
Stratum: topo 032105 to sgrd cell 7 topo-032105 sgrd-cell7	222,037	85,202	136,834	(C) Composite
Stratum: topo 032105 to sgrd cell 8 topo-032105 sgrd-cell8	242,630	105,976	136,654	(C) Composite
Stratum: topo 032105 to sgrd cell 9 topo-032105 sgrd-cell9	68,999	178,758	109,759	(F) Composite
Stratum: topo 032105 to sgrd cell 10 topo-032105 sgrd-cell10	151,736	21,326	130,410	(C) Composite

volume report 090905.txt

```
Project: land projects                              Fri September 09 16:53:05 2005
                    Site Volume Table: Unadjusted
                 Cut              Fill              Net
                yards           yards           yards      Method
=====================================================================

Site: CELL 6-10

  Stratum: cell 6-10 fcvr airspace  sgrd-cell6-10  fcvr-cell6-10
                      30          15,374,052         15,374,022 (F) Composite

  Stratum: cell 6-10 sgrd cut-fill  topo-032105  sgrd-cell6-10
                 962,425             431,448            530,977 (C) Composite


  Stratum: cell 6-8 fcvr airspace  sgrd-cell6-10  fcvr-cell6-8
                       1           5,386,536          5,386,535 (F) Composite

  Stratum: cell 9 fcvr airspace  sgrd-cell6-10-fcvr8-paste  fcvr-cell9
                      82           6,812,047          6,811,964 (F) Composite

  Stratum: cell 10 fcvr airspace  sgrd-cell6-10-fcvr9-paste  fcvr-cell10
                       0           3,174,786          3,174,785 (F) Composite
```

PROJECT Johnston County C&D Landfill - Area 2

JOB NO. JOHNSTON-22

DATE 7/14/05

SUBJECT Anchor Trench Analysis

COMPUTED BY PKS

CHECKED BY

Objective To analyze the geomembrane anchor trench to ensure that it will anchor the membrane during normal construction and operation but will pull out before the sheet tears under excessive loads. Note that LLDPE geomembranes do not yield as do HDPE geomembranes.

Assumptions

1. Max. Anchorage (σ_{max}) = 1,300 psi
2. Min. Anchorage (σ_{min}) = 20 psi

Analysis Use the procedure outlined in Equation 3.21 page III-23, "Geosynthetic Design Guidance For Hazardous Waste Landfills & Surface Impoundments."

- Trench Resisting Force (T) (lb/ft):

$$T = \frac{qL\tan\delta + (K_P + K_A)\tan\delta(0.5\gamma d^2 + qd)}{FS_{\min}\cos\beta - \sin\beta\tan\delta}$$

Where:

β = slope angle (degrees)
L = trench set-back from crest (feet)
d = trench depth (feet)
FS_{min} = minimum factor of safety

Backfill Parameters:

ϕ = internal friction angle (degrees)
δ = friction angle between backfill & geomembrane (degrees)
(20 -25+° for textured LLDPE)
γ = backfill unit weight (pcf)
K_A = active soil pressure coef. = $\frac{1-\sin\phi}{1+\sin\phi}$
K_P = Passive Soil Pressure Coefficient
(Varies from K_o (AT REST) = 1 - $\sin\phi$ to $K_P = 1/K_A$)
q = $d\gamma$

Determine T over range of δ. Compute stress in geomembrane by taking T/A, where A = Thickness of Geomembrane (ft) over unit width of 1 foot. Compare stress with allowable anchorage requirements. Also, compare stress of the geomembrane (40 mil LLDPE σ_{break} = 1,500 psi.).

ANCHORTR.WPD

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Raleigh, NC 27603
Tel: 919-828-0577
Fax: 919-828-3899

SHEET: 2 /2
JOB #: JOHNSTON-22
DATE: 7/14/05
BY: PKS
CHKD BY:

Johnston County C&D Landfill - Area 2
Anchor Trench Analysis

Input Parameters:

Side Slope Angle: 18.4 degrees

Geomembrane:

Yield Stress (σ_{max}) = 1,500 psi

Thickness = 0.04 in

Backfill Parameters:

Internal Friction Angle (ϕ)= 25 degrees K_A = 0.41

Unit Weight (γ) = 110 pcf K_P = 2.46

Trench Parameters:

Set-Back (L) = 3.0 feet

Depth (d) = 1.5 feet

$FS_{min.}$ = 1.5

Stress Calculations:

δ	tan δ	T (lb/ft)	Stress in GM (psi)	FS_{break}
10	0.176	201.2	419.1	3.6
15	0.268	312.3	650.7	2.3
20	0.364	434.1	904.3	1.7
25	0.466	570.2	1,187.9	1.3

PROJECT Johnston County C&D Landfill - Area 2

SUBJECT Filter Geotextile Analysis

JOB NO. JOHNSTON-22
DATE 7/14/05
COMPUTED BY PKS
CHECKED BY

Objective

To determine the maximum geotextile apparent opening size (AOS) to provide proper retention to protect drainage media from piping and clogging from adjacent soil. Additionally, to determine the minimum required geotextile permittivity to provide proper drainage from the adjacent soil.

References

Koerner, R.M., Designing With Geosynthetics, Fourth Ed., Prentice Hall, Upper Saddle River, N.J., 1999, pp. 84-91.

Mirafi - Geotextile Filter Design, Application, and Product Selection Guide, Ten Cate Nicolon Corp. (www.mirafi.com).

Analysis

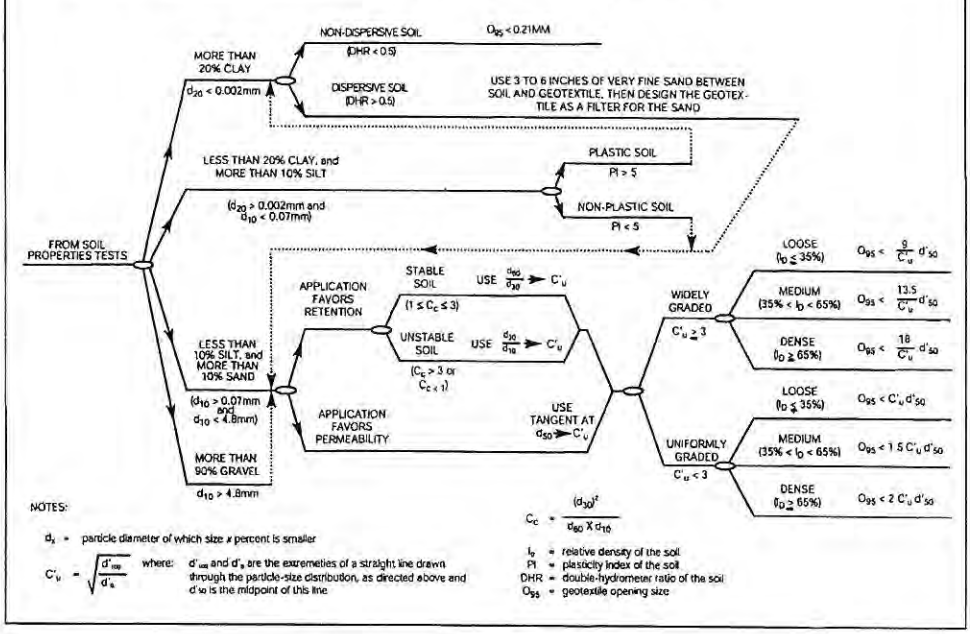
Steps 1 and 2:

Determine the application and function of the geotextile (i.e. where the geotextile is to be used and whether retention or permeability is the key function of the material) and also the confining stress (i.e. high - leachate collection system; low - final cover system) and flow conditions (i.e. steady-state - landfill drains; dynamic - shoreline protection).

Step 3:

Determine the soil retention requirements (maximum AOS). For steady-state conditions, use the following chart.

Chart 1. Soil Retention Criteria of Steady-State Flow Conditions



GT FILTER.WPD

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U.S. Sieve vs. Opening Size:

U.S. Sieve	Opening Size (mm)
100	0.150
80	0.180
70	0.212
60	0.250
50	0.300
40	0.425
30	0.600

Step 4:

Determine the geotextile permittivity requirements:

$$\Psi = \frac{k_g}{t_g} \qquad (\text{sec}^{-1})$$

Where:
Ψ = minimum required geotextile permittivity (sec^{-1})
k_g = minimum allowable geotextile permeability (cm/sec)

$$k_g \geq i_S k_S$$

t_g = geotextile thickness under design load (cm)
i_S = hydraulic gradient (use 1.5 for landfills)
k_S = permeability of retained soil (cm/sec).

Other Considerations:

Other things to consider in the design of a filter geotextile include anti-clogging requirements and survivability/durability requirements. For anti-clogging, it is generally best to use the largest AOS that satisfies the retention criteria. For non-woven geotextiles used in landfill applications, an AOS of 0.21 mm (No. 70 sieve) is typically the largest AOS that is available. For survivability/durability concerns, generally an adequately UV stabilized geotextile made from polypropylene or polyester with an AASHTO M288 Strength Class of 2 is suitable for use in subsurface drainage applications.

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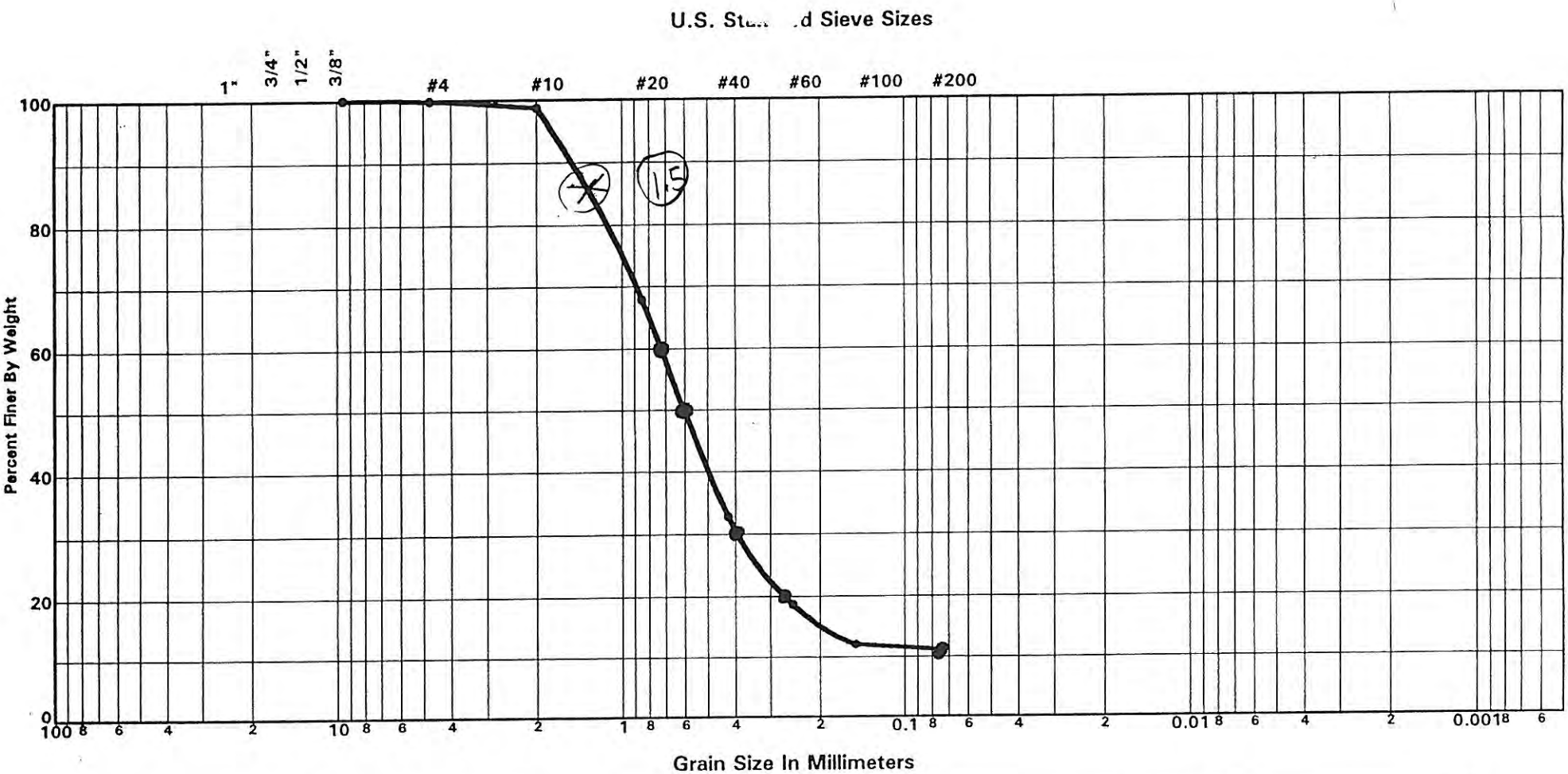
SHEET: 3/5
JOB #: JOHNSTON-22
DATE: 7/14/05
BY: PKS
CHKD BY:

Johnston County C&D Landfill - Area 2
Filter Geotextile Analysis

Application: Drainage Geocomposite (LCS or Final Cover)
Primary Function: Retention
Relative Confining Stress: Low to High
Flow Conditions: Steady-State

	Soil Evaluated		
	B-2	CC-61-P	
Soil Description:	Clayey Silty Sand	Silty Clayey Sand	
Soil Type:	SM	SC-SM	
D_{60}:	0.720	0.340	
D_{50}:	0.600	0.280	
D_{30}:	0.400	0.010	
D_{20}:	0.280	0.001	
D_{10}:	0.007	0.001	
PI:	16	20	
C_c	31.75	0.29	
Soil Dispersion (When Applicable):	Is Soil Dispersive? (Y/N)	Is Soil Dispersive? (Y/N)	
	N	N	
Recommended Maximum AOS (mm) (When Applicable):	**0.210**	**0.210**	
	No. 70 Sieve	**No. 70 Sieve**	
Soil Stability (When Applicable):	NA	NA	
C'_u (When Applicable):			
Soil Relative Density (I_D) (Losse (L), Medium (M), Dense (D) (When Applicable):			
Recommended Maximum AOS (mm) (When Applicable):			
Required Geotextile Properties:	-----	-----	
Hydraulic Gradient (i_g):	1.5	1.5	
Estimated Soil Permeability (k_s) (cm/sec):	5.0E-04	5.0E-04	
Min. Allowable Geotextile Permeability (k_g) (cm/sec):	7.5E-04	7.5E-04	
Geotextile Thickness (t_g) (cm):	0.25	0.25	
Min. Required Geotextile Permittivity (Ψ) (sec^{-1}):	**0.003**	**0.003**	

