51-03 1/16/09 DIN 6615

APPROVED
DIVISION OF WASTE MANAGEMENT
SOLID WASTE SECTION
DATE 01-16-09 BY DWilson
PTC 51-03 Attch. 1, Part II, Doc 20

# Permit Amendment Application

## Johnston County MSW Landfill - Phase 4A - Cell 3
## Smithfield, North Carolina

Prepared For:

**Johnston County Department of Public Utilities**
**309 E. Market Street**
**Smithfield, North Carolina 27577**

Prepared By:

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Received
DEC 2008
Waste Management

**June 2007**
**Revised: December 2008**

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**June 2007**
**Revised: December 2008**

Revised Jan. 2009

# PERMIT AMENDMENT APPLICATION

## Johnston County MSW Landfill - Phase 4A - Cell 3
## Smithfield, North Carolina

Prepared for:
**Johnston County Department of Public Utilities**
**Smithfield, NC**

RSG Project No. JOHNSTON-07-2

Pieter K. Scheer, P.E.
Principal, Project Manager

**June 2007**
**Revised: December 2008**

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**JOHNSTON COUNTY MSW LANDFILL**
**PHASE 4A - CELL 3**

**PERMIT AMENDMENT APPLICATION**

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| ATTACHMENT I | WATER QUALITY MONITORING PLAN *(15A NCAC 13B.1623)* |

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# EXECUTIVE SUMMARY

## GENERAL

The following is a Permit Amendment Application submitted on behalf of Johnston County for construction of the Phase 4A - Cell 3 municipal solid waste (MSW) landfill unit at Johnston County's existing landfill facility. Phase 4A - Cell 3, will be a lined Subtitle D landfill unit located adjacent to and west of the existing Phase 4A - Cells 1 & 2 landfill units currently in operation. Phase 4A - Cell 3 will piggyback over a portion of the existing unlined Phase 4 landfill unit and the Area 1 C&D landfill vertical expansion. It is the intent of Johnston County to proceed with the construction of Cell 3 in January 2009.

The proposed Phase 4A - Cell 3 landfill unit will occupy approximately 7.4 acres (lined). As described in the Engineering Plan (**Attachment A**), Phase 4A - Cell 3 (Fill Sequence 1) has been designed for approximately 5.9 years of disposal capacity based on projected County tonnages. Another fill sequence (Fill Sequence 2) will provide approximately an additional 2.6 years of disposal capacity based on projected County tonnages. Life expectancies will be reduced should the County elect to accept any out-of-County waste from their approved service area of the State of North Carolina (*reference: Facility & Engineering Plan portion of the Permit to Construct Application - Johnston County C&D Landfill - Area 2 - Approved August 31, 2006.*).

The Phase 4A - Cell 3 landfill unit will use an alternative liner system, as allowed under North Carolina regulations. The components of the liner and leachate collection systems will consist of the following components (top-down):

Alternative Liner System:

- a leachate collection system (LCS) consisting of:

  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.

- a 60-mil HDPE geomembrane liner;
- a geosynthetic clay liner (GCL);
- a leak detection system (LDS) consisting of:

  Base and Side Slopes:
  - a drainage geocomposite; and
  - a leak detection trench (stone and collection pipe).

- and a 40-mil thick LLDPE geomembrane liner.

According to the guidelines set forth by North Carolina Division of Waste Management (DWM) the alternative liner system described above is considered an approved alternative having previously been demonstrated to provide at least the same protection as the standard composite liner (*reference: Permit to Construct Application - Johnston County MSWLF - Phase 4A - Approved April 3, 2002*).

Leachate generated from Phase 4A - Cell 3 will be collected and routed to the Phase 4A sump at the north end of Cell 1. From the sump, the leachate is pumped using side riser pumps to the existing leachate storage lagoon.

## REGULATORY REFERENCES

This submittal has been prepared in accordance with the requirements of the North Carolina Solid Waste Management Rules (15A NCAC 13B.1600) and the North Carolina Sedimentation Control Rules (15A NCAC 4), which are enforced by the Division of Waste Management (DWM) and the Division of Land Quality, respectively, of the North Carolina Department of Environment and Natural Resources (DENR). Included in this submittal are the following documents *(with applicable rule(s) in italics)*:

Facility and Engineering Plan *(.1619 - .1620)*;
Technical Specifications *(.1620)*;
Construction Quality Assurance (CQA) Manual *(.1621)*;
Operations Manual *(.1625)*;
Closure and Post-Closure Plan *(.1629)*;
Erosion and Sedimentation Control Plan *(.1624 and 15A NCAC 4)*;
Slope Stability, Settlement, and Bearing Capacity Evaluation *(.1620)*;
Permit Amendment Drawings *(.1620, .1624, .1625, .1629, and 15A NCAC 4)*:
Water Quality Monitoring Plan *(.1623)*.

The Facility and Engineering Plan presents plans for the development of the landfill facility and the detailed engineering design of the Phase 4A - Cell 3 landfill unit, and, along with the Technical Specifications, slope stability and settlement, and bearing capacity evaluation, and Project Drawings, has been prepared to comply with the requirements of 15A NCAC 13B.1619 and .1620.

The Construction Quality Assurance (CQA) Manual has been prepared to provide the Owner, Engineer, and CQA Engineer the means to govern the construction quality and to satisfy landfill certification requirements under current North Carolina Solid Waste Management regulations. This document has been prepared to comply with the requirements of 15A NCAC 13B.1621.

The Operations Manual outlines and describes protocols for facility operation and maintenance and was prepared to provide landfill personnel with a clear understanding of how the Design Engineer assumed that the completed facility would be operated. Along with the Project Drawings, the Operations Manual has been prepared to comply with the requirements of 15A NCAC 13B.1625.

The Closure and Post-Closure Plan was prepared to outline the requirements for closure and post-closure activities at the landfill and includes a cost analysis for each. Along with the Project Drawings, this document has been prepared to comply with the requirements of 15A NCAC 13B.1629.

The Erosion and Sedimentation Control Plan was prepared to describe both initial and long term (final) erosion and sedimentation control measures used at the site. This document, along with the Project Drawings, was prepared to satisfy the requirements of 15A NCAC 13B.1624 and 15A NCAC 4.

The currently approved Water Quality Monitoring Plan is included and was prepared to satisfy the requirements of 15A NCAC 13B.1623.

**REFERENCE TO PRIOR DOCUMENTS**

Design Hydrogeologic Report:

The Design Hydrogeologic Report required by 15A NCAC 13B.1623 was performed for all of Phase 4A and is included in the following reference: *Permit to Construct Application - Johnston County MSWLF - Phase 4A - Approved April 3, 2002.* This report includes documentation of location restriction demonstrations as required by 15A NCAC 13B.1622.

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# Facility and Engineering Plan

## Johnston County MSW Landfill - Phase 4A - Cell 3
## Smithfield, North Carolina

Prepared for:

**Johnston County Department of Public Utilities**
**Smithfield, NC**

**June 2007**
**Revised: December 2008**

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**JOHNSTON COUNTY MSW LANDFILL**
**PHASE 4A - CELL 3**

**FACILITY AND ENGINEERING PLAN**

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# SECTION 1.0
# INTRODUCTION

## 1.1 OVERVIEW

The Johnston County Landfill facility is located on County Home Road off Highway 210 near Smithfield, North Carolina and operates under NC Solid Waste Permit 51-03. The landfill facility includes an active ± 22 acre Subtitle D municipal solid waste (MSW) landfill (Phase 4A - Cells 1 & 2), a separate active ± 11.9 acre construction and demolition debris (C&D) landfill unit (Area 2 - Cell 1), a landfill office, scales and scalehouse, a citizen's convenience center, and a yard waste processing area.

Based on current projections, the active MSW landfill unit (Phase 4A - Cells 1 - 2) is expected to remain in operation until early to mid 2009. Once Cells 1 & 2 have reached capacity, the County will need to expand operations laterally into Cell 3 constructed to the west and overlying the existing closed unlined Phase 4 MSW landfill unit. It is the intent of Johnston County to proceed with the construction of Cell 3 in January 2009.

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 Phase 4A - Cell 3 MSW landfill unit. Additionally, the Facility Report (Section 2) has been updated from the version previously approved in August 2006.

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 currently proposed Phase 4A - Cell 3 MSW landfill unit as well as 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 Phase 4A - Cell 3 unit, respectively.

## 1.2 SITE DESCRIPTION

The Phase 4A - Cell 3 site is situated within the currently approved facility boundary, which consists of approximately 500 acres. Existing conditions are shown on **Drawing S1** of the Project Drawings (**Attachment H** to the Permit Amendment Application).

The proposed Phase 4A - Cell 3 landfill unit will occupy approximately 7.4 acres (lined). As described in Section 2, Phase 4A - Cell 3 (Fill Sequence 1) has been designed for approximately 5.9 years of disposal volume based on projected County tonnages. Another fill sequence (Fill Sequence 2) will provide approximately an additional 2.6 years of disposal capacity based on projected County tonnages. Life expectancies will be reduced should the County elect to accept any out-of-County waste from their approved service area of the State of North Carolina[1].

[1] Permit to Construct Application - Johnston County C&D Landfill - Area 2 - Approved August 31, 2006.

The Phase 4A - Cell 3 landfill unit has been designed to meet current DWM setback and horizontal buffer requirements for MSW landfills: 300 feet from property lines; 500 feet from residences or active water wells.

## 1.3 SITE DEVELOPMENT HISTORY

MSW Landfill Units

The Johnston County Landfill facility has four 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 and 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 and 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 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. In 2004, Cell 2 was constructed and both cells are currently active. 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 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 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.

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).

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# SECTION 2.0
# FACILITY REPORT

## 2.1 OVERVIEW

This section presents a plan for the development of the Johnston County Landfill facility. This report, which updates the previously approved Facility Plan[1], has been prepared in accordance with the requirements of Rule .1619 of the North Carolina Solid Waste Management Regulations.

## 2.2 FACILITY SERVICES AND WASTE STREAM

### 2.2.1 Facility Services

Currently, the following activities or services are provided at the Johnston County Landfill facility:

- Scales and scale house facilities
- Administrative offices
- Maintenance building
- Convenience center
- Yard waste processing area
- Lined municipal solid waste (MSW) landfill - (Phase 4A - Cells 1&2) (NC Permit No. 51-03)
- Construction and demolition debris (C&D) landfill - (Area 2 - Cell 1) (NC Permit No. 51-03).

The following facilities are proposed for the facility:

- Lined MSW landfill - Phase 4A - Cell 3 and Phases 6-10
- C&D landfill - Area 2 - Cell 2.

### 2.2.2 Types of Waste

The Johnston County Landfill accepts mixed municipal solid waste (MSW) originating from residential, commercial, and industrial sources, construction and demolition debris (C&D), and other wastes (i.e. white goods, tires, and yard waste). These wastes are segregated and directed to on-site facilities for disposal/processing as described below.

[1]Permit to Construct Application - Johnston County C&D Landfill - Area 2 - Approved August 31, 2006.



Revised date should be Jan. 2009

## 2.2.3 Disposal Rates and Estimated Variances

### 2.2.3.1 Projected County Disposal Rates

Based on the 2005-2006 Solid Waste Management Annual Report information provided by the County, the landfill accepted 113,684 tons of MSW and 40,832 tons of C&D waste from 7/1/06 to 6/30/07 (MSW: average 9,474 tons per month or 364 tons per day based on 312 operating days per year; C&D: average 3,403 tons per month or 131 tons per day based on 312 operating days per year). The population served during this time period was estimated as 151,589 which translates to 0.75 tons/person/year of MSW and 0.27 tons/person/year of C&D waste being disposed of at the landfill. Due to recent decreases in C&D tonnages, the per capita disposal rate was assumed to be 0.20 tons/person/year for the determination of disposal rates.

Based on the anticipated population figures and increases projected through 2030 from the NC Demographics Unit and the current per capita disposal rate, **Table 2.1A and Table 2.1B** give the projected annual and monthly tonnages to be disposed of at the Johnston County Landfill facility (in-County waste only) for MSW and C&D waste, respectively. Note that monthly variances shown in the tables are based on County records which indicate that the maximum anticipated monthly variance is about plus or minus 20 percent from average. Also note that population figures after 2029 are based on an assumed constant percentage increase from 2029 onward.

### 2.2.3.2 Maximum Disposal Rates

Based upon the projected in-County disposal rates shown in **Tables 2.1A and 2.1B** and the maximum out-of-County disposal rate stated below, the landfill facility will accept waste at the following maximum rates (tons/day is based on 312 operating days per year):

| | |
|---|---|
| 2008-2015 | 350,000 tons/year (1,122 tons/day) |
| 2016-2025 | 401,000 tons/year (1,285 tons/day) |
| 2026-2035 | 452,000 tons/year (1,449 tons/day) |
| 2036-2045 | 505,000 tons/year (1,619 tons/day) |
| 2046-2055 | 568,000 tons/year (1,821 tons/day) |

Of the rates shown, a maximum of 156,000 tons/year (500 tons/day) will be from outside the County. Note that the above disposal rates are the same as previously approved.

## 2.2.4 Service Area

The landfill serves the State of North Carolina.

### 2.2.5 Procedures for Waste Segregation

Procedures for waste segregation at the proposed landfill will be similar to existing operations. A brief description of planned procedures is as follows.

Wastes are segregated at the scales. Operators at the scalehouse are trained to classify and segregate the waste stream. MSW and C&D wastes are directed to the active MSW or C&D landfill unit. Yard wastes are directed toward the yard waste processing area. Tires and white goods are stockpiled temporarily for disposal by private recycling contractors. directed to the white goods processing area. Small loads and recyclables are 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 is 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 is rejected and not permitted into the facility. If hazardous waste is found at the tipping area, identification of the truck or persons is made (if possible) and documented, then the hazardous waste is identified and placed in a hazardous waste container and taken to a designated hazardous waste staging area for proper disposal. If this occurs, the event is reported to the appropriate authorities.

### 2.2.6 Equipment Requirements

The equipment required for operation and maintenance of the proposed landfill units are anticipated to be the same as or similar to those currently used at the facility.

## 2.3 LANDFILL CAPACITY

### 2.3.1 Total Operating Capacity and Life Expectancy

#### 2.3.1.1 MSW Landfill Units

**Drawings P1 - P3** (MSW Landfill Phasing Plan), show conceptual base and final cover grades for the development of Phases 4A and 6 through 10. The final cover side slopes will be at a 4H to 1V slope, then transition at flatter slopes (5 - 8%) to the peak elevations.

#### 2.3.1.2 C&D Landfill Units

**Drawing P4** (C&D Landfill Phasing Plan) identifies the conceptual base and final cover grades for the development of Areas 1 & 2. The final cover side slopes will be at a 4H to 1V slope, then transition at flatter slopes (5 - 8%) to the peak elevations.

The estimated total gross and net operating capacities, life expectancies, and areas of existing and planned MSW and C&D landfill units are shown in **Tables 2.2A and 2.2B**, respectively. Note that the approximate total capacities and waste footprint areas for closed unlined MSW landfill units are also shown in **Table 2.2A**. The gross capacity for each landfill unit reflects the total volume from bottom of waste to the top of the final cover. The net capacity for waste and corresponding life expectancy of each landfill unit accounts for daily and intermediate cover and/or final cover. For MSW landfill units, a range of life expectancies are given to cover projected County-only tonnages (longer life expectancy) through the maximum disposal rates given in **Section 2.2.3.2** (shorter life expectancy). For C&D landfill units, a range of life expectancies are given to cover projected County-only tonnages (longer life expectancy) through projected County-only tonnages plus the anticipated 20% variance (shorter life expectancy).

Note that, although the base and final grades for the MSW and C&D landfill units approximate those shown in the previously approved facility plan, the total gross capacity is approximately 765,800 CY (3.8%) more than reported in the previously approved plan (19.9 MCY (MSW units - Phases 4A & 5-10 and C&D units - Areas 1 and 2)) mainly due to differences in Phase 4A. Thus, this is a minor (less than 10%) change and does not require a new local government approval.

## 2.3.2 In-Place Ratio of Waste to Soil and Compaction Factors

### 2.3.2.1 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 based on recent analyses of waste density. A compaction factor of 1,400 pcy was assumed for areas with the greatest height (i.e. Phase 4A - Cell 3, Phase 9, and Phase 10).

### 2.3.2.2 C&D Landfill Units

The capacities obtained above were based on a 10 percent periodic cover ratio and a compaction factor of 1,200 pounds per cubic yard. The assumed periodic cover ratio is typical for C&D landfills. The assumed compaction factor is based on a recent analysis of waste density in Area 2.

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.

## 2.4 AVAILABLE SOIL RESOURCES AND REQUIRED SOIL QUANTITIES

### 2.4.1 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, compacted soil liner, and/or general fill. These excavation (cut) and structural fill (fill) volumes are shown in **Table 2.3**.

### 2.4.2 Soil Liner

The soil required for the soil liner will be on-site or imported soils. The in-place volume required for each landfill unit is shown in **Table 2.4**.

### 2.4.3 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 2.5**. A portion of this volume will consist of aggregate, which will come from off-site sources.

### 2.4.4 Daily and Intermediate Cover

Assuming the previously mentioned periodic cover ratios, the required in-place volume for use as daily and intermediate cover during landfill operations is shown in **Table 2.6**.

### 2.4.5 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 2.7**.

### 2.4.6 Soil Summary

The above on-site and off-site soil quantities are summarized in **Table 2.8**. Note that, based on the proposed base grades, long-term there is a soil deficit, which will be made up from off-site sources.

## 2.5 FACILITY DESIGN CRITERIA

### 2.5.1 MSW Landfill Units

The Johnston County MSW landfill base liner and final cover systems will be constructed in accordance with Section .1624 of the North Carolina Administrative Code, Title 15A, Chapter 13, Subchapter 13B including the following requirements.

2.5.1.1 Horizontal Separation Requirements

The horizontal separation requirement between the disposal boundary (edge of waste) and the property lines is a minimum of 300 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.

2.5.1.2 Vertical Separation Requirements

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

### 2.5.2 C&D Landfill Units

The Johnston County C&D landfill is designed and operates in accordance with Section .0540 of the North Carolina Administrative Code, Title 15A, Chapter 13, Subchapter 13B including the following requirements.

2.5.2.1 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.

2.5.2.2 Vertical Separation Requirements

For Area 2, the post-settlement elevation of the base liner system (as measured from the top of the soil liner or GCL) will meet the minimum requirement of four feet above the seasonal high groundwater table and bedrock.

## 2.6 CONTAINMENT AND ENVIRONMENTAL CONTROL SYSTEMS

Technical specifications and construction quality assurance requirements for the materials used in the construction of Phase 4A - Cell 3 can be found in **Attachments B and C**, respectively. Geosynthetics used in the construction of Phase 4A - Cell 3 are discussed in greater detail in **Section 3.0** (Geosynthetics Design) of this document.

### 2.6.1 Landfill Subgrade and Perimeter Berms

The landfill subgrade elevations for lined landfill units have been designed for minimum post-settlement slopes of 2 percent (NCAC .1624(b)(7)). 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. Some areas may also require placement of a bridge lift prior to placement of 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.

### 2.6.2 Base Liner System

The following is a general discussion of the base liner systems for MSW landfill units and lined C&D landfill units. The specific design requirements are discussed in the permit applications for each individual unit.

#### 2.6.2.1 MSW Landfill Units

The base liner areas for Phase 4A - Cell 3, and Phases 6-10 are shown on **Drawing S2** (Site Development Plan - Base Grades). The base liner will consist of either a standard composite liner system or an alternative liner system as allowed under North Carolina regulations. The components of this liner system will consist of the following components (top-down):

Standard Liner System - Phases 6-10:

- a leachate collection system (LCS) consisting of natural and/or geosynthetic drainage media and collection piping;
- a 60 mil HDPE geomembrane liner; and
- a 24 inch thick compacted soil liner with a permeability of no more than 1 x $10^{-7}$ cm/sec.

**OR**

Alternative Liner System - Phase 4A - Cell 3:

- a LCS (components as listed above for the standard liner system);
- a 60 mil HDPE geomembrane liner;
- a geosynthetic clay liner (GCL);
- a drainage geocomposite (leak detection system); and

- a 40 mil LLDPE geomembrane liner.

Alternative Liner System - Phases 6-10:

- a LCS (components as listed above for the standard liner system);
- a 60 mil HDPE geomembrane liner;
- a geosynthetic clay liner (GCL); and
- an 18 inch thick compacted soil liner with a permeability of no more than 1 x $10^{-5}$ cm/sec.

2.6.2.2 Lined C&D Landfill Units

The base liner area for Area 2 is shown on **Drawing S5** (Area 2 - Composite Liner Grading and Leachate Collection System Plan). Area 2 will have a liner system consisting of the following components (top-down):

Type 1:

- a leachate collection system (LCS) consisting of:

  Base and Side Slopes:
  - a drainage geocomposite; and
  - a system of collection pipes and gravel columns.

- a 40 mil LLDPE geomembrane liner; and
- a 12 inch thick compacted soil liner with a permeability of no more than 1 x $10^{-5}$ cm/sec.

**OR**

Type 2:

- a LCS (components as listed above for the Type 1 liner system);
- a 40 mil LLDPE geomembrane liner;
- a geosynthetic clay liner (GCL); and
- a 12 inch thick layer of structural fill (no permeability criteria).

The compacted soil liner (if used) will consist of compacted on-site or imported borrow soils. The compacted soil liner will be placed and compacted in 6 inch lifts to achieve the required permeability and strength requirements.

The GCL (if used) will consist of a layer of sodium bentonite bonded between two geotextiles. The GCL will provide a maximum hydrated permeability of 5 x $10^{-9}$ cm/sec.

The geomembrane components of the liner systems will consist of a 40 mil thick Linear

Low Density Polyethylene (LLDPE) synthetic liner (Phase 4A - secondary geomembrane; Area 2 - primary geomembrane) and/or a 60 mil thick High Density Polyethylene (HDPE) synthetic liner (Phase 4A and Phases 6-10 - primary geomembrane). These geomembranes will be installed by a qualified contractor.

For the Phase 4A - Cell 3 MSW landfill unit, all geosynthetics have been selected to comply with the performance requirements identified in **Section 3.0** (Liner System Design) as well as the Specifications presented in **Attachment B**.

Note that, for the purposes of this report and the calculations of volumes, the above listed Type 1 liner (Area 2 C&D) and alternative liner system (Phase 4A - Cell 3 and Phases 6-10) have been assumed. It is possible that a different alternative liner system will be proposed at a future date for future areas.

### 2.6.3 Leachate Collection System (LCS)

The LCS will be constructed directly above the geomembrane on both the base and side slopes of the landfill. Components of the LCS will be as listed above (see **Section 2.6.2**). The LCS functions to collect leachate as quickly as is practical and to conduct the fluid out of the landfill via the sumps. The goal of the LCS is to minimize the hydraulic head acting on the liner, thereby reducing the leak potential. For the Phase 4A - Cell 3 MSW landfill unit, a detailed discussion of the LCS can be found in **Section 4.0** (Leachate Management System Design).

### 2.6.4 Protective Cover

A protective cover layer of soil or stone may be used as the upper component of the LCS. For the Phase 4A - Cell 3 MSW landfill unit, 24 inches of protective cover soil will be placed over the drainage geocomposite of the LCS. Where soil is used, a separator/filter geotextile is required between drainage aggregate and the soil.

### 2.6.5 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 lagoon. 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 - that is, treated for removal of sediment only.

For disposal areas that have waste placed in them, precipitation is allowed to percolate or run-off into the LCS. For areas that have no waste, the percolation or run off to the sump where a pump conducts the water to a perimeter drainage structure. This runoff 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 (or suitably shredded) 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**).

### 2.6.6 Final Cover System

As a minimum, the components of the final cover system (bottom up) will consist of a 6 to 12 inch foundation layer (daily or intermediate cover), 30 mil textured LLDPE geomembrane, drainage geocomposite (pore pressure reduction), and a 24 inch thick vegetative soil layer which includes a 6 inch thick topsoil layer. For the MSW landfill units, this system differs from the standard regulatory final cover in that an 18 inch layer of $1 \times 10^{-5}$ cm/sec soil below the geomembrane is removed and the drainage geocomposite is added above the geomembrane. The addition of the drainage geocomposite reduces head on the geomembrane for both reduced infiltration through the geomembrane and increased stability of the overlying soil veneer.

For the Phase 4A - Cell 3 MSW landfill unit, a detailed discussion of final cover system design can be found in **Section 5.0** (Final Cover System Design).

### 2.6.7 Erosion and Sedimentation Control

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

For the Phase 4A - Cell 3 landfill unit, a detailed discussion of site erosion and sedimentation control can be found in the Project Erosion And Sedimentation Control Plan (**Attachment F**).

### 2.6.8 Landfill Gas Control

#### 2.6.8.1 MSW Landfill Units

Landfill gas (LFG) control will consist of a series of vertical wells and/or collector trenches which are connected to passive vents or utility flares or to an active gas extraction system. The selected system will be designed to limit the gas pressures on the final cover geosynthetics.

Note that the volume of waste projected in the Phase 4A - Cell 3 unit will cause the total volume of MSW waste at the facility to exceed the 2.75 million ton threshold of the EPA's New Source Performance Standards (NSPS) on landfill gas emissions and will, therefore, bring this facility under these guidelines. In accordance with State requirements, a Title V air quality permit application will

be made once the Phase 4A - Cell 3 unit receives its Permit to Operate. The final design will be made as part of the required Collection and Control System Design Plan.

2.6.8.2 C&D Landfill Units

For the Area 1 C&D landfill unit, which overlies the closed unlined Phase 4 MSW landfill unit, LFG control will consist of a series of vertical wells and/or collector trenches which are connected to passive vents or utility flares or to an active gas extraction system. The selected system will be designed to limit the gas pressures on the final cover geosynthetics. Likewise, a series of collector trenches has been designed to be placed under the portion of the Area 2 C&D landfill unit which overlies the Phase 3 unlined MSW landfill unit. Due to the limited amount of LFG expected from the C&D waste, minimal LFG control features are planned as part of the Area 2 final cover system.

Also refer to the facility Operations Manual (**Attachment D**) for a discussion of LFG monitoring and record keeping requirements.

### 2.6.9 Access and Roadways

The site has been designed to provide all-weather access to active areas as well as areas under intermediate cover. Access ramps into the lined areas will be provided where necessary.

## 2.7 SLOPE STABILITY AND SETTLEMENT

The slope stability of the overall waste mass and perimeter berms, the protective cover veneer, and the final cover veneer, as well as estimates of foundation settlement are addressed in **Attachment G**. Slope stability analyses indicated that the proposed Phase 4A - Cell 3 landfill configuration will be stable. Veneer stability analyses on the liner system side slopes and final cover showed that for maximum slopes, these areas will be stable.

## 2.8 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 above. From the storage lagoon, the leachate will be pumped via force main on a regular basis 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.

For the Phase 4A - Cell 3 MSW landfill unit, a detailed discussion of the leachate management system, including anticipated leachate volumes, can be found in **Section 4.0** (Leachate Management System Design).

## 2.9 SPECIAL ENGINEERING FEATURES

Special engineering features proposed for Phase 4A - Cell 3 includes an alternative liner system.

### 2.9.1 Alternative Liner Systems

Alternative liner systems, as described above, are proposed for use at the facility due to the lack of 1 x $10^{-7}$ cm/sec soil on-site.

## TABLE 2.1A
## PROJECTED (COUNTY-ONLY) MSW TONNAGES

| Year | Population | Projected Annual MSW Tonnage | Projected Average Monthly MSW Tonnage | Projected Monthly Variance (± 20%) |
|---|---|---|---|---|
| 2008 | 162,609 | 121,957 | 10,163 | 8,130 - 12,196 |
| 2009 | 167,849 | 125,887 | 10,491 | 8,392 - 12,589 |
| 2010 | 172,857 | 129,643 | 10,804 | 8,646 - 12,964 |
| 2011 | 178,094 | 133,571 | 11,131 | 8,905 - 13,357 |
| 2012 | 183,333 | 137,500 | 11,458 | 9,167 - 13,750 |
| 2013 | 188,570 | 141,428 | 11,786 | 9,429 - 14,143 |
| 2014 | 193,808 | 145,356 | 12,113 | 9,690 - 14,536 |
| 2015 | 199,109 | 149,332 | 12,444 | 9,955 - 14,933 |
| 2016 | 204,600 | 153,450 | 12,788 | 10,230 - 15,345 |
| 2017 | 210,092 | 157,569 | 13,131 | 10,505 - 15,757 |
| 2018 | 215,584 | 161,688 | 13,474 | 10,779 - 16,169 |
| 2019 | 221,075 | 165,806 | 13,817 | 11,054 - 16,581 |
| 2020 | 226,622 | 169,967 | 14,164 | 11,331 - 16,997 |
| 2021 | 232,333 | 174,250 | 14,521 | 11,617 - 17,425 |
| 2022 | 238,043 | 178,532 | 14,878 | 11,902 - 17,853 |
| 2023 | 243,755 | 182,816 | 15,235 | 12,188 - 18,282 |
| 2024 | 249,466 | 187,100 | 15,592 | 12,473 - 18,710 |
| 2025 | 255,232 | 191,424 | 15,952 | 12,762 - 19,142 |
| 2026 | 261,161 | 195,871 | 16,323 | 13,058 - 19,587 |
| 2027 | 267,092 | 200,319 | 16,693 | 13,355 - 20,032 |
| 2028 | 273,023 | 204,767 | 17,064 | 13,651 - 20,477 |
| 2029 | 278,953 | 209,215 | 17,435 | 13,948 - 20,921 |
| 2030 | 284,532 | 213,399 | 17,783 | 14,227 - 21,340 |
| 2031 | 290,223 | 217,667 | 18,139 | 14,511 - 21,767 |
| 2032 | 296,027 | 222,020 | 18,502 | 14,801 - 22,202 |
| 2033 | 301,948 | 226,461 | 18,872 | 15,097 - 22,646 |
| 2034 | 307,987 | 230,990 | 19,249 | 15,399 - 23,099 |

| Year | Population | Projected Annual MSW Tonnage | Projected Average Monthly MSW Tonnage | Projected Monthly Variance (± 20%) |
|---|---|---|---|---|
| 2035 | 314,146 | 235,610 | 19,634 | 15,707 - 23,561 |
| 2036 | 320,429 | 240,322 | 20,027 | 16,021 - 24,032 |
| 2037 | 326,838 | 245,128 | 20,427 | 16,342 - 24,513 |
| 2038 | 333,375 | 250,031 | 20,836 | 16,669 - 25,003 |
| 2039 | 340,042 | 255,032 | 21,253 | 17,002 - 25,503 |
| 2040 | 346,843 | 260,132 | 21,678 | 17,342 - 26,013 |
| 2041 | 353,780 | 265,335 | 22,111 | 17,689 - 26,533 |
| 2042 | 360,855 | 270,642 | 22,553 | 18,043 - 27,064 |
| 2043 | 368,073 | 276,054 | 23,005 | 18,404 - 27,605 |
| 2044 | 375,434 | 281,576 | 23,465 | 18,772 - 28,158 |
| 2045 | 382,943 | 287,207 | 23,934 | 19,147 - 28,721 |
| 2046 | 390,602 | 292,951 | 24,413 | 19,530 - 29,295 |
| 2047 | 398,414 | 298,810 | 24,901 | 19,921 - 29,881 |
| 2048 | 406,382 | 304,786 | 25,399 | 20,319 - 30,479 |
| 2049 | 414,509 | 310,882 | 25,907 | 20,725 - 31,088 |
| 2050 | 422,800 | 317,100 | 26,425 | 21,140 - 31,710 |
| 2051 | 431,256 | 323,442 | 26,953 | 21,563 - 32,344 |
| 2052 | 439,881 | 329,911 | 27,493 | 21,994 - 32,991 |
| 2053 | 448,678 | 336,509 | 28,042 | 22,434 - 33,651 |
| 5054 | 457,652 | 343,239 | 28,603 | 22,883 - 34,324 |
| 2055 | 466,805 | 350,104 | 29,175 | 23,340 - 35,010 |

**TABLE 2.1B**
**PROJECTED (COUNTY-ONLY) C&D TONNAGES**

| Year | Population | Projected Annual C&D Tonnage | Projected Average Monthly C&D Tonnage | Projected Monthly Variance (± 20%) |
|---|---|---|---|---|
| 2008 | 162,609 | 32,522 | 2,710 | 2,168 - 3,252 |
| 2009 | 167,849 | 33,570 | 2,797 | 2,238 - 3,357 |
| 2010 | 172,857 | 34,571 | 2,881 | 2,305 - 3,457 |
| 2011 | 178,094 | 35,619 | 2,968 | 2,375 - 3,562 |
| 2012 | 183,333 | 36,667 | 3,056 | 2,444 - 3,667 |
| 2013 | 188,570 | 37,714 | 3,143 | 2,514 - 3,771 |
| 2014 | 193,808 | 38,762 | 3,230 | 2,584 - 3,876 |
| 2015 | 199,109 | 39,822 | 3,318 | 2,655 - 3,982 |
| 2016 | 204,600 | 40,920 | 3,410 | 2,728 - 4,092 |
| 2017 | 210,092 | 42,018 | 3,502 | 2,801 - 4,202 |
| 2018 | 215,584 | 43,117 | 3,593 | 2,874 - 4,312 |
| 2019 | 221,075 | 44,215 | 3,685 | 2,948 - 4,422 |
| 2020 | 226,622 | 45,324 | 3,777 | 3,022 - 4,532 |
| 2021 | 232,333 | 46,467 | 3,872 | 3,098 - 4,647 |
| 2022 | 238,043 | 47,609 | 3,967 | 3,174 - 4,761 |
| 2023 | 243,755 | 48,751 | 4,063 | 3,250 - 4,875 |
| 2024 | 249,466 | 49,893 | 4,158 | 3,326 - 4,989 |
| 2025 | 255,232 | 51,046 | 4,254 | 3,403 - 5,105 |
| 2026 | 261,161 | 52,232 | 4,353 | 3,482 - 5,223 |
| 2027 | 267,092 | 53,418 | 4,452 | 3,561 - 5,342 |
| 2028 | 273,023 | 54,605 | 4,550 | 3,640 - 5,460 |
| 2029 | 278,953 | 55,791 | 4,649 | 3,719 - 5,579 |
| 2030 | 284,532 | 56,906 | 4,742 | 3,794 - 5,691 |

## TABLE 2.2A
## TOTAL OPERATING CAPACITY AND LIFE EXPECTANCY - MSW LANDFILL UNITS

| Landfill Unit | Area (Acres) | Gross Capacity (CY) | Net (Waste) Capacity (CY/Tons) | Life Expectancy (Years) |
|---|---|---|---|---|
| **Unlined Landfill Units** | | | | |
| Phase 1/2 | 22.1 | 732,363 | 495,790 CY<br>297,474 Tons | Closed |
| Phase 3 | 25.4 | 1,174,139 | 819,136 CY<br>491,482 Tons | Closed |
| Phase 4 | 37.3 | 1,631,731 | 1,133,533 CY<br>680,120 Tons | Closed |
| Total (Unlined): | 84.8 | 3,538,233 | 2,448,459 CY<br>1,469,076 Tons | Closed |
| **Lined (Subtitle D) Landfill Units** | | | | |
| Phase 5 | 19.2 | 1,087,199 | 884,625 CY<br>514,181 Tons | Inactive |
| Phase 4A<br>(Cells 1&2) | 22.0 | 1,111,382 | 944,675 CY<br>538,079 Tons | At Capacity<br>(See Note 1) |
| Phase 4A - Cell 3<br>(Fill Sequence 1) | 7.4 | 1,420,566 | 1,207,481 CY<br>845,237 Tons | 3.1 - 5.9<br>(See Note 2) |
| Phase 4A - Cell 3<br>(Fill Sequence 2) | 0.0<br>(See Note 3) | 746,481 | 553,874 CY<br>387,712 Tons | 1.3 - 2.6 |
| Phase 6 | 21.1 | 1,402,016 | 1,167,578 CY<br>700,547 Tons | 2.3 - 4.3 |
| Phase 7 | 19.8 | 1,758,991 | 1,462,230 CY<br>877,338 Tons | 2.8 - 4.8 |
| Phase 8 | 25.2 | 1,844,867 | 1,495,182 CY<br>897,109 Tons | 2.8 - 4.4 |
| Phase 9 | 22.5 | 6,684,914 | 5,611,690 CY<br>3,928,183 Tons | 11.2 - 15.7 |
| Phase 10 | 17.5 | 3,075,968 | 2,524,065 CY<br>1,766,846 Tons | 4.6 - 5.7 |
| Total (Lined): | 154.7 | 19,132,384 | 15,851,400 CY<br>10,455,232 Tons | 23.7 - 34.9 |
| Total (Overall): | 239.5 | 22,670,617 | 18,299,859 CY<br>11,924,308 Tons | 23.7 - 34.9 |

Notes:

1. Current operations in Phase 4A have expanded vertically into the Cell 3 Fill Sequence 1 volume.
2. Life expectancies for the active Phase 4A - Cells 1 & 2 shown above is from June 6, 2008.
3. Fill Sequence 2 is a vertical expansion.

**TABLE 2.2B**
**TOTAL OPERATING CAPACITY AND LIFE EXPECTANCY - C&D LANDFILL UNITS**

| Landfill Unit | Area (Acres) | Gross Capacity (CY) | Net (Waste) Capacity (CY/Tons) | Life Expectancy (Years) |
|---|---|---|---|---|
| Area 1 | 16.2 | 614,472 | 515,563 CY<br>304,780 Tons | Inactive |
| Area 2 - Cell 1 | 11.9 | 410,675 | 353,056 CY<br>212,920 Tons | 4.3 - 5.1<br>(See Note 1) |
| Area 2 - Cell 2 | 3.9 | 462,658 | 387,062 CY<br>232,237 Tons | 4.9 - 5.7 |
| Total: | 32.0 | 1,487,805 | 1,255,681 CY<br>749,937 Tons | 9.2 - 10.8 |

Notes:
1. Life expectancy for the active Area 2 - Cell 1 unit shown above is from June 6, 2008.

**TABLE 2.3**
**GENERAL EARTHWORK QUANTITIES**

| Landfill Unit[1] | Cut (CY) | Fill (CY) |
|---|---|---|
| **MSW Landfill Units** | | |
| 4A - Cell 3 | 1,824 | 28,455 |
| 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 |

Notes:
1. Includes site roads and infrastructure.

**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 |

Notes:
1. Or structural fill layer.

**TABLE 2.5**
**LEACHATE COLLECTION SYSTEM/PROTECTIVE COVER QUANTITIES**

| Landfill Unit | Required Volume (CY) |
|---|---|
| **MSW Landfill Units** | |
| 4A - Cell 3 | 23,877 |
| 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 |

**TABLE 2.6**
**DAILY AND INTERMEDIATE COVER QUANTITIES**

| Landfill Unit | Required Volume (CY) |
|---|---|
| **MSW Landfill Units** | |
| 4A - Cell 3 | 199,468 (Fill Seq. 1)<br>97,743 (Fill Seq. 2)<br>(See Note 1) |
| 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 | 33,130<br>(See Note 1) |
| Area 2 - Cell 2 | 43,007 |

Notes:

1. Volumes shown above for Phase 4A - Cell 3 and Area 2 - Cell 1 are from June 6, 2008.

**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 1 | 41,624 |
| Area 2 | 50,981 |

**TABLE 2.8**
**SOIL SUMMARY**

| Material | Quantity (CY) |
|---|---|
| Excavation | 966,699 |
| Structural Fill | (478,766) |
| Soil Liner | (263,054) |
| LCS/Protective Cover[1] | (378,811) |
| Daily/Intermediate Cover | (2,537,009) |
| Vegetative Soil Layer | (591,771) |
| Total[2]: | (3,282,712) |

Notes:

1. A portion of this material will come from off-site sources.
2. Soil deficit shown will be made up from off-site sources.

# SECTION 3.0
# LINER SYSTEM DESIGN

## 3.1 OVERVIEW

This section addresses the design of the Phase 4A - Cell 3 liner system. Note that the Phase 4A landfill unit is a double-lined piggyback landfill unit. Technical specifications and construction quality assurance requirements for liner system components can be found in **Attachments B and C**, respectively. Also refer to the Permit Amendment Drawings (**Attachment H**) for liner system details.

## 3.2 LINER SYSTEM COMPONENTS

The components of the double liner system will consist of the following components (top-down):

- a leachate collection system (LCS) (see **Section 4.2**);
- a 60-mil HDPE geomembrane liner;
- a geosynthetic clay liner (GCL);
- a leak detection system (LDS) (see **Section 4.3**); and
- a 40-mil thick LLDPE geomembrane liner.

The liner system will be placed on structurally sound, compacted, or adequately prepared native soil subgrades at a maximum slope of 3H:1V. All geosynthetics between existing Cell 1 and Cell 3 will be tied in such that each layer is continuous. This includes welding of the geomembranes and proper overlap of the GCL component and connections of drainage geocomposites in accordance with the technical specifications.

Note that an alternative liner evaluation was performed for the above liner system as part of the Permit to Construct application for Phase 4A Cells 1 & 2.

### 3.2.1 Geomembranes

The geomembrane components of the liner system will function as the primary barrier layers. The primary geomembrane will be a textured 60-mil thick High Density Polyethylene (HDPE) synthetic liner and the secondary geomembrane will be a textured 40-mil thick Linear Low Density Polyethylene (LLDPE) synthetic liner. The geomembranes will be installed by a qualified contractor.

### 3.2.2 Geosynthetic Clay Liner (GCL)

The GCL will function as a secondary barrier layer beneath the primary geomembrane. The selected material for the GCL will consist of a layer of sodium bentonite bonded between two geotextiles. The selected GCL will provide a maximum hydraulic conductivity of $5 \times 10^{-9}$ cm/sec when hydrated and will be reinforced to prevent potential shearing in the bentonite layer. A GCL also offers the addition of self healing

capabilities, there is no required seaming (other than overlapping), and the bentonite has a high cation exchange rate.

## 3.3 LINER SYSTEM DESIGN

### 3.3.1 Slope Stability

An evaluation of the slope stability of the landfill is provided in **Attachment G**. Even though the project site lies outside a seismic impact zone, both static and seismic slope stability analyses were performed. The evaluation indicates 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 = 20.0 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, textured geomembranes and reinforced GCL 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 is met.

### 3.3.2 Settlement

#### 3.3.2.1 Virgin Ground

An evaluation of the settlement of the Phase 4A landfill foundation under the central portion of Cell 1 (over virgin ground) is provided in **Attachment G**.

Based on a worst case cross section, the evaluation indicates that the maximum total foundation settlement will be approximately 1.6 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.

3.3.2.2 Piggyback Areas

See **Section 3.5**.

### 3.3.3 Bearing Capacity

An evaluation of the bearing capacity of the landfill is provided in **Attachment G**. 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**).

### 3.3.4 Anchor Trench Design

An anchor trench size of 1.5 feet wide by 2.0 feet deep (1.0 feet deep for primary geomembrane) with a 3 foot setback from the crest of the slope was evaluated to allow pullout of the primary geomembrane before the yield stress in the primary 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 primary geomembrane is, however, prevented under extreme loading conditions since the primary 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 3.3.1**) provide for an inherently stable system (see also **Section 3.4.1**).

### 3.3.5 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 11 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.

In that the analysis was based on a maximum load for Cells 1-3, the existing 12 oz./SY nonwoven cushion geotextile in Cell 1 and the double-bonded drainage geocomposite in both Cells 1 and 2 are suitable as a cushion under the proposed Cell 3 loads.

## 3.4 ANTICIPATED STRESSES

### 3.4.1 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 HDPE and LLDPE geomembranes on facility side slopes, interface friction angles for geosynthetics are expected to be greater than the maximum 3H:1V side slope angle (see **Section 3.3.1**). Thus, negligible stresses will be placed on geosynthetics and the system will be inherently stable.

Installation of the drainage geocomposite, GCL, and/or aggregate/protective cover over the geomembranes (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) ($\leq$ 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. 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.

### 3.4.2 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).

### 3.4.3 Long-Term Stresses

Settlement analyses included in **Attachment G** demonstrate that the anticipated tensile stresses in the liner system due to settlement of underlying subgrade will be negligible. Also, refer to **Section 3.5.1** for a discussion of anticipated stresses in the piggyback liner system from the settlement of underlying waste.

## 3.5 PIGGYBACK LINER CONSIDERATIONS

### 3.5.1 Settlement and Liner System Stresses

The original analysis performed as part of the Permit to Construct application for Phase 4A Cells 1 & 2 was revisited to evaluate the effect of increasing the height of Cell 3. The original analysis considered a worst case cross section running east-west through Phase 4A under the maximum waste thicknesses (Cross Section B). This section was compared with an updated section (see **Figure 3-1**) to evaluate the changes in waste thickness and the corresponding changes in liner system stresses along critical sections. The evaluation, which is provided in **Appendix A**, shows that long-term stresses in the liner system are expected to be less than 1 percent. This maximum amount of strain is well below the 5% level, which is considered to be the tolerable limit.

Additionally, an evaluation of settlement along the alignment of the Cell 3 leachate collection header pipe (running north-south) was evaluated (see **Attachment G**). This evaluation also shows that maximum anticipated strains in the Cell 3 liner system will be well below the 5% level. The evaluation also demonstrated that positive slope will be maintained along this header pipe after settlement.

### 3.5.2 Localized Subsidence

The original analysis performed as part of the Permit to Construct application for Phase 4A Cells 1 & 2 evaluated the effect of localized subsidence (i.e. "rusted refrigerator" evaluation) on the piggyback liner system. The best method for ensuring that localized subsidence is not a concern is to use geophysical methods to check the near surface for potentially large metal objects and physically removing them (or verifying that they are not present within about 5 feet of the surface).

A geophysical survey which utilized frequency-domain electromagnetic (EM) imaging techniques was performed across the Cells 1-3 area by The Hutchinson Group, Ltd. prior to the construction of Cell 1. The survey indicated no potential near-surface metal anomalies in the Cell 1 or Cell 2 area but did identify five potential anomalies; four of which are within the Cell 3 limits (see **Figure 3-2**). The anomalies within the Cell 3 limits will be marked and evaluated in the field prior to or as part of the construction of Cell 3.

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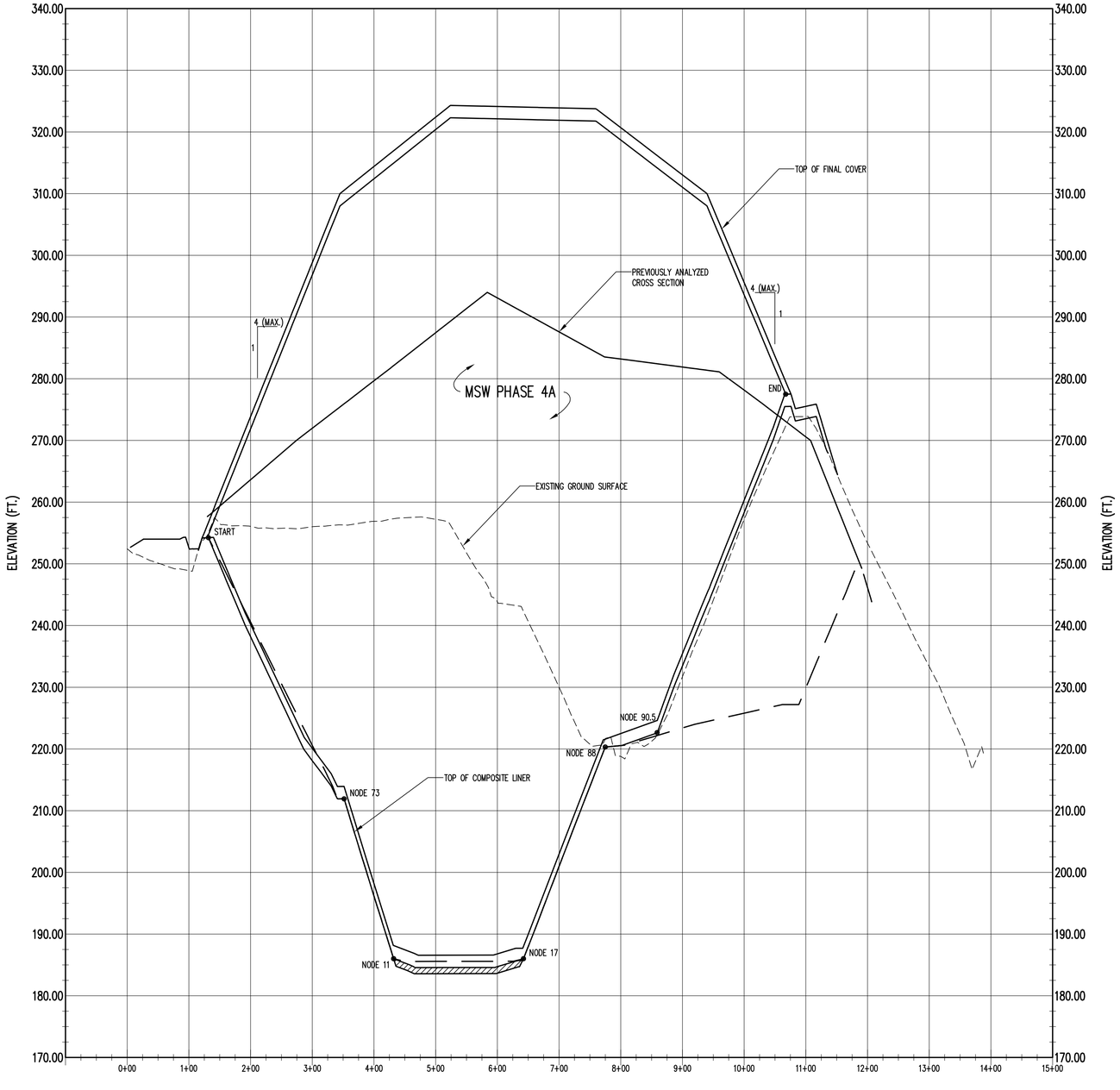
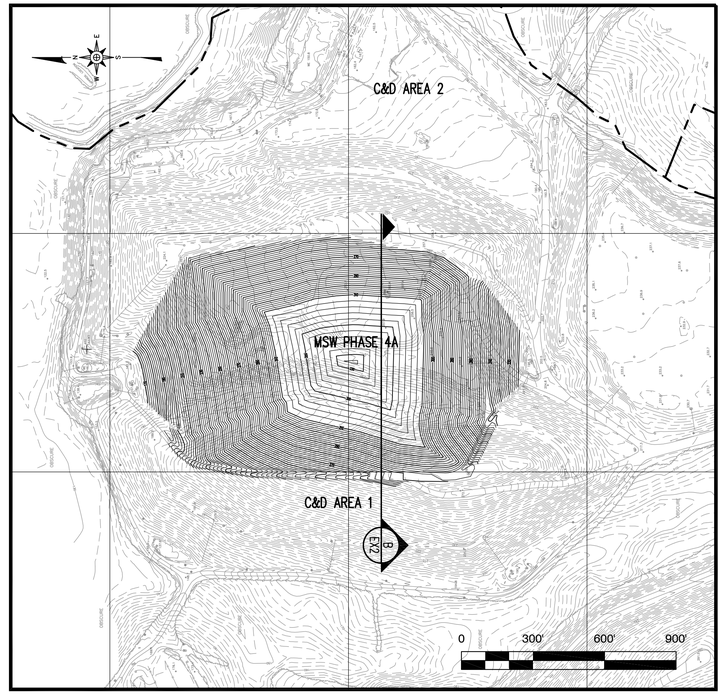



SECTION B

SECTION B / EX2
NOT TO SCALE




30'
20'
10'
0

0 100' 200' 300'

LEGEND

- 200 — EXISTING 10' CONTOUR
- EXISTING 2' CONTOUR
- 150 — PROPOSED 10' CONTOUR
- PROPOSED 2' CONTOUR
- PROPERTY LINE

REFERENCES

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

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

SEAL

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

DRAWING TITLE:
PIGGYBACK LINER ANALYSIS
COMPARISON OF CRITICAL
CROSS SECTION

| DESIGNED BY: | DRAWN BY: |
|---|---|
| P.K.S. | J.A.L. |
| CHECKED BY: | PROJECT NO.: |
| | JOHN 07-2 |
| SCALE: | DATE: |
| AS SHOWN | MAY 2007 |
| FILE NAME: | |
| JOHN-D0509A | |
| SHEET NO. | DRAWING NO. |
| FIG. 3-1 | |

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C&D AREA 2–CELL 1
(ACTIVE)

PROPERTY LINE (FACILITY BOUNDARY)

C&D AREA 2–CELL 2
(FUTURE)

SEDIMENT BASIN NO. 4

WASTE LIMITS (TYP.)

MSW PHASE 3 (CLOSED)

MSW
PHASES 1 & 2
(CLOSED)

MSW PHASE 4A–CELLS 1 AND 2
(ACTIVE)

SEDIMENT BASIN NO. 3

SEDIMENT BASIN NO. 5A

MSW PHASE 4 (CLOSED)

MSW PHASE 4A–CELL 3
(FUTURE)

C&D VERTICAL
EXPANSION (AREA 1)
(INACTIVE)

SEDIMENT BASIN NO. 2

SEDIMENT BASIN NO. 1

OBSCURE

APPROX LOCATION

## LEGEND

- EXISTING 10' CONTOUR (SEE REFERENCE 1)
- EXISTING 2' CONTOUR
- PROPERTY LINE
- LIMIT OF LINER (LINED LANDFILL UNITS)
- APPROXIMATE EXISTING WASTE LIMITS (UNLINED UNITS)
- FUTURE LANDFILL AREAS
- NEAR SURFACE METAL ANOMALY (IDENTIFIED BY HUTCHINSON GROUP SURVEY 2002)

## REFERENCES

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

0 100' 200' 300'

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


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www.rsgengineers.com


SEAL

SEAL

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

DRAWING TITLE:
APPROXIMATE LOCATION
OF NEAR-SURFACE
METAL ANOMALIES

| DESIGNED BY: | DRAWN BY: |
|---|---|
| P.K.S. | C.T.J. |
| CHECKED BY: | PROJECT NO.: |
| | JOHN 07-2 |
| SCALE: | DATE: |
| AS SHOWN | JUNE 2007 |
| FILE NAME | |
| JOHN-D0511A | |
| SHEET NO. | DRAWING NO. |
| FIG. 3-2 | |

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# SECTION 4.0
# LEACHATE MANAGEMENT SYSTEM DESIGN

## 4.1 OVERVIEW

This section addresses the design of the Phase 4A - Cell 3 leachate management system. The leachate management system for the Phase 4A landfill unit consists of a leachate collection system (LCS), a leak detection system (LDS), and a leachate transmission and storage system. Note that the design of the existing leachate transmission and storage system was evaluated as part of the Permit to Construct application for Phase 4A - Cells 1 and 2.

The LCS and LDS for Cell 3 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. Both the Cell 3 LCS and LDS will tie into existing piping installed with Cell 1. Leachate collected from Phase 4A is pumped via an existing HDPE force main to the existing leachate storage lagoon. Technical specifications and construction quality assurance requirements for leachate management system components can be found in **Attachments B and C**, respectively. Also refer to the Permit Amendment Drawings (**Attachment H**) for leachate management system details.

## 4.2 LEACHATE COLLECTION SYSTEM (LCS) COMPONENTS

The LCS will be constructed directly above the primary 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. The components of the leachate collection system (LCS) will consist of the following components (top-down):

- 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, the County may elect to install geosynthetic rain cover over the LCS to aid stormwater/leachate separation.

### 4.2.1 Drainage Aggregate

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

### 4.2.2 Drainage Geocomposite

The drainage geocomposite will function as a blanket drain to conduct leachate to

collection piping. 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 detection/collection drainage layer analysis (see **Section 4.4.1** 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 3.3.5** and **Appendix A**).

### 4.2.3 Separator (Type GT-S) Geotextile

A nonwoven separator (Type GT-S) geotextile will be used as a component of the drainage geocomposite and will be installed over gravel columns to keep the aggregate from fouling prior to waste placement. Due to long-term bio-clogging concerns, the geotextile installed over the gravel columns 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 4.4.4** and **Appendix A**).

### 4,2.4 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 4.4.3** and **Appendix A**).

Collection pipes have coarse aggregate placed over and around them and are referred to as "gravel columns" (see **Drawing S5** (Leachate Management Systems - Primary Collection Piping)). 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 Cell 1 sump for the removal from the landfill by the existing side riser pumps.

### 4.2.5 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.

## 4.3 LEAK DETECTION SYSTEM (LDS) COMPONENTS

The LDS will be constructed directly above the secondary geomembrane on both the base and side slopes of the landfill. The purpose of the LDS is to provide rapid detection of a major breach in the primary geomembrane and limit the head on the secondary geomembrane, thereby reducing the leak potential. The components of the leachate collection system (LDS) will consist of the following components (top-down):

- a drainage geocomposite; and
- a leak detection trench (stone and collection pipe).

### 4.3.1 Drainage Aggregate

Drainage aggregate used in the LCS will consist of coarse aggregate (No. 78 or similar aggregate meeting required permeability and angularity criteria) placed around collection piping.

### 4.3.2 Drainage Geocomposite

The drainage geocomposite will function as a blanket drain to conduct any leachate which leaks through the overlying primary geomembrane and GCL to collection piping. 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 detection/collection drainage layer analysis (see **Section 4.4.1** and **Appendix A**).

### 4.3.3 Collection Piping

As for the LCS, the collection piping of the LDS will be high density polyethylene (HDPE) (DR 17) pipe. The required pipe dimension ratio (DR) was selected based upon the maximum static and dynamic loading conditions to be placed on the pipe (see **Section 4.4.3** and **Appendix A**).

The collection piping of the LDS will conduct the leachate to the existing leak detection pump station where the leachate is pumped to the leachate storage lagoon via the existing force main.

## 4.4 LEACHATE MANAGEMENT SYSTEM DESIGN

### 4.4.1 LDS/LCS Drainage Layer Analysis

The spacing of the LDS/LCS collection pipes was evaluated to verify that the maximum hydraulic head on the geomembrane will be within the thickness of the drainage geocomposite during normal operating conditions. The analysis (see **Appendix A**) was conducted using McEnroe's mounding equations and considered various impingement

rates corresponding to active, intermediate, and final conditions (based on HELP Model projections - See **Section 4.5**). The analyses for intermediate and final conditions conservatively includes reduction factors (intrusion, creep deformation, chemical clogging, and biological clogging plus an overall factor of safety) to represent these longer-term cases.

Based on the analysis, a minimum transmissivity of $5.0 \times 10^{-4}$ $m^3/m/sec$ was selected for the drainage geocomposite in both the LDS and the LCS. Transmissivity tests should be conducted based on anticipated field conditions (maximum normal load, boundary conditions, and gradient).

### 4.4.2 LDS/LCS Pipe Sizing

The capacity of LDS piping was evaluated by comparing the maximum capacity of the assumed pipe diameter with the peak daily leachate generation rate (100 gallons/acre/day assumed) (see **Appendix A**). Based on this evaluation, a 4-inch diameter HDPE (DR 17) (I.D. = 4.0-inches) will handle a maximum drainage area of over 50 acres with a factor of safety of over 50. This maximum drainage area exceeds the maximum drainage area to be drained by any one pipe.

The capacity of LCS piping was evaluated by comparing the maximum capacity of the assumed pipe diameter with the peak daily leachate generation rate (0.55 inches/day = 14,900 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 over 20 acres with a factor of safety of 2.0. This maximum drainage area exceeds the maximum drainage area to be drained by any one pipe.

#### 4.4.2.1 LDS/LCS Pipe Perforation Analysis

The maximum LDS/LCS pipe perforation size was evaluated based on the size of the pipe bedding. LDS/LCS pipe perforation calculations are presented in **Appendix A**. For No. 78 stone (or similarly graded) bedding, a maximum perforation size of 0.375 inches (diameter of circular holes) is acceptable. For No. 57 stone (or similarly graded) bedding, a maximum perforation size of 0.5 inches (diameter of circular holes) is acceptable.

The number of perforations required will depend on the quantity of leachate being handled by the pipe. However, for collection piping located along the center of each cell, 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.).

### 4.4.3 Leachate Pipe Mechanical Properties

All leachate piping will be HDPE. For HDPE pipe, the required pipe dimension ratio (DR) for collection piping was 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 piping will be bedded coarse aggregate to ensure a safe load distribution on the piping under long-term conditions.

#### 4.4.3.1 Static Load Requirement

The vertical stress applied by the fully constructed landfill, including (for collection 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, the analysis for static loading were 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 4.5 for crushing and buckling, respectively.

The analysis indicates that pipe deflections for the proposed piping will be within acceptable limits.

Note that the analysis verified that the existing DR 13.5 piping in Cells 1 and 2 will handle the additional loading of Cell 3.

#### 4.4.3.2 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 and No. 57 stone (18 inch minimum cover (including gravel column) over LCS piping) -

low ground pressure (LGP) ($\leq$ 6 psi) equipment only.

- Placement of initial lift of waste (with 3 foot minimum cover (including gravel column) over LCS piping) - no equipment limitations.

### 4.4.4 Filter Geotextile Analysis

A filter geotextile analysis was performed to determine the apparent opening size (AOS) and permittivity required for the proper performance of both the upper geotextile component of the drainage geocomposite and the Type GT-S geotextile over gravel columns to act as a filter. The analysis (see **Appendix A**) assumes that the protective cover will be sands and silty 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 non-woven 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.

## 4.5 LEACHATE GENERATION

The leachate management system for Phase 4A 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 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 two acre open area of the landfill 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 191,000 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 Phase 4A operations is anticipated to be less than 20,000 gallons per day.

The ability to prevent ponding in the landfill rests on the ability to hold leachate in the storage lagoon. The capacity storage lagoon is approximately 4,300,000 gallons, which is far 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 tanks at a rate to maintain a typical volume of 3,500,000 gallons (approximate 6.5 foot depth), or less, of leachate in the lagoon until all areas are covered by waste.

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# SECTION 5.0
# FINAL COVER SYSTEM DESIGN

## 5.1 OVERVIEW

This section addresses the design of the final cover system for Phase 4A. Technical specifications and construction quality assurance requirements for final cover system components can be found in **Attachments B and C**, respectively. A facility Closure and Post-Closure Plan, including cost analyses, is provided as **Attachment E**. Also refer to the Permit Amendment Drawings (**Attachment H**) for final cover system details.

Note that based on the results of the final cover infiltration analysis (see **Section 5.3.1**), the final cover system described in **Section 5.2** is also acceptable for the Phase 5 MSW landfill unit and the Areas 1 and 2 C&D landfill units. Refer to the appropriate permit application for details related to landfill gas and/or surface water control measures for closure of each landfill unit.

## 5.2 FINAL COVER SYSTEM COMPONENTS

The final cover system for Phase 4A 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. A landfill gas (LFG) control system 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.

Note that this system differs from the regulatory minimum final cover (RMC) in that an 18 inch layer of 1 x $10^{-5}$ cm/sec soil below the geomembrane is removed and the drainage geocomposite is added above the geomembrane. The addition of the drainage geocomposite reduces head on the geomembrane for both reduced infiltration through the geomembrane and increased stability of the overlying soil veneer. The final cover infiltration analysis demonstrates that the proposed final cover system allows less infiltration than the RMC (see **Section 5.3.1** and **Appendix A**).

### 5.2.1 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 (including at least 6 inches of topsoil).

### 5.2.2 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. The minimum required transmissivity of the drainage geocomposite was determined in the final cover drainage layer analysis (see **Section 5.3.3** and **Appendix A**).

### 5.2.3 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.

### 5.2.4 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.

### 5.2.5 Landfill Gas (LFG) Control System

The landfill gas (LFG) control system will consist of collection wells placed within the waste to capture the gas and either passively vent or flare the gas via utility flares or, as required, actively collect and flare the gas via header piping and a blower/flare system. The collection wells should be placed before any geosynthetics are placed. The selected system will be designed to limit the gas pressures on the final cover geosynthetics.

### 5.2.6 Surface Water Control Devices

Surface water run-off will be controlled in the final cover by a system of drainage breaks (rain gutters) 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 and/or detention basins. The design of rain gutters and down pipes is discussed in **Section 5.3.5**.

## 5.3 FINAL COVER SYSTEM DESIGN

### 5.3.1 Final Cover Infiltration Analysis

The Hydrologic Evaluation of Landfill Performance (HELP) Model (version 3.07) was

used to evaluate the effectiveness of the proposed final cover at minimizing infiltration on both the flatter top slopes and the steeper side slopes. The HELP Model analyzes the fraction of precipitation that leaves the landfill cover via runoff, infiltration, evaporation, and transpiration.

In that the proposed final cover system is an alternate system to the regulatory minimum cover (RMC) (18 inches of 1 x $10^{-5}$ cm/s soil with overlying 30 mil geomembrane), the infiltration through the proposed system was compared to the infiltration through the regulatory system. For both the top and side slopes, the infiltration analysis demonstrates that the addition of a drainage geocomposite over the geomembrane significantly reduces the head on the barrier and, thereby, significantly reduces the calculated infiltration as compared to the RMC (see **Appendix A**). The results of the infiltration analysis are summarized as follows:

| Slope | Average Annual Infiltration | |
|---|---|---|
| | (inches) | (gallons/acre) |
| **Proposed Final Cover System:** | | |
| Top Slopes (8%) | 0.0058 | 157 |
| Side Slopes (4H:1V) | 0.0017 | 46 |
| **Regulatory Minimum Final Cover System (RMC):** | | |
| Top Slopes (8%) | 0.540 | 14,662 |
| Side Slopes (4H:1V) | 0.536 | 14,553 |

### 5.3.2 Slope Stability

An evaluation of the veneer stability of the landfill final cover is provided in **Attachment G**. The evaluation indicates that the final cover system will satisfy design criteria ($FS_{static}$ = 1.5; $FS_{seismic}$ = 1.0) 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 = 24.0 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 is met.

### 5.3.3 Drainage Layer Analysis

The analysis of the final cover drainage layer (drainage geocomposite) is provided in **Appendix A**. This analysis focused on determining 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 $1 \times 10^{-4}$ cm/sec (typical for on-site soils to be used). The calculations, which include a factor of safety of 6 to account for long-term intrusion, creep, and clogging concerns, indicate that a minimum transmissivity of $1 \times 10^{-3}$ $m^3/m/sec$ 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.

### 5.3.4 Filter Geotextile Analysis

A filter geotextile analysis was performed to determine the apparent opening size (AOS) and permittivity required to ensure the proper performance of the upper geotextile component of the drainage geocomposite as a filter. The analysis (see **Appendix A**) assumes that the vegetative soil layer will be clayey sands (based on the typical grain size curves evaluated) and non-dispersive (that is having a double-hydrometer ratio (DHR) (ASTM D 4221) of < 0.5). 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 non-woven geotextile.

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.

### 5.3.5 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. Other related perimeter drainage features are discussed in the Erosion and Sedimentation Control Plan (**Attachment F**).

## 5.4 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 5.3.2**). 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) ($\leq$ 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.

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# Appendix A

# Landfill Design Calculations

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**JOHNSTON COUNTY MSW LANDFILL**
**PHASE 4A - CELL 3**

**FACILITY AND ENGINEERING PLAN**
**APPENDIX A: LANDFILL DESIGN CALCULATIONS**

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|---|---|
| PROJECT Johnston County MSWLF - Phase 4A - Cell 3 | SHEET 1 OF 19 |
| | JOB NO. JOHNSTON-07-2 |
| | DATE 12/4/08 |
| SUBJECT Capacity Evaluation (Density & Life Calcs.) | COMPUTED BY PKS |
| | CECKED 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 evaluation 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.



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SHEET: 2 / 9
JOB #: JOHNSTON-07-2
DATE: 11/21/08
BY: PKS
CHKD BY:

# Johnston County Landfill - MSW - Phase 4A - Cells 1 & 2
# Capacity Evaluation - Filling Rate & Density Calculations

**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) |
|---|---|---|---|---|---|---|---|---|---|
| 1/9/2003 | 5/21/2004 | 1.36 | 312,843 | 139,098 | **889** | 15 | 46,926 | 265,917 | **1,046** |
| 5/22/2004 | 3/21/2005 | 0.83 | 200,019 | 89,280 | **893** | 15 | 30,003 | 170,016 | **1,050** |
| 3/22/2005 | 6/4/2006 | 1.20 | 287,402 | 131,910 | **918** | 15 | 43,110 | 244,292 | **1,080** |
| 6/5/2006 | 5/20/2007 | 0.96 | 209,118 | 110,112 | **1,053** | 15 | 31,368 | 177,750 | **1,239** |
| 5/21/2007 | 6/6/2008 | 1.05 | 192,780 | 121,693 | **1,263** | 15 | 28,917 | 163,863 | **1,485** |
| | | **SUM =** | **1,202,162** | **592,093** | | | **180,324** | **1,021,838** | |
| | | | | | | | | **Avg. =** | **1,174** |

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

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DATE: 12/3/08
BY: PKS
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# Johnston County Landfill
## Capacity Evaluation - MSW - Phase 4A - Cell 3 (Fill Sequence 1)

**Waste & Periodic Cover Parameters:**

| | | |
|---|---|---|
| Waste Density (pcy) = | 1,400 | (From Filling Rate and Density Calcs.) (Recent Trend) |
| Waste Density (tcy) = | 0.70 | |
| Percentage of Periodic Cover = | 15 | |

**Volume Calculations:**

| | | |
|---|---|---|
| Volume From AutoCAD (cy) = | 1,420,566 | (Cell 1 & 2 Permitted Grades vs. Fill Seq. 1) **(= Gross Capacity)** |

**Net (Waste) Capacity:**

| | |
|---|---|
| **Volume of Waste and Periodic Cover (cy) =** | 1,420,566 |
| **Volume of Periodic Cover (cy) =** | (213,085) |
| **Net (Waste) Capacity (cy) =** | 1,207,481 |
| **Net (Waste) Capacity (tons) =** | 845,237 |

**Life Expectancy Calculations:**

| | | |
|---|---|---|
| Volume of Waste & Periodic Cover Already Used From AutoCAD (cy) = | 90,780 | (From 6/08 Volume Study) |
| Volume of Periodic Cover Already Used (cy) = | (13,617) | |
| Net (Waste) Capacity Already Used (cy) = | 77,163 | |
| Net (Waste) Capacity Already Used (tons) = | 54,014 | |
| Net (Waste) Capacity Remaining (tons) = | 791,223 | |

**County-Only:**

| Start Time | End Time | Tons Disposed | Total Tons | Remainder | |
|---|---|---|---|---|---|
| 2008.43 | 2009 | 69,515 | 69,515 | 721,708 | |
| 2009 | 2014 | 668,027 | 737,542 | 53,681 | Based on Est. Waste Generation |
| 2014 | 2014.37 | 53,681 | 791,223 | (0) | (Attached) |

**Landfill Life Expectancy (years) =** 5.9 May 2014

**Maximum (+ 500 TPD):**

| Start Time | End Time | Tons Disposed | Total Tons | Remainder | |
|---|---|---|---|---|---|
| 2008.43 | 2009 | 69,515 | 69,515 | 721,708 | |
| 2009 | 2011 | 567,530 | 637,045 | 154,178 | Based on Est. Waste Generation |
| 2011 | 2011.53 | 154,178 | 791,223 | (0) | (Attached) |

**Landfill Life Expectancy (years) =** 3.1 July 2011

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DATE: 12/3/08
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# Johnston County Landfill
## Capacity Evaluation - MSW - Phase 4A - Cell 3 (Fill Sequence 2)

**Waste & Periodic Cover Parameters:**

| | | |
|---|---|---|
| Waste Density (pcy) = | 1,400 | (Assumed Density) |
| Waste Density (tcy) = | 0.70 | |
| Percentage of Periodic Cover = | 15 | (Assumed) |

**Volume Calculations:**

Volume From AutoCAD (cy) = 746,481 (Cell 3 - Seq. 1 to Phase 4A Final Cover)
**(= Gross Capacity)**

**Net (Waste) Capacity:**

Adjustment For Other Layers:

| | | |
|---|---|---|
| | Area of Final Cover (Ac.) = | 29.4 |
| 2 feet | Vegetative Soil Layer = | (94,864) cy |
| | Sum = | (94,864) cy |

**Volume of Waste and Periodic Cover (cy) =** 651,617

**Volume of Periodic Cover (cy) =** (97,743)

**Net (Waste) Capacity (cy) =** 553,874

**Net (Waste) Capacity (tons) =** 387,712

**Life Expectancy Calculations:**

**County-Only:**

| Start Time | End Time | Tons Disposed | Total Tons | Remainder | |
|---|---|---|---|---|---|
| 2014.37 | 2015 | 91,675 | 91,675 | 296,037 | |
| 2015 | 2016 | 149,332 | 241,007 | 146,705 | Based on Est. Waste Generation |
| 2016 | 2016.96 | 146,705 | 387,712 | 0 | (Attached) |

**Landfill Life Expectancy (years) =** 2.6 December 2016

**Maximum (+ 500 TPD):**

| Start Time | End Time | Tons Disposed | Total Tons | Remainder | |
|---|---|---|---|---|---|
| 2011.53 | 2012 | 135,393 | 135,393 | 252,319 | |
| 2012 | 2012 | 0 | 135,393 | 252,319 | Based on Est. Waste Generation |
| 2012 | 2012.86 | 252,319 | 387,712 | 0 | (Attached) |

**Landfill Life Expectancy (years) =** 1.3 November 2012

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# Johnston County Landfill
# Capacity Evaluation - MSW - Phase 6

**Waste & Periodic Cover Parameters:**

| | | |
|---|---|---|
| Waste Density (pcy) = | 1,200 | (Assumed Density) |
| Waste Density (tcy) = | 0.60 | |
| Percentage of Periodic Cover = | 15 | (Assumed) |

**Volume Calculations:**

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

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

Adjustment For Other Layers:

| | | |
|---|---|---|
| | Area of Waste Footprint (Ac.) = | 21.1 |
| 1.5 feet | Soil Liner = | (51,062) cy |
| 2 feet | Protective Cover = | (68,083) cy |
| | Sum = | (119,145) cy |
| | **Gross Capacity (cy) =** | 1,402,016 |

**Net (Waste) Capacity:**

Adjustment For Other Layers:

| | | |
|---|---|---|
| | Area of Final Cover (Ac.) = | 8.8 |
| 2 feet | Vegetative Soil Layer = | (28,395) cy |
| | Sum = | (28,395) cy |

**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:**

**County-Only:**

| Start Time | End Time | Tons Disposed | Total Tons | Remainder | |
|---|---|---|---|---|---|
| 2016.96 | 2017 | 6,745 | 6,745 | 693,802 | |
| 2017 | 2021 | 655,030 | 661,775 | 38,772 | Based on Est. Waste Generation |
| 2021 | 2021.22 | 38,772 | 700,547 | 0 | (Attached) |

**Landfill Life Expectancy (years) =** 4.3 March 2021

**Maximum (+ 500 TPD):**

| Start Time | End Time | Tons Disposed | Total Tons | Remainder | |
|---|---|---|---|---|---|
| 2012.86 | 2013 | 41,141 | 41,141 | 659,406 | |
| 2014 | 2015 | 598,784 | 639,925 | 60,622 | Based on Est. Waste Generation |
| 2015 | 2015.2 | 60,622 | 700,547 | 0 | (Attached) |

**Landfill Life Expectancy (years) =** 2.3 March 2015

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# Johnston County Landfill
# Capacity Evaluation - MSW - Phase 7

**Waste & Periodic Cover Parameters:**

| | | |
|---|---|---|
| Waste Density (pcy) = | 1,200 | (Assumed Density) |
| Waste Density (tcy) = | 0.60 | |
| Percentage of Periodic Cover = | 15 | (Assumed) |

**Volume Calculations:**

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

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

Adjustment For Other Layers:

| | | |
|---|---|---|
| | Area of Waste Footprint (Ac.) = | 19.8 |
| 1.5 feet | Soil Liner = | (47,916) cy |
| 2 feet | Protective Cover = | (63,888) cy |
| | Sum = | (111,804) cy |
| | **Gross Capacity (cy) =** | 1,758,991 |

**Net (Waste) Capacity:**

Adjustment For Other Layers:

| | | |
|---|---|---|
| | Area of Final Cover (Ac.) = | 12.0 |
| 2 feet | Vegetative Soil Layer = | (38,720) cy |
| | Sum = | (38,720) cy |
| | **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:**

**County-Only:**

| Start Time | End Time | Tons Disposed | Total Tons | Remainder | |
|---|---|---|---|---|---|
| 2021.22 | 2022 | 135,478 | 135,478 | 741,860 | |
| 2022 | 2026 | 739,872 | 875,350 | 1,988 | Based on Est. Waste Generation |
| 2026 | 2026.01 | 1,988 | 877,338 | 0 | (Attached) |

**Landfill Life Expectancy (years) =** 4.8 January 2026

**Maximum (+ 500 TPD):**

| Start Time | End Time | Tons Disposed | Total Tons | Remainder | |
|---|---|---|---|---|---|
| 2015.2 | 2016 | 244,710 | 244,710 | 632,628 | |
| 2016 | 2018 | 623,019 | 867,729 | 9,609 | Based on Est. Waste Generation |
| 2018 | 2018.03 | 9,609 | 877,338 | 0 | (Attached) |

**Landfill Life Expectancy (years) =** 2.8 January 2018

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BY: PKS
CHKD BY:

# Johnston County Landfill
# Capacity Evaluation - MSW - Phase 8

**Waste & Periodic Cover Parameters:**

| | | |
|---|---|---|
| Waste Density (pcy) = | 1,200 | (Assumed Density) |
| Waste Density (tcy) = | 0.60 | |
| Percentage of Periodic Cover = | 15 | (Assumed) |

**Volume Calculations:**

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

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

Adjustment For Other Layers:

Area of Waste Footprint (Ac.) = 25.2

| | | |
|---|---|---|
| 1.5 feet | Soil Liner = | (60,984) cy |
| 2 feet | Protective Cover = | (81,312) cy |
| | Sum = | (142,296) cy |

**Gross Capacity (cy) =** 1,844,867

**Net (Waste) Capacity:**

Adjustment For Other Layers:

Area of Final Cover (Ac.) = 26.6

| | | |
|---|---|---|
| 2 feet | Vegetative Soil Layer = | (85,829) cy |
| | Sum = | (85,829) cy |

**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:**

**County-Only:**

| Start Time | End Time | Tons Disposed | Total Tons | Remainder | |
|---|---|---|---|---|---|
| 2026.01 | 2027 | 193,883 | 193,883 | 703,226 | |
| 2027 | 2030 | 614,301 | 808,184 | 88,925 | Based on Est. Waste Generation |
| 2030 | 2030.42 | 88,925 | 897,109 | 0 | (Attached) |

**Landfill Life Expectancy (years) =** 4.4 June 2030

**Maximum (+ 500 TPD):**

| Start Time | End Time | Tons Disposed | Total Tons | Remainder | |
|---|---|---|---|---|---|
| 2018.03 | 2019 | 308,079 | 308,079 | 589,030 | |
| 2019 | 2020 | 321,806 | 629,885 | 267,224 | Based on Est. Waste Generation |
| 2020 | 2020.82 | 267,224 | 897,109 | 0 | (Attached) |

**Landfill Life Expectancy (years) =** 2.8 October 2020

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DATE: 12/3/08
BY: PKS
CHKD BY:

# Johnston County Landfill
# Capacity Evaluation - MSW - Phase 9

**Waste & Periodic Cover Parameters:**

| | | |
|---|---|---|
| Waste Density (pcy) = | 1,400 | (Assumed Density) |
| Waste Density (tcy) = | 0.70 | |
| Percentage of Periodic Cover = | 15 | (Assumed) |

**Volume Calculations:**

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

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

Adjustment For Other Layers:

Area of Waste Footprint (Ac.) = 22.5

| | | |
|---|---|---|
| 1.5 feet | Soil Liner = | (54,450) cy |
| 2 feet | Protective Cover = | (72,600) cy |
| | Sum = | (127,050) cy |

**Gross Capacity (cy) =** 6,684,914

**Net (Waste) Capacity:**

Adjustment For Other Layers:

Area of Final Cover (Ac.) = 25.7

| | | |
|---|---|---|
| 2 feet | Vegetative Soil Layer = | (82,925) cy |
| | Sum = | (82,925) cy |

**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:**

**County-Only:**

| Start Time | End Time | Tons Disposed | Total Tons | Remainder | |
|---|---|---|---|---|---|
| 2030.42 | 2031 | 124,474 | 124,474 | 3,803,709 | |
| 2031 | 2046 | 3,764,207 | 3,888,681 | 39,502 | Based on Est. Waste Generation |
| 2046 | 2046.13 | 39,502 | 3,928,183 | 0 | (Attached) |

**Landfill Life Expectancy (years) =** 15.7 February 2046

**Maximum (+ 500 TPD):**

| Start Time | End Time | Tons Disposed | Total Tons | Remainder | |
|---|---|---|---|---|---|
| 2020.82 | 2021 | 58,743 | 58,743 | 3,869,440 | |
| 2021 | 2031 | 3,497,693 | 3,556,436 | 371,747 | Based on Est. Waste Generation |
| 2031 | 2031.99 | 371,747 | 3,928,183 | 0 | (Attached) |

**Landfill Life Expectancy (years) =** 11.2 December 2031

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# Johnston County Landfill
# Capacity Evaluation - MSW - Phase 10

**Waste & Periodic Cover Parameters:**

| | | |
|---|---|---|
| Waste Density (pcy) = | 1,400 | (Assumed Density) |
| Waste Density (tcy) = | 0.70 | |
| Percentage of Periodic Cover = | 15 | (Assumed) |

**Volume Calculations:**

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

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

Adjustment For Other Layers:

| | | |
|---|---|---|
| | Area of Waste Footprint (Ac.) = | 17.5 |
| 1.5 feet | Soil Liner = | (42,350) cy |
| 2 feet | Protective Cover = | (56,467) cy |
| | Sum = | (98,817) cy |
| | **Gross Capacity (cy) =** | 3,075,968 |

**Net (Waste) Capacity:**

Adjustment For Other Layers:

| | | |
|---|---|---|
| | Area of Final Cover (Ac.) = | 33.0 |
| 2 feet | Vegetative Soil Layer = | (106,480) cy |
| | Sum = | (106,480) cy |
| | **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:**

**County-Only:**

| Start Time | End Time | Tons Disposed | Total Tons | Remainder | |
|---|---|---|---|---|---|
| 2046.13 | 2047 | 253,449 | 253,449 | 1,513,397 | |
| 2047 | 2051 | 1,231,578 | 1,485,027 | 281,819 | Based on Est. Waste Generation |
| 2051 | 2051.87 | 281,819 | 1,766,846 | (0) | (Attached) |

**Landfill Life Expectancy (years) =** 5.7 November 2051

**Maximum (+ 500 TPD):**

| Start Time | End Time | Tons Disposed | Total Tons | Remainder | |
|---|---|---|---|---|---|
| 2031.99 | 2032 | 1,920 | 1,920 | 1,764,926 | |
| 2032 | 2036 | 1,539,081 | 1,541,001 | 225,845 | Based on Est. Waste Generation |
| 2036 | 2036.57 | 225,845 | 1,766,846 | (0) | (Attached) |

**Landfill Life Expectancy (years) =** 4.6 July 2036

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# Johnston County Landfill
## Waste Generaton Analysis - MSW (County-Only)

Per-Capita Disposal Rate (tons/person/yr.) = 0.75 (Based on FY 2006-07 Data)
Estimated Monthly Tonnage Variance (%) = 20 (Estimated by County)

| Year | Population (See Note 1) | % Increase From Previous | Projected County Tonnage | Projected Out of County Tonnage | Projected Avg. Monthly Tonnage | Projected Monthly Variance (Min.) | Projected Monthly Variance (Max.) |
|---|---|---|---|---|---|---|---|
| 2008 | 162,609 | ----- | 121,957 | 0 | 10,163 | 8,130 | 12,196 |
| 2009 | 167,849 | 3.22 | 125,887 | 0 | 10,491 | 8,392 | 12,589 |
| 2010 | 172,857 | 2.98 | 129,643 | 0 | 10,804 | 8,643 | 12,964 |
| 2011 | 178,094 | 3.03 | 133,571 | 0 | 11,131 | 8,905 | 13,357 |
| 2012 | 183,333 | 2.94 | 137,500 | 0 | 11,458 | 9,167 | 13,750 |
| 2013 | 188,570 | 2.86 | 141,428 | 0 | 11,786 | 9,429 | 14,143 |
| 2014 | 193,808 | 2.78 | 145,356 | 0 | 12,113 | 9,690 | 14,536 |
| 2015 | 199,109 | 2.74 | 149,332 | 0 | 12,444 | 9,955 | 14,933 |
| 2016 | 204,600 | 2.76 | 153,450 | 0 | 12,788 | 10,230 | 15,345 |
| 2017 | 210,092 | 2.68 | 157,569 | 0 | 13,131 | 10,505 | 15,757 |
| 2018 | 215,584 | 2.61 | 161,688 | 0 | 13,474 | 10,779 | 16,169 |
| 2019 | 221,075 | 2.55 | 165,806 | 0 | 13,817 | 11,054 | 16,581 |
| 2020 | 226,622 | 2.51 | 169,967 | 0 | 14,164 | 11,331 | 16,997 |
| 2021 | 232,333 | 2.52 | 174,250 | 0 | 14,521 | 11,617 | 17,425 |
| 2022 | 238,043 | 2.46 | 178,532 | 0 | 14,878 | 11,902 | 17,853 |
| 2023 | 243,755 | 2.40 | 182,816 | 0 | 15,235 | 12,188 | 18,282 |
| 2024 | 249,466 | 2.34 | 187,100 | 0 | 15,592 | 12,473 | 18,710 |
| 2025 | 255,232 | 2.31 | 191,424 | 0 | 15,952 | 12,762 | 19,142 |
| 2026 | 261,161 | 2.32 | 195,871 | 0 | 16,323 | 13,058 | 19,587 |
| 2027 | 267,092 | 2.27 | 200,319 | 0 | 16,693 | 13,355 | 20,032 |
| 2028 | 273,023 | 2.22 | 204,767 | 0 | 17,064 | 13,651 | 20,477 |
| 2029 | 278,953 | 2.17 | 209,215 | 0 | 17,435 | 13,948 | 20,921 |
| 2030 | 284,532 | 2.00 | 213,399 | 0 | 17,783 | 14,227 | 21,340 |
| 2031 | 290,223 | 2.00 | 217,667 | 0 | 18,139 | 14,511 | 21,767 |
| 2032 | 296,027 | 2.00 | 222,020 | 0 | 18,502 | 14,801 | 22,202 |
| 2033 | 301,948 | 2.00 | 226,461 | 0 | 18,872 | 15,097 | 22,646 |
| 2034 | 307,987 | 2.00 | 230,990 | 0 | 19,249 | 15,399 | 23,099 |
| 2035 | 314,146 | 2.00 | 235,610 | 0 | 19,634 | 15,707 | 23,561 |
| 2036 | 320,429 | 2.00 | 240,322 | 0 | 20,027 | 16,021 | 24,032 |
| 2037 | 326,838 | 2.00 | 245,128 | 0 | 20,427 | 16,342 | 24,513 |
| 2038 | 333,375 | 2.00 | 250,031 | 0 | 20,836 | 16,669 | 25,003 |
| 2039 | 340,042 | 2.00 | 255,032 | 0 | 21,253 | 17,002 | 25,503 |
| 2040 | 346,843 | 2.00 | 260,132 | 0 | 21,678 | 17,342 | 26,013 |
| 2041 | 353,780 | 2.00 | 265,335 | 0 | 22,111 | 17,689 | 26,533 |
| 2042 | 360,855 | 2.00 | 270,642 | 0 | 22,553 | 18,043 | 27,064 |
| 2043 | 368,073 | 2.00 | 276,054 | 0 | 23,005 | 18,404 | 27,605 |
| 2044 | 375,434 | 2.00 | 281,576 | 0 | 23,465 | 18,772 | 28,158 |
| 2045 | 382,943 | 2.00 | 287,207 | 0 | 23,934 | 19,147 | 28,721 |
| 2046 | 390,602 | 2.00 | 292,951 | 0 | 24,413 | 19,530 | 29,295 |
| 2047 | 398,414 | 2.00 | 298,810 | 0 | 24,901 | 19,921 | 29,881 |
| 2048 | 406,382 | 2.00 | 304,786 | 0 | 25,399 | 20,319 | 30,479 |
| 2049 | 414,509 | 2.00 | 310,882 | 0 | 25,907 | 20,725 | 31,088 |
| 2050 | 422,800 | 2.00 | 317,100 | 0 | 26,425 | 21,140 | 31,710 |
| 2051 | 431,256 | 2.00 | 323,442 | 0 | 26,953 | 21,563 | 32,344 |
| 2052 | 439,881 | 2.00 | 329,911 | 0 | 27,493 | 21,994 | 32,991 |
| 2053 | 448,678 | 2.00 | 336,509 | 0 | 28,042 | 22,434 | 33,651 |
| 2054 | 457,652 | 2.00 | 343,239 | 0 | 28,603 | 22,883 | 34,324 |
| 2055 | 466,805 | 2.00 | 350,104 | 0 | 29,175 | 23,340 | 35,010 |
| 2056 | 476,141 | 2.00 | 357,106 | 0 | 29,759 | 23,807 | 35,711 |
| 2057 | 485,664 | 2.00 | 364,248 | 0 | 30,354 | 24,283 | 36,425 |
| 2058 | 495,377 | 2.00 | 371,533 | 0 | 30,961 | 24,769 | 37,153 |

Notes:
1. Population figures and increases from 2005 to 2029 are from the NC Demographics Unit (June 2008). Figures from 2030 onward are based on an assumed constant percentage increase from 2030 onward.

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DATE: 6/12/07
BY: PKS
CHKD BY:

## Johnston County Landfill
## Waste Generaton Analysis - MSW (+500 TPD Out of County) - FROM APPROVED FACILITY PLAN

Per-Capita Disposal Rate (tons/person/yr.) = 0.75 (Based on FY 2006-07 Data)
Estimated Monthly Tonnage Variance (%) = 20 (Estimated by County)

| Year | Population (See Note 1) | % Increase From Previous | Projected County Tonnage | Projected Out of County Tonnage | Projected Total Tonnage | Projected Avg. Monthly Tonnage | Projected Monthly Variance (Min.) | Projected Monthly Variance (Max.) |
|---|---|---|---|---|---|---|---|---|
| 2008 | 162,609 | ----- | 121,957 | 0 | 121,957 | 10,163 | 8,130 | 12,196 |
| 2009 | 167,849 | 3.22 | 125,887 | 156,000 | 281,887 | 23,491 | 18,792 | 28,189 |
| 2010 | 172,857 | 2.98 | 129,643 | 156,000 | 285,643 | 23,804 | 19,043 | 28,564 |
| 2011 | 178,094 | 3.03 | 133,571 | 156,000 | 289,571 | 24,131 | 19,305 | 28,957 |
| 2012 | 183,333 | 2.94 | 137,500 | 156,000 | 293,500 | 24,458 | 19,567 | 29,350 |
| 2013 | 188,570 | 2.86 | 141,428 | 156,000 | 297,428 | 24,786 | 19,829 | 29,743 |
| 2014 | 193,808 | 2.78 | 145,356 | 156,000 | 301,356 | 25,113 | 20,090 | 30,136 |
| 2015 | 199,109 | 2.74 | 149,332 | 156,000 | 305,332 | 25,444 | 20,355 | 30,533 |
| 2016 | 204,600 | 2.76 | 153,450 | 156,000 | 309,450 | 25,788 | 20,630 | 30,945 |
| 2017 | 210,092 | 2.68 | 157,569 | 156,000 | 313,569 | 26,131 | 20,905 | 31,357 |
| 2018 | 215,584 | 2.61 | 161,688 | 156,000 | 317,688 | 26,474 | 21,179 | 31,769 |
| 2019 | 221,075 | 2.55 | 165,806 | 156,000 | 321,806 | 26,817 | 21,454 | 32,181 |
| 2020 | 226,622 | 2.51 | 169,967 | 156,000 | 325,967 | 27,164 | 21,731 | 32,597 |
| 2021 | 232,333 | 2.52 | 174,250 | 156,000 | 330,250 | 27,521 | 22,017 | 33,025 |
| 2022 | 238,043 | 2.46 | 178,532 | 156,000 | 334,532 | 27,878 | 22,302 | 33,453 |
| 2023 | 243,755 | 2.40 | 182,816 | 156,000 | 338,816 | 28,235 | 22,588 | 33,882 |
| 2024 | 249,466 | 2.34 | 187,100 | 156,000 | 343,100 | 28,592 | 22,873 | 34,310 |
| 2025 | 255,232 | 2.31 | 191,424 | 156,000 | 347,424 | 28,952 | 23,162 | 34,742 |
| 2026 | 261,161 | 2.32 | 195,871 | 156,000 | 351,871 | 29,323 | 23,458 | 35,187 |
| 2027 | 267,092 | 2.27 | 200,319 | 156,000 | 356,319 | 29,693 | 23,755 | 35,632 |
| 2028 | 273,023 | 2.22 | 204,767 | 156,000 | 360,767 | 30,064 | 24,051 | 36,077 |
| 2029 | 278,953 | 2.17 | 209,215 | 156,000 | 365,215 | 30,435 | 24,348 | 36,521 |
| 2030 | 284,532 | 2.00 | 213,399 | 156,000 | 369,399 | 30,783 | 24,627 | 36,940 |
| 2031 | 290,223 | 2.00 | 217,667 | 156,000 | 373,667 | 31,139 | 24,911 | 37,367 |
| 2032 | 296,027 | 2.00 | 222,020 | 156,000 | 378,020 | 31,502 | 25,201 | 37,802 |
| 2033 | 301,948 | 2.00 | 226,461 | 156,000 | 382,461 | 31,872 | 25,497 | 38,246 |
| 2034 | 307,987 | 2.00 | 230,990 | 156,000 | 386,990 | 32,249 | 25,799 | 38,699 |
| 2035 | 314,146 | 2.00 | 235,610 | 156,000 | 391,610 | 32,634 | 26,107 | 39,161 |
| 2036 | 320,429 | 2.00 | 240,322 | 156,000 | 396,322 | 33,027 | 26,421 | 39,632 |
| 2037 | 326,838 | 2.00 | 245,128 | 156,000 | 401,128 | 33,427 | 26,742 | 40,113 |
| 2038 | 333,375 | 2.00 | 250,031 | 156,000 | 406,031 | 33,836 | 27,069 | 40,603 |
| 2039 | 340,042 | 2.00 | 255,032 | 156,000 | 411,032 | 34,253 | 27,402 | 41,103 |
| 2040 | 346,843 | 2.00 | 260,132 | 156,000 | 416,132 | 34,678 | 27,742 | 41,613 |
| 2041 | 353,780 | 2.00 | 265,335 | 156,000 | 421,335 | 35,111 | 28,089 | 42,133 |
| 2042 | 360,855 | 2.00 | 270,642 | 156,000 | 426,642 | 35,553 | 28,443 | 42,664 |
| 2043 | 368,073 | 2.00 | 276,054 | 156,000 | 432,054 | 36,005 | 28,804 | 43,205 |
| 2044 | 375,434 | 2.00 | 281,576 | 156,000 | 437,576 | 36,465 | 29,172 | 43,758 |
| 2045 | 382,943 | 2.00 | 287,207 | 156,000 | 443,207 | 36,934 | 29,547 | 44,321 |
| 2046 | 390,602 | 2.00 | 292,951 | 156,000 | 448,951 | 37,413 | 29,930 | 44,895 |
| 2047 | 398,414 | 2.00 | 298,810 | 156,000 | 454,810 | 37,901 | 30,321 | 45,481 |
| 2048 | 406,382 | 2.00 | 304,786 | 156,000 | 460,786 | 38,399 | 30,719 | 46,079 |
| 2049 | 414,509 | 2.00 | 310,882 | 156,000 | 466,882 | 38,907 | 31,125 | 46,688 |
| 2050 | 422,800 | 2.00 | 317,100 | 156,000 | 473,100 | 39,425 | 31,540 | 47,310 |
| 2051 | 431,256 | 2.00 | 323,442 | 156,000 | 479,442 | 39,953 | 31,963 | 47,944 |
| 2052 | 439,881 | 2.00 | 329,911 | 156,000 | 485,911 | 40,493 | 32,394 | 48,591 |
| 2053 | 448,678 | 2.00 | 336,509 | 156,000 | 492,509 | 41,042 | 32,834 | 49,251 |

Notes:
1. Population figures and increases from 2005 to 2029 are from the NC Demographics Unit (June 2008). Figures from 2030 onward are based on an assumed constant percentage increase from 2030 onward.

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 |

Combine For Fill Seq.2

746,481 CY

6/21

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CHKD BY:

# Johnston County Landfill - C&D - Area 1
## Capacity Evaluation - Filling Rate & Density Calculations

**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) |
|---|---|---|---|---|---|---|---|---|---|
| 4/1/1999 | 5/21/2004 | 5.14 | 343,193 | 187,514 | **1,093** | 10 | 34,319 | 308,874 | **1,214** |
| 5/22/2004 | 3/21/2005 | 0.83 | 48,788 | 25,654 | **1,052** | 10 | 4,879 | 43,909 | **1,169** |
| 3/22/2005 | 6/4/2006 | 1.20 | 99,886 | 45,745 | **916** | 10 | 9,989 | 89,897 | **1,018** |
| 6/5/2006 | 5/20/2007 | 0.96 | 64,938 | 39,155 | **1,206** | 10 | 6,494 | 58,444 | **1,340** |
| 5/21/2007 | 7/17/2007 | 0.16 | 16,043 | 6,712 | **837** | 10 | 1,604 | 14,439 | **930** |
| | **Sum =** | | **572,848** | **304,780** | | | **57,285** | **515,563** | |
| | | | | | | | | **Avg. =** | **1,190** |

+12.9 Ac x 2' ⇒ 41,624 CY

614,472 CY
↑
Gross Capacity
(Subgrade To Top of F. Cut.)

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

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# Johnston County Landfill - C&D - Area 2
## Capacity Evaluation - Filling Rate & Density Calculations

**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) |
|---|---|---|---|---|---|---|---|---|---|
| 7/18/2007 | 6/6/2008 | 0.89 | 60,989 | 34,021 | **1,116** | 10 | 6,099 | 54,890 | **1,240** |
| | | | | | | | | **Avg. =** | **1,240** |

Cell 1 Gross Cap. ⇒ ↓ (used) + 349,686 CY (↑ Vol. Remaining) = 410,675 CY

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

Cell 1 Net Cap. (CY) ⇒ 54,890 CY used + 298,166 CY (↑ Rem.) = 353,056 CY

Cell 1 Net Cap. (Tons) ⇒ 34,021 Tons used + 178,899 Tons (↑ Rem.) = 212,920 Tons

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CHKD BY:

# Johnston County Landfill
## Capacity Evaluation - C&D - Area 2 - Cell 1

**Waste & Periodic Cover Parameters:**

| | | |
|---|---|---|
| Waste Density (pcy) = | 1,200 | (Assumed Density) |
| Waste Density (tcy) = | 0.60 | |
| Percentage of Periodic Cover = | 10 | (Assumed) |

**Volume Calculations:**

Volume From AutoCAD (cy) = 349,687 (2008 Topo. to Top of Cell 1 Fill Grades)
**(= Remaining Gross Capacity)**

**Net (Waste) Capacity:**

Adjustment For Other Layers:

| | | |
|---|---|---|
| | Area of Final Cover (Ac.) = | 5.7 |
| 2 feet | Vegetative Soil Layer = | (18,392) cy |
| | Sum = | (18,392) cy |
| | **Volume of Waste and Periodic Cover (cy) =** | 331,295 |
| | **Volume of Periodic Cover (cy) =** | (33,130) |
| | **Net (Waste) Capacity (cy) =** | 298,166 |
| | **Net (Waste) Capacity (tons) =** | 178,899 |

**Life Expectancy Calculations:**

**County Average:**

| Start Time | End Time | Tons Disposed | Total Tons | Remainder | |
|---|---|---|---|---|---|
| 2008.43 | 2009 | 18,538 | 18,538 | 160,361 | |
| 2009 | 2013 | 140,427 | 158,965 | 19,934 | Based on Est. Waste Generation |
| 2013 | 2013.53 | 19,934 | 178,899 | 0 | (Attached) |

**Landfill Life Expectancy (years) =** 5.1 July 2013

**Maximum (+ 20%):**

| Start Time | End Time | Tons Disposed | Total Tons | Remainder | |
|---|---|---|---|---|---|
| 2008.43 | 2009 | 22,245 | 22,245 | 156,654 | |
| 2009 | 2012 | 124,512 | 146,757 | 32,142 | Based on Est. Waste Generation |
| 2012 | 2012.73 | 32,142 | 178,899 | 0 | (Attached) |

**Landfill Life Expectancy (years) =** 4.3 September 2012

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BY: PKS
CHKD BY:

# Johnston County Landfill
# Capacity Evaluation - C&D - Area 2 - Cell 2

**Waste & Periodic Cover Parameters:**

Waste Density (pcy) = 1,200 (Assumed Density)
Waste Density (tcy) = 0.60
Percentage of Periodic Cover = 10 (Assumed)

**Volume Calculations:**

Volume From AutoCAD (cy) = 462,658 (Cell 1 Fill Grades to Area 2 Final Cover Grades)
**(= Gross Capacity)**

**Net (Waste) Capacity:**

Adjustment For Other Layers:

Area of Final Cover (Ac.) = 10.1

2 feet Vegetative Soil Layer = (32,589) cy

Sum = (32,589) cy

**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:**

**County-Only:**

| Start Time | End Time | Tons Disposed | Total Tons | Remainder | |
|---|---|---|---|---|---|
| 2013.53 | 2014 | 17,780 | 17,780 | 214,457 | |
| 2014 | 2019 | 204,639 | 222,419 | 9,818 | Based on Est. Waste Generation |
| 2019 | 2019.22 | 9,818 | 232,237 | 0 | (Attached) |

**Landfill Life Expectancy (years) =** 5.7 March 2019

**Maximum (+ 20%):**

| Start Time | End Time | Tons Disposed | Total Tons | Remainder | |
|---|---|---|---|---|---|
| 2012.73 | 2013 | 11,858 | 11,858 | 220,379 | |
| 2013 | 2017 | 188,661 | 200,519 | 31,718 | Based on Est. Waste Generation |
| 2017 | 2017.63 | 31,718 | 232,237 | 0 | (Attached) |

**Landfill Life Expectancy (years) =** 4.9 August 2017

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SHEET: 17 / 19
JOB #: JOHNSTON-07-2
DATE: 12/3/08
BY: PKS
CHKD BY:

# Johnston County Landfill
## Waste Generaton Analysis - C&D (County-Only)

Per-Capita Disposal Rate (tons/person/yr.) = 0.2 (Value Estimated to Reflect Current Reduced Trend in C&D Disposal)
Estimated Monthly Tonnage Variance (%) = 20 (Estimated by County)

| Year | Population (See Note 1) | % Increase From Previous | Projected County Tonnage | Projected Maximum Tonnage (+ 20%) | Projected Avg. Monthly Tonnage | Projected Monthly Variance (Min.) | Projected Monthly Variance (Max.) |
|---|---|---|---|---|---|---|---|
| 2008 | 162,609 | ----- | 32,522 | 39,026 | 2,710 | 2,168 | 3,252 |
| 2009 | 167,849 | 3.22 | 33,570 | 40,284 | 2,797 | 2,238 | 3,357 |
| 2010 | 172,857 | 2.98 | 34,571 | 41,486 | 2,881 | 2,305 | 3,457 |
| 2011 | 178,094 | 3.03 | 35,619 | 42,743 | 2,968 | 2,375 | 3,562 |
| 2012 | 183,333 | 2.94 | 36,667 | 44,000 | 3,056 | 2,444 | 3,667 |
| 2013 | 188,570 | 2.86 | 37,714 | 45,257 | 3,143 | 2,514 | 3,771 |
| 2014 | 193,808 | 2.78 | 38,762 | 46,514 | 3,230 | 2,584 | 3,876 |
| 2015 | 199,109 | 2.74 | 39,822 | 47,786 | 3,318 | 2,655 | 3,982 |
| 2016 | 204,600 | 2.76 | 40,920 | 49,104 | 3,410 | 2,728 | 4,092 |
| 2017 | 210,092 | 2.68 | 42,018 | 50,422 | 3,502 | 2,801 | 4,202 |
| 2018 | 215,584 | 2.61 | 43,117 | 51,740 | 3,593 | 2,874 | 4,312 |
| 2019 | 221,075 | 2.55 | 44,215 | 53,058 | 3,685 | 2,948 | 4,422 |
| 2020 | 226,622 | 2.51 | 45,324 | 54,389 | 3,777 | 3,022 | 4,532 |
| 2021 | 232,333 | 2.52 | 46,467 | 55,760 | 3,872 | 3,098 | 4,647 |
| 2022 | 238,043 | 2.46 | 47,609 | 57,130 | 3,967 | 3,174 | 4,761 |
| 2023 | 243,755 | 2.40 | 48,751 | 58,501 | 4,063 | 3,250 | 4,875 |
| 2024 | 249,466 | 2.34 | 49,893 | 59,872 | 4,158 | 3,326 | 4,989 |
| 2025 | 255,232 | 2.31 | 51,046 | 61,256 | 4,254 | 3,403 | 5,105 |
| 2026 | 261,161 | 2.32 | 52,232 | 62,679 | 4,353 | 3,482 | 5,223 |
| 2027 | 267,092 | 2.27 | 53,418 | 64,102 | 4,452 | 3,561 | 5,342 |
| 2028 | 273,023 | 2.22 | 54,605 | 65,526 | 4,550 | 3,640 | 5,460 |
| 2029 | 278,953 | 2.17 | 55,791 | 66,949 | 4,649 | 3,719 | 5,579 |
| 2030 | 284,532 | 2.00 | 56,906 | 68,288 | 4,742 | 3,794 | 5,691 |
| 2031 | 290,223 | 2.00 | 58,045 | 69,653 | 4,837 | 3,870 | 5,804 |
| 2032 | 296,027 | 2.00 | 59,205 | 71,047 | 4,934 | 3,947 | 5,921 |
| 2033 | 301,948 | 2.00 | 60,390 | 72,467 | 5,032 | 4,026 | 6,039 |
| 2034 | 307,987 | 2.00 | 61,597 | 73,917 | 5,133 | 4,106 | 6,160 |
| 2035 | 314,146 | 2.00 | 62,829 | 75,395 | 5,236 | 4,189 | 6,283 |
| 2036 | 320,429 | 2.00 | 64,086 | 76,903 | 5,340 | 4,272 | 6,409 |
| 2037 | 326,838 | 2.00 | 65,368 | 78,441 | 5,447 | 4,358 | 6,537 |
| 2038 | 333,375 | 2.00 | 66,675 | 80,010 | 5,556 | 4,445 | 6,667 |
| 2039 | 340,042 | 2.00 | 68,008 | 81,610 | 5,667 | 4,534 | 6,801 |
| 2040 | 346,843 | 2.00 | 69,369 | 83,242 | 5,781 | 4,625 | 6,937 |
| 2041 | 353,780 | 2.00 | 70,756 | 84,907 | 5,896 | 4,717 | 7,076 |
| 2042 | 360,855 | 2.00 | 72,171 | 86,605 | 6,014 | 4,811 | 7,217 |
| 2043 | 368,073 | 2.00 | 73,615 | 88,337 | 6,135 | 4,908 | 7,361 |
| 2044 | 375,434 | 2.00 | 75,087 | 90,104 | 6,257 | 5,006 | 7,509 |
| 2045 | 382,943 | 2.00 | 76,589 | 91,906 | 6,382 | 5,106 | 7,659 |
| 2046 | 390,602 | 2.00 | 78,120 | 93,744 | 6,510 | 5,208 | 7,812 |
| 2047 | 398,414 | 2.00 | 79,683 | 95,619 | 6,640 | 5,312 | 7,968 |
| 2048 | 406,382 | 2.00 | 81,276 | 97,532 | 6,773 | 5,418 | 8,128 |
| 2049 | 414,509 | 2.00 | 82,902 | 99,482 | 6,908 | 5,527 | 8,290 |
| 2050 | 422,800 | 2.00 | 84,560 | 101,472 | 7,047 | 5,637 | 8,456 |
| 2051 | 431,256 | 2.00 | 86,251 | 103,501 | 7,188 | 5,750 | 8,625 |
| 2052 | 439,881 | 2.00 | 87,976 | 105,571 | 7,331 | 5,865 | 8,798 |
| 2053 | 448,678 | 2.00 | 89,736 | 107,683 | 7,478 | 5,982 | 8,974 |
| 2054 | 457,652 | 2.00 | 91,530 | 109,836 | 7,628 | 6,102 | 9,153 |
| 2055 | 466,805 | 2.00 | 93,361 | 112,033 | 7,780 | 6,224 | 9,336 |
| 2056 | 476,141 | 2.00 | 95,228 | 114,274 | 7,936 | 6,349 | 9,523 |
| 2057 | 485,664 | 2.00 | 97,133 | 116,559 | 8,094 | 6,476 | 9,713 |
| 2058 | 495,377 | 2.00 | 99,075 | 118,891 | 8,256 | 6,605 | 9,908 |

Notes:
1. Population figures and increases from 2005 to 2029 are from the NC Demographics Unit (June 2008). Figures from 2030 onward are based on an assumed constant percentage increase from 2030 onward.

Johnston County Landfill
Airspace Report 6/6/08
7/22/2008

| version | date | time | surfBase | surfCompare | volCut | volFill | volNet | |
|---|---|---|---|---|---|---|---|---|
| 1 | 7/22/2008 | 18-46-12 | TOPO 052007_MSW PH4A AREA | TOPO 060608 | 14,762.30 | 207,542.59 | 192,780.29 | ph4A consumed |
| 1 | 7/22/2008 | 18-46-12 | TOPO 052007_CD AREA 1 | TOPO 060608 | 6,794.67 | 22,837.65 | 16,042.99 | CD area 1 consumed |
| 1 | 7/22/2008 | 18-46-12 | TOPO 052007_CD AREA 2 | TOPO 060608 | 4,339.45 | 65,328.13 | 60,988.68 | CD area 2 consumed |
| 1 | 7/22/2008 | 18-56-09 | TOPO 060608 | PHASE 3 ICVR | 138,166.52 | 47,387.02 | (90,779.50) | ph4A remaining |
| 1 | 7/22/2008 | 18-56-09 | TOPO 060608 | CD-FCVR-120503 | 34,609.95 | 41,985.32 | 7,375.36 | CD area 1 remaining |
| 1 | 7/22/2008 | 18-56-09 | TOPO 060608 | CD AREA 2_FCVR CELL 2 | 1,886.54 | 351,573.47 | 349,686.93 | CD area 2 remaining |

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SHEET: 19 / 19
JOB #: JOHNSTON-07-2
DATE: 12/3/08
BY: PKS
CHKD BY:

# Johnston County Landfill
# Capacity Evaluation - Summary

| Landfill Unit | Area (Acres) | Gross Capacity (CY) | Net (Waste) Capacity | | Life Expectancy (Years) (Max/Min) | |
|---|---|---|---|---|---|---|
| | | | (CY) | (Tons) | | |
| **Unlined MSW Landfill Units** | | | | | | |
| Phase 1/2 (Closed) | 22.1 | 732,363 | 495,790 | 297,474 | Closed | |
| Phase 3 (Closed) | 25.4 | 1,174,139 | 819,136 | 491,482 | Closed | |
| Phase 4 (Closed) | 37.3 | 1,631,731 | 1,133,533 | 680,120 | Closed | |
| Total (Unlined MSW) | 84.8 | 3,538,233 | 2,448,459 | 1,469,076 | Closed | |
| **Lined MSW Landfill Units** | | | | | | |
| Phase 5 (Inactive) | 19.2 | 1,087,199 | 884,625 | 514,181 | Inactive | |
| Phase 4 (Cells 1 & 2) (Active) (See Note 1) | 22.0 | 1,111,382 | 944,675 | 538,079 | At Capacity (See Note 2) | |
| Phase 4A (Cell 3 - Fill Sequence 1) | 7.4 | 1,420,566 | 1,207,481 | 845,237 | 5.9 | 3.1 |
| Phase 4A (Cell 3 - Fill Sequence 2) | 0.0 | 746,481 | 553,874 | 387,712 | 2.6 | 1.3 |
| Phase 6 | 21.1 | 1,402,016 | 1,167,578 | 700,547 | 4.3 | 2.3 |
| Phase 7 | 19.8 | 1,758,991 | 1,462,230 | 877,338 | 4.8 | 2.8 |
| Phase 8 | 25.2 | 1,844,867 | 1,495,182 | 897,109 | 4.4 | 2.8 |
| Phase 9 | 22.5 | 6,684,914 | 5,611,690 | 3,928,183 | 15.7 | 11.2 |
| Phase 10 | 17.5 | 3,075,968 | 2,524,065 | 1,766,846 | 5.7 | 4.6 |
| Total (Lined MSW) | 154.7 | 19,132,384 | 15,851,400 | 10,455,232 | 34.9 | 23.7 |
| Total (MSW) | 239.5 | 22,670,617 | 18,299,859 | 11,924,308 | 34.9 | 23.7 |
| **C&D Landfill Units** | | | | | | |
| Area 1 (Vertical Expn.) (Active) (See Note 1) | 16.2 | 614,472 | 515,563 | 304,780 | Inactive | |
| Area 2 - Cell 1 | 11.9 | 410,675 | 353,056 | 212,920 | 5.1 | 4.3 |
| Area 2 - Cell 2 | 3.9 | 462,658 | 387,062 | 232,237 | 5.7 | 4.9 |
| Total (C&D) | 32.0 | 1,487,805 | 1,255,681 | 749,937 | 10.8 | 9.2 |

Notes:
1. Life Expectancy as of June 6, 2008.
2. Operations in Cells 1 and 2 have expanded vertically into the Cell 3 Fill Seq. 1 volume.

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PROJECT Johnston County MSWLF - Phase 4A - Cell 3

SUBJECT Earthwork Quantities

SHEET 1 OF 4
JOB NO. JOHNSTON-07-2
DATE 12/4/08
COMPUTED BY PKS
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 will be calculated by taking design thicknesses and/or cross sections and multiplying by design areas and/or lengths. Areas and lengths are determined using AutoCAD, a planimeter, and/or direct measurement.

**EARTHWORK.WPD**

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SHEET: 24
JOB #: JOHNSTON-07-2
DATE: 12/4/08
BY: PKS
CHKD BY:

# Johnston County MSW Landfill - Phase 4A - Cell 3
## Earthwork Quantities

**Subgrade Cut and Fill Volumes:**

| | | |
|---|---|---|
| Volume of Cut (cy) = | 1,824 | **(From AutoCAD - See Attached)** |
| Volume of Fill (cy) = | 28,455 | **(From AutoCAD - See Attached)** |

**LCS/Protective Cover Volume:**

| | | |
|---|---|---|
| Area of LCS/Protective Cover (Ac.) = | 7.4 | **(From AutoCAD - See Attached)** |
| Thickness of LCS/Protective Cover (ft) = | 2.0 | |
| Volume of LCS/Protective Cover (cy) = | 23,877 | |

**Periodic Cover Soil Volumes:**

| | | |
|---|---|---|
| Volume of Periodic Cover (cy) = | 199,468 | **(From Volume/Life Calculations - Cell 3 - Fill Seq. 1)** |
| Volume of Periodic Cover (cy) = | 97,743 | **(From Volume/Life Calculations - Cell 3 - Fill Seq. 2)** |

**Vegetative Soil Layer (VSL) Volume:**

| | | |
|---|---|---|
| Area of VSL (Ac.) = | 29.4 | **(From AutoCAD - Phase 4A)** |
| Thickness of VSL (ft) = | 2.0 | |
| Volume of VSL (cy) = | 94,864 | |

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SHEET: 3 / 4
JOB #: JOHNSTON-07-2
DATE: 12/4/08
BY: PKS
CHKD BY:

## Johnston County MSW Landfill - Phase 4A - Cell 3
## Earthwork Quantities - Summary

| Landfill Unit | General Earthwork | | Soil Liner (CY) | LCS/Pro. Cover (CY) | Periodic Cover (CY) | Vegetative Soil Layer (CY) |
|---|---|---|---|---|---|---|
| | Cut (CY) | Fill (CY) | | | | |
| **MSW Units** | | | | | | |
| Phase 4A - Cell 3 - Fill Sequence 1 | 1,824 | 28,455 | ----- | 23,877 | 199,468 | ----- |
| Phase 4A - Cell 3 - Fill Sequence 2 | ----- | ----- | ----- | ----- | 97,743 | 94,864 |
| Phase 5 | ----- | ----- | ----- | ----- | ----- | 61,952 |
| Phase 6 | 279,473 | 55,613 | 51,062 | 68,083 | 206,043 | 68,083 |
| Phase 7 | 222,037 | 85,202 | 47,916 | 63,888 | 258,041 | 63,888 |
| Phase 8 | 242,630 | 105,976 | 60,984 | 81,312 | 263,856 | 81,312 |
| Phase 9 | 68,999 | 178,758 | 54,450 | 72,600 | 990,298 | 72,600 |
| Phase 10 | 151,736 | 21,326 | 42,350 | 56,467 | 445,423 | 56,467 |
| **C&D Units** | | | | | | |
| Area 1 | ----- | ----- | ----- | ----- | ----- | 41,624 |
| Area 2 - Cell 1 | ----- | ----- | ----- | ----- | 33,130 | ----- |
| Area 2 - Cell 2 | 0 | 3,436 | 6,292 | 12,584 | 43,007 | 50,981 |
| **Totals (CY) =** | **966,699** | **478,766** | **263,054** | **378,811** | **2,537,009** | **591,771** |
| Location (On-Site/Off-Site): | On-Site | On-Site | On-Site | On-Site | On-Site | On-Site |
| | | | | | **On-Site Soil Balance (CY) =** | **(3,282,712)** |

Client - Johnston County
Project - 07-2 Phase 4A - Cell 3
Date - 11/03/08

| version | date | time | surfBase | surfCompare | volCut | volFill | volNet |
|---|---|---|---|---|---|---|---|
| 1 | 11/3/2008 | 16-41-29 | TOPO 060608 | PHASE 4A_CELL 3 SGRD_BEI | 1,824.21 | 28,454.96 | 26,630.75 |
| 1 | 11/3/2008 | 16-41-29 | PHASE 4A_CELL 3 SGRD_BEI | PHASE 4A_CELL 3 PCVR_BEF | 2.04 | 28,716.47 | 28,714.42 |

4/4

PROJECT Johnston County MSWLF - Phase 4A - Cell 3

SUBJECT Anchor Trench Analysis

SHEET 1 OF 2
JOB NO. JOHNSTON-07-2
DATE 2/16/07
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 yields under excessive loads.

**Reference** Richardson, G.N. & Koerner, R.M. (1987), "Geosynthetic Design Guidance for Hazardous Waste Landfill Cells & Surface Impoundments", EPA Guidance Document (EPA 600/2-87/097).

**Assumptions**
1. Max. Anchorage ($\sigma_{max}$) = 1,300 psi
2. Min. Anchorage ($\sigma_{min}$) = 20 psi

**Analysis** Use the procedure outlined in EPA 600/S2-87/097.

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

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

(EPA Eq. 3.21)

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

Backfill Parameters:

- $\phi$ = internal friction angle (degrees)
- $\delta$ = friction angle between backfill & geomembrane (degrees) (for smooth HDPE/Clay 10-20° is typical) (20 -25+° for textured HDPE)
- $\gamma$ = 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 $\delta$. 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 (60 mil HDPE $\sigma_{yield}$ = 2,000 psi.).

**ANCHOR TRENCH.WPD**

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SHEET: 2 / 2
JOB #: JOHNSTON-07-2
DATE: 3/19/07
BY: PKS
CHKD BY:

# Johnston County MSW Landfill - Phase 4A - Cell 3
# Anchor Trench Analysis

**Input Parameters:**

**Side Slope Angle:** 18.4 degrees

**Geomembrane:**

Yield Stress ($\sigma_{max}$) = 2,000 psi — Primary (HDPE) Geomembrane
Thickness = 0.06 in

**Backfill Parameters:**

Internal Friction Angle ($\phi$)= 30 degrees — $K_A$ = 0.33
Unit Weight ($\gamma$) = 110 pcf — $K_P$ = 3.00

**Trench Parameters:**

Set-Back (L) = 3.0 feet
Depth (d) = 2.0 feet (Worst Case - Secondary GM)
$FS_{min.}$ = 1.5

**Stress Calculations:**

| $\delta$ | tan $\delta$ | T (lb/ft) | Stress in GM (psi) | $FS_{yield}$ |
|---|---|---|---|---|
| 10 | 0.176 | 368.7 | 512.1 | 3.9 |
| 15 | 0.268 | 572.4 | 795.0 | 2.5 |
| 20 | 0.364 | 795.6 | 1,105.0 | 1.8 |
| 25 | 0.466 | 1,045.1 | 1,451.5 | 1.4 |

PROJECT Johnston County MSWLF - Phase 4A - Cell 3

SUBJECT Filter Geotextile Analysis - LCS

SHEET 1 OF 9
JOB NO. JOHNSTON-07-2
DATE 3/15/07
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. Geotextile filtration properties must be selected based on the up-gradient soil gradation and plasticity and site specific hydraulic conditions.

**References**

Bhatia, S.K. and Huang, Q. (1995), "Geotextile Filters for Internally Stable/Unstable Soils", *Geosynthetics International*, Vol. 2, No. 3, pp. 537-565.

Koerner, Robert M. (1999), Designing with Geosynthetics, 4th Ed., Prentice-Hall Inc., Englewood Cliffs, NJ, pp. 84-91.

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

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

**Assumption** The design criteria given assume that the soil is "set" in intimate contact with the geotextile.

**Background** From Richardson et. al.:

For the purposes of filtration design, soils can be characterized as stable or unstable. Stable soils perform an internal filtration process that limits migration of fines within the soil. Typically, these soil types include well-graded soils. Unstable soils are those which cannot perform self-filtration (i.e. they have the potential to pipe internally). They may include gap-graded, broad-graded, and other highly erodible soils. In gap-graded soils, there exists a coarse and fine fraction, but very little medium fraction. If there is an insufficient quantity of soil particles in the medium fraction, fine soil particles pipe through the coarse fraction. In broad-graded soils, the gradation is distributed over a very wide range of particle sizes such that fine soil tends to pipe through coarser particles.

**Analysis**

1. **Define Application and Function of Geotextile:**

   Define 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).



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**2. Evaluate Soils Information:**

For representative soils, evaluate grain size and plasticity information. From the grain size curves determine the coefficients of uniformity and curvature as follows:

$$C_u = \frac{d_{60}}{d_{10}}$$

$$C_c = \frac{d_{30}^{\ 2}}{(d_{10} \times d_{60})}$$

where: $C_u$ = coefficient of uniformity (quantifies the distribution of particle sizes)
$C_c$ = coefficient of curvature (identifies internal soil stability)
$d_x$ = the diameter at which x percent of the soil is finer

For $C_u \leq 4$, the soil is uniformly-graded; for $4 < C_u \leq 20$, the soil is well-graded; and for $C_u > 20$, the soil is broad-graded. Uniformly-graded and broad-graded soils require careful analysis. Gap-graded soils which have a coarse and fine fraction, but limited medium fraction are of particular concern and should be avoided. Gap-graded soils are readily identified by the appearance of the grain size curve. For $1 \leq C_c \leq 3$, the soil should be internally stable (Bhatia and Huang state that soils having $C_c \leq 7$ are internally stable.).

Additionally, in general, particles do not move within soils having a plasticity index (PI) greater than 15% so there is no clogging potential (Richardson et. al.).

**3. Selection of Soil Retention Requirements (Maximum AOS):**

To determine the maximum AOS, use the method given in Koerner/Mirafi (after Luettich) and the method given in Bhatia and Huang. For the AOS determined by either method, the following shows the relationship between opening size and the corresponding U.S. sieve number (with typical non-woven geotextile information as shown).

| Opening Size (mm) | U.S. Sieve |
|---|---|
| 0.150 | 100 (most 8 to 16 oz/sy non-wovens) |
| 0.180 | 80 |
| 0.212 | 70 (most 4 to 6 oz/sy non-wovens) |
| 0.250 | 60 |
| 0.300 | 50 |
| 0.425 | 40 |
| 0.600 | 30 |

**- Luettich Method:**

For steady-state conditions, use the chart below.

**- Bhatia and Huang Method:**

Bhatia and Huang developed the following retention criteria:

For $n \geq 60\%$: $O_{95} < d_{85}(2.71 - 0.36C_c)$ $\quad C_c \leq 7$

$O_{95} < d_{85}(0.65 - 0.05C_c)$ $\quad C_c > 7$

For $n < 60\%$: $O_{95} < d_{85}$

where: $O_{95}$ = apparent opening size
$n$ = geotextile porosity (%) (for non-woven geotextiles this value is typically 70 to 90%)

**4. Determine Geotextile Permittivity Requirements:**

Determine the geotextile permittivity requirements:

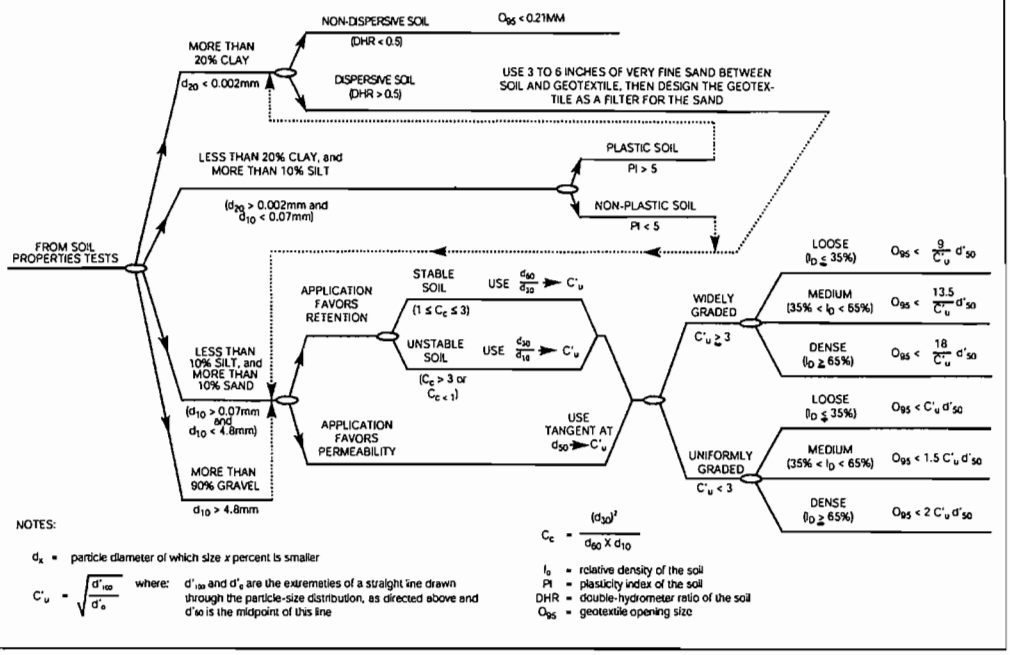
$$\Psi = \frac{k_g}{t_g} \qquad (\text{sec}^{-1})$$

where: $\Psi$ = minimum required geotextile permittivity ($\text{sec}^{-1}$)
$k_g$ = 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).

**5. 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.

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




*Ref: Mirafi (After Luettich)*

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JOB #: JOHNSTON-07-2
DATE: 3/19/07
BY: PKS
CHKD BY:

## Johnston County MSW Landfill - Phase 4A - Cell 3
## Filter Geotextile Analysis (Leachate Collection System)

**Application:** Leachate Collection System Drainage Geocomposite
**Primary Function:** Retention/Permeability
**Relative Confining Stress:** High
**Flow Conditions:** Steady-State

| | Soil Evaluated | | | | |
|---|---|---|---|---|---|
| | 643-01-01 | 643-01-03 | 643-04-01 | 643-06-01 | |
| Soil Description: | Brown Sandy Silt | Brown Clayey Sand | Tan Clayey Sand | Reddish Tan Sand w/ Silt | |
| Soil Type: | ML | SC | SC | SP-SM | |
| Particle Size (mm) $d_{85}$: | 0.700 | 0.600 | 1.000 | 0.850 | |
| $d_{60}$: | 0.060 | 0.320 | 0.480 | 0.500 | |
| $d_{50}$: | 0.020 | 0.270 | 0.370 | 0.400 | |
| $d_{30}$: | 0.003 | 0.110 | 0.200 | 0.270 | |
| $d_{20}$: | 0.001 | 0.010 | 0.120 | 0.160 | |
| $d_{10}$: | 0.001 | 0.001 | 0.010 | 0.100 | |
| PI: | 11 | 25 | 18 | 2 | |
| $C_u$: | 120.00 | 320.00 | 48.00 | 5.00 | |
| | Use Caution - Soil is Broad Graded! | Use Caution - Soil is Broad Graded! | Use Caution - Soil is Broad Graded! | Soil is Well Graded. | |
| $C_c$: | 0.30 | 37.81 | 8.33 | 1.46 | |
| **Luettich Method:*** | ----- | ----- | ----- | ----- | |
| Soil Dispersion (When Applicable): | Is Soil Dispersive? (Y/N) | Is Soil Dispersive? (Y/N) | Is Soil Dispersive? (Y/N) | NA | |
| | N | N | N | | |
| Recommended Maximum AOS (mm) (When Applicable): | **0.210** | **0.210** | **0.210** | | |
| | **No. 70 Sieve** | **No. 70 Sieve** | **No. 70 Sieve** | | |
| Internal Soil Stability (When Applicable): | NA | NA | NA | Soil is Stable | |
| | | | | Draw straight line through d60 and d30 to obtain C'u. | |
| Particle Size (mm) for Determining $C'_u$ $d'_{100}$: | | | | 1.300 | |
| $d'_{60}$: | | | | 0.400 | |
| $d'_{30}$: | | | | 0.110 | |
| $C'_u$ (When Applicable): | | | | 3.44 | |
| | | | | Soil is Widely Graded. | |
| Soil Relative Density ($I_D$) (Loose (L), Medium (M), Dense (D) (When Applicable): | | | | D | |
| Recommended Maximum AOS (mm) (When Applicable): | | | | **2.094** | |
| | | | | **No. 30 Sieve** | |
| **Bhatia & Huang Method:** | ----- | ----- | ----- | ----- | |
| Internal Soil Stability: | Soil is Stable. | Soil is Unstable. | Soil is Unstable. | Soil is Stable. | |
| Geotextile Porosity (%): | 80 | 80 | 80 | 80 | |
| Recommended Max. AOS (mm): | **1.821** | **-0.744** | **0.233** | **1.857** | |
| | **No. 30 Sieve** | **Check Available Geotextiles.** | **No. 70 Sieve** | **No. 30 Sieve** | |
| Required Geotextile Properties: | ----- | ----- | ----- | ----- | |
| Hydraulic Gradient ($i_s$): | 1.5 | 1.5 | 1.5 | 1.5 | |
| Estimated Soil Permeability ($k_s$) (cm/sec): | 1.0E-03 | 1.0E-03 | 1.0E-03 | 1.0E-03 | |
| Min. Allowable Geotextile Permeability ($k_g$) (cm/sec): | 1.5E-03 | 1.5E-03 | 1.5E-03 | 1.5E-03 | |
| Geotextile Thickness ($t_g$) (cm): | 0.25 | 0.25 | 0.25 | 0.25 | |
| Min. Required Geotextile Permittivity ($\Psi$) ($sec^{-1}$): | **0.006** | **0.006** | **0.006** | **0.006** | |

***Note: Spreadsheet assumes retention application in using the Luettich Method.**

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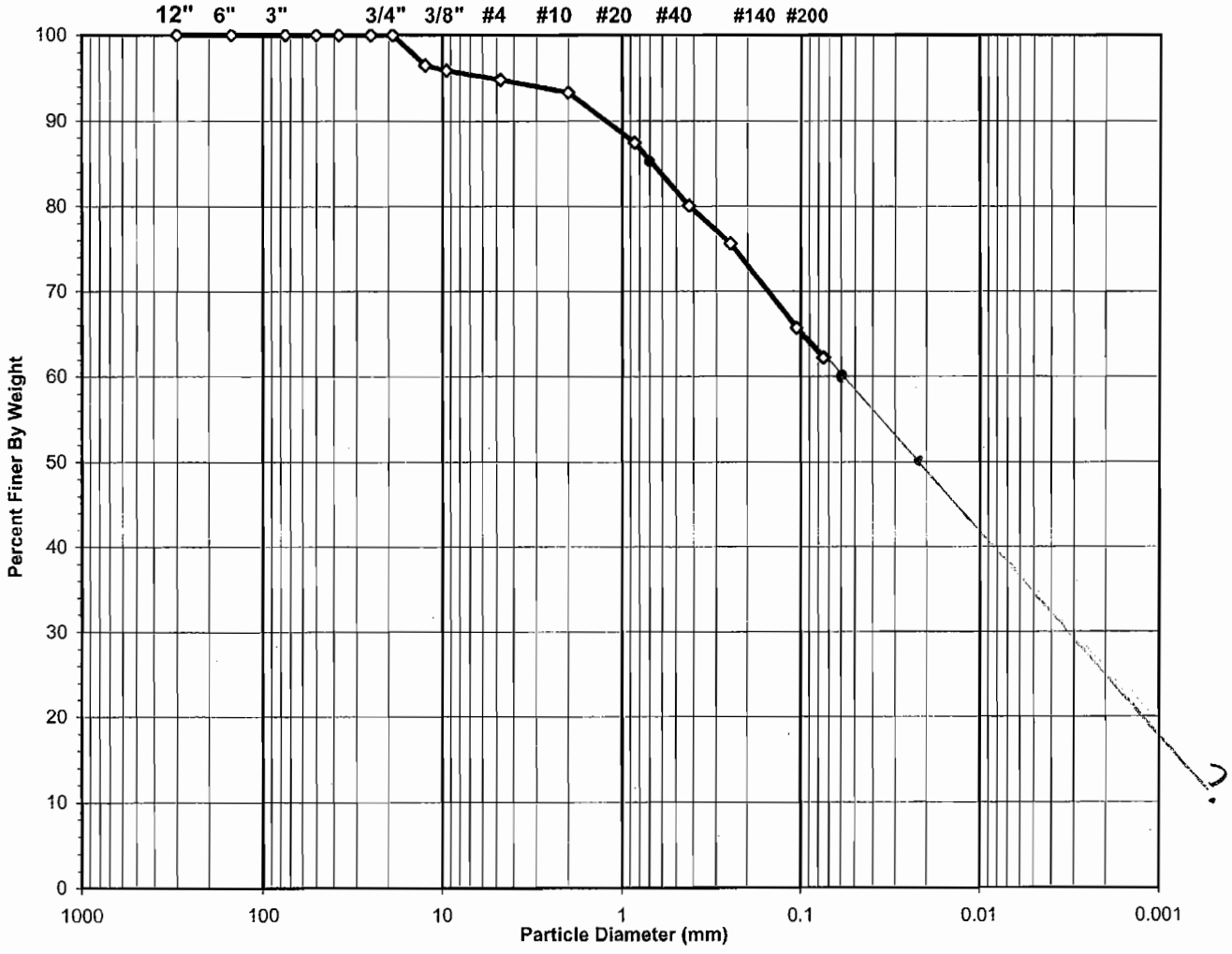
Geotechnics
INTEGRITY IN TESTING

## SIEVE ANALYSIS
ASTM D 422-63 (SOP-S3)

| | | | |
|---|---|---|---|
| Client | GN RICHARDSON & ASSOC. | Boring No. | TP-01 |
| Client Reference | JOHNSTON CO. C&D LF AREA 2 CELL 1 | Depth (ft) | 1-5' |
| Project No. | 2006-643-01 | Sample No. | SF-01 |
| Lab ID | 2006-643-01-01 | Soil Color | **BROWN** |

| | *SIEVE ANALYSIS* | | *HYDROMETER* |
|---|---|---|---|
| ***USCS*** | **gravel** | **sand** | **silt and clay** |




***USCS Symbol*** ***ML, TESTED***

***USCS Classification*** ***SANDY SILT***

Tested By JSC Date 10/24/2006 Checked By GSM Date 10-25-06



DCN: CT-S3C DATE 6-25-98 REVISION: 2 *\\Lab1\c\2006 PROJECTS\2006-643 GNRA JOHNSTON CO\[2006-643-01-01 SIEVE.XLS]Sheet1*

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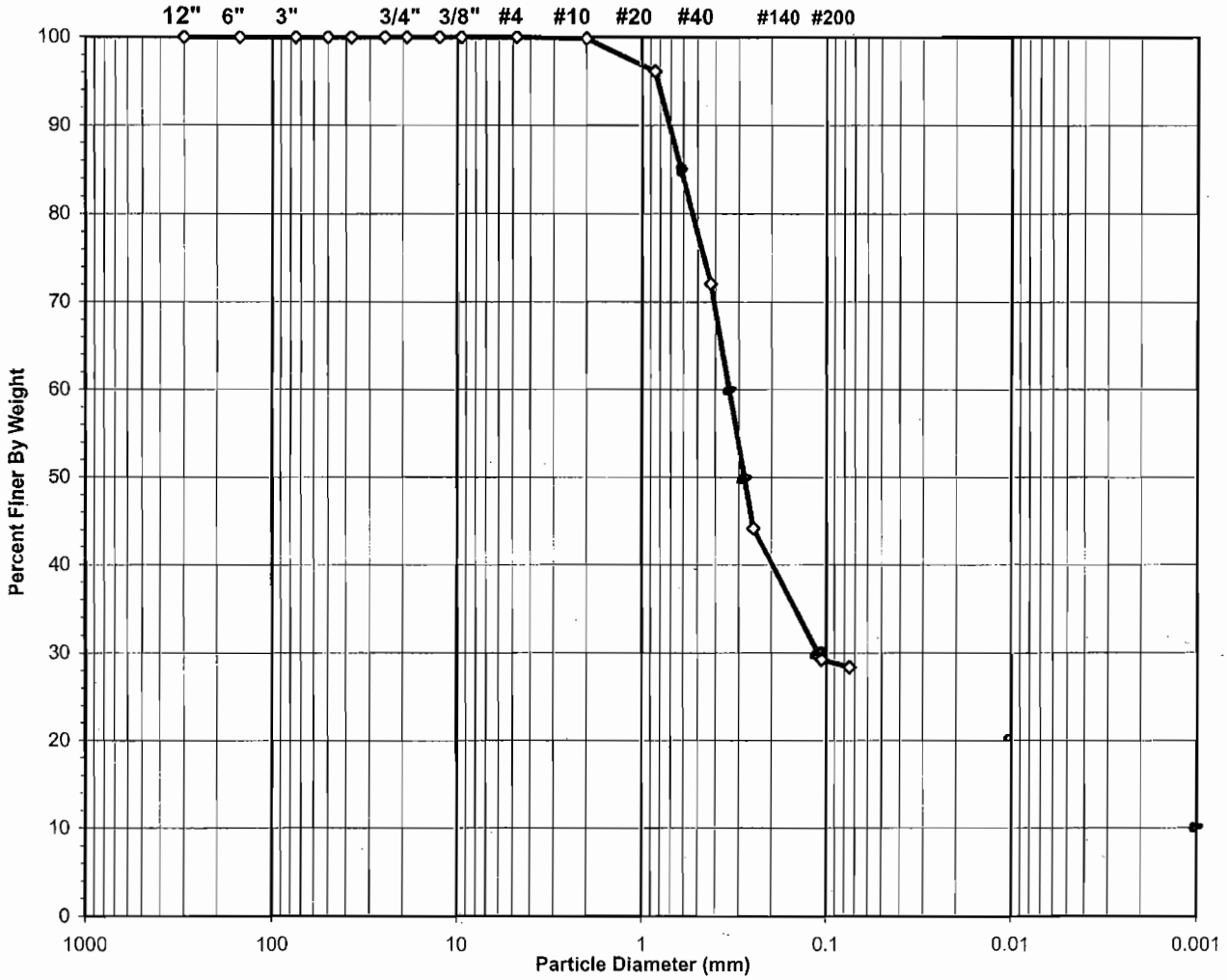
Geotechnics
INTEGRITY IN TESTING

## SIEVE ANALYSIS
ASTM D 422-63 (SOP-S3)

| | | | |
|---|---|---|---|
| Client | GN RICHARDSON & ASSOC. | Boring No. | TP-03 |
| Client Reference | JOHNSTON CO. C&D LF AREA 2 CELL 1 | Depth (ft) | 0.5-3' |
| Project No. | 2006-643-01 | Sample No. | SF-03 |
| Lab ID | 2006-643-01-03 | Soil Color | **BROWN** |

| | *SIEVE ANALYSIS* | | *HYDROMETER* |
|---|---|---|---|
| *USCS* | gravel | sand | silt and clay |




***USCS Symbol*** ***SC, TESTED***

***USCS Classification*** ***CLAYEY SAND***

Tested By JSC Date 10/24/2006 Checked By Gsm Date 10.25.06



DCN: CT-S3C DATE 6-25-98 REVISION: 2 *\\Lab1\c\2006 PROJECTS\2006-643 GNRA JOHNSTON CO\[2006-643-01-03 SIEVE.XLS]Sheet1*

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Geotechnics
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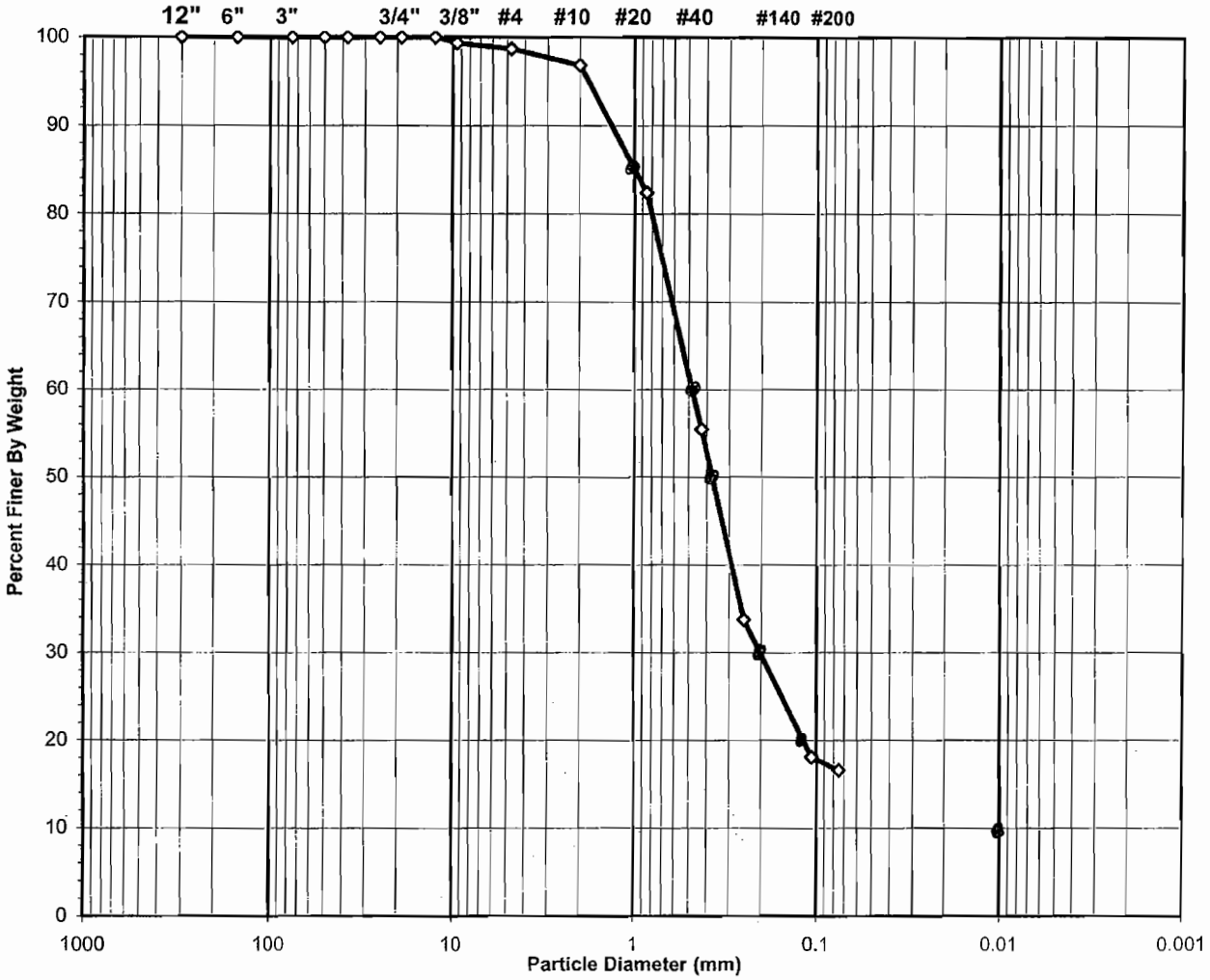
## SIEVE ANALYSIS
ASTM D 422-63 (SOP-S3)

| | | | |
|---|---|---|---|
| Client | G.N. RICHARDSON & ASSOC. | Boring No. | NA |
| Client Reference | JOHNSTON CO. C&D LF AREA 2 CELL 1 | Depth (ft) | SURFACE |
| Project No. | 2006-643-04 | Sample No. | NA |
| Lab ID | 2006-643-04-01 | Soil Color | TAN |

| USCS | SIEVE ANALYSIS | | HYDROMETER |
|---|---|---|---|
| | gravel | sand | silt and clay |




***USCS Symbol*** ***SC, TESTED***

***USCS Classification*** ***CLAYEY SAND***

Tested By JBD Date 11/21/06 Checked By MCW Date 11/21/06



DCN: CT-S3C DATE 6-25-98 REVISION: 2

*C:\2006 PROJECTS\2006-643 GNRA JOHNSTON CO\[2006-643-04-01 SIEVE.XLS]Sheet1*

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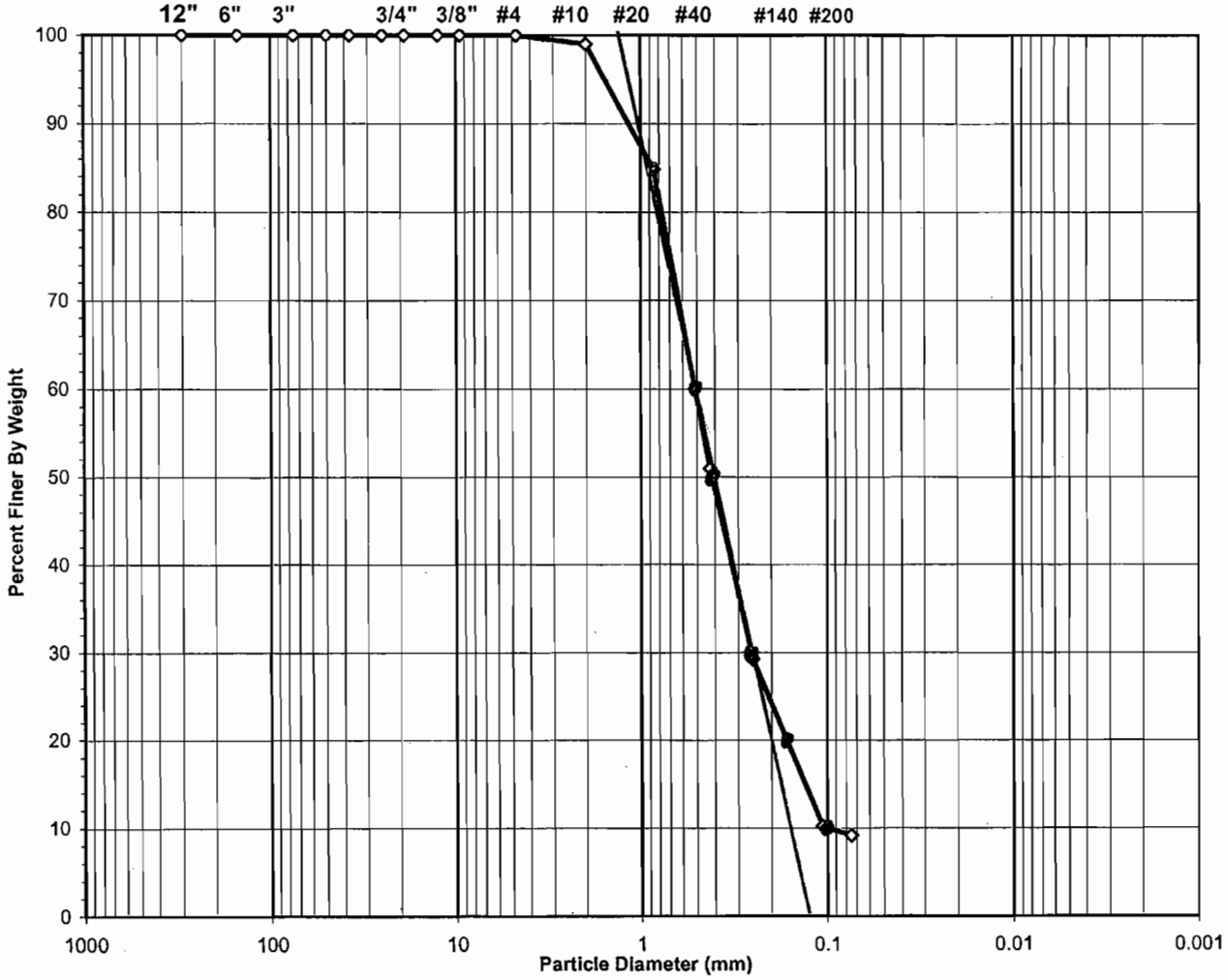
Geotechnics
INTEGRITY IN TESTING

## SIEVE ANALYSIS
ASTM D 422-63 (SOP-S3)

| | | | |
|---|---|---|---|
| Client | GN RICHARDSON & ASSOC. | Boring No. | TP-10 |
| Client Reference | JOHNSTON CO. C&D LF AREA 2 CELL 1 | Depth (ft) | 2-3 |
| Project No. | 2006-643-06 | Sample No. | 12-04-06 |
| Lab ID | 2006-643-06-01 | Soil Color | **REDDISH TAN** |

| | *SIEVE ANALYSIS* | | *HYDROMETER* |
|---|---|---|---|
| ***USCS*** | **gravel** | **sand** | **silt and clay** |




***USCS Symbol*** ***SP-SM, TESTED*** **D60 = 0.5** **CC = 1.3**

***USCS Classification*** ***POORLY GRADED SAND WITH SILT*** **D30 = 0.3** **CU = 5.1**

**D10 = 0.1**

Tested By SGH Date 12/11/2006 Checked By GSM Date 12-12-06



**DCN: CT-S3C DATE 6-25-98 REVISION: 2** *\\Lab1\c\2006 PROJECTS\2006-643 GNRA JOHNSTON CO\[2006-643-06-01 SIEVE.XLS]Sheet1*

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PROJECT Johnston County MSWLF - Phase 4A - Cell 3

SUBJECT Cushion Geotextile Analysis

SHEET 1 OF 3
JOB NO. JOHNSTON-07-2
DATE 2/16/07
COMPUTED BY PKS
CHECKED BY

**Objective**

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

**References**

Koerner, R.M., Designing With Geosynthetics (1999), Fourth Ed., Prentice Hall, Upper Saddle River, N.J., 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 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).

$$p_{allow} = (50 + 0.00045\frac{M}{H^2})\frac{1}{MS_S MF_{PD} MF_A} \bullet \frac{1}{RF_{CR} RF_{CBD}}$$ (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* |

*(see attached table from Koerner)

GT CUSHION.WPD

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**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**

| | | $RF_{CR}$ | | | |
|---|---|---|---|---|---|
| | | | Protrusion (mm) | | |
| $RF_{CBD}$ | | Mass per unit area ($g/m^2$) | 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

*Ref: Designing With Geosynthetics*

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SHEET: 3 / 3
JOB #: JOHNSTON-07-2
DATE: 2/28/07
BY: PKS
CHKD BY:

## Johnston County MSW Landfill - Phase 4A - Cell 3
## Cushion Geotextile Analysis

**Input Parameters:**

Maximum Height of Waste (ft) = 150 **(> Max. Waste Thickness over Cell 1; Conservative for Cell 3)**
Waste Density (pcf) = 70
$P_{actual}$ (psf) = 10,500 **(=Max Height x Waste Density)**
$P_{actual}$ (kPa) = 503
Factor of Safety, FS = 3
$P_{allow}$ (kPa) = 1,509

| Type of Stone | Stone Information: Stone Angularity | 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: ($g/m^3$) | (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** |
| Leachate Collection Media (NCDOT No. 78) | Angular | 0.375 | 9.5 | 0.010 | 1.00 | 0.50 | 0.25 | 1.5 | 1.3 | 64 | **1.9** |

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PROJECT Johnston County MSWLF - Phase 4A - Cell 3

SUBJECT LDS/LCS Drainage Layer Analysis

SHEET 1 OF 7
JOB NO. JOHNSTON-07-2
DATE 3/21/07
COMPUTED BY PKS
CHECKED BY

**Objective**

To evaluate the ability of the leak detection system (LDS) and the leachate collection system (LCS) to maintain at most 1 foot of head on the geomembrane under Normal Operating Conditions (for drainage geocomposites head should be maintained within the thickness of the geonet drainage core). The analysis determines the maximum head using input values for permeability (natural drainage media - stone/sand) or transmissivity (drainage geocomposite) and selected slope and collection pipe spacing combinations.

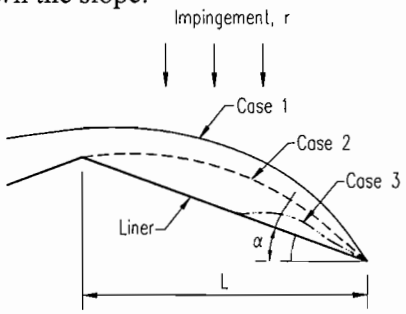
**References**

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.