Typ. Range of Soils
Anticipated As
Protective Cover (LCS)
or Vegetative Soil Layer (FCS)



GRAVEL		SAND			FINES	
COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

Boring No.	Elev./Depth	Nat. W.C.	L.L.	P.L.	P.I.	Soil Description or Classification
2			45.0	29.0	16.0	Orange Slightly Clayey Silty SAND (SM)

Project:

G.N. Richardson & Associates Lab Services
Raleigh, North Carolina

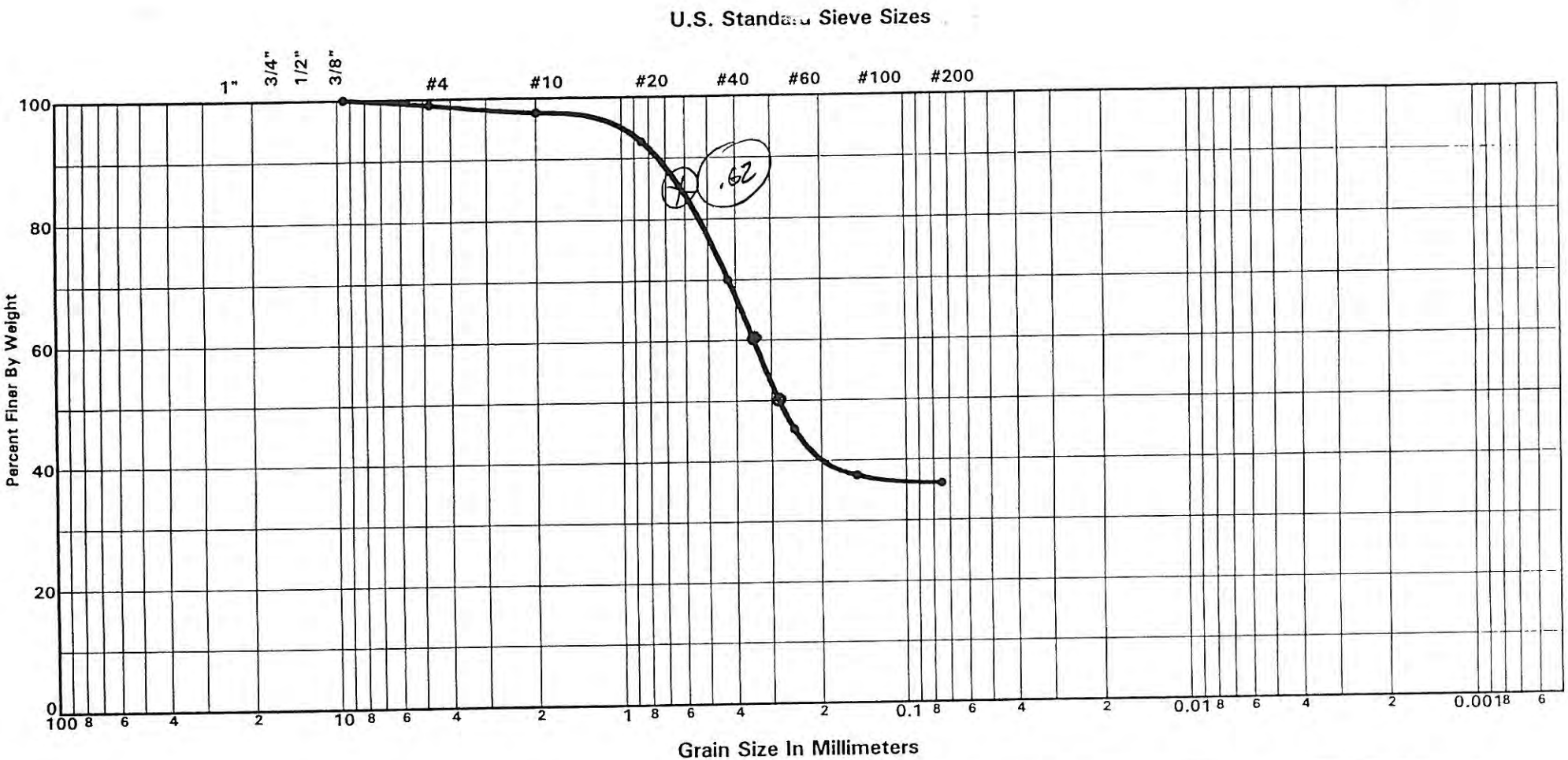
Job No.: 1-95-0084 CA

Date: 4/17/98

GRAIN SIZE DISTRIBUTION

GeoTechnologies, Inc.

4/5



GRAVEL		SAND			FINES	
COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

Boring No.	Elev./Depth	Nat. W.C.	L.L.	P.L.	P.I.	Soil Description or Classification
CC-61-P	3rd Lift		46.0	26.0	20.0	Orange Tan Silty Clayey Medium to Fine SAND (SC-SM)

Project:

Johnston County Landfill
Johnston County, North Carolina

Job No.: 1-98-1034-CA

Date: 12/9/98

GRAIN SIZE DISTRIBUTION

GeoTechnologies, Inc.

5/5

Objective To evaluate the required weight of cushion geotextile to adequately protect the base geomembrane against the possibility of puncture.

Reference Koerner, R.M., Designing With Geosynthetics, Fourth Ed., Prentice Hall, Upper Saddle River, N.J., 1999, pp. 535-537.

Richardson, G.N. (1996), "Field Evaluation of Geosynthetic Protective Cushions," *Geotechnical Fabrics Report*, (vol. 14, no. 2, March), pp. 20-25.

Richardson, G.N. and Johnson, S. (1998), "Field Evaluation of Geosynthetic Protective Cushions: Phase 2," *Geotechnical Fabrics Report*, (October - November), pp. 44-49.

Analysis Use the equation given below to determine the required mass per unit area of a cushion geotextile to protect a 60 mil HDPE (40 mil LLDPE in this case) geomembrane under final design loads. The selected cushion geotextile should be a minimum of 12 oz. per square yard to provide adequate protection during construction loading (Richardson, 1996 & 1998).

$$p_{allow} = (50 + 0.00045\frac{M}{H^2})\frac{1}{MS_S\, MF_{PD}\, MF_A} \bullet \frac{1}{RF_{CR}\, RF_{CBD}} \qquad \text{(Koerner Eqn. 5.33)}$$

Where:

p_{allow}	=	allowable pressure (kPa)
	=	$p_{actual}\, x\, FS$
p_{actual}	=	actual pressure (kPa)
FS	=	factor of safety
M	=	geotextile mass per unit area (g/m^2)
H	=	protrusion height (m) (assume H = d_{50} = soil particle size (mm) for which 50% of the total soil is finer)
MF_S	=	modification factor for protrusion shape
MF_{PD}	=	modification factor for packing density
MF_A	=	modification factor for arching in solids
RF_{CR}	=	reduction factor for long-term creep
RF_{CBD}	=	reduction factor for long-term chemical/biological degradation

GT CUSHION.WPD

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Raleigh, NC 27603 Fax: 919-828-3899

SHEET: 2/3
JOB #: JOHNSTON-22
DATE: 9/8/05
BY: PKS
CHKD BY:

Johnston County C&D Landfill - Area 2
Cushion Geotextile Analysis

Input Parameters:

Maximum Height of Waste (ft) =	150	**(User Input)**
Waste Density (pcf) =	70	**(User Input)**
P_{actual} (psf) =	10,500	**(=Max Height x Waste Density)**
P_{actual} (kPa) =	503	
Factor of Safety, FS =	3	**(User Input)**
P_{allow} (kPa) =	1,509	

Type of Stone	Stone Angularity	Stone Information: Stone d50 (in)	Stone d50 (mm)	Protrusion Height (m)	Modification Factors: MF_S	MF_{PD}	MF_A	Reduction Factors: RF_{CR}	RF_{CBD}	Geotextile Mass Per Unit Area: (g/m^2)	(oz/sy)
Coarse Aggregate (NCDOT No. 57)	Angular	0.750	19.1	0.019	1.00	0.67	0.25	1.5	1.3	357	**10.5**

Dr. Geocomposite w/ 2-6oz Non-Woven OK

3/3

TABLE 5.18 MODIFICATION FACTORS AND REDUCTION FACTORS FOR GEOMEMBRANE PROTECTION DESIGN USING NONWOVEN NEEDLE-PUNCHED GEOTEXTILES

Modification Factors

MF_S		MF_{PD}		MF_A	
Angular	1.0 *	Isolated	1.0	Hydrostatic	1.0
Subrounded	0.5	Dense, 38 mm	0.83	Geostatic, shallow	0.75
Rounded	0.25	Dense, 25 mm	0.67 *	Geostatic, mod.	0.50
		Dense, 12 mm	0.50	Geostatic, deep	0.25 *

Reduction Factors

RF_{CBD}		RF_{CR}			
		Mass per unit area (g/m^2)	Protrusion (mm)		
			38	25	12
Mild leachate	1.1	Geomembrane alone	N/R	N/R	N/R
Moderate leachate	1.3 *	270	N/R	N/R	> 1.5
Harsh leachate	1.5	550	N/R	1.5	1.3
		1100	1.3	1.2	1.1
		> 1100	≅ 1.2	≅ 1.1	≅ 1.0

N/R = Not recommended

p_{allow} = allowable pressure using different types of geotextiles and site-specific conditions.

Based on a large number of ASTM 5514 experiments, an empirical relationship for p_{allow} has been obtained, Eq. (5.33). It requires the set of modification factors and reduction factors given in Table 5.18.

$$p_{allow} = \left(50 + 0.00045\,\frac{M}{H^2}\right)\left[\frac{1}{MF_S \times MF_{PD} \times MF_A}\right]\left[\frac{1}{RF_{CR} \times RF_{CBD}}\right] \quad (5.33)$$

where

p_{allow} = allowable pressure (kPa),
M = geotextile mass per unit area (g/m^2),
H = protrusion height (m),
MF_S = modification factor for protrusion shape,
MF_{PD} = modification factor for packing density,
MF_A = modification factor for arching in solids,
RF_{CR} = reduction factor for long-term creep, and
RF_{CBD} = reduction factor for long-term chemical/biological degradation.

Note that in the above all MF values ≤ 1.0 and all RF values ≥ 1.0.

REF: DESIGNING WITH GEOSYNTHETICS, KOERNER 4th EDITION, 1997

PROJECT Johnston County C&D Landfill - Area 2	SHEET 1 OF 3
	JOB NO. JOHNSTON-22
	DATE 7/14/05
SUBJECT Leachate Collection Pipe Spacing	COMPUTED BY PKS
	CHECKED BY

Objective

To evaluate the required leachate collection pipe spacing which will maintain at most 1 foot of head on the geomembrane under Normal Operating Conditions. Analysis will calculate the maximum head using required values for permeability (leachate collection media) or transmissivity (drainage geocomposite). If the selected pipe spacing indicates an acceptable head, then the selected pipe spacing is acceptable.

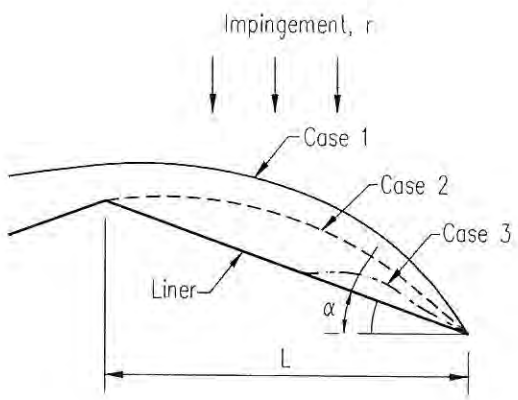
References

McEnroe, Bruce (1993), "Maximum Saturated Depth Over Landfill Liners," Journal of Environmental Engineering, Vol. 119, No. 2, pp. 262-270.

Richardson, G.N., Giroud, J-P. and Zhao, A. (2000), Design of Lateral Drainage Systems for Landfills, Tenax Corp., Baltimore.

Analysis

The McEnroe equations require the input of an impingement rate, a drainage media permeability, pipe spacing, and a liner slope. This information is used to find the maximum head on the liner. The McEnroe solution is for three cases (see figure below). Case 1 is for a saw-tooth bottom, with the liquid mound overtopping the peak. Case 2 has the liquid mound starting at the peak of the saw-tooth. Case three has the mound starting below the peak of the tooth. Cases two and three are appropriate for modeling a liner on an infinite slope with collector pipes uniformly spaced down the slope.



LCS PIPE SPACE.WPD

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Step 1: Input the necessary physical factors: slope, permeability and impingement rate.

Step 2: The controlling value R is calculated

$$R = \frac{r}{k \sin^2 \alpha}$$

Where:
- r = impingement rate
- k = permeability of the drainage media (for Drainage Geocomposite, k = transmissivity/thickness)
- α = slope angle of the liner

Step 3: The maximum head is calculated, using a formula dependent on the value of R:

For R > 1/4 (Case 1):

$$h_{max} = SL\left(R - RS + R^2S^2\right)^{\frac{1}{2}} \exp\left[\frac{1}{B}\arctan\left(\frac{2RS-1}{B}\right) - \frac{1}{B}\arctan\left(\frac{2R-1}{B}\right)\right]$$

For R = 1/4 (Case 2):

$$h_{max} = SL\frac{R(1-2RS)}{1-2R}\exp\left[\frac{2R(S-1)}{(1-2RS)(1-2R)}\right]$$

For R < 1/4 (Case 3):

$$h_{max} = SL\left(R - RS + R^2S^2\right)^{\frac{1}{2}}\left[\frac{(1-A-2R)(1+A-2RS)}{(1+A-2R)(1-A-2RS)}\right]^{\frac{1}{2A}}$$

Where:
- h_{max} = maximum head (m - convert to desired units)
- L = horizontal length of pipe spacing or distance to peak (m) (see figure above)
- S = liner slope (m/m)
- A = $(1 - 4R)^{0.5}$
- B = $(4R - 1)^{0.5}$

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SHEET: 3 / 3
JOB #: JOHNSTON-22
DATE: 9/8/05
BY: PKS
CHKD BY:

Johnston County C&D Landfill - Area 2
Leachate Collection Pipe Spacing

Drainage Geocomposite:

Maximum Allowable Head (h_{max}):	0.25 inches	(= Thickness of Geonet Drainage Core)
Impingement (r):	1.3E-06 cm/sec	(= 1,200 gpad - Conservative for Active Case Based on HELP Model)
Drainage Geocomposite Transmissivity (θ):	7.5E-04 m^3/m/sec	(Specified Minimum)
Thickness of Geonet Drainage Core:	0.25 inches	(Specified Minimum)
Reduction Factors for Drainage Geocomposite:		(Per Richardson, Zhao, & Giroud)
$RF_{intrusion}$:	1.2	
RF_{creep}:	2.0	
$RF_{chemical\ clogging}$:	2.0	
$RF_{biological\ clogging}$:	2.0	
Overall Factor of Safety:	2.0	
Reduction Factor for Drainage Geocomposite in LCS:	19.2	(Conservative for Short-Term Load on Geocomposite)
Design Drainage Geocomposite Transmissivity (θ):	3.9E-05 m^3/m/sec	
Design Drainage Geocomposite Permeability (k):	0.62 cm/sec	(Design Transmissivity/Thickness of Geonet Drainage Core)

Slope (%)	Slope (Deg.)	S	R	Pipe Spacing (ft)	Pipe Spacing (m)	A	B	h_{max} (in) R < 0.25	R = 0.25	R > 0.25	Comment
2	1.15	0.020	0.00529	200	61.0	0.989	NA	0.25	N/A	N/A	O.K.
2.2	1.26	0.022	0.00437	200	61.0	0.991	NA	0.23	N/A	N/A	O.K.

Flow In Net - O.K. << 1'

Note: Spreadsheet Converts Units as Required.

Objective To design leachate collection pipes to handle the maximum leachate generation rate.

References

Cedargren, Harry R. (1974), Drainage of Highway and Airfield Pavements, John Wiley & Sons, New York, pp. 166-167.

Debo, T.N., and Reese, A.J. (1995), Municipal Storm Water Management, Lewis Publishers, Boca Raton, FL, pp. 438-442.

Malcom, H. Rooney (1989), Elements of Urban Stormwater Design, N.C. State University, Raleigh, NC.

Analysis

1. For each pipe size, determine the maximum area (A), to handle the predicted flow (Q) with an added factor of safety. Compare the full flow capacity of each pipe size with the calculated peak flow rate to verify the desired factor of safety. Also, analyze leachate collection pipes based on partial flow to determine flow depth and velocity.

2. Determine the allowable perforation size for leachate collection pipes based on the size of the stone in the gravel columns.

3. Analyze leachate collection pipe perforations as orifice flow to ensure adequate flow capacity into collection piping.

Calculations

- Determine Peak Flow Rate:

Use the peak daily leachate generation rate from the active condition (see leachate generation calculations).

Determine the drainage area (A) to each pipe such that $Q_{max}/Q \geq 2.0$, where Q_{max} is the full flow capacity (see below).

LCS PIPE SIZE.WPD

- Leachate Collection Pipes:

Determine Flow Capacity (Q_{max}):

$$Q_{max} = \frac{0.463 D^{\frac{8}{3}} S^{\frac{1}{2}}}{n}$$ (D&R Equation 8.24)

Where:
Q_{max} = Flow capacity (cfs)
D = Pipe inside diameter (in)
S = Pipe slope (ft/ft)
n = Manning's roughness coefficient

Determine Factor of Safety (FS):

$$FS = \frac{Q_{max}}{Q}$$

Determine Flow Depth:

$$h = \frac{1}{2}\left(1 - \cos\left(\frac{\theta}{2}\right)\right) D$$ (D&R Equation 8.29)

Where:
h = Flow depth (inches)
θ = Central angle

$$\theta = \frac{3\pi}{2}\left[1 - (1 - \pi K)^{\frac{1}{2}}\right]^{\frac{1}{2}}$$ (D&R Equation 8.28)

K = Constant

$$K = 0.673 Q_n^{\frac{-8}{3}} S^{\frac{-1}{2}}$$ (D&R Equation 8.27)

Determine Flow Velocity:

$$V = \frac{Q}{A} = \frac{Q}{D^2 \frac{(\theta - \sin\theta)}{8}}$$ (D&R Equation 8.30 for "A")

Where: V = Flow velocity (ft/sec)
A = Cross-sectional area of flow (ft^3)

- Leachate Collection Pipe Perforations:

Determine Maximum Allowable Size of Perforations (D_{max}):

$$D_{max} = \frac{D_{85}}{F}$$ (Reformulation of Cedargren Equation 5.11)

Where: D_{max} = Maximum perforation diameter to provide particle retention
D_{85} = Particle size of pipe bedding material for which 85% by weight of the particles are finer
F = Factor varying between 1 and 2 (F = 1.2 for slots)

Determine Flow Capacity (Q_{max}):

$$Q_{max} = C_d A \sqrt{2gh}$$ (Malcom Equation I-7)

Where: Q_{max} = Flow capacity (cfs)
C_d = Coefficient of discharge
A = Cross-sectional area of flow (ft^3)
g = Acceleration of gravity (32.2 ft/sec^2)
h = Driving head - centroid of orifice to water surface (ft)

Determine Factor of Safety (FS):

$$FS = \frac{Q_{max}}{Q}$$

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SHEET: 4/4
JOB #: ABC-1
DATE: 8/29/05
BY: PKS
CHKD BY:

Johnston County C&D Landfill - Area 2
Leachate Collection System (LCS) Pipe Sizing - HDPE Pipe

Input Parameters:

Manning's Rougness Coefficient =	**0.009**		**(HDPE Pipe)**
Design Leachate Flow =	**14,000**	gal/acre/day	**(Peak Daily Leachate Generation - Active Condition)**
Design Leachate Flow =	0.02	cfs/acre	
Orifice Coef. Of Discharge (LCS Pipe Perforations) =	**0.6**		

LCS Piping

ID	Drainage Area (AC)	Peak Flow Rate (Q) (CFS)	Pipe I.D. (IN)	Pipe Slope (%)	Flow Capacity (Q_{max}) (CFS)	Factor of Safety (>/= 2.0)	K (CONSTANT)	θ (< 265°)	Flow Depth (IN)	Flow Area (SF)	Flow Velocity (FPS)
Max. Area - 6"	**17.0**	0.37	**5.8**	**1**	0.74	2.0	0.155	181	2.93	0.09	3.96

→ Max. - O.K.

LCS Pipe Perforations

Determine Maximum Perforation Size:

Stone Used for Pipe Bedding:	**No. 57**		
D_{85} =	**0.750**	inches	**(Typ. for No. 57 Stone)**
F =	**1.5**		
Max. Diameter - Circular Holes/Max. Width - Slots =	0.50	inches	

Circular Holes

ID	Drainage Area (AC)	Peak Flow Rate (Q) (CFS)	Hole Diameter (IN)	Allowable Head (IN)	X-Sectional Area (SF/Hole)	Flow Capacity (Q_{max}) (CFS/Hole)	No. Holes/LF	Min. Length of Collection Pipe (FT)	Actual Length of Collection Pipe (FT)	Factor of Safety (>/= 2.0)
Max. Area - 6"	**14.1**	0.31	**0.50**	**4**	0.001	0.004	**4**	20	300	14.9

Note: Conservatively Neglects Upper Holes (Where Used).

LCS Pipe Dimensions

Standard Dimension Ratio (SDR) of Pipe = **17** **(From Pipe Stress Calculations)**

Nominal Pipe Size (IN)	Pipe O.D. (IN)	Min. Wall Thickness (IN)	Pipe I.D. (IN)
6	**6.625**	0.390	5.8

Note: User Input Values are in **Bold**.

Objective Evaluate collection pipe stresses due to long-term static (overburden) and short-term dynamic (equipment) loads. For long-term static loads, check crushing and buckling failure modes as well as ring deflection. For short-term dynamic loads, check crushing failure mode.

References

The Performance Pipe Engineering Manual, (2002), CPChem Performance Pipe, Chapters 5 and 7.

Guidelines for HDPE Pipes in Deep Fills, (1998), Chevron Phillips Chemical Co.

Driscopipe Systems Design Manual, (1991), Phillips Driscopipe, Inc., p. 47.

Holtz, R.D., & Kovacs, W.D. (1981), An Introduction To Geotechnical Engineering, Prentice-Hall, Englewood Cliffs, NJ, p. 348.

Analysis Use FS_{min} (Static) = 2.0, FS_{min} (Dynamic) = 2.0.

Equations

- Crushing Failure:

$$S = \left(\frac{P_T}{288}\right) SDR$$ (Perf. Pipe Eng. Man. Eq. 7-23)

Where: S = Compressive Stress in Pipe Wall (psi)

SDR = Standard Dimensional Ratio = $\frac{Outside\ Diameter}{Thickness}$

P_T = External Pressure (psf)

$$FS_{crush} = \frac{\sigma_{yield}(HDPE = 1{,}600\,psi)}{S}$$

HDPE PIPE STRESS.WPD

- Buckling Failure (Constrained Wall):

$$P_{CR} = 1.63\sqrt{\frac{RB'E'E}{(SDR-1)^3}}$$ (Guidelines - HDPE - Deep Fills - Eq. 10)

Where:

P_{CR} = Critical Buckling Soil Pressure (psi)

R = Groundwater Buoyancy Factor

$$= 1 - 0.33\frac{H_{GW}}{H}$$

B' = Elastic Support Coefficient

$$= \frac{1}{1+4e^{(-0.065H)}}$$

E' = Constrained Soil Modulus (psi) (See Attached Table)

H = Height of Fill (ft)

H_{GW} = Height of Groundwater (ft)

E = Long-Term Modulus of Elasticity of Pipe (psi) (See Attached Table)

$$FS_{buckle} = \frac{P_T}{P_{CR}}$$

- Ring Deflection:

For constrained HDPE pipe, pipe deflection equals the strain in the surrounding bedding soil. The safe pipe deflection for each SDR is shown on the attached table.

Pipe Deflection (%) = $\frac{P_T}{E'}$ (Driscopipe p. 47)

-Equipment Loading:

Line Loads: (H&K Eq. 8-26)

$$P_T = P_L = \frac{2WZ^3}{\pi Z^5}$$

Point Loads: (Perf. Pipe Eng. Man. Eq. 7-13)

$$P_T = P_P = \frac{3WZ^3}{2\pi Z^5}$$

Where: W = Dynamic Equipment Load (lbs/ft or lbs) (= 1.5 times weight of machine)

Z = Vertical Distance From the Point of Loading to the Top of the Pipe (feet)

Using the above calculations for P_T, calculate the factor of safety for crushing failure as shown above.

Table : Typical Design Values* for Constrained Modulus, E'

Vertical Soil Stress (psi)	Gravelly Sand/Gravels 95% Std. Proctor (psi)	Gravelly Sand/Gravels 90% Std. Proctor (psi)	Gravelly Sand/Gravels 85% Std. Proctor (psi)
10	3000	1500	500
20	3500	1700	650
40	4500	2100	900
60	5500 *	2500	1150
80	6000	2900	1300
100	6500	3200	1450

(GUIDELINES FOR HDPE PIPE IN DEEP FILLS - TABLE 1)

Table · Typical Elastic Modulus for DRISCOPLEX™ PE 3408

Load Duration	Elastic Modulus†, 1000 psi (MPa), at Temperature, °F (°C)							
	-20 (-29)	0 (-18)	40 (4)	60 (16)	73 (23)	100 (38)	120 (49)	140 (60)
Short-Term	300.0 (2069)	260.0 (1793)	170.0 (1172)	130.0 (896)	110.0 (758)	100.0 (690)	65.0 (448)	50.0 (345)
10 h	140.8 (971)	122.0 (841)	79.8 (550)	61.0 (421)	57.5 (396)	46.9 (323)	30.5 (210)	23.5 (162)
100 h	125.4 (865)	108.7 (749)	71.0 (490)	54.3 (374)	51.2 (353)	41.8 (288)	27.2 (188)	20.9 (144)
1000 h	107.0 (738)	92.8 (640)	60.7 (419)	46.4 (320)	43.7 (301)	35.7 (246)	23.2 (160)	17.8 (123)
1 y	93.0 (641)	80.6 (556)	52.7 (363)	40.3 (278)	38.0 (262)	31.0 (214)	20.2 (139)	15.5 (107)
10 y	77.4 (534)	67.1 (463)	43.9 (303)	33.5 (231)	31.6 (218)	25.8 (178)	16.8 (116)	12.9 (89)
50 y	69.1 (476)	59.9 (413)	39.1 (270)	29.9 (206)	* 28.2 (194)	23.0 (159)	15.0 (103)	11.5 (79)

† Typical values based on ASTM D 638 testing of molded plaque material specimens.

(PERFORMANCE PIPE ENG. MANUAL - TABLE 5-1)

Table · Safe Pressure Pipe Deflection

DR	Safe Deflection as % of Diameter
32.5	8.5
26	7.0
21	6.0
17	5.0
13.5	4.0
11	3.0
9	2.5

(PERFORMANCE PIPE ENG. MANUAL - TABLE 7-9)

G.N. Richardson & Associates
Engineering and Geological Services
14 N. Boylan Avenue Tel: 919-828-0577
Raleigh, NC 27603 Fax: 919-828-3899

SHEET 5 / 5
JOB #. JOHNSTON-22
DATE: 9/8/05
BY PKS
CHKD BY:

Johnston County C&D Landfill - Area 2
HDPE Pipe Stress Analysis - LCS Piping

Case 1: Long-Term Static Loading

>> >Max.

Max. Height of Fill (H) (ft) = 150
Avg. Unit Weight (pcf) = 70

Max. Vertical Stress (P_T) (psf) = 10,500
Max. Vertical Stress (P_T) (psi) = 73

Height of Groundwater (H_{GW}) (ft) = 1 **(12" Max. Head)**
Constrained Soil Modulus (E') (psi) = 5,500
Long-Term Modulus of Elasticity of Pipe (E) (psi) = 28,200
Groundwater Buoyancy Factor (R) = 0.998
Elastic Support Coefficient (B') = 1.000

Calculate Safety Factors Against Crushing, Buckling, and Ring Deflection:

SDR	S (psi)	E (psi)	P_{CR} (psi)	FS_{Crush}	FS_{Buckle}	Ring Defl. (%)	Comment
17	620	28,200	317	2.58	4.34	1.3	O.K.
13.5	492	28,200	459	3.25	6.29	1.3	O.K.
11	401	28,200	641	3.99	8.79	1.3	O.K.