**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
- $k$ = design permeability of the drainage media (for Drainage Geocomposite, $k$ = transmissivity/thickness) (See Note 1)
- $\alpha$ = slope angle of the liner



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Note:

1. For stone/sand: The design permeability ($k$) = (specified minimum permeability)/(overall reduction factor ($RF$))
   For drainage geocomposites: $k$ = (specified minimum transmissivity/thickness of geonet drainage core)/($RF$)

$$RF = RF_{IN} \times RF_{CR} \times RF_{CC} \times RF_{BC} \times FS$$

where:
- $RF_{IN}$ = reduction factor for intrusion
- $RF_{CR}$ = reduction factor for creep
- $RF_{CC}$ = reduction factor for chemical clogging
- $RF_{BC}$ = reduction factor for biological clogging
- $FS$ = overall factor of safety

Based on the recommendations of Richardson, Giroud, & Zhao, use the following values for a leachate collection system (LCS). An overall factor of safety of 2.0 for long-term conditions is also recommended. For shorter term (lower load) conditions, lower values may be used.

| | $RF_{IN}$ | $RF_{CR}$ | $RF_{CC}$ | $RF_{BC}$ |
|---|---|---|---|---|
| Stone/Sand: | 1.0 | 1.0 | 1.5-2.0 | 1.5-2.0 |
| Dr. Geocomposite: | 1.0-1.2 | 1.4-2.0 | 1.5-2.0 | 1.5-2.0 |

**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: 4 / 7
JOB #: JOHNSTON-07-2
DATE: 5/11/07
BY: PKS
CHKD BY:

**Johnston County MSW Landfill - Phase 4A - Cell 3**
**Leak Detection System (LDS) Drainage Layer Analysis**

## Drainage Geocomposite:

| | | | |
|---|---|---|---|
| Maximum Allowable Head ($h_{max}$): | 0.25 | inches | (= Thickness of Geonet Drainage Core) |
| Impingement (r): | 1.1E-07 | cm/sec | (= 100 gpad >> HELP Model) |
| Drainage Geocomposite Transmissivity (θ): | 5.0E-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 | | |
| $RF_{chemical\ clogging}$: | 1.5 | | |
| $RF_{biological\ clogging}$: | 1.5 | | |
| Overall Factor of Safety: | 2.0 | | |
| Reduction Factor for Drainage Geocomposite in LCS: | 10.8 | | |
| Design Drainage Geocomposite Transmissivity (θ): | 4.6E-05 | $m^3/m/sec$ | |
| Design Drainage Geocomposite Permeability (k): | 0.73 | 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 | $h_{max}$ (in) R = 0.25 | $h_{max}$ (in) R > 0.25 | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.5 | 1.43 | 0.025 | 0.00024 | 400 | 121.9 | 1.000 | NA | 0.03 | N/A | N/A | O.K. |
| 3 | 1.72 | 0.030 | 0.00017 | 400 | 121.9 | 1.000 | NA | 0.02 | N/A | N/A | O.K. |
| 4 | 2.29 | 0.040 | 0.00009 | 400 | 121.9 | 1.000 | NA | 0.02 | N/A | N/A | O.K. |
| 6 | 3.43 | 0.060 | 0.00004 | 400 | 121.9 | 1.000 | NA | 0.01 | N/A | N/A | O.K. |

Typ. Ranges

Note: Spreadsheet Converts Units as Required.

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**Johnston County MSW Landfill - Phase 4A - Cell 3**
**Leachate Collection System (LCS) Drainage Layer Analysis - Active Condition**

## Drainage Geocomposite:

| | | | |
|---|---|---|---|
| Maximum Allowable Head ($h_{max}$): | 0.25 | inches | (= Thickness of Geonet Drainage Core) |
| Impingement (r): | 1.6E-05 | cm/sec | (Peak Daily Flow from HELP Model - Active Case) |
| Drainage Geocomposite Transmissivity (θ): | 5.0E-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) |
| $RF_{intrusion}$: | 1.0 | | |
| $RF_{creep}$: | 1.0 | | |
| $RF_{chemical\ clogging}$: | 1.0 | | |
| $RF_{biological\ clogging}$: | 1.0 | | |
| Overall Factor of Safety: | 1.0 | | |
| Reduction Factor for Drainage Geocomposite in LCS: | 1.0 | | |
| Design Drainage Geocomposite Transmissivity (θ): | 5.0E-04 | $m^3/m/sec$ | |
| Design Drainage Geocomposite Permeability (k): | 7.87 | 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 | $h_{max}$ (in) R = 0.25 | $h_{max}$ (in) R > 0.25 | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.5 | 1.43 | 0.025 | 0.00325 | 200 | 61.0 | 0.993 | NA | 0.19 | N/A | N/A | O.K. |
| 3 | 1.72 | 0.030 | 0.00226 | 200 | 61.0 | 0.995 | NA | 0.16 | N/A | N/A | O.K. |
| 4 | 2.29 | 0.040 | 0.00127 | 200 | 61.0 | 0.997 | NA | 0.12 | N/A | N/A | O.K. |
| 6 | 3.43 | 0.060 | 0.00057 | 200 | 61.0 | 0.999 | NA | 0.08 | N/A | N/A | O.K. |
| 25 | 14.04 | 0.250 | 0.00003 | 200 | 61.0 | 1.000 | NA | 0.02 | N/A | N/A | O.K. |

Typ. Ranges

**Note:** Spreadsheet Converts Units as Required.

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SHEET: 6 / 7
JOB #: JOHNSTON-07-2
DATE: 5/11/07
BY: PKS
CHKD BY:

**Johnston County MSW Landfill - Phase 4A - Cell 3**
**Leachate Collection System (LCS) Drainage Layer Analysis - Intermediate Condition**

## Drainage Geocomposite:

| | | | |
|---|---|---|---|
| Maximum Allowable Head ($h_{max}$): | 0.25 | inches | (= Thickness of Geonet Drainage Core) |
| Impingement (r): | 5.1E-06 | cm/sec | (Peak Daily Flow from HELP Model - Intermediate Case) |
| Drainage Geocomposite Transmissivity (θ): | 5.0E-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) |
| $RF_{intrusion}$: | 1.1 | | |
| $RF_{creep}$: | 1.3 | | |
| $RF_{chemical\ clogging}$: | 1.3 | | |
| $RF_{biological\ clogging}$: | 1.3 | | |
| Overall Factor of Safety: | 1.5 | | |
| Reduction Factor for Drainage Geocomposite in LCS: | 3.6 | | |
| Design Drainage Geocomposite Transmissivity (θ): | 1.4E-04 | $m^3$/m/sec | |
| Design Drainage Geocomposite Permeability (k): | 2.17 | 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 | $h_{max}$ (in) R = 0.25 | $h_{max}$ (in) R > 0.25 | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.5 | 1.43 | 0.025 | 0.00376 | 200 | 61.0 | 0.992 | NA | 0.22 | N/A | N/A | **O.K.** |
| 4 | 2.29 | 0.040 | 0.00147 | 200 | 61.0 | 0.997 | NA | 0.14 | N/A | N/A | **O.K.** |
| 5 | 2.86 | 0.050 | 0.00094 | 200 | 61.0 | 0.998 | NA | 0.11 | N/A | N/A | **O.K.** |
| 6 | 3.43 | 0.060 | 0.00065 | 200 | 61.0 | 0.999 | NA | 0.09 | N/A | N/A | **O.K.** |
| 25 | 14.04 | 0.250 | 0.00004 | 200 | 61.0 | 1.000 | NA | 0.02 | N/A | N/A | **O.K.** |

**Note:** Spreadsheet Converts Units as Required.

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**Johnston County MSW Landfill - Phase 4A - Cell 3**
**Leachate Collection System (LCS) Drainage Layer Analysis - Final Condition**

## Drainage Geocomposite:

| | | | |
|---|---|---|---|
| Maximum Allowable Head ($h_{max}$): | 0.25 | inches | (= Thickness of Geonet Drainage Core) |
| Impingement (r): | 1.1E-07 | cm/sec | (= 100 gpad >> HELP Model) |
| Drainage Geocomposite Transmissivity (θ): | 7.0E-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 | | |
| Design Drainage Geocomposite Transmissivity (θ): | 3.6E-05 | $m^3/m/sec$ | |
| Design Drainage Geocomposite Permeability (k): | 0.57 | 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 | $h_{max}$ (in) R = 0.25 | $h_{max}$ (in) R > 0.25 | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.5 | 1.43 | 0.025 | 0.00031 | 200 | 61.0 | 0.999 | NA | 0.02 | N/A | N/A | **O.K.** |
| 4 | 2.29 | 0.040 | 0.00012 | 200 | 61.0 | 1.000 | NA | 0.01 | N/A | N/A | **O.K.** |
| 5 | 2.86 | 0.050 | 0.00008 | 200 | 61.0 | 1.000 | NA | 0.01 | N/A | N/A | **O.K.** |
| 6 | 3.43 | 0.060 | 0.00005 | 200 | 61.0 | 1.000 | NA | 0.01 | N/A | N/A | **O.K.** |
| 25 | 14.04 | 0.250 | 0.00000 | 200 | 61.0 | 1.000 | NA | 0.00 | N/A | N/A | **O.K.** |

**Note:** Spreadsheet Converts Units as Required.

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PROJECT Johnston County MSWLF - Phase 4A - Cell 3

SUBJECT LDS/LCS Collection Pipe Sizing

SHEET 1 OF 5
JOB NO. JOHNSTON-07-2
DATE 3/21/07
COMPUTED BY PKS
CHECKED BY

**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).



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- Leachate Collection Pipes:

Determine Flow Capacity of Pipe:

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

where: $Q_{max}$ = flow capacity of pipe (cfs)
$D$ = inside diameter of pipe (ft)
$S$ = pipe slope (ft/ft)
$n$ = Manning's roughness coefficient

Determine Factor of Safety (FS):

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

Iterate the drainage area (A) to each pipe such that $Q_{max}/Q \geq$ the desired factor of safety.

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)
$\theta$ = central angle

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

$K$ = constant

$$K = 0.673 Q n D^{-8/3} S^{-1/2}$$ (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 size (hole diameter or slot width) 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:
- $C_d$ = 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):

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

Iterate the perforation spacing and/or other factors such that $Q_{max}/Q \geq$ the desired factor of safety.

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## Johnston County MSW Landfill - Phase 4A - Cell 3
## Leak Detection System (LDS) Pipe Sizing - HDPE Pipe

**Input Parameters:**

| | | | |
|---|---|---|---|
| Manning's Rougness Coefficient = | **0.009** | | **(HDPE Pipe)** |
| Design Leachate Flow = | **100** | gal/acre/day | **(Assumed >> HELP Model Predictions)** |
| Design Leachate Flow = | 0.00 | 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 - 4"** | **50.0** | 0.01 | **4.0** | **2** | 0.39 | 50.2 | 0.006 | 73 | 0.39 | 0.00 | 1.78 |

**LCS Pipe Perforations**

**Determine Maximum Perforation Size:**

| | | | |
|---|---|---|---|
| Stone Used for Pipe Bedding: | **No. 78** | | |
| $D_{85}$ = | **0.375** | inches | **(Typ. for No. 57 Stone)** |
| F = | **1.0** | | |
| Max. Diameter - Circular Holes/Max. Width - Slots = | 0.38 | 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 - 4"** | **50.0** | 0.01 | **0.38** | **4** | 0.001 | 0.002 | **4** | **1** | 1,000 | 1102.4 | |

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) |
|---|---|---|---|
| **4** | **4.5** | 0.265 | 4.0 |

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

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## Johnston County MSW Landfill - Phase 4A - Cell 3
## Leachate Collection System (LCS) Pipe Sizing - HDPE Pipe

**Input Parameters:**

| | | | |
|---|---|---|---|
| Manning's Rougness Coefficient = | **0.009** | | **(HDPE Pipe)** |
| Design Leachate Flow = | **14,900** | 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"** | **22.5** | 0.52 | **5.8** | **2** | 1.05 | 2.0 | 0.154 | 181 | 2.92 | 0.09 | 5.60 |

**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"** | **22.5** | 0.52 | **0.50** | **4** | 0.001 | 0.004 | **4** | 34 | 1,000 | 29.2 | |

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**.

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PROJECT Johnston County MSWLF - Phase 4A - Cell 3

SUBJECT HDPE Pipe Stress Analysis

SHEET 1 OF 4
JOB NO. JOHNSTON-07-2
DATE 2/16/07
COMPUTED BY PKS
CHECKED BY

**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**

CPChem Performance Pipe (2003), The Performance Pipe Engineering Manual, Chapters 5 and 7.

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

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

Phillips Driscopipe (1998), Polyethylene Piping Systems Manual, pp. 35-46.

**Requirements** $FS_{min}$ (Static) = 2.0; $FS_{min}$ (Dynamic) = 2.0.

**Analysis**

- Crushing Failure:

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

where:
$S$ = compressive stress in pipe wall (psi)
$DR$ = pipe dimension ratio
= outside diameter/wall thickness
$P_T$ = external pressure (psf)

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

- Buckling Failure (Constrained Wall):

$$P_{CR} = 1.63\sqrt{\frac{RB'E'E}{(DR-1)^3}} \qquad \text{(Perf. Pipe Eng. Man. Eq. 7-32 Mod.)}$$

PIPE STRESS - HDPE.WPD

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where: $P_{CR}$ = critical buckling soil pressure (psi)
$R$ = groundwater buoyancy reduction factor

$$= 1 - 0.33\frac{H_{GW}}{H}$$ (Perf. Pipe Eng. Man. Eq. 7-34)

$B'$ = elastic support coefficient

$$= \frac{1}{1 + 4e^{(-0.065H)}}$$ (Perf. Pipe Eng. Man. Eq. 7-35)

$E'$ = constrained soil modulus (psi) (see attached table)
$H$ = height of cover above pipe (ft)
$H_{GW}$ = height of groundwater (ft)
$E$ = long-term modulus of elasticity of pipe (psi) (see attached table)

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

- Ring Deflection:

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

$$Deflection = \frac{P_T}{E'} \times 100$$ (%) (Driscopipe p. 47)

-Equipment Loading:

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

$$P_T = P_L = \frac{2WZ^3}{\pi Z^4}$$

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)

Note: The equations conservatively assumes loads are applied directly over the pipe)

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

**Table : Typical Design Values[a] 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 |

*Ref: Guidelines for HDPE Pipe in Deep Fills*

Table 5-1 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.

*Ref: Performance Pipe Engineering Manual*

Table 7-9 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 |

*Ref: Performance Pipe Engineering Manual*

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**Johnston County MSW Landfill - Phase 4A - Cell 3**
**HDPE Pipe Stress Analysis**

Case 1: Long-Term Static Loading

Max. Height of Fill (H) (ft) = 150 **(> Max. Above Cell 1)** (*)
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) = 5,800
Groundwater Buoyancy Factor (R) = 0.998
Elastic Support Coefficient (B') = 1.000

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

| DR | Long-Term Elastic Modulus E (psi) | Allowable Ring Defl. (%) | Comp. Stress in Pipe Wall S (psi) | Critical Buckling Pressure $P_{CR}$ (psi) | $FS_{Crush}$ | $FS_{Buckle}$ | Ring Defl. (%) | Comment |
|---|---|---|---|---|---|---|---|---|
| 19 | 28,200 | 5.5 | 693 | 273 | 2.3 | 3.7 | 1.3 | O.K. |
| 17 | 28,200 | 5.0 | 620 | 325 | 2.6 | 4.5 | 1.3 | O.K. |
| 13.5 | 28,200 | 4.0 | 492 | 471 | 3.3 | 6.5 | 1.3 | O.K. |
| 11 | 28,200 | 3.0 | 401 | 658 | 4.0 | 9.0 | 1.3 | O.K. |

(*) ← Cell 1 O.K.

Case 2: Short-Term Dynamic (Equipment) Loading

DR (Determine From Static Loading Analysis) = 17 → Same Holds True For LCS Piping & GCS Piping Under Cell 3.

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.

**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** - 683 gallons/acre/day
**Interim** - 292 gallons/acre/day
**Final** - 0.04 gallons/acre/day (see Final Cover Infiltration Analysis for output).

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

**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:



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

A. Initial filling of Phase 4A - Cell 3 (various areas under Open, Interim, Active, and Interim conditions) (maximum value is taken as the surge event for Phase 4A);

B. Waste covers Phase 4A (no areas open; various areas under active and interim conditions) (maximum value is taken as the typical generation rate for Phase 4A);

C. Completion of Phase 4A operations (Phase 4A under Interim conditions);

E. Closure of Phase 4A (Phase 4A under Final conditions) (this value is taken as the typical generation rate for Post-Closure conditions).

**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 Phase 4A operations and under post-closure conditions.

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

SHEET: 3/13
JOB #: JOHNSTON-07-2
DATE: 5/11/07
BY: PKS
CHKD BY:

## Johnston County MSW Landfill - Phase 4A - Cell 3
## 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 Phase 4A - Cell 3 (Maximum Value is "Surge" Event) | | | | | | | | |
| 2.0 | 173,775 | 0.0 | 0 | 22.0 | 11,000 | 0.0 | 0 | 184,775 |
| 2.0 | 173,775 | 1.4 | 1,680 | 22.0 | 11,000 | 0.0 | 0 | 186,455 |
| 2.0 | 173,775 | 3.4 | 4,080 | 22.0 | 11,000 | 0.0 | 0 | 188,855 |
| 2.0 | 173,775 | 5.4 | 6,480 | 22.0 | 11,000 | 0.0 | 0 | 191,255 |
| B. Waste Covers Phase 4A (Maximum Value is "Typical" for Phase 4A) | | | | | | | | |
| 0.0 | 0 | 7.4 | 8,880 | 22.0 | 11,000 | 0.0 | 0 | 19,880 |
| 0.0 | 0 | 6.0 | 7,200 | 23.4 | 11,700 | 0.0 | 0 | 18,900 |
| 0.0 | 0 | 4.0 | 4,800 | 25.4 | 12,700 | 0.0 | 0 | 17,500 |
| 0.0 | 0 | 2.0 | 2,400 | 27.4 | 13,700 | 0.0 | 0 | 16,100 |
| C. Completion of Phase 4A Operations | | | | | | | | |
| 0.0 | 0 | 0.0 | 0 | 29.4 | 14,700 | 0.0 | 0 | 14,700 |
| D. Closure of Phase 4A (Value is "Typical" for Post-Closure Conditions) | | | | | | | | |
| 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 29.4 | 2,940 | 2,940 |

| | |
|---|---|
| SHEET: | 4 / 13 |
| JOB #: | JOHNSTON-07-2 |
| DATE: | 5/11/07 |
| BY: | PKS |
| CHKD BY: | |

**REQUIRED REMOVAL RATES:**

**Case 1: Surge Event:**

Quantity of Leachate Produced = 191,255 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 |
| 4,000,000 | 300,000 | 491,255 | 0 | 0.0 | 0.0 |
| 3,000,000 | 1,300,000 | 1,491,255 | 0 | 0.0 | 0.0 |
| 2,000,000 | 2,300,000 | 2,491,255 | 0 | 0.0 | 0.0 |
| 1,500,000 | 2,800,000 | 2,991,255 | 0 | 0.0 | 0.0 |
| 1,000,000 | 3,300,000 | 3,491,255 | 0 | 0.0 | 0.0 |
| 800,000 | 3,500,000 | 3,691,255 | 0 | 0.0 | 0.0 |
| 600,000 | 3,700,000 | 3,891,255 | 0 | 0.0 | 0.0 |
| 400,000 | 3,900,000 | 4,091,255 | 0 | 0.0 | 0.0 |
| 300,000 | 4,000,000 | 4,191,255 | 0 | 0.0 | 0.0 |
| 200,000 | 4,100,000 | 4,291,255 | 0 | 0.0 | 0.0 |
| 150,000 | 4,150,000 | 4,300,000 | 41,255 | 2.8 | 1.4 |
| 100,000 | 4,200,000 | 4,300,000 | 91,255 | 6.1 | 3.0 |
| 50,000 | 4,250,000 | 4,300,000 | 141,255 | 9.4 | 4.7 |
| 25,000 | 4,275,000 | 4,300,000 | 166,255 | 11.1 | 5.5 |
| 0 | 4,300,000 | 4,300,000 | 191,255 | 12.8 | 6.4 |

**Case 2: Typical Phase 4A Leachate Generation:**

Typical Leachate Generation Rate = 19,880 gallons/day **(See Above)**

Days of Storage Capacity = 216.3 days

**Case 3: Typical Post-Closure Leachate Generation:**

Typical Leachate Generation Rate = 2,940 gallons/day **(See Above)**

Days of Storage Capacity = 1462.6 days

**STORAGE CAPACITY OF LEACHATE LAGOON:**

Capacity = 4,300,000 gallons **(See Attached)**
**(@ 2' Freeboard)**

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

SHEET: 5 / 13
JOB #: JOHNSTON-07-2
DATE: 2/28/07
BY: PKS
CHKD BY:

# Johnston County MSW Landfill - Phase 4A - Cell 3
# 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 |

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

PRECIPITATION DATA FILE:    C:\PROGRA~1\HELP3\RALNCP.D4
TEMPERATURE DATA FILE:      C:\PROGRA~1\HELP3\RALNCT.D7
SOLAR RADIATION DATA FILE:  C:\PROGRA~1\HELP3\RALNCS.D13
EVAPOTRANSPIRATION DATA:    C:\PROGRA~1\HELP3\RALNCE.D11
SOIL AND DESIGN DATA FILE:  C:\PROGRA~1\HELP3\JCACT.D10
OUTPUT DATA FILE:           C:\PROGRA~1\HELP3\JCACT.OUT

TIME:  15:56     DATE:   3/19/2007

**********************************************************************

     TITLE:  Johnston County MSWLF - Phase 4A - 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  10
        THICKNESS                    =      6.00   INCHES
        POROSITY                     =      0.3980 VOL/VOL
        FIELD CAPACITY               =      0.2440 VOL/VOL
        WILTING POINT                =      0.1360 VOL/VOL
        INITIAL SOIL WATER CONTENT   =      0.2550 VOL/VOL
        EFFECTIVE SAT. HYD. COND.    =  0.119999997000E-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   =      0.3068 VOL/VOL
        EFFECTIVE SAT. HYD. COND.    =  0.100000005000E-02 CM/SEC


                                LAYER  3
                                --------

                  TYPE 1 - VERTICAL PERCOLATION LAYER
                       MATERIAL TEXTURE NUMBER  10
        THICKNESS                    =     24.00   INCHES
        POROSITY                     =      0.3980 VOL/VOL
        FIELD CAPACITY               =      0.2440 VOL/VOL
        WILTING POINT                =      0.1360 VOL/VOL
        INITIAL SOIL WATER CONTENT   =      0.2535 VOL/VOL
        EFFECTIVE SAT. HYD. COND.    =  0.119999997000E-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                        =      4.00   PERCENT
        DRAINAGE LENGTH              =    250.0    FEET


                                LAYER  5
                                --------

                  TYPE 4 - FLEXIBLE MEMBRANE LINER
                       MATERIAL TEXTURE NUMBER  35
        THICKNESS                    =      0.06   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.    =  0.199999996000E-12 CM/SEC
        FML PINHOLE DENSITY          =      1.00   HOLES/ACRE
        FML INSTALLATION DEFECTS     =      8.00   HOLES/ACRE
        FML PLACEMENT QUALITY        =  3 - GOOD
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LAYER 6

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 0

| | | | |
|---|---|---|---|
| THICKNESS | = | 0.20 | INCHES |
| POROSITY | = | 0.7500 | VOL/VOL |
| FIELD CAPACITY | = | 0.7470 | VOL/VOL |
| WILTING POINT | = | 0.4000 | VOL/VOL |
| INITIAL SOIL WATER CONTENT | = | 0.7500 | VOL/VOL |
| EFFECTIVE SAT. HYD. COND. | = | 0.499999997000E-08 | 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 | = | 4.00 | PERCENT |
| DRAINAGE LENGTH | = | 300.0 | 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 | |

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #10 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 4.% AND A SLOPE LENGTH OF 300. FEET.

| | | | |
|---|---|---|---|
| SCS RUNOFF CURVE NUMBER | = | 94.00 | |
| 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 | = | 6.094 | INCHES |
| UPPER LIMIT OF EVAPORATIVE STORAGE | = | 13.124 | INCHES |
| LOWER LIMIT OF EVAPORATIVE STORAGE | = | 2.048 | INCHES |
| INITIAL SNOW WATER | = | 0.000 | INCHES |
| INITIAL WATER IN LAYER MATERIALS | = | 44.591 | INCHES |
| TOTAL INITIAL WATER | = | 44.591 | 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

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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 | 1.411 | 1.734 | 2.964 | 2.740 | 4.229 | 4.636 |
| | 4.132 | 4.167 | 2.651 | 1.283 | 1.147 | 1.028 |
| STD. DEVIATIONS | 0.153 | 0.244 | 0.312 | 0.928 | 0.790 | 1.492 |
| | 1.506 | 1.289 | 1.115 | 0.413 | 0.153 | 0.170 |
| LATERAL DRAINAGE COLLECTED FROM LAYER 4 | | | | | | |
| TOTALS | 1.3087 | 1.7061 | 1.6026 | 1.2675 | 0.5253 | 0.5382 |
| | 0.2149 | 0.0762 | 0.7054 | 0.2418 | 0.2205 | 0.7641 |
| STD. DEVIATIONS | 0.8402 | 1.2275 | 1.0796 | 1.0775 | 0.4081 | 0.9068 |
| | 0.3136 | 0.1266 | 2.0960 | 0.6877 | 0.4067 | 1.1743 |
| PERCOLATION/LEAKAGE THROUGH LAYER 6 | | | | | | |
| TOTALS | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| STD. DEVIATIONS | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| LATERAL DRAINAGE COLLECTED FROM LAYER 7 | | | | | | |
| TOTALS | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| STD. DEVIATIONS | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| PERCOLATION/LEAKAGE THROUGH LAYER 8 | | | | | | |
| TOTALS | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| STD. DEVIATIONS | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

| | | | | | | |
|---|---|---|---|---|---|---|
| DAILY AVERAGE HEAD ON TOP OF LAYER 5 | | | | | | |
| AVERAGES | 0.0047 | 0.0067 | 0.0057 | 0.0047 | 0.0019 | 0.0020 |
| | 0.0008 | 0.0003 | 0.0026 | 0.0009 | 0.0008 | 0.0027 |
| STD. DEVIATIONS | 0.0030 | 0.0047 | 0.0038 | 0.0040 | 0.0015 | 0.0033 |
| | 0.0011 | 0.0005 | 0.0077 | 0.0024 | 0.0015 | 0.0042 |
| 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 | 0.000 | ( 0.0000) | 0.00 | 0.000 |
| EVAPOTRANSPIRATION | 32.123 | ( 3.6400) | 116604.97 | 77.874 |
| LATERAL DRAINAGE COLLECTED FROM LAYER 4 | 9.17133 | ( 5.29157) | 33291.934 | 22.23380 |
| PERCOLATION/LEAKAGE THROUGH LAYER 6 | 0.00000 | ( 0.00000) | 0.009 | 0.00001 |
| AVERAGE HEAD ON TOP OF LAYER 5 | 0.003 | ( 0.002) | | |

683 gpad

8/13

| | | | | |
|---|---|---|---|---|
| LATERAL DRAINAGE COLLECTED FROM LAYER 7 | 0.00000 | ( 0.00000) | 0.000 | 0.00000 |
| PERCOLATION/LEAKAGE THROUGH LAYER 8 | 0.00000 | ( 0.00000) | 0.009 | 0.00001 |
| AVERAGE HEAD ON TOP OF LAYER 8 | 0.000 | ( 0.000) | | |
| CHANGE IN WATER STORAGE | -0.044 | ( 1.8910) | -161.23 | -0.108 |

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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 | 0.54818 | 1989.88538 |
| PERCOLATION/LEAKAGE THROUGH LAYER 6 | 0.000000 | 0.00019 |
| AVERAGE HEAD ON TOP OF LAYER 5 | 0.061 | |
| MAXIMUM HEAD ON TOP OF LAYER 5 | 0.120 | |
| LOCATION OF MAXIMUM HEAD IN LAYER 4 (DISTANCE FROM DRAIN) | 2.2 FEET | |
| DRAINAGE COLLECTED FROM LAYER 7 | 0.00000 | 0.00000 |
| PERCOLATION/LEAKAGE THROUGH LAYER 8 | 0.000000 | 0.00019 |
| 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 |

$1.6 \times 10^{-5}$ cm/sec

| | |
|---|---|
| MAXIMUM VEG. SOIL WATER (VOL/VOL) | 0.4238 |
| MINIMUM VEG. SOIL WATER (VOL/VOL) | 0.0931 |

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

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

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FINAL WATER STORAGE AT END OF YEAR 20

| LAYER | (INCHES) | (VOL/VOL) |
|---|---|---|
| 1 | 1.4896 | 0.2483 |
| 2 | 34.8564 | 0.2905 |
| 3 | 7.1899 | 0.2996 |
| 4 | 0.0142 | 0.0566 |
| 5 | 0.0000 | 0.0000 |
| 6 | 0.1500 | 0.7500 |
| 7 | 0.0025 | 0.0100 |
| 8 | 0.0000 | 0.0000 |
| SNOW WATER | 0.000 | |

**********
**********

```
**********************************************************************
**********************************************************************
**                                                                  **
**                                                                  **
**             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:     C:\PROGRA~1\HELP3\RALNCP.D4
TEMPERATURE DATA FILE:       C:\PROGRA~1\HELP3\RALNCT.D7
SOLAR RADIATION DATA FILE:   C:\PROGRA~1\HELP3\RALNCS.D13
EVAPOTRANSPIRATION DATA:     C:\PROGRA~1\HELP3\RALNCE.D11
SOIL AND DESIGN DATA FILE:   C:\PROGRA~1\HELP3\JCINT.D10
OUTPUT DATA FILE:            C:\PROGRA~1\HELP3\JCINT.OUT

TIME:  16: 0     DATE:   3/19/2007

**********************************************************************

     TITLE:  Johnston County MSWLF - Phase 4A - 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  10
        THICKNESS                    =     12.00   INCHES
        POROSITY                     =      0.3980 VOL/VOL
        FIELD CAPACITY               =      0.2440 VOL/VOL
        WILTING POINT                =      0.1360 VOL/VOL
        INITIAL SOIL WATER CONTENT   =      0.2473 VOL/VOL
        EFFECTIVE SAT. HYD. COND.    =  0.119999997000E-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   =      0.2942 VOL/VOL
        EFFECTIVE SAT. HYD. COND.    =  0.100000005000E-02 CM/SEC

                                LAYER  3
                                --------

                  TYPE 1 - VERTICAL PERCOLATION LAYER
                     MATERIAL TEXTURE NUMBER  10
        THICKNESS                    =     24.00   INCHES
        POROSITY                     =      0.3980 VOL/VOL
        FIELD CAPACITY               =      0.2440 VOL/VOL
        WILTING POINT                =      0.1360 VOL/VOL
        INITIAL SOIL WATER CONTENT   =      0.2549 VOL/VOL
        EFFECTIVE SAT. HYD. COND.    =  0.119999997000E-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                        =      4.00   PERCENT
        DRAINAGE LENGTH              =    250.0    FEET

                                LAYER  5
                                --------

                  TYPE 4 - FLEXIBLE MEMBRANE LINER
                     MATERIAL TEXTURE NUMBER  35
        THICKNESS                    =      0.06   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.    =  0.199999996000E-12 CM/SEC
        FML PINHOLE DENSITY          =      1.00   HOLES/ACRE
        FML INSTALLATION DEFECTS     =      8.00   HOLES/ACRE
        FML PLACEMENT QUALITY        =  3 - GOOD
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LAYER 6

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 0

| | | | |
|---|---|---|---|
| THICKNESS | = | 0.20 | INCHES |
| POROSITY | = | 0.7500 | VOL/VOL |
| FIELD CAPACITY | = | 0.7470 | VOL/VOL |
| WILTING POINT | = | 0.4000 | VOL/VOL |
| INITIAL SOIL WATER CONTENT | = | 0.7500 | VOL/VOL |
| EFFECTIVE SAT. HYD. COND. | = | 0.499999997000E-08 | 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 | = | 4.00 | PERCENT |
| DRAINAGE LENGTH | = | 300.0 | 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 | |

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #10 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 4.% AND A SLOPE LENGTH OF 300. FEET.

| | | | |
|---|---|---|---|
| SCS RUNOFF CURVE NUMBER | = | 94.00 | |
| 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 | = | 5.847 | INCHES |
| UPPER LIMIT OF EVAPORATIVE STORAGE | = | 11.486 | INCHES |
| LOWER LIMIT OF EVAPORATIVE STORAGE | = | 2.402 | INCHES |
| INITIAL SNOW WATER | = | 0.000 | INCHES |
| INITIAL WATER IN LAYER MATERIALS | = | 150.439 | INCHES |
| TOTAL INITIAL WATER | = | 150.439 | 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 | 0.936 | 0.457 | 0.637 | 0.279 | 0.985 | 0.634 |
| | 0.700 | 1.397 | 0.519 | 0.596 | 0.739 | 0.498 |
| STD. DEVIATIONS | 1.050 | 0.376 | 0.534 | 0.391 | 1.078 | 0.548 |
| | 0.626 | 1.809 | 0.579 | 0.719 | 0.624 | 0.348 |
| **EVAPOTRANSPIRATION** | | | | | | |
| TOTALS | 1.338 | 1.676 | 2.902 | 2.642 | 3.964 | 3.814 |
| | 3.543 | 3.585 | 2.208 | 1.229 | 1.133 | 0.944 |
| STD. DEVIATIONS | 0.215 | 0.266 | 0.267 | 0.907 | 0.852 | 1.441 |
| | 1.284 | 1.203 | 1.091 | 0.414 | 0.170 | 0.149 |
| **LATERAL DRAINAGE COLLECTED FROM LAYER 4** | | | | | | |
| TOTALS | 0.5402 | 0.7473 | 1.0216 | 0.8510 | 0.3302 | 0.0916 |
| | 0.0067 | 0.0012 | 0.0361 | 0.0802 | 0.0364 | 0.1888 |
| STD. DEVIATIONS | 0.4870 | 0.4807 | 0.7485 | 0.7366 | 0.2479 | 0.0969 |
| | 0.0198 | 0.0019 | 0.1110 | 0.2670 | 0.0811 | 0.3226 |
| **PERCOLATION/LEAKAGE THROUGH LAYER 6** | | | | | | |
| TOTALS | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| STD. DEVIATIONS | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| **LATERAL DRAINAGE COLLECTED FROM LAYER 7** | | | | | | |
| TOTALS | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| STD. DEVIATIONS | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| **PERCOLATION/LEAKAGE THROUGH LAYER 8** | | | | | | |
| TOTALS | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| STD. DEVIATIONS | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

| | | | | | | |
|---|---|---|---|---|---|---|
| **DAILY AVERAGE HEAD ON TOP OF LAYER 5** | | | | | | |
| AVERAGES | 0.0019 | 0.0029 | 0.0036 | 0.0031 | 0.0012 | 0.0003 |
| | 0.0000 | 0.0000 | 0.0001 | 0.0003 | 0.0001 | 0.0007 |
| STD. DEVIATIONS | 0.0017 | 0.0019 | 0.0027 | 0.0027 | 0.0009 | 0.0004 |
| | 0.0001 | 0.0000 | 0.0004 | 0.0010 | 0.0003 | 0.0011 |
| **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 | 8.376 ( 3.6493) | 30403.85 | 20.305 |
| EVAPOTRANSPIRATION | 28.980 ( 3.7250) | 105197.30 | 70.255 |
| LATERAL DRAINAGE COLLECTED FROM LAYER 4 | 3.93122 ( 1.89696) | 14270.332 | 9.53035 |
| PERCOLATION/LEAKAGE THROUGH LAYER 6 | 0.00000 ( 0.00000) | 0.006 | 0.00000 |
| AVERAGE HEAD ON TOP OF LAYER 5 | 0.001 ( 0.001) | | |
| LATERAL DRAINAGE COLLECTED FROM LAYER 7 | 0.00000 ( 0.00000) | 0.000 | 0.00000 |

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| | | | | |
|---|---|---|---|---|
| PERCOLATION/LEAKAGE THROUGH LAYER 8 | 0.00000 | ( 0.00000) | 0.006 | 0.00000 |
| AVERAGE HEAD ON TOP OF LAYER 8 | 0.000 | ( 0.000) | | |
| CHANGE IN WATER STORAGE | -0.037 | ( 1.5183) | -135.80 | -0.091 |

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 20

| | (INCHES) | (CU. FT.) |
|---|---|---|
| PRECIPITATION | 5.22 | 18948.600 |
| RUNOFF | 3.935 | 14285.0703 |
| DRAINAGE COLLECTED FROM LAYER 4 | 0.17334 | 629.23462 |
| PERCOLATION/LEAKAGE THROUGH LAYER 6 | 0.000000 | 0.00008 |
| AVERAGE HEAD ON TOP OF LAYER 5 | 0.019 | |
| MAXIMUM HEAD ON TOP OF LAYER 5 | 0.040 | |
| LOCATION OF MAXIMUM HEAD IN LAYER 4 (DISTANCE FROM DRAIN) | 0.0 FEET | |
| DRAINAGE COLLECTED FROM LAYER 7 | 0.00000 | 0.00000 |
| PERCOLATION/LEAKAGE THROUGH LAYER 8 | 0.000000 | 0.00008 |
| 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 |

$5.1 \times 10^{-6}$ cm/sec

| | |
|---|---|
| MAXIMUM VEG. SOIL WATER (VOL/VOL) | 0.3374 |
| MINIMUM VEG. SOIL WATER (VOL/VOL) | 0.1092 |

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

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

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FINAL WATER STORAGE AT END OF YEAR 20

| LAYER | (INCHES) | (VOL/VOL) |
|---|---|---|
| 1 | 3.0050 | 0.2504 |
| 2 | 139.9430 | 0.2915 |
| 3 | 6.5878 | 0.2745 |
| 4 | 0.0025 | 0.0100 |
| 5 | 0.0000 | 0.0000 |
| 6 | 0.1500 | 0.7500 |
| 7 | 0.0025 | 0.0100 |
| 8 | 0.0000 | 0.0000 |
| SNOW WATER | 0.000 | |

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**Objective** To evaluate the maximum travel (detection) time to each sump for leachate within the leak detection system (LDS). The maximum travel (detection) time is the sum of times through collection media and piping.

**Reference**

Lindeburg, M.R. (1994), Civil Engineering Reference Manual, Sixth Edition, Professional Publications, Inc., Belmont, CA, p. 5-25.

Malcom, H. Rooney (1989 & 2003 Supplement), Elements of Urban Stormwater Design, NC State Univ., Raleigh, NC.

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

**Assumptions**

1. Leakage is uniform over the entire landfill.
2. Darcy's Law is valid for all flow conditions considered.
3. For the purpose of determining the travel time in piping, assume that pipes are flowing at a depth to diameter (d/D) ratio of 0.10.

**Analysis**

- Flow in Collection Media (Natural Drainage Media and/or Drainage Geocomposite):

Based on the method described in Richardson, Giroud, and Zhao use Darcy's Law ($Q = kiA$) to determine the travel (detection) time along the longest flow path.

Darcy's Law:

$$Q = kiA = (kt)iw = \theta iw$$

where:

| | | |
|---|---|---|
| $Q$ | = | flow |
| $k$ | = | design permeability of the collection media (See Note 1) |
| $i$ | = | hydraulic gradient (assume equal to slope) |
| $A$ | = | area of flow (= $t$ x $w$) |
| $t$ | = | thickness of drainage layer |
| $w$ | = | width of drainage layer |
| $\theta$ | = | design transmissivity of the collection media (See Note 1) |



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

Travel Time:

In that continuity must exist:

$$Q = VA = Vwt$$

where: $V$ = flow velocity

For natural drainage media (stone/sand):

$$V = ki$$

For a drainage geocomposite:

$$V = \frac{\theta \times i}{t}$$

For a drainage geocomposite use the true flow velocity:

$$V_{true} = \frac{V}{n}$$

where: $V_{true}$ = true flow velocity
$n$ = porosity (0.4 to 0.8 is typical)

Note:

1. For stone/sand: The design permeability ($k$) = (specified minimum permeability)/(overall reduction factor ($RF$))
   For drainage geocomposites: The design transmissivity ($\theta$) = (specified minimum transmissivity)/($RF$)

$$RF = RF_{IN} \times RF_{CR} \times RF_{CC} \times RF_{BC} \times FS$$

where: $RF_{IN}$ = reduction factor for intrusion
$RF_{CR}$ = reduction factor for creep
$RF_{CC}$ = reduction factor for chemical clogging
$RF_{BC}$ = reduction factor for biological clogging
$FS$ = overall factor of safety

Based on the recommendations of Richardson, Giroud, & Zhao, use the following values for a leak detection system (LDS). For the LDS, the lower bound values for chemical and biological clogging are typically used as the LDS is subject to minimal flow. An overall factor of safety of 2.0 for long-term conditions is also recommended. For shorter term (lower load) conditions, lower values may be used.

| | $RF_{IN}$ | $RF_{CR}$ | $RF_{CC}$ | $RF_{BC}$ |
|---|---|---|---|---|
| Stone/Sand: | 1.0 | 1.0 | 1.5-2.0 | 1.5-2.0 |
| Dr. Geocomposite: | 1.0-1.2 | 1.4-2.0 | 1.5-2.0 | 1.5-2.0 |

- Flow in Piping:

Using Manning's equation for pipe flow and relationships between full and partial flow in circular pipes, determine the travel (detection) time along the longest flow path.

Manning's Equation (Reformulated to Determine Flow Velocity):

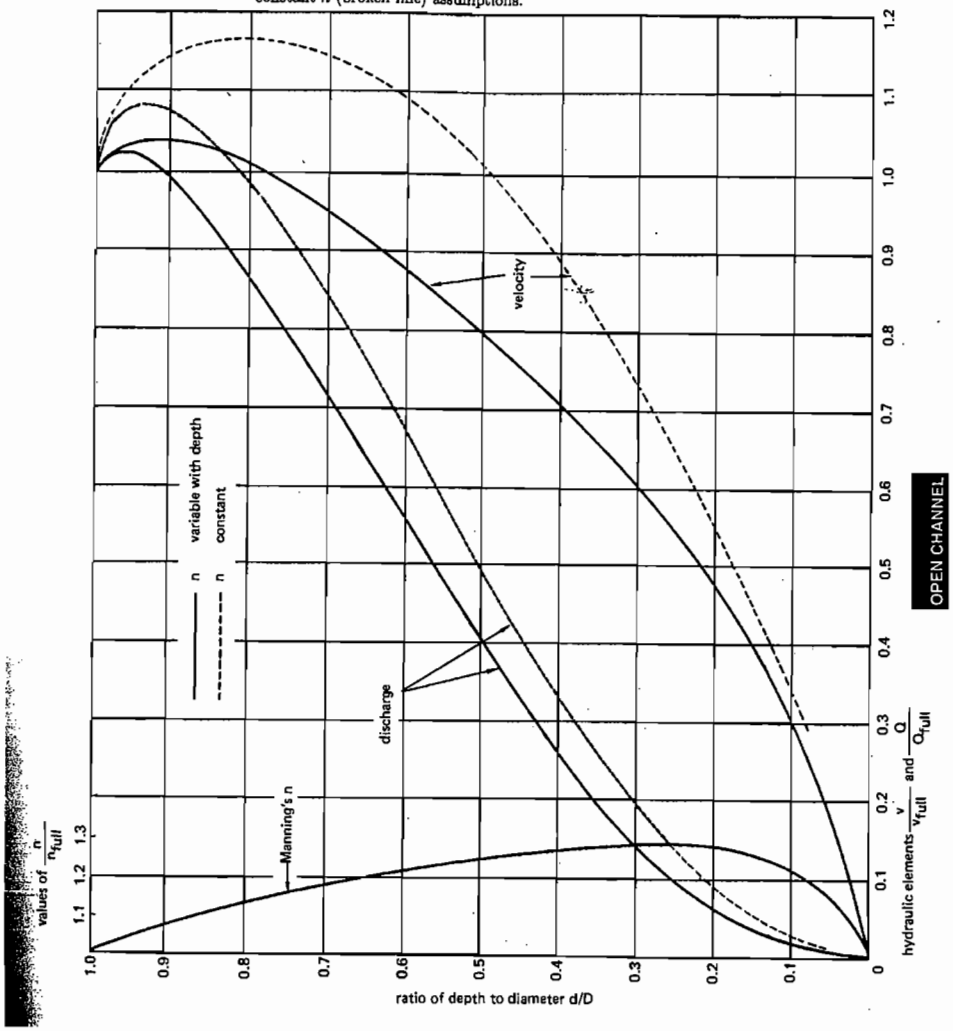
$$V = \frac{s^{0.5} D^{2/3}}{8.9n} \qquad \text{(Malcom Eq. I-10)}$$

where: $V$ = full flow velocity (ft/sec)
$s$ = pipe slope (ft/ft)
$D$ = pipe diameter (inches)
$n$ = Manning's roughness coefficient

To estimate partial flow velocity, use the design chart for circular pipes (see below).

## Appendix C: Circular Channel Ratios

Experiments have shown that $n$ varies slightly with depth. This figure gives velocity and flow rate ratios for varying $n$ (solid line) and constant $n$ (broken line) assumptions.




*Ref: Civil Engineering Reference Manual*

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Raleigh, NC 27603 Fax: 919-828-3899

SHEET: 5 / 7
JOB #: JOHNSTON-07-2
DATE: 5/11/07
BY: PKS
CHKD BY:

**Johnston County MSW Landfill - Phase 4A - Cell 3**
**Leak Detection System Travel Time Analysis**

## Drainage Geocomposite Information:

| | | | |
|---|---|---|---|
| Drainage Geocomposite Transmissivity (θ): | 5.0E-04 | $m^3/m/sec$ | (Specified Minimum) |
| Thickness of Geonet Drainage Core: | 0.25 | inches | (Specified Minimum) |
| Porosity of Geonet Drainage Core: | 0.60 | | (Assumed - Typical for Drainage Geocomposites) |
| **Reduction Factors for Drainage Geocomposite:** | | | (Per Richardson, Zhao, & Giroud) |
| $RF_{intrusion}$: | 1.2 | | |
| $RF_{creep}$: | 2.0 | | |
| $RF_{chemical\ clogging}$: | 1.5 | | |
| $RF_{biological\ clogging}$: | 1.5 | | |
| Overall Factor of Safety: | 2.0 | | |
| Reduction Factor for Drainage Geocomposite in LDS: | 10.8 | | |
| Design Drainage Geocomposite Transmissivity (θ): | 4.6E-05 | $m^3/m/sec$ | |

## Pipe Information:

| | | | |
|---|---|---|---|
| Type of Pipe: | HDPE | | |
| Pipe Diameter (D): | 4 | in | |
| Manning's Roughness Coefficient (n): | 0.009 | | (Typical for HDPE Pipe - Smooth Interior Wall) |
| Ratio of Flow Depth to Diameter (d/D): | 10 | % | (Assumed) |
| Flow Ratio ($Q/Q_{full}$): | 0.34 | | (From Chart based on d/D) |

**Note:** Spreadsheet Converts Units as Required.

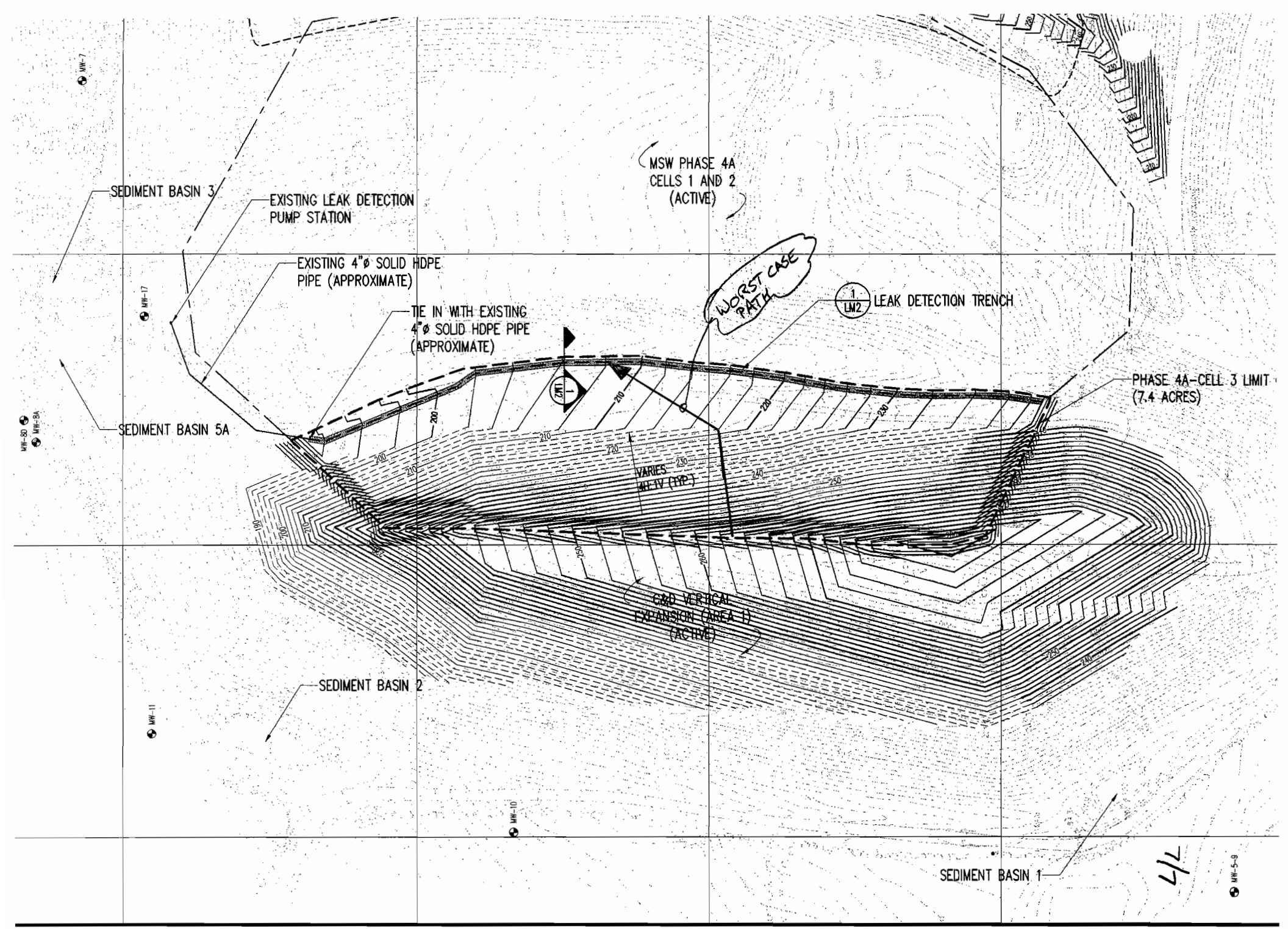
| | |
|---|---|
| SHEET: | 6 / 7 |
| JOB #: | JOHNSTON-07-2 |
| DATE: | 5/11/07 |
| BY: | PKS |
| CHKD BY: | |

## Travel Time Calculations:

**Landfill Unit: Cell 3**

| LDS Component | Flow Distance (ft) (*) | Slope (%) | Gradient (ft/ft) | | Drainage Geocomposite: Apparent Flow Velocity (ft/sec) | Drainage Geocomposite: True Flow Velocity (ft/sec) | Pipe: Full Flow Velocity (ft/sec) | Pipe: Partial Flow Velocity (ft/sec) | Travel Time (min) | Travel Time (days) |
|---|---|---|---|---|---|---|---|---|---|---|
| Drainage Geocomposite: | | | | | | | | | | |
| | 180 | 25 | 0.250 | | 6.0E-03 | 1.0E-02 | ---- | ---- | 301 | 0.21 |
| | 220 | 4 | 0.040 | | 9.6E-04 | 1.6E-03 | ---- | ---- | 2,299 | 1.60 |
| Piping: | | | | | | | | | | |
| | 725 | 2 | 0.020 | | ---- | ---- | 0.8 | 0.3 | 42 | 0.03 |
| | 150 | 20 | 0.200 | | ---- | ---- | 2.7 | 0.9 | 3 | 0.00 |
| | | | | | | | | **Total:** | **2,645** | **1.84** |

(*) Based on Worst Case Flow Path → See Attached.


SEDIMENT BASIN 3
EXISTING LEAK DETECTION PUMP STATION
EXISTING 4"ø SOLID HDPE PIPE (APPROXIMATE)
TIE IN WITH EXISTING 4"ø SOLID HDPE PIPE (APPROXIMATE)
SEDIMENT BASIN 5A
MSW PHASE 4A CELLS 1 AND 2 (ACTIVE)
WORST CASE PATH
1 / LM2 LEAK DETECTION TRENCH
PHASE 4A-CELL 3 LIMIT (7.4 ACRES)
VARIES 4H:1V (TYP.)
C&D VERTICAL EXPANSION (AREA 1) (ACTIVE)
SEDIMENT BASIN 2
SEDIMENT BASIN 1
MW-7
MW-17
MW-8D
MW-8A
MW-11
MW-10
MW-5-9

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PROJECT Johnston County MSWLF - Phase 4A - Cell 3

SUBJECT Final Cover Infiltration Analysis

SHEET 1 OF 15
JOB NO. JOHNSTON-07-2
DATE 3/21/07
COMPUTED BY PKS
CHECKED BY

**Objective**

To determine the expected average annual infiltration into the landfill through the proposed final cover system. In that the proposed final cover system is an alternate system to the regulatory final cover, the infiltration through the proposed system is compared to the infiltration through the regulatory system. Use the EPA HELP Model (v. 3.07) in the analysis.

**References**

Schroeder, P.R., Lloyd, C.M., et. al, (1994), "The Hydrologic Evaluation of Landfill Performance (HELP) Model - User's Guide for Version 3," EPA/600/9-94/168a, USEPA Risk Reduction Laboratory, Cincinnati, Ohio.

Schroeder, P.R., Lloyd, C.M., et. al, (1994), "The Hydrologic Evaluation of Landfill Performance (HELP) Model - Engineering Documentation for Version 3," EPA/600/9-94/168b, USEPA Risk Reduction Laboratory, Cincinnati, Ohio.

**Analysis**

Final Cover Systems Analyzed:

1. Proposed Final Cover System: (Top Down)

   A. 24 inches Vegetative Soil Layer
   B. Drainage Geocomposite
   C. 30 mil Textured LLDPE Geomembrane
   D. 12 inches Intermediate Cover

2. Regulatory Final Cover System: (Top Down)

   A. 24 inches Vegetative Soil Layer
   B. 30 mil LLDPE Geomembrane
   C. 18 inches Compacted Soil Barrier ($k = 1 \times 10^{-5}$ cm/sec)
   D. 12 inches Intermediate Cover

**Results**

| Case | Slope of Final Cover System (percent) | Average Annual Infiltration (inches) |
|---|---|---|
| 1. | 8.0 | 0.00058 |
| 1A. | 25.0 | 0.00017 |
| 2. | 8.0 | 0.540 |
| 2A. | 25.0 | 0.536 |

The results show that the proposed final cover system allows less infiltration than the regulatory final cover system. HELP Model runs are attached.

**FCS HELP.WPD**

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

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

PRECIPITATION DATA FILE:     C:\PROGRA~1\HELP3\RALNCP.D4
TEMPERATURE DATA FILE:       C:\PROGRA~1\HELP3\RALNCT.D7
SOLAR RADIATION DATA FILE:   C:\PROGRA~1\HELP3\RALNCS.D13
EVAPOTRANSPIRATION DATA:     C:\PROGRA~1\HELP3\RALNCE.D11
SOIL AND DESIGN DATA FILE:   C:\PROGRA~1\HELP3\JCCLD08.D10
OUTPUT DATA FILE:            C:\PROGRA~1\HELP3\JCCLD08.OUT

TIME:  16:50     DATE:   3/19/2007

**********************************************************************

     TITLE:  Johnston County MSWLF - 8% Slope - Final Cover

**********************************************************************

     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  10
          THICKNESS                    =     24.00   INCHES
          POROSITY                     =      0.3980 VOL/VOL
          FIELD CAPACITY               =      0.2440 VOL/VOL
          WILTING POINT                =      0.1360 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.2650 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.119999997000E-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   =      0.0200 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  10.0000000000     CM/SEC
          SLOPE                        =      8.00   PERCENT
          DRAINAGE LENGTH              =    200.0    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 3 - BARRIER SOIL LINER
                      MATERIAL TEXTURE NUMBER  10
          THICKNESS                    =     12.00   INCHES
          POROSITY                     =      0.3980 VOL/VOL
          FIELD CAPACITY               =      0.2440 VOL/VOL
          WILTING POINT                =      0.1360 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.3980 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.119999997000E-03 CM/SEC

              GENERAL DESIGN AND EVAPORATIVE ZONE DATA
              ---------------------------------------

     NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
              SOIL DATA BASE USING SOIL TEXTURE #10 WITH A
              FAIR STAND OF GRASS, A SURFACE SLOPE OF  8.%
              AND A SLOPE LENGTH OF  200. FEET.

     SCS RUNOFF CURVE NUMBER             =     86.50
     FRACTION OF AREA ALLOWING RUNOFF    =    100.0    PERCENT
     AREA PROJECTED ON HORIZONTAL PLANE  =      1.000  ACRES
```

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| | | | |
|---|---|---|---|
| EVAPORATIVE ZONE DEPTH | = | 22.0 | INCHES |
| INITIAL WATER IN EVAPORATIVE ZONE | = | 5.764 | INCHES |
| UPPER LIMIT OF EVAPORATIVE STORAGE | = | 8.756 | INCHES |
| LOWER LIMIT OF EVAPORATIVE STORAGE | = | 2.992 | INCHES |
| INITIAL SNOW WATER | = | 0.000 | INCHES |
| INITIAL WATER IN LAYER MATERIALS | = | 11.141 | INCHES |
| TOTAL INITIAL WATER | = | 11.141 | 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

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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 | 0.359 | 0.098 | 0.158 | 0.054 | 0.327 | 0.151 |
| | 0.156 | 0.532 | 0.142 | 0.165 | 0.236 | 0.127 |
| STD. DEVIATIONS | 0.472 | 0.112 | 0.207 | 0.139 | 0.547 | 0.201 |
| | 0.236 | 1.066 | 0.308 | 0.297 | 0.273 | 0.165 |
| EVAPOTRANSPIRATION | | | | | | |
| TOTALS | 1.477 | 1.780 | 3.008 | 2.702 | 3.993 | 3.689 |
| | 3.869 | 4.083 | 2.424 | 1.281 | 1.236 | 1.084 |
| STD. DEVIATIONS | 0.151 | 0.254 | 0.329 | 0.971 | 0.964 | 1.704 |
| | 1.420 | 1.285 | 1.236 | 0.466 | 0.161 | 0.141 |
| LATERAL DRAINAGE COLLECTED FROM LAYER 2 | | | | | | |
| TOTALS | 1.7564 | 1.2166 | 1.0441 | 0.3527 | 0.3096 | 0.1048 |
| | 0.0695 | 0.5593 | 0.2123 | 0.2393 | 0.9954 | 1.2714 |
| STD. DEVIATIONS | 1.3024 | 1.0383 | 0.8780 | 0.5139 | 0.6269 | 0.1991 |
| | 0.1691 | 1.3196 | 0.6020 | 0.6533 | 1.0929 | 0.9345 |
| PERCOLATION/LEAKAGE THROUGH LAYER 4 | | | | | | |
| TOTALS | 0.0001 | 0.0001 | 0.0001 | 0.0000 | 0.0000 | 0.0000 |
| | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0001 | 0.0001 |
| STD. DEVIATIONS | 0.0001 | 0.0001 | 0.0001 | 0.0000 | 0.0000 | 0.0000 |
| | 0.0000 | 0.0001 | 0.0000 | 0.0000 | 0.0001 | 0.0001 |

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

| | | | | | | |
|---|---|---|---|---|---|---|
| DAILY AVERAGE HEAD ON TOP OF LAYER 3 | | | | | | |
| AVERAGES | 0.0025 | 0.0019 | 0.0015 | 0.0005 | 0.0004 | 0.0002 |
| | 0.0001 | 0.0008 | 0.0003 | 0.0003 | 0.0015 | 0.0018 |

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| | | | | | | |
|---|---|---|---|---|---|---|
| STD. DEVIATIONS | 0.0019 | 0.0016 | 0.0013 | 0.0008 | 0.0009 | 0.0003 |
| | 0.0002 | 0.0019 | 0.0009 | 0.0009 | 0.0016 | 0.0013 |

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

| | INCHES | | CU. FEET | PERCENT |
|---|---|---|---|---|
| PRECIPITATION | 41.25 | ( 8.104) | 149735.7 | 100.00 |
| RUNOFF | 2.504 | ( 1.8955) | 9090.71 | 6.071 |
| EVAPOTRANSPIRATION | 30.627 | ( 3.6083) | 111174.84 | 74.247 |
| LATERAL DRAINAGE COLLECTED FROM LAYER 2 | 8.13130 | ( 4.24176) | 29516.629 | 19.71249 |
| PERCOLATION/LEAKAGE THROUGH LAYER 4 | 0.00058 | ( 0.00028) | 2.096 | 0.00140 |
| AVERAGE HEAD ON TOP OF LAYER 3 | 0.001 | ( 0.001) | | |
| CHANGE IN WATER STORAGE | -0.013 | ( 0.8851) | -48.58 | -0.032 |

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 20

| | (INCHES) | (CU. FT.) |
|---|---|---|
| PRECIPITATION | 5.22 | 18948.600 |
| RUNOFF | 2.901 | 10531.6211 |
| DRAINAGE COLLECTED FROM LAYER 2 | 1.06056 | 3849.81836 |
| PERCOLATION/LEAKAGE THROUGH LAYER 4 | 0.000059 | 0.21280 |
| AVERAGE HEAD ON TOP OF LAYER 3 | 0.047 | |
| MAXIMUM HEAD ON TOP OF LAYER 3 | 0.091 | |
| LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN) | 4.5 FEET | |
| SNOW WATER | 1.80 | 6547.7266 |

| | |
|---|---|
| MAXIMUM VEG. SOIL WATER (VOL/VOL) | 0.3557 |
| MINIMUM VEG. SOIL WATER (VOL/VOL) | 0.1360 |

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

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

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FINAL WATER STORAGE AT END OF YEAR 20

| LAYER | (INCHES) | (VOL/VOL) |
|---|---|---|
| 1 | 6.0943 | 0.2539 |
| 2 | 0.0033 | 0.0131 |
| 3 | 0.0000 | 0.0000 |
| 4 | 4.7760 | 0.3980 |
| SNOW WATER | 0.000 | |

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

PRECIPITATION DATA FILE:    C:\PROGRA~1\HELP3\RALNCP.D4
TEMPERATURE DATA FILE:      C:\PROGRA~1\HELP3\RALNCT.D7
SOLAR RADIATION DATA FILE:  C:\PROGRA~1\HELP3\RALNCS.D13
EVAPOTRANSPIRATION DATA:    C:\PROGRA~1\HELP3\RALNCE.D11
SOIL AND DESIGN DATA FILE:  C:\PROGRA~1\HELP3\JCCLD25.D10
OUTPUT DATA FILE:           C:\PROGRA~1\HELP3\JCCLD25.OUT

TIME:  16:51     DATE:   3/19/2007

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     TITLE:  Johnston County MSWLF -25% Slope - Final Cover

**********************************************************************

     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  10
          THICKNESS                    =     24.00   INCHES
          POROSITY                     =      0.3980 VOL/VOL
          FIELD CAPACITY               =      0.2440 VOL/VOL
          WILTING POINT                =      0.1360 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.2653 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.119999997000E-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   =      0.0126 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 3 - BARRIER SOIL LINER
                    MATERIAL TEXTURE NUMBER  10
          THICKNESS                    =     12.00   INCHES
          POROSITY                     =      0.3980 VOL/VOL
          FIELD CAPACITY               =      0.2440 VOL/VOL
          WILTING POINT                =      0.1360 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.3980 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.119999997000E-03 CM/SEC


              GENERAL DESIGN AND EVAPORATIVE ZONE DATA
              ---------------------------------------

       NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
              SOIL DATA BASE USING SOIL TEXTURE #10 WITH A
              FAIR STAND OF GRASS, A SURFACE SLOPE OF 25.%
              AND A SLOPE LENGTH OF  150. FEET.

     SCS RUNOFF CURVE NUMBER             =     87.10
     FRACTION OF AREA ALLOWING RUNOFF    =    100.0    PERCENT
     AREA PROJECTED ON HORIZONTAL PLANE  =      1.000  ACRES
     EVAPORATIVE ZONE DEPTH              =     22.0    INCHES
```

6/15

| | | | |
|---|---|---|---|
| INITIAL WATER IN EVAPORATIVE ZONE | = | 5.770 | INCHES |
| UPPER LIMIT OF EVAPORATIVE STORAGE | = | 8.756 | INCHES |
| LOWER LIMIT OF EVAPORATIVE STORAGE | = | 2.992 | INCHES |
| INITIAL SNOW WATER | = | 0.000 | INCHES |
| INITIAL WATER IN LAYER MATERIALS | = | 11.147 | INCHES |
| TOTAL INITIAL WATER | = | 11.147 | 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 | 0.394 | 0.115 | 0.181 | 0.063 | 0.361 | 0.171 |
| | 0.179 | 0.581 | 0.160 | 0.187 | 0.263 | 0.144 |
| STD. DEVIATIONS | 0.514 | 0.128 | 0.233 | 0.158 | 0.587 | 0.220 |
| | 0.259 | 1.129 | 0.331 | 0.328 | 0.297 | 0.177 |
| EVAPOTRANSPIRATION | | | | | | |
| TOTALS | 1.475 | 1.778 | 3.006 | 2.704 | 3.984 | 3.679 |
| | 3.845 | 4.067 | 2.418 | 1.269 | 1.233 | 1.081 |
| STD. DEVIATIONS | 0.156 | 0.253 | 0.330 | 0.971 | 0.961 | 1.704 |
| | 1.410 | 1.287 | 1.221 | 0.466 | 0.163 | 0.142 |
| LATERAL DRAINAGE COLLECTED FROM LAYER 2 | | | | | | |
| TOTALS | 1.7163 | 1.2063 | 1.0244 | 0.3458 | 0.2864 | 0.0991 |
| | 0.0708 | 0.5313 | 0.2056 | 0.2181 | 0.9603 | 1.2620 |
| STD. DEVIATIONS | 1.2574 | 1.0359 | 0.8498 | 0.4948 | 0.5752 | 0.1759 |
| | 0.1556 | 1.2396 | 0.5801 | 0.6229 | 1.0802 | 0.9342 |
| PERCOLATION/LEAKAGE THROUGH LAYER 4 | | | | | | |
| 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 | 0.0001 | 0.0001 | 0.0000 |
| | 0.0000 | 0.0002 | 0.0001 | 0.0001 | 0.0004 | 0.0005 |

| | | | | | | |
|---|---|---|---|---|---|---|
| STD. DEVIATIONS | 0.0005 | 0.0004 | 0.0003 | 0.0002 | 0.0002 | 0.0001 |
| | 0.0001 | 0.0004 | 0.0002 | 0.0002 | 0.0004 | 0.0003 |

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

| | INCHES | | CU. FEET | PERCENT |
|---|---|---|---|---|
| PRECIPITATION | 41.25 | ( 8.104) | 149735.7 | 100.00 |
| RUNOFF | 2.798 | ( 2.0344) | 10155.29 | 6.782 |
| EVAPOTRANSPIRATION | 30.539 | ( 3.6077) | 110855.87 | 74.034 |
| LATERAL DRAINAGE COLLECTED FROM LAYER 2 | 7.92628 | ( 4.08113) | 28772.396 | 19.21546 |
| PERCOLATION/LEAKAGE THROUGH LAYER 4 | 0.00017 | ( 0.00008) | 0.602 | 0.00040 |
| AVERAGE HEAD ON TOP OF LAYER 3 | 0.000 | ( 0.000) | | |
| CHANGE IN WATER STORAGE | -0.013 | ( 0.8740) | -48.49 | -0.032 |

**********

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 20

| | (INCHES) | (CU. FT.) |
|---|---|---|
| PRECIPITATION | 5.22 | 18948.600 |
| RUNOFF | 2.989 | 10850.7207 |
| DRAINAGE COLLECTED FROM LAYER 2 | 0.94199 | 3419.43384 |
| PERCOLATION/LEAKAGE THROUGH LAYER 4 | 0.000015 | 0.05543 |
| AVERAGE HEAD ON TOP OF LAYER 3 | 0.011 | |
| MAXIMUM HEAD ON TOP OF LAYER 3 | 0.043 | |
| LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN) | 0.0 FEET | |
| SNOW WATER | 1.80 | 6547.7266 |

| | |
|---|---|
| MAXIMUM VEG. SOIL WATER (VOL/VOL) | 0.3564 |
| MINIMUM VEG. SOIL WATER (VOL/VOL) | 0.1360 |

*** 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 | 6.1012 | 0.2542 |
| 2 | 0.0027 | 0.0108 |
| 3 | 0.0000 | 0.0000 |
| 4 | 4.7760 | 0.3980 |
| SNOW WATER | 0.000 | |

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

PRECIPITATION DATA FILE:    C:\PROGRA~1\HELP3\RALNCP.D4
TEMPERATURE DATA FILE:      C:\PROGRA~1\HELP3\RALNCT.D7
SOLAR RADIATION DATA FILE:  C:\PROGRA~1\HELP3\RALNCS.D13
EVAPOTRANSPIRATION DATA:    C:\PROGRA~1\HELP3\RALNCE.D11
SOIL AND DESIGN DATA FILE:  C:\PROGRA~1\HELP3\JCRMC08.D10
OUTPUT DATA FILE:           C:\PROGRA~1\HELP3\JCRMC08.OUT

TIME:  10:42     DATE:   3/20/2007

**********************************************************************

     TITLE:  Johnston County MSWLF - 8% Slope - RMC

**********************************************************************

     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  10
          THICKNESS                    =     24.00   INCHES
          POROSITY                     =      0.3980 VOL/VOL
          FIELD CAPACITY               =      0.2440 VOL/VOL
          WILTING POINT                =      0.1360 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.3894 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.119999997000E-03 CM/SEC
       NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
              FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

                                LAYER  2
                                --------

                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  3
                                --------

                TYPE 3 - BARRIER SOIL LINER
                    MATERIAL TEXTURE NUMBER  0
          THICKNESS                    =     18.00   INCHES
          POROSITY                     =      0.4610 VOL/VOL
          FIELD CAPACITY               =      0.3600 VOL/VOL
          WILTING POINT                =      0.2030 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.4610 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 #10 WITH A
            FAIR STAND OF GRASS, A SURFACE SLOPE OF  8.%
            AND A SLOPE LENGTH OF  200. FEET.

     SCS RUNOFF CURVE NUMBER             =     86.50
     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   =      8.551   INCHES
     UPPER LIMIT OF EVAPORATIVE STORAGE  =      8.756   INCHES
     LOWER LIMIT OF EVAPORATIVE STORAGE  =      2.992   INCHES
     INITIAL SNOW WATER                  =      0.000   INCHES
     INITIAL WATER IN LAYER MATERIALS    =     17.645   INCHES
     TOTAL INITIAL WATER                 =     17.645   INCHES
     TOTAL SUBSURFACE INFLOW             =      0.00    INCHES/YEAR
```

5/01

## 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 | 1.695 | 1.181 | 1.049 | 0.299 | 0.705 | 0.222 |
| | 0.147 | 0.762 | 0.238 | 0.217 | 0.637 | 0.468 |
| STD. DEVIATIONS | 1.797 | 0.953 | 1.069 | 0.647 | 1.206 | 0.325 |
| | 0.212 | 1.679 | 0.728 | 0.419 | 1.060 | 0.436 |
| EVAPOTRANSPIRATION | | | | | | |
| TOTALS | 1.451 | 1.764 | 2.986 | 2.657 | 4.178 | 5.544 |
| | 4.481 | 4.132 | 2.470 | 1.221 | 1.150 | 1.062 |
| STD. DEVIATIONS | 0.152 | 0.256 | 0.331 | 0.932 | 0.782 | 0.869 |
| | 1.536 | 1.279 | 1.213 | 0.427 | 0.147 | 0.142 |
| PERCOLATION/LEAKAGE THROUGH LAYER 3 | | | | | | |
| TOTALS | 0.0774 | 0.0717 | 0.0756 | 0.0625 | 0.0570 | 0.0330 |
| | 0.0149 | 0.0163 | 0.0165 | 0.0184 | 0.0362 | 0.0602 |
| STD. DEVIATIONS | 0.0143 | 0.0074 | 0.0065 | 0.0068 | 0.0080 | 0.0150 |
| | 0.0124 | 0.0157 | 0.0163 | 0.0159 | 0.0285 | 0.0253 |

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

| | | | | | | |
|---|---|---|---|---|---|---|
| DAILY AVERAGE HEAD ON TOP OF LAYER 2 | | | | | | |
| AVERAGES | 20.4395 | 20.7831 | 19.9665 | 16.9915 | 14.9386 | 8.7824 |
| | 3.6478 | 4.0189 | 4.2237 | 4.5979 | 9.6865 | 15.8028 |
| STD. DEVIATIONS | 3.8443 | 2.1197 | 1.7499 | 1.8891 | 2.1560 | 4.1764 |
| | 3.3118 | 4.2172 | 4.4969 | 4.2604 | 7.9088 | 6.8019 |

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

| | INCHES | | CU. FEET | PERCENT |
|---|---|---|---|---|
| PRECIPITATION | 41.25 | ( 8.104) | 149735.7 | 100.00 |
| RUNOFF | 7.619 | ( 5.6068) | 27657.79 | 18.471 |
| EVAPOTRANSPIRATION | 33.095 | ( 3.5981) | 120134.73 | 80.231 |
| PERCOLATION/LEAKAGE THROUGH LAYER 3 | 0.53981 | ( 0.10670) | 1959.510 | 1.30865 |
| AVERAGE HEAD ON TOP OF LAYER 2 | 11.990 | ( 2.425) | | |
| CHANGE IN WATER STORAGE | -0.005 | ( 1.6045) | -16.35 | -0.011 |

PEAK DAILY VALUES FOR YEARS 1 THROUGH 20

| | (INCHES) | (CU. FT.) |
|---|---|---|
| PRECIPITATION | 5.22 | 18948.600 |
| RUNOFF | 2.870 | 10416.4375 |
| PERCOLATION/LEAKAGE THROUGH LAYER 3 | 0.002927 | 10.62599 |
| AVERAGE HEAD ON TOP OF LAYER 2 | 24.000 | |
| SNOW WATER | 1.80 | 6547.7266 |
| MAXIMUM VEG. SOIL WATER (VOL/VOL) | 0.3980 | |
| MINIMUM VEG. SOIL WATER (VOL/VOL) | 0.1360 | |

FINAL WATER STORAGE AT END OF YEAR 20

| LAYER | (INCHES) | (VOL/VOL) |
|---|---|---|
| 1 | 9.2566 | 0.3857 |
| 2 | 0.0000 | 0.0000 |
| 3 | 8.2980 | 0.4610 |
| SNOW WATER | 0.000 | |

51/21

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

PRECIPITATION DATA FILE:    C:\PROGRA~1\HELP3\RALNCP.D4
TEMPERATURE DATA FILE:      C:\PROGRA~1\HELP3\RALNCT.D7
SOLAR RADIATION DATA FILE:  C:\PROGRA~1\HELP3\RALNCS.D13
EVAPOTRANSPIRATION DATA:    C:\PROGRA~1\HELP3\RALNCE.D11
SOIL AND DESIGN DATA FILE:  C:\PROGRA~1\HELP3\JCRMC25.D10
OUTPUT DATA FILE:           C:\PROGRA~1\HELP3\JCRMC25.OUT

TIME:  10:42     DATE:   3/20/2007

**********************************************************************

     TITLE:  Johnston County MSWLF -25% Slope - RMC

**********************************************************************

     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  10
          THICKNESS                    =     24.00   INCHES
          POROSITY                     =      0.3980 VOL/VOL
          FIELD CAPACITY               =      0.2440 VOL/VOL
          WILTING POINT                =      0.1360 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.3894 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.119999997000E-03 CM/SEC
       NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
                FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

                                LAYER  2
                                --------

                  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  3
                                --------

                  TYPE 3 - BARRIER SOIL LINER
                      MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =     18.00   INCHES
          POROSITY                     =      0.4610 VOL/VOL
          FIELD CAPACITY               =      0.3600 VOL/VOL
          WILTING POINT                =      0.2030 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.4610 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 #10 WITH A
                FAIR STAND OF GRASS, A SURFACE SLOPE OF 25.%
                AND A SLOPE LENGTH OF  150. FEET.