Case 2: Short-Term Dynamic (Equipment) Loading

SDR (Determine From Static Loading Analysis) = 17

Line Loads:

Equipment	Weight* (lbs)	Track Length (ft)	Dynamic Line Loads (psi) 6" Cover	12" Cover	18" Cover	S 6" Cover	12" Cover	18" Cover	FS 6" Cover	12" Cover	18" Cover
D4 Bulldozer (D4C-II)	19,485	6.74	19	10	6	163	81	54	9.8	19.6	29.5
D6 Bulldozer (D6H-II)	46,305	8.63	36	18	12	302	151	101	5.3	10.6	15.9
D8 Bulldozer (D8L)	95,838	10.5	61	30	20	514	257	171	3.1	6.2	9.3
953 Track Loader	37,560	7.5	33	17	11	282	141	94	5.7	11.3	17.0
963Track Loader	48,914	8.08	40	20	13	341	171	114	4.7	9.4	14.1

Point Loads:

Equipment	Weight* (lbs)	Number of Tires	Dynamic Point Loads (psi) 6" Cover	12" Cover	18" Cover	S 6" Cover	12" Cover	18" Cover	FS 6" Cover	12" Cover	18" Cover
950 Wheel Loader	48,628	4	242	60	27	2,056	514	228	0.8	3.1	7.0
615 Scraper	91,000	4	453	113	50	3,847	962	427	0.4	1.7	3.7
621 Scraper	115,195	4	573	143	64	4,870	1,217	541	0.3	1.3	3.0
816B Compactor	45,477	4	226	57	25	1,923	481	214	0.8	3.3	7.5
826C Compactor	69,733	4	347	87	39	2,948	737	328	0.5	2.2	4.9

* Includes Blades, Loaded Buckets, etc.

OPS. RESTRICTIONS HANDLE THIS

PROJECT Johnston County C&D Landfill - Area 2

SUBJECT Evaluation of Leachate Generation Rates

JOB NO. JOHNSTON-22
DATE 10/6/05
COMPUTED BY PKS
CHECKED BY

Objective To predict leachate generation rates for various operational conditions and evaluate rates of removal for the "surge" condition.

Assumptions Assume four operational conditions as follows:

Open -	Small quantity of waste in cell; almost all of runoff is leachate
Active -	One 10 foot lift of waste in place; no runoff
Interim -	40 feet of waste in place under intermediate cover
Final -	Final cover in-place; minimal infiltration.

Assume that the design storm for the landfill unit during initial filling (placement of initial lift of waste over open cells) is the 1-year 24-hour storm. This value is used to estimate leachate generation for "open" conditions.

Assumed empirical leachate generation rates are as follows for the above operational conditions:

Active -	1,200 gallons/acre/day
Interim -	500 gallons/acre/day
Final -	100 gallons/acre/day.

These rates are based on back calculations from observed generation rates from High Point, NC (Phase 1), Alamance County, NC, and several New York facilities (Reference Robert Pheneuf (NY-DEC)).

Analysis

Step 1: Determine the leachate generation rates for the above conditions using the HELP (v. 3.07) Model. These rates are as follows (see attached computer output files):

Active -	678 gallons/acre/day
Interim -	537 gallons/acre/day
Final -	0.11 gallons/acre/day.

Step 2: Compare results from the HELP Model with the empirical rates shown above. In that the empirical results are greater (or about the same), use the empirical values in estimating the leachate generation rates.

LEACHATEGENERATION.WPD

G.N. RICHARDSON & ASSOCIATES
Engineering and Geological Services
14 N. Boylan Avenue, Raleigh, NC 27603
Telephone: (919) 828-0577

Step 3: Estimate leachate generation rates using empirical values for the various conditions expected before, during, and after landfill operations. In this case, leachate generation rates are predicted for the following scenarios:

A. Completion of Phase 5 and Phase 4A - Cells 1 and 2 (MSW) operations (Phase 5 and Phase 4A - Cells 1 and 2 (MSW) under Interim conditions);

B. Initial filling of Area 2 (various areas under Open, Active, and Interim conditions) (maximum value is taken as the surge event for Area 2); and

C. Waste covers Area 2 (no areas Open; various areas under Active and Interim conditions) (maximum value is taken as the typical generation rate for Area 2).

Step 4: Based on the leachate generation rates determined above, estimate the pumping rates required to ensure that enough capacity remains in the leachate storage lagoon to handle the surge event. Also, estimate the days of capacity for the lagoon under typical Area 2 operations.

3/12

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 3.07 (1 NOVEMBER 1997)
DEVELOPED BY ENVIRONMENTAL LABORATORY
USAE WATERWAYS EXPERIMENT STATION
FOR USEPA RISK REDUCTION ENGINEERING LABORATORY

PRECIPITATION DATA FILE: D:\PKSFIL~1\2ENGPR~1\HELP3\RALNCP.D4
TEMPERATURE DATA FILE: D:\PKSFIL~1\2ENGPR~1\HELP3\RALNCT.D7
SOLAR RADIATION DATA FILE: D:\PKSFIL~1\2ENGPR~1\HELP3\RALNCS.D13
EVAPOTRANSPIRATION DATA: D:\PKSFIL~1\2ENGPR~1\HELP3\RALNCE.D11
SOIL AND DESIGN DATA FILE: D:\PKSFIL~1\2ENGPR~1\HELP3\JCACTIV.D10
OUTPUT DATA FILE: D:\PKSFIL~1\2ENGPR~1\HELP3\JCACTIV.OUT

TIME: 18:21 DATE: 7/14/2005

TITLE: Johnston County C&DLF - Area 2 - Active Condition

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

LAYER 1

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 7

THICKNESS	=	6.00 INCHES
POROSITY	=	0.4730 VOL/VOL
FIELD CAPACITY	=	0.2220 VOL/VOL
WILTING POINT	=	0.1040 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2357 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.520000001000E-03 CM/SEC

NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 3.00 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 18

THICKNESS	=	120.00 INCHES
POROSITY	=	0.6710 VOL/VOL
FIELD CAPACITY	=	0.2920 VOL/VOL
WILTING POINT	=	0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3065 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000005000E-02 CM/SEC

LAYER 3

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 7

THICKNESS	=	24.00 INCHES
POROSITY	=	0.4730 VOL/VOL
FIELD CAPACITY	=	0.2220 VOL/VOL
WILTING POINT	=	0.1040 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2309 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.520000001000E-03 CM/SEC

LAYER 4

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 20

THICKNESS	=	0.25 INCHES
POROSITY	=	0.8500 VOL/VOL
FIELD CAPACITY	=	0.0100 VOL/VOL
WILTING POINT	=	0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0100 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	10.0000000000 CM/SEC
SLOPE	=	2.00 PERCENT
DRAINAGE LENGTH	=	200.0 FEET

LAYER 5

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 36

THICKNESS	=	0.04 INCHES
POROSITY	=	0.0000 VOL/VOL
FIELD CAPACITY	=	0.0000 VOL/VOL
WILTING POINT	=	0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.399999993000E-12 CM/SEC
FML PINHOLE DENSITY	=	1.00 HOLES/ACRE
FML INSTALLATION DEFECTS	=	8.00 HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD

LAYER 6

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00 INCHES
POROSITY	=	0.4750 VOL/VOL
FIELD CAPACITY	=	0.3780 VOL/VOL
WILTING POINT	=	0.2650 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4750 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.999999975000E-05 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 7 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 2.% AND A SLOPE LENGTH OF 300. FEET.

SCS RUNOFF CURVE NUMBER	=	88.20
FRACTION OF AREA ALLOWING RUNOFF	=	0.0 PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000 ACRES
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	5.966 INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	13.574 INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.856 INCHES
INITIAL SNOW WATER	=	0.000 INCHES
INITIAL WATER IN LAYER MATERIALS	=	49.441 INCHES
TOTAL INITIAL WATER	=	49.441 INCHES
TOTAL SUBSURFACE INFLOW	=	0.00 INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM RALEIGH NORTH CAROLINA

STATION LATITUDE	=	35.87 DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00
START OF GROWING SEASON (JULIAN DATE)	=	86
END OF GROWING SEASON (JULIAN DATE)	=	310
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	7.70 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	66.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	78.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	72.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR RALEIGH NORTH CAROLINA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.55	3.43	3.69	2.91	3.67	3.66
4.38	4.44	3.29	2.73	2.87	3.14

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR RALEIGH NORTH CAROLINA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
39.60	41.60	49.30	59.50	67.20	73.90
77.70	77.00	71.00	59.70	50.00	42.00

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR RALEIGH NORTH CAROLINA AND STATION LATITUDE = 35.87 DEGREES

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 20

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.44	2.92	3.81	2.20	4.34	3.74
	4.24	5.43	2.40	2.87	3.05	2.80
STD. DEVIATIONS	2.07	1.23	1.51	1.52	2.22	1.98
	1.91	3.72	1.67	2.00	1.79	1.04
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	1.404	1.729	2.964	2.732	4.210	4.665
	4.191	4.168	2.641	1.296	1.141	1.022
STD. DEVIATIONS	0.154	0.243	0.311	0.925	0.790	1.464
	1.513	1.292	1.115	0.405	0.153	0.172
LATERAL DRAINAGE COLLECTED FROM LAYER 4						
TOTALS	1.1493	1.7106	1.6137	1.2909	0.6079	0.5976
	0.2564	0.1102	0.6624	0.2594	0.1671	0.6833
STD. DEVIATIONS	0.8153	1.1576	1.1032	1.0332	0.4231	0.8138
	0.3488	0.1542	1.9467	0.7273	0.3119	1.1593
PERCOLATION/LEAKAGE THROUGH LAYER 6						
TOTALS	0.0000	0.0001	0.0001	0.0001	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000

4/12

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 5

AVERAGES	0.0065	0.0107	0.0092	0.0076	0.0035	0.0035
	0.0015	0.0006	0.0039	0.0015	0.0010	0.0039
STD. DEVIATIONS	0.0046	0.0071	0.0063	0.0061	0.0024	0.0048
	0.0020	0.0009	0.0115	0.0041	0.0018	0.0066

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 20

	INCHES		CU. FEET	PERCENT
PRECIPITATION	41.25	(8.104)	149735.7	100.00
RUNOFF	0.000	(0.0000)	0.00	0.000
EVAPOTRANSPIRATION	32.163	(3.6299)	116753.15	77.973
LATERAL DRAINAGE COLLECTED FROM LAYER 4	9.10874	(5.18516)	33064.723	22.08206
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00037	(0.00019)	1.360	0.00091
AVERAGE HEAD ON TOP OF LAYER 5	0.004	(0.003)		
CHANGE IN WATER STORAGE	-0.023	(1.9521)	-83.56	-0.056

678 gpad

PEAK DAILY VALUES FOR YEARS 1 THROUGH 20

	(INCHES)	(CU. FT.)
PRECIPITATION	5.22	18948.600
RUNOFF	0.000	0.0000
DRAINAGE COLLECTED FROM LAYER 4	0.51536	1870.74683
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000017	0.06250
AVERAGE HEAD ON TOP OF LAYER 5	0.091	
MAXIMUM HEAD ON TOP OF LAYER 5	0.179	
LOCATION OF MAXIMUM HEAD IN LAYER 4 (DISTANCE FROM DRAIN)	3.5 FEET	
SNOW WATER	1.80	6547.7266

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4806
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0844

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

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

FINAL WATER STORAGE AT END OF YEAR 20

LAYER	(INCHES)	(VOL/VOL)
1	1.3805	0.2301
2	34.8402	0.2903
3	7.0430	0.2935
4	0.0166	0.0662
5	0.0000	0.0000
6	5.7000	0.4750
SNOW WATER	0.000	

5/12

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 3.07 (1 NOVEMBER 1997)
DEVELOPED BY ENVIRONMENTAL LABORATORY
USAE WATERWAYS EXPERIMENT STATION
FOR USEPA RISK REDUCTION ENGINEERING LABORATORY

PRECIPITATION DATA FILE:	D:\PKSFIL~1\2ENGPR~1\HELP3\RALNCP.D4
TEMPERATURE DATA FILE:	D:\PKSFIL~1\2ENGPR~1\HELP3\RALNCT.D7
SOLAR RADIATION DATA FILE:	D:\PKSFIL~1\2ENGPR~1\HELP3\RALNCS.D13
EVAPOTRANSPIRATION DATA:	D:\PKSFIL~1\2ENGPR~1\HELP3\RALNCE.D11
SOIL AND DESIGN DATA FILE:	D:\PKSFIL~1\2ENGPR~1\HELP3\JCINTRM.D10
OUTPUT DATA FILE:	D:\PKSFIL~1\2ENGPR~1\HELP3\JCINTRM.OUT

TIME: 18:21 DATE: 7/14/2005

TITLE: Johnston County C&DLF - Area 2 - Interim Condition

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

LAYER 1

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 7

THICKNESS	=	12.00 INCHES
POROSITY	=	0.4730 VOL/VOL
FIELD CAPACITY	=	0.2220 VOL/VOL
WILTING POINT	=	0.1040 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2268 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.520000001000E-03 CM/SEC

NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 3.00 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 18

THICKNESS	=	480.00 INCHES
POROSITY	=	0.6710 VOL/VOL
FIELD CAPACITY	=	0.2920 VOL/VOL
WILTING POINT	=	0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2960 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000005000E-02 CM/SEC

LAYER 3

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 7

THICKNESS	=	24.00 INCHES
POROSITY	=	0.4730 VOL/VOL
FIELD CAPACITY	=	0.2220 VOL/VOL
WILTING POINT	=	0.1040 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2322 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.520000001000E-03 CM/SEC

LAYER 4

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 20

THICKNESS	=	0.25 INCHES
POROSITY	=	0.8500 VOL/VOL
FIELD CAPACITY	=	0.0100 VOL/VOL
WILTING POINT	=	0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0100 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	10.0000000000 CM/SEC
SLOPE	=	2.00 PERCENT
DRAINAGE LENGTH	=	200.0 FEET

LAYER 5

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 36

THICKNESS	=	0.04 INCHES
POROSITY	=	0.0000 VOL/VOL
FIELD CAPACITY	=	0.0000 VOL/VOL
WILTING POINT	=	0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.399999993000E-12 CM/SEC
FML PINHOLE DENSITY	=	1.00 HOLES/ACRE
FML INSTALLATION DEFECTS	=	8.00 HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD

LAYER 6

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00 INCHES
POROSITY	=	0.4750 VOL/VOL
FIELD CAPACITY	=	0.3780 VOL/VOL
WILTING POINT	=	0.2650 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4750 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.999999975000E-05 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 7 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 2.% AND A SLOPE LENGTH OF 300. FEET.

SCS RUNOFF CURVE NUMBER	=	88.20
FRACTION OF AREA ALLOWING RUNOFF	=	100.0 PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000 ACRES
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	5.658 INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	12.386 INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	2.018 INCHES
INITIAL SNOW WATER	=	0.000 INCHES
INITIAL WATER IN LAYER MATERIALS	=	156.096 INCHES
TOTAL INITIAL WATER	=	156.096 INCHES
TOTAL SUBSURFACE INFLOW	=	0.00 INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM RALEIGH NORTH CAROLINA

STATION LATITUDE	=	35.87 DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00
START OF GROWING SEASON (JULIAN DATE)	=	86
END OF GROWING SEASON (JULIAN DATE)	=	310
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	7.70 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	66.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	78.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	72.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR RALEIGH NORTH CAROLINA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.55	3.43	3.69	2.91	3.67	3.66
4.38	4.44	3.29	2.73	2.87	3.14

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR RALEIGH NORTH CAROLINA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
39.60	41.60	49.30	59.50	67.20	73.90
77.70	77.00	71.00	59.70	50.00	42.00

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR RALEIGH NORTH CAROLINA AND STATION LATITUDE = 35.87 DEGREES

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 20

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.44	2.92	3.81	2.20	4.34	3.74
	4.24	5.43	2.40	2.87	3.05	2.80
STD. DEVIATIONS	2.07	1.23	1.51	1.52	2.22	1.98
	1.91	3.72	1.67	2.00	1.79	1.04
RUNOFF						
TOTALS	0.366	0.097	0.169	0.059	0.362	0.176
	0.189	0.554	0.158	0.175	0.244	0.131
STD. DEVIATIONS	0.485	0.116	0.194	0.127	0.554	0.217
	0.258	1.029	0.263	0.273	0.278	0.170
EVAPOTRANSPIRATION						
TOTALS	1.417	1.738	2.976	2.712	4.197	4.281
	3.999	4.060	2.504	1.295	1.173	1.035
STD. DEVIATIONS	0.162	0.246	0.306	0.935	0.784	1.545
	1.460	1.295	1.169	0.405	0.143	0.160
LATERAL DRAINAGE COLLECTED FROM LAYER 4						
TOTALS	0.7733	1.1764	1.3642	1.2311	0.9787	0.4166
	0.1999	0.0776	0.0861	0.3109	0.1611	0.4388
STD. DEVIATIONS	0.6343	0.5936	0.7360	0.7780	1.0281	0.3702
	0.2524	0.1192	0.1875	0.8946	0.4802	0.6571
PERCOLATION/LEAKAGE THROUGH LAYER 6						
TOTALS	0.0000	0.0000	0.0001	0.0001	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

6/12

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 5

AVERAGES	0.0044	0.0073	0.0078	0.0072	0.0056	0.0025
	0.0011	0.0004	0.0005	0.0018	0.0009	0.0025
STD. DEVIATIONS	0.0036	0.0037	0.0042	0.0046	0.0059	0.0022
	0.0014	0.0007	0.0011	0.0051	0.0028	0.0037

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 20

	INCHES		CU. FEET	PERCENT
PRECIPITATION	41.25	(8.104)	149735.7	100.00
RUNOFF	2.680	(1.8280)	9729.88	6.498
EVAPOTRANSPIRATION	31.386	(3.7355)	113932.33	76.089
LATERAL DRAINAGE COLLECTED FROM LAYER 4	7.21475	(3.58314)	26189.551	17.49052
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00031	(0.00014)	1.109	0.00074
AVERAGE HEAD ON TOP OF LAYER 5	0.004	(0.002)		
CHANGE IN WATER STORAGE	-0.032	(2.2263)	-117.18	-0.078

537 spad

PEAK DAILY VALUES FOR YEARS 1 THROUGH 20

	(INCHES)	(CU. FT.)
PRECIPITATION	5.22	18948.600
RUNOFF	2.948	10701.5029
DRAINAGE COLLECTED FROM LAYER 4	0.18915	686.61426
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000007	0.02534
AVERAGE HEAD ON TOP OF LAYER 5	0.033	
MAXIMUM HEAD ON TOP OF LAYER 5	0.066	
LOCATION OF MAXIMUM HEAD IN LAYER 4 (DISTANCE FROM DRAIN)	1.0 FEET	
SNOW WATER	1.80	6547.7266

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.3608

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0917

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

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

FINAL WATER STORAGE AT END OF YEAR 20

LAYER	(INCHES)	(VOL/VOL)
1	2.6406	0.2200
2	140.6111	0.2929
3	6.4959	0.2707
4	0.0025	0.0100
5	0.0000	0.0000
6	5.7000	0.4750
SNOW WATER	0.000	

7/12

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 3.07 (1 NOVEMBER 1997)
DEVELOPED BY ENVIRONMENTAL LABORATORY
USAE WATERWAYS EXPERIMENT STATION
FOR USEPA RISK REDUCTION ENGINEERING LABORATORY

PRECIPITATION DATA FILE:	D:\PKSFIL~1\2ENGPR~1\HELP3\RALNCP.D4
TEMPERATURE DATA FILE:	D:\PKSFIL~1\2ENGPR~1\HELP3\RALNCT.D7
SOLAR RADIATION DATA FILE:	D:\PKSFIL~1\2ENGPR~1\HELP3\RALNCS.D13
EVAPOTRANSPIRATION DATA:	D:\PKSFIL~1\2ENGPR~1\HELP3\RALNCE.D11
SOIL AND DESIGN DATA FILE:	D:\PKSFIL~1\2ENGPR~1\HELP3\JCFINAL.D10
OUTPUT DATA FILE:	D:\PKSFIL~1\2ENGPR~1\HELP3\JCFINAL.OUT

TIME: 18:21 DATE: 7/14/2005

TITLE: Johnston County C&DLF - Area 2 - Final Cover Condition

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

LAYER 1

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 7

THICKNESS	=	24.00 INCHES
POROSITY	=	0.4730 VOL/VOL
FIELD CAPACITY	=	0.2220 VOL/VOL
WILTING POINT	=	0.1040 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2318 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.520000001000E-03 CM/SEC

NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 3.00 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 20

THICKNESS	=	0.25 INCHES
POROSITY	=	0.8500 VOL/VOL
FIELD CAPACITY	=	0.0100 VOL/VOL
WILTING POINT	=	0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0121 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	10.0000000000 CM/SEC
SLOPE	=	25.00 PERCENT
DRAINAGE LENGTH	=	150.0 FEET

LAYER 3

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 36

THICKNESS	=	0.03 INCHES
POROSITY	=	0.0000 VOL/VOL
FIELD CAPACITY	=	0.0000 VOL/VOL
WILTING POINT	=	0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.399999993000E-12 CM/SEC
FML PINHOLE DENSITY	=	1.00 HOLES/ACRE
FML INSTALLATION DEFECTS	=	8.00 HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 7

THICKNESS	=	12.00 INCHES
POROSITY	=	0.4730 VOL/VOL
FIELD CAPACITY	=	0.2220 VOL/VOL
WILTING POINT	=	0.1040 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2220 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.520000001000E-03 CM/SEC

LAYER 5

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 18

THICKNESS	=	480.00 INCHES
POROSITY	=	0.6710 VOL/VOL
FIELD CAPACITY	=	0.2920 VOL/VOL
WILTING POINT	=	0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2920 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000005000E-02 CM/SEC

LAYER 6

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 7

THICKNESS	=	24.00 INCHES
POROSITY	=	0.4730 VOL/VOL
FIELD CAPACITY	=	0.2220 VOL/VOL
WILTING POINT	=	0.1040 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2220 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.520000001000E-03 CM/SEC

LAYER 7

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 20

THICKNESS	=	0.25 INCHES
POROSITY	=	0.8500 VOL/VOL
FIELD CAPACITY	=	0.0100 VOL/VOL
WILTING POINT	=	0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0100 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	10.0000000000 CM/SEC
SLOPE	=	2.00 PERCENT
DRAINAGE LENGTH	=	200.0 FEET

LAYER 8

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 36

THICKNESS	=	0.04 INCHES
POROSITY	=	0.0000 VOL/VOL
FIELD CAPACITY	=	0.0000 VOL/VOL
WILTING POINT	=	0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.399999993000E-12 CM/SEC
FML PINHOLE DENSITY	=	1.00 HOLES/ACRE
FML INSTALLATION DEFECTS	=	8.00 HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD

LAYER 9

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00 INCHES
POROSITY	=	0.4750 VOL/VOL
FIELD CAPACITY	=	0.3780 VOL/VOL
WILTING POINT	=	0.2650 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4750 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.999999975000E-05 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 7 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 2.% AND A SLOPE LENGTH OF 300. FEET.

SCS RUNOFF CURVE NUMBER	=	88.20
FRACTION OF AREA ALLOWING RUNOFF	=	100.0 PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000 ACRES
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	4.985 INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	10.406 INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	2.288 INCHES
INITIAL SNOW WATER	=	0.000 INCHES
INITIAL WATER IN LAYER MATERIALS	=	159.421 INCHES
TOTAL INITIAL WATER	=	159.421 INCHES
TOTAL SUBSURFACE INFLOW	=	0.00 INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM RALEIGH NORTH CAROLINA

STATION LATITUDE	=	35.87 DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00
START OF GROWING SEASON (JULIAN DATE)	=	86
END OF GROWING SEASON (JULIAN DATE)	=	310
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	7.70 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	66.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	78.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	72.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR RALEIGH NORTH CAROLINA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.55	3.43	3.69	2.91	3.67	3.66
4.38	4.44	3.29	2.73	2.87	3.14

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR RALEIGH NORTH CAROLINA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
39.60	41.60	49.30	59.50	67.20	73.90
77.70	77.00	71.00	59.70	50.00	42.00

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR RALEIGH NORTH CAROLINA AND STATION LATITUDE = 35.87 DEGREES

8/12

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 20

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.44	2.92	3.81	2.20	4.34	3.74
	4.24	5.43	2.40	2.87	3.05	2.80
STD. DEVIATIONS	2.07	1.23	1.51	1.52	2.22	1.98
	1.91	3.72	1.67	2.00	1.79	1.04
RUNOFF						
TOTALS	0.385	0.105	0.182	0.064	0.373	0.181
	0.194	0.575	0.167	0.178	0.250	0.136
STD. DEVIATIONS	0.509	0.121	0.209	0.139	0.575	0.224
	0.266	1.068	0.293	0.281	0.284	0.173
EVAPOTRANSPIRATION						
TOTALS	1.405	1.729	2.912	2.729	3.990	3.628
	3.650	3.757	2.313	1.287	1.195	1.038
STD. DEVIATIONS	0.210	0.287	0.354	0.939	0.916	1.571
	1.366	1.279	1.102	0.406	0.198	0.137
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	1.5498	1.2165	1.1222	0.4777	0.3354	0.3309
	0.3306	0.7587	0.3953	0.2594	0.9335	1.1060
STD. DEVIATIONS	1.0681	0.8922	0.8515	0.4884	0.5255	0.2506
	0.2739	0.9669	0.6473	0.4436	0.9249	0.6307
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0000	0.0002	0.0002
STD. DEVIATIONS	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000
	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001
LATERAL DRAINAGE COLLECTED FROM LAYER 7						
TOTALS	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0000	0.0001	0.0002
STD. DEVIATIONS	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000
	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001
PERCOLATION/LEAKAGE THROUGH LAYER 9						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3						
AVERAGES	0.0006	0.0005	0.0004	0.0002	0.0001	0.0001
	0.0001	0.0003	0.0001	0.0001	0.0003	0.0004
STD. DEVIATIONS	0.0004	0.0004	0.0003	0.0002	0.0002	0.0001
	0.0001	0.0004	0.0002	0.0002	0.0003	0.0002
DAILY AVERAGE HEAD ON TOP OF LAYER 8						
AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 20

	INCHES		CU. FEET	PERCENT
PRECIPITATION	41.25	(8.104)	149735.7	100.00
RUNOFF	2.790	(1.9297)	10129.09	6.765
EVAPOTRANSPIRATION	29.632	(3.6903)	107565.02	71.837
LATERAL DRAINAGE COLLECTED FROM LAYER 2	8.81614	(3.81136)	32002.582	21.37271
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.00144	(0.00048)	5.224	0.00349
AVERAGE HEAD ON TOP OF LAYER 3	0.000	(0.000)		
LATERAL DRAINAGE COLLECTED FROM LAYER 7	0.00144	(0.00048)	5.212	0.00348
PERCOLATION/LEAKAGE THROUGH	0.00000	(0.00000)	0.012	0.00001

0.11 gpad

LAYER 9

AVERAGE HEAD ON TOP OF LAYER 8	0.000	(0.000)		
CHANGE IN WATER STORAGE	0.009	(1.1053)	33.78	0.023

PEAK DAILY VALUES FOR YEARS 1 THROUGH 20

	(INCHES)	(CU. FT.)
PRECIPITATION	5.22	18948.600
RUNOFF	2.955	10724.8623
DRAINAGE COLLECTED FROM LAYER 2	1.02055	3704.58569
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.000085	0.30740
AVERAGE HEAD ON TOP OF LAYER 3	0.011	
MAXIMUM HEAD ON TOP OF LAYER 3	0.059	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	0.0 FEET	
DRAINAGE COLLECTED FROM LAYER 7	0.00008	0.28166
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.000000	0.00007
AVERAGE HEAD ON TOP OF LAYER 8	0.000	
MAXIMUM HEAD ON TOP OF LAYER 8	0.000	
LOCATION OF MAXIMUM HEAD IN LAYER 7 (DISTANCE FROM DRAIN)	0.0 FEET	
SNOW WATER	1.80	6547.7266

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.3536

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.1040

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

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

FINAL WATER STORAGE AT END OF YEAR 20

LAYER	(INCHES)	(VOL/VOL)
1	5.7499	0.2396
2	0.0027	0.0110
3	0.0000	0.0000
4	2.6640	0.2220
5	140.1600	0.2920
6	5.3280	0.2220
7	0.0025	0.0100
8	0.0000	0.0000
9	5.7000	0.4750
SNOW WATER	0.000	

G.N. Richardson & Associates
Engineering and Geological Services
14 N. Boylan Avenue
Raleigh, NC 27603
Tel: 919-828-0577
Fax: 919-828-3899