     SCS RUNOFF CURVE NUMBER             =     87.10
     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   =      8.550  INCHES
     UPPER LIMIT OF EVAPORATIVE STORAGE  =      8.756  INCHES
     LOWER LIMIT OF EVAPORATIVE STORAGE  =      2.992  INCHES
     INITIAL SNOW WATER                  =      0.000  INCHES
     INITIAL WATER IN LAYER MATERIALS    =     17.643  INCHES
     TOTAL INITIAL WATER                 =     17.643  INCHES
     TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR
```

13/15

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 | 1.679 | 1.174 | 1.052 | 0.302 | 0.721 | 0.241 |
| | 0.168 | 0.775 | 0.249 | 0.227 | 0.635 | 0.472 |
| STD. DEVIATIONS | 1.785 | 0.948 | 1.065 | 0.641 | 1.198 | 0.339 |
| | 0.231 | 1.665 | 0.728 | 0.418 | 1.053 | 0.434 |
| EVAPOTRANSPIRATION | | | | | | |
| TOTALS | 1.450 | 1.763 | 2.986 | 2.647 | 4.170 | 5.542 |
| | 4.454 | 4.119 | 2.461 | 1.221 | 1.151 | 1.061 |
| STD. DEVIATIONS | 0.153 | 0.256 | 0.332 | 0.938 | 0.808 | 0.879 |
| | 1.537 | 1.282 | 1.219 | 0.427 | 0.148 | 0.142 |
| PERCOLATION/LEAKAGE THROUGH LAYER 3 | | | | | | |
| TOTALS | 0.0769 | 0.0715 | 0.0755 | 0.0622 | 0.0566 | 0.0328 |
| | 0.0147 | 0.0160 | 0.0164 | 0.0180 | 0.0356 | 0.0594 |
| STD. DEVIATIONS | 0.0146 | 0.0075 | 0.0066 | 0.0068 | 0.0081 | 0.0148 |
| | 0.0120 | 0.0152 | 0.0162 | 0.0156 | 0.0284 | 0.0256 |

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

| | | | | | | |
|---|---|---|---|---|---|---|
| DAILY AVERAGE HEAD ON TOP OF LAYER 2 | | | | | | |
| AVERAGES | 20.2908 | 20.7283 | 19.9223 | 16.9295 | 14.8554 | 8.7066 |
| | 3.5854 | 3.9388 | 4.1999 | 4.4888 | 9.4994 | 15.5833 |
| STD. DEVIATIONS | 3.9259 | 2.1215 | 1.7578 | 1.8812 | 2.1809 | 4.1257 |
| | 3.2204 | 4.0755 | 4.4826 | 4.1830 | 7.8959 | 6.8923 |

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

| | INCHES | | CU. FEET | PERCENT |
|---|---|---|---|---|
| PRECIPITATION | 41.25 | ( 8.104) | 149735.7 | 100.00 |
| RUNOFF | 7.694 | ( 5.5988) | 27928.45 | 18.652 |
| EVAPOTRANSPIRATION | 33.024 | ( 3.6036) | 119877.87 | 80.060 |
| PERCOLATION/LEAKAGE THROUGH LAYER 3 | 0.53558 | ( 0.10661) | 1944.154 | 1.29839 |
| AVERAGE HEAD ON TOP OF LAYER 2 | 11.894 | ( 2.422) | | |
| CHANGE IN WATER STORAGE | -0.004 | ( 1.6087) | -14.80 | -0.010 |

PEAK DAILY VALUES FOR YEARS 1 THROUGH 20

| | (INCHES) | (CU. FT.) |
|---|---|---|
| PRECIPITATION | 5.22 | 18948.600 |
| RUNOFF | 2.945 | 10690.1592 |
| PERCOLATION/LEAKAGE THROUGH LAYER 3 | 0.002927 | 10.62599 |
| AVERAGE HEAD ON TOP OF LAYER 2 | 24.000 | |
| SNOW WATER | 1.80 | 6547.7266 |
| MAXIMUM VEG. SOIL WATER (VOL/VOL) | 0.3980 | |
| MINIMUM VEG. SOIL WATER (VOL/VOL) | 0.1360 | |

FINAL WATER STORAGE AT END OF YEAR 20

| LAYER | (INCHES) | (VOL/VOL) |
|---|---|---|
| 1 | 9.2639 | 0.3860 |
| 2 | 0.0000 | 0.0000 |
| 3 | 8.2980 | 0.4610 |
| SNOW WATER | 0.000 | |

15/15

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

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

**Analysis**

**Step 1:**

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

$$\theta_{reqd} = \frac{RF_{dc} q_n L i}{\sin\beta} = \frac{RF_{dc} q_n L \cos\beta}{\sin\beta} = \frac{RF_{dc} q_n L}{\tan\beta}$$ (Richardson et. al. Eq. 4-6 Mod.)

where:
- $\theta_{reqd}$ = required transmissivity ($m^3/m/sec$)
- $RF_{dc}$ = 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)
- $\beta$ = 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:

$$Q = q_n A$$

where:
- $Q$ = flow capacity (cfs)
- $q_n$ = 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.

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SHEET: 3 / 3
JOB #: JOHNSTON-07-2
DATE: 2/28/07
BY: PKS
CHKD BY:

# Johnston County MSW Landfill - Phase 4A - Cell 3
# Final Cover Drainage Layer Analysis

**Input Parameters:**

| | | | |
|---|---|---|---|
| Side Slope Angle ($\beta$): | 14.0 | degrees | |
| Impingement ($q_n$): | 0.0001 | cm/sec | (= Permeability of Vegetative Soil Layer) |
| Drain Spacing ($L$): | 140 | ft | (= Horizontally Projected Distance Up & Down Slope) |
| **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 | (= Distance Across Slope at Toe) |
| Final Cover: Thickness: | 2.0 | ft | |
| Unit Weight: | 110 | pcf | |

**Note:** Spreadsheet Converts Units as Required.

**Transmissivity Requirements:**

**Determine Minimum Transmissivity:**

$\theta_{min}$ = 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.

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**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. Geotextile filtration properties must be selected based on the up-gradient soil gradation and plasticity and site specific hydraulic conditions.

**References**

Bhatia, S.K. and Huang, Q. (1995), "Geotextile Filters for Internally Stable/Unstable Soils", *Geosynthetics International*, Vol. 2, No. 3, pp. 537-565.

Koerner, Robert M. (1999), Designing with Geosynthetics, 4th Ed., Prentice-Hall Inc., Englewood Cliffs, NJ, pp. 84-91.

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

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

**Assumption** The design criteria given assume that the soil is "set" in intimate contact with the geotextile.

**Background** From Richardson et. al.:

For the purposes of filtration design, soils can be characterized as stable or unstable. Stable soils perform an internal filtration process that limits migration of fines within the soil. Typically, these soil types include well-graded soils. Unstable soils are those which cannot perform self-filtration (i.e. they have the potential to pipe internally). They may include gap-graded, broad-graded, and other highly erodible soils. In gap-graded soils, there exists a coarse and fine fraction, but very little medium fraction. If there is an insufficient quantity of soil particles in the medium fraction, fine soil particles pipe through the coarse fraction. In broad-graded soils, the gradation is distributed over a very wide range of particle sizes such that fine soil tends to pipe through coarser particles.

**Analysis**

1. **Define Application and Function of Geotextile:**

   Define 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).



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**2. Evaluate Soils Information:**

For representative soils, evaluate grain size and plasticity information. From the grain size curves determine the coefficients of uniformity and curvature as follows:

$$C_u = \frac{d_{60}}{d_{10}}$$

$$C_c = \frac{d_{30}^{\,2}}{(d_{10} \times d_{60})}$$

where: $C_u$ = coefficient of uniformity (quantifies the distribution of particle sizes)
$C_c$ = coefficient of curvature (identifies internal soil stability)
$d_x$ = the diameter at which x percent of the soil is finer

For $C_u \leq 4$, the soil is uniformly-graded; for $4 < C_u \leq 20$, the soil is well-graded; and for $C_u > 20$, the soil is broad-graded. Uniformly-graded and broad-graded soils require careful analysis. Gap-graded soils which have a coarse and fine fraction, but limited medium fraction are of particular concern and should be avoided. Gap-graded soils are readily identified by the appearance of the grain size curve. For $1 \leq C_c \leq 3$, the soil should be internally stable (Bhatia and Huang state that soils having $C_c \leq 7$ are internally stable.).

Additionally, in general, particles do not move within soils having a plasticity index (PI) greater than 15% so there is no clogging potential (Richardson et. al.).

**3. Selection of Soil Retention Requirements (Maximum AOS):**

To determine the maximum AOS, use the method given in Koerner/Mirafi (after Luettich) and the method given in Bhatia and Huang. For the AOS determined by either method, the following shows the relationship between opening size and the corresponding U.S. sieve number (with typical non-woven geotextile information as shown).

| Opening Size (mm) | U.S. Sieve |
|---|---|
| 0.150 | 100 (most 8 to 16 oz/sy non-wovens) |
| 0.180 | 80 |
| 0.212 | 70 (most 4 to 6 oz/sy non-wovens) |
| 0.250 | 60 |
| 0.300 | 50 |
| 0.425 | 40 |
| 0.600 | 30 |

**- Luettich Method:**

For steady-state conditions, use the chart below.

**- Bhatia and Huang Method:**

Bhatia and Huang developed the following retention criteria:

For $n \geq 60\%$: $O_{95} < d_{85}(2.71 - 0.36C_c)$ $\quad C_c \leq 7$

$O_{95} < d_{85}(0.65 - 0.05C_c)$ $\quad C_c > 7$

For $n < 60\%$: $O_{95} < d_{85}$

where: $O_{95}$ = apparent opening size
$n$ = geotextile porosity (%) (for non-woven geotextiles this value is typically 70 to 90%)

**4. Determine Geotextile Permittivity Requirements:**

Determine the geotextile permittivity requirements:

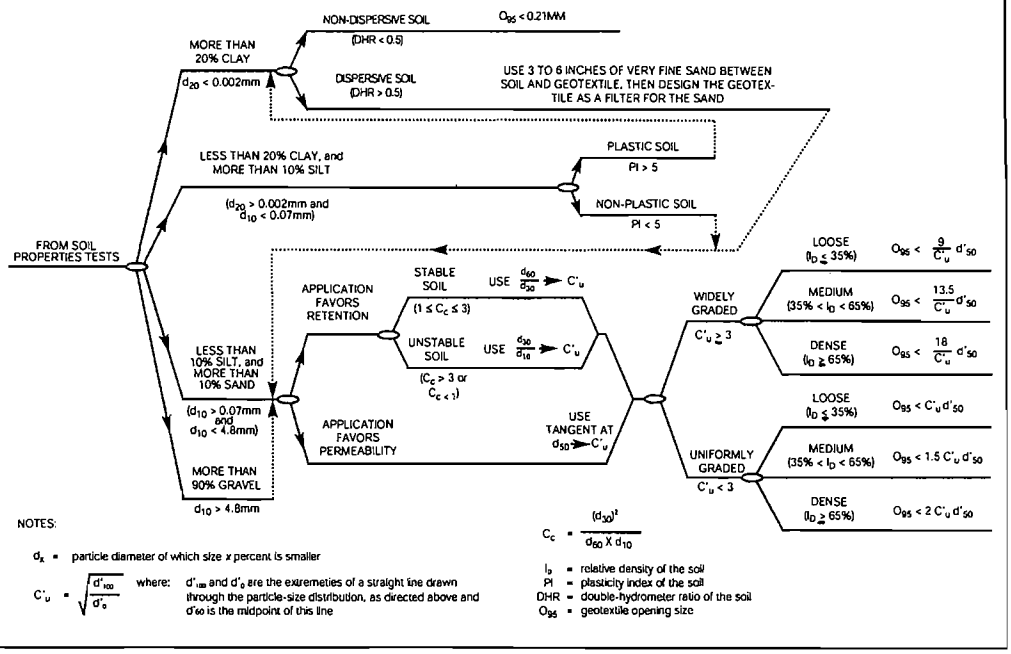
$$\Psi = \frac{k_g}{t_g} \qquad (\text{sec}^{-1})$$

where: $\Psi$ = minimum required geotextile permittivity ($\text{sec}^{-1}$)
$k_g$ = 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).

**5. 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.

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




*Ref: Mirafi (After Luettich)*

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JOB #: JOHNSTON-07-2
DATE: 3/19/07
BY: PKS
CHKD BY:

## Johnston County MSW Landfill - Phase 4A
## Filter Geotextile Analysis (Final Cover System)

**Application:** Final Cover Drainage Geocomposite
**Primary Function:** Retention
**Relative Confining Stress:** Low
**Flow Conditions:** Steady-State

| | | Soil Evaluated | | | |
|---|---|---|---|---|---|
| | | 643-01-01 | 643-01-03 | 643-04-01 | 643-06-01 |
| | Soil Description: | Brown Sandy Silt | Brown Clayey Sand | Tan Clayey Sand | Reddish Tan Sand w/ Silt |
| | Soil Type: | ML | SC | SC | SP-SM |
| Particle Size (mm) | $d_{85}$: | 0.700 | 0.600 | 1.000 | 0.850 |
| | $d_{60}$: | 0.060 | 0.320 | 0.480 | 0.500 |
| | $d_{50}$: | 0.020 | 0.270 | 0.370 | 0.400 |
| | $d_{30}$: | 0.003 | 0.110 | 0.200 | 0.270 |
| | $d_{20}$: | 0.001 | 0.010 | 0.120 | 0.160 |
| | $d_{10}$: | 0.001 | 0.001 | 0.010 | 0.100 |
| | PI: | 11 | 25 | 18 | 2 |
| | $C_u$: | 120.00 | 320.00 | 48.00 | 5.00 |
| | | Use Caution - Soil is Broad Graded! | Use Caution - Soil is Broad Graded! | Use Caution - Soil is Broad Graded! | Soil is Well Graded. |
| | $C_c$ | 0.30 | 37.81 | 8.33 | 1.46 |
| **Luettich Method:*** | | ----- | ----- | ----- | ----- |
| Soil Dispersion (When Applicable): | | Is Soil Dispersive? (Y/N) | Is Soil Dispersive? (Y/N) | Is Soil Dispersive? (Y/N) | NA |
| | | N | N | N | |
| Recommended Maximum AOS (mm) (When Applicable): | | **0.210** | **0.210** | **0.210** | |
| | | **No. 70 Sieve** | **No. 70 Sieve** | **No. 70 Sieve** | |
| Internal Soil Stability (When Applicable): | | NA | NA | NA | Soil is Stable |
| | | | | | Draw straight line through d60 and d30 to obtain C'u. |
| Particle Size (mm) for Determining $C'_u$ | $d'_{100}$: | | | | 1.300 |
| | $d'_{50}$: | | | | 0.400 |
| | $d'_0$: | | | | 0.110 |
| $C'_u$ (When Applicable): | | | | | 3.44 |
| | | | | | Soil is Widely Graded. |
| Soil Relative Density ($I_D$) (Loose (L), Medium (M), Dense (D) (When Applicable): | | | | | M |
| Recommended Maximum AOS (mm) (When Applicable): | | | | | **1.571** |
| | | | | | **No. 30 Sieve** |
| **Bhatia & Huang Method:** | | ----- | ----- | ----- | ----- |
| Internal Soil Stability: | | Soil is Stable. | Soil is Unstable. | Soil is Unstable. | Soil is Stable. |
| Geotextile Porosity (%): | | 80 | 80 | 80 | 80 |
| Recommended Max. AOS (mm): | | **1.821** | **-0.744** | **0.233** | **1.857** |
| | | **No. 30 Sieve** | **Check Available Geotextiles.** | **No. 70 Sieve** | **No. 30 Sieve** |
| Required Geotextile Properties: | | ----- | ----- | ----- | ----- |
| Hydraulic Gradient ($i_a$): | | 1.5 | 1.5 | 1.5 | 1.5 |
| Estimated Soil Permeability ($k_s$) (cm/sec): | | 1.0E-03 | 1.0E-03 | 1.0E-03 | 1.0E-03 |
| Min. Allowable Geotextile Permeability ($k_g$) (cm/sec): | | 1.5E-03 | 1.5E-03 | 1.5E-03 | 1.5E-03 |
| Geotextile Thickness ($t_g$) (cm): | | 0.25 | 0.25 | 0.25 | 0.25 |
| Min. Required Geotextile Permittivity ($\Psi$) ($sec^{-1}$): | | **0.006** | **0.006** | **0.006** | **0.006** |

***Note: Spreadsheet assumes retention application in using the Luettich Method.**

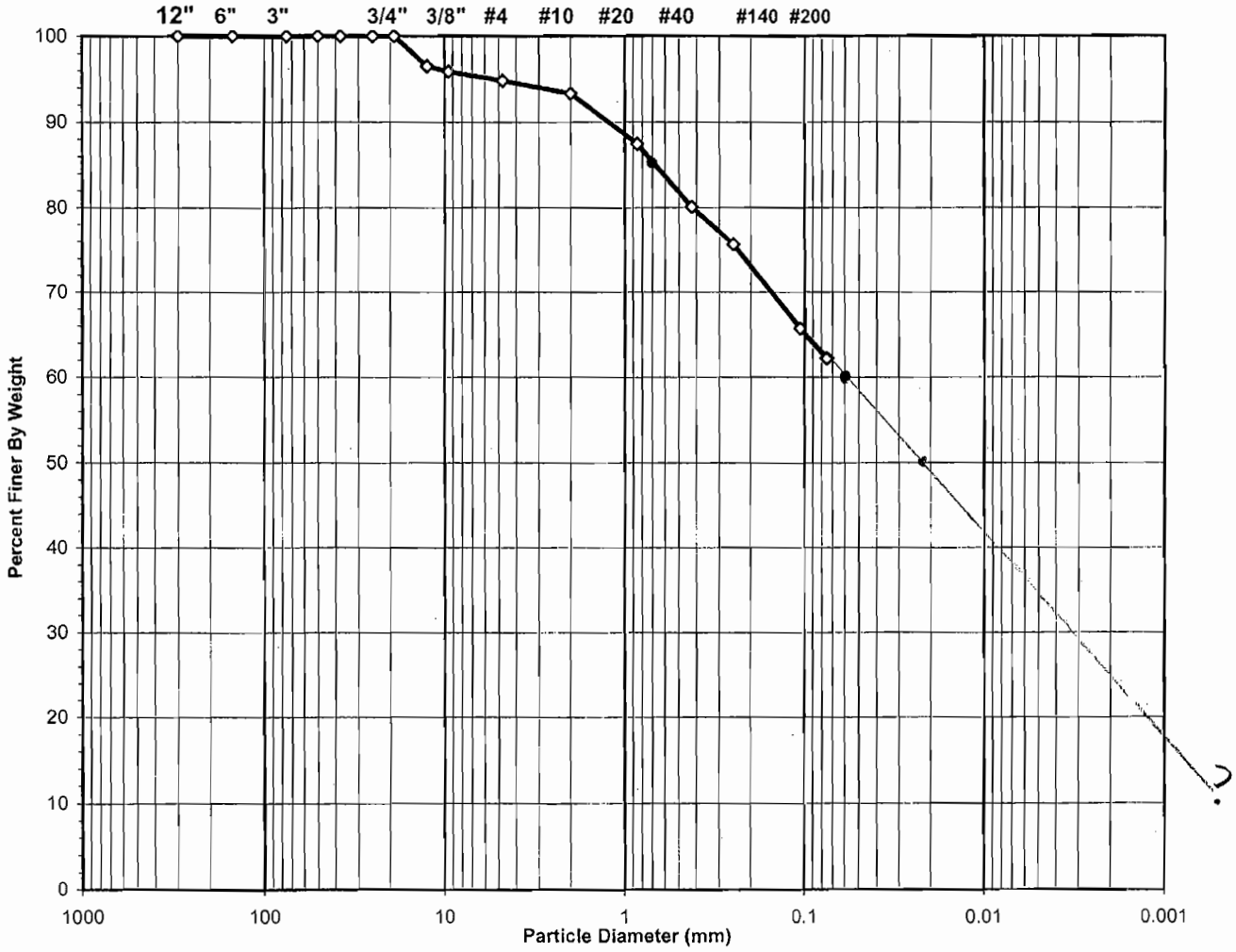
6A

Geotechnics
INTEGRITY IN TESTING

## SIEVE ANALYSIS
ASTM D 422-63 (SOP-S3)

| | | | |
|---|---|---|---|
| Client | GN RICHARDSON & ASSOC. | Boring No. | TP-01 |
| Client Reference | JOHNSTON CO. C&D LF AREA 2 CELL 1 | Depth (ft) | 1-5' |
| Project No. | 2006-643-01 | Sample No. | SF-01 |
| Lab ID. | 2006-643-01-01 | Soil Color | **BROWN** |

| | *SIEVE ANALYSIS* | | *HYDROMETER* |
|---|---|---|---|
| *USCS* | gravel | sand | silt and clay |




***USCS Symbol*** ***ML, TESTED***

***USCS Classification*** ***SANDY SILT***

Tested By JSC Date 10/24/2006 Checked By GRM Date 10-25-06



DCN: CT-S3C DATE 6-25-98 REVISION: 2 *\\Lab1\c\2006 PROJECTS\2006-643 GNRA JOHNSTON CO\[2006-643-01-01 SIEVE.XLS]Sheet1*

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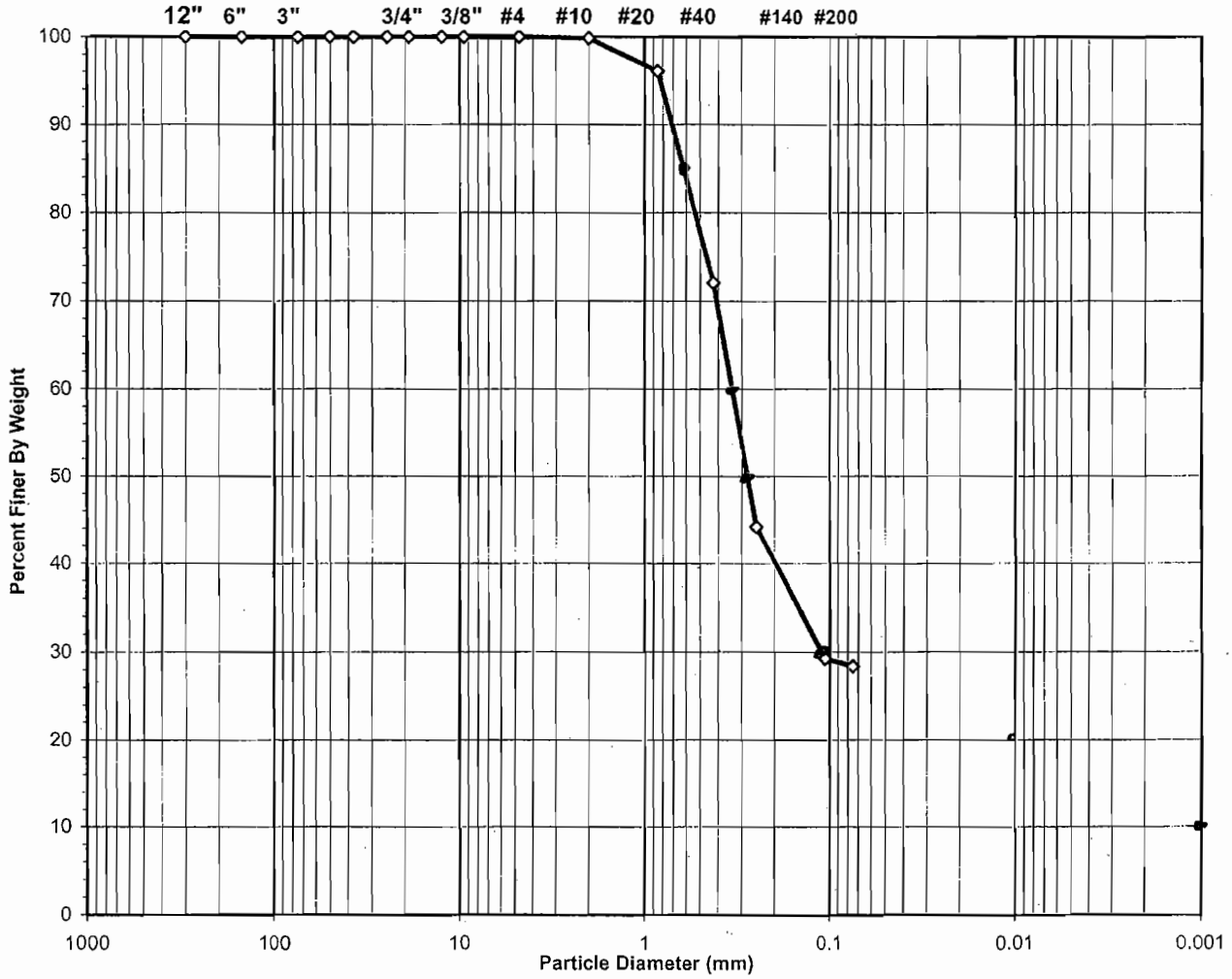
Geotechnics
INTEGRITY IN TESTING

## SIEVE ANALYSIS
ASTM D 422-63 (SOP-S3)

| | | | |
|---|---|---|---|
| Client | GN RICHARDSON & ASSOC. | Boring No. | TP-03 |
| Client Reference | JOHNSTON CO. C&D LF AREA 2 CELL 1 | Depth (ft) | 0.5-3' |
| Project No. | 2006-643-01 | Sample No. | SF-03 |
| Lab ID | 2006-643-01-03 | Soil Color | **BROWN** |

| | *SIEVE ANALYSIS* | | *HYDROMETER* |
|---|---|---|---|
| *USCS* | gravel | sand | silt and clay |




***USCS Symbol*** ***SC, TESTED***

***USCS Classification*** ***CLAYEY SAND***

Tested By JSC Date 10/24/2006 Checked By GRM Date 10-25-06



DCN: CT-S3C DATE 6-25-98 REVISION: 2 *\\Lab1\c\2006 PROJECTS\2006-643 GNRA JOHNSTON CO\[2006-643-01-03 SIEVE.XLS]Sheet1*

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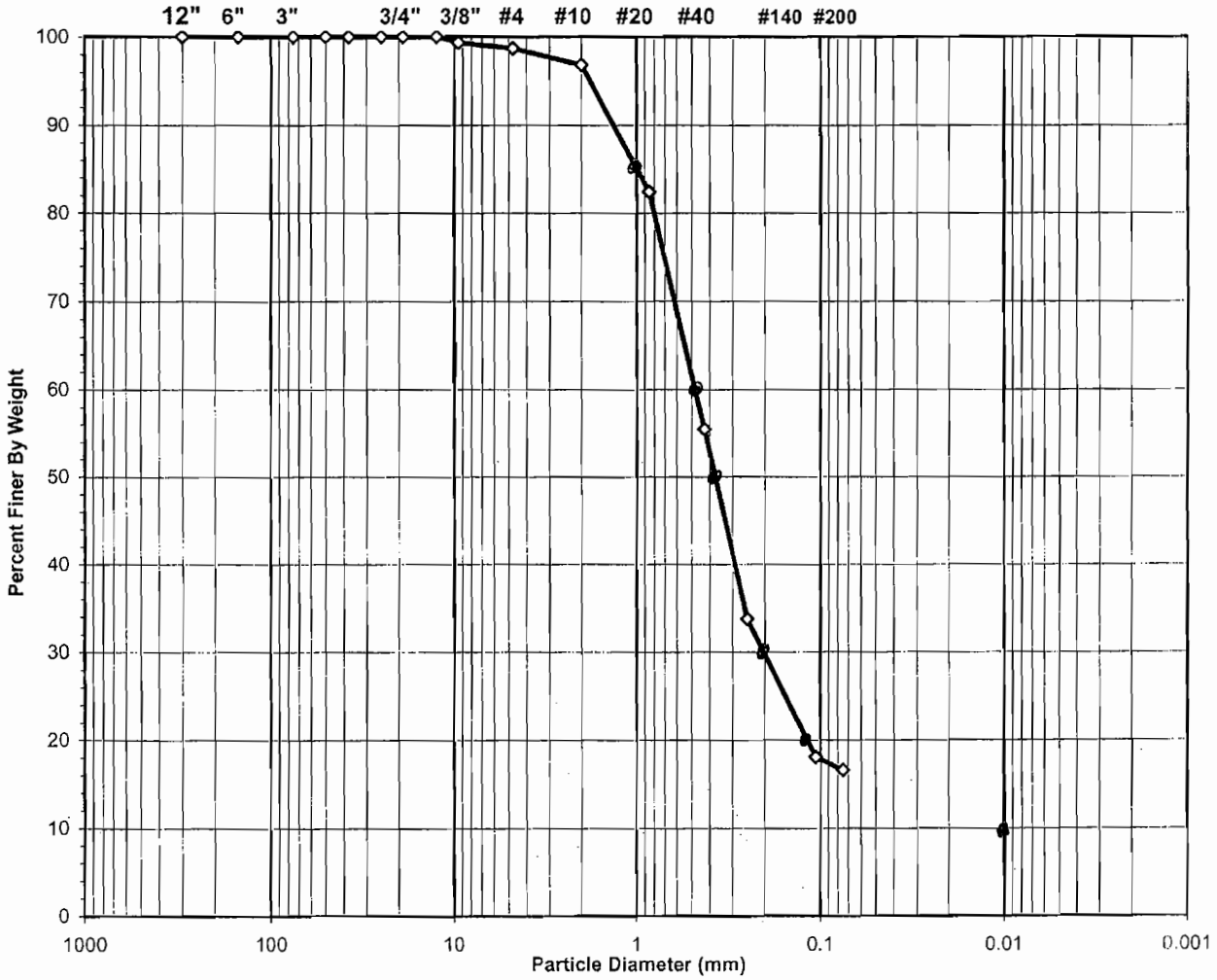
Geotechnics
INTEGRITY IN TESTING

## SIEVE ANALYSIS
ASTM D 422-63 (SOP-S3)

| | | | |
|---|---|---|---|
| Client | G.N. RICHARDSON & ASSOC. | Boring No. | NA |
| Client Reference | JOHNSTON CO. C&D LF AREA 2 CELL 1 | Depth (ft) | SURFACE |
| Project No. | 2006-643-04 | Sample No. | NA |
| Lab ID | 2006-643-04-01 | Soil Color | **TAN** |

| | *SIEVE ANALYSIS* | | *HYDROMETER* |
|---|---|---|---|
| *USCS* | gravel | sand | silt and clay |




***USCS Symbol*** ***SC, TESTED***

***USCS Classification*** ***CLAYEY SAND***

Tested By JBD Date 11/21/06 Checked By MCW Date 11/21/06



DCN: CT-S3C DATE 6-25-98 REVISION: 2

*C:\2006 PROJECTS\2006-643 GNRA JOHNSTON CO\[2006-643-04-01 SIEVE.XLS]Sheet1*

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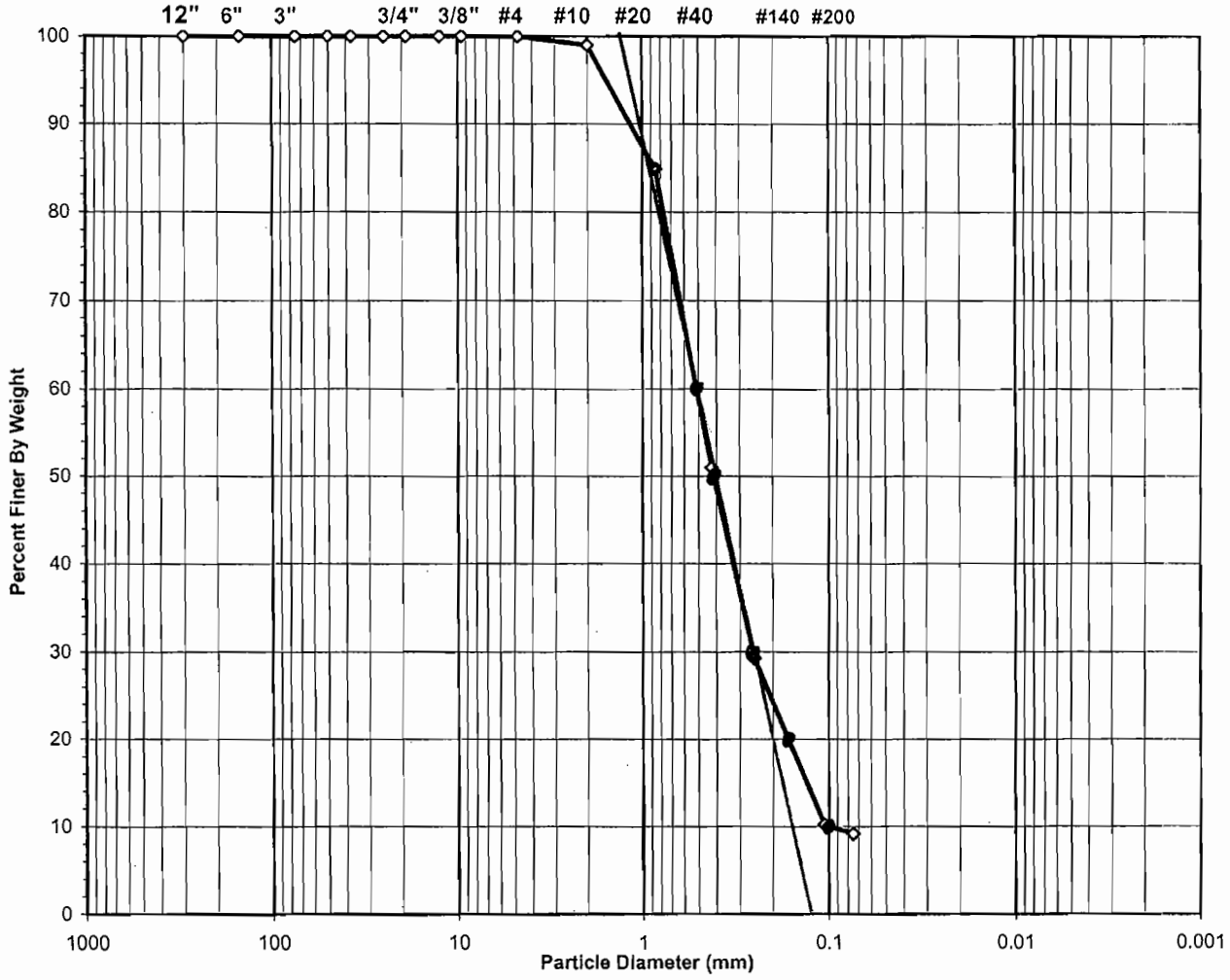
Geotechnics
INTEGRITY IN TESTING

## SIEVE ANALYSIS
ASTM D 422-63 (SOP-S3)

| | | | |
|---|---|---|---|
| Client | GN RICHARDSON & ASSOC. | Boring No. | TP-10 |
| Client Reference | JOHNSTON CO. C&D LF AREA 2 CELL 1 | Depth (ft) | 2-3 |
| Project No. | 2006-643-06 | Sample No. | 12-04-06 |
| Lab ID | 2006-643-06-01 | Soil Color | **REDDISH TAN** |

| | *SIEVE ANALYSIS* | | *HYDROMETER* |
|---|---|---|---|
| *USCS* | gravel | sand | silt and clay |




| | | | | | |
|---|---|---|---|---|---|
| ***USCS Symbol*** | ***SP-SM, TESTED*** | **D60 =** | **0.5** | **CC =** | **1.3** |
| ***USCS Classification*** | ***POORLY GRADED SAND WITH SILT*** | **D30 =** | **0.3** | **CU =** | **5.1** |
| | | **D10 =** | **0.1** | | |

Tested By SGH Date 12/11/2006 Checked By [signature] Date 12-12-06



DCN: CT-S3C DATE 6-25-98 REVISION: 2 *\\Lab1\c\2006 PROJECTS\2006-643 GNRA JOHNSTON CO\[2006-643-06-01 SIEVE.XLS]Sheet1*

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PROJECT Johnston County MSWLF - Phase 4A - Cell 3

SUBJECT Rain Gutters & Down Pipe Sizing

SHEET 1 OF 4
JOB NO. JOHNSTON-07-2
DATE 2/16/07
COMPUTED BY PKS
CHECKED BY

**Objective** To design rain gutters and down pipes to handle the peak discharge from the design storm.

**Reference** Debo, T.N., and Reese, A.J. (1995), Municipal Storm Water Management, Lewis Publishers, Boca Raton, FL.

Malcom, H. Rooney (1989 & 2003 Supplement), Elements of Urban Stormwater Design, NC State Univ., Raleigh, NC.

**Analysis** The following approach is used in the design of rain gutters and down pipes:

1. Determine the peak discharge from the design storm(s). Use the Rational Method.

2. For each pipe size, determine the maximum area (A), to handle the predicted peak discharge (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.

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

**Calculations**

- Rain Gutters & Down Pipes:

Determine Flow Capacity of Pipe:

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

where:
$Q_{max}$ = flow capacity of pipe (cfs)
$D$ = inside diameter of pipe (ft)
$S$ = pipe slope (ft/ft)
$n$ = Manning's roughness coefficient

FCS RAIN GUTTERS & DPIPES.WPD

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Determine Factor of Safety (FS):

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

Iterate the drainage area (A) to each drainage structure such that $Q_{max}/Q \geq$ the desired factor of safety.

Determine Flow Depth:

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

where: $h$ = flow depth (inches)
$\theta$ = central angle

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

$K$ = constant

$$K = 0.673 Q n D^{-8/3} S^{-1/2} \qquad \text{(D\&R Equation 8.27)}$$

Determine Flow Velocity:

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

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):

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

Iterate the drainage area (A) to each drainage structure such that $Q_{max}/Q \geq$ the desired factor of safety.

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SHEET: 4 / 4
JOB #: JOHNSTON-07-2
DATE: 2/28/07
BY: PKS
CHKD BY:

**Johnston County MSW Landfill - Phase 4A - Cell 3**
**Rain Gutters & Down Pipe Sizing**

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" | 3.65 | 14.95 | 12.9 | 7 | 16.51 | 1.10 | 0.282 | 235 | 9.43 | 0.71 | 21.02 |
| 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" | 7.15 | 29.28 | 16.6 | 7 | 32.34 | 1.10 | 0.282 | 235 | 12.14 | 1.18 | 24.86 |

**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 |

RICHARDSON SMITH GARDNER & ASSOCIATES
Engineering and Geological Services
14 N. Boylan Avenue Tel: 919-828-0577
Raleigh, NC 27603 Fax: 919-828-3899

SHEET: 1 / 2
JOB #: JOHNSTON-07-2
DATE: 6/5/07
BY: PKS
CHKD BY:

**Johnston County MSW Landfill - Phase 4A**
**Piggyback Liner Evaluation**

**Objective:** To estimate the amount of strain in the piggyback liner system.

**Given:**
1. Results from analysis of original piggyback liner critical Cross Section B (**See Attached**).
2. Revised Critical Cross Section B.

**Assumptions:**
1. Conservatively assume that the increase in load at originally analyzed node results in a linear increase in Y displacement.
2. Ignore any X displacement. This was a very small number in the original analysis.
3. As in the original analysis, assume that there is zero displacement at Start, End, and Nodes 11 and 17.

**Calculations:**

| Node * | X Base (ft) | Y Base (ft) | Segment Length (ft) | From Original Analysis (Load Step 4) Y Displacement (Primary) (ft) | Y Displacement (Secondary) (ft) | Y Displacement (Total) (ft) | Waste Thickness Over Liner (Original) (ft) | (Revised) (ft) | Increase in Load (%) | Assumed Y Displacement (Total) (ft) | Revised Segment Length (ft) | Strain Total (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Start | 31.000 | 254.000 | | 0.000 | 0.000 | 0.000 | 0 | 0 | 0.00 | 0.000 | | |
| 73 | 350.000 | 212.000 | 321.753 | -3.203 | -0.572 | -3.775 | 64 | 99 | 54.69 | -5.839 | 322.567 | 0.25 |
| 11 | 431.000 | 186.000 | 85.071 | 0.000 | 0.000 | 0.000 | 97 | 132 | 36.08 | 0.000 | 83.471 | -1.88 |
| 17 | 641.000 | 186.000 | | 0.000 | 0.000 | 0.000 | 105 | 139 | 32.38 | 0.000 | 667.441 | |
| 88 | 773.000 | 220.500 | 136.434 | -3.979 | -0.616 | -4.595 | 63 | 101 | 60.32 | -7.367 | 134.760 | -1.23 |
| 90-91 | 882.000 | 223.500 | 109.041 | -3.802 | -0.606 | -4.408 | 60 | 90 | 50.00 | -6.612 | 109.065 | 0.02 |
| End | 1063.000 | 271.500 | 187.257 | 0.000 | 0.000 | 0.000 | 0 | 0 | 0.00 | 0.000 | 189.059 | 0.96 |

=> MAX. O.K.

* — Ref. Fig 3-1 in Engineering Plan.

G.N. Richardson & Associates
ENGINEERING AND GEOLOGICAL SERVICES

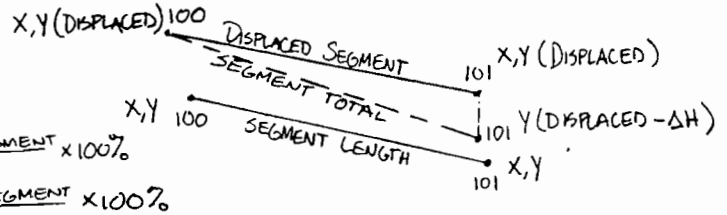
**Johnston County Landfill**
**Johnston County, NC**
**Piggyback Liner Strains - Revised Waste Unit Weight**

SHEET: 2/2
JOB #: Johnston-9
DATE STARTED: 10/20/99
DATE PRINTED: 10/29/99
BY: DTD
CHKD BY: PKS

**Objective:** To determine the amount of strain applied to the piggyback liner system.

**Given:**
$C_c$ = 0.04
$\gamma$ = 80 pcf - existing waste
$\gamma$ = 70 pcf - proposed waste

$\Delta H = C_c H_o \log(P_F/P_o)$
$\Delta H$ = Settlement
$P_o$ = Intial average vertical stre = 0.5 X Ex. Waste Ht. X $\gamma_1$
$P_F$ = Final average vertical str = 0.5 X Prop. Waste Ht. X $\gamma_2$




**Reference:**
1) Section B-B
2) Johnston County Site Plan
3) Load Step 4 - Finite Element Analysis

$$\text{STRAIN (ELASTIC)} = \frac{\text{DISPLACED SEG.} - \text{SEGMENT}}{\text{SEGMENT}} \times 100\%$$

$$\text{STRAIN (TOTAL)} = \frac{\text{SEGMENT TOTAL} - \text{SEGMENT}}{\text{SEGMENT}} \times 100\%$$

**Calculations:**

| Node | X Base (ft) | Y Base (ft) | X Displacement (ft) | Y Displacement (ft) | Segment Length (ft) | Displaced Segment (ft) | Strain (%) | Ex. Waste Height (ft) | Prop. Waste Height (ft) | $P_o$ Stress (psf) | $P_F$ Stress (psf) | $\Delta H$ (ft) | Segment Total (ft) | Strain Total (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 100 | 99.995934 | 254.07133 | 8.447E-02 | 9.697E-02 | | | | 74 | 0 | 2962.85 | 2962.85 | 0.00000 | | |
| 101 | 140.10295 | 245.32902 | 9.249E-03 | -1.099E+00 | 41.0488 | 41.2470 | 0.48 | 65 | 17 | 2613.16 | 3208.16 | 0.23281 | 41.3037 | 0.62 |
| 102 | 180.17428 | 236.85308 | -8.913E-02 | -2.477E+00 | 40.9579 | 41.1696 | 0.52 | 57 | 29 | 2274.12 | 3289.12 | 0.36446 | 41.2013 | 0.59 |
| 70 | 220.31863 | 228.81292 | -1.294E-01 | -2.980E+00 | 40.9416 | 41.0039 | 0.15 | 49 | 40 | 1952.52 | 3352.52 | 0.45840 | 41.0236 | 0.20 |
| 71 | 260.29230 | 220.49789 | -5.117E-02 | -3.175E+00 | 40.8293 | 40.9459 | 0.29 | 40 | 53 | 1619.92 | 3474.92 | 0.53692 | 40.9623 | 0.33 |
| 72 | 308.17599 | 211.09450 | -1.421E-01 | -2.893E+00 | 48.7983 | 48.6554 | -0.29 | 31 | 66 | 1243.78 | 3553.78 | 0.56710 | 48.6611 | -0.28 |
| → 73 | 330.19894 | 211.02300 | -2.011E-01• | -3.203E+00 | 22.0231 | 21.9673 | -0.25 | 31 | 67 | 1240.92 | 3585.92 | 0.57189 | 21.9674 | -0.25 |
| 74 | 345.16376 | 203.73478 | -1.835E-01 | -2.540E+00 | 16.6452 | 16.3820 | -1.58 | 24 | 78 | 949.39 | 3679.39 | 0.55856 | 16.3766 | -1.61 |
| 41 | 360.07881 | 196.38848 | -2.078E-01• | -1.857E+00 | 16.6261 | 16.3136 | -1.88 | 16 | 85 | 655.54 | 3630.54 | 0.48731 | 16.2847 | -2.05 |
| 42 | 372.54187 | 190.66988 | -1.223E-01 | -9.847E-01 | 13.7124 | 13.4519 | -1.90 | 11 | 85 | 426.80 | 3401.80 | 0.38475 | 13.4153 | -2.17 |
| 11 | 385.00000 | 185.00000 | 0.000E+00 | 0.000E+00 | 13.6877 | 13.4245 | -1.92 | 0 | 97 | 0.00 | 3395.00 | 0.00000 | 13.2952 | -2.87 |
| 17 | 590.00000 | 185.00000 | 0.000E+00 | 0.000E+00 | | | | 0 | 107 | 0.00 | 3745.00 | 0.00000 | | |
| 50 | 605.00472 | 188.75805 | 7.452E-02 | -8.627E-01 | 15.4682 | 15.3547 | -0.73 | 9 | 103 | 350.32 | 3955.32 | 0.36879 | 15.2894 | -1.16 |
| 51 | 619.99317 | 192.57837 | 1.185E-01 | -1.628E+00 | 15.4677 | 15.3398 | -0.83 | 13 | 99 | 503.13 | 3968.13 | 0.45126 | 15.3236 | -0.93 |
| 84 | 639.90879 | 197.45355 | 8.593E-02 | -2.192E+00 | 20.5036 | 20.3450 | -0.77 | 17 | 92 | 698.14 | 3918.14 | 0.52300 | 20.3299 | -0.85 |
| 85 | 659.82456 | 202.20224 | 3.109E-02 | -2.813E+00 | 20.4741 | 20.2854 | -0.92 | 22 | 86 | 888.09 | 3898.09 | 0.57050 | 20.2757 | -0.97 |
| 87 | 699.83782 | 210.82952 | -1.270E-02 | -3.523E+00 | 40.9328 | 40.7461 | -0.46 | 31 | 76 | 1233.18 | 3893.18 | 0.61570 | 40.7373 | -0.48 |
| → 88 | 736.89066 | 221.57476 | -1.741E-01 | -3.979E+00 | 38.5794 | 38.2994 | -0.73 | 42 | 64 | 1662.99 | 3902.99 | 0.61615 | 38.2993 | -0.73 |
| 89 | 779.94734 | 221.39990 | 3.929E-03 | -3.763E+00 | 43.0570 | 43.2347 | 0.41 | 41 | 64 | 1656.00 | 3896.00 | 0.61530 | 43.2347 | 0.41 |
| 90 | 819.94947 | 222.16585 | 2.022E-02 | -3.802E+00 | 40.0095 | 40.0250 | 0.04 | 42 | 62 | 1686.63 | 3856.63 | 0.60582 | 40.0252 | 0.04 |
| → 91 | 859.96052 | 222.91228 | 6.655E-02 | -3.791E+00 | 40.0180 | 40.0645 | 0.12 | 43 | 60 | 1716.49 | 3816.49 | 0.59566 | 40.0647 | 0.12 |
| 92 | 899.95651 | 223.65015 | 1.296E-01 | -3.732E+00 | 40.0028 | 40.0670 | 0.16 | 44 | 60 | 1746.01 | 3846.01 | 0.59882 | 40.0669 | 0.16 |
| 93 | 939.93539 | 224.38966 | 1.995E-01 | -3.597E+00 | 39.9857 | 40.0584 | 0.18 | 44 | 56 | 1775.59 | 3735.59 | 0.57354 | 40.0589 | 0.18 |
| 94 | 979.89604 | 225.17327 | 2.757E-01 | -3.468E+00 | 39.9683 | 40.0472 | 0.20 | 45 | 52 | 1806.93 | 3626.93 | 0.54677 | 40.0478 | 0.20 |
| 95 | 1033.8250 | 225.07101 | 3.233E-01 • | -3.143E+00 | 53.9291 | 53.9770 | 0.09 | 45 | 48 | 1802.84 | 3482.84 | 0.51557 | 53.9772 | 0.09 |
| 129 | 1068.9224 | 232.29706 | 2.024E-01 | -2.590E+00 | 35.8335 | 35.8313 | -0.01 | 52 | 37 | 2091.88 | 3386.88 | 0.43775 | 35.8482 | 0.04 |
| 131 | 1087.8997 | 236.77086 | 1.700E-01 | -2.134E+00 | 19.4975 | 19.5758 | 0.40 | 57 | 28 | 2270.83 | 3250.83 | 0.35382 | 19.5971 | 0.51 |
| 133 | 1139.9943 | 248.03772 | -4.947E-02 | -5.456E-01 | 53.2991 | 53.4441 | 0.27 | 68 | 0 | 2721.51 | 2721.51 | 0.00000 | 53.5304 | 0.43 |

↑ Primary Finite Element

↑ Secondary

# Technical Specifications

## Johnston County Landfill
## Smithfield, North Carolina

Prepared for:
**Johnston County Department of Public Utilities**
**Smithfield, NC**

**June 2007**
**Revised: December 2008**

RICHARDSON SMITH GARDNER & ASSOCIATES
Engineering and Geological Services
14 N. Boylan Avenue
Raleigh, North Carolina 27603

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**JOHNSTON COUNTY LANDFILL**

**TECHNICAL SPECIFICATIONS**

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| 02710 | Drainage Aggregate (Leachate Management) |
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| 02930 | Revegetation |
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| 13255 | Landfill Gas System |

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## SECTION 02110

## SITE PREPARATION

Site Preparation: Site Preparation includes clearing, grubbing, and stripping operations which precede the proposed construction.

A. DESCRIPTION

1. General:

a. The Contractor shall furnish all labor, material, and equipment to complete Site Preparation in accordance with the Contract Drawings and these Specifications.

b. Principal items of work include:

1. Notifying all authorities owning utility lines running to or on the property. Protect and maintain all utility lines to remain and cap those that are not required in accordance with instructions of the Utility Companies, and all other authorities having jurisdiction.

2. Clearing the site within the clearing limits, including removal of grass, brush, shrubs, trees, loose debris, and other encumbrances except for trees to remain.

3. Boxing and protecting all areas to be preserved.

4. Removing all topsoil from designated areas and stockpiling on site where directed by the Engineer for future use.

5. Disposing from the site all debris resulting from work under this Section.

2. Related Work:

Related Contract Work is described in the following sections of the Specifications:

| Work | Section |
|---|---|
| Excavation | 02222 |
| Embankment | 02223 |

B. MATERIALS Not Used.

C. SUBMITTALS Not Used.

D. CONSTRUCTION

1. Clearing of the Site:

a. Clearing limits, as shown on the Contract Drawings, shall be established by the Contractor's Surveyor. Once established, the clearing limits shall be inspected and approved by the Engineer prior to clearing the affected areas.

b. Before removal of topsoil, and start of excavation and grading operations, the areas within the clearing limits shown on the Contract Drawings shall be cleared and grubbed.

c. Clearing shall consist of cutting, removal, and satisfactory disposal of all trees, fallen timber, brush, bushes, rubbish, fencing, and other perishable and objectionable material.

Should it become necessary to remove a tree, bush, brush, or other plants outside the clearing limits, the Contractor shall do so only after permission has been granted by the Engineer.

d. Excavation resulting from the removal of trees, roots, and the like shall be filled with suitable material, as approved by the Engineer, and thoroughly compacted per the requirements contained in Section 02223, Embankment, of these Specifications.

e. In temporary construction easement locations, only those trees and shrubs shall be removed which are in actual interference with excavation or grading work under this Contract, and removal shall be subject to approval by the Engineer. However, the Engineer reserves the right to order additional trees and shrubs removed at no additional cost to the Owner, if such, in his opinion, they are too close to the work to be maintained or have become damaged due to the Contractor's operations.

2. Stripping and Stockpiling Existing Topsoil:

a. Existing topsoil and sod on the site within areas designated on the Contract Drawings shall be stripped to whatever depth it may occur, and stored in locations directed by the Engineer.

b. The topsoil shall be free of stones, roots, brush, rubbish, or other unsuitable materials before stockpiling.

c. Care shall be taken not to contaminate the stockpiled topsoil with any unsuitable materials.

3. Grubbing:

a. Grubbing shall consist of the removal and disposal of all stumps, roots, logs, sticks, and other perishable materials to a depth of at least 6 inches below ground surfaces.

b. Large stumps located in areas to be excavated may be removed during grading operations, subject to the approval of the Engineer.

4. Disposal of Cleared and Grubbed Material:

All trees, stumps, roots, and bushes shall be disposed of by burning (Only if allowed by the Owner and local zoning) or shall be removed from the site and disposed of by the Contractor. The Contractor shall receive written authorization from the Owner prior to burning. Any material other than plant growth shall not be burned. On-site and off-site disposal areas are subject to approval by the Engineer. Ashes and residue from burning operations shall be removed from the site and disposed of by the Contractor. The Contractor shall also obtain all of the required permits for his burning operations, as applicable.

END OF SECTION

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# SECTION 02140

# DEWATERING

Dewatering: Dewatering refers to controlling and disposing of surface and shallow ground water as is necessary for proper excavation, compaction, and other operations requiring dry conditions.

## A. DESCRIPTION

### 1. General:

The Contractor shall furnish all labor, material, and equipment to complete Dewatering in accordance with the Contract Drawings and these Specifications.

### 2. Related Work:

Related Contract Work is described in the following sections of the Specifications:

| Work | Section |
|---|---|
| Excavation | 02222 |
| Embankment | 02223 |

## B. MATERIALS

Not Used.

## C. SUBMITTALS

Procedures for Dewatering proposed by the Contractor shall be submitted to the Engineer for review prior to any Dewatering operations.

## D. CONSTRUCTION

1. The Contractor shall do all Dewatering as required for the completion of the work. All surface or ground water removed by Dewatering operations shall be disposed of in accordance with all applicable regulations.

2. The Dewatering system shall be of sufficient size and capacity as required to control ground water or seepage to permit proper excavation operations, embankment construction and reconstruction, subgrade preparation, and to allow concrete to be placed in a dry condition. The system shall include a sump system or other equipment, appurtenances, and other related earthwork necessary for the required control of surface water. The Contractor shall drawdown ground water

to at least 3 feet below the bottom of excavations at all times in order to maintain a dry and undisturbed condition.

3. The Contractor shall take all the steps that he considers necessary to familiarize himself with the surface and subsurface site conditions, and shall obtain the data that is required to analyze the water and soil environment at the site and to assure that the materials used for the Dewatering systems will not erode, deteriorate, or clog to the extent that the Dewatering systems will not perform properly during the period of Dewatering.

4. The Contractor shall control, by acceptable means, all water regardless of source. Water shall be controlled and its disposal provided for at each berm, structure, etc. when necessary. The entire periphery of the excavation area shall be ditched and diked to prevent surface water from entering the excavation where applicable. The Contractor shall be fully responsible for disposal of the water and shall provide all necessary means at no additional expense to the Owner. The Contractor shall be solely responsible for proper design, installation, proper operation, maintenance, and any failure of any component of the system.

5. The Contractor shall be responsible for and shall repair without cost to the Owner, any damage to work in place and the excavation, including damage to the bottom due to heave and including removal of material and pumping out of the excavated area. The Contractor shall be responsible for damages to any other area or structure caused by his failure to maintain and operate the Dewatering system proposed and installed by the Contractor.

6. Leachate Seeps:

   Due to the nature of this project, the Contractor is responsible for the control of leachate seeps which develop within the Contract Limits whether created by his construction activities or not. The method(s) of control for leachate seeps shall be subject to the approval of the Owner and the Engineer.

END OF SECTION

# SECTION 02222

# EXCAVATION

Excavation: Excavation includes excavating, sealing, hauling, scraping, undercutting, removal of accumulated surface water or ground water, stockpiling, and all necessary and incidental items as required for bringing the landfill and related structures to the specified lines and grades.

## A. DESCRIPTION

### 1. General:

The Contractor shall furnish all labor, material, and equipment required to complete Excavation of the project area in accordance with the Contract Drawings and these Specifications, except as noted below:

a. Clearing and grubbing and removal of topsoil is addressed in Section 02110, Site Preparation, of these Specifications.

### 2. Related Work:

Related Contract Work is described in the following sections of the Specifications:

| Work | Section |
|---|---|
| Site Preparation | 02110 |
| Dewatering | 02140 |
| Embankment | 02223 |
| Erosion and Sedimentation Control | 02270 |
| Roadway Work | 02500 |
| CQA Manual | Attached |

### 3. Quality Assurance:

Quality Assurance during Excavation will be provided by the Owner as described in the accompanying Project CQA Manual.

### 4. Definitions:

a. Excavation: shall consist of the removal and satisfactory disposal and/or stockpiling of materials located with the limits of construction including widening cuts and shaping of slopes necessary for the preparation of

roadbeds, landfill slope areas, cutting of any ditches, channels, waterways, entrances, and other work incidental thereto.

b. Borrow: shall consist of approved on-site material required for the construction of embankments/fills or for other portions of the work.

c. Select Borrow: shall consist of approved off-site material required for the construction of embankments/fills, roadway subgrade, backfilling, or for other portions of the work as shown on Contract Drawings or in these Specifications. The Contractor shall make his own arrangements for obtaining select borrow and pay all costs involved.

d. Unsuitable Material: is any in-place or excavated material which contains undesirable materials, or is in a state which is not appropriate; in the opinion of the CQA Engineer, for the intended use or support of planned structures, embankment, or excavation. This may include but not be limited to organic material, waste/refuse, soft, or wet material not meeting required specifications, etc.

e. Unsuitable Materials Excavation (Overexcavation): shall consist of the removal and satisfactory disposal of all unsuitable material located within the limits of construction. Where excavation to the finished grade section shown results in a subgrade or slopes of unsuitable material, the Contractor shall overexcavate such material to below the grade shown on the Contract Drawings or as directed by the Engineer and CQA Engineer.

## B. MATERIALS

Excavation shall include the removal of all soil, weathered rock, boulders, conduits, pipe, and all other obstacles encountered and shown on the Contract Drawings or specified herein.

## C. SUBMITTALS

The Contractor shall submit the following to the CQA Engineer before approval is given to proceed:

1. Plans of open cut excavations showing side slopes and limits of the excavation at grade.

2. List of disposal site(s) for waste and unsuitable materials.

3. Descriptive information on Excavation equipment to be used.

D. CONSTRUCTION

1. The Contractor shall conduct Excavation activities in such a manner that erosion of disturbed areas and off site sedimentation is absolutely minimized as outlined in Section 02270, Erosion and Sedimentation Control, of these Specifications.

2. The Contractor shall excavate to the lines and grades shown on the Contract Drawings and stockpile all suitable excavated materials. As the excavation is made, the materials will be examined and identified to the CQA Engineer.

   The Contractor will perform all surveys necessary to establish and verify lines and grades for all Excavation, including pipe excavations, soil overexcavation, and anchor trenches.

3. Stockpiling:

   The Contractor shall stockpile the materials in appropriate stockpiles as approved by the CQA Engineer.

   Stockpiles shall be properly sloped and the surfaces sealed by the Contractor at the end of each working day, or during the day in the event of heavy rain, to the satisfaction of the Engineer.

4. The Contractor shall protect all existing facilities and structures including, but not limited to, existing utilities, monitoring wells, signs, grade stakes, etc. during the grading and stockpiling operations.

5. All excavations shall be made in the dry and in such a manner and to such widths as will give ample room for properly constructing and inspecting the structures and/or piping they are to contain and for such sheeting, timbering, pumping, and drainage as may be required.

6. The Contractor shall be responsible for Dewatering as described in Section 02140, Dewatering, of these Specifications, when necessary.

7. Excavation slopes shall be flat enough to avoid sloughs and slides that will cause disturbance of the subgrade or damage of adjacent areas. Slides and overbreaks which occur due to negligence, carelessness, or improper construction techniques on the part of the Contractor shall be removed and disposed of by the Contractor as directed by the Engineer at no additional cost to the Owner.

8. The intersection of slopes with natural ground surfaces, including the beginning and ending of cut slopes, shall be uniformly rounded. All protruding roots and other vegetation shall be removed from slopes.

9. The bottom of all excavations for structures and pipes shall be examined by the CQA Engineer for bearing value and the presence of unsuitable material. If, in the opinion of the CQA Engineer, additional Excavation is required due to the low bearing value of the subgrade material, or if the in-place materials are soft, yielding, pumping and wet, the Contractor shall remove such material to the required width and depth and replace it with thoroughly compacted structural fill, or material directed by the CQA Engineer. No payment will be made for subgrade disturbance caused by inadequate Dewatering or improper construction methods.

10. Any areas excavated below design subgrade elevations by the Contractor, unless directed by the CQA Engineer, shall be brought back to design elevations at no cost to the Owner. The Contractor shall place and compact such material in accordance with Section 02223, Embankment, of these Specifications.

11. The Contractor shall dispose of excess or unsuitable excavation materials on-site at location(s) approved by the Owner.

12. The Contractor shall properly level-off bottoms of all excavations. Proof-rolling shall be conducted with appropriate equipment.

13. Upon reaching subgrade elevations shown in excavation areas, the Contractor shall scarify subgrade soils to a minimum depth of 6" and obtain the CQA Engineer's approval of quality. If unsuitable materials are encountered at the subgrade elevation, perform additional excavations as approved by the CQA Engineer to remove unsuitable materials.

14. Overexcavation and Backfill:

    Where subgrade materials are determined to be unsuitable, such materials shall be removed by the Contractor to the lengths, widths and depths approved by the CQA Engineer and backfilled with suitable material in accordance with Section 02223, Embankment, of these Specifications unless further excavation or earthwork is required. No additional payment will be made for such excavation and backfill 1 foot or less than the finished subgrade. Unsuitable material excavation greater than 1 foot beneath the finished subgrade shall be made on a unit price basis for excavation and backfill, only as approved by the Engineer and CQA Engineer prior to the work. Unit price for overexcavation and backfill greater than 1 foot in depth shall include disposal of unsuitable materials.

15. All cuts shall be brought to the grade and cross section shown on the Contract Drawings, or established by the Engineer, prior to final inspection.

16. The Contractor shall protect finished lines and grades of completed excavation against excessive erosion, damage from trafficking, or other causes and shall repair any damage at no additional cost to the Owner.

17. Trench Excavation:

a. All pipe Excavation and trenching shall be done in strict accordance with these Specifications, all applicable parts of the OSHA Regulations, 29 CFR 1926, Subpart P, and other applicable regulations. In the event of any conflicts in this information, safe working conditions as established by the appropriate OSHA guidelines shall govern.

b. The minimum trench widths shall be as indicated on the Contract Drawings. Enlargements of the trench shall be made as needed to give ample space for operations at pipe joints. The width of the trench shall be limited to the maximum dimensions shown on the Contract Drawings, except where a wider trench is needed for the installation of and work within sheeting and bracing.

c. Except where otherwise specified, excavation slopes shall be flat enough to avoid slides which will cause disturbance of the subgrade, damage to adjacent areas, or endanger the lives or safety of persons in the vicinity.

d. Hand excavation shall be employed wherever, in the opinion of the Engineer, it is necessary for the protection of existing utilities, poles, trees, pavements, obstructions, or structures.

e. No greater length of trench in any location shall be left open, in advance of pipe laying, than shall be authorized or directed by the Engineer and, in general, such length shall be limited to approximately one hundred (100) feet.

f. Pipe Bedding: All pipe bedding shall be as shown on the Contract Drawings, unless otherwise specified herein.

18. Sheeting and Bracing:

a. The Contractor shall furnish, place, and maintain such sheeting and bracing which may be required to support sides of Excavation or to protect pipes and structures from possible damage and to provide safe working conditions in accordance with current OSHA requirements. If the Engineer is of the opinion that at any point sufficient or proper supports have not been provided, he may order additional supports put in at the sole expense of the Contractor. The Contractor shall be responsible for the adequacy of all sheeting and bracing used and for all damage resulting from sheeting and bracing failure or from placing, maintaining, and removing it.

b. The Contractor shall exercise caution in the installation and removal of sheeting to insure that excessive or unusual loadings are not transmitted to any new or existing structure. The Contractor shall promptly repair at his expense any and all damage that can be reasonably attributed to sheeting installation or removal.

c. All sheeting and bracing shall be removed upon completion of the work.

19. If grading operations are suspended for any reason whatsoever, partially completed cut and fill slopes shall be brought to the required slope and the work of seeding and mulching or other required erosion and sedimentation control operations shall be performed at the Contractor's sole expense.

END OF SECTION

## SECTION 02223

## EMBANKMENT

Embankment: Embankment is the on-site compacted fill that provides the foundation and the berms for the containment area, the subgrade for some access roadways and structures, and backfill around structures and piping.

A. DESCRIPTION

1. General:

The Contractor shall furnish all labor, material, and equipment to complete Embankment including borrowing, hauling, screening, discing, drying, compaction, control of surface and subsurface water, final grading, sealing, and all necessary and incidental items as detailed or required to complete the Embankment, all in accordance with the Contract Drawings and these Specifications.

2. Related Work:

Related Contract Work is described in the following sections of the Specifications:

| Work | Section |
|---|---|
| Dewatering | 02140 |
| Excavation | 02222 |
| Erosion and Sedimentation Control | 02270 |
| Roadway Work | 02500 |
| CQA Manual | Attached |

3. Reference Standards:

The latest revision of the following standards of the American Society of Testing and Materials (ASTM) are hereby made a part of these Specifications.

| | |
|---|---|
| ASTM D 698 | Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft$^3$). |
| ASTM D 1556 | Standard Test Method for Density and Unit Weight of Soil in Place by the Sand-Cone Method. |

| | |
|---|---|
| ASTM D 2167 | Standard Test Method for Density and Unit Weight of Soil in Place by the Rubber Balloon Method. |
| ASTM D 2216 | Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass. |
| ASTM D 2488 | Standard Practice for Description and Identification of Soils (Visual-Manual Procedure). |
| ASTM D 2937 | Standard Test Method for Density of Soil in Place by the Drive Cylinder Method. |
| ASTM D 4643 | Standard Test Method for Determination of Water (Moisture) Content of Soil by the Microwave Oven Method. |
| ASTM D 4959 | Standard Test Method for Determination of Water (Moisture) Content of Soil by Direct Heating Method. |
| ASTM D 6938 | Standard Test Methods for In-Place Density and Water Content of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth). |

4. Quality Assurance:

Quality Assurance during placement of Embankment will be provided by the Owner as described in the accompanying Project CQA Manual.

5. Definitions:

a Embankment: Shall include construction of all site earthwork including roadways, subgrade, perimeter berm embankments, including preparation of the areas upon which materials are to be placed. Embankment may also be referred to as structural and/or controlled fill. All Embankment materials may be either (off-site) Select Borrow or (on-site) Borrow unless otherwise noted on Contract Drawings or specified by the Engineer.

b. Prepared Subgrade: The ground surface after clearing, grubbing, stripping, excavation, scarification, and/or compaction, and/or proof rolling to the satisfaction of the CQA Engineer.

c. Well-Graded: A mixture of particle sizes that has no specific concentration or lack thereof of one or more sizes. Well-graded does not define any numerical value that must be placed on the coefficient of uniformity, coefficient of curvature, or other specific grain size

distribution parameters. Well-graded is used to define a material type that, when compacted, produces a strong and relatively incompressible soil mass free from detrimental voids.

d. Unclassified Fill: The nature of materials to be used is not identified or described herein but must be approved by the Engineer prior to use.

B. MATERIALS

1. Embankment materials shall consist of clean well-graded natural soil classified as SW, SM, SM-SC, SC, ML, CL-ML, or CL (ASTM D 2488) containing no topsoil or other deleterious material. Other material classifications may be approved by the Engineer.

2. Stones or rock fragments shall not exceed one half the maximum lift thickness as compacted in any dimension. Isolated rocks shall be a maximum of 24-inches in any dimension.

C. SUBMITTALS

The Contractor shall submit the following to the CQA Engineer before approval is given to proceed:

1. Descriptive information on compaction equipment to be used for construction of Embankment.

2. Descriptive information on the location and source of any off-site borrow material to be used for Embankment, where applicable. Information shall include Standard Proctor curves (ASTM D698) for each borrow material.

D. CONSTRUCTION

1. The Contractor shall conduct Embankment activities in such a manner that erosion of disturbed areas and off-site sedimentation is absolutely minimized as outlined in Section 02270, Erosion and Sedimentation Control, of these Specifications.

2. All placement and compaction of Embankment shall be performed only when the CQA Engineer is informed by the Contractor of intent to perform such work.

3. Embankment shall be placed and compacted to the lines and grades shown on the Contract Drawings. Placement of Embankment outside the construction limits shall occur only as directed and approved by the Engineer.

The Contractor will perform all surveys necessary to establish and verify lines and grades for all Embankment.

4. The Contractor shall protect all existing facilities including, but not limited to, utilities and monitoring wells.

5. Subgrade Preparation:

   a. The CQA Engineer shall inspect the exposed subgrade prior to placement of Embankment to assure that all rocks, topsoil, vegetation, roots, debris, or other deleterious materials have been removed.

   b. Prior to placement of Embankment, the exposed subgrade shall be proofrolled using a static smooth-drum roller, loaded tandem axle dump truck, or other suitable equipment in the presence of the CQA Engineer. Any soft or unsuitable materials revealed before or during the in-place compaction shall be removed as directed by the CQA Engineer and replaced with suitable Embankment.

6. Surfaces on which Embankment is to be placed, shall be scarified or stepped in a manner which will permit bonding of the Embankment with the existing surface.

7. The Contractor shall be responsible for preparing the materials for the Embankment, including but not limited to, in-place drying or wetting of the soil necessary to achieve the compaction criteria of these Specifications.

8. The Contractor shall be responsible for Dewatering as described in Section 02140, Dewatering, of these Specifications, when necessary.

9. Embankment materials shall be placed in a manner permitting drainage and in continuous, approximately horizontal layers.

10. Compaction Requirements:

    a. The Contractor shall compact Embankment in accordance with the requirements shown in Table 1 of this section. If Embankment does not meet the specified requirements, the Contractor shall rework the material, as may be necessary and continue compaction to achieve these requirements, or remove and replace the material to achieve the specified requirements, at Contractor's expense.

    b. Each lift shall be compacted prior to placement of succeeding lifts. In confined areas, mechanical equipment, suitable for small areas and capable of achieving the density requirements, shall be required.

c. Lift compaction shall be performed with an appropriately heavy, properly ballasted, penetrating-foot or smooth-drum vibratory compactor depending on soil type. Compaction equipment shall be subject to approval by the CQA Engineer.

11. Embankment that becomes excessively eroded, soft, or otherwise unsuitable shall be removed or repaired by the Contractor as directed by the CQA Engineer, at no cost to the Owner.

12. The exposed surface of Embankment shall be rolled with a smooth-drum roller at the end of each work day to protect from adverse weather conditions.

13. Where Embankment is to be placed and compacted on slopes that are steeper than 3:1, the subgrade shall be benched to a minimum depth of 6 inches and the Embankment shall be placed in horizontal lifts.

14. Backfilling for Structures and Piping:

a. All structures, including manholes and pipes shall be backfilled with Embankment as shown in the Contract Drawings and as described in these Specifications.

b. Where sheeting is used, the Contractor shall take all reasonable measures to prevent loss of support beneath and adjacent to pipes and existing structures when sheeting is removed. If significant volumes of soil cannot be prevented from clinging to the extracted sheets, the voids shall be continuously backfilled as rapidly as possible. The Contractor shall thereafter limit the depth below subgrade that sheeting will be driven in similar soil conditions or employ other appropriate means to prevent loss of support.

c. When backfilling around structures, do not backfill until concrete has sufficiently cured (as determined by the CQA Engineer) and is properly supported. Place backfill in a manner to avoid displacement or damage of structures.

**TABLE 1: REQUIRED EMBANKMENT PROPERTIES**

| ITEM | Required % Standard Proctor (ASTM D698)[2] | Required Moisture Content[3] | Maximum Lift Thickness (Compacted) (inches) |
|---|---|---|---|
| Embankment | 95 | As Required for Compaction | 8 |
| Embankment Beneath Structures and Roads[1] | 98 | | 8 |
| Backfill Around Structures | 95 | | 8 |
| Backfill in Pipe Trenches | 95 | | 6 |
| Unclassified Fill | N/A | N/A | N/A |

Notes:

1. Embankment beneath structures shall be considered to include a zone 10 feet out from the foundation of the structure extending down to the natural ground on a 45° slope. Embankment beneath roads shall be considered to include all embankment placed within 2 vertical feet of the final wearing surface and shall also include shoulders.
2. Determine field density using ASTM D 6938, ASTM D 1556, ASTM D 2167, or ASTM D 2937.
3. Determine field moisture content using ASTM D 6938, ASTM D 2216, ASTM D 4643, or ASTM D 4959.
4. The Engineer may allow exceptions to the above criteria for areas outside of the containment area which are not subject to significant long-term loads.

END OF SECTION

**SECTION 02240**

**GEOTEXTILES**

Geotextiles: For the proposed construction, a Type GT-S (Separator/Filter) Geotextile is specified. The Type GT-S Geotextile will be placed in the landfill gas system, leachate collection system, between soil subgrade and aggregate in access roads, and in some erosion control and drainage applications.

A. DESCRIPTION

1. General:

The Contractor shall furnish all labor, material, and equipment to complete installation of Geotextiles including all necessary and incidental items as detailed or required for the Contractor to complete the installation in accordance with the Contract Drawings and these Specifications, except as noted below:

a. Geotextiles used as a Silt Fence is covered under Section 02270, Erosion and Sedimentation Control, of these Specifications.

2. Related Work:

Related Contract Work is described in the following sections of the Specifications:

| Work | Section |
|---|---|
| Erosion and Sedimentation Control | 02270 |
| Roadway Work | 02500 |
| Drainage Aggregate (Leachate Management) | 02710 |
| Drainage Aggregate (Final Cover) | 02711 |
| Landfill Gas System | 13255 |
| CQA Manual | Attached |

3. Reference Standards:

The latest revision of the following standards of the American Society of Testing and Materials (ASTM) and the American Association of State Highway and Transportation Officials (AASHTO) are hereby made a part of these specifications.

| | |
|---|---|
| ASTM D 3786 | Test Method for Hydraulic Bursting Strength of Knitted Goods and Nonwoven Fabrics: Diaphragm Bursting Strength Tester Method. |
| ASTM D 4355 | Standard Test Method for Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water (Xenon-Arc Type Apparatus). |
| ASTM D 4491 | Standard Test Methods for Water Permeability of Geotextiles by Permittivity. |
| ASTM D 4533 | Standard Test Method for Trapezoid Tearing Strength of Geotextiles. |
| ASTM D 4632 | Standard Test Method for Grab Breaking Load and Elongation of Geotextiles. |
| ASTM D 4751 | Standard Test Method for Determining Apparent Opening Size of a Geotextile. |
| ASTM D 4833 | Standard Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products. |
| ASTM D 5261 | Standard Test Method for Measuring Mass per Unit Area of Geotextiles. |
| AASHTO M 288 | Standard Specification for Geotextiles. |

4. Quality Assurance:

Quality Assurance during installation of Geotextiles will be provided by the Owner as described in the accompanying Project CQA Manual.

B. MATERIALS

1. General:

The materials supplied under these Specifications shall consist of new, first-quality products designed and manufactured specifically for the purpose of this work, which shall have been satisfactorily demonstrated, by prior use, to be suitable and durable for such purposes.

Labels on each roll of Geotextile shall identify the length, width, lot and roll numbers, and name of Manufacturer.

2. The Type GT-S Geotextile shall be a nonwoven spunbonded or nonwoven needlepunched synthetic fabric consisting of polyester or polypropylene manufactured in a manner approved by the Engineer. Woven fabrics may be used in certain applications if approved in advance by the Engineer.

3. The Type GT-C Geotextile shall be a nonwoven needlepunched synthetic fabric consisting of polyester or polypropylene manufactured in a manner approved by the Engineer.

4. All Geotextiles shall conform to the properties listed in Table 1 of this section.

C. SUBMITTALS

Prior to the installation of Geotextiles, the Contractor shall submit the following to the CQA Engineer:

1. Mill Certificate and Sample: Prior to shipping to the site, the Contractor shall submit a mill certificate or affidavit signed by a legally authorized official of the Manufacturer for each type of Geotextile attesting that the Geotextiles meet the physical and manufacturing requirements stated in these Specifications. The Contractor shall also submit a sample of each Geotextile to be used. The samples shall be labeled with the product name and be accompanied by the Manufacturer's specifications.

2. Shipping, Handling, and Storage Instructions: The Manufacturer's plan for shipping, handling, and storage shall be submitted for review.

3. Seaming Procedures:

   Submit proposed seaming procedures including proposed method and equipment.

4. Quality Control Certificates: For Geotextiles delivered to the site, quality control certificates, signed by the Manufacturer's quality assurance manager shall be provided which represent every roll of each type of Geotextile supplied. Each certificate shall have the roll identification number(s), test methods, frequency, and test results. At a minimum, the test results and frequency of testing shall be as shown in Table 2 of this section.

5. Furnish copies of the delivery tickets or other approved receipts as evidence for materials received that will be incorporated into the construction.

D. CONSTRUCTION

1. Shipping, Handling, and Storage:

All Geotextiles shall be shipped, handled, and stored in strict accordance with the Manufacturer's recommendations.

2. Failing CQA Material Control Tests:

Geotextiles that are rejected upon testing shall be removed from the project site and replaced at Contractor's cost. Sampling and CQA testing of Geotextiles supplied as replacement for rejected material shall be performed by the CQA Engineer at Contractor's cost.

3. Installation:

a. The surface receiving the Geotextiles shall be prepared to a relatively smooth condition, free of obstructions, standing water, excessive depressions, debris, and very soft, excessively wet, and/or loose pockets of soil. This surface shall be approved by the CQA Engineer prior to Geotextile placement.

b. Geotextiles shall be placed to the lines and grades shown on the Contract Drawings. At the time of installation, Geotextiles shall be rejected by the CQA Engineer if they have defects, rips, holes, flaws, evidence of deterioration, or other damage.

c. The Geotextiles shall be placed smooth and free of excessive wrinkles.

d. On slopes, Geotextiles shall be anchored at the top and unrolled down the slope. In the presence of wind, all Geotextiles shall be weighted with sandbags or other material as approved by the CQA Engineer. Geotextiles uplifted by wind may be reused upon approval by the CQA Engineer.

4. Seams:

a. All Geotextile seams shall be continuously sewn or heat bonded with methods approved by the Engineer. All seams must be approved by the CQA Engineer.

b. On slopes of 6H:1V or steeper, all seams shall be oriented parallel to (in the direction of) the slope unless otherwise approved by the Engineer.

c. Seams to be sewn shall be sewn using a Type 401 stitch. One or two rows of stitching may be used. Each row of stitching shall consist of 4 to 7

stitches per inch. The minimum distance from the geotextile edge to the stitch line nearest to that edge (seam allowance) shall be 1.5 inches if a Type SSa (prayer or flat) seam is used. The minimum seam allowance for all other seam types shall be 1.0 inches.

d. Seams to be heat bonded shall be bonded using hot plate, hot knife, ultrasonic, or other approved devices.

5. Repair Procedures:

a. Any Geotextile that is torn, punctured, or otherwise damaged shall be repaired or replaced, as directed by the CQA Engineer, by the Contractor at no additional cost to the Owner. The repair shall consist of a patch of the same type of Geotextile placed over the failed areas and shall overlap the existing Geotextile a minimum of 18 inches from any point of the rupture. Patches shall be spot sewn or heat bonded so as not to shift during cover placement.

b. Slopes Flatter Than 6H:1V: Damaged areas of a size exceeding 10 percent of the roll width shall be removed and replaced across the entire roll width with new material. Damaged areas of a size less than 10 percent of the roll width may be patched.

c. Slopes of 6H:1V or Steeper: Geotextile panels which require repair shall be removed and replaced with new material. Replacement material shall be sewn as previously described in this specification.

6. Cover Placement:

Placement of cover over Geotextiles shall be performed in a manner as to ensure that the Geotextiles or underlying materials are not damaged. Cover material shall be placed such that excess tensile stress is not mobilized in the Geotextile.

## TABLE 1: REQUIRED GEOTEXTILE PROPERTIES

| PROPERTY | TEST METHOD | UNITS | VALUE[1] |
|---|---|---|---|
| | | | TYPE GT-S |
| Geotextile Construction (NW = Nonwoven) (W = Woven) | ---------- | ---------- | NW[2] or W[3] |
| Mass per Unit Area (Unit Weight) | ASTM D 5261 | oz/yd$^2$ | N/A |
| Ultraviolet Resistance (500 hrs) | ASTM D 4355 | % | 70 |
| Strength Class[4] | AASHTO M 288 | Class | 2 |
| Tensile Properties: | ASTM D 4632 | | |
| Grab Strength | | lbs | 160 (NW)<br>250 (W) |
| Grab Elongation | | % | $\geq$ 50 (NW)<br>< 50 (W) |
| Puncture Resistance | ASTM D 4833 | lbs | 55 (NW)<br>90 (W) |
| Trapezoidal Tear Strength | ASTM D 4533 | lbs | 55 (NW)<br>90 (W) |
| Burst Strength | ASTM D 3786 | psi | 200 (NW)<br>400 (W) |
| Apparent Opening Size (AOS) | ASTM D 4751 | U.S. Sieve | 70+ |
| Permittivity | ASTM D 4491 | sec$^{-1}$ | 1.0 |

Notes:

1. Minimum Average Roll Value (MARV).
2. Nonwoven geotextiles that have been heat calendered are not acceptable, unless approved by the Engineer in advance.
3. Woven geotextiles shall be approved in advance by the Engineer. Woven geotextiles formed exclusively with slit film fibers are not acceptable.
4. AASHTO M 288 criteria includes the above listed requirements for: Tensile Properties, Puncture Resistance, Trapezoidal Tear Strength, and Burst Strength.

**TABLE 2: REQUIRED MANUFACTURER QUALITY CONTROL TESTS**

| PROPERTY | TEST METHOD | MINIMUM TEST FREQUENCY |
|---|---|---|
| Mass per Unit Area (Unit Weight) | ASTM D 5261 | 200,000 $ft^2$ |
| Ultraviolet Resistance (500 hrs) | ASTM D 4355 | Periodic |
| Tensile Properties | ASTM D 4632 | 200,000 $ft^2$ |
| Burst Strength (Diaphragm Methods) | ASTM D 3786 | 200,000 $ft^2$ |
| Apparent Opening Size (AOS) | ASTM D 4751 | Periodic |
| Permittivity | ASTM D 4491 | Periodic |
| Puncture Resistance | ASTM D 4833 | 200,000 $ft^2$ |
| Trapezoidal Tear Strength | ASTM D 4533 | 200,000 $ft^2$ |

END OF SECTION

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## SECTION 02256

## PROTECTIVE COVER

Protective Cover: The Protective Cover consists of clean fill material. The Protective Cover protects the leachate collection layer and Geomembrane from damage due to the placement of waste.

A. DESCRIPTION

1. General:

The Contractor shall furnish all labor, material, and equipment to complete installation of the Protective Cover, including borrowing, hauling, screening, removal of surface water and removal of all previously placed material that is unsuitable due to weather conditions, final grading and sealing, and all necessary and incidental items as detailed or required to complete the Protective Cover, all in accordance with the Contract Drawings and these Specifications.

2. Related Work:

Related Contract Work is described in the following sections of the Specifications:

| Work | Section |
|---|---|
| Geotextiles | 02240 |
| HDPE Pipe | 02614 |
| Drainage Aggregate (Leachate Management) | 02710 |
| Drainage Geocomposite | 02712 |
| HDPE Geomembrane | 02775 |
| CQA Manual | Attached |

3. Reference Standards:

The latest revision of the following standards of the American Society of Testing and Materials (ASTM) are hereby made a part of these Specifications.

| | |
|---|---|
| ASTM D 698 | Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft$^3$). |
| ASTM D 2488 | Standard Practice for Description and Identification of Soils (Visual-Manual Procedure). |

4. Quality Assurance:

Quality Assurance during placement of Protective Cover will be provided by the Owner as described in the accompanying Project CQA Manual.

B. MATERIALS

1. Soil that meets all of the following requirements shall be classified as select soil fill for use in construction of the Protective Cover.

   a. Soil shall be classified according to the Unified Soil Classification System (USCS) as SW, SP, SM, SM-SC, or SC (ASTM D 2488). Other material classifications may be approved by the Engineer.

   b. Select soil fill materials shall be reasonably free of gypsum, ferrous, and/or calcareous concretions and nodules, refuse, roots, or other deleterious substances.

   c. The soil cover shall be uniform, smooth, and free of debris, plant materials, and other foreign material. The maximum rock size shall be 3 inches in diameter. The material should contain no sharp edges.

C. SUBMITTALS

The Contractor shall submit the following to the CQA Engineer:

1. Before approval is given to proceed, the Contractor shall submit descriptive information on equipment to be used in construction of the Protective Cover.

2. Survey Results:

After completion of a segment of Protective Cover, survey results shall be submitted for review prior to Protective Cover acceptance.

D. CONSTRUCTION

1. The Protective Cover is placed directly over geosynthetics and/or piping; thus, extreme caution shall be exercised by the Contractor to prevent damage to these materials.

2. All placement and compaction of Protective Cover shall be performed only when the CQA Engineer is informed by the Contractor of intent to perform such work.

3. Protective Cover shall be placed over geosynthetics only after areas have been released by the Geosynthetics Installer and the CQA Engineer. Protective Cover shall be placed as specified below:

   a. Protective Cover shall be placed and spread using tracked equipment. On slopes of 6H:1V or steeper, low ground pressure (6 psi or less) tracked equipment shall be used. On slopes flatter than 6H:1V, tracked equipment shall have a ground pressure of 12 psi or less. The CQA Engineer shall approve the equipment used to place Protective Cover.

   b. Tracked equipment used to place and spread Protective Cover shall operate on at least 1 foot of material overlying geosynthetics and/or piping. Sharp turning of tracked equipment on the Protective Cover will not be permitted.

   c. On slopes of 6H:1V or steeper, Protective Cover shall be placed and spread from the bottom up unless otherwise approved by the Engineer. No material shall be dumped down a slope.

   d. Protective Cover shall be placed and compacted to the lines and grades shown on the Contract Drawings with the exception that a 0.15 foot overbuild at Contractor's expense is allowed. The Contractor will perform all surveys necessary to establish and verify lines and grades for all Protective Cover.

   e. Protective Cover shall be compacted by tracking the final lift with tracked equipment.

4. The Protective Cover shall be spread in a manner that minimizes development of wrinkles or tension in the underlying geosynthetics. Any portion of the underlying geosynthetics that develops excessive wrinkles or crimp or is otherwise damaged shall be repaired by the Geosynthetics Installer at no expense to the Owner.

   a. Protective Cover shall not be placed when conditions are warm enough to produce excessive wrinkles in the underlying geosynthetics. Likewise, Protective Cover shall not be placed when conditions are cold enough to produce tension in the underlying geosynthetics.

   b. If during spreading, excessive wrinkles develop, the Contractor shall adjust placement and spreading methods, or cease until the underlying geosynthetics cool and wrinkles decrease in size.

   c. Wrinkles that exceed approximately 6 inches in height and cannot be eliminated by amended placement and spreading methods or underlying

geosynthetics that become crimped shall be cut and repaired by the Geosynthetics Installer in a method approved by the Engineer.

5. Stockpiling of Protective Cover within the limits of the containment area shall be subject to advance approval by the Engineer. Any hauling equipment (dump trucks, etc.) operating over geosynthetics shall have a minimum of 3 feet of separation between the vehicle wheels and the Geomembrane.

6. Protective Cover shall not be placed over the gravel columns or over the coarse aggregate in the sump area(s) without a protective geotextile or other approved means.

   The Contractor shall minimize equipment operations directly over coarse aggregate.

7. The CQA Engineer may require removal of Protective Cover and/or other underlying layers at the Contractor's sole expense to allow examination of the underlying geosynthetics and/or piping. Any damage to underlying layers or excessive wrinkling or crimping during placement or compaction of the Protective Cover shall be repaired in accordance with the applicable section of these Specifications at the Contractor's sole expense.

8. Surveying:

   After completion of a segment of Protective Cover, the Protective Cover shall be surveyed on 100 foot centers and at slope breaks (including all tops and toes of slope, points of grade change, etc.) to ensure:

   a. The specified thickness has been achieved.

   b. The top of the Protective Cover slopes at grades specified on the Contract Drawings; and

   c. Protective Cover placed more than 0.15 feet beyond the limits of the lines and grades as shown on the Contract Drawings will not be accepted and must be removed at the Contractor's expense if required by the Engineer.

   This work shall be performed at the Contractor's cost by a registered surveyor.

END OF SECTION

## SECTION 02258

## VEGETATIVE SOIL LAYER

Vegetative Soil Layer (VSL): The Vegetative Soil Layer (VSL) is placed in the final cover system in order to support permanent vegetative cover. This section includes the topsoil to be placed as the upper 6 inches of the VSL.

A. DESCRIPTION

1. General:

The Contractor shall furnish all labor, material, and equipment to complete installation of the VSL (including topsoil) for the landfill cover, including borrowing, hauling, spreading, and final grading and all necessary and incidental items as detailed or required to complete the VSL, all in accordance with the Contract Drawings and these Specifications.

2. Related Work:

Related Contract Work is described in the following sections of the Specifications:

| Work | Section |
|---|---|
| HDPE Pipe | 02614 |
| Drainage Aggregate (Final Cover) | 02711 |
| Drainage Geocomposite | 02712 |
| LLDPE Geomembrane | 02778 |
| Revegetation | 02930 |
| CQA Manual | Attached |

3. Reference Standards:

The latest revision of the following standards of the American Society of Testing and Materials (ASTM) are hereby made a part of these Specifications.

| | |
|---|---|
| ASTM D 422 | Standard Test Method for Particle Size Analysis of Soils. |
| ASTM D 2487 | Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System). |

4. Quality Assurance:

Quality Assurance during placement of Vegetative Soil Layer will be provided by the Owner as described in the accompanying Project CQA Manual.

B. MATERIALS

Soil that meets all of the following requirements shall be classified as select soil fill for use in construction of the VSL.

1. Soil shall be classified according to the Unified Soil Classification System (USCS) as SC or CL (ASTM D 2487) and shall have no more than 15% non-plastic fines (ASTM D 422). Alternatives to these requirements must be approved in advance by the Engineer.

2. Select soil fill materials shall be reasonably free of gypsum, ferrous, and/or calcareous concretions and nodules, refuse, roots, or other deleterious substances.

3. Continuous and repeated visual inspection of the materials being used will be performed by the Contractor to ensure proper soils are being used. In addition, the CQA Engineer shall make frequent inspections of the placement operations and materials, and will consult with the Engineer.

4. The VSL shall be uniform, smooth, and free of debris, rock, plant materials, and other foreign material larger than 3 inches in diameter. The material should contain no sharp edges. This material must be capable of supporting growth of vegetative cover.

5. Topsoil: The upper 6 inches of VSL shall be natural or blended soil material capable of supporting the growth of vegetative cover.

C. SUBMITTALS

The Contractor shall submit the following to the CQA Engineer:

1. Before approval is given to proceed, the Contractor shall submit descriptive information on placement equipment to be used in construction of the VSL.

2. Survey Results:

After completion of a segment of VSL, survey results shall be submitted for review prior to VSL acceptance.

D. CONSTRUCTION

1. The VSL is placed directly over geosynthetics and/or piping; thus, extreme caution shall be exercised by the Contractor to prevent damage to these materials.

2. All placement and compaction of VSL shall be performed only when the CQA Engineer is informed by the Contractor of intent to perform such work.

3. VSL shall be placed over geosynthetics only after areas have been released by the Geosynthetics Installer and the CQA Engineer. VSL shall be placed as specified below:

   a. The VSL, including topsoil, shall be placed and spread using low ground pressure (6 psi or less) tracked equipment. The CQA Engineer shall approve the equipment used to place the VSL.

   b. Tracked equipment used to place and spread VSL shall operate on at least 1 foot of material overlying geosynthetics and/or piping. Sharp turning of tracked equipment on the VSL will not be permitted.

   c. On slopes of 6H:1V or steeper, VSL shall be placed and spread from the bottom up unless otherwise approved by the Engineer. No material shall be dumped down a slope.

   d. VSL shall be placed and compacted to the lines and grades shown on the Contract Drawings with the exception that a 0.15 foot overbuild at Contractor's expense is allowed. The Contractor will perform all surveys necessary to establish and verify lines and grades for all VSL.

   e. VSL shall be compacted by tracking the final lift with tracked equipment.

4. The VSL shall be spread in a manner that minimizes development of wrinkles or tension in the underlying geosynthetics. Any portion of the underlying geosynthetics that develops excessive wrinkles or crimp or is otherwise damaged shall be repaired by the Geosynthetics Installer at no expense to the Owner.

   a. VSL shall not be placed when conditions are warm enough to produce excessive wrinkles in the underlying geosynthetics. Likewise, VSL shall not be placed when conditions are cold enough to produce tension in the underlying geosynthetics.

   b. If during spreading, excessive wrinkles develop, the Contractor shall adjust placement and spreading methods, or cease until the underlying geosynthetics cool and wrinkles decrease in size.

c. Wrinkles that exceed approximately 6 inches in height and cannot be eliminated by amended placement and spreading methods or underlying geosynthetics that become crimped shall be cut and repaired by the Geosynthetics Installer in a method approved by the Engineer.

5. Stockpiling of VSL on the final cover shall be subject to advance approval by the Engineer. Any hauling equipment (dump trucks, etc.) operating over geosynthetics shall have a minimum of 3 feet of separation between the vehicle wheels and the Geomembrane.

6. The CQA Engineer may require removal of VSL and/or other underlying layers at the Contractor's sole expense to allow examination of the underlying geosynthetics and/or piping. Any damage to underlying layers or excessive wrinkling or crimping during placement of the VSL shall be repaired in accordance with the applicable section of these Specifications at the Contractor's sole expense.

7. After the specified thickness has been achieved and verified, the Contractor shall proceed immediately with seeding.

8. Surveying:

After completion of a segment of VSL, the VSL shall be surveyed on 100 foot centers and at slope breaks (including all tops and toes of slope, points of grade change, etc.) to ensure:

a. The specified thickness has been achieved. A hand auger or similar method may be used to check for thickness at each location.

b. The top of the VSL slopes at grades specified on the Contract Drawings; and

c. VSL placed more than 0.15 feet beyond the limits of the lines and grades as shown on the Contract Drawings will not be accepted and must be removed at the Contractor's sole expense if required by the Engineer.

This work shall be performed at the Contractor's cost by a registered surveyor.

END OF SECTION

## SECTION 02270

## EROSION AND SEDIMENTATION CONTROL

Erosion and Sedimentation Control: Erosion and Sedimentation Control is a system of construction and engineered measures (devices, structures, practices, etc.) which act to minimize surface water induced erosion of disturbed areas and the resulting off-site sedimentation.

A. DESCRIPTION

1. General:

The Contractor shall furnish all labor, material, and equipment to complete installation of and maintain Erosion and Sedimentation Control measures and related work in accordance with the Contract Drawings and these Specifications.

All Erosion and Sedimentation Control work shall be in accordance with the latest edition of the North Carolina Erosion and Sediment Control Planning and Design Manual as well as applicable regulations.

2. Related Work:

Related Contract Work is described in the following sections of the Specifications:

| Work | Section |
|---|---|
| Geotextiles | 02240 |
| Rip Rap | 02271 |
| Rolled Erosion Control Products | 02275 |
| Precast Concrete Structures | 02608 |
| HDPE Pipe | 02614 |
| Storm Water Systems | 02720 |
| Revegetation | 02930 |
| Concrete Work | 03310 |

3. Reference Standards:

The latest revision of the following standards of the American Society of Testing and Materials (ASTM) are hereby made a part of these specifications.

| | |
|---|---|
| ASTM D 3786 | Test Method for Hydraulic Bursting Strength of Knitted Goods and Nonwoven Fabrics: Diaphragm Bursting Strength Tester Method. |
| ASTM D 4355 | Standard Test Method for Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water (Xenon-Arc Type Apparatus). |
| ASTM D 4491 | Standard Test Methods for Water Permeability of Geotextiles by Permittivity. |
| ASTM D 4533 | Standard Test Method for Trapezoid Tearing Strength of Geotextiles. |
| ASTM D 4632 | Standard Test Method for Grab Breaking Load and Elongation of Geotextiles. |
| ASTM D 4751 | Standard Test Method for Determining Apparent Opening Size of a Geotextile. |
| ASTM D 4833 | Standard Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products. |

B. MATERIALS

1. Permanent Sediment Basins:

Permanent sediment basins shall be constructed as shown on the Contract Drawings.

2. Permanent Drainage Channels, Diversions, Swales, and Ditches:

Permanent drainage channels, diversions, swales, and ditches shall be constructed as shown on the Contract Drawings.

3. Silt Fence:

Silt fences shall be constructed as shown on the Contract Drawings and as needed, based on the Contractor's discretion and Engineer's approval. The silt fence is a permeable barrier erected within and downgradient of small disturbed areas to capture sediment from sheet flow. It is made of filter fabric buried at the bottom, stretched, and supported by posts and wire mesh backing. Silt fence shall conform to the following properties:

a. Posts: Posts shall be 1.33 lb/linear foot steel (preferred) or wood with a minimum length of 5 feet. Steel posts shall be "U" or "T"-type. Wood posts shall have a minimum diameter of 4-inches.

b. Filter Fabric: Filter fabric shall be a woven geotextile made specifically for sediment control. Filter fabric shall conform to the properties listed in Table 1 of this section.

4. Geotextiles:

Geotextiles shall conform to the requirements of Section 02240, Geotextiles, of these Specifications.

5. Down Pipes:

Down pipes shall be constructed as shown on the Contract Drawings.

6. Rip Rap:

Rip Rap shall conform to the requirements of Section 02271, Rip Rap, of these Specifications.

7. Rolled Erosion Control Products (RECPs):

Rolled Erosion Control Products (RECPs) shall conform to the requirements of Section 02275, Rolled Erosion Control Products, of these Specifications.

8. Other Work:

In addition to the Erosion and Sedimentation Control measures shown on the Contract Drawings, the Contractor shall provide adequate means to prevent any sediment from entering any storm drains, drop inlets, ditches, streams, or bodies of water downstream of any area disturbed by construction. Excavation materials shall be placed upstream of any trench or other excavation to prevent sedimentation of off-site areas. In areas where a natural buffer area exists between the work area and the closest stream or water course, this area shall not be disturbed. All paved areas shall be scraped and swept as necessary to prevent the accumulation of dirt and debris. Work associated with this provision shall be considered incidental to the project and no separate payment will be made.

9. Temporary and Permanent Ground Cover:

The Contractor shall provide temporary or permanent ground cover (or other acceptable measure(s)) adequate to restrain erosion on erodible slopes or other areas within 21 calendar days following completion of any phase of grading. The

Contractor shall provide permanent ground cover for all disturbed areas within 15 working days or 90 calendar days (whichever is shorter) following the completion of construction.

C. SUBMITTALS

The Contractor shall submit the following to the Engineer:

1. Submit a certification and summary of all required test results, prior to installation, that all Erosion and Sedimentation Control materials manufactured for the project have been produced in accordance with these Specifications.

2. Furnish copies of the delivery tickets or other approved receipts as evidence for materials received that will be incorporated into construction.

D. CONSTRUCTION

1. Establishment of Erosion and Sedimentation Control Measues:

   a. All Erosion and Sedimentation Control measures will be constructed according to the Contract Drawings and these Specifications.

   b. Due to the nature of the work required by this Contract, it is anticipated that the location and nature of the Erosion and Sedimentation Control measures may need to be adjusted on several occasions to reflect the current phase of construction.

   c. Erosion and Sedimentation Control measures shall be established prior to the work in a given area. Where such practice is not feasible, the Erosion and Sedimentation Control measure(s) shall be established immediately following completion of the clearing operation.

   d. The construction schedule adopted by the Contractor will impact the placement and need for specific measures required for the control of erosion. The Contractor shall develop and implement such additional techniques as may be required to minimize erosion and prevent or correct the discharge of sediment outside the limits of construction (unless controlled by other on-site measure(s)).

   e. The location and extent of Erosion and Sedimentation Control measures shall be revised at each phase of construction that results in a change in either the quantity or direction of surface runoff from construction areas. All deviations from the control provisions shown on the Contract Drawings shall have the prior approval of the Engineer.

2. Inspection and Maintenance of Erosion and Sedimentation Control Measures:

a. The Contractor shall furnish the labor, material, and equipment required for the inspection and maintenance of all Erosion and Sedimentation Control measures. Maintenance shall be scheduled as required for a particular measure to maintain the removal efficiency and intent of the measure.

b. All Erosion and Sedimentation Control measures shall be inspected at least once every seven calendar days and within 24 hours after any storm event of greater than 0.5 inches of rain per 24 hour period and appropriate maintenance conducted. A rain gauge shall be maintained on the site and a record of the rainfall amounts and dates shall be kept properly.

c. Maintenance shall include, but not be limited to:

(1) The removal and satisfactory disposal of trapped or deposited sediments from basins, traps, barriers, filters, and/or drainage features/devices;

(2) Replacement of filter fabrics used for silt fences upon loss of efficiency; and

(3) Replacement of any other components which are damaged or cannot serve the intended use.

d. The Contractor shall accept and maintain any existing sediments that are included in existing sediment traps or basins that accept or will accept stormwater flow and or sediment accumulation from all areas within the Contractor's limits of construction.

e. Sediments removed from Erosion and Sedimentation Control measures shall be disposed of in locations that will not result in off-site sedimentation as approved by the Engineer.

f. All Erosion and Sedimentation Control measures shall be maintained to the satisfaction of the Engineer until the site has been stabilized.

3. Graded Slopes and Fills:

The angle for graded slopes and fills shall be no greater than the angle that can be retained by vegetated cover or other adequate measures.

4. Finish Grading:

All disturbed areas shall be uniformly graded to the lines, grades, and elevations shown on the Contract Drawings. Finished surfaces shall be reasonably smooth, compacted, and free from irregular surface changes. Unless otherwise specified, the degree of finish shall be that ordinarily obtainable from either blade or scraper operations. Areas shall be finished to a smoothness suitable for application of topsoil.

5. Revegetation:

Revegetation shall conform to the requirements of Section 02930, Revegetation, of these Specifications.

6. Cleanup:

a. The Contractor shall remove from the site all subsoil excavated from his work and all other debris including, but not limited to, branches, paper, and rubbish in all landscape areas, and remove temporary barricades as the work proceeds.

b. All areas shall be kept in a neat, orderly condition at all times. Prior to final acceptance, the Contractor shall clean up the entire landscaped area to the satisfaction of the Engineer.

**TABLE 1: REQUIRED SILT FENCE FILTER FABRIC PROPERTIES**

| PROPERTY | TEST METHOD | UNITS | VALUE[1] |
|---|---|---|---|
| Grab Tensile Strength[2] | ASTM D 4632 | lbs | 100 x 100 |
| Grab Elongation | ASTM D 4632 | % | 20 (Max.) |
| Trapezoidal Tear Strength[2] | ASTM D 4533 | lbs | 65 x 65 |
| Burst Strength | ASTM D 3786 | psi | 300 |
| Puncture Resistance | ASTM D 4833 | lbs | 65 |
| Ultraviolet Resistance (500 hrs) | ASTM D 4355 | % | 80 |
| Apparent Opening Size (AOS) | ASTM D 4751 | U.S. Sieve | 30+ |
| Permittivity | ASTM D 4491 | $sec^{-1}$ | 0.05 |

Notes:
1. Minimum Average Roll Value (MARV).
2. Values for machine and cross machine direction (MD x XD), respectively.

END OF SECTION

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**SECTION 02271**

**RIP RAP**

Rip Rap: This section includes all rip rap aprons and channel protection.

A. DESCRIPTION

1. General:

The Contractor shall furnish all labor, material, and equipment to complete installation of Rip Rap for protection of earthen slopes against erosion as indicated, including all necessary and incidental items, in accordance with the Contract Drawings and these Specifications.

2. Related Work:

Related Contract Work is described in the following sections of the Specifications:

| Work | Section |
|---|---|
| Geotextiles | 02240 |
| Erosion and Sedimentation Control | 02270 |

3. Reference Standards:

The latest revision of the following standards of the North Carolina Department of Transportation (NCDOT) are hereby made a part of these Specifications.

NCDOT Standard Specifications for Roads and Structures.

B. MATERIALS

1. Rip Rap: Rip Rap shall be of the size indicated on the Contract Drawings and shall conform to NCDOT Section 1042, Rip Rap Materials.

2. Geotextiles: Geotextiles shall conform to the requirements outlined in Section 02240, Geotextiles, of these Specifications.

C. SUBMITTALS

The Contractor shall submit the following to the Engineer:

1. Submit a certification and summary of all required test results prior to installation, that all Rip Rap has been produced in accordance with these Specifications.

2. Furnish copies of the delivery tickets or other approved receipts as evidence for materials received that will be incorporated into construction.

D. CONSTRUCTION

1. Surface Preparation:

   a. Trim and dress all areas to conform to the Contract Drawings as indicated with tolerance of 2 inches from theoretical slope lines and grades.

   b. Bring areas that are below allowable minimum tolerance limit to grade by filling with compacted Embankment material similar to adjacent material.

   c. Geotextiles shall be placed as shown on the Contract Drawings and in accordance with Section 02240, Geotextiles, of these Specifications.

   d. Do not place any stone material on the prepared surface prior to inspection and approval to proceed from the Engineer.

2. Placing Rip Rap:

   Rip Rap shall be placed in accordance with NCDOT Section 868, Rip Rap.

END OF SECTION

## SECTION 02275

## ROLLED EROSION CONTROL PRODUCTS

Rolled Erosion Control Products: Rolled Erosion Control Products (RECPs) include erosion control blankets (ECB) and turf reinforcement mats (TRM) placed in channels and on slopes.

A. DESCRIPTION

1. General:

The Contractor shall furnish all labor, material, and equipment to complete installation of all RECPs in accordance with the Contract Drawings and these Specifications.

2. Related Work:

Related Contract Work is described in the following sections of the Specifications:

| Work | Section |
|---|---|
| Erosion and Sedimentation Control | 02270 |
| Revegetation | 02930 |

3. Reference Standards:

The latest revision of the following standards of the American Society of Testing and Materials (ASTM) are hereby made a part of these specifications.

| | |
|---|---|
| ASTM D 4355 | Standard Test Method for Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water (Xenon-Arc Type Apparatus). |
| ASTM D 6475 | Standard Test Method for Measuring Mass per Unit Area of Erosion Control Blankets. |
| ASTM D 6524 | Standard Test Method for Measuring the Resiliency of Turf Reinforcement Mats. |
| ASTM D 6525 | Standard Test Method for Measuring Nominal Thickness of Permanent Erosion Control Products. |

| | |
|---|---|
| ASTM D 6566 | Standard Test Method for Measuring Mass per Unit Area of Turf Reinforcement Mats. |
| ASTM D 6818 | Standard Test Method for Ultimate Tensile Properties of Turf Reinforcement Mats. |

B. MATERIALS

1. General:

The materials supplied under these Specifications shall consist of new, first-quality products designed and manufactured specifically for the purpose of this work, which shall have been satisfactorily demonstrated, by prior use, to be suitable and durable for such purposes.

Labels on each RECP shall identify the length, width, product name, and name of Manufacturer.

2. Erosion Control Blanket (ECB):

ECB shall consist of a machine-produced mat of straw or wood excelsior fiber covered on the top side with a photodegradable extruded plastic or woven biodegradable netting and sewn together with degradable thread. ECB shall also conform to the properties listed in Table 1 of this section. ECB shall be S75, as manufactured by North American Green, CURLEX I, as manufactured by American Excelsior Company, LANDLOK S1, as manufactured by Propex Fabrics, or approved equal.

3. Turf Reinforcement Mat (TRM):

TRM shall consist of a dense web of crimped and interlocking polypropylene fibers positioned between two biaxially oriented nets and mechanically bound together by parallel stitching with polypropylene thread. TRM shall be designed to accelerate seedling emergence, exhibit high resiliency, and possess strength and elongation properties to limit stretching in a saturated condition. TRM shall be stabilized against chemical and UV degradation which are normally found in a natural soil environment and shall have no biodegradable components. TRM shall also conform to the properties listed in Table 1 of this section. TRM shall be LANDLOK TRM 435, as manufactured by Propex Fabrics, or approved equal.

4. Anchors: Anchors for RECPs shall consist of machine made staples of No. 8 gauge new steel wire formed into a "U" shape. The size when formed shall be not less that 8 inches in length with a throat of not less than 1 inch in width. Longer anchors may be required for loose soils. Other anchors, such as metal pins or plastic pegs, may also be used if approved in advance by the Engineer.

C. SUBMITTALS

The Contractor shall submit the following to the Engineer:

1. Mill Certificate and Sample: Prior to shipping to the site, the Contractor shall submit a mill certificate or affidavit signed by a legally authorized official of the Manufacturer for each RECP attesting that each RECP meets the physical and manufacturing requirements stated in these Specifications. The Contractor shall also submit a sample of each RECP to be used. The sample shall be labeled with the product name and be accompanied by the Manufacturer's specifications.

2. Shipping, Handling, and Storage Instructions: The Manufacturer's plan for shipping, handling, and storage shall be submitted for review.

3. Installation Guidelines/Instructions: The Manufacturer's guidelines/instructions for installation shall be submitted for review.

4. Furnish copies of delivery tickets or other approved receipts as evidence for materials received that will be incorporated into the construction.

D. CONSTRUCTION

1. Shipping, Handling, and Storage:

All RECPs shall be shipped, handled, and stored in strict accordance with the Manufacturer's recommendations.

2. Installation - General:

a. Placing of RECPs shall be done immediately following seeding. Seeding shall be performed in accordance with Section 02930, Revegetation, of these Specifications.

b. RECPs shall be placed to the lines and grades shown on the Contract Drawings. The earth surface shall be smooth and free from stones, clods, or debris which will prevent the contact of the RECP with the soil. Care shall be taken to preserve the required line, grade, and cross section of the area.

c. RECPs shall be unrolled in the direction of the flow of water and shall be applied without stretching so that it will lie smoothly but loosely on the soil surface.

d. At the time of installation, RECPs shall be rejected, if they have defects, rips, holes, flaws, evidence of deterioration, or other damage.

e. The Engineer may require adjustments in the installation requirements to fit individual conditions.

3. Installation - Channels:

RECPs installed in channels shall be unrolled parallel to the direction of water flow. The first roll shall be centered longitudinally in the channel and anchored with staples. Subsequent rolls shall be installed outward to the edges of the channel and be lapped to allow installation of a common row of anchors. RECP ends shall be overlapped with the upstream ends on top ("shingled"). Refer to the Contract Drawings and/or the Manufacturer's installation guidelines/instructions for installation details.

4. Installation - Slopes:

RECPs installed on slopes shall be oriented in vertical strips and anchored. Subsequent rolls shall be installed outward to the edge(s) of the original roll and be lapped to allow installation of a common row of anchors. RECP ends shall be shingled. Refer to the Contract Drawings and/or the Manufacturer's installation guidelines/instructions for installation details.

5. Maintenance:

Maintenance of RECPs shall be in accordance with Section 02270, Erosion and Sedimentation Control, of these Specifications.

**TABLE 1: REQUIRED ROLLED EROSION CONTROL PRODUCT PROPERTIES**

| PROPERTY | TEST METHOD | UNITS | VALUE[1] |
|---|---|---|---|
| **Erosion Control Blanket (ECB)** | | | |
| Mass per Unit Area | ASTM D 6475 | lbs/yd$^2$ | 0.5 ± 10% (Straw) 0.7 ± 10% (Excelsior) |
| Tensile Strength[2] | ASTM D 6818 | lbs/ft | 50 x 65 |
| Tensile Elongation | ASTM D 6818 | % | 20 |
| Maximum Permissible Shear Stress (Un-Vegetated) | ----- | lb/ft$^2$ | 1.55 |
| Functional Longevity | ----- | months | 12 |
| **Turf Reinforcement Mat (TRM)** | | | |
| Mass per Unit Area | ASTM D 6566 | oz/yd$^2$ | 8 |
| Thickness | ASTM D 6525 | inches | 0.35 |
| Tensile Strength[2] | ASTM D 6818 | lbs/ft | 225 x 175 |
| Tensile Elongation | ASTM D 6818 | % | 50 (max.) |
| Resiliency | ASTM D 6524 | % | 80 |
| UV Resistance (1,000 Hours) | ASTM D 4355 | % | 80 |
| Maximum Permissible Shear Stress (Long-Term Vegetated) | Large Scale | lb/ft$^2$ | 5 |

Notes:

1. Typical for ECB; Minimum Average Roll Value (MARV) for TRM.
2. Values for machine and cross machine direction (MD x XD), respectively.

END OF SECTION

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**SECTION 02500**

**ROADWAY WORK**

Roadway Work: Roadway Work refers to the construction of gravel road surfaces.

A. DESCRIPTION

1. General:

The Contractor shall furnish all labor, material, and equipment required to complete construction of all Roadway Work including gravel roads and the repair of existing gravel roads in accordance with the Contract Drawings and these Specifications.

2. Related Work:

Related Contract Work is described in the following sections of the Specifications:

| Work | Section |
|---|---|
| Excavation | 02222 |
| Embankment | 02223 |
| Geotextiles | 02240 |

3. Reference Standards:

The latest revision of the following standards of the North Carolina Department of Transportation (NCDOT) are hereby made a part of these Specifications:

NCDOT Standard Specifications for Roads and Structures.

B. MATERIALS

1. Geotextiles:

Geotextiles shall conform to the requirements outlined in Section 02240, Geotextiles, of these Specifications.

2. Aggregate Base Course (ABC):

All work, including materials, associated with ABC shall be in accordance with NCDOT Section 520, Aggregate Base Course, except that Articles 520-7

(Contractor Furnished Laboratory), 520-12 (Method of Measurement), and 520-13 (Basis of Payment) shall be deleted. Type "A" or "B" aggregate will be acceptable for this project.

C. SUBMITTALS

The Contractor shall submit the following to the Engineer:

1. Submit a certification and summary of all required test results, prior to installation, that all materials for Roadway Work have been produced in accordance with these Specifications.

2. Furnish copies of the delivery tickets or other approved receipts as evidence for materials received that will be incorporated into construction.

D. CONSTRUCTION

1. General:

All Roadway Work including the replacement of portions of the existing roads shall be to the limits, grades, thicknesses, and types as shown on the Contract Drawings. Patches for pipe crossings and areas damaged during the construction work shall be asphalt or gravel, depending upon the material encountered, unless otherwise indicated.

2. Earthwork:

The earthwork for all Roadway Work shall be completed in accordance with Section 02222, Excavation, and Section 02223, Embankment, of these Specifications and as shown on the Contract Drawings.

3. Geotextiles:

Geotextiles shall be placed as shown on the Contract Drawings and in accordance with Section 02240, Geotextiles, of these Specifications. If overlapped seams are used, overlaps shall be a minimum of 12 inches.

4. Aggregate Base Course:

ABC shall be constructed in accordance with NCDOT Section 520.

END OF SECTION

## SECTION 02608

## PRECAST CONCRETE STRUCTURES

| |
|---|
| Precast Concrete Structures: Precast Concrete Structures are used in the storm water system. |

A. DESCRIPTION

1. General:

The Contractor shall furnish all labor, material, and equipment to complete installation of Precast Concrete Structures in accordance with the Contract Drawings and these Specifications.

2. Related Work:

Related Contract Work is described in the following sections of the Specifications:

| Work | Section |
|---|---|
| Excavation | 02222 |
| Embankment | 02223 |
| Erosion and Sedimentation Control | 02270 |
| HDPE Pipe | 02614 |
| Storm Water Systems | 02720 |
| Concrete Work | 03310 |

3. Reference Standards:

The latest revision of the following standards of the American Society of Testing and Materials (ASTM) are hereby made a part of these Specifications.

| | |
|---|---|
| ASTM A 615 | Standard Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement. |
| ASTM C 443 | Standard Specification for Joints for Circular Concrete Sewer and Culvert Pipe, Using Rubber Gaskets. |
| ASTM C 478 | Standard Specification for Precast Reinforced Concrete Manhole Sections. |
| ASTM C 497 | Standard Test Methods for Concrete Pipe, Manhole Sections, or Tile. |

| | |
|---|---|
| ASTM C 789 | Standard Specification for Precast Reinforced Concrete Box Sections for Culverts, Strom Drains, and Sewers. |
| ASTM C 850 | Standard Specification for Precast Reinforced Concrete Box Sections for Culverts, Strom Drains, and Sewers with Less Than 2 feet of Cover Subjected to Highway Loadings. |
| ASTM C 990 | Standard Specification for Joints for Concrete Pipe, Manholes, and Precast Box Sections Using Preformed Flexible Joint Sealants. |

B. MATERIALS

1. Precast Concrete Manholes: All precast concrete manholes shall be constructed from non-shrink, 4,000 psi compressive strength concrete in conformance with ASTM C 478 and as detailed on the Contract Drawings.

2. Precast Concrete Boxes: All precast concrete boxes shall be constructed from non-shrink, 4,000 psi compressive strength concrete in conformance with ASTM C 789 or ASTM C 850, as applicable, and as detailed on the Contract Drawings.

3. Precast Energy Dissipaters: All precast energy dissipaters shall meet the requirements of NCDOT and shall be constructed from non-shrink, 4,000 psi compressive strength concrete in conformance with ASTM C 789 or ASTM C 850, as applicable, and as detailed on the Contract Drawings.

4. Joints: All joints shall be sealed with preformed plastic gaskets in conformance with ASTM C 990 or rubber gaskets in conformance with ASTM C 443.

5. Steps: All steps shall be constructed of 0.5 inch reinforcing rod completely encased in corrosion-resistant rubber or plastic. The upper surfaces of each step shall have a traction tread of self cleaning rubber cleats and guide lugs on both sides to prevent slippage.

6. Frames and Covers: Frames and covers shall consist of cast iron frames and covers (Vulcan Foundry, or equal) equipped with steel handles and shall be of the opening size as indicated on the Contract Drawings. Markings on the covers shall indicate the intended use of the structure and shall be acceptable to the Owner.

7. Markings: All Precast Concrete Structures shall include markings clearly identifying the date of manufacture, the name of the manufacturer, and any other pertinent information.

C. SUBMITTALS

The Contractor shall submit the following to the Engineer:

1. The Contractor shall submit shop drawings for Precast Concrete Structures for approval at least 4 weeks prior to construction. Shop drawings shall show complete design, installation, and construction information in such detail as to enable the Engineer to determine the adequacy of the proposed units for the intended purpose. Details of steel reinforcement size and placement shall be included. The shop drawings shall include a schedule which will list the size and type of precast structure at each location where the precast structures are to be used.

2. Submit a certification and summary of all required test results, prior to installation, that all Precast Concrete Structures have been produced in accordance with these Specifications.

D. CONSTRUCTION

1. The Precast Concrete Structures shall be installed at the locations and to the elevations indicated on the Contract Drawings. The Contractor shall give the Engineer sufficient notice so he may observe the field location and installation activities.

2. The Precast Concrete Structures will be bedded and backfilled as indicated on the Contract Drawings.

3. Precast Concrete Structures which are damaged or become damaged will be rejected or shall be repaired in a manner approved by the Engineer at the Contractor's sole expense.

END OF SECTION

## SECTION 02614

## HIGH DENSITY POLYETHYLENE (HDPE) PIPE

High Density Polyethylene (HDPE) Pipe: HDPE Pipe is used in the storm water and leachate management systems.

A. DESCRIPTION

1. General:

The Contractor shall furnish all labor, material, and equipment to complete installation of HDPE Pipe in accordance with the Contract Drawings and these Specifications. The Contractor shall also clean and test pipelines where required.

2. Related Work:

Related Contract Work is described in the following sections of the Specifications:

| Work | Section |
|---|---|
| Excavation | 02222 |
| Embankment | 02223 |
| Precast Concrete Structures | 02608 |
| Drainage Aggregate (Leachate Management) | 02710 |
| Drainage Aggregate (Final Cover) | 02711 |
| Drainage Geocomposite | 02712 |
| HDPE Geomembrane | 02775 |
| LLDPE Geomembrane | 02778 |
| Concrete Work | 03310 |
| Landfill Gas Wells | 13252 |
| Landfill Gas System | 13255 |
| CQA Manual | Attached |

3. Reference Standards:

The latest revision of the following standards of the American Society of Testing and Materials (ASTM) are hereby made a part of these specifications.

ASTM D 638 Standard Test Method for Tensile Properties of Plastics.

| | |
|---|---|
| ASTM D 790 | Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials. |
| ASTM D 1238 | Standard Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer. |
| ASTM D 1505 | Standard Test Method for Density of Plastics by the Density-Gradient Technique. |
| ASTM D 1603 | Standard Test Method for Carbon Black in Olefin Plastics. |
| ASTM D 2837 | Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials. |
| ASTM D 3035 | Standard Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter. |
| ASTM D 3261 | Standard Specification for Butt Heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing. |
| ASTM D 3350 | Standard Specification for Polyethylene Plastics Pipe and Fitting Materials. |
| ASTM F 412 | Standard Terminology Relating to Plastic Piping Systems. |
| ASTM F 714 | Standard Specification for Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Outside Diameter. |
| ASTM F 1417 | Standard Test Method for Installation Acceptance of Plastic Gravity Sewer Lines Using Low-Pressure Air. |
| ASTM F 1473 | Standard Test Method for Notch Tensile Test to Measure the Resistance to Slow Crack Growth of Polyethylene Pipes and Resins. |
| ASTM F 2164 | Standard Practice for Field Leak Testing of Polyethylene (PE) Pressure Piping Systems Using Hydrostatic Pressure. |

4. Quality Control:

The Contractor shall perform pressure testing of HDPE Pipe as described in this section.

5. Quality Assurance:

Quality Assurance during placement of HDPE Pipe will be provided by the Owner as described in the accompanying Project CQA Manual.

B. MATERIALS

1. All HDPE Pipe shall be manufactured from new materials meeting the physical requirements shown in Table 1 of this section.

2. All HDPE Pipe shall have smooth interior walls and the DR (dimension ratio) and diameter of the pipe shall be as shown on the Contract Drawings.

3. All HDPE Pipe having an outside diameter 3.5 inches and larger shall meet the requirements of ASTM F 714. All HDPE Pipe having an outside diameter less than 3.5 inches shall meet the requirements of ASTM D 3035.

4. Visible defects, such as cracks, creases, crazing, non-uniformly pigmented areas, or undispersed raw materials shall not be acceptable and will result in rejection of the pipe by the CQA Engineer.

5. Pipe Perforations: The perforations of the perforated HDPE Pipe shall be as shown on the Contract Drawings.

6. All HDPE Pipe fittings shall be in accordance with ASTM D 3261 and shall be pressure rated to match the system piping. The fittings shall be manufactured from the same materials as the pipe itself. The butt fusion outlets of fittings shall be machined to the same DR as the system piping to which they are to be fused.

7. Materials used as anchorage for pipe cleanouts shall be provided and installed under this section. Concrete shall be in accordance with Section 03310, Concrete Work, of these Specifications.

C. SUBMITTALS

The Contractor shall submit the following to the CQA Engineer:

1. Submit a certification and summary of all required test results, prior to installation, that all HDPE Pipe manufactured for the project has been produced in accordance with these Specifications.

2. Submit a copy of the HDPE Pipe Manufacturer's recommendations for shipping, handling, and storage of pipe.

3. Furnish copies of the delivery tickets or other approved receipts as evidence for materials received that will be incorporated into construction.

4. Survey Results:

After placement of HDPE Pipe, survey results shall be submitted for review prior to acceptance.

D. CONSTRUCTION

1. Shipping , Handling, and Storage:

All HDPE Pipe shall be shipped, handled, and stored in strict accordance with the Manufacturer's recommendations.

2. HDPE Pipe Installation:

a. The Contractor shall install HDPE Pipe to the lines and grades shown on the Contract Drawings. Line and grade of piping shall be maintained with laser or approved equivalent. The Contractor shall give the CQA Engineer sufficient notice so that the he may observe field location and installation activities.

b. Excavation for leachate transmission lines shall be backfilled as directed by the Engineer as shown on the Contract Drawings. Sand backfill or approved soil backfill compacted to at least 95 percent of the Standard Proctor dry density (ASTM D 698) shall be used.

Sharp stones or other potentially damaging material shall be removed from the base of the trench prior to placement of the piping. A leveling course, as required, shall consist of sand or other approved material.

c. Pipe Connections: Joining of HDPE Pipe shall be as follows:

(1) General pipe sections shall be butt-fusion welded according to the Manufacturer's recommendations and shall be performed by a Manufacturer's authorized, trained fusion technician.

(2) Pipe ends to be butt-fusion welded shall be clean and dry at the time of welding. No welding shall occur during precipitation or excessive moisture.

(3) The Contractor shall grind burrs or other potentially damaging areas in the welds prior to placement of the pipe.

(4) Specified bolted pipe connections shall be made as specified on the Contract Drawings using stainless steel hardware and neoprene gaskets.

(5) Polyethylene stub ends and flanges must be at the ambient temperature of the surrounding soil at the time they are bolted tight to prevent relaxation of the flange bolts and loosening of the joint due to thermal contraction of the polyethylene.

(6) Properly executed electrofusion fittings may be used.

d. Perforated HDPE Pipe shall be placed during construction as shown on the Contract Drawings.

3. Cleaning:

a. All HDPE Pipe shall be cleaned of any accumulation of silt, debris, or foreign matter of any kind and shall be kept clear of such accumulation until final acceptance of the work.

b. Final Flushing: The Contractor shall flush all leachate collection piping accessible by cleanout ports with potable water at or near the completion of the work. Any sediment remaining at collection points (sumps, manholes, etc.) shall be removed and disposed of as directed by the Engineer.

4. Pressure Testing:

a. All solid piping where factory or field joints have been performed require pressure testing except as noted below.

(1) Any unjointed section of pipe showing visual signs of damage or that is of questionable quality may be required to be pressure tested as directed by the CQA Engineer.

(2) Cleanout risers within the containment areas do not require pressure testing.

b. All leachate transmission lines shall be pressure tested by the Contractor prior to approval by the CQA Engineer.

c. Pressure testing shall be conducted by the Contractor in a manner approved by the Engineer. Such testing shall be observed by the CQA Engineer.

d. The leachate transmission lines shall be tested as follows:

(1) All gravity piping shall be tested using low-pressure air in accordance with ASTM F 1417.

(2) All force main piping shall be tested using hydrostatic pressure in accordance with ASTM F 2164.

The pressures used in testing must not exceed the working pressure of the lowest rated component in the system (i.e. valves, meters, flanges, unions, etc.). The Manufacturer's recommendation for pressure testing may also be acceptable as an alternative if approved in advance by the Engineer.

Pressure testing of short sections of leachate transmission line or leachate transmission line to be placed in confined or inaccessible areas may be pressure tested by the Contractor prior to installation when approved by the Engineer. Temporary fittings, etc. required to plug section ends shall be provided by the Contractor at no expense to the Owner.

Any leachate transmission line that does not meet the pressure test criteria shall be repaired and retested at the Contractor's expense. No leachate transmission line shall be approved until successful pressure testing is completed.

5. Camera Inspection of Leachate Collection Piping:

At or near the completion of the placement of all materials within the limits of the liner system (through protective cover), the Contractor shall document by video camera inspection that all leachate collection piping is clean and connected and that no portions of piping are visibly damaged or deformed. Unless otherwise indicated, the piping to be inspected includes all piping within the limits of the liner system. The Contractor shall locate and protect all pipe ends which must be accessed for the camera inspection.

6. Surveying:

The Contractor shall survey all HDPE Pipe on 100 foot centers and at bends to ensure the proper location and grade of the piping.

**TABLE 1: REQUIRED HDPE PIPE PROPERTIES**

| PROPERTY | TEST METHOD | UNITS | VALUE[1] |
|---|---|---|---|
| Material Designation | ASTM D 412 | ---------- | PE 3408 |
| Cell Classification | ASTM D 3350 | ---------- | 345464 C |
| Density | ASTM D 1505 | $g/cm^3$ | 0.955 |
| Melt Flow Index | ASTM D 1238 | g/10 min | 0.1 |
| Flexural Modulus | ASTM D 790 | psi | 130,000 |
| Tensile Strength @ Yield | ASTM D 638 | psi | 3,200 |
| SCG (PENT) | ASTM F 1473 | hrs. | > 100 |
| Hydrostatic Design Basis at 73° F | ASTM D 2837 | psi | 1,600 |
| UV Stabilizer | ASTM D 1603 | % Carbon Black | 2 - 3% |

Notes:
1. Nominal Values.

END OF SECTION

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## SECTION 02710

## DRAINAGE AGGREGATE (LEACHATE MANAGEMENT)

Drainage Aggregate: Drainage Aggregate includes leachate collection media and coarse aggregate, which is placed on top of the geomembrane, around leachate collection pipes (gravel columns), and in the sump for the purpose of leachate collection and removal.

A. DESCRIPTION

1. General:

The Contractor shall furnish all labor, material, and equipment to complete the installation of Drainage Aggregate in accordance with the Contract Drawings and these Specifications.

2. Related Work:

Related Contract Work is described in the following sections of the Specifications:

| Work | Section |
|---|---|
| Geotextiles | 02240 |
| Protective Cover | 02256 |
| HDPE Pipe | 02614 |
| Drainage Geocomposite | 02712 |
| HDPE Geomembrane | 02775 |
| CQA Manual | Attached |

3. Reference Standards:

The latest revision of the following standards of the American Society of Testing and Materials (ASTM) and the North Carolina Department of Transportation (NCDOT) are hereby made a part of these specifications.

| | |
|---|---|
| ASTM C 136 | Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates. |
| ASTM D 2434 | Standard Test Method for Permeability of Granular Soils (Constant Head). |
| ASTM D 3042 | Standard Test Method for Insoluble Residue in Carbonate Aggregates. |

NCDOT Standard Specifications for Roads and Structures.

4. Quality Assurance:

Quality Assurance during placement of Drainage Aggregate will be provided by the Owner as described in the accompanying Project CQA Manual.

B. MATERIALS

1. Leachate Collection Media:

a. A granular material (NCDOT No. 78 or alternate gradation if approved by the Engineer) from a non-carbonate source (≤ 15% carbonate content by ASTM D 3042) shall be used as a leachate collection media on the base of the containment area as shown on the Contract Drawings and shall be approved by the CQA Engineer at least four weeks prior to construction.

b. The collection media shall consist of sub-angular or smoother particles and shall be sound, durable, and free from seams, cracks, or other structural defects. The material shall be free of shale, clay, friable materials, and debris.

c. The collection media shall meet the following gradation criteria and have a coefficient of permeability of 1 cm/sec. (ASTM D 2434) or greater.

| Sieve Size | Percent Passing |
|---|---|
| ¾ Inch | 100 |
| ½ Inch | 98-100 |
| ⅜ Inch | 75-100 |
| No. 4 | 20-45 |
| No. 8 | 0-15 |
| No. 200 | 0-2 |

The Engineer may approve an alternate gradation if the material meets permeability criteria.

2. Coarse Aggregate:

a. Coarse aggregate (NCDOT No. 57 or alternate gradation if approved by the Engineer) from a non-carbonate source (≤ 15% carbonate content by ASTM D 3042) shall be placed around the collection pipes where shown

on the Contract Drawings and shall be approved by the CQA Engineer at least four weeks prior to construction.

b. Coarse aggregate shall consist of rounded or sub-angular or smoother particles and shall be sound, durable, and free from seams, cracks, or other structural defects. The material shall be free of shale, clay, friable materials, and debris. Coarse aggregate consisting of long, thin, angular particles may be rejected at the sole discretion of the Engineer.

c. Coarse aggregate shall meet the following gradation criteria.

| Sieve Size | Percent Passing |
|---|---|
| 1½ Inch | 100 |
| 1 Inch | 95-100 |
| ½ Inch | 25-60 |
| No. 4 | 0-10 |
| No. 8 | 0-5 |
| No. 200 | 0-2 |

C. SUBMITTALS

The Contractor shall submit the following to the CQA Engineer:

1. Before approval is given to proceed, the Contractor shall submit descriptive information on equipment to be used for placement of the Drainage Aggregate.

2. The Contractor shall submit at least two bulk samples each of leachate collection media and coarse aggregate from each material source for approval at least four weeks prior to beginning construction of the leachate collection system. Along with the bulk samples, the Contractor shall also submit a certification from each material source that the materials proposed meet the specified gradation requirements.

3. Survey Results:

After completion of a segment of Drainage Aggregate, survey results shall be submitted for review prior to Drainage Aggregate acceptance.

D. CONSTRUCTION

1. Failing CQA Material Control Tests:

Drainage Aggregate that is rejected upon testing shall be removed from the project site and replaced at Contractor's cost. Sampling and CQA testing of Drainage Aggregate supplied as replacement for rejected material shall be performed by the CQA Engineer at the Contractor's cost.

2. The Drainage Aggregate is placed directly over geosynthetics and piping; thus, extreme caution shall be exercised by the Contractor to prevent damage to these materials.

Test areas to evaluate potential damage due to equipment operations may be required by the Engineer to assess equipment to be used by the Contractor at the Contractor's sole expense. Test area parameters shall be determined by the Engineer and Contractor in advance of construction of the leachate collection system.

3. All placement of Drainage Aggregate shall be performed only when the CQA Engineer is informed by the Contractor of intent to perform such work.

4. The Contractor shall exercise care in maintaining a true line and grade for all piping during placement and spreading of Drainage Aggregate.

5. Drainage Aggregate shall be placed over geosynthetics and/or piping only after areas have been released by the Geosynthetics Installer and the CQA Engineer. Drainage Aggregate shall be placed as specified below:

a. Drainage Aggregate shall be placed and spread using tracked equipment. On slopes of 6H:1V or steeper, low ground pressure (6 psi or less) tracked equipment shall be used. On slopes flatter than 6H:1V, tracked equipment shall have a ground pressure of 12 psi or less. The CQA Engineer shall approve the equipment used to place Drainage Aggregate. The Contractor shall place plastic traffic cones or other markers approved by the CQA Engineer on 100 foot centers to monitor thickness during placement.

b. Tracked equipment used to place and spread Drainage Aggregate shall operate on at least 1 foot of material overlying geosynthetics and/or piping. Sharp turning of tracked equipment on the Drainage Aggregate will not be permitted.

c. On slopes of 6H:1V or steeper, Drainage Aggregate shall be placed and spread from the bottom up unless otherwise approved by the Engineer. No material shall be dumped down a slope.

d. Drainage Aggregate shall not be placed over standing water or ice.

e. Drainage Aggregate shall not be compacted within the limits of the containment area.

f. Drainage Aggregate shall be placed to the lines and grades as shown on the Contract Drawings except that a 0.15 foot overbuild at the Contractor's expense is allowed. Drainage Aggregate placed beyond these limits shall be removed at the Contractor's sole expense if required by the Engineer.

6. The Drainage Aggregate shall be spread in a manner that minimizes development of wrinkles or tension in the underlying geosynthetics. Any portion of the underlying geosynthetics that develops excessive wrinkles or crimp or is otherwise damaged shall be repaired by the Geosynthetics Installer at no expense to the Owner.

   a. Drainage Aggregate shall not be placed when conditions are warm enough to produce excessive wrinkles in the underlying geosynthetics. Likewise, Drainage Aggregate shall not be placed when conditions are cold enough to produce tension in the underlying geosynthetics.

   b. If during spreading, excessive wrinkles develop, the Contractor shall adjust placement and spreading methods, or cease until the underlying geosynthetics cool and wrinkles decrease in size.

   c. Wrinkles that exceed approximately 6 inches in height and cannot be eliminated by amended placement and spreading methods or underlying geosynthetics that become crimped shall be cut and repaired by the Geosynthetics Installer in a method approved by the Engineer.

7. Stockpiling of Drainage Aggregate within the limits of the containment area shall be subject to advance approval by the Engineer. Any hauling equipment (dump trucks, etc.) operating within the containment area shall have a minimum of 3 feet of separation between the vehicle wheels and the Geomembrane.

   The Contractor shall minimize equipment operations directly over coarse aggregate.

8. The CQA Engineer may require removal of Drainage Aggregate and/or other underlying layers at the Contractor's sole expense to allow examination of the underlying geosynthetics and/or piping. Any damage to the underlying layers or excessive wrinkling or crimping during placement of Drainage Aggregate shall be repaired in accordance with the applicable section of these Specifications at the Contractor's sole expense.

9. Surveying:

After completion of a segment of Drainage Aggregate, the Drainage Aggregate shall be surveyed on 100 foot centers and at slope breaks (including all tops and toes of slope, points of grade change, etc.) (Note that the tops of gravel columns may be surveyed along with the Protective Cover.) to ensure:

a. The specified thickness has been achieved.

b. The top of the Drainage Aggregate slopes at grades specified on the Contract Drawings; and

c. Drainage Aggregate placed more than 0.15 feet beyond the limits of the lines and grades as shown on the Contract Drawings will not be accepted and must be removed at the Contractor's sole expense if required by the Engineer.

This work shall be performed at the Contractor's cost by a registered surveyor.

END OF SECTION

## SECTION 02711

## DRAINAGE AGGREGATE (FINAL COVER)

Drainage Aggregate: Drainage Aggregate includes coarse aggregate, which is placed in the final cover system for the purpose of surface and subsurface water collection and removal.

A. DESCRIPTION

1. General:

The Contractor shall furnish all labor, material, and equipment to complete the installation of Drainage Aggregate in accordance with the Contract Drawings and these Specifications.

2. Related Work:

Related Contract Work is described in the following sections of the Specifications:

| Work | Section |
|---|---|
| Geotextiles | 02240 |
| Vegetative Soil Layer | 02258 |
| HDPE Pipe | 02614 |
| Drainage Geocomposite | 02712 |
| LLDPE Geomembrane | 02778 |
| CQA Manual | Attached |

3. Reference Standards:

The latest revision of the following standards of the American Society of Testing and Materials (ASTM) and the North Carolina Department of Transportation (NCDOT) are hereby made a part of these specifications.

| | |
|---|---|
| ASTM C 136 | Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates. |
| ASTM D 2434 | Standard Test Method for Permeability of Granular Soils (Constant Head). |
| ASTM D 3042 | Standard Test Method for Insoluble Residue in Carbonate Aggregates. |

NCDOT Standard Specifications for Roads and Structures.

4. Quality Assurance:

Quality Assurance during placement of Drainage Aggregate will be provided by the Owner as described in the accompanying Project CQA Manual.

B. MATERIALS

1. Coarse Aggregate:

a. Coarse aggregate (Rain Gutters: 1½ to 3 inch or alternate gradation if approved by the Engineer) (Other Drains: NCDOT No. 78 and/or 57 Stone) shall be placed around the collection pipes where shown on the Contract Drawings and shall be approved by the CQA Engineer at least four weeks prior to construction.

b. Coarse aggregate shall consist of rounded or sub-angular or smoother particles and shall be sound, durable, and free from seams, cracks, or other structural defects. The material shall be free of shale, clay, friable materials, and debris. Coarse aggregate consisting of long, thin, angular particles may be rejected at the sole discretion of the Engineer.

C. SUBMITTALS

The Contractor shall submit the following to the CQA Engineer:

1. Before approval is given to proceed, the Contractor shall submit descriptive information on equipment to be used for placement of the Drainage Aggregate.

2. The Contractor shall submit at least two bulk samples of each type of coarse aggregate from each material source for approval at least four weeks prior to beginning construction of the final cover system. Along with the bulk samples, the Contractor shall also submit a certification from each material source that the materials proposed meet the specified gradation requirements.

D. CONSTRUCTION

1. Failing CQA Material Control Tests:

Drainage Aggregate that is rejected upon testing shall be removed from the project site and replaced at Contractor's cost. Sampling and CQA testing of Drainage Aggregate supplied as replacement for rejected material shall be performed by the CQA Engineer at the Contractor's cost.

2. The Drainage Aggregate is placed directly over geosynthetics and/or piping; thus, extreme caution shall be exercised by the Contractor to prevent damage to these materials.

   Test areas to evaluate potential damage due to equipment operations may be required by the Engineer to assess equipment to be used by the Contractor at the Contractor's sole expense. Test area parameters shall be determined by the Engineer and Contractor in advance of construction of the final cover system.

3. All placement of Drainage Aggregate shall be performed only when the CQA Engineer is informed by the Contractor of intent to perform such work.

4. The Contractor shall exercise care in maintaining a true line and grade for all piping during placement and spreading of Drainage Aggregate.

5. Drainage Aggregate shall be placed over geosynthetics and/or piping only after areas have been released by the Geosynthetics Installer and the CQA Engineer. Drainage Aggregate shall be placed as specified below:

   a. Drainage Aggregate shall be placed and spread with low ground pressure (6 psi or less) tracked equipment. The CQA Engineer shall approve the equipment used to place Drainage Aggregate.

   b. Tracked equipment used to spread Drainage Aggregate shall operate on at least 1 foot of material overlying geosynthetics and/or piping. Sharp turning of tracked equipment on the Drainage Aggregate will not be permitted.

   c. On slopes of 6H:1V or steeper, Drainage Aggregate shall be placed and spread from the bottom up unless otherwise approved by the Engineer. No material shall be dumped down a slope.

   d. Drainage Aggregate shall not be placed over standing water or ice.

   e. Drainage Aggregate shall not be compacted within the limits of the final cover.

6. The Drainage Aggregate shall be spread in a manner that minimizes development of wrinkles or tension in the underlying geosynthetics. Any portion of the underlying geosynthetics that develops excessive wrinkles or crimp or is otherwise damaged shall be repaired by the Geosynthetics Installer at no expense to the Owner.

   a. Drainage Aggregate shall not be placed when conditions are warm enough to produce excessive wrinkles in the underlying geosynthetics. Likewise,

Drainage Aggregate shall not be placed when conditions are cold enough to produce tension in the underlying geosynthetics.

b. If during spreading, excessive wrinkles develop, the Contractor shall adjust placement and spreading methods, or cease until the underlying geosynthetics cool and wrinkles decrease in size.

c. Wrinkles that exceed approximately 6 inches in height and cannot be eliminated by amended placement and spreading methods or underlying geosynthetics that become crimped shall be cut and repaired by the Geosynthetics Installer in a method approved by the Engineer.

7. Stockpiling of Drainage Aggregate within the limits of the final cover shall be subject to advance approval by the Engineer. Any hauling equipment (dump trucks, etc.) operating on the final cover shall have a minimum of 3 feet of separation between the vehicle wheels and the Geomembrane.

   The Contractor shall minimize equipment operations directly over coarse aggregate.

8. The CQA Engineer may require removal of Drainage Aggregate and/or other underlying layers at the Contractor's sole expense to allow examination of the underlying geosynthetics and/or piping. Any damage to the underlying layers or excessive wrinkling or crimping during placement of Drainage Aggregate shall be repaired in accordance with the applicable section of these Specifications at the Contractor's sole expense.

END OF SECTION

## SECTION 02712

## DRAINAGE GEOCOMPOSITE

Drainage Geocomposite (DGC): The Drainage Geocomposite (DGC) consists of a geonet drainage core and heat-bonded nonwoven geotextile. The purpose of the DGC is to rapidly transmit flow to collection piping.

A. DESCRIPTION

1. General:

The Contractor shall furnish all labor, material, and equipment to complete installation of DGC, including all necessary and incidental items, in accordance with the Contract Drawings and these Specifications.

2. Related Work:

Related Contract Work is described in the following sections of the Specifications:

| Work | Section |
|---|---|
| Protective Cover | 02256 |
| Vegetative Soil Layer | 02258 |
| HDPE Pipe | 02614 |
| Drainage Aggregate (Leachate Management) | 02710 |
| Drainage Aggregate (Final Cover) | 02711 |
| HDPE Geomembrane | 02775 |
| LLDPE Geomembrane | 02778 |
| Landfill Gas System | 13252 |
| CQA Manual | Attached |

3. Reference Standards:

The latest revision of the following standards of the American Society of Testing and Materials (ASTM) and the Geosynthetic Research Institute (GRI) are hereby made a part of these specifications.

| | |
|---|---|
| ASTM D 413 | Standard Test Methods for Rubber Property - Adhesion to Flexible Substrate. |
| ASTM D 1505 | Standard Test Method for Density of Plastics by the Density-Gradient Technique. |

| | |
|---|---|
| ASTM D 1603 | Standard Test Method for Carbon Black in Olefin Plastics. |
| ASTM D 4218 | Standard Test Method for Determination of Carbon Black Content in Polyethylene Compounds By the Muffle-Furnace Technique. |
| ASTM D 4355 | Standard Test Method for Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water (Xenon-Arc Type Apparatus). |
| ASTM D 4491 | Standard Test Methods for Water Permeability of Geotextiles by Permittivity. |
| ASTM D 4632 | Standard Test Method for Grab Breaking Load and Elongation of Geotextiles. |
| ASTM D 4716 | Standard Test Method for Constant Head Hydraulic Transmissivity (In-Plane Flow) of Geotextiles and Geotextile Related Products. |
| ASTM D 4751 | Standard Test Method for Determining Apparent Opening Size of a Geotextile. |
| ASTM D 4833 | Standard Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products. |
| ASTM D 5199 | Standard Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes. |
| ASTM D 5261 | Standard Test Method for Measuring Mass per Unit Area of Geotextiles. |
| ASTM D 5321 | Standard Test Method for Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method. |
| ASTM D 6243 | Standard Test Method for Determining the Internal and Interface Shear Resistance of Geosynthetic Clay Liner by the Direct Shear Method. |
| GRI GC7 | Determination of Adhesion and Bond Strength of Geocomposites. |

4. Quality Control:

The Contractor shall perform Quality Control tests in accordance with Table 3 of this section.

5. Quality Assurance:

Quality Assurance during installation of DGC will be provided by the Owner as described in the accompanying Project CQA Manual.

B. MATERIALS

1. General:

The materials supplied under these Specifications shall consist of new, first-quality products designed and manufactured specifically for the purpose of this work, which shall have been satisfactorily demonstrated, by prior use, to be suitable and durable for such purposes.

Labels on each roll of DGC shall identify the length, width, lot and roll numbers, and name of Manufacturer.

2. The geonet drainage core shall be manufactured by extruding polyethylene strands to form a three dimensional structure to provide planer water flow.

3. A nonwoven needlepunched geotextile, consisting of polyester or polypropylene and manufactured in a manner approved by the Engineer, shall be heat-bonded to the geonet drainage core. Roll edges shall have a maximum unbonded length of 6 inches, unless otherwise approved by the Engineer. Heat bonding shall be performed by the Manufacturer prior to shipping to the site.

4. The geonet drainage core shall contain UV inhibitors to prevent ultraviolet light degradation.

5. Base Liner Drainage Geocomposite:

Base Liner DGC shall have a nonwoven geotextile heat-bonded to both sides of the geonet drainage core. Physical properties of the DGC shall be as shown in Table 1 of this section.

6. Final Cover Drainage Geocomposite:

Final Cover DGC shall have a nonwoven geotextile heat-bonded to both sides of the geonet drainage core. Physical properties of the DGC shall be as shown in Table 1 of this section.

C. SUBMITTALS

Prior to DGC installation, the Contractor shall submit the following to the CQA Engineer:

1. Mill Certificate and Sample: Prior to shipping to the site, the Contractor shall submit a mill certificate or affidavit signed by a legally authorized official of the Manufacturer for the DGC attesting that the DGC meets the physical and manufacturing requirements stated in these Specifications. The Contractor shall also submit a sample of the DGC to be used. The sample shall be labeled with the product name and be accompanied by the Manufacturer's specifications.

2. Shipping, Handling, and Storage Instructions: The Manufacturer's plan for shipping, handling, and storage shall be submitted for review.

3. Seaming Procedures:

   Submit proposed seaming procedures including proposed method and equipment.

4. Quality Control Certificates: For DGC delivered to the site, quality control certificates, signed by the Manufacturer's quality assurance manager shall be provided which represent every roll of DGC. Each certification shall have the roll identification number(s), test methods, frequency, and test results. At a minimum, the test results and frequency of testing shall be as shown in Table 2 of this section.

5. Contractor Quality Control Test Results: The Contractor shall provide the results of required testing.

6. Furnish copies of delivery tickets or other approved receipts as evidence for materials received that will be incorporated into the construction.

D. CONSTRUCTION

1. Shipping, Handling, and Storage:

   All DGC shall be shipped, handled, and stored in strict accordance with the Manufacturer's recommendations.

2. Failing CQA Material Control Tests:

   DGC that is rejected upon testing shall be removed from the project site and replaced at Contractor's cost. Sampling and quality assurance testing of DGC supplied as replacement for rejected material shall be performed by the CQA Engineer at Contractor's cost.

3. Installation:

a. The DGC shall be placed only on Geomembrane that has been approved by the Geomembrane Installer and accepted by the CQA Engineer. The Contractor shall remove debris, including sediment to the degree possible, from the Geomembrane prior to placement of the DGC.

b. DGC shall be placed to the lines and grades shown on the Contract Drawings. At the time of installation, the DGC shall be rejected, if it has defects, rips, holes, flaws, evidence of deterioration, or other damage. Isolated areas of up to 1 square yard where the geotextile has become delaminated from the geonet drainage core may be allowed by the CQA Engineer as long as there appears to be a good bond between the geotextile and the geonet in surrounding areas. Rolls where the geotextile appears to be easily delaminated from the geonet such as by foot or ATV traffic shall be rejected.

c. Orientation: If the DGC transmits flow in a predominant direction (typically along the roll length), then the DGC shall be installed with the predominant flow direction laid approximately perpendicular to contour lines (i.e. in the direction of the slope) or as specified by the Engineer. Otherwise, DGC shall be installed with the machine direction (along the roll length) generally in the direction of flow or as specified by the Engineer.

d. The DGC shall be placed smooth and free of excessive wrinkles.

e. The Contractor shall provide temporary anchorage of the DGC at the top of perimeter and interior berms during installation as necessary to prevent movement during construction. Such anchorage may include sandbags and the like, as approved by the CQA Engineer. Permanent bonding to the Geomembrane shall be prohibited.

4. Seams:

a. All seams constructed on slopes of 6H:1V or steeper or within 10 feet of the toe of a slope of 6H:1V or steeper shall be vertical seams, except where slope lengths exceed standard roll lengths and elsewhere as approved in advance by the Engineer. Where allowed by the Engineer, end seams on slopes of 6H:1V or steeper shall be staggered a minimum of 5 feet between adjacent rolls.

b. Geonet Drainage Core: The geonet drainage core shall be laid with a 3 inch minimum overlap seam along roll edges and a 6 inch minimum overlap seam along roll ends and shall be secured using plastic ties. Ties

shall be placed every 5 feet along roll edges; every 12 inches along roll ends; and every 6 inches in the anchor trench.

c. Geotextile Component(s): Where applicable, the bottom geotextile of the DGC shall be overlapped with the same of the adjacent rolls. The top geotextile of the DGC shall be continuously sewn or heat bonded to the same of the adjacent rolls with methods approved by the Engineer.

(1) Seams to be sewn shall be sewn using a Type 401 stitch. One or two rows of stitching may be used. Each row of stitching shall consist of 4 to 7 stitches per inch. The minimum distance from the geotextile edge to the stitch line nearest to that edge (seam allowance) shall be 1.5 inches if a Type SSa (prayer or flat) seam is used. The minimum seam allowance for all other seam types shall be 1.0 inches.

(2) Seams to be heat bonded shall be bonded using hot plate, hot knife, ultrasonic, or other approved devices.

5. Repairs:

Any DGC that is torn, crushed, punctured, or otherwise damaged shall be repaired or replaced, as directed by the CQA Engineer, by the Contractor at no additional cost to the Owner. The repair shall consist of a patch of the same type of material, placed over the damaged area and shall overlap the existing material a minimum of 12 inches from any point of the damage. The patch shall be connected to the geonet drainage core of the damaged material using plastic cable ties at a 6 inch spacing and the upper geotextile of the patch shall be spot sewn or heat bonded to the upper geotextile of the damaged material. A geotextile patch, spot sewn or heat bonded to the damaged material, may be used where damage is to only that portion of the DGC.

6. Cover Placement:

Placement of materials over DGC shall be performed in a manner as to ensure that DGC and the underlying geosynthetics are not damaged; minimal slippage of DGC on the underlying geosynthetics occurs; no excess tensile stresses occur in the DGC; and that no portion of the DGC develops excessive wrinkles or crimp. Wrinkles that exceed approximately 6 inches in height and cannot be eliminated by amended placement and covering methods or DGC that becomes crimped shall be cut and repaired by the Geosynthetics Installer in a method approved by the Engineer.

## TABLE 1: REQUIRED DRAINAGE GEOCOMPOSITE PROPERTIES

| PROPERTY | TEST METHOD | UNITS | VALUE |
|---|---|---|---|
| **Geonet:** | | | |
| Thickness | ASTM D 5199 | inches | 0.25<br>(See Note 1) |
| Density | ASTM D 1505 | $g/cm^3$ | 0.94 |
| Carbon Black Content | ASTM D 1603/D 4218 | % | 2-3 |
| **Geotextile:** | | | |
| Mass per Unit Area (Unit Wt.) | ASTM D 5261 | $oz/yd^2$ | 6 |
| Tensile Properties: | ASTM D 4632 | | |
| Grab Strength | | lbs | 160 |
| Grab Elongation | | % | $\geq$ 50 |
| Puncture Resistance | ASTM D 4833 | lbs | 55 |
| Apparent Opening Size (AOS) | ASTM D 4751 | U.S. Sieve | 70+ |
| Permittivity | ASTM D 4491 | $sec^{-1}$ | 1.0 |
| Ultraviolet Resistance (500 hrs) | ASTM D 4355 | % | 70 |
| **Geocomposite:** | | | |
| Ply Adhesion | ASTM D 413/<br>GRI GC7 | lb/inch | 2.0 Typ.<br>1.0 Min. Avg. |
| Transmissivity:<br>(Base Liner)<br><br>(Final Cover) | ASTM D 4716 | $m^3/m/sec$ | $5.0 \times 10^{-4}$<br>(See Notes 2 and 4)<br>$1.0 \times 10^{-3}$<br>(See Note 2) |
| Interface Shear Strength (Peak)[3]<br>(Base Liner)<br><br><br><br>(Final Cover) | ASTM D 5321<br>ASTM D 6243 (GCL) | psf | <br>100 psf (Load = 200 psf)<br>1,000 psf (2,500 psf)<br>2,000 psf (5,000 psf)<br>4,000 psf (10,000 psf)<br><br>115 psf (Load = 200 psf) |

Notes:

1. A thicker geonet may be required depending on transmissivity requirements.

2. Base Liner:
   Conduct test for transmissivity at a normal compressive load of 10,000 psf and at a hydraulic gradient of 0.1 after a seating period of at least 100 hours. Boundary conditions are soil (sand) interface on the upper geotextile and textured HDPE geomembrane against the lower geotextile.

   Final Cover:
   Conduct test for transmissivity at a normal compressive load of 1,000 psf and at a hydraulic gradient of 0.25 after a seating period of at least 24 hours. Boundary conditions are soil (sand) interface on the upper geotextile and textured LLDPE geomembrane against the lower geotextile.

3. DGC shall have adequate adhesion against adjacent materials under low normal loads to achieve the successful installation of overlying components without slippage.

4. Transmissivity testing is not required for drainage geocomposite to be used in the Landfill Gas System.

**TABLE 2: REQUIRED MANUFACTURER QUALITY CONTROL TESTS**

| PROPERTY | TEST METHOD | MINIMUM TEST FREQUENCY |
|---|---|---|
| **Geonet:** | | |
| Thickness | ASTM D 5199 | 50,000 $ft^2$ |
| Density | ASTM D 1505 | 50,000 $ft^2$ |
| Carbon Black Content | ASTM D 1603/D 4218 | 50,000 $ft^2$ |
| **Geotextile:** | | |
| Mass Per Unit Area | ASTM D 5261 | 200,000 $ft^2$ |
| Tensile Properties | ASTM D 4632 | 200,000 $ft^2$ |
| Puncture Resistance | ASTM D 4833 | 200,000 $ft^2$ |
| Apparent Opening Size (AOS) | ASTM D 4751 | 600,000 $ft^2$ |
| Permittivity | ASTM D 4491 | 600,000 $ft^2$ |
| UV Resistance | ASTM D 4355 | 600,000 $ft^2$ |
| **Geocomposite:** | | |
| Ply Adhesion | ASTM D 413/ GRI GC7 | 100,000 $ft^2$ |
| Transmissivity[1] | ASTM D 4716 | 100,000 $ft^2$ (See Note 2) |

Notes:

1. Conduct transmissivity tests in accordance with the criteria given in Table 1.
2. The required Manufacturer's quality control testing for transmissivity may be reduced to one test per resin lot or one test per 500,000 $ft^2$ (whichever provides the larger number of tests) if the minimum measured transmissivity is at least 50% greater than specified.

**TABLE 3: REQUIRED CONTRACTOR QUALITY CONTROL TESTS**

| PROPERTY | TEST METHOD | MINIMUM TEST FREQUENCY |
|---|---|---|
| Interface Shear Strength | ASTM D 5321<br>ASTM D 6243 (GCL) | (See Note 1) |

Notes:

1. Test each interface to be used on this project using representative samples of materials to be supplied under normal loads indicated and using test parameters as specified by the Engineer. For this project, interfaces to be tested are:

   Base Liner:

   A. Textured LLDPE-GM (40 mil) against existing cover soils (intermediate cover);
   B. Drainage Geocomposite against textured LLDPE-GM (40 mil);
   C. Geosynthetic Clay Liner against Drainage Geocomposite;
   D. Textured HDPE-GM (60 mil) against Geosynthetic Clay Liner;
   E. Drainage Geocomposite against textured HDPE-GM (60 mil);
   F. Protective Cover against Drainage Geocomposite.

   Final Cover:

   A. Textured LLDPE-GM (30 mil) against existing cover soils (intermediate cover);
   B. Drainage Geocomposite against textured LLDPE-GM (30 mil); and
   C. Vegetative Soil Layer against Drainage Geocomposite.

   If there are material differences in the surface of any of the geosynthetic materials from one side to the other, then all possible combinations of interfaces shall be tested. This testing shall be performed at Contractor cost by an independent GAI accredited laboratory and submitted to the Engineer for review prior to shipping. Upon review of test results, the Engineer may allow exceptions to the above criteria.

   For tests involving textured geomembranes, the laboratory shall also report the asperity height (GRI GM12) for the material samples used in the actual direct shear tests.

END OF SECTION

## SECTION 02720

## STORM WATER SYSTEMS

Storm Water Systems: Storm Water Systems shall include all piping, pipe fittings, headwalls, flared end sections, drop inlets, manholes, and other appurtenances designated to convey stormwater.

A. DESCRIPTION

1. General:

The contractor shall furnish all labor, material, and equipment to complete installation of Storm Water Systems in accordance with the Contract Drawings and these Specifications.

2. Related Work:

Related Contract Work is described in the following sections of the Specifications:

| Work | Section |
|---|---|
| Excavation | 02222 |
| Embankment | 02223 |
| Erosion and Sedimentation Control | 02270 |
| Rip Rap | 02271 |
| Precast Concrete Structures | 02608 |
| HDPE Pipe | 02614 |
| Concrete Work | 03310 |

3. Reference Standards:

The latest revision of the following standards of the American Society of Testing and Materials (ASTM), the American Association of State Highway and Transportation Officials (AASHTO), and the North Carolina Department of Transportation (NCDOT) are hereby made a part of these specifications.

| | |
|---|---|
| ASTM C 76 | Standard Specification for Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe. |
| ASTM C 150 | Standard Specification for Portland Cement. |

| | |
|---|---|
| ASTM D 1248 | Standard Specification for Polyethylene Plastics Molding and Extrusion Materials For Wire and Cable. |
| ASTM D 2321 | Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications. |
| ASTM D 3350 | Standard Specification for Polyethylene Plastics Pipe and Fittings Materials. |
| AASHTO M 36 | Specification for Corrugated Steel Pipe. |
| AASHTO M 252 | Specification for Corrugated Polyethylene Drainage Tubing, 3 to 10 Inch Diameter. |
| AASHTO M 294 | Specification for Corrugated Polyethylene Pipe, 12 to 36 Inch Diameter. |
| NCDOT | Standard Specifications for Roads and Structures and Roadway Standard Drawings. |

B. MATERIALS

1. Reinforced Concrete Pipe (RCP):

   a. All reinforced concrete pipe shall be manufactured in accordance with ASTM C 76, Wall Type B or C, and shall be of the class that equals or exceeds the pipe class as shown on the Contract Drawings. All pipe shall be aged at the manufacturing plant for at least fourteen (14) days before delivery to the job site.

   b. Minimum pipe laying lengths shall be four (4) feet.

   c. Joints for the reinforced concrete pipe shall have bell and spigot ends with flexible preformed plastic gaskets.

2. Corrugated Metal Pipe (CMP):

   a. Corrugated metal pipe and fittings shall be of the sizes shown or specified and shall conform to every aspect of AASHTO M 36.

   b. Corrugated metal pipe shall be fabricated from galvanized steel sheets. Corrugation profile shall be 2⅔ inch crest to crest and ½ inch crest to valley, and sheet thickness shall be 16 gage/.064 inch minimum.

c. Pipe sections shall be helically corrugated with each pipe end rerolled to obtain no less than two (2) annular corrugations.

d. Coupling Bands: CMP shall be firmly joined by coupling bands in accordance with the manufacturer's recommendations. These bands shall be not more than two nominal sheet thicknesses lighter than the thickness of the pipe to be connected and in no case lighter than 0.052 inches.

e. All CMP utilized for permanent installation shall have gasketed joints.

f. Asphaltic or bituminous coatings shall be applied in conformance with the manufacturer's requirements, as applicable.

3. Corrugated Polyethylene (CPE) Pipe:

CPE pipe and fittings shall be of the sizes and type shown on the Contract Drawings and shall conform to every aspect of AASHTO M 252 (3 to 10 inch diameters) or AASHTO M 294 (12 to 36 inch diameters). All Type S CPE pipe shall have watertight joints.

4. Flared End Sections:

Flared end sections shall be reinforced and shall be fabricated from the same materials meeting the same requirements as the pipe to which they are connected. All reinforced concrete and corrugated metal flared end sections shall meet the requirements of the NCDOT. Corrugated polyethylene flared end sections shall be as recommended by the pipe manufacturer.

5. Headwalls:

Headwalls shall be as described in the Contract Drawings.

6. Precast Concrete Structures:

Precast Concrete Structures shall be constructed as shown in the Contract Drawings and in accordance with Section 02608, Precast Concrete Structures, of these Specifications.

C. SUBMITTALS

The Contractor shall submit the following to the CQA Engineer:

1. Submit a certification and summary of all required test results, prior to installation, that all Storm Water Systems have been produced in accordance with these Specifications.

2. Furnish copies of the delivery tickets or other approved receipts as evidence for materials received that will be incorporated into construction.

D. CONSTRUCTION

1. All piping shall be installed by skilled workmen and in accordance with the best standards for piping installation. Proper tools and appliances for the safe and convenient handling and installation of the pipe and fittings shall be used.

2. All pieces shall be carefully examined for defects, and no piece shall be installed which is known to be defective. If any defective piece should be discovered after having been installed, it shall be removed and replaced at the Contractor's expense.

3. Excavation and backfilling of pipe trenches shall be as described in Section 02222, Excavation and Section 02223, Embankment, respectively, of these Specifications.

4. Following proper preparation of the trench subgrade, pipe and fittings shall be carefully lowered into the trench so as to prevent dirt and other foreign substances from gaining entrance into the pipe and fittings. Proper facilities shall be provided for lowering sections of pipe into trenches. No materials shall be dropped or dumped into the trench.

5. Water shall be kept out of the trench until jointing and backfilling are completed. When work is not in progress, open ends of pipe, fittings, and valves shall be securely closed so that no water, earth, or other substance will enter the pipes, fittings, or valves. Pipe ends left for future connections shall be valved, plugged, or capped, and anchored as required.

6. All piping shall be erected to accurate lines and grades with no abrupt changes in line or grade.

7. The full length of each section of pipe shall rest solidly upon the bed of the trench, with recesses excavated to accommodate bells, couplings, joints, and fittings. Before joints are made, each pipe shall be well bedded on a solid foundation. No pipe shall be brought into position until the preceding length has been thoroughly bedded and secured in place. Pipe that has the grade or joint disturbed after laying shall be taken up and relaid by the Contractor at his own expense.

8. The laying of reinforced concrete pipe shall conform to the applicable sections of the Concrete Pipe Handbook as published by the American Concrete Pipe Association.

END OF SECTION

## SECTION 02775

## HDPE GEOMEMBRANE

HDPE Geomembrane (HDPE-GM): The HDPE Geomembrane serves as the primary hydraulic containment barrier for the leachate to be developed in the landfill. Thus, it is of great importance that the HDPE-GM be free from defects and installed free from damage.

A. DESCRIPTION

1. General:

The Contractor shall furnish all labor, material, and equipment to complete installation of HDPE-GM including all necessary and incidental items as detailed or required to complete the installation in accordance with the Contract Drawings and these Specifications.

2. Related Work:

Related Contract Work is described in the following sections of the Specifications:

| Work | Section |
|---|---|
| Protective Cover | 02256 |
| Drainage Aggregate (Leachate Management) | 02710 |
| Drainage Geocomposite | 02712 |
| Geosynthetic Clay Liner | 02776 |
| CQA Manual | Attached |

3. Reference Standards:

The latest revision of the following standards of the American Society of Testing and Materials (ASTM) and the Geosynthetic Research Institute (GRI) are hereby made a part of these Specifications.

| | |
|---|---|
| ASTM D 792 | Standard Test Method for Density and Specific Gravity (Relative Density) of Plastics by Displacement. |
| ASTM D 1004 | Standard Test Method for Initial Tear Resistance of Plastic Film and Sheeting. |
| ASTM D 1505 | Standard Test Method for Density of Plastics by the Density-Gradient Technique. |

| | |
|---|---|
| ASTM D 1603 | Standard Test Method for Carbon Black in Olefin Plastics. |
| ASTM D 5199 | Standard Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes. |
| ASTM D 5321 | Standard Test Method for Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method. |
| ASTM D 5397 | Standard Test Method for Evaluation of Stress Crack Resistance of Polyolefin Geomembranes Using Notched Constant Tensile Load Test. |
| ASTM D 5596 | Standard Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics. |
| ASTM D 5820 | Standard Practice for Pressurized Air Channel Evaluation of Dual Seamed Geomembranes. |
| ASTM D 5994 | Standard Test Method for Measuring Core Thickness of Textured Geomembrane. |
| ASTM D 6243 | Standard Test Method for Determining the Internal and Interface Shear Resistance of Geosynthetic Clay Liner by the Direct Shear Method. |
| ASTM D 6392 | Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods. |
| ASTM D 6693 | Standard Test Method for Determining Tensile Properties of Nonreinforced Flexible Polyethylene and Nonreinforced Polypropylene Geomembranes. |
| GRI GM9 | Cold Weather Seaming of Geomembranes. |
| GRI GM12 | Asperity Measurement of Textured Geomembranes Using a Depth Gage. |
| GRI GM13 | Standard Specification for Test Properties, Testing Frequency and Recommended Warranty for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes. |

GRI GM19 Seam Strength and Related Properties of Thermally Bonded Polyolefin Geomembranes.

4. Quality Control:

   a. The Contractor shall perform Quality Control tests in accordance with Table 2 of this section.

   b. The Geomembrane Installer shall follow the procedures and requirements described in the accompanying Project CQA Manual during installation of HDPE-GM including performing and documenting trial seams, nondestructive and destructive Quality Control tests, and repairs.

5. Quality Assurance:

   Quality Assurance during installation of HDPE-GM will be provided by the Owner as described in the accompanying Project CQA Manual.

6. Manufacturers Qualifications:

   The Manufacturer shall have previously demonstrated his ability to produce the required HDPE-GM by having successfully manufactured a minimum of 10,000,000 $ft^2$ of HDPE-GM for hydraulic containment purposes.

7. Installer Qualifications:

   a. Installation of the HDPE-GM shall be performed by an Installer that has installed a minimum of 5,000,000 $ft^2$ of the material within the past five (5) years in similar landfill installations.

   b. All Installation Supervisors assigned to the Project shall have previously managed the installation of at least 2,000,000 $ft^2$ of HDPE-GM using the same techniques to be used on site.

   c. All seaming equipment operators shall have demonstrated performance on previous geomembrane installations and/or documented training.

8. Warranties:

   a. General: Should a defect occur, which is covered under warranty, the Warrantor shall bear all costs for repair and/or relocation and replacement of the HDPE-GM.

   b. Workmanship: The Contractor shall furnish the Owner a warranty from the Installer of the HDPE-GM which warrants their workmanship to be

free of defects on a prorata basis for five (5) years after the final acceptance of the Work. This warranty shall include but not be limited to all field seams, anchor trenches, attachments to appurtenances, and penetration seals, as applicable.

c. Manufacturer's Warranty: The Contractor shall furnish the Owner a warranty from the HDPE-GM Manufacturer for the materials used. The material warranty shall be for defects or failures related to manufacture on a prorata basis for five (5) years after the date of shipment.

B. MATERIALS

1. General:

The materials supplied under these Specifications shall consist of new, first-quality products designed and manufactured specifically for the purpose of this work, which shall have been satisfactorily demonstrated, by prior use, to be suitable and durable for such purposes. The HDPE-GM and HDPE-GM Manufacturer shall be approved by the Engineer.

The HDPE-GM shall be supplied in rolls which shall have a minimum width of 22 feet. The roll length shall be maximized to provide the largest manageable sheet for the fewest seams. However, no factory seaming of HDPE-GM panels shall be accepted. Labels on the roll shall identify the thickness, length, width, lot and roll numbers, and name of Manufacturer.

2. HDPE-GM Materials:

Textured HDPE-GM shall be 60 mils thick. Resin and sheet properties of HDPE-GM shall meet or exceed the requirements of GRI GM13 and Table 1 of this section.

3. Extrusion Resin/Typical Extrudate:

Extrusion resin/typical extrudate used for extrusion seaming of HDPE-GM shall be high density polyethylene (HDPE). Physical properties shall be the same as the HDPE-GM sheet. The extrudate's additives shall be thoroughly dispersed throughout the rod or bead. The extrudate shall be free of contamination by moisture or foreign matter and shall be recommended for use with the associated sheet material.

4. Texturing:

Textured HDPE-GM, where required, shall be fabricated using coextrusion or impingement methods. Texturing shall not be created by lamination, structuring,

or embossing. Texturing applied to HDPE-GM using impingement methods shall be bonded securely to the parent HDPE-GM. All texturing shall be uniform in appearance and coverage on the finished sheet. Textured HDPE-GM shall be textured on both sides of the sheet.

C. SUBMITTALS

The Contractor shall submit the following to the CQA Engineer:

1. Pre-Installation Requirements:

Prior to HDPE-GM installation, the Contractor shall submit the following:

a. Mill Certificate and Sample: Prior to shipping to the site, the Contractor shall submit a mill certificate or affidavit signed by a legally authorized official of the Manufacturer for the HDPE-GM attesting that the HDPE-GM meets the physical and manufacturing requirements stated in these Specifications. The Contractor shall also submit a sample of the HDPE-GM to be used. The sample shall be labeled with the product name and be accompanied by the Manufacturer's specifications.

b. Qualifications:

(1) Submit list of equipment and personnel proposed for the Project. Include equipment type and quantities. Include personnel experience on similar projects.

(2) Submit resume and references of Installation Supervisor to be assigned to the Project, including data and duration of employment and pertinent experience information.

(3) Submit resumes and references of installation personnel who will perform seaming operations, including dates and durations of employment and pertinent experience information.

c. Shipping, Handling, and Storage Instructions: The Manufacturer's plan for shipping, handling, and storage shall be submitted for review.

d. Delivery Date: Submit notification of the scheduled delivery dates for the materials.

e. Installation Procedures and Drawings:

Submit installation procedures and (shop) drawings for carrying out the work.

(1) Installation procedures to be addressed shall include but not be limited to material installation, repair, and protection to be provided in the event of rain or strong winds.

(2) Shop drawings shall have HDPE-GM sheet layout with proposed size, number, position, and sequence of placing all panels, and indicating the location of all field seams. Shop drawings shall also show complete details and/or methods for anchoring the HDPE-GM, making field seams, and making seals around pipes and structures penetrating the HDPE-GM (if applicable).

Following review, these procedures and drawings shall be used for installation of the HDPE-GM. Any deviations from these procedures and drawings must be approved by the Engineer and CQA Engineer.

f. Quality Control Certificates: For HDPE-GM delivered to the site, quality control certificates, signed by the Manufacturer's quality assurance manager shall be provided which represent every roll of HDPE-GM. Each certificate shall have the roll identification number(s), test methods, frequency, and test results. At a minimum, the test results and frequency of testing shall meet or exceed the requirements of GRI GM13.

g. Contractor Quality Control Test Results: The Contractor shall provide the results of required testing.

h. Furnish copies of the delivery tickets or other approved receipts as evidence for materials received that will be incorporated into the construction.

2. Post-Installation Requirements:

Upon completion of the HDPE-GM installation, the Contractor shall submit the following:

a. Certificate stating that the HDPE-GM has been installed in accordance with the Drawings, Specifications, and the Manufacturer's recommendations.

b. Completed Manufacturer's and workmanship warranties.

c. Record Information: Record information shall include but not be limited to:

(1) CQC Documentation: Includes trial seam logs, panel placement logs, panel seaming logs, non-destructive seam testing report forms, field destructive seam testing report forms, and repair logs.

(2) As-Built Drawing: Includes the requirements listed in Paragraph D.8 (Surveying) of this Specification.

Finalization of payment for HDPE-GM installation shall not be made until the above submittals have been reviewed by the CQA Engineer.

D. CONSTRUCTION

1. Shipping, Handling, and Storage:

The HDPE-GM shall be shipped, handled, and stored in strict accordance with the Manufacturer's recommendations.

2. Failing CQA Material Control Tests:

HDPE-GM that is rejected upon testing shall be removed from the project site and replaced at Contractor's cost. Sampling and CQA testing of HDPE-GM supplied as replacement for rejected material shall be performed by the CQA Engineer at Contractor's cost.

3. Subgrade Preparation:

a. The surface of the subgrade (surface of GCL) shall be smooth, uniform, free from sudden changes in grade (such as vehicular ruts), rocks or stones, debris, and deleterious materials. During actual placing and seaming of the HDPE-GM, the subgrade shall be kept free of all standing water. If the subgrade below the HDPE-GM becomes excessively wet and unstable as determined by the CQA Engineer, it shall be dried and recompacted, and replaced if needed. Likewise, GCL which becomes hydrated shall be removed and replaced at Contractor expense.

b. Before an individual panel of HDPE-GM is installed; the Contractor and Installer shall verify in writing and submit to the CQA Engineer:

(1) Lines and grades are in conformance with the Contract Drawings and Specifications.

(2) The surface area to be lined has been rolled and compacted, free of irregularities and abrupt changes in grade.

c. The Contractor shall not proceed with HDPE-GM installation until a complete report on all GCL CQA testing has been submitted and approved by the CQA Engineer. If the Contractor proceeds with HDPE-GM installation prior to completion of these tests, the Contractor will do so at his own risk. If any tests fail, the Contractor shall be required to remove HDPE-GM and reconstruct the underlying components to specification requirements. All costs associated with such actions (including the costs of additional testing) shall be paid for entirely by the Contractor.

4. HDPE-GM Placement:

a. Weather Conditions:

HDPE-GM placement shall not proceed at an ambient temperature below 32° F or above 100° F unless otherwise authorized, in writing, by the Engineer. Installation of HDPE-GM at temperatures below 32° F, if authorized by the Engineer, shall follow GRI GM9. HDPE-GM placement shall not be performed during precipitation, excessive moisture, in an area of ponded water, or in excessive winds. Any portion of HDPE-GM or subgrade damaged due to weather conditions shall be repaired at the Contractor's cost.

b. Method of Placement:

(1) Each panel of the HDPE-GM shall be installed in accordance with the approved shop drawings prepared by the Contractor. The layout shall be designed to keep field seaming of the HDPE-GM to a minimum, shall avoid seams parallel to and under leachate collection piping, and shall be consistent with proper methods of HDPE-GM installation.

(2) Panels shall be oriented perpendicular to the line of the slope crest (i.e., down and not across slope).

(3) The HDPE-GM shall be placed smooth and free of excessive wrinkles.

(4) HDPE-GM rolls shall be placed using proper spreader and rolling bars with cloth slings. If a sheet must be displaced a distance greater than its width, a slip sheet shall be used.

(5) The CQA Engineer shall inspect each panel, after placement and prior to seaming, for damage and/or defects. Defective or damaged panels shall be replaced or repaired, as approved by the CQA Engineer and as described in this section.

(6) The Installer shall avoid dragging the HDPE-GM on rough soil subgrades.

(7) All HDPE-GM shall be anchored as shown on the Contract Drawings and consistent with Manufacturer's recommendations.

(8) Personnel working on the HDPE-GM shall not smoke, wear damaging shoes, or involve themselves in any activity that may damage the HDPE-GM, in the opinion of the CQA Engineer.

(9) The HDPE-GM shall be properly weighted to avoid uplift due to wind.

(10) Vehicular traffic across the HDPE-GM shall not be allowed, except that four-wheel (or greater) all-terrain vehicles (ATVs) with low ground pressure may be allowed if approved in advance by the Engineer. The Contractor shall submit proposed equipment and procedures for use of ATVs to the CQA Engineer as part of his submittals. If ATVs are allowed by the Engineer, each ATV shall be operated such that no sudden stops, starts, or turns are made.

(11) All damage shall be recorded and located on the record drawings.

(12) When tying into existing HDPE-GM, excavation of previously installed geosynthetics shall be performed in a manner that minimizes damage to the existing geosynthetics and as approved by the Engineer. All damage to the existing geosynthetics shall be repaired by the Geosynthetics Installer at the Contractor's sole expense.

(13) The HDPE-GM shall be kept free of debris, unnecessary tools, and materials. In general, the HDPE-GM area shall remain neat in appearance.

c. Pipe Penetrations:

All pipe penetrations through the HDPE-GM shall be as shown in the Contract Drawings. Alternative penetration details may be approved by the Engineer and CQA Engineer.

5. Field Seams:

a. Individual panels of HDPE-GM shall be laid out and overlapped by a minimum of 4 inches prior to seaming. The area to be seamed shall be

cleaned and prepared in accordance with the Manufacturer's recommendations.

b. Dual or single track hot wedge methods shall be used for straight seams.

c. Extrusion fillet methods shall be used to seam cross seam tees, patches, repairs, and penetration boots. All extrudate shall be free of dirt, dry, and protected from damage. To limit overgrinding, the amount of grinding exposed after an extrusion seam is completed shall be less than ¼ inch.

d. The seaming equipment used shall be capable of continuously monitoring and controlling the temperatures in the zone of contact where the machine is actually fusing the HDPE-GM so as to ensure that changes in environmental conditions will not affect the integrity of the seam.

e. All seams shall have a seam number that corresponds with the panel layout numbers. The numbering system shall be used in the development of the record drawings. Seam numbers shall be derived from the combination of the two panel numbers that are to be seamed together.

f. Where horizontal seams are required on sloped surfaces, the panels shall be placed such that the "upstream" panel forms the upper panel and overlaps the "downstream" panel in order to minimize infiltration potential. All seams constructed on slopes of 6H:1V or steeper shall be vertical seams, except where slope lengths exceed standard roll lengths and elsewhere as approved in advance by the Engineer. Where approved, end seams on slopes of 6H:1V or steeper shall be staggered a minimum of 5 feet and shall be made at an angle of approximately 45 degrees.

g. All panels placed on slopes of 6H:1V or steeper shall extend a minimum of 5 feet beyond the grade break with a slope flatter than 6H:1V.

h. All seams shall extend to the full extent of the anchor trench.

i. Unless otherwise approved by the Engineer, all "T" seams (i.e., the result of three panels placed together) shall be staggered a minimum of 3 feet along either seam and shall be covered with a patch.

j. No junctions of four or more panels shall be allowed unless approved by the Engineer.

k. If extrusion seaming equipment is stopped for longer than one minute, it shall be purged to remove heat-degraded extrudate. All purged extrudate shall be placed on a sacrificial sheet and disposed of.

l. To prevent moisture buildup during seaming, it may be necessary to place a movable protective layer of plastic directly below each overlap of HDPE-GM that is to be seamed.

m. If required, a firm substrate shall be provided by using a flat board or similar hard surface directly under the seam overlap to achieve proper support.

n. All seams (including repairs) shall meet or exceed the requirements of GRI GM19 and Table 3 of this section.

o. No overlying material (i.e., leachate collection layer) shall be placed over the HDPE-GM until approved by the CQA Engineer.

6. Anchor Trench:

a. The anchor trench shall be constructed as shown on the Contract Drawings and as specified herein. The anchor trench shall be maintained by the Contractor.

b. Slightly rounded corners shall be provided in the trench to avoid sharp bends in the HDPE-GM.

c. The anchor trench shall be adequately drained to prevent water ponding and softening to adjacent soils. The anchor trench shall be backfilled with structural fill material and compacted to 90% standard Proctor dry density (ASTM D 698).

d. If the anchor trench is located in a clay susceptible to desiccation, the amount of trench open at any time shall be limited to one day of HDPE-GM installation capacity.

e. Edge of Liner Markers: The Contractor shall place edge of liner markers where shown on the Contract Drawings at the edge of the anchor trench. These markers shall be considered incidental to the HDPE-GM installation.

7. Repair Procedures:

a. Any portion of the HDPE-GM exhibiting signs of defect or failing a nondestructive or a destructive test, shall be repaired by the Geomembrane Installer. Several procedures exist for the repair of these areas. The final decision as to the appropriate repair procedure shall be made by the CQA Engineer. The procedures available include:

(1) Patching - Apply a new piece of HDPE-GM sheet over, and at least 6-inches beyond the limits of a defect. The patch shall be extrusion seamed to the underlying HDPE-GM. This method should be used to repair holes, tears, destructive test locations, undispersed raw materials, contamination by foreign matter, dents, pinholes, and pressure test holes.

(2) Capping - Apply a new strip of HDPE-GM along the length of a delineated faulty seam. The cap strip shall extend at least 6-inches beyond the limit of the seam and the edges shall be extrusion seamed to the underlying HDPE-GM. This method should be used to repair lengths of extrusion or hot wedge seams.

(3) Replacement - The faulty seam is removed and replaced.

b. In addition, the following provisions shall be satisfied:

(1) Surfaces of the HDPE-GM which are to be repaired shall be abraded no more than one hour prior to the repair;

(2) All surfaces must be clean and dry at the time of the repair;

(3) All seaming equipment used in repairing procedures must be approved;

(4) The repair procedures, materials, and techniques shall be approved in advance of the specific repair by the CQA Engineer;

(5) Extrusion seaming of flaps of dual track hot wedge seams is not acceptable. A patch or cap strip shall be used; and

(6) Patches or caps shall extend at least 6-inches beyond the edge of the defect, and all patch corners shall be rounded.

8. Surveying:

a. After completion of a segment of HDPE-GM, the Contractor shall survey HDPE-GM to obtain the following information:

(1) Location and numbering of all panels/seams.

(2) Location of all repairs/patches;

(3) Location of all destructive test locations; and

(4) Location of all pipe penetrations and other appurtenances (if applicable).

b. No overlying materials shall be placed before survey information is obtained.

c. The Contractor shall provide the CQA Engineer with updated survey information when requested by the CQA Engineer to verify that the required information is being obtained.

9. Cover Placement:

Placement of materials over HDPE-GM shall be performed in a manner as to ensure that HDPE-GM and the underlying geosynthetics are not damaged; minimal slippage of HDPE-GM on the underlying geosynthetics occurs; no excess tensile stresses occur in the HDPE-GM; and that no portion of the HDPE-GM develops excessive wrinkles or crimp. Wrinkles that exceed approximately 6 inches in height and cannot be eliminated by amended placement and covering methods or HDPE-GM that becomes crimped shall be cut and repaired by the Geosynthetics Installer in a method approved by the Engineer.

## TABLE 1: REQUIRED HDPE-GM PROPERTIES

| PROPERTY | TEST METHOD | UNITS | VALUE |
|---|---|---|---|
| | | | TEXTURED HDPE-GM |
| Interface Shear Strength (Peak)[1, 2] | ASTM D 5321<br>ASTM D 6243 (GCL) | psf | 100 psf (Load = 200 psf)<br>1,000 psf (2,500 psf)<br>2,000 psf (5,000 psf)<br>4,000 psf (10,000 psf) |

Notes:

1. Textured HDPE-GM shall have adequate adhesion against adjacent materials under low normal loads to achieve the successful installation of overlying components without slippage.
2. Note that the required values for textured HDPE-GM may require an aggressively textured sheet.

## TABLE 2: REQUIRED CONTRACTOR QUALITY CONTROL TESTS

| PROPERTY | TEST METHOD | MINIMUM TEST FREQUENCY |
|---|---|---|
| Interface Shear Strength | ASTM D 5321<br>ASTM D 6243 (GCL) | (See Note 1) |

Notes:

1. Test each interface to be used on this project using representative samples of materials to be supplied under normal loads indicated and using test parameters as specified by the Engineer. For this project, interfaces to be tested are:

   Base Liner:

   A. Textured LLDPE-GM (40 mil) against existing cover soils (intermediate cover);
   B. Drainage Geocomposite against textured LLDPE-GM (40 mil);
   C. Geosynthetic Clay Liner against Drainage Geocomposite;
   D. Textured HDPE-GM (60 mil) against Geosynthetic Clay Liner;
   E. Drainage Geocomposite against textured HDPE-GM (60 mil);

F. Protective Cover against Drainage Geocomposite.

If there are material differences in the surface of any of the geosynthetic materials from one side to the other, then all possible combinations of interfaces shall be tested. This testing shall be performed at Contractor cost by an independent GAI accredited laboratory and submitted to the Engineer for review prior to shipping. Upon review of test results, the Engineer may allow exceptions to the above criteria.

For tests involving textured geomembranes, the laboratory shall also report the asperity height (GRI GM12) for the material samples used in the actual direct shear tests.

**TABLE 3: REQUIRED SEAM STRENGTH PROPERTIES**

| PROPERTY | TEST METHOD | VALUE | |
|---|---|---|---|
| | | **Hot Wedge Seams** | **Extrusion Fillet Seams** |
| Shear Strength[1] | ASTM D 6392 | 120 lbs/inch | |
| Shear Elongation at Break[2] | | 50% | |
| Peel Strength[1] | | 91 lbs/inch | 78 lbs/inch |
| Peel Separation (Incursion) | | ≤ 25% | |
| Locus-of-Break | | See Note 3 | |

Notes:

1. Values listed for shear and peel strengths are for 4 out of 5 test specimens; the 5th specimen can be as low as 80% of the listed values.
2. Omit elongation measurements when performing field tests.
3. Regarding the locus-of-break patterns of the different seaming methods in shear and peel, the following are unacceptable break codes per their description in ASTM D 6392 (in this regard, SIP is an acceptable break code):

   Hot Wedge: AD and AD-BRK with > 25% Separation
   Extrusion Fillet: AD1, AD2, and AD-WLD (unless strength is achieved).

END OF SECTION

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## SECTION 02776

## GEOSYNTHETIC CLAY LINER (GCL)

Geosynthetic Clay Liner (GCL): The GCL is used as a secondary hydraulic barrier beneath the HDPE Geomembrane.

A. DESCRIPTION

1. General:

The Contractor shall furnish all labor, material, and equipment to complete installation of GCL in accordance with the Contract Drawings and these Specifications.

2. Related Work:

Related Contract Work is described in the following sections of the Specifications:

| Work | Section |
|---|---|
| Drainage Geocomposite | 02712 |
| HDPE Geomembrane | 02775 |
| CQA Manual | Attached |

3. Reference Standards:

The latest revision of the following standards of the American Society of Testing and Materials (ASTM) are hereby made a part of these specifications.

| | |
|---|---|
| ASTM D 5887 | Standard Test Method for Measurement of Index Flux Through Saturated Geosynthetic Clay Liner Specimens Using a Flexible Wall Permeameter. |
| ASTM D 5890 | Standard Test Method for Swell Index of Clay Mineral Component of Geosynthetic Clay Liners. |
| ASTM D 5891 | Standard Test Method for Fluid Loss of Clay Component of Geosynthetic Clay Liners. |
| ASTM D 5993 | Standard Test Method for Measuring Mass per Unit of Geosynthetic Clay Liners. |

| | |
|---|---|
| ASTM D 6243 | Standard Test Method for Determining the Internal and Interface Shear Resistance of Geosynthetic Clay Liner by the Direct Shear Method. |
| ASTM D 6496 | Standard Test Method for Determining Average Bonding Peel Strength Between the Top and Bottom Layers of Needle-Punched Geosynthetic Clay Liners. |
| ASTM D 6768 | Standard Test Method for Tensile Strength of Geosynthetic Clay Liners. |

4. Quality Control:

The Contractor shall perform Quality Control tests in accordance with Table 3 of this section.

5. Quality Assurance:

Quality Assurance during installation of GCL will be provided by the Owner as described in the accompanying Project CQA Manual.

6. Manufacturer Qualifications:

The GCL shall be furnished by a Manufacturer that has previously produced a minimum of 10,000,000 square feet of the material for use in similar projects.

7. Installer Qualifications:

The GCL Installer shall have installed a minimum of 500,000 square feet of GCL in the past two (2) years in similar landfill installations.

8. Warranties:

a. General: Should a defect occur, which is covered under warranty, the Warrantor shall bear all costs for repair and/or relocation and replacement of the GCL.

b. Workmanship: The Contractor shall furnish the Owner a warranty from the GCL Installer which warrants their workmanship to be free of defects on a prorata basis for five (5) years after the final acceptance of the Work. This warranty shall include but not be limited to overlapped seams, anchor trenches, attachments to appurtenances, and penetration seals, as applicable.

c. Manufacturer's Warranty: The Contractor shall furnish the Owner a warranty from the GCL Manufacturer for the materials used. The material warranty shall be for defects or failures related to manufacture on a prorata basis for five (5) years after date of shipment.

## B. MATERIALS

### 1. General:

The GCL shall consist of bentonite encased, top and bottom, with 6 oz./square yard non-woven geotextiles needle-punched together for reinforcement. GCL with a lighter non-woven geotextile on one side may be considered by the Engineer as long as all other criteria are met. Needle-punched GCL shall be essentially free of broken needles and fragments of needles that would negatively effect the performance of the final product. The materials supplied under these Specifications shall be first quality products designed and manufactured specifically for the purposes of this work.

The GCL shall be supplied in rolls which have a minimum width of 14 feet. The roll length shall be maximized to provide the largest manageable sheet for the fewest overlaps. Labels on the roll shall identify the length, width, lot and roll numbers, name of Manufacturer, proper direction of unrolling, and minimum recommended overlap.

### 2. Needle Detection and Removal Procedures:

The GCL Manufacturer shall use continuous needle detection and removal devices (e.g. metal detectors and magnets) in the manufacture of needle-punched GCL.

### 3. Physical Properties:

Physical properties of GCL shall be as shown in Table 1 of this section.

## C. SUBMITTALS

The Contractor shall submit the following to the CQA Engineer:

### 1. Pre-Installation Requirements:

Prior to GCL installation, the Contractor shall submit the following:

a. Mill Certificate and Sample: Prior to shipping to the site, the Contractor shall submit a mill certificate or affidavit signed by a legally authorized official of the Manufacturer for the GCL attesting that the GCL meets the

physical and manufacturing requirements stated in these Specifications including needle detection and removal procedures. The Contractor shall also submit a sample of the GCL to be used. The sample shall be labeled with the product name and be accompanied by the Manufacturer's specifications.

b. Qualifications:

(1) Submit list of equipment and personnel proposed for the Project. Include equipment type and quantities. Include personnel experience on similar projects.

(2) Submit resume and references of Installation Supervisor to be assigned to the Project, including data and duration of employment and pertinent experience information.

c. Shipping, Handling, and Storage Instructions: The Manufacturer's recommendations for shipping, handling, and storage shall be submitted for review.

d. Delivery Date: Submit notification of the scheduled delivery date for the materials.

e. Installation Procedures and Drawings:

Submit installation procedures and (shop) drawings for carrying out the work. Procedures addressed by the Contractor shall include but not be limited to material installation, repair, and protection to be provided in the event of rain. Submit drawings showing typical details including pipe penetrations (if applicable). Following review, these procedures and drawings will be used for installation of the GCL. Any deviations from these procedures and drawings must be approved by the Engineer and CQA Engineer.

f. Quality Control Certificates: For GCL delivered to the site, quality control certificates, signed by the Manufacturer's quality assurance manager shall be provided which represent every roll of GCL. Each certificate shall have the roll identification number(s), test methods, frequency, and test results. At a minimum, the test results and frequency of testing shall be as shown in Table 2 of this section. Each certificate shall also include a certification that each roll of GCL has been continually checked by the Manufacturer for needles and that any needles detected have been removed.

g. Contractor Quality Control Test Results: The Contractor shall provide the results of required testing.

h. Furnish copies of the delivery tickets or other approved receipts as evidence for materials received that will be incorporated into the construction.

2. Post-Installation Requirements:

Upon completion of GCL installation the Contractor shall submit the following:

a. A certificate stating that the GCL has been installed in accordance with the Drawings, Specifications, and the Manufacturer's recommendations.

b. Completed Manufacturer's and Workmanship Warranties.

Finalization of payment for GCL installation shall not be made until the above submittals have been reviewed by the CQA Engineer.

D. CONSTRUCTION

1. Shipping , Handling, and Storage:

The GCL shall be shipped, handled, and stored in strict accordance with the Manufacturer's recommendations.

2. Failing CQA Material Control Tests:

GCL that is rejected upon testing shall be removed from the project site and replaced at Contractor's cost. Sampling and CQA testing of GCL supplied as replacement for rejected material shall be performed by the CQA Engineer at Contractor's cost.

3. Installation of GCL:

a. The surface receiving the GCL shall be prepared to a relatively smooth condition, free of obstructions, standing water, excessive depressions, debris, and very soft, excessively wet, and/or loose pockets of soil. This surface shall be approved by the CQA Engineer prior to GCL placement.

b. GCL shall be placed to the lines and grades shown on the Contract Drawings. At the time of installation, GCL shall be rejected by the CQA Engineer if it has defects, rips, holes, flaws, evidence of deterioration, or other damage.

c. The GCL shall not be placed during precipitation. Any material that becomes hydrated shall be removed and replaced at Contractor expense.

d. The GCL shall be placed smooth and free of excessive wrinkles.

e. Where horizontal seams are required on sloped surfaces, the panels shall be placed such that the "upstream" panel forms the upper panel and overlaps the "downstream" panel in order to minimize infiltration potential. All seams constructed on slopes of 6H:1V or steeper shall be vertical seams, except where slope lengths exceed standard roll lengths and elsewhere as approved in advance by the Engineer.

f. All vertical panels placed on slopes of 6H:1V or steeper shall extend a minimum of 5 feet beyond the grade break with a slope flatter than 6H:1V.

g. The GCL shall be laid with a 6 inch minimum overlap seam along roll edges and a 12 inch minimum overlap seam along roll ends. Granular sodium bentonite shall be added between all overlapped seams at a rate of approximately 0.25 lbs/linear foot. As an alternative to the addition of bentonite along roll edges, GCL with slits cut in one of the geotextiles may be used if approved in advance by the Engineer.

h. GCL shall be temporarily secured in a manner approved by the CQA Engineer prior to placement of overlying materials.

i. Any GCL that is torn, punctured, or otherwise damaged shall be repaired or replaced as directed by the CQA Engineer, by the Contractor at no additional cost to the Owner. The repair shall consist of a patch of GCL placed over the damaged areas and shall overlap the existing GCL a minimum of 12 inches from any point of the damage.

j. GCL shall be covered with the overlying HDPE Geomembrane or otherwise protected from hydration due to rainfall (i.e. temporary tarps, scrap geomembrane, etc.) within 24 hours of GCL placement, or sooner if rain is imminent.

k. Penetrations: All penetrations of GCL shall be made in accordance with the Contract Drawings and/or as directed by the Engineer.

4. Cover Placement:

Placement of materials over GCL shall be performed in a manner as to ensure that GCL and the underlying geosynthetics are not damaged; minimal slippage of GCL on the underlying geosynthetics occurs; no excess tensile stresses occur in the GCL; and that no portion of the GCL develops excessive wrinkles or crimp. Wrinkles that exceed approximately 6 inches in height and cannot be eliminated by amended placement and covering methods or GCL that becomes crimped shall

be cut and repaired by the Geosynthetics Installer in a method approved by the Engineer.

**TABLE 1: REQUIRED GCL PROPERTIES**

| PROPERTY | TEST METHOD | UNITS | VALUE |
|---|---|---|---|
| **Clay:** | | | |
| Bentonite Swell Index | ASTM D 5890 | ml/2g | 24 |
| Bentonite Fluid Loss | ASTM D 5891 | ml | $\leq 18$ |
| **GCL:** | | | |
| Bentonite Content | ASTM D 5993 | psf | 0.75 (@ 0% moisture) |
| Tensile Strength | ASTM D 6768 | lbs/in | 30 |
| Peel Strength | ASTM D 6496 | lbs/in | 7.5 Avg. Peak<br>5.3 Min. Avg. |
| Hydraulic Conductivity | ASTM D 5887 | cm/sec | $\leq 5 \times 10^{-9}$ |
| Internal Shear Strength[1] (Hydrated) (Peak) | ASTM D 6243 | psf | 500 |
| Interface Shear Strength (Hydrated) (Peak)[2] | ASTM D 6243 | psf | 100 psf (Load = 200 psf)<br>1,000 psf (2,500 psf)<br>2,000 psf (5,000 psf)<br>4,000 psf (10,000 psf) |

Notes:

1. Peak value measured at a normal load of 200 psf after a minimum 24 hour hydration period.
2. GCL shall have adequate adhesion against adjacent materials under low normal loads to achieve the successful installation of overlying components without slippage.

**TABLE 2: REQUIRED MANUFACTURER QUALITY CONTROL TESTS**

| PROPERTY | TEST METHOD | MINIMUM TEST FREQUENCY |
|---|---|---|
| **Clay:** | | |
| Bentonite Swell Index | ASTM D 5890 | 50 tons |
| Bentonite Fluid Loss | ASTM D 5891 | 50 tons |
| **GCL:** | | |
| Bentonite Content | ASTM D 5993 | 5,000 $yd^2$ |
| Tensile Strength | ASTM D 6768 | 25,000 $yd^2$ |
| Peel Strength[1] | ASTM D 6496 | 5,000 $yd^2$ |
| Hydraulic Conductivity | ASTM D 5887 | 30,000 $yd^2$ |
| Internal Shear Strength[2] (Hydrated) | ASTM D 6243 | Periodic |

Notes:

1. Conduct peel strength tests in accordance with the criteria given in Table 1.
2. Conduct shear strength tests in accordance with the criteria given in Table 1.

**TABLE 3: REQUIRED CONTRACTOR QUALITY CONTROL TESTS**

| PROPERTY | TEST METHOD | MINIMUM TEST FREQUENCY |
|---|---|---|
| Interface Shear Strength | ASTM D 6243 | (See Note 1) |

Notes:

1. Test each interface to be used on this project using representative samples of materials to be supplied under normal loads indicated and using test parameters as specified by the Engineer. For this project, interfaces to be tested are:

Base Liner:

A. Textured LLDPE-GM (40 mil) against existing cover soils (intermediate cover);
B. Drainage Geocomposite against textured LLDPE-GM (40 mil);
C. Geosynthetic Clay Liner against Drainage Geocomposite;
D. Textured HDPE-GM (60 mil) against Geosynthetic Clay Liner;
E. Drainage Geocomposite against textured HDPE-GM (60 mil);
F. Protective Cover against Drainage Geocomposite.

If there are material differences in the surface of any of the geosynthetic materials from one side to the other, then all possible combinations of interfaces shall be tested. This testing shall be performed at Contractor cost by an independent GAI accredited laboratory and submitted to the Engineer for review prior to shipping. Upon review of test results, the Engineer may allow exceptions to the above criteria.

For tests involving textured geomembranes, the laboratory shall also report the asperity height (GRI GM12) for the material samples used in the actual direct shear tests.

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## SECTION 02778

## LLDPE GEOMEMBRANE

LLDPE Geomembrane (LLDPE-GM): The LLDPE Geomembrane serves as a secondary hydraulic barrier in the piggyback landfill liner system and as the primary hydraulic barrier in the landfill final cover. It is of great importance that the LLDPE-GM be free from defects and installed free from damage.

A. DESCRIPTION

1. General:

The Contractor shall furnish all labor, material, and equipment to complete installation of LLDPE-GM including all necessary and incidental items as detailed or required to complete the installation in accordance with the Contract Drawings and these Specifications.

2. Related Work:

Related Contract Work is described in the following sections of the Specifications:

| Work | Section |
|---|---|
| Excavation | 02222 |
| Embankment | 02223 |
| Vegetative Soil Layer | 02258 |
| Drainage Geocomposite | 02712 |
| CQA Manual | Attached |

3. Reference Standards:

The latest revision of the following standards of the American Society of Testing and Materials (ASTM) and the Geosynthetic Research Institute (GRI) are hereby made a part of these Specifications.

| | |
|---|---|
| ASTM D 792 | Standard Test Method for Density and Specific Gravity (Relative Density) of Plastics by Displacement. |
| ASTM D 1004 | Standard Test Method for Initial Tear Resistance of Plastic Film and Sheeting. |

| | |
|---|---|
| ASTM D 1505 | Standard Test Method for Density of Plastics by the Density-Gradient Technique. |
| ASTM D 1603 | Standard Test Method for Carbon Black in Olefin Plastics. |
| ASTM D 5199 | Standard Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes. |
| ASTM D 5321 | Standard Test Method for Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method. |
| ASTM D 5596 | Standard Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics. |
| ASTM D 5820 | Standard Practice for Pressurized Air Channel Evaluation of Dual Seamed Geomembranes. |
| ASTM D 5994 | Standard Test Method for Measuring Core Thickness of Textured Geomembrane. |
| ASTM D 6392 | Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods. |
| ASTM D 6693 | Standard Test Method for Determining Tensile Properties of Nonreinforced Flexible Polyethylene and Nonreinforced Polypropylene Geomembranes. |
| GRI GM9 | Cold Weather Seaming of Geomembranes. |
| GRI GM12 | Asperity Measurement of Textured Geomembranes Using a Depth Gage. |
| GRI GM17 | Standard Specification for Test Properties, Testing Frequency and Recommended Warranty for Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes. |
| GRI GM19 | Seam Strength and Related Properties of Thermally Bonded Polyolefin Geomembranes. |

4. Quality Control:

   a. The Contractor shall perform Quality Control tests in accordance with Table 2 of this section.

   b. The Geomembrane Installer shall follow the procedures and requirements described in the accompanying Project CQA Manual during installation of LLDPE-GM including performing and documenting trial seams, nondestructive and destructive Quality Control tests, and repairs.

5. Quality Assurance:

   Quality Assurance during installation of LLDPE-GM will be provided by the Owner as described in the accompanying Project CQA Manual.

6. Manufacturers Qualifications:

   The Manufacturer shall have previously demonstrated his ability to produce the required LLDPE-GM by having successfully manufactured a minimum of 5,000,000 $ft^2$ of LLDPE-GM for hydraulic containment purposes.

7. Installer Qualifications:

   a. Installation of the LLDPE-GM shall be performed by an Installer that has installed a minimum of 5,000,000 $ft^2$ of LLDPE-GM (or similar material) within the past five (5) years in similar landfill installations.

   b. All Installation Supervisors assigned to the Project shall have previously managed the installation of at least 2,000,000 $ft^2$ of LLDPE-GM (or similar material) using the same techniques to be used on site.

   c. All seaming equipment operators shall have demonstrated performance on previous geomembrane installations and/or documented training.

8. Warranties:

   a. General: Should a defect occur, which is covered under warranty, the Warrantor shall bear all costs for repair and/or relocation and replacement of the LLDPE-GM.

   b. Workmanship: The Contractor shall furnish the Owner a warranty from the Installer of the LLDPE-GM which warrants their workmanship to be free of defects on a prorata basis for five (5) years after the final acceptance of the Work. This warranty shall include but not be limited to

all field seams, anchor trenches, attachments to appurtenances, and penetration seals, as applicable.

c. Manufacturer's Warranty: The Contractor shall furnish the Owner a warranty from the LLDPE-GM Manufacturer for the materials used. The material warranty shall be for defects or failures related to manufacture on a prorata basis for five (5) years after the date of shipment.

B. MATERIALS

1. General:

The materials supplied under these Specifications shall consist of new, first-quality products designed and manufactured specifically for the purpose of this work, which shall have been satisfactorily demonstrated, by prior use, to be suitable and durable for such purposes. The LLDPE-GM and LLDPE-GM Manufacturer shall be approved by the Engineer.

The LLDPE-GM shall be supplied in rolls which shall have a minimum width of 22 feet. The roll length shall be maximized to provide the largest manageable sheet for the fewest seams. Labels on the roll shall identify the thickness, length, width, lot and roll numbers, and name of Manufacturer.

2. LLDPE-GM Materials:

a. Textured LLDPE-GM shall be 40 mils thick (base liner system) or 30 mils thick (final cover system) . Resin and sheet properties of LLDPE-GM shall meet or exceed the requirements of GRI GM17 and Table 1 of this section.

b. Materials classified as Very Flexible Polyethylene (VFPE) which otherwise meet the requirements of this section are also acceptable.

3. Extrusion Resin/Typical Extrudate:

Extrusion resin/typical extrudate used for extrusion seaming of LLDPE-GM shall be linear low density polyethylene (LLDPE). Physical properties shall be the same as the LLDPE-GM sheet. The extrudate's additives shall be thoroughly dispersed throughout the rod or bead. The extrudate shall be free of contamination by moisture or foreign matter and shall be recommended for use with the associated sheet material.

4. Texturing:

Textured LLDPE-GM, where required, shall be fabricated using coextrusion or impingement methods. Texturing shall not be created by lamination, structuring, or embossing. Texturing applied to LLDPE-GM using impingement methods shall be bonded securely to the parent LLDPE-GM. All texturing shall be uniform in appearance and coverage on the finished sheet. Textured LLDPE-GM shall be textured on both sides of the sheet.

C. SUBMITTALS

The Contractor shall submit the following to the CQA Engineer:

1. Pre-Installation Requirements:

Prior to LLDPE-GM installation, the Contractor shall submit the following:

a. Mill Certificate and Sample: Prior to shipping to the site, the Contractor shall submit a mill certificate or affidavit signed by a legally authorized official of the Manufacturer for the LLDPE-GM attesting that the LLDPE-GM meets the physical and manufacturing requirements stated in these Specifications. The Contractor shall also submit a sample of the LLDPE-GM to be used. The sample shall be labeled with the product name and be accompanied by the Manufacturer's specifications.

b. Qualifications:

(1) Submit list of equipment and personnel proposed for the Project. Include equipment type and quantities. Include personnel experience on similar projects.

(2) Submit resume and references of Installation Supervisor to be assigned to the Project, including data and duration of employment and pertinent experience information.

(3) Submit resumes and references of installation personnel who will perform seaming operations, including dates and durations of employment and pertinent experience information.

c. Shipping, Handling, and Storage Instructions: The Manufacturer's plan for shipping, handling, and storage shall be submitted for review.

d. Delivery Date: Submit notification of the scheduled delivery dates for the materials.

e. Installation Procedures and Drawings:

Submit installation procedures and (shop) drawings for carrying out the work.

(1) Installation procedures to be addressed shall include but not be limited to material installation, repair, and protection to be provided in the event of rain or strong winds.

(2) Shop drawings shall have LLDPE-GM sheet layout with proposed size, number, position, and sequence of placing all panels, and indicating the location of all field seams. Shop drawings shall also show complete details and/or methods for anchoring the LLDPE-GM, making field seams, and making seals around pipes and structures penetrating the LLDPE-GM (if applicable).

Following review, these procedures and drawings shall be used for installation of the LLDPE-GM. Any deviations from these procedures and drawings must be approved by the Engineer and CQA Engineer.

f. Quality Control Certificates: For LLDPE-GM delivered to the site, quality control certificates, signed by the Manufacturer's quality assurance manager shall be provided which represent every roll of LLDPE-GM. Each certificate shall have the roll identification number(s), test methods, frequency, and test results. At a minimum, the test results and frequency of testing shall meet or exceed the requirements of GRI GM17.

g. Contractor Quality Control Test Results: The Contractor shall provide the results of required testing.

h. Furnish copies of the delivery tickets or other approved receipts as evidence for materials received that will be incorporated into the construction.

2. Post-Installation Requirements:

Upon completion of the LLDPE-GM installation, the Contractor shall submit the following:

a. Certificate stating that the LLDPE-GM has been installed in accordance with the Drawings, Specifications, and the Manufacturer's recommendations.

b. Completed Manufacturer's and workmanship warranties.

c. Record Information: Record information shall include but not be limited to:

(1) CQC Documentation: Includes trial seam logs, panel placement logs, panel seaming logs, non-destructive seam testing report forms, field destructive seam testing report forms, and repair logs.

(2) As-Built Drawing: Includes the requirements listed in Paragraph D.8 (Surveying) of this Specification.

Finalization of payment for LLDPE-GM installation shall not be made until the above submittals have been reviewed by the CQA Engineer.

D. CONSTRUCTION

1. Shipping, Handling, and Storage:

The LLDPE-GM shall be shipped, handled, and stored in strict accordance with the Manufacturer's recommendations.

2. Failing CQA Material Control Tests:

LLDPE-GM that is rejected upon testing shall be removed from the project site and replaced at Contractor's cost. Sampling and CQA testing of LLDPE-GM supplied as replacement for rejected material shall be performed by the CQA Engineer at Contractor's cost.

3. Subgrade Preparation:

a. The surface of the subgrade shall be smooth, uniform, free from sudden changes in grade (such as vehicular ruts), rocks or stones greater than ½ inch in size, debris, and deleterious materials. During actual placing and seaming of the LLDPE-GM, the subgrade shall be kept free of all standing water. If the subgrade below the LLDPE-GM becomes excessively wet and unstable as determined by the CQA Engineer, it shall be dried and recompacted, and replaced if needed.

b. Before an individual panel of LLDPE-GM is installed; the Contractor and Installer shall verify in writing and submit to the CQA Engineer:

(1) Lines and grades are in conformance with the Drawings and Specifications.

(2) The surface area to be lined has been rolled and compacted, free of irregularities and abrupt changes in grade.

4. LLDPE-GM Placement:

a. Weather Conditions:

LLDPE-GM placement shall not proceed at an ambient temperature below 32° F or above 100° F unless otherwise authorized, in writing, by the Engineer. Installation of LLDPE-GM at temperatures below 32° F, if authorized by the Engineer, shall follow GRI GM9. LLDPE-GM placement shall not be performed during precipitation, excessive moisture, in an area of ponded water, or in excessive winds. Any portion of LLDPE-GM or subgrade damaged due to weather conditions shall be repaired at the Contractor's cost.

b. Method of Placement:

(1) Each panel of the LLDPE-GM shall be installed in accordance with the approved shop drawings prepared by the Contractor. The layout shall be designed to keep field seaming of the LLDPE-GM to a minimum and consistent with proper methods of LLDPE-GM installation.

(2) Panels shall be oriented perpendicular to the line of the slope crest (i.e., down and not across slope).

(3) The LLDPE-GM shall be placed smooth and free of excessive wrinkles.

(4) LLDPE-GM rolls shall be placed using proper spreader and rolling bars with cloth slings. If a sheet must be displaced a distance greater than its width, a slip sheet shall be used.

(5) The CQA Engineer shall inspect each panel, after placement and prior to seaming, for damage and/or defects. Defective or damaged panels shall be replaced or repaired, as approved by the CQA Engineer and as described in this section.

(6) The Installer shall avoid dragging the LLDPE-GM on rough soil subgrades.

(7) All LLDPE-GM shall be anchored as shown on the Contract Drawings and consistent with Manufacturer's recommendations.

(8) Personnel working on the LLDPE-GM shall not smoke, wear damaging shoes, or involve themselves in any activity that may damage the LLDPE-GM, in the opinion of the CQA Engineer.

(9) The LLDPE-GM shall be properly weighted to avoid uplift due to wind.

(10) Vehicular traffic across the LLDPE-GM shall not be allowed, except that four-wheel (or greater) all-terrain vehicles (ATVs) with low ground pressure may be allowed if approved in advance by the Engineer. The Contractor shall submit proposed equipment and procedures for use of ATVs to the CQA Engineer as part of his submittals. If ATVs are allowed by the Engineer, each ATV shall be operated such that no sudden stops, starts, or turns are made.

(11) All damage shall be recorded and located on the record drawings.

(12) The LLDPE-GM shall be kept free of debris, unnecessary tools, and materials. In general, the LLDPE-GM area shall remain neat in appearance.

c. Pipe Penetrations:

All pipe penetrations through the LLDPE-GM shall be as shown in the Contract Drawings. Alternative penetration details may be approved by the Engineer and CQA Engineer.

5. Field Seams:

a. Individual panels of LLDPE-GM shall be laid out and overlapped by a minimum of 4 inches prior to seaming. The area to be seamed shall be cleaned and prepared in accordance with the Manufacturer's recommendations.

b. Dual or single track hot wedge methods shall be used for straight seams.

c. Extrusion fillet methods shall be used to seam cross seam tees, patches, repairs, and penetration boots. All extrudate shall be free of dirt, dry, and protected from damage. To limit overgrinding, the amount of grinding exposed after an extrusion seam is completed shall be less than ¼ inch.

d. The seaming equipment used shall be capable of continuously monitoring and controlling the temperatures in the zone of contact where the machine is actually fusing the LLDPE-GM so as to ensure that changes in environmental conditions will not affect the integrity of the seam.

e. All seams shall have a seam number that corresponds with the panel layout numbers. The numbering system shall be used in the development of the

record drawings. Seam numbers shall be derived from the combination of the two panel numbers that are to be seamed together.

f. Where horizontal seams are required on sloped surfaces, the panels shall be placed such that the "upstream" panel forms the upper panel and overlaps the "downstream" panel in order to minimize infiltration potential. All seams constructed on slopes of 6H:1V or steeper shall be vertical seams, except where slope lengths exceed standard roll lengths and elsewhere as approved in advance by the Engineer. Where approved, end seams on slopes of 6H:1V or steeper shall be staggered a minimum of 5 feet and shall be made at an angle of approximately 45 degrees.

g. All panels placed on slopes of 6H:1V or steeper shall extend a minimum of 5 feet beyond the grade break with a slope flatter than 6H:1V.

h. All seams shall extend to the full extent of the anchor trench (where applicable).

i. Unless otherwise approved by the Engineer, all "T" seams (i.e., the result of three panels placed together) shall be staggered a minimum of 3 feet along either seam and shall be covered with a patch.

j. No junctions of four or more panels shall be allowed unless approved by the Engineer.

k. If extrusion seaming equipment is stopped for longer than one minute, it shall be purged to remove heat-degraded extrudate. All purged extrudate shall be placed on a sacrificial sheet and disposed of.

l. To prevent moisture buildup during seaming, it may be necessary to place a movable protective layer of plastic directly below each overlap of LLDPE-GM that is to be seamed.

m. If required, a firm substrate shall be provided by using a flat board or similar hard surface directly under the seam overlap to achieve proper support.

n. All seams (including repairs) shall meet or exceed the requirements of GRI GM19 and Table 3 of this section.

o. No overlying material shall be placed over the LLDPE-GM until approved by the CQA Engineer.

6. Anchor Trench:

a. The anchor trench shall be constructed as shown on the Contract Drawings and as specified herein. The anchor trench shall be maintained by the Contractor.

b. Slightly rounded corners shall be provided in the trench to avoid sharp bends in the LLDPE-GM.

c. The anchor trench shall be adequately drained to prevent water ponding and softening to adjacent soils. The anchor trench shall be backfilled with controlled fill material and compacted to 90% standard Proctor dry density (ASTM D 698).

d. If the anchor trench is located in a clay susceptible to desiccation, the amount of trench open at any time shall be limited to one day of LLDPE-GM installation capacity.

7. Repair Procedures:

a. Any portion of the LLDPE-GM exhibiting signs of defect or failing a nondestructive or a destructive test, shall be repaired by the Geomembrane Installer. Several procedures exist for the repair of these areas. The final decision as to the appropriate repair procedure shall be made by the CQA Engineer. The procedures available include:

(1) Patching - Apply a new piece of LLDPE-GM sheet over, and at least 6-inches beyond the limits of a defect. The patch shall be extrusion seamed to the underlying LLDPE-GM. This method should be used to repair holes, tears, destructive test locations, undispersed raw materials, contamination by foreign matter, dents, pinholes, and pressure test holes.

(2) Capping - Apply a new strip of LLDPE-GM along the length of a delineated faulty seam. The cap strip shall extend at least 6-inches beyond the limit of the seam and the edges shall be extrusion seamed to the underlying LLDPE-GM. This method should be used to repair lengths of extrusion or hot wedge seams.

(3) Replacement - The faulty seam is removed and replaced.

b. In addition, the following provisions shall be satisfied:

(1) Surfaces of the LLDPE-GM which are to be repaired shall be abraded no more than one hour prior to the repair;

(2) All surfaces must be clean and dry at the time of the repair;

(3) All seaming equipment used in repairing procedures must be approved;

(4) The repair procedures, materials, and techniques shall be approved in advance of the specific repair by the CQA Engineer;

(5) Extrusion seaming of flaps of dual track hot wedge seams is not acceptable. A patch or cap strip shall be used; and

(6) Patches or caps shall extend at least 6-inches beyond the edge of the defect, and all patch corners shall be rounded.

8. Surveying:

a. After completion of a segment of LLDPE-GM, the Contractor shall survey LLDPE-GM to obtain the following information:

(1) Location and numbering of all panels/seams.

(2) Location of all repairs/patches;

(3) Location of all destructive test locations; and

(4) Location of all pipe penetrations and other appurtenances (if applicable).

b. No overlying materials shall be placed before survey information is obtained.

c. The Contractor shall provide the CQA Engineer with updated survey information when requested by the CQA Engineer to verify that the required information is being obtained.

9. Cover Placement:

Placement of materials over LLDPE-GM shall be performed in a manner as to ensure that LLDPE-GM and the underlying geosynthetics are not damaged; minimal slippage of LLDPE-GM on the underlying geosynthetics occurs; no excess tensile stresses occur in the LLDPE-GM; and that no portion of the LLDPE-GM develops excessive wrinkles or crimp. Wrinkles that exceed approximately 6 inches in height and cannot be eliminated by amended placement and covering methods or LLDPE-GM that becomes crimped shall be cut and repaired by the Geosynthetics Installer in a method approved by the Engineer.

**TABLE 1: REQUIRED LLDPE-GM PROPERTIES**

| PROPERTY | TEST METHOD | UNITS | VALUE | |
|---|---|---|---|---|
| | | | 30 mil Textured | 40 mil Textured |
| Interface Shear Strength (Peak)[1, 2]<br>(Base Liner) | ASTM D 5321 | psf | 100 psf (Load = 200 psf)<br>1,000 psf (2,500 psf)<br>2,000 psf (5,000 psf)<br>4,000 psf (10,000 psf) | |
| (Final Cover) | | | 115 psf (Load = 200 psf) | |

Notes:

1. Textured LLDPE-GM shall have adequate adhesion against adjacent materials under low normal loads to achieve the successful installation of overlying components without slippage.
2. Note that the required values for textured LLDPE-GM may require an aggressively textured sheet.

**TABLE 2: REQUIRED CONTRACTOR QUALITY CONTROL TESTS**

| PROPERTY | TEST METHOD | MINIMUM TEST FREQUENCY |
|---|---|---|
| Interface Shear Strength | ASTM D 5321 | (See Note 1) |

Notes:

1. Test each interface to be used on this project using representative samples of materials to be supplied under normal loads indicated and using test parameters as specified by the Engineer. For this project, interfaces to be tested are:

Base Liner:

A. Textured LLDPE-GM (40 mil) against existing cover soils (intermediate cover);
B. Drainage Geocomposite against textured LLDPE-GM (40 mil);
C. Geosynthetic Clay Liner against Drainage Geocomposite;
D. Textured HDPE-GM (60 mil) against Geosynthetic Clay Liner;
E. Drainage Geocomposite against textured HDPE-GM (60 mil);
F. Protective Cover against Drainage Geocomposite.

Final Cover:

A. Textured LLDPE-GM (30 mil) against existing cover soils (intermediate cover);
B. Drainage Geocomposite against textured LLDPE-GM (30 mil); and
C. Vegetative Soil Layer against Drainage Geocomposite.

If there are material differences in the surface of any of the geosynthetic materials from one side to the other, then all possible combinations of interfaces shall be tested. This testing shall be performed at Contractor cost by an independent GAI accredited laboratory and submitted to the Engineer for review prior to shipping. Upon review of test results, the Engineer may allow exceptions to the above criteria.

For tests involving textured geomembranes, the laboratory shall also report the asperity height (GRI GM12) for the material samples used in the actual direct shear tests.

**TABLE 3: REQUIRED SEAM STRENGTH PROPERTIES**

| PROPERTY | TEST METHOD | VALUE | |
|---|---|---|---|
| | | Hot Wedge Seams | Extrusion Fillet Seams |
| **30 mil** | | | |
| Shear Strength[1] | ASTM D 6392 | 45 lbs/inch | |
| Shear Elongation at Break[2] | | 50% | |
| Peel Strength[1] | | 38 lbs/inch | 34 lbs/inch |
| Peel Separation (Incursion) | | ≤ 25% | |
| Locus-of-Break | | See Note 3 | |
| **40 mil** | | | |
| Shear Strength[1] | ASTM D 6392 | 60 lbs/inch | |
| Shear Elongation at Break[2] | | 50% | |
| Peel Strength[1] | | 50 lbs/inch | 44 lbs/inch |
| Peel Separation (Incursion) | | ≤ 25% | |
| Locus-of-Break | | See Note 3 | |

Notes:

1. Values listed for shear and peel strengths are for 4 out of 5 test specimens; the 5th specimen can be as low as 80% of the listed values.
2. Omit elongation measurements when performing field tests.
3. Regarding the locus-of-break patterns of the different seaming methods in shear and peel, the following are unacceptable break codes per their description in ASTM D 6392 (in this regard, SIP is an acceptable break code):

   Hot Wedge: AD and AD-BRK with > 25% Separation
   Extrusion Fillet: AD1, AD2, and AD-WLD (unless strength is achieved).

END OF SECTION

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## SECTION 02782

## GEOSYNTHETIC RAIN COVER

Geosynthetic Rain Cover (GRC): The Geosynthetic Rain Cover serves to minimize infiltration of precipitation within inactive portions of the landfill into the underlying leachate collection system. It is of great importance that the GRC be free from defects and installed free from damage.

A. DESCRIPTION

1. General:

The Contractor shall furnish all labor, material, and equipment to install GRC including all necessary and incidental items as detailed or required to complete the installation in accordance with the Contract Drawings and these Specifications.

2. Related Work:

Related Contract Work is described in the following sections of the Specifications:

| Work | Section |
|---|---|
| Protective Cover | 02256 |
| Drainage Aggregate (Leachate Management) | 02710 |
| CQA Manual | Attached |

3. Reference Standards:

The latest revision of the following standards of the Geosynthetic Research Institute (GRI) are hereby made a part of these Specifications.

| | |
|---|---|
| GRI GM22 | Standard Specification for Test Methods, Required Properties, and Testing Frequencies for Scrim Reinforced Polyethylene Geomembranes Used in Exposed Temporary Applications. |

4. Quality Assurance:

Quality Assurance during installation of GRC will be provided by the Owner as described in the accompanying Project CQA Manual.

5. Manufacturers Qualifications:

The Manufacturer shall have previously demonstrated his ability to produce the required GRC by having successfully manufactured a minimum of 5,000,000 $ft^2$ of GRC (or similar material) for hydraulic containment purposes.

6. Installer Qualifications:

The GRC Installer shall have installed a minimum of 500,000 $ft^2$ of GRC (or similar material) in similar landfill installations.

7. Warranties:

a. General: Should a defect occur, which is covered under warranty, the Warrantor shall bear all costs for repair and/or relocation and replacement of the GRC.

b. Material Performance: The Contractor shall furnish the Owner a warranty from the Installer of the GRC which warrants the material performance on a non-prorata basis for one (1) year after the final acceptance of the Work. This warranty shall include but not be limited to defects related to workmanship and manufacturing and damage caused by exposure and wind.

B. MATERIALS

1. General:

The materials supplied under these Specifications shall consist of first-quality products designed and manufactured specifically for the purpose of this work, which shall have been satisfactorily demonstrated, by prior use, to be suitable and durable for such purposes.

The GRC shall be supplied in panels which shall be of maximum size to provide the largest manageable sheet for the fewest seams. Labels on the panels shall identify the thickness, length, width, lot and panel numbers, and name of Manufacturer.

2. GRC Materials:

a. GRC shall be manufactured to meet the following requirements:

(1) GRC shall be a reinforced geomembrane composed of a polyethylene, polypropylene, or polyvinyl chloride (PVC) based material, or a woven coated polyethylene material. Properties of

GRC shall meet or exceed the requirements of GRI GM22 (Category 2 - Moderate - 12 mil nominal) or shall be an approved GRC as listed below.

(2) GRC shall be impermeable and capable of repelling water with no absorption.

b. Approved GRC:

(1) Dura-Skrim 12WB or 12BBR as manufactured by Raven Industries of Sioux Falls, SD.

(2) Integra 12 BW as manufactured by Integra Plastics, Inc. of Madison, South Dakota.

(3) Approved equal material.

3. Seaming Materials:

Materials used for seaming GRC (if used) shall be as recommended by the Manufacturer and approved by the Engineer.

4. Ballast System:

In addition to anchoring the edges of the GRC within the Protective Cover (as shown on the Contract Drawings, or, if not shown, in a 1 foot by 1 foot min. anchor trench), the Contractor shall place tires (typical auto - off rim) (or other ballast as approved by the Owner and Engineer) on top of the GRC on 8 foot centers over the entire area covered by the GRC. Ballast shall have sufficient UV resistance to maintain its integrity over the Contractor's Performance Warranty period. The Owner anticipates receiving an adequate supply of used tires on-site (at convenience center) during the duration of the project which the Contractor may use as ballast. The Contractor shall coordinate with the Owner to collect and move these tires as required by the Owner.

For slopes 5H:1V and steeper, the Contractor shall tie bags together with ⅜ inch min. nylon rope on a horizontal and vertical grid with anchors at the top of the slope for the rope. Anchors shall be 1 inch by 1 inch (actual dimensions) by 2 foot long treated wood stakes, or approved equal.

C. SUBMITTALS

The Contractor shall submit the following to the CQA Engineer:

1. Pre-Installation Requirements:

Prior to GRC installation the Contractor shall submit the following:

a. Mill Certificate and Sample: Prior to shipping to the site, the Contractor shall submit a mill certificate or affidavit signed by a legally authorized official of the Manufacturer for the GRC attesting that the GRC meets the physical and manufacturing requirements stated in these Specifications. The Contractor shall also submit a sample of the GRC to be used. The sample shall be labeled with the product name and be accompanied by the Manufacturer's specifications.

b. Shipping, Handling, and Storage Instructions: The Manufacturer's plan for shipping, handling, and storage shall be submitted for review.

c. Installation Procedures:

Submit installation procedures for carrying out the work. Installation procedures to be addressed shall include but not be limited to material installation, repair, and protection to be provided in the event of rain or strong winds. With regard to protection, the Contractor shall provide a plan of anchoring the GRC sufficient to satisfy the Contractor's Performance Warranty. At a minimum, this plan shall meet the criteria described in Paragraph B.4 above and shall indicate the selected spacing and weight of the ballast to be used. This plan shall be approved by the Engineer prior to construction.

d. Furnish copies of the delivery tickets or other approved receipts as evidence for materials received that will be incorporated into the construction.

2. Post-Installation Requirements:

Upon completion of the GRC installation, the Contractor shall submit the following:

a. Completed material performance warranty.

Finalization of payment for GRC installation shall not be made until the above submittals have been reviewed by the CQA Engineer.

D. CONSTRUCTION

1. Shipping, Handling, and Storage:

The GRC shall be shipped, handled, and stored in strict accordance with the Manufacturer's recommendations.

2. Subgrade Preparation:

The surface of the subgrade shall be smooth, uniform, free from sudden changes in grade (such as vehicular ruts), rocks or stones greater than ½ inch in maximum size (except for gravel columns), debris, and deleterious materials. During actual placing and seaming of the GRC, the subgrade shall be kept free of all standing water. If the subgrade below the GRC becomes excessively wet and unstable, as determined by the CQA Engineer it shall be dried and recompacted, and replaced if needed.

3. GRC Placement:

a. Weather Conditions:

GRC placement shall not proceed at an ambient temperature below 32° F or above 100° F unless otherwise authorized, in writing, by the Engineer. GRC placement shall not be performed during precipitation, excessive moisture, in an area of ponded water, or in excessive winds. Any portion of GRC or subgrade damaged due to weather conditions shall be repaired at the Contractor's cost.

b. Method of Placement:

(1) Each panel of the GRC shall be installed in accordance with the Manufacturer's recommendations.

(2) The CQA Engineer shall inspect each panel, after placement and prior to seaming, for damage and/or defects. Defective or damaged panels shall be replaced or repaired, as approved by the CQA Engineer and as described in this section.

(3) The Installer shall avoid dragging the GRC on rough soil subgrades.

(4) Personnel working on the GRC shall not smoke, wear damaging shoes, or involve themselves in any activity that may damage the GRC, in the opinion of the CQA Engineer.

(5) The GRC shall be properly weighted to avoid uplift due to wind.

(6) Vehicular traffic across the GRC shall not be allowed.

(7) The GRC shall be kept free of debris, unnecessary tools, and materials. In general, the GRC area shall remain neat in appearance.

c. Pipe Penetrations:

All pipe penetrations through the GRC shall be booted unless otherwise shown in the Contract Drawings. Alternate penetration details may be approved by the Engineer.

4. Field Seams:

a. Field seams shall be made according to the Manufacturer's recommendations and may include fusion welding, taping, chemical fusion, or other methods as appropriate for the selected material and as approved by the Engineer.

b. Individual panels of GRC shall be laid out and overlapped by a minimum of 4 inches prior to seaming. The area to be seamed shall be cleaned and prepared in accordance with the Manufacturer's recommendations.

c. All seams constructed on sloped surfaces shall be vertical seams. Where horizontal seams are required and no other option is available on sloped surfaces, the panels shall be placed such that the "upstream" panel forms the upper panel and overlaps the "downstream" panel in order to minimize infiltration potential.

5. Repair Procedures:

a. Any portion of the GRC exhibiting signs of defect shall be repaired. Several procedures exist for the repair of these areas. The final decision as to the appropriate repair procedure shall be made by the CQA Engineer.

6. Ballasting:

The Contractor shall add ballasting in accordance with the approved plan.

7. No overlying material shall be placed over the GRC until approved by the CQA Engineer.

END OF SECTION

**SECTION 02930**

**REVEGETATION**

Revegetation: Revegetation includes permanent Revegetation of all site areas disturbed by the Contractor whether inside the Contract Limits or not.

A. DESCRIPTION

1. General:

The Contractor shall furnish all labor, material, and equipment to complete Revegetation in accordance with the Contract Drawings and these Specifications.

2. Related Work:

Related Contract Work is described in the following sections of the Specifications:

| Work | Section |
|---|---|
| Embankment | 02223 |
| Vegetative Soil Layer | 02258 |
| Erosion and Sedimentation Control | 02270 |
| Rolled Erosion Control Products | 02275 |

3. Warranty:

The Contractor shall be responsible for the satisfactory establishment and growth of a permanent stand of vegetation for a period of one year following the final seeding as judged by the Engineer. During this period, the Contractor shall be responsible for the maintenance items described in Paragraph D.4 (Maintenance) of this Specification.

B. MATERIALS

1. Limestone: Unless otherwise defined by specific soil tests, supply agricultural grade ground limestone conforming to the current "Rules, Regulations, and Standards of the Fertilizer Board of Control."

2. Fertilizer: Unless otherwise defined by specific soil tests, supply commercial fertilizer of 10-20-10 analysis, meeting applicable requirements of State and Federal law. Do not use cyanamic compounds of hydrated lime. Deliver fertilizer in original containers labeled with content analysis.

3. Grass Seed: Supply fresh, clean, new-crop seed as specified in Table 1 of this section. Do not use seed which is wet, moldy, or otherwise damaged. Deliver seed in standard sealed containers labeled with producer's name and seed analysis, and in accord with US Department of Agriculture Rules and Regulations under Federal Seed Act.

4. Mulch: Supply clean, seed-free, threshed straw of oats, wheat, barley, rye, beans, or other locally available mulch material.

   a. Do not use mulch containing a quantity of matured, noxious weed seeds or other species that will be detrimental to seeding, or provide a menace to surrounding land.

   b. Do not use mulch material which is fresh or excessively brittle, or which is decomposed and will smother or retard growth of grass.

5. Binder: Supply emulsified asphalt or synthetic binder.

6. Water: Supply potable, free of substances harmful to growth.

C. SUBMITTALS

The Contractor shall submit the following to the Engineer:

1. Results of soil tests performed and proposed modifications, if any, to the specified requirements.

2. Certificates for each grass seed mixture, stating botanical and common name, percentage by weight, and percentages of purity, germination, and weed seed. Certify that each container of seed delivered is fully labeled in accordance with Federal Seed Act and equals or exceeds specification requirements.

3. Copies of invoices for fertilizer, showing grade furnished and total quantity applied.

D. CONSTRUCTION

1. The Contractor shall establish a smooth, healthy, uniform, close stand of grass from the specified seed. Prior to Revegetation, the Contractor shall adequately test the soils to be revegetated to ensure the adequacy of the specified requirements. Any modifications to these requirements deemed necessary after the review of soil test results, shall be at the Contractor's sole expense. The Engineer will perform the observations to determine when successful Revegetation is achieved.

2. Soil Preparation:

a. Limit preparation to areas which will be planted soon after preparation.

b. Loosen surface to minimum depth of four (4) inches.

c. Remove stones, sticks, roots, rubbish and other extraneous matter over three (3) inches in any dimension.

d. Spread lime uniformly over designated areas at the rate specified in Table 1 of this section.

e. After application of lime, prior to applying fertilizer, loosen areas to be seeded with double disc or other suitable device if soil has become hard or compacted. Correct any surface irregularities in order to prevent pocket or low areas which will allow water to stand.

f. Distribute fertilizer uniformly over areas to be seeded at the rate specified in Table 1 of this section.

(1) Use suitable distributor.

(2) Incorporate fertilizer into soil to depth of a least two (2) inches.

(3) Remove stones or other substances which will interfere with turf development or subsequent mowing.

g. Grade seeded areas to smooth, even surface with loose, uniformly fine texture.

(1) Roll and rake, remove ridges and fill depressions, as required to meet finish grades.

(2) Fine grade just prior to planting.

3. Seeding:

a. Use approved mechanical power driven drills or seeders, mechanical hand seeders, or other approved equipment.

b. Distribute seed evenly over entire area at the rate specified in Table 1 of this section.

c. Stop work when work extends beyond most favorable planting season for species designated, or when satisfactory results cannot be obtained because of drought, high winds, excessive moisture, or other factors.

d. Resume work only when favorable condition develops, or as directed by the Engineer.

e. Lightly rake seed into soil followed by light rolling or cultipacking.

f. Immediately protect seeded areas against erosion by mulching or placing Rolled Erosion Control Products in accordance with Section 02275 of these Specifications, where applicable.

(1) Spread mulch in a continuous blanket at the rate specified in Table 1 of this section.

(2) Immediately following spreading mulch, secure with evenly distributed binder at the rate specified in Table 1 of this section.

4. Maintenance:

The Contractor shall be responsible for maintaining all seeded areas through the end of his warranty period. The Contractor shall provide, at his expense, protection of all seeded areas against damage at all times until acceptance of the work. Maintenance shall include, but not be limited to, the following items:

a. Regrade and revegetate all eroded areas until adequately stabilized by grass.

b. Remulch with new mulch in areas where mulch has been disturbed by wind or maintenance operations sufficiently to nullify its purpose. Anchor as required to prevent displacement.

c. Replant bare areas using same materials specified.

**TABLE 1: SEEDING SCHEDULE**

| MATERIAL | SEED TYPE | APPLICATION RATE[1] |
|---|---|---|
| Lime | ----- | 4,000 lbs/acre |
| Fertilizer | ----- | 1,000 lbs/acre |
| Seed | | |
| Permanent: | Kentucky 31 Tall Fescue | 80 lbs/acre |
| | Pensacola Bahiagrass | 50 lbs/acre |
| | Sericea Lespedeza[3] | 30 lbs/acre |
| | Kobe Lespedeza | 10 lbs/acre |
| | Seasonal Nurse Crop[2] | See Note 2 |
| Temporary: | Seasonal Nurse Crop[2] | See Note 2 |
| Mulch | ----- | 4,000 - 5,000 lbs/acre |
| Binder | ----- | 150 gallons/acre |

Notes:

1. Application rates and/or chemical analysis shall be confirmed or established by a soil test(s).
2. Use seasonal nurse crop in accordance with seeding dates as stated below:

| | |
|---|---|
| April 15 - August 15 | 10 lbs/acre German Millet or<br>15 lbs/acre Sudangrass |
| August 16 - April 14 | 25 lbs/acre Rye (grain). |

3. From September 1 - March 1, use unscarified Sericea seed.

END OF SECTION

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## SECTION 03310

## CONCRETE WORK

Concrete Work: Concrete will be used as ballast at leachate risers and pipe cleanouts.

A. DESCRIPTION

1. General:

The Contractor shall furnish all labor, material, and equipment to complete installation of all concrete including all necessary and incidental items, in accordance with the Contract Drawings and these Specifications.

2. Related Work:

Related Contract Work is described in the following sections of the Specifications:

| Work | Section |
|---|---|
| Erosion and Sedimentation Control | 02270 |
| HDPE Pipe | 02614 |
| Storm Water Systems | 02720 |

3. Reference Standards:

The latest revision of the following standards of the American Concrete Institute (ACI) and the American Society for Testing and Materials (ASTM) are hereby made a part of these specifications:

| | |
|---|---|
| ACI 301 | Specifications for Structural Concrete for Buildings. |
| ACI 315 | Manual of Standard Practice for Detailing Reinforced Concrete Structures. |
| ACI 318 | Building Code Requirements for Structural Concrete. |
| ASTM C 31 | Standard Method of Making and Curing Concrete Test Specimens in the Field. |
| ASTM C 39 | Standard Method of Test for Compressive Strength of Cylindrical Concrete Specimens. |

| | |
|---|---|
| ASTM C 42 | Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete. |
| ASTM C 94 | Standard Specification for Ready Mixed Concrete. |
| ASTM C 143 | Standard Method of Test for Slump of Portland Cement Concrete. |
| ASTM C 150 | Standard Specification for Portland Cement. |
| ASTM C 172 | Standard Method of Sampling Fresh Concrete. |
| ASTM C 309 | Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete. |

B. MATERIALS

1. Concrete Materials:

a. Portland Cement:

ASTM C 150, Type I or Type II, unless otherwise acceptable to the Engineer.

Use one brand of cement throughout project, unless otherwise acceptable to the Engineer.

b. Normal Weight Aggregates:

ASTM C 33, and as herein specified. Provide aggregates from a single source for exposed concrete.

For exterior exposed surfaces, do not use fine or coarse aggregates containing spalling-causing deleterious substances.

Local aggregates not complying with ASTM C 33 but which have shown by special test or actual service to produce concrete of adequate strength and durability may be used when acceptable to the Engineer.

c. Water: Potable.

2. Class B Concrete:

Nonstructural concrete (Class B) may be used for fill concrete, thrust blocks, etc. Class B concrete shall conform to the following requirements:

Compressive Strength (28 day): 3,000 psi.

C. SUBMITTALS

1. The Contractor shall submit concrete mix designs to the Engineer for approval at least 15 days prior to the first concrete placement.

D. CONSTRUCTION

1. Concrete shall be placed per the procedures specified in ACI 301.

2. Inserted and Embedded Items:

   Pipes, anchor bolts, steps, and other inserts, as indicated on the Contract Drawings or as required, shall be encased in concrete.

3. Structures shall be formed, chamfered, and finished in a workman-like manner.

4. Curing:

   Curing shall be with curing compound conforming to ASTM C309, Type 2, Class A in two uniform thoroughly covering coats applied at right angles to each other.

END OF SECTION

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## SECTION 13252

## LANDFILL GAS WELLS

Landfill Gas Wells: Landfill Gas Wells are installed within the landfill in order to vent landfill gases, particularly methane, which builds up due to the decomposition of waste.

A. DESCRIPTION

1. General:

The Contractor shall furnish all labor, material, and equipment to complete installation of Landfill Gas Wells in accordance with the Contract Drawings and these Specifications.

2. Related Work:

Related Contract Work is described in the following sections of the Specifications:

| Work | Section |
|---|---|
| Vegetative Soil Layer | 02258 |
| HDPE Pipe | 02614 |
| Drainage Geocomposite | 02712 |
| LLDPE Geomembrane | 02778 |
| CQA Manual | Attached |

3. Reference Standards:

The latest revision of the following standards of the American Society of Testing and Materials (ASTM) are hereby made a part of these specifications.

ASTM D 1785 Standard Specification for Poly (Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120.

4. Quality Assurance:

Quality Assurance during installation of LFG Wells will be provided by the Owner as described in the accompanying Project CQA Manual.

5. Site Conditions:

Obstructions and saturated conditions are sometimes encountered when drilling in a landfill, many of which can be drilled through. The Contractor is expected to make reasonable efforts to drill through obstructions and saturated conditions and will be paid for offset redrilling and boring abandonment only if prior written approval is obtained from the Owner. The Contractor will be paid for abandonment of abandoned hole and for well installation at the new location.

B. MATERIALS

1. Solid Wall Pipe:

All pipe and fittings shall be rigid PVC Schedule 80. Alternately, SDR 11 HDPE pipe and fittings may be used, if approved in advance by the Engineer.

2. Slotted Pipe:

Slots in PVC well piping shall be 6 to 8 inches long by ¼ inch wide, spaced at 90 degrees around the circumference of the pipe and 12 inches center to center. Stagger adjacent rows of slots evenly along the pipe. Alternatively, perforated PVC or HDPE piping may be used if approved in advance by the Engineer. Perforations in PVC or HDPE well piping shall be ¾ inch diameter hole spaced at 90 degrees around the circumference of the pipe and 3 inches on center. Stagger adjacent rows of perforations evenly along the pipe.

3. Bentonite:

Coarse-ground, pelletized bentonite from an approved source is to be mixed thoroughly with potable water at a ratio of 5 gallons of water to every 50 lbs. of bentonite.

4. Stone Backfill:

Stone backfill for Landfill Gas Wells shall be No. 3 stone (1.5 inch nom.), or approved equal.

5. Soil Backfill:

Soil backfill shall be on-site soils as approved by the Engineer.

C. SUBMITTALS

The Contractor shall furnish copies of the delivery tickets or other approved receipts to the Engineer as evidence for materials received that will be incorporated into construction.

D. CONSTRUCTION

1. All Methane Gas Vents shall be constructed at the locations and according to the details shown on the Contract Drawings. Care shall be taken to ensure that these locations are not in areas which are prone to pond water. The Engineer shall be notified prior to drilling Landfill Gas Wells, such that he may observe the installation.

2. Drilling:

a. Landfill Gas Wells are to be 36 inch diameter, drilled to the depth shown on the Contract Drawings. The Contractor must use dry drilling equipment; wet rotary drilling equipment may not be used. All borings shall be made with bucket type augers.

b. The boring depths shown on the Contract Drawings are estimated and may be adjusted in the field by the Engineer. One reason limiting depth might be as follows:

(1) If water is encountered in a boring, the Contractor may be directed to drill beyond the point at which it was encountered. If wet conditions remain, the boring may be terminated and the length of perforated pipe adjusted by the Engineer, or the well may be relocated. If wet conditions cease (e.g. due to trapped water layer), then drilling will continue to the design depth.

c. As soon as drilling is completed, a safety screen shall be placed over the top of the bore. This screen shall stay in place until backfilling is within 4 feet of the surface. Safety screen size should be large enough to accommodate all backfill materials and any tools used during backfill yet not large enough for any human to accidently fall through.

d. The bore for the well shall be straight and the well pipe shall be installed in the center of the bore hole. The Contractor will take all tension off of the pipe by mechanical means and center the pipe in the middle of the borehole before starting to backfill.

e. PVC well pipe shall be solvent cemented and lag bolted using stainless steel hardware.

3. Backfilling:

a. Backfilling of the well shall commence immediately after well drilling is completed and the well piping has been installed in the borehole. Backfill materials shall be installed as indicated on the Contract Drawings and as approved by the Engineer.

b. Stone backfill shall be poured or scooped through the screen at a rate that will not endanger the integrity of the well casing.

c. The well seal will be formed by evenly distributing two 50 lb. bags of bentonite material around the annulus of the well and then adding 10 gallons of fresh water in a manner that will allow for a thorough saturation of the bentonite material. This process will be continued until a minimum plug thickness of 2 feet has been achieved (approximately 14 to 16 sacks).

d. Soil backfill shall be used above the bentonite seal up to the existing top of intermediate cover elevation.

4. Abandonment of Boreholes:

Borings which have been advanced into the waste and which have been required to be abandoned by the Engineer shall be backfilled up to the top of existing intermediate cover elevations with on-site soils. Final cover materials will be installed above this elevation.

5. Disposal of Waste:

All waste materials removed during construction of Landfill Gas Wells shall be disposed of on site in the active lined landfill as directed by the Owner and Engineer. The Contractor shall weigh waste materials at the facility scales prior to disposal. No tipping fee will be charged to the Contractor for disposal of these wastes.

END OF SECTION

## SECTION 13255

## LANDFILL GAS SYSTEM

Landfill Gas System: The Landfill Gas System includes a network of surface collector trenches and landfill gas flares installed under the piggyback liner system in order to collect and vent/burn landfill gas, which builds up due to the decomposition of waste.

A. DESCRIPTION

1. General:

The Contractor shall furnish all labor, material, and equipment to complete installation of the Landfill Gas System in accordance with the Contract Drawings and these Specifications.

2. Related Work:

Related Contract Work is described in the following sections of the Specifications:

| Work | Section |
|---|---|
| Excavation | 02222 |
| Geotextiles | 02240 |
| HDPE Pipe | 02614 |
| Drainage Geocomposite | 02712 |
| LLDPE Geomembrane | 02778 |

3. Reference Standards:

The latest revision of the following standards of the North Carolina Department of Transportation (NCDOT) are hereby made a part of these specifications.

NCDOT Standard Specifications for Roads and Structures.

B. MATERIALS

1. All pipe used for construction of Landfill Gas System shall be either solid (riser pipe) or perforated (collector pipe) HDPE Pipe in accordance with Section 02614, HDPE Pipe, of these Specifications. The pipe DR (dimension ratio) and diameter shall be as shown on the Contract Drawings.

2. Backfill for collector trenches shall be NCDOT #57 stone.

3. Geotextiles used for collector trenches shall conform to the requirements outlined in Section 02240, Geotextiles, of these Specifications.

4. Drainage Geocomposite used for collector trenches shall conform to the requirements outlined in Section 02712, Drainage Geocomposite, of these Specifications.

5. Landfill Gas Utility Flares: Landfill gas utility flares shall be solar ignited. Utility flares shall be Model CF-5 as manufactured by Landfill Technologies, Inc., or approved equal.

C. SUBMITTALS

1. Submit a certification and summary of all required test results, prior to installation, that all Landfill Gas System components manufactured for the project have been produced in accordance with these Specifications.

2. Submit Shop Drawings for all components and accessories prior to installation. Submittals shall include all layout dimensions, size and materials of construction for all components, information on support and anchoring where necessary, and complete descriptive information to demonstrate full compliance with the Contract Documents.

3. Furnish copies of the delivery tickets or other approved receipts as evidence for materials received that will be incorporated into construction.

4. Operation and maintenance manuals and installation instructions shall be submitted for all utility flares and accessories. The Manufacturer(s) shall delete all information which does not apply to the equipment being furnished.

D. CONSTRUCTION

1. All Landfill Gas System components shall be constructed at the locations and according to the details shown on the Contract Drawings. Care shall be taken to ensure that these locations are not in areas which are prone to pond water.

2. The depth of surface collector trenches shall be adjusted such that the perforated HDPE piping and stone backfill breaches the existing final/intermediate cover or to a maximum depth of four feet if no waste is encountered.

3. The Contractor shall exercise caution as excavations will extend into existing municipal solid waste. The Contractor shall construct surface collector trenches such that Contractor personnel are not required to enter the excavation.

4. All waste materials removed during construction of Landfill Gas System components shall be disposed of on site in the active lined landfill as directed by the Owner and Engineer. The Contractor shall weigh waste materials at the facility scales prior to disposal. No tipping fee will be charged to the Contractor for disposal of these wastes.

END OF SECTION

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# Construction Quality Assurance Manual

## Johnston County Landfill
## Smithfield, North Carolina

Prepared for:

**Johnston County Department of Public Utilities**
**Smithfield, NC**

**June 2007**

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**JOHNSTON COUNTY LANDFILL**

**CONSTRUCTION QUALITY ASSURANCE MANUAL**

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# SECTION 1.0
# GENERAL

## 1.1 INTRODUCTION

This Construction Quality Assurance (CQA) Manual has been prepared to provide the Owner, (Design) Engineer, and CQA Engineer the means to govern the construction quality and to satisfy landfill certification requirements under current solid waste management regulations.

More specifically, this CQA Manual addresses the soils and geosynthetics components of the liner, leachate management, and the final cover systems (as applicable) for both the MSW and C&D landfill units at the facility.

The CQA Manual is divided into the following sections:

- Section 1.0 General
- Section 2.0 CQA Documentation
- Section 3.0 Earthwork CQA
- Section 4.0 Soil Liner CQA
- Section 5.0 Geomembrane CQA
- Section 6.0 Leachate Management System CQA
- Section 7.0 Geotextile CQA
- Section 8.0 Drainage Geocomposite CQA
- Section 9.0 Geosynthetic Clay Liner CQA
- Section 10.0 Final Cover System CQA

## 1.2 DEFINITIONS RELATING TO CONSTRUCTION QUALITY

### 1.2.1 Construction Quality Assurance (CQA)

In the context of this Manual, Construction Quality Assurance is defined as a planned and systematic program employed by the Owner to assure conformity of the liner, leachate management, and final cover systems installation with the project drawings and the project specifications. CQA is provided by the CQA Engineer as a representative of the Owner and is independent from the Contractor and all manufacturers. The CQA program is designed to provide adequate confidence that items or services meet contractual and regulatory requirements and will perform satisfactorily in service.

### 1.2.2 Construction Quality Control (CQC)

Construction Quality Control refers to actions taken by manufacturers, fabricators, installers, and/or the Contractor to ensure that the materials and the workmanship meet the requirements of the project drawings and the project specifications. The manufacturer's specifications and quality control (QC) requirements are included in this CQA Manual by

reference only. A complete updated version of each geosynthetic component manufacturer's QC Plan shall be incorporated as part of the Contractor's CQC Plan.

### 1.2.3 CQA Certification Document

At the completion of construction, a certification document will be prepared by the CQA Engineer and submitted to State Solid Waste Regulators. The certification report will include all QC testing performed by the Geosynthetics Manufacturers, all CQC testing performed by the Geosynthetic Installers, and all CQA testing performed by the CQA Engineer.

### 1.2.4 Discrepancies Between Documents

The Contractor is instructed to bring discrepancies to the attention of the CQA Engineer who shall then notify the Engineer for resolution. The Engineer has the sole authority to determine resolution of discrepancies existing within the Contract Documents (this may also require the approval of State Solid Waste Regulators). Unless otherwise determined by the Engineer, the more stringent requirement shall be the controlling resolution.

## 1.3 PARTIES TO CONSTRUCTION QUALITY ASSURANCE

### 1.3.1 Description of the Parties

The parties to Construction Quality Assurance and Quality Control include the Owner, Engineer, Contractor, Geosynthetics Manufacturer, Geosynthetics Installer, CQA Engineer, Geosynthetics CQA Laboratory, and Soils CQA Laboratory.

#### 1.3.1.1 Owner

The Owner is Johnston County, who owns and/or is responsible for the facility.

#### 1.3.1.2 Engineer

The Engineer is responsible for the engineering design, drawings, and project specifications for the liner, leachate management, and final cover systems. The Engineer is an official representative of the Owner. The Engineer serves as communications coordinator for the project, initiating the meetings outlined in **Section 1.7**. The Engineer will also be responsible for proper resolution of all quality issues that arise during construction. The Engineer is Richardson Smith Gardner & Associates, Inc.

#### 1.3.1.3 Contractor

The Contractor is responsible for the construction of the subgrade, earthwork, and for placement of the liner, leachate management, and final cover systems. The

Contractor is responsible for the overall CQC on the project and coordination of submittals to the CQA Engineer. Additional responsibilities of the Contractor are defined by the project specifications.

1.3.1.4 Geosynthetics Manufacturer

The Geosynthetics Manufacturer(s) is (are) responsible for the production of the geosynthetic components used in landfill construction. The Manufacturer(s) is (are) responsible for Quality Control (QC) during manufacture of the geosynthetic components, certification of the properties of the geosynthetic components, and field installation criteria.

1.3.1.5 Geosynthetics Installer

The Geosynthetics Installer(s) is (are) routinely a subcontractor of the Contractor and is (are) responsible for field handling, storing, placing, seaming, protection of (against wind, etc.), and other aspects of the geosynthetics installations. The Installer may also be responsible for transportation of these materials to the site, and for the preparation and completion of anchor trenches.

1.3.1.6 CQA Engineer

The CQA Engineer is a representative of the Owner, is independent from the Contractor, and is responsible for observing, testing, and documenting activities related to the CQA of the earthworks at the site, and the installation of the soil and geosynthetic components of the liner, leachate management, and final cover systems. The CQA Engineer may make field observations and review submittals for the Engineer and is responsible for notifying the Owner and Engineer of all quality issues that arise during construction. The CQA Engineer is also responsible for issuing a facility certification report, sealed by a Professional Engineer registered in The State of North Carolina.

1.3.1.7 Geosynthetics CQA Laboratory

The Geosynthetics CQA Laboratory is a party, independent from the Owner, that is responsible for conducting tests on conformance samples of geosynthetics used in the liner, leachate management, and final cover systems. The Geosynthetics CQA Laboratory service cannot be provided by any party involved with the manufacture, fabrication, or installation of any of the geosynthetic components. The services of the Geosynthetics CQA Laboratory are coordinated by the CQA Engineer and are paid for by the Owner.

#### 1.3.1.8 Soils CQA Laboratory

The Soils CQA Laboratory is a party, independent from the Owner, that is responsible for conducting geotechnical tests on conformance samples of soils and aggregates used in structural fills and the liner, leachate management, and final cover systems. The services of the Soils CQA Laboratory are coordinated by the CQA Engineer and are paid for by the Owner.

### 1.3.2 Qualifications of the Parties

The following qualifications are required of all parties involved with the manufacture, fabrication, installation, transportation, and CQA of all materials for the liner, leachate management, and final cover systems. Where applicable, these qualifications must be submitted by the Contractor to the Owner and Engineer for review and approval.

#### 1.3.2.1 Contractor

Qualifications of the Contractor are specific to the construction contract and independent of this CQA Manual.

#### 1.3.2.2 Geosynthetics Manufacturers

Each Geosynthetics Manufacturer must satisfy the qualifications presented in the project specifications.

#### 1.3.2.3 Geosynthetic Installer(s)

The Geosynthetic Installer(s) will be trained and qualified to install the geosynthetics components of the liner, leachate management, and final cover systems. Each Geosynthetics Installer must meet the requirements of the project specifications and be approved by the Engineer.

#### 1.3.2.4 CQA Engineer

The CQA Engineer will act as the Owner's Quality Assurance Representative. The CQA Engineer will perform CQA testing to satisfy the requirements of this CQA Manual and will prepare the CQA certification document. The CQA Engineer will have experience in the CQA aspects of the construction and testing of landfill liner, leachate management, and final cover systems, and be familiar with ASTM and other related industry standards. The activities of the CQA Engineer will be performed under the supervision of a Registered Professional Engineer.

1.3.2.5 Geosynthetics CQA Laboratory

The Geosynthetics CQA Laboratory should be certified by the Geosynthetics Accreditation Institute, will have experience in testing geosynthetics, and be familiar with ASTM, GRI, and other applicable test standards. The Geosynthetics CQA Laboratory will be capable of providing test results within 24 hours or a reasonable time after receipt of samples depending on the test(s) to be conducted, as agreed to at the outset of the project by affected parties, and will maintain that standard throughout the installation.

1.3.2.6 Soils CQA Laboratory

The Soils CQA Laboratory will have experience in testing structural fills, soil liners, and aggregates, and be familiar with ASTM and other applicable test standards. The Soils CQA Laboratory will be capable of providing test results within 24 hours or a reasonable time after receipt of samples depending on the test(s) to be conducted, as agreed to at the outset of the project by affected parties, and will maintain that standard throughout the installation.

## 1.4 SCOPE OF CONSTRUCTION QUALITY ASSURANCE MANUAL

The scope of this CQA Manual includes the CQA of the soils and geosynthetic components of the liner, leachate management, and final cover systems for the subject facility. The CQA for the selection, evaluation, and placement of the soils is included in the scope.

## 1.5 UNITS

In this CQA Manual, all properties and dimensions are expressed in U.S. units.

## 1.6 REFERENCES

The CQA Manual includes references to the most recent version of the test procedures of the American Society of Testing and Materials (ASTM) and/or the Geosynthetic Research Institute (GRI). **Appendix A** contains a list of these procedures.

## 1.7 CQA MEETINGS

To facilitate the specified degree of quality during installation, clear, open channels of communication are essential. To that end, meetings are critical.

### 1.7.1 Soil Liner CQA Meeting

Prior to the start of the soil liner system construction a CQA Meeting will be held. This meeting will include all parties then involved, including the Engineer, the CQA Engineer, and the Contractor.

The purpose of this meeting is to begin planning for coordination of tasks, anticipate any problems which might cause difficulties and delays in construction, and, above all, review the CQA Manual to all of the parties involved. It is very important that the rules regarding testing, repair, etc., be known and accepted by all.

This meeting should include all of the activities referenced in the project specifications.

The meeting will be documented by the Engineer and minutes will be transmitted to all parties. The Soil Liner CQA Meeting and the Geosynthetics CQA Meeting may be held as one meeting or separate meetings, depending on the direction of the Engineer.

### 1.7.2 Geosynthetics CQA Meeting

A CQA Meeting will be held at the site prior to placement of the geosynthetics. At a minimum, the meeting will be attended by the Engineer, the CQA Engineer, the Contractor, and the Geosynthetic Installation Superintendent(s).

The purpose of this meeting is to begin planning for coordination of tasks, anticipate any problems which might cause difficulties and delays in construction, and, above all, review the CQA Manual to all of the parties involved. It is very important that the rules regarding testing, repair, etc., be known and accepted by all.

This meeting should include all of the activities referenced in the project specifications.

The meeting will be documented by the Engineer and minutes will be transmitted to all parties. The Soil Liner CQA Meeting and the Geosynthetics CQA Meeting may be held as one meeting or separate meetings, depending on the direction of the Engineer.

### 1.7.3 CQA Progress Meetings

Progress meetings will be held between the Engineer, the CQA Engineer, the Contractor, the Geosynthetic Installation Superintendent(s), and representatives from any other involved parties at the frequency dictated in the project specifications or, at a minimum, once per month during active construction. These meetings will discuss current progress, planned activities for the next week, and any new business or revisions to the work. The CQA Engineer will log any problems, decisions, or questions arising at this meeting in his daily or periodic reports. Any matter requiring action which is raised in this meeting will be reported to the appropriate parties. These meetings will be documented by the Engineer and minutes will be transmitted to affected parties.

### 1.7.4 Problem or Work Deficiency Meetings

A special meeting will be held when and if a problem or deficiency is present or likely to occur. At a minimum, the meeting will be attended by the Engineer, the CQA Engineer,

the Contractor, and representatives from any other involved parties. The purpose of the meeting is to define and resolve the problem or work deficiency as follows:

- define and discuss the problem or deficiency;
- review alternative solutions; and
- implement an action plan to resolve the problem or deficiency.

The meeting will be documented by the Engineer and minutes will be transmitted to affected parties.

## 1.8 CONTROL VERSUS RECORD TESTING

### 1.8.1 Control Testing

In the context of this CQA Manual, Control Tests are those tests performed on a material prior to its actual use in construction to demonstrate that it can meet the requirements of the project plans and specifications. Control Test data may be used by the Engineer as the basis for approving alternative material sources.

### 1.8.2 Record Testing

Record Tests are those tests performed during the actual placement of a material to demonstrate that its in-place properties meet or exceed the requirements of the project drawings and specifications.

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# SECTION 2.0
# CQA DOCUMENTATION

## 2.1 DOCUMENTATION

An effective CQA plan depends largely on recognition of construction activities that should be monitored and on assigning responsibilities for the monitoring of each activity. This is most effectively accomplished and verified by the documentation of quality assurance activities. The CQA Engineer will document that quality assurance requirements have been addressed and satisfied.

The CQA Engineer will provide the Owner and Engineer with his daily and weekly progress reports including signed descriptive remarks, data sheets, and logs to verify that required CQA activities have been carried out. These reports will also identify potential quality assurance problems. The CQA Engineer will also maintain at the job site a complete file of project drawings, reports, project specifications, a CQA Manual, checklists, test procedures, daily logs, and other pertinent documents.

## 2.2 DAILY CQA REPORT

The CQA Engineer's reporting procedures will include preparation of a daily report which, at a minimum, will include the following information, where applicable:

- a unique identifying sheet number for cross referencing and document control;
- date, project name, location, and other identification;
- data on weather conditions;
- a reduced-scale Site Plan showing all proposed work areas and test locations;
- descriptions and locations of ongoing construction;
- descriptions and specific locations of areas, or units, of work being tested and/or observed and documented;
- locations where tests and samples were taken;
- a summary of test results;
- calibrations or recalibrations of test equipment, and actions taken as a result of recalibration;
- off-site materials received, including quality verification documentation;

- decisions made regarding acceptance of units of work, and/or corrective actions to be taken in instances of substandard quality;

- summaries of pertinent discussions with the Contractor and/or Geosynthetic Installers; and

- the CQA Engineer's signature.

The daily report must be completed at the end of each CQA Engineer's shift, prior to leaving the site. This information will be submitted weekly to and reviewed by the Owner and Engineer.

## 2.3 CQA PROGRESS REPORTS

The CQA Engineer will prepare a summary progress report each week, or at time intervals established at the pre-construction meeting. As a minimum, this report will include the following information, where applicable:

- a unique identifying sheet number for cross-referencing and document control;

- the date, project name, location, and other information;

- a summary of work activities during the progress reporting period;

- a summary of construction situations, deficiencies, and/or defects occurring during the progress reporting period;

- summary of all test results, failures and retests, and

- signature of the CQA Engineer.

The CQA Engineer's progress reports must summarize the major events that occurred during that week. Critical problems that occur shall be communicated verbally to the Engineer immediately as well as being included in the weekly reports. The CQA Engineer's weekly report must be submitted to the Owner and Engineer no later than the Monday following the week reported.

## 2.4 CQA PHOTOGRAPHIC REPORTING

Photographs will be taken by the CQA Engineer at regular intervals during the construction process and in all areas deemed critical by the CQA Engineer.

These photographs will serve as a pictorial record of work progress, problems, and mitigation activities. These records will be presented to the Engineer upon completion of the project.

In lieu of photographic documentation, videotaping may be used to record work progress,

problems, and mitigation activities. The Engineer may require that a portion of the documentation be recorded by photographic means in conjunction with videotaping.

## 2.5 DEFICIENCIES

The Owner and Engineer will be made aware of any significant recurring nonconformance with the project specifications. The Engineer will then determine the cause of the non-conformance and recommend appropriate changes in procedures or specification. When this type of evaluation is made, the results will be documented, and any revision to procedures or project specifications will be approved by the Owner and Engineer.

## 2.6 DESIGN AND/OR PROJECT TECHNICAL SPECIFICATION CHANGES

Design and/or project specification changes may be required during construction. In such cases, the CQA Engineer will notify the Engineer. The Engineer will then notify the appropriate agency, if necessary.

Design and/or project specification changes will be made only with the written agreement of the Engineer, and will take the form of an addendum to the project specifications. All design changes will include a detail (if necessary) and state which detail it replaces in the plans.

## 2.7 FINAL CQA REPORT

At the completion of each major construction activity at the landfill unit, the CQA Engineer will certify all required forms, observation logs, field and laboratory testing data sheets including sample location plans, etc. The CQA Engineer will also provide a final report which will certify that the work has been performed in compliance with the plans and project technical specifications, and that the supporting documents provide the necessary information.

The CQA Engineer will also provide summaries of all the data listed above with the report. The Record Drawings will include scale drawings depicting the location of the construction and details pertaining to the extent of construction (e.g., depths, plan dimensions, elevations, soil component thicknesses, etc.). All surveying and base maps required for development of the Record Drawings will be done by the Contractor's Construction Surveyor. These documents will be certified by the Contractor and delivered to the CQA Engineer and included as part of the final CQA (Certification) report.

It may be necessary to prepare interim certifications, as allowed by the regulatory agency to expedite completion and review.

At a minimum, the items shown in **Table 2.1** will be included in the Final CQA Report. Note that some items may not be applicable to all projects.

## 2.8 STORAGE OF RECORDS

All handwritten data sheet originals, especially those containing signatures, will be stored by the CQA Engineer in a safe repository on site. Other reports may be stored by any standard method which will allow for easy access. All written documents will become property of the Owner.

## TABLE 2.1A: FINAL CQA REPORT GENERAL OUTLINE (LINER SYSTEM)

1.0 Introduction
2.0 Project Description
3.0 CQA Program
  3.1 Scope of Services
  3.2 Personnel
4.0 Earthwork CQA
5.0 Soil Liner CQA
6.0 GCL CQA
7.0 Geomembrane CQA
8.0 Leachate Management System CQA
9.0 Geotextile CQA
10.0 Drainage Geocomposite CQA
11.0 Summary and Conclusions
12.0 Project Certification

Appendices

Appendix A Design Clarifications and Modifications
Appendix B Piezometer Abandonment (if applicable)
Appendix C Geophysical Investigation (if applicable)
Appendix D Photographic Documentation
Appendix E CQA Reporting
  E1. CQA Reports
  E2. CQA Meeting Minutes
Appendix F Earthwork CQA Data
  F1. CQA Test Results - Control Tests
  F2. CQA Test Results - Record Tests
Appendix G Soil Liner CQA Data
  G1. CQA Test Results - Control Tests
  G2. CQA Test Results - Record Tests
Appendix H Interface Shear Strength Test Data
Appendix I GCL CQA Data
  I1. Manufacturer's Product Data Submittals and Quality Control Certificates
  I2. Geosynthetics Inventory - GCL
  I3. CQA Test Results - Material Control Tests
  I4. GCL Installation Certification

**TABLE 2.1A (CONTINUED):**

| | |
|---|---|
| Appendix J | Geomembrane CQA Data |
| | J1. Manufacturer's Product Data Submittals and Quality Control Certificates |
| | J2. Geosynthetics Inventory - Geomembrane(s) |
| | J3. CQA Test Results - Material Control Tests |
| | J4. Subgrade Acceptance Certificates |
| | J5. Trial Seam Logs |
| | J6. Panel Placement Logs |
| | J7. Panel Seaming Logs |
| | J8. CQC Test Results - Nondestructive Seam Testing Report Forms |
| | J9. CQC Test Results - Destructive Seam Testing Report Forms (Field) |
| | J10. CQA Test Results - Destructive Seam Testing Report Forms (Laboratory) |
| | J11. Repair Logs |
| | J12. Geomembrane Installation Certification |
| Appendix K | Leachate Management System CQA Data |
| | K1. Manufacturer's Product Data Submittals and Quality Control Certificates |
| | K2. CQA Test Results - Drainage Aggregate |
| | K3. CQA Test Results - Protective Cover |
| | K4. CQC Test Results - Pressure Testing of HDPE Transmission Piping |
| | K5. Documentation of Pump Start Up |
| Appendix L | Geotextile CQA Data |
| | L1. Manufacturer's Product Data Submittals and Quality Control Certificates |
| | L2. Geosynthetics Inventory - Geotextiles |
| | L3. CQA Test Results - Material Control Tests |
| Appendix M | Drainage Geocomposite CQA Data |
| | M1. Manufacturer's Product Data Submittals and Quality Control Certificates |
| | M2. Geosynthetics Inventory - Drainage Geocomposite |
| | M3. CQA Test Results - Material Control Tests |
| Appendix N | Record Drawings |
| | N1. Subgrade As-Built |
| | N2. Soil Liner As-Built |
| | N3. Geomembrane As-Built(s) |
| | N4. Leachate Collection Media As-Built |
| | N5. HDPE Pipe As-Built |
| | N6. Protective Cover As-Built |

## TABLE 2.1B: FINAL CQA REPORT GENERAL OUTLINE (FINAL COVER SYSTEM)

1.0 Introduction
2.0 Project Description
3.0 CQA Program
  3.1 Scope of Services
  3.2 Personnel
4.0 Earthwork CQA
5.0 Final Cover System CQA
6.0 Geomembrane CQA
7.0 Geotextile CQA
8.0 Drainage Geocomposite CQA
9.0 Summary and Conclusions
10.0 Project Certification

Appendices

Appendix A Design Clarifications/Modifications
Appendix B Photographic Documentation
Appendix C CQA Reporting
  C1. CQA Reports
  C2. CQA Meeting Minutes
Appendix D Earthwork CQA Data
  D1. CQA Test Results - Control Tests
  D2. CQA Test Results - Record Tests
Appendix E Final Cover System CQA Data
  E1. Manufacturer's Product Data Submittals and Quality Control Certificates
  E2. CQA Test Results - Drainage Aggregate
  E3. CQA Test Results - Vegetative Soil Layer
  E4. CQC Test Results - Pressure Testing of HDPE Piping
Appendix F Interface Shear Strength Test Data
Appendix G Geomembrane CQA Data
  G1. Manufacturer's Product Data Submittals and Quality Control Certificates
  G2. Geosynthetics Inventory - Geomembrane
  G3. CQA Test Results - Material Control Tests
  G4. Subgrade Acceptance Certificates
  G5. Trial Seam Logs
  G6. Panel Placement Logs
  G7. Panel Seaming Logs
  G8. CQC Test Results - Nondestructive Seam Testing Report Forms
  G9. CQC Test Results - Destructive Seam Testing Report Forms (Field)
  G10. CQA Test Results - Destructive Seam Testing Report Forms (Laboratory)
  G11. Repair Logs
  G12. Geomembrane Installation Certification

**TABLE 2.1B (CONTINUED):**

| | | |
|---|---|---|
| Appendix H | Geotextile CQA Data | |
| | H1. | Manufacturer's Product Data Submittals and Quality Control Certificates |
| | H2. | Geosynthetics Inventory - Geotextiles |
| | H3. | CQA Test Results - Material Control Tests |
| Appendix I | Drainage Geocomposite CQA Data | |
| | I1. | Manufacturer's Product Data Submittals and Quality Control Certificates |
| | I2. | Geosynthetics Inventory - Drainage Geocomposite |
| | I3. | CQA Test Results - Material Control Tests |
| Appendix J | Record Drawings | |
| | J1 | Subgrade As-Built |
| | J2 | Geomembrane As-Built |
| | J3 | HDPE Pipe As-Built |
| | J4 | Vegetative Soil Layer As-Built |

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# SECTION 3.0
# EARTHWORK CQA

## 3.1 INTRODUCTION

This section of the CQA Manual addresses earthwork (excavation and embankment) and outlines the soils CQA program to be implemented with regard to material approval, subgrade approval, field control and record tests, and resolution of problems.

## 3.2 EMBANKMENT MATERIAL APPROVAL

All material to be used as compacted embankment shall be approved in advance by the CQA Engineer. Approval is based upon successful completion of CQA control testing outlined below. Such testing can be performed either during excavation and stockpiling or from existing stockpiles prior to use.

### 3.2.1 Control Tests

The procedure for CQA testing during excavation and stockpiling (including existing stockpiles) is outlined below.

Each load of soil will be examined either at the borrow source or the stockpile area. Any unsuitable material will be rejected or routed to separate stockpiles consistent with its end use. Appropriate entries will be made in the daily log.

During stockpiling operations, control tests, as shown on **Table 3.1**, will be performed by the CQA Engineer prior to placement of any compacted embankment.

## 3.3 SUBGRADE APPROVAL

The CQA Engineer will verify that the compacted embankment subgrade is constructed in accordance with the project specifications.

## 3.4 EARTHWORK CONSTRUCTION

### 3.4.1 Construction Monitoring

A. Earthwork shall be performed as described in the project specifications.

B. Only soil previously approved by the CQA Engineer (see **Section 3.2**) shall be used in construction of the compacted embankment. Unsuitable material will be removed prior to acceptance by the CQA Engineer.

C. All required field density and moisture content tests shall be completed before the overlying lift of soil is placed. The surface preparation (e.g. wetting, drying,

scarification, etc.) shall be completed before the CQA Engineer will allow placement of subsequent lifts.

D. The CQA Engineer will monitor protection of the earthwork during and after construction.

### 3.4.2 Control Tests

The control tests, as shown on **Table 3.2**, will be performed by the CQA Engineer prior to placement of compacted embankment.

### 3.4.3 Record Tests

The record tests, as shown on **Table 3.2**, will be performed by the CQA Engineer during placement of compacted embankment.

#### 3.4.3.1 Record Test Failure

Recompaction of the failed area shall be performed and retested until the area meets or exceeds requirements outlined in the specifications.

### 3.4.4 Judgmental Testing

During construction, the frequency of control and/or record testing may be increased at the discretion of the CQA Engineer when visual observations of construction performance indicate a potential problem. Additional testing for suspected areas will be considered when:

- the rollers slip during rolling operation;
- the lift thickness is greater than specified;
- the fill material is at an improper moisture content;
- fewer than the specified number of roller passes are made;
- dirt-clogged rollers are used to compact the material;
- the rollers may not have used optimum ballast;
- the fill materials differ substantially from those specified; or
- the degree of compaction is doubtful.

## 3.5 DEFICIENCIES

The CQA Engineer will immediately determine the extent and nature of all defects and deficiencies and report them to the Owner and Engineer. All defects and deficiencies will be documented by the CQA Engineer. The Contractor shall correct defects and deficiencies to the satisfaction of the CQA Engineer. The CQA Engineer will observe all retests on repaired defects.

**TABLE 3.1: CQA TESTING PROGRAM FOR EMBANKMENT MATERIAL APPROVAL**

| PROPERTY | TEST METHOD | MINIMUM TEST FREQUENCY |
|---|---|---|
| **CONTROL TESTS:** | | |
| Visual Classification | ASTM D 2488 | Each Soil |
| Moisture-Density Relationship | ASTM D 698 | 5,000 CY per Each Soil |

**TABLE 3.2: CQA TESTING PROGRAM FOR COMPACTED EMBANKMENT**

| PROPERTY | TEST METHOD | MINIMUM TEST FREQUENCY |
|---|---|---|
| **CONTROL TESTS:** (See **Table 3.1**) | | |
| **RECORD TESTS:** | | |
| Lift Thickness | ----- | Each Lift |
| In-Place Density | ASTM D 6938[1] | 20,000 $ft^2$ per lift & 1 per 500 LF/lift of Berms (< 200 ft. base width) |
| Moisture Content | ASTM D 6938[2] | 20,000 $ft^2$ per lift & 1 per 500 LF/lift of Berms (< 200 ft. base width) |

Notes:

1. Optionally use ASTM D 1556, ASTM D 2167, or ASTM D 2937. For every 10 nuclear density tests perform at least 1 density test by ASTM D 1556, ASTM D 2167, or ASTM D 2937 as a verification of the accuracy of the nuclear testing device.
2. Optionally use ASTM D 2216, ASTM D 4643, or ASTM D 4959. For every 10 nuclear moisture tests perform at least 1 moisture test by ASTM D 2216, ASTM D 4643, or ASTM D 4959 as a verification of the accuracy of the nuclear testing device.

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# SECTION 4.0
# SOIL LINER CQA

## 4.1 INTRODUCTION

This section of the CQA Manual addresses the soil liner component of the liner system and outlines the soils CQA program to be implemented with regard to material approval, subgrade approval, test fill construction, field and laboratory control and record tests, and resolution of problems.

## 4.2 SOIL LINER MATERIAL APPROVAL

All material to be used as soil liner shall be approved in advance by the CQA Engineer. Approval is based upon successful completion of CQA control testing outlined below. Such testing can be performed either during excavation and stockpiling or from existing stockpiles prior to use.

### 4.2.1 Control Tests

The procedure for CQA testing during excavation and stockpiling (including existing stockpiles) is outlined below.

Each load of soil will be examined either at the borrow source or the stockpile area. Any unsuitable material will be rejected or routed to separate stockpiles consistent with its end use. Appropriate entries will be made in the daily log.

During stockpiling operations, control tests, as shown on **Table 4.1**, will be performed by the CQA Engineer prior to placement of any soil liner material.

## 4.3 SUBGRADE APPROVAL

The CQA Engineer will verify that the soil liner subgrade is constructed in accordance with the project specifications.

## 4.4 TEST FILL CONSTRUCTION

A test fill meeting the requirements of the project specifications will be constructed using the same construction methods, equipment, and material to be used for the soil liner component. The test fill construction will be conducted prior to or coincide with the beginning of construction of the soil liner component.

Construction equipment and methods will be reviewed by the CQA Engineer prior to test fill placement.

### 4.4.1 Control Tests

The control tests, as shown on **Table 4.2**, will be performed by the CQA Engineer prior to placement of soil liner material in the test fill.

### 4.4.2 Record Tests

The record tests, as shown on **Table 4.2**, will be performed by the CQA Engineer during placement of soil liner material in the test fill.

### 4.4.3 Test Fill Completion

The test fill program is completed when the Contractor has shown that the soil liner constructed using the same construction methods, equipment, and material to be used in construction of the soil liner will satisfy project specifications. No soil liner can be placed until the test fill program is completed.

## 4.5 SOIL LINER CONSTRUCTION

### 4.5.1 Construction Monitoring

A. Soil liner shall be placed as described in the applicable section(s) of the project specifications using the construction methods, equipment, and material demonstrated in the test fill construction.

B. Only soil previously approved by the CQA Engineer (see **Section 4.2**) shall be used in construction of the soil liner. Unsuitable material will be removed prior to acceptance by the CQA Engineer.

C. All required field density and moisture content tests shall be completed before the overlying lift of soil is placed. The surface preparation (e.g. wetting, drying, scarification, etc.) shall be completed before the CQA Engineer will allow placement of subsequent lifts.

D. The CQA Engineer will monitor protection of the soil liner during and after construction.

E. The liner surface shall be sprinkled with water as needed to prevent desiccation. Should desiccation occur, the last lift shall be reconstructed in accordance with the project specifications. Standing water should not be present on the soil liner.

F. Frost heave or other damage due to freezing shall require lift reconstruction in accordance with the project specifications.

G. The CQA Engineer will inspect the soil liner and certify that it is in accordance with

the project specifications and approved plans prior to the Contractor beginning installation of overlying geosynthetics.

H. The finished soil liner shall be free of all rock protrusions. All cracks and voids shall be filled and the surface made uniform. This shall be accomplished by final dressing of the soil liner with smooth-drum rollers and hand raking. No rubber tired vehicles are permitted on the final dressed surface unless authorized by the CQA Engineer.

I. The surface on which the overlying geosynthetics are to be placed shall be maintained in a firm, clean, and smooth condition and shall be within the acceptable moisture range before and during the geosynthetics installation.

### 4.5.2 Control Tests

The control tests, as shown on **Table 4.3**, will be performed by the CQA Engineer prior to placement of soil liner material.

### 4.5.3 Record Tests

The record tests, as shown on **Table 4.3** and as described below, will be performed by the CQA Engineer during placement of soil liner material.

A. Each lift will be checked visually for soil clods, rocks, debris, plant materials and other foreign material. Any such material which does not meet specified requirements shall be identified and removed prior to and during the compaction process.

B. The thickness of the loose lift will be measured at random locations after spreading and leveling is completed. Loose lift thickness should not exceed the depth of penetration of the compaction feet.

C. Moisture content will be monitored by the CQA Engineer prior to compaction. If the soil is drier than the specified minimum moisture content, water will be added and the lift will be disced to distribute the moisture evenly.

Results of testing will be certified within 7 days of soil liner placement.

#### 4.5.3.1 Record Test Failure

The following procedures shall be used in the event of density or hydraulic conductivity test failure:

A. Failed Density Test: Recompaction of the failed area shall be performed and retested until the area meets or exceeds requirements outlined in the

specifications.

B. Failed Hydraulic Conductivity Test: The area of failure shall be localized and reconstructed in accordance with the project specifications. This area will be retested as outlined within the plan by the CQA Engineer. Optionally, at least five replicate samples shall be obtained and tested by the Contractor in the immediate vicinity of the failed test. If all five samples pass, then the initial failing test will be discounted. However, should the replicate samples confirm the failure of the soil liner to meet specifications, the area of failure shall be localized, reconstructed, and retested as described above.

### 4.5.4 Judgmental Testing

During construction, the frequency of control and/or record testing may be increased at the discretion of the CQA Engineer when visual observations of construction performance indicate a potential problem. Additional testing for suspected areas will be considered when:

- the rollers slip during rolling operation;
- the lift thickness is greater than specified;
- the fill material is at an improper moisture content;
- fewer than the specified number of roller passes are made;
- dirt-clogged rollers are used to compact the material;
- the rollers may not have used optimum ballast;
- the fill materials differ substantially from those specified; or
- the degree of compaction is doubtful.

### 4.5.5 Perforations In Soil Liner

All holes shall be patched with compacted soil liner (if allowed by the project specifications) or sodium bentonite compacted and hydrated in the holes.

## 4.6 DEFICIENCIES

The CQA Engineer will immediately determine the extent and nature of all defects and deficiencies and report them to the Owner and Engineer. All defects and deficiencies will be documented by the CQA Engineer. The Contractor shall correct defects and deficiencies to the satisfaction of the CQA Engineer. The CQA Engineer will observe all retests on repaired defects.

**TABLE 4.1: CQA TESTING PROGRAM FOR SOIL LINER MATERIAL APPROVAL**

| PROPERTY | TEST METHOD | MINIMUM TEST FREQUENCY |
|---|---|---|
| **CONTROL TESTS:** | | |
| Visual Classification | ASTM D 2488 | Each Soil |
| Moisture Content | ASTM D 2216 | 2,000 CY per Each Soil |
| Grain Size Analysis | ASTM D 422 | 2,000 CY per Each Soil |
| Atterberg Limits | ASTM D 4318 | 2,000 CY per Each Soil |
| Moisture-Density Relationship | ASTM D 698 | 5,000 CY per Each Soil |
| Hydraulic Conductivity - Lab Remolded | ASTM D 5084[3] | 10,000 CY per Each Soil |

**TABLE 4.2: CQA TESTING PROGRAM FOR SOIL LINER TEST FILL**

| PROPERTY | TEST METHOD | MINIMUM TEST FREQUENCY |
|---|---|---|
| **CONTROL TESTS:** (See **Table 4.1**) | | |
| Moisture-Density Relationship | ASTM D 698[4] | 1 per lift |
| Hydraulic Conductivity - Lab Remolded | ASTM D 5084[3,4] | 1 per lift |
| **RECORD TESTS:** | | |
| Lift Thickness | ----- | Each Lift |
| Atterberg Limits | ASTM D 4318 | 1 per lift |
| Grain Size Analysis | ASTM D 422 | 1 per lift |
| In-Place Density | ASTM D 2922[1] | 3 per lift |
| Moisture Content | ASTM D 6938[2] | 3 per lift |
| Hydraulic Conductivity - Undisturbed (Shelby Tube) | ASTM D 6938[3] | 1 per lift |

**TABLE 4.3: CQA TESTING PROGRAM FOR SOIL LINER**

| PROPERTY | TEST METHOD | MINIMUM TEST FREQUENCY |
|---|---|---|
| **CONTROL TESTS:** (See **Table 4.1**) | | |
| **RECORD TESTS:** | | |
| Lift Thickness | ----- | Each Lift |
| In-Place Density | ASTM D 6938[1] | 10,000 $ft^2$ per lift |
| Moisture Content | ASTM D 6938[2] | 10,000 $ft^2$ per lift |
| Hydraulic Conductivity - Undisturbed (Shelby Tube) | ASTM D 5084[3] | 80,000 $ft^2$ per lift |

Notes:

1. Optionally use ASTM D 1556, ASTM D 2167, or ASTM D 2937. For every 10 nuclear density tests perform at least 1 density test by ASTM D 1556, ASTM D 2167, or ASTM D 2937 as a verification of the accuracy of the nuclear testing device.
2. Optionally use ASTM D 2216, ASTM D 4643, or ASTM D 4959. For every 10 nuclear moisture tests perform at least 1 moisture test by ASTM D 2216, ASTM D 4643, or ASTM D 4959 as a verification of the accuracy of the nuclear testing device.
3. Maximum effective confining pressure and hydraulic gradient as required by the project specifications. Backpressure as recommended by ASTM D 5084.
4. These tests performed on the test fill may count toward the minimum frequencies established in **Table 4.1**.

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# SECTION 5.0
# GEOMEMBRANE CQA

## 5.1 INTRODUCTION

This section of the CQA Manual addresses the geomembrane components of the liner and final cover systems and outlines the CQA program to be implemented with regard to manufacturer and installer approval, material approval, subgrade approval, field and laboratory control and record tests, repairs, and resolution of problems.

## 5.2 GEOMEMBRANE MANUFACTURER AND INSTALLER APPROVAL

The Contractor shall submit the qualifications of the Geomembrane Manufacturer and the Geomembrane Installer, as described in the specifications, to the CQA Engineer for approval.

## 5.3 GEOMEMBRANE MATERIAL APPROVAL

### 5.3.1 Geomembrane Product Data

The CQA Engineer will review the Contractor's submittals for conformance with the project specifications.

### 5.3.2 Shipment And Storage

During shipment and storage, all geomembrane will be protected as required by the project specifications. The CQA Engineer will observe rolls upon delivery at the site.

### 5.3.3 Quality Control Certificates

Upon delivery, the CQA Engineer will:

- verify that the Manufacturer's quality control certificates have been provided at the specified frequency and that each certificate identified the rolls or sheets related to it; and

- review the Manufacturer's quality control certificates and verify that the certified properties meet the project technical specifications.

### 5.3.4 Material Control Tests

Samples for material control tests, as shown on **Table 5.1**, will be obtained by the CQA Engineer at the indicated frequencies upon delivery of the geomembrane. Alternatively, samples may be randomly obtained at the manufacturing site by the CQA Engineer or representatives of the Geosynthetics CQA Laboratory.

Unless otherwise specified, samples will be 3 feet long by the roll or sheet width. The CQA Engineer will mark the machine direction on the samples with an arrow.

All material control tests will be performed by the Geosynthetics CQA Laboratory.

All control test results must be available at the site prior to the deployment of all geomembrane. The CQA Engineer will examine all results from laboratory conformance testing.

5.3.4.1 Material Control Test Failure

The following procedure will apply whenever a sample fails a material control test:

A. The Geomembrane Installer will replace the roll or sheet of geomembrane that is in nonconformance with the project specifications with a roll or sheet that meets project specifications.

B. The Geomembrane Installer will remove conformance samples for testing by the Geosynthetics CQA Laboratory from the closest numerical roll or sheet on both sides of the failed roll or sheet. These two samples must both conform to project specifications. If either of these samples fail, then the next numerical roll or sheet will be tested until a passing roll or sheet is found. This additional conformance testing will be at the expense of the Geomembrane Installer. If either of the two closest rolls or sheets fail, the Engineer will dictate the frequency of additional testing.

The CQA Engineer will document actions taken in conjunction with material control test failures.

## 5.4 GEOMEMBRANE INSTALLATION

### 5.4.1 Handling

The Geosynthetic Installer will handle all geomembrane in such a manner as required by the project specifications.

### 5.4.2 Earthwork

5.4.2.1 Surface Preparation

The Geomembrane Installer will certify in writing that the surface on which the geomembrane will be installed meets line and grade, and the surface preparation requirements of the project specifications. The certificate of acceptance will be given to the CQA Engineer prior to commencement of geomembrane installation in the area under consideration. The CQA Engineer will give a copy of this certificate

to the Engineer.

To ensure a timely covering of the subgrade (or soil liner) surface, the Engineer may allow subgrade acceptance in areas as small as one acre. After the supporting soil has been accepted by the Geomembrane Installer, it will be the Geomembrane Installer's responsibility to indicate to the Engineer and CQA Engineer any change in the supporting soil condition that may require repair work. If the CQA Engineer concurs with the Geomembrane Installer, then the Engineer will ensure that the supporting soil is repaired.

5.4.2.2 Anchorage System

The CQA Engineer will verify that anchor trenches have been constructed and backfilled according to project specifications and design drawings.

## 5.4.3 Geomembrane Placement

5.4.3.1 Field Panel Identification

The CQA Engineer will document that the Geomembrane Installer labels each field panel with an "identification code" (number or letter-number consistent with the layout plan) agreed upon by the Geomembrane Installer and CQA Engineer at the Geosynthetics CQA Meeting (see **Section 1.7.2**).

The Geomembrane Installer will establish a table or chart showing correspondence between roll or sheet numbers and field panel identification codes. This documentation shall be submitted to the CQA Engineer weekly for review and verification. The field panel identification code will be used for all quality control and quality assurance records.

5.4.3.2 Field Panel Placement

5.4.3.2.1 Location: The CQA Engineer will verify that field panels are installed at the location indicated in the Geomembrane Installer's layout plan, as approved or modified in **Section 5.4.3.1**.

5.4.3.2.2 Installation Schedule: The CQA Engineer will evaluate every change in the schedule proposed by the Geomembrane Installer and advise the Engineer on the acceptability of that change.

The CQA Engineer will record the identification code, location, and date of installation of each field panel.

5.4.3.2.3 Placement of Geomembrane: The CQA Engineer will verify that project specification related restrictions on placement of geomembrane are fulfilled. Additionally, the CQA Engineer will verify that the supporting soil has not been damaged by weather conditions.

5.4.3.2.4 Damage: The CQA Engineer will visually observe each panel, after placement and prior to seaming, for damage. The CQA Engineer will advise the Engineer which panels, or portion of panels, should be rejected, repaired, or accepted. Damaged panels or portions of damaged panels which have been rejected will be marked and their removal from the work area recorded by the CQA Engineer. Repairs will be made according to procedures described in this section.

As a minimum, the CQA Engineer will document that:

- the panel is placed in such a manner that it is unlikely to be damaged; and
- any tears, punctures, holes, thin spots, etc. are either marked by the Geomembrane Installer for repair or the panel is rejected.

## 5.4.4 Field Seaming

### 5.4.4.1 Seam Layout

The Geomembrane Installer will provide the CQA Engineer with a seam layout drawing, i.e., a drawing of the area to be lined showing all expected seams. The CQA Engineer and Engineer will review the seam layout drawing and verify that it is consistent with the accepted state of practice and this CQA Manual.

A seam numbering system compatible with the panel numbering system will be agreed upon at the Geosynthetics CQA Meeting (see **Section 1.7.2**). An on-going written record of the seams and repair areas shall be maintained by the Geomembrane Installer with weekly review by the CQA Engineer.

### 5.4.4.2 Requirements of Personnel

The Geomembrane Installer will provide the CQA Engineer with a list of proposed seaming personnel and their experience records. This document will be reviewed by the CQA Engineer for compliance with project specifications.

5.4.4.3 Seaming Equipment and Products

Field seaming processes must comply with project specifications. Proposed alternate processes will be documented and submitted to the Engineer and CQA Engineer for their approval. Only seaming apparatus which have been specifically approved by make and model will be used. The CQA Engineer will submit all documentation to the Engineer for his concurrence.

## 5.4.5 Field Seam Control Tests

5.4.5.1 Trial Seams

A. Prior to production seaming, after four (4) hours of continuous seaming, and/or when significant changes in geomembrane or ambient temperature occurs, the Geomembrane Installer shall perform trial seams to verify that seaming conditions and procedures are adequate. Trial seams shall be performed by each operator of extrusion welders and by the primary operator of each wedge welder using seaming equipment to be used in production seaming.

B. Trial seams shall be made on appropriate sized pieces of identical or equivalent geomembrane material.

C. Hot wedge trial seams shall be approximately 72" x 12" with the seam centered lengthwise. Extrusion fillet trial seams shall be approximately 36" x 12" with the seam centered lengthwise. A minimum of four coupons shall be tested in peel and shear (two each) (ASTM D 6392) by the Geomembrane Installer using a field tensiometer. All coupons shall meet the minimum seam strength requirements as shown in the project specifications.

D. Each trial seam shall be assigned a number and the test results recorded in the appropriate log by the Geomembrane Installer. The CQA Engineer will observe all trial seams and compile all trial seam logs.

## 5.4.6 Field Seam Record Tests

5.4.6.1 Nondestructive Seam Continuity Testing

The Geomembrane Installer shall test and document all seams continuously over their full length using one of the following nondestructive seam tests. This testing shall be performed simultaneously with geomembrane deployment as the work progresses and not at the completion of all field seaming.

A. Vacuum Testing shall conform to ASTM D 5641 requirements.

B. Air Pressure Testing (for double seam with an enclosed space) shall conform to ASTM D 5820 requirements and the requirements listed in **Table 5.2**.

The CQA Engineer will observe the nondestructive testing on a full time basis to ensure conformance with this CQA Manual and the project specifications.

5.4.6.2 Field Destructive Seam Testing

A. The Geomembrane Installer shall obtain 12" x 30" (or longer as needed) samples of field seams with the seam centered lengthwise, suitable for testing, at an average frequency of one sample per 500 linear feet of seam. The sample shall be cut into two equal-length pieces, one for field destructive seam testing by the Geosynthetics Installer and one given to the CQA Engineer as an archive sample. The date, time, equipment, seam number, and seaming parameters will be marked on each sample and recorded by the CQA Engineer.

B. The Geomembrane Installer shall perform and document field destructive seam testing using a field tensiometer. A minimum of five coupons each will be tested in peel and shear (ASTM D 6392). Coupons shall meet the minimum seam strength requirements as shown in the project specifications.

C. The CQA Engineer or the Owner may require additional random samples to be taken for testing in areas which visually appear defective and not in accordance with the project requirements.

D. All holes in the geomembrane resulting from destructive seam sampling shall be immediately repaired in accordance with repair procedures described in this manual.

5.4.6.3 Geosynthetics CQA Laboratory Destructive Testing

A. The Geomembrane Installer shall obtain 12" x 30" (or longer as needed) samples of field seams with the seam centered lengthwise, suitable for testing, at an average frequency of one sample per day to confirm field destructive seam tests. The sample shall be cut into two equal-length pieces, both to be given to the CQA Engineer for laboratory destructive seam testing and as an archive sample. The date, time, equipment, seam number, and seaming parameters will be marked on each sample and recorded by the CQA Engineer.

B. Laboratory destructive test samples will be packaged and shipped to the Geosynthetics CQA Laboratory by the CQA Engineer in a manner that

will not damage the test sample.

C. A minimum of five coupons each will be tested in peel and shear (ASTM D 6392) by the Geosynthetics CQA Laboratory. Coupons shall meet the minimum seam strength requirements as shown in the project specifications.

D. All geomembrane destructive test samples that fail to meet project specifications will be saved and sent to the CQA Engineer for observation.

E. The CQA Engineer will review laboratory test results as soon as they become available.

5.4.6.4 Field Seam Record Test Failure

For noncomplying tests, the CQA Engineer will:

- observe continuity testing of the repaired areas performed by the Geomembrane Installer;
- confirm the record location, date, test unit number, name of tester, and compile the record of testing provided by the Geomembrane Installer;
- provide a walk-through inspection of all impacted seam areas and verify that the areas have been tested in accordance with the CQA Manual and project specifications; and
- verify that the Geomembrane Installer has marked repair areas with the appropriate color-coded marking pencil.

5.4.6.5 Defining Extent of Field Seam Record Test Failure

All defective seam test failures must be bounded by acceptable destructive tests. The CQA Engineer will document repair actions taken in conjunction with all seam test failures.

## 5.4.7 Repairs & Verification

5.4.7.1 Repair Procedures

A. All repair procedures shall be in accordance with the project specifications. The CQA Engineer will observe all repair procedures.

B. All surfaces shall be clean and dry at the time of the repair.

C. After an extrusion seam is made, no more than ¼ inch of abrasion shall be visible beyond the weld.

5.4.7.2 Repair Verification

A. Each repair shall be numbered and logged by the Geomembrane Installer.

B. Each repair shall be non-destructively tested by the Geomembrane Installer using the methods described above. Repairs which pass non-destructive testing shall be taken as an indication of an adequate repair.

C. Repairs more than 150 feet long may be of sufficient length to require destructive test sampling, at the discretion of the CQA Engineer. A failed test indicates that the repair shall be redone and retested until passing test results are achieved.

## 5.5 LINER SYSTEM ACCEPTANCE

The geomembrane component of the liner system will be accepted by the Owner when:

- the installation is finished;
- verification of the adequacy of all seams and repairs, including associated testing, is complete;
- CQA Engineer provides the Engineer with a final copy of the nondestructive test documentation, repair information, and as-built drawings, as submitted by the Geomembrane Installer;
- CQA Engineer provides the Engineer with a certification, submitted by the Geomembrane Installer that the geomembrane was installed in accordance with the Geomembrane Manufacturer's recommendations as well as the project drawings and project specifications; and
- all documentation of the installation is completed including the CQA Engineer's final report.

## 5.6 MATERIALS IN CONTACT WITH GEOMEMBRANES

The quality assurance procedures indicated in this subsection are only intended to assure that the installation of these materials does not damage the geomembrane. All reasonable measures to protect the geomembrane and provide additional quality assurance procedures are necessary to assure that systems built with these materials will be constructed to ensure proper performance.

### 5.6.1 Soils

Prior to placement, the CQA Engineer will visually confirm that all soil materials to be placed against the geomembrane comply with project specifications. The Geomembrane Installer will provide the CQA Engineer a written surface acceptance certificate in accordance with **Section 5.4.2**. All soil materials shall be placed and compacted in accordance with project specifications.

### 5.6.2 Sumps and Appurtenances

The CQA Engineer will verify that:

- installation of the geomembrane in appurtenance areas, and connection of the geomembrane to appurtenances have been made according to the project specifications;
- extreme care is taken while seaming around appurtenances since neither nondestructive nor destructive testing may be feasible in these areas; and
- the geomembrane or appurtenances have not been visibly damaged while making connections to appurtenances.

## 5.7 DEFICIENCIES

The CQA Engineer will immediately determine the extent and nature of all defects and deficiencies and report them to the Owner and Engineer. All defects and deficiencies will be documented by the CQA Engineer. The Contractor shall correct defects and deficiencies to the satisfaction of the CQA Engineer. The CQA Engineer will observe all retests on repaired defects.

**TABLE 5.1: CQA TESTING PROGRAM FOR GEOMEMBRANE MATERIAL APPROVAL**

| PROPERTY | TEST METHOD | TEST FREQUENCY |
|---|---|---|
| Thickness | ASTM D 5199/D 5994 | 100,000 $ft^2$ or 1 per Lot[1] |
| Density | ASTM D 1505/D 792 | 100,000 $ft^2$ or 1 per Lot[1] |
| Carbon Black Content | ASTM D 1603 | 100,000 $ft^2$ or 1 per Lot[1] |
| Carbon Black Dispersion | ASTM D 5596 | 100,000 $ft^2$ or 1 per Lot[1] |
| Tensile Properties: | ASTM D 6693 (Type IV) | |
| Tensile Strength at Yield | | 100,000 $ft^2$ or 1 per Lot[1] |
| Tensile Strength at Break | | 100,000 $ft^2$ or 1 per Lot[1] |
| Elongation at Yield | | 100,000 $ft^2$ or 1 per Lot[1] |
| Elongation at Break | | 100,000 $ft^2$ or 1 per Lot[1] |
| Tear Resistance | ASTM D 1004 | 100,000 $ft^2$ or 1 per Lot[1] |

Notes:

1. Whichever provides the larger number of tests.

**TABLE 5.2 AIR PRESSURE TEST REQUIREMENTS**

| MATERIAL | MIN. PRESSURE (PSI) | MAX. PRESSURE DROP (PSI) AFTER 5 MINUTES |
|---|---|---|
| 30 Mil LLDPE | 15 | 3 |
| $\geq$ 60 Mil HDPE | 25 | 3 |

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# SECTION 6.0
# LEACHATE MANAGEMENT SYSTEM CQA

## 6.1 INTRODUCTION

This section of the CQA Manual addresses the components of the leachate management system including components of the leachate collection system (LCS) (drainage aggregate, collection pipe, protective cover, and geosynthetic rain cover), leak detection system (LDS) (Phase 4A only), and the leachate transmission and storage system (sumps, transmission piping, manholes, valves, etc.). By reference to **Sections 7.0 and 8.0** of this CQA Manual, this section also addresses the geotextiles and drainage geocomposite that are components of the LCS. This section outlines the CQA program to be implemented with regard to material approval, construction monitoring, and resolution of problems.

## 6.2 LEACHATE MANAGEMENT SYSTEM MATERIAL APPROVAL

The CQA Engineer will verify that the following are provided and installed in accordance with the project drawings, specifications, and this CQA Manual.

### 6.2.1 Coarse Aggregate (Drainage Aggregate)

A. Receipt of Contractor's submittals on coarse aggregate.

B. Review of submittals for coarse aggregate for conformity to the project specifications.

C. Verify that coarse aggregate in stockpiles or at borrow sources conforms to the project specifications.

D. Conduct material control tests in accordance with **Table 6.1**.

### 6.2.2 Leachate Collection Media (Drainage Aggregate)

A. Receipt of Contractor's submittals on leachate collection media.

B. Review of submittals for leachate collection media for conformity to the project specifications.

C. Verify that collection media in stockpiles or at borrow sources conforms to the project specifications.

D. Conduct material control tests in accordance with **Table 6.1**.

### 6.2.3 High Density Polyethylene (HDPE) Pipe

A. Receipt of Contractor's submittals on HDPE pipe.

B. Review of submittals for HDPE pipe for conformity to the project specifications.

### 6.2.4 Geotextiles (Verify for each type of Geotextile)

The CQA program for geotextiles is presented in **Section 7.0** of this CQA Manual.

### 6.2.5 Drainage Geocomposite

The CQA program for drainage geocomposite is presented in **Section 8.0** of this CQA Manual.

### 6.2.6 Protective Cover

A. Review the proposed source of protective cover for conformance with the project specifications.

B. Conduct material control tests in accordance with **Table 6.1**.

### 6.2.7 Geosynthetic Rain Cover

A. Receipt of Contractor's submittals on Geosynthetic Rain Cover.

B. Review of submittals for Geosynthetic Rain Cover for conformity to the project specifications.

### 6.2.8 Sumps/Manholes/Leachate Storage

A. Receipt of Contractor's submittals on sumps/manholes/leachate storage.

B. Review of submittals for sumps/manholes/leachate storage for conformity to the project specifications.

### 6.2.9 Valves

A. Receipt of Contractor's submittals on valves.

B. Review of submittals for valves for conformity to the project specifications.

## 6.3 LEACHATE MANAGEMENT SYSTEM INSTALLATION

### 6.3.1 Leachate Collection System (LCS)

The CQA Engineer will allow installation of the LCS to proceed only after he has been provided certification of the installed HDPE geomembrane.

The CQA Engineer will monitor and document the construction of all LCS components for compliance with the project specifications. Monitoring the construction work includes the following:

- monitoring the minimum vertical buffer maintained between field equipment and the geomembrane;
- monitoring that the placement of the LCS components does not fold or damage the geomembrane or other underlying layers; and
- witness and verify the installation of collection piping and gravel columns.

### 6.3.2 Leachate Transmission and Storage System

The CQA Engineer will monitor and document the construction of all leachate transmission and storage system components for compliance with the project specifications. Monitoring the construction work includes the following:

- witness and verify the installation of transmission piping;
- witness and verify the leak testing of transmission piping; and
- witness and verify the leak testing of manholes, etc. (where applicable).

## 6.4 DEFICIENCIES

The CQA Engineer will immediately determine the extent and nature of all defects and deficiencies and report them to the Owner and Engineer. All defects and deficiencies will be documented by the CQA Engineer. The Contractor shall correct defects and deficiencies to the satisfaction of the CQA Engineer. The CQA Engineer will observe all retests on repaired defects.

## TABLE 6.1: CQA TESTING PROGRAM FOR LEACHATE MANAGEMENT SYSTEM

| COMPONENT | PROPERTY | TEST METHOD | MINIMUM TEST FREQUENCY |
|---|---|---|---|
| **CONTROL TESTS:** | | | |
| **Coarse Aggregate:** | Gradation | ASTM C 136 | 5,000 CY |
| | Carbonate Content | ASTM D 3042 | 1 per source |
| **Leachate Collection Media:** | Gradation | ASTM C 136 | 5,000 CY |
| | Permeability[1] | ASTM D 2434 | 10,000 CY |
| | Carbonate Content | ASTM D 3042 | 1 per source |
| **Protective Cover: (Soil Only - See Note 2)** | Visual Classification | ASTM D 2488 | Each Load |
| | Grain Size Analysis | ASTM D 422 | 5,000 CY per Each Soil |

Notes:

1. Option for Failed Permeability Test:
   In the case of a failed permeability test value within 20% of the specified value, an additional three tests may be run on the proposed material. If all three tests pass, then the results from the first test can be discounted. Otherwise a different material or material from a different source shall be submitted. The cost for additional testing shall be borne solely by the Contractor.
2. If protective cover consists of additional leachate collection media, perform control tests in accordance with the requirements for leachate collection media.

# SECTION 7.0
# GEOTEXTILE CQA

## 7.1 INTRODUCTION

This section of the CQA Manual addresses geotextiles and outlines the CQA program to be implemented with regard to material approval, material control tests, repairs, and resolution of problems.

## 7.2 GEOTEXTILE MATERIAL APPROVAL

### 7.2.1 Geotextile Product Data

For each type of geotextile to be used, the CQA Engineer will review the Contractor's submittals for conformance with the project specifications.

### 7.2.2 Shipment And Storage

During shipment and storage, all geotextiles will be protected as required by the project specifications. The CQA Engineer will observe rolls upon delivery at the site.

### 7.2.3 Quality Control Certificates

Upon delivery, the CQA Engineer will:

- verify that the Manufacturer's quality control certificates have been provided at the specified frequency and that each certificate identified the rolls related to it; and

- review the Manufacturer's quality control certificates and verify that the certified properties meet the project technical specifications.

### 7.2.4 Geotextile Material Control Tests

Samples for material control tests, as shown on **Table 7.1**, will be obtained by the CQA Engineer at the indicated frequencies upon delivery of the geotextiles. Alternatively, samples may be randomly obtained at the manufacturing site by the CQA Engineer or representatives of the Geosynthetics CQA Laboratory.

Unless otherwise specified, samples will be 3 feet long by the roll width. The CQA Engineer will mark the machine direction on the samples with an arrow.

All material control tests will be performed by the Geosynthetics CQA Laboratory.

All test results must be available at the site prior to the deployment of all geotextiles. The

CQA Engineer will examine all results from laboratory testing.

7.2.4.1 Material Control Test Failure

The following procedure will apply whenever a sample fails a material control test:

A. The Geosynthetic Installer will replace the roll of geotextile that is in nonconformance with the project specifications with a roll that meets project specifications.

B. The Geosynthetic Installer will remove samples for testing by the Geosynthetics CQA Laboratory from the closest numerical roll on both sides of the failed roll. These two samples must both conform to project specifications. If either of these samples fail, then the next numerical roll will be tested until a passing roll is found. This additional testing will be at the expense of the Geosynthetic Installer. If either of the two closest rolls fail, the Engineer will dictate the frequency of additional testing.

The CQA Engineer will document actions taken in conjunction with material control test failures.

## 7.3 GEOTEXTILE INSTALLATION

### 7.3.1 Handling And Placement

The Geosynthetic Installer will handle and place all geotextiles in such a manner as required by the project specifications.

### 7.3.2 Seams And Overlaps

All geotextiles will be seamed or overlapped in accordance with project specifications or as approved by the CQA Engineer and Engineer.

### 7.3.3 Repairs

Any holes or tears in the geotextile will be repaired in accordance with the project specifications. The CQA Engineer will observe any repair.

### 7.3.4 Placement Of Overlying Materials

All soil materials located on top of a geotextile shall be placed in accordance with the project specifications.

## 7.4 DEFICIENCIES

The CQA Engineer will immediately determine the extent and nature of all defects and deficiencies and report them to the Owner and Engineer. All defects and deficiencies will be documented by the CQA Engineer. The Contractor shall correct defects and deficiencies to the satisfaction of the CQA Engineer. The CQA Engineer will observe all retests on repaired defects.

### TABLE 7.1: CQA TESTING PROGRAM FOR GEOTEXTILE MATERIAL APPROVAL

| PROPERTY | TEST METHOD | TEST FREQUENCY |
|---|---|---|
| **CONTROL TESTS:** | | |
| Tensile Properties | ASTM D 4632 | 100,000 $ft^2$ or 1 per Lot[1] |
| Puncture Resistance | ASTM D 4833 | 100,000 $ft^2$ or 1 per Lot[1] |
| Trapezoidal Tear Strength | ASTM D 4533 | 100,000 $ft^2$ or 1 per Lot[1] |
| Apparent Opening Size (AOS) (Type GT-S Geotextile Only) | ASTM D 4751 | 100,000 $ft^2$ or 1 per Lot[1] |

Notes:

1. Whichever provides the larger number of tests.
2. CQA testing is not required for geotextiles placed outside of the containment area.

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# SECTION 8.0
# DRAINAGE GEOCOMPOSITE CQA

## 8.1 INTRODUCTION

This section of the CQA Manual addresses drainage geocomposite (DGC) and outlines the CQA program to be implemented with regard to material approval, material control tests, repairs, and resolution of problems.

## 8.2 DGC MATERIAL APPROVAL

### 8.2.1 DGC Product Data

The CQA Engineer will review the Contractor's submittals for conformance with the project specifications.

### 8.2.2 Shipment And Storage

During shipment and storage, all DGC will be protected as required by the project specifications. The CQA Engineer will observe rolls upon delivery at the site.

### 8.2.3 Quality Control Certificates

Upon delivery, the CQA Engineer will:

- verify that the Manufacturer's quality control certificates have been provided at the specified frequency and that each certificate identified the rolls related to it; and

- review the Manufacturer's quality control certificates and verify that the certified properties meet the project technical specifications.

### 8.2.4 DGC Material Control Tests

Samples for material control tests, as shown on **Table 8.1**, will be obtained by the CQA Engineer at the indicated frequencies upon delivery of the DGC. Alternatively, samples may be randomly obtained at the manufacturing site by the CQA Engineer or representatives of the Geosynthetics CQA Laboratory.

Unless otherwise specified, samples will be 3 feet long by the roll width. The CQA Engineer will mark the machine direction on the samples with an arrow.

All material control tests will be performed by the Geosynthetics CQA Laboratory.

All test results must be available at the site prior to the deployment of all DGC. The CQA

Engineer will examine all results from laboratory testing.

8.2.4.1 Material Control Test Failure

The following procedure will apply whenever a sample fails a material control test:

A. The Geosynthetic Installer will replace the roll of DGC that is in nonconformance with the project specifications with a roll that meets project specifications.

B. The Geosynthetic Installer will remove samples for testing by the Geosynthetics CQA Laboratory from the closest numerical roll on both sides of the failed roll. These two samples must both conform to project specifications. If either of these samples fail, then the next numerical roll will be tested until a passing roll is found. This additional testing will be at the expense of the Geosynthetic Installer. If either of the two closest rolls fail, the Engineer will dictate the frequency of additional testing.

The CQA Engineer will document actions taken in conjunction with material control test failures.

## 8.3 DGC INSTALLATION

### 8.3.1 Handling And Placement

The Geosynthetic Installer will handle and place all DGC in such a manner as required by the project specifications.

### 8.3.2 Stacking And Joining

When several layers of DGC are stacked, care should be taken to ensure that stacked DGC are placed in the same direction. Stacked DGC will never be laid in perpendicular directions to the underlying DGC (unless otherwise specified by the Engineer). The CQA Engineer will observe the stacking of DGC.

Adjacent rolls of DGC will be joined according to construction drawings and project specifications.

### 8.3.3 Repairs

Any holes or tears in the DGC will be repaired in accordance with the project specifications. The CQA Engineer will observe any repair.

### 8.3.4 Placement Of Overlying Materials

All soil materials located on top of DGC shall be placed in accordance with the project specifications.

## 8.4 DEFICIENCIES

The CQA Engineer will immediately determine the extent and nature of all defects and deficiencies and report them to the Owner and Engineer. All defects and deficiencies will be documented by the CQA Engineer. The Contractor shall correct defects and deficiencies to the satisfaction of the CQA Engineer. The CQA Engineer will observe all retests on repaired defects.

**TABLE 8.1: CQA TESTING PROGRAM FOR DGC MATERIAL APPROVAL**

| PROPERTY | TEST METHOD | TEST FREQUENCY |
|---|---|---|
| **CONTROL TESTS:** | | |
| Thickness (geonet only) | ASTM D 5199 | 100,000 $ft^2$ or 1 per Lot[1] |
| Density (geonet only) | ASTM D 1505 | 100,000 $ft^2$ or 1 per Lot[1] |
| Ply Adhesion | ASTM D 413/ GRI GC7 | 100,000 $ft^2$ or 1 per Lot[1] |
| Transmissivity | ASTM D 4716[2] | 1 per Resin Lot |

Notes:

1. Whichever provides the larger number of tests.
2. Conduct tests for transmissivity in accordance with the conditions given in the project specifications.

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# SECTION 9.0
# GEOSYNTHETIC CLAY LINER (GCL) CQA

## 9.1 INTRODUCTION

This section of the CQA Manual addresses geosynthetic clay liner (GCL) and outlines the CQA program to be implemented with regard to material approval, material control tests, repairs, and resolution of problems.

## 9.2 GCL MANUFACTURER AND INSTALLER APPROVAL

The Contractor shall submit the qualifications of the GCL Manufacturer and the GCL Installer, as described in the specifications, to the CQA Engineer for approval.

## 9.3 GCL MATERIAL APPROVAL

### 9.3.1 GCL Product Data

The CQA Engineer will review the Contractor's submittals for conformance with the project specifications.

### 9.3.2 Shipment And Storage

During shipment and storage, GCL will be protected as required by the project specifications. The CQA Engineer will observe rolls upon delivery at the site.

### 9.3.3 Quality Control Certificates

Upon delivery, the CQA Engineer will:

- verify that the Manufacturer's quality control certificates have been provided at the specified frequency and that each certificate identified the rolls related to it; and
- review the Manufacturer's quality control certificates and verify that the certified properties meet the project technical specifications.

### 9.3.4 GCL Material Control Tests

Samples for material control tests, as shown on **Table 9.1**, will be obtained by the CQA Engineer at the indicated frequencies upon delivery of the GCL. Alternatively, samples may be randomly obtained at the manufacturing site by the CQA Engineer or representatives of the Geosynthetics CQA Laboratory.

Unless otherwise specified, samples will be 3 feet long by the roll width. The CQA

Engineer will mark the machine direction on the samples with an arrow.

All material control tests will be performed by the Geosynthetics CQA Laboratory.

All test results must be available at the site prior to the deployment of all GCL. The CQA Engineer will examine all results from laboratory testing.

9.3.4.1 Material Control Test Failure

The following procedure will apply whenever a sample fails a material control test:

A. The Geosynthetic Installer will replace the roll of GCL that is in nonconformance with the project specifications with a roll that meets project specifications.

B. The Geosynthetic Installer will remove samples for testing by the Geosynthetics CQA Laboratory from the closest numerical roll on both sides of the failed roll. These two samples must both conform to project specifications. If either of these samples fail, then the next numerical roll will be tested until a passing roll is found. This additional testing will be at the expense of the Geosynthetic Installer. If either of the two closest rolls fail, the Engineer will dictate the frequency of additional testing.

The CQA Engineer will document actions taken in conjunction with material control test failures.

## 9.4 GCL INSTALLATION

### 9.4.1 Handling And Placement

The Geosynthetic Installer will handle and place all GCL in such a manner as required by the project specifications.

### 9.4.2 Seams And Overlaps

All GCL will be seamed or overlapped in accordance with project specifications or as approved by the CQA Engineer and Engineer.

### 9.4.3 Repairs

Any holes or tears in the GCL will be repaired in accordance with the project specifications. The CQA Engineer will observe any repair.

### 9.4.4 Placement Of Overlying Materials

All soil materials located on top of the GCL shall be placed in accordance with the project specifications.

## 9.5 DEFICIENCIES

The CQA Engineer will immediately determine the extent and nature of all defects and deficiencies and report them to the Owner and Engineer. All defects and deficiencies will be documented by the CQA Engineer. The Contractor shall correct defects and deficiencies to the satisfaction of the CQA Engineer. The CQA Engineer will observe all retests on repaired defects.

**TABLE 9.1: CQA TESTING PROGRAM FOR GCL MATERIAL APPROVAL**

| PROPERTY | TEST METHOD | TEST FREQUENCY |
|---|---|---|
| **CONTROL TESTS:** | | |
| Hydraulic Conductivity | ASTM D 5084/D 5887 | 100,000 $ft^2$ or 1 per Lot[1] |
| Bentonite Content | ASTM D 5993 (@ 0% moisture) | 100,000 $ft^2$ or 1 per Lot[1] |
| Peel Strength | ASTM D 6496 | 100,000 $ft^2$ or 1 per Lot[1] |

Notes:

1. Whichever provides the larger number of tests.

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# SECTION 10.0
# FINAL COVER SYSTEM CQA

## 10.1 INTRODUCTION

This section of the CQA Manual addresses the landfill gas (LFG) system, drainage aggregate and piping, and the vegetative soil layer of the final cover system. By reference to **Sections 5.0, 7.0, and 8.0** of this CQA Manual, this section also addresses the geomembrane, geotextiles, and drainage geocomposite that are included in the final cover system. This section outlines the CQA program to be implemented with regard to material approval, construction monitoring, and resolution of problems.

## 10.2 FINAL COVER SYSTEM MATERIAL APPROVAL

The CQA Engineer shall verify that the following are provided and installed in accordance with the project drawings, specifications, and this CQA Manual.

### 10.2.1 High Density Polyethylene (HDPE) Pipe

A. Receipt of Contractor's submittals on HDPE pipe.

B. Review of submittals for HDPE pipe for conformity to the project specifications.

### 10.2.2 Polyvinyl Chloride (PVC) Pipe

A. Receipt of Contractor's submittals on PVC pipe.

B. Review of submittals for PVC pipe for conformity to the project specifications.

### 10.2.3 Corrugated Polyethylene (CPE) Pipe

A. Receipt of Contractor's submittals on CPE pipe.

B. Review of submittals for CPE pipe for conformity to the project specifications.

### 10.2.4 LFG System Components

A. Receipt of Contractor's submittals on LFG system components.

B. Review of submittals for LFG system components for conformity to the project specifications.

### 10.2.5 Aggregates (Verify for each type of aggregate)

A. Receipt of Contractor's submittals on aggregates.

B. Review of submittals for aggregates for conformity to the project specifications.

C. Verify that aggregates in stockpiles or at borrow sources conform to the project specifications.

D. Conduct material control tests in accordance with **Table 10.1**.

### 10.2.6 Geomembrane

The CQA program for geomembranes is presented in **Section 5.0** of this CQA Manual.

### 10.2.7 Geotextiles

The CQA program for geotextiles is presented in **Section 7.0** of this CQA Manual.

### 10.2.8 Drainage Geocomposite

The CQA program for drainage geocomposite is presented in **Section 8.0** of this CQA Manual.

### 10.2.9 Vegetative Soil Layer

A. Review the proposed source of vegetative soil layer for conformance with the project specifications.

B. Conduct material control tests in accordance with **Table 10.1**.

## 10.3 FINAL COVER SYSTEM INSTALLATION

The CQA Engineer will monitor and document the construction of all final cover system components for compliance with the project specifications. Monitoring the construction work for the components of the final cover system includes the following:

- verify location and depth of LFG wells;
- verify location of all piping;
- monitoring the minimum vertical buffer maintained between field equipment and geosynthetics/piping; and
- monitoring that the placement of the final cover system components does not fold or damage the geosynthetics or other underlying layers.

## 10.4 DEFICIENCIES

The CQA Engineer will immediately determine the extent and nature of all defects and deficiencies and report them to the Owner and Engineer. All defects and deficiencies will be documented by the CQA Engineer. The Contractor shall correct defects and deficiencies to the satisfaction of the CQA Engineer. The CQA Engineer will observe all retests on repaired defects.

**TABLE 10.1: CQA TESTING PROGRAM FOR FINAL COVER SYSTEM**

| COMPONENT | PROPERTY | TEST METHOD | MINIMUM TEST FREQUENCY |
|---|---|---|---|
| **CONTROL TESTS:** | | | |
| **Coarse Aggregate:** | Gradation | ASTM C 136 | 5,000 CY |
| **Vegetative Soil Layer:** | Visual Classification | ASTM D 2488 | Each Load |
| | Grain Size Analysis | ASTM D 422 | 5,000 CY |
| | Atterberg Limits | ASTM D 4318 | 5,000 CY |

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# Appendix A

# Reference List of Test Methods

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**JOHNSTON COUNTY LANDFILL**

**CQA MANUAL**
**APPENDIX A: REFERENCE LIST OF TEST METHODS**

**American Society American Society of Testing and Materials (ASTM):**

| | |
|---|---|
| ASTM C 136 | Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates. |
| ASTM D 413 | Standard Test Methods for Rubber Property - Adhesion to Flexible Substrate. |
| ASTM D 422 | Standard Test Method for Particle Size Analysis of Soils. |
| ASTM D 698 | Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft$^3$). |
| ASTM D 792 | Standard Test Method for Density and Specific Gravity (Relative Density) of Plastics by Displacement. |
| ASTM D 1004 | Standard Test Method for Initial Tear Resistance of Plastic Film and Sheeting. |
| ASTM D 1505 | Standard Test Method for Density of Plastics by the Density-Gradient Technique. |
| ASTM D 1556 | Standard Test Method for Density and Unit Weight of Soil in Place by the Sand-Cone Method. |
| ASTM D 1603 | Standard Test Method for Carbon Black in Olefin Plastics. |
| ASTM D 2167 | Standard Test Method for Density and Unit Weight of Soil in Place by the Rubber Balloon Method. |
| ASTM D 2216 | Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass. |
| ASTM D 2434 | Standard Test Method for Permeability of Granular Soils (Constant Head). |
| ASTM D 2488 | Standard Practice for Description and Identification of Soils (Visual-Manual Procedure). |

| | |
|---|---|
| ASTM D 2937 | Standard Test Method for Density of Soil in Place by the Drive Cylinder Method. |
| ASTM D 3042 | Standard Test Method for Insoluble Residue in Carbonate Aggregates. |
| ASTM D 4318 | Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils. |
| ASTM D 4533 | Standard Test Method for Trapezoid Tearing Strength of Geotextiles. |
| ASTM D 4632 | Standard Test Method for Grab Breaking Load and Elongation of Geotextiles. |
| ASTM D 4643 | Standard Test Method for Determination of Water (Moisture) Content of Soil by the Microwave Oven Method. |
| ASTM D 4716 | Standard Test Method for Constant Head Hydraulic Transmissivity (In-Plane Flow) of Geotextiles and Geotextile Related Products. |
| ASTM D 4751 | Standard Test Method for Determining Apparent Opening Size of a Geotextile. |
| ASTM D 4833 | Standard Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products. |
| ASTM D 4959 | Standard Test Method for Determination of Water (Moisture) Content of Soil by Direct Heating Method. |
| ASTM D 5084 | Standard Test Method for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter. |
| ASTM D 5199 | Standard Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes. |
| ASTM D 5596 | Standard Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics. |
| ASTM D 5641 | Standard Practice for Geomembrane Seam Evaluation by Vacuum Chamber. |
| ASTM D 5820 | Standard Practice for Pressurized Air Channel Evaluation of Dual Seamed Geomembranes. |

| | |
|---|---|
| ASTM D 5887 | Standard Test Method for Measurement of Index Flux Through Saturated Geosynthetic Clay Liner Specimens Using a Flexible Wall Permeameter. |
| ASTM D 5993 | Standard Test Method for Measuring Mass per Unit of Geosynthetic Clay Liners. |
| ASTM D 5994 | Standard Test Method for Measuring Core Thickness of Textured Geomembrane. |
| ASTM D 6392 | Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods. |
| ASTM D 6496 | Standard Test Method for Determining Average Bonding Peel Strength Between the Top and Bottom Layers of Needle-Punched Geosynthetic Clay Liners. |
| ASTM D 6693 | Standard Test Method for Determining Tensile Properties of Nonreinforced Flexible Polyethylene and Nonreinforced Polypropylene Geomembranes. |
| ASTM D 6938 | Standard Test Methods for In-Place Density and Water Content of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth). |

**Geosynthetic Research Institute (GRI):**

| | |
|---|---|
| GRI GC7 | Determination of Adhesion and Bond Strength of Geocomposites. |

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# Operations Manual

## Johnston County Landfill Facility
## Smithfield, North Carolina

Prepared for:

**Johnston County Department of Public Utilities**
**Smithfield, NC**

**June 2007**
**Revised: December 2008**

RICHARDSON SMITH GARDNER & ASSOCIATES
Engineering and Geological Services
14 N. Boylan Avenue
Raleigh, North Carolina 27603

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**JOHNSTON COUNTY**
**JOHNSTON COUNTY LANDFILL FACILITY**

**OPERATIONS MANUAL**

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# SECTION 1.0
# GENERAL FACILITY OPERATIONS

## 1.1 OVERVIEW

This Operations Manual was prepared for operations of the Johnston County Landfill facility (Permit No. 51-03) located off of Highway 210 on County Home Road near Smithfield. This document discusses the operation of the following landfill units and other solid waste management activities:

- Phase 4A Lined Subtitle D MSW Landfill Unit (Cell 3 - Proposed);
- Area 1 C&D Vertical Expansion;
- Area 2 Lined C&D Landfill Unit;
- Yard Waste Processing Area; and
- Convenience Center.

Refer to **Figure 1** for the location of existing and proposed landfill units and other solid waste management activities.

The information contained herein was prepared to provide landfill personnel with a clear understanding of how the Design Engineer assumed that the completed facility would be operated. While deviations from the operations outlined here may be acceptable, they should be reviewed and approved by the Design Engineer. Please refer to the appropriate permit application for a detailed discussion and calculations for the individual components of each landfill unit, including phasing plans.

## 1.2 CONTACT INFORMATION

All correspondence and questions concerning the operation of the Johnston County Landfill should be directed to the appropriate County and State personnel listed below. For fire or police emergencies dial 911.

### 1.2.1 Johnston County

Johnston County Department of Public Utilities
309 E. Market Street
P.O. Box 2263
Smithfield, NC 27577
Phone: (919) 209-8333
Fax: (919) 934-7174

Contacts: Tim Broome, P.E., Director
Haywood Phthisic, Assistant Director

Johnston County Solid Waste Management Department
680 County Home Road
P.O. Box 2263
Smithfield, NC 27577
Phone: (919) 938-4750
Fax: (919) 989-7152

Contact: Rick Proctor, Solid Waste Manager

### 1.2.2 North Carolina Department of Environment and Natural Resources

North Carolina DENR - Raleigh Central Office (RCO)
401 Oberlin Road
Raleigh, NC 27605
Phone: (919) 508-8400
Fax: (919) 715-3605

North Carolina DENR - Raleigh Regional Office (RRO)
3800 Barrett Drive
Raleigh, NC 27609
Phone: (919) 571-4700
Fax: (919) 571-4718

North Carolina DENR - Fayetteville Regional Office (FRO)
225 Green Street, Suite 714
Fayetteville, NC 28301
Phone: (910) 486-1541
Fax: (910) 486-0707

Division of Waste Management (DWM) - Solid Waste Section:

| | |
|---|---|
| Field Operations Branch Head: | Mark Poindexter (RCO) |
| Eastern Regional Supervisor: | Dennis Shackelford (FRO) |
| Waste Management Specialist: | Brad Bailey (RCO) |

Division of Land Resources - Land Quality Section:

| | |
|---|---|
| Regional Engineer: | John Holley, P.E. (RRO) |

## 1.3 ACCESS CONTROL

Limiting access to the landfill facility is important for the following reasons:

- Unauthorized and illegal dumping of waste materials is prevented.
- Trespassing, and injury resulting therefrom, is discouraged.

- The risk of vandalism is greatly reduced.

Access to active areas of the landfill will be controlled by a combination of fences and natural barriers, and strictly enforced operating hours. A landfill attendant will be on duty at all times when the facility is open for public use to enforce access restrictions.

### 1.3.1 Physical Restraints

The site will be accessed by the existing entrance on County Home Road. Scales and a scale house and office are provided at the entrance. All waste will have been weighed prior to being placed in the landfill. The entrances have gates which will be securely locked during non-operating hours.

### 1.3.2 Security

Frequent inspections of gates and fences will be performed by landfill personnel. The County will arrange for a random security patrol of the main gate to further discourage trespassing. Evidence of trespassing, vandalism, or illegal operation will be reported to the County Solid Waste Manager.

## 1.4 SIGNAGE

A prominent sign(s) containing the information required by the DWM will be placed at the landfill entrance. This sign(s) will provide information on operating hours, operating procedures, and acceptable wastes. Additional signage will be provided within the landfill complex to distinctly distinguish the roadway to the active landfill unit(s). Service and maintenance roads for use by operations personnel will be clearly marked and barriers (e.g., traffic cones, barrels, etc.) will be provided as required.

## 1.5 COMMUNICATIONS

Two way radio communication will be maintained between the active landfill unit(s) and the landfill scale house and office. The scale house and office have telephones in case of emergency and for the conduct of day-to-day business. Emergency telephone numbers are displayed in the scale house and office.

## 1.6 FIRE AND SAFETY

### 1.6.1 Fire Control

The possibility of fire within the landfill or a piece of equipment must be anticipated in the daily operation of the landfill. A combination of factory installed fire suppression systems and/or portable fire extinguishers will be operational on all heavy pieces of equipment at all times. For larger or more serious outbreaks, the local fire department will respond.

Fires within the landfill will be limited by the use of daily and intermediate cover as a fire break and control of "hot" loads entering the landfill. Landfill personnel at the scale house will turn away all trucks containing waste that is suspected to be hot. If a hot load is placed on the working face, then the load will be spread as thin as possible and daily cover soil will be immediately placed on the waste to extinguish the fire.

In general, fires that break out close to the surface of the disposal area should be excavated and smothered with cover material. Deep fires should be smothered out by placing moist soil on the surface and by constructing soil barriers around the fire. Where the smothering technique fails, the burning material must be excavated and smothered or quenched with water once the burning material is brought to the surface. Water is usually not effective unless it can be directly applied to the burning material.

For the lined landfill unit(s), in the event a fire occurs in the first lift of waste immediately above the protective cover layer, the possibility of damage to geosynthetics and collection piping exists. Once the fire is extinguished, the residue must be removed to allow limited inspection of the geosynthetics and piping. Damaged sections of geosynthetics, piping, etc. must be removed and replaced with new items of the same or equal material. The new materials must be placed in accordance with the technical specifications and construction quality assurance (CQA) documents prepared for this facility.

The County will verbally notify the DWM (see **Section 1.2.2**) within 24 hours of discovery of a fire within any landfill disposal area. In addition, written documentation describing the fire, the actions carried out to extinguish the fire, and a strategy for preventing future occurrences will be provided to the DWM within 15 days following any such occurrence.

### 1.6.2 Safety

All aspects of the operation of the landfill facility were developed with the health and safety of the landfill's operating staff, customers, and neighbors in mind. Prior to commencement of operations in the new landfill phase/area, a member of the landfill operating staff will be designated site safety officer. This individual, together with the facility's management will modify the site safety and emergency response program to remain consistent with National Solid Waste Management Association and Occupational Safety and Health Administration (OSHA) guidance.

Safety equipment provided includes equipment rollover protective cabs, seat belts, audible reverse warning devices, hard hats, safety shoes, and first aid kits. Landfill personnel will be encouraged to complete the American Red Cross Basic First Aid Course. Other safety requirements as designated by the County will also be implemented.

## 1.7 SEVERE WEATHER CONDITIONS

Unusual weather conditions can directly affect the operation of the landfill facility. Some of these weather conditions and recommended operational responses are as follows.

### 1.7.1 Ice Storms

An ice storm can make access to the landfill dangerous, prevent movement or placement of daily cover, and, thus, may require closure of the landfill until the ice is removed or has melted.

### 1.7.2 Heavy Rains

Exposed soil surfaces can create a muddy situation in some portions of the landfill during rainy periods. The control of drainage and use of crushed stone on unpaved roads should provide all-weather access for the site and promote drainage away from critical areas. In areas where the aggregate surface is washed away or otherwise damaged, new aggregate should be used for repair.

Intense rains can affect newly constructed drainage structures such as swales, diversions, cover soils, and vegetation. After such a rain event, inspection by landfill personnel will be initiated and corrective measures taken to repair any damage found before the next rainfall.

### 1.7.3 Electrical Storms

The open area of a landfill is susceptible to the hazards of an electrical storm. If necessary, landfilling activities will be temporarily suspended during such an event. To guarantee the safety of all field personnel, refuge will be taken in the on-site buildings or in rubber-tired vehicles.

### 1.7.4 Windy Conditions

Landfill operations during a particularly windy period may require that the working face be temporarily shifted to a more sheltered area. When this is done, the previously exposed face will be immediately covered with daily cover.

### 1.7.5 Violent Storms

In the event of hurricane, tornado, or severe winter storm warning issued by the National Weather Service, landfill operations may be temporarily suspended until the warning is lifted. Daily cover will be placed on exposed waste and buildings and equipment will be properly secured.

## 1.8 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 outside of the landfill.

## 1.9 PERSONNEL REQUIREMENTS

At least one member of the landfill supervisory staff will be certified as a Manager of Landfill Operations (MOLO) by the Solid Waste Association of North America (SWANA). Each landfill employee will go through an annual training course (led by supervisory staff) and is certified by SWANA as Landfill Operations personnel. As part of this training, personnel learn to recognize loads which may contain prohibited wastes.

## 1.10 UTILITIES

Electrical power, water, telephone, and restrooms are provided at the landfill scale house and/or office.

## 1.11 RECORD KEEPING PROGRAM

The County will maintain the following records in an operating record at the landfill:

A. Waste inspection records (see **Section 2.4**);
B. Daily tonnage records - including source of generation;
C. Waste determination records;
D. Quantity, location of disposal, generator, and special handling procedures for all special wastes disposed of at the site;
E. List of generators and haulers that have attempted to dispose of restricted wastes;
F. Employee training procedures and records of training completed;
G. Documentation of cell activation (see **Section 2.5.2.2**)
H. Leachate records (see **Section 3.3.3**);
I. Gas monitoring results and remediation measures as required (see **Section 3.4.2**);
J. All ground water monitoring and surface water quality information (See the current **Water Quality Monitoring Plan**) including:
    1. Monitoring well construction records;
    2. Sampling dates and results;
    3. Statistical analyses; and
    4. Results of inspections, repairs, etc.
K. Annual landfill reports;
L. All closure and post-closure information, where applicable, including:
    1. Testing;
    2. Certification; and
    3. Recording.
M. Cost estimates or financial assurance documentation.

The operating record will be kept up to date by the Solid Waste Manager or his designee. It will be presented upon request to the DWM for inspection. A copy of this Operations Manual will be kept at the landfill and will be available for use at all times.

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# SECTION 2.0
# WASTE HANDLING OPERATIONS

## 2.1 OVERVIEW

This section describes the required waste handling operations for the Johnston County Landfill facility. In addition to the MSW and C&D waste disposed of at this facility, the County also processes recyclables, scrap tires, and white goods. These materials are stored at the landfill facility until there are sufficient quantities for pick up by various recycling contractors.

## 2.2 ACCEPTABLE WASTES

### 2.2.1 MSW Landfill Units

Only the waste as defined by NCGS 130A-290(a)(18a) generated within the approved service area may be disposed of in the MSW landfill units. In addition, the special wastes described in **Section 2.5.4** may also be disposed of in the MSW landfill units.

### 2.2.2 C&D Landfill Units

Only the following wastes generated within the approved service area may be disposed of in the C&D landfill unit:

- Construction and Demolition Debris: as defined in 15A NCAC 13B.0532(8) means solid waste resulting solely from construction, remodeling, repair, or demolition operations on pavement, buildings, or other structures. C&D waste does not include municipal and industrial waste that may be generated by on-going operations at buildings or structures.
- Land Clearing and Inert Debris Landfill: as defined in 15A NCAC 13B.0101(54) means a facility for the disposal of land-clearing waste, concrete, brick, concrete block, uncontaminated soil, gravel and rock, untreated and unpainted wood, and yard trash.
- Land Clearing Waste: as defined in 15A NCAC 13B.0101(53) means solid waste which is generated solely from land-clearing activities, limited to stumps, trees, limbs, brush, grass, and other naturally occurring vegetative material.
- Asphalt: in accordance with NCGS 130A-294(m).
- Other Wastes as Approved by the Solid Waste Section of the Division of Waste Management.

In addition, the special wastes (asbestos only) described in **Section 2.5.4** may also be disposed of in the C&D landfill units.

## 2.3 PROHIBITED WASTES

### 2.3.1 MSW Landfill Units

The following wastes are prohibited from disposal within the MSW landfill units:

- Whole Scrap Tires
- Used Oil
- White Goods
- Lead Acid Batteries
- Yard Waste
- Construction and Demolition Debris (C&D) (Except when allowed by the County)
- Aluminum Cans

In addition, operating criteria prohibit other materials from disposal within the MSW landfill units. These materials include:

- Hazardous waste as defined by NCGS 130A-290(a)(8), including hazardous waste from conditionally exempt small quantity generators.
- Polychlorinated biphenyls (PCB) wastes as defined in 40 CFR 761 with the exception of trace amounts found in materials such as consumer electronics.
- Bulk or non-containerized liquid wastes unless the waste is household waste other than septic waste and waste oil; or the waste is leachate or gas condensate derived from the MSW landfill unit. A liquid determination will be performed by the paint filter test (see **Appendix A** for apparatus and procedure).
- Containers holding liquid wastes unless the waste is household waste.

### 2.3.2 C&D Landfill Units

Only wastes, as defined in **Section 2.2.2** above may be accepted for disposal in the C&D landfill units. No other wastes may be accepted.

## 2.4 WASTE SCREENING PROGRAMS

In order to assure that prohibited wastes are not entering the landfill facility, screening programs have been implemented at the landfill. Waste received at both the scale house entrance and waste taken to the working face is inspected by trained personnel. These individuals have been trained to spot indications of suspicious wastes, including: hazardous placarding or markings, liquids, powders or dusts, sludges, bright or unusual colors, drums or commercial size containers, and "chemical" odors. Screening programs for visual and olfactory characteristics of prohibited wastes are an ongoing part of the landfill operation.

### 2.4.1 Waste Receiving and Inspection

All vehicles must stop at the scale house located at the entrance of the facility and visitors are required to sign-in. All waste transportation vehicles are weighed and the content of the load assessed. The scale attendant(s) requests from the driver of the vehicle a description of the waste it is carrying to ensure that unacceptable waste is not allowed into the landfill. The attendant(s) then visually checks the vehicle as it crosses the scale. Signs informing users of the acceptable and unacceptable types of waste are posted at the scale house. Once passing the scales, the vehicles are routed to the appropriate landfill unit or other area (convenience center, etc.) as appropriate.

Vehicles are randomly selected for screening at a rate of approximately 1% of industrial, commercial, and institutional vehicles entering the landfill. However, if something looks suspicious is spotted in any waste load, that load is inspected further. The number of loads inspected is determined by the total vehicle count as per scales tickets. Each calendar year the number is recalculated (For example, for 2001, 1% was equal to 252 vehicles; 264 vehicles were actually inspected).

Vehicles selected for inspection are directed to an area of intermediate cover adjacent to the working face where the vehicle will be unloaded. Waste is carefully spread using suitable equipment. An attendant trained to identify wastes that are unacceptable at the landfill inspects the waste discharged at the screening site. If unacceptable waste is found, including wastes generated from outside of the service area, the load will be isolated and secured by berming off the area. For unacceptable wastes that are non-hazardous, the Solid Waste Manager will then notify officials of the DWM (see **Section 1.2.2**) within 24 hours of attempted disposal of any waste the landfill is not permitted to receive in order to determine the proper course of action. For unacceptable wastes that are hazardous, the Hazardous Waste Contingency Plan outlined in **Section 2.4.2** will be followed. The hauler is responsible for removing unacceptable waste from the landfill property.

If no unacceptable waste is found, the load will be pushed to the working face and incorporated into the daily waste cell. All random waste inspections will be documented by landfill staff using the waste screening form provided in **Appendix B**.

In addition to random waste screening described above, waste unloaded on the active face will be inspected by the equipment operators, trained to spot unacceptable wastes, before and during spreading and compaction. Any suspicious looking waste is reported immediately to the designated primary inspector for further evaluation.

### 2.4.2 Hazardous Waste Contingency Plan

In the event that identifiable hazardous waste or waste of questionable character is detected at the landfill, appropriate equipment, protective gear, personnel, and materials as necessary will be employed to isolate the wastes. The DWM will be notified

immediately (see **Section 1.2.2**) that an attempt was made to dispose of hazardous waste at the landfill. If the vehicle attempting disposal of such waste is known, all attempts will be made to prevent that vehicle from leaving the site or, if the vehicle has left the site, immediate notice will be served on the owner of the vehicle that hazardous waste, for which they have responsibility, has been disposed of at the landfill.

The County will assist the DWM as necessary and appropriate in the removal and disposition of the hazardous waste and in the prosecution of responsible parties. If needed, the hazardous waste will be covered with either on-site soils or other tarping material until such time when an appropriate method can be implemented to properly handle the waste. The cost of the removal and disposing of the hazardous waste will be charged to the owner of the vehicle involved. Any vehicle owner or operator who knowingly dumps hazardous waste in the landfill may be barred from using the landfill.

Should an incident where hazardous waste is found at the landfill occur, the event will be documented by landfill staff using the waste screening form provided in **Appendix B**.

Records of information gathered as part of the waste screening programs will be maintained at the landfill site during its active life and as long as required by the County and the DWM.

## 2.5 WASTE DISPOSAL

### 2.5.1 Access

Traffic will be clearly directed to the appropriate active access road. For the active lined landfill unit(s), all vehicles entering the unit will use the active ramp to avoid damaging the liner system. Traffic speed on the ramp should be less than 10 MPH. Rutting of gravel roadway surfaces must be repaired by placement of additional gravel on the roadway and not solely by grading the rut. This will maintain the separator geotextile placed below most gravel roadway surfaces.

The location of access roads during waste placement will be determined by operations personnel in order to reflect waste placement strategy.

### 2.5.2 General Procedures

For each active landfill unit, waste transportation vehicles will arrive at the working face at random intervals. There may be a number of vehicles unloading waste at the same time, while other vehicles are waiting. In order to maintain control over the unloading of waste, a certain number of vehicles will be allowed on the working face at a time. The actual number will be determined by the truck spotter. This procedure will be used in order to minimize the potential of unloading unacceptable waste and to control disposal activity. Operations at the working face will be conducted in a manner which will encourage the efficient movement of transportation vehicles to and from the working

face, and to expedite the unloading of waste.

The approach to the working face will be maintained such that two or more vehicles may safely unload side by side. A vehicle turn-around area large enough to enable vehicles to arrive and turn around safely with reasonable speed will be provided adjacent to the unloading area. The vehicles will back to a vacant area near the working face to unload. Upon completion of the unloading operation, the transportation vehicles will immediately leave the working face area. Personnel will direct traffic necessary to expedite safe movement of vehicles.

Waste unloading at the landfill will be controlled to prevent disposal in locations other than those specified by site management. Such control will also be used to confine the working face to a minimum width, yet allow safe and efficient operations. The width and length of the working face will be maintained as small as practical in order to maintain the appearance of the site, control windblown waste, and minimize the amount of cover required each day. Normally, only one working face will be active on any given day, with all deposited waste in other areas covered by either daily/periodic, intermediate, or final cover, as appropriate.

The procedures for placement and compaction of solid waste include: unloading of vehicles, spreading of waste into 2 foot lifts, and compaction on relatively flat slopes (i.e. 5H:1V max.) using a landfill compactor and a minimum number of three full passes.

Wind screens adjacent to the working face may be used as required to control windblown waste.

The use of portable signs with directional arrows and portable traffic barricades will facilitate the unloading of wastes to the designated disposal locations. These signs and barricades will be placed along the access route to the working face of the landfill or other designated areas which may be established.

### 2.5.3 Waste Disposal - Lined (MSW or C&D) Landfill Units

#### 2.5.3.1 Cell Operations and Phasing

Each lined landfill unit is divided into cells. Each cell will be filled in sequence until the entire footprint is covered with waste. Phasing drawings are presented in the appropriate permit application for each landfill unit.

It is advantageous to begin to establish final cover grades along the perimeter berms as soon as is possible. This will allow earlier construction of intermediate or final cover to promote "clean" runoff and to spread out final cover construction costs.

2.5.3.2 Cell Activation

Before placing waste in a particular area of any cell, that area must be connected to the leachate collection system (LCS) by removing (or suitably shredding by tracking with a dozer) geosynthetic rain cover (if any) and/or making any required piping connections such that all liquid collected in that area will flow to the sump. Next, just ahead of waste placement operations, the Type GT-S geotextile placed over the gravel columns is to be cut and removed such that waste will be placed in direct contact with the coarse aggregate.

Once an area has reached its effective capacity, operations will move to the next scheduled area. Prior to placing waste in a new area, it must be connected to the LCS as described above.

See **Appendix C** for cell activation forms to be used in the documentation of cell activation activities.

2.5.3.3 Placement of Initial Lift

During waste placement operations, the landfill liner system is most vulnerable during the placement of the first lift of waste. The first lift of waste should be comprised of select loads spread on top of the protective cover layer. These select loads must be free of long or large pieces of waste that may push through the protective cover layer and damage the liner system. Workers will be positioned near the working face to check for any waste which could possibly penetrate the protective cover layer. The first lift should be a minimum of four (4) feet thick and provide sufficient area for at least one day's operation without placing other areas of the liner in jeopardy.

The side slopes of the liner system are also vulnerable during placement of the first lift of waste. As with the bottom slopes, the first lift of waste against the side slopes should be comprised of select loads.

In the event that the landfill staff identifies any damage to any part of the landfill's liner system, they should immediately initiate its repair. Additionally, they should document the damage and the repair as a part of the operating record.

2.5.3.4 Equipment Operations Within the Landfill

Both the facility's operational vehicles and waste transportation vehicles must be restricted as follows within the lined landfill:

- Equipment operation directly on the protective cover will be limited to rubber-tired vehicles having a maximum ground contact, i.e., tire pressure, of less than 32 psi.

- A minimum vertical separation of 3 feet will be maintained between the geomembrane liner and all waste transportation vehicles.
- A minimum vertical separation of 5 feet will be maintained between the geomembrane liner and waste compactors.

The operation of vehicles within those portions of the landfill not actively receiving waste should be restricted to activities associated with erosion and sedimentation control.

## 2.5.4 Special Waste Management

### 2.5.4.1 Asbestos Management (MSW or C&D Landfill Units)

The County may dispose of asbestos within either the MSW or C&D landfill units. Asbestos will only be accepted if it has been processed and packaged in accordance with State and Federal (40 CFR 61) regulations. Asbestos will arrive at the site in vehicles that contain only the asbestos waste and only after advance notification by the generator.

Once the hauler brings the asbestos to the landfill, the hauler will be directed to the designated asbestos disposal area by operations personnel. The designated disposal area will be prepared by operations personnel by leveling a small area using a dozer or loader. Prior to disposal, the landfill operators will stockpile cover soil near the designated asbestos disposal area. The volume of soil stockpiled will be sufficient to cover the waste and to provide any berms, etc. to maintain temporary separation from other landfill traffic.

Once placed in the prepared area, the asbestos waste will be covered with a minimum of 18 inches of cover soil placed in a single lift. The surface of the cover soil will be compacted and graded using a tracked dozer or loader. The landfill compactor will be prohibited from operating over asbestos disposal areas until at least 18 inches of cover are in-place.

The landfill staff will record the approximate location and elevation of the asbestos waste once cover is in-place. The Solid Waste Manager will then review pertinent disposal and location information to assure compliance with regulatory requirements and enter the information into the Operating Record.

Once disposal and recording for asbestos waste is completed, the disposal area may be covered with waste. No excavation into designated asbestos disposal areas will be permitted.

In general, for the lined landfill unit(s), no asbestos will be stored over gravel columns or over sump areas in order to minimize the potential for future disturbance.

2.5.4.2 Sewage Sludge Management (MSW Landfill Units)

Sewage sludge may be accepted for disposal within the MSW landfill units in accordance with Federal and State requirements. Sewage sludge will be co-disposed along with other wastes if the sludge passes the liquids restriction criteria (i.e., the Paint Filter Test) and has an acceptable Toxicity Characteristic Leaching Procedure (TCLP) test. Such testing will be the responsibility of the generator, but landfill staff may conduct spot testing.

In order to minimize the potential for clogging of the leachate collection and removal system, sewage sludge will not be placed within the first lift of waste. Sewage sludge may also be used as a soil conditioner incorporated into the vegetative soil layer of the final cover.

2.5.4.3 Spoiled Food and Animal Waste (MSW Landfill Units)

The disposal of spoiled foods, animal carcasses, and other animal wastes within the MSW landfill units will be handled as follows. The generator of the material must call in advance to the landfill, and a determination will be made as to whether or not the waste will be accepted. If the waste is approved, the generator will present the waste at a predetermined time. An area for disposal will already have been prepared and the waste will be covered immediately.

## 2.5.5 Daily or Periodic Cover

### 2.5.5.1 MSW Landfill Units

At the completion of waste placement each day, a 6 inch layer of earthen material or approved alternate daily cover (i.e. tarps (see **Section 2.5.5.3)**, etc.) will be placed over the working face. This daily cover is intended to control vectors, fire, odors, and blowing litter. If the County should desire to use an alternate daily cover, a formal request and an appropriate demonstration will be made to the DWM.

### 2.5.5.2 C&D Landfill Units

At the completion of waste placement each week, or sooner if the area of exposed waste exceeds one acre in size, a 6-inch layer of earthen material or other material as approved by the DWM will be placed over the exposed waste. This periodic cover is intended to control vectors, fire, odors, and blowing debris.

### 2.5.5.3 Tarpomatic Alternative Daily Cover

The Tarpomatic apparatus consists of a 60' wide x 8' deep x 10' tall tubular steel support frame, a diesel engine, a hydraulic pump, stationary and remote control

boxes, and a detachable 50 foot tarp spool. The frame has two carrier arms at the top that will latch over the blade of a compactor (or dozer) allowing the apparatus to become mobile when needed. Each spool may carry three 40' x 100' tarps which provide up to 12,000 square feet of coverage. Tarps are made from a woven high density polyethylene fire retardant material with reinforced seams and edges and connecting straps on each end. Heavy steel chains are installed in pockets throughout the tarp to provide ballast to prevent wind uplift. Carrier arm adjustment, tarp spool drive, and spool locking levers are hydraulically controlled and are activated by the remote control box located inside the compactor cab.

To operate the Tarpomatic, the operator will drive the compactor up to the apparatus and align the blade with the carrier arms. The blade is then lifted upward into the carrier arms, raising the frame off the ground. Once the operator has positioned the compactor and Tarpomatic over the area of waste to be covered, each tarp is applied to the surface while backing over the waste. The tarp is unrolled at the same rate as the compactor movement so that it may be applied to the surface without pulling the tarp through the waste. Once the tarp is completely applied, the operator will detach the tarp straps and set the frame to the side. Tarps are rolled back onto the spool in the reverse order.

Typically, the Tarpomatic is used to cover over the daily working face only. As migration occurs throughout cell development, all traffic areas and side slopes are covered with daily or intermediate cover soil. Severe thunderstorms, high winds, or freezing precipitation may prohibit the use of the Tarpomatic. Daily or intermediate cover soil is used as cover every Friday or whenever inclement weather is forecasted.

Tarps that become damaged will be repaired or replaced as necessary. The County typically maintains 4 tarps on 2 spools and replaces tarps every 2 years.

### 2.5.6 Intermediate Cover

A 12 inch layer of soil cover should be placed on all waste surfaces that have not received waste in 30 days but are below final elevation. This intermediate cover should be seeded immediately and graded such that all precipitation run-off is channeled to the surface water systems.

### 2.5.7 Height Monitoring

Approximately every month, the landfill staff will monitor landfill top and side slope elevations with a level. When such elevations approach design grades, the final top-of-waste grades will be staked to limit over-placement of waste.

## 2.6 YARD WASTE PROCESSING AREA OPERATIONS

The operation of the yard waste processing area is as follows:

Acceptable wood and yard wastes are stockpiled to an approximate height of 10 feet over an area of approximately 1 acre (approximate weight of 1,500 to 2,000 lbs.). At that time a contractor is brought in to grind the waste. Once the waste is ground and becomes mulch, it is used either around the site, primarily for surface stabilization, or placed in windrows to be given to the public or otherwise used in the future. A full time attendant looks over both the yard waste processing area and the convenience center operations.

Adjacent to the yard waste processing area, there is approximately 14 acres available within two former borrow areas that are designated for use in the handling of debris from a natural disaster.

## 2.7 CONVENIENCE CENTER OPERATIONS

The operation of the citizen's convenience center is as follows:

The convenience center is set up with up to eight 40 yard roll-off containers for the collection of MSW (small loads) and recyclables. The County currently typically separately collects aluminum cans, newspaper, cardboard, mixed no. 1 and no. 2 plastics, and brown, green, and clear glass. The convenience center also includes collection facilities for white goods, used tires, waste oil, and batteries.

The white goods area currently occupies approximately a 50 foot by 100 foot area. County personnel remove the Freon, as necessary, and load the white goods into three to four 40 yard roll-off containers. Typically, every Wednesday, the County hauls the full containers to a local salvage yard, where the white goods can be recycled.

Used tires are collected at the convenience center in up to three tire trailers. Once one or more trailers are full, the used tires are taken to a tire recycler for recycling.

A full time attendant looks over both the convenience center and yard waste processing area operations.

# SECTION 3.0
# ENVIRONMENTAL MANAGEMENT

## 3.1 OVERVIEW

This section reviews the overall environmental management tasks required for the successful operation of the landfill facility. Emphasis is given to the supplemental tasks required for the lined landfill units.

## 3.2 SURFACE WATER CONTROL

As used herein, the definition of "surface water" is water which results from precipitation or site run-on that has not contacted the waste.

Proper control of surface water at the landfill will accomplish the following goals:

- Prevent the run-on of surface water into the lined landfill unit(s) or the active face(s);
- Prevent the run-off of surface water that has come into contact with the waste (i.e. leachate);
- Limit the erosion caused by surface waters;
- Limit sediments carried off-site by surface waters; and
- Maximize the SEPARATION of SURFACE water from LEACHATE.

Separate erosion and sedimentation control plans have been provided for the various landfill units. These plans describe both short and long term engineered features and practices for preventing erosion and controlling sedimentation at this site. The following is a brief discussion of some of these features and practices, focusing more on the landfill units.

### 3.2.1 Surface Water Run-On Control

The perimeter berms and/or perimeter channels around the landfill unit(s) are designed to prevent the run-on of surface water from adjacent land into the landfill. Additional structures such as diversion berms, channels, down pipes, etc. carry surface water away from the landfill.

### 3.2.2 Active Face Run-Off Control - MSW Landfill Units

Particular care is required to ensure that surface water coming from the active face, e.g. having potential contact with the waste, is captured by the leachate collection system (LCS). Only run-off from waste surfaces that have received adequate cover is not

considered leachate and should be directed to the stormwater drainage system where practical.

### 3.2.3 Erosion Control

The serviceability of the landfill relies heavily on soil berms, barrier layers, and agricultural layers that are readily eroded by flowing water. Erosion control provisions incorporated in the landfill include the following:

- The slope of the working face must be no steeper than 5H:1V where practical to limit erosion of the daily cover.
- Intermediate cover that has been exposed for more than 30 days must be seeded immediately and repaired when erosion features are identified.
- Drainage breaks (diversion berms, rain gutters, etc.) are provided on the final cover to limit the flow length of run-off.
- Water collected by each drainage break is routed to stormwater drainage channels or down pipes so that the run-off volume does not accumulate going down the slope.
- The vegetative soil layer placed over the final cover must be seeded immediately.

Additional erosion control measures have been taken within the drainage channels and at points of stormwater discharge. All final cover should be inspected regularly for erosion damage and promptly repaired.

### 3.2.4 Sedimentation Control

Stormwater run-off from the landfill unit(s) is conveyed to one of the on site sediment basins and/or traps. These basins and/or traps should be inspected regularly for sediment build-up or erosion damage. The basins and/or traps should be cleaned out when sediments fill the lower half of the basin.

### 3.2.5 Separation of Stormwater/Leachate - Lined (MSW and C&D) Landfill Units

The stormwater separation system is accomplished by dividing the lined landfill units into separate cells to reduce the volume of leachate generated and minimize the impoundment of stormwater within the landfill. The separation system allows stormwater in cells which have not yet received waste to be pumped out of the landfill to perimeter drainage features. During activation of a cell, the Owner will connect the cell to the LCS as discussed in **Section 2.5.3.2**.

## 3.3 LEACHATE MANAGEMENT - LINED (MSW AND C&D) LANDFILL UNITS

The leachate management system for the existing and proposed lined landfill units consists of the LCS, the leachate discharge piping, pumps, valve boxes, valves, and the existing leachate storage lagoon.

Leachate from the lined landfill units is collected in the leachate sumps at the low end(s) of each unit. Leachate collected in each sump is pumped to the leachate storage lagoon via a HDPE force main (except for Phase 5 which drains via a HDPE gravity main). From the storage lagoon, the leachate is pumped via force main to a County-owned wastewater treatment plant (WWTP) or back into the Phase 5 MSW landfill unit as part of an approved leachate recirculation plan (See **Appendix D**). Refer to the appropriate permit application for a detailed discussion and details of the leachate management system for each lined landfill unit.

The County has approval to modify the existing leachate storage lagoon for use as an equalization basin for raw wastewater. These modifications are described in **Section 3.3.6**.

### 3.3.1 Leachate Collection System (LCS)

A blanket drainage layer (either natural and/or geosynthetic drainage media) covers the liner system to collect and remove leachate draining from the waste. In addition, a large flow capacity network of perforated pipe and gravel drains is constructed in the blanket drain. The LCS is designed to remove inflow from a 25-year, 24-hour rainstorm. As such, its capacity is very large compared to that required to accommodate routine leachate generation rates once waste covers the landfill footprint.

The LCS has been designed to minimize the impact of long-term biological clogging as follows:

- Cleanouts are provided on the major perforated leachate collection pipes;
- No geotextiles will be used between the waste and the gravel columns; and
- The use of coarse aggregate around collection pipes (gravel columns) allows hydro-washing of the pipe and aggregate to remove biological growth.

#### 3.3.1.1 Gravel Column Maintenance

The exposed surface of the drainage aggregate should be inspected monthly and after each large rain storm to check for buildup of sediment on the aggregate. Sediment buildup must be periodically removed carefully with a backhoe. Aggregate that is removed must be replaced with new clean material. Per **Section 2.5.3.2**, the Type GT-S geotextile overlying the gravel columns must be removed just prior to the placement of waste over that portion of gravel column.

3.3.1.2 Collection Pipe Cleanout

Remote camera inspection and flushing (if necessary) of all leachate collection piping accessible with a cleanout port will be performed every 3 years or earlier if an abnormal reduction in leachate production is observed. An abnormal reduction is defined as a drop in monthly leachate production of 30% or more as compared to the monthly average over the prior 6 month period and which does not appear to be the result of a reduction in rainfall, the covering of new cell areas, etc. If piping is mostly clean at the initial 3 year inspection, the County may petition the DWM to increase the inspection frequency to 5 year intervals.

The locations of the collection system that have sediment or biological growth buildup will be cleaned using high pressure water jetting equipment. The water jetting system should generate greater than 2,000 psi water pressure. Use of the high pressure water jetting equipment should be limited to only those portions of the piping system with buildup.

3.3.1.3 Leachate Removal

As constructed, leachate is collected in one or more sumps at the low points of the landfill and is removed from the landfill via a side riser pump or through a gravity penetration. The leachate is routed to the leachate storage lagoon via a HDPE force main or gravity main.

Under normal conditions, the County will remove (via forcemain) leachate from the storage lagoon at a rate to maintain a typical volume of 3,500,000 gallons (approximate 6.5 foot depth), or less, of leachate in the lagoon (see also **Section 3.3.6**). This allows ample volume in the lagoon to handle the anticipated "surge" event caused by a design storm and minimizes the potential for ponding within the landfill. Additional draw-down of the lagoon will be performed in advance of predicted heavy rainfall (tropical storm, hurricane, etc.).

3.3.1.4 Operation and Maintenance of Leachate Pumps and Storage Lagoon

Operation and maintenance of leachate pumps shall be in accordance with the appropriate manufacturer's recommendations. If required, the leachate storage lagoon may require cleanout of sediment and/or maintenance of aerators. The County Solid Waste Manager or his designee will be responsible for following and documenting, as required, these activities.

## 3.3.2 Leak Detection System - Phase 4A MSW Landfill Unit

A leak detection system (LDS) is part of the Phase 4A MSW landfill unit. The purpose of the LDS is to provide rapid detection of a major breach in the primary liner system and to limit the head on the secondary liner to less than the thickness of the LDS.