SHEET: 9/12
JOB #: JOHNSTON-22
DATE: 10/6/05
BY: PKS
CHKD BY:

Johnston County C&D Landfill - Area 2
Evaluation of Leachate Generation Rates

LEACHATE GENERATION RATES:

1 Year, 24 Hour Design Storm Depth = 3.20 inches **(US Weather Bureau TP-40)**

Open: 86,888 gallons/acre/day
Active: 1,200 gallons/acre/day
Interim: 500 gallons/acre/day
Final: 100 gallons/acre/day

OPEN		ACTIVE		INTERIM		FINAL		TOTAL
Acres	GPD	Acres	GPD	Acres	GPD	Acres	GPD	GPD
A. Initial Filling of Area 2 (Maximum Value is "Surge" Event) (Phases 4A & Phase 5 under Interim Conditions)								
2.0	173,775	0.0	0	48.6	24,300	0.0	0	198,075
2.0	173,775	2.0	2,400	48.6	24,300	0.0	0	200,475
2.0	173,775	4.0	4,800	48.6	24,300	0.0	0	202,875
2.0	173,775	6.0	7,200	48.6	24,300	0.0	0	205,275
2.0	173,775	8.0	9,600	48.6	24,300	0.0	0	207,675
3.0	260,663	12.8	15,360	48.6	24,300	0.0	0	300,323
B. Waste Covers Area 2 (Value is "Typical" for Area 2)								
0.0	0	15.8	18,960	48.6	24,300	0.0	0	43,260
C. Completion of Area 2 Operations								
0.0	0	0.0	0	64.4	32,200	0.0	0	32,200
D. Closure of Phase 4A, Phase 5, & Area 2 (Value is "Typical" for Post-Closure Conditions)								
0.0	0	0.0	0	0.0	0	64.4	6,440	6,440

SHEET:	10 / 12
JOB #:	JOHNSTON-22
DATE:	10/6/05
BY:	PKS
CHKD BY:	

REQUIRED REMOVAL RATES:

Case 1: Surge Event:

Quantity of Leachate Produced = 300,323 gallons **(See Above)**
Maximum Storage Capacity = 4,300,000 gallons **(See Below)**

Before Surge Event		After Surge Event		Maximum Detention Time In in Landfill (days)	
Available Storage Capacity (gallons)	Volume Retained in Lagoon (gallons)	Volume Retained in Lagoon (gallons)	Volume Retained in Landfill (gallons)	Pump Rate = 15,000 gpd	Pump Rate = 30,000 gpd
2,000,000	2,300,000	2,600,323	0	0.0	0.0
1,800,000	2,500,000	2,800,323	0	0.0	0.0
1,600,000	2,700,000	3,000,323	0	0.0	0.0
1,400,000	2,900,000	3,200,323	0	0.0	0.0
1,200,000	3,100,000	3,400,323	0	0.0	0.0
1,000,000	3,300,000	3,600,323	0	0.0	0.0
800,000	3,500,000	3,800,323	0	0.0	0.0
600,000	3,700,000	4,000,323	0	0.0	0.0
400,000	3,900,000	4,200,323	0	0.0	0.0
200,000	4,100,000	4,300,000	100,323	6.7	3.3
100,000	4,200,000	4,300,000	200,323	13.4	6.7
0	4,300,000	4,300,000	300,323	20.0	10.0

Case 2: Typical Phase 3 Leachate Generation:

Typical Leachate Generation Rate = 43,260 gallons/day **(See Above)**

Days of Storage Capacity = 99.4 days

Case 3: Typical Post-Closure Leachate Generation:

Typical Leachate Generation Rate = 6,440 gallons/day **(See Above)**

Days of Storage Capacity = 667.7 days

STORAGE CAPACITY OF LEACHATE LAGOON:

Capacity = 4,300,000 gallons **(With 2 Feet of Freeboard)**
(See Attached)

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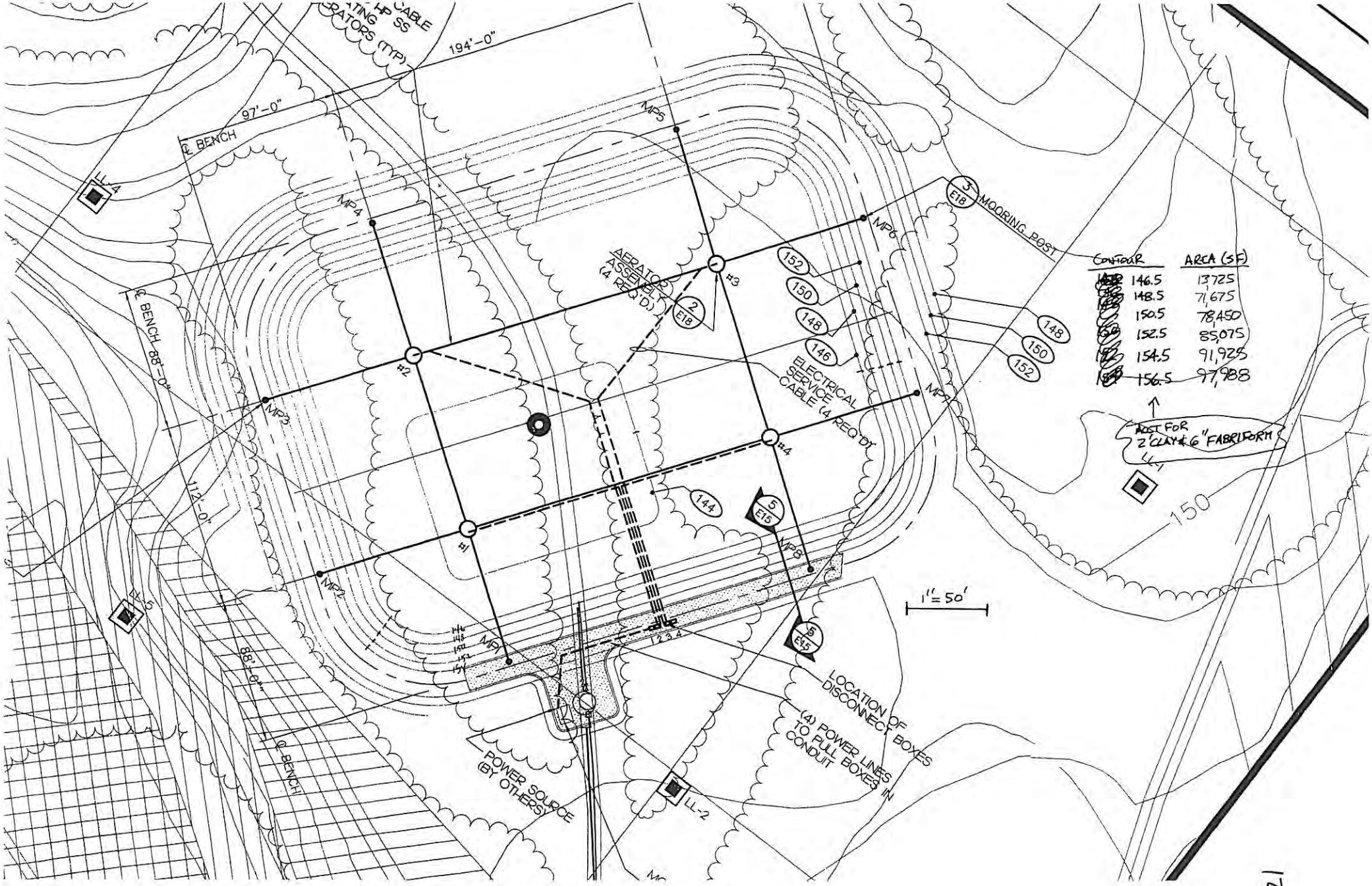
Tel: 919-828-0577
Fax: 919-828-3899

SHEET: 11 / 12
JOB #: JOHNSTON-22
DATE: 9/9/05
BY: PKS
CHKD BY:

Johnston County C&D Landfill - Area 2
Volume of Leachate Storage Lagoon

STORAGE CAPACITY OF LEACHATE STORAGE LAGOON:

Contour	Area (SF)	Incr Vol (CF)	Accum Vol (CF)	Accum Vol (Gallons)	Stage (FT)
146.5	13,725		0	0	0
148.5	71,675	85,400	85,400	638,792	2
150.5	78,450	150,125	235,525	1,761,727	4
152.5	85,075	163,525	399,050	2,984,894	6
154.5	91,925	177,000	576,050	4,308,854	8
156.5	97,988	189,913	765,963	5,729,403	10


194'-0"
97'-0"
℄ BENCH
℄ BENCH 88'-0"
112'-0"
88'-0"
℄ BENCH
MP1
MP2
MP3
MP4
MP5
MP6
#1
#2
#3
#4
AERATOR ASSEMBLY (4 REQ'D)
ELECTRICAL SERVICE CABLE (4 REQ'D)
MOORING POST
LOCATION OF DISCONNECT BOXES
(4) POWER LINES TO PULL BOXES IN CONDUIT
POWER SOURCE (BY OTHERS)
LL-1
LL-2
LL-3
LL-4
1" = 50'
144
146
148
150
152
154
156
CONTOUR
AREA (SF)
146.5
13,725
148.5
71,675
150.5
78,450
152.5
85,075
154.5
91,925
156.5
97,988
ADJ FOR 2' CLAY & 6" FABRIFORM
150

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ENGINEERING AND GEOLOGICAL SERVICES

DATE 18-Oct-05
BY SAS
JOB NO JOHNSTON-21

√ PKS

Leachate Management
Johnston County C&D Landfill
Leachate Pumping System Design

Objective: Determine pumping system parameters for the proposed leachate collection system.

Given:

1.	Cell Area	15.8	AC	------> Ref. 1
2	Normal Flow Conditions	20,000	GPD	------> Leachate Generation Calculations
3	Peak Flow Conditions	150,000	GPD	------> Leachate Generation Calculations (Assume use of GRC)
4	Minimum Flow Velocity.	2	fps	------> Ref. 3 (for "Self Cleaning")
5	Maximum Flow Velocity	5	fps	------> Ref. 3 (for "Water Hammer" Reduction)

Reference:

1 Johnston County C&D Landfill Area 2 Permit Drawings
2 Driscopipe Design Manual
3 "Pumping Station Design", 2nd Edition, Robert L. Sanks, Editor in Chief, 1998, by Butterworth Heineman
4. "Elements of Urban Stormwater Design", H. Rooney Malcom, NCSU

Calculations: The pumps will be designed for critical elements as follows:

* Piping Requirements
* Pump Requirements
* System Cycle Time
* Riser Fit
* System Surge Pressures

1. *Piping Requirements*

——> Determine Nominal Pumping Rate

The Nominal Pumping Rate is the greater of 2.5 times normal conditions or equal to peak conditions.

Therefore, @ Normal Conditions, Qreq = 35GPM and @ Peak Conditions, Qreq = 104GPM

Nominal Pumping Rate: 100 **GPM**

------> Determine Typical Pipe Size:

Pipes are sized to keep flow velocities within GIVEN ranges to insure turbulent flow.

Use the Continuity Equation for incompressible steady flow to determine flow velocity, Q = V*A

Where: Q = Flowrate (cfs)
V = Velocity (fps)
A = Area (square feet)

Standard Pipe Diameter (I.D.) =	3.088	inches	------>	SDR =	17
Nominal Pumping Rate, Q =	0.223	cfs			
Area, A =	0.052	square feet			
Velocity, V =	4.28	fps	------> OK!		

Therefore, Use 3 Inch - SDR 17 Pipe

2. *Pump Requirements*

Flow is desired in fully turbulent conditions. The Reynolds, R, number is used to verify this condition as follows:

Reynolds Number, $R_e = V*D / \upsilon$

Where: V = velocity, fps
D = pipe inside diameter, inches
υ = kinematic viscosity, square feet per second

Velocity, V =	4.28	fps	
Pipe Inside Diameter (I.D.) =	3.09	inches	
kinematic viscosity, υ =	5.58E-06	square feet per second	------> App. A, Table A-9 @ 130 degrees - Ref. 3

Reynolds Number, Re = 197,573 > 10,000 OK ------> Turbulent flow conditions exist

Pumps will be sized according to balance energy by the Bernoulli equation. The equation has been modified as follows:

$TDH = H_e + H_f + H_m$

Where: TDH = Total Dynamic Head, feet
H_e = Elevation Head, feet
H_f = Friction Head, feet
H_m = Minor Losses, feet

Calculations for these values are continued on a spreadsheet model of the system. Please refer to Table 1 (attached)

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Leachate Management
Johnston County C&D Landfill
Leachate Pumping System Design

3 System Cycle Time

——> ~~Determine available storage if a wet well:~~

~~Bottom Elevation of Well =~~	~~162~~	~~FT~~	——>	~~Ref. 1~~
~~Diameter of Well =~~	~~5~~	~~FT~~	——>	~~Ref. 1~~
~~Top Elevation of Well =~~	~~172~~	~~FT~~	——>	~~Ref. 1~~
~~Total Volume of Well =~~	~~196~~	~~CF~~		
~~Total Volume of Well =~~	~~1,469~~	~~GAL~~		
~~Pump ON Elevation =~~	~~168~~	~~FT~~		
~~Pump OFF Elevation =~~	~~165~~	~~FT~~		
~~Pump ON to OFF Volume =~~	~~441~~	~~GAL~~		

——> Determine available storage if a sideslope riser.

Storage volume is calculated according to the Average End Area Method. Assumes 3:1 Sideslopes.

Contour Elevation	Length (feet)	Width (feet)	Area (square feet)	Volume* (cubic feet)	Storage, S (cubic feet)	Storage, S (gallons)	Stage Z
0.0	16.0	16.0	256		0	0	0.0
0.5	19.0	19.0	361	154	154	1154	0.5
1.0	22.0	22.0	484	211	366	2734	1.0
1.5	25.0	25.0	625	277	643	4808	1.5
2.0	28.0	28.0	784	352	995	7443	2.0

Note:
* Calculated according to Average End Area Method

Available Volume =	841	cubic feet	*6289*	*gallons*
Minimum liquid elevation =	0.50	feet above bottom		

The sump is filled with No. 57 Stone therefore volume is reduced. The assumed porosity of the stone is 30%.