For Phase 4A, the LDS consists of a layer of drainage geocomposite directly overlying the secondary LLDPE geomembrane and a series of four leak detection trenches. Flow that is collected in the leak detection trenches is routed through 4 inch diameter HDPE piping to a pump station. The LDS pump station consists of a prefabricated HDPE manhole, valving, and submersible pumps. Leachate collected in the LDS pump station is pumped to the existing leachate storage lagoon via the same force main as leachate collected in the LCS described above.

The LDS has been designed with an Action Leakage Rate (ALR) of 3,000 gallons per day. Should leakage collected in the LDS exceed the ALR based on routine flowmeter readings from the LDS pump station, the County will take steps (placement of soil cover, tarps, etc.) to limit leachate generation from in-place waste.

### 3.3.3 Leachate Quality Sampling

Semi-annual leachate quality sampling and analysis will be performed during operation of the lined landfill units. Samples will be recovered as grab samples from the following locations:

- MSW Phase 5: Sample from existing gravity line in leachate manhole;
- MSW Phase 4A (Leachate Collection System): Sample from side risers;
- MSW Phase 4A (Leak Detection System): Sample from leak detection pump station; and
- C&D Area 2: Sample from side risers.

The parameters to be analyzed will include BOD, COD, temperature, conductivity, pH, ammonia, suspended solids, Appendix I constituents, sulfates, and nitrates.

### 3.3.4 Record Keeping

Accurate records for the following will be maintained at the landfill in accordance with **Section 1.11**.

Leachate Generation (Monthly):

- Phase 5 (Leachate storage lagoon pump station flowmeters minus flow from Phase 4A);
- Phase 4A (Leachate collection system flowmeter); and
- Phase 4A (Leak detection system pump station flowmeter).

Leachate Quality (Quarterly and/or Semi-Annual):

- Phase 5 (Quarterly during active leachate recirculation);
- Phase 4A (Leachate Collection System); and
- Phase 4A (Leak Detection System).

### 3.3.5 Leachate Contingency Plan

In the unlikely event that leachate levels within the existing leachate storage lagoon approach the freeboard capacity, due to unforeseen events, the DWM will be verbally notified (see **Section 1.2.2**) and the leachate flow will be valved off and temporarily stored in the landfill until the level of leachate in the lagoon can be lowered by direct pumping. Written documentation describing the unforeseen events, the actions carried out to remove the stored leachate, and a strategy for preventing future occurrences will be provided to the DWM within 30 days following any such occurrence.

### 3.3.6 Modification of Leachate Pond as an Equalization Basin

The existing leachate storage lagoon (pond) has an approximate capacity of 4.2M gallons with 2 feet of freeboard. Due to the large size of the pond and typical leachate generation at the site (between 1.26M and 3.05M gallons per year based on 2004 and 2005 data), the capacity of this pond has been very much underutilized. The County received approval in October 2008 to modify the existing leachate storage lagoon for use as an equalization basin for raw wastewater. Most of the proposed modifications will be on the southwest side of the existing leachate pond.

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 will be connected to the pond, the ability to handle leachate generation at the site is very high.

The modified capacity and/or operation of the leachate pond 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.).

## 3.4 WATER QUALITY MONITORING

The monitoring program and procedures outlined in the current Water Quality Monitoring Plan will be followed for the monitoring of site groundwater monitoring wells and surface water monitoring locations. The results of the water quality monitoring program will be placed in the facility operating record as described in **Section 1.11**.

## 3.5 LANDFILL GAS (LFG) MANAGEMENT - MSW LANDFILL UNITS

A landfill gas (LFG) management system is included as part of the design of the MSW landfill units. Refer to the appropriate permit application for a detailed discussion and details of the LFG management system for each landfill unit.

### 3.5.1 Methane Monitoring Program

The County will implement a routine methane monitoring program to ensure that methane concentrations do not exceed 25 percent of the lower explosive limit (LEL) in facility structures, or 100 percent of the LEL at property boundaries. Gas monitoring wells will be sampled on a quarterly basis. Monitoring of facility structures will be performed continually.

### 3.5.2 Record Keeping

Results of the methane monitoring program will be placed in the facility operating record as described in **Section 1.11**.

### 3.5.3 LFG Contingency Plan

In the event methane concentrations exceed allowable limits, the emergency response plan will be as follows:

Open Air Areas

1. For 100% LEL at distances less than 250 feet from structures:

    a. Recalibrate equipment and recheck reading.
    b. Immediately take all necessary steps to ensure protection of human health (i.e. remove sources of ignition and limit access to the area).
    c. Call Fire Department.
    d. Notify the DWM (see **Section 1.2.2**).
    e. Notify the Consulting Engineer.
    f. Note the current weather and ground moisture conditions.
    g. Within seven days of detection, place in the operating record the methane gas levels detected and a description of the steps taken to protect human health.
    h. Within 60 days of detection, implement a remediation plan for the methane gas releases, place a copy of the plan in the operating record, and notify the DWM that the plan has been implemented. The plan will describe the nature and extent of the problem and the proposed remedy.

2. For 100% LEL at distances greater than 250 feet from structures:

    a. Recalibrate equipment and recheck reading.
    b. Immediately take all necessary steps to ensure protection of human health (i.e. remove sources of ignition and limit access to the area).
    c. Notify the DWM.
    d. Notify the Consulting Engineer.
    e. Note the current weather and ground moisture conditions.

Structures

1. For structures with greater than 25% LEL:

   a. Recalibrate equipment and recheck reading.
   b. Immediately take all necessary steps to ensure protection of human health as above - including immediate evacuation leaving all doors open.
   c. Call Fire Department.
   d. Notify the DWM.
   e. Notify the Consulting Engineer.
   f. Note the current weather and ground moisture conditions.
   g. Within seven days of detection, place in the operating record the methane gas levels detected and a description of the steps taken to protect human health.
   h. Within 60 days of detection, implement a remediation plan for the methane gas releases, place a copy of the plan in the operating record, and notify the DWM that the plan has been implemented. The plan will describe the nature and extent of the problem and the proposed remedy.

2. For structures with 0-25% LEL:

   a. Recalibrate equipment and recheck reading.
   b. Discuss with the Consulting Engineer.

## 3.6 LANDFILL GAS (LFG) MANAGEMENT - C&D LANDFILL UNITS

Due to the nature of the waste disposed in the C&D landfill units, landfill gas control is not anticipated to be of concern. As such, the only LFG management devices are those associated with underlying MSW waste. Refer to the appropriate permit application for a detailed discussion and details of the LFG management system for each landfill unit.

## 3.7 VECTOR CONTROL

### 3.7.1 MSW Landfill Units

Control of insects, rodents, and birds will be accomplished by compaction of the waste and the use of daily cover. Spilled or wind-blown debris along the access road will be cleaned up daily and placed in the landfill. If vector control becomes a problem, additional measures will be taken to ensure the protection of human health.

### 3.7.2 C&D Landfill Units

Due to the nature of the waste disposed in the C&D landfill units, vector control is not anticipated to be of concern. Note that the use of periodic cover will discourage animals

from nesting in the waste.

## 3.8 ODOR CONTROL

### 3.8.1 MSW Landfill Units

Odorous or potentially odorous materials will be covered as soon as possible to avoid odor problems. If odor control becomes a problem, additional measures will be taken to ensure odor control.

### 3.8.2 C&D Landfill Units

Due to the nature of the waste disposed in the C&D landfill units, odor control is not anticipated to be of concern.

## 3.9 DUST CONTROL

Dust related to waste hauler traffic on the access roads will be minimized by using a water truck to limit dust on the gravel portion of the road. Dust generated by excavation of cover soil will be limited by watering the cut soil areas if accessible to the water truck.

## 3.10 IRRIGATION OF RECLAIMED WASTEWATER

The County is approved to spray irrigate reclaimed wastewater at the landfill. The operation of the spray irrigation system will be as described in **Appendix E**. The operation of the system will also follow the requirements of the current permit issued by the NC Division of Water Quality.

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| PROPERTY REFERENCES | |
|---|---|
| PROPERTY | COUNTY DEED BOOK REFERENCE(S) |
| 1 | D.B. 775, PG. 410 |
| 2 | D.B. 952, PG. 376 |
| 3 | D.B. 763, PG. 525 |
| 4 | D.B. 1228, PG. 652 |
| 5 | D.B. 1215, PG. 747 |
| 6 | D.B. E-3, PG. 1 |

NOTE:
PROPERTY INFORMATION FROM "MAP FOR JOHNSTON COUNTY" PREPARED BY L. DENNIS LEE, P.A., SMITHFIELD, NC, DATED MARCH 22, 1994, AS REVISED THROUGH JANUARY 30, 1995 (COUNTY PLAT BOOK 59, PAGE A37) AND COUNTY REGISTER OF DEEDS OFFICE.

SEDIMENT BASIN NO. 6
3"Ø HDPE LEACHATE FORCE MAIN
SEDIMENT BASIN NO. 4
BORROW AREA E (ACTIVE)
JOHNSTON COUNTY
(D.B. 2109, PG. 509)
NC DOT BORROW AREA
(D.B. 862, PG. 667)
JOHNSTON COUNTY
(D.B. E-3, PG. 1)
C&D AREA 2 CELL 1 (ACTIVE)
MSW PHASE 3 (CLOSED)
CELL 2 (FUTURE)
WASTE LIMITS (APPROXIMATE) (TYP.)
YARD WASTE PROCESSING AREA
MSW PHASES 1 & 2 (CLOSED)
LANDFILL MAINTENANCE BUILDING
MSW PHASE 4A-CELLS 1 & 2 (ACTIVE)
SEDIMENT BASIN NO. 3
COUNTY LIVESTOCK ARENA
SEDIMENT BASIN NO. 5A
CELL 3 (PROPOSED)
COUNTY BULK RECLAIMED WATER TRANSFER STATION
C&D AREA 1 (INACTIVE)
WHITE GOODS AND SCRAP METAL AREA
STATE OF NC
MSW PHASE 4 (CLOSED)
CONVENIENCE CENTER (MSW, RECYCLABLES, WASTE OIL)
COUNTY HOME ROAD
3"Ø HDPE LEACHATE FORCE MAIN (x2)
SCALEHOUSE & SCALES
LANDFILL OFFICE
MSW PHASE 10 (FUTURE)
8"Ø HDPE LEACHATE GRAVITY MAIN
MSW PHASE 5 (INACTIVE)
USED TIRES AND BATTERY STORAGE AREA
3"Ø HDPE LEACHATE RECIRCULATION FORCE MAIN
PROPERTY LINE (FACILITY BOUNDARY)
MSW PHASE 8 (FUTURE)
MSW PHASE 9 (FUTURE)
MSW PHASE 6 (FUTURE)
LEACHATE STORAGE LAGOON
MSW PHASE 7 (FUTURE)

MW-5A, MW-20, MW-19D, MW-19, PZ-9, PZ-9D, MW-21, PZ-10, MW-4D, MW-4B, MW-6, MW-12D, PZ-3, MW-7B, MW-7, MW-14D, MW-7D, MW-15D, MW-17, MW-16D, MW-8A, MW-16S, MW-18, MW-3, MW-5-10, MW-5-9, MW-5-1, MW-9C, MW-9D, MW-5-7, MW-5-8, MW-10, MW-5-6, MW-5-2, MW-5-3, MW-5-5, MW-5-4, LL-2, LL-1, LL-3, LL-4

1 2 3 4 5 6

LEGEND

- 200 — EXISTING 10' CONTOUR (SEE REFERENCE 1)
- EXISTING 2' CONTOUR
- PROPERTY LINE (FACILITY BOUNDARY)
- PROPERTY LINE (OTHER)
- PARCEL BOUNDARY (APPROXIMATE)
- LIMIT OF LINER (EXISTING LINED UNITS)
- APPROXIMATE EXISTING WASTE LIMITS (UNLINED UNITS)
- FUTURE LANDFILL AREAS
- MW-8D EXISTING MONITORING WELL
- PZ-4 EXISTING PIEZOMETER
- 5 PROPERTY IDENTIFIER (SEE TABLE)

REFERENCES

1. OVERALL SITE TOPOGRAPHY PROVIDED BY GEODATA CORPORATION, BASED ON MARCH 8, 2001 AERIAL PHOTOGRAPHY. TOPOGRAPHY IN LANDFILL AREA PROVIDED BY GEODATA CORPORATION BASED ON JUNE 6, 2008 AERIAL PHOTOGRAPHY. TOPOGRAPHY IN BORROW AREAS PROVIDED BY GEODATA CORPORATION BASED ON MAY 20, 2007 AERIAL PHOTOGRAPHY.

0 300' 600' 900'

E 2173000 E 2172500 E 2172000 E 2171500 E 2171000 E 2170500 E 2170000 E 2169500 E 2169000 E 2168500 E 2168000 E 2167500 E 2167000

N 648000 N 647500 N 647000 N 646500 N 646000 N 645500 N 645000 N 644500 N 644000 N 643500 N 643000 N 642500 N 642000 N 641500 N 641000 N 640500

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


RICHARDSON SMITH GARDNER & ASSOCIATES
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www.rsgengineers.com


SEAL

SEAL

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

DRAWING TITLE:
EXISTING AND PROPOSED LANDFILL UNITS AND SOLID WASTE MANAGEMENT ACTIVITIES

| | |
|---|---|
| DESIGNED BY: P.K.S. | DRAWN BY: C.T.J. |
| CHECKED BY: | PROJECT NO.: JOHN 07-2 |
| SCALE: AS SHOWN | DATE: JUNE 2007 |
| FILE NAME: JOHN-D0510A | |
| SHEET NO.: FIG. 1 | DRAWING NO. |

G:\CAD\Johnston\John 07-2\rev 102108\Sheets\JOHN-D0510A.dwg - 12/4/2008 1:14 PM

# Appendix A

## EPA Method 9095

## Paint Filter Liquids Test

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**METHOD 9095**
**PAINT FILTER LIQUIDS TEST**
**From EPA SW-846**

## 1.0 SCOPE AND APPLICATION

1.1 This method is used to determine the presence of free liquids in a representative sample of waste.

1.2 The method is used to determine compliance with 40 CFR 264.314 and 265.314.

## 2.0 SUMMARY OF METHOD

2.1 A predetermined amount of material is placed in a paint filter. If any portion of the material passes through and drops from the filter within the 5 minute test period, the material is deemed to contain free liquids.

## 3.0 INTERFERENCES

3.1 Filter media were observed to separate from the filter cone on exposure to alkaline materials. This development causes no problem if the sample is not disturbed.

## 4.0 APPARATUS AND MATERIALS

4.1 Conical paint filter: Mesh number 60 (fine meshed size). Available at local paint stores such as Sherwin-Williams and Glidden for an approximate cost of $0.07 each.

4.2 Glass funnel: If the paint filter, with the waste, cannot sustain its weight on the ring stand, then a fluted glass funnel or glass funnel with a mouth large enough to allow at least 1 inch of the filter mesh to protrude should be used to support the filter. The funnel is to be fluted or have a large open mouth in order to support the paint filter yet not interfere with the movement, to the graduated cylinder, of the liquid that passes through the filter mesh.

4.3 Ring stand and ring or tripod.

4.4 Graduated cylinder or beaker: 100-mL.

## 5.0 REAGENTS

5.1 None.

## 6.0 SAMPLE COLLECTION, PRESERVATION, AND HANDLING

6.1 All samples must be collected according to the directions in Chapter Nine of EPA SW-846.

6.2 A 100 mL or 100 g representative sample is required for the test. If it is not possible to obtain a sample of 100 mL or 100 g that is sufficiently representative of the waste, the analyst may use larger size samples in multiples of 100 mL or 100 g, i.e., 200, 300, 400 mL or g. However, when larger samples are used, analysts shall divide the sample into 100-mL or 100-g portions and test each portion separately. If any portion contains free liquids, the entire sample is considered to have free liquids.

## 7.0 PROCEDURE

7.1 Assemble test apparatus as shown in Figure 1.

7.2 Place sample in the filter. A funnel may be used to provide support for the paint filter.

7.3 Allow sample to drain for 5 minutes into the graduated cylinder.

7.4 If any portion of the test material collects in the graduated cylinder in the 5-min. period, then the material is deemed to contain free liquids for purposes of 40 CFR 264.314 and 265.314.

## 8.0 QUALITY CONTROL

8.1 Duplicate samples should be analyzed on a routine basis.

## 9.0 METHOD PERFORMANCE

9.1 No data provided.

## 10.0 REFERENCES

10.1 None required.

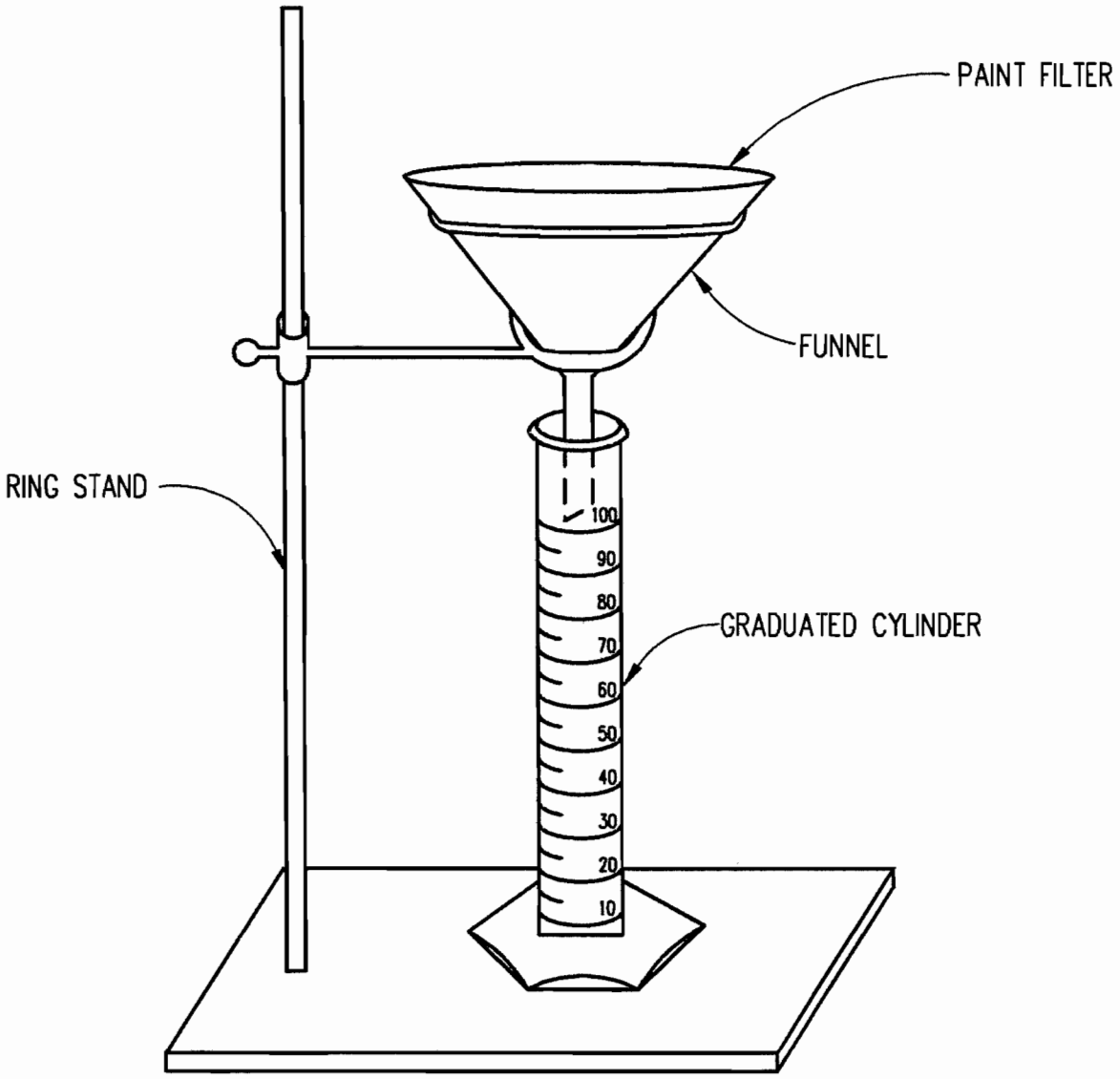
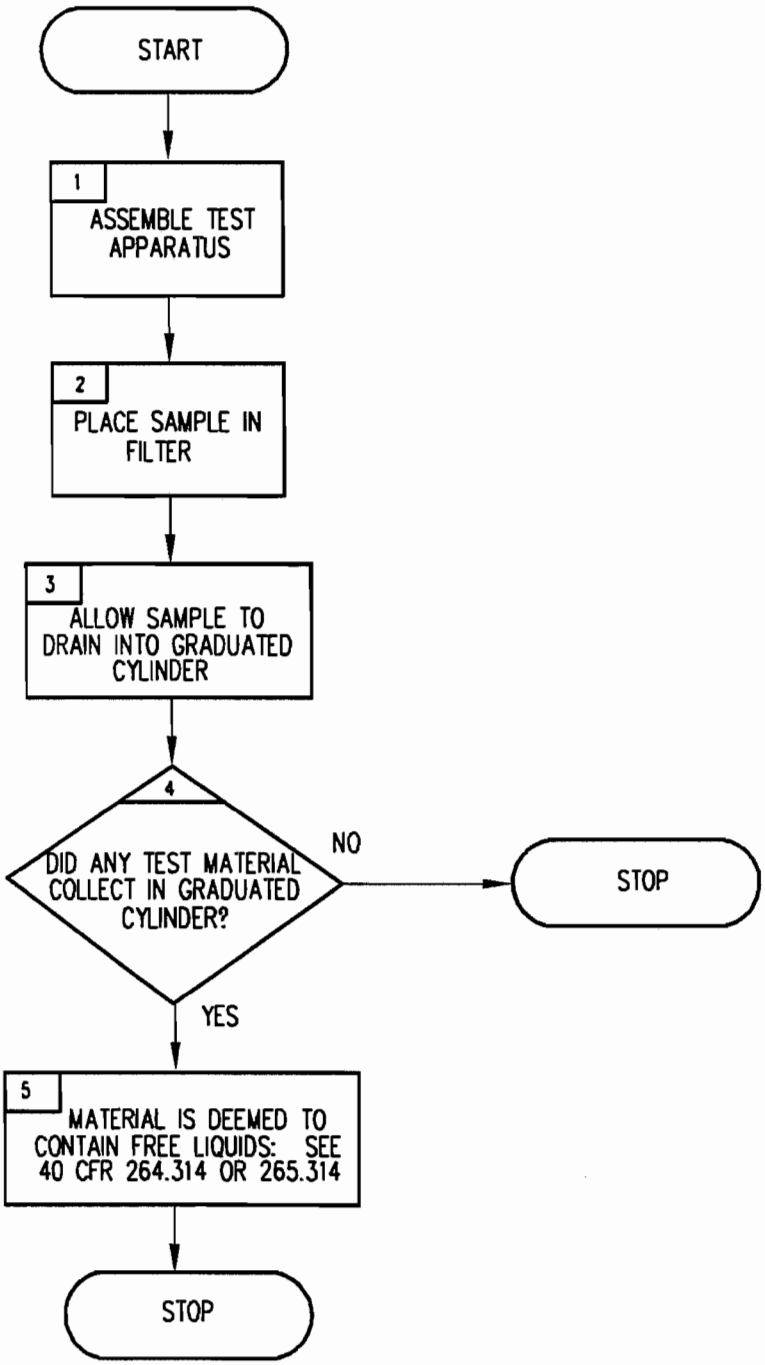



FIGURE 1. PAINT FILTER TEST APPARATUS.

# METHOD 9095
# PAINT FILTER LIQUIDS TEST



# Appendix B

# Waste Screening Form

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Johnston County Department of Public Utilities
Johnston County Landfill Facility
Permit No. 51-03
(919) 938-4750

# WASTE SCREENING FORM

Day / Date: _____ Time Weighed in: _____
Truck Owner: _____ Driver Name: _____
Truck Type: _____ Vehicle ID / Tag No: _____
Weight _____ Tare: _____
Waste Generator / Source: _____

---

Reason Load Inspected: Random Inspection _____ Staff Initials _____
Detained at Scales _____ Staff Initials _____
Detained by Operating Staff _____ Staff Initials _____

Inspection Location: _____

Approved Waste Determination Form Present? Yes _____ No _____ N/A _____

Description of Load: _____

Load Accepted (signature) _____ Date _____
Load Not Accepted (signature) _____ Date _____

---

Reason Load Not Accepted (complete only if load not accepted)

Description of Suspicious Contents: Color _____ Haz. Waste Markings _____
Texture _____
Drums Present _____ Smell _____
Est. Cu. Yds. Present in Load _____
Est. Tons Present in Load _____

Johnston County Emergency Management Contacted? Yes _____ No _____

Company or Authority Contacted? _____
Hazardous Materials Present: _____

Hauler Notified (if waste not accepted) Phone: Time Contacted:
Other Observations: _____

Final Disposition
Signed _____ Date _____
Waste Screening Inspector or Solid Waste Manager

Attach related correspondence to this form.
File completed form in Operating Record.

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# Appendix C

# Cell Activation Forms

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**JOHNSTON COUNTY MSW LANDFILL - PHASE 4A**
**CELL ACTIVATION FORM**

Date: _____

Cell: _____

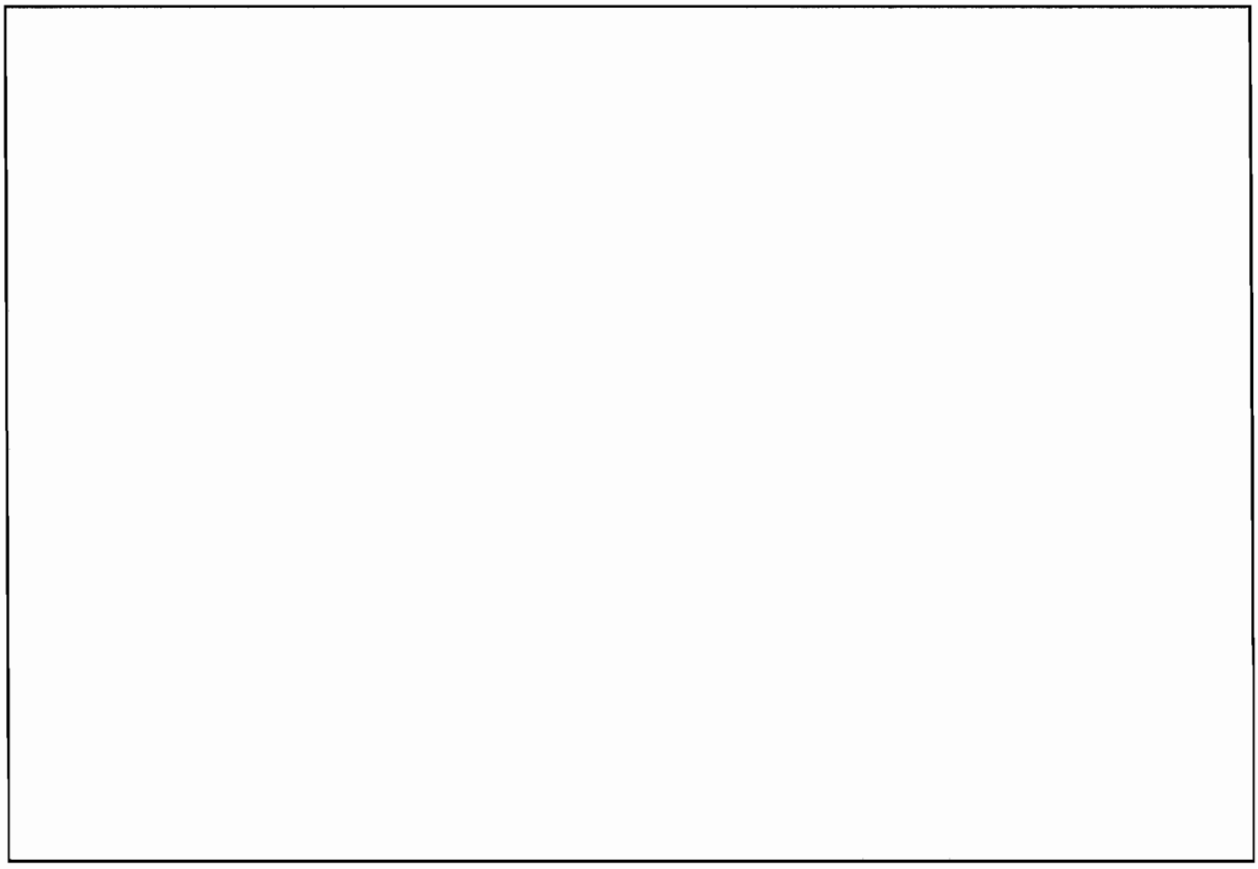
Size of Geosynthetic Rain Cover Removed (Length/Width): _____

Length of Type GT-S Geotextile Removed from Gravel Column(s): _____

Remarks: _____
_____
_____
_____
_____
_____
_____

Signed: _____

Sketch:



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**JOHNSTON COUNTY C&D LANDFILL - AREA 2**
**CELL ACTIVATION FORM**

Date: _____

Cell: _____

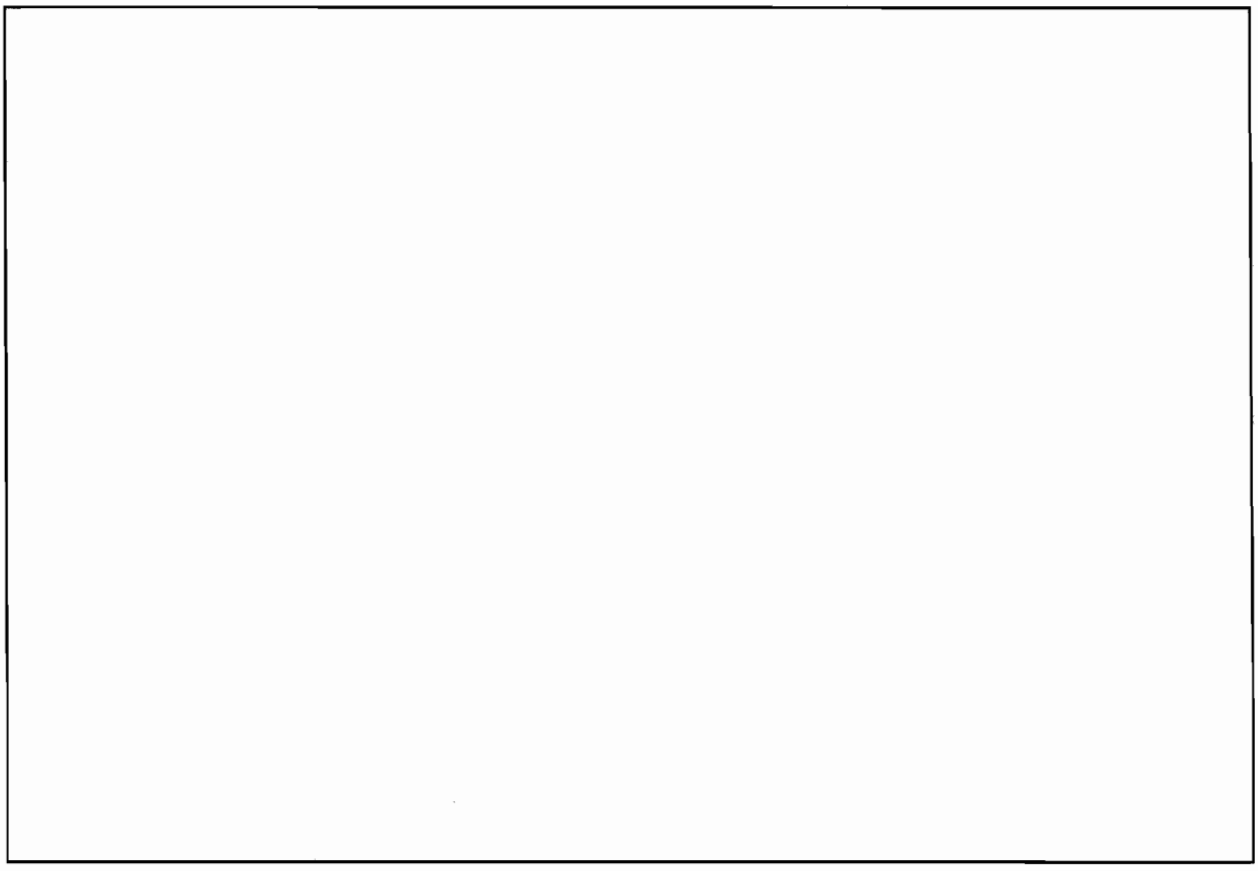
Size of Geosynthetic Rain Cover Removed (Length/Width): _____

Length of Type GT-S Geotextile Removed from Gravel Column(s): _____

Remarks: _____
_____
_____
_____
_____
_____
_____

Signed: _____

Sketch:



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# Appendix D

# Leachate Recirculation Plan

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# Operations Manual
# Appendix D: Leachate Recirculation Plan

## Johnston County Landfill Facility
## Smithfield, North Carolina

Prepared for:

**Johnston County Department of Public Utilities**
**Smithfield, NC**

**June 2007**

RICHARDSON SMITH GARDNER & ASSOCIATES
Engineering and Geological Services
14 N. Boylan Avenue
Raleigh, North Carolina 27603

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**JOHNSTON COUNTY**
**JOHNSTON COUNTY LANDFILL FACILITY**

# OPERATIONS MANUAL
# APPENDIX D: LEACHATE RECIRCULATION PLAN

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- Leachate Recirculation Monthly Reporting Form
- Leachate Recirculation Daily Log
- Horizontal Well Installation Log

**PROJECT DRAWINGS** Refer to the approved drawing set entitled "Leachate Recirculation Plan, Permit Drawings, dated February 2001, by G.N. Richardson & Associates, Inc., Raleigh, NC).

# JOHNSTON COUNTY
# JOHNSTON COUNTY LANDFILL FACILITY

## OPERATIONS MANUAL
## APPENDIX D: LEACHATE RECIRCULATION PLAN

## 1.0 OVERVIEW

Water is the most significant factor influencing waste stabilization and leachate quality. Moisture addition has been demonstrated repeatedly to have a stimulating effect on methanogenesis (Barlaz et al, 1990), although some researchers indicate that it is the movement of moisture through the waste as much as it is water addition that is important (Klink and Ham, 1982). Moisture within the landfill serves as a reactant in the hydrolysis reactions, transports nutrients and enzymes, dissolves metabolites, provides pH buffering, dilutes inhibitory compounds, exposes surface area to microbial attack, and controls microbial cell swelling (Noble, et al, 1991). Lu, et at, (1985) stated that high moisture flow rates can flush soluble organics and microbial cells out of the landfill and in such cases microbial activity plays a lesser role in determining leachate quality. Also, high moisture application rates can remove the majority of waste contaminants early in the life of the fill. Under low flow rate conditions, anaerobic microbial activity is the significant factor governing leachate organic strength (McBean et al, 1995). The quantity of moisture is important because it directly affects stabilization rates within the landfill. Sulfita et al, (1992) and Miller, et al, (1994) both noted the important role of moisture in supporting methanogenic fermentation of solid waste when examining samples removed from operating landfills. Relatively dry landfills (i.e. 20-40% water) have very slow stabilization rates because there is only a small quantity of moisture for biological degradation. Recommended moisture content reported in the literature ranges from a minimum of 25 percent (wet basis) to optimum levels of 40 to 70 percent (Barlaz, et al, 1990; Chen and Bowerman, 1974).

Leachate is recirculated in MSW landfills for one or more of the following reasons:

- as an alternative to leachate treatment,
- to promote biodegradation of the waste as detailed above to produce a smaller and more stable waste mass, and
- to accelerate the production of landfill gas (LFG).

Johnston County's plan to recirculate leachate within the Phase 5 area of their Subtitle D landfill is based on a desire to stabilize the waste and associated contaminants prior to placement of the final cover. The County facility is presently equipped with a leachate force main to a County owned and operated wastewater treatment plant (WWTP) so that disposal of leachate is not a concern. As such, this recirculation plan is developed with the goal of maximizing the rate of degradation of the waste and not for the purpose of leachate disposal.

## 2.0 REGULATORY REQUIREMENTS

The recirculation of leachate within lined MSW landfills is provided for in Federal RCRA Subtitle D regulations and not prohibited in North Carolina regulations. It is anticipated that design and operational requirements for recirculation will evolve from guidance provided by the Solid Waste Section of the North Carolina Division of Waste Management (DWM).

### 2.1 40 CFR 258 RCRA Subtitle D

Federal regulations provide both specific and implied requirements that must be met by landfills recirculating leachate. Relevant sections of the Federal regulations are as follows:

*§258.28 (a):* Bulk or non-containerized liquid waste may not be placed in the MSWLF units unless: (1) The waste is household waste other than septic waste; or (2) The waste is leachate or gas condensate from the MSWLF unit and the MSWLF unit, whether it is a new or existing MSWLF, or lateral expansion, is designed with a composite liner and leachate collection system as described in §258.40(a)(2) of this part...

*§258.40(a)(2):* With a composite liner, as defined in paragraph (b) of this section and a leachate collection system that is designed and constructed to maintain less than a 30-cm depth of leachate over the liner. (b) For purposes of this section, *composite liner* means a system consisting of two components: the upper component must consist of a minimum 30-mil flexible membrane liner (FML), and the lower component must consist of at least a two-foot layer of compacted soil with a hydraulic conductivity of no more than $1x10^{-7}$ cm/sec...

### 2.2 North Carolina Rule NCAC T15A: 13B.1600

North Carolina regulations mirror the above referenced Federal regulations in Rule .1624(b)(1) related to design and construction, Rule .1624(b)(2)(A) related to maximum head, and Rule .1626(9)(a)(ii) related to recirculation of leachate. Currently, however, implementation of leachate recirculation is administered using policy established in DWM guidance for leachate recirculation. This guidance establishes basic elements that must be incorporated into a leachate recirculation plan prior to implementation of a 120-day trial period and eventual long-term operation. Key elements of this guidance are listed on **Table 1** along with the location in this manual where the element is addressed.

## 3.0 FACILITY LIQUIDS CONTROL - ENGINEERED PERFORMANCE

Significant engineering effort has been expended to ensure that the maximum head acting on the liner system during routine recirculation does not exceed 30 cm and that the recirculation system itself does not adversely affect the integrity or stability of the landfill. This section provides a general description of these systems and the technical evaluation performed to ensure adequate performance.

## 3.1 Leachate Recirculation System

The leachate recirculation system uses a network of horizontal porous galleries to both inject leachate into the waste and to vent landfill gas (LFG) generated by the degradation of the waste. The galleries are designed to minimize leachate short circuiting of the waste and the potential for landfill fires in the LFG collection system. Each gallery consists of a family of parallel trench drains that are individually fitted with a leachate injection pipe. The **Project Drawings** show the general geometry and placement of the injection/LFG galleries and details for their construction. The galleries are placed at an approximate 30 foot vertical spacing and a maximum 80 foot horizontal spacing. Each successive vertical gallery is staggered to provide for more uniform leachate distribution and gas collection. The porous LFG collection and leachate distribution media can be constructed using gravel, tire chips, or other relatively inert media having a permeability greater than $1 \times 10^{-2}$ cm/sec. The leachate injection and LFG collection pipes are high density polyethylene (HDPE) fusion welded pipe having a maximum SDR of 11. Leachate is injected under a minimum 10 psi pressure through a series of 1/8 inch holes spaced 10 feet apart. Field tests by GNRA have confirmed that this hole size and spacing allows for a very uniform release of leachate from each hole for pipe lengths up to 800 feet in length. For this project, lengths were designed up to $\pm$400 feet in length. Installation details for each injection/LFG gallery are recorded using the form provided in **Appendix D1**.

Significant settlement of the waste is anticipated during the service life of the recirculation system. HDPE was selected for use in the injection/LFG pipes due to both its chemical resistance and its low coefficient of friction which minimizes potential tensile forces caused by differential settlement of the waste. The selected SDR of the pipes is based on anticipated maximum tensile forces related to differential settlement and not the stresses generated by the leachate pressure.

## 3.2 Leachate Collection System (LCS)

The leachate collection system (LCS) for Phase 5 was modified by the County as follows. The modification consisted of removal of 12 inches of sand and a geotextile that had originally been placed between the primary leachate collection pipes and the waste. This material was replaced with a NC DOT #57 stone that provides a significant increase in the transmissivity of the pipe/stone drain and resistance to bioclogging of the drain. This conversion of the primary collection pipe system is performed just in advance of the placement of waste immediately on the #57 stone to ensure that the stone remains free of fines from the protective cover.

The HELP (v. 3.07) Model was used to evaluate the impact of leachate recirculation on the head acting on the composite liner system. This analysis indicates that the average head acting on the liner system is less than 12 inches when a minimum of 30 feet of waste is in place prior to initiating recirculation. The short-term HELP evaluations are conservative in that only a single 30 foot lift of waste is modeled for a 5 year period. As the height of waste is increased, the storage capacity within the waste increases and the

resulting head on the liner system decreases. For example, modeling a 60 foot layer of waste under intermediate cover reduces the short term head from 10.2 inches to 5.4 inches.

## 4.0 FACILITY EQUIPMENT AND OPERATING PRACTICES

Leachate recirculation must be performed in a manner that does not create odor or stability problems and produces heads on the liner system less than 30 cm. Odor problems are minimized in the proposed system by the use of leachate injection galleries such that raw leachate is not applied to the surface of the waste. The permanent system for injection of leachate is shown in the **Project Drawings** and requires operational steps as follows:

- Leachate to be recirculated is collected in the existing leachate pump station located adjacent to the existing leachate storage lagoon.

- Leachate is pumped from the pump station to the injection galleries using a submersible high-head pump capable of maintaining a minimum 10 psi pressure at the inlet of the injection gallery. Each injection gallery is provided with a positive on-off ball valve as shown in the **Project Drawings**.

- Leachate is pumped into individual injection galleries in metered ±6,000 gallon slugs designed to prevent localized saturation of the waste and stability problems. Injection is sequenced between the galleries and recorded using the form provided in **Appendix D1**.

- A backup system can be provided using a water truck that receives leachate from the leachate lagoon and then transports it back to the top of Phase 5 and injects it directly from the truck to one of the injection galleries. This system may be utilized in the event of a shutdown of the recirculation pump.

The general recirculation philosophy is to avoid visible discharge of leachate, e.g., spraying into the air by truck, sprinklers, or hoses, to minimize the potential for odor problems and excessive discharge in one zone of waste to minimize stability and seep related problems. This section discusses the facility hardware and operational procedures employed to successfully recirculate leachate to the waste.

### 4.1 Leachate Injection Gallery

Each injection gallery extends horizontally from the face of the final cover into the waste a distance of no more than about 400 (±10%) feet in length. Each injection gallery consists of a granular windrow or trench drain containing a HDPE leachate injection pipe. The details of this system are discussed in **Section 3.1**. Each leachate injection gallery pipe is fitted at its exposed end with a positive on-off valve connected to the supply line. A check valve and cleanout are also provided for each injection gallery pipe.

The injection pipe diameter and pressure are selected to ensure that leachate flow velocities are sufficient to prevent fouling of the injection pipe and the perforations. It is not anticipated that the leachate injection pipes will require servicing during their estimated 5-8 year service life. The granular drain surrounding the injection pipe is designed to both allow a more uniform distribution of the leachate and for the collection of LFG within the waste. The size and permeability of the granular trench drain is based on the desire to maintain internal LFG pressures less than 6-inches $H_2O$ (0.22 psi). All injection gallery installation details will be recorded using the form provided in **Appendix D1**.

### 4.2 Leachate Injection Equipment

One submersible pump will be provided in the existing pump station for recirculating leachate. This pump is rated for a flow of 50 gpm at a head of 210 feet. This pump was selected to provide the required minimum inlet pressure to the leachate injection gallery of 10 psi and approximately 2 hours pumping time to inject 6,000 gallons of leachate. The injection pump is equipped with on-off controls within the pump station.

### 4.3 Leachate Amendment

With time it is anticipated that the leachate draining from Phase 5 will become increasingly acidic. Research by Barlaz (1990) has shown that the rate of waste decomposition actually decreases with increasing acidity. Therefore it may be necessary to buffer the leachate prior to future recirculation. This will be accomplished using a liquid lime injector as needed. Currently there are no plans for leachate amendment other than buffering.

## 5.0 FACILITY MONITORING PRACTICES

The facility must be monitored to ensure that the combination of leachate recirculation and natural precipitation does not produce excessive head on the liner system, side slope seeps, or stability problems. This section reviews a monitoring system to be installed at Phase 5 to monitor both weather and leachate quantities.

### 5.1 Weather Monitoring

Daily weather monitoring will be obtained using a rain gauge and tell-tale equipped thermometer located at the landfill office. Daily readings would be obtained for the maximum temperature, total rainfall, and general weather conditions. This information would be recorded on the form provided in **Appendix D1**. This data allows an accurate evaluation of the water-balance over time within the waste.

### 5.2 Leachate Monitoring

Leachate from Phase 5 gravity drains to the leachate lagoon. The cumulative flow through the gravity drain line will be monitored via flowmeters for all pumps. Calculations commonly performed to determine action leakage rates (ALR) for leak detection systems show that the flow rate will be 130,600 gallons per day when the maximum head acting on the liner is 30 cm. The cumulative flow monitoring will provide verification that the head acting on the liner system is less than 30 cm.

Landfill personnel will pay particular attention to sudden increases in leachate generation during or immediately after recirculation activities. Sudden increases in rate of leachate generation from the facility not accompanied by precipitation indicates that injected leachate is moving through the waste faster than normal. This may imply either saturation of the waste due to over injection of leachate or short circuiting (via voids in the waste) of the waste by a single injection. Both situations require a cessation of injection to the injection gallery in question and a modification of the injection sequence.

## 6.0 REPORTS

The following reports will be prepared:

- Pre-Operational Report;
- 120-Day Trial Period Reporting (Progress and Final Reports); and
- Quarterly Operational Reports.

Reporting forms proposed in this pre-operational report will be revised with experience.

### 6.1 Pre-Operational Report

The pre-operational report provides sufficient information to justify the 120-day trial recirculation period. This Leachate Recirculation Plan is the pre-operational report for the Johnston County Phase 5 leachate recirculation program.

#### 6.1.1 Weather Monitoring

A daily rain gauge and thermometer will be installed at the landfill office to allow daily recording of total rainfall and maximum temperature. This data will be recorded at the end of each working day.

#### 6.1.2 Baseline Leachate Sampling

Baseline leachate quality data for Phase 5 will be provided within the last 30 days prior to the initiation of leachate recirculation. This data will include test results

for BOD, COD, temperature, conductivity, pH, ammonia, suspended solids, metals, and volatiles.

### 6.1.3 Operational Procedures

Johnston County plans on proceeding with the installation of the recirculation pump and force main. Thus, the operational procedures during the 120-day trial recirculation period will be the same as for long-term operations as previously described in **Section 4**.

### 6.1.4 Operational Equipment

The operational equipment during the 120-day trial will include the recirculation pump and force main and a portion of the first level of injection galleries as shown in the **Project Drawings** and installed at a nominal elevation of 30 feet of waste.

### 6.1.5 Record Keeping

Daily readings for rainfall, maximum temperature, quantity of leachate generated/recirculated, and leachate injection galleries used will be maintained using the form provided in **Appendix D1**. This form provides for a week of data and allows comments on the daily weather conditions and unusual operating conditions, e.g., odor or seeps. These data sheets will be provided to the State as part of the technical report submitted to DWM in support of implementation of the long-term leachate recirculation program.

## 6.2 120-Day Trial Period Reporting

### 6.2.1 Progress Report

After a minimum of 60 days, a progress report will be prepared which describes and documents the monitoring activities since initiation of the 120-day trial period, presents observed difficulties and/or operational modifications, and presents leachate quality data. Leachate quality data will include test results for BOD, COD, temperature, conductivity, pH, ammonia, suspended solids, metals, and volatiles.

### 6.2.2 Final Report

At the completion of the 120-day trial period, a final report will be prepared which describes and documents the monitoring activities for the entire trial period, presents observed difficulties and/or operational modifications, and presents leachate quality data. Leachate quality data will include test results for BOD, COD, temperature, conductivity, pH, ammonia, suspended solids, metals, and

volatiles. The most critical aspect of this report is confirmation that the proposed leachate injection sequence results in acceptable performance. Final drawings and specifications for the facility modifications will also be submitted with this report. Based on this report, Johnston County will request approval by DWM to implement the long-term leachate recirculation program.

### 6.3 Quarterly Operational Reports

Quarterly leachate recirculation operational reports will be submitted to DWM after the 120-day trial period. These reports will provide the daily log sheets provided in **Appendix D1**, identify all leachate injection galleries in service, and provide updated leachate quality data.

## 7.0 REFERENCES


1- Barlaz, M.A., R.K. Ham, and D.M. Schaefer, 1990. "Methane Production from Municipal Refuse: A review of Enhancement Techniques and Microbial Dynamics," Critical Reviews in Environmental Control, 19(6): 557.

2- Chen, K.Y. and F.R. Bowerman, 1974. "Mechanisms of Leachate Formation in Sanitary Landfills," in: Recycling and Disposal of Solid Wastes: Industrial, Agricultural, Domestic., Yen, T.F. editor, Ann Arbor, Ann Arbor Science Publication.

3- Klink, R.E. and R.K. Ham, 1982. "Effect of Moisture Movement on Methane Production in Solid Waste Landfill Samples," Resources and Conservation, 8: 29.

4- Lu, J.C.S., et al., editor, 1985. Leachate from Municipal Landfills, Production and Management, Noyes Publisher, Park Ridge, New Jersey.

5- McBean, E.A., F.A. Rovers, and G.J. Farquhar, 1995. Solid Waste Landfill Engineering and Design, Prentice Hall, Englewood Cliffs, NJ.

6- Miller, W.L., T. Townsend, J. Earle, H. Lee, and D.R. Reinhart, 1994. "Leachate Recycle and the Augmentation of Biological Decomposition at Municipal Solid Waste Landfills," Presented at the Second Annual Research Symposium, Florida center for Solid and Hazardous Waste Management, Florida.

7- Noble, J.J. and A.E. Arnold, 1991. "Experimental and Mathematical Modeling of Moisture Transport in Landfills," Chemical Eng. Comm., 100: 95-111.

8- Sulfita, J., C. Gerba, R. Ham, A. Palmisano, W. Rathje, and J. Robinson, 1992. "The World's Largest Landfill," Environmental Science & Technology, 26(8): 1486-1495.

**TABLE 1: NC DWM POLICY ELEMENTS FOR LEACHATE RECIRCULATION**

| Conditions | Policy Element | Section(s) |
|---|---|---|
| Preoperative Conditions | A rain gauge and thermometer shall be placed on the site. | 6.1.1 |
| | A Baseline sampling of leachate shall be performed. | 6.1.2 |
| | An outline of expected operational procedures shall be submitted. | 4.0 |
| | A brief description of the equipment and its' associated specifications shall be submitted. | 4.0 & Specs. |
| | A brief description of record-keeping forms shall be submitted including:<br>• daily/weekly record of leachate generated<br>• daily/weekly record of leachate recirculated<br>• weather conditions and other pertinent daily information<br>• a log for reporting operating or other unusual problems, and their subsequent rectification<br>• any other forms or procedures, etc., that the owner/operator will use. | 5.0/6.0 |
| | An estimation of height of waste in the cell where leachate is anticipated to be applied. | Project Drawings |
| | An analysis of the field capacity of the waste where leachate is to be applied, such that the gallons per unit area does not exceed the field capacity of the waste volume. | 3.2 |
| Operating Conditions | Records shall be kept or a daily/weekly basis as outlined. | 6.0 |
| | No leachate shall be applied on less than one lift (10 feet) of waste. | 3.1 |
| | No leachate shall be spray applied or surface circulated when it is raining, or when the waste is too wet. | 4.0 |
| | No run-off or side seepage will be allowed. | 4.0 |
| | Odors will be controlled. | 4.0 |
| | Leachate depth shall be monitored in the manhole to ensure that the head on the liner does not exceed one foot for more than 24 hours. | 5.2 |
| | Leachate will be spray applied or surface circulated during daylight hours only. | N/A |
| | The application system will be properly maintained and documented. | 5.0/6.0 |
| | Subsurface distribution systems will be outlined. | 4.1 |
| | Operation and maintenance of subsurface systems will be proposed. | 4.0 |

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# Appendix D1

# Reporting Forms and Logs

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**JOHNSTON COUNTY MSW LANDFILL - PHASE 5**
**LEACHATE RECIRCULATION**
**120-DAY TRIAL PERIOD MONTHLY REPORTING FORM**

Start Date (Day 1): _____

| Day | Rain (Inch) | Max. Temp. | Leachate Generated | Leachate Recirculated | Injection Galleries Used | Problems/Weather (Use Extra Sheet if Required) |
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**JOHNSTON COUNTY MSW LANDFILL - PHASE 5**
**LEACHATE RECIRCULATION**
**LEACHATE RECIRCULATION MONTHLY REPORTING FORM**

Start Date (Day 1): _____

| Day | Rain (Inch) | Max. Temp. | Leachate Generated | Leachate Recirculated | Injection Galleries Used | Problems/Weather (Use Extra Sheet if Required) |
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**JOHNSTON COUNTY MSW LANDFILL - PHASE 5**
**LEACHATE RECIRCULATION**
**LEACHATE RECIRCULATION DAILY LOG**

Date: _____

| Time | Injection Gallery | Volume Pumped | Remarks |
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**JOHNSTON COUNTY MSW LANDFILL - PHASE 5**
**LEACHATE RECIRCULATION**
**HORIZONTAL WELL INSTALLATION LOG**

Well Number: _____

Date(s) Installed: _____

Length Installed: _____

Elevation: _____

Number of Holes/Spacing: _____

Hole Size: _____

Coordinates:

Point #: _____ X: _____ Y: _____ Z: _____

Point #: _____ X: _____ Y: _____ Z: _____

Point #: _____ X: _____ Y: _____ Z: _____

Remarks: _____
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Installation Sketch:

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# Appendix E

# Irrigation of Reclaimed Wastewater

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# Operations Manual
# Appendix E: Irrigation of Reclaimed Wastewater

## Johnston County Landfill Facility
## Smithfield, North Carolina

Prepared for:
**Johnston County Department of Public Utilities**
**Smithfield, NC**

**June 2007**
**Revised: December 2008**

RICHARDSON SMITH GARDNER & ASSOCIATES
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**JOHNSTON COUNTY**
**JOHNSTON COUNTY LANDFILL FACILITY**

# OPERATIONS MANUAL
# APPENDIX E: IRRIGATION OF RECLAIMED WASTEWATER

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## FIGURES


Figure 1 Landfill Site Irrigation Plan

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**JOHNSTON COUNTY**
**JOHNSTON COUNTY LANDFILL FACILITY**

# OPERATIONS MANUAL
# APPENDIX E: IRRIGATION OF RECLAIMED WASTEWATER

## 1.0 OVERVIEW

This Operations Manual Addendum was prepared for the Johnston County MSW Landfill located off of Highway 210 on County Home Road for the purpose of describing the operation of an irrigation system for reclaimed wastewater. The system is owned and operated by Johnston County.

## 2.0 CONTACT INFORMATION

All correspondence and questions concerning the operation of the reclaimed wastewater irrigation system should be directed to the appropriate County personnel listed below:

Johnston County Department of Public Utilities
309 E. Market Street, P.O. Box 2263
Smithfield, NC 27577
Phone: (919) 209-8333 (Downtown); (919) 938-4750 (Landfill)
Fax: (919) 934-7174 (Downtown); (919) 989-7152 (Landfill)

| | |
|---|---|
| Solid Waste Manager: | Rick Proctor |
| Public Utilities Director: | Tim Broome, P.E. |
| Public Utilities Asst. Director: | Haywood Phthisic |

## 3.0 IRRIGATION SYSTEM OPERATION

### 3.1 Areas to be Irrigated

Areas to be irrigated and order of priority (1 being the highest) include the following:

Priority 1:

- Wooded area behind (south and east of) NC Forest Service building (Field 1) (Not on Solid Waste Permit Site);
- Agricultural fields to the south and west of the landfill office (Field 2) (majority not on Solid Waste Permit Site);
- Area behind (west of) landfill office (Fields 3 & 4 - future Phases 6, 9, and 10); and
- Wooded area south of the leachate storage lagoon (Fields 6, 7, & 8 - future Phases 7 and 8).

Priority 2:

- Closed landfill areas on Phase 1 & 2, 3, 4, and 5 (LF Cap 1 & 2, LF Cap 3, LF Cap 4, and LF Cap 5).

Priority 3:

- Inactive borrow areas (Field 5 - future Phases 6 and 7) (Fields 9, 10, & 11).

In addition to these areas, the County plans to use reclaimed wastewater for the control of dust within the facility and around the County livestock arena (not on Solid Waste Permit Site). **Figure 1** presents the location of the various planned irrigation areas.

## 3.2 Periods of Operation

The irrigation system will be operated during the months of April through October with the exception of Fields 1, 2, and 3. In addition, irrigation will be discontinued on any day that rainfall exceeds 0.2 inches.

For Fields 1, 2, and 3, irrigation will be year-round. A winter cover crop, such as annual rye, will be used as required. No irrigation will take place during freezing temperatures. Equipment will be drained as required to prevent problems due to freezing temperatures.

## 3.3 Irrigation Amounts

Irrigation amounts off the landfills will be in accordance with the agronomic rates determined for the landfill site (based on "wettest" year amounts) in an analysis performed by Robert Evans, Ph.D., P.E. of N.C. State University and entitled "Hydrologic Wastewater Reuse Irrigation Analysis for Johnston County". Irrigation amounts on the landfill final covers will be in accordance with HELP model evaluations performed by Richardson Smith Gardner & Associates, Inc. (formerly G.N. Richardson & Associates, Inc.). A tabulation of amounts to be irrigated is given in **Table 1**. Restrictions to these amounts are as stated herein. Note that based on site monitoring of the irrigation program (see **Section 3.5**), future increases to these amounts may be allowed.

## 3.4 Irrigation Restrictions

### 3.4.1 Monitoring Wells

No irrigation will occur within 100 feet of an actively monitored site monitoring well.

### 3.4.2 Closed Landfill Areas

Irrigation over closed landfill areas shall only take place over closed areas which have at least 2 feet of soil cover or at least 1.5 feet of soil cover and a synthetic barrier.

### 3.4.3 Future Landfill Areas

Irrigation over areas designated as future landfill areas (or areas within 300 feet of future landfill areas) will be discontinued within 2 years before the anticipated start of construction for that area unless it is demonstrated by use of piezometers, monitoring wells, or other method (see **Section 3.5**) that irrigation rates are not creating an artificial rise in groundwater levels. Closed landfill areas, if to be lined over as part of a future landfill area may be irrigated in accordance with **Section 3.4.2**.

### 3.4.4 Borrow Areas

No irrigation will be performed in active borrow areas. Irrigation may be performed in inactive borrow areas as long as the ground surface is prepared to promote vegetation (soil type, nutrients, etc.).

## 3.5 Site Monitoring of Irrigation Program

In order to monitor the effect of the irrigation program both to ground water quality and to the ground water table a monitoring program will be implemented. This program will consist of two elements. One will be the addition of sampling and testing of the treated irrigation water as part of the regular Spring and Fall ground water sampling/testing events already performed as part of site operations. After sampling, the irrigation water will be tested for the same detection monitoring parameters as for the other site samples.

In addition, the second element of the monitoring program will be the installation of piezometers in each future landfill area to be irrigated (i.e. Phases 6-10). At a minimum, one piezometer will be installed roughly in the central portion of the proposed future landfill phase before irrigation can begin over that area. The water elevations in these piezometers will be measured and recorded both during the spring and fall, concurrent with regular site ground water monitoring, and in the mid-summer. These levels will be evaluated in order to determine if there appears to be a rise in ground water elevations due to the irrigation activities. Should ground water elevations be maintained within a couple of feet of initial levels or levels that might otherwise be considered normal considering other factors such as weather, etc., the irrigation amounts for that area may be increased. Likewise, if there appears to be a significant (more than a couple of feet) increase in ground water elevation, which cannot be otherwise explained, irrigation activities in this area will be reduced or suspended. Also, as stated in **Section 3.4.3**, irrigation in future landfill areas will be halted at least two years prior to planned

construction activities in that area.

### 3.6 System Maintenance and Inspections

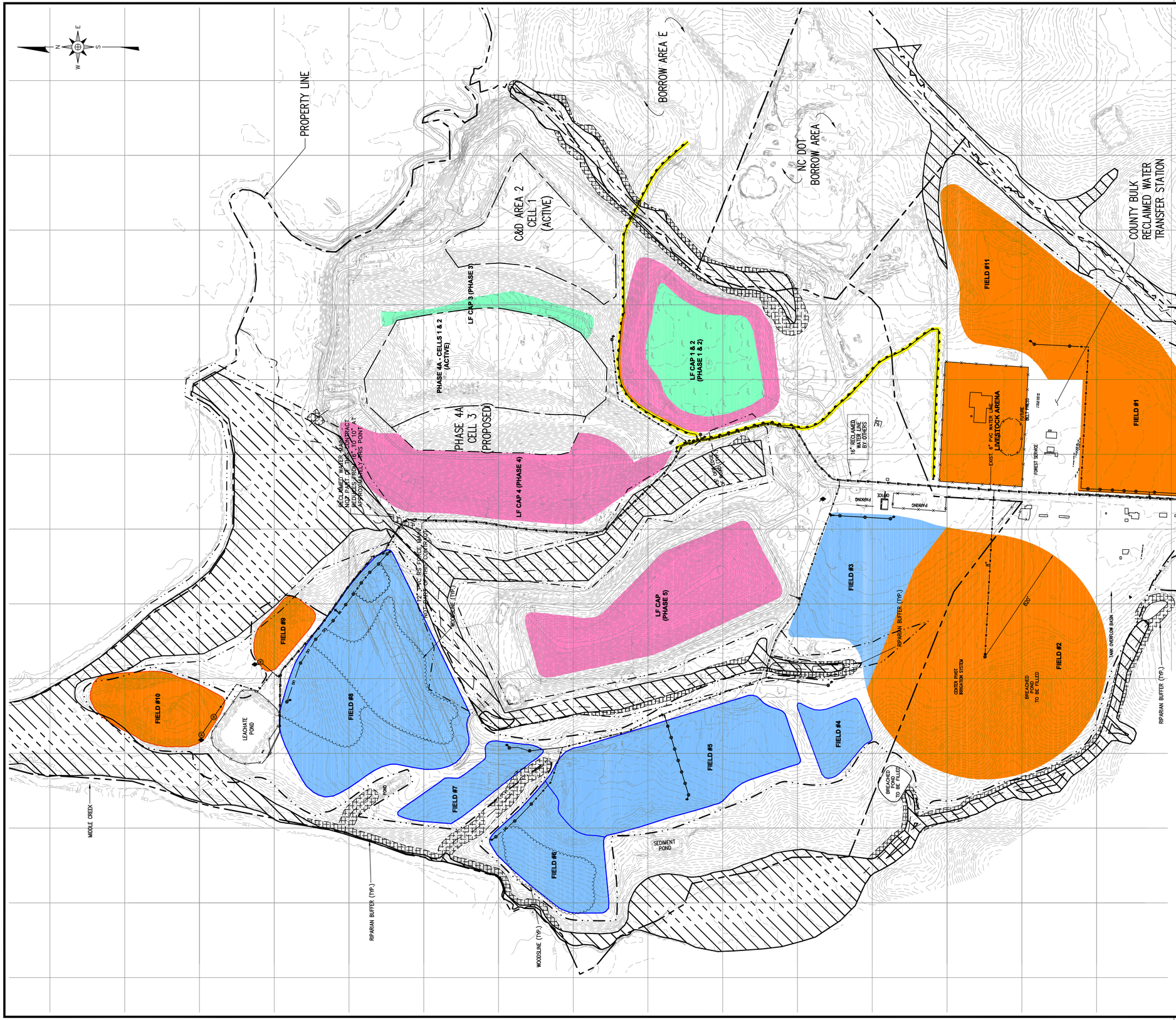
Inspection of the irrigation system during periods of operation will be performed by landfill staff on a weekly basis for the closed landfill areas. Other areas may be inspected less frequently, but not less than once per month. As much of the proposed system will be above ground, inspection for damaged piping, valves, sprinklers, etc. will be done on a mostly visual basis. Should maintenance be required to any portion of the irrigation system, that part of the system will be shut off until adequate repairs are made.

**Table 1: Irrigation Amounts**

| Field | Max. Daily Application Rate cm/day (inch/day) | Annual Application Rate cm/year (inch/year) |
|---|---|---|
| Fields 1 and 2 | 0.60 (0.25) | 70 (28) |
| Fields 3, 4, and 5 | 0.60 (0.25) | 62 (25) |
| Fields 6, 7, and 8 | 0.60 (0.25) | 42 (17) |
| Fields 9 and 10 Livestock Arena | 0.60 (0.25) | 50 (20) |
| Dust Control | 0.60 (0.25) | 45 (18) |
| Field 11 | 0.60 (0.25) | 40 (16) |
| Landfill Final Cover[1] | 0.25 (0.1) | 12 (5) |

Note:

1) At a rate less than that which would cause saturation of the upper 9 inches of soil cover. This will be controlled by the use of soil moisture devices, which will automatically shut off the irrigation system if the upper 9 inches becomes saturated.




## LEGEND

- LF CAP – TOP WITH SYNTHETIC BARRIER
- LF CAP – TOP WITHOUT SYNTHETIC BARRIER – SIDE SLOPE
- IRRIGATION AREA OUTSIDE OF FUTURE LANDFILL AREAS
- IRRIGATION WITHIN FUTURE LANDFILL AREAS (PIEZOMETER REQUIREMENT)
- HAUL ROAD IRRIGATION (DUST CONTROL)
- POTENTIAL WETLANDS
- RIPARIAN BUFFER

## REFERENCES

1. OVERALL SITE TOPOGRAPHY PROVIDED BY GEODATA CORPORATION, BASED ON MAY 21, 2004 AERIAL PHOTOGRAPHY. TOPOGRAPHY IN ACTIVE AREAS BASED ON JUNE 6, 2008 AERIAL PHOTOGRAPHY. TOPOGRAPHY OF PHASE 4 CELL 2 PROVIDED BY 4D SITE SOLUTIONS INC., DATED JUNE 2, 2005. TOPOGRAPHY IN PHASE 5 AREA PROVIDED BY SOUTHWIND SURVEYING AND ENGINEERING, GARNER, NC, DATED JUNE 16, 2003.

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| DATE | NO. | REVISION |
|---|---|---|
| 11/08 | 5 | RESPONSE TO NCDENR COMMENTS AND ADDITIONAL CHANGES |
| 6/07 | 4 | GENERAL UPDATES |
| 2/06 | 3 | REMOVED SIDE SLOPE LFG CAP 3 (PHASE 3) |
| 8/05 | 2 | GENERAL MAP UPDATES |
| 3/04 | 1 | ADDED FIELD 11 AND LF CAP 5 |


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SEAL

SEAL

PROJECT TITLE:
JOHNSTON COUNTY LANDFILL
IRRIGATION OF RECLAIMED
WASTEWATER

DRAWING TITLE:
LANDFILL SITE
IRRIGATION PLAN

| | |
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| DESIGNED BY: P.K.S. | DRAWN BY: J.A.L. |
| CHECKED BY: | PROJECT NO.: JOHN 07-2 |
| SCALE: AS SHOWN | DATE: OCT. 2001 |
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# Closure And Post-Closure Plan

## Johnston County Landfill
## Smithfield, North Carolina

Prepared for:

**Johnston County Department of Public Utilities**
**Smithfield, NC**

**June 2008**
**Revised: December 2008**

RICHARDSON SMITH GARDNER & ASSOCIATES
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# JOHNSTON COUNTY LANDFILL

## CLOSURE AND POST-CLOSURE PLAN

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# SECTION 1.0
# CLOSURE PLAN

## 1.1 OVERVIEW

This plan is intended to serve as a guide for the proposed closure. A formalized Closure Plan for each landfill unit (or incremental portion thereof) will be submitted to the Solid Waste Section of the North Carolina Department of Environment and Natural Resources Division of Waste Management (DWM) for approval prior to beginning closure construction.

## 1.2 MAXIMUM CLOSURE AREA AND WASTE CAPACITY

The following are the estimated areas and capacity for each landfill unit to be closed under this plan.

| Landfill Unit | Closure Area (Acres) | Gross Capacity (CY)[1] | Net (Waste) Capacity (CY/Tons)[1] |
|---|---|---|---|
| **MSW Landfill Units** | | | |
| Phase 4A (Through Cell 3 - Fill Sequence 1) | 29.4 | 2,531,948 | 2,152,156 CY<br>1,383,316 Tons |
| Phase 5 | 19.2 | 1,087,199 | 884,625 CY<br>514,181 Tons |
| Total (MSW): | 48.6 | 3,619,147 | 3,036,781 CY<br>1,897,497 Tons |
| **C&D Units** | | | |
| Area 1 | 12.9<br>(See Note 2) | 614,472 | 515,563 CY<br>304,780 Tons |
| Area 2 (Cell 1) | 11.9 | 410,675 | 353,056 CY<br>212,920 Tons |
| Total (C&D): | 24.8 | 1,027,345 | 868,619 CY<br>517,700 Tons |

Notes:

1. The volume and tonnage figures assumed for each landfill unit are based on the site's Facility Plan. Refer to Section 2.0 (Facility Report) of the Facility and Engineering Plan (**Attachment A**).

2. The Area 1 C&D landfill unit has a total area of 16.2 acres but has a reduced closure area due to the overlying Phase 4A - Cell 3 MSW landfill unit.

## 1.3 FINAL COVER SYSTEM

The final cover system 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. Surface water control devices will also be incorporated into the final cover of each landfill unit and some units will have a landfill gas (LFG) control system. The final cover surface will be vegetated upon completion of the final cover installation according to the project seeding specifications.

Placement of the vegetative soil layer over the cover geosynthetics must be done with care to avoid damage to these materials. This soil layer should be placed from the bottom up using a small dozer equipped with low ground contact pressure (6 psi or less) tracks. A minimum of 12 inches of soil should be maintained between the dozer tracks and the underlying geosynthetics. The soil buffer should receive no compaction other than that provided by the dozer tracks. Pans or other heavy equipment should not operate on the vegetative soil layer.

Refer to the appropriate permit application for a detailed discussion and details related to the design of the final cover system for each landfill unit.

## 1.4 LANDFILL GAS SYSTEM

For the MSW landfill units and C&D landfill units overlying MSW units, a landfill gas system is provided in the final cover design. This system includes a system of collection wells placed within the waste to capture the gas and either passively vent or flare the gas via utility flares or, as required, actively collect and flare the gas via header piping and a blower/flare system. The collection wells should be placed before any geosynthetics are placed.

Refer to the appropriate permit application for a detailed discussion and details related to the design of the landfill gas system for each landfill unit.

## 1.5 SURFACE WATER SYSTEMS

Precipitation falling on the cover will infiltrate into the cover or run off the cover. Short-term the run-off runs down the surface of the intermediate cover. Long-term the run-off is collected in a series of drainage breaks built into the areas covered by final cover. These drainage breaks are provided along side slopes (rain gutters and diversion berms). Water captured by rain gutters or diversion berms is routed toward one of the down pipes. Flow in the down pipes is routed to the base of the landfill and to one of the site sediment basins.

Refer to the appropriate permit application for a detailed discussion and details related to the design of surface water systems for each landfill unit.

### 1.5.1 Incremental Operation

During much of the life of the landfill, surface run-off will be handled by the intermediate cover system. Operations must strive to provide operational grading that encourages run-off from the intermediate cover to drain to the perimeter channels along the perimeter berms or to areas covered by final cover. Corrugated polyethylene (CPE) piping and temporary soil berms must be installed if required to accomplish this run-off routing.

### 1.5.2 Required Maintenance

The surface water systems must be inspected annually and immediately after every major storm. Sediment build-up in the drainage features/devices must be cleaned out on a regular basis to promote run-off. Sediments removed can be used as daily or intermediate cover.

## 1.6 CLOSURE SCHEDULE

In general , closure activities will occur on the following schedule:

MSW Landfill Units (15A NCAC 13B.1627(c)(5)):

- No later that 30 days after the date on which the MSWLF unit receives the known final receipt of wastes; or
- If the MSWLF unit has remaining capacity and there is a reasonable likelihood that the MSWLF unit will receive additional wastes, no later than one year after the most recent receipt of wastes.

C&D Landfill Units (15A NCAC 13B.0543(c)(5)):

- No later that 30 days after the date on which the C&DLF unit receives the known final receipt of wastes;
- No later than 30 days after the date that a 10 acre or greater area of waste, is within in 15 feet of final design grades; or
- No later than one year after the most recent receipt of wastes, if the C&DLF unit has remaining capacity.

All closure activities shall be completed within 180 days. Exemptions and extensions may be approved by the DWM.

For the Area 1 C&D landfill unit, closure will occur in two stages. The first stage will be the construction of the Phase 4A Cell 3 landfill unit in early to mid 2009 which will close the eastern half of Area 1. After construction of Phase 4A Cell 3, the remainder of Area 1 will be closed beginning in fall 2009. Closure of Area 1 is scheduled to be complete by the end of FY 2009-10.

## 1.7 CLOSURE VERIFICATION

The following procedures will be implemented following closure:

- A Construction Quality Assurance (CQA) report will be submitted to the DWM. This report will describe the observations and tests used before, during, and upon completion of construction to ensure that the construction materials meet the final cover design specifications and the construction and certification requirements. The CQA report will contain as-built drawings.

- A signed certification from a registered Professional Engineer verifying that closure has been completed in accordance with the closure plan will be submitted to the DWM.

- At least one sign notifying all persons of the closing of the landfill (or incremental portions thereof) and that wastes are no longer accepted will be posted. Suitable barriers will be installed as necessary at former access points to prevent new waste from being deposited.

- Within 90 days, a survey plat, prepared by a registered Professional Land Surveyor, indicating the location and dimensions of landfill disposal areas, will be prepared.

- A notation will be recorded on the deed notifying any potential purchaser of the property that the land has been used as a landfill facility and that future use is restricted under the approved closure plan. A copy of the deed notation as recorded will be filed with the operating record.

# SECTION 2.0
# POST-CLOSURE PLAN

## 2.1 OVERVIEW

This Post-Closure Plan has been developed to outline steps to be taken to ensure the integrity of the landfill during its post-closure care period. The post-closure care period will last at least 30 years after final closure and, at a minimum, will consist of the following:

- Maintaining the integrity and effectiveness of final cover system;
- Performing groundwater and surface water monitoring;
- Maintaining and operating a gas monitoring system; and
- Maintaining run-on/run-off controls.

No wastes will remain exposed after closure of the landfill. Access to the closed site by the public will not pose a health hazard.

## 2.2 POST-CLOSURE CONTACT

All correspondence and questions concerning the post-closure care of the unit should be directed to:

Johnston County Department of Public Utilities
Attn: Director
309 E. Market Street
Smithfield, NC 27577
Phone: (919) 209-8333
Fax: (919) 934-7174.

## 2.3 POST-CLOSURE USE

After filling operations cease at the landfill and the landfill is officially closed in accordance with the Closure Plan, each landfill unit will be maintained as a grassy hill. Johnston County will maintain control of the property and prevent public access to it during the post-closure period.

There may be (an) access road(s) on the final cover to allow proper maintenance during post-closure. Precise location of the access road(s) will be determined as a part of operations. Low ground pressure and rubber tire vehicles will be used for maintenance.

## 2.4 MAINTENANCE

### 2.4.1 Repair of Security Control Devices

All security control devices will be inspected and maintained as necessary to ensure access to the site is controlled. Locks, vehicular gates, and fencing will be replaced if functioning improperly. Warning signs will be kept legible at all times and will be replaced if damaged by inclement weather or vandalism.

### 2.4.2 Erosion Damage Repair

If erosion of the final cover occurs during post-closure, the affected area will be repaired and reseeded as necessary. If necessary, rolled erosion control products (RECPs) will be used to expedite rapid revegetation of slopes and to secure topsoil in place.

### 2.4.3 Correction of Settlement, Subsidence, and Displacement

Minimum slopes of 5 percent will be maintained after settlement in order to prevent ponding and allow for proper drainage without infiltration. If vertical or horizontal displacement occurs due to differential settlement, cracks will be filled with appropriate material and final cover will be reestablished. Excessive vertical displacement is not anticipated.

### 2.4.4 Leachate Management System (Lined Units)

In order to maintain the free flow in leachate collection piping, they will be cleared of debris using the manholes or cleanout locations for access. If pipes should crush or buckle within the landfill, leachate will flow through the gravel columns. The leachate collection system (LCS) includes a continuous blanket drain on the base of the landfill which will allow drainage of leachate even in the very unlikely event of total failure of the leachate collection pipes.

### 2.4.5 Closure of Leachate Storage Lagoon

After closure of the lined landfill units has been achieved, the generation of leachate will eventually curtail. The flow rate immediately after closure should decrease to approximately 100 gallons/acre/day. Toward the end of the 30-year post-closure period, the flow should approach zero, at which time the storage lagoon will not be required. The following procedures will be followed to properly close the leachate storage lagoon:

- Completely drain and remove all liquids, sludges, sediments, etc. from the storage lagoon.
- Disassemble the lagoon, piping, and appurtenances and dispose of the contents in a manner approved by the DWM.

- Sample and analyze the underlying soil for appropriate constituents inherent to leachate. Assess the results for evidence of contaminant migration.

- If contamination of underlying soils is exhibited, perform an assessment as to the degree of contamination and develop remedial actions.

- Obtain approval of the DWM for the assessment and associated remedial measures.

- Perform the remedial actions as necessary to limit any threats to public health and the environment.

- Restore the area to closely match pre-existing conditions in the vicinity of the containment areas. Activities may include: filling, grading, topsoiling, and seeding.

### 2.4.6 Repair of Run-On/Run-Off Control Structures

All drainage swales, ditches, and perimeter channels will be repaired, cleaned, or realigned in order to maintain their original condition. Any culverts that are damaged will be repaired or replaced.

### 2.4.7 Landfill Gas System

The landfill gas system will be maintained by the County and operated in accordance with any site air quality permits. Proper operation of the system is verified through testing at the landfill gas monitoring wells.

If gas wells/vents do not function as a result of irregular settlement, accumulation of liquids (condensate, leachate, water), binding or corrosion, additional and/or replacement wells/vents can be installed if necessary in accordance with the current Landfill Gas Management Plan.

### 2.4.8 Groundwater Monitoring Wells

Procedures outlined in the current Water Quality Monitoring Plan or subsequent revision will take precedence; however, a brief description follows. All groundwater monitoring wells have been installed with concrete pads and protective casings to prevent accidental damage by vehicles and equipment. The wells are also equipped with a locking cap to discourage vandalism. Groundwater wells will be inspected regularly (at the time of sampling) to ensure integrity. Persons inspecting a well should look at the overall condition of the well, for signs of well tampering, and cracking or degradation of the concrete pad. Should a well require replacement, the defective well should be abandoned in accordance with specifications provided in the SAP and a new well installed at a

location that is approved by the DWM.

## 2.5 MONITORING PLAN

The closed unit will be monitored for a minimum of 30 years. A series of inspections will be scheduled to ensure the integrity and effectiveness of the final cover system, surface water systems, groundwater monitoring system, landfill gas system, and to protect human health and the environment.

### 2.5.1 Inspection Frequencies

Inspections to be conducted during the post-closure care period will occur regularly as shown in **Table 2.1**.

### 2.5.2 Quarterly Inspections

Quarterly inspections of the closed site will be conducted by the County. These inspections will include examination of the security control devices for signs of deterioration or vandalism to ensure access to the site is limited to authorized persons. Each disposal area will be checked to ensure the integrity of the final cover system is maintained, erosion damage is repaired, vegetative cover persists, and that cover settlement, subsidence, and displacement are minimal. Drainage swales and channels will be cleared of litter and debris and benchmark integrity will be noted and maintained.

### 2.5.3 Semi-Annual Inspections

Semi-annual inspections of the site during the post-closure period will be conducted by the County with attention paid to integrity and drainage of the final cover system and condition of the groundwater and gas monitoring systems.

A report of findings will be made to the responsible party, including recommendations for actions deemed necessary to ensure the site continues to meet the closure performance standard.

## 2.6 ENGINEERING CERTIFICATION

Based on the County's monitoring reports, annual certifications by a registered engineer will be placed in the operating record. They will certify that the closure plan has been followed, noting discrepancies along with the corrective actions undertaken. At the end of the post closure period, the individual certifications will be compiled into a final document and forwarded to the DWM.

**TABLE 2.1: POST-CLOSURE INSPECTION FREQUENCIES**

| INSPECTION ACTIVITY | YEAR 1 | YEARS 2-30 |
|---|---|---|
| Security Control Devices | Quarterly | Quarterly |
| Vegetative Cover Condition | Quarterly[1] | Quarterly |
| Surface Water Systems | Quarterly[1] | Quarterly |
| Erosion Damage | Quarterly[1] | Quarterly |
| Cover Drainage System | Quarterly[1] | Semi-Annually |
| Cover Settlement, Subsidence, and Displacement | Quarterly[1] | Semi-Annually |
| Leachate Management System | Quarterly | Semi-Annually |
| Landfill Gas System | Quarterly[3] | Semi-Annually[3] |
| Groundwater Monitoring System | Semi-Annually | Semi-Annually[2] |
| Benchmark Integrity | Annually | Annually |
| Leachate Collection Pipe Cleanout | Annually | Annually |

Notes:

1. These items will be inspected after each large storm event (i.e. $\geq$ 1 inch in any 24 hours).
2. Or in accordance with groundwater monitoring schedule described in the current Water Quality Monitoring Plan.
3. Or in accordance with the current Landfill Gas Management Plan or air quality permit(s).

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# SECTION 3.0
# CLOSURE/POST-CLOSURE COST ANALYSIS

## 3.1 OVERVIEW

The purpose of this section is to provide a written estimate in current dollars of costs associated with all activities specified in the written closure and post-closure plans which have been developed for the MSW and C&D landfill units of the Johnston County Landfill.

## 3.2 ESTIMATED CLOSURE COSTS

**Tables 3.1A, 3.1B, 3.1C, and 3.1D** summarize the estimated costs for complete closure of the MSW Phase 4A (Cells 1-3), MSW Phase 5, C&D Area 1, and C&D Area 2 (Cell 1) landfill units, respectively (the maximum area to be closed). The cost estimate for each unit is based on a third party providing the necessary services and includes labor in the unit prices given. The estimated closure costs will be reviewed and updated as required to reflect adjustments for inflation, increased costs in construction or materials, or any other adjustments to the Closure Plan.

## 3.3 ESTIMATED POST-CLOSURE COSTS

**Tables 3.2A and 3.2B** summarize the estimated costs for the post-closure care maintenance activities for MSW Phases 1-4A and C&D Areas 1-2[1] and the MSW Phase 5 landfill unit. The cost estimate for each is based on a third party providing the necessary services and includes labor in the unit prices given. The estimated post-closure costs will be reviewed and updated as required to reflect adjustments for inflation, rising costs of anticipated post-closure care, or any other adjustments to the Post-Closure Plan.

## 3.4 FINANCIAL ASSURANCE MECHANISM

Johnston County intends to continue to use the Local Government Financial Test (15A NCAC 13B.1628(e)(1)(f)) to demonstrate financial assurance for this facility.

[1]The MSW Phases 1-4 units (previously closed), the MSW Phase 4A unit, and the C&D Areas 1 and 2 units are combined in that these units are in the same portion of the site.

## TABLE 3.1A: MSW - PHASE 4A - CLOSURE COST ESTIMATE[1]

| ITEM | QUANTITY | UNITS | UNIT COST | ITEM COST (2008 $) |
|---|---|---|---|---|
| Surface Preparation | 29.4 | Acre | $10,000 | $294,000 |
| Landfill Gas System | 29.4 | Acre | $15,000 | $441,000 |
| 30 mil Textured LLDPE Geomembrane | 1,281,000 | SF | $0.45 | $576,450 |
| Drainage Geocomposite | 1,281,000 | SF | $0.55 | $704,550 |
| Vegetative Soil Layer (24") | 95,000 | CY | $5.00 | $475,000 |
| Erosion Control (Rain Gutters, Diversion Berms, Down Pipes, Drainage Channels, Etc.) | 29.4 | Acre | $15,000 | $441,000 |
| Revegetation | 29.4 | Acre | $1,500 | $44,100 |
| Surveying | 29.4 | Acre | $2,000 | $58,800 |
| | | | Subtotal: | $3,034,900 |
| Bonds, Mobilization, & Insurance | | | (4% of Subtotal): | $121,396 |
| | | | Subtotal: | $3,156,296 |
| | | | Contingency (10%): | $315,630 |
| | | | **Construction Subtotal:** | **$3,471,926** |
| Engineering | 29.4 | Acre | $2,000 | $58,800 |
| CQA | 29.4 | Acre | $6,000 | $176,400 |
| | | | **TOTAL:** | **$3,707,126** |

Notes:

1. Assumes closure of 29.4 acres (Phase 4A).

## TABLE 3.1B: MSW - PHASE 5 - CLOSURE COST ESTIMATE[1]

| ITEM | QUANTITY | UNITS | UNIT COST | ITEM COST (2008 $) |
|---|---|---|---|---|
| Surface Preparation | 19.2 | Acre | $10,000 | $192,000 |
| Landfill Gas System | 19.2 | Acre | $15,000 | $288,000 |
| 30 mil Textured LLDPE Geomembrane | 837,000 | SF | $0.45 | $376,650 |
| Drainage Geocomposite | 837,000 | SF | $0.55 | $460,350 |
| Vegetative Soil Layer (24") | 62,000 | CY | $5.00 | $310,000 |
| Erosion Control (Rain Gutters, Diversion Berms, Down Pipes, Drainage Channels, Etc.) | 19.2 | Acre | $15,000 | $288,000 |
| Revegetation | 19.2 | Acre | $1,500 | $28,800 |
| Surveying | 19.2 | Acre | $2,000 | $38,400 |
| | | | Subtotal: | $1,982,200 |
| Bonds, Mobilization, & Insurance | | | (4% of Subtotal): | $79,288 |
| | | | Subtotal: | $2,061,488 |
| | | | Contingency (10%): | $206,149 |
| | | | **Construction Subtotal:** | **$2,267,637** |
| Engineering | 19.2 | Acre | $2,000 | $38,400 |
| CQA | 19.2 | Acre | $6,000 | $115,200 |
| | | | **TOTAL:** | **$2,421,237** |

Notes:

1. Assumes closure of 19.2 acres (Phase 5).

## TABLE 3.1C: C&D - AREA 1 - CLOSURE COST ESTIMATE[1]

| ITEM | QUANTITY | UNITS | UNIT COST | ITEM COST (2008 $) |
|---|---|---|---|---|
| Surface Preparation | 12.9 | Acre | $10,000 | $129,000 |
| Landfill Gas System | 12.9 | Acre | $15,000 | $193,500 |
| 30 mil Textured LLDPE Geomembrane | 562,000 | SF | $0.45 | $252,900 |
| Drainage Geocomposite | 562,000 | SF | $0.55 | $309,100 |
| Vegetative Soil Layer (24") | 42,000 | CY | $5.00 | $210,000 |
| Erosion Control (Rain Gutters, Diversion Berms, Down Pipes, Drainage Channels, Etc.) | 12.9 | Acre | $15,000 | $193,500 |
| Revegetation | 12.9 | Acre | $1,500 | $19,350 |
| Surveying | 12.9 | Acre | $2,000 | $25,800 |
| | | | Subtotal: | $1,333,150 |
| Bonds, Mobilization, & Insurance | | | (4% of Subtotal): | $53,326 |
| | | | Subtotal: | $1,386,476 |
| | | | Contingency (10%): | $138,648 |
| | | | **Construction Subtotal:** | **$1,525,124** |
| Engineering | 12.9 | Acre | $2,000 | $25,800 |
| CQA | 12.9 | Acre | $6,000 | $77,400 |
| | | | **TOTAL:** | **$1,628,324** |

Notes:

1. Assumes closure of 12.9 acres (Area 1).

## TABLE 3.1D: C&D - AREA 2 - CLOSURE COST ESTIMATE[1]

| ITEM | QUANTITY | UNITS | UNIT COST | ITEM COST (2008 $) |
|---|---|---|---|---|
| Surface Preparation | 11.9 | Acre | $10,000 | $119,000 |
| Landfill Gas System | 11.9 | Acre | $15,000 | $178,500 |
| 30 mil Textured LLDPE Geomembrane | 519,000 | SF | $0.45 | $233,550 |
| Drainage Geocomposite | 519,000 | SF | $0.55 | $285,450 |
| Vegetative Soil Layer (24") | 39,000 | CY | $5.00 | $195,000 |
| Erosion Control (Rain Gutters, Diversion Berms, Down Pipes, Drainage Channels, Etc.) | 11.9 | Acre | $15,000 | $178,500 |
| Revegetation | 11.9 | Acre | $1,500 | $17,850 |
| Surveying | 11.9 | Acre | $2,000 | $23,800 |
| | | | Subtotal: | $1,231,650 |
| Bonds, Mobilization, & Insurance | | | (4% of Subtotal): | $49,266 |
| | | | Subtotal: | $1,280,916 |
| | | | Contingency (10%): | $128,092 |
| | | | **Construction Subtotal:** | **$1,409,008** |
| Engineering | 11.9 | Acre | $2,000 | $23,800 |
| CQA | 11.9 | Acre | $6,000 | $71,400 |
| | | | **TOTAL:** | **$1,504,208** |

Notes:

1. Assumes closure of 11.9 acres (Area 2 - Cell 1).

## TABLE 3.2A: MSW PHASES 1-4A - C&D AREAS 1-2 - POST-CLOSURE COST ESTIMATE[1]

| ITEM | QUANTITY | UNIT | UNIT COST | TOTAL (2008 $) |
|---|---|---|---|---|
| Site Inspection And Record Keeping | 80 | HR | $75 | $6,000 |
| Revegetation (5% Total Area) | 5 | Acre | $1,500 | $7,500 |
| Mowing (once per year) | 100 | Acre | $100 | $10,000 |
| Erosion Control | 1 | LS | $5,000 | $5,000 |
| Gates/Fences | 1 | LS | $1,000 | $1,000 |
| Groundwater/Surface Water Monitoring & Reporting (36 Long-Term Wells/Points - Semi-Annual) | 36 | Each | $1,000 | $72,000 |
| Methane Monitoring & Reporting (Semi-Annual After Year 1) | 2 | Each | $2,500 | $5,000 |
| Leachate Management[2] | 1 | LS | $45,149 | $45,149 |
| | | | Subtotal: | $151,649 |
| | | | Contingency (10%): | $15,165 |
| | | | **ANNUAL TOTAL:** | **$166,814** |
| | | | **30-YEAR TOTAL:** | **$5,004,417** |

Notes:

1. Assumes post-closure of 100 acres (MSW Phases 1-4A and C&D Areas 1 and Area 2 - Cell 1).
2. Leachate treatment based on 100 gal/ac/day x 41.3 acres lined x 365 x $20/1,000 gal. ($30,149/year) plus $5,000/year staff cost plus $3,000/year lab cost plus $2,000/year leachate collection line cleanout costs. Also include $5,000 per year to account for decommissioning leachate facilities (storage lagoon) (half of assumed $300,000 assumed cost) at the end of the post-closure period.

## TABLE 3.2B: MSW PHASE 5 - POST-CLOSURE COST ESTIMATE[1]

| ITEM | QUANTITY | UNIT | UNIT COST | TOTAL (2008 $) |
|---|---|---|---|---|
| Site Inspection And Record Keeping | 20 | HR | $75 | $1,500 |
| Revegetation (5% Total Area) | 1 | Acre | $1,500 | $1,500 |
| Mowing (once per year) | 20 | Acre | $100 | $2,000 |
| Erosion Control | 1 | LS | $5,000 | $5,000 |
| Gates/Fences | 1 | LS | $1,000 | $1,000 |
| Groundwater/Surface Water Monitoring & Reporting (17 Long-Term Wells/Points - Semi-Annual) | 17 | Each | $1,000 | $34,000 |
| Methane Monitoring & Reporting (Semi-Annual After Year 1) | 2 | Each | $2,500 | $5,000 |
| Leachate Management[2] | 1 | LS | $29,016 | $29,016 |
| | | | Subtotal: | $79,016 |
| | | | Contingency (10%): | $7,902 |
| | | | **ANNUAL TOTAL:** | **$86,918** |
| | | | **30-YEAR TOTAL:** | **$2,607,528** |

Notes:

1. Assumes post-closure of 19.2 acres (MSW Phase 5).
2. Leachate treatment based on 100 gal/ac/day x 19.2 acres lined x 365 x $20/1,000 gal. ($14,016/year) plus $5,000/year staff cost plus $3,000/year lab cost plus $2,000/year leachate collection line cleanout costs. Also include $5,000 per year to account for decommissioning leachate facilities (storage lagoon) (half of assumed $300,000 assumed cost) at the end of the post-closure period.

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# Erosion And Sedimentation Control Plan

## Johnston County MSW Landfill - Phase 4A
## Smithfield, North Carolina

Prepared for:

**Johnston County Department of Public Utilities**
**Smithfield, NC**

**June 2007**
**Revised: December 2008**

RICHARDSON SMITH GARDNER & ASSOCIATES
Engineering and Geological Services
14 N. Boylan Avenue
Raleigh, North Carolina 27603

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**JOHNSTON COUNTY MSW LANDFILL**
**PHASE 4A**

**EROSION AND SEDIMENTATION CONTROL PLAN**

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- Appendix A Erosion and Sedimentation Control Calculations
- Appendix B Erosion and Sedimentation Control Technical Specifications (see **Attachment B**)
- Appendix C Erosion and Sedimentation Control Plans and Details (see **Attachment H**)

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**JOHNSTON COUNTY MSW LANDFILL**
**PHASE 4A**

**EROSION AND SEDIMENTATION CONTROL PLAN**

# 1.0 NARRATIVE

## 1.1 Project Description

Johnston County plans to construct a lined expansion (Phase 4A - Cell 3) of their existing municipal solid waste (MSW) landfill at their landfill facility located off of County Home Road near Smithfield. The construction and operation of the landfill expansion will require the disturbance of approximately 7.4 acres (which was previously permitted - see No. 3 below). The plan for development of Cell 3 calls for some modifications to the final drainage features for the Phase 4A MSW landfill unit, as well as modifications to the Area 1 and Area 2 construction and demolition debris (C&D) landfill units, which are adjacent to Phase 4A. The previously approved plans for this portion of the site include:

1. Johnston County C&D Landfill - Area 2 (Approved July 10, 2006);
2. Johnston County C&D Landfill Vertical Expansion (Area 1) (Approved January 5, 2004); and
3. Johnston County MSW Landfill - Phase 4A (Approved July 11, 2001).

This plan discusses both the initial and long-term (final) erosion and sedimentation control measures to be used on this project.

## 1.2 Contact Information

1.2.1 Engineer: For questions regarding this erosion and sedimentation control plan, please contact the following:

Richardson Smith Gardner & Associates, Inc.
Attn.: Pieter K. Scheer, P.E.
14 N. Boylan Ave.
Raleigh, NC 27607
Phone: (919) 828-0577
Fax: (919) 828-3899.

1.2.2 Owner: The owner of the site and the person to contact should sediment control issues arise during the land-disturbing activity is as follows:

Johnston County Department of Public Utilities
Attn.: Tim Broome, P.E., Director
P.O. Box 2263
309 E. Market Street

Smithfield, NC 27577
Phone: (919) 209-8333
Fax: (919) 934-7174.

### 1.3 Existing Site Conditions

The Phase 4A MSW landfill unit is located between and partially overlying the side of the closed Phase 3 and Phase 4 MSW landfill units and the active Area 1 C&D landfill unit. Existing ground surface elevations vary from El. 260 (feet) to the west at the top of the Phase 3 unit to El. 138 in existing Sediment Basin No. 5A. All closed and inactive areas are vegetated with grass.

### 1.4 Adjacent Areas

The project site lies within County-owned property on all sides. Middle Creek, a tributary to the Neuse River, lies to the north of the project site. The site is accessed from existing site access roads leading from the main gate at the end of County Home Road.

### 1.5 Site Soils Information

The native surficial soils at the site (including Borrow Area E (active site borrow area)) fall under the categories of Blanton (BnA), Uchee (UcB, and UcC), and Wagram (WaB) with lesser areas of Udorthents (Ud) and Faceville (FaB) according to USGS soil survey data. These soils are classified as being in hydrologic soil groups (HSG) "A" or "B". Conservatively, HSG "B" was assumed in the calculations.

## 2.0 DESIGN GUIDELINES AND PROCEDURES

The erosion and sediment control design for the landfill was conducted based on guidelines and procedures as set forth in the following references:

1. HydroCAD Software Solutions, LLC (2006), HydroCAD Stormwater Modeling System Owner's Manual - Version 8, Chocorua, NH.

2. North Carolina Division of Land Resources (2006 Update), North Carolina Erosion & Sediment Control Planning & Design Manual, Raleigh, NC.

3. Malcom, H. Rooney (1989 & 2003 Supplement), Elements of Urban Stormwater Design, NC State Univ., Raleigh, NC.

## 3.0 RUNOFF CALCULATIONS

All stormwater flow volumes were calculated using the HydroCAD computer program (utilizing USDA-NRCS (SCS) methods) and/or the Rational Method based on a 25-year 24-hour storm event. This storm event, which is a requirement of current North Carolina solid waste

regulations, exceeds the 10-year event required by current North Carolina Sediment Control regulations. Rainfall quantities and/or intensities used in the analyses were derived from an analysis of design storms for the site. Drainage areas were determined using a planimeter and/or AutoCAD on topographic sheets of the project area. For each drainage area, runoff curve numbers (SCS methods) and/or runoff coefficients (Rational Method) were selected based on ground cover conditions. Times of concentration were calculated by HydroCAD using SCS methods.

## 4.0 EROSION AND SEDIMENTATION CONTROL MEASURES - INITIAL

The following erosion and sedimentation control measures are to be constructed as part of the proposed construction. Appendices A, B, and C to this plan include calculations, technical specifications, and plans and details for each of these measures, respectively.

### 4.1 Sediment Basins

There are six existing permanent (Sediment Basins 1, 2, 3, 4, 5A, and 6) sediment basins which will serve the site. Sediment Basins 1 and 2 are located on the west side of the project area; Sediment Basins 3 and 5A are located on the north side of the project area; and Sediment Basins 4 and 6 are located on the east side of the project area.

The six existing sediment basins will receive flow from no more disturbed area than originally designed. However, each sediment basin was modeled with the HydroCAD computer program to verify that they can handle the flow from the design storm event.

### 4.2 Drainage Channels

Drainage channel calculations were conducted using a reformulation of Manning's Equation in a spreadsheet format. The calculations determine the normal depth of flow based on the peak discharge from the design storm (from HydroCAD) and assumed channel dimensions/slope(s). Both temporary and/or permanent channel linings were chosen, as appropriate, based on the calculated velocity and/or shear stress. Steeper rip rap lined channels (if specified) were analyzed as rock chutes in accordance with NRCS procedures. Temporary channel linings (if specified) were designed based on the peak discharge from a 2-year 24-hour design storm.

### 4.3 Culverts

There are several culverts which will be used at the site to convey flow beneath roadways and embankments. These culverts will be directed to one of the site sediment basins. Culverts were designed either using HydroCAD or a spreadsheet based on an analysis of inlet and outlet control under the influence of the design storm to determine the maximum headwater elevation. Where required, culvert outlets were designed for outlet stabilization based on criteria set forth in E&SCP&DM, Section 6.41.

### 4.4 Silt Fence

Silt fencing design was based on criteria set forth in E&SCP&DM, Section 6.62 including the limitation of 100 feet of fencing for each ¼ acre of drainage area.

### 4.5 Vegetative Stabilization

Vegetative stabilization will be in accordance with the seeding schedule in the project specifications (provided as an attachment to this plan). The seeding schedule was based on Table 6.11k of E&SCP&DM which is applicable to this site.

## 5.0 EROSION AND SEDIMENTATION CONTROL MEASURES - FINAL

The following erosion and sedimentation control measures are to be constructed as part of final cover construction. Appendices A, B, and C to this plan include calculations, technical specifications, and plans and details for each of these measures, respectively.

### 5.1 Cap Diversion Berms

Cap diversion berms will be placed near the slope break of the final cover where the 4H:1V side slopes break to a flatter grade. Flow from the cap diversion berms is directed to the down pipes. The capacity and need for lining of cap diversion berms was checked using the same procedures as described above for drainage channels.

### 5.2 Rain Gutters

Rain gutters will be placed along final cover side slopes at a maximum spacing of approximately 140 feet. Flow from the rain gutters will be directed to the down pipes. Rain gutters were designed using a spreadsheet. The capacity of the rain gutters was checked based on partial flow to determine flow depth and velocity then compared with the full flow capacity of each pipe size with the calculated peak discharge to verify the desired factor of safety. Rain gutter drop inlets (inlet to down pipes) were analyzed as orifices.

### 5.3 Down Pipes

Down pipes will be used to carry flows from diversion berms and/or rain gutters to the bottom of final cover slopes. Down pipes were designed based on the same procedures as rain gutters. Down pipes will be adequately anchored to the landfill side slopes by use of a soil cover and each will be outleted either directly to perimeter sediment basins (with rip rap apron at outlet) or to energy dissipating structures (precast energy dissipaters, drop inlets, stone structures, etc.) at the base of each slope.

## 6.0 SCHEDULE FOR IMPLEMENTATION

All erosion control measures will be placed before any land disturbance or waste placement may begin in that portion of the site which drains to the erosion control measures. Vegetative stabilization of disturbed areas will be in accordance with the following requirements:

- Temporary or permanent ground cover (or other acceptable measure(s)) adequate to restrain erosion on erodible slopes or other areas will be provided within 21 calendar days following completion of any phase of grading.

- Permanent ground cover for all disturbed areas will be provided within 15 working days or 90 calendar days (whichever is shorter) following the completion of construction.

## 7.0 INSPECTION AND MAINTENANCE

All erosion and sedimentation control measures will be inspected at least once every seven calendar days and within 24 hours after any storm event of greater than 0.5 inches of rain per 24 hour period. A rain gauge will be maintained on the site and a record of the rainfall amounts and dates will be kept properly.

During inspections, any stormwater discharges from the site will be observed for stormwater discharge characteristics to evaluate the effectiveness of the erosion and sedimentation control measures incorporating Best Management Practices (BMPs). If visible sedimentation is leaving the disturbed limits of the site, corrective action will be taken immediately to control the discharge of sediments.

Repairs to erosion and sedimentation control measures will be made as needed and accumulated sediment removed if necessary. All sediments which are removed from erosion and sedimentation control measures will be disposed of in an approved manner at a location to be designated by the Engineer in such a manner that further erosion and sedimentation will not occur.

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# Appendix A

## Erosion & Sedimentation Control Calculations

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**JOHNSTON COUNTY MSW LANDFILL**
**PHASE 4A**

**EROSION AND SEDIMENTATION CONTROL PLAN**
**APPENDIX A: EROSION AND SEDIMENTATION CONTROL CALCULATIONS**

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2.0 Analysis of Design Storms
3.0 Drainage Areas and Curve Numbers
4.0 Stormwater Routing (HydroCAD output)*
- 25-Year 24-Hour Storm **(Rev. 12/08)**

5.0 Drainage Channel Analysis
- DC-21AB **(Rev. 12/08)**
- DC-21BC **(Rev. 12/08)**
- DC-41AB
- DC-51AB **(New: 12/08)**
- DC-51BC **(New: 12/08)**
- DC-64AB
- DC-66AB
- DC-67AB **(New: 12/08)**
- Cap Diversion Berms

6.0 Drop Inlet Analysis
- DI-51

7.0 Culvert Analysis
- C-41

8.0 Rain Gutters and Down Pipe Sizing
9.0 Concrete Pipe Strength Analysis
- C-41
- C-51

10.0 Outlet Protection Analysis
- C-41
- C-51


*The design of C-51 as well as verification of the capacity of existing measures is included in the HydroCAD output.

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|---|---|
| PROJECT Johnston County MSWLF - Phase 4A - Cell 3 | SHEET 1 OF 2 |
| | JOB NO. JOHNSTON-07-2 |
| | DATE 2/16/07 |
| SUBJECT Drainage and E&SC Calculations - Overview | COMPUTED BY PKS |
| | CHECKED BY |

**Objective**

To design stormwater conveyance, detention, and erosion and sedimentation control measures to remove and contain stormwater flow from the design storm. The design of these measures will be based on:

- Design storm information for the site;
- Peak discharge calculations using the Rational Method and/or USDA-NRCS (SCS) Methods; and
- Stormwater routing using USDA-NRCS (SCS) or other methods.

**References**


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

Federal Highway Administration (2001), Urban Drainage Design Manual, Hydraulic Engineering Circular No. 22, FHWA NHI-01-021, Second Ed., U.S. Dept. of Transportation, Washington, D.C.

Georgia Soil and Water Conservation Commission (2000), Manual for Erosion and Sediment Control in Georgia, Fifth Edition, Athens, GA.

HydroCAD Software Solutions, LLC (2006), HydroCAD Stormwater Modeling System Owner's Manual - Version 8, Chocorua, NH.

Malcom, H. Rooney (1989 & 2003 Supplement), Elements of Urban Stormwater Design, NC State Univ., Raleigh, NC.

North Carolina Division of Land Resources (2006), North Carolina Erosion & Sediment Control Planning & Design Manual, Raleigh, NC.

North Carolina Division of Water Quality (July 2005) Updated Draft Manual of Stormwater Best Management Practices, (Public Comment Version), Raleigh, NC.

Pennsylvania DEP Bureau of Watershed Protection (2000), Erosion and Sediment Pollution Control Program Manual.

USDA-NRCS (1992), Computer Program for Project Formulation Hydrology (TR-20).

USDA-NRCS (1986 & 1999 Update), Urban Hydrology for Small Watersheds (TR-55).

Virginia Department of Conservation and Recreation (1992), Virginia Erosion & Sediment Control Handbook, Third Edition, Richmond, VA.





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**Analysis** The main design criteria will be to ensure that all stormwater conveyance and detention measures will be able to accommodate the runoff from the design storm. Drainage channels, culverts, etc. were designed based on the peak discharge to each measure. Detention measures were designed based on stormwater routing methods and/or State/local criteria.

**Calculations**

- Peak Discharge Calculations:

- USDA-NRCS (SCS) Methods:

Use HydroCAD program to determine the peak discharge to each device or structure. HydroCAD is based on the SCS unit hydrograph procedure, which is a principal component of NRCS TR-20. Alternatively spreadsheets can be used to determine flow rates using the procedures detailed in NRCS TR-55.

- Rational Method:

$$Q = CIA \qquad \text{(Malcom Eq. I -1)}$$

where:
- $Q$ = peak discharge (cfs)
- $C$ = rational runoff coefficient
- $I$ = applicable rainfall intensity (in/hr) of storm event (based on time of concentration)
- $A$ = drainage area (acres)

- Time of Concentration:

The time of concentration for use in determining the peak discharge in the NRCS and/or Rational methods can be determined by the methods detailed in NRCS TR-55 or other methods. HydroCAD uses the NRCS methods.

- Stormwater Routing:

Stormwater routing was accomplished using the HydroCAD program, which is based on USDA-NRCS (SCS) methods. Unless otherwise specified, the unit hydrograph method was used. The storm type (i.e. Type I 24-hr., Type II 24-hr., etc.) was selected as appropriate for the project location.

| | |
|---|---|
| PROJECT Johnston County MSWLF - Phase 4A - Cell 3 | SHEET 1 OF 2 |
| | JOB NO. JOHNSTON-07-2 |
| | DATE 2/16/07 |
| SUBJECT Analysis of Design Storms | COMPUTED BY PKS |
| | CHECKED BY |

**Objective**

To compile the expected design storm depths and intensities over various return periods. These design storm values will be used in various calculations.

**References**

Rainfall data was obtained from the following references:

Frederick, R.H., V.A. Myers, and E.P. Anciello (1977), "Five to 60-Minute Precipitation Frequency for the Eastern and Central United States," NOAA Technical Memo. NWS HYDRO-35, National Weather Service, NOAA, U.S. Dept. Of Commerce, Silver Spring, MD.

U.S. Weather Bureau (1961), "Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years," U.S. Weather Bureau Technical Paper 40.



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SHEET: 2 / 2
JOB #: JOHNSTON-07-2
DATE: 2/28/07
BY: PKS
CHKD BY:

**Johnston County MSW Landfill - Phase 4A - Cell 3**
**Analysis of Design Storms**

LOCATION: **Smithfield, NC**

| DURATION | RETURN PERIOD 2-YR P (in) | 100-YR P (in) | SOURCE |
|---|---|---|---|
| 5 min | 0.48 | 0.81 | NOAA HYDRO-35 |
| 15 min | 1.03 | 1.81 | NOAA HYDRO-35 |
| 60 min | 1.80 | 3.75 | NOAA HYDRO-35 |
| 2 hr to 24 hr Rainfall Events = | **USER INPUT** | | USWB TP-40 |

**DEPTH-DURATION-FREQUENCY TABLE**

| DURATION | RETURN PERIOD 2-YR (in) | 5-YR (in) | 10-YR (in) | 25-YR (in) | 50-YR (in) | 100-YR (in) |
|---|---|---|---|---|---|---|
| 5 min | 0.48 | 0.55 | 0.60 | 0.68 | 0.75 | 0.81 |
| 10 min | 0.80 | 0.93 | 1.03 | 1.17 | 1.29 | 1.40 |
| 15 min | 1.03 | 1.20 | 1.32 | 1.51 | 1.66 | 1.81 |
| 30 min | 1.41 | 1.72 | 1.94 | 2.26 | 2.51 | 2.76 |
| 60 min | 1.80 | 2.26 | 2.58 | 3.04 | 3.39 | 3.75 |
| 2 hr | 2.20 | 2.80 | 3.25 | 3.70 | 4.20 | 4.60 |
| 3 hr | 2.40 | 3.10 | 3.60 | 4.10 | 4.55 | 5.10 |
| 6 hr | 2.85 | 3.60 | 4.20 | 4.90 | 5.50 | 6.10 |
| 12 hr | 3.35 | 4.20 | 5.00 | 5.80 | 6.40 | 7.20 |
| 24 hr | 3.70 | 4.85 | 5.80 | 6.60 | 7.40 | 8.20 |

**INTENSITY-DURATION-FREQUENCY TABLE**

| DURATION | RETURN PERIOD 2-YR (in/hr) | 5-YR (in/hr) | 10-YR (in/hr) | 25-YR (in/hr) | 50-YR (in/hr) | 100-YR (in/hr) |
|---|---|---|---|---|---|---|
| 5 min | 5.76 | 6.58 | 7.22 | 8.19 | 8.96 | 9.72 |
| 10 min | 4.83 | 5.59 | 6.17 | 7.03 | 7.72 | 8.40 |
| 15 min | 4.12 | 4.79 | 5.29 | 6.05 | 6.65 | 7.24 |
| 30 min | 2.81 | 3.43 | 3.88 | 4.52 | 5.02 | 5.52 |
| 60 min | 1.80 | 2.26 | 2.58 | 3.04 | 3.39 | 3.75 |
| 2 hr | 1.10 | 1.40 | 1.63 | 1.85 | 2.10 | 2.30 |
| 3 hr | 0.80 | 1.03 | 1.20 | 1.37 | 1.52 | 1.70 |
| 6 hr | 0.48 | 0.60 | 0.70 | 0.82 | 0.92 | 1.02 |
| 12 hr | 0.28 | 0.35 | 0.42 | 0.48 | 0.53 | 0.60 |
| 24 hr | 0.15 | 0.20 | 0.24 | 0.28 | 0.31 | 0.34 |

PROJECT Johnston County MSWLF - Phase 4A - Cell 3

SUBJECT Drainage Areas & Curve Numbers

SHEET 1 OF 2
JOB NO. JOHNSTON-07-2
DATE 6/8/07
COMPUTED BY PKS
CHECKED BY

**Objective**

To breakout drainage areas and associated runoff curve numbers for the drainage and erosion control plan(s). Drainage areas and runoff curve numbers will be used to determine the design flow to each stormwater conveyance and/or detention measure. Drainage areas and runoff curve numbers are tabulated on the table on the attached drawing. Areas were measured by planimeter or AutoCAD on the attached plan drawings. Curve numbers are as shown on the HydroCAD output.

**DRAIN AREAS & CURVE NUMBERS.WPD**

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

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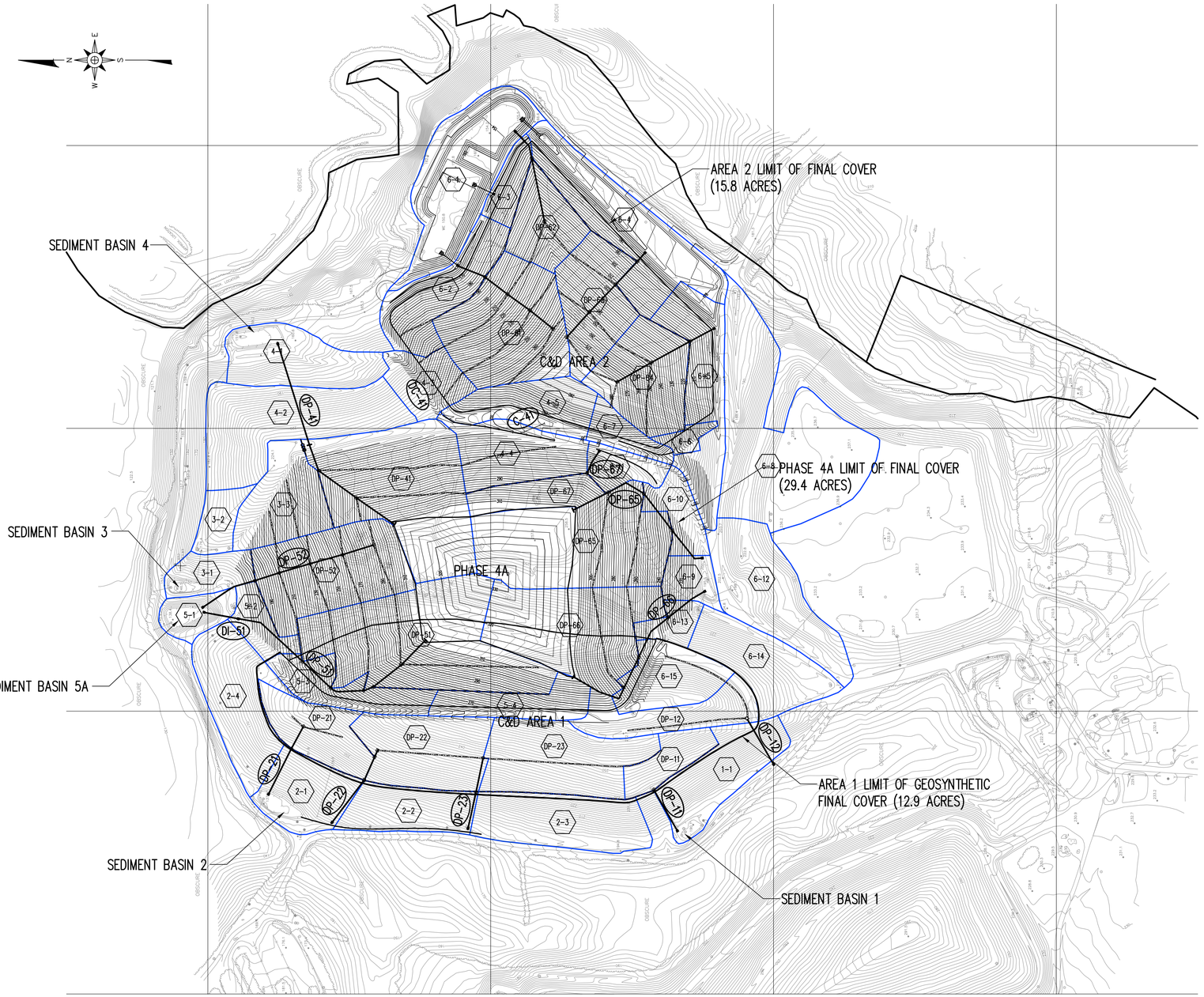
| DRAINAGE AREAS | |
|---|---|
| AREA | SIZE (AC.) |
| 1–1 | 2.17 |
| DP–11 | 0.91 |
| DP–12 | 1.64 |
| 2–1 | 1.73 |
| 2–2 | 1.62 |
| 2–3 | 2.54 |
| 2–4 | 2.56 |
| DP–21 | 1.61 |
| DP–22 | 2.55 |
| DP–23 | 2.99 |
| 3–1 | 0.93 |
| 3–2 | 0.71 |
| 3–3 | 2.00 |
| 4–1 | 2.24 |
| 4–2 | 3.74 |
| 4–3 | 1.23 |
| 4–4 | 2.05 |
| 4–5 | 1.75 |
| DP–41 | 5.01 |
| 5–1 | 0.79 |
| 5–2 | 0.76 |
| 5–3 | 1.48 |
| 5–4 | 1.32 |
| DP–51 | 5.48 |
| DP–52 | 3.42 |
| 6–1 | 3.69 |
| 6–2 | 2.09 |
| 6–3 | 0.67 |
| 6–4 | 3.60 |
| 6–5 | 2.58 |
| 6–6 | 0.30 |
| 6–7 | 0.71 |
| 6–8 | 5.98 |
| 6–9 | 0.70 |
| 6–10 | 0.92 |
| 6–11 | 0.75 |
| 6–12 | 3.07 |
| 6–13 | 0.57 |
| 6–14 | 2.25 |
| 6–15 | 1.65 |
| DP–61 | 3.60 |
| DP–62 | 1.49 |
| DP–63 | 2.20 |
| DP–64 | 2.39 |
| DP–65 | 4.58 |
| DP–66 | 3.82 |
| DP–67 | 1.04 |




LEGEND

- EXISTING 10' CONTOUR (SEE REFERENCE 1)
- EXISTING 2' CONTOUR
- APPROXIMATE PROPERTY LINE
- LIMITS OF FINAL COVER
- PROPOSED 10' CONTOUR (SEE NOTE 1)
- PROPOSED 2' CONTOUR
- DRAINAGE CHANNEL
- DIVERSION BERM
- SILT FENCE
- CULVERT/DROP INLET
- CAP DIVERSION BERM
- DP–3 DOWN PIPE
- DC–1 DRAINAGE CHANNEL
- C–1 CULVERT NUMBER
- DI–1 DROP INLET NUMBER
- DOWN PIPE DROP INLET
- PRECAST ENERGY DISSIPATER
- RAIN GUTTER
- DOWN PIPE WITH TEE INLET

NOTES

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

REFERENCES

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

0 200' 400' 600'

| NO. | DATE | REVISION |
|---|---|---|
| 1 | 12/08 | REVISED DRAINAGE AREAS |


RICHARDSON SMITH GARDNER & ASSOCIATES
Engineering and Geological Services
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PROJECT TITLE:
JOHNSTON COUNTY MSW LANDFILL
PHASE 4A - CELL 3
PERMIT AMENDMENT DRAWINGS

DRAWING TITLE:
DRAINAGE AREAS

| DESIGNED BY: | DRAWN BY: |
|---|---|
| P.K.S. | J.A.L. |
| CHECKED BY: | PROJECT NO.: JOHN 07-2 |
| SCALE: AS SHOWN | DATE: MAY 2007 |
| FILE NAME: JOHN-D0508A | |
| SHEET NO. | DRAWING NO. |

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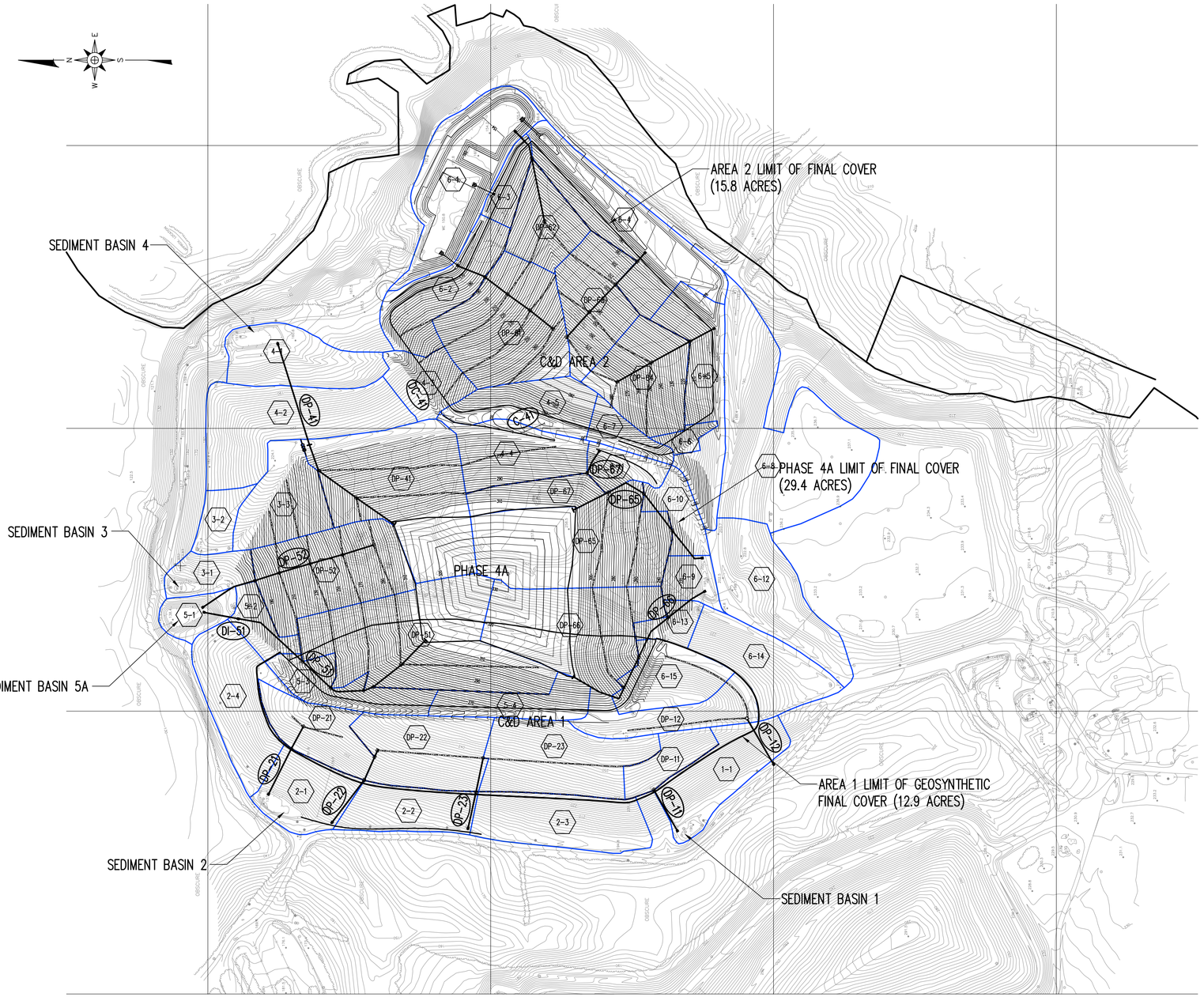
| DRAINAGE AREAS | |
|---|---|
| AREA | SIZE (AC.) |
| 1–1 | 2.17 |
| DP–11 | 0.91 |
| DP–12 | 1.64 |
| 2–1 | 1.73 |
| 2–2 | 1.62 |
| 2–3 | 2.54 |
| 2–4 | 2.56 |
| DP–21 | 1.61 |
| DP–22 | 2.55 |
| DP–23 | 2.99 |
| 3–1 | 0.93 |
| 3–2 | 0.71 |
| 3–3 | 2.00 |
| 4–1 | 2.24 |
| 4–2 | 3.74 |
| 4–3 | 1.23 |
| 4–4 | 2.05 |
| 4–5 | 1.75 |
| DP–41 | 5.01 |
| 5–1 | 0.79 |
| 5–2 | 0.76 |
| 5–3 | 1.48 |
| 5–4 | 1.32 |
| DP–51 | 5.48 |
| DP–52 | 3.42 |
| 6–1 | 3.69 |
| 6–2 | 2.09 |
| 6–3 | 0.67 |
| 6–4 | 3.60 |
| 6–5 | 2.58 |
| 6–6 | 0.30 |
| 6–7 | 0.71 |
| 6–8 | 5.98 |
| 6–9 | 0.70 |
| 6–10 | 0.92 |
| 6–11 | 0.75 |
| 6–12 | 3.07 |
| 6–13 | 0.57 |
| 6–14 | 2.25 |
| 6–15 | 1.65 |
| DP–61 | 3.60 |
| DP–62 | 1.49 |
| DP–63 | 2.20 |
| DP–64 | 2.39 |
| DP–65 | 4.58 |
| DP–66 | 3.82 |
| DP–67 | 1.04 |

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0 200' 400' 600'

| NO. | DATE | REVISION |
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| 1 | 12/08 | REVISED DRAINAGE AREAS |


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SEAL

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

DRAWING TITLE:
DRAINAGE AREAS

| DESIGNED BY: | DRAWN BY: |
|---|---|
| P.K.S. | J.A.L. |
| CHECKED BY: | PROJECT NO.: JOHN 07-2 |
| SCALE: AS SHOWN | DATE: MAY 2007 |
| FILE NAME: JOHN-D0508A | |
| SHEET NO. | DRAWING NO. |

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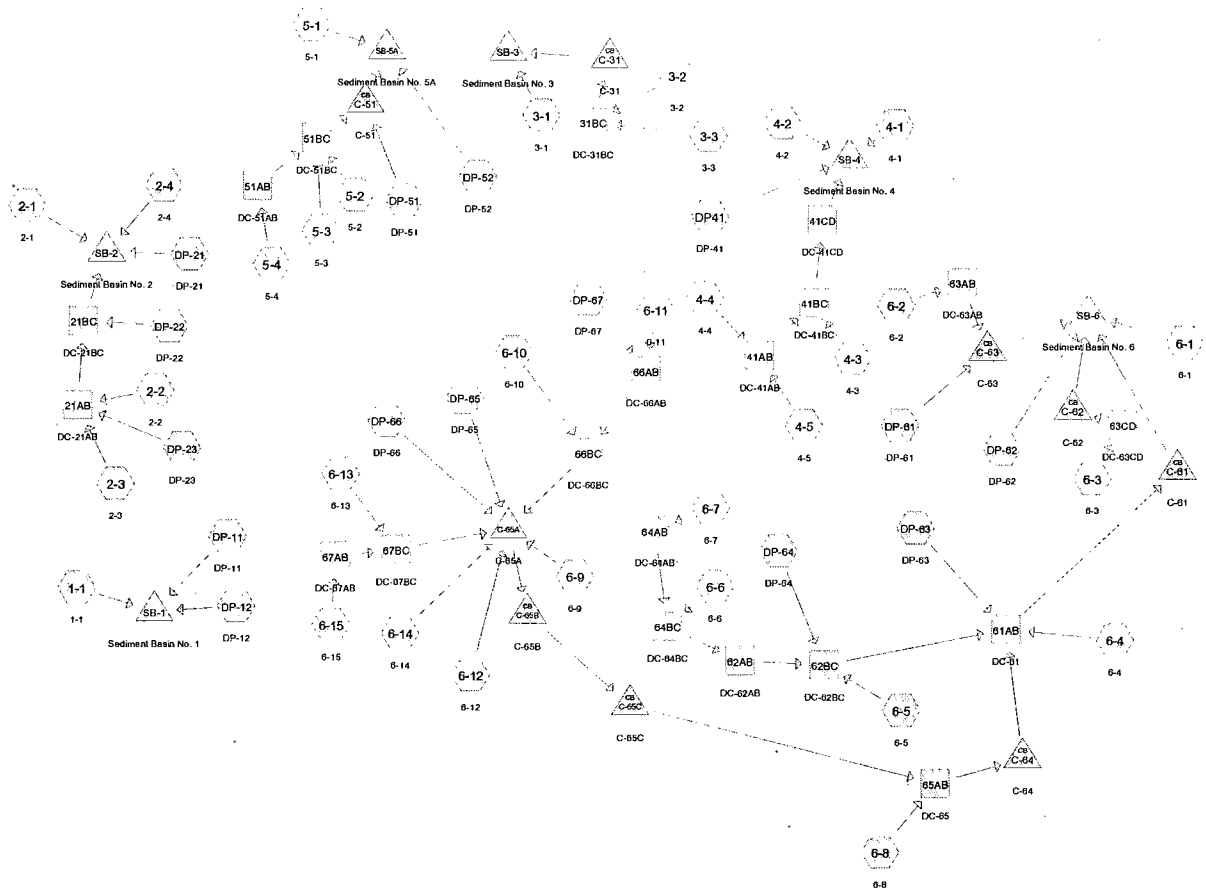



Subcat Reach Pond Link

**Drainage Diagram for Johnston County MSW Ph. 4A R1**
Prepared by Richardson Smith Gardner & Assocs., Inc. 12/4/2008
HydroCAD® 8.00 s/n 004004 © 2006 HydroCAD Software Solutions LLC

## Area Listing (all nodes)

| Area (acres) | CN | Description (subcats) |
|---|---|---|
| 99.470 | 61 | >75% Grass cover, Good, HSG B (1-1,2-1,2-2,2-3,2-4,3-1,3-2,3-3,4-1,4-2,4-3,4-4,4-5,5-1,5-2,! |
| 0.110 | 98 | Sed. Basin No. 1 - Riser Elev. (1-1) |
| 0.250 | 98 | Sed. Basin No. 2 - Riser Elev. (2-1) |
| 0.120 | 98 | Sed. Basin No. 3 - Riser Elev. (3-1) |
| 0.230 | 98 | Sed. Basin No. 4 - Riser Elev. (4-1) |
| 0.200 | 98 | Sed. Basin No. 5A - Riser Elev. (5-1) |
| 1.500 | 98 | Sed. Basin No. 6 - Riser Elev. (6-1) |
| 101.880 | | |

Time span=0.00-20.00 hrs, dt=0.01 hrs, 2001 points x 3
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

**Subcatchment 1-1: 1-1** Runoff Area=2.170 ac Runoff Depth>2.37"
Flow Length=510' Tc=4.6 min CN=63 Runoff=10.69 cfs 0.429 af

**Subcatchment 2-1: 2-1** Runoff Area=1.730 ac Runoff Depth>2.65"
Flow Length=200' Slope=0.2000 '/' Tc=6.3 min CN=66 Runoff=8.87 cfs 0.381 af

**Subcatchment 2-2: 2-2** Runoff Area=1.620 ac Runoff Depth>2.19"
Flow Length=180' Slope=0.2000 '/' Tc=5.8 min CN=61 Runoff=7.05 cfs 0.296 af

**Subcatchment 2-3: 2-3** Runoff Area=2.540 ac Runoff Depth>2.19"
Flow Length=760' Tc=7.0 min CN=61 Runoff=10.55 cfs 0.464 af

**Subcatchment 2-4: 2-4** Runoff Area=2.560 ac Runoff Depth>2.19"
Flow Length=1,000' Tc=10.9 min CN=61 Runoff=9.13 cfs 0.467 af

**Subcatchment 3-1: 3-1** Runoff Area=0.930 ac Runoff Depth>2.65"
Flow Length=115' Slope=0.2500 '/' Tc=3.7 min CN=66 Runoff=5.26 cfs 0.205 af

**Subcatchment 3-2: 3-2** Runoff Area=0.710 ac Runoff Depth>2.19"
Flow Length=375' Tc=6.2 min CN=61 Runoff=3.04 cfs 0.130 af

**Subcatchment 3-3: 3-3** Runoff Area=2.000 ac Runoff Depth>2.19"
Flow Length=200' Slope=0.2000 '/' Tc=6.3 min CN=61 Runoff=8.54 cfs 0.365 af

**Subcatchment 4-1: 4-1** Runoff Area=2.240 ac Runoff Depth>2.55"
Flow Length=200' Slope=0.1500 '/' Tc=7.1 min CN=65 Runoff=10.77 cfs 0.476 af

**Subcatchment 4-2: 4-2** Runoff Area=3.740 ac Runoff Depth>2.19"
Flow Length=920' Tc=7.7 min CN=61 Runoff=15.11 cfs 0.683 af

**Subcatchment 4-3: 4-3** Runoff Area=1.230 ac Runoff Depth>2.19"
Flow Length=200' Slope=0.2500 '/' Tc=5.8 min CN=61 Runoff=5.36 cfs 0.225 af

**Subcatchment 4-4: 4-4** Runoff Area=2.050 ac Runoff Depth>2.19"
Flow Length=150' Slope=0.2500 '/' Tc=4.6 min CN=61 Runoff=9.36 cfs 0.375 af

**Subcatchment 4-5: 4-5** Runoff Area=1.750 ac Runoff Depth>2.19"
Flow Length=270' Tc=7.9 min CN=61 Runoff=7.02 cfs 0.319 af

**Subcatchment 5-1: 5-1** Runoff Area=0.790 ac Runoff Depth>3.03"
Flow Length=100' Slope=0.2500 '/' Tc=3.3 min CN=70 Runoff=5.12 cfs 0.199 af

**Subcatchment 5-2: 5-2** Runoff Area=0.760 ac Runoff Depth>2.19"
Flow Length=140' Slope=0.2000 '/' Tc=4.7 min CN=61 Runoff=3.46 cfs 0.139 af

**Subcatchment 5-3: 5-3** Runoff Area=1.480 ac Runoff Depth>2.19"
Flow Length=200' Slope=0.2500 '/' Tc=5.8 min CN=61 Runoff=6.44 cfs 0.270 af

**Subcatchment 5-4: 5-4** Runoff Area=1.320 ac Runoff Depth>2.19"
Flow Length=140' Slope=0.2500 '/' Tc=4.3 min CN=61 Runoff=6.10 cfs 0.241 af

**Subcatchment 6-1: 6-1** Runoff Area=3.690 ac Runoff Depth>3.62"
Flow Length=50' Slope=0.3300 '/' Tc=1.7 min CN=76 Runoff=29.47 cfs 1.114 af

**Subcatchment 6-10: 6-10** Runoff Area=0.920 ac Runoff Depth>2.19"
Flow Length=150' Slope=0.2500 '/' Tc=4.6 min CN=61 Runoff=4.20 cfs 0.168 af

**Subcatchment 6-11: 6-11** Runoff Area=0.750 ac Runoff Depth>2.19"
Flow Length=150' Slope=0.2500 '/' Tc=4.6 min CN=61 Runoff=3.42 cfs 0.137 af

**Subcatchment 6-12: 6-12** Runoff Area=3.070 ac Runoff Depth>2.19"
Flow Length=500' Tc=4.5 min CN=61 Runoff=14.07 cfs 0.561 af

**Subcatchment 6-13: 6-13** Runoff Area=0.570 ac Runoff Depth>2.19"
Flow Length=200' Slope=0.2500 '/' Tc=5.8 min CN=61 Runoff=2.48 cfs 0.104 af

**Subcatchment 6-14: 6-14** Runoff Area=2.250 ac Runoff Depth>2.19"
Flow Length=650' Tc=6.8 min CN=61 Runoff=9.42 cfs 0.411 af

**Subcatchment 6-15: 6-15** Runoff Area=1.650 ac Runoff Depth>2.19"
Flow Length=320' Tc=4.3 min CN=61 Runoff=7.62 cfs 0.302 af

**Subcatchment 6-2: 6-2** Runoff Area=2.090 ac Runoff Depth>2.19"
Flow Length=135' Slope=0.2500 '/' Tc=4.2 min CN=61 Runoff=9.69 cfs 0.382 af

**Subcatchment 6-3: 6-3** Runoff Area=0.670 ac Runoff Depth>2.19"
Flow Length=100' Slope=0.2500 '/' Tc=3.3 min CN=61 Runoff=3.22 cfs 0.123 af

**Subcatchment 6-4: 6-4** Runoff Area=3.600 ac Runoff Depth>2.18"
Flow Length=300' Slope=0.0200 '/' Tc=21.9 min CN=61 Runoff=8.86 cfs 0.653 af

**Subcatchment 6-5: 6-5** Runoff Area=2.580 ac Runoff Depth>2.19"
Flow Length=120' Slope=0.2500 '/' Tc=3.8 min CN=61 Runoff=12.15 cfs 0.472 af

**Subcatchment 6-6: 6-6** Runoff Area=0.300 ac Runoff Depth>2.19"
Flow Length=170' Slope=0.2500 '/' Tc=5.1 min CN=61 Runoff=1.34 cfs 0.055 af

**Subcatchment 6-7: 6-7** Runoff Area=0.710 ac Runoff Depth>2.19"
Flow Length=140' Slope=0.2500 '/' Tc=4.3 min CN=61 Runoff=3.28 cfs 0.130 af

**Subcatchment 6-8: 6-8** Runoff Area=5.980 ac Runoff Depth>2.17"
Flow Length=450' Tc=24.7 min CN=61 Runoff=13.62 cfs 1.083 af

**Subcatchment 6-9: 6-9** Runoff Area=0.700 ac Runoff Depth>2.19"
Flow Length=140' Slope=0.2500 '/' Tc=4.3 min CN=61 Runoff=3.23 cfs 0.128 af

**Subcatchment DP-11: DP-11** Runoff Area=0.910 ac Runoff Depth>2.19"
Flow Length=450' Tc=5.0 min CN=61 Runoff=4.09 cfs 0.166 af

**Subcatchment DP-12: DP-12** Runoff Area=1.640 ac Runoff Depth>2.19"
Flow Length=410' Tc=3.8 min CN=61 Runoff=7.72 cfs 0.300 af

**Subcatchment DP-21: DP-21** Runoff Area=1.610 ac Runoff Depth>2.19"
Flow Length=475' Tc=5.1 min CN=61 Runoff=7.21 cfs 0.294 af

**Subcatchment DP-22: DP-22** Runoff Area=2.550 ac Runoff Depth>2.19"
Flow Length=810' Tc=5.5 min CN=61 Runoff=11.24 cfs 0.466 af

**Subcatchment DP-23: DP-23** Runoff Area=2.990 ac Runoff Depth>2.19"
Flow Length=650' Tc=5.2 min CN=61 Runoff=13.33 cfs 0.546 af

**Subcatchment DP-51: DP-51** Runoff Area=5.480 ac Runoff Depth>2.19"
Flow Length=1,300' Tc=11.8 min CN=61 Runoff=18.87 cfs 0.999 af

**Subcatchment DP-52: DP-52** Runoff Area=3.420 ac Runoff Depth>2.19"
Flow Length=855' Tc=4.5 min CN=61 Runoff=15.67 cfs 0.625 af

**Subcatchment DP-61: DP-61** Runoff Area=3.600 ac Runoff Depth>2.19"
Flow Length=600' Tc=3.8 min CN=61 Runoff=16.96 cfs 0.658 af

**Subcatchment DP-62: DP-62** Runoff Area=1.490 ac Runoff Depth>2.19"
Flow Length=600' Tc=3.8 min CN=61 Runoff=7.02 cfs 0.272 af

**Subcatchment DP-63: DP-63** Runoff Area=2.200 ac Runoff Depth>2.19"
Flow Length=575' Tc=4.4 min CN=61 Runoff=10.12 cfs 0.402 af

**Subcatchment DP-64: DP-64** Runoff Area=2.390 ac Runoff Depth>2.19"
Flow Length=500' Tc=3.7 min CN=61 Runoff=11.30 cfs 0.437 af

**Subcatchment DP-65: DP-65** Runoff Area=4.580 ac Runoff Depth>2.19"
Flow Length=1,140' Tc=11.0 min CN=61 Runoff=16.27 cfs 0.835 af

**Subcatchment DP-66: DP-66** Runoff Area=3.820 ac Runoff Depth>2.19"
Flow Length=1,270' Tc=12.1 min CN=61 Runoff=13.00 cfs 0.696 af

**Subcatchment DP-67: DP-67** Runoff Area=1.040 ac Runoff Depth>2.19"
Flow Length=605' Tc=3.7 min CN=61 Runoff=4.92 cfs 0.190 af

**Subcatchment DP41: DP-41** Runoff Area=5.010 ac Runoff Depth>2.19"
Flow Length=1,285' Tc=10.7 min CN=61 Runoff=17.98 cfs 0.913 af

**Reach 21AB: DC-21AB** Avg. Depth=0.79' Max Vel=5.96 fps Inflow=30.68 cfs 1.306 af
n=0.040 L=500.0' S=0.0560 '/' Capacity=198.69 cfs Outflow=29.96 cfs 1.303 af

**Reach 21BC: DC-21BC** Avg. Depth=0.87' Max Vel=5.46 fps Inflow=40.87 cfs 1.769 af
n=0.050 L=150.0' S=0.0600 '/' Capacity=206.71 cfs Outflow=40.76 cfs 1.767 af

**Reach 31BC: DC-31BC** Avg. Depth=0.55' Max Vel=2.73 fps Inflow=11.58 cfs 0.495 af
n=0.050 L=120.0' S=0.0250 '/' Capacity=133.43 cfs Outflow=11.51 cfs 0.494 af

**Reach 41AB: DC-41AB** Avg. Depth=0.43' Max Vel=3.85 fps Inflow=15.84 cfs 0.694 af
n=0.040 L=400.0' S=0.0400 '/' Capacity=254.87 cfs Outflow=15.38 cfs 0.692 af

**Reach 41BC: DC-41BC** Avg. Depth=0.39' Max Vel=5.73 fps Inflow=20.64 cfs 0.916 af
n=0.050 L=320.0' S=0.1563 '/' Capacity=402.98 cfs Outflow=20.46 cfs 0.914 af

**Reach 41CD: DC-41CD** Avg. Depth=0.44' Max Vel=4.93 fps Inflow=20.46 cfs 0.914 af
n=0.050 L=360.0' S=0.1000 '/' Capacity=322.39 cfs Outflow=20.16 cfs 0.912 af

**Reach 51AB: DC-51AB** Avg. Depth=0.28' Max Vel=2.70 fps Inflow=6.10 cfs 0.241 af
n=0.050 L=300.0' S=0.0533 '/' Capacity=215.08 cfs Outflow=5.86 cfs 0.240 af

**Reach 51BC: DC-51BC** Avg. Depth=0.32' Max Vel=4.52 fps Inflow=15.70 cfs 0.650 af
n=0.050 L=800.0' S=0.1200 '/' Capacity=383.90 cfs Outflow=14.53 cfs 0.645 af

**Reach 61AB: DC-61** Avg. Depth=1.35' Max Vel=4.53 fps Inflow=89.97 cfs 6.745 af
n=0.050 L=800.0' S=0.0225 '/' Capacity=179.62 cfs Outflow=86.25 cfs 6.713 af

**Reach 62AB: DC-62AB** Avg. Depth=0.32' Max Vel=2.59 fps Inflow=4.55 cfs 0.184 af
n=0.050 L=450.0' S=0.0444 '/' Capacity=141.61 cfs Outflow=4.18 cfs 0.183 af

**Reach 62BC: DC-62BC** Avg. Depth=0.74' Max Vel=3.51 fps Inflow=26.80 cfs 1.092 af
n=0.050 L=180.0' S=0.0278 '/' Capacity=169.91 cfs Outflow=26.51 cfs 1.090 af

**Reach 63AB: DC-63AB** Avg. Depth=0.47' Max Vel=2.65 fps Inflow=9.69 cfs 0.382 af
n=0.040 L=280.0' S=0.0179 '/' Capacity=140.97 cfs Outflow=9.31 cfs 0.381 af

**Reach 63CD: DC-63CD** Avg. Depth=0.30' Max Vel=1.45 fps Inflow=3.22 cfs 0.123 af
n=0.040 L=220.0' S=0.0091 '/' Capacity=100.58 cfs Outflow=2.98 cfs 0.122 af

**Reach 64AB: DC-64AB** Avg. Depth=0.20' Max Vel=3.50 fps Inflow=3.28 cfs 0.130 af
n=0.040 L=200.0' S=0.0900 '/' Capacity=136.87 cfs Outflow=3.24 cfs 0.130 af

**Reach 64BC: DC-64BC** Avg. Depth=0.21' Max Vel=4.62 fps Inflow=4.58 cfs 0.184 af
n=0.050 L=190.0' S=0.2316 '/' Capacity=175.65 cfs Outflow=4.55 cfs 0.184 af

**Reach 65AB: DC-65** Avg. Depth=1.32' Max Vel=4.77 fps Inflow=63.25 cfs 4.611 af
n=0.050 L=450.0' S=0.0289 '/' Capacity=1,604.71 cfs Outflow=62.87 cfs 4.600 af

**Reach 66AB: DC-66AB** Avg. Depth=0.34' Max Vel=3.39 fps Inflow=8.31 cfs 0.327 af
n=0.050 L=240.0' S=0.0667 '/' Capacity=217.90 cfs Outflow=8.15 cfs 0.326 af

**Reach 66BC: DC-66BC** Avg. Depth=0.36' Max Vel=4.67 fps Inflow=12.34 cfs 0.495 af
n=0.050 L=375.0' S=0.1173 '/' Capacity=289.07 cfs Outflow=12.05 cfs 0.493 af

**Reach 67AB: DC-67AB** Avg. Depth=0.23' Max Vel=4.18 fps Inflow=7.62 cfs 0.302 af
n=0.050 L=280.0' S=0.1571 '/' Capacity=369.20 cfs Outflow=7.50 cfs 0.301 af

**Reach 67BC: DC-67BC** Avg. Depth=0.29' Max Vel=5.01 fps Inflow=9.97 cfs 0.405 af
n=0.050 L=225.0' S=0.1778 '/' Capacity=355.82 cfs Outflow=9.90 cfs 0.404 af

**Pond C-31: C-31** Peak Elev=178.04' Inflow=11.51 cfs 0.494 af
24.0" x 110.0' Culvert Outflow=11.51 cfs 0.494 af

**Pond C-51: C-51** Peak Elev=154.42' Inflow=32.39 cfs 1.644 af
36.0" x 120.0' Culvert Outflow=32.39 cfs 1.644 af

**Pond C-61: C-61** Peak Elev=160.64' Inflow=86.25 cfs 6.713 af
42.0" x 80.0' Culvert Outflow=86.25 cfs 6.713 af

**Pond C-62: C-62** Peak Elev=154.73' Inflow=2.98 cfs 0.122 af
24.0" x 56.0' Culvert Outflow=2.98 cfs 0.122 af

**Pond C-63: C-63** Peak Elev=155.06' Inflow=25.89 cfs 1.039 af
30.0" x 52.0' Culvert Outflow=25.89 cfs 1.039 af

**Pond C-64: C-64** Peak Elev=180.24' Inflow=62.87 cfs 4.600 af
36.0" x 72.0' Culvert Outflow=62.87 cfs 4.600 af

**Pond C-65A: C-65A** Peak Elev=201.08' Storage=11,596 cf Inflow=72.25 cfs 3.528 af
36.0" x 15.0' Culvert Outflow=53.26 cfs 3.528 af

**Pond C-65B: C-65B** Peak Elev=198.65' Inflow=53.26 cfs 3.528 af
36.0" x 265.0' Culvert Outflow=53.26 cfs 3.528 af

**Pond C-65C: C-65C** Peak Elev=195.95' Inflow=53.26 cfs 3.528 af
36.0" x 355.0' Culvert Outflow=53.26 cfs 3.528 af

**Pond SB-1: Sediment Basin No. 1** Peak Elev=194.79' Storage=15,211 cf Inflow=22.42 cfs 0.895 af
Primary=4.74 cfs 0.848 af Secondary=0.00 cfs 0.000 af Outflow=4.74 cfs 0.848 af

**Pond SB-2: Sediment Basin No. 2** Peak Elev=145.57' Storage=44,062 cf Inflow=64.55 cfs 2.909 af
Primary=5.55 cfs 1.830 af Secondary=28.43 cfs 0.546 af Outflow=33.98 cfs 2.376 af

**Pond SB-3: Sediment Basin No. 3** Peak Elev=151.97' Storage=14,922 cf Inflow=16.08 cfs 0.700 af
Primary=1.33 cfs 0.588 af Secondary=0.00 cfs 0.000 af Outflow=1.33 cfs 0.588 af

**Pond SB-4: Sediment Basin No. 4** Peak Elev=158.49' Storage=53,155 cf Inflow=63.00 cfs 2.984 af
Primary=5.93 cfs 1.919 af Secondary=11.76 cfs 0.328 af Outflow=17.69 cfs 2.247 af

**Pond SB-5A: Sediment Basin No. 5A** Peak Elev=143.30' Storage=43,092 cf Inflow=48.65 cfs 2.468 af
Primary=12.10 cfs 2.361 af Secondary=0.00 cfs 0.000 af Outflow=12.10 cfs 2.361 af

**Pond SB-6: Sediment Basin No. 6** Peak Elev=154.52' Storage=213,402 cf Inflow=128.84 cfs 9.260 af
Primary=18.65 cfs 5.042 af Secondary=0.00 cfs 0.000 af Outflow=18.65 cfs 5.042 af

**Total Runoff Area = 101.880 ac Runoff Volume = 19.289 af Average Runoff Depth = 2.27"**
**97.63% Pervious Area = 99.470 ac 2.37% Impervious Area = 2.410 ac**

## Subcatchment 1-1: 1-1

Runoff = 10.69 cfs @ 11.96 hrs, Volume= 0.429 af, Depth> 2.37"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 2.060 | 61 | >75% Grass cover, Good, HSG B |
| 0.110 | 98 | Sed. Basin No. 1 - Riser Elev. |
| 2.170 | 63 | Weighted Average |
| 2.060 | | Pervious Area |
| 0.110 | | Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 3.6 | 110 | 0.2500 | 0.51 | | **Sheet Flow, Sheet Flow** Grass: Short n= 0.150 P2= 3.70" |
| 1.0 | 400 | 0.0300 | 6.43 | 57.91 | **Channel Flow, Drainage Channel** Area= 9.0 sf Perim= 9.0' r= 1.00' n= 0.040 |
| 4.6 | 510 | Total | | | |

## Subcatchment 2-1: 2-1

Runoff = 8.87 cfs @ 11.98 hrs, Volume= 0.381 af, Depth> 2.65"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 1.480 | 61 | >75% Grass cover, Good, HSG B |
| 0.250 | 98 | Sed. Basin No. 2 - Riser Elev. |
| 1.730 | 66 | Weighted Average |
| 1.480 | | Pervious Area |
| 0.250 | | Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 6.3 | 200 | 0.2000 | 0.53 | | **Sheet Flow, Sheet Flow** Grass: Short n= 0.150 P2= 3.70" |

## Subcatchment 2-2: 2-2

Runoff = 7.05 cfs @ 11.98 hrs, Volume= 0.296 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 1.620 | 61 | >75% Grass cover, Good, HSG B |
| 1.620 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 5.8 | 180 | 0.2000 | 0.52 | | **Sheet Flow, Sheet Flow**<br>Grass: Short n= 0.150 P2= 3.70" |

## Subcatchment 2-3: 2-3

Runoff = 10.55 cfs @ 11.99 hrs, Volume= 0.464 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 2.540 | 61 | >75% Grass cover, Good, HSG B |
| 2.540 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 5.3 | 180 | 0.2500 | 0.57 | | **Sheet Flow, Sheet Flow**<br>Grass: Short n= 0.150 P2= 3.70" |
| 1.7 | 580 | 0.0240 | 5.76 | 51.80 | **Channel Flow, Drainage Channel**<br>Area= 9.0 sf Perim= 9.0' r= 1.00' n= 0.040 |
| 7.0 | 760 | Total | | | |

## Subcatchment 2-4: 2-4

Runoff = 9.13 cfs @ 12.03 hrs, Volume= 0.467 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 2.560 | 61 | >75% Grass cover, Good, HSG B |
| 2.560 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 8.7 | 300 | 0.2000 | 0.57 | | **Sheet Flow, Sheet Flow**<br>Grass: Short n= 0.150 P2= 3.70" |
| 2.2 | 700 | 0.0200 | 5.25 | 47.28 | **Channel Flow, Drainage Channel**<br>Area= 9.0 sf Perim= 9.0' r= 1.00' n= 0.040 |
| 10.9 | 1,000 | Total | | | |

## Subcatchment 3-1: 3-1

Runoff = 5.26 cfs @ 11.95 hrs, Volume= 0.205 af, Depth> 2.65"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 0.810 | 61 | >75% Grass cover, Good, HSG B |
| 0.120 | 98 | Sed. Basin No. 3 - Riser Elev. |
| 0.930 | 66 | Weighted Average |
| 0.810 | | Pervious Area |
| 0.120 | | Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 3.7 | 115 | 0.2500 | 0.52 | | **Sheet Flow, Sheet Flow**<br>Grass: Short n= 0.150 P2= 3.70" |

## Subcatchment 3-2: 3-2

Runoff = 3.04 cfs @ 11.98 hrs, Volume= 0.130 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 0.710 | 61 | >75% Grass cover, Good, HSG B |
| 0.710 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 5.7 | 175 | 0.2000 | 0.51 | | **Sheet Flow, Sheet Flow**<br>Grass: Short n= 0.150 P2= 3.70" |
| 0.5 | 200 | 0.0300 | 6.43 | 57.91 | **Channel Flow, Drainage Channel**<br>Area= 9.0 sf Perim= 9.0' r= 1.00' n= 0.040 |
| 6.2 | 375 | Total | | | |

## Subcatchment 3-3: 3-3

Runoff = 8.54 cfs @ 11.98 hrs, Volume= 0.365 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 2.000 | 61 | >75% Grass cover, Good, HSG B |
| 2.000 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 6.3 | 200 | 0.2000 | 0.53 | | **Sheet Flow, Sheet Flow**<br>Grass: Short n= 0.150 P2= 3.70" |

## Subcatchment 4-1: 4-1

Runoff = 10.77 cfs @ 11.99 hrs, Volume= 0.476 af, Depth> 2.55"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 2.010 | 61 | >75% Grass cover, Good, HSG B |
| 0.230 | 98 | Sed. Basin No. 4 - Riser Elev. |
| 2.240 | 65 | Weighted Average |
| 2.010 | | Pervious Area |
| 0.230 | | Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 7.1 | 200 | 0.1500 | 0.47 | | **Sheet Flow, Sheet Flow**<br>Grass: Short n= 0.150 P2= 3.70" |

## Subcatchment 4-2: 4-2

Runoff = 15.11 cfs @ 12.00 hrs, Volume= 0.683 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 3.740 | 61 | >75% Grass cover, Good, HSG B |
| 3.740 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 6.3 | 200 | 0.2000 | 0.53 | | **Sheet Flow, Sheet Flow**<br>Grass: Short n= 0.150 P2= 3.70" |
| 1.3 | 570 | 0.0400 | 7.43 | 66.87 | **Channel Flow, Drainage Channel**<br>Area= 9.0 sf Perim= 9.0' r= 1.00' n= 0.040 |
| 0.1 | 150 | 0.2000 | 17.28 | 30.53 | **Circular Channel (pipe), Down Pipe**<br>Diam= 18.0" Area= 1.8 sf Perim= 4.7' r= 0.38'<br>n= 0.020 Corrugated PE, corrugated interior |
| 7.7 | 920 | Total | | | |

## Subcatchment 4-3: 4-3

Runoff = 5.36 cfs @ 11.98 hrs, Volume= 0.225 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 1.230 | 61 | >75% Grass cover, Good, HSG B |
| 1.230 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 5.8 | 200 | 0.2500 | 0.58 | | **Sheet Flow, Sheet Flow** Grass: Short n= 0.150 P2= 3.70" |

## Subcatchment 4-4: 4-4

Runoff = 9.36 cfs @ 11.96 hrs, Volume= 0.375 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 2.050 | 61 | >75% Grass cover, Good, HSG B |
| 2.050 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 4.6 | 150 | 0.2500 | 0.54 | | **Sheet Flow, Sheet Flow** Grass: Short n= 0.150 P2= 3.70" |

## Subcatchment 4-5: 4-5

Runoff = 7.02 cfs @ 12.00 hrs, Volume= 0.319 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 1.750 | 61 | >75% Grass cover, Good, HSG B |
| 1.750 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 4.4 | 80 | 0.0800 | 0.30 | | **Sheet Flow, Sheet Flow**<br>Grass: Short n= 0.150 P2= 3.70" |
| 3.3 | 100 | 0.2500 | 0.50 | | **Sheet Flow, Sheet Flow**<br>Grass: Short n= 0.150 P2= 3.70" |
| 0.2 | 90 | 0.0200 | 9.93 | 17.56 | **Circular Channel (pipe), Culvert**<br>Diam= 18.0" Area= 1.8 sf Perim= 4.7' r= 0.38'<br>n= 0.011 Concrete pipe, straight & clean |
| 7.9 | 270 | Total | | | |

## Subcatchment 5-1: 5-1

Runoff = 5.12 cfs @ 11.94 hrs, Volume= 0.199 af, Depth> 3.03"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 0.590 | 61 | >75% Grass cover, Good, HSG B |
| 0.200 | 98 | Sed. Basin No. 5A - Riser Elev. |
| 0.790 | 70 | Weighted Average |
| 0.590 | | Pervious Area |
| 0.200 | | Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 3.3 | 100 | 0.2500 | 0.50 | | **Sheet Flow, Sheet Flow**<br>Grass: Short n= 0.150 P2= 3.70" |

## Subcatchment 5-2: 5-2

Runoff = 3.46 cfs @ 11.96 hrs, Volume= 0.139 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 0.760 | 61 | >75% Grass cover, Good, HSG B |
| 0.760 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 4.7 | 140 | 0.2000 | 0.49 | | **Sheet Flow, Sheet Flow**<br>Grass: Short n= 0.150 P2= 3.70" |

## Subcatchment 5-3: 5-3

Runoff = 6.44 cfs @ 11.98 hrs, Volume= 0.270 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 1.480 | 61 | >75% Grass cover, Good, HSG B |
| 1.480 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 5.8 | 200 | 0.2500 | 0.58 | | **Sheet Flow, Sheet Flow** Grass: Short n= 0.150 P2= 3.70" |

## Subcatchment 5-4: 5-4

Runoff = 6.10 cfs @ 11.96 hrs, Volume= 0.241 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 1.320 | 61 | >75% Grass cover, Good, HSG B |
| 1.320 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 4.3 | 140 | 0.2500 | 0.54 | | **Sheet Flow, Sheet Flow** Grass: Short n= 0.150 P2= 3.70" |

## Subcatchment 6-1: 6-1

Runoff = 29.47 cfs @ 11.92 hrs, Volume= 1.114 af, Depth> 3.62"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 2.190 | 61 | >75% Grass cover, Good, HSG B |
| 1.500 | 98 | Sed. Basin No. 6 - Riser Elev. |
| 3.690 | 76 | Weighted Average |
| 2.190 | | Pervious Area |
| 1.500 | | Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 1.7 | 50 | 0.3300 | 0.49 | | **Sheet Flow, Sheet Flow** Grass: Short n= 0.150 P2= 3.70" |

## Subcatchment 6-10: 6-10

Runoff = 4.20 cfs @ 11.96 hrs, Volume= 0.168 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 0.920 | 61 | >75% Grass cover, Good, HSG B |
| 0.920 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 4.6 | 150 | 0.2500 | 0.54 | | **Sheet Flow, Sheet Flow** Grass: Short n= 0.150 P2= 3.70" |

## Subcatchment 6-11: 6-11

Runoff = 3.42 cfs @ 11.96 hrs, Volume= 0.137 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 0.750 | 61 | >75% Grass cover, Good, HSG B |
| 0.750 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 4.6 | 150 | 0.2500 | 0.54 | | **Sheet Flow, Sheet Flow** Grass: Short n= 0.150 P2= 3.70" |

## Subcatchment 6-12: 6-12

Runoff = 14.07 cfs @ 11.96 hrs, Volume= 0.561 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 3.070 | 61 | >75% Grass cover, Good, HSG B |
| 3.070 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 3.6 | 100 | 0.2000 | 0.46 | | **Sheet Flow, Sheet Flow** Grass: Short n= 0.150 P2= 3.70" |
| 0.9 | 400 | 0.0400 | 7.43 | 66.87 | **Channel Flow, Drainage Channel** Area= 9.0 sf Perim= 9.0' r= 1.00' n= 0.040 |
| 4.5 | 500 | Total | | | |

## Subcatchment 6-13: 6-13

Runoff = 2.48 cfs @ 11.98 hrs, Volume= 0.104 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 0.570 | 61 | >75% Grass cover, Good, HSG B |
| 0.570 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 5.8 | 200 | 0.2500 | 0.58 | | **Sheet Flow, Sheet Flow** Grass: Short n= 0.150 P2= 3.70" |

## Subcatchment 6-14: 6-14

Runoff = 9.42 cfs @ 11.99 hrs, Volume= 0.411 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 2.250 | 61 | >75% Grass cover, Good, HSG B |
| 2.250 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 5.5 | 150 | 0.1600 | 0.46 | | **Sheet Flow, Sheet Flow** Grass: Short n= 0.150 P2= 3.70" |
| 1.3 | 500 | 0.0300 | 6.43 | 57.91 | **Channel Flow, Drainage Channel** Area= 9.0 sf Perim= 9.0' r= 1.00' n= 0.040 |
| 6.8 | 650 | Total | | | |

## Subcatchment 6-15: 6-15

Runoff = 7.62 cfs @ 11.96 hrs, Volume= 0.302 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 1.650 | 61 | >75% Grass cover, Good, HSG B |
| 1.650 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 3.8 | 120 | 0.2500 | 0.52 | | **Sheet Flow, Sheet Flow** Grass: Short n= 0.150 P2= 3.70" |
| 0.5 | 200 | 0.0200 | 6.36 | 2.22 | **Circular Channel (pipe), Rain Gutter** Diam= 8.0" Area= 0.3 sf Perim= 2.1' r= 0.17' n= 0.010 |
| 4.3 | 320 | Total | | | |

## Subcatchment 6-2: 6-2

Runoff = 9.69 cfs @ 11.96 hrs, Volume= 0.382 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 2.090 | 61 | >75% Grass cover, Good, HSG B |
| 2.090 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 4.2 | 135 | 0.2500 | 0.53 | | **Sheet Flow, Sheet Flow** Grass: Short n= 0.150 P2= 3.70" |

## Subcatchment 6-3: 6-3

Runoff = 3.22 cfs @ 11.94 hrs, Volume= 0.123 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 0.670 | 61 | >75% Grass cover, Good, HSG B |
| 0.670 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 3.3 | 100 | 0.2500 | 0.50 | | **Sheet Flow, Sheet Flow** Grass: Short n= 0.150 P2= 3.70" |

## Subcatchment 6-4: 6-4

Runoff = 8.86 cfs @ 12.16 hrs, Volume= 0.653 af, Depth> 2.18"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 3.600 | 61 | >75% Grass cover, Good, HSG B |
| 3.600 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 21.9 | 300 | 0.0200 | 0.23 | | **Sheet Flow, Sheet Flow** Grass: Short n= 0.150 P2= 3.70" |

## Subcatchment 6-5: 6-5

Runoff = 12.15 cfs @ 11.95 hrs, Volume= 0.472 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 2.580 | 61 | >75% Grass cover, Good, HSG B |
| 2.580 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 3.8 | 120 | 0.2500 | 0.52 | | **Sheet Flow, Sheet Flow** Grass: Short n= 0.150 P2= 3.70" |

## Subcatchment 6-6: 6-6

Runoff = 1.34 cfs @ 11.97 hrs, Volume= 0.055 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 0.300 | 61 | >75% Grass cover, Good, HSG B |
| 0.300 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 5.1 | 170 | 0.2500 | 0.56 | | **Sheet Flow, Sheet Flow** Grass: Short n= 0.150 P2= 3.70" |

## Subcatchment 6-7: 6-7

Runoff = 3.28 cfs @ 11.96 hrs, Volume= 0.130 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 0.710 | 61 | >75% Grass cover, Good, HSG B |
| 0.710 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 4.3 | 140 | 0.2500 | 0.54 | | **Sheet Flow, Sheet Flow**<br>Grass: Short n= 0.150 P2= 3.70" |

## Subcatchment 6-8: 6-8

Runoff = 13.62 cfs @ 12.19 hrs, Volume= 1.083 af, Depth> 2.17"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 5.980 | 61 | >75% Grass cover, Good, HSG B |
| 5.980 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 24.6 | 300 | 0.0150 | 0.20 | | **Sheet Flow, Sheet Flow**<br>Grass: Short n= 0.150 P2= 3.70" |
| 0.1 | 150 | 0.2000 | 17.28 | 30.53 | **Circular Channel (pipe), Down Pipe**<br>Diam= 18.0" Area= 1.8 sf Perim= 4.7' r= 0.38'<br>n= 0.020 Corrugated PE, corrugated interior |
| 24.7 | 450 | Total | | | |

## Subcatchment 6-9: 6-9

Runoff = 3.23 cfs @ 11.96 hrs, Volume= 0.128 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 0.700 | 61 | >75% Grass cover, Good, HSG B |
| 0.700 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 4.3 | 140 | 0.2500 | 0.54 | | **Sheet Flow, Sheet Flow** Grass: Short n= 0.150 P2= 3.70" |

## Subcatchment DP-11: DP-11

Runoff = 4.09 cfs @ 11.97 hrs, Volume= 0.166 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 0.910 | 61 | >75% Grass cover, Good, HSG B |
| 0.910 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 4.6 | 150 | 0.2500 | 0.54 | | **Sheet Flow, Sheet Flow** Grass: Short n= 0.150 P2= 3.70" |
| 0.3 | 150 | 0.0400 | 9.00 | 3.14 | **Circular Channel (pipe), Rain Gutter** Diam= 8.0" Area= 0.3 sf Perim= 2.1' r= 0.17' n= 0.010 |
| 0.1 | 150 | 0.2500 | 38.64 | 68.28 | **Circular Channel (pipe), Down Pipe** Diam= 18.0" Area= 1.8 sf Perim= 4.7' r= 0.38' n= 0.010 |
| 5.0 | 450 | Total | | | |

## Subcatchment DP-12: DP-12

Runoff = 7.72 cfs @ 11.95 hrs, Volume= 0.300 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 1.640 | 61 | >75% Grass cover, Good, HSG B |
| 1.640 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 3.3 | 100 | 0.2500 | 0.50 | | **Sheet Flow, Sheet Flow** Grass: Short n= 0.150 P2= 3.70" |
| 0.4 | 140 | 0.0200 | 6.36 | 2.22 | **Circular Channel (pipe), Rain Gutter** Diam= 8.0" Area= 0.3 sf Perim= 2.1' r= 0.17' n= 0.010 |
| 0.1 | 170 | 0.2500 | 38.64 | 68.28 | **Circular Channel (pipe), Down Pipe** Diam= 18.0" Area= 1.8 sf Perim= 4.7' r= 0.38' n= 0.010 |
| 3.8 | 410 | Total | | | |

## Subcatchment DP-21: DP-21

Runoff = 7.21 cfs @ 11.97 hrs, Volume= 0.294 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 1.610 | 61 | >75% Grass cover, Good, HSG B |
| 1.610 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 4.6 | 150 | 0.2500 | 0.54 | | **Sheet Flow, Sheet Flow** Grass: Short n= 0.150 P2= 3.70" |
| 0.4 | 150 | 0.0200 | 6.36 | 2.22 | **Circular Channel (pipe), Rain Gutter** Diam= 8.0" Area= 0.3 sf Perim= 2.1' r= 0.17' n= 0.010 |
| 0.1 | 175 | 0.2000 | 34.56 | 61.07 | **Circular Channel (pipe), Down Pipe** Diam= 18.0" Area= 1.8 sf Perim= 4.7' r= 0.38' n= 0.010 |
| 5.1 | 475 | Total | | | |

## Subcatchment DP-22: DP-22

Runoff = 11.24 cfs @ 11.97 hrs, Volume= 0.466 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 2.550 | 61 | >75% Grass cover, Good, HSG B |
| 2.550 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 4.7 | 140 | 0.2000 | 0.49 | | **Sheet Flow, Sheet Flow** Grass: Short n= 0.150 P2= 3.70" |
| 0.7 | 370 | 0.0400 | 9.00 | 3.14 | **Circular Channel (pipe), Rain Gutter** Diam= 8.0" Area= 0.3 sf Perim= 2.1' r= 0.17' n= 0.010 |
| 0.1 | 300 | 0.2500 | 38.64 | 68.28 | **Circular Channel (pipe), Down Pipe** Diam= 18.0" Area= 1.8 sf Perim= 4.7' r= 0.38' n= 0.010 |
| 5.5 | 810 | Total | | | |

## Subcatchment DP-23: DP-23

Runoff = 13.33 cfs @ 11.97 hrs, Volume= 0.546 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 2.990 | 61 | >75% Grass cover, Good, HSG B |
| 2.990 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 4.6 | 150 | 0.2500 | 0.54 | | **Sheet Flow, Sheet Flow** Grass: Short n= 0.150 P2= 3.70" |
| 0.5 | 250 | 0.0400 | 9.00 | 3.14 | **Circular Channel (pipe), Rain Gutter** Diam= 8.0" Area= 0.3 sf Perim= 2.1' r= 0.17' n= 0.010 |
| 0.1 | 250 | 0.2500 | 38.64 | 68.28 | **Circular Channel (pipe), Down Pipe** Diam= 18.0" Area= 1.8 sf Perim= 4.7' r= 0.38' n= 0.010 |
| 5.2 | 650 | Total | | | |

## Subcatchment DP-51: DP-51

Runoff = 18.87 cfs @ 12.04 hrs, Volume= 0.999 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 5.480 | 61 | >75% Grass cover, Good, HSG B |
| 5.480 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 10.5 | 240 | 0.0800 | 0.38 | | **Sheet Flow, Sheet Flow** Grass: Short n= 0.150 P2= 3.70" |
| 0.9 | 200 | 0.0100 | 3.72 | 115.16 | **Channel Flow, Cap Diversion Berm** Area= 31.0 sf Perim= 31.0' r= 1.00' n= 0.040 |
| 0.4 | 860 | 0.2000 | 34.56 | 61.07 | **Circular Channel (pipe), Down Pipe** Diam= 18.0" Area= 1.8 sf Perim= 4.7' r= 0.38' n= 0.010 |
| 11.8 | 1,300 | Total | | | |

## Subcatchment DP-52: DP-52

Runoff = 15.67 cfs @ 11.96 hrs, Volume= 0.625 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 3.420 | 61 | >75% Grass cover, Good, HSG B |
| 3.420 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 4.0 | 125 | 0.2500 | 0.53 | | **Sheet Flow, Sheet Flow** Grass: Short n= 0.150 P2= 3.70" |
| 0.3 | 180 | 0.0400 | 9.00 | 3.14 | **Circular Channel (pipe), Rain Gutter** Diam= 8.0" Area= 0.3 sf Perim= 2.1' r= 0.17' n= 0.010 |
| 0.2 | 550 | 0.2500 | 38.64 | 68.28 | **Circular Channel (pipe), Down Pipe** Diam= 18.0" Area= 1.8 sf Perim= 4.7' r= 0.38' n= 0.010 |
| 4.5 | 855 | Total | | | |

## Subcatchment DP-61: DP-61

Runoff = 16.96 cfs @ 11.95 hrs, Volume= 0.658 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 3.600 | 61 | >75% Grass cover, Good, HSG B |
| 3.600 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 3.3 | 100 | 0.2500 | 0.50 | | **Sheet Flow, Sheet Flow** Grass: Short n= 0.150 P2= 3.70" |
| 0.4 | 200 | 0.0400 | 9.00 | 3.14 | **Circular Channel (pipe), Rain Gutter** Diam= 8.0" Area= 0.3 sf Perim= 2.1' r= 0.17' n= 0.010 |
| 0.1 | 300 | 0.2500 | 38.64 | 68.28 | **Circular Channel (pipe), Down Pipe** Diam= 18.0" Area= 1.8 sf Perim= 4.7' r= 0.38' n= 0.010 |
| 3.8 | 600 | Total | | | |

## Subcatchment DP-62: DP-62

Runoff = 7.02 cfs @ 11.95 hrs, Volume= 0.272 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 1.490 | 61 | >75% Grass cover, Good, HSG B |
| 1.490 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 3.3 | 100 | 0.2500 | 0.50 | | **Sheet Flow, Sheet Flow** Grass: Short n= 0.150 P2= 3.70" |
| 0.3 | 150 | 0.0400 | 9.00 | 3.14 | **Circular Channel (pipe), Rain Gutter** Diam= 8.0" Area= 0.3 sf Perim= 2.1' r= 0.17' n= 0.010 |
| 0.2 | 350 | 0.1500 | 29.93 | 52.89 | **Circular Channel (pipe), Down Pipe** Diam= 18.0" Area= 1.8 sf Perim= 4.7' r= 0.38' n= 0.010 |
| 3.8 | 600 | Total | | | |

## Subcatchment DP-63: DP-63

Runoff = 10.12 cfs @ 11.96 hrs, Volume= 0.402 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 2.200 | 61 | >75% Grass cover, Good, HSG B |
| 2.200 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 4.0 | 125 | 0.2500 | 0.53 | | **Sheet Flow, Sheet Flow** Grass: Short n= 0.150 P2= 3.70" |
| 0.3 | 150 | 0.0400 | 9.00 | 3.14 | **Circular Channel (pipe), Rain Gutter** Diam= 8.0" Area= 0.3 sf Perim= 2.1' r= 0.17' n= 0.010 |
| 0.1 | 300 | 0.2500 | 38.64 | 68.28 | **Circular Channel (pipe), Down Pipe** Diam= 18.0" Area= 1.8 sf Perim= 4.7' r= 0.38' n= 0.010 |
| 4.4 | 575 | Total | | | |

## Subcatchment DP-64: DP-64

Runoff = 11.30 cfs @ 11.95 hrs, Volume= 0.437 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 2.390 | 61 | >75% Grass cover, Good, HSG B |
| 2.390 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 3.3 | 100 | 0.2500 | 0.50 | | **Sheet Flow, Sheet Flow** Grass: Short n= 0.150 P2= 3.70" |
| 0.3 | 150 | 0.0400 | 9.00 | 3.14 | **Circular Channel (pipe), Rain Gutter** Diam= 8.0" Area= 0.3 sf Perim= 2.1' r= 0.17' n= 0.010 |
| 0.1 | 250 | 0.2500 | 38.64 | 68.28 | **Circular Channel (pipe), Down Pipe** Diam= 18.0" Area= 1.8 sf Perim= 4.7' r= 0.38' n= 0.010 |
| 3.7 | 500 | Total | | | |

## Subcatchment DP-65: DP-65

Runoff = 16.27 cfs @ 12.04 hrs, Volume= 0.835 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 4.580 | 61 | >75% Grass cover, Good, HSG B |
| 4.580 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 9.1 | 200 | 0.0800 | 0.37 | | **Sheet Flow, Sheet Flow** Grass: Short n= 0.150 P2= 3.70" |
| 1.6 | 350 | 0.0100 | 3.72 | 115.16 | **Channel Flow, Cap Diversion Berm** Area= 31.0 sf Perim= 31.0' r= 1.00' n= 0.040 |
| 0.3 | 590 | 0.2000 | 34.56 | 61.07 | **Circular Channel (pipe), Down Pipe** Diam= 18.0" Area= 1.8 sf Perim= 4.7' r= 0.38' n= 0.010 |
| 11.0 | 1,140 | Total | | | |

## Subcatchment DP-66: DP-66

Runoff = 13.00 cfs @ 12.05 hrs, Volume= 0.696 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 3.820 | 61 | >75% Grass cover, Good, HSG B |
| 3.820 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 10.2 | 230 | 0.0800 | 0.38 | | **Sheet Flow, Sheet Flow** Grass: Short n= 0.150 P2= 3.70" |
| 1.6 | 350 | 0.0100 | 3.72 | 115.16 | **Channel Flow, Cap Diversion Berm** Area= 31.0 sf Perim= 31.0' r= 1.00' n= 0.040 |
| 0.3 | 690 | 0.2000 | 34.56 | 61.07 | **Circular Channel (pipe), Down Pipe** Diam= 18.0" Area= 1.8 sf Perim= 4.7' r= 0.38' n= 0.010 |
| 12.1 | 1,270 | Total | | | |

## Subcatchment DP-67: DP-67

Runoff = 4.92 cfs @ 11.95 hrs, Volume= 0.190 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 1.040 | 61 | >75% Grass cover, Good, HSG B |
| 1.040 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 2.9 | 85 | 0.2500 | 0.49 | | **Sheet Flow, Sheet Flow** Grass: Short n= 0.150 P2= 3.70" |
| 0.8 | 430 | 0.0400 | 9.00 | 3.14 | **Circular Channel (pipe), Rain Gutter** Diam= 8.0" Area= 0.3 sf Perim= 2.1' r= 0.17' n= 0.010 |
| 0.0 | 90 | 0.2500 | 38.64 | 68.28 | **Circular Channel (pipe), Down Pipe** Diam= 18.0" Area= 1.8 sf Perim= 4.7' r= 0.38' n= 0.010 |
| 3.7 | 605 | Total | | | |

## Subcatchment DP41: DP-41

Runoff = 17.98 cfs @ 12.03 hrs, Volume= 0.913 af, Depth> 2.19"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Johnston 25Yr 24Hr Rainfall=6.60"

| Area (ac) | CN | Description |
|---|---|---|
| 5.010 | 61 | >75% Grass cover, Good, HSG B |
| 5.010 | | Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 9.1 | 200 | 0.0800 | 0.37 | | **Sheet Flow, Sheet Flow** Grass: Short n= 0.150 P2= 3.70" |
| 1.2 | 270 | 0.0100 | 3.72 | 115.16 | **Channel Flow, Cap Diversion Berm** Area= 31.0 sf Perim= 31.0' r= 1.00' n= 0.040 |
| 0.4 | 815 | 0.2000 | 34.56 | 61.07 | **Circular Channel (pipe), Down Pipe** Diam= 18.0" Area= 1.8 sf Perim= 4.7' r= 0.38' n= 0.010 |
| 10.7 | 1,285 | Total | | | |

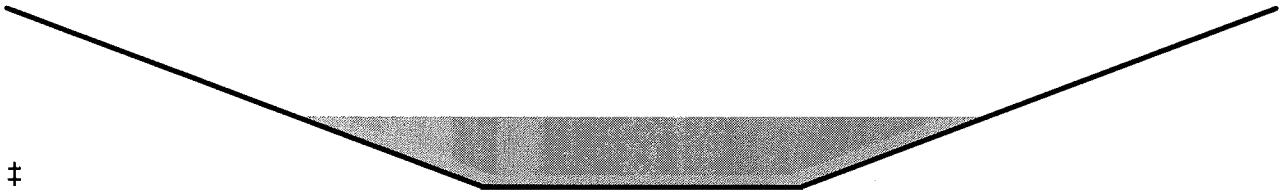
## Reach 21AB: DC-21AB

Inflow Area = 7.150 ac, Inflow Depth > 2.19" for Johnston 25Yr 24Hr event
Inflow = 30.68 cfs @ 11.98 hrs, Volume= 1.306 af
Outflow = 29.96 cfs @ 11.99 hrs, Volume= 1.303 af, Atten= 2%, Lag= 1.0 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 5.96 fps, Min. Travel Time= 1.4 min
Avg. Velocity = 1.95 fps, Avg. Travel Time= 4.3 min

Peak Storage= 2,511 cf @ 11.99 hrs, Average Depth at Peak Storage= 0.79'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 198.69 cfs

4.00' x 2.00' deep channel, n= 0.040
Side Slope Z-value= 3.0 '/' Top Width= 16.00'
Length= 500.0' Slope= 0.0560 '/'
Inlet Invert= 180.00', Outlet Invert= 152.00'



‡

## Reach 21BC: DC-21BC

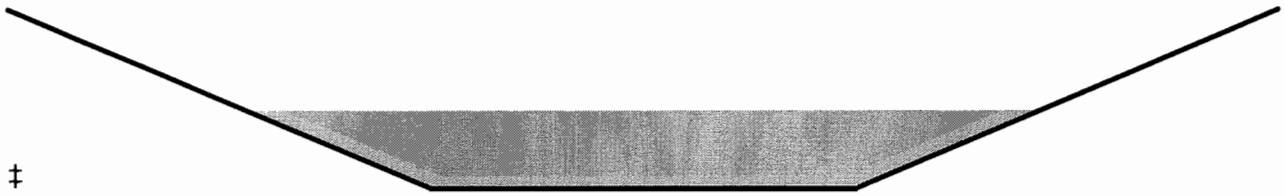
[61] Hint: Submerged 3% of Reach 21AB bottom

Inflow Area = 9.700 ac, Inflow Depth > 2.19" for Johnston 25Yr 24Hr event
Inflow = 40.87 cfs @ 11.99 hrs, Volume= 1.769 af
Outflow = 40.76 cfs @ 11.99 hrs, Volume= 1.767 af, Atten= 0%, Lag= 0.3 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 5.46 fps, Min. Travel Time= 0.5 min
Avg. Velocity = 1.71 fps, Avg. Travel Time= 1.5 min

Peak Storage= 1,119 cf @ 11.99 hrs, Average Depth at Peak Storage= 0.87'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 206.71 cfs

6.00' x 2.00' deep channel, n= 0.050
Side Slope Z-value= 3.0 '/' Top Width= 18.00'
Length= 150.0' Slope= 0.0600 '/'
Inlet Invert= 152.00', Outlet Invert= 143.00'



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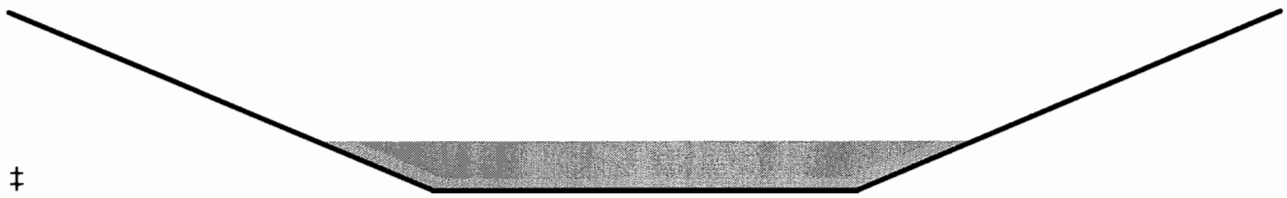
## Reach 31BC: DC-31BC

Inflow Area = 2.710 ac, Inflow Depth > 2.19" for Johnston 25Yr 24Hr event
Inflow = 11.58 cfs @ 11.98 hrs, Volume= 0.495 af
Outflow = 11.51 cfs @ 11.99 hrs, Volume= 0.494 af, Atten= 1%, Lag= 0.5 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 2.73 fps, Min. Travel Time= 0.7 min
Avg. Velocity = 0.82 fps, Avg. Travel Time= 2.4 min

Peak Storage= 505 cf @ 11.99 hrs, Average Depth at Peak Storage= 0.55'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 133.43 cfs

6.00' x 2.00' deep channel, n= 0.050
Side Slope Z-value= 3.0 '/' Top Width= 18.00'
Length= 120.0' Slope= 0.0250 '/'
Inlet Invert= 180.00', Outlet Invert= 177.00'



‡

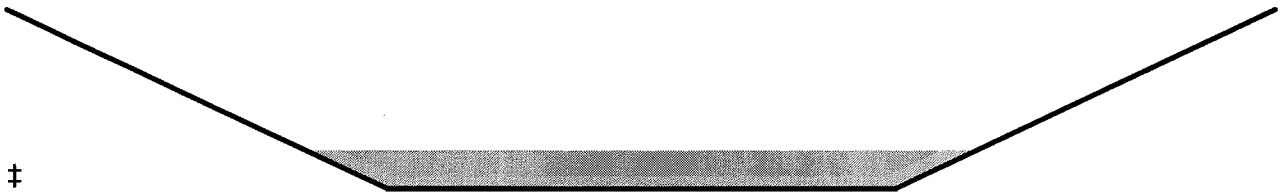
## Reach 41AB: DC-41AB

Inflow Area = 3.800 ac, Inflow Depth > 2.19" for Johnston 25Yr 24Hr event
Inflow = 15.84 cfs @ 11.97 hrs, Volume= 0.694 af
Outflow = 15.38 cfs @ 11.99 hrs, Volume= 0.692 af, Atten= 3%, Lag= 1.1 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 3.85 fps, Min. Travel Time= 1.7 min
Avg. Velocity = 1.12 fps, Avg. Travel Time= 5.9 min

Peak Storage= 1,598 cf @ 11.99 hrs, Average Depth at Peak Storage= 0.43'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 254.87 cfs

8.00' x 2.00' deep channel, n= 0.040
Side Slope Z-value= 3.0 '/' Top Width= 20.00'
Length= 400.0' Slope= 0.0400 '/'
Inlet Invert= 256.00', Outlet Invert= 240.00'



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## Reach 41BC: DC-41BC

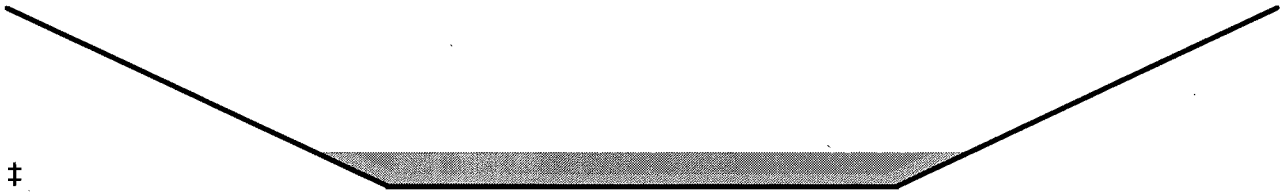
[61] Hint: Submerged 2% of Reach 41AB bottom

Inflow Area = 5.030 ac, Inflow Depth > 2.19" for Johnston 25Yr 24Hr event
Inflow = 20.64 cfs @ 11.99 hrs, Volume= 0.916 af
Outflow = 20.46 cfs @ 12.00 hrs, Volume= 0.914 af, Atten= 1%, Lag= 0.6 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 5.73 fps, Min. Travel Time= 0.9 min
Avg. Velocity = 1.67 fps, Avg. Travel Time= 3.2 min

Peak Storage= 1,141 cf @ 12.00 hrs, Average Depth at Peak Storage= 0.39'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 402.98 cfs

8.00' x 2.00' deep channel, n= 0.050
Side Slope Z-value= 3.0 '/' Top Width= 20.00'
Length= 320.0' Slope= 0.1563 '/'
Inlet Invert= 240.00', Outlet Invert= 190.00'



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## Reach 41CD: DC-41CD

[61] Hint: Submerged 1% of Reach 41BC bottom

Inflow Area = 5.030 ac, Inflow Depth > 2.18" for Johnston 25Yr 24Hr event
Inflow = 20.46 cfs @ 12.00 hrs, Volume= 0.914 af
Outflow = 20.16 cfs @ 12.01 hrs, Volume= 0.912 af, Atten= 1%, Lag= 0.8 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 4.93 fps, Min. Travel Time= 1.2 min
Avg. Velocity = 1.45 fps, Avg. Travel Time= 4.2 min

Peak Storage= 1,473 cf @ 12.01 hrs, Average Depth at Peak Storage= 0.44'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 322.39 cfs

8.00' x 2.00' deep channel, n= 0.050
Side Slope Z-value= 3.0 '/' Top Width= 20.00'
Length= 360.0' Slope= 0.1000 '/'
Inlet Invert= 190.00', Outlet Invert= 154.00'

‡

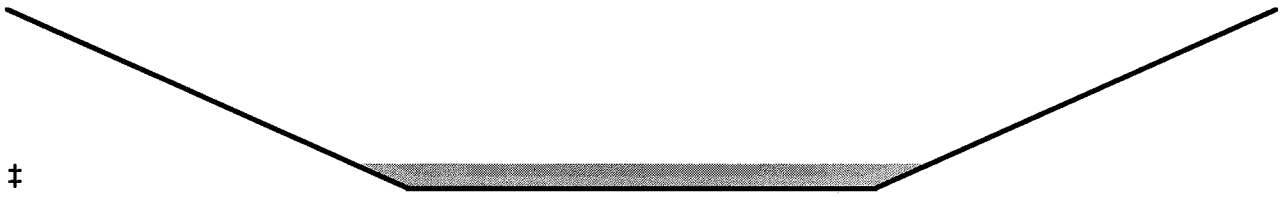
## Reach 51AB: DC-51AB

Inflow Area = 1.320 ac, Inflow Depth > 2.19" for Johnston 25Yr 24Hr event
Inflow = 6.10 cfs @ 11.96 hrs, Volume= 0.241 af
Outflow = 5.86 cfs @ 11.98 hrs, Volume= 0.240 af, Atten= 4%, Lag= 1.1 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 2.70 fps, Min. Travel Time= 1.8 min
Avg. Velocity = 0.77 fps, Avg. Travel Time= 6.5 min

Peak Storage= 649 cf @ 11.98 hrs, Average Depth at Peak Storage= 0.28'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 215.08 cfs

7.00' x 2.00' deep channel, n= 0.050
Side Slope Z-value= 3.0 '/' Top Width= 19.00'
Length= 300.0' Slope= 0.0533 '/'
Inlet Invert= 270.00', Outlet Invert= 254.00'



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## Reach 51BC: DC-51BC

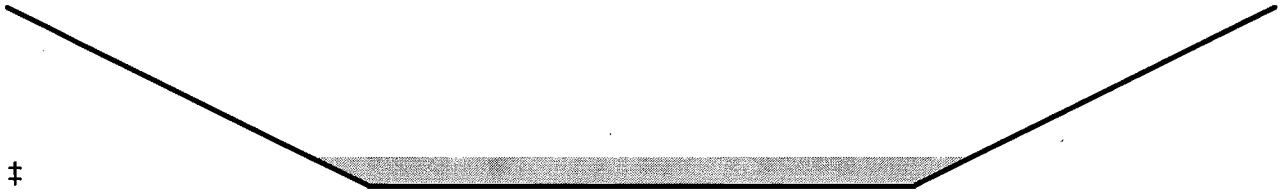
[61] Hint: Submerged 2% of Reach 51AB bottom

Inflow Area = 3.560 ac, Inflow Depth > 2.19" for Johnston 25Yr 24Hr event
Inflow = 15.70 cfs @ 11.97 hrs, Volume= 0.650 af
Outflow = 14.53 cfs @ 12.00 hrs, Volume= 0.645 af, Atten= 7%, Lag= 1.7 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 4.52 fps, Min. Travel Time= 2.9 min
Avg. Velocity = 1.30 fps, Avg. Travel Time= 10.2 min

Peak Storage= 2,570 cf @ 12.00 hrs, Average Depth at Peak Storage= 0.32'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 383.90 cfs

9.00' x 2.00' deep channel, n= 0.050
Side Slope Z-value= 3.0 '/' Top Width= 21.00'
Length= 800.0' Slope= 0.1200 '/'
Inlet Invert= 254.00', Outlet Invert= 158.00'



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## Reach 61AB: DC-61

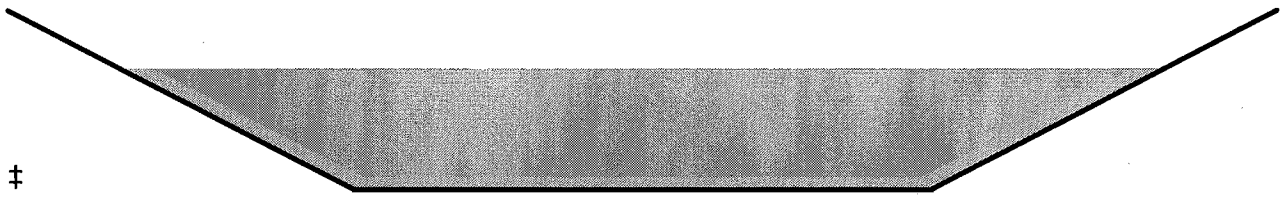
[61] Hint: Submerged 87% of Reach 62BC bottom

Inflow Area = 37.110 ac, Inflow Depth > 2.18" for Johnston 25Yr 24Hr event
Inflow = 89.97 cfs @ 12.00 hrs, Volume= 6.745 af
Outflow = 86.25 cfs @ 12.04 hrs, Volume= 6.713 af, Atten= 4%, Lag= 2.4 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 4.53 fps, Min. Travel Time= 2.9 min
Avg. Velocity = 1.74 fps, Avg. Travel Time= 7.7 min

Peak Storage= 15,222 cf @ 12.04 hrs, Average Depth at Peak Storage= 1.35'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 179.62 cfs

10.00' x 2.00' deep channel, n= 0.050
Side Slope Z-value= 3.0 '/' Top Width= 22.00'
Length= 800.0' Slope= 0.0225 '/'
Inlet Invert= 176.00', Outlet Invert= 158.00'



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## Reach 62AB: DC-62AB

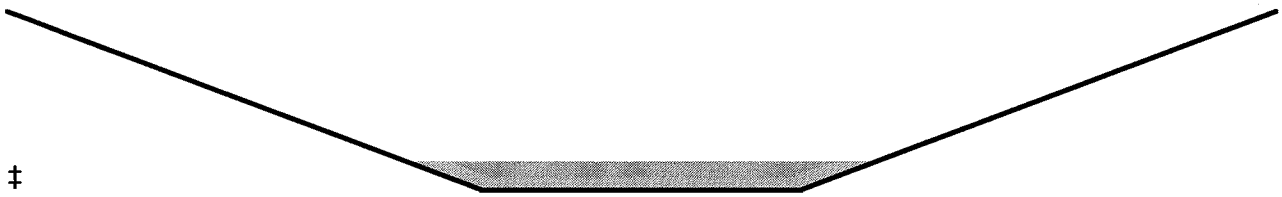
[61] Hint: Submerged 10% of Reach 64BC bottom

Inflow Area = 1.010 ac, Inflow Depth > 2.19" for Johnston 25Yr 24Hr event
Inflow = 4.55 cfs @ 11.98 hrs, Volume= 0.184 af
Outflow = 4.18 cfs @ 12.00 hrs, Volume= 0.183 af, Atten= 8%, Lag= 1.7 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 2.59 fps, Min. Travel Time= 2.9 min
Avg. Velocity = 0.79 fps, Avg. Travel Time= 9.5 min

Peak Storage= 725 cf @ 12.00 hrs, Average Depth at Peak Storage= 0.32'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 141.61 cfs

4.00' x 2.00' deep channel, n= 0.050
Side Slope Z-value= 3.0 '/' Top Width= 16.00'
Length= 450.0' Slope= 0.0444 '/'
Inlet Invert= 198.00', Outlet Invert= 178.00'



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## Reach 62BC: DC-62BC

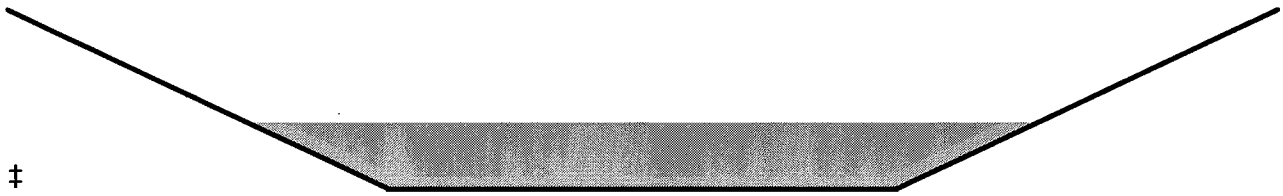
[61] Hint: Submerged 4% of Reach 62AB bottom

Inflow Area = 5.980 ac, Inflow Depth > 2.19" for Johnston 25Yr 24Hr event
Inflow = 26.80 cfs @ 11.95 hrs, Volume= 1.092 af
Outflow = 26.51 cfs @ 11.96 hrs, Volume= 1.090 af, Atten= 1%, Lag= 0.6 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 3.51 fps, Min. Travel Time= 0.9 min
Avg. Velocity = 1.03 fps, Avg. Travel Time= 2.9 min

Peak Storage= 1,360 cf @ 11.96 hrs, Average Depth at Peak Storage= 0.74'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 169.91 cfs

8.00' x 2.00' deep channel, n= 0.050
Side Slope Z-value= 3.0 '/' Top Width= 20.00'
Length= 180.0' Slope= 0.0278 '/'
Inlet Invert= 178.00', Outlet Invert= 173.00'



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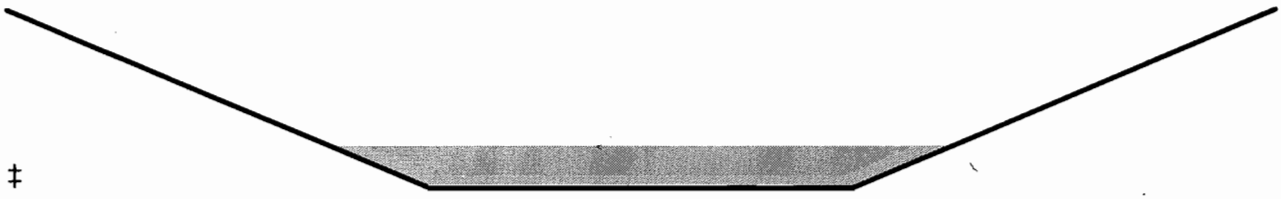
## Reach 63AB: DC-63AB

Inflow Area = 2.090 ac, Inflow Depth > 2.19" for Johnston 25Yr 24Hr event
Inflow = 9.69 cfs @ 11.96 hrs, Volume= 0.382 af
Outflow = 9.31 cfs @ 11.97 hrs, Volume= 0.381 af, Atten= 4%, Lag= 1.1 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 2.65 fps, Min. Travel Time= 1.8 min
Avg. Velocity = 0.77 fps, Avg. Travel Time= 6.1 min

Peak Storage= 983 cf @ 11.97 hrs, Average Depth at Peak Storage= 0.47'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 140.97 cfs

6.00' x 2.00' deep channel, n= 0.040
Side Slope Z-value= 3.0 '/' Top Width= 18.00'
Length= 280.0' Slope= 0.0179 '/'
Inlet Invert= 165.00', Outlet Invert= 160.00'



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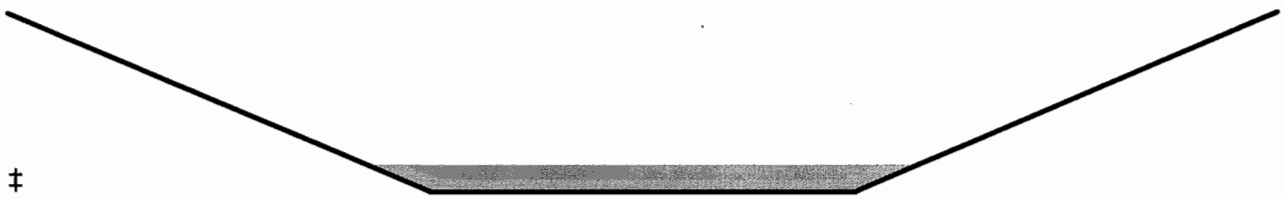
## Reach 63CD: DC-63CD

Inflow Area = 0.670 ac, Inflow Depth > 2.19" for Johnston 25Yr 24Hr event
Inflow = 3.22 cfs @ 11.94 hrs, Volume= 0.123 af
Outflow = 2.98 cfs @ 11.97 hrs, Volume= 0.122 af, Atten= 7%, Lag= 1.4 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 1.45 fps, Min. Travel Time= 2.5 min
Avg. Velocity = 0.41 fps, Avg. Travel Time= 8.9 min

Peak Storage= 453 cf @ 11.97 hrs, Average Depth at Peak Storage= 0.30'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 100.58 cfs

6.00' x 2.00' deep channel, n= 0.040
Side Slope Z-value= 3.0 '/' Top Width= 18.00'
Length= 220.0' Slope= 0.0091 '/'
Inlet Invert= 164.00', Outlet Invert= 162.00'



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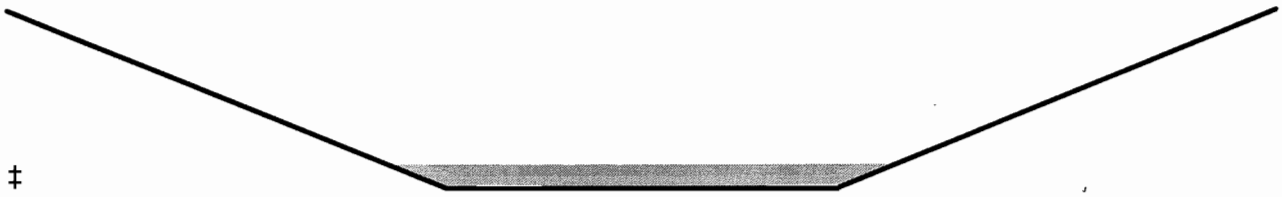
## Reach 64AB: DC-64AB

Inflow Area = 0.710 ac, Inflow Depth > 2.19" for Johnston 25Yr 24Hr event
Inflow = 3.28 cfs @ 11.96 hrs, Volume= 0.130 af
Outflow = 3.24 cfs @ 11.97 hrs, Volume= 0.130 af, Atten= 1%, Lag= 0.6 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 3.50 fps, Min. Travel Time= 1.0 min
Avg. Velocity = 1.00 fps, Avg. Travel Time= 3.3 min

Peak Storage= 185 cf @ 11.97 hrs, Average Depth at Peak Storage= 0.20'
Bank-Full Depth= 1.50', Capacity at Bank-Full= 136.87 cfs

4.00' x 1.50' deep channel, n= 0.040
Side Slope Z-value= 3.0 '/' Top Width= 13.00'
Length= 200.0' Slope= 0.0900 '/'
Inlet Invert= 256.00', Outlet Invert= 238.00'



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## Reach 64BC: DC-64BC

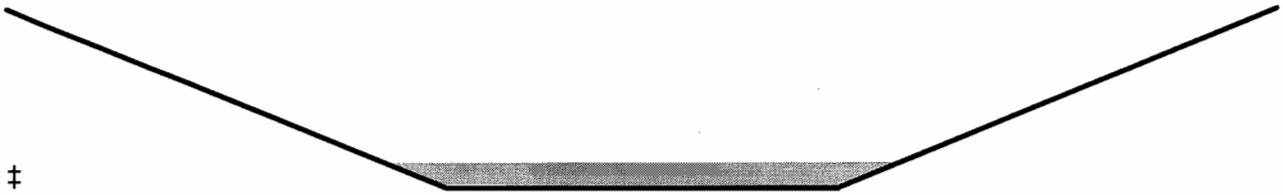
[61] Hint: Submerged 1% of Reach 64AB bottom

Inflow Area = 1.010 ac, Inflow Depth > 2.19" for Johnston 25Yr 24Hr event
Inflow = 4.58 cfs @ 11.97 hrs, Volume= 0.184 af
Outflow = 4.55 cfs @ 11.98 hrs, Volume= 0.184 af, Atten= 1%, Lag= 0.4 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 4.62 fps, Min. Travel Time= 0.7 min
Avg. Velocity = 1.33 fps, Avg. Travel Time= 2.4 min

Peak Storage= 187 cf @ 11.98 hrs, Average Depth at Peak Storage= 0.21'
Bank-Full Depth= 1.50', Capacity at Bank-Full= 175.65 cfs

4.00' x 1.50' deep channel, n= 0.050
Side Slope Z-value= 3.0 '/' Top Width= 13.00'
Length= 190.0' Slope= 0.2316 '/'
Inlet Invert= 238.00', Outlet Invert= 194.00'



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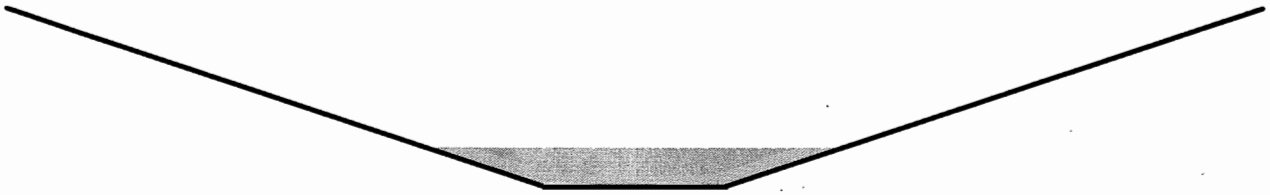
## Reach 65AB: DC-65

Inflow Area = 25.330 ac, Inflow Depth > 2.18" for Johnston 25Yr 24Hr event
Inflow = 63.25 cfs @ 12.08 hrs, Volume= 4.611 af
Outflow = 62.87 cfs @ 12.10 hrs, Volume= 4.600 af, Atten= 1%, Lag= 1.3 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 4.77 fps, Min. Travel Time= 1.6 min
Avg. Velocity = 1.93 fps, Avg. Travel Time= 3.9 min

Peak Storage= 5,931 cf @ 12.10 hrs, Average Depth at Peak Storage= 1.32'
Bank-Full Depth= 6.00', Capacity at Bank-Full= 1,604.71 cfs

6.00' x 6.00' deep channel, n= 0.050
Side Slope Z-value= 3.0 '/' Top Width= 42.00'
Length= 450.0' Slope= 0.0289 '/'
Inlet Invert= 191.00', Outlet Invert= 178.00'



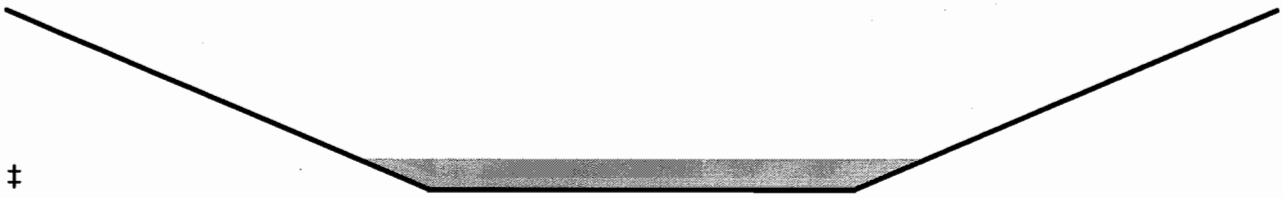
## Reach 66AB: DC-66AB

Inflow Area = 1.790 ac, Inflow Depth > 2.19" for Johnston 25Yr 24Hr event
Inflow = 8.31 cfs @ 11.95 hrs, Volume= 0.327 af
Outflow = 8.15 cfs @ 11.97 hrs, Volume= 0.326 af, Atten= 2%, Lag= 0.8 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 3.39 fps, Min. Travel Time= 1.2 min
Avg. Velocity = 0.97 fps, Avg. Travel Time= 4.1 min

Peak Storage= 576 cf @ 11.97 hrs, Average Depth at Peak Storage= 0.34'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 217.90 cfs

6.00' x 2.00' deep channel, n= 0.050
Side Slope Z-value= 3.0 '/' Top Width= 18.00'
Length= 240.0' Slope= 0.0667 '/'
Inlet Invert= 256.00', Outlet Invert= 240.00'



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## Reach 66BC: DC-66BC

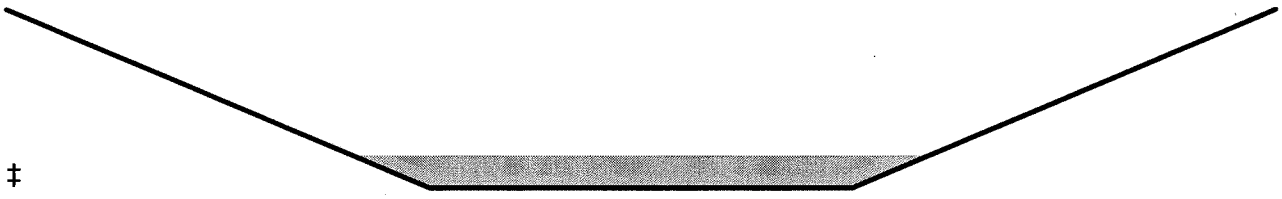
[61] Hint: Submerged 2% of Reach 66AB bottom

Inflow Area = 2.710 ac, Inflow Depth > 2.19" for Johnston 25Yr 24Hr event
Inflow = 12.34 cfs @ 11.96 hrs, Volume= 0.495 af
Outflow = 12.05 cfs @ 11.98 hrs, Volume= 0.493 af, Atten= 2%, Lag= 0.9 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 4.67 fps, Min. Travel Time= 1.3 min
Avg. Velocity = 1.34 fps, Avg. Travel Time= 4.7 min

Peak Storage= 968 cf @ 11.98 hrs, Average Depth at Peak Storage= 0.36'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 289.07 cfs

6.00' x 2.00' deep channel, n= 0.050
Side Slope Z-value= 3.0 '/' Top Width= 18.00'
Length= 375.0' Slope= 0.1173 '/'
Inlet Invert= 240.00', Outlet Invert= 196.00'



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## Reach 67AB: DC-67AB

Inflow Area = 1.650 ac, Inflow Depth > 2.19" for Johnston 25Yr 24Hr event
Inflow = 7.62 cfs @ 11.96 hrs, Volume= 0.302 af
Outflow = 7.50 cfs @ 11.97 hrs, Volume= 0.301 af, Atten= 2%, Lag= 0.7 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 4.18 fps, Min. Travel Time= 1.1 min
Avg. Velocity = 1.17 fps, Avg. Travel Time= 4.0 min

Peak Storage= 502 cf @ 11.97 hrs, Average Depth at Peak Storage= 0.23'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 369.20 cfs

7.00' x 2.00' deep channel, n= 0.050
Side Slope Z-value= 3.0 '/' Top Width= 19.00'
Length= 280.0' Slope= 0.1571 '/'
Inlet Invert= 282.00', Outlet Invert= 238.00'

‡

## Reach 67BC: DC-67BC

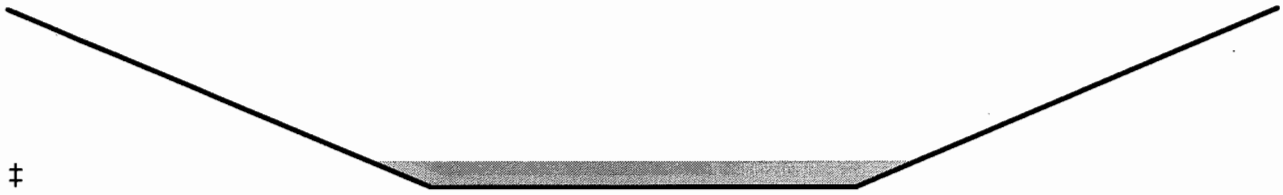
[61] Hint: Submerged 1% of Reach 67AB bottom

Inflow Area = 2.220 ac, Inflow Depth > 2.19" for Johnston 25Yr 24Hr event
Inflow = 9.97 cfs @ 11.97 hrs, Volume= 0.405 af
Outflow = 9.90 cfs @ 11.98 hrs, Volume= 0.404 af, Atten= 1%, Lag= 0.5 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 5.01 fps, Min. Travel Time= 0.7 min
Avg. Velocity = 1.43 fps, Avg. Travel Time= 2.6 min

Peak Storage= 445 cf @ 11.98 hrs, Average Depth at Peak Storage= 0.29'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 355.82 cfs

6.00' x 2.00' deep channel, n= 0.050
Side Slope Z-value= 3.0 '/' Top Width= 18.00'
Length= 225.0' Slope= 0.1778 '/'
Inlet Invert= 238.00', Outlet Invert= 198.00'



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## Pond C-31: C-31

[61] Hint: Submerged 35% of Reach 31BC bottom

Inflow Area = 2.710 ac, Inflow Depth > 2.19" for Johnston 25Yr 24Hr event
Inflow = 11.51 cfs @ 11.99 hrs, Volume= 0.494 af
Outflow = 11.51 cfs @ 11.99 hrs, Volume= 0.494 af, Atten= 0%, Lag= 0.0 min
Primary = 11.51 cfs @ 11.99 hrs, Volume= 0.494 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 178.04' @ 11.99 hrs
Flood Elev= 180.00'

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 177.00' | **24.0" x 110.0' long Culvert X 2.00**<br>CPP, end-section conforming to fill, Ke= 0.500<br>Outlet Invert= 151.00' S= 0.2364 '/' Cc= 0.900<br>n= 0.013 Corrugated PE, smooth interior |

**Primary OutFlow** Max=11.50 cfs @ 11.99 hrs HW=178.04' TW=150.80' (Dynamic Tailwater)
└**1=Culvert** (Inlet Controls 11.50 cfs @ 3.48 fps)

## Pond C-51: C-51

Inflow Area = 9.040 ac, Inflow Depth > 2.18" for Johnston 25Yr 24Hr event
Inflow = 32.39 cfs @ 12.02 hrs, Volume= 1.644 af
Outflow = 32.39 cfs @ 12.02 hrs, Volume= 1.644 af, Atten= 0%, Lag= 0.0 min
Primary = 32.39 cfs @ 12.02 hrs, Volume= 1.644 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 154.42' @ 12.02 hrs
Flood Elev= 162.00'

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 152.00' | **36.0" x 120.0' long Culvert** RCP, square edge headwall, Ke= 0.500<br>Outlet Invert= 140.00' S= 0.1000 '/' Cc= 0.900 n= 0.012 |

**Primary OutFlow** Max=32.38 cfs @ 12.02 hrs HW=154.42' TW=141.83' (Dynamic Tailwater)
↑—**1=Culvert** (Inlet Controls 32.38 cfs @ 5.30 fps)

## Pond C-61: C-61

[61] Hint: Submerged 15% of Reach 61AB bottom

Inflow Area = 37.110 ac, Inflow Depth > 2.17" for Johnston 25Yr 24Hr event
Inflow = 86.25 cfs @ 12.04 hrs, Volume= 6.713 af
Outflow = 86.25 cfs @ 12.04 hrs, Volume= 6.713 af, Atten= 0%, Lag= 0.0 min
Primary = 86.25 cfs @ 12.04 hrs, Volume= 6.713 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 160.64' @ 12.04 hrs
Flood Elev= 167.00'

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 158.00' | **42.0" x 80.0' long Culvert X 2.00**<br>RCP, square edge headwall, Ke= 0.500<br>Outlet Invert= 156.00' S= 0.0250 '/' Cc= 0.900 n= 0.012 |

**Primary OutFlow** Max=86.20 cfs @ 12.04 hrs HW=160.64' TW=152.67' (Dynamic Tailwater)
↑—**1=Culvert** (Inlet Controls 86.20 cfs @ 5.53 fps)

## Pond C-62: C-62

Inflow Area = 0.670 ac, Inflow Depth > 2.18" for Johnston 25Yr 24Hr event
Inflow = 2.98 cfs @ 11.97 hrs, Volume= 0.122 af
Outflow = 2.98 cfs @ 11.97 hrs, Volume= 0.122 af, Atten= 0%, Lag= 0.0 min
Primary = 2.98 cfs @ 11.97 hrs, Volume= 0.122 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 154.73' @ 11.97 hrs
Flood Elev= 164.00'

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 154.00' | **24.0" x 56.0' long Culvert** RCP, square edge headwall, Ke= 0.500<br>Outlet Invert= 153.44' S= 0.0100 '/' Cc= 0.900 n= 0.012 |

**Primary OutFlow** Max=2.98 cfs @ 11.97 hrs HW=154.73' TW=152.05' (Dynamic Tailwater)
└**1=Culvert** (Barrel Controls 2.98 cfs @ 4.29 fps)

## Pond C-63: C-63

Inflow Area = 5.690 ac, Inflow Depth > 2.19" for Johnston 25Yr 24Hr event
Inflow = 25.89 cfs @ 11.96 hrs, Volume= 1.039 af
Outflow = 25.89 cfs @ 11.96 hrs, Volume= 1.039 af, Atten= 0%, Lag= 0.0 min
Primary = 25.89 cfs @ 11.96 hrs, Volume= 1.039 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 155.06' @ 11.96 hrs
Flood Elev= 162.00'

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 152.50' | **30.0" x 52.0' long Culvert** RCP, square edge headwall, Ke= 0.500<br>Outlet Invert= 151.98' S= 0.0100 '/' Cc= 0.900 n= 0.012 |

**Primary OutFlow** Max=25.85 cfs @ 11.96 hrs HW=155.05' TW=151.95' (Dynamic Tailwater)
└**1=Culvert** (Barrel Controls 25.85 cfs @ 6.41 fps)

## Pond C-64: C-64

[61] Hint: Submerged 17% of Reach 65AB bottom

Inflow Area = 25.330 ac, Inflow Depth > 2.18" for Johnston 25Yr 24Hr event
Inflow = 62.87 cfs @ 12.10 hrs, Volume= 4.600 af
Outflow = 62.87 cfs @ 12.10 hrs, Volume= 4.600 af, Atten= 0%, Lag= 0.0 min
Primary = 62.87 cfs @ 12.10 hrs, Volume= 4.600 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 180.24' @ 12.10 hrs
Flood Elev= 182.00'

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 177.80' | **36.0" x 72.0' long Culvert X 2.00**<br>RCP, end-section conforming to fill, Ke= 0.500<br>Outlet Invert= 177.00' S= 0.0111 '/' Cc= 0.900 n= 0.012 |

**Primary OutFlow** Max=62.86 cfs @ 12.10 hrs HW=180.24' TW=177.32' (Dynamic Tailwater)
└**1=Culvert** (Barrel Controls 62.86 cfs @ 6.95 fps)

## Pond C-65A: C-65A

[61] Hint: Submerged 12% of Reach 66BC bottom
[61] Hint: Submerged 8% of Reach 67BC bottom

Inflow Area = 19.350 ac, Inflow Depth > 2.19" for Johnston 25Yr 24Hr event
Inflow = 72.25 cfs @ 11.99 hrs, Volume= 3.528 af
Outflow = 53.26 cfs @ 12.06 hrs, Volume= 3.528 af, Atten= 26%, Lag= 4.2 min
Primary = 53.26 cfs @ 12.06 hrs, Volume= 3.528 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 201.08' @ 12.06 hrs Surf.Area= 4,313 sf Storage= 11,596 cf
Flood Elev= 203.00' Surf.Area= 6,850 sf Storage= 21,788 cf

Plug-Flow detention time= 1.2 min calculated for 3.528 af (100% of inflow)
Center-of-Mass det. time= 1.1 min ( 806.2 - 805.1 )

| Volume | Invert | Avail.Storage | Storage Description |
|---|---|---|---|
| #1 | 195.00' | 29,563 cf | **Custom Stage Data (Prismatic)**Listed below (Recalc) |

| Elevation (feet) | Surf.Area (sq-ft) | Inc.Store (cubic-feet) | Cum.Store (cubic-feet) |
|---|---|---|---|
| 195.00 | 25 | 0 | 0 |
| 196.00 | 100 | 63 | 63 |
| 198.00 | 1,850 | 1,950 | 2,013 |
| 200.00 | 3,500 | 5,350 | 7,363 |
| 202.00 | 5,000 | 8,500 | 15,863 |
| 204.00 | 8,700 | 13,700 | 29,563 |

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 195.00' | **36.0" x 15.0' long Culvert** RCP, square edge headwall, Ke= 0.500<br>Outlet Invert= 194.80' S= 0.0133 '/' Cc= 0.900 n= 0.012 |

**Primary OutFlow** Max=53.13 cfs @ 12.06 hrs HW=201.08' TW=198.64' (Dynamic Tailwater)
↑**1=Culvert** (Inlet Controls 53.13 cfs @ 7.52 fps)

## Pond C-65B: C-65B

Inflow Area = 19.350 ac, Inflow Depth > 2.19" for Johnston 25Yr 24Hr event
Inflow = 53.26 cfs @ 12.06 hrs, Volume= 3.528 af
Outflow = 53.26 cfs @ 12.06 hrs, Volume= 3.528 af, Atten= 0%, Lag= 0.0 min
Primary = 53.26 cfs @ 12.06 hrs, Volume= 3.528 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 198.65' @ 12.06 hrs
Flood Elev= 203.00'

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 194.70' | **36.0" x 265.0' long Culvert** RCP, square edge headwall, Ke= 0.500<br>Outlet Invert= 192.10' S= 0.0098 '/' Cc= 0.900 n= 0.012 |

**Primary OutFlow** Max=53.21 cfs @ 12.06 hrs HW=198.64' TW=195.94' (Dynamic Tailwater)
└**1=Culvert** (Inlet Controls 53.21 cfs @ 7.53 fps)

## Pond C-65C: C-65C

Inflow Area = 19.350 ac, Inflow Depth > 2.19" for Johnston 25Yr 24Hr event
Inflow = 53.26 cfs @ 12.06 hrs, Volume= 3.528 af
Outflow = 53.26 cfs @ 12.06 hrs, Volume= 3.528 af, Atten= 0%, Lag= 0.0 min
Primary = 53.26 cfs @ 12.06 hrs, Volume= 3.528 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 195.95' @ 12.06 hrs
Flood Elev= 808.00'

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 192.00' | **36.0" x 355.0' long Culvert** RCP, square edge headwall, Ke= 0.500<br>Outlet Invert= 188.80' S= 0.0090 '/' Cc= 0.900 n= 0.012 |

**Primary OutFlow** Max=53.21 cfs @ 12.06 hrs HW=195.94' TW=192.30' (Dynamic Tailwater)
└**1=Culvert** (Inlet Controls 53.21 cfs @ 7.53 fps)

## Pond SB-1: Sediment Basin No. 1

Inflow Area = 4.720 ac, Inflow Depth > 2.28" for Johnston 25Yr 24Hr event
Inflow = 22.42 cfs @ 11.96 hrs, Volume= 0.895 af
Outflow = 4.74 cfs @ 12.09 hrs, Volume= 0.848 af, Atten= 79%, Lag= 8.2 min
Primary = 4.74 cfs @ 12.09 hrs, Volume= 0.848 af
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 194.79' @ 12.09 hrs Surf.Area= 5,812 sf Storage= 15,211 cf
Flood Elev= 196.00' Surf.Area= 7,350 sf Storage= 23,150 cf

Plug-Flow detention time= 80.9 min calculated for 0.848 af (95% of inflow)
Center-of-Mass det. time= 61.6 min ( 861.8 - 800.2 )

| Volume | Invert | Avail.Storage | Storage Description |
|---|---|---|---|
| #1 | 190.00' | 23,150 cf | **Custom Stage Data (Prismatic)**Listed below (Recalc) |

| Elevation (feet) | Surf.Area (sq-ft) | Inc.Store (cubic-feet) | Cum.Store (cubic-feet) |
|---|---|---|---|
| 190.00 | 0 | 0 | 0 |
| 192.00 | 3,100 | 3,100 | 3,100 |
| 194.00 | 4,800 | 7,900 | 11,000 |
| 196.00 | 7,350 | 12,150 | 23,150 |

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 190.00' | **12.0" x 60.0' long Culvert** CMP, square edge headwall, Ke= 0.500<br>Outlet Invert= 189.00' S= 0.0167 '/' Cc= 0.900<br>n= 0.025 Corrugated metal |
| #2 | Device 1 | 190.33' | **0.5" Vert. Orifice/Grate X 18.00 columns**<br>X 10 rows with 4.0" cc spacing C= 0.600 |
| #3 | Device 1 | 194.00' | **24.0" Horiz. Orifice/Grate** Limited to weir flow C= 0.600 |
| #4 | Secondary | 195.00' | **143.0 deg x 10.0' long Sharp-Crested Vee/Trap Weir** C= 2.47 |

**Primary OutFlow** Max=4.74 cfs @ 12.09 hrs HW=194.79' (Free Discharge)
└**1=Culvert** (Barrel Controls 4.74 cfs @ 6.04 fps)
└**2=Orifice/Grate** (Passes < 2.00 cfs potential flow)
└**3=Orifice/Grate** (Passes < 13.47 cfs potential flow)

**Secondary OutFlow** Max=0.00 cfs @ 0.00 hrs HW=190.00' (Free Discharge)
└**4=Sharp-Crested Vee/Trap Weir** ( Controls 0.00 cfs)

## Pond SB-2: Sediment Basin No. 2

[61] Hint: Submerged 29% of Reach 21BC bottom

| | | | | |
|---|---|---|---|---|
| Inflow Area = | 15.600 ac, | Inflow Depth > | 2.24" | for Johnston 25Yr 24Hr event |
| Inflow = | 64.55 cfs @ | 11.99 hrs, Volume= | 2.909 af | |
| Outflow = | 33.98 cfs @ | 12.09 hrs, Volume= | 2.376 af, Atten= 47%, Lag= 5.7 min | |
| Primary = | 5.55 cfs @ | 12.09 hrs, Volume= | 1.830 af | |
| Secondary = | 28.43 cfs @ | 12.09 hrs, Volume= | 0.546 af | |

Routing by Dyn-Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 145.57' @ 12.09 hrs Surf.Area= 14,480 sf Storage= 44,062 cf
Flood Elev= 146.00' Surf.Area= 15,500 sf Storage= 50,500 cf

Plug-Flow detention time= 96.9 min calculated for 2.375 af (82% of inflow)
Center-of-Mass det. time= 43.1 min ( 846.8 - 803.6 )

| Volume | Invert | Avail.Storage | Storage Description |
|---|---|---|---|
| #1 | 140.00' | 50,500 cf | **Custom Stage Data (Prismatic)**Listed below (Recalc) |

| Elevation (feet) | Surf.Area (sq-ft) | Inc.Store (cubic-feet) | Cum.Store (cubic-feet) |
|---|---|---|---|
| 140.00 | 100 | 0 | 0 |
| 142.00 | 6,700 | 6,800 | 6,800 |
| 144.00 | 10,750 | 17,450 | 24,250 |
| 146.00 | 15,500 | 26,250 | 50,500 |

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 140.00' | **12.0" x 60.0' long Culvert** CMP, square edge headwall, Ke= 0.500<br>Outlet Invert= 138.00' S= 0.0333 '/' Cc= 0.900<br>n= 0.025 Corrugated metal |
| #2 | Device 1 | 140.33' | **0.5" Vert. Orifice/Grate X 14.00 columns**<br>X 10 rows with 4.0" cc spacing C= 0.600 |
| #3 | Device 1 | 144.00' | **18.0" Horiz. Orifice/Grate** Limited to weir flow C= 0.600 |
| #4 | Secondary | 145.00' | **143.0 deg x 20.0' long Sharp-Crested Vee/Trap Weir** C= 2.47 |

**Primary OutFlow** Max=5.55 cfs @ 12.09 hrs HW=145.57' (Free Discharge)
└**1=Culvert** (Barrel Controls 5.55 cfs @ 7.07 fps)
  ├**2=Orifice/Grate** (Passes < 1.76 cfs potential flow)
  └**3=Orifice/Grate** (Passes < 10.66 cfs potential flow)

**Secondary OutFlow** Max=28.35 cfs @ 12.09 hrs HW=145.57' (Free Discharge)
└**4=Sharp-Crested Vee/Trap Weir** (Weir Controls 28.35 cfs @ 2.29 fps)

## Pond SB-3: Sediment Basin No. 3

| | | | | | |
|---|---|---|---|---|---|
| Inflow Area = | 3.640 ac, | Inflow Depth > | 2.31" | for | Johnston 25Yr 24Hr event |
| Inflow = | 16.08 cfs @ | 11.97 hrs, | Volume= | 0.700 af | |
| Outflow = | 1.33 cfs @ | 12.60 hrs, | Volume= | 0.588 af, | Atten= 92%, Lag= 37.8 min |
| Primary = | 1.33 cfs @ | 12.60 hrs, | Volume= | 0.588 af | |
| Secondary = | 0.00 cfs @ | 0.00 hrs, | Volume= | 0.000 af | |

Routing by Dyn-Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 151.97' @ 12.60 hrs Surf.Area= 5,268 sf Storage= 14,922 cf
Flood Elev= 154.00' Surf.Area= 7,350 sf Storage= 27,750 cf

Plug-Flow detention time= 153.6 min calculated for 0.588 af (84% of inflow)
Center-of-Mass det. time= 104.8 min ( 905.7 - 800.9 )

| Volume | Invert | Avail.Storage | Storage Description |
|---|---|---|---|
| #1 | 148.00' | 27,750 cf | **Custom Stage Data (Prismatic)**Listed below (Recalc) |

| Elevation (feet) | Surf.Area (sq-ft) | Inc.Store (cubic-feet) | Cum.Store (cubic-feet) |
|---|---|---|---|
| 148.00 | 3,000 | 0 | 0 |
| 150.00 | 3,400 | 6,400 | 6,400 |
| 152.00 | 5,300 | 8,700 | 15,100 |
| 154.00 | 7,350 | 12,650 | 27,750 |

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 148.00' | **18.0" x 60.0' long Culvert** CMP, square edge headwall, Ke= 0.500<br>Outlet Invert= 146.00' S= 0.0333 '/' Cc= 0.900<br>n= 0.025 Corrugated metal |
| #2 | Device 1 | 148.33' | **0.5" Vert. Orifice/Grate X 18.00 columns**<br>X 7 rows with 4.0" cc spacing C= 0.600 |
| #3 | Device 1 | 152.00' | **24.0" Horiz. Orifice/Grate** Limited to weir flow C= 0.600 |
| #4 | Secondary | 153.00' | **143.0 deg x 20.0' long Sharp-Crested Vee/Trap Weir** C= 2.47 |

**Primary OutFlow** Max=1.33 cfs @ 12.60 hrs HW=151.97' (Free Discharge)
└**1=Culvert** (Passes 1.33 cfs of 12.71 cfs potential flow)
  ├**2=Orifice/Grate** (Orifice Controls 1.33 cfs @ 7.72 fps)
  └**3=Orifice/Grate** ( Controls 0.00 cfs)

**Secondary OutFlow** Max=0.00 cfs @ 0.00 hrs HW=148.00' (Free Discharge)
└**4=Sharp-Crested Vee/Trap Weir** ( Controls 0.00 cfs)

## Pond SB-4: Sediment Basin No. 4

[61] Hint: Submerged 12% of Reach 41CD bottom

Inflow Area = 16.020 ac, Inflow Depth > 2.24" for Johnston 25Yr 24Hr event
Inflow = 63.00 cfs @ 12.01 hrs, Volume= 2.984 af
Outflow = 17.69 cfs @ 12.19 hrs, Volume= 2.247 af, Atten= 72%, Lag= 11.0 min
Primary = 5.93 cfs @ 12.19 hrs, Volume= 1.919 af
Secondary = 11.76 cfs @ 12.19 hrs, Volume= 0.328 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 158.49' @ 12.19 hrs Surf.Area= 13,320 sf Storage= 53,155 cf
Flood Elev= 159.00' Surf.Area= 14,600 sf Storage= 60,300 cf

Plug-Flow detention time= 126.2 min calculated for 2.246 af (75% of inflow)
Center-of-Mass det. time= 61.0 min ( 866.0 - 805.0 )

| Volume | Invert | Avail.Storage | Storage Description |
|---|---|---|---|
| #1 | 152.00' | 60,300 cf | **Custom Stage Data (Prismatic)**Listed below (Recalc) |

| Elevation (feet) | Surf.Area (sq-ft) | Inc.Store (cubic-feet) | Cum.Store (cubic-feet) |
|---|---|---|---|
| 152.00 | 2,550 | 0 | 0 |
| 154.00 | 6,750 | 9,300 | 9,300 |
| 156.00 | 9,400 | 16,150 | 25,450 |
| 158.00 | 12,100 | 21,500 | 46,950 |
| 159.00 | 14,600 | 13,350 | 60,300 |

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 152.00' | **12.0" x 60.0' long Culvert** CMP, square edge headwall, Ke= 0.500<br>Outlet Invert= 150.00' S= 0.0333 '/' Cc= 0.900<br>n= 0.025 Corrugated metal |
| #2 | Device 1 | 152.33' | **0.5" Vert. Orifice/Grate X 14.00 columns**<br>X 10 rows with 4.0" cc spacing C= 0.600 |
| #3 | Device 1 | 157.00' | **18.0" Horiz. Orifice/Grate** Limited to weir flow C= 0.600 |
| #4 | Secondary | 158.00' | **143.0 deg x 10.0' long Sharp-Crested Vee/Trap Weir** C= 2.47 |

**Primary OutFlow** Max=5.93 cfs @ 12.19 hrs HW=158.49' (Free Discharge)
└**1=Culvert** (Barrel Controls 5.93 cfs @ 7.55 fps)
  ├**2=Orifice/Grate** (Passes < 1.97 cfs potential flow)
  └**3=Orifice/Grate** (Passes < 10.38 cfs potential flow)

**Secondary OutFlow** Max=11.75 cfs @ 12.19 hrs HW=158.49' (Free Discharge)
└**4=Sharp-Crested Vee/Trap Weir** (Weir Controls 11.75 cfs @ 2.10 fps)

## Pond SB-5A: Sediment Basin No. 5A

Inflow Area = 13.250 ac, Inflow Depth > 2.24" for Johnston 25Yr 24Hr event
Inflow = 48.65 cfs @ 11.99 hrs, Volume= 2.468 af
Outflow = 12.10 cfs @ 12.23 hrs, Volume= 2.361 af, Atten= 75%, Lag= 14.8 min
Primary = 12.10 cfs @ 12.23 hrs, Volume= 2.361 af
Secondary = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 143.30' @ 12.23 hrs Surf.Area= 9,895 sf Storage= 43,092 cf
Flood Elev= 147.00' Surf.Area= 12,700 sf Storage= 73,700 cf

Plug-Flow detention time= 92.0 min calculated for 2.361 af (96% of inflow)
Center-of-Mass det. time= 76.0 min ( 880.3 - 804.3 )

| Volume | Invert | Avail.Storage | Storage Description |
|---|---|---|---|
| #1 | 136.00' | 73,700 cf | **Custom Stage Data (Prismatic)**Listed below (Recalc) |

| Elevation (feet) | Surf.Area (sq-ft) | Inc.Store (cubic-feet) | Cum.Store (cubic-feet) |
|---|---|---|---|
| 136.00 | 1,000 | 0 | 0 |
| 138.00 | 3,900 | 4,900 | 4,900 |
| 140.00 | 7,000 | 10,900 | 15,800 |
| 142.00 | 8,400 | 15,400 | 31,200 |
| 144.00 | 10,700 | 19,100 | 50,300 |
| 146.00 | 12,700 | 23,400 | 73,700 |

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 136.00' | **24.0" x 70.0' long Culvert** CMP, square edge headwall, Ke= 0.500<br>Outlet Invert= 134.00' S= 0.0286 '/' Cc= 0.900<br>n= 0.025 Corrugated metal |
| #2 | Device 1 | 136.33' | **0.5" Vert. Orifice/Grate X 35.00 columns**<br>X 10 rows with 4.0" cc spacing C= 0.600 |
| #3 | Device 1 | 143.00' | **48.0" Horiz. Orifice/Grate** Limited to weir flow C= 0.600 |
| #4 | Secondary | 145.00' | **143.0 deg x 20.0' long Sharp-Crested Vee/Trap Weir** C= 2.47 |

**Primary OutFlow** Max=12.09 cfs @ 12.23 hrs HW=143.30' (Free Discharge)
└**1=Culvert** (Passes 12.09 cfs of 31.33 cfs potential flow)
  ├**2=Orifice/Grate** (Orifice Controls 5.34 cfs @ 11.20 fps)
  └**3=Orifice/Grate** (Weir Controls 6.75 cfs @ 1.79 fps)

**Secondary OutFlow** Max=0.00 cfs @ 0.00 hrs HW=136.00' (Free Discharge)
└**4=Sharp-Crested Vee/Trap Weir** ( Controls 0.00 cfs)

## Pond SB-6: Sediment Basin No. 6

| | | | | | |
|---|---|---|---|---|---|
| Inflow Area = | 48.650 ac, | Inflow Depth > | 2.28" | for | Johnston 25Yr 24Hr event |
| Inflow = | 128.84 cfs @ | 11.97 hrs, | Volume= | 9.260 af | |
| Outflow = | 18.65 cfs @ | 12.78 hrs, | Volume= | 5.042 af, | Atten= 86%, Lag= 48.7 min |
| Primary = | 18.65 cfs @ | 12.78 hrs, | Volume= | 5.042 af | |
| Secondary = | 0.00 cfs @ | 0.00 hrs, | Volume= | 0.000 af | |

Routing by Dyn-Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 154.52' @ 12.78 hrs Surf.Area= 67,250 sf Storage= 213,402 cf
Flood Elev= 158.00' Surf.Area= 92,500 sf Storage= 498,900 cf

Plug-Flow detention time= 180.0 min calculated for 5.039 af (54% of inflow)
Center-of-Mass det. time= 95.3 min ( 901.9 - 806.6 )

| Volume | Invert | Avail.Storage | Storage Description |
|---|---|---|---|
| #1 | 150.00' | 498,900 cf | **Custom Stage Data (Prismatic)**Listed below (Recalc) |

| Elevation (feet) | Surf.Area (sq-ft) | Inc.Store (cubic-feet) | Cum.Store (cubic-feet) |
|---|---|---|---|
| 150.00 | 30,800 | 0 | 0 |
| 152.00 | 43,500 | 74,300 | 74,300 |
| 154.00 | 61,900 | 105,400 | 179,700 |
| 156.00 | 82,400 | 144,300 | 324,000 |
| 158.00 | 92,500 | 174,900 | 498,900 |

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 150.00' | **24.0" x 60.0' long Culvert** CMP, square edge headwall, Ke= 0.500<br>Outlet Invert= 148.00' S= 0.0333 '/' Cc= 0.900<br>n= 0.025 Corrugated metal |
| #2 | Device 1 | 150.33' | **0.5" Vert. Orifice/Grate X 35.00 columns**<br>X 8 rows with 4.0" cc spacing C= 0.600 |
| #3 | Device 1 | 154.00' | **48.0" Horiz. Orifice/Grate** Limited to weir flow C= 0.600 |
| #4 | Secondary | 156.00' | **143.0 deg x 20.0' long Sharp-Crested Vee/Trap Weir** C= 2.47 |

**Primary OutFlow** Max=18.65 cfs @ 12.78 hrs HW=154.52' (Free Discharge)
└**1=Culvert** (Passes 18.65 cfs of 25.96 cfs potential flow)
  ├**2=Orifice/Grate** (Orifice Controls 3.16 cfs @ 8.28 fps)
  └**3=Orifice/Grate** (Weir Controls 15.49 cfs @ 2.36 fps)

**Secondary OutFlow** Max=0.00 cfs @ 0.00 hrs HW=150.00' (Free Discharge)
└**4=Sharp-Crested Vee/Trap Weir** ( Controls 0.00 cfs)

PROJECT Johnston County MSWLF - Phase 4A - Cell 3

SUBJECT Drainage Channel Analysis

SHEET 1 OF 14
JOB NO. JOHNSTON-07-2
DATE 12/4/08
COMPUTED BY PKS
CHECKED BY

**Objective**

To design drainage channels, ditches, etc. to handle stormwater flow from the design storm(s). The main design criteria will be to ensure that all drainage channels, ditches, etc. will be able to accommodate the peak discharge from the design storm without overtopping and without exceeding the allowable shear stress and/or velocity of the selected channel lining.

**References**

Federal Highway Administration (2001), Urban Drainage Design Manual, Hydraulic Engineering Circular No. 22, FHWA NHI-01-021, Second Ed., U.S. Dept. of Transportation, Washington, D.C.

North Carolina Division of Land Resources (2006), North Carolina Erosion & Sediment Control Planning & Design Manual, Raleigh, NC.

Malcom, H. Rooney (1989 & 2003 Supplement), Elements of Urban Stormwater Design, NC State Univ., Raleigh, NC.

Pennsylvania DEP Bureau of Watershed Protection (2000), Erosion and Sediment Pollution Control Program Manual.

**Analysis**

The following approach is used in the design of drainage channels:

1. Determine the peak discharge from the design storm(s) (from HydroCAD or spreadsheet methods). For permanent linings (Grass, TRM, rip rap, gabions, etc.) use the peak discharge from the 25-Yr 24-Hr storm unless otherwise specified. For grass lined channels, a smaller design storm (2-Yr 24-Hr - unless otherwise specified) is used to evaluate temporary linings.
2. Input other design parameters (bottom width; side slopes; minimum freeboard, min./max. slopes; and channel lining).
3. Based on the design parameters calculate normal depth of flow, velocity, Froude number, and maximum shear stress for both max./min. slopes. Also determine the critical slope and corresponding normal depth.
4. Compare the velocity and/or shear stress to allowable values (the maximum slope values will control). If values are exceeded, revise design parameters as required.
5. Based on normal depth values and required freeboard (generally use the greater of 6 inches or 25% of the flow depth), determine the minimum channel depth and top width for both max./min. slopes (the minimum slope values will control).
6. If the channel has a significant curved reach, evaluate the shear stress and superelevation of the water surface in the bend.



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**Calculations**

- Manning's Equation:

$$Q = \frac{1.49 A R^{2/3} S^{1/2}}{n} = AV \qquad \text{(HEC-22 Eq. 5-5)}$$

where:
- $Q$ = discharge (cfs)
- $n$ = Manning's roughness coefficient (See Below)
- $A$ = cross sectional area of flow ($ft^2$)
- $R$ = hydraulic radius (ft) = $A/P$
- $P$ = wetted perimeter
- $S$ = slope of channel (ft/ft)
- $V$ = average channel velocity (ft/sec)

- Maximum Shear Stress (Tractive Force Method):

$$\tau_d = \gamma d S \qquad \text{(HEC-22 Eq. 5-13)}$$

where:
- $\tau_d$ = maximum shear stress on channel lining ($lb/ft^2$)
- $\gamma$ = unit weight of water (62.4 $lb/ft^3$)
- $d$ = maximum depth of flow (ft)
- $S$ = channel slope (ft/ft)

- Froude Number:

$$Fr = \frac{v}{\sqrt{\frac{gA}{T}}}$$

where:
- $Fr$ = Froude number (dimensionless)
- $v$ = flow velocity (ft/sec)
- $g$ = acceleration of gravity (32.2 $ft/sec^2$)
- $A$ = cross-sectional area of flow ($ft^2$)
- $T$ = top width of flow (ft)

Note that $A/T$ = the hydraulic depth ($D$). For $Fr > 1.0$, flow is supercritical; $Fr < 1.0$, flow is subcritical; $Fr = 1.0$, flow is critical.

Critical Slope:

The critical slope ($S_c$) is the slope at which $Fr = 1.0$. When the slope is between $0.7S_c$ and $1.3S_c$, unstable flow may occur as small flow disturbances can initiate a change in the flow state. If slopes are within this range, consider additional freeboard.

- Manning's Roughness Coefficient ($n$):

Grass:

$$n = \frac{R^{1/6}}{\left[K + 19.97\log\left(R^{1.4}S^{0.4}\right)\right]}$$ (HEC-22 Eq. 5-6 - 5-10)

where:
$R$ = hydraulic radius (ft)
$K$ = vegetative coefficient (depending on retardance class)
= 15.8 (Class A)
= 23.0 (Class B)
= 30.2 (Class C)
= 34.6 (Class D)
= 37.7 (Class E)
$S$ = slope of channel (ft/ft)

Rip Rap:

$$n = \frac{y^{1/6}}{21.6\log\left(\frac{y}{d_{50}}\right) + 14}$$ (PA DEP Manual Fig. 3)

where:
$y$ = depth of flow (ft)
$d_{50}$ = median size of rip rap (ft)

- Curved Channels (Where Applicable):

Shear Stress in Bend:

$$\tau_b = K_b \tau_d \qquad \text{(HEC-22 Eq. 5-15)}$$

where:
- $\tau_d$ = bend shear stress (lb/ft$^2$)
- $K_b$ = function of $R_c/B$ (use HEC-22 Chart 21)
- $\tau_d$ = maximum shear stress on channel lining (lb/ft$^2$)
- $R_c$ = radius to the centerline of the channel (ft)
- $B$ = bottom width of channel (ft)

Superelevation at Outside of Bend:

$$\Delta d = 0.5\frac{V^2 T}{gR_c} \qquad \text{(HEC-22 Eq. 5-11 modified)}$$

where:
- $\Delta d$ = superelevation of water surface between the outer channel bank and the centerline of the channel (avg. water surface before bend) (ft)
- $V$ = average channel velocity (ft/sec)
- $T$ = top width of flow (ft)
- $g$ = acceleration of gravity (32.2 ft/sec$^2$)
- $R_c$ = radius to the centerline of the channel (ft)

- Allowable Shear Stress/Velocity:

Grass-Lined Channels:

For grass-lined channels, an allowable velocity approach is applicable for slopes flatter than 10%. For slopes of 10% and steeper appropriate permanent linings should be used. For use in the evaluation of curved channels, the following allowable shear stress values (lb/ft$^2$) can be assumed based on retardance class:

| | |
|---|---|
| Class A: | 3.70 |
| Class B: | 2.10 |
| Class C: | 1.00 |
| Class D: | 0.60 |
| Class E: | 0.35 |

Rip Rap-Lined Channels:

For rip rap-lined channels, an allowable velocity approach is applicable for slopes flatter than 10% (see attached table). For slopes of 10% or steeper, use the following equation:

$$\tau_{allow} = 4 \times d_{50} \qquad \text{(HEC-22 Eq. 5-17)}$$

where: $\tau_{allow}$ = allowable shear stress (lb/ft$^2$)
$d_{50}$ = median size of rip rap (ft)

Reno Mattress or Gabion-Lined Channels:

For Reno mattress or gabion-lined channels, use allowable velocity for slopes flatter than 10% and allowable shear stress for slopes of 10% or steeper (see attached table).

**Riprap Gradation, Filter Blanket Requirements, Maximum Velocities**

| | Graded Rock Size (in) | | | Filter Blanket Requirements** | | |
|---|---|---|---|---|---|---|
| NSA No. | Max. | $d_{50}$* | Min. | Size NSA No. | Placement Thickness | $V_{max}$ (ft/sec |
| R-1 | 1.5 | .75 | No. 8 | FS-1 | N/A | 2.5 |
| R-2 | 3 | 1.5 | 1 | FS-1 | N/A | 4.5 |
| R-3 | 6 | 3 | 2 | FS-1 | 3 | 6.5 |
| R-4 | 12 | 6 | 3 | FS-2 | 4 | 9.0 |
| R-5 | 18 | 9 | 5 | FS-2 | 6 | 11.5 |
| R-6 | 24 | 12 | 7 | FS-3 | 8 | 13.0 |
| R-7 | 30 | 15 | 12 | FS-3 | 10 | 14.5 |

* The $d_{50}$ stone size is the size exceeded by 50% of the total weight of the tonnage shipped (i.e. 50% by weight shall consist of pieces larger than the $d_{50}$ stone size").

** This is a general standard. Soil conditions at each site should be analyzed to determine actual filter size. A suitable woven or non-woven geotextile underlayment, used according to manufacturer's recommendations, may be substituted for the filter stone.

*Ref: PA DEP Manual Table 9*

**Maximum Permissible Velocities for Reno Mattress & Gabions**

| Type | n | Thickness Inches | Rock Fill Gradation (in) | Permissible* Velocity (fps) | Permissible** Shear Stress (lb/ft$^2$) |
|---|---|---|---|---|---|
| Reno Mattress | .025 - .030 | 6 | 3 - 6 | 6.0 | 8.35 |
| | .025 - .030 | 6 - 10 | 3 - 6 | 12.0 | 8.35 |
| | .025 - .030 | 10 - 12 | 3 - 6 | 15.0 | 8.35 |
| | .025 - .030 | 12 - 18 | 4 - 6 | 18.0 | 8.35 |
| Gabion | .027 | >18 | 5 - 9 | 22.0 | 8.35 |

* Permissible velocities may be increased by the introduction of sand mastic grout. Refer to manufacturer's recommendations/specifications for permissible velocities and for recommendations regarding filters or geotextile fabric underlayment when using Reno mattresses or gabions for channel linings.
**Based on vegetation completely grown.

*Ref: PA DEP Manual Table 13*

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SHEET: 6 / 14
JOB #: JOHNSTON-07-2
DATE: 12/4/08
BY: PKS
CHKD BY:

**Johnston County MSW Landfill - Phase 4A**
**Drainage Channel Analysis (TRM Lined)**

**Channel No. DC-21AB**

**Design Parameters:**

PEAK DISCHARGE, $Q25$ = 30.7 $ft^3/s$ Source: HydroCAD 25-Yr 24-Hr

Bottom Width, $B$ = 4.0 ft
Left Side Slope, $z_1$ = 3.0 horizontal :1 vertical
Right Side Slope, $z_2$ = 3.0 horizontal :1 vertical
Minimum Freeboard = 0.5 ft

Maximum Channel Slope, $S_{max}$ = 0.060 ft/ft
Minimum Channel Slope, $S_{min}$ = 0.025 ft/ft

Turf Reinforcement Matting (TRM) Lining:
Grass Retardance = D
K = 34.6
TRM Product Name = Propex - Landlok TRM 435, or equal
$\tau_{allow}$ = 5.0 $lb/ft^2$

**Normal Depth**

| Depth of Flow (Norm. Depth) $Y_n$ ft | Manning's Roughness Coefficient $n$ | Area of Flow $A$ $ft^2$ | Wetted Perimeter $P$ ft | Hydraulic Radius $R=A/P$ ft | Top Width $T$ ft | Hydraulic Depth $D=A/T$ ft | Average Velocity $V_n$ ft/s | Flow Rate $Q$ $ft^3/s$ | Froude Number $F_r$ (Normal) # | Maximum Shear Stress $\tau_d$ $lb/ft^2$ | Factor of Safety $\tau_{allow}/\tau_d$ | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Maximum Slope: | | | | | | | | | | | | |
| **0.87** | 0.049 | 5.75 | 9.50 | 0.61 | 9.22 | 0.62 | 5.33 | 30.7 | 1.19 | **3.3** | 1.5 | **O.K.** |
| Minimum Slope: | | | | | | | | | | | | |
| **1.12** | 0.052 | 8.24 | 11.08 | 0.74 | 10.72 | 0.77 | 3.71 | 30.5 | 0.74 | **1.7** | 2.9 | **O.K.** |

**Critical Depth**

| Depth of Flow (Crit. Depth) $Y_c$ ft | Manning's Roughness Coefficient $n$ | Area of Flow $A$ $ft^2$ | Wetted Perimeter $P$ ft | Hydraulic Radius $R=A/P$ ft | Top Width $T$ ft | Hydraulic Depth $D=A/T$ ft | Section Factor $Z=AD^{1/2}$ $ft^{2.5}$ | Flow Rate $Q$ $ft^3/s$ | Average Velocity $V_c$ ft/s | Froude Number $F_r$ (Critical) # | Uniform-Flow Critical Slope $S_c$ ft/ft | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **0.96** | 0.050 | 6.60 | 10.07 | 0.66 | 9.76 | 0.68 | 5.43 | 30.8 | 4.67 | 1.00 | 0.044 | **Flow is Stable.** |

**Determination of Minimum Channel Depth & Top Width**

| Maximum Slope | | Minimum Slope | |
|---|---|---|---|
| Minimum Channel Depth ft | Minimum Top Width $T$ ft | Minimum Channel Depth ft | Minimum Top Width $T$ ft |
| 1.37 | 12.22 | **1.62** | **13.72** |

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JOB #: JOHNSTON-07-2
DATE: 12/4/08
BY: PKS
CHKD BY:

**Johnston County MSW Landfill - Phase 4A**
**Drainage Channel Analysis (Rip Rap Lined)**

**Channel No. DC-21BC**

**Design Parameters:**

PEAK DISCHARGE, Q25 = 40.9 $ft^3/s$ Source: HydroCAD 25-Yr 24-Hr

Bottom Width, $B$ = 6.0 ft
Left Side Slope, $z_1$ = 3.0 horizontal :1 vertical
Right Side Slope, $z_2$ = 3.0 horizontal :1 vertical
Minimum Freeboard = 0.5 ft

Maximum Channel Slope, $S_{max}$ = 0.090 ft/ft
Minimum Channel Slope, $S_{min}$ = 0.040 ft/ft

Rip Rap Lining:
$D_{50}$ = 1.00 ft
$V_{allow}$ = 13.0 ft/sec
$\tau_{allow}$ = 4.0 $lb/ft^2$

**Normal Depth**

| Depth of Flow (Norm. Depth) $Y_n$ ft | Manning's Roughness Coefficient $n$ | Area of Flow $A$ $ft^2$ | Wetted Perimeter $P$ ft | Hydraulic Radius $R=A/P$ ft | Top Width $T$ ft | Hydraulic Depth $D=A/T$ ft | Average Velocity $V_n$ ft/s | Flow Rate $Q$ $ft^3/s$ | Froude Number $F_r$ (Normal) # | Maximum Shear Stress $\tau_d$ $lb/ft^2$ | Allowable Velocity (V) or Sh. Stress (S) Used? | Factor of Safety $V_{allow}/V_n$ or $\tau_{allow}/\tau_d$ | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Maximum Slope: | | | | | | | | | | | | | |
| **0.95** | 0.073 | 8.41 | 12.01 | 0.70 | 11.70 | 0.72 | 4.81 | 40.4 | 1.00 | **5.3** | V | 2.7 | **O.K.** |
| Minimum Slope: | | | | | | | | | | | | | |
| **1.13** | 0.067 | 10.61 | 13.15 | 0.81 | 12.78 | 0.83 | 3.83 | 40.7 | 0.74 | **2.8** | V | 3.4 | **O.K.** |

**Critical Depth**

| Depth of Flow (Crit. Depth) $Y_c$ ft | Manning's Roughness Coefficient $n$ | Area of Flow $A$ $ft^2$ | Wetted Perimeter $P$ ft | Hydraulic Radius $R=A/P$ ft | Top Width $T$ ft | Hydraulic Depth $D=A/T$ ft | Section Factor $Z=AD^{1/2}$ $ft^{2.5}$ | Flow Rate $Q$ $ft^3/s$ | Average Velocity $V_c$ ft/s | Froude Number $F_r$ (Critical) # | Uniform-Flow Critical Slope $S_c$ ft/ft | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **0.96** | 0.073 | 8.52 | 12.07 | 0.71 | 11.76 | 0.72 | 7.26 | 41.2 | 4.83 | 1.00 | 0.089 | **Slopes Near Sc - Check Freeboard.** |

**Determination of Minimum Channel Depth & Top Width**

| Maximum Slope | | Minimum Slope | |
|---|---|---|---|
| Minimum Channel Depth ft | Minimum Top Width $T$ ft | Minimum Channel Depth ft | Minimum Top Width $T$ ft |
| 1.45 | 14.70 | **1.63** | **15.78** |

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JOB #: JOHNSTON-07-2
DATE: 6/7/07
BY: PKS
CHKD BY:

**Johnston County MSW Landfill - Phase 4A**
**Drainage Channel Analysis (TRM Lined)**

**Channel No. DC-41AB**

**Design Parameters:**

PEAK DISCHARGE, $Q25$ = 15.8 $ft^3/s$ Source: HydroCAD 25-Yr 24-Hr

Bottom Width, $B$ = 6.0 ft
Left Side Slope, $z_1$ = 3.0 horizontal :1 vertical
Right Side Slope, $z_2$ = 3.0 horizontal :1 vertical
Minimum Freeboard = 0.5 ft

Maximum Channel Slope, $S_{max}$ = 0.040 ft/ft
Minimum Channel Slope, $S_{min}$ = 0.020 ft/ft

Turf Reinforcement Matting (TRM) Lining:
Grass Retardance = D
K = 34.6
TRM Product Name = Propex - Landlok TRM 435, or equal
$\tau_{allow}$ = 5.0 $lb/ft^2$

**Normal Depth**

| Depth of Flow (Norm. Depth) $Y_n$ ft | Manning's Roughness Coefficient $n$ | Area of Flow $A$ $ft^2$ | Wetted Perimeter $P$ ft | Hydraulic Radius $R=A/P$ ft | Top Width $T$ ft | Hydraulic Depth $D=A/T$ ft | Average Velocity $V_n$ ft/s | Flow Rate $Q$ $ft^3/s$ | Froude Number $F_r$ (Normal) # | Maximum Shear Stress $\tau_d$ $lb/ft^2$ | Factor of Safety $\tau_{allow}/\tau_d$ | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Maximum Slope: | | | | | | | | | | | | |
| **0.63** | 0.059 | 4.97 | 9.98 | 0.50 | 9.78 | 0.51 | 3.16 | 15.7 | 0.78 | **1.6** | 3.2 | **O.K.** |
| Minimum Slope: | | | | | | | | | | | | |
| **0.79** | 0.062 | 6.61 | 11.00 | 0.60 | 10.74 | 0.62 | 2.42 | 16.0 | 0.54 | **1.0** | 5.1 | **O.K.** |

**Critical Depth**

| Depth of Flow (Crit. Depth) $Y_c$ ft | Manning's Roughness Coefficient $n$ | Area of Flow $A$ $ft^2$ | Wetted Perimeter $P$ ft | Hydraulic Radius $R=A/P$ ft | Top Width $T$ ft | Hydraulic Depth $D=A/T$ ft | Section Factor $Z=AD^{1/2}$ $ft^{2.5}$ | Flow Rate $Q$ $ft^3/s$ | Average Velocity $V_c$ ft/s | Froude Number $F_r$ (Critical) # | Uniform-Flow Critical Slope $S_c$ ft/ft | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **0.54** | 0.057 | 4.11 | 9.42 | 0.44 | 9.24 | 0.45 | 2.75 | 15.6 | 3.79 | 1.00 | 0.064 | **Flow is Stable.** |

**Determination of Minimum Channel Depth & Top Width**

| Maximum Slope | | Minimum Slope | |
|---|---|---|---|
| Minimum Channel Depth ft | Minimum Top Width $T$ ft | Minimum Channel Depth ft | Minimum Top Width $T$ ft |
| 1.13 | 12.78 | **1.29** | **13.74** |

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JOB #: JOHNSTON-07-2
DATE: 12/4/08
BY: PKS
CHKD BY:

**Johnston County MSW Landfill - Phase 4A**
**Drainage Channel Analysis (TRM Lined)**

**Channel No. DC-51AB**

**Design Parameters:**

PEAK DISCHARGE, Q25 = 6.1 $ft^3/s$ Source: HydroCAD 25-Yr 24-Hr

Bottom Width, $B$ = 7.0 ft
Left Side Slope, $z_1$ = 3.0 horizontal :1 vertical
Right Side Slope, $z_2$ = 3.0 horizontal :1 vertical
Minimum Freeboard = 0.5 ft

Maximum Channel Slope, $S_{max}$ = 0.070 ft/ft
Minimum Channel Slope, $S_{min}$ = 0.050 ft/ft

Turf Reinforcement Matting (TRM) Lining:
Grass Retardance = D
K = 34.6
TRM Product Name = Propex - Landlok TRM 435, or equal
$\tau_{allow}$ = 5.0 $lb/ft^2$

**Normal Depth**

| Depth of Flow (Norm. Depth) $Y_n$ ft | Manning's Roughness Coefficient $n$ | Area of Flow $A$ $ft^2$ | Wetted Perimeter $P$ ft | Hydraulic Radius $R=A/P$ ft | Top Width $T$ ft | Hydraulic Depth $D=A/T$ ft | Average Velocity $V_n$ ft/s | Flow Rate $Q$ $ft^3/s$ | Froude Number $F_r$ (Normal) # | Maximum Shear Stress $\tau_d$ $lb/ft^2$ | Factor of Safety $\tau_{allow}/\tau_d$ | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Maximum Slope: | | | | | | | | | | | | |
| **0.34** | 0.078 | 2.73 | 9.15 | 0.30 | 9.04 | 0.30 | 2.27 | 6.2 | 0.73 | **1.5** | 3.4 | **O.K.** |
| Minimum Slope: | | | | | | | | | | | | |
| **0.37** | 0.078 | 3.00 | 9.34 | 0.32 | 9.22 | 0.33 | 1.99 | 6.0 | 0.61 | **1.2** | 4.3 | **O.K.** |

**Critical Depth**

| Depth of Flow (Crit. Depth) $Y_c$ ft | Manning's Roughness Coefficient $n$ | Area of Flow $A$ $ft^2$ | Wetted Perimeter $P$ ft | Hydraulic Radius $R=A/P$ ft | Top Width $T$ ft | Hydraulic Depth $D=A/T$ ft | Section Factor $Z=AD^{1/2}$ $ft^{2.5}$ | Flow Rate $Q$ $ft^3/s$ | Average Velocity $V_c$ ft/s | Froude Number $F_r$ (Critical) # | Uniform-Flow Critical Slope $S_c$ ft/ft | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **0.28** | 0.076 | 2.20 | 8.77 | 0.25 | 8.68 | 0.25 | 1.10 | 6.3 | 2.85 | 1.00 | 0.135 | **Flow is Stable.** |

**Determination of Minimum Channel Depth & Top Width**

| Maximum Slope | | Minimum Slope | |
|---|---|---|---|
| Minimum Channel Depth ft | Minimum Top Width $T$ ft | Minimum Channel Depth ft | Minimum Top Width $T$ ft |
| 0.84 | 12.04 | **0.87** | **12.22** |

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JOB #: JOHNSTON-07-2
DATE: 12/4/08
BY: PKS
CHKD BY:

**Johnston County MSW Landfill - Phase 4A**
**Drainage Channel Analysis (Rip Rap Lined)**

**Channel No. DC-51BC**

**Design Parameters:**

PEAK DISCHARGE, $Q25$ = 15.7 $ft^3/s$ Source: HydroCAD 25-Yr 24-Hr

Bottom Width, $B$ = 7.0 ft
Left Side Slope, $z_1$ = 3.0 horizontal :1 vertical
Right Side Slope, $z_2$ = 3.0 horizontal :1 vertical
Minimum Freeboard = 0.5 ft

Rip Rap Lining:
$D_{50}$ = 1.00 ft
$V_{allow}$ = 13.0 ft/sec
$\tau_{allow}$ = 4.0 $lb/ft^2$

Maximum Channel Slope, $S_{max}$ = 0.100 ft/ft
Minimum Channel Slope, $S_{min}$ = 0.050 ft/ft

**Normal Depth**

| Depth of Flow (Norm. Depth) $Y_n$ ft | Manning's Roughness Coefficient $n$ | Area of Flow $A$ $ft^2$ | Wetted Perimeter $P$ ft | Hydraulic Radius $R=A/P$ ft | Top Width $T$ ft | Hydraulic Depth $D=A/T$ ft | Average Velocity $V_n$ ft/s | Flow Rate $Q$ $ft^3/s$ | Froude Number $F_r$ (Normal) # | Maximum Shear Stress $\tau_d$ $lb/ft^2$ | Allowable Velocity (V) or Sh. Stress (S) Used? | Factor of Safety $V_{allow}/V_n$ or $\tau_{allow}/\tau_d$ | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Maximum Slope: | | | | | | | | | | | | | |
| **0.60** | 0.100 | 5.28 | 10.79 | 0.49 | 10.60 | 0.50 | 2.93 | 15.5 | 0.73 | **3.7** | S | 1.1 | **O.K.** |
| Minimum Slope: | | | | | | | | | | | | | |
| **0.69** | 0.089 | 6.26 | 11.36 | 0.55 | 11.14 | 0.56 | 2.50 | 15.7 | 0.59 | **2.2** | V | 5.2 | **O.K.** |

**Critical Depth**

| Depth of Flow (Crit. Depth) $Y_c$ ft | Manning's Roughness Coefficient $n$ | Area of Flow $A$ $ft^2$ | Wetted Perimeter $P$ ft | Hydraulic Radius $R=A/P$ ft | Top Width $T$ ft | Hydraulic Depth $D=A/T$ ft | Section Factor $Z=AD^{1/2}$ $ft^{2.5}$ | Flow Rate $Q$ $ft^3/s$ | Average Velocity $V_c$ ft/s | Froude Number $F_r$ (Critical) # | Uniform-Flow Critical Slope $S_c$ ft/ft | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **0.50** | 0.119 | 4.25 | 10.16 | 0.42 | 10.00 | 0.43 | 2.77 | 15.7 | 3.70 | 1.00 | 0.278 | **Flow is Stable.** |

**Determination of Minimum Channel Depth & Top Width**

| Maximum Slope | | Minimum Slope | |
|---|---|---|---|
| Minimum Channel Depth ft | Minimum Top Width $T$ ft | Minimum Channel Depth ft | Minimum Top Width $T$ ft |
| 1.10 | 13.60 | **1.19** | **14.14** |

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SHEET: 11 / 14
JOB #: JOHNSTON-07-2
DATE: 6/7/07
BY: PKS
CHKD BY:

**Johnston County MSW Landfill - Phase 4A**
**Drainage Channel Analysis (TRM Lined)**

**Channel No. DC-64AB**

**Design Parameters:**

PEAK DISCHARGE, Q25 = 3.3 $ft^3/s$ Source: HydroCAD 25-Yr 24-Hr

Bottom Width, $B$ = 4.0 ft
Left Side Slope, $z_1$ = 3.0 horizontal :1 vertical
Right Side Slope, $z_2$ = 3.0 horizontal :1 vertical
Minimum Freeboard = 0.5 ft

Maximum Channel Slope, $S_{max}$ = 0.100 ft/ft
Minimum Channel Slope, $S_{min}$ = 0.040 ft/ft

Turf Reinforcement Matting (TRM) Lining:
Grass Retardance = D
K = 34.6
TRM Product Name = Propex - Landlok TRM 435, or equal
$\tau_{allow}$ = 5.0 $lb/ft^2$

**Normal Depth**

| Depth of Flow (Norm. Depth) $Y_n$ ft | Manning's Roughness Coefficient $n$ | Area of Flow $A$ $ft^2$ | Wetted Perimeter $P$ ft | Hydraulic Radius $R=A/P$ ft | Top Width $T$ ft | Hydraulic Depth $D=A/T$ ft | Average Velocity $V_n$ ft/s | Flow Rate $Q$ $ft^3/s$ | Froude Number $F_r$ (Normal) # | Maximum Shear Stress $\tau_d$ $lb/ft^2$ | Factor of Safety $\tau_{allow}/\tau_d$ | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Maximum Slope: | | | | | | | | | | | | |
| **0.30** | 0.083 | 1.47 | 5.90 | 0.25 | 5.80 | 0.25 | 2.26 | 3.3 | 0.79 | **1.9** | 2.7 | **O.K.** |
| Minimum Slope: | | | | | | | | | | | | |
| **0.40** | 0.086 | 2.08 | 6.53 | 0.32 | 6.40 | 0.33 | 1.62 | 3.4 | 0.50 | **1.0** | 5.0 | **O.K.** |

**Critical Depth**

| Depth of Flow (Crit. Depth) $Y_c$ ft | Manning's Roughness Coefficient $n$ | Area of Flow $A$ $ft^2$ | Wetted Perimeter $P$ ft | Hydraulic Radius $R=A/P$ ft | Top Width $T$ ft | Hydraulic Depth $D=A/T$ ft | Section Factor $Z=AD^{1/2}$ $ft^{2.5}$ | Flow Rate $Q$ $ft^3/s$ | Average Velocity $V_c$ ft/s | Froude Number $F_r$ (Critical) # | Uniform-Flow Critical Slope $S_c$ ft/ft | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **0.26** | 0.082 | 1.24 | 5.64 | 0.22 | 5.56 | 0.22 | 0.59 | 3.3 | 2.68 | 1.00 | 0.166 | **Flow is Stable.** |

**Determination of Minimum Channel Depth & Top Width**

| Maximum Slope | | Minimum Slope | |
|---|---|---|---|
| Minimum Channel Depth ft | Minimum Top Width $T$ ft | Minimum Channel Depth ft | Minimum Top Width $T$ ft |
| 0.80 | 8.80 | **0.90** | **9.40** |

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DATE: 6/7/07
BY: PKS
CHKD BY:

**Johnston County MSW Landfill - Phase 4A**
**Drainage Channel Analysis (TRM Lined)**

**Channel No. DC-66AB**

**Design Parameters:**

PEAK DISCHARGE, Q25 = 8.3 $ft^3/s$ Source: HydroCAD 25-Yr 24-Hr

Bottom Width, $B$ = 6.0 ft
Left Side Slope, $z_1$ = 3.0 horizontal :1 vertical
Right Side Slope, $z_2$ = 3.0 horizontal :1 vertical
Minimum Freeboard = 0.5 ft

Maximum Channel Slope, $S_{max}$ = 0.080 ft/ft
Minimum Channel Slope, $S_{min}$ = 0.040 ft/ft

Turf Reinforcement Matting (TRM) Lining:
Grass Retardance = D
K = 34.6
TRM Product Name = Propex - Landlok TRM 435, or equal
$\tau_{allow}$ = 5.0 $lb/ft^2$

**Normal Depth**

| Depth of Flow (Norm. Depth) $Y_n$ ft | Manning's Roughness Coefficient $n$ | Area of Flow $A$ $ft^2$ | Wetted Perimeter $P$ ft | Hydraulic Radius $R=A/P$ ft | Top Width $T$ ft | Hydraulic Depth $D=A/T$ ft | Average Velocity $V_n$ ft/s | Flow Rate $Q$ $ft^3/s$ | Froude Number $F_r$ (Normal) # | Maximum Shear Stress $\tau_d$ $lb/ft^2$ | Factor of Safety $\tau_{allow}/\tau_d$ | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Maximum Slope: | | | | | | | | | | | | |
| **0.39** | 0.068 | 2.80 | 8.47 | 0.33 | 8.34 | 0.34 | 2.97 | 8.3 | 0.90 | **1.9** | 2.6 | **O.K.** |
| Minimum Slope: | | | | | | | | | | | | |
| **0.49** | 0.070 | 3.66 | 9.10 | 0.40 | 8.94 | 0.41 | 2.32 | 8.5 | 0.64 | **1.2** | 4.1 | **O.K.** |

**Critical Depth**

| Depth of Flow (Crit. Depth) $Y_c$ ft | Manning's Roughness Coefficient $n$ | Area of Flow $A$ $ft^2$ | Wetted Perimeter $P$ ft | Hydraulic Radius $R=A/P$ ft | Top Width $T$ ft | Hydraulic Depth $D=A/T$ ft | Section Factor $Z=AD^{1/2}$ $ft^{2.5}$ | Flow Rate $Q$ $ft^3/s$ | Average Velocity $V_c$ ft/s | Froude Number $F_r$ (Critical) # | Uniform-Flow Critical Slope $S_c$ ft/ft | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **0.37** | 0.067 | 2.63 | 8.34 | 0.32 | 8.22 | 0.32 | 1.49 | 8.4 | 3.21 | 1.00 | 0.098 | **Slopes Near Sc - Check Freeboard.** |

**Determination of Minimum Channel Depth & Top Width**

| Maximum Slope | | Minimum Slope | |
|---|---|---|---|
| Minimum Channel Depth ft | Minimum Top Width $T$ ft | Minimum Channel Depth ft | Minimum Top Width $T$ ft |
| 0.89 | 11.34 | **0.99** | **11.94** |

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JOB #: JOHNSTON-07-2
DATE: 12/4/08
BY: PKS
CHKD BY:

**Johnston County MSW Landfill - Phase 4A**
**Drainage Channel Analysis (Rip Rap Lined)**

**Channel No. DC-67AB**

**Design Parameters:**

PEAK DISCHARGE, $Q25$ = 7.6 $ft^3/s$ Source: HydroCAD 25-Yr 24-Hr

Bottom Width, $B$ = 7.0 ft
Left Side Slope, $z_1$ = 3.0 horizontal :1 vertical
Right Side Slope, $z_2$ = 3.0 horizontal :1 vertical
Minimum Freeboard = 0.5 ft

Rip Rap Lining:
$D_{50}$ = 1.00 ft
$V_{allow}$ = 13.0 ft/sec
$\tau_{allow}$ = 4.0 $lb/ft^2$

Maximum Channel Slope, $S_{max}$ = 0.200 ft/ft
Minimum Channel Slope, $S_{min}$ = 0.050 ft/ft

**Normal Depth**

| Depth of Flow (Norm. Depth) $Y_n$ ft | Manning's Roughness Coefficient $n$ | Area of Flow $A$ $ft^2$ | Wetted Perimeter $P$ ft | Hydraulic Radius $R=A/P$ ft | Top Width $T$ ft | Hydraulic Depth $D=A/T$ ft | Average Velocity $V_n$ ft/s | Flow Rate $Q$ $ft^3/s$ | Froude Number $F_r$ (Normal) # | Maximum Shear Stress $\tau_d$ $lb/ft^2$ | Allowable Velocity (V) or Sh. Stress (S) Used? | Factor of Safety $V_{allow}/V_n$ or $\tau_{allow}/\tau_d$ | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Maximum Slope: | | | | | | | | | | | | | |
| **0.41** | 0.153 | 3.37 | 9.59 | 0.35 | 9.46 | 0.36 | 2.17 | 7.3 | 0.64 | **5.1** | V | 6.0 | **O.K.** |
| Minimum Slope: | | | | | | | | | | | | | |
| **0.52** | 0.114 | 4.45 | 10.29 | 0.43 | 10.12 | 0.44 | 1.67 | 7.4 | 0.44 | **1.6** | V | 7.8 | **O.K.** |

**Critical Depth**

| Depth of Flow (Crit. Depth) $Y_c$ ft | Manning's Roughness Coefficient $n$ | Area of Flow $A$ $ft^2$ | Wetted Perimeter $P$ ft | Hydraulic Radius $R=A/P$ ft | Top Width $T$ ft | Hydraulic Depth $D=A/T$ ft | Section Factor $Z=AD^{1/2}$ $ft^{2.5}$ | Flow Rate $Q$ $ft^3/s$ | Average Velocity $V_c$ ft/s | Froude Number $F_r$ (Critical) # | Uniform-Flow Critical Slope $S_c$ ft/ft | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **0.32** | 0.250 | 2.55 | 9.02 | 0.28 | 8.92 | 0.29 | 1.36 | 7.7 | 3.03 | 1.00 | 1.395 | **Flow is Stable.** |

**Determination of Minimum Channel Depth & Top Width**

| Maximum Slope | | Minimum Slope | |
|---|---|---|---|
| Minimum Channel Depth ft | Minimum Top Width $T$ ft | Minimum Channel Depth ft | Minimum Top Width $T$ ft |
| 0.91 | 12.46 | **1.02** | **13.12** |

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SHEET: 14 / 14
JOB #: JOHNSTON-07-2
DATE: 6/7/07
BY: PKS
CHKD BY:

**Johnston County MSW Landfill - Phase 4A**
**Drainage Channel Analysis (TRM Lined)**

**Channel No. Cap Diversion Berms**

**Design Parameters:**

PEAK DISCHARGE, Q25 = 10.2 $ft^3/s$ Source: Estimated Worst Case - - Q = CIA = 0.5 x 8.19 in/hr x 2.5 acres

Bottom Width, $B$ = 0.0 ft
Left Side Slope, $z_1$ = 2.0 horizontal :1 vertical
Right Side Slope, $z_2$ = 12.5 horizontal :1 vertical
Minimum Freeboard = 0.5 ft

Maximum Channel Slope, $S_{max}$ = 0.020 ft/ft
Minimum Channel Slope, $S_{min}$ = 0.010 ft/ft

Turf Reinforcement Matting (TRM) Lining:
Grass Retardance = D
K = 34.6
TRM Product Name = Propex - Landlok TRM 435, or equal
$\tau_{allow}$ = 5.0 $lb/ft^2$

**Normal Depth**

| Depth of Flow (Norm. Depth) $Y_n$ ft | Manning's Roughness Coefficient $n$ | Area of Flow $A$ $ft^2$ | Wetted Perimeter $P$ ft | Hydraulic Radius $R=A/P$ ft | Top Width $T$ ft | Hydraulic Depth $D=A/T$ ft | Average Velocity $V_n$ ft/s | Flow Rate $Q$ $ft^3/s$ | Froude Number $F_r$ (Normal) # | Maximum Shear Stress $\tau_d$ $lb/ft^2$ | Factor of Safety $\tau_{allow}/\tau_d$ | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Maximum Slope: | | | | | | | | | | | | |
| **0.93** | 0.077 | 6.27 | 13.74 | 0.46 | 13.49 | 0.47 | 1.63 | 10.2 | 0.42 | **1.2** | 4.3 | **O.K.** |
| Minimum Slope: | | | | | | | | | | | | |
| **1.08** | 0.082 | 8.46 | 15.96 | 0.53 | 15.66 | 0.54 | 1.19 | 10.1 | 0.29 | **0.7** | 7.4 | **O.K.** |

**Critical Depth**

| Depth of Flow (Crit. Depth) $Y_c$ ft | Manning's Roughness Coefficient $n$ | Area of Flow $A$ $ft^2$ | Wetted Perimeter $P$ ft | Hydraulic Radius $R=A/P$ ft | Top Width $T$ ft | Hydraulic Depth $D=A/T$ ft | Section Factor $Z=AD^{1/2}$ $ft^{2.5}$ | Flow Rate $Q$ $ft^3/s$ | Average Velocity $V_c$ ft/s | Froude Number $F_r$ (Critical) # | Uniform-Flow Critical Slope $S_c$ ft/ft | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **0.66** | 0.066 | 3.16 | 9.75 | 0.32 | 9.57 | 0.33 | 1.81 | 10.3 | 3.26 | 1.00 | 0.094 | **Flow is Stable.** |

**Determination of Minimum Channel Depth & Top Width**

| Maximum Slope | | Minimum Slope | |
|---|---|---|---|
| Minimum Channel Depth ft | Minimum Top Width $T$ ft | Minimum Channel Depth ft | Minimum Top Width $T$ ft |
| 1.43 | 20.74 | **1.58** | **22.91** |

PROJECT Johnston County MSWLF - Phase 4A - Cell 3

SUBJECT Drop Inlet Analysis

SHEET 1 OF 2
JOB NO. JOHNSTON-07--2
DATE 6/8/07
COMPUTED BY PKS
CHECKED BY

**Objective** To design drop inlets to handle stormwater flow from the design storm(s). The main design criteria will be to ensure that all drop inlets will be able to accommodate the peak rate of run off from the design storm without exceeding the allowable headwater depth.

**Reference** Malcom, H. Rooney (1989 & 2003 Supplement), Elements of Urban Stormwater Design, NC State Univ., Raleigh, NC.

**Analysis** The following approach is used in the design of drop Inlets:

1. Determine the peak discharge from the design storm(s) (from HydroCAD or spreadsheet methods). Use the peak discharge from the 25-Yr 24-Hr storm unless otherwise specified.
2. As appropriate, analyze the inlet structure as a weir-type inlet and/or grated inlet.
3. Analyze the outlet structure separately by evaluating its behavior as a culvert.

**Calculations**

- Weir-Type Inlet ⇒ Use the Weir Equation:

$$Q = C_W L H^{3/2} \qquad \text{(Malcom Eq. I-6)}$$

where:
$Q$ = peak discharge (cfs)
$C_w$ = weir coefficient (=3.0 for free overfall)
$L$ = length of weir (ft)
$H$ = driving head (ft) (= allowable headwater above crest of weir)

- Grated Inlet ⇒ Use the Orifice Equation:

$$Q = C_d A\sqrt{2gh} \qquad \text{(Malcom Eq. I-7)}$$

where:
$Q$ = peak discharge (cfs)
$C_d$ = coefficient of discharge (0.6 = typical value)
$A$ = cross-sectional area of flow at orifice entrance ($ft^2$)
$g$ = acceleration of gravity (32.2 $ft/sec^2$)
$h$ = driving head (ft) (= allowable headwater above grate)



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SHEET: 2 / 2
JOB #: JOHNSTON-07-2
DATE: 6/8/07
BY: PKS
CHKD BY:

**Johnston County MSW Landfill - Phase 4A - Cell 3**
**Drop Inlet Analysis** **Drop Inlet No.: DI-51**

**Peak Discharge:**

PEAK DISCHARGE, *Q25* (cfs) = 24.4 Source: HydroCAD 25-Yr 24-Hr

**Drop Inlet Parameters:**

| | |
|---|---|
| Weir Coefficient = | 3.0 |
| Coefficient of Discharge (Orifice) = | 0.6 |
| Allowable Driving Head (ft) = | 1.5 |

**Weir-Type Inlet:**

| | |
|---|---|
| L (ft) = | 12 |
| Q (cfs) = | 66.1 |

PROJECT Johnston County MSWLF - Phase 4A - Cell 3

SUBJECT Culvert Analysis

SHEET 1 OF 5
JOB NO. JOHNSTON-07-2
DATE 6/8/07
COMPUTED BY PKS
CHECKED BY

**Objective** To design culverts to handle stormwater flow from the design storm(s). The main design criteria will be to ensure that all culverts will be able to accommodate the peak discharge from the design storm without exceeding the allowable headwater depth.

**Reference** Debo, T.N., and Reese, A.J., Municipal Storm Water Management, Lewis Publishers, Boca Raton, FL, 1995, p. 333.

**Analysis** The following approach is used in the design of culverts (after Debo and Reese):

1. Determine the peak discharge from the design storm(s) (from HydroCAD or spreadsheet methods). Use the peak discharge from the 25-Yr 24-Hr storm unless otherwise specified.

2. Input Culvert Parameters:

   $HW_A$ = allowable headwater depth (ft)
   $N$ = number of pipes used
   $Q_{PIPE}$ = peak discharge /N (cfs)
   $D$ = culvert diameter (in)
   Type of Culvert (i.e., Concrete, CMP, etc.)
   $L$ = culvert length (ft)
   $s$ = culvert slope (ft/ft)
   $n$ = Manning's number
   $k_e$ = entrance loss coefficient
   $d_c$ = critical depth (use critical depth figures) (ft)

3. Find actual headwater (*HW*) for the culvert for both inlet & outlet control: (The condition with the maximum *HW* governs.)

   Inlet Control:

   A. Enter Inlet Control Nomograph with $D$ & $Q_{PIPE}$ and find *HW/D* for the proper entrance type.

   B. Compute HW. If *HW* exceeds $HW_A$, try larger culvert.

   Outlet Control:

   A. Enter outlet control nomograph with $L$, $K_e$, & $D$.

CULVERT.WPD

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B. To compute *HW*, connect the length scale for the type of entrance condition and culvert diameter scale with a straight line, pivot on the turning line, and draw a straight line from the design discharge through the turning point to the head loss scale H. Compute *HW* from the following equation:

$$HW = H + h_O - LS$$

where: $h_O = \left( \frac{d_c + D}{2} \right)$ or tailwater depth, whichever is greater.

C. If *HW* exceeds $HW_A$, try larger culvert.

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SHEET: 3 / 5
JOB #: JOHNSTON-07-2
DATE: 6/8/07
BY: PKS
CHKD BY:

## Johnston County MSW Landfill - Phase 4A - Cell 3
## Culvert Analysis Culvert No.: C-41

**Peak Discharge:**

PEAK DISCHARGE, *Q25* (cfs) = 7.0 Source: HydroCAD 25-Yr 24-Hr

**Culvert Parameters:**

| | | | |
|---|---|---|---|
| Allowable HW Depth (ft) = | 2 | | |
| Number of Pipes, N = | 1 | Qpipe (cfs) = | 7.0 |
| Culvert Diameter, D (in) = | 18 | | |
| Type of Culvert = | RCP | | |
| Invert In Elev. (ft) = | 253.0 | Invert Out Elev. (ft) = | 251.0 |
| Culvert Length, L (ft) = | 84 | | |
| Culvert Slope, S (ft/ft) = | 0.024 | | |
| Manning's Number, n = | 0.012 | | |
| Entrance Loss Coef., ke = | 0.5 | | |
| Critical Depth (ft) = | 1.2 | | |
| Tailwater Depth (ft) = | 1.0 | | |

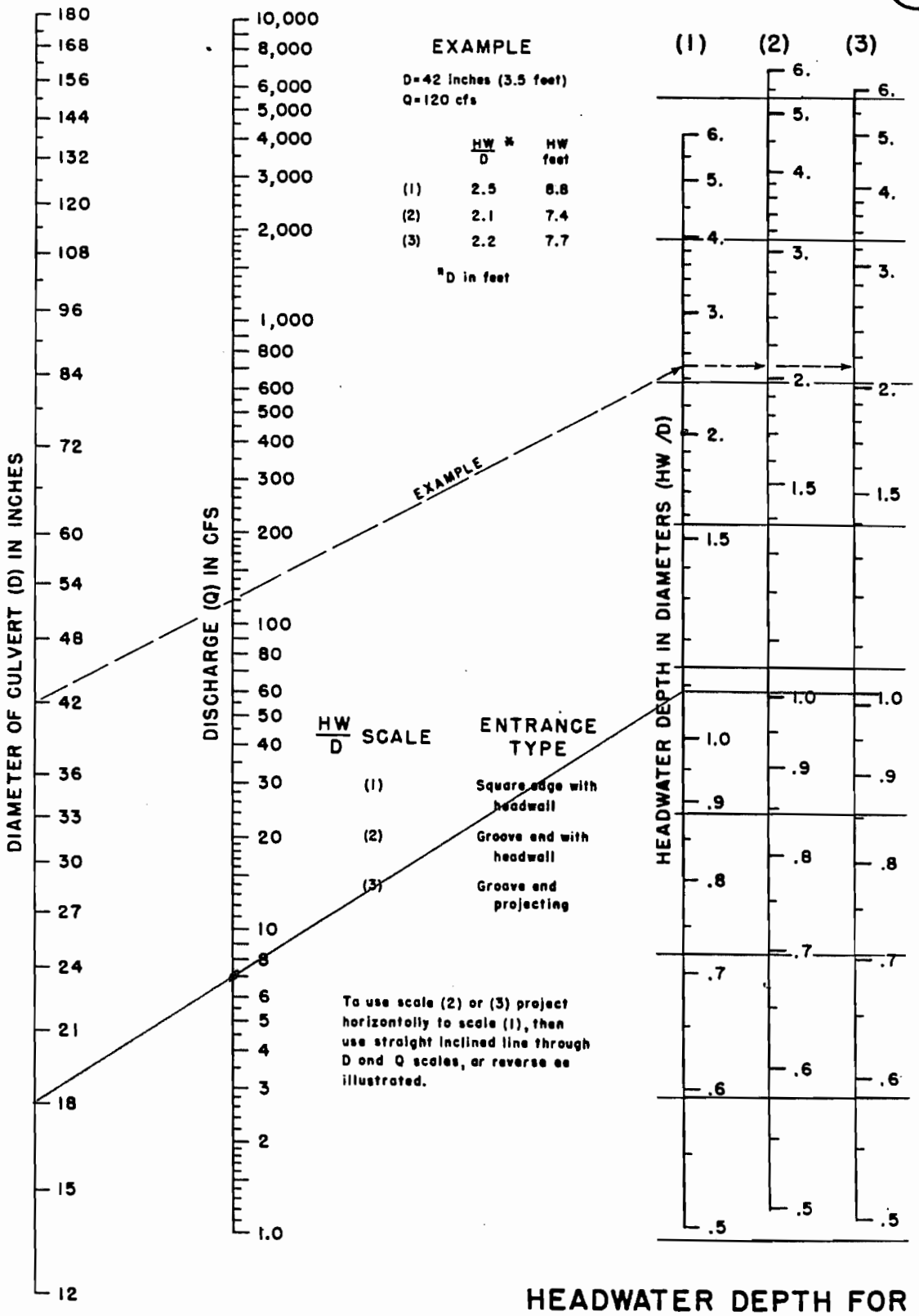
**Case 1: Inlet Control**

HW/D = 1.1 **(From Inlet Control Nomograph)**
HW (ft) = 1.6 **INLET CONTROL GOVERNS!**

**Case 2: Outlet Control**

ho (ft) = 1.4
H (ft) = 0.7 **(From Outlet Control Nomograph)**
HW (ft) = 0.0

4/5

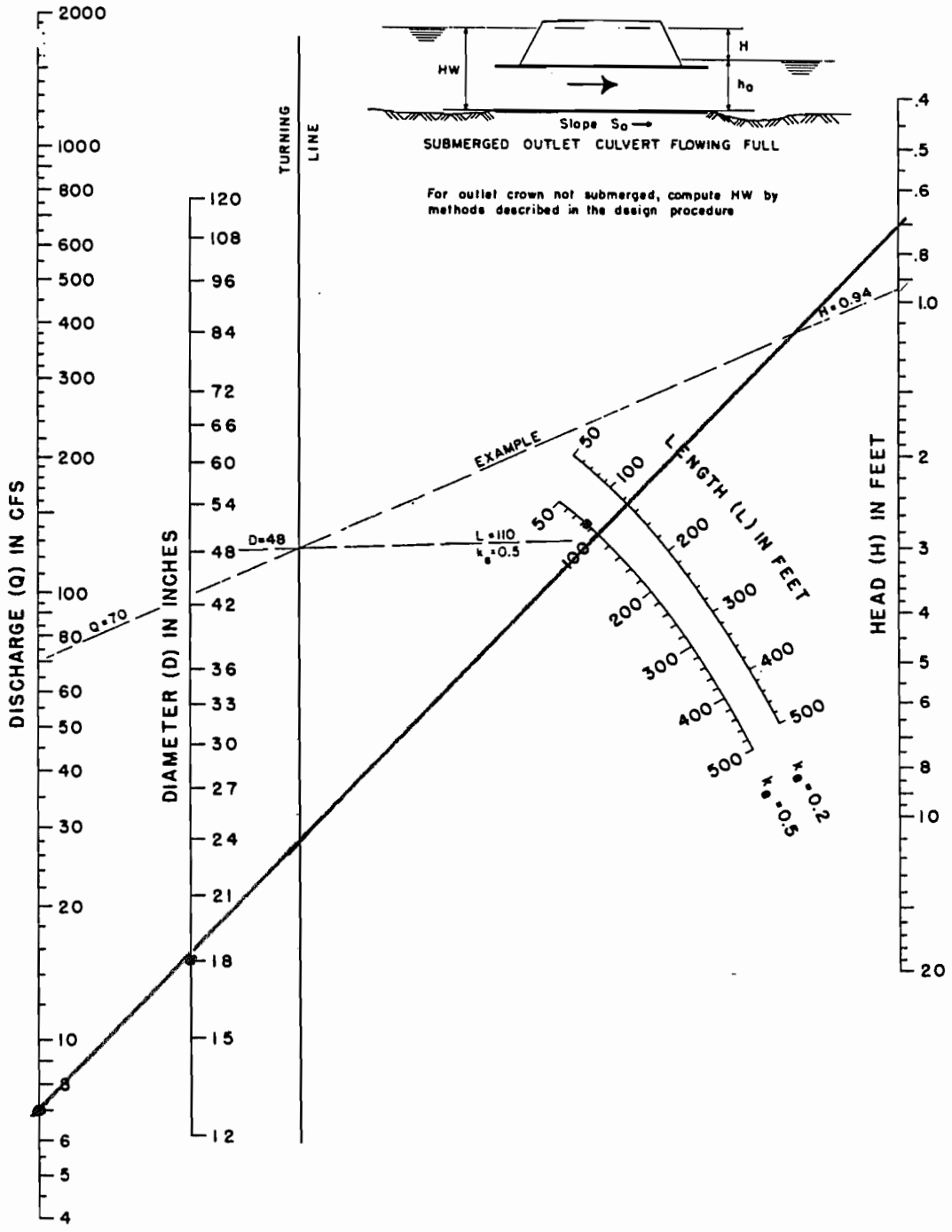



# HEADWATER DEPTH FOR CONCRETE PIPE CULVERTS WITH INLET CONTROL

HEADWATER SCALES 2&3
REVISED MAY 1964

BUREAU OF PUBLIC ROADS JAN. 1963

5/5




## HEAD FOR CONCRETE PIPE CULVERTS FLOWING FULL n = 0.012

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**Objective** To design rain gutters and down pipes to handle the peak discharge from the design storm.

**Reference** Debo, T.N., and Reese, A.J. (1995), Municipal Storm Water Management, Lewis Publishers, Boca Raton, FL.

Malcom, H. Rooney (1989 & 2003 Supplement), Elements of Urban Stormwater Design, NC State Univ., Raleigh, NC.

**Analysis** The following approach is used in the design of rain gutters and down pipes:

1. Determine the peak discharge from the design storm(s). Use the Rational Method.
2. For each pipe size, determine the maximum area (A), to handle the predicted peak discharge (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.
3. Analyze rain gutter pipe perforations as orifice flow to ensure adequate flow capacity into rain gutters.

**Calculations**

- Rain Gutters & Down Pipes:

Determine Flow Capacity of Pipe:

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

where:
$Q_{max}$ = flow capacity of pipe (cfs)
$D$ = inside diameter of pipe (ft)
$S$ = pipe slope (ft/ft)
$n$ = Manning's roughness coefficient

FCS RAIN GUTTERS & DPIPES.WPD

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Determine Factor of Safety (FS):

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

Iterate the drainage area (A) to each drainage structure such that $Q_{max}/Q \geq$ the desired factor of safety.

Determine Flow Depth:

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

where: $h$ = flow depth (inches)
$\theta$ = central angle

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

$K$ = constant

$$K = 0.673 Q n D^{-8/3} S^{-1/2} \qquad \text{(D\&R Equation 8.27)}$$

Determine Flow Velocity:

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

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):

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

Iterate the drainage area (A) to each drainage structure such that $Q_{max}/Q \geq$ the desired factor of safety.

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SHEET: 44
JOB #: JOHNSTON-07-2
DATE: 2/28/07
BY: PKS
CHKD BY:

**Johnston County MSW Landfill - Phase 4A - Cell 3**
**Rain Gutters & Down Pipe Sizing**

**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" | **3.65** | 14.95 | **12.9** | **7** | 16.51 | 1.10 | 0.282 | 235 | 9.43 | 0.71 | 21.02 |
| 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" | **7.15** | 29.28 | **16.6** | **7** | 32.34 | 1.10 | 0.282 | 235 | 12.14 | 1.18 | 24.86 |

**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 |

PROJECT Johnston County MSWLF - Phase 4A - Cell 3

SUBJECT Concrete Pipe Strength Analysis

SHEET 1 OF 5
JOB NO. JOHNSTON-07-2
DATE 2/16/07
COMPUTED BY PKS
CHECKED BY

**Objective**

To determine the loads acting on each concrete pipe and evaluate the required pipe strength. Select the appropriate class of pipe to satisfy the strength requirement.

**Reference**

American Concrete Pipe Association (1992), Concrete Pipe Design Manual, ACPA, Vienna, VA.

American Concrete Pipe Association (1994), "Design Data 40 - Standard Installations and Bedding Factors for the Indirect Design Method", ACPA, Vienna, VA.

American Society for Testing and Materials, "ASTM C 76 - Standard Specification for Reinforced Concrete Culvert, Storm Drain, & Sewer Pipe", ASTM, Philadelphia.

**Analysis**

The analysis is based on the following procedure recommended by the American Concrete Pipe Association (ACPA). Note that the design parameters will vary depending on the type of installation (embankment or trench).

1. Determination of Earth Load, $W_E$:

   Based on the assumed concrete pipe parameters (size, backfill, etc.) use the tables and figures in the Concrete Pipe Design Manual to determine the earth load acting on the pipe. Note that the values determined in the tables and figures are based on a backfill unit weight of 100 lbs/ft$^3$. This value must be adjusted for the anticipated backfill unit weight. Also, for non-trench installations, values for projection ratio, p (vertical distance between the top of the pipe and natural ground divided by the outside vertical height of the pipe), and settlement ratio, $r_{sd}$, must be determined in order to use the figures. Table 43 of the Concrete Pipe Design Manual gives suggested values for $r_{sd}$ based on the known or assumed value of p.

2. Determination of Live Load, $W_L$:

   Based on the concrete pipe parameters (size, backfill, etc.) use the tables in the Concrete Pipe Design Manual to determine the live load acting on the pipe. Note that the values for backfill heights of 10 feet or more and considered insignificant to the design of the pipe.

3. Selection of Standard Installation:

   Select the Standard Installation based on the guidance given in Design Data 40. Note that a Type 1 Standard Installation requires the highest construction quality and degree of inspection while a Type 4 Standard Installation requires virtually no construction quality or inspection.

**CONCRETE PIPE.WPD**

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4. Determination of Bedding Factors:

Determine the bedding factors based on the guidance given in Design Data 40. For embankment installations, the bedding factor, $B_{fe}$, is found from Table 4 of Design Data 40 depending on the selected Standard Installation. For trench installations the bedding factor is based on the following equation:

$$B_{fv} = \frac{\left(B_{fe} - B_{fo}\right)\left(B_d - B_c\right)}{\left(B_{dt} - B_c\right)} - B_{fo} \qquad \text{(Design Data 40 Eqn. 5)}$$

where:
$B_{fv}$ = variable bedding factor, trench
$B_{fe}$ = bedding factor, embankment (Design Data 40 Table 4)
$B_{fo}$ = minimum bedding factor, trench (Design Data 40 Table 6)
$B_d$ = trench width at top of pipe (ft)
$B_c$ = outside horizontal span of pipe (ft)
$B_{dt}$ = transition width at top of pipe (ft) (given in Concrete Pipe Design Manual tables for earth load).

Use Table 7A of Design Data 40 to determine the live load bedding factor, $B_{fLL}$.

5. Application of Factor of Safety, FS:

According to the ACPA, a factor of safety of 1.0 should be applied if the 0.01-inch crack strength is used as the design criterion rather than the ultimate strength.

6. Selection of Pipe Strength/Class:

The required three-edge bearing strength of circular reinforced concrete pipe is expressed as $D_{load}$ in the following equation:

$$D_{load} = \left[\frac{W_E}{BF} + \frac{W_L}{B_{fLL}}\right] + \frac{FS}{D} \qquad \text{(Design Data 40 Eqn. 6)}$$

where:
$W_E$ = earth load on pipe (lbs/linear ft)
$W_L$ = live load on pipe (lbs/linear ft)
$BF$ = bedding factor
= $B_{fe}$ for embankment installations
= $B_{fv}$ for trench installations
$B_{fLL}$ = live load bedding factor
$FS$ = factor of safety
$D$ = pipe diameter (ft)

Note that if $B_{fLL}$ is greater than $B_{fe}$ for embankment installations or $B_{fv}$ for trench installations, use $B_{fe}$ or $B_{fv}$ in place of $B_{fLL}$.

Select class of reinforced concrete pipe based on the following ASTM C-76 guidelines:

| Pipe Class | Maximum D-Load For 0.01-inch Crack (lbs/lf/ft of diameter) |
|---|---|
| I | 800 |
| II | 1,000 |
| III | 1,350 |
| IV | 2,000 |
| V | 3,000 |

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SHEET: 4.5
JOB #: JOHNSTON-07-2
DATE: 6/8/07
BY: PKS
CHKD BY:

**Johnston County MSW Landfill - Phase 4A - Cell 3**
**Concrete Pipe Strength Analysis** **Culvert No.: C-41**
**(Positive Projecting Embankment Installation)**

**Concrete Pipe Parameters:**

| | | |
|---|---|---|
| Type of Pipe = | Circular, Concrete | |
| Pipe Diameter, *D* (in) = | 18 | |
| Outside Horzontal Span, *Bc* (ft) = | 1.92 | **(From Concrete Pipe Design Manual Table 45)** |
| Height of Backfill, *H* (ft) = | 2 | |
| Backfill Type = | Sand | |
| Backfill Unit Wt. (lbs/ft$^3$) = | 120 | |
| Standard Installation = | Type 2 | |

**Determine Earth Load:**

| | | |
|---|---|---|
| Projection Ratio, *p* = | 0.7 | **(Known or Assumed)** |
| Settlement Ratio, *rsd* = | 0.7 | **(From Concrete Pipe Design Manual Table 43)** |
| *rsd* x *p* = | 0.49 | |
| $W_E$ (lbs/LF) (@ 100 pcf) = | 1,000 | **(From Concrete Pipe Design Manual - Figure 166)** |
| $W_E$ (lbs/LF) (Adjusted) = | 1,200 | |

**Determine Live Load:**

| | | |
|---|---|---|
| $W_L$ (lbs/LF) = | 2,610 | **(From Concrete Pipe Design Manual Table 45)** |

**Determine Bedding Factors:**

| | | |
|---|---|---|
| Embankment Bedding Factor, *Bfe* = | 3 | **(From ACPA Design Data 40 Table 4)** |
| Live Load Bedding Factor, *Bfll* = | 2.2 | **(From ACPA Design Data 40 Table 7A)** |

**Factor of Safety:**

| | | |
|---|---|---|
| Factor of Safety, *FS* = | 1.0 | **(Use 1.0 for Reinforced; 1.25 to 1.5 for Non-Reinforced)** |

**Selection of Required Pipe Strength/Class:**

$D_{load}$ (lbs/LF/ft) = 1,058

| Pipe Class | Max. D-Load | |
|---|---|---|
| I | 800 | |
| II | 1,000 | |
| III | 1,350 | **Use Class III RCP** |
| IV | 2,000 | |
| V | 3,000 | |

**(Table per ASTM C 76)**

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JOB #: JOHNSTON-07-2
DATE: 6/8/07
BY: PKS
CHKD BY:

# Johnston County MSW Landfill - Phase 4A - Cell 3
## Concrete Pipe Strength Analysis
## Culvert No.: C-51
**(Trench Installation)**

**Concrete Pipe Parameters:**

| | | |
|---|---|---|
| Type of Pipe = | Circular, Concrete | |
| Pipe Diameter, *D* (in) = | 36 | |
| Outside Horzontal Span, *Bc* (ft) = | 3.67 | **(From Concrete Pipe Design Manual Table 45)** |
| Height of Backfill, *H* (ft) = | 15 | |
| Backfill Type = | Sand | |
| Backfill Unit Wt. (lbs/ft$^3$) = | 120 | |
| Standard Installation = | Type 2 | |
| Trench Width, *Bd* (ft) = | 7.5 | |

**Determine Earth Load:**

| | | |
|---|---|---|
| *WE* (lbs/LF) (@ 100 pcf) = | 8,160 | **(From Concrete Pipe Design Manual - Table 24)** |
| WE (lbs/LF) (Adjusted) = | 9,792 | |

**Determine Live Load:**

| | | |
|---|---|---|
| WL (lbs/LF) = | 0 | **(From Concrete Pipe Design Manual Table 45)** |

**Determine Bedding Factors:**

| | | |
|---|---|---|
| Embankment Bedding Factor, Bfe = | 2.9 | **(From ACPA Design Data 40 Table 4)** |
| Transition Width, Bdt (ft) = | 7.4 | **(From Concrete Pipe Design Manual - Table 24)** |
| Min. Trench Bedding Factor, Bfo = | 1.9 | **(From ACPA Design Data 40 Table 6)** |
| Variable Trench Bedding Factor, Bfv = | 2.9 | |
| Live Load Bedding Factor, Bfll = | 2.2 | **(From ACPA Design Data 40 Table 7A)** |

**Factor of Safety:**

| | | |
|---|---|---|
| Factor of Safety, FS = | 1 | **(Use 1.0 for Reinforced; 1.25 to 1.5 for Non-Reinforced)** |

**Selection of Required Pipe Strength/Class:**

D-Load (lbs/LF/ft) = 1,115

| Pipe Class | Max. D-Load | |
|---|---|---|
| I | 800 | |
| II | 1,000 | |
| III | 1,350 | **Use Class III RCP** |
| IV | 2,000 | |
| V | 3,000 | |

**(Table per ASTM C 76)**

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PROJECT Johnston County MSWLF - Phase 4A - Cell 3

SUBJECT Outlet Protection Analysis

SHEET 1 OF 3
JOB NO. JOHNSTON-07-2
DATE 6/8/07
COMPUTED BY PKS
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**Objective** To design outlet protection for culverts and/or drainage channels based on the maximum flow from the design storm. Rip rap aprons are applicable when the Froude Number (Fr) is less than or equal to 2.5 (Debo and Reese). For higher Froude Numbers, rip rap outlet basins, baffled outlets, and/or other methods are more appropriate.

**Reference**

Debo, T.N., and Reese, A.J. (1995), Municipal Storm Water Management, Lewis Publishers, Boca Raton, FL, Section 8.11 - pp. 289-290; Section 12.6 - pp. 523-526.

Federal Highway Administration (2000), Hydraulic Design of Energy Dissipators for Culverts and Channels, Hydraulic Engineering Circular No. 14, FHWA EPD-86-110, Metric Ed., U.S. Dept. of Transportation, Washington, D.C.

North Carolina Division of Land Resources (2006), North Carolina Erosion & Sediment Control Planning & Design Manual, Raleigh, NC.

**Analysis** For each outlet, determine the Froude Number (Fr) based on the pipe Manning's number, diameter, slope, and design discharge. Use the methods described in Section 8.11 of Debo and Reese. Select the method of outlet protection, as appropriate, and perform design calculations.

Rip Rap Aprons:

If $Fr \leq 2.5$, a rip rap apron may be used. The following design approach is based on Section 12.6 of Debo and Reese and Section 8.06 of the NC Erosion & Sediment Control Planning and Design Manual:

1. Determine the tailwater condition and select the appropriate design chart.
2. Using the appropriate design chart, determine the $d_{50}$ rip-rap size and minimum apron length (La) based on the maximum design flow (Q), flow depth (d), and/or velocity (v) (depending on whether the pipe is flowing full or partially full).
3. Using the same chart, determine apron dimensions.
4. Determine the maximum stone diameter: $d_{max} = 1.5 \times d_{50}$
5. Determine the apron thickness:
   Thickness = $1.5 \times d_{max}$ (No Filter Geotextile)
   Thickness = $1.5 \times d_{50}$ (With Filter Geotextile)

Other Methods:

If $Fr > 2.5$, consider the use of a rip rap basin, baffled outlet, or other device. Design method according to FHA guidelines using HY8-Energy program (or other documented source).



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BY: PKS
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**Johnston County MSW Landfill - Phase 4A - Cell 3**
**Outlet Protection Analysis - Rip Rap Aprons (Circular Pipe)**

Rip Rap Aprons:

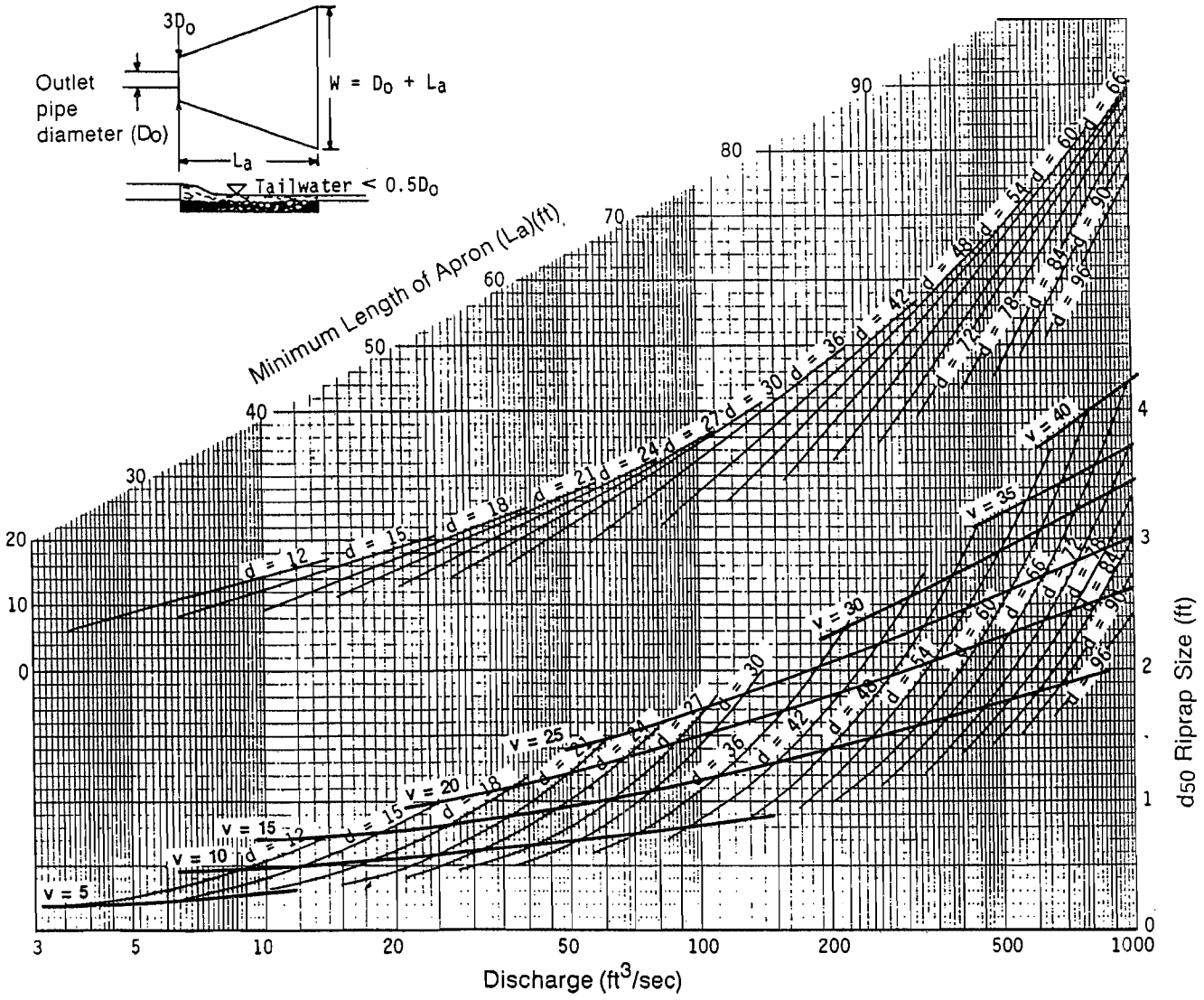
| | C-41 | C-51 | Outlet | | |
|---|---|---|---|---|---|
| Pipe Type: | Concrete | Concrete | | | |
| Manning's Coefficient: | 0.012 | 0.012 | | | |
| Diameter ($D_O$) (in) = | 18 | 36 | | | |
| Slope (%) = | 2.4 | 5.0 | | | |
| Design Discharge (cfs) = | **7.0** | **24.4** | | | |
| Source of Discharge Data: | HydroCAD 25-Yr 24-Hr | HydroCAD 25-Yr 24-Hr | | | |
| K = | 0.124 | 0.047 | | | |
| θ (degrees) = | 168 | 125 | | | |
| Flow Depth (d) (in) = | **8.0** | **9.7** | | | |
| Flow Area ($ft^2$) = | 0.8 | 1.5 | | | |
| Flow Velocity (v) (ft/sec) = | **9.2** | **15.8** | | | |
| Froude Number = | 1.97 | 3.09 | | | |
| Rip Rap Aprons Applicable? | **Yes** | **No - Try Different Method** | | | |
| Tailwater Condition (Low or High)*: | Low | | | | |
| $d_{50}$ (ft)** = | **0.50** | | | | |
| $d_{max}$ (ft) = | 0.75 | | | | |
| Apron Thickness (X) (ft): | ----- | | | | |
| No Geotextile: | 1.13 | | | | |
| With Geotextile: | **0.75** | | | | |
| Apron Dimensions (ft): | ----- | | | | |
| Length (La)** = | **10** | | | | |
| Width (W) = | **11.5** | | | | |

*Tailwater Conditions: Low: $Tw < 0.5D_O$; High: $Tw > 0.5D_O$

** Value from Chart.

Depth & Velocity Fall off of Limits
⇒ Use 10' WIDE X 10' LONG RIP RAP APRON IN DC-41

3/3




Curves may not be extrapolated.

Figure 8.06a Design of outlet protection protection from a round pipe flowing full, minimum tailwater condition ($T_w$ < 0.5 diameter).

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# Slope Stability, Settlement, and Bearing Capacity Evaluation

## Johnston County MSW Landfill - Phase 4A
## Smithfield, North Carolina

Prepared for:

**Johnston County Department of Public Utilities**
**Smithfield, NC**

**June 2007**
**Revised: December 2008**

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**JOHNSTON COUNTY MSW LANDFILL**
**PHASE 4A**

**SLOPE STABILITY, SETTLEMENT, AND BEARING CAPACITY EVALUATION**

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# JOHNSTON COUNTY MSW LANDFILL
# PHASE 4A

## SLOPE STABILITY, SETTLEMENT, AND BEARING CAPACITY EVALUATION

## 1.0 OVERVIEW

The stability of the overall waste mass and perimeter berms (deep-seated failure surfaces) and the stability of the side slope liner/protective cover and final cover (shallow failure surfaces) are addressed herein in addition to evaluations of foundation settlement and bearing capacity.

## 2.0 SEISMIC CONSIDERATIONS

Although the project site lies outside a seismic impact zone ($a_{max}$ > 0.10 g according to USGS (Frankel et. al)) (see **Figure 1**), seismic (pseudo-static) slope stability analyses were performed and the potential for liquefaction was evaluated.

### 2.1 Regulatory Requirements/Guidance

On October 9, 1993, RCRA Subtitle D regulations (40 CFR Part 258) governing landfills receiving municipal solid waste (MSW) went into effect. These regulations require that:

- Section 258.13: landfills cannot be sited within 200-feet of a fault that has had displacement in the Holocene Epoch (past 11,000 years) unless it can be demonstrated that a lesser set back is safe.

- Section 258.14: landfills must be designed for seismic conditions if they are within a seismic impact zone defined as having a peak bedrock acceleration exceeding 0.10 g based on a 10% probability of being exceeded in a 250 year time period (equivalent of 2% probability of being exceeded in 50 years).

The EPA guidance for seismic design guidance for municipal solid waste landfills (EPA/600/R-95/051) states that, within the United States and east of the Rocky Mountains, only the Meers Fault in Oklahoma and the Reelfoot Fault in Tennessee (source of the 1811/1812 New Madrid earthquake sequence) (see **Figure 2** (Krinitsky et. al)) have had displacement evidenced at the ground surface. The project site thus satisfies the requirements of 258.13.

### 2.2 Seismic Coefficients

The peak bedrock acceleration at the project site is obtained from 2002 USGS information (Frankel et. al) (tabulated projected ground acceleration -- 2% probability of being exceeded in 50 years). This indicates that a peak bedrock acceleration of 0.09 g can be assigned to the site based on the site longitude (-78.4 degrees) and latitude (35.5

degrees).

The peak bedrock acceleration must be modified for site conditions to predict the peak ground surface acceleration at the site. The site amplification or attenuation of the peak bedrock acceleration can be evaluated using one-dimensional wave propagation analysis either specifically performed for the site or based on parametric studies. The site amplification or attenuation is estimated using the parametric relationships shown on **Figure 3** (Seed and Idriss). Site boring information indicates that much of the site is underlain by medium dense soils and rock is relatively shallow. The site amplification factor is taken from **Figure 3** and results in a ground surface acceleration of 0.09 g.

For the seismic evaluation of deep-seated failure surfaces, the pseudo-static seismic coefficient used in each analysis was taken as half of the ground surface acceleration value to account for the average acceleration predicted within the waste mass (EPA/600/R-95/051). For the seismic evaluation of shallow failure surfaces, the pseudo-static seismic coefficient was taken as equal to the full ground surface acceleration value.

### 2.3 Liquefaction Evaluation

The first step in any liquefaction evaluation is to assess whether the potential for liquefaction of cohesionless soils exists at a site. Because of the lack of loose cohesionless soils on-site, liquefaction is not a concern for this site.

## 3.0 SLOPE STABILITY

The stability of deep-seated and shallow failure surfaces was evaluated based on EPA guidance and standard industry practices.

### 3.1 Required Factors of Safety

The minimum acceptable factors of safety for long-term slope stability were selected to be 1.5 for static conditions and 1.0 for seismic conditions. For interim conditions, the minimum acceptable static factors of safety were selected to be 1.3 for static conditions and 1.0 for seismic conditions.

### 3.2 Deep-Seated Failure Surfaces

The stability of deep-seated failure surfaces was evaluated using the computer program STABL5M, a computer program developed by Purdue University, with the STEDWIN (v. 2.80) Windows interface program. Both block (translational along liner) and circular (rotational within waste mass and/or subgrade) failure surfaces were analyzed. For block failure surfaces, the factor of safety was determined using the modified Janbu Method, which is typically conservative (US Army). The modified Bishop Method was used to analyze circular failure surfaces.

Analyses were performed for the cross section shown in **Figure 4** (Location of Slope Stability Cross Section and Settlement Evaluation Points) and **Appendix A**. This cross section was chosen based on inspection as representative of worst case conditions.

### 3.2.1 Material Properties

A summary of material properties used in the evaluation of deep-seated failure surfaces is presented in **Table 1**. A discussion of these values is as follows:

Perimeter Berms/Subgrade:

The assumed material properties for the perimeter berms/subgrade were:

| | |
|---|---|
| Unit Weight: | 110 pcf (moist); 115 pcf (saturated) |
| Cohesion: | 100 psf |
| Friction Angle (phi): | 25 degrees |

These properties are considered typical soil strength properties (NAVFAC DM 7.02) based on site data.

Waste:

The assumed material properties for the MSW were:

| | |
|---|---|
| Unit Weight: | 70 pcf (moist); 90 pcf (saturated) |
| Cohesion (c): | 500 psf |
| Friction Angle (phi): | 30 degrees |

The assumed unit weight is typical of landfills that do not recirculate leachate. The assumed shear strength envelope (cohesion and friction angle values) was based on EPA guidance and summarized strength properties for MSW waste by Kavazanjian et. al. (1995) and Eid et. al. (2000). These data came from published lab and field tests on MSW wastes and from values back figured from steep landfill slopes. Kavazanjian et. al. (1995) recommend a bilinear strength envelope for MSW materials as shown on **Figure 5**. This envelope represents a lower bound to the MSW strength data collected in that study. Also shown on **Figure 5** is the strength envelope recommended by Eid et. al and the strength envelope used in this evaluation. Note that the strength envelope used in this evaluation ranges between the Kavazanjian and Eid values for a waste thickness up to approximately 260 kPa ($\pm$ 5,400 psf or $\pm$ 75 feet of waste @ 70 pcf) and is more conservative than the two for greater waste thicknesses.

Liner System:

The assumed material properties for the liner system were:

| | |
|---|---|
| Unit Weight: | 100 pcf (moist and saturated) |
| Cohesion: | 0 psf |
| Friction Angle (phi): | 20 degrees |

The assumed unit weight is not critical as the liner system is very thin relative to the cross sections analyzed. The assumed shear strength envelope for the liner system is considered to be conservative of the geosynthetic/soil and geosynthetic/geosynthetic interfaces involved.

Note that based on performing a parametric analysis of the worst case slope stability cross section, an interface shear strength envelope defined by c = 0 psf and phi = 11 degrees is the minimum required for liner system components to satisfy minimum slope stability factors of safety.

The actual interface shear strength properties for the liner system interfaces should be confirmed prior to construction of the liner system. Based on this evaluation, RSG recommends the use of a textured geomembrane and reinforced GCL on this project to satisfy minimum slope stability factors of safety.

#### 3.2.2 Results

**Table 2** provides a summary of the results of the stability analyses for deep-seated failure surfaces. The results demonstrate that minimum factors of safety for both static and seismic conditions meet or exceed the minimum criteria (1.5 for final static conditions; 1.3 for interim static conditions; 1.0 for seismic conditions). These analyses are presented in **Appendix A**. In that the factors of safety for seismic conditions are at least 1.0, no deformation analyses were required.

## 3.3 Shallow Failure Surfaces

The stability of shallow translational (veneer) failure surfaces was evaluated using spreadsheet analyses. Translational failure surfaces along/through the side slope liner/protective cover and the final cover were analyzed.

#### 3.3.1 Material Properties

A summary of material properties used in the evaluation of shallow failure surfaces is presented in **Table 1**. A discussion of these values is as follows:

Side Slope Liner/Protective Cover:

The assumed material properties for the side slope liner/protective cover were:

| | |
|---|---|
| Unit Weight: | 110 pcf |
| Cohesion: | 0 psf |

Friction Angle (phi): 26.5 degrees

The assumed shear strength envelope for the side slope liner/protective cover is considered to be conservative of the geosynthetic/soil and geosynthetic/geosynthetic interfaces involved - especially considering the low (≤ 1,000 psf) that will be acting on this interface.

The actual interface shear strength properties for the side slope liner/protective cover interfaces should be confirmed prior to construction of the liner system. Based on this evaluation, RSG recommends the use of a textured geomembrane and reinforced GCL (if used) on this project to satisfy minimum slope stability factors of safety.

Final Cover System:

The assumed material properties for the final cover were:

| | |
|---|---|
| Unit Weight: | 110 pcf |
| Cohesion: | 0 psf |
| Friction Angle (phi): | 24 degrees |

The assumed shear strength envelope for the final cover is considered to be conservative of the geosynthetic/soil and geosynthetic/geosynthetic interfaces involved - especially considering the low (≤ 1,000 psf) that will be acting on this interface.

Additionally, the analysis of the final cover system considered 6 inches of head acting on the final cover geomembrane. This is conservative for head acting on top of the geomembrane as the drainage geocomposite has been designed to limit the head to no more than the thickness of the geonet drainage core (< 1 inch). However, the assumed 6 inches of head also models the condition of excess gas pressure acting on the bottom of the geomembrane.

The actual interface shear strength properties for the final cover interfaces should be confirmed prior to construction of the final cover system. Based on this evaluation, RSG recommends the use of a textured geomembrane on this project to satisfy minimum slope stability factors of safety.

### 3.3.2 Results

**Table 3** provides a summary of the results of the stability analyses for shallow failure surfaces. The results demonstrate that minimum factors of safety for both static and seismic conditions meet or exceed the minimum criteria (1.5 for final static conditions; 1.3 for interim static conditions; 1.0 for seismic conditions). These analyses are presented in **Appendix B** (Protective Cover Veneer) and

**Appendix C** (Final Cover Veneer).

## 4.0 FOUNDATION SETTLEMENT

The anticipated total and differential settlements of the Phase 4A foundation were estimated under maximum Phase 4A loading. These values do not include subsidence of the waste above the liner system, only settlement of the subgrade soils and, where applicable, underlying waste. The settlement analysis evaluated both elastic and consolidation settlement at various points in the landfill in predicting total and differential settlements.

Based upon site boring information, Phase 4A is underlain by 20 to 30+ feet of medium dense clayey and silty sands (SC and SM) and clayey silt (ML) grading down to partially weathered rock (PWR).

Settlement calculations were performed along two worst case sections (see **Figure 4** Points 1-7 and Points 8-18) through the landfill (e.g. along sections including the highest waste depths and along the general slope of the leachate collection system) to estimate the total and differential foundation settlements due to the weight of the planned waste and embankment loads. The resulting post-settlement slopes were evaluated to ensure that 1) positive drainage is maintained toward collection piping and/or sumps and 2) the maximum tensile strains in the liner system do not exceed allowable values.

For the section comprised of Points 1-7, which is cut through Cell 1 and along base grades, the settlement calculations show that maximum total foundation settlement will be approximately 1.6 feet and that positive slope will be maintained along leachate collection piping. Additionally, strains resulting from differential settlements are expected to be negligible (less than 0.1%) meaning that no adverse impacts on the function of the leachate collection or liner systems are anticipated. Note that the settlement calculations demonstrate that a 2% minimum post-settlement slope will be maintained along base grades.

For the section comprised of Points 8-18, which is cut through Cell 3 along the location of the leachate header pipe, the settlement calculations show that maximum total foundation settlement will be approximately 8.6 feet and that a positive slope (> 1.0%) will be maintained along leachate piping. Note that the larger value of maximum settlement along this section is due to settlement of the underlying waste, which is likely conservatively high in that strain hardening is not accounted for. Additionally, strains resulting from differential settlements are expected to be negligible (less than 0.1%) meaning that no adverse impacts on the function of the leachate collection or liner systems are anticipated.

Foundation settlement calculations are provided in **Appendix D**.

## 5.0 BEARING CAPACITY

Both the bearing capacity of the subgrade materials beneath the landfill footprint and the bearing capacity of the leachate collection system under anticipated construction and operations

equipment loads were evaluated. Based on the anticipated conditions, the overall landfill and the leachate collection system have adequate bearing capacity. The evaluation of the equipment loads also demonstrates the required separation between equipment and the underlying geomembrane(s).

Bearing capacity calculations are provided in **Appendix E**.

## 6.0 REFERENCES


Eid, H.T., Stark, T.D., Evans, W.D., and Sherry, P.E. (2000), "Municipal Solid Waste Slope Failure. I: Waste and Foundation Soil Properties," *Journal of Geotechnical and Geoenvironmental Engineering*, ASCE, Vol. 126, No. 5, pp. 397-407.

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Naval Facilities Engineering Command (1986), Foundations and Earth Structures (Design Manual 7.02), Naval Facilities Engineering Command, Alexandria, VA, p. 7.2-39.

Richardson, G.N., Kavazanjian, E., and N. Matasovic (1995), RCRA Subtitle D (258) Seismic Design Guidance for Municipal Solid Waste Landfill Facilities, EPA/600/R-95/051, U.S. Environmental Protection Agency, Washington, D.C.

Seed, H.B. and Idriss, I.M. (1982), "Ground Motions and Soil Liquefaction During Earthquakes," Monograph No. 5, Earthquake Engineering Research Institute, Berkeley, California.

U.S. Army Corps of Engineers (2003), Engineering and Design - Slope Stability, Engineer Manual, EM 1110-2-1902, Dept. of the Army, Washington, D.C.

## TABLE 1: MATERIAL PROPERTIES USED IN SLOPE STABILITY ANALYSES

| Material | Unit Weight (pcf) | Shear Strength Properties[1] | |
|---|---|---|---|
| | | Cohesion/ Adhesion ($c$) (psf) | Friction Angle ($\phi$) (degrees) |
| Perimeter Berms/Subgrade | 110 (Moist)<br>115 (Saturated) | 100 | 25 |
| Waste (MSW) | 70 (Moist)<br>90 (Saturated) | 500 | 30 |
| Liner:<br>(Textured GM Interface)[2] | 100 | 0 | 20 |
| Side Slope Liner/Protective Cover[3] | 110 | 0 | 26.5 |
| Final Cover[3] | 110 | 0 | 24 |

Notes:

1. Combinations of cohesion/adhesion and friction angle that are different than these values that produce the same shear strength could also be used here (shear strength ($\tau$) = normal load x tan ($\phi$) + $c$).

2. A parametric evaluation of the worst case slope stability run (Cross Section A - Static) revealed that an interface shear strength envelope defined by at least c = 0 psf and phi = 11 degrees would be required to satisfy the minimum required FS values of 1.5 (static) and 1.0 (seismic).

3. The shear strength values given for the side slope liner/protective cover and final cover are the minimum required to satisfy the required factors of safety under low ($\leq$ 1,000 psf) normal loads.

## TABLE 2: RESULTS SUMMARY - DEEP-SEATED FAILURE SURFACES

| Cross Section Analyzed (Condition) | Failure Type | Method of Analysis | Factor of Safety[1] | |
|---|---|---|---|---|
| | | | Static (FS ≥ 1.5 - Final) (FS ≥ 1.3 - Interim) | Seismic[2] (FS ≥ 1.0) |
| A (Final) | Block Along Liner | Modified Janbu | 2.16 | 1.75 |
| | Circular | Modified Bishop | 2.54 | 2.03 |

Notes:

1. See **Table 1** for material properties used in each run.
2. Seismic coefficient (a) = 0.5 x 0.09 g = 0.05 g.

## TABLE 3: RESULTS SUMMARY - SHALLOW FAILURE SURFACES

| Condition Analyzed (Condition) | Failure Type | Factor of Safety[1] | |
|---|---|---|---|
| | | Static (FS ≥ 1.5) | Seismic[2] (FS ≥ 1.0) |
| Side Slope Liner/Protective Cover | Translational | 1.50 | 1.12 |
| Final Cover | Translational | 1.53 | 1.10 |

Notes:

1. See **Table 1** for material properties used in each run.
2. Seismic coefficient (a) = 0.09 g.

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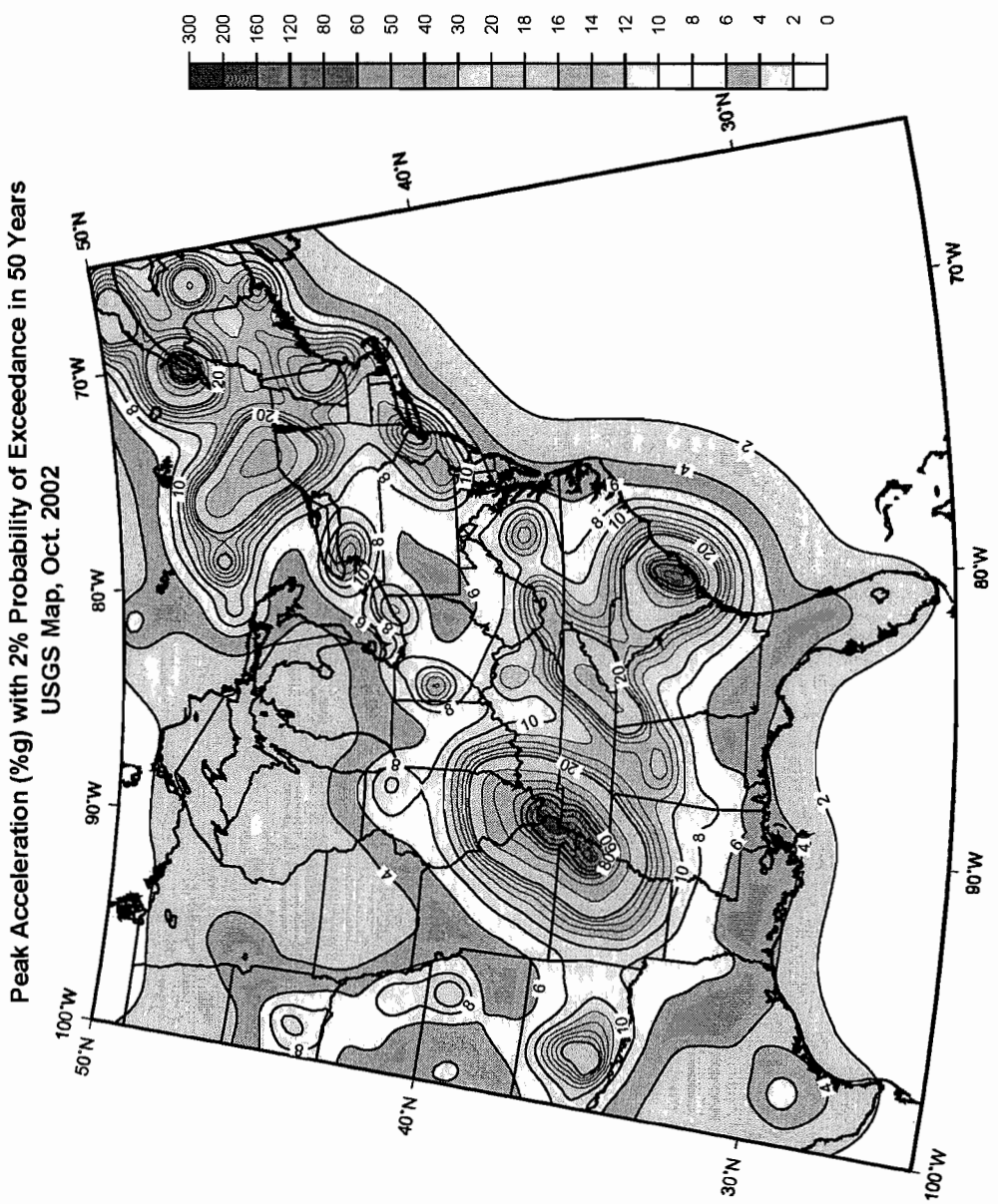


# USGS SEISMIC HAZARD MAP


**RICHARDSON SMITH GARDNER & ASSOCIATES**
Engineering and Geological Services
14 N. Boylan Ave. ph: 919-828-0577
Raleigh, NC 27603 fax: 919-828-3899


| SCALE: | DRAWN BY: | CHECKED BY: | DATE: | PROJECT NO. | FIGURE NO. |
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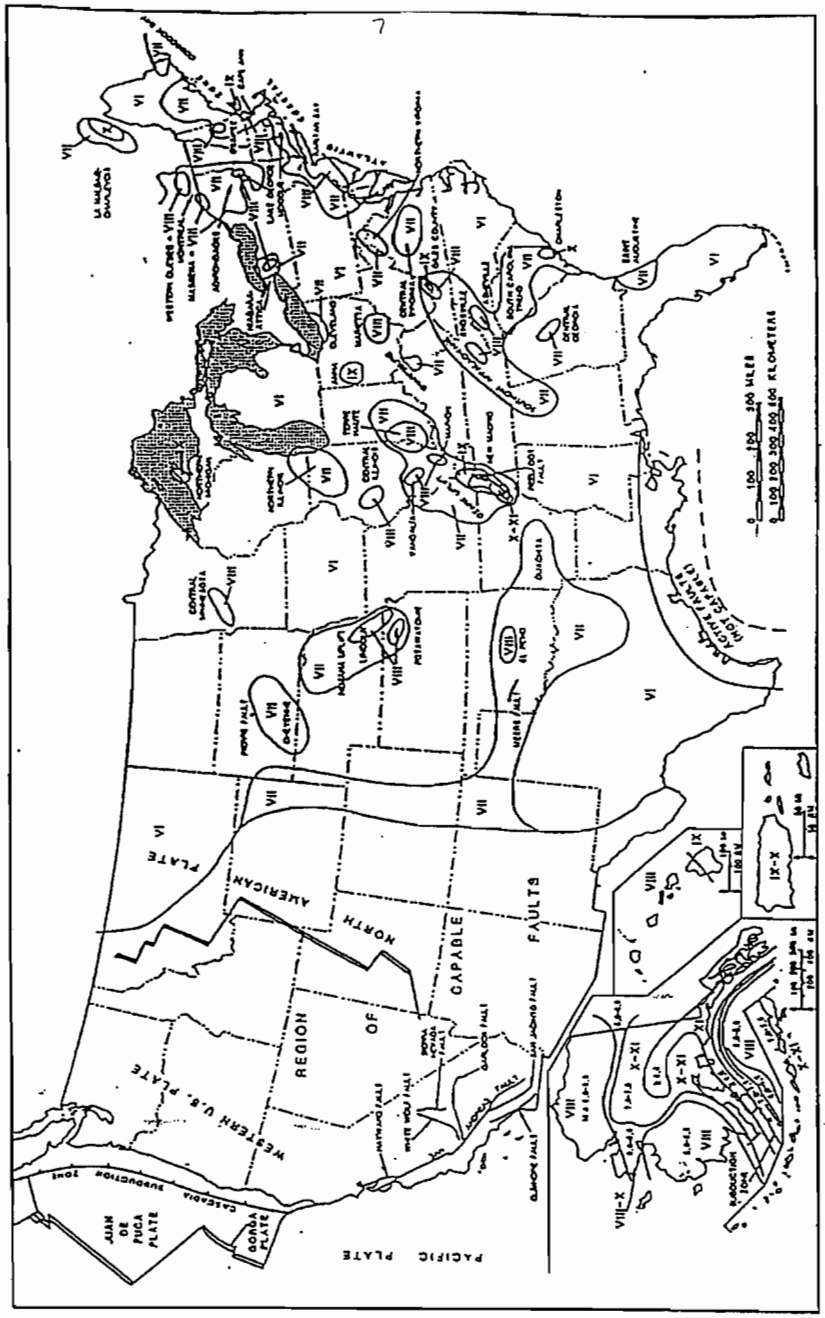


CAPABLE FAULTS
(KRINITZKY et. al., 1993)

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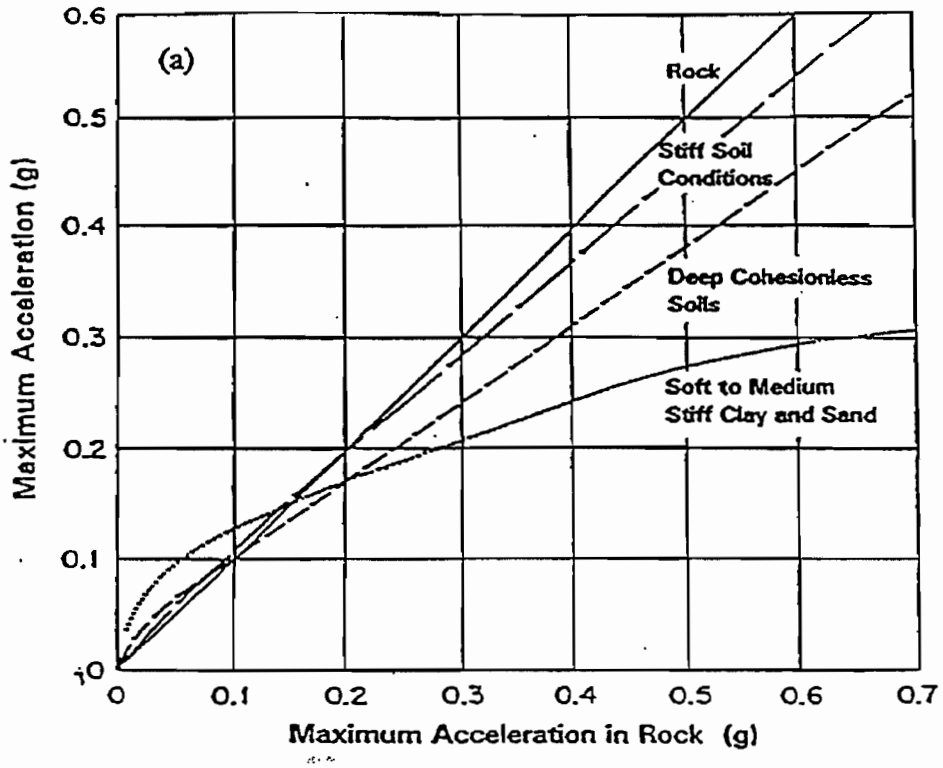


SITE AMPLIFICATION/ATTENUATION RELATIONSHIPS
(SEED & IDRISS, 1982)

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SLOPE STABILITY CROSS SECTION A

MSW PHASE 4A CELLS 1 AND 2 (ACTIVE)

PHASE 4A–CELL 3 LIMIT OF LINER (7.4 ACRES)

C&D VERTICAL EXPANSION (AREA 1) (INACTIVE)

0 200' 400' 600'

## LEGEND

- 150 — EXISTING 10' CONTOUR (SEE REFERENCE 1)
- EXISTING 2' CONTOUR
- APPROXIMATE PROPERTY LINE
- LIMITS OF EXISTING LINER
- CELL 3 LIMIT OF LINER
- 300 — PROPOSED 10' CONTOUR
- PROPOSED 2' CONTOUR
- ✕6 SETTLEMENT EVALUATION POINT

## REFERENCES

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


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| | |
|---|---|
| FIGURE NO. | 4 |
| SCALE: | AS SHOWN |
| FILE NAME | JOHN-B0512A |
| CHECKED BY: | |
| PROJECT NO. | JOHN 07-2 |
| DRAWN BY: | J.A.L. |
| DATE: | Nov. 2008 |

TITLE: LOCATION OF SLOPE STABILITY CROSS SECTION AND SETTLEMENT EVALUATION POINTS

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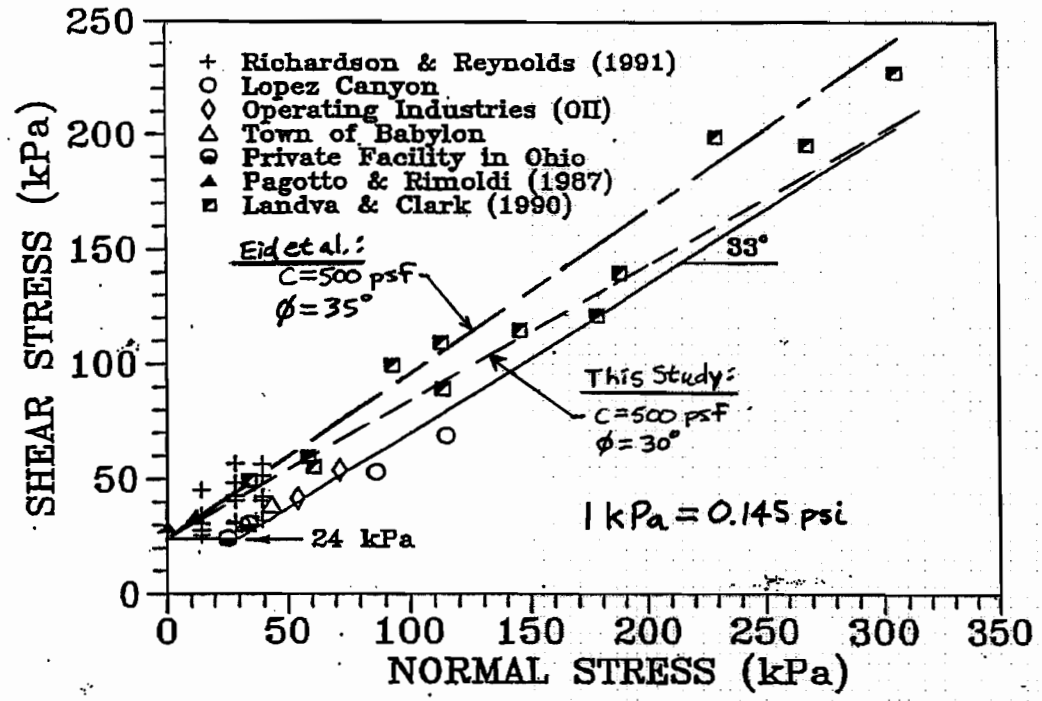


SHEAR STRENGTH OF MUNICIPAL SOLID WASTE


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|---|---|---|---|---|---|
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# Appendix A

## Deep-Seated Slope Stability Analyses

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# Johnston County Phase 4A - Section A Block Static

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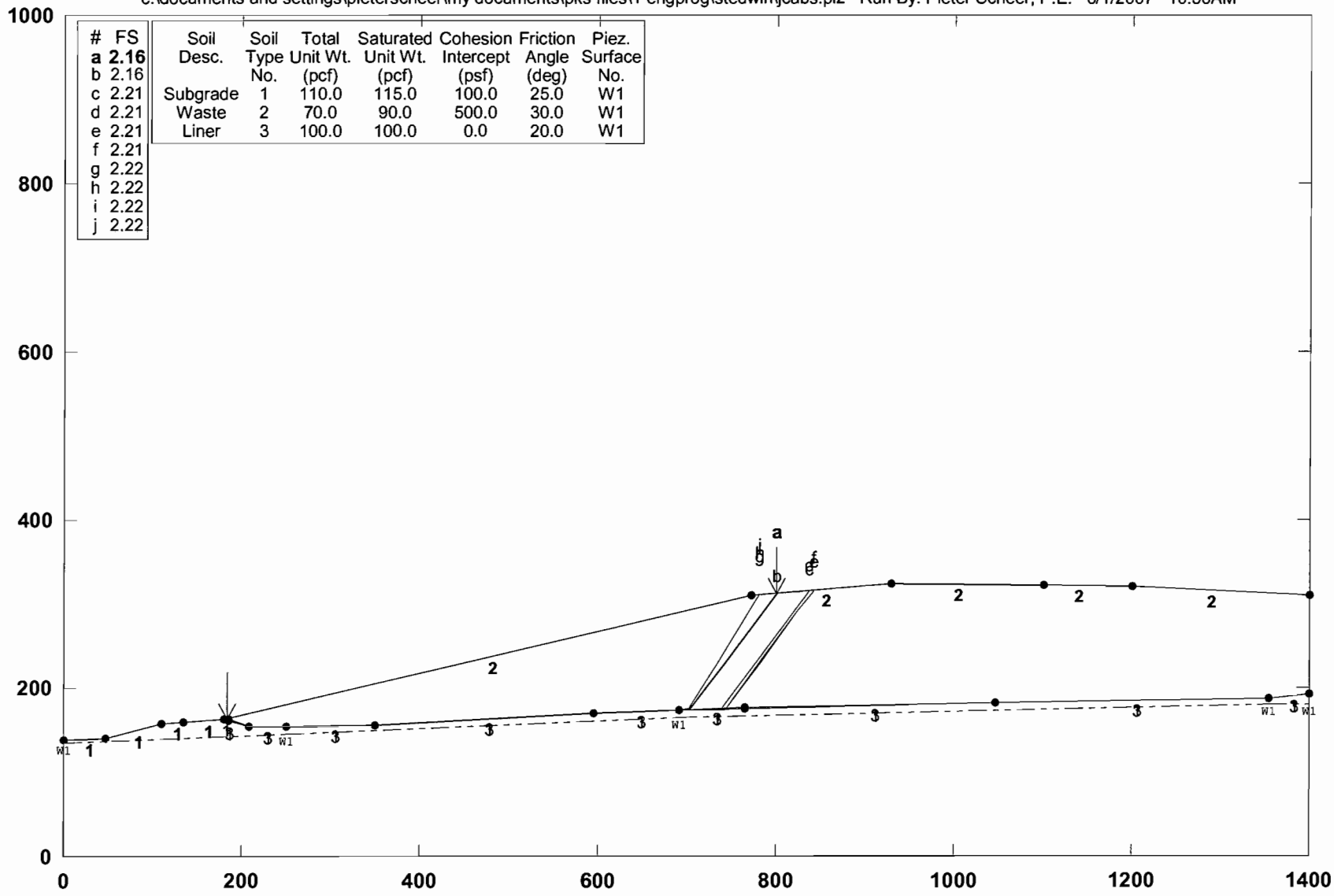
| # | FS |
|---|---|
| **a** | **2.16** |
| b | 2.16 |
| c | 2.21 |
| d | 2.21 |
| e | 2.21 |
| f | 2.21 |
| g | 2.22 |
| h | 2.22 |
| i | 2.22 |
| j | 2.22 |

| Soil Desc. | Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Piez. Surface No. |
|---|---|---|---|---|---|---|
| Subgrade | 1 | 110.0 | 115.0 | 100.0 | 25.0 | W1 |
| Waste | 2 | 70.0 | 90.0 | 500.0 | 30.0 | W1 |
| Liner | 3 | 100.0 | 100.0 | 0.0 | 20.0 | W1 |




**PCSTABL5M/si FSmin=2.16**

**Safety Factors Are Calculated By The Modified Janbu Method**

1/26

**** PCSTABL5M ****
by
Purdue University
--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

Run Date: 6/1/2007
Time of Run: 10:56AM
Run By: Pieter Scheer, P.E.
Input Data Filename: C:jcabs.in
Output Filename: C:jcabs.OUT
Unit: ENGLISH
Plotted Output Filename: C:jcabs.PLT
PROBLEM DESCRIPTION Johnston County Phase 4A - Section A
Block Static

BOUNDARY COORDINATES
9 Top Boundaries
28 Total Boundaries

| Boundary No. | X-Left (ft) | Y-Left (ft) | X-Right (ft) | Y-Right (ft) | Soil Type Below Bnd |
|---|---|---|---|---|---|
| 1 | .00 | 139.00 | 48.00 | 140.00 | 1 |
| 2 | 48.00 | 140.00 | 110.00 | 158.00 | 1 |
| 3 | 110.00 | 158.00 | 135.00 | 160.00 | 1 |
| 4 | 135.00 | 160.00 | 180.00 | 162.00 | 1 |
| 5 | 180.00 | 162.00 | 772.00 | 310.00 | 2 |
| 6 | 772.00 | 310.00 | 930.00 | 323.00 | 2 |
| 7 | 930.00 | 323.00 | 1100.00 | 322.00 | 2 |
| 8 | 1100.00 | 322.00 | 1200.00 | 320.00 | 2 |
| 9 | 1200.00 | 320.00 | 1400.00 | 310.00 | 2 |
| 10 | 180.00 | 162.00 | 185.00 | 162.00 | 1 |
| 11 | 185.00 | 162.00 | 208.00 | 154.00 | 3 |
| 12 | 208.00 | 154.00 | 250.00 | 154.00 | 3 |
| 13 | 250.00 | 154.00 | 350.00 | 156.00 | 3 |
| 14 | 350.00 | 156.00 | 595.00 | 170.00 | 3 |
| 15 | 595.00 | 170.00 | 692.00 | 174.00 | 3 |
| 16 | 692.00 | 174.00 | 765.00 | 176.00 | 3 |
| 17 | 765.00 | 176.00 | 1047.00 | 182.00 | 3 |
| 18 | 1047.00 | 182.00 | 1355.00 | 188.00 | 3 |
| 19 | 1355.00 | 188.00 | 1400.00 | 192.00 | 3 |
| 20 | 185.00 | 161.80 | 208.00 | 153.80 | 1 |
| 21 | 208.00 | 153.80 | 250.00 | 153.80 | 1 |
| 22 | 250.00 | 153.80 | 350.00 | 155.80 | 1 |
| 23 | 350.00 | 155.80 | 595.00 | 169.80 | 1 |
| 24 | 595.00 | 169.80 | 692.00 | 173.80 | 1 |
| 25 | 692.00 | 173.80 | 765.00 | 175.80 | 1 |
| 26 | 765.00 | 175.80 | 1047.00 | 181.80 | 1 |
| 27 | 1047.00 | 181.80 | 1355.00 | 187.80 | 1 |
| 28 | 1355.00 | 187.80 | 1400.00 | 191.80 | 1 |

ISOTROPIC SOIL PARAMETERS
3 Type(s) of Soil

| Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Pore Pressure Param. | Pressure Constant (psf) | Piez. Surface No. |
|---|---|---|---|---|---|---|---|
| 1 | 110.0 | 115.0 | 100.0 | 25.0 | .00 | .0 | 1 |
| 2 | 70.0 | 90.0 | 500.0 | 30.0 | .00 | .0 | 1 |
| 3 | 100.0 | 100.0 | .0 | 20.0 | .00 | .0 | 1 |

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED
Unit Weight of Water = 62.40
Piezometric Surface No. 1 Specified by 5 Coordinate Points

| Point No. | X-Water (ft) | Y-Water (ft) |
|---|---|---|
| 1 | .00 | 135.00 |
| 2 | 250.00 | 145.00 |
| 3 | 692.00 | 165.00 |
| 4 | 1355.00 | 180.00 |
| 5 | 1400.00 | 181.00 |

A Critical Failure Surface Searching Method, Using A Random

Technique For Generating Sliding Block Surfaces, Has Been Specified.
The Active And Passive Portions Of The Sliding Surfaces Are Generated According To The Rankine Theory.
500 Trial Surfaces Have Been Generated.
7 Boxes Specified For Generation Of Central Block Base
Length Of Line Segments For Active And Passive Portions Of Sliding Block Is 70.0

| Box No. | X-Left (ft) | Y-Left (ft) | X-Right (ft) | Y-Right (ft) | Height (ft) |
|---|---|---|---|---|---|
| 1 | 185.00 | 161.90 | 185.00 | 161.90 | .00 |
| 2 | 208.00 | 153.90 | 208.00 | 153.90 | .00 |
| 3 | 250.00 | 153.90 | 250.00 | 153.90 | .00 |
| 4 | 350.00 | 155.90 | 350.00 | 155.90 | .00 |
| 5 | 595.00 | 169.90 | 595.00 | 169.90 | .00 |
| 6 | 692.00 | 173.90 | 692.00 | 173.90 | .00 |
| 7 | 692.01 | 173.90 | 765.00 | 175.90 | .00 |

****** ERROR - BK12 ******

**>>Points on active or passive wedges are outside defined ground surface**

Following Are Displayed The Ten Most Critical Of The Trial Failure Surfaces Examined. They Are Ordered - Most Critical First.
* * Safety Factors Are Calculated By The Modified Janbu Method * *
Failure Surface Specified By 13 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 183.39 | 162.85 |
| 2 | 184.86 | 162.00 |
| 3 | 185.00 | 161.90 |
| 4 | 208.00 | 153.90 |
| 5 | 250.00 | 153.90 |
| 6 | 350.00 | 155.90 |
| 7 | 595.00 | 169.90 |
| 8 | 692.00 | 173.90 |
| 9 | 703.18 | 174.21 |
| 10 | 703.25 | 174.31 |
| 11 | 743.40 | 231.65 |
| 12 | 783.55 | 288.99 |
| 13 | 799.87 | 312.29 |

*** 2.158 ***

Individual data on the 13 slices

| Slice No. | Width (ft) | Weight (lbs) | Water Force Top (lbs) | Water Force Bot (lbs) | Tie Force Norm (lbs) | Tie Force Tan (lbs) | Earthquake Force Hor (lbs) | Earthquake Force Ver (lbs) | Surcharge Load (lbs) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.5 | 62.4 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 2 | .1 | 13.1 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 3 | 23.0 | 13311.3 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 4 | 42.0 | 59955.0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 5 | 100.0 | 260000.1 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 6 | 245.0 | ******** | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 7 | 97.0 | 719861.3 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 8 | 11.2 | 91855.7 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 9 | .1 | 594.2 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 10 | 40.2 | 266586.2 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 11 | 28.6 | 108814.8 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 12 | 11.6 | 24041.6 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 13 | 16.3 | 12541.9 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

Failure Surface Specified By 13 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 183.39 | 162.85 |
| 2 | 184.86 | 162.00 |
| 3 | 185.00 | 161.90 |
| 4 | 208.00 | 153.90 |
| 5 | 250.00 | 153.90 |
| 6 | 350.00 | 155.90 |

| | | |
|---|---|---|
| 7 | 595.00 | 169.90 |
| 8 | 692.00 | 173.90 |
| 9 | 703.21 | 174.21 |
| 10 | 703.29 | 174.31 |
| 11 | 743.44 | 231.65 |
| 12 | 783.59 | 288.99 |
| 13 | 799.91 | 312.30 |

*** 2.158 ***

Failure Surface Specified By 13 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 183.39 | 162.85 |
| 2 | 184.86 | 162.00 |
| 3 | 185.00 | 161.90 |
| 4 | 208.00 | 153.90 |
| 5 | 250.00 | 153.90 |
| 6 | 350.00 | 155.90 |
| 7 | 595.00 | 169.90 |
| 8 | 692.00 | 173.90 |
| 9 | 738.68 | 175.18 |
| 10 | 738.75 | 175.28 |
| 11 | 778.90 | 232.62 |
| 12 | 819.05 | 289.96 |
| 13 | 836.81 | 315.33 |

*** 2.206 ***

Failure Surface Specified By 13 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 183.39 | 162.85 |
| 2 | 184.86 | 162.00 |
| 3 | 185.00 | 161.90 |
| 4 | 208.00 | 153.90 |
| 5 | 250.00 | 153.90 |
| 6 | 350.00 | 155.90 |
| 7 | 595.00 | 169.90 |
| 8 | 692.00 | 173.90 |
| 9 | 738.71 | 175.18 |
| 10 | 738.78 | 175.28 |
| 11 | 778.93 | 232.62 |
| 12 | 819.08 | 289.96 |
| 13 | 836.85 | 315.34 |

*** 2.206 ***

Failure Surface Specified By 13 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 183.39 | 162.85 |
| 2 | 184.86 | 162.00 |
| 3 | 185.00 | 161.90 |
| 4 | 208.00 | 153.90 |
| 5 | 250.00 | 153.90 |
| 6 | 350.00 | 155.90 |
| 7 | 595.00 | 169.90 |
| 8 | 692.00 | 173.90 |
| 9 | 742.88 | 175.29 |
| 10 | 742.95 | 175.40 |
| 11 | 783.10 | 232.74 |
| 12 | 823.25 | 290.08 |
| 13 | 841.19 | 315.69 |

*** 2.214 ***

Failure Surface Specified By 13 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 183.39 | 162.85 |
| 2 | 184.86 | 162.00 |
| 3 | 185.00 | 161.90 |
| 4 | 208.00 | 153.90 |
| 5 | 250.00 | 153.90 |

| | | |
|---|---|---|
| 6 | 350.00 | 155.90 |
| 7 | 595.00 | 169.90 |
| 8 | 692.00 | 173.90 |
| 9 | 742.95 | 175.30 |
| 10 | 743.02 | 175.40 |
| 11 | 783.17 | 232.74 |
| 12 | 823.32 | 290.08 |
| 13 | 841.26 | 315.70 |

*** 2.214 ***

Failure Surface Specified By 13 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 183.39 | 162.85 |
| 2 | 184.86 | 162.00 |
| 3 | 185.00 | 161.90 |
| 4 | 208.00 | 153.90 |
| 5 | 250.00 | 153.90 |
| 6 | 350.00 | 155.90 |
| 7 | 595.00 | 169.90 |
| 8 | 692.00 | 173.90 |
| 9 | 701.11 | 174.15 |
| 10 | 701.18 | 174.25 |
| 11 | 736.18 | 234.87 |
| 12 | 771.18 | 295.50 |
| 13 | 779.93 | 310.65 |

*** 2.215 ***

Failure Surface Specified By 13 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 183.39 | 162.85 |
| 2 | 184.86 | 162.00 |
| 3 | 185.00 | 161.90 |
| 4 | 208.00 | 153.90 |
| 5 | 250.00 | 153.90 |
| 6 | 350.00 | 155.90 |
| 7 | 595.00 | 169.90 |
| 8 | 692.00 | 173.90 |
| 9 | 701.25 | 174.15 |
| 10 | 701.33 | 174.26 |
| 11 | 736.33 | 234.88 |
| 12 | 771.33 | 295.50 |
| 13 | 780.08 | 310.66 |

*** 2.215 ***

Failure Surface Specified By 13 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 183.39 | 162.85 |
| 2 | 184.86 | 162.00 |
| 3 | 185.00 | 161.90 |
| 4 | 208.00 | 153.90 |
| 5 | 250.00 | 153.90 |
| 6 | 350.00 | 155.90 |
| 7 | 595.00 | 169.90 |
| 8 | 692.00 | 173.90 |
| 9 | 701.57 | 174.16 |
| 10 | 701.65 | 174.26 |
| 11 | 736.65 | 234.89 |
| 12 | 771.65 | 295.51 |
| 13 | 780.41 | 310.69 |

*** 2.215 ***

Failure Surface Specified By 13 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 183.39 | 162.85 |
| 2 | 184.86 | 162.00 |
| 3 | 185.00 | 161.90 |
| 4 | 208.00 | 153.90 |

| | | |
|---|---|---|
| 5 | 250.00 | 153.90 |
| 6 | 350.00 | 155.90 |
| 7 | 595.00 | 169.90 |
| 8 | 692.00 | 173.90 |
| 9 | 701.33 | 174.16 |
| 10 | 701.40 | 174.26 |
| 11 | 736.40 | 234.88 |
| 12 | 771.40 | 295.50 |
| 13 | 780.16 | 310.67 |
| *** | 2.215 | *** |

# Johnston County Phase 4A - Section A Block Seismic

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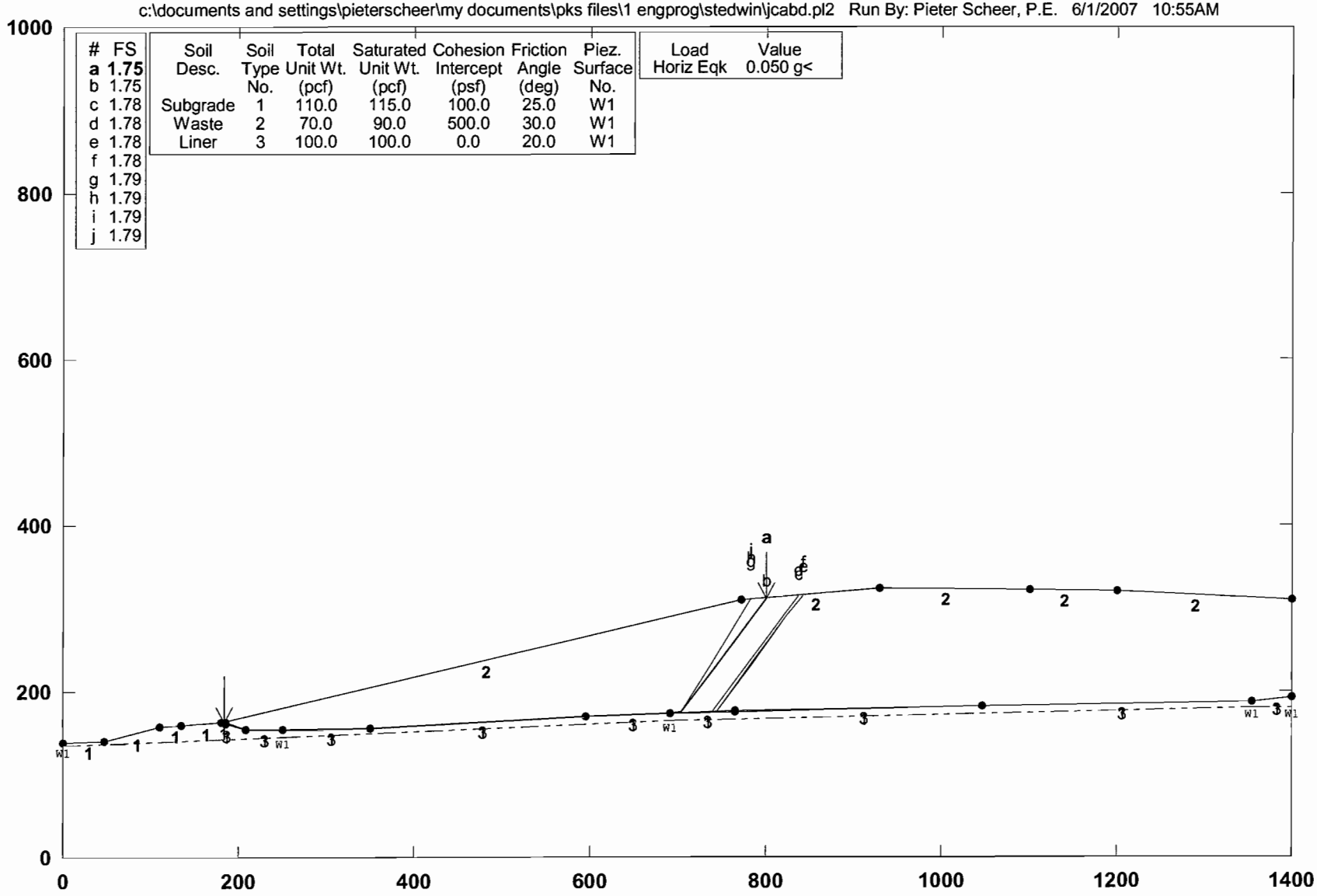
| # | FS |
|---|---|
| **a** | **1.75** |
| b | 1.75 |
| c | 1.78 |
| d | 1.78 |
| e | 1.78 |
| f | 1.78 |
| g | 1.79 |
| h | 1.79 |
| i | 1.79 |
| j | 1.79 |

| Soil Desc. | Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Piez. Surface No. |
|---|---|---|---|---|---|---|
| Subgrade | 1 | 110.0 | 115.0 | 100.0 | 25.0 | W1 |
| Waste | 2 | 70.0 | 90.0 | 500.0 | 30.0 | W1 |
| Liner | 3 | 100.0 | 100.0 | 0.0 | 20.0 | W1 |

| Load | Value |
|---|---|
| Horiz Eqk | 0.050 g< |




**PCSTABL5M/si FSmin=1.75**

**Safety Factors Are Calculated By The Modified Janbu Method**

7/26

**** PCSTABL5M ****
by
Purdue University
--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

Run Date: 6/1/2007
Time of Run: 10:55AM
Run By: Pieter Scheer, P.E.
Input Data Filename: C:jcabd.in
Output Filename: C:jcabd.OUT
Unit: ENGLISH
Plotted Output Filename: C:jcabd.PLT
PROBLEM DESCRIPTION Johnston County Phase 4A - Section A
Block Seismic

BOUNDARY COORDINATES
9 Top Boundaries
28 Total Boundaries

| Boundary No. | X-Left (ft) | Y-Left (ft) | X-Right (ft) | Y-Right (ft) | Soil Type Below Bnd |
|---|---|---|---|---|---|
| 1 | .00 | 139.00 | 48.00 | 140.00 | 1 |
| 2 | 48.00 | 140.00 | 110.00 | 158.00 | 1 |
| 3 | 110.00 | 158.00 | 135.00 | 160.00 | 1 |
| 4 | 135.00 | 160.00 | 180.00 | 162.00 | 1 |
| 5 | 180.00 | 162.00 | 772.00 | 310.00 | 2 |
| 6 | 772.00 | 310.00 | 930.00 | 323.00 | 2 |
| 7 | 930.00 | 323.00 | 1100.00 | 322.00 | 2 |
| 8 | 1100.00 | 322.00 | 1200.00 | 320.00 | 2 |
| 9 | 1200.00 | 320.00 | 1400.00 | 310.00 | 2 |
| 10 | 180.00 | 162.00 | 185.00 | 162.00 | 1 |
| 11 | 185.00 | 162.00 | 208.00 | 154.00 | 3 |
| 12 | 208.00 | 154.00 | 250.00 | 154.00 | 3 |
| 13 | 250.00 | 154.00 | 350.00 | 156.00 | 3 |
| 14 | 350.00 | 156.00 | 595.00 | 170.00 | 3 |
| 15 | 595.00 | 170.00 | 692.00 | 174.00 | 3 |
| 16 | 692.00 | 174.00 | 765.00 | 176.00 | 3 |
| 17 | 765.00 | 176.00 | 1047.00 | 182.00 | 3 |
| 18 | 1047.00 | 182.00 | 1355.00 | 188.00 | 3 |
| 19 | 1355.00 | 188.00 | 1400.00 | 192.00 | 3 |
| 20 | 185.00 | 161.80 | 208.00 | 153.80 | 1 |
| 21 | 208.00 | 153.80 | 250.00 | 153.80 | 1 |
| 22 | 250.00 | 153.80 | 350.00 | 155.80 | 1 |
| 23 | 350.00 | 155.80 | 595.00 | 169.80 | 1 |
| 24 | 595.00 | 169.80 | 692.00 | 173.80 | 1 |
| 25 | 692.00 | 173.80 | 765.00 | 175.80 | 1 |
| 26 | 765.00 | 175.80 | 1047.00 | 181.80 | 1 |
| 27 | 1047.00 | 181.80 | 1355.00 | 187.80 | 1 |
| 28 | 1355.00 | 187.80 | 1400.00 | 191.80 | 1 |

ISOTROPIC SOIL PARAMETERS
3 Type(s) of Soil

| Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Pore Pressure Param. | Pressure Constant (psf) | Piez. Surface No. |
|---|---|---|---|---|---|---|---|
| 1 | 110.0 | 115.0 | 100.0 | 25.0 | .00 | .0 | 1 |
| 2 | 70.0 | 90.0 | 500.0 | 30.0 | .00 | .0 | 1 |
| 3 | 100.0 | 100.0 | .0 | 20.0 | .00 | .0 | 1 |

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED
Unit Weight of Water = 62.40
Piezometric Surface No. 1 Specified by 5 Coordinate Points

| Point No. | X-Water (ft) | Y-Water (ft) |
|---|---|---|
| 1 | .00 | 135.00 |
| 2 | 250.00 | 145.00 |
| 3 | 692.00 | 165.00 |
| 4 | 1355.00 | 180.00 |
| 5 | 1400.00 | 181.00 |

A Horizontal Earthquake Loading Coefficient

Of .050 Has Been Assigned
A Vertical Earthquake Loading Coefficient
Of .000 Has Been Assigned
Cavitation Pressure = .0 (psf)
A Critical Failure Surface Searching Method, Using A Random
Technique For Generating Sliding Block Surfaces, Has Been
Specified.
The Active And Passive Portions Of The Sliding Surfaces
Are Generated According To The Rankine Theory.
500 Trial Surfaces Have Been Generated.
7 Boxes Specified For Generation Of Central Block Base
Length Of Line Segments For Active And Passive Portions Of
Sliding Block Is 70.0

| Box No. | X-Left (ft) | Y-Left (ft) | X-Right (ft) | Y-Right (ft) | Height (ft) |
|---|---|---|---|---|---|
| 1 | 185.00 | 161.90 | 185.00 | 161.90 | .00 |
| 2 | 208.00 | 153.90 | 208.00 | 153.90 | .00 |
| 3 | 250.00 | 153.90 | 250.00 | 153.90 | .00 |
| 4 | 350.00 | 155.90 | 350.00 | 155.90 | .00 |
| 5 | 595.00 | 169.90 | 595.00 | 169.90 | .00 |
| 6 | 692.00 | 173.90 | 692.00 | 173.90 | .00 |
| 7 | 692.01 | 173.90 | 765.00 | 175.90 | .00 |

****** ERROR - BK12 ******
**>>Points on active or passive wedges are outside defined ground surface**

Following Are Displayed The Ten Most Critical Of The Trial
Failure Surfaces Examined. They Are Ordered - Most Critical
First.
* * Safety Factors Are Calculated By The Modified Janbu Method * *
Failure Surface Specified By 13 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 183.39 | 162.85 |
| 2 | 184.86 | 162.00 |
| 3 | 185.00 | 161.90 |
| 4 | 208.00 | 153.90 |
| 5 | 250.00 | 153.90 |
| 6 | 350.00 | 155.90 |
| 7 | 595.00 | 169.90 |
| 8 | 692.00 | 173.90 |
| 9 | 703.18 | 174.21 |
| 10 | 703.25 | 174.31 |
| 11 | 743.40 | 231.65 |
| 12 | 783.55 | 288.99 |
| 13 | 799.87 | 312.29 |

*** 1.747 ***

Individual data on the 13 slices

| Slice No. | Width (ft) | Weight (lbs) | Water Force Top (lbs) | Water Force Bot (lbs) | Tie Force Norm (lbs) | Tie Force Tan (lbs) | Earthquake Force Hor (lbs) | Earthquake Force Ver (lbs) | Surcharge Load (lbs) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.5 | 62.4 | .0 | .0 | .0 | .0 | 3.1 | .0 | .0 |
| 2 | .1 | 13.1 | .0 | .0 | .0 | .0 | .7 | .0 | .0 |
| 3 | 23.0 | 13311.3 | .0 | .0 | .0 | .0 | 665.6 | .0 | .0 |
| 4 | 42.0 | 59955.0 | .0 | .0 | .0 | .0 | 2997.8 | .0 | .0 |
| 5 | 100.0 | 260000.1 | .0 | .0 | .0 | .0 | 13000.0 | .0 | .0 |
| 6 | 245.0 | ******** | .0 | .0 | .0 | .0 | 61969.7 | .0 | .0 |
| 7 | 97.0 | 719861.3 | .0 | .0 | .0 | .0 | 35993.1 | .0 | .0 |
| 8 | 11.2 | 91855.7 | .0 | .0 | .0 | .0 | 4592.8 | .0 | .0 |
| 9 | .1 | 594.2 | .0 | .0 | .0 | .0 | 29.7 | .0 | .0 |
| 10 | 40.2 | 266586.2 | .0 | .0 | .0 | .0 | 13329.3 | .0 | .0 |
| 11 | 28.6 | 108814.8 | .0 | .0 | .0 | .0 | 5440.7 | .0 | .0 |
| 12 | 11.6 | 24041.6 | .0 | .0 | .0 | .0 | 1202.1 | .0 | .0 |
| 13 | 16.3 | 12541.9 | .0 | .0 | .0 | .0 | 627.1 | .0 | .0 |

Failure Surface Specified By 13 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 183.39 | 162.85 |