If pumps cycle through one (1) foot of elevation volume is 7,443 GAL - 1,154 GAL = 6,289 GALLONS
@ 30% porsity ——> Available Volume = 1887 GALLONS

——> Determine Cycle Time

The pumps should not operate more than 9 times per hour. Minimum cycle time will be determined by the equation below: ——> Sanks, Ref. 3

$t = V/(Q-S) + V/S$ where:
t = Cycle time (min)
V = Volume of Liquid (gallons)
Q = Pumping rate (GPM)
S = Inflow (GPM)

Therefore, V =	1887	GAL ——> from above
Q =	100	GPM ——> Nominal Pumping Rate
S =	14	GPM ——> Normal Flow Conditions
t =	158	minutes

Pump will start once every 3 hours

Pump drawdown time will be 22 minutes

4. Riser Fit

——> Determine minimum dimensions of sideslope riser pipe to allow pump to fit and manage turn at the bottom of the slope

At half of the pump length (L/2), the pump will equally straddle the turn in the pipe and will be at its closest point to the upper edge of the interior of the pipe riser. This value will be compared with the available space with a Factor of Safety of 10% for pipe irregularities.

Pipe Dimensions:

Riser Slope:	3	H to 1 V
Riser Pipe I.D. =	15.882	inches ——> AVAILABLE

Pump Dimensions:

Pump Length, L =	55	inches ——>	*Leachator LPS150MSTG12075-04*
Total Width	6.5	inches ——>	
Clearance =	4.92	inches	

Riser Fit ? **OK ——> USE 18 inch HDPE SDR 17 PIPE**

Standard Pipe Sizes:

Inside* Diameter (inches)	Standard Design Ratio (SDR)	Nominal Pipe Size (inches)
10.432	11	12
11.250	17	12
14.728	11	18
15.882	17	18
19.636	11	24
21.176	17	24

* Ref. 2

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Leachate Management
Johnston County C&D Landfill
Leachate Pumping System Design

5. *System Surge Pressures*

--------> Determine if pipe is sufficient strength to withstand system surges

System surge pressure is determined by the equation:

$\Delta P = (a/g)*(\Delta v/2\ 31)$ -------->Ref. 3, pg. 143

Where: ΔP = Pressure (psi)
a = Pressure wave velocity (fps)
Δv = Change in velocity (fps)
g = acceleration of gravity (32.1 ft/sec^2)

and

$a = 4822/(1+k/E*(D/t)*C_2)^{0.5}$ -------->Ref. 3, pg. 144.

Where. k = Bulk modulus of water (psi)
E = Pipe modulus of elasticity (psi)
D = Internal diameter of pipe (inches)
t = Pipe wall thickness (inches)
C_2 = Constant dependent upon pipe constraints
μ = poisson's ratio, use 0.45 for HDPE pipe (buried), Table 6-1, Ref. 2

k =	296,000	psi ------>	App. A, Table A-9 @ 40°F - Ref. 3	Conservative Case
E =	100,000	psi ------>	HDPE , Ref. 2	
Δv =	5	fps ------>	Maximum allowable velocity	
μ =	0.45			
C_2 =	0.80			
FS =	1.5	Minimum Allowable		

P(allowable) Ref. 2 (psi)	Standard Design Ratio (SDR)	Nominal Pipe Size (inches)	Outside Diameter (inches)	Inside Diameter (inches)	Pipe Wall Thickness (inches)	Pressure Wave Velocity (fps)	Pressure (psi)	Factor of Safety	Comment
267	7	2	2.375	1.697	0.339	1347	91	2.94	OKAY
200	9	2	2.375	1.847	0.264	1152	78	2.57	OKAY
160	11	2	2.375	1.943	0.216	1023	69	2.32	OKAY
128	13.5	2	2.375	2.023	0.176	909	61	2.09	OKAY
110	15.5	2	2.375	2.069	0.153	840	57	1.94	OKAY
100	17	2	2.375	2.095	0.140	800	54	1.85	OKAY
267	7	3	3.500	2.500	0.500	1348	91	2.94	OKAY
200	9	3	3.500	2.722	0.389	1152	78	2.57	OKAY
160	11	3	3.500	2.864	0.318	1022	69	2.32	OKAY
128	13.5	3	3.500	2.982	0.259	908	61	2.09	OKAY
110	15.5	3	3.500	3.048	0.226	841	57	1.94	OKAY
100	**17**	**3**	**3.500**	**3.088**	**0.206**	**799**	**54**	**1.86**	**OKAY**
89	19	3	3.500	3.132	0.184	751	51	1.76	OKAY
80	21	3	3.500	3.166	0.167	713	48	1.66	OKAY
64	26	3	3.500	3.230	0.135	636	43	1.49	NO GOOD
51	32.5	3	3.500	3.284	0.108	565	38	1.34	NO GOOD
267	7	4	4.500	3.214	0.643	1348	91	2.94	OKAY
200	9	4	4.500	3.500	0.500	1152	78	2.57	OKAY
160	11	4	4.500	3.682	0.409	1022	69	2.32	OKAY
128	13.5	4	4.500	3.834	0.333	908	61	2.09	OKAY
110	15.5	4	4.500	3.020	0.290	953	64	1.71	OKAY
100	17	4	4.500	3.970	0.265	800	54	1.85	OKAY
89	19	4	4.500	4.026	0.237	752	51	1.75	OKAY
80	21	4	4.500	4.072	0.214	712	48	1.67	OKAY
64	26	4	4.500	4.154	0.173	635	43	1.49	NO GOOD
51	32.5	4	4.500	4.224	0.138	563	38	2.68	OKAY
267	7	6	6.625	4.733	0.946	1347	91	5.88	OKAY
200	9	6	6.625	5.153	0.736	1152	78	5.15	OKAY
160	11	6	6.625	5.421	0.602	1022	69	4.64	OKAY
128	13.5	6	6.625	5.643	0.491	909	61	4.18	OKAY
110	15.5	6	6.625	5.771	0.427	841	57	3.88	OKAY
100	17	6	6.625	5.845	0.390	799	54	3.71	OKAY
89	19	6	6.625	5.927	0.349	752	51	3.51	OKAY
80	21	6	6.625	5.995	0.315	712	48	3.33	OKAY
64	26	6	6.625	6.115	0.255	635	43	2.99	OKAY
51	32.5	6	6.625	6.217	0.204	565	38	2.68	OKAY

Use 3 inch HDPE - SDR 17 Pipe

G.N. Richardson & Associates, Inc.
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DATE 19-Oct-05
BY SAS
JOB NO JOHNSTON-21

Leachate Management
Johnston County C&D Landfill
Leachate Pumping System Design

Section From	Section To	3. Total Flow (GPM)	4. Velocity (1) (FPS)	4a. Pipe Slope (%)	5. Pipe Size (IN)	6. Pipe Length (FT)	7. Friction Loss (2) (PSI)	8. Sum of Energy Loss Coefficients (3) (K)	9. Minor Losses (4) (PSI)	10. Elevation Head (5) (FT)	10. Additional Pressures (PSI)	11. Sum of Losses (PSI)	12. Subtotal Dynamic Head (FT)	13. Total Dynamic Head (FT)
Area 2 Sump	Valve Box	100	4.54	N/A	3.000	50	0.66	23	7.37	12	0.00	13.22	30.51	151
Valve Box	Air Release	100	4.29	N/A	3.088	700	8.04	4	1.14	40	0.00	26.50	61.15	
Air Release	Phase 4A, LDS Manhole	100	5.92	5.00	3.088	1400	16.07	4	2.18	-40	0.00	0.93	2.14	
Phase 4A, LDS Manhole	Low Point (29+00 Profile)	100	5.92	5.00	3.088	800	9.19	4	2.18	-17	0.00	4.00	9.24	
Low Point (29+00 Profile)	Existing Manhole	100	4.29	N/A	3.088	600	6.89	4	1.14	29	0.00	20.59	47.51	
Existing Manhole (See Note 6)	Leachate Storage Lagoon	260	4.59	1.00	7.057	1600	1.93	4	1.31	-12	0.00	-1.96	-4.51	-5

Pipe Roughness, C = 130 ---> Conservative for HDPE Pipe, Ref. 2
Manning's Roughness, n = 0.009 ---> Recommended for HDPE Pipe, Ref. 2

Notes:

1. Velocity determined by V = Q/A for forced systems and by V = (sqrt (slope)*D^(2/3))/(8.9*n) for gravity systems
2. Friction losses determined by Hazen-Williams Formula.
3. Enegy Loss Coefficient, K was calculated according to values in Tables B-6 and B-7, "Pumping Station Design", 2nd Edition by Robert L. Sanks
4. Minor losses determined by a portion of Bernoulli's Principle ($kv^2/2g$).
5. Elevation head determined from the site plan.
6. Flows through existing manhole were evaluated assuming all flows from Phase 5, Phase 4A (Primary and LDS), and from Area II at simultaneous condition.

< 0
∴ ok!

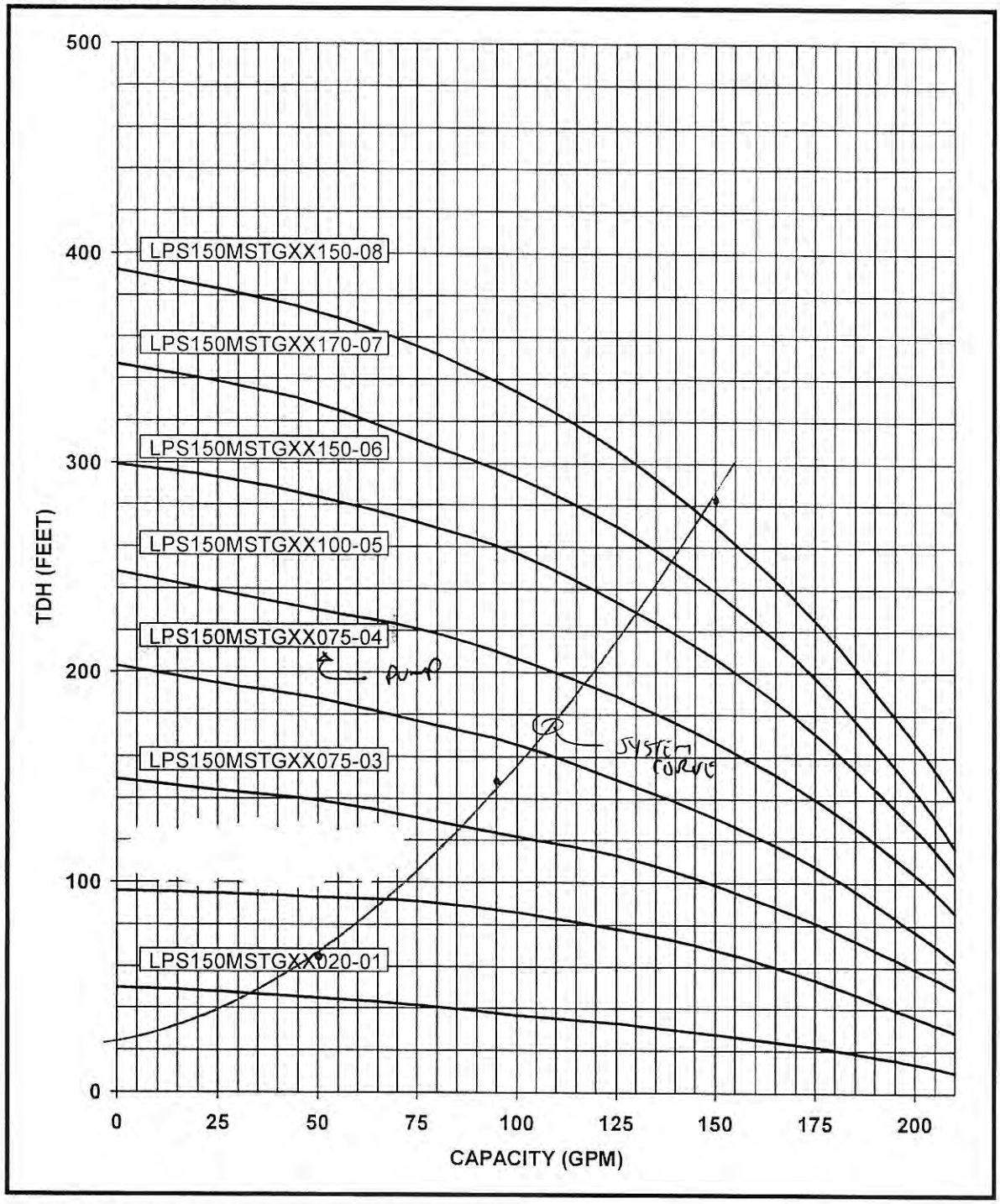
Pump Schedule: Area II Pump —> USE LEACHATOR PUMP MODEL LPS150MSTG12075-04

4/6

MODEL LPS150MSTG

PUMP PERFORMANCE DATA

Performance Curve



SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE
Performance conforms to ISO 2548 Annex B @ 5 ft. min. submergence.
4" MOTOR STANDARD, 2 – 5HP, 3450 RPM
6" MOTOR STANDARD, 7-1/2 – 60HP, 3450 RPM
8" MOTOR STANDARD, 75HP, 3525

Models

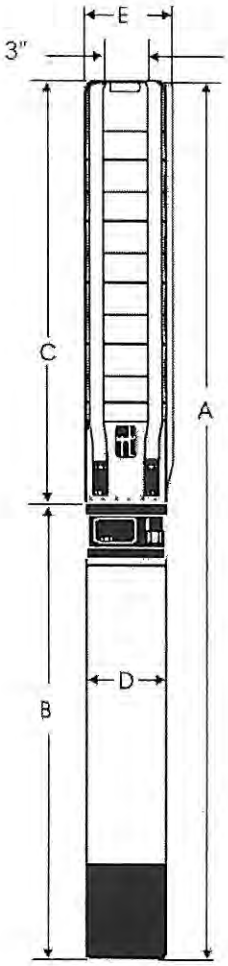
Model Number	Motor Size	HP	RPM	Voltage
LPS150MSTG12020-01	4"	2	3450	230V/1Ph/60Hz
LPS150MSTG3X020-01	4"	2	3450	230-460V/3Ph/60Hz
LPS150MSTG12050-02	4"	5	3450	230V/1Ph/60Hz
LPS150MSTG3X050-02	4"	5	3450	230-460V3Ph/60Hz
LPS150MSTG12075-03	6"	7-1/2	3450	230V/1Ph/60Hz
LPS150MSTG3X075-03	6"	7-1/2	3450	230-460V/3Ph/60Hz
LPS150MSTG12075-04	6"	7-1/2	3450	230V/1Ph/60Hz
LPS150MSTG3X075-04	6"	7-1/2	3450	230-460V/3Ph/60Hz
LPS150MSTG12100-05	6"	10	3450	230V/1Ph/60Hz
LPS150MSTG3X100-05	6"	10	3450	230-460V/3Ph/60Hz
LPS150MSTG12150-06	6"	15	3450	230V/1Ph/60Hz
LPS150MSTG3X150-06	6"	15	3450	230-460V3Ph/60Hz
LPS150MSTG12150-07	6"	15	3450	230V/1Ph/60Hz
LPS150MSTG3X150-07	6"	15	3450	230-460V/3Ph/60Hz
LPS150MSTG12150-08	6"	15	3450	230V/1Ph/60Hz
LPS150MSTG3X150-08	6"	15	3450	230-460V/3Ph/60Hz

Please insert a "2" (230V) or "4" (460V) to complete the model number.

Dimensions And Weights

Model Number	Disch Size	Dimensions In Inches					Approx. Wt
		A	B	C	D	E	
LPS150MSTGXX020-01	3" NPT	27.3	13.6	13.7	3.75	5.2	55
LPS150MSTGXX050-02	3" NPT	41.1	23.6	17.5	3.75	5.2	75
LPS150MSTGXX075-03	3" NPT	45.5	24.2	21.3	5.38	5.2	101
LPS150MSTGXX075-04	3" NPT	49.9	24.2	25.7	5.38	5.6	135
LPS150MSTGXX100-05	3" NPT	54.9	25.4	29.5	5.38	5.6	148
LPS150MSTGXX150-06	3" NPT	61.3	28.0	33.3	5.38	5.6	167
LPS150MSTGXX150-07	3" NPT	65.0	28.0	37.0	5.38	5.6	169
LPS150MSTGXX150-08	3" NPT	68.8	28.0	40.8	5.38	5.6	174

Note(s): *Dimensions and weight are approximate (subject to change) and does not include the carriage.*



Materials Of Construction

Impeller	304 Stainless Steel
Impeller Seal Ring	Teflon
Motor Adapter	304 Stainless Steel
Inlet Screen	304 Stainless Steel
Pump Shaft	431 Stainless Steel
Coupling	329/416 Stainless Steel
Check Valve Housing	304 Stainless Steel
Check Valve	304 Stainless Steel
Check Valve Seat	Teflon/316 Stainless Steel
Diffuser Chamber	304 Stainless Steel
Fasteners	304 Stainless Steel
Bearing	Teflon/316 Stainless Steel
Suspension Cables	304 Stainless Steel

PROJECT Johnston County C&D Landfill - Area 2
JOB NO. JOHNSTON-22
DATE 7/14/05
SUBJECT Final Cover Drainage Layer Analysis
COMPUTED BY PKS
CHECKED BY

Objective To evaluate the required transmissivity for the drainage geocomposite placed in the final cover system.

References Richardson, G.N., Giroud, J.P., and Zhao, A. (2001), Design Manual of Lateral Drainage Systems for Landfills, Tenax Corp., Baltimore.

Analysis

Step 1:

Determine the required transmissivity (θ_{reqd}) of the drainage geocomposite based on the following equation:

$$\theta_{reqd} = \frac{RF_{dc} q_n L i}{\sin\beta} = \frac{RF_{dc} q_n L \cos\beta}{\sin\beta} = \frac{RF_{dc} q_n L}{\tan\beta} \qquad (m^3/m/sec)$$

Where:
RF_{dc} = drainage geocomposite reduction factor (See Note 1)
q_n = fluid input rate/impingement rate (m/s) (See Note 2)
L = flow length/drain spacing (horizontally projected) (m)
β = slope angle of final cover (degrees).

Notes:

1. Based on the recommendations of Richardson, Giroud, & Zhao, use $RF_{dc} = 6$. This accounts for an overall factor of safety of 2, plus a factor of safety of 3 for long-term intrusion, creep, and clogging concerns.

2. Typically the impingement into the drainage geocomposite is determined by the **lessor** of:

   a. Permeability of the Overlying Vegetative Soil Layer(k_{veg}) or
   b. Design Rainfall.

   Per Richardson,Giroud, & Zhao, use $q_n = k_{veg}$ except in arid/semi-arid areas.

Step 2:

Determine the required transmissivity test parameters:

- Normal Stress (Cover Thickness x Unit Weight of Cover Soil) and
- Hydraulic Gradient (Equals Slope of Cover System).

FCS DRAIN LAYER.WPD

Step 3:

Calculate the required total flow capacity (Q) of the drain based on the following equation:

$$Q = q_n A \qquad \text{(cfs)}$$

Where:
q_n = impingement (ft/s)
A = total area served by the drain (= L x DL) (ft^2)
DL = length of drain between outlet locations (ft).

Step 4:

After finding Q for each drain, the designer shall select the appropriate type and size of drain.

G.N. Richardson & Associates
Engineering and Geological Services
14 N. Boylan Avenue
Raleigh, NC 27603
Tel: 919-828-0577
Fax: 919-828-3899

SHEET: 3 / 3
JOB #: JOHNSTON-22
DATE: 7/15/05
BY: PKS
CHKD BY:

Johnston County C&D Landfill - Area 2
Final Cover Drainage Layer Analysis

Input Parameters:

Side Slope Angle (β):	14.0 degrees	
Impingement (q_n):	0.0001 cm/sec	(= Permeability of Vegetative Soil Layer)
Drain Spacing (L):	140 ft	
Reduction Factors for Drainage Geocomposite:		(Per Richardson, Giroud, & Zhao Recommendations)
$RF_{intrusion}$:	1.2	
RF_{creep}:	1.4	
$RF_{chemical\ clogging}$:	1.2	
$RF_{biological\ clogging}$:	1.5	
Overall Factor of Safety:	2.0	
Reduction Factor for Drainage Geocomposite in Final Cover (RF_{dc}):	6.0	
Drain Length (DL):	200 ft	
Final Cover: Thickness:	2.0 ft	
Unit Weight:	110 pcf	

Note: Spreadsheet Converts Units as Required.

Transmissivity Requirements:

Determine Minimum Transmissivity:

θ_{min} = 1.0E-03 m^3/m/sec = 5.0 gpm/ft

Determine Transmissivity Test Parameters:

Min. Normal Stress = 220.0 psf

Hydraulic Gradient = 0.25

Determine Required Drain Capacity:

Calculate Required Total Flow Capacity:

Q = 0.09 cfs

*Based on 200 foot spacing between outlets.

Objective To design rain gutters and down pipes to handle the maximum flow from the design storm.

References

Debo, T.N., and Reese, A.J., Municipal Storm Water Management, Lewis Publishers, Boca Raton, FL, 1995, pp. 438-442.

Malcom, H. Rooney, Elements of Urban Stormwater Design, N.C. State University, Raleigh, NC, 1989.

Analysis

1. For each pipe size, determine the maximum area (A), to handle the predicted flow (Q) with an added factor of safety. Analyze rain gutters and down pipes based on partial flow to determine flow depth and velocity then compare the full flow capacity of each pipe size with the calculated peak flow rate to verify the desired factor of safety. Analyze rain gutter drop inlets (inlet to down pipes) as orifices.

2. Analyze rain gutter pipe perforations as orifice flow to ensure adequate flow capacity into rain gutters.

Calculations

- Determine Peak Flow Rate Into Each Respective Conveyance:

Use Rational Method:

$$Q = CIA$$

Where:
Q = Flow (cfs)
C = Runoff Coefficient
I = Rainfall Intensity (Use 25-Year, 24-Hour Storm)
A = Drainage Area (Ac.)

Iterate the drainage area (A) to each drainage structure such that $Q_{max}/Q \geq 1.1$, where Q_{max} is the full flow capacity of the conveyance (see below).

G.N. RICHARDSON & ASSOCIATES
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14 N. Boylan Avenue, Raleigh, NC 27603
Telephone: (919) 828-0577

- Rain Gutters & Down Pipes:

Determine Flow Capacity (Q_{max}):

$$Q_{max} = \frac{0.463 D^{\frac{8}{3}} S^{\frac{1}{2}}}{n}$$ (D&R Equation 8.24)

Where:
D = Pipe Inside Diameter (in)
S = Pipe Slope (ft/ft)
n = Manning's Roughness Coefficient

Determine Factor of Safety (FS):

$$FS = \frac{Q_{max}}{Q}$$

Determine Flow Depth:

$$h = \frac{1}{2}\left(1 - \cos\left(\frac{\theta}{2}\right)\right) D$$ (D&R Equation 8.29)

Where:
h = Flow Depth (inches)
θ = Central Angle

$$\theta = \frac{3\pi}{2}\left[1 - (1 - \pi K)^{\frac{1}{2}}\right]^{\frac{1}{2}}$$ (D&R Equation 8.28)

K = Constant

$$K = 0.673 Q_n^{\frac{-8}{3}} S^{\frac{-1}{2}}$$ (D&R Equation 8.27)

Determine Flow Velocity:

$$V = \frac{Q}{A} = \frac{Q}{D^2 \frac{(\theta - \sin\theta)}{8}}$$ (D&R Equation 8.30 for "A")

Where: V = Flow Velocity (ft/sec)
A = Cross-Sectional Area of Flow (ft^3)

- Down Pipe Drop Inlets and Rain Gutter Pipe Perforations:

Determine Q_{max}:

$$Q_{max} = C_d A \sqrt{2gh}$$ (Malcom Equation I-7)

Where: C_d = Coefficient of Discharge
A = Cross-Sectional Area of Flow (ft^3)
g = Acceleration of Gravity (32.2 ft/sec^2)
h = Driving Head - Centroid of Orifice to Water Surface (ft)

Determine Factor of Safety (FS):

$$FS = \frac{Q_{max}}{Q}$$

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JOB #: JOHNSTON-22
DATE: 7/15/05
BY: PKS
CHKD BY:

Johnston County C&D Landfill - Area 2
Rain Gutter/Down Pipe Design

Input Parameters:

Manning's Rougness Coefficient =	**0.009**	--> HDPE Pipe
Runoff Coefficient =	**0.5**	
Rainfall Intensity =	**8.19**	IN/HR ---> 25 YR - 5 MIN STORM
Allowable Head (Down Pipe Drop Inlets) =	**24**	INCHES
Orifice Coef. Of Discharge (Down Pipe Drop Inlets) =	**0.6**	TYPICAL
Hole Diameter (Rain Gutter Pipe Bottom Perforations) =	**0.5**	INCHES
Allowable Head (Rain Gutter Pipe Bottom Perforations) =	**12**	INCHES
Orifice Coef. Of Discharge (Rain Gutter Pipe Perforations) =	**0.6**	TYPICAL

Rain Gutters

ID	Drainage Area (AC)	Runoff Volume (Q) (CFS)	Pipe I.D. (SDR 26) (IN)	Pipe Slope (%)	Flow Capacity (Q_{max}) (CFS)	Factor of Safety (>/= 1.10)	K (CONSTANT)	θ (< 265°)	Flow Depth (IN)	Flow Area (SF)	Flow Velocity (FPS)
Max. Area - 6"	**0.32**	1.31	**6.1**	**3**	1.47	1.12	0.278	233	4.41	0.16	8.33
Max. Area - 8"	**0.67**	2.74	**8.0**	**3**	3.02	1.10	0.283	235	5.86	0.27	10.01
Max. Area - 10"	**1.18**	4.83	**9.9**	**3**	5.33	1.10	0.282	235	7.24	0.42	11.53
Max. Area - 12"	**1.89**	7.74	**11.8**	**3**	8.52	1.10	0.283	236	8.65	0.60	12.97

Down Pipe Drop Inlets

ID	Drainage Area (AC)	Runoff Volume (Q) (CFS)	Pipe I.D. (SDR 26) (IN)	X-Sectional Area (SF)	Flow Capacity (Q_{max}) (CFS)	Factor of Safety (>/= 1.10)
Max. Area - 8"	**0.52**	2.13	**8.0**	0.35	2.38	1.12
Max. Area - 10"	**0.80**	3.28	**9.9**	0.53	3.64	1.11
Max. Area - 12"	**1.14**	4.67	**11.8**	0.76	5.17	1.11
Max. Area - 14"	**1.37**	5.61	**12.9**	0.91	6.18	1.10
Max. Area - 16"	**1.80**	7.37	**14.8**	1.19	8.14	1.10
Max. Area - 18"	**2.27**	9.30	**16.6**	1.50	10.23	1.10

Down Pipes

ID	Drainage Area (AC)	Runoff Volume (Q) (CFS)	Pipe I.D. (SDR 26) (IN)	Pipe Slope (%)	Flow Capacity (Q_{max}) (CFS)	Factor of Safety (>/= 1.10)	K (CONSTANT)	θ (< 265°)	Flow Depth (IN)	Flow Area (SF)	Flow Velocity (FPS)
Max. Area - 8"	**1.02**	4.18	**8.0**	**7**	4.62	1.11	0.282	235	5.85	0.27	15.28
Max. Area - 10"	**1.80**	7.37	**9.9**	**7**	8.15	1.11	0.282	235	7.23	0.42	17.61
Max. Area - 12"	**2.88**	11.79	**11.8**	**7**	13.01	1.10	0.282	235	8.63	0.60	19.81
Max. Area - 14"	**3.66**	14.99	**12.9**	**7**	16.51	1.10	0.283	236	9.45	0.71	21.03
Max. Area - 16"	**5.27**	21.58	**14.8**	**7**	23.81	1.10	0.282	235	10.83	0.94	23.04
Max. Area - 18"	**7.17**	29.36	**16.6**	**7**	32.34	1.10	0.283	236	12.16	1.18	24.88

Rain Gutter Pipe Perforations

ID	Max. Drainage Length (LF)	Runoff Volume/LF Pipe (CFS)	No. Holes/LF	X-Sectional Area (SF/Hole)	Flow Capacity (Q_{max}) (CFS/LF)	Factor of Safety (>/= 1.10)
2 Bottom Perfs. @ 4" O.C.	**200**	0.019	**6**	0.001	0.039	2.10

Note: Conservatively Neglects Upper Holes.

Pipe Dimensions

Standard Dimension Ratio (SDR) of Pipe = **26**

Nominal Pipe Size (IN)	Pipe O.D. (IN)	Min. Wall Thickness (IN)	Pipe I.D. (IN)
6	**6.625**	0.255	6.1
8	**8.625**	0.332	8.0
10	**10.75**	0.413	9.9
12	**12.75**	0.490	11.8
14	**14**	0.538	12.9
16	**16**	0.615	14.8
18	**18**	0.692	16.6
24	**24**	0.923	22.2