| | | |
|---|---|---|
| 2 | 184.86 | 162.00 |
| 3 | 185.00 | 161.90 |
| 4 | 208.00 | 153.90 |
| 5 | 250.00 | 153.90 |
| 6 | 350.00 | 155.90 |
| 7 | 595.00 | 169.90 |
| 8 | 692.00 | 173.90 |
| 9 | 703.21 | 174.21 |
| 10 | 703.29 | 174.31 |
| 11 | 743.44 | 231.65 |
| 12 | 783.59 | 288.99 |
| 13 | 799.91 | 312.30 |
| *** | 1.747 | *** |

Failure Surface Specified By 13 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 183.39 | 162.85 |
| 2 | 184.86 | 162.00 |
| 3 | 185.00 | 161.90 |
| 4 | 208.00 | 153.90 |
| 5 | 250.00 | 153.90 |
| 6 | 350.00 | 155.90 |
| 7 | 595.00 | 169.90 |
| 8 | 692.00 | 173.90 |
| 9 | 738.68 | 175.18 |
| 10 | 738.75 | 175.28 |
| 11 | 778.90 | 232.62 |
| 12 | 819.05 | 289.96 |
| 13 | 836.81 | 315.33 |
| *** | 1.776 | *** |

Failure Surface Specified By 13 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 183.39 | 162.85 |
| 2 | 184.86 | 162.00 |
| 3 | 185.00 | 161.90 |
| 4 | 208.00 | 153.90 |
| 5 | 250.00 | 153.90 |
| 6 | 350.00 | 155.90 |
| 7 | 595.00 | 169.90 |
| 8 | 692.00 | 173.90 |
| 9 | 738.71 | 175.18 |
| 10 | 738.78 | 175.28 |
| 11 | 778.93 | 232.62 |
| 12 | 819.08 | 289.96 |
| 13 | 836.85 | 315.34 |
| *** | 1.776 | *** |

Failure Surface Specified By 13 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 183.39 | 162.85 |
| 2 | 184.86 | 162.00 |
| 3 | 185.00 | 161.90 |
| 4 | 208.00 | 153.90 |
| 5 | 250.00 | 153.90 |
| 6 | 350.00 | 155.90 |
| 7 | 595.00 | 169.90 |
| 8 | 692.00 | 173.90 |
| 9 | 742.88 | 175.29 |
| 10 | 742.95 | 175.40 |
| 11 | 783.10 | 232.74 |
| 12 | 823.25 | 290.08 |
| 13 | 841.19 | 315.69 |
| *** | 1.781 | *** |

Failure Surface Specified By 13 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|

| | | |
|---|---|---|
| 1 | 183.39 | 162.85 |
| 2 | 184.86 | 162.00 |
| 3 | 185.00 | 161.90 |
| 4 | 208.00 | 153.90 |
| 5 | 250.00 | 153.90 |
| 6 | 350.00 | 155.90 |
| 7 | 595.00 | 169.90 |
| 8 | 692.00 | 173.90 |
| 9 | 742.95 | 175.30 |
| 10 | 743.02 | 175.40 |
| 11 | 783.17 | 232.74 |
| 12 | 823.32 | 290.08 |
| 13 | 841.26 | 315.70 |
| *** | 1.781 | *** |

Failure Surface Specified By 13 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 183.39 | 162.85 |
| 2 | 184.86 | 162.00 |
| 3 | 185.00 | 161.90 |
| 4 | 208.00 | 153.90 |
| 5 | 250.00 | 153.90 |
| 6 | 350.00 | 155.90 |
| 7 | 595.00 | 169.90 |
| 8 | 692.00 | 173.90 |
| 9 | 703.46 | 174.21 |
| 10 | 703.54 | 174.32 |
| 11 | 738.54 | 234.94 |
| 12 | 773.54 | 295.56 |
| 13 | 782.36 | 310.85 |
| *** | 1.790 | *** |

Failure Surface Specified By 13 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 183.39 | 162.85 |
| 2 | 184.86 | 162.00 |
| 3 | 185.00 | 161.90 |
| 4 | 208.00 | 153.90 |
| 5 | 250.00 | 153.90 |
| 6 | 350.00 | 155.90 |
| 7 | 595.00 | 169.90 |
| 8 | 692.00 | 173.90 |
| 9 | 703.39 | 174.21 |
| 10 | 703.46 | 174.31 |
| 11 | 738.46 | 234.94 |
| 12 | 773.46 | 295.56 |
| 13 | 782.29 | 310.85 |
| *** | 1.790 | *** |

Failure Surface Specified By 13 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 183.39 | 162.85 |
| 2 | 184.86 | 162.00 |
| 3 | 185.00 | 161.90 |
| 4 | 208.00 | 153.90 |
| 5 | 250.00 | 153.90 |
| 6 | 350.00 | 155.90 |
| 7 | 595.00 | 169.90 |
| 8 | 692.00 | 173.90 |
| 9 | 702.75 | 174.19 |
| 10 | 702.82 | 174.30 |
| 11 | 737.82 | 234.92 |
| 12 | 772.82 | 295.54 |
| 13 | 781.63 | 310.79 |
| *** | 1.790 | *** |

Failure Surface Specified By 13 Coordinate Points

| Point | X-Surf | Y-Surf |
|---|---|---|

| No. | (ft) | (ft) |
|---|---|---|
| 1 | 183.39 | 162.85 |
| 2 | 184.86 | 162.00 |
| 3 | 185.00 | 161.90 |
| 4 | 208.00 | 153.90 |
| 5 | 250.00 | 153.90 |
| 6 | 350.00 | 155.90 |
| 7 | 595.00 | 169.90 |
| 8 | 692.00 | 173.90 |
| 9 | 703.50 | 174.21 |
| 10 | 703.57 | 174.32 |
| 11 | 738.57 | 234.94 |
| 12 | 773.57 | 295.56 |
| 13 | 782.40 | 310.86 |
| *** | 1.790 | *** |

# Johnston County Phase 4A - Section A Circular Static

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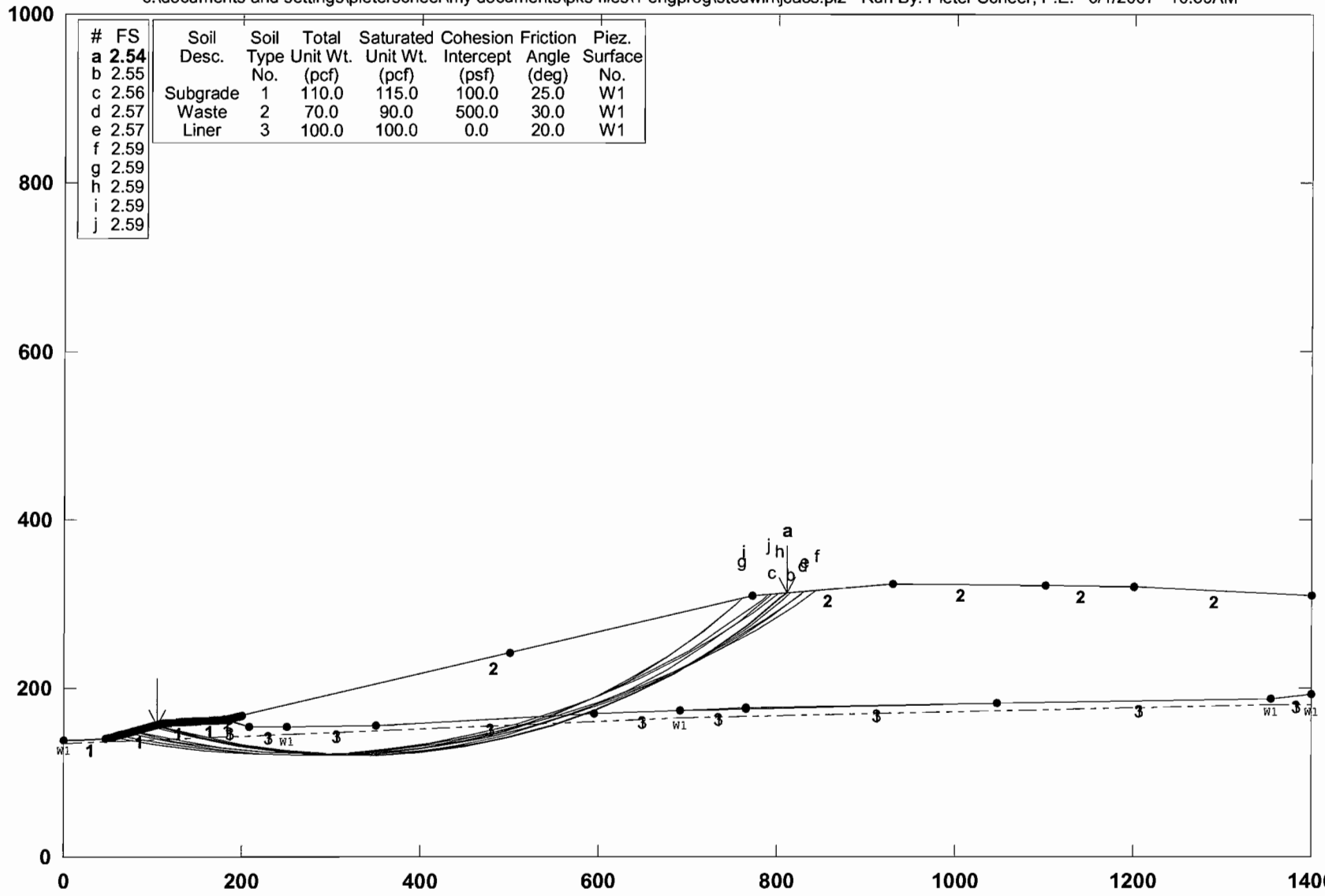
| # | FS |
|---|---|
| **a** | **2.54** |
| b | 2.55 |
| c | 2.56 |
| d | 2.57 |
| e | 2.57 |
| f | 2.59 |
| g | 2.59 |
| h | 2.59 |
| i | 2.59 |
| j | 2.59 |

| Soil Desc. | Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Piez. Surface No. |
|---|---|---|---|---|---|---|
| Subgrade | 1 | 110.0 | 115.0 | 100.0 | 25.0 | W1 |
| Waste | 2 | 70.0 | 90.0 | 500.0 | 30.0 | W1 |
| Liner | 3 | 100.0 | 100.0 | 0.0 | 20.0 | W1 |




**PCSTABL5M/si FSmin=2.54**

**Safety Factors Are Calculated By The Modified Bishop Method**

13/26

**** PCSTABL5M ****
by
Purdue University
--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

Run Date: 6/1/2007
Time of Run: 10:59AM
Run By: Pieter Scheer, P.E.
Input Data Filename: C:jcacs.in
Output Filename: C:jcacs.OUT
Unit: ENGLISH
Plotted Output Filename: C:jcacs.PLT
PROBLEM DESCRIPTION Johnston County Phase 4A - Section A
Circular Static

BOUNDARY COORDINATES
9 Top Boundaries
28 Total Boundaries

| Boundary No. | X-Left (ft) | Y-Left (ft) | X-Right (ft) | Y-Right (ft) | Soil Type Below Bnd |
|---|---|---|---|---|---|
| 1 | .00 | 139.00 | 48.00 | 140.00 | 1 |
| 2 | 48.00 | 140.00 | 110.00 | 158.00 | 1 |
| 3 | 110.00 | 158.00 | 135.00 | 160.00 | 1 |
| 4 | 135.00 | 160.00 | 180.00 | 162.00 | 1 |
| 5 | 180.00 | 162.00 | 772.00 | 310.00 | 2 |
| 6 | 772.00 | 310.00 | 930.00 | 323.00 | 2 |
| 7 | 930.00 | 323.00 | 1100.00 | 322.00 | 2 |
| 8 | 1100.00 | 322.00 | 1200.00 | 320.00 | 2 |
| 9 | 1200.00 | 320.00 | 1400.00 | 310.00 | 2 |
| 10 | 180.00 | 162.00 | 185.00 | 162.00 | 1 |
| 11 | 185.00 | 162.00 | 208.00 | 154.00 | 3 |
| 12 | 208.00 | 154.00 | 250.00 | 154.00 | 3 |
| 13 | 250.00 | 154.00 | 350.00 | 156.00 | 3 |
| 14 | 350.00 | 156.00 | 595.00 | 170.00 | 3 |
| 15 | 595.00 | 170.00 | 692.00 | 174.00 | 3 |
| 16 | 692.00 | 174.00 | 765.00 | 176.00 | 3 |
| 17 | 765.00 | 176.00 | 1047.00 | 182.00 | 3 |
| 18 | 1047.00 | 182.00 | 1355.00 | 188.00 | 3 |
| 19 | 1355.00 | 188.00 | 1400.00 | 192.00 | 3 |
| 20 | 185.00 | 161.80 | 208.00 | 153.80 | 1 |
| 21 | 208.00 | 153.80 | 250.00 | 153.80 | 1 |
| 22 | 250.00 | 153.80 | 350.00 | 155.80 | 1 |
| 23 | 350.00 | 155.80 | 595.00 | 169.80 | 1 |
| 24 | 595.00 | 169.80 | 692.00 | 173.80 | 1 |
| 25 | 692.00 | 173.80 | 765.00 | 175.80 | 1 |
| 26 | 765.00 | 175.80 | 1047.00 | 181.80 | 1 |
| 27 | 1047.00 | 181.80 | 1355.00 | 187.80 | 1 |
| 28 | 1355.00 | 187.80 | 1400.00 | 191.80 | 1 |

ISOTROPIC SOIL PARAMETERS
3 Type(s) of Soil

| Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Pore Pressure Param. | Pressure Constant (psf) | Piez. Surface No. |
|---|---|---|---|---|---|---|---|
| 1 | 110.0 | 115.0 | 100.0 | 25.0 | .00 | .0 | 1 |
| 2 | 70.0 | 90.0 | 500.0 | 30.0 | .00 | .0 | 1 |
| 3 | 100.0 | 100.0 | .0 | 20.0 | .00 | .0 | 1 |

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED
Unit Weight of Water = 62.40
Piezometric Surface No. 1 Specified by 5 Coordinate Points

| Point No. | X-Water (ft) | Y-Water (ft) |
|---|---|---|
| 1 | .00 | 135.00 |
| 2 | 250.00 | 145.00 |
| 3 | 692.00 | 165.00 |
| 4 | 1355.00 | 180.00 |
| 5 | 1400.00 | 181.00 |

A Critical Failure Surface Searching Method, Using A Random
Technique For Generating Circular Surfaces, Has Been Specified.
2500 Trial Surfaces Have Been Generated.
50 Surfaces Initiate From Each Of 50 Points Equally Spaced

Along The Ground Surface Between X = 50.00 ft.
and X = 200.00 ft.
Each Surface Terminates Between X = 500.00 ft.
and X =1200.00 ft.
Unless Further Limitations Were Imposed, The Minimum Elevation
At Which A Surface Extends Is Y =120.00 ft.
50.00 ft. Line Segments Define Each Trial Failure Surface.
**** ERROR - RC11 ****

**>>200 attempts to generate failure surface have failed. Revise limitations**

Following Are Displayed The Ten Most Critical Of The Trial Failure Surfaces Examined. They Are Ordered - Most Critical First.

* * Safety Factors Are Calculated By The Modified Bishop Method * *

Failure Surface Specified By 17 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 105.10 | 156.58 |
| 2 | 153.04 | 142.38 |
| 3 | 201.88 | 131.64 |
| 4 | 251.35 | 124.41 |
| 5 | 301.22 | 120.73 |
| 6 | 351.22 | 120.63 |
| 7 | 401.10 | 124.09 |
| 8 | 450.60 | 131.11 |
| 9 | 499.48 | 141.64 |
| 10 | 547.48 | 155.64 |
| 11 | 594.36 | 173.02 |
| 12 | 639.88 | 193.71 |
| 13 | 683.80 | 217.60 |
| 14 | 725.91 | 244.57 |
| 15 | 765.98 | 274.47 |
| 16 | 803.82 | 307.15 |
| 17 | 809.79 | 313.11 |

Circle Center At X = 327.7 ; Y = 820.1 and Radius, 699.8

*** 2.539 ***

Individual data on the 28 slices

| Slice No. | Width (ft) | Weight (lbs) | Water Force Top (lbs) | Water Force Bot (lbs) | Tie Force Norm (lbs) | Tie Force Tan (lbs) | Earthquake Force Hor (lbs) | Earthquake Force Ver (lbs) | Surcharge Load (lbs) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 4.9 | 773.7 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 2 | 25.0 | 20831.8 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 3 | 18.0 | 30468.9 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 4 | 4.8 | 10128.4 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 5 | 22.1 | 55389.5 | .0 | 4062.6 | .0 | .0 | .0 | .0 | .0 |
| 6 | 5.0 | 14734.8 | .0 | 2043.5 | .0 | .0 | .0 | .0 | .0 |
| 7 | 16.9 | 55654.7 | .0 | 9961.0 | .0 | .0 | .0 | .0 | .0 |
| 8 | 6.1 | 22084.3 | .0 | 4633.9 | .0 | .0 | .0 | .0 | .0 |
| 9 | 42.0 | 184538.2 | .0 | 43631.2 | .0 | .0 | .0 | .0 | .0 |
| 10 | 1.4 | 6947.1 | .0 | 1746.8 | .0 | .0 | .0 | .0 | .0 |
| 11 | 49.9 | 291170.5 | .0 | 73615.7 | .0 | .0 | .0 | .0 | .0 |
| 12 | 48.8 | 340044.3 | .0 | 84361.3 | .0 | .0 | .0 | .0 | .0 |
| 13 | 1.2 | 9044.5 | .0 | 2191.8 | .0 | .0 | .0 | .0 | .0 |
| 14 | 49.9 | 386708.1 | .0 | 88364.4 | .0 | .0 | .0 | .0 | .0 |
| 15 | 49.5 | 403202.5 | .0 | 79040.3 | .0 | .0 | .0 | .0 | .0 |
| 16 | 48.9 | 396888.5 | .0 | 58628.5 | .0 | .0 | .0 | .0 | .0 |
| 17 | 48.0 | 368599.1 | .0 | 27233.3 | .0 | .0 | .0 | .0 | .0 |
| 18 | 8.7 | 62955.0 | .0 | 814.9 | .0 | .0 | .0 | .0 | .0 |
| 19 | 27.8 | 190967.9 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 20 | .6 | 4186.7 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 21 | 9.8 | 63589.8 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 22 | 45.5 | 280107.8 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 23 | 43.9 | 236144.7 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 24 | 42.1 | 183127.8 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 25 | 40.1 | 123346.8 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 26 | 6.0 | 13556.1 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 27 | 31.8 | 39872.2 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |

28 6.0 1143.2 .0 .0 .0 .0 .0 .0 .0

Failure Surface Specified By 17 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 105.10 | 156.58 |
| 2 | 153.15 | 142.75 |
| 3 | 202.05 | 132.31 |
| 4 | 251.56 | 125.31 |
| 5 | 301.43 | 121.78 |
| 6 | 351.43 | 121.76 |
| 7 | 401.31 | 125.22 |
| 8 | 450.83 | 132.16 |
| 9 | 499.74 | 142.55 |
| 10 | 547.80 | 156.32 |
| 11 | 594.79 | 173.43 |
| 12 | 640.46 | 193.77 |
| 13 | 684.60 | 217.25 |
| 14 | 726.99 | 243.77 |
| 15 | 767.43 | 273.18 |
| 16 | 805.71 | 305.34 |
| 17 | 814.12 | 313.47 |

Circle Center At X = 326.8 ; Y = 836.5 and Radius, 715.1

*** 2.546 ***

Failure Surface Specified By 16 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 98.98 | 154.80 |
| 2 | 147.02 | 140.92 |
| 3 | 195.93 | 130.56 |
| 4 | 245.46 | 123.75 |
| 5 | 295.36 | 120.54 |
| 6 | 345.36 | 120.95 |
| 7 | 395.20 | 124.96 |
| 8 | 444.62 | 132.57 |
| 9 | 493.35 | 143.73 |
| 10 | 541.16 | 158.38 |
| 11 | 587.78 | 176.45 |
| 12 | 632.97 | 197.84 |
| 13 | 676.50 | 222.44 |
| 14 | 718.14 | 250.12 |
| 15 | 757.67 | 280.74 |
| 16 | 792.12 | 311.66 |

Circle Center At X = 314.7 ; Y = 811.3 and Radius, 691.0

*** 2.556 ***

Failure Surface Specified By 18 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 71.43 | 146.80 |
| 2 | 120.23 | 135.92 |
| 3 | 169.58 | 127.88 |
| 4 | 219.31 | 122.73 |
| 5 | 269.26 | 120.47 |
| 6 | 319.26 | 121.11 |
| 7 | 369.13 | 124.65 |
| 8 | 418.72 | 131.08 |
| 9 | 467.85 | 140.37 |
| 10 | 516.35 | 152.51 |
| 11 | 564.07 | 167.43 |
| 12 | 610.85 | 185.10 |
| 13 | 656.52 | 205.45 |
| 14 | 700.93 | 228.42 |
| 15 | 743.93 | 253.93 |
| 16 | 785.38 | 281.89 |
| 17 | 825.14 | 312.21 |
| 18 | 827.93 | 314.60 |

Circle Center At X = 283.2 ; Y = 981.2 and Radius, 860.8

*** 2.565 ***

Failure Surface Specified By 17 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 80.61 | 149.47 |
| 2 | 129.33 | 138.19 |
| 3 | 178.62 | 129.84 |
| 4 | 228.33 | 124.44 |
| 5 | 278.27 | 122.00 |
| 6 | 328.27 | 122.54 |
| 7 | 378.14 | 126.06 |
| 8 | 427.72 | 132.54 |
| 9 | 476.83 | 141.95 |
| 10 | 525.28 | 154.28 |
| 11 | 572.92 | 169.46 |
| 12 | 619.57 | 187.46 |
| 13 | 665.07 | 208.20 |
| 14 | 709.25 | 231.61 |
| 15 | 751.96 | 257.61 |
| 16 | 793.04 | 286.11 |
| 17 | 829.46 | 314.73 |

Circle Center At X = 294.2 ; Y = 961.5 and Radius, 839.6

*** 2.574 ***

Failure Surface Specified By 18 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 56.12 | 142.36 |
| 2 | 105.30 | 133.35 |
| 3 | 154.88 | 126.86 |
| 4 | 204.72 | 122.89 |
| 5 | 254.70 | 121.47 |
| 6 | 304.69 | 122.59 |
| 7 | 354.56 | 126.26 |
| 8 | 404.17 | 132.45 |
| 9 | 453.41 | 141.16 |
| 10 | 502.14 | 152.36 |
| 11 | 550.23 | 166.03 |
| 12 | 597.57 | 182.13 |
| 13 | 644.03 | 200.61 |
| 14 | 689.48 | 221.44 |
| 15 | 733.82 | 244.55 |
| 16 | 776.93 | 269.88 |
| 17 | 818.69 | 297.38 |
| 18 | 843.96 | 315.92 |

Circle Center At X = 257.7 ; Y = 1102.4 and Radius, 981.0

*** 2.585 ***

Failure Surface Specified By 16 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 102.04 | 155.69 |
| 2 | 149.94 | 141.36 |
| 3 | 198.82 | 130.81 |
| 4 | 248.37 | 124.11 |
| 5 | 298.29 | 121.30 |
| 6 | 348.28 | 122.40 |
| 7 | 398.03 | 127.40 |
| 8 | 447.23 | 136.26 |
| 9 | 495.60 | 148.95 |
| 10 | 542.82 | 165.37 |
| 11 | 588.62 | 185.43 |
| 12 | 632.72 | 209.01 |
| 13 | 674.83 | 235.95 |
| 14 | 714.72 | 266.11 |
| 15 | 752.13 | 299.28 |
| 16 | 759.43 | 306.86 |

Circle Center At X = 309.2 ; Y = 759.9 and Radius, 638.7

*** 2.586 ***

Failure Surface Specified By 17 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 62.25 | 144.14 |
| 2 | 111.24 | 134.18 |
| 3 | 160.73 | 127.06 |
| 4 | 210.55 | 122.80 |
| 5 | 260.53 | 121.42 |
| 6 | 310.51 | 122.92 |
| 7 | 360.32 | 127.29 |
| 8 | 409.79 | 134.53 |
| 9 | 458.77 | 144.60 |
| 10 | 507.08 | 157.47 |
| 11 | 554.58 | 173.11 |
| 12 | 601.09 | 191.46 |
| 13 | 646.47 | 212.45 |
| 14 | 690.56 | 236.02 |
| 15 | 733.23 | 262.09 |
| 16 | 774.32 | 290.57 |
| 17 | 802.36 | 312.50 |

Circle Center At X = 259.5 ; Y = 989.4 and Radius, 868.0

*** 2.588 ***

Failure Surface Specified By 16 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 105.10 | 156.58 |
| 2 | 153.04 | 142.36 |
| 3 | 201.94 | 131.93 |
| 4 | 251.50 | 125.34 |
| 5 | 301.43 | 122.64 |
| 6 | 351.41 | 123.83 |
| 7 | 401.15 | 128.93 |
| 8 | 450.35 | 137.88 |
| 9 | 498.69 | 150.65 |
| 10 | 545.89 | 167.15 |
| 11 | 591.66 | 187.28 |
| 12 | 635.72 | 210.91 |
| 13 | 677.80 | 237.91 |
| 14 | 717.65 | 268.11 |
| 15 | 755.02 | 301.33 |
| 16 | 760.63 | 307.16 |

Circle Center At X = 311.0 ; Y = 762.3 and Radius, 639.8

*** 2.589 ***

Failure Surface Specified By 17 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 77.55 | 148.58 |
| 2 | 126.22 | 137.10 |
| 3 | 175.52 | 128.77 |
| 4 | 225.25 | 123.63 |
| 5 | 275.22 | 121.70 |
| 6 | 325.20 | 122.98 |
| 7 | 375.00 | 127.47 |
| 8 | 424.40 | 135.15 |
| 9 | 473.21 | 146.00 |
| 10 | 521.23 | 159.96 |
| 11 | 568.24 | 176.97 |
| 12 | 614.07 | 196.97 |
| 13 | 658.51 | 219.88 |
| 14 | 701.39 | 245.59 |
| 15 | 742.53 | 274.01 |
| 16 | 781.76 | 305.02 |
| 17 | 788.83 | 311.38 |

Circle Center At X = 280.3 ; Y = 899.2 and Radius, 777.5

*** 2.591 ***

# Johnston County Phase 4A - Section A Circular Seismic

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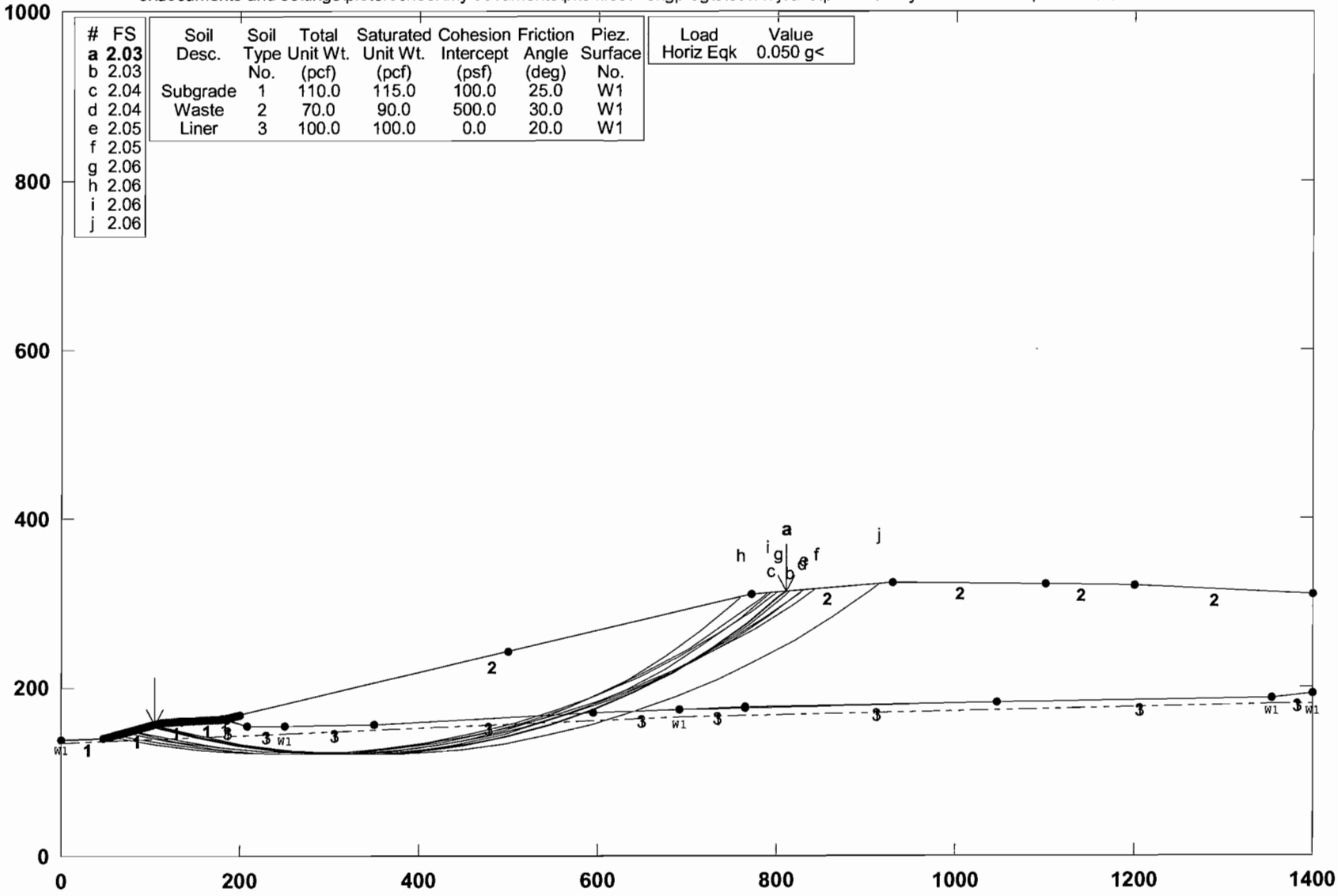
| # | FS |
|---|---|
| **a** | **2.03** |
| b | 2.03 |
| c | 2.04 |
| d | 2.04 |
| e | 2.05 |
| f | 2.05 |
| g | 2.06 |
| h | 2.06 |
| i | 2.06 |
| j | 2.06 |

| Soil Desc. | Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Piez. Surface No. |
|---|---|---|---|---|---|---|
| Subgrade | 1 | 110.0 | 115.0 | 100.0 | 25.0 | W1 |
| Waste | 2 | 70.0 | 90.0 | 500.0 | 30.0 | W1 |
| Liner | 3 | 100.0 | 100.0 | 0.0 | 20.0 | W1 |

| Load | Value |
|---|---|
| Horiz Eqk | 0.050 g< |




**PCSTABL5M/si FSmin=2.03**

**Safety Factors Are Calculated By The Modified Bishop Method**

19/26

**** PCSTABL5M ****
by
Purdue University
--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

Run Date: 6/1/2007
Time of Run: 11:01AM
Run By: Pieter Scheer, P.E.
Input Data Filename: C:jcacd.in
Output Filename: C:jcacd.OUT
Unit: ENGLISH
Plotted Output Filename: C:jcacd.PLT
PROBLEM DESCRIPTION Johnston County Phase 4A - Section A
Circular Seismic

BOUNDARY COORDINATES
9 Top Boundaries
28 Total Boundaries

| Boundary No. | X-Left (ft) | Y-Left (ft) | X-Right (ft) | Y-Right (ft) | Soil Type Below Bnd |
|---|---|---|---|---|---|
| 1 | .00 | 139.00 | 48.00 | 140.00 | 1 |
| 2 | 48.00 | 140.00 | 110.00 | 158.00 | 1 |
| 3 | 110.00 | 158.00 | 135.00 | 160.00 | 1 |
| 4 | 135.00 | 160.00 | 180.00 | 162.00 | 1 |
| 5 | 180.00 | 162.00 | 772.00 | 310.00 | 2 |
| 6 | 772.00 | 310.00 | 930.00 | 323.00 | 2 |
| 7 | 930.00 | 323.00 | 1100.00 | 322.00 | 2 |
| 8 | 1100.00 | 322.00 | 1200.00 | 320.00 | 2 |
| 9 | 1200.00 | 320.00 | 1400.00 | 310.00 | 2 |
| 10 | 180.00 | 162.00 | 185.00 | 162.00 | 1 |
| 11 | 185.00 | 162.00 | 208.00 | 154.00 | 3 |
| 12 | 208.00 | 154.00 | 250.00 | 154.00 | 3 |
| 13 | 250.00 | 154.00 | 350.00 | 156.00 | 3 |
| 14 | 350.00 | 156.00 | 595.00 | 170.00 | 3 |
| 15 | 595.00 | 170.00 | 692.00 | 174.00 | 3 |
| 16 | 692.00 | 174.00 | 765.00 | 176.00 | 3 |
| 17 | 765.00 | 176.00 | 1047.00 | 182.00 | 3 |
| 18 | 1047.00 | 182.00 | 1355.00 | 188.00 | 3 |
| 19 | 1355.00 | 188.00 | 1400.00 | 192.00 | 3 |
| 20 | 185.00 | 161.80 | 208.00 | 153.80 | 1 |
| 21 | 208.00 | 153.80 | 250.00 | 153.80 | 1 |
| 22 | 250.00 | 153.80 | 350.00 | 155.80 | 1 |
| 23 | 350.00 | 155.80 | 595.00 | 169.80 | 1 |
| 24 | 595.00 | 169.80 | 692.00 | 173.80 | 1 |
| 25 | 692.00 | 173.80 | 765.00 | 175.80 | 1 |
| 26 | 765.00 | 175.80 | 1047.00 | 181.80 | 1 |
| 27 | 1047.00 | 181.80 | 1355.00 | 187.80 | 1 |
| 28 | 1355.00 | 187.80 | 1400.00 | 191.80 | 1 |

ISOTROPIC SOIL PARAMETERS
3 Type(s) of Soil

| Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Pore Pressure Param. | Pressure Constant (psf) | Piez. Surface No. |
|---|---|---|---|---|---|---|---|
| 1 | 110.0 | 115.0 | 100.0 | 25.0 | .00 | .0 | 1 |
| 2 | 70.0 | 90.0 | 500.0 | 30.0 | .00 | .0 | 1 |
| 3 | 100.0 | 100.0 | .0 | 20.0 | .00 | .0 | 1 |

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED
Unit Weight of Water = 62.40
Piezometric Surface No. 1 Specified by 5 Coordinate Points

| Point No. | X-Water (ft) | Y-Water (ft) |
|---|---|---|
| 1 | .00 | 135.00 |
| 2 | 250.00 | 145.00 |
| 3 | 692.00 | 165.00 |
| 4 | 1355.00 | 180.00 |
| 5 | 1400.00 | 181.00 |

A Horizontal Earthquake Loading Coefficient

Of .050 Has Been Assigned
A Vertical Earthquake Loading Coefficient
Of .000 Has Been Assigned
Cavitation Pressure = .0 (psf)
A Critical Failure Surface Searching Method, Using A Random
Technique For Generating Circular Surfaces, Has Been Specified.
2500 Trial Surfaces Have Been Generated.
50 Surfaces Initiate From Each Of 50 Points Equally Spaced
Along The Ground Surface Between X = 50.00 ft.
and X = 200.00 ft.
Each Surface Terminates Between X = 500.00 ft.
and X =1200.00 ft.
Unless Further Limitations Were Imposed, The Minimum Elevation
At Which A Surface Extends Is Y =120.00 ft.
50.00 ft. Line Segments Define Each Trial Failure Surface.
**** ERROR - RC11 ****
**>>200 attempts to generate failure surface have failed. Revise limitations**
Following Are Displayed The Ten Most Critical Of The Trial
Failure Surfaces Examined. They Are Ordered - Most Critical
First.
* * Safety Factors Are Calculated By The Modified Bishop Method * *
Failure Surface Specified By 17 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 105.10 | 156.58 |
| 2 | 153.04 | 142.38 |
| 3 | 201.88 | 131.64 |
| 4 | 251.35 | 124.41 |
| 5 | 301.22 | 120.73 |
| 6 | 351.22 | 120.63 |
| 7 | 401.10 | 124.09 |
| 8 | 450.60 | 131.11 |
| 9 | 499.48 | 141.64 |
| 10 | 547.48 | 155.64 |
| 11 | 594.36 | 173.02 |
| 12 | 639.88 | 193.71 |
| 13 | 683.80 | 217.60 |
| 14 | 725.91 | 244.57 |
| 15 | 765.98 | 274.47 |
| 16 | 803.82 | 307.15 |
| 17 | 809.79 | 313.11 |

Circle Center At X = 327.7 ; Y = 820.1 and Radius, 699.8
*** 2.026 ***
Individual data on the 28 slices

| Slice No. | Width (ft) | Weight (lbs) | Water Force Top (lbs) | Water Force Bot (lbs) | Tie Force Norm (lbs) | Tie Force Tan (lbs) | Earthquake Force Hor (lbs) | Earthquake Force Ver (lbs) | Surcharge Load (lbs) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 4.9 | 773.7 | .0 | .0 | .0 | .0 | 38.7 | .0 | .0 |
| 2 | 25.0 | 20831.8 | .0 | .0 | .0 | .0 | 1041.6 | .0 | .0 |
| 3 | 18.0 | 30468.9 | .0 | .0 | .0 | .0 | 1523.4 | .0 | .0 |
| 4 | 4.8 | 10128.4 | .0 | .0 | .0 | .0 | 506.4 | .0 | .0 |
| 5 | 22.1 | 55389.5 | .0 | 4062.6 | .0 | .0 | 2769.5 | .0 | .0 |
| 6 | 5.0 | 14734.8 | .0 | 2043.5 | .0 | .0 | 736.7 | .0 | .0 |
| 7 | 16.9 | 55654.7 | .0 | 9961.0 | .0 | .0 | 2782.7 | .0 | .0 |
| 8 | 6.1 | 22084.3 | .0 | 4633.9 | .0 | .0 | 1104.2 | .0 | .0 |
| 9 | 42.0 | 184538.2 | .0 | 43631.2 | .0 | .0 | 9226.9 | .0 | .0 |
| 10 | 1.4 | 6947.1 | .0 | 1746.8 | .0 | .0 | 347.4 | .0 | .0 |
| 11 | 49.9 | 291170.5 | .0 | 73615.7 | .0 | .0 | 14558.5 | .0 | .0 |
| 12 | 48.8 | 340044.3 | .0 | 84361.3 | .0 | .0 | 17002.2 | .0 | .0 |
| 13 | 1.2 | 9044.5 | .0 | 2191.8 | .0 | .0 | 452.2 | .0 | .0 |
| 14 | 49.9 | 386708.1 | .0 | 88364.4 | .0 | .0 | 19335.4 | .0 | .0 |
| 15 | 49.5 | 403202.5 | .0 | 79040.3 | .0 | .0 | 20160.1 | .0 | .0 |
| 16 | 48.9 | 396888.5 | .0 | 58628.5 | .0 | .0 | 19844.4 | .0 | .0 |
| 17 | 48.0 | 368599.1 | .0 | 27233.3 | .0 | .0 | 18430.0 | .0 | .0 |
| 18 | 8.7 | 62955.0 | .0 | 814.9 | .0 | .0 | 3147.7 | .0 | .0 |
| 19 | 27.8 | 190967.9 | .0 | .0 | .0 | .0 | 9548.4 | .0 | .0 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 20 | .6 | 4186.7 | .0 | .0 | .0 | .0 | 209.3 | .0 | .0 |
| 21 | 9.8 | 63589.8 | .0 | .0 | .0 | .0 | 3179.5 | .0 | .0 |
| 22 | 45.5 | 280107.8 | .0 | .0 | .0 | .0 | 14005.4 | .0 | .0 |
| 23 | 43.9 | 236144.7 | .0 | .0 | .0 | .0 | 11807.2 | .0 | .0 |
| 24 | 42.1 | 183127.8 | .0 | .0 | .0 | .0 | 9156.4 | .0 | .0 |
| 25 | 40.1 | 123346.8 | .0 | .0 | .0 | .0 | 6167.3 | .0 | .0 |
| 26 | 6.0 | 13556.1 | .0 | .0 | .0 | .0 | 677.8 | .0 | .0 |
| 27 | 31.8 | 39872.2 | .0 | .0 | .0 | .0 | 1993.6 | .0 | .0 |
| 28 | 6.0 | 1143.2 | .0 | .0 | .0 | .0 | 57.2 | .0 | .0 |

Failure Surface Specified By 17 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 105.10 | 156.58 |
| 2 | 153.15 | 142.75 |
| 3 | 202.05 | 132.31 |
| 4 | 251.56 | 125.31 |
| 5 | 301.43 | 121.78 |
| 6 | 351.43 | 121.76 |
| 7 | 401.31 | 125.22 |
| 8 | 450.83 | 132.16 |
| 9 | 499.74 | 142.55 |
| 10 | 547.80 | 156.32 |
| 11 | 594.79 | 173.43 |
| 12 | 640.46 | 193.77 |
| 13 | 684.60 | 217.25 |
| 14 | 726.99 | 243.77 |
| 15 | 767.43 | 273.18 |
| 16 | 805.71 | 305.34 |
| 17 | 814.12 | 313.47 |

Circle Center At X = 326.8 ; Y = 836.5 and Radius, 715.1

*** 2.032 ***

Failure Surface Specified By 16 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 98.98 | 154.80 |
| 2 | 147.02 | 140.92 |
| 3 | 195.93 | 130.56 |
| 4 | 245.46 | 123.75 |
| 5 | 295.36 | 120.54 |
| 6 | 345.36 | 120.95 |
| 7 | 395.20 | 124.96 |
| 8 | 444.62 | 132.57 |
| 9 | 493.35 | 143.73 |
| 10 | 541.16 | 158.38 |
| 11 | 587.78 | 176.45 |
| 12 | 632.97 | 197.84 |
| 13 | 676.50 | 222.44 |
| 14 | 718.14 | 250.12 |
| 15 | 757.67 | 280.74 |
| 16 | 792.12 | 311.66 |

Circle Center At X = 314.7 ; Y = 811.3 and Radius, 691.0

*** 2.037 ***

Failure Surface Specified By 18 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 71.43 | 146.80 |
| 2 | 120.23 | 135.92 |
| 3 | 169.58 | 127.88 |
| 4 | 219.31 | 122.73 |
| 5 | 269.26 | 120.47 |
| 6 | 319.26 | 121.11 |
| 7 | 369.13 | 124.65 |
| 8 | 418.72 | 131.08 |
| 9 | 467.85 | 140.37 |
| 10 | 516.35 | 152.51 |
| 11 | 564.07 | 167.43 |
| 12 | 610.85 | 185.10 |

| | | |
|---|---|---|
| 13 | 656.52 | 205.45 |
| 14 | 700.93 | 228.42 |
| 15 | 743.93 | 253.93 |
| 16 | 785.38 | 281.89 |
| 17 | 825.14 | 312.21 |
| 18 | 827.93 | 314.60 |

Circle Center At X = 283.2 ; Y = 981.2 and Radius, 860.8

*** 2.039 ***

Failure Surface Specified By 17 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 80.61 | 149.47 |
| 2 | 129.33 | 138.19 |
| 3 | 178.62 | 129.84 |
| 4 | 228.33 | 124.44 |
| 5 | 278.27 | 122.00 |
| 6 | 328.27 | 122.54 |
| 7 | 378.14 | 126.06 |
| 8 | 427.72 | 132.54 |
| 9 | 476.83 | 141.95 |
| 10 | 525.28 | 154.28 |
| 11 | 572.92 | 169.46 |
| 12 | 619.57 | 187.46 |
| 13 | 665.07 | 208.20 |
| 14 | 709.25 | 231.61 |
| 15 | 751.96 | 257.61 |
| 16 | 793.04 | 286.11 |
| 17 | 829.46 | 314.73 |

Circle Center At X = 294.2 ; Y = 961.5 and Radius, 839.6

*** 2.049 ***

Failure Surface Specified By 18 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 56.12 | 142.36 |
| 2 | 105.30 | 133.35 |
| 3 | 154.88 | 126.86 |
| 4 | 204.72 | 122.89 |
| 5 | 254.70 | 121.47 |
| 6 | 304.69 | 122.59 |
| 7 | 354.56 | 126.26 |
| 8 | 404.17 | 132.45 |
| 9 | 453.41 | 141.16 |
| 10 | 502.14 | 152.36 |
| 11 | 550.23 | 166.03 |
| 12 | 597.57 | 182.13 |
| 13 | 644.03 | 200.61 |
| 14 | 689.48 | 221.44 |
| 15 | 733.82 | 244.55 |
| 16 | 776.93 | 269.88 |
| 17 | 818.69 | 297.38 |
| 18 | 843.96 | 315.92 |

Circle Center At X = 257.7 ; Y = 1102.4 and Radius, 981.0

*** 2.054 ***

Failure Surface Specified By 17 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 62.25 | 144.14 |
| 2 | 111.24 | 134.18 |
| 3 | 160.73 | 127.06 |
| 4 | 210.55 | 122.80 |
| 5 | 260.53 | 121.42 |
| 6 | 310.51 | 122.92 |
| 7 | 360.32 | 127.29 |
| 8 | 409.79 | 134.53 |
| 9 | 458.77 | 144.60 |
| 10 | 507.08 | 157.47 |
| 11 | 554.58 | 173.11 |

| | | |
|---|---|---|
| 12 | 601.09 | 191.46 |
| 13 | 646.47 | 212.45 |
| 14 | 690.56 | 236.02 |
| 15 | 733.23 | 262.09 |
| 16 | 774.32 | 290.57 |
| 17 | 802.36 | 312.50 |

Circle Center At X = 259.5 ; Y = 989.4 and Radius, 868.0

*** 2.057 ***

Failure Surface Specified By 16 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 102.04 | 155.69 |
| 2 | 149.94 | 141.36 |
| 3 | 198.82 | 130.81 |
| 4 | 248.37 | 124.11 |
| 5 | 298.29 | 121.30 |
| 6 | 348.28 | 122.40 |
| 7 | 398.03 | 127.40 |
| 8 | 447.23 | 136.26 |
| 9 | 495.60 | 148.95 |
| 10 | 542.82 | 165.37 |
| 11 | 588.62 | 185.43 |
| 12 | 632.72 | 209.01 |
| 13 | 674.83 | 235.95 |
| 14 | 714.72 | 266.11 |
| 15 | 752.13 | 299.28 |
| 16 | 759.43 | 306.86 |

Circle Center At X = 309.2 ; Y = 759.9 and Radius, 638.7

*** 2.060 ***

Failure Surface Specified By 17 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 77.55 | 148.58 |
| 2 | 126.22 | 137.10 |
| 3 | 175.52 | 128.77 |
| 4 | 225.25 | 123.63 |
| 5 | 275.22 | 121.70 |
| 6 | 325.20 | 122.98 |
| 7 | 375.00 | 127.47 |
| 8 | 424.40 | 135.15 |
| 9 | 473.21 | 146.00 |
| 10 | 521.23 | 159.96 |
| 11 | 568.24 | 176.97 |
| 12 | 614.07 | 196.97 |
| 13 | 658.51 | 219.88 |
| 14 | 701.39 | 245.59 |
| 15 | 742.53 | 274.01 |
| 16 | 781.76 | 305.02 |
| 17 | 788.83 | 311.38 |

Circle Center At X = 280.3 ; Y = 899.2 and Radius, 777.5

*** 2.061 ***

Failure Surface Specified By 19 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 98.98 | 154.80 |
| 2 | 147.48 | 142.66 |
| 3 | 196.58 | 133.20 |
| 4 | 246.12 | 126.45 |
| 5 | 295.96 | 122.43 |
| 6 | 345.95 | 121.16 |
| 7 | 395.92 | 122.63 |
| 8 | 445.75 | 126.85 |
| 9 | 495.26 | 133.79 |
| 10 | 544.32 | 143.45 |
| 11 | 592.77 | 155.78 |
| 12 | 640.48 | 170.76 |
| 13 | 687.29 | 188.33 |

| | | |
|---|---|---|
| 14 | 733.06 | 208.45 |
| 15 | 777.66 | 231.05 |
| 16 | 820.95 | 256.07 |
| 17 | 862.80 | 283.43 |
| 18 | 903.09 | 313.04 |
| 19 | 913.54 | 321.65 |

Circle Center At X = 344.1 ; Y = 1031.2 and Radius, 910.0

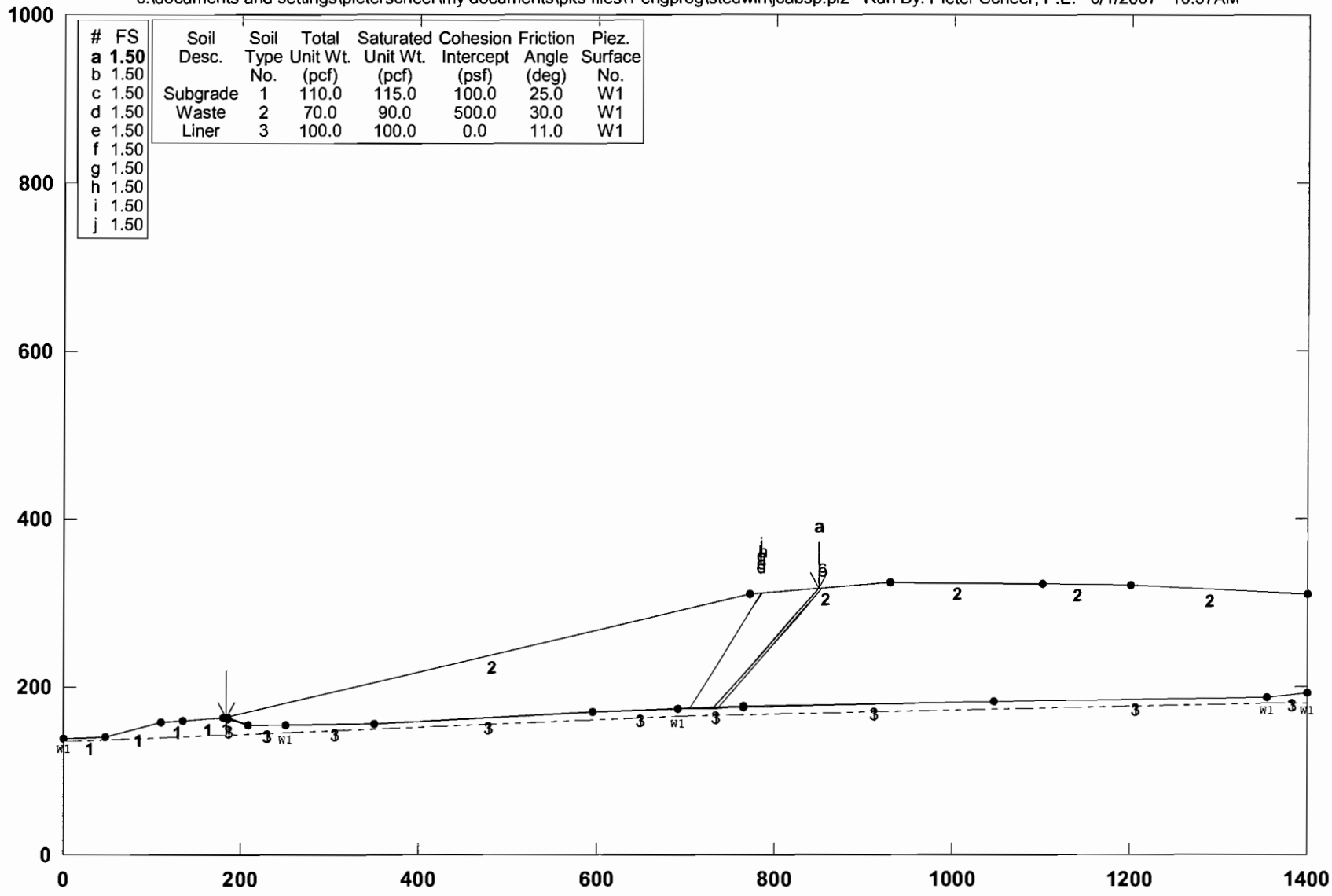
*** 2.063 ***

# Johnston County Phase 4A - Section A Block Static - Parametric

c:\documents and settings\pieterscheer\my documents\pks files\1 engprog\stedwin\jcabsp.pl2 Run By: Pieter Scheer, P.E. 6/1/2007 10:57AM

| # | FS |
|---|---|
| **a** | **1.50** |
| b | 1.50 |
| c | 1.50 |
| d | 1.50 |
| e | 1.50 |
| f | 1.50 |
| g | 1.50 |
| h | 1.50 |
| i | 1.50 |
| j | 1.50 |

| Soil Desc. | Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Piez. Surface No. |
|---|---|---|---|---|---|---|
| Subgrade | 1 | 110.0 | 115.0 | 100.0 | 25.0 | W1 |
| Waste | 2 | 70.0 | 90.0 | 500.0 | 30.0 | W1 |
| Liner | 3 | 100.0 | 100.0 | 0.0 | 11.0 | W1 |




**PCSTABL5M/si FSmin=1.50**

**Safety Factors Are Calculated By The Modified Janbu Method**

# Appendix B

## Protective Cover Veneer Stability Evaluation

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PROJECT Johnston County MSWLF - Phase 4A - Cell 3

SUBJECT Protective Cover Veneer Stability Evaluation

SHEET 1 OF 2
JOB NO. JOHNSTON-07-2
DATE 2/16/07
COMPUTED BY PKS
CHECKED BY

**Objective** To determine the interface shear strength requirements for the liner/leachate collection system/protective cover veneer to satisfy the required factor(s) of safety against sliding.

**Reference** Matasovic, N. (1991), "Selection of Method for Seismic Slope Stability Analysis," Proc. 2nd International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics, St. Louis, Vol. 2, pp.1057-1062.

**Requirements** $FS_{min}$(Static) = 1.5
$FS_{min}$(Seismic) = 1.0 (If Applicable)

**Analysis** 1. Treat the protective cover as an infinite slope and use the following equation:

$$FS = \frac{\dfrac{c}{\gamma_c z_c \cos^2\beta} + \tan\phi\left[1 - \dfrac{\gamma_w (z_c - d_w)}{\gamma_c z_c}\right] - k_s(\tan\beta)(\tan\phi)}{k_s + \tan\beta}$$ (Matasovic, 1991)

where:
- $FS$ = factor of safety against shallow veneer failure
- $k_s$ = seismic coefficient (= 0 for static conditions) (= peak ground acceleration for seismic conditions)
- $\gamma_c$ = unit weight of protective cover material(s) (pcf)
- $\gamma_w$ = unit weight of water (62.4 pcf) (pcf)
- $c$ = cohesion/adhesion along assumed failure surface (psf)
- $\phi$ = interface friction angle along assumed failure surface (degrees)
- $z_c$ = depth of protective cover (depth to failure surface) (ft)
- $d_w$ = depth to seepage surface (assumed parallel to slope) (ft) (= z if slope is dry)
- $\beta$ = slope angle of protective cover (degrees).

2. Determine minimum interface shear strength as follows:

$$\tau = \sigma \tan\phi + c$$

where:
- $\tau$ = interface shear strength (lbs)
- $\sigma$ = normal load (psf)
- $\phi$ = interface friction angle (min. value from analysis or greater)
- $c$ = cohesion/adhesion (min. value from analysis or greater)

**STABILITY PROCVR.WPD**

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Raleigh, NC 27603 Fax: 919-828-3899

SHEET: 2 / 2
JOB #: JOHNSTON-07-2
DATE: 2/28/07
BY: PKS
CHKD BY:

# Johnston County MSW Landfill - Phase 4A - Cell 3
# Protective Cover Veneer Stability Evaluation

**Input Parameters:**

Side Slope Angle ($\beta$): 18.4 degrees (3H:1V Slopes)

Protective Cover:
- Thickness ($z_c$): 2 ft
- Unit Weight ($\gamma_c$): 110 pcf
- Cohesion ($c$): 0 psf
- Depth to Seepage ($d_w$): 2 ft (= z if Slope is Dry)

Seismic Coefficient ($k_s$):
- 0 Static Conditions
- 0.09 Seismic Conditions (= Peak Ground Acceleration For The Site)

Required Factors of Safety:
- Static: 1.5
- Dynamic: 1.0

**Static Conditions:**

| Interface Friction Angle ($\phi$) (degrees) | Resisting Force | Driving Force | FS | Comment |
|---|---|---|---|---|
| 22 | 0.40 | 0.33 | 1.21 | **NO GOOD** |
| 23 | 0.42 | 0.33 | 1.28 | **NO GOOD** |
| 24 | 0.45 | 0.33 | 1.34 | **NO GOOD** |
| 25 | 0.47 | 0.33 | 1.40 | **NO GOOD** |
| 26 | 0.49 | 0.33 | 1.47 | **NO GOOD** |
| 26.5 | 0.50 | 0.33 | 1.50 | **OK** |

**Seismic Conditions:**

| Interface Friction Angle ($\phi$) (degrees) | Resisting Force | Driving Force | FS | Comment |
|---|---|---|---|---|
| 22 | 0.39 | 0.42 | 0.93 | **NO GOOD** |
| 23 | 0.41 | 0.42 | 0.97 | **NO GOOD** |
| 24 | 0.43 | 0.42 | 1.02 | **OK** |
| 25 | 0.45 | 0.42 | 1.07 | **OK** |
| 26 | 0.47 | 0.42 | 1.12 | **OK** |
| 27 | 0.49 | 0.42 | 1.17 | **OK** |

**Minimum Interface Shear Strength Requirements:**

Cohesion ($c$) (From Above) = 0 psf
Interface Friction Angle ($\phi$) = 26.5 degrees (Use Min. Value From Above or Greater)

| Normal Load (psf) | Interface Shear Strength (psf) |
|---|---|
| 100 | 50 |
| 200 | 100 |
| 500 | 249 |

# Appendix C

## Final Cover Veneer Stability Evaluation

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PROJECT Johnston County MSWLF - Phase 4A - Cell 3

SUBJECT Final Cover Veneer Stability Evaluation

SHEET 1 OF 2
JOB NO. JOHNSTON-07-2
DATE 2/16/07
COMPUTED BY PKS
CHECKED BY

**Objective** To determine the interface shear strength requirements for the final cover system veneer to satisfy the required factor(s) of safety against sliding.

**Reference** Matasovic, N. (1991), "Selection of Method for Seismic Slope Stability Analysis," Proc. 2nd International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics, St. Louis, Vol. 2, pp.1057-1062.

**Requirements** $FS_{min}$(Static) = 1.5
$FS_{min}$(Seismic) = 1.0 (If Applicable)

**Analysis** 1. Treat the final cover as an infinite slope and use the following equation:

$$FS = \frac{\dfrac{c}{\gamma_c z_c \cos^2\beta} + \tan\phi\left[1 - \dfrac{\gamma_w\left(z_c - d_w\right)}{\gamma_c z_c}\right] - k_s\left(\tan\beta\right)\left(\tan\phi\right)}{k_s + \tan\beta}$$

(Matasovic, 1991)

where:
- $FS$ = factor of safety against shallow veneer failure
- $k_s$ = seismic coefficient (= 0 for static conditions) (= peak ground acceleration for seismic conditions)
- $\gamma_c$ = unit weight of final cover material(s) (pcf)
- $\gamma_w$ = unit weight of water (62.4 pcf) (pcf)
- $c$ = cohesion/adhesion along assumed failure surface (psf)
- $\phi$ = interface friction angle along assumed failure surface (degrees)
- $z_c$ = depth of final cover (depth to failure surface) (ft)
- $d_w$ = depth to seepage surface (assumed parallel to slope) (ft) (= z if slope is dry)
- $\beta$ = slope angle of final cover (degrees)\

$$u = \gamma_w\left(z_c - d_w\right)$$

*Note: Based on an allowable LFG pressure of 6 inch-w.c. (= 31.2 psf), the use of a depth to seepage of 1.5 feet or less (for evaluation of interfaces above the geomembrane) will satisfy the evaluation for LFG pressure against the bottom of the geomembrane as well.

2. Determine minimum interface shear strength as follows:

$$\tau = \sigma\tan\phi + c$$

where:
- $\tau$ = interface shear strength (lbs)
- $\sigma$ = normal load (psf)
- $\phi$ = interface friction angle (min. value from analysis or greater)
- $c$ = cohesion/adhesion (min. value from analysis or greater)

**STABILITY FCS.WPD**

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SHEET: 2/2
JOB #: JOHNSTON-07-2
DATE: 2/28/07
BY: PKS
CHKD BY:

# Johnston County MSW Landfill - Phase 4A - Cell 3
# Final Cover Veneer Stability Evaluation

**Input Parameters:**

Side Slope Angle ($\beta$): 14.0 degrees (4H:1V Slopes)

Final Cover:
Thickness ($z_c$): 2 ft
Unit Weight ($\gamma_c$): 110 pcf
Cohesion ($c$): 0 psf
Depth to Seepage ($d_w$): 1.5 ft (= z if Slope is Dry)

Seismic Coefficient ($k_s$): 0 Static Conditions
0.09 Seismic Conditions (= Peak Ground Acceleration For The Site)

Required Factors of Safety:
Static: 1.5
Dynamic: 1.0

**Static Conditions:**

| Interface Friction Angle ($\phi$) (degrees) | Resisting Force | Driving Force | FS | Comment |
|---|---|---|---|---|
| 22 | 0.35 | 0.25 | 1.39 | **NO GOOD** |
| 23 | 0.36 | 0.25 | 1.46 | **NO GOOD** |
| 24 | 0.38 | 0.25 | 1.53 | **OK** |
| 25 | 0.40 | 0.25 | 1.61 | **OK** |
| 26 | 0.42 | 0.25 | 1.68 | **OK** |
| 27 | 0.44 | 0.25 | 1.75 | **OK** |

**Seismic Conditions:**

| Interface Friction Angle ($\phi$) (degrees) | Resisting Force | Driving Force | FS | Comment |
|---|---|---|---|---|
| 22 | 0.34 | 0.34 | 1.00 | **NO GOOD** |
| 23 | 0.35 | 0.34 | 1.05 | **OK** |
| 24 | 0.37 | 0.34 | 1.10 | **OK** |
| 25 | 0.39 | 0.34 | 1.15 | **OK** |
| 26 | 0.41 | 0.34 | 1.20 | **OK** |
| 27 | 0.43 | 0.34 | 1.25 | **OK** |

**Minimum Interface Shear Strength Requirements:**

Cohesion ($c$) (From Above) = 0 psf
Interface Friction Angle ($\phi$) = 24 degrees (Use Min. Value From Above or Greater)

| Normal Load (psf) | Interface Shear Strength (psf) |
|---|---|
| 100 | 45 |
| 200 | 89 |
| 500 | 223 |

# Appendix D

# Foundation Settlement Evaluation

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| | |
|---|---|
| **PROJECT** Johnston County MSW Landfill - Phase 4A | SHEET 1 OF 14 |
| | JOB NO. JOHNSTON-07-2 |
| | DATE 12/4/08 |
| **SUBJECT** Foundation Settlement Evaluation | COMPUTED BY PKS |
| | CHECKED BY |

**Objective**

To estimate the total and differential foundation settlements due to the weight of the planned waste and embankment loads. The resulting post-settlement slopes are evaluated to ensure that 1) positive drainage is maintained toward collection piping and/or sumps and 2) the maximum tensile strains in the liner system do not exceed allowable values.

**References**

Holtz, R.D., & Kovacs, W.D. (1981), An Introduction To Geotechnical Engineering, Prentice-Hall, Englewood Cliffs, NJ, Chapters 8 and 9.

Ohio EPA - Geotechnical Resource Group (2004), "Geotechnical and Stability Analyses for Ohio Waste Containment Facilities", Ohio EPA, Columbus, Ohio, Chapter 6.

Quian, X., Koerner, R.M., & Gray, D.H. (2001), Geotechnical Aspects of Landfill Design and Construction, Prentice Hall, Upper Saddle River, N.J., pp. 310, 469-473.

**Assumptions**

1. Vertical stresses acting on the liner are assumed to be one-dimensional (1-D).
2. Assumptions for soil properties are listed in the attached spreadsheet.

**Analysis**

The following approach is used to perform the evaluation:

1. Identify the critical cross section(s) to be evaluated (maximum waste fill, minimum liner slopes, etc.).
2. Select points along each cross section to perform calculations (points of grade breaks in final cover and/or liner system).
3. For each calculation point, determine the subsurface profile beneath the liner system and separate into distinct layers (thickness and material properties) (Include structural fill where applicable).
4. For each calculation point, determine the stresses acting on the midpoint of each layer both before and after liner construction.
5. For each calculation point, determine the stress change at the liner. Take into account the stress decrease due to excavation (where applicable) and the stress increase due to waste loads.
6. Calculate elastic settlements for each granular soil layer using the equations below.
7. Calculate consolidation (primary and secondary) settlements for each clay/silt soil layer using the equations below.
8. Calculate total settlements at each calculation point and resulting post-settlement slopes and liner strain between each point. Verify that slopes meet or exceed the minimum allowable slope. Verify that tensile strains do not exceed allowable values.



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**Calculations**

- Elastic Settlement Equation:

$$S_e = \frac{\Delta p}{M_S} H$$

where:
$S_e$ = elastic settlement (ft)
$\Delta p$ = net stress change acting on middle of soil layer (psf)
$Ms$ = constrained modulus of soil (psf)

$$M_S = \frac{E_S(1-\upsilon_S)}{(1+\upsilon_S)(1-2\upsilon_S)}$$

$Es$ = elastic modulus of soil (psf)
$\nu_s$ = Poisson's ratio of soil
H = initial thickness of soil layer (ft).

- Primary Consolidation Settlement Equations:

*for* $p'_O + \Delta p \geq p'_{mp}$

$$S_C = H\left( C_{r\varepsilon} \log \frac{p'_{mp}}{p'_o} + C_{c\varepsilon} \log \frac{p'_o + \Delta p}{p'_{mp}} \right)$$

*for* $p'_O + \Delta p < p'_{mp}$

$$S_C = H\left( C_{r\varepsilon} \log \frac{p'_o + \Delta p}{p'_o} \right)$$

where:
$S_C$ = primary consolidation settlement (ft)
$H$ = initial thickness of soil layer (ft)
$p'_{mp}$ = maximum past consolidation pressure (psf)
$p'_o$ = effective vertical stress in middle of soil layer afer excavation, but before loading (psf)
$\Delta p$ = net stress change acting on middle of soil layer (psf).
$C_{r\epsilon}$ = modified recompression index

$$C_{r\varepsilon} = \frac{C_r}{1+e_o}$$

$C_{c\epsilon}$ = modified primary compression index

$$C_{c\varepsilon} = \frac{C_c}{1+e_o}$$

$C_r$ = recompression index
$C_c$ = primary compression index
$e_O$ = initial void ratio

- Secondary Consolidation Settlement Equation:

$$S_s = C_{s\varepsilon} H \log \frac{t_s}{t_{pf}}$$

where:
$S_s$ = secondary consolidation settlement (ft)
$C_{s\epsilon}$ = modified secondary compression index
$H$ = initial thickness of soil layer (ft)
$t_s$ = time over which secondary settlement is to be calculated (typ. this is a max. of 100 years plus the max. time to complete primary consolidation)
$t_{pf}$ = time to complete primary consolidation

$$t_{pf} = \frac{T_V * H_t^2}{C_V}$$

$T_V$ = dimensionless time factor associated with the time it takes for primary consolidation settlement to be completed

$$For U < 60\%: \; T_V = \frac{\pi}{4}\left(\frac{U\%}{100}\right)^2$$

$$For U \geq 60\%: \; T_V = 1.781 - 0.933\log(100 - U\%)$$

$H_t$ = maximum length of drainage in the consolidating layer (= H for single-drained; = 0.5H for double-drained)
$C_V$ = coefficient of consolidation ($ft^2$/year)
$U$ = percent of primary consolidation (%) (typ. max. is 99.999; results in $T_V$ = 4.58).

- Total Settlement Equation:

$$S_{Total} = S_e + S_c + S_s$$

where:
$S_{Total}$ = total settlement (ft)
$Se$ = elastic settlement (ft)
$S_C$ = primary consolidation settlement (ft)
$S_s$ = secondary consolidation settlement (ft).

- Liner Strain Equation:

$$E_T = \frac{L_f - L_o}{L_o} \text{x} 100$$

where:
$E_T$ = total strain (%) ("+" = tension; "-" = compression)
$L_o$ = original distance separating two adjacent calculation points (ft)
$L_f$ = final distance separating two adjacent calculation points after settlement is complete (ft).

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JOB #: JOHNSTON-07-1
DATE: 12/1/08
BY: PKS
CHKD BY:

**Johnston County MSW Landfill - Phase 4A - Cells 1-3**
**Settlement Analysis** **Cross Section No.: 1** **(Points 1-7)**

**Soils Information:** (Note: When elastic or consolidation settlement is not applicable to a particular layer, enter "NA" for requested parameters.)

| Soil Layer | Description | Dry Unit Wt. (pcf) | Natural Moisture Content (%) | Wet Unit Wt. (pcf) | Elastic Settlement Parameters | | | Consolidation Settlement Parameters | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | $E_s$ (psf) | $\nu_s$ | $M_s$ (psf) | OCR | $C_{vc}$ | $C_{rc}$ | $C_{sc}$ |
| 1 | Structural Fill | 115.0 | 15.0 | 132.3 | NA | NA | NA | NA | NA | NA | NA |
| 2 | Clayey and Silty Sands (N = 20) | 110.0 | 25.0 | 137.5 | 188,000 | 0.30 | 253,077 | NA | NA | NA | NA |
| 3 | Clayey and Silty Sands (N = 7) | 110.0 | 25.0 | 137.5 | 89,000 | 0.30 | 119,808 | NA | NA | NA | NA |
| 4 | Clayey and Silty Sands (N = 12) | 110.0 | 25.0 | 137.5 | 127,000 | 0.30 | 170,962 | NA | NA | NA | NA |
| 5 | Silty Sand (N = 5) | 110.0 | 25.0 | 137.5 | 74,000 | 0.30 | 99,615 | NA | NA | NA | NA |
| 6 | Clayey and Silty Sands (N = 20) | 110.0 | 25.0 | 137.5 | 188,000 | 0.30 | 253,077 | NA | NA | NA | NA |
| 7 | Clayey Silt (N = 20) | 110.0 | 25.0 | 137.5 | 100,000 | 0.30 | 134,615 | NA | NA | NA | NA |
| 8 | | | | | | | | | | | |
| 9 | | | | | | | | | | | |
| 10 | | | | | | | | | | | |

**Waste Information:**

Average Unit Weight, $\gamma_{Waste}$ (pcf) = 70

**Assumptions:**

For soil types 2 through 6, use Es = $(300(N_{55} + 6))/50$, where $N_{55} = 1.27 \times N_{70}$
For soil types 7 use Es per Bowles Table 2-7.
Poisson's Ratio is assumed.
Unit wts. and moisture values are assumed based on site data.

**Settlement Points - Location Information:**

| Parameter | Point 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Position: | 65 | 210 | 412 | 590 | 845 | 1,210 | 1,595 | | | | | |
| Original Ground Surface Elevation (ft) = | 150.0 | 168.0 | 170.0 | 176.0 | 180.0 | 186.0 | 195.0 | | | | | |
| Avg. Unit Wt. of Soil Excavated (pcf) = | 110.0 | 110.0 | 110.0 | 110.0 | 110.0 | 110.0 | 110.0 | | | | | |
| Top of Landfill Elevation (ft) = | 180.0 | 216.0 | 266.0 | 310.0 | 330.0 | 310.0 | 214.0 | | | | | |
| Top of Liner Elevation (ft) = | 154.0 | 160.0 | 170.0 | 176.5 | 182.0 | 189.0 | 196.8 | | | | | |
| Liner Thickness (ft) = | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | | | | | |
| Top of Groundwater Elevation (ft) = | 148.0 | 152.0 | 161.0 | 169.0 | 175.0 | 182.0 | 190.0 | | | | | |
| Initial GW Separation to Bottom of Liner (ft) = | 5.0 | 7.0 | 8.0 | 6.5 | 6.0 | 6.0 | 5.8 | | | | | |
| **Layer 1:** Thickness (ft) = | 4.0 | 0.0 | 0.0 | 0.5 | 2.0 | 3.0 | 1.8 | | | | | |
| Elevation of Mid Point (ft) = | 152.0 | 160.0 | 170.0 | 176.3 | 181.0 | 187.5 | 195.9 | | | | | |
| (Before Liner Construct.) $p'_o$ at Mid Point (psf) = | -265 | 880 | 0 | -33 | -132 | -198 | -119 | | | | | |
| $p'_{mp}$ at Mid Point (psf) = | NA | NA | NA | NA | NA | NA | NA | | | | | |
| (After Liner Construct.) $p'_o$ at Mid Point (psf) = | 265 | 0 | 0 | 33 | 132 | 198 | 119 | | | | | |
| **Layer 2:** Thickness (ft) = | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10.0 | 0.0 | | | | | |
| Elevation of Mid Point (ft) = | 150.0 | 160.0 | 170.0 | 176.0 | 180.0 | 181.0 | 195.0 | | | | | |
| (Before Liner Construct.) $p'_o$ at Mid Point (psf) = | 0 | 880 | 0 | 0 | 0 | 625 | 0 | | | | | |
| $p'_{mp}$ at Mid Point (psf) = | NA | NA | NA | NA | NA | NA | NA | | | | | |
| (After Liner Construct.) $p'_o$ at Mid Point (psf) = | 529 | 0 | 0 | 66 | 265 | 1,022 | 238 | | | | | |
| **Layer 3:** Thickness (ft) = | 10.0 | 13.0 | 13.0 | 0.0 | 0.0 | 0.0 | 7.0 | | | | | |
| Elevation of Mid Point (ft) = | 145.0 | 153.5 | 163.5 | 176.0 | 180.0 | 176.0 | 191.5 | | | | | |
| (Before Liner Construct.) $p'_o$ at Mid Point (psf) = | 500 | 1,774 | 894 | 0 | 0 | 1,001 | 481 | | | | | |
| $p'_{mp}$ at Mid Point (psf) = | NA | NA | NA | NA | NA | NA | NA | | | | | |
| (After Liner Construct.) $p'_o$ at Mid Point (psf) = | 1,029 | 894 | 894 | 66 | 265 | 1,397 | 719 | | | | | |
| **Layer 4:** Thickness (ft) = | 0.0 | 0.0 | 0.0 | 10.0 | 10.0 | 5.0 | 5.0 | | | | | |
| Elevation of Mid Point (ft) = | 140.0 | 147.0 | 157.0 | 171.0 | 175.0 | 173.5 | 185.5 | | | | | |
| (Before Liner Construct.) $p'_o$ at Mid Point (psf) = | 876 | 2,356 | 1,538 | 688 | 688 | 1,188 | 1,025 | | | | | |
| $p'_{mp}$ at Mid Point (psf) = | NA | NA | NA | NA | NA | NA | NA | | | | | |
| (After Liner Construct.) $p'_o$ at Mid Point (psf) = | 1,405 | 1,476 | 1,538 | 754 | 952 | 1,585 | 1,264 | | | | | |
| **Layer 5:** Thickness (ft) = | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10.0 | | | | | |
| Elevation of Mid Point (ft) = | 140.0 | 147.0 | 157.0 | 166.0 | 170.0 | 171.0 | 178.0 | | | | | |
| (Before Liner Construct.) $p'_o$ at Mid Point (psf) = | 876 | 2,356 | 1,538 | 1,188 | 1,063 | 1,376 | 1,589 | | | | | |
| $p'_{mp}$ at Mid Point (psf) = | NA | NA | NA | NA | NA | NA | NA | | | | | |
| (After Liner Construct.) $p'_o$ at Mid Point (psf) = | 1,405 | 1,476 | 1,538 | 1,254 | 1,328 | 1,773 | 1,827 | | | | | |
| **Layer 6:** Thickness (ft) = | 5.0 | 7.0 | 7.0 | 0.0 | 0.0 | 12.0 | 10.0 | | | | | |
| Elevation of Mid Point (ft) = | 137.5 | 143.5 | 153.5 | 166.0 | 170.0 | 165.0 | 168.0 | | | | | |
| (Before Liner Construct.) $p'_o$ at Mid Point (psf) = | 1,064 | 2,618 | 1,801 | 1,188 | 1,063 | 1,827 | 2,340 | | | | | |
| $p'_{mp}$ at Mid Point (psf) = | NA | NA | NA | NA | NA | NA | NA | | | | | |
| (After Liner Construct.) $p'_o$ at Mid Point (psf) = | 1,593 | 1,738 | 1,801 | 1,254 | 1,328 | 2,223 | 2,578 | | | | | |
| **Layer 7:** Thickness (ft) = | 0.0 | 0.0 | 0.0 | 13.0 | 13.0 | 0.0 | 6.0 | | | | | |
| Elevation of Mid Point (ft) = | 135.0 | 140.0 | 150.0 | 159.5 | 163.5 | 159.0 | 160.0 | | | | | |
| (Before Liner Construct.) $p'_o$ at Mid Point (psf) = | 1,251 | 2,881 | 2,064 | 1,676 | 1,551 | 2,277 | 2,941 | | | | | |
| $p'_{mp}$ at Mid Point (psf) = | NA | NA | NA | NA | NA | NA | NA | | | | | |
| (After Liner Construct.) $p'_o$ at Mid Point (psf) = | 1,780 | 2,001 | 2,064 | 1,742 | 1,816 | 2,674 | 3,179 | | | | | |
| **Layer 8:** Thickness (ft) = | | | | | | | | | | | | |
| Elevation of Mid Point (ft) = | | | | | | | | | | | | |
| (Before Liner Construct.) $p'_o$ at Mid Point (psf) = | | | | | | | | | | | | |
| $p'_{mp}$ at Mid Point (psf) = | | | | | | | | | | | | |
| (After Liner Construct.) $p'_o$ at Mid Point (psf) = | | | | | | | | | | | | |
| **Layer 9:** Thickness (ft) = | | | | | | | | | | | | |
| Elevation of Mid Point (ft) = | | | | | | | | | | | | |
| (Before Liner Construct.) $p'_o$ at Mid Point (psf) = | | | | | | | | | | | | |
| $p'_{mp}$ at Mid Point (psf) = | | | | | | | | | | | | |
| (After Liner Construct.) $p'_o$ at Mid Point (psf) = | | | | | | | | | | | | |
| **Layer 10:** Thickness (ft) = | | | | | | | | | | | | |
| Elevation of Mid Point (ft) = | | | | | | | | | | | | |
| (Before Liner Construct.) $p'_o$ at Mid Point (psf) = | | | | | | | | | | | | |
| $p'_{mp}$ at Mid Point (psf) = | | | | | | | | | | | | |
| (After Liner Construct.) $p'_o$ at Mid Point (psf) = | | | | | | | | | | | | |

**Stress Change, $\Delta p$, at Liner:**

| Parameter | Point 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stress Decrease From Excavation (psf) = | 0 | 880 | 0 | 0 | 0 | 0 | 0 | | | | | |
| Stress Increase From Waste Load (psf) = | 1,820 | 3,920 | 6,720 | 9,345 | 10,360 | 8,470 | 1,204 | | | | | |
| Net Stress Increase/Decrease, $\Delta_p$ (psf) = | 1,820 | 3,040 | 6,720 | 9,345 | 10,360 | 8,470 | 1,204 | | | | | |

**Elastic Settlement:**

| Parameter | | Point 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Elastic Settlement (ft): | | | | | | | | | | | | | |
| Layer 1: | $S_e$ = | NA | NA | NA | NA | NA | NA | NA | | | | | |
| Layer 2: | $S_e$ = | NA | NA | NA | NA | NA | 0.33 | NA | | | | | |
| Layer 3: | $S_e$ = | 0.15 | 0.33 | 0.73 | NA | NA | NA | 0.07 | | | | | |
| Layer 4: | $S_e$ = | NA | NA | NA | 0.55 | 0.61 | 0.25 | 0.04 | | | | | |
| Layer 5: | $S_e$ = | NA | NA | NA | NA | NA | NA | 0.12 | | | | | |
| Layer 6: | $S_e$ = | 0.04 | 0.08 | 0.19 | NA | NA | 0.40 | 0.05 | | | | | |
| Layer 7: | $S_e$ = | NA | NA | NA | 0.90 | 1.00 | NA | 0.05 | | | | | |
| Layer 8: | $S_e$ = | | | | | | | | | | | | |
| Layer 9: | $S_e$ = | | | | | | | | | | | | |
| Layer 10: | $S_e$ = | | | | | | | | | | | | |
| **Total Elastic Settlement (ft) =** | | 0.19 | 0.41 | 0.92 | 1.45 | 1.61 | 0.98 | 0.33 | | | | | |

Elastic Settlement Equation:

$$Se = \frac{\Delta p}{M_S} H$$

**Primary Consolidation Settlement:**

| Parameter | | Point 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Primary Consolidation Settlement (ft): | | | | | | | | | | | | | |
| Layer 1: | $S_c$ = | NA | NA | NA | NA | NA | NA | NA | | | | | |
| | | --- | --- | --- | --- | --- | --- | --- | | | | | |
| Layer 2: | $S_c$ = | NA | NA | NA | NA | NA | NA | NA | | | | | |
| | | --- | --- | --- | --- | --- | --- | --- | | | | | |
| Layer 3: | $S_c$ = | NA | NA | NA | NA | NA | NA | NA | | | | | |
| | | --- | --- | --- | --- | --- | --- | --- | | | | | |
| Layer 4: | $S_c$ = | NA | NA | NA | NA | NA | NA | NA | | | | | |
| | | --- | --- | --- | --- | --- | --- | --- | | | | | |
| Layer 5: | $S_c$ = | NA | NA | NA | NA | NA | NA | NA | | | | | |
| | | --- | --- | --- | --- | --- | --- | --- | | | | | |
| Layer 6: | $S_c$ = | NA | NA | NA | NA | NA | NA | NA | | | | | |
| | | --- | --- | --- | --- | --- | --- | --- | | | | | |
| Layer 7: | $S_c$ = | NA | NA | NA | NA | NA | NA | NA | | | | | |
| | | --- | --- | --- | --- | --- | --- | --- | | | | | |
| Layer 8: | $S_c$ = | | | | | | | | | | | | |
| Layer 9: | $S_c$ = | | | | | | | | | | | | |
| Layer 10: | $S_c$ = | | | | | | | | | | | | |
| **Total Primary Consol. Settlement (ft) =** | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | |

Primary Consolidation Settlement Equations:

For primary recompression and compression (designated C):

$$S_C = H\left(C_{re}\log\frac{p'_{mp}}{p'_o} + C_{ce}\log\frac{p'_o+\Delta p}{p'_{mp}}\right)$$

For primary recompression only (designated R):

$$S_C = H\left(C_{rs}\log\frac{p'_o+\Delta p}{p'_o}\right)$$

**Secondary Consolidation Settlement:**

Assumed % Primary Consolidation (U) = 99.999 **(Max. = 99.999)**
$T_v$ (dimensionless) = 4.58
$t_s = t_{pf}$ + "X" (years) = 100

| Parameter | | Point 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Secondary Consolidation Settlement (ft): | | | | | | | | | | | | | |
| **Layer 1:** | Drainage* = | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | | |
| | $H_t$ (ft) = | 4.0 | 0.0 | 0.0 | 0.5 | 2.0 | 3.0 | 1.8 | | | | | |
| | $C_v$ ($in^2$/min) = | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | | | | |
| | $t_{pf}$ (years) = | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | | | | |
| | **$S_s$ =** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | | | | | |
| **Layer 2:** | Drainage* = | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | | |
| | $H_t$ (ft) = | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10.0 | 0.0 | | | | | |
| | $C_v$ ($in^2$/min) = | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | | | | | |
| | $t_{pf}$ (years) = | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.5 | 0.0 | | | | | |
| | **$S_s$ =** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | | | | | |
| **Layer 3:** | Drainage* = | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | | |
| | $H_t$ (ft) = | 10.0 | 13.0 | 13.0 | 0.0 | 0.0 | 0.0 | 7.0 | | | | | |
| | $C_v$ ($in^2$/min) = | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | | | | | |
| | $t_{pf}$ (years) = | 2.5 | 4.2 | 4.2 | 0.0 | 0.0 | 0.0 | 1.2 | | | | | |
| | **$S_s$ =** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | | | | | |
| **Layer 4:** | Drainage* = | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | | |
| | $H_t$ (ft) = | 0.0 | 0.0 | 0.0 | 10.0 | 10.0 | 5.0 | 5.0 | | | | | |
| | $C_v$ ($in^2$/min) = | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | | | | | |
| | $t_{pf}$ (years) = | 0.0 | 0.0 | 0.0 | 2.5 | 2.5 | 0.6 | 0.6 | | | | | |
| | **$S_s$ =** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | | | | | |
| **Layer 5:** | Drainage* = | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | | |
| | $H_t$ (ft) = | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10.0 | | | | | |
| | $C_v$ ($in^2$/min) = | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | | | | | |
| | $t_{pf}$ (years) = | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.5 | | | | | |
| | **$S_s$ =** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | | | | | |
| **Layer 6:** | Drainage* = | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | | |
| | $H_t$ (ft) = | 5.0 | 7.0 | 7.0 | 0.0 | 0.0 | 12.0 | 10.0 | | | | | |
| | $C_v$ ($in^2$/min) = | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | | | | | |
| | $t_{pf}$ (years) = | 0.6 | 1.2 | 1.2 | 0.0 | 0.0 | 3.6 | 2.5 | | | | | |
| | **$S_s$ =** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | | | | | |
| **Layer 7:** | Drainage* = | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | | |
| | $H_t$ (ft) = | 0.0 | 0.0 | 0.0 | 13.0 | 13.0 | 0.0 | 6.0 | | | | | |
| | $C_v$ ($in^2$/min) = | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | | | | | |
| | $t_{pf}$ (years) = | 0.0 | 0.0 | 0.0 | 4.2 | 4.2 | 0.0 | 0.9 | | | | | |
| | **$S_s$ =** | | | | | | | | | | | | |
| **Layer 8:** | Drainage* = | | | | | | | | | | | | |
| | $H_t$ (ft) = | | | | | | | | | | | | |
| | $C_v$ ($in^2$/min) = | | | | | | | | | | | | |
| | $t_{pf}$ (years) = | | | | | | | | | | | | |
| | **$S_s$ =** | | | | | | | | | | | | |
| **Layer 9:** | Drainage* = | | | | | | | | | | | | |
| | $H_t$ (ft) = | | | | | | | | | | | | |
| | $C_v$ ($in^2$/min) = | | | | | | | | | | | | |
| | $t_{pf}$ (years) = | | | | | | | | | | | | |
| | **$S_s$ =** | | | | | | | | | | | | |
| **Layer 10:** | Drainage* = | | | | | | | | | | | | |
| | $H_t$ (ft) = | | | | | | | | | | | | |
| | $C_v$ ($in^2$/min) = | | | | | | | | | | | | |
| | $t_{pf}$ (years) = | | | | | | | | | | | | |
| | **$S_s$ =** | | | | | | | | | | | | |
| **Total Sec. Consol. Settlement (ft) =** | | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | | | | | |

* Single-Drained = 1; Double-Drained = 2

Secondary Consolidation Settlement Equation:

$$S_s = C_{sc} H \log \frac{t_s}{t_{pf}}$$

**Total Settlement:**

| Parameter | | Point 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Settlement (ft): | | | | | | | | | | | | | |
| **Layer 1:** | $S_{Total}$ = | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | | | | | |
| **Layer 2:** | $S_{Total}$ = | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.33** | **0.00** | | | | | |
| **Layer 3:** | $S_{Total}$ = | **0.15** | **0.33** | **0.73** | **0.00** | **0.00** | **0.00** | **0.07** | | | | | |
| **Layer 4:** | $S_{Total}$ = | **0.00** | **0.00** | **0.00** | **0.55** | **0.61** | **0.25** | **0.04** | | | | | |
| **Layer 5:** | $S_{Total}$ = | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.12** | | | | | |
| **Layer 6:** | $S_{Total}$ = | **0.04** | **0.08** | **0.19** | **0.00** | **0.00** | **0.40** | **0.05** | | | | | |
| **Layer 7:** | $S_{Total}$ = | **0.00** | **0.00** | **0.00** | **0.90** | **1.00** | **0.00** | **0.05** | | | | | |
| **Layer 8:** | $S_{Total}$ = | | | | | | | | | | | | |
| **Layer 9:** | $S_{Total}$ = | | | | | | | | | | | | |
| **Layer 10:** | $S_{Total}$ = | | | | | | | | | | | | |
| **Total Settlement (ft) =** | | **0.19** | **0.41** | **0.92** | **1.45** | **1.61** | **0.98** | **0.33** | | | | | |

Total Settlement Equation:

$$S_{Total} = S_e + S_c + S_s$$

**Liner Slopes, Liner Strain, & Groundwater Separation:**

Min. Post-Settlement Liner Slope (%) = 0.5
Max. Liner Strain (%) = 0.5 **(Assumed Max. Tensile Strain in Compacted Clay Liner)**

| Parameter | Point 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Position: | 65 | 210 | 412 | 590 | 845 | 1,210 | 1,595 | | | | | |
| **Before Settlement:** | | | | | | | | | | | | |
| Top of Liner Elevation (ft) = | 154.0 | 160.0 | 170.0 | 176.5 | 182.0 | 189.0 | 196.8 | | | | | |
| Slope of Liner (%) (+ up;- down)= | ----- | 4.1 | 5.0 | 3.7 | 2.2 | 1.9 | 2.0 | | | | | |
| Length Along Liner ($L_o$) Bet. Points (ft) = | ----- | 145.124 | 202.247 | 178.119 | 255.059 | 365.067 | 385.079 | | | | | |
| **After Settlement:** | | | | | | | | | | | | |
| Top of Liner Elevation (ft) = | 153.8 | 159.6 | 169.1 | 175.1 | 180.4 | 188.0 | 196.5 | | | | | |
| **Slope of Liner (%) (+ up; - down)=** | ----- | **4.0** | **4.7** | **3.4** | **2.1** | **2.1** | **2.2** | | | | | |
| Slope Change (%) (+ steeper; - flatter)= | ----- | -0.2 | -0.2 | -0.3 | -0.1 | 0.2 | 0.2 | | | | | |
| Length Along Liner ($L_f$) Bet. Points (ft) = | ----- | 145.115 | 202.223 | 178.100 | 255.056 | 365.080 | 385.093 | | | | | |
| **Liner Strain ($E_T$) (%) (+ tension; - comp.)=** | ----- | **-0.01** | **-0.01** | **-0.01** | **0.00** | **0.00** | **0.00** | | | | | |
| **Final GW Separation to Bottom of Liner (ft) =** | **4.8** | **6.6** | **7.1** | **5.1** | **4.4** | **5.0** | **5.5** | | | | | |
| **Comments:** | | | | | | | | | | | | |
| **Liner Slope:** | ----- | **O.K.** | **O.K.** | **O.K.** | **O.K.** | **O.K.** | **O.K.** | | | | | |
| **Liner Strain:** | ----- | **O.K.** | **O.K.** | **O.K.** | **O.K.** | **O.K.** | **O.K.** | | | | | |

Base Slopes ≥ 2% O.K.
Strain < 0.1% - Negligible
GW Sep. > 4' O.K.

Liner Strain Equation:

$$E_T = \frac{L_f - L_o}{L_o} \times 100$$

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SHEET: 10 / 14
JOB #: JOHNSTON-07-1
DATE: 12/1/08
BY: PKS
CHKD BY:

**Johnston County MSW Landfill - Phase 4A - Cells 1-3**
**Settlement Analysis** **Cross Section No.: 2** **(Points 8-18)**

**Soils Information:** (Note: When elastic or consolidation settlement is not applicable to a particular layer, enter "NA" for requested parameters.)

| Soil Layer | Description | Dry Unit Wt. (pcf) | Natural Moisture Content (%) | Wet Unit Wt. (pcf) | Elastic Settlement Parameters | | | Consolidation Settlement Parameters | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | $E_s$ (psf) | $\nu_s$ | $M_s$ (psf) | OCR | $C_{vc}$ | $C_{rc}$ | $C_{sc}$ |
| 1 | Structural Fill | 115.0 | 15.0 | 132.3 | NA | NA | NA | NA | NA | NA | NA |
| 2 | Existing Waste | 70.0 | 25.0 | 87.5 | NA | NA | NA | 1 | 0.27 | 0.040 | 0.040 |
| 3 | Clayey and Silty Sands (N = 20) | 110.0 | 25.0 | 137.5 | 188,000 | 0.30 | 253,077 | NA | NA | NA | NA |
| 4 | Clayey and Silty Sands (N = 7) | 110.0 | 25.0 | 137.5 | 89,000 | 0.30 | 119,808 | NA | NA | NA | NA |
| 5 | Clayey and Silty Sands (N = 12) | 110.0 | 25.0 | 137.5 | 127,000 | 0.30 | 170,962 | NA | NA | NA | NA |
| 6 | Silty Sand (N = 5) | 110.0 | 25.0 | 137.5 | 74,000 | 0.30 | 99,615 | NA | NA | NA | NA |
| 7 | Clayey and Silty Sands (N = 20) | 110.0 | 25.0 | 137.5 | 188,000 | 0.30 | 253,077 | NA | NA | NA | NA |
| 8 | Clayey Silt (N = 20) | 110.0 | 25.0 | 137.5 | 100,000 | 0.30 | 134,615 | NA | NA | NA | NA |
| 9 | | | | | | | | | | | |
| 10 | | | | | | | | | | | |

**Waste Information:**

Average Unit Weight, $\gamma_{Waste}$ (pcf) = 70

**Assumptions:**

For soil types 2 through 6, use Es = $(300(N_{55} + 6))/50$, where $N_{55} = 1.27 \times N_{70}$
For soil types 7 use Es per Bowles Table 2-7.
Poisson's Ratio is assumed.
Unit wts. and moisture values for soils are assumed based on site data.
Settlement values for waste area assumed based on past studies.

**Settlement Points - Location Information:**

| Parameter | Point 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Position: | 30 | 115 | 185 | 250 | 315 | 380 | 465 | 690 | 845 | 1,030 | 1,270 | |
| Original Ground Surface Elevation (ft) = | 193.0 | 196.0 | 198.0 | 200.0 | 202.0 | 204.0 | 206.0 | 214.0 | 220.0 | 230.0 | 238.0 | |
| Avg. Unit Wt. of Soil Excavated (pcf) = | 110.0 | 110.0 | 110.0 | 110.0 | 110.0 | 110.0 | 110.0 | 110.0 | 110.0 | 110.0 | 110.0 | |
| Top of Landfill Elevation (ft) = | 202.0 | 222.0 | 240.0 | 256.0 | 273.0 | 289.0 | 310.0 | 318.0 | 319.0 | 310.0 | 250.0 | |
| Top of Liner Elevation (ft) = | 193.0 | 196.0 | 198.0 | 200.0 | 202.0 | 204.0 | 206.0 | 214.0 | 220.0 | 230.0 | 238.0 | |
| Top of Groundwater Elevation (ft) = | 152.0 | 155.0 | 158.0 | 161.0 | 164.0 | 166.0 | 170.0 | 175.0 | 178.0 | 182.0 | 187.0 | |
| **Layer 1:** Thickness (ft) = | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| Elevation of Mid Point (ft) = | 193.0 | 196.0 | 198.0 | 200.0 | 202.0 | 204.0 | 206.0 | 214.0 | 220.0 | 230.0 | 238.0 | |
| (Before Liner Construct.) $p'_o$ at Mid Point (psf) = | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| $p'_{mp}$ at Mid Point (psf) = | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | |
| (After Liner Construct.) $p'_o$ at Mid Point (psf) = | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| **Layer 2:** Thickness (ft) = | 35.0 | 35.0 | 30.0 | 30.0 | 30.0 | 30.0 | 28.0 | 30.0 | 30.0 | 30.0 | 30.0 | |
| Elevation of Mid Point (ft) = | 175.5 | 178.5 | 183.0 | 185.0 | 187.0 | 189.0 | 192.0 | 199.0 | 205.0 | 215.0 | 223.0 | |
| (Before Liner Construct.) $p'_o$ at Mid Point (psf) = | 1,531 | 1,531 | 1,313 | 1,313 | 1,313 | 1,313 | 1,225 | 1,313 | 1,313 | 1,313 | 1,313 | |
| $p'_{mp}$ at Mid Point (psf) = | 1,531 | 1,531 | 1,313 | 1,313 | 1,313 | 1,313 | 1,225 | 1,313 | 1,313 | 1,313 | 1,313 | |
| (After Liner Construct.) $p'_o$ at Mid Point (psf) = | 1,531 | 1,531 | 1,313 | 1,313 | 1,313 | 1,313 | 1,225 | 1,313 | 1,313 | 1,313 | 1,313 | |
| **Layer 3:** Thickness (ft) = | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.0 | 10.0 | 0.0 | |
| Elevation of Mid Point (ft) = | 158.0 | 161.0 | 168.0 | 170.0 | 172.0 | 174.0 | 178.0 | 184.0 | 187.5 | 195.0 | 208.0 | |
| (Before Liner Construct.) $p'_o$ at Mid Point (psf) = | 3,063 | 3,063 | 2,625 | 2,625 | 2,625 | 2,625 | 2,450 | 2,625 | 2,969 | 3,313 | 2,625 | |
| $p'_{mp}$ at Mid Point (psf) = | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | |
| (After Liner Construct.) $p'_o$ at Mid Point (psf) = | 3,063 | 3,063 | 2,625 | 2,625 | 2,625 | 2,625 | 2,450 | 2,625 | 2,969 | 3,313 | 2,625 | |
| **Layer 4:** Thickness (ft) = | 13.0 | 13.0 | 13.0 | 13.0 | 8.5 | 4.0 | 0.0 | 0.0 | 0.0 | 0.0 | 7.0 | |
| Elevation of Mid Point (ft) = | 151.5 | 154.5 | 161.5 | 163.5 | 167.8 | 172.0 | 178.0 | 184.0 | 185.0 | 190.0 | 204.5 | |
| (Before Liner Construct.) $p'_o$ at Mid Point (psf) = | 3,925 | 3,925 | 3,519 | 3,519 | 3,209 | 2,900 | 2,450 | 2,625 | 3,313 | 4,000 | 3,106 | |
| $p'_{mp}$ at Mid Point (psf) = | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | |
| (After Liner Construct.) $p'_o$ at Mid Point (psf) = | 3,925 | 3,925 | 3,519 | 3,519 | 3,209 | 2,900 | 2,450 | 2,625 | 3,313 | 4,000 | 3,106 | |
| **Layer 5:** Thickness (ft) = | 0.0 | 0.0 | 0.0 | 0.0 | 3.0 | 6.5 | 10.0 | 10.0 | 7.0 | 5.0 | 5.0 | |
| Elevation of Mid Point (ft) = | 145.0 | 148.0 | 155.0 | 157.0 | 162.0 | 166.8 | 173.0 | 179.0 | 181.5 | 187.5 | 198.5 | |
| (Before Liner Construct.) $p'_o$ at Mid Point (psf) = | 4,413 | 4,413 | 4,225 | 4,163 | 3,875 | 3,622 | 3,138 | 3,313 | 3,794 | 4,344 | 3,931 | |
| $p'_{mp}$ at Mid Point (psf) = | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | |
| (After Liner Construct.) $p'_o$ at Mid Point (psf) = | 4,413 | 4,413 | 4,225 | 4,163 | 3,875 | 3,622 | 3,138 | 3,313 | 3,794 | 4,344 | 3,931 | |
| **Layer 6:** Thickness (ft) = | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10.0 | |
| Elevation of Mid Point (ft) = | 145.0 | 148.0 | 155.0 | 157.0 | 160.5 | 163.5 | 168.0 | 174.0 | 178.0 | 185.0 | 191.0 | |
| (Before Liner Construct.) $p'_o$ at Mid Point (psf) = | 4,413 | 4,413 | 4,225 | 4,163 | 3,988 | 3,913 | 3,700 | 3,938 | 4,275 | 4,688 | 4,963 | |
| $p'_{mp}$ at Mid Point (psf) = | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | |
| (After Liner Construct.) $p'_o$ at Mid Point (psf) = | 4,413 | 4,413 | 4,225 | 4,163 | 3,988 | 3,913 | 3,700 | 3,938 | 4,275 | 4,688 | 4,963 | |
| **Layer 7:** Thickness (ft) = | 7.0 | 7.0 | 7.0 | 7.0 | 4.5 | 2.0 | 0.0 | 0.0 | 6.0 | 12.0 | 10.0 | |
| Elevation of Mid Point (ft) = | 141.5 | 144.5 | 151.5 | 153.5 | 158.3 | 162.5 | 168.0 | 174.0 | 175.0 | 179.0 | 181.0 | |
| (Before Liner Construct.) $p'_o$ at Mid Point (psf) = | 4,676 | 4,676 | 4,488 | 4,426 | 4,157 | 3,988 | 3,700 | 3,938 | 4,500 | 5,325 | 5,963 | |
| $p'_{mp}$ at Mid Point (psf) = | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | |
| (After Liner Construct.) $p'_o$ at Mid Point (psf) = | 4,676 | 4,676 | 4,488 | 4,426 | 4,157 | 3,988 | 3,700 | 3,938 | 4,500 | 5,325 | 5,963 | |
| **Layer 8:** Thickness (ft) = | 0.0 | 0.0 | 0.0 | 0.0 | 4.0 | 8.5 | 13.0 | 13.0 | 6.5 | 0.0 | 6.0 | |
| Elevation of Mid Point (ft) = | 138.0 | 141.0 | 148.0 | 150.0 | 154.0 | 157.3 | 161.5 | 167.5 | 168.8 | 173.0 | 173.0 | |
| (Before Liner Construct.) $p'_o$ at Mid Point (psf) = | 4,939 | 4,939 | 4,751 | 4,689 | 4,201 | 3,798 | 3,295 | 3,532 | 4,523 | 5,776 | 6,151 | |
| $p'_{mp}$ at Mid Point (psf) = | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | |
| (After Liner Construct.) $p'_o$ at Mid Point (psf) = | 4,939 | 4,939 | 4,751 | 4,689 | 4,201 | 3,798 | 3,295 | 3,532 | 4,523 | 5,776 | 6,151 | |
| **Layer 9:** Thickness (ft) = | | | | | | | | | | | | |
| Elevation of Mid Point (ft) = | | | | | | | | | | | | |
| (Before Liner Construct.) $p'_o$ at Mid Point (psf) = | | | | | | | | | | | | |
| $p'_{mp}$ at Mid Point (psf) = | | | | | | | | | | | | |
| (After Liner Construct.) $p'_o$ at Mid Point (psf) = | | | | | | | | | | | | |
| **Layer 10:** Thickness (ft) = | | | | | | | | | | | | |
| Elevation of Mid Point (ft) = | | | | | | | | | | | | |
| (Before Liner Construct.) $p'_o$ at Mid Point (psf) = | | | | | | | | | | | | |
| $p'_{mp}$ at Mid Point (psf) = | | | | | | | | | | | | |
| (After Liner Construct.) $p'_o$ at Mid Point (psf) = | | | | | | | | | | | | |

**Stress Change, $\Delta p$, at Liner:**

| Parameter | Point 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stress Decrease From Excavation (psf) = | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Stress Increase From Waste Load (psf) = | 630 | 1,820 | 2,940 | 3,920 | 4,970 | 5,950 | 7,280 | 7,280 | 6,930 | 5,600 | 840 | |
| Net Stress Increase/Decrease, $\Delta_p$ (psf) = | 630 | 1,820 | 2,940 | 3,920 | 4,970 | 5,950 | 7,280 | 7,280 | 6,930 | 5,600 | 840 | |

**Elastic Settlement:**

| Parameter | | Point 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Elastic Settlement (ft): | | | | | | | | | | | | | |
| Layer 1: | $S_e$ = | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | |
| Layer 2: | $S_e$ = | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | |
| Layer 3: | $S_e$ = | NA | NA | NA | NA | NA | NA | NA | NA | 0.14 | 0.22 | NA | |
| Layer 4: | $S_e$ = | 0.07 | 0.20 | 0.32 | 0.43 | 0.35 | 0.20 | NA | NA | NA | NA | 0.05 | |
| Layer 5: | $S_e$ = | NA | NA | NA | NA | 0.09 | 0.23 | 0.43 | 0.43 | 0.28 | 0.16 | 0.02 | |
| Layer 6: | $S_e$ = | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | 0.08 | |
| Layer 7: | $S_e$ = | 0.02 | 0.05 | 0.08 | 0.11 | 0.09 | 0.05 | NA | NA | 0.16 | 0.27 | 0.03 | |
| Layer 8: | $S_e$ = | NA | NA | NA | NA | 0.15 | 0.38 | 0.70 | 0.70 | 0.33 | NA | 0.04 | |
| Layer 9: | $S_e$ = | | | | | | | | | | | | |
| Layer 10: | $S_e$ = | | | | | | | | | | | | |
| **Total Elastic Settlement (ft) =** | | 0.09 | 0.25 | 0.40 | 0.53 | 0.68 | 0.85 | 1.13 | 1.13 | 0.92 | 0.65 | 0.23 | |

Elastic Settlement Equation:

$$Se = \frac{\Delta p}{M_S} H$$

**Primary Consolidation Settlement:**

| Parameter | | Point 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Primary Consolidation Settlement (ft): | | | | | | | | | | | | | |
| Layer 1: | $S_c$ = | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | |
| | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | |
| Layer 2: | $S_c$ = | 1.41 | 3.21 | 4.14 | 4.86 | 5.51 | 6.02 | 6.36 | 6.61 | 6.46 | 5.84 | 1.74 | |
| | | C | C | C | C | C | C | C | C | C | C | C | |
| Layer 3: | $S_c$ = | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | |
| | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | |
| Layer 4: | $S_c$ = | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | |
| | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | |
| Layer 5: | $S_c$ = | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | |
| | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | |
| Layer 6: | $S_c$ = | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | |
| | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | |
| Layer 7: | $S_c$ = | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | |
| | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | |
| Layer 8: | $S_c$ = | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | |
| | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | |
| Layer 9: | $S_c$ = | | | | | | | | | | | | |
| Layer 10: | $S_c$ = | | | | | | | | | | | | |
| **Total Primary Consol. Settlement (ft) =** | | 1.41 | 3.21 | 4.14 | 4.86 | 5.51 | 6.02 | 6.36 | 6.61 | 6.46 | 5.84 | 1.74 | |

Primary Consolidation Settlement Equations:

For primary recompression and compression (designated C):

$$S_C = H\left(C_{rc}\log\frac{p'_{mp}}{p'_o} + C_{cc}\log\frac{p'_o+\Delta p}{p'_{mp}}\right)$$

For primary recompression only (designated R):

$$S_C = H\left(C_{rc}\log\frac{p'_o+\Delta p}{p'_o}\right)$$

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**Secondary Consolidation Settlement:**

Assumed % Primary Consolidation (U) = 99.999 **(Max. = 99.999)**
$T_v$ (dimensionless) = 4.58
$t_s = t_{pf}$ + "X" (years) = 100

| Parameter | | Point 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Secondary Consolidation Settlement (ft): | | | | | | | | | | | | | |
| **Layer 1:** | Drainage* = | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| | $H_t$ (ft) = | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| | $C_v$ ($in^2$/min) = | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | |
| | $t_{pf}$ (years) = | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| | **$S_s$ =** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | |
| **Layer 2:** | Drainage* = | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| | $H_t$ (ft) = | 35.0 | 35.0 | 30.0 | 30.0 | 30.0 | 30.0 | 28.0 | 30.0 | 30.0 | 30.0 | 30.0 | |
| | $C_v$ ($in^2$/min) = | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | |
| | $t_{pf}$ (years) = | 30.7 | 30.7 | 22.6 | 22.6 | 22.6 | 22.6 | 19.7 | 22.6 | 22.6 | 22.6 | 22.6 | |
| | **$S_s$ =** | **0.88** | **0.88** | **0.88** | **0.88** | **0.88** | **0.88** | **0.88** | **0.88** | **0.88** | **0.88** | **0.88** | |
| **Layer 3:** | Drainage* = | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| | $H_t$ (ft) = | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.0 | 10.0 | 0.0 | |
| | $C_v$ ($in^2$/min) = | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | |
| | $t_{pf}$ (years) = | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 2.5 | 0.0 | |
| | **$S_s$ =** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | |
| **Layer 4:** | Drainage* = | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| | $H_t$ (ft) = | 13.0 | 13.0 | 13.0 | 13.0 | 8.5 | 4.0 | 0.0 | 0.0 | 0.0 | 0.0 | 7.0 | |
| | $C_v$ ($in^2$/min) = | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | |
| | $t_{pf}$ (years) = | 4.2 | 4.2 | 4.2 | 4.2 | 1.8 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 1.2 | |
| | **$S_s$ =** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | |
| **Layer 5:** | Drainage* = | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| | $H_t$ (ft) = | 0.0 | 0.0 | 0.0 | 0.0 | 3.0 | 6.5 | 10.0 | 10.0 | 7.0 | 5.0 | 5.0 | |
| | $C_v$ ($in^2$/min) = | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | |
| | $t_{pf}$ (years) = | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 1.1 | 2.5 | 2.5 | 1.2 | 0.6 | 0.6 | |
| | **$S_s$ =** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | |
| **Layer 6:** | Drainage* = | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| | $H_t$ (ft) = | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10.0 | |
| | $C_v$ ($in^2$/min) = | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | |
| | $t_{pf}$ (years) = | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.5 | |
| | **$S_s$ =** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | |
| **Layer 7:** | Drainage* = | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| | $H_t$ (ft) = | 7.0 | 7.0 | 7.0 | 7.0 | 4.5 | 2.0 | 0.0 | 0.0 | 6.0 | 12.0 | 10.0 | |
| | $C_v$ ($in^2$/min) = | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | |
| | $t_{pf}$ (years) = | 1.2 | 1.2 | 1.2 | 1.2 | 0.5 | 0.1 | 0.0 | 0.0 | 0.9 | 3.6 | 2.5 | |
| | **$S_s$ =** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | |
| **Layer 8:** | Drainage* = | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| | $H_t$ (ft) = | 0.0 | 0.0 | 0.0 | 0.0 | 4.0 | 8.5 | 13.0 | 13.0 | 6.5 | 0.0 | 6.0 | |
| | $C_v$ ($in^2$/min) = | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | |
| | $t_{pf}$ (years) = | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 1.8 | 4.2 | 4.2 | 1.1 | 0.0 | 0.9 | |
| | **$S_s$ =** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | |
| **Layer 9:** | Drainage* = | | | | | | | | | | | | |
| | $H_t$ (ft) = | | | | | | | | | | | | |
| | $C_v$ ($in^2$/min) = | | | | | | | | | | | | |
| | $t_{pf}$ (years) = | | | | | | | | | | | | |
| | **$S_s$ =** | | | | | | | | | | | | |
| **Layer 10:** | Drainage* = | | | | | | | | | | | | |
| | $H_t$ (ft) = | | | | | | | | | | | | |
| | $C_v$ ($in^2$/min) = | | | | | | | | | | | | |
| | $t_{pf}$ (years) = | | | | | | | | | | | | |
| | **$S_s$ =** | | | | | | | | | | | | |
| **Total Sec. Consol. Settlement (ft) =** | | **0.88** | **0.88** | **0.88** | **0.88** | **0.88** | **0.88** | **0.88** | **0.88** | **0.88** | **0.88** | **0.88** | |

* Single-Drained = 1; Double-Drained = 2

Secondary Consolidation Settlement Equation:

$$S_s = C_{sc} H \log \frac{t_s}{t_{pf}}$$

**Total Settlement:**

| Parameter | | Point 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Settlement (ft): | | | | | | | | | | | | | |
| Layer 1: | $S_{Total}$ = | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | |
| Layer 2: | $S_{Total}$ = | 2.29 | 4.09 | 5.02 | 5.75 | 6.39 | 6.90 | 7.24 | 7.49 | 7.34 | 6.73 | 2.62 | |
| Layer 3: | $S_{Total}$ = | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.14 | 0.22 | 0.00 | |
| Layer 4: | $S_{Total}$ = | 0.07 | 0.20 | 0.32 | 0.43 | 0.35 | 0.20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | |
| Layer 5: | $S_{Total}$ = | 0.00 | 0.00 | 0.00 | 0.00 | 0.09 | 0.23 | 0.43 | 0.43 | 0.28 | 0.16 | 0.02 | |
| Layer 6: | $S_{Total}$ = | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.08 | |
| Layer 7: | $S_{Total}$ = | 0.02 | 0.05 | 0.08 | 0.11 | 0.09 | 0.05 | 0.00 | 0.00 | 0.16 | 0.27 | 0.03 | |
| Layer 8: | $S_{Total}$ = | 0.00 | 0.00 | 0.00 | 0.00 | 0.15 | 0.38 | 0.70 | 0.70 | 0.33 | 0.00 | 0.04 | |
| Layer 9: | $S_{Total}$ = | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | |
| Layer 10: | $S_{Total}$ = | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | |
| **Total Settlement (ft) =** | | 2.38 | 4.34 | 5.42 | 6.28 | 7.07 | 7.75 | 8.37 | 8.62 | 8.26 | 7.38 | 2.85 | |

Total Settlement Equation:

$$S_{Total} = S_e + S_c + S_s$$

**Liner Slopes & Liner Strain:**

Min. Post-Settlement Liner Slope (%) = 0.5
Max. Liner Strain (%) = 5.0 **(Assumed Max. Tensile Strain in Geosynthetics)**

| Parameter | Point 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Position: | 30 | 115 | 185 | 250 | 315 | 380 | 465 | 690 | 845 | 1,030 | 1,270 | |
| **Before Settlement:** | | | | | | | | | | | | |
| Top of Liner Elevation (ft) = | 193.0 | 196.0 | 198.0 | 200.0 | 202.0 | 204.0 | 206.0 | 214.0 | 220.0 | 230.0 | 238.0 | |
| Slope of Liner (%) (+ up;- down)= | ----- | 3.5 | 2.9 | 3.1 | 3.1 | 3.1 | 2.4 | 3.6 | 3.9 | 5.4 | 3.3 | |
| Length Along Liner ($L_o$) Bet. Points (ft) = | ----- | 85.053 | 70.029 | 65.031 | 65.031 | 65.031 | 85.024 | 225.142 | 155.116 | 185.270 | 240.133 | |
| **After Settlement:** | | | | | | | | | | | | |
| Top of Liner Elevation (ft) = | 190.6 | 191.7 | 192.6 | 193.7 | 194.9 | 196.3 | 197.6 | 205.4 | 211.7 | 222.6 | 235.1 | |
| **Slope of Liner (%) (+ up; - down)=** | ----- | **1.2** | **1.3** | **1.7** | **1.9** | **2.0** | **1.6** | **3.4** | **4.1** | **5.9** | **5.2** | |
| Slope Change (%) (+ steeper; - flatter)= | ----- | -2.3 | -1.5 | -1.3 | -1.2 | -1.0 | -0.7 | -0.1 | 0.2 | 0.5 | 1.9 | |
| Length Along Liner ($L_f$) Bet. Points (ft) = | ----- | 85.006 | 70.006 | 65.010 | 65.011 | 65.013 | 85.011 | 225.133 | 155.130 | 185.320 | 240.327 | |
| **Liner Strain ($E_T$) (%) (+ tension; - comp.)=** | ----- | **-0.05** | **-0.03** | **-0.03** | **-0.03** | **-0.03** | **-0.01** | **0.00** | **0.01** | **0.03** | **0.08** | |
| **Comments:** | | | | | | | | | | | | |
| **Liner Slope:** | ----- | **O.K.** | **O.K.** | **O.K.** | **O.K.** | **O.K.** | **O.K.** | **O.K.** | **O.K.** | **O.K.** | **O.K.** | |
| **Liner Strain:** | ----- | **O.K.** | **O.K.** | **O.K.** | **O.K.** | **O.K.** | **O.K.** | **O.K.** | **O.K.** | **O.K.** | **O.K.** | |

Slope of Pipe O.K.

Strain < 0.1 % - Negligible -

Liner Strain Equation:

$$E_T = \frac{L_f - L_o}{L_o} \times 100$$

# Appendix E

# Bearing Capacity Evaluation

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PROJECT Johnston County MSWLF - Phase 4A - Cell 3

SUBJECT Bearing Capacity Analysis

SHEET 1 OF 4
JOB NO. JOHNSTON-07-2
DATE 2/16/07
COMPUTED BY PKS
CHECKED BY

**Objective** To evaluate the bearing capacity of the subgrade materials beneath the landfill footprint and the bearing capacity of the leachate collection system (LCS) and the protective cover under anticipated construction and operations equipment loads. The evaluation of the equipment loads also demonstrates the required separation between equipment and the underlying geomembrane(s).

**Reference** Naval Facilities Engineering Command (NAVFAC) (1986), Foundations & Earth Structures - Design Manual 7.02 Alexandria, VA, Change 1, September 1986, p. 7.2-131.

**Analysis** Use bearing capacity equations as presented in NAVFAC DM 7.02 (see attached).

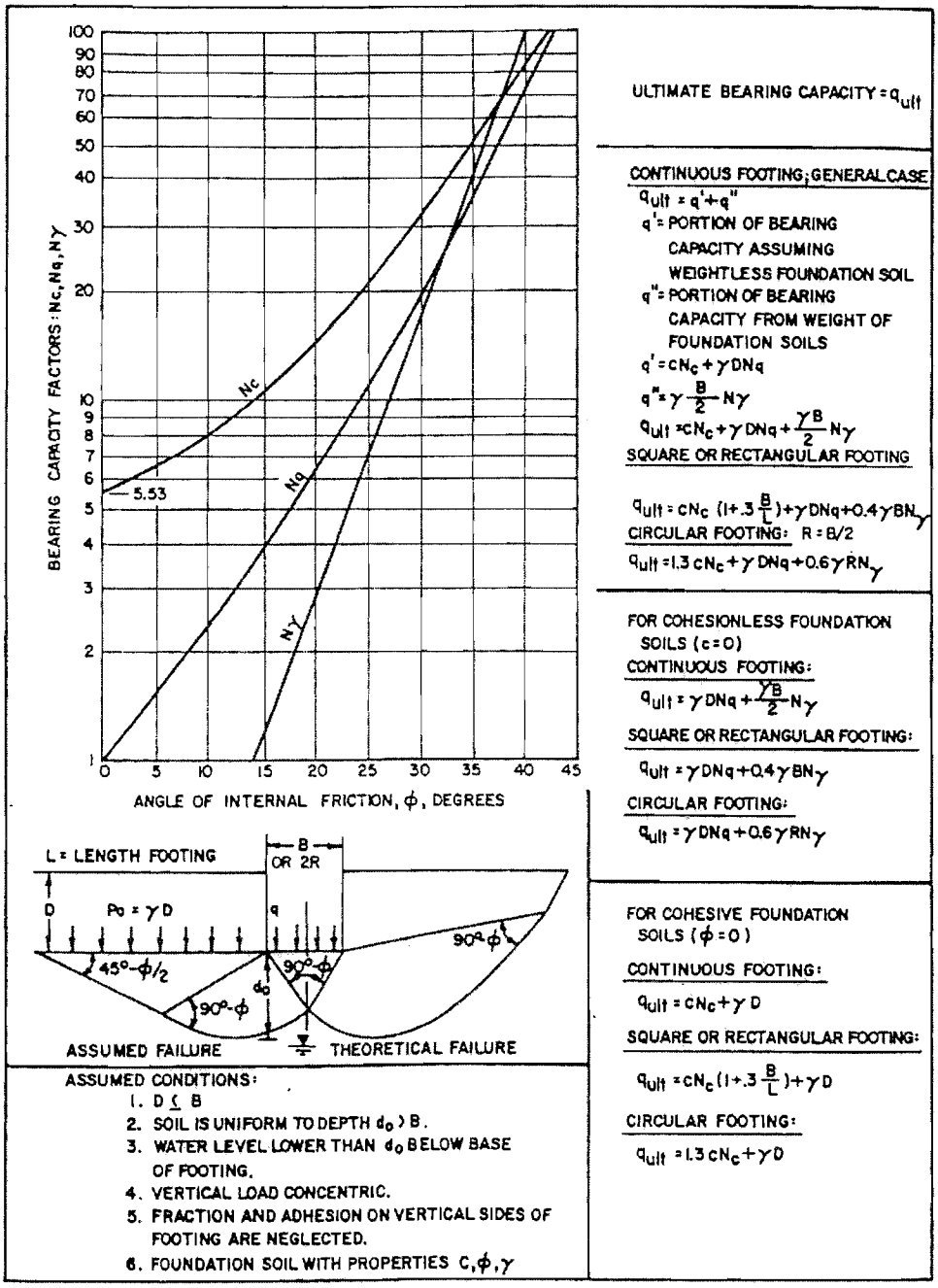
**Requirements** $FS_{min}$ (Overall) = 3.0; $FS_{min}$ (LCS/Protective Cover) = 2.0.

**Assumptions**

1. General shear failure mode controls.
2. For the overall bearing capacity of the landfill, the landfill footprint is simplified as a rectangle.
3. For the evaluation of equipment loads, the stress is distributed at depth based on 2V:1H (2:1 approximation).
4. Tracked equipment are modeled as rectangular loads; wheeled equipment are modeled as circular loads.

**BEARING CAPACITY.WPD**

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




ULTIMATE BEARING CAPACITY = $q_{ult}$

CONTINUOUS FOOTING; GENERAL CASE

$q_{ult} = q' + q''$

q' = PORTION OF BEARING CAPACITY ASSUMING WEIGHTLESS FOUNDATION SOIL

q'' = PORTION OF BEARING CAPACITY FROM WEIGHT OF FOUNDATION SOILS

$q' = cN_c + \gamma D N_q$

$q'' = \gamma \frac{B}{2} N_\gamma$

$q_{ult} = cN_c + \gamma D N_q + \frac{\gamma B}{2} N_\gamma$

SQUARE OR RECTANGULAR FOOTING

$q_{ult} = cN_c\,(1+.3\frac{B}{L}) + \gamma D N_q + 0.4\gamma B N_\gamma$

CIRCULAR FOOTING: R = B/2

$q_{ult} = 1.3cN_c + \gamma D N_q + 0.6\gamma R N_\gamma$

FOR COHESIONLESS FOUNDATION SOILS (c = 0)

CONTINUOUS FOOTING:

$q_{ult} = \gamma D N_q + \frac{\gamma B}{2} N_\gamma$

SQUARE OR RECTANGULAR FOOTING:

$q_{ult} = \gamma D N_q + 0.4\gamma B N_\gamma$

CIRCULAR FOOTING:

$q_{ult} = \gamma D N_q + 0.6\gamma R N_\gamma$

FOR COHESIVE FOUNDATION SOILS ($\phi = 0$)

CONTINUOUS FOOTING:

$q_{ult} = cN_c + \gamma D$

SQUARE OR RECTANGULAR FOOTING:

$q_{ult} = cN_c(1+.3\frac{B}{L}) + \gamma D$

CIRCULAR FOOTING:

$q_{ult} = 1.3cN_c + \gamma D$

ASSUMED CONDITIONS:

1. $D \leq B$
2. SOIL IS UNIFORM TO DEPTH $d_o > B$.
3. WATER LEVEL LOWER THAN $d_o$ BELOW BASE OF FOOTING.
4. VERTICAL LOAD CONCENTRIC.
5. FRACTION AND ADHESION ON VERTICAL SIDES OF FOOTING ARE NEGLECTED.
6. FOUNDATION SOIL WITH PROPERTIES $c, \phi, \gamma$

FIGURE 1
Ultimate Bearing Capacity of Shallow Footings With Concentric Loads
7.2-131

NAVFAC DM7.2



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

SHEET: 3 / 4
JOB #: JOHNSTON-07-2
DATE: 3/20/07
BY: PKS
CHKD BY:

# Johnston County MSW Landfill - Phase 4A - Cell 3
# Overall Bearing Capacity Analysis

Subsurface Bearing Soil & Load Information:

Soil Parameters:

| | | |
|---|---|---|
| Friction Angle ($\phi$) = | 25 | Degrees |
| Cohesion ($c$) = | 150 | psf |
| Unit Weight ($\gamma$) = | 100 | pcf |
| Eff. Unit Weight ($\gamma_{eff}$)= | 37.6 | pcf |

Soil Bearing Capacity Factors:

| | |
|---|---|
| $N_c$ = | 20 |
| $N_q$ = | 10 |
| $N_g$ = | 7 |

→ Conservative For Sands

Load Information:

| | | |
|---|---|---|
| Depth of Footing ($D_f$) = | 5 | ft (Depth of Landfill Base Below Outside Ground Surface - Typ. Min.) |
| Foundation Width ($B$) = | 900 | ft → All of Ph. 4A |
| Foundation Length ($L$) = | 1,600 | ft |
| Waste Unit Weight ($\gamma$) = | 70 | pcf |
| Waste Thickness = | 100 | ft (Typ. Thickness) |

Bearing Capacity:

| | | |
|---|---|---|
| Soil Surcharge ($\gamma \times D_f$) = | 500 psf | |
| Ultimate Bearing Cap. ($q_{ult}$) = | 100,138 psf | |
| Allowable Bearing Cap. ($q_{allow}$) = | 33,379 psf | (Ultimate Bearing Capacity/3) |
| Applied Load = | 7,000 psf | |
| Bearing Capacity FS = | **14.3** | **OK - GREATER THAN 3** |

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Raleigh, NC 27603 Fax: 919-828-3899


JOB #: JOHNSTON-07-2
DATE: 3/20/07
BY: PKS
CHKD BY:

**Johnston County MSW Landfill - Phase 4A - Cell 3**
**Equipment Contact Stress & Bearing Capacity Analysis - Leachate Collection System/Protective Cover**

Bearing Soil & Load Information (USER INPUT):

Soil Parameters:
Friction Angle ($\phi$) = 30 Degrees
Cohesion ($c$) = 0 psf
Unit Weight ($\gamma$) = 110 pcf

Soil Bearing Capacity Factors:
$N_c$ = 32
$N_q$ = 20
$N_\gamma$ = 16

→ Conservative For Compacted S. grade or Pro Cover

Equipment Contact Stress & Bearing Capacity:

LGP Dozer:

Max. Contact Stress = 6 psi
Typ. Track Width = 34 in CAT D6N LGP DS
Typ. Track Length = 122 in

| Depth (ft) | Contact Area ($in^2$) | Contact Stress (psi) | qult (psi) | FS | | Comment |
|---|---|---|---|---|---|---|
| 0 | 4,148 | 6.0 | 13.9 | 2.3 | | OK |
| 0.5 | 5,120 | 4.9 | 21.5 | 4.4 | | OK |
| 0.75 | 5,633 | 4.4 | 25.3 | 5.7 | | OK |
| 1 | 6,164 | 4.0 | 29.1 | 7.2 | | OK |
| 1.5 | 7,280 | 3.4 | 36.8 | 10.8 | | OK |
| 2 | 8,468 | 2.9 | 44.4 | 15.1 | | OK |

Non-LGP Dozer:

Max. Contact Stress = 12 psi
Typ. Track Width = 22 in CAT D7R Series II
Typ. Track Length = 112 in

| Depth (ft) | Contact Area ($in^2$) | Contact Stress (psi) | qult (psi) | FS | | Comment |
|---|---|---|---|---|---|---|
| 0 | 2,464 | 12.0 | 9.0 | 0.7 | Expect Rutting | - More Separation Reqd. |
| 0.5 | 3,304 | 8.9 | 16.6 | 1.9 | | - More Separation Reqd. |
| 0.75 | 3,751 | 7.9 | 20.4 | 2.6 | | OK |
| 1 | 4,216 | 7.0 | 24.2 | 3.5 | | OK |
| 1.5 | 5,200 | 5.7 | 31.9 | 5.6 | | OK |
| 2 | 6,256 | 4.7 | 39.5 | 8.4 | | OK |

Truck ($H_{20}$):

Max. Contact Stress = 90 psi
Typ. Contact Diemeter = 9 in

| Depth (ft) | Contact Area ($in^2$) | Contact Stress (psi) | qult (psi) | FS | | Comment |
|---|---|---|---|---|---|---|
| 0 | 64 | 90.0 | 2.8 | 0.0 | Expect Rutting | - More Separation Reqd. |
| 0.5 | 177 | 32.4 | 10.4 | 0.3 | Expect Rutting | - More Separation Reqd. |
| 0.75 | 254 | 22.5 | 14.2 | 0.6 | Expect Rutting | - More Separation Reqd. |
| 1 | 346 | 16.5 | 18.0 | 1.1 | | - More Separation Reqd. |
| 1.5 | 573 | 10.0 | 25.7 | 2.6 | | OK |
| 2 | 855 | 6.7 | 33.3 | 5.0 | | OK |
| 2.5 | 1,195 | 4.8 | 40.9 | 8.5 | | OK |
| 3 | 1,590 | 3.6 | 48.6 | 13.5 | | OK |

Truck (Off-Road):

Max. Contact Stress = 60 psi
Typ. Contact Diameter = 30 in

| Depth (ft) | Contact Area ($in^2$) | Contact Stress (psi) | qult (psi) | FS | | Comment |
|---|---|---|---|---|---|---|
| 0 | 707 | 60.0 | 9.2 | 0.2 | Expect Rutting | - More Separation Reqd. |
| 0.5 | 1,018 | 41.7 | 16.8 | 0.4 | Expect Rutting | - More Separation Reqd. |
| 0.75 | 1,195 | 35.5 | 20.6 | 0.6 | Expect Rutting | - More Separation Reqd. |
| 1 | 1,385 | 30.6 | 24.4 | 0.8 | Expect Rutting | - More Separation Reqd. |
| 1.5 | 1,810 | 23.4 | 32.1 | 1.4 | | - More Separation Reqd. |
| 2 | 2,290 | 18.5 | 39.7 | 2.1 | | OK |
| 2.5 | 2,827 | 15.0 | 47.4 | 3.2 | | OK |
| 3 | 3,421 | 12.4 | 55.0 | 4.4 | | OK |

Waste Compector:

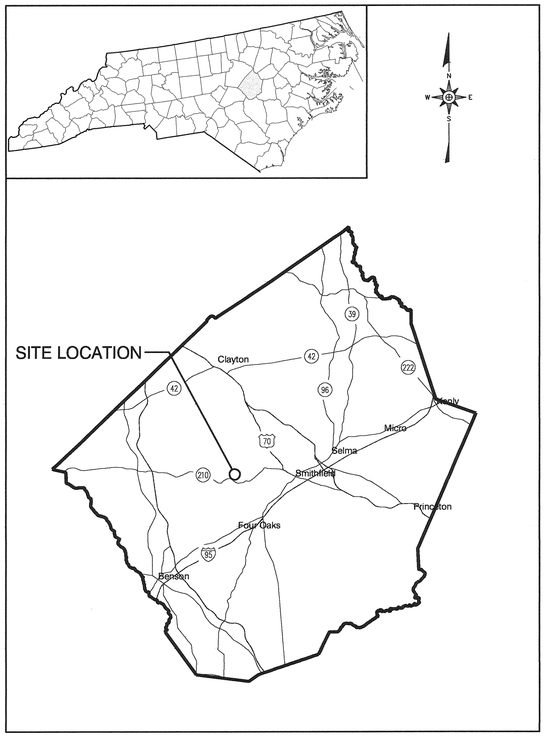
Max. Contact Stress = 70 psi
Typ. Drum Contact Width = 12 in Typ. Drum - Large Compactor
Typ. Drum Length = 48 in

| Depth (ft) | Contact Area ($in^2$) | Contact Stress (psi) | qult (psi) | FS | | Comment |
|---|---|---|---|---|---|---|
| 0 | 576 | 70.0 | 4.9 | 0.1 | Expect Rutting | - More Separation Reqd. |
| 0.5 | 972 | 41.5 | 12.5 | 0.3 | Expect Rutting | - More Separation Reqd. |
| 0.75 | 1,197 | 33.7 | 16.3 | 0.5 | Expect Rutting | - More Separation Reqd. |
| 1 | 1,440 | 28.0 | 20.2 | 0.7 | Expect Rutting | - More Separation Reqd. |
| 1.5 | 1,980 | 20.4 | 27.8 | 1.4 | | - More Separation Reqd. |
| 2 | 2,592 | 15.6 | 35.4 | 2.3 | | OK |
| 2.5 | 3,276 | 12.3 | 43.1 | 3.5 | | OK |
| 3 | 4,032 | 10.0 | 50.7 | 5.1 | | OK |

JOHNSTON COUNTY, NORTH CAROLINA
DEPARTMENT OF PUBLIC UTILITIES

# JOHNSTON COUNTY MSW LANDFILL
# PHASE 4A - CELL 3
# PERMIT AMENDMENT DRAWINGS

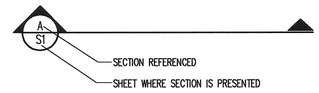
JUNE 2007
REVISED: DECEMBER 2008



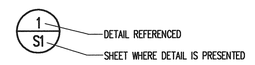

SITE LOCATION MAP
NOT TO SCALE

| SHEET NO. | DRAWING NO. | DRAWING TITLE | REVISION |
|---|---|---|---|
| 1 | | TITLE – COVER SHEET | 1 |
| 2 | S1 | EXISTING CONDITIONS | 1 |
| 3 | S2 | CELL 3 SUBGRADE GRADING PLAN | 1 |
| 4 | S3 | CELL 3 PROTECTIVE COVER GRADING AND DRAINAGE PLAN | 1 |
| 5 | S4 | LEACHATE MANAGEMENT SYSTEMS LEAK DETECTION PIPING | 1 |
| 6 | S5 | LEACHATE MANAGEMENT SYSTEMS LEACHATE COLLECTION PIPING | 1 |
| 7 | L1 | LINER AND BERM DETAILS (SHEET 1 OF 2) | 1 |
| 8 | L2 | LINER AND BERM DETAILS (SHEET 2 OF 2) | 1 |
| 9 | LM1 | LEACHATE MANAGEMENT SYSTEM DETAILS (SHEET 1 OF 2) | 1 |
| 10 | LM2 | LEACHATE MANAGEMENT SYSTEM DETAILS (SHEET 2 OF 2) | 1 |
| 11 | EC1 | EROSION AND SEDIMENTATION DETAILS (SHEET 1 OF 2) | |
| 12 | EC2 | EROSION AND SEDIMENTATION DETAILS (SHEET 2 OF 2) | |
| 13 | FC1 | PHASE 4A FINAL COVER GRADING AND DRAINAGE PLAN | 1 |
| 14 | FC2 | FINAL COVER DETAILS (SHEET 1 OF 2) | |
| 15 | FC3 | FINAL COVER DETAILS (SHEET 2 OF 2) | 1 |
| 16 | LFG1 | CELL 3 LANDFILL GAS MANAGEMENT SYSTEM | 1 |
| 17 | LFG2 | LANDFILL GAS MANAGEMENT DETAILS (SHEET 1 OF 3) | |
| 18 | LFG3 | LANDFILL GAS MANAGEMENT DETAILS (SHEET 2 OF 3) | |
| 19 | LFG4 | LANDFILL GAS MANAGEMENT DETAILS (SHEET 3 OF 3) | |
| 20 | EX1 | ENGINEERING CROSS SECTIONS (SHEET 1 OF 2) | 1 |
| 21 | EX2 | ENGINEERING CROSS SECTIONS (SHEET 2 OF 2) | 1 |
| 22 | P1 | MSW LANDFILL PHASING PLAN (SHEET 1 OF 3) | 1 |
| 23 | P2 | MSW LANDFILL PHASING PLAN (SHEET 2 OF 3) | 1 |
| 24 | P3 | MSW LANDFILL PHASING PLAN (SHEET 3 OF 3) | 1 |
| 25 | P4 | C&D LANDFILL PHASING PLAN | 1 |

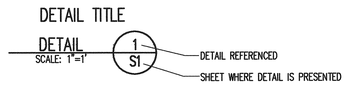
STANDARD SECTION LOCATION CALLOUT (SHEET AND DETAIL)



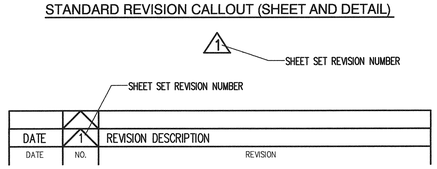

STANDARD DETAIL CALLOUT




STANDARD DETAIL LABEL AND CALLOUT




STANDARD REVISION CALLOUT (SHEET AND DETAIL)





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FILE NAME
JOHN-D0479A

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| PARCEL REFERENCES | |
|---|---|
| PARCEL | COUNTY DEED BOOK REFERENCE |
| (1) | D.B. 775, PG. 410 |
| (2) | D.B. 952, PG. 376 |
| (3) | D.B. 763, PG. 525 |
| (4) | D.B. 1228, PG. 652 |
| (5) | D.B. 1215, PG. 747 |
| (6) | D.B. E-3, PG. 1 |

NOTE:
PROPERTY INFORMATION FROM "MAP FOR JOHNSTON COUNTY" PREPARED BY L. DENNIS LEE, P.A., SMITHFIELD, NC, DATED MARCH 22, 1994, AS REVISED THROUGH JANUARY 30, 1995 (COUNTY PLAT BOOK 59, PAGE 437) AND COUNTY REGISTER OF DEEDS OFFICE.

SEDIMENT BASIN NO. 6
3"ø HDPE LEACHATE FORCE MAIN
SEDIMENT BASIN NO. 4
BORROW AREA E (ACTIVE) JOHNSTON COUNTY (D.B. 2109, PG. 509)
NC DOT BORROW AREA (D.B. 862, PG. 667)
JOHNSTON COUNTY (D.B. E-3, PG. 1)
C&D AREA 2 CELL 1 (ACTIVE)
MSW PHASE 3 (CLOSED)
CELL 2 (FUTURE)
WASTE LIMITS (APPROXIMATE) (TYP.)
YARD WASTE PROCESSING AREA
MSW PHASES 1 & 2 (CLOSED)
LANDFILL MAINTENANCE BUILDING
MSW PHASE 4A-CELLS 1 & 2 (ACTIVE)
COUNTY LIVESTOCK ARENA
SEDIMENT BASIN NO. 3
SEDIMENT BASIN NO. 5A
CELL 3 (PROPOSED)
COUNTY BULK RECLAIMED WATER TRANSFER STATION
C&D AREA 1 (INACTIVE)
WHITE GOODS AND SCRAP METAL AREA
STATE OF NC
MSW PHASE 4 (CLOSED)
CONVENIENCE CENTER (MSW, RECYCLABLES, WASTE OIL)
COUNTY HOME ROAD
3"ø HDPE LEACHATE FORCE MAIN (x2)
SCALEHOUSE & SCALES
LANDFILL OFFICE
MSW PHASE 10 (FUTURE)
8"ø HDPE LEACHATE GRAVITY MAIN
USED TIRES AND BATTERY STORAGE AREA
MSW PHASE 5 (INACTIVE)
3"ø HDPE LEACHATE RECIRCULATION FORCE MAIN
MSW PHASE 8 (FUTURE)
MSW PHASE 9 (FUTURE)
MSW PHASE 6 (FUTURE)
MSW PHASE 7 (FUTURE)
LEACHATE STORAGE LAGOON
PROPERTY LINE (FACILITY BOUNDARY) (SEE IDENTIFIED PARCELS)

MW-5A, MW-20, MW-19D, MW-19, PZ-9, PZ-9D, MW-21, PZ-10, MW-4D, MW-4B, MW-6, MW-12B, PZ-3, MW-7B, MW-14D, MW-7, MW-7D, MW-15D, MW-17, MW-16S, MW-8A, MW-18D, MW-1, MW-10, MW-5-10, MW-5-9, MW-5-1, MW-9C, MW-9D, MW-5-7, MW-5-8, MW-3, MW-5-6, MW-5-2, MW-5-3, MW-5-5, MW-5-4, LL-2, LL-1, LL-3, LL-4

E 2173000, E 2172500, E 2172000, E 2171500, E 2171000, E 2170500, E 2170000, E 2169500, E 2169000, E 2168500, E 2168000, E 2167500, E 2167000

N. 648000, N. 647500, N. 647000, N. 646500, N. 646000, N. 645500, N. 645000, N. 644500, N. 644000, N. 643500, N. 643000, N. 642500, N. 642000, N. 641500, N. 641000, N. 640500

LEGEND

- EXISTING 10' CONTOUR (SEE REFERENCE 1)
- EXISTING 2' CONTOUR
- PROPERTY LINE (FACILITY BOUNDARY)
- PROPERTY LINE (OTHER)
- PARCEL BOUNDARY (APPROXIMATE)
- LIMIT OF LINER (EXISTING LINED UNITS)
- APPROXIMATE EXISTING WASTE LIMITS (UNLINED UNITS)
- FUTURE LANDFILL AREAS
- MW-8D EXISTING MONITORING WELL
- PZ-4 EXISTING PIEZOMETER
- (5) PARCEL IDENTIFIER (SEE TABLE)

REFERENCES

1. OVERALL SITE TOPOGRAPHY PROVIDED BY GEODATA CORPORATION, BASED ON MARCH 8, 2001 AERIAL PHOTOGRAPHY. TOPOGRAPHY IN LANDFILL AREA PROVIDED BY GEODATA CORPORATION BASED ON JUNE 6, 2008 AERIAL PHOTOGRAPHY. TOPOGRAPHY IN BORROW AREAS PROVIDED BY GEODATA CORPORATION BASED ON MAY 20, 2007 AERIAL PHOTOGRAPHY.

0 300' 600' 900'

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


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SEAL
SEAL 026065 ENGINEER PETER K. SMITH 12/4/08

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

DRAWING TITLE:
EXISTING CONDITIONS

| DESIGNED BY: | DRAWN BY: |
|---|---|
| P.K.S. | J.A.L. |
| CHECKED BY: | PROJECT NO.: JOHN 07-2 |
| SCALE: AS SHOWN | DATE: JUNE 2007 |
| FILE NAME: JOHN-D0480A | |
| SHEET NO.: 2 | DRAWING NO.: S1 |

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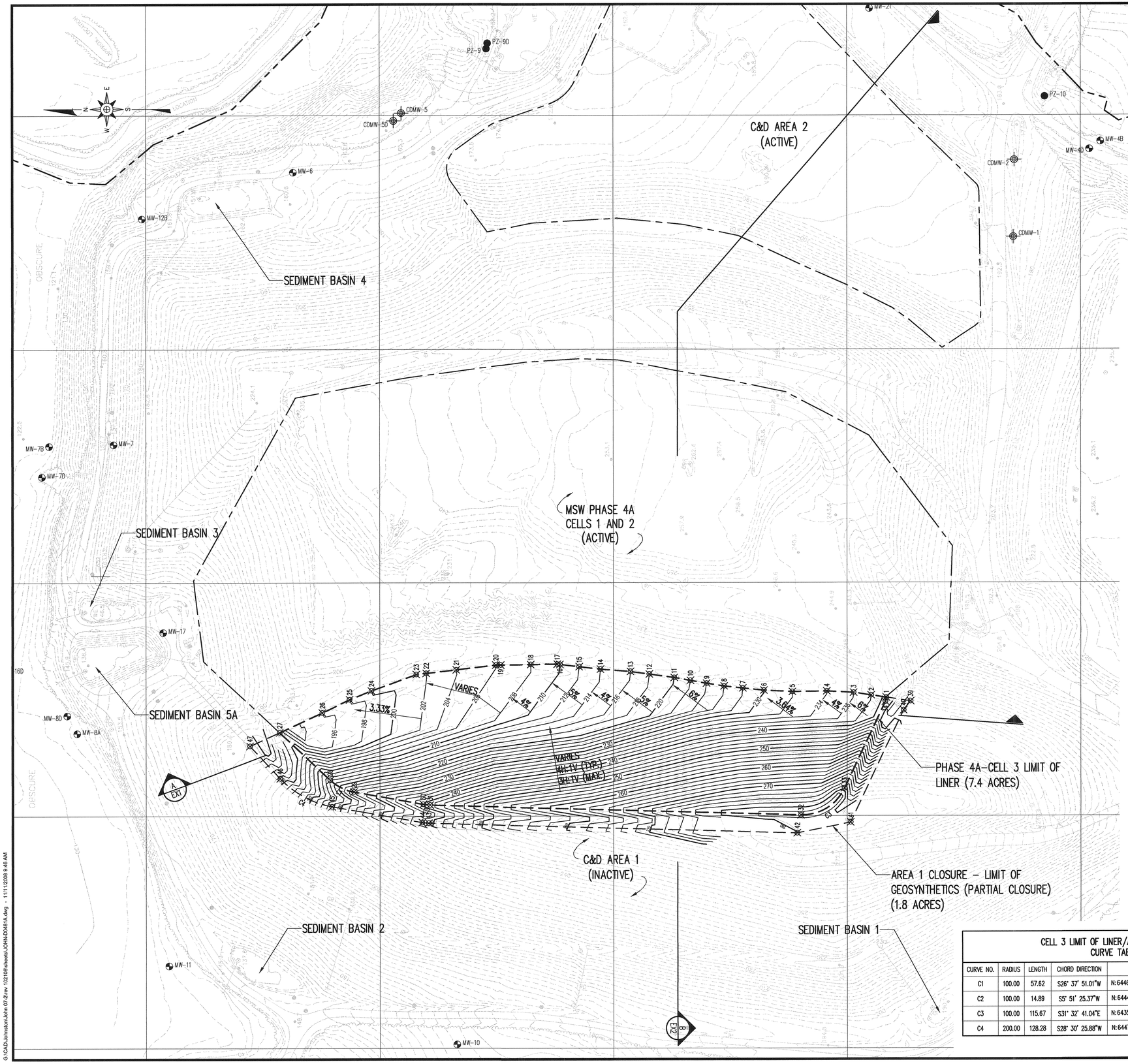


| CELL 3 LIMIT OF LINER/ AREA 1 CLOSURE CONTROL POINTS | | |
|---|---|---|
| POINT NO. | NORTHING | EASTING |
| 1 | 643415.64 | 2170253.12 |
| 2 | 643448.04 | 2170258.05 |
| 3 | 643485.64 | 2170263.87 |
| 4 | 643543.01 | 2170267.03 |
| 5 | 643616.60 | 2170265.87 |
| 6 | 643677.54 | 2170269.06 |
| 7 | 643722.77 | 2170273.92 |
| 8 | 643762.60 | 2170278.19 |
| 9 | 643800.25 | 2170284.17 |
| 10 | 643834.73 | 2170290.32 |
| 11 | 643869.44 | 2170296.50 |
| 12 | 643922.55 | 2170303.96 |
| 13 | 643962.87 | 2170309.59 |
| 14 | 644027.16 | 2170314.70 |
| 15 | 644072.85 | 2170320.04 |
| 16 | 644113.97 | 2170324.84 |
| 17 | 644119.74 | 2170325.52 |
| 18 | 644176.50 | 2170324.62 |
| 19 | 644240.72 | 2170323.59 |
| 20 | 644251.12 | 2170323.43 |
| 21 | 644335.78 | 2170313.47 |
| 22 | 644400.22 | 2170305.89 |
| 23 | 644421.33 | 2170303.41 |
| 24 | 644517.45 | 2170268.29 |
| 25 | 644564.24 | 2170249.20 |
| 26 | 644622.66 | 2170221.12 |
| 27 | 644714.09 | 2170179.06 |
| 28 | 644605.75 | 2170077.54 |
| 29 | 644554.95 | 2170052.07 |
| 30 | 644406.81 | 2170025.62 |
| 31 | 644392.01 | 2170024.10 |
| 32 | 643598.45 | 2170002.06 |
| 33 | 643505.28 | 2170059.26 |
| 34 | 643417.78 | 2170244.20 |
| 39 | 643363.78 | 2170245.24 |
| 40 | 643378.86 | 2170225.91 |
| 41 | 643492.17 | 2169986.44 |
| 42 | 643606.28 | 2169963.26 |
| 43 | 644395.17 | 2169985.19 |
| 44 | 644408.93 | 2169986.46 |
| 45 | 644601.99 | 2170020.86 |
| 46 | 644712.79 | 2170081.04 |
| 47 | 644777.33 | 2170149.97 |

| CELL 3 LIMIT OF LINER/AREA 1 CLOSURE CURVE TABLE | | | | | |
|---|---|---|---|---|---|
| CURVE NO. | RADIUS | LENGTH | CHORD DIRECTION | START POINT | END POINT |
| C1 | 100.00 | 57.62 | S26° 37' 51.01"W | N:644605.75, E:2170077.54 | N:644554.95, E:2170052.07 |
| C2 | 100.00 | 14.89 | S5° 51' 25.37"W | N:644406.81, E:2170025.62 | N:644392.01, E:2170024.10 |
| C3 | 100.00 | 115.67 | S31° 32' 41.04"E | N:643598.45, E:2170002.06 | N:643505.28, E:2170059.26 |
| C4 | 200.00 | 128.28 | S28° 30' 25.88"W | N:644712.79, E:2170081.04 | N:644601.99, E:2170020.86 |

LEGEND

- 150 — EXISTING 10' CONTOUR (SEE REFERENCE 1)
- EXISTING 2' CONTOUR
- APPROXIMATE PROPERTY LINE
- LIMITS OF EXISTING LINER
- CELL 3 LIMIT OF LINER
- AREA 1 CLOSURE – LIMIT OF GEOSYNTHETICS
- 300 — PROPOSED 10' CONTOUR (SEE NOTE 1)
- PROPOSED 2' CONTOUR
- EXISTING MONITORING WELL
- EXISTING PIEZOMETER
- MONITORING WELL FOR C&D LANDFILL (UNSURVEYED LOCATION)
- CONTROL POINT (SEE TABLE)

NOTES

1. GRADES SHOWN REPRESENT TOP OF SUBGRADE.

REFERENCES

1. OVERALL SITE TOPOGRAPHY PROVIDED BY GEODATA CORPORATION, BASED ON JUNE 6, 2008.

GENERAL EROSION AND SEDIMENTATION CONTROL NOTES

1. ALL EROSION AND SEDIMENTATION CONTROL WORK SHALL BE IN ACCORDANCE WITH THE LATEST EDITION OF THE NORTH CAROLINA EROSION AND SEDIMENT CONTROL PLANNING AND DESIGN MANUAL AS WELL AS APPLICABLE REGULATIONS.
2. EROSION AND SEDIMENTATION CONTROL MEASURES SHALL BE ESTABLISHED PRIOR TO, OR AS SOON AS PRACTICAL THEREAFTER, ANY LAND CLEARING OR CONSTRUCTION ACTIVITIES MAY BEGIN.
3. ALL EROSION AND SEDIMENTATION CONTROL MEASURES SHALL BE CONSTRUCTED ACCORDING TO THE CONTRACT DRAWINGS AND SPECIFICATIONS.
4. ALL EROSION AND SEDIMENTATION CONTROL MEASURES SHALL BE INSPECTED AT LEAST ONCE EVERY SEVEN CALENDAR DAYS AND WITHIN 24 HOURS AFTER ANY STORM EVENT OF GREATER THAN 0.5 INCHES OF RAIN PER 24 HOUR PERIOD AND APPROPRIATE MAINTENANCE CONDUCTED. MAINTENANCE SHALL INCLUDE, BUT NOT BE LIMITED TO:
   A. THE REMOVAL AND SATISFACTORY DISPOSAL OF TRAPPED OR DEPOSITED SEDIMENTS FROM BASINS, TRAPS, BARRIERS, FILTERS, AND/OR DRAINAGE FEATURES/DEVICES;
   B. REPLACEMENT OF FILTER FABRICS USED FOR SILT FENCES UPON LOSS OF EFFICIENCY; AND
   C. REPLACEMENT OF ANY OTHER COMPONENTS WHICH ARE DAMAGED OR CANNOT SERVE THE INTENDED USE.
5. THE CONTRACTOR SHALL PROVIDE TEMPORARY OR PERMANENT GROUND COVER (OR OTHER ACCEPTABLE MEASURES) ADEQUATE TO RESTRAIN EROSION ON ERODIBLE SLOPES OR OTHER AREAS WITHIN 21 CALENDAR DAYS FOLLOWING COMPLETION OF ANY PHASE OF GRADING. THE CONTRACTOR SHALL PROVIDE PERMANENT GROUND COVER FOR ALL DISTURBED AREAS WITHIN 15 WORKING DAYS OR 90 CALENDER DAYS (WHICHEVER IS SHORTER) FOLLOWING THE COMPLETION OF CONSTRUCTION.

0 100' 200' 300'

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


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SEAL

SEAL 029166 ENGINEER PIETER K. SWART 11/24/08

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

DRAWING TITLE:
CELL 3 SUBGRADE GRADING PLAN

| DESIGNED BY: | DRAWN BY: |
|---|---|
| P.K.S. | J.A.L. |
| CHECKED BY: | PROJECT NO.: JOHN 07-2 |
| SCALE: AS SHOWN | DATE: JUNE 2007 |
| FILE NAME: JOHN-D0481A | |
| SHEET NO.: 3 | DRAWING NO.: S2 |

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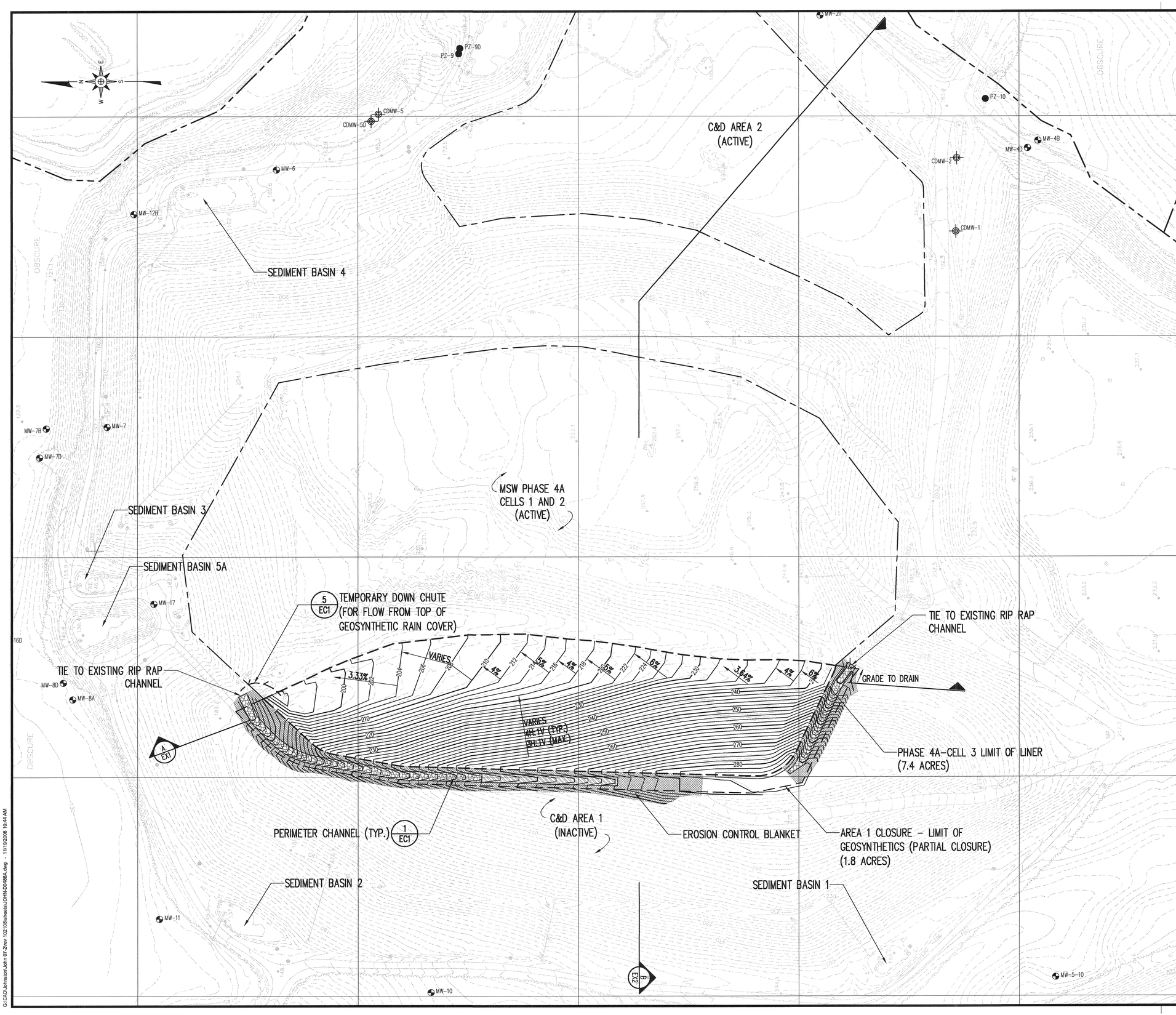


## LEGEND

- EXISTING 10' CONTOUR (SEE REFERENCE 1)
- EXISTING 2' CONTOUR
- APPROXIMATE PROPERTY LINE
- LIMITS OF EXISTING LINER
- CELL 3 LIMIT OF LINER
- AREA 1 CLOSURE – LIMIT OF GEOSYNTHETICS
- PROPOSED 10' CONTOUR (SEE NOTE 1)
- PROPOSED 2' CONTOUR
- EXISTING MONITORING WELL
- EXISTING PIEZOMETER
- MONITORING WELL FOR C&D LANDFILL (UNSURVEYED LOCATION)
- EROSION CONTROL BLANKET (ECB)
- TURF REINFORCEMENT MATTING (TRM)
- RIP RAP

## NOTES

1. GRADES SHOWN REPRESENT TOP OF PROTECTIVE COVER.
2. REFER TO THE DETAILS FOR PROPER TIE-IN OF LINER SYSTEM AND PROTECTIVE COVER AROUND THE PERIMETER OF CELL 3.

## REFERENCES

1. OVERALL SITE TOPOGRAPHY PROVIDED BY GEODATA CORPORATION, BASED ON JUNE 6, 2008.

0 100' 200' 300'

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


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fax: 919-828-3899


SEAL

SEAL

PROFESSIONAL ENGINEER SEAL 021068 PIETER K. SCHEIER 12/4/08

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

DRAWING TITLE:
CELL 3
PROTECTIVE COVER GRADING
AND DRAINAGE 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-D0488A | |
| SHEET NO. 4 | DRAWING NO. S3 |

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N 645,000
N 644,500
N 644,000
N 643,500
N 643,000
E 2,171,500
E 2,171,000
E 2,170,500
E 2,170,000

C&D AREA 2
(ACTIVE)

MSW PHASE 4A
CELLS 1 AND 2
(ACTIVE)

C&D AREA 1
(INACTIVE)

SEDIMENT BASIN 4

SEDIMENT BASIN 3

SEDIMENT BASIN 5A

SEDIMENT BASIN 2

SEDIMENT BASIN 1

EXISTING LEAK DETECTION
PUMP STATION

EXISTING 4"ø SOLID HDPE
PIPE (APPROXIMATE)

TIE IN WITH EXISTING
4"ø SOLID HDPE PIPE
(APPROXIMATE)

BOOTED PENETRATION
FOR SOLID PIPE
(INV. = ±191.0)

1 / LM2 LEAK DETECTION TRENCH

PHASE 4A-CELL 3 LIMIT OF LINER
(7.4 ACRES)

AREA 1 CLOSURE – LIMIT OF
GEOSYNTHETICS (PARTIAL CLOSURE)
(1.8 ACRES)

CONTRACTOR SHALL TEMPORARILY
DAYLIGHT NEW PIPE SO AS TO
MINIMIZE THE FLOW OF STORMWATER
TO THE EXISTING LEAK DETECTION
PUMP STATION DURING CONSTRUCTION

ABANDON PORTION OF
EXISTING 4" HDPE PIPE
(REMOVE AND/OR GROUT)

VARIES
4H:1V (TYP.)
5H:1V (MAX.)

MW-21
PZ-10
MW-4B
MW-4D
CDMW-2
CDMW-1
PZ-9D
PZ-9
CDMW-5D
CDMW-5
MW-6
MW-12B
MW-7B
MW-7
MW-7D
MW-17
MW-8D
MW-8A
MW-11
MW-10
MW-5-10

## LEGEND

- EXISTING 10' CONTOUR (SEE REFERENCE 1)
- EXISTING 2' CONTOUR
- APPROXIMATE PROPERTY LINE
- LIMITS OF EXISTING LINER
- CELL 3 LIMIT OF LINER
- AREA 1 CLOSURE – LIMIT OF GEOSYNTHETICS
- PROPOSED 10' CONTOUR (SEE NOTE 1)
- PROPOSED 2' CONTOUR
- PERFORATED PIPING/STONE TRENCH
- SOLID PIPING
- EXISTING MONITORING WELL
- EXISTING PIEZOMETER
- MONITORING WELL FOR C&D LANDFILL (UNSURVEYED LOCATION)

## NOTES

1. GRADES SHOWN REPRESENT TOP OF SUBGRADE.

## REFERENCES

1. OVERALL SITE TOPOGRAPHY PROVIDED BY GEODATA CORPORATION, BASED ON JUNE 6, 2008.

0 100' 200' 300'

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


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SEAL

SEAL
REGISTERED PROFESSIONAL ENGINEER SEAL 021055 PETER K. SMITH

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

DRAWING TITLE:
LEACHATE MANAGEMENT SYSTEMS
LEAK DETECTION PIPING

| DESIGNED BY: | DRAWN BY: |
|---|---|
| P.K.S. | J.A.L. |
| CHECKED BY: | PROJECT NO.: JOHN 07-2 |
| SCALE: AS SHOWN | DATE: JUNE 2007 |
| FILE NAME: JOHN-D0483A | |
| SHEET NO. 5 | DRAWING NO. S4 |

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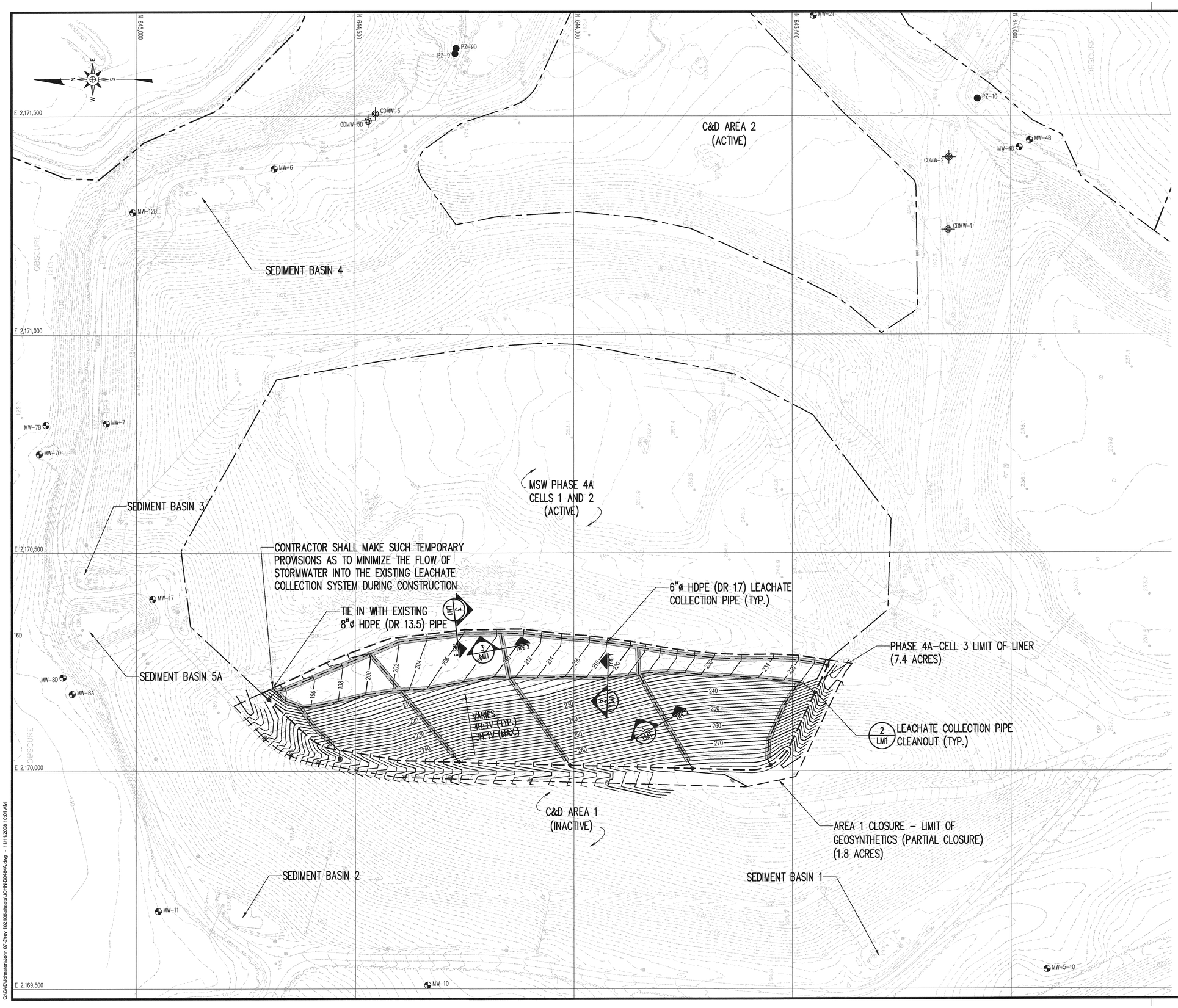


## LEGEND

- EXISTING 10' CONTOUR (SEE REFERENCE 1)
- EXISTING 2' CONTOUR
- APPROXIMATE PROPERTY LINE
- LIMITS OF EXISTING LINER
- CELL 3 LIMIT OF LINER
- AREA 1 CLOSURE - LIMIT OF GEOSYNTHETICS
- PROPOSED 10' CONTOUR (SEE NOTE 1)
- PROPOSED 2' CONTOUR
- PERFORATED PIPING/STONE TRENCH
- SOLID PIPING
- CLEANOUT
- EXISTING MONITORING WELL
- EXISTING PIEZOMETER
- MONITORING WELL FOR C&D LANDFILL (UNSURVEYED LOCATION)

## NOTES

1. GRADES SHOWN REPRESENT TOP OF SUBGRADE.

## REFERENCES

1. OVERALL SITE TOPOGRAPHY PROVIDED BY GEODATA CORPORATION, BASED ON JUNE 6, 2008.

0 100' 200' 300'

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


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

DRAWING TITLE:
LEACHATE MANAGEMENT SYSTEMS
LEACHATE COLLECTION PIPING

| | |
|---|---|
| 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-D0484A | |
| SHEET NO. 6 | DRAWING NO. S5 |

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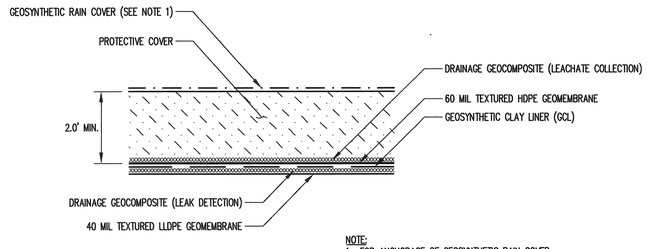
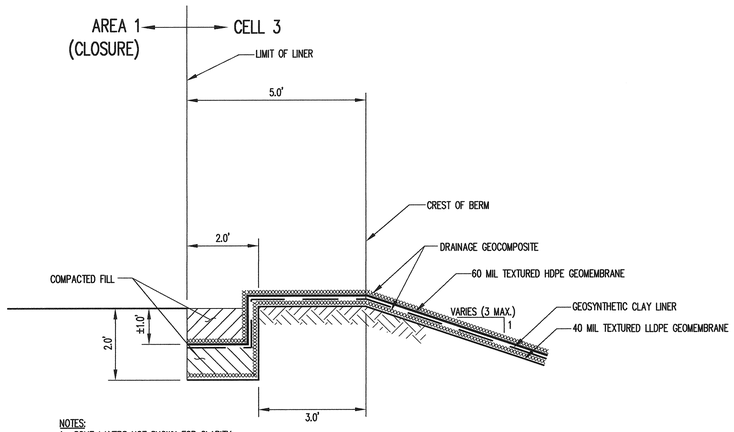


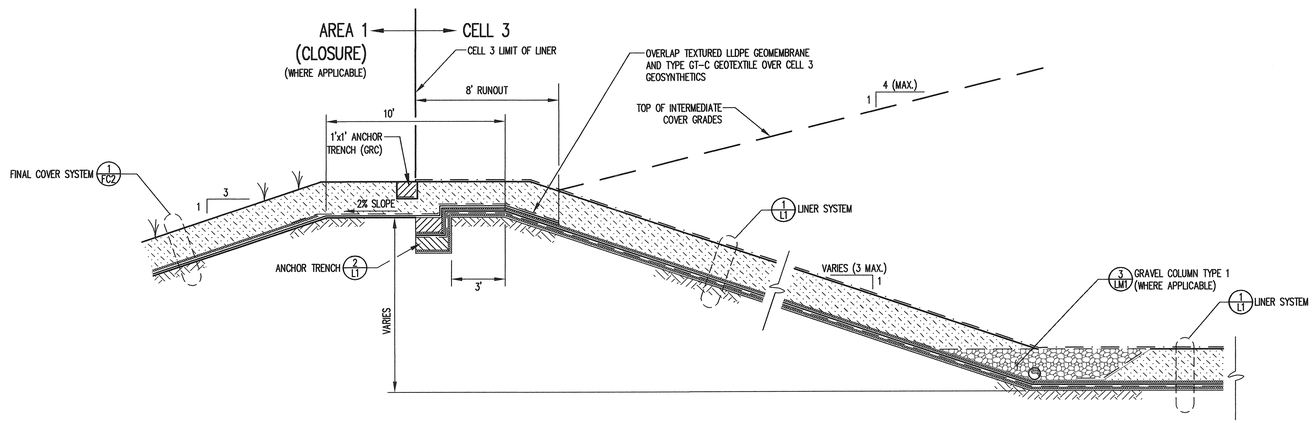

LINER AND LEACHATE COLLECTION SYSTEM CROSS SECTIONS

DETAIL 1/L1 NOT TO SCALE




ANCHOR TRENCH

DETAIL 2/L1 NOT TO SCALE




PERIMETER BERM

DETAIL 3/L1 NOT TO SCALE

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

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

DRAWING TITLE:
LINER AND BERM DETAILS
(SHEET 1 OF 2)

| | |
|---|---|
| DESIGNED BY: P.K.S. | DRAWN BY: C.T.J. |
| CHECKED BY: | PROJECT NO.: JOHN 07-2 |
| SCALE: AS SHOWN | DATE: JUNE 2007 |
| FILE NAME: JOHN-D0486A | |
| SHEET NO.: 7 | DRAWING NO.: L1 |

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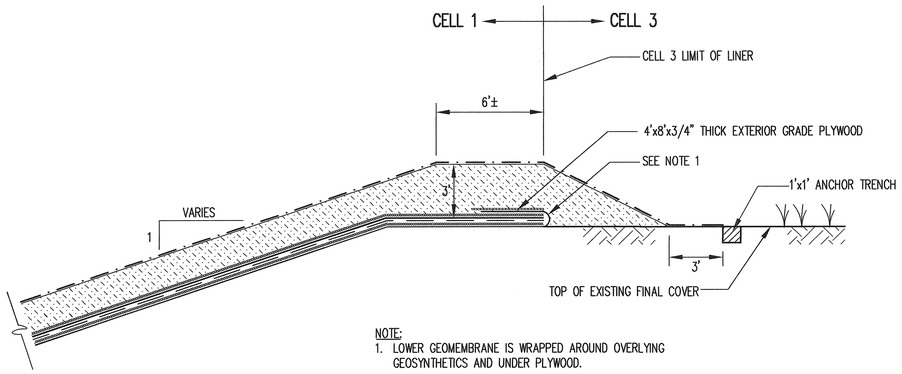
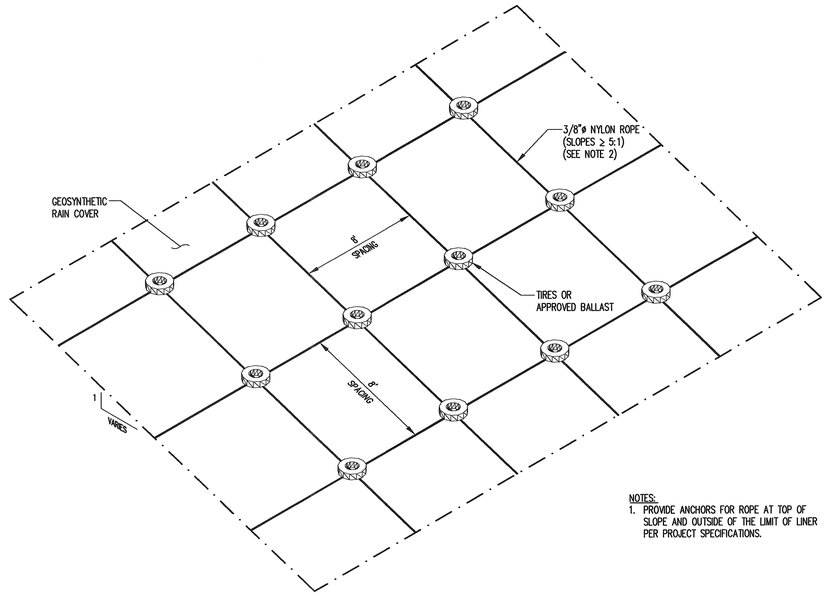



NOTE:
1. LOWER GEOMEMBRANE IS WRAPPED AROUND OVERLYING GEOSYNTHETICS AND UNDER PLYWOOD.

TYPICAL EXISTING LINER TERMINATION

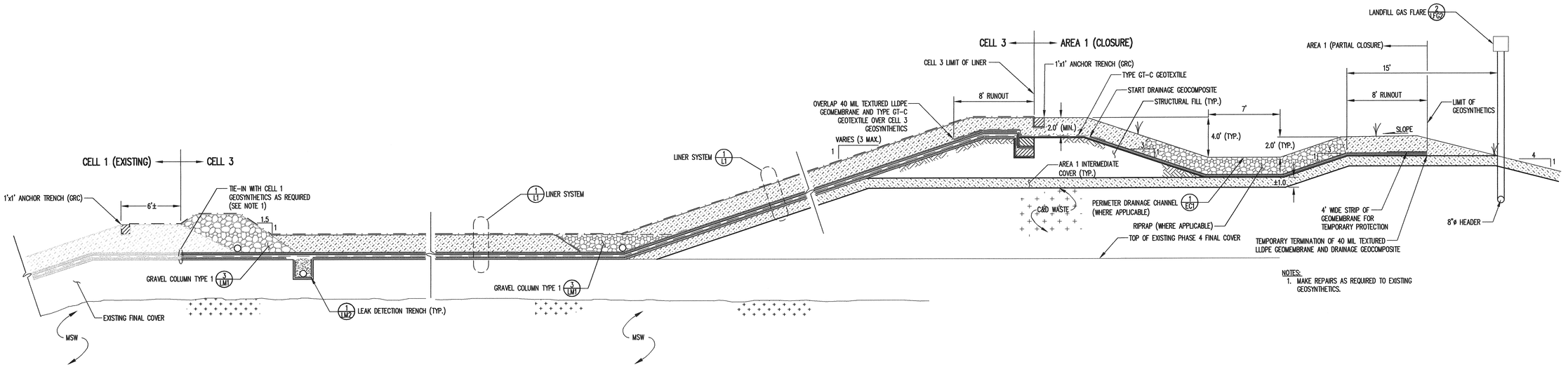
DETAIL 1/L2
NOT TO SCALE




NOTES:
1. PROVIDE ANCHORS FOR ROPE AT TOP OF SLOPE AND OUTSIDE OF THE LIMIT OF LINER PER PROJECT SPECIFICATIONS.

ANCHORAGE OF GEOSYNTHETIC RAIN COVER

DETAIL 3/L2
NOT TO SCALE




NOTES:
1. MAKE REPAIRS AS REQUIRED TO EXISTING GEOSYNTHETICS.

TYPICAL CELL 3 LINER AND LEACHATE COLLECTION SYSTEM CROSS SECTION

DETAIL 2/L2
NOT TO SCALE

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

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fax: 919-828-3899

SEAL

SEAL
12/4/08

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

DRAWING TITLE:
LINER AND BERM DETAILS
(SHEET 2 OF 2)

| | |
|---|---|
| DESIGNED BY: P.K.S. | DRAWN BY: C.T.J. |
| CHECKED BY: | PROJECT NO.: JOHN 07-2 |
| SCALE: AS SHOWN | DATE: JUNE 2007 |
| FILE NAME: JOHN-D0487A | |
| SHEET NO. 8 | DRAWING NO. L2 |

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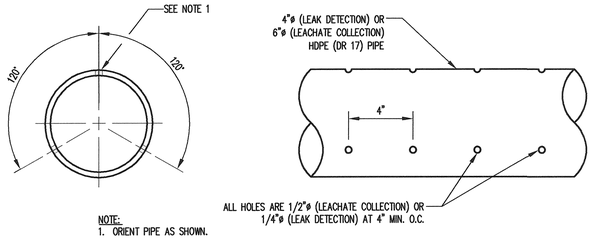
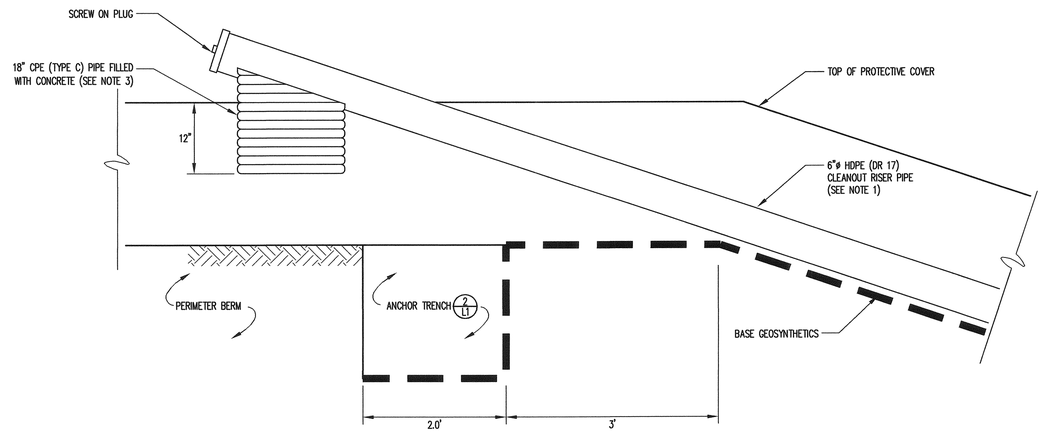



NOTE:
1. ORIENT PIPE AS SHOWN.

LEAK DETECTION / LEACHATE COLLECTION PIPING

HDPE PIPE PERFORATIONS

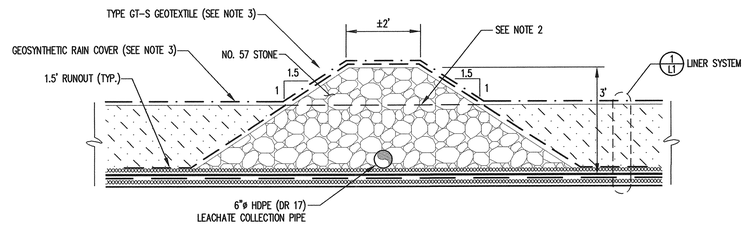
DETAIL 1 / LM1
NOT TO SCALE



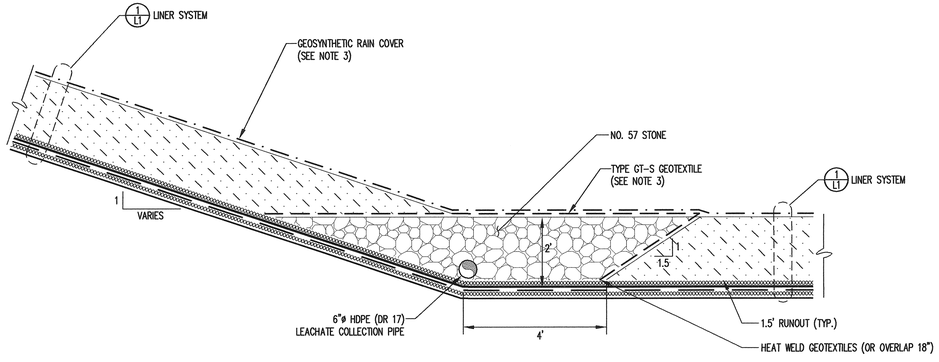

NOTES:
1. RISER PIPE TO BE CONSTRUCTED OF SAME PIPE MATERIAL AS LEACHATE COLLECTION PIPE EXCEPT THAT RISER PIPE IS SOLID WALL.
2. SOME LAYERS NOT SHOWN FOR CLARITY.
3. FORM CRADLE AT TOP OF 18" PIPE TO HOLD CLEANOUT RISER PIPE.

LEACHATE COLLECTION PIPE CLEANOUT AT CREST OF SLOPE

DETAIL 2 / LM1
NOT TO SCALE



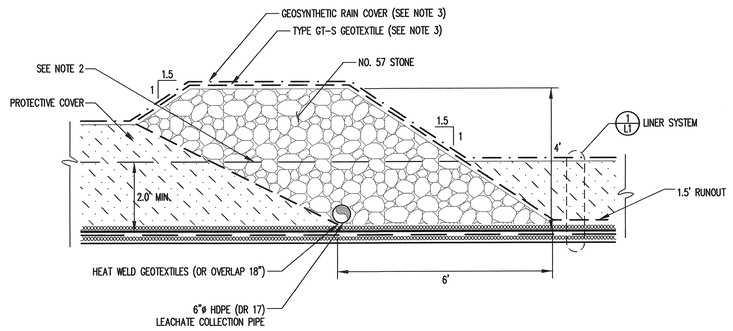

TYPE 2




TYPE 1

GRAVEL COLUMN CROSS SECTIONS

DETAIL 3 / LM1
NOT TO SCALE




TYPE 3

NOTES:
1. SOME LAYERS OF LINER SYSTEM AND LEAK DETECTION TRENCHES (WHERE APPLICABLE) NOT SHOWN FOR CLARITY.
2. AT THE LOW END OF TYPE 2 GRAVEL COLUMNS, LEAVE THE LAST 5 TO 10 FEET FLUSH WITH THE TOP OF PROTECTIVE COVER TO ALLOW STORMWATER TO FLOW TO THE LOW END OF THE CELL. AT THE LOW END OF TYPE 3 GRAVEL COLUMNS, LEAVE THE LAST 10 FEET FLUSH WITH THE TOP OF THE PROTECTIVE COVER TO ALLOW FOR RUNOFF OF STORMWATER.
3. OPERATIONS:
   PRIOR TO ACTIVATION OF AN AREA DRAINING TO A PARTICULAR GRAVEL COLUMN, OR PORTION THEREOF, THE OWNER SHALL REMOVE ALL GEOSYNTHETIC RAIN COVER FROM THE AREA TO BE ACTIVATED, INCLUDING FROM GRAVEL COLUMNS. SUBSEQUENTLY, THE EXPOSED TYPE GT-S GEOTEXTILE SHALL BE REMOVED PRIOR TO THE PLACEMENT OF WASTE OVER THAT PORTION OF THE GRAVEL COLUMN.

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

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NORTH CAROLINA SEAL 027608 REGISTERED PROFESSIONAL ENGINEER PIETER K. SWART
12/10/08

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

DRAWING TITLE:
LEACHATE MANAGEMENT
SYSTEM DETAILS
(SHEET 1 OF 2)

| DESIGNED BY: | DRAWN BY: |
|---|---|
| P.K.S. | C.T.J. |
| CHECKED BY: | PROJECT NO.: JOHN 07-2 |
| SCALE: AS SHOWN | DATE: JUNE 2007 |
| FILE NAME: JOHN-D0490A | |
| SHEET NO.: 9 | DRAWING NO.: LM1 |

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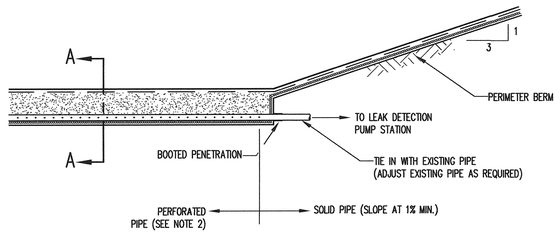
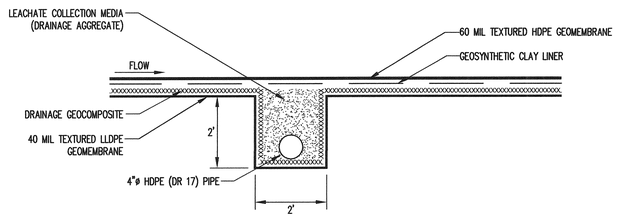



ELEVATION–DOWNSTREAM TERMINATION
SCALE: 1"= 4'




SECTION A–A
SCALE: 1"= 2'

NOTE:
1. LAYERS ABOVE UPPER GEOMEMBRANE ARE NOT SHOWN FOR CLARITY.
2. SEE DETAIL 1/LM1 FOR HDPE PIPE PERFORATIONS.

LEAK DETECTION TRENCH
DETAIL 1/LM2
NOT TO SCALE

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| DATE | NO. | REVISION |
|---|---|---|
| | | |

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PROFESSIONAL ENGINEER SEAL 021635 PIETER K. SCHAFER 12/4/08

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

DRAWING TITLE:
LEACHATE MANAGEMENT SYSTEM DETAILS (SHEET 2 OF 2)

| | |
|---|---|
| DESIGNED BY: P.K.S. | DRAWN BY: C.T.J. |
| CHECKED BY: | PROJECT NO.: JOHN 07-2 |
| SCALE: AS SHOWN | DATE: JUNE 2007 |
| FILE NAME JOHN-D0491 | |
| SHEET NO. 10 | DRAWING NO. LM2 |

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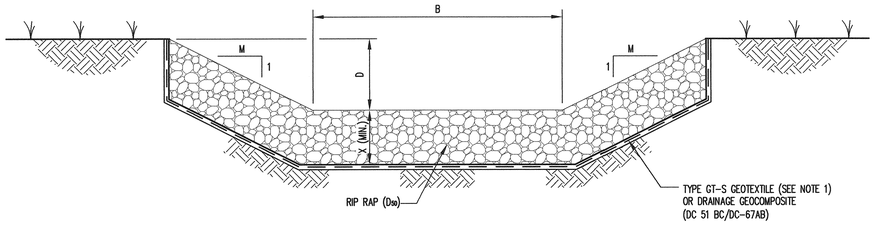
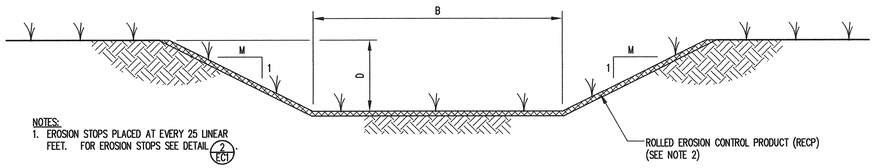



RIP RAP LINED CHANNELS




NOTES:
1. EROSION STOPS PLACED AT EVERY 25 LINEAR FEET. FOR EROSION STOPS SEE DETAIL 2/EC1.
2. FOR ANCHORAGE OF RECP, SEE DETAIL 1/EC7.

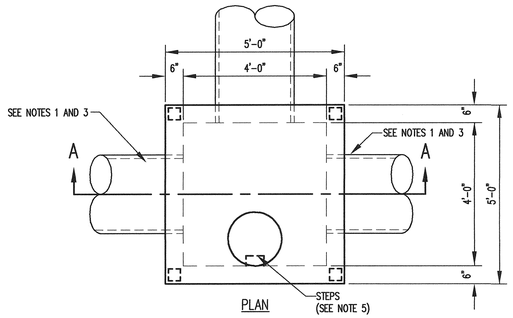
RECP LINED CHANNELS

DRAINAGE CHANNEL DETAILS

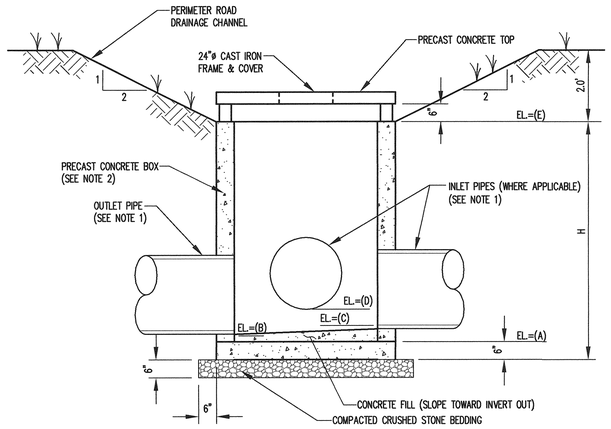
DETAIL 1/EC1 — NOT TO SCALE

| DRAINAGE CHANNEL SCHEDULE | | | | | | |
|---|---|---|---|---|---|---|
| DRAINAGE CHANNEL NO. | LINING | B (FEET) | D (FEET) | M | $D_{50}$ (INCHES) | X (FEET) |
| DC-21AB | TRM* | 4.0 | 2.0 | 3 | – | – |
| DC-21BC | RIP RAP | 6.0 | 2.0 | 3 | 12 | 2.0 |
| DC-41AB | TRM | 6.0 | 2.0 | 3 | – | – |
| DC-51AB | TRM | 7.0 | 2.0 | 3 | – | – |
| DC-51BC | RIP RAP | 7.0 | 2.0 | 3 | 12 | 2.0 |
| DC-64AB | TRM | 4.0 | 2.0 | 3 | – | – |
| DC-66AB | TRM | 6.0 | 2.0 | 3 | – | – |
| DC-67AB | RIP RAP | 7.0 | 2.0 | 3 | 12 | 2.0 |

*TRM – TURF REINFORCEMENT MATTING




PLAN



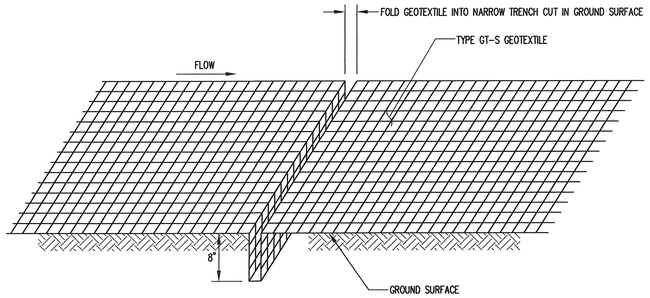

SECTION A-A

| DROP INLET SCHEDULE | | | | | | |
|---|---|---|---|---|---|---|
| DROP INLET | A (FEET) | B (FEET) | C (FEET) | D (FEET) | E (FEET) | H (FEET) |
| DI-51 | 151.5 | 152.0 | 154.0 | N/A | 157.0 | 6.0 |

DROP INLET DETAILS

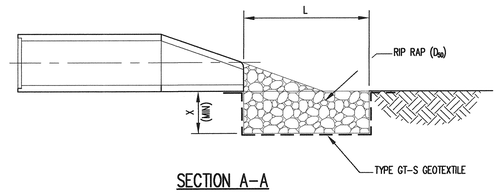
DETAIL 3/EC1 — NOT TO SCALE

NOTES:
1. PROVIDE WATERTIGHT JOINTS ON ALL PIPING.
2. PRECAST CONCRETE BOXES SHALL CONFORM TO THE FOLLOWING REQUIREMENTS:
   A. CONCRETE: COMPRESSIVE STRENGTH 4000 PSI
   B. REINFORCING: ASTM A-615, GRADE 60
   C. MEETS H-20 LOADING.
3. PIPES MAY BE ORIENTED DIFFERENTLY WITH RESPECT TO THE THE CHANNEL THAN DISPLAYED HERE. SEE DRAWING EC1 FOR PROPER ORIENTATION.
4. THE CONTRACTOR SHALL PROVIDE ADEQUATE PROTECTION FROM SEDIMENTATION FOR ALL DROP INLETS USING GRAVEL AND WIRE MESH FILTERS OR OTHER METHOD AS APPROVED BY THE ENGINEER.
5. PROVIDE STEPS FOR DROP INLETS WITH H>4.5'. STEPS SHALL HAVE A 16" SPACING THE FULL HEIGHT OF THE DROP INLET. START FIRST STEP 6" BELOW TOP.



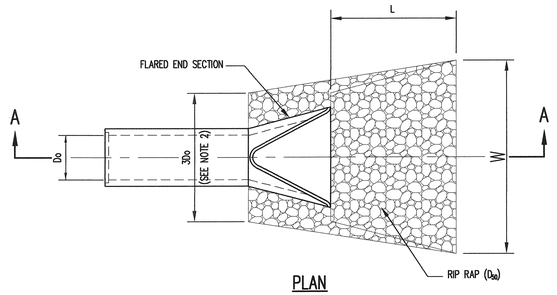

EROSION STOP DETAIL

DETAIL 2/EC1 — NOT TO SCALE




SECTION A-A

| RIP RAP OUTLET PROTECTION SCHEDULE | | | | | |
|---|---|---|---|---|---|
| PIPE | $D_o$ | L | W | X | $D_{50}$ |
| C-41 | 18" | 10' | 10' | 12" | 6" |

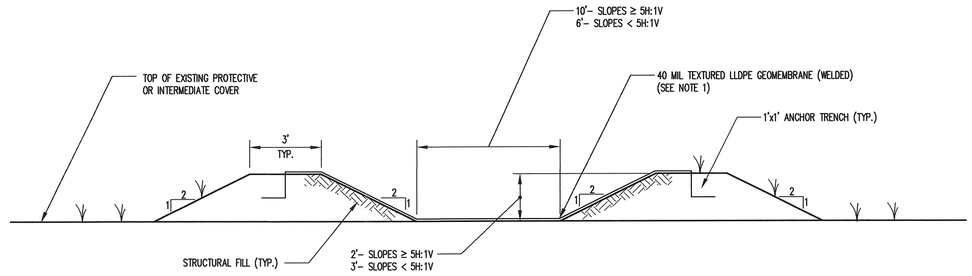



PLAN

NOTES:
1. $D_{50}$ REFERS TO THE MINIMUM REQUIRED AVERAGE STONE SIZE.
2. FOR MORE THAN ONE PIPE, EXTEND RIP RAP 1.0' MIN. BEYOND OUTSIDE EDGES OF PIPES.

RIP RAP OUTLET PROTECTION (OUTLET TO FLAT AREA)

DETAIL 4/EC1 — NOT TO SCALE




TEMPORARY DOWN CHUTE

DETAIL 5/EC1 — NOT TO SCALE

NOTES:
1. EXTEND LLDPE GEOMEMBRANE UNDER GEOSYNTHETIC RAIN COVER (GRC) PAST LOCATION OF GRAVEL COLUMN. ATTATCH GRC TO LLDPE GEOMEMBRANE USING METHOD APPROVED BY THE ENGINEER.
2. TERMINATE DOWN CHUTE INTO EXISTING RIP RAP LINED DRAINAGE CHANNEL. TUCK GEOMEMBRANE UNDER EDGE OF RIP RAP.

| NO. | DATE | REVISION |
|---|---|---|
| 1 | 11/08 | RESPONSE TO NCDENR COMMENTS AND ADDITIONAL CHANGES |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PROJECT TITLE:
JOHNSTON COUNTY MSW LANDFILL
PHASE 4A - CELL 3
PERMIT AMENDMENT DRAWINGS

DRAWING TITLE:
EROSION AND SEDIMENTATION DETAILS
(SHEET 1 OF 2)

| DESIGNED BY: | DRAWN BY: |
|---|---|
| P.K.S. | C.T.J. |
| CHECKED BY: | PROJECT NO.: JOHN 07-2 |
| SCALE: AS SHOWN | DATE: JUNE 2007 |
| FILE NAME: JOHN-D0482A | |
| SHEET NO.: 11 | DRAWING NO.: EC1 |

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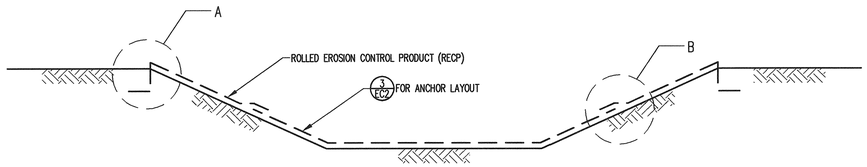
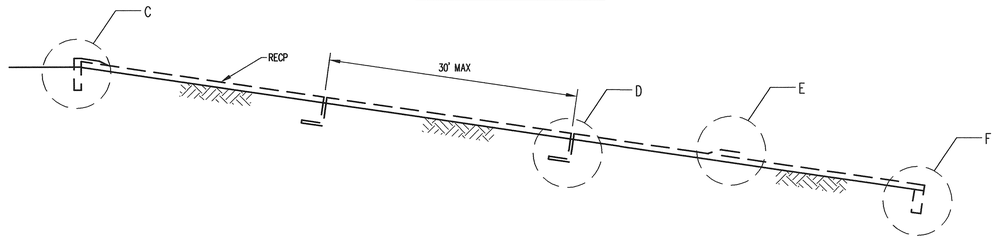
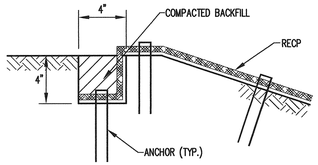


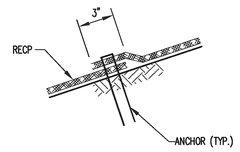

TYPICAL CHANNEL CROSS SECTION



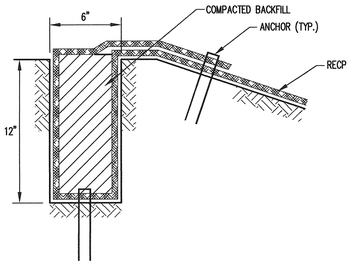

TYPICAL CHANNEL PROFILE



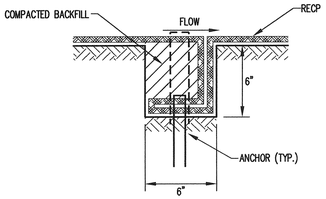

A. LONGITUDINAL ANCHOR TRENCH



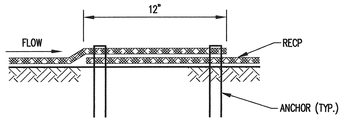

B. OVERLAP AT ADJACENT EDGES



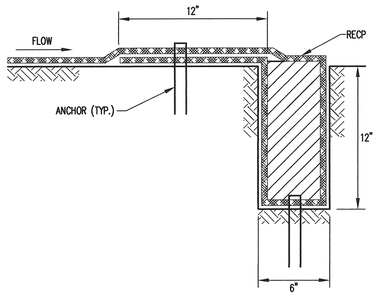

C. UPSTREAM TERMINAL ANCHOR TRENCH




D. INTERMITTENT CHECK SLOT




E. OVERLAP AT ROLL ENDS




F. DOWNSTREAM TERMINAL ANCHOR TRENCH

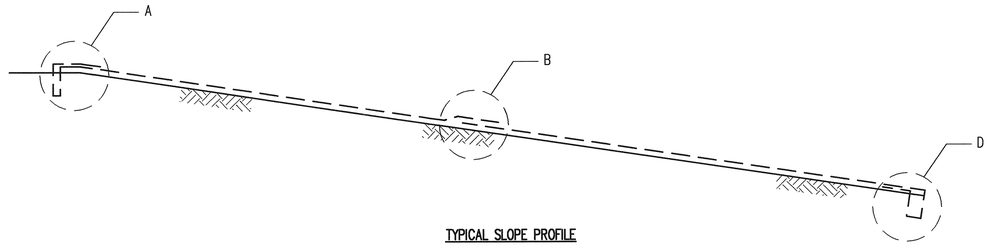
NOTES:

1. PLACE ANCHORS AT ANCHOR TRENCHES, OVERLAPS, AND CHECK SLOTS ON 1 FOOT CENTERS. IF APPLICABLE, STAGGER ANCHOR SPACING BETWEEN MULTIPLE ROWS OF ANCHORS.

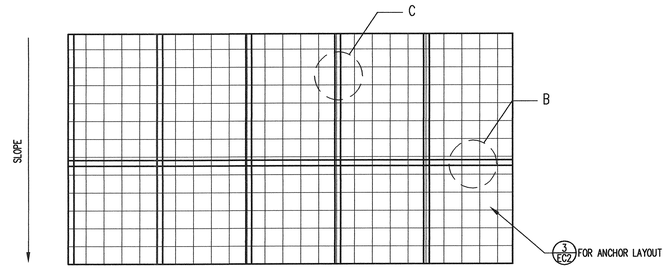
INSTALLATION OF ROLLED EROSION CONTROL PRODUCTS (CHANNELS)

DETAIL 1 / EC2 — NOT TO SCALE

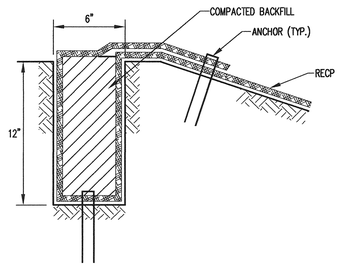
| ANCHOR SPACING SCHEDULE | |
|---|---|
| LOCATION | REQUIRED ANCHOR SPACING (ANCHORS/YD²) |
| ALL CHANNELS | 2.5 |
| 1.5H:1V SLOPES | 2.0 |
| 2H:1V SLOPES | 2.0 |
| 2.5H:1V SLOPES | 1.5 |
| 3H:1V SLOPES | 1.5 |
| 3.5H:1V SLOPES | 1.0 |
| 4H:1V SLOPES | 1.0 |



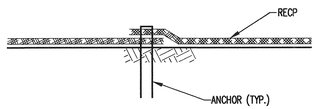

TYPICAL SLOPE PROFILE



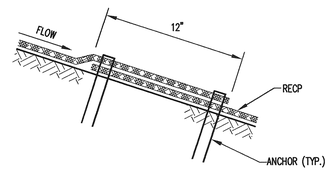

TYPICAL SLOPE PLAN VIEW



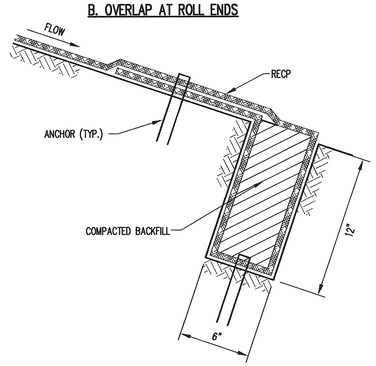

A. UPSLOPE TERMINAL ANCHOR TRENCH




C. OVERLAP AT ADJACENT EDGES




B. OVERLAP AT ROLL ENDS



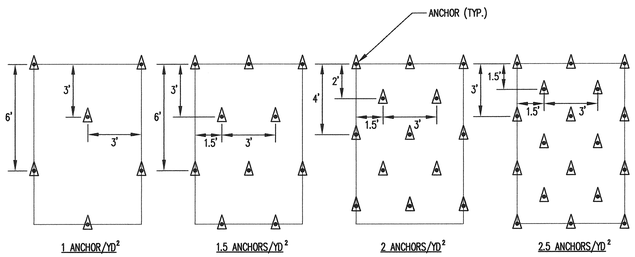

D. DOWNSLOPE TERMINAL ANCHOR TRENCH

NOTE:

1. PLACE ANCHORS AT ANCHOR TRENCHES, OVERLAPS, AND CHECK SLOTS ON 1 FOOT CENTERS. IF APPLICABLE, STAGGER ANCHOR SPACING BETWEEN MULTIPLE ROWS OF ANCHORS.

INSTALLATION OF ROLLED EROSION CONTROL PRODUCTS (SLOPES)

DETAIL 2 / EC2 — NOT TO SCALE




ANCHOR LAYOUT

DETAIL 3 / EC2 — NOT TO SCALE

REVISION | NO. | DATE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PROJECT TITLE: JOHNSTON COUNTY MSW LANDFILL
PHASE 4A - CELL 3
PERMIT AMENDMENT DRAWINGS

DRAWING TITLE: EROSION AND SEDIMENTATION DETAILS (SHEET 2 OF 2)

| DESIGNED BY: P.K.S. | DRAWN BY: C.T.J. |
|---|---|
| CHECKED BY: | PROJECT NO.: JOHN 07-2 |
| SCALE: AS SHOWN | DATE: JUNE 2007 |
| FILE NAME: JOHN-D0493 | |
| SHEET NO.: 12 | DRAWING NO.: EC2 |

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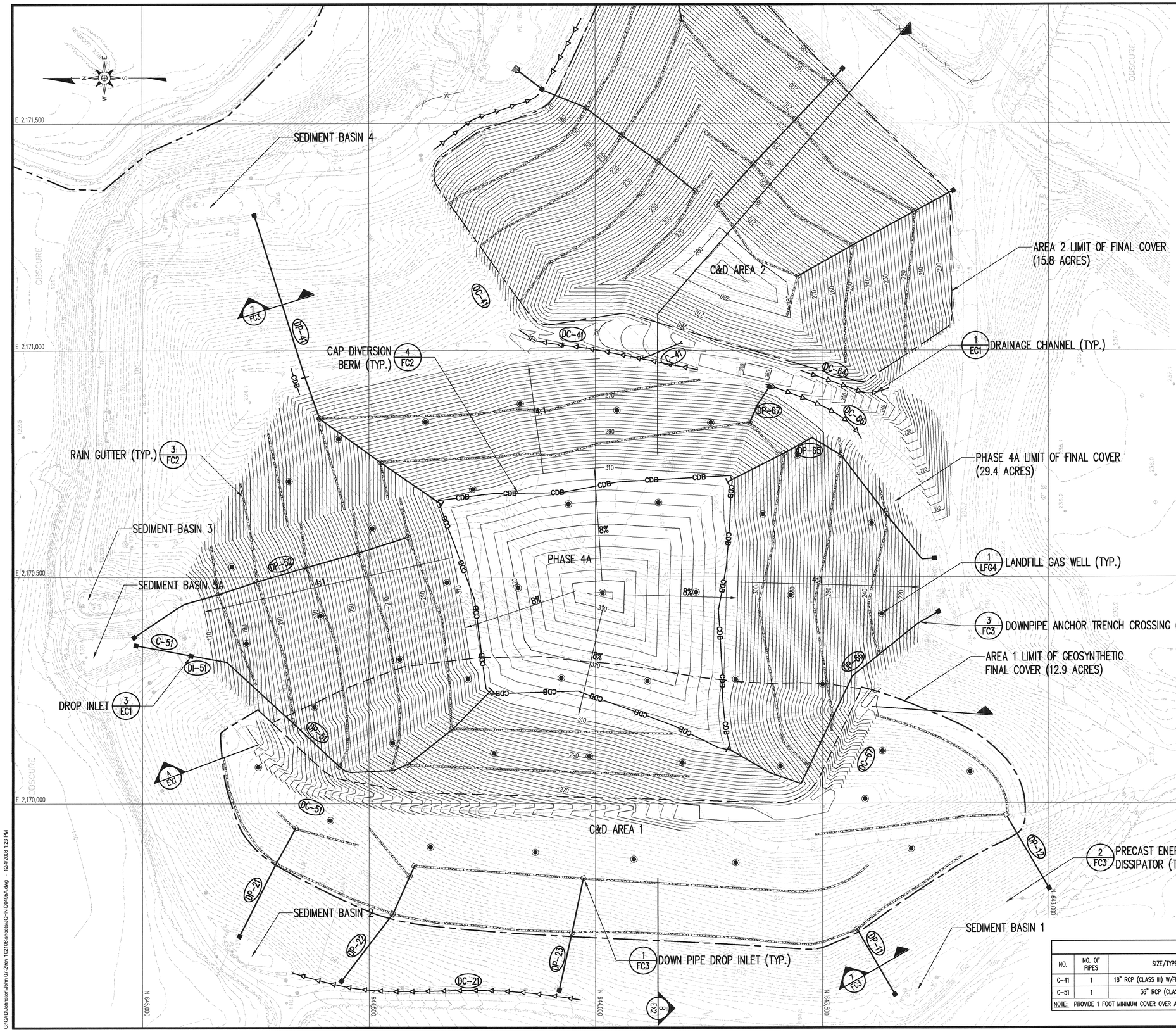


| RAIN GUTTERS & DOWN PIPES SCHEDULE | |
|---|---|
| **RAIN GUTTERS** | |
| PIPE DIAMETER (INCHES) | MAX DRAINAGE AREA (ACRES) |
| 6 | 0.32 |
| 8 | 0.67 |
| 10 | 1.18 |
| 12 | 1.89 |
| **DOWN PIPE DROP INLETS** | |
| PIPE DIAMETER (INCHES) | MAX DRAINAGE AREA (ACRES) |
| 8 | 0.52 |
| 10 | 0.80 |
| 12 | 1.14 |
| 14 | 1.37 |
| 16 | 1.80 |
| 18 | 2.27 |
| **DOWN PIPES** | |
| PIPE DIAMETER (INCHES) | MAX DRAINAGE AREA (ACRES) |
| 8 | 1.02 |
| 10 | 1.80 |
| 12 | 2.88 |
| 14 | 3.65 |
| 16 | 5.27 |
| 18 | 7.15 |

**LEGEND**

- EXISTING 10' CONTOUR (SEE REFERENCE 1)
- EXISTING 2' CONTOUR
- APPROXIMATE PROPERTY LINE
- LIMITS OF FINAL COVER
- PROPOSED 10' CONTOUR (SEE NOTE 1)
- PROPOSED 2' CONTOUR
- DRAINAGE CHANNEL
- DIVERSION BERM
- SILT FENCE
- CULVERT/DROP INLET
- CDB — CAP DIVERSION BERM
- DP-3 — DOWN PIPE
- DC-1 — DRAINAGE CHANNEL
- C-1 — CULVERT NUMBER
- DI-1 — DROP INLET NUMBER
- DOWN PIPE DROP INLET
- PRECAST ENERGY DISSIPATOR
- RAIN GUTTER
- DOWN PIPE WITH TEE INLET
- LANDFILL GAS WELL

**NOTES**

1. GRADES SHOWN FOR PHASE 4A AND AREA 2 REPRESENT TOP OF FINAL COVER. GRADES SHOWN FOR AREA 1 REPRESENT TOP OF INTERMEDIATE COVER.

**REFERENCES**

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

0 100' 200' 300'

| CULVERT SCHEDULE | | | | | | |
|---|---|---|---|---|---|---|
| NO. | NO. OF PIPES | SIZE/TYPE | LENGTH (FEET) | SLOPE (%) | INV. IN (FEET) | INV. OUT (FEET) | REMARKS |
| C-41 | 1 | 18" RCP (CLASS III) W/FES (BOTH ENDS) | 84 | 2.4 | 253.0 | 251.0 | – |
| C-51 | 1 | 36" RCP (CLASS III) | 120 | 10.0 | 152.0 | 140.0 | INLET IN DI-51 |

NOTE: PROVIDE 1 FOOT MINIMUM COVER OVER ALL CULVERTS UNLESS OTHERWISE APPROVED BT THE ENGINEER.

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


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SEAL

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

DRAWING TITLE:
PHASE 4A FINAL COVER
GRADING AND DRAINAGE PLAN

| DESIGNED BY: | DRAWN BY: |
|---|---|
| P.K.S. | J.A.L. |
| CHECKED BY: | PROJECT NO.: JOHN 07-2 |
| SCALE: AS SHOWN | DATE: JUNE 2007 |
| FILE NAME: JOHN-D0495A | |
| SHEET NO.: 13 | DRAWING NO.: FC1 |

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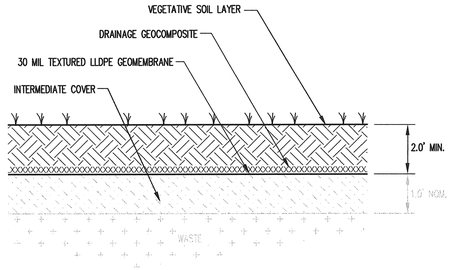
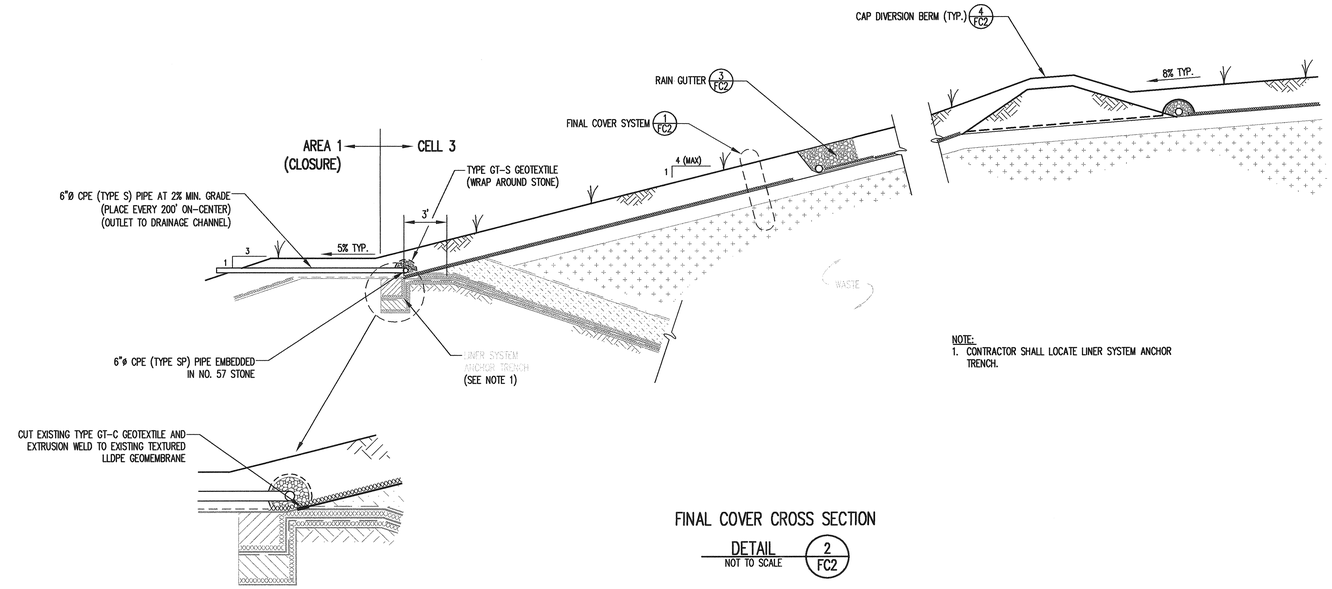



FINAL COVER

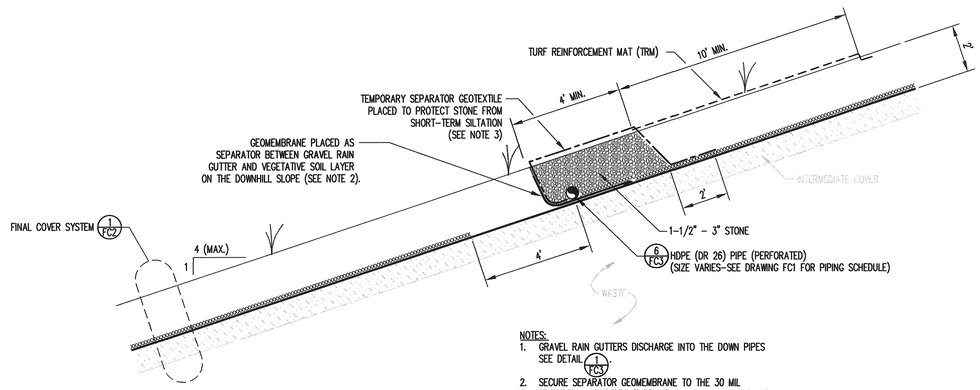
DETAIL 1/FC2
NOT TO SCALE




NOTE:
1. CONTRACTOR SHALL LOCATE LINER SYSTEM ANCHOR TRENCH.

FINAL COVER CROSS SECTION

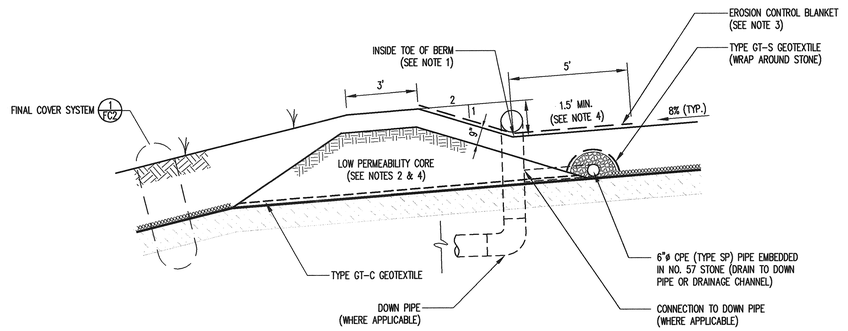
DETAIL 2/FC2
NOT TO SCALE




NOTES:
1. GRAVEL RAIN GUTTERS DISCHARGE INTO THE DOWN PIPES SEE DETAIL 1/FC3.
2. SECURE SEPARATOR GEOMEMBRANE TO THE 30 MIL TEXTURED LLDPE GEOMEMBRANE BY EXTRUSION WELD, OR WITH TAPECOAT 9-25 (2"), OR EQUAL.
2. 4 OZ./ SY NON-WOVEN GEOTEXTILE SHALL BE USED.

RAIN GUTTER

DETAIL 3/FC2
NOT TO SCALE




NOTES:
1. GRADE INSIDE TOE OF BERM TOWARD DOWN CHUTE OR DOWN PIPE AT 0.5% MIN. SLOPE.
2. CONSTRUCT CORE FROM TYPE CH, CL, MH, ML, SC, OR SM MATERIALS (USCS CLASSIFICATION).
3. ANCHOR OF EROSION CONTROL BLANKET, ACCORDING TO THE MANUFACTURER'S RECOMMENDATIONS.
4. TAPER BERM HEIGHT UP TO 3' AT DOWN PIPE LOCATION.

CAP DIVERSION BERM

DETAIL 4/FC2
NOT TO SCALE

| DATE | NO. | REVISION |
|---|---|---|
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PROJECT TITLE:
JOHNSTON COUNTY MSW LANDFILL
PHASE 4A - CELL 3
PERMIT AMENDMENT DRAWINGS

DRAWING TITLE:
FINAL COVER DETAILS
(SHEET 1 OF 2)

| | |
|---|---|
| DESIGNED BY: P.K.S. | DRAWN BY: C.T.J. |
| CHECKED BY: | PROJECT NO.: JOHN 07-2 |
| SCALE: AS SHOWN | DATE: JUNE 2007 |
| FILE NAME: JOHN-D0496A | |
| SHEET NO. 14 | DRAWING NO. FC2 |

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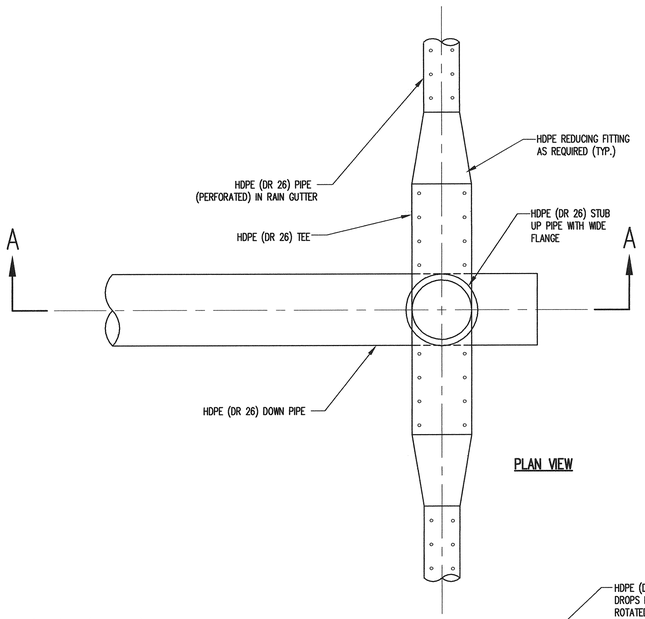
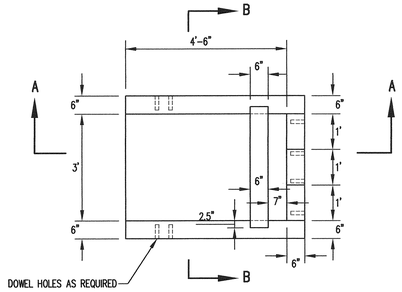
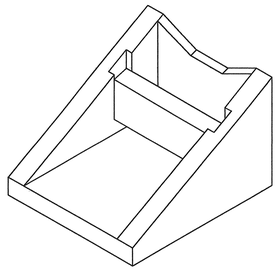


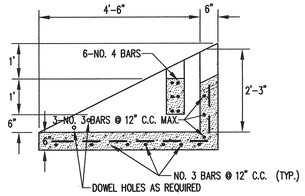

PLAN VIEW



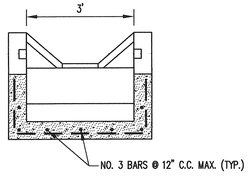

PLAN VIEW



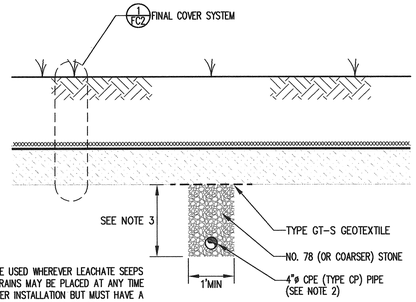
ISOMETRIC VIEW




SECTION A–A




SECTION B–B




NOTES:
1. THIS DETAIL IS TO BE USED WHEREVER LEACHATE SEEPS ARE A PROBLEM. DRAINS MAY BE PLACED AT ANY TIME PRIOR TO FINAL COVER INSTALLATION BUT MUST HAVE A MINIMUM OF 12" OF INTERMEDIATE COVER SOIL.
2. CONNECT CPE PIPE TO A LEACHATE COLLECTION PIPE CLEANOUT OR TURN DOWN INTO THE LEACHATE COLLECTION SYSTEM STONE TO DRAIN SEEP COLLECTION TRENCH.
3. DEPTH OF TRENCH IS AS REQUIRED TO DRAIN SEEP(S).

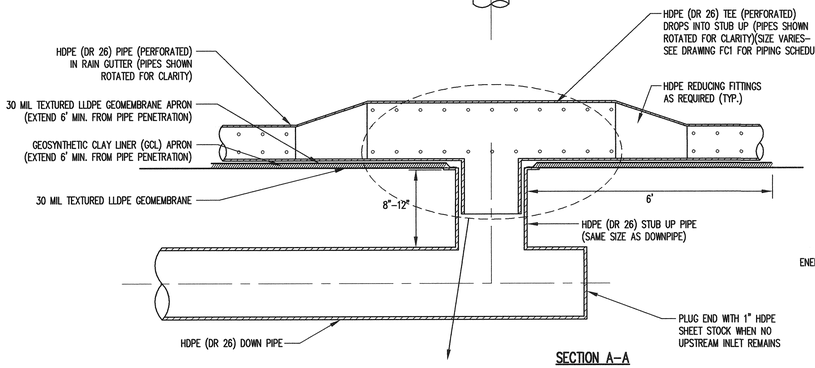
SEEP COLLECTION TRENCH

DETAIL NOT TO SCALE 5/FC3

PRECAST ENERGY DISSIPATOR

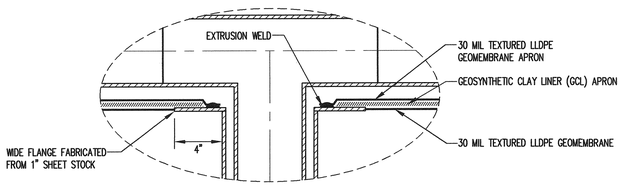
DETAIL NOT TO SCALE 2/FC3

NOTES:
1. CONCRETE STRENGTH 4000 PSI MINIMUM.
2. REINFORCING STEEL SHALL CONFORM TO ASTM A-615, GRADE 40.
3. DIMENSIONS SHOWN FOR CONCRETE THICKNESS ARE MINIMUMS. ACTUAL MEASUREMENTS MAY VARY WITH MANUFACTURER'S TOLERANCES.




SECTION A–A

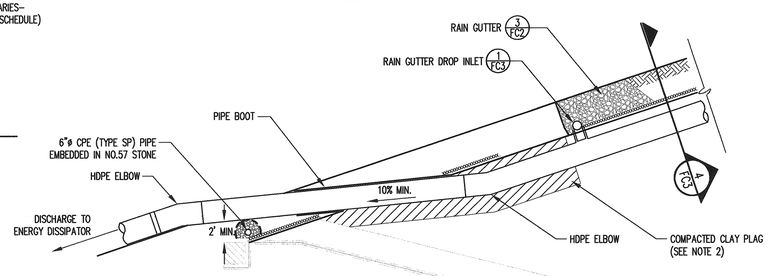
SEE DETAIL




DETAIL

RAIN GUTTER DROP INLET

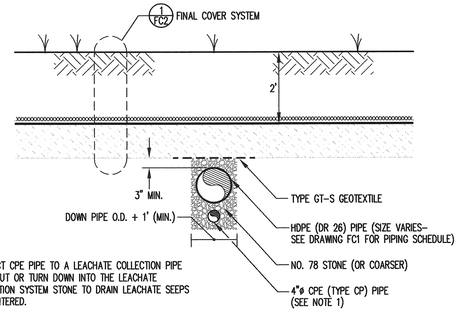
DETAIL NOT TO SCALE 1/FC3




NOTES:
1. SEE SCHEDULE ON DRAWING FC1 FOR PIPE SIZES.
2. PLACE COMPACTED CLAY PLUG ALONG LAST 20 FEET OF PIPE AND APPROXIMATELY 12 INCH THICKNESS AROUND PIPE.

DOWN PIPE AT ANCHOR TRENCH CROSSING

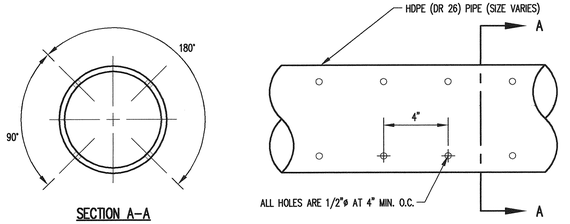
DETAIL NOT TO SCALE 3/FC3




NOTE:
1. CONNECT CPE PIPE TO A LEACHATE COLLECTION PIPE CLEANOUT OR TURN DOWN INTO THE LEACHATE COLLECTION SYSTEM STONE TO DRAIN LEACHATE SEEPS ENCOUNTERED.

TYPICAL DOWN PIPE SECTION

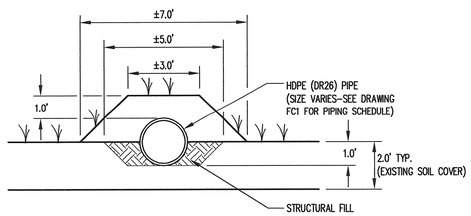
DETAIL NOT TO SCALE 4/FC3




SECTION A–A

RAIN GUTTER PIPE PERFORATIONS

DETAIL NOT TO SCALE 6/FC3




TYPICAL DOWN PIPE SECTION (SOIL-ONLY FINAL COVER)

DETAIL NOT TO SCALE 7/FC3

| NO. | DATE | REVISION |
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SEAL

SEAL 021695 REGISTERED PROFESSIONAL ENGINEER PETER K. SMITH 12/4/08

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

DRAWING TITLE:
FINAL COVER DETAILS
(SHEET 2 OF 2)

| DESIGNED BY: | DRAWN BY: |
|---|---|
| P.K.S. | J.A.L. |
| CHECKED BY: | PROJECT NO.: |
| | JOHN 07-2 |
| SCALE: | DATE: |
| AS SHOWN | JUNE 2007 |
| FILE NAME | |
| JOHN-D0497A | |
| SHEET NO. | DRAWING NO. |
| 15 | FC3 |

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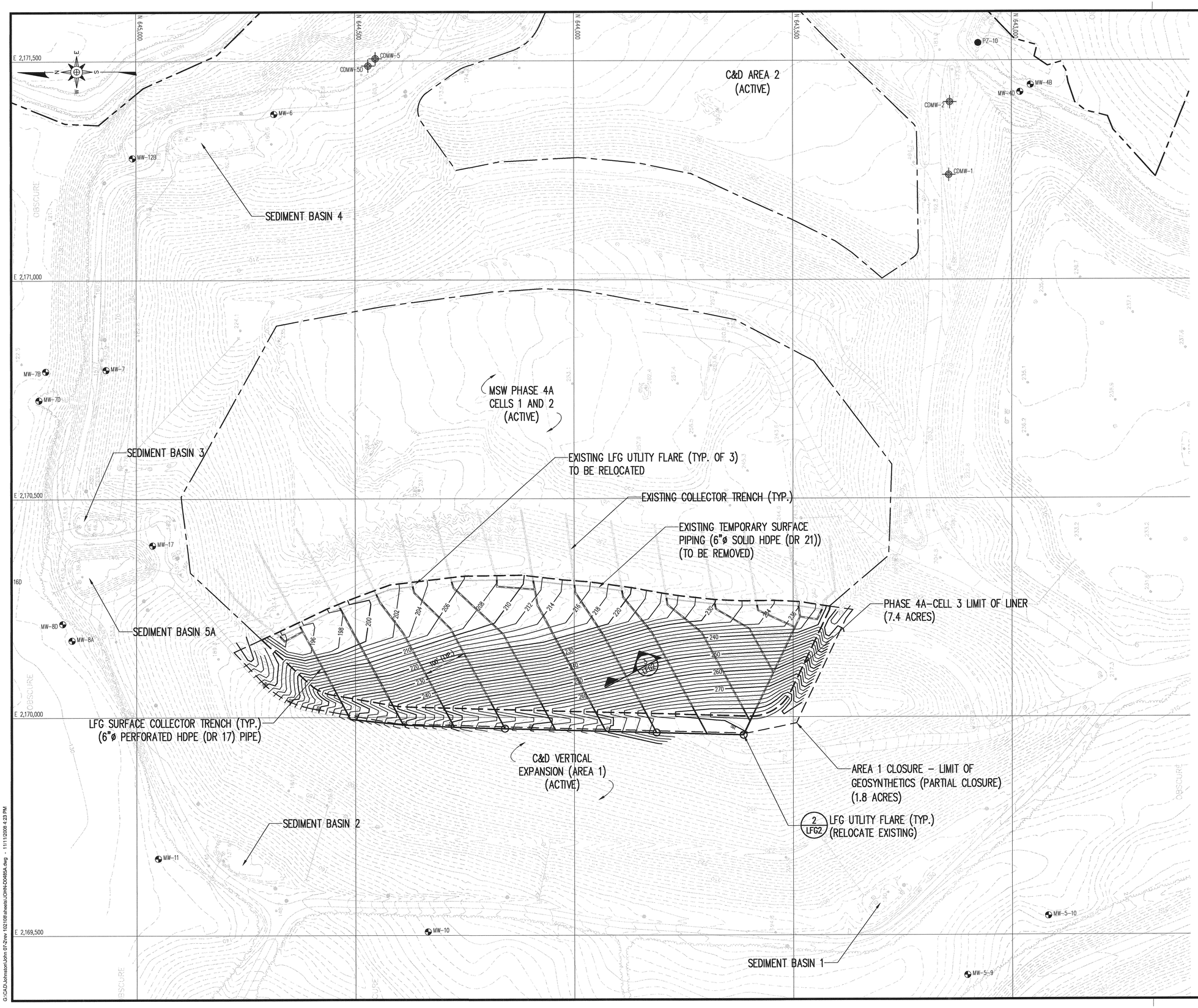


| NO. | REVISION | DATE |
|---|---|---|
| 1 | RESPONSE TO NCDENR COMMENTS AND ADDITIONAL CHANGES | 11/08 |


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

DRAWING TITLE:
CELL 3 LANDFILL GAS
MANAGEMENT SYSTEM

| | |
|---|---|
| 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-D0485A | |
| SHEET NO.: 16 | DRAWING NO.: LFG1 |

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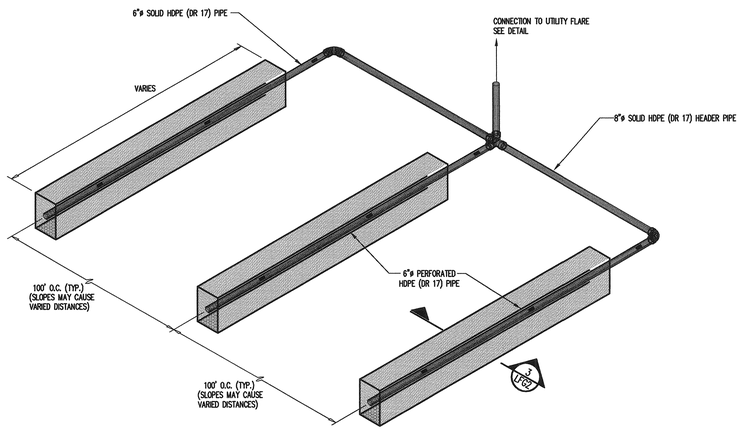
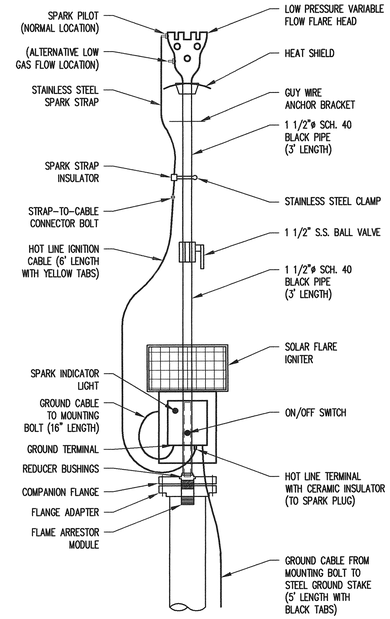


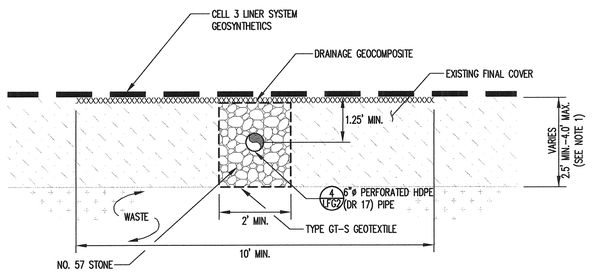

GAS COLLECTION NETWORK

DETAIL 1 LFG2
NOT TO SCALE




LFG UTILITY FLARE

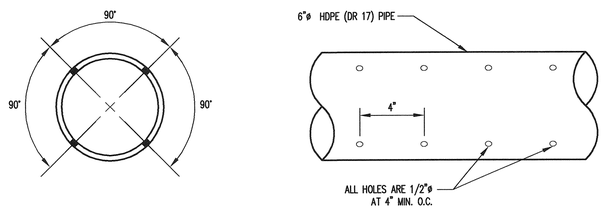
DETAIL 2 LFG2
NOT TO SCALE




NOTE:
1. EXCAVATE TRENCH SUCH THAT EXISTING COVER IS BREACHED OR TO A MAXIMUM DEPTH OF 4 FEET.

LFG SURFACE COLLECTOR TRENCH CROSS SECTION

DETAIL 3 LFG2
NOT TO SCALE




LANDFILL GAS PIPING

HDPE PIPE PERFORATIONS – LFG

DETAIL 4 LFG2
NOT TO SCALE

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| 11/08 | 1 | RESPONSE TO NCDENR COMMENTS AND ADDITIONAL CHANGES |

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PROFESSIONAL ENGINEER SEAL 021665 PIETER K. SCHEER 12/4/08

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

DRAWING TITLE:
LANDFILL GAS MANAGEMENT DETAILS
(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-D0498A | |
| SHEET NO. 17 | DRAWING NO. LFG2 |

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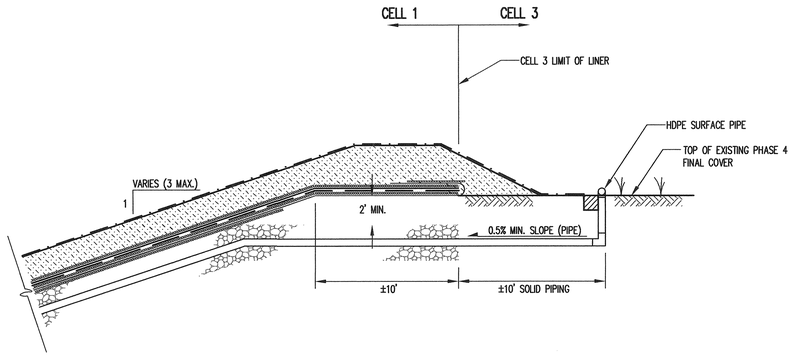
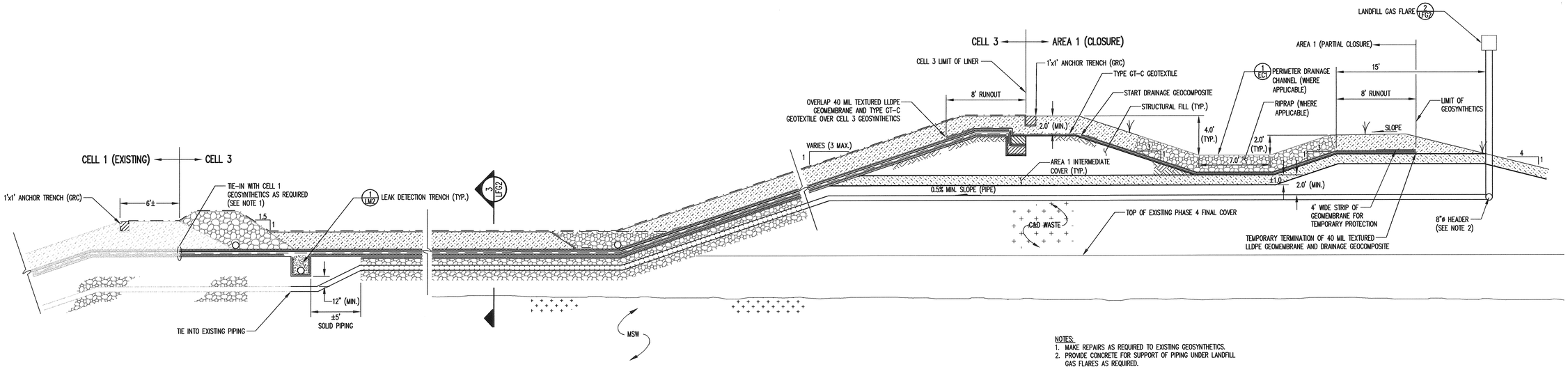



TYPICAL EXISTING LFG PIPING

DETAIL 1 LFG3
NOT TO SCALE




NOTES:
1. MAKE REPAIRS AS REQUIRED TO EXISTING GEOSYNTHETICS.
2. PROVIDE CONCRETE FOR SUPPORT OF PIPING UNDER LANDFILL GAS FLARES AS REQUIRED.

LFG PIPING CROSS SECTION

DETAIL 2 LFG3
NOT TO SCALE

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

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

DRAWING TITLE:
LANDFILL GAS MANAGEMENT DETAILS
(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-D0499A | |
| SHEET NO. 18 | DRAWING NO. LFG3 |

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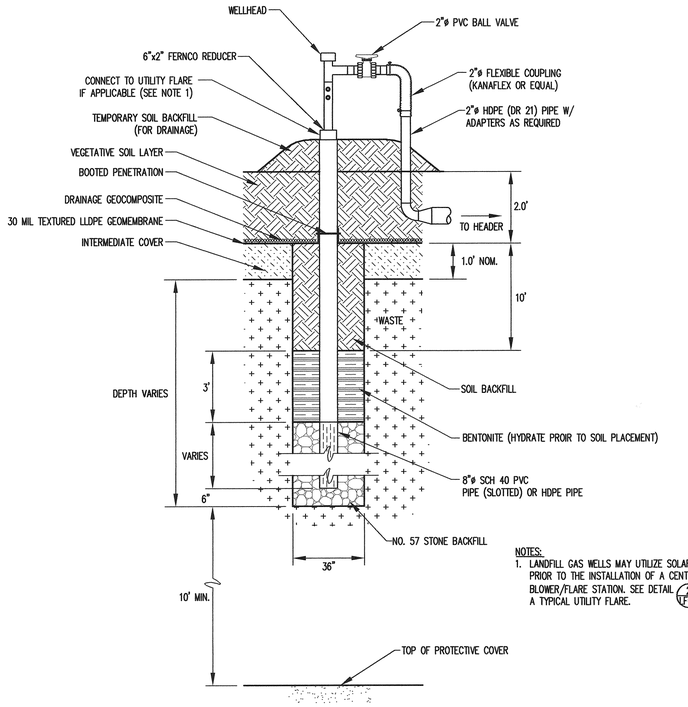
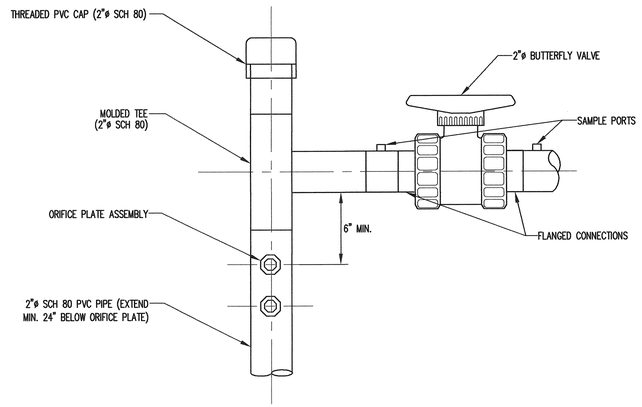



NOTES:
1. LANDFILL GAS WELLS MAY UTILIZE SOLAR FLARES PRIOR TO THE INSTALLATION OF A CENTRAL BLOWER/FLARE STATION. SEE DETAIL 2/LFG2 FOR A TYPICAL UTILITY FLARE.

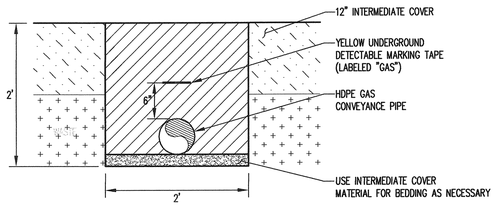
TYPICAL LANDFILL GAS WELL

DETAIL 1/LFG4
NOT TO SCALE




TYPICAL WELLHEAD

DETAIL 2/LFG4
NOT TO SCALE




GAS CONVEYANCE PIPE TRENCH

DETAIL 3/LFG4
NOT TO SCALE

| DATE | NO. | REVISION |
|---|---|---|
| | | |

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

DRAWING TITLE:
LANDFILL GAS MANAGEMENT DETAILS
(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-D0500 | |
| SHEET NO. 19 | DRAWING NO. LFG4 |

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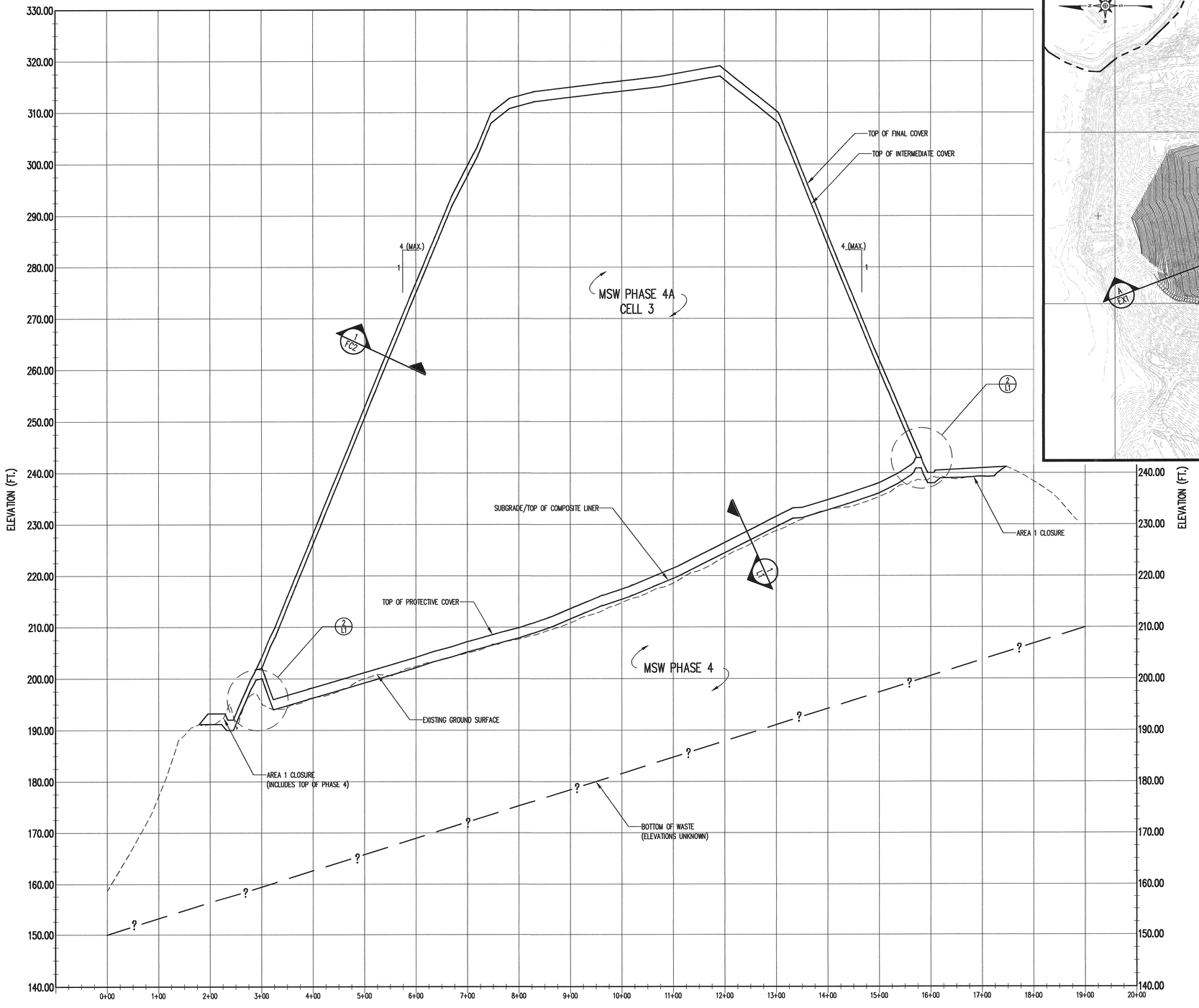
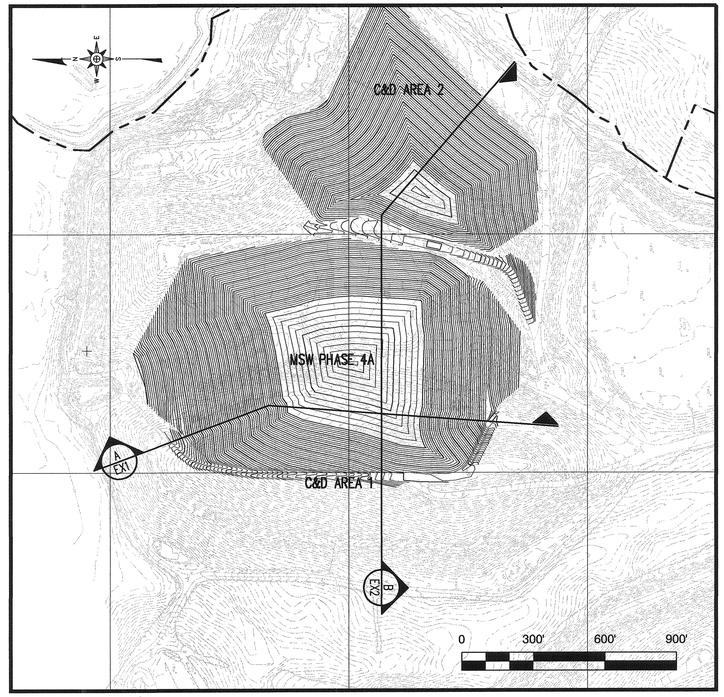



SECTION A

SECTION A / EX1
NOT TO SCALE




## LEGEND

| | |
|---|---|
| 200 | EXISTING 10' CONTOUR |
| | EXISTING 2' CONTOUR |
| 150 | PROPOSED 10' CONTOUR |
| | PROPOSED 2' CONTOUR |
| | PROPERTY LINE |

## REFERENCES

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

30'
20'
10'
0

0 100' 200' 300'

| DATE | NO. | REVISION |
|---|---|---|
| 11/08 | 1 | RESPONSE TO NCDENR COMMENTS AND ADDITIONAL CHANGES |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PROFESSIONAL ENGINEER SEAL 021668 PIETER K. SCHEER 12/4/08

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

DRAWING TITLE:
ENGINEERING CROSS SECTIONS
(SHEET 1 OF 2)

| | |
|---|---|
| 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-D0501A | |
| SHEET NO. 20 | DRAWING NO. EX1 |

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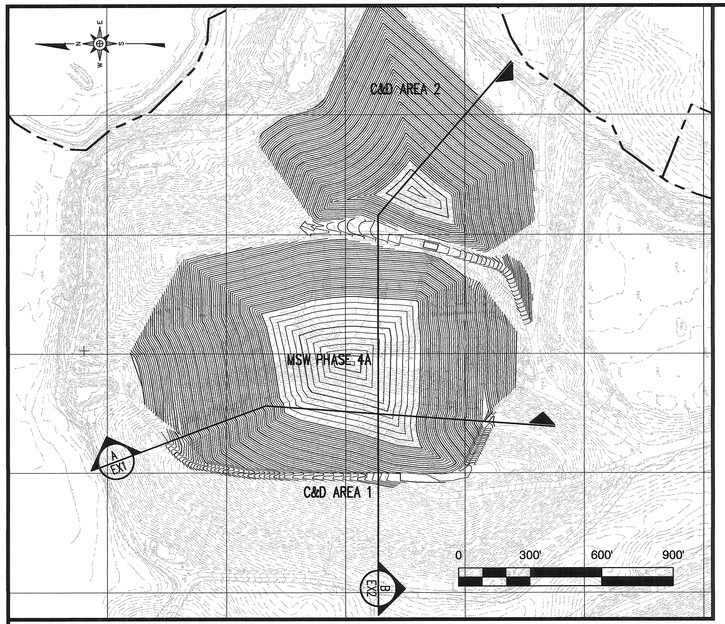


SECTION B

SECTION B / EX2
NOT TO SCALE

LEGEND

- 200 — EXISTING 10' CONTOUR
- EXISTING 2' CONTOUR
- 150 — PROPOSED 10' CONTOUR
- PROPOSED 2' CONTOUR
- PROPERTY LINE

NOTES

1. EXISTING FINAL COVER SYSTEM AT TOP OF PHASE 3 CONSISTS OF 18" MIN. VEGETATIVE SOIL LAYER OVER DRAINAGE GEOCOMPOSITE AND GCL.

REFERENCES

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

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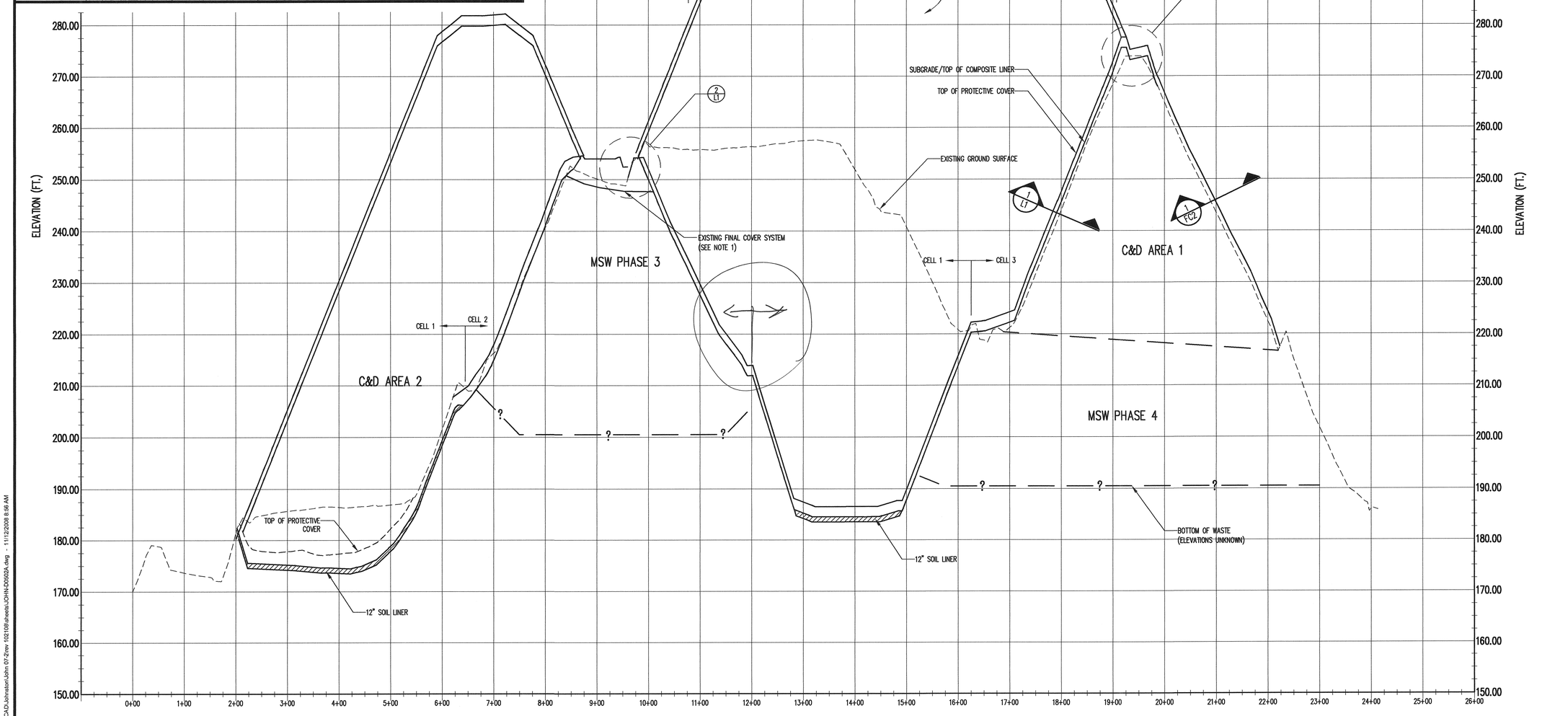


| NO. | DATE | REVISION |
|---|---|---|
| 1 | 11/08 | RESPONSE TO NCDENR COMMENTS AND ADDITIONAL CHANGES |


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

DRAWING TITLE:
ENGINEERING CROSS SECTIONS
(SHEET 2 OF 2)

| DESIGNED BY: | DRAWN BY: |
|---|---|
| P.K.S. | J.A.L. |
| CHECKED BY: | PROJECT NO.: |
| | JOHN 07-2 |
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| AS SHOWN | JUNE 2007 |
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| JOHN-D0502A | |
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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

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



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.

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SEAL 021008 ENGINEER PIETER K. SMITH 12/4/08

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

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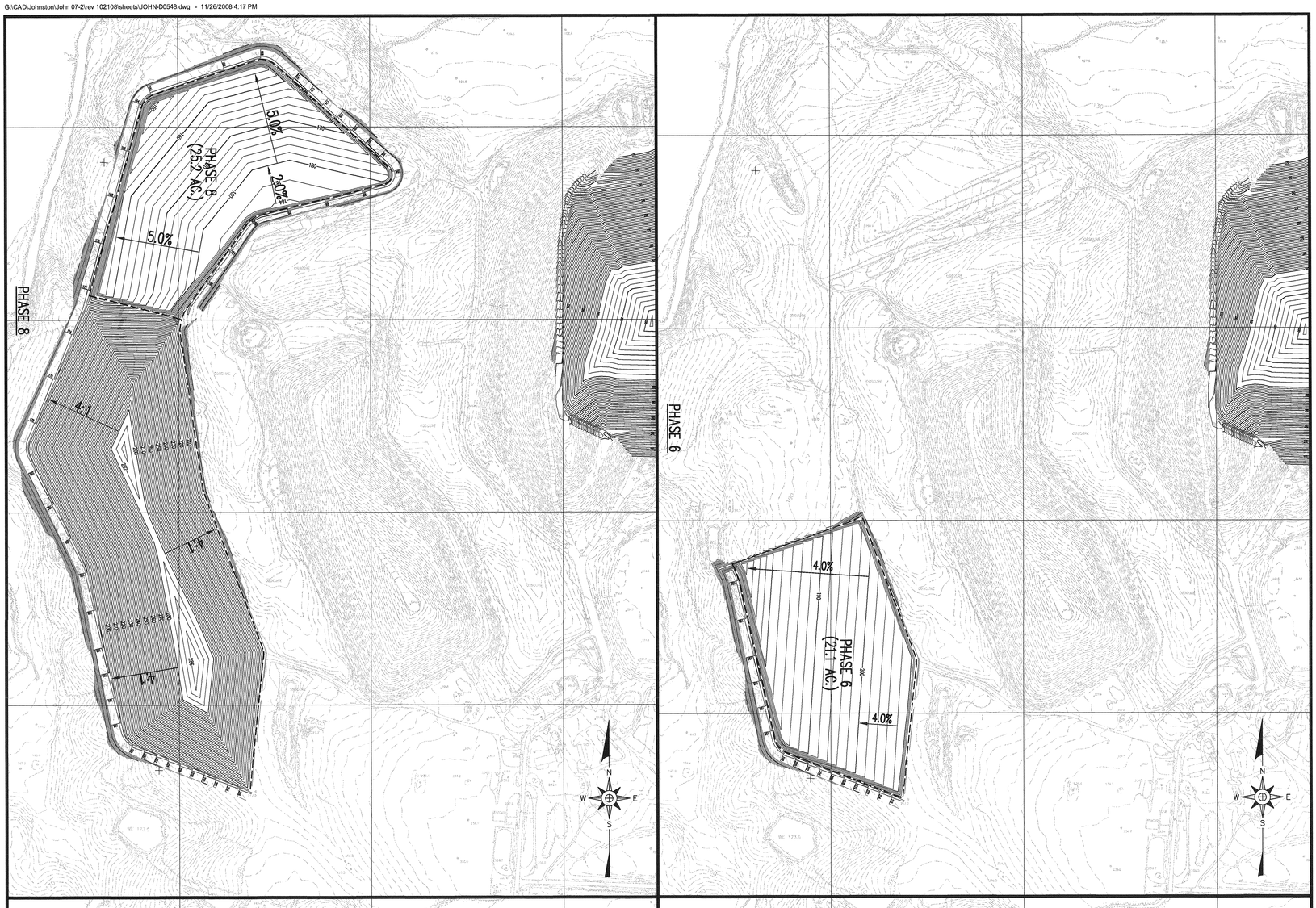

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REFERENCES
1. TOPOGRAPHY IN LANDFILL AREA PROVIDED BY RICHARDSON SMITH GARDNER & ASSOCIATES, 2008. AERIAL PHOTOGRAPHY, TOPOGRAPHY IN OTHER AREAS PROVIDED BY GEODATA CORPORATION BASED ON JUNE 2, 2005 AERIAL PHOTOGRAPHY.

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

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

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12/4/08

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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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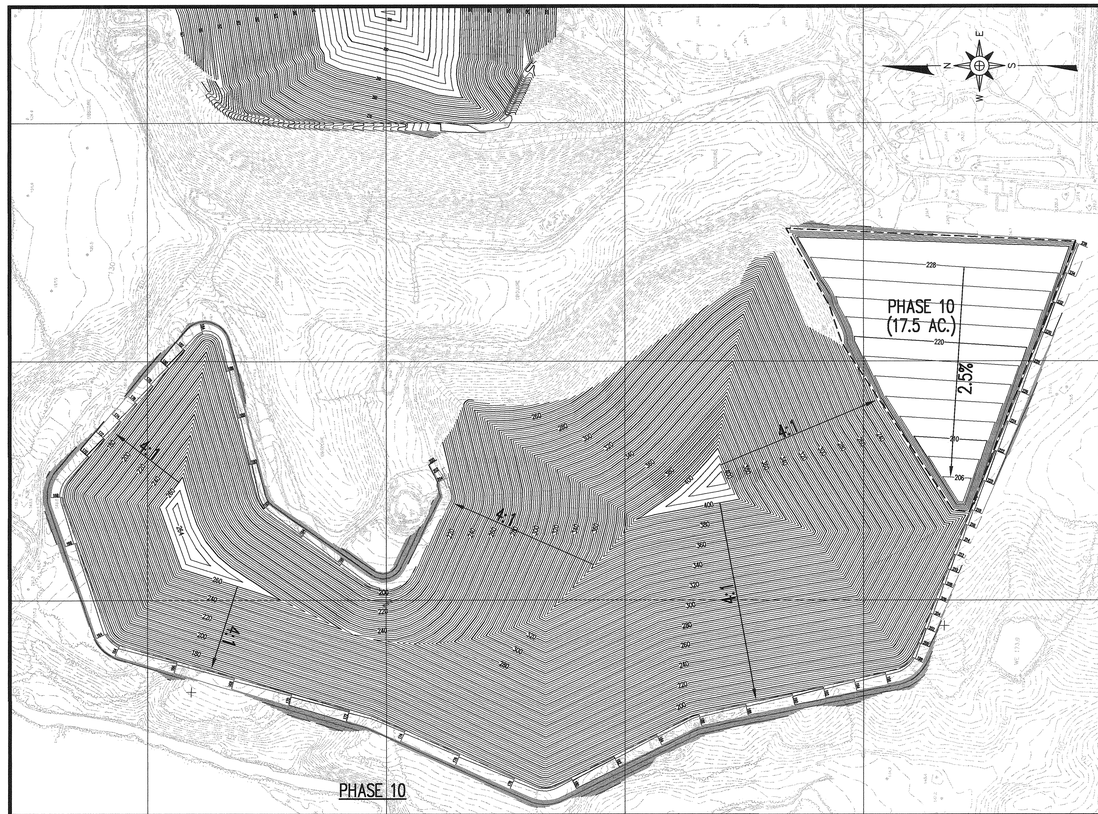
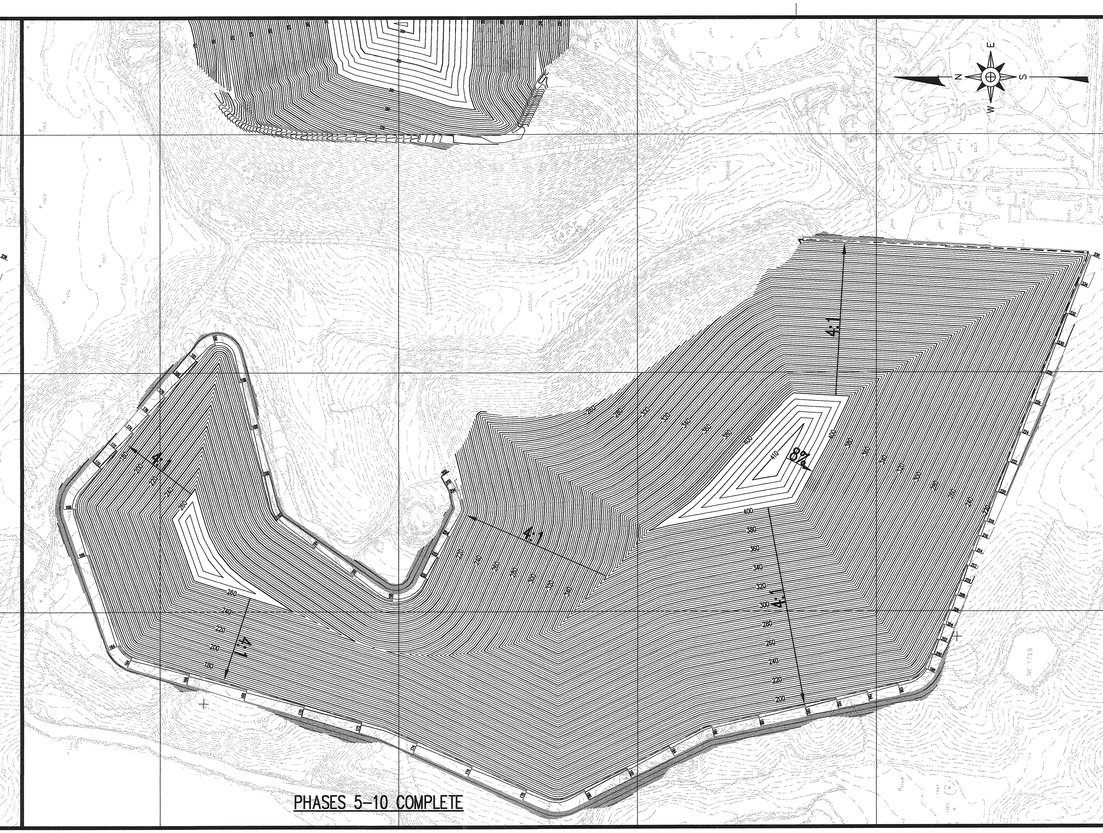



PHASE 10




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.

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

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

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| DESIGNED BY: P.K.S. | DRAWN BY: J.A.L. |
| CHECKED BY: | PROJECT NO.: JOHN 07-2 |
| SCALE: AS SHOWN | DATE: JUNE 2007 |
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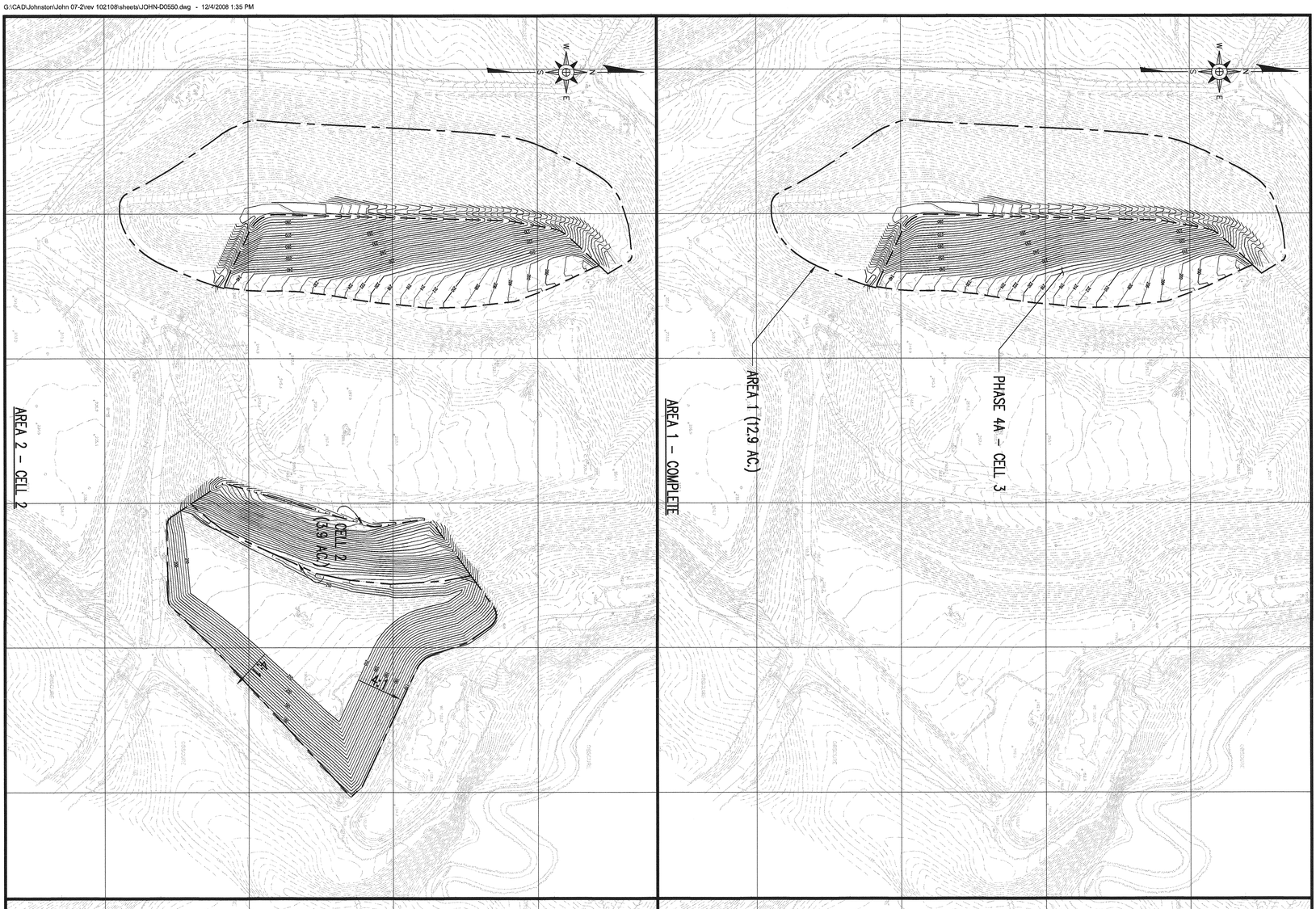

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REFERENCES

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.

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

DRAWING TITLE: C&D LANDFILL PHASING PLAN

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

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SEAL 021669 ENGINEER PETER K. SMITH 12/4/08

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| DESIGNED BY: | P.K.S. |
| DRAWN BY: | J.A.L. |
| CHECKED BY: | P.K.S. |
| 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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# Johnston County Landfill
# Phases 1-4, 4A and 5
## Water Quality Monitoring Plan

Prepared For:
**Johnston County**
**Department of Public Utilities**
**Smithfield, North Carolina**

The Water Quality Monitoring Plan for this facility has been prepared by a qualified geologist who is licensed to practice in the State of North Carolina. The plan has been prepared based on knowledge of site conditions and familiarity with North Carolina solid waste rules and industry standard protocol. The Plan described herein should provide for the effective detection of anthropic release of hazardous constituents into ground and surface waters of the State, due to, or caused by, past activities at the landfill.

Joan A. Smyth 1/9/02

Joan A. Smyth, P.G.
Project Hydrogeologist

NORTH CAROLINA LICENSED SEAL 1369 GEOLOGIST JOAN A. SMYTH

**January 2002**

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Figure 1: Water Quality Monitoring Locations
Figure 2: Surface Water Monitoring Locations

# 1.0 Introduction

## 1.1 Plan Background

Johnston County, North Carolina, owns and has sequentially operated four separate, unlined sanitary landfill units since1973 under Solid Waste Facility Permit #51-01, and one lined landfill (Phase 5) under permit 51-02. Permit 51-02 also includes the area previously included in Permit 51-01. The five distinct municipal solid waste disposal units are located on a single property off State Route 210 in Johnston County.

**Phases 1 through 4a**

The ground water detection monitoring network for Phases 1 through 4 originally consisted of 11 monitoring wells. Appendix I analyses that were performed during 1994 and 1995 confirmed the presence of several organic constituents at low levels, but exceeding limits established in the North Carolina Ground Water Quality Standards (15A NCAC 2L .0202).

Johnston County initiated an assessment monitoring program in 1995 in response to the detection of Ground Water Quality Standard violations. The ground water assessment monitoring was initiated for the more extensive suite of hazardous inorganic and organic constituents listed under RCRA Subtitle-D Appendix II (Appendix II).

During permitting for Phase 4A, six (6) additional monitoring wells were added to the monitoring well network to better evaluate the subsurface and contaminant movement in this area. Of these, five(5) wells (MW-4d, MW-7d, MW-8d, MW-9d, and MW-13d) were constructed as deep wells into the bedrock aquifer to evaluate contaminant movement in that aquifer. The sixth well, constructed as a shallow well (PZ-3), was installed to evaluate contaminant movement from Phases 1 & 2. All of these well have been added to the ground water monitoring network.

**Phase 5**

Phase 5 is the currently operating lined, Subtitle-D, landfill. This landfill was opened in 1998 and will continue operation until 2002 as a bioreactor landfill utilizing leachate recirculation. There are

10 wells (MW-5-1 through MW-5 -10) associated with this landfill. Additionally, four (4) wells located around the leachate pond are also monitored on a semi-annual basis. These wells are currently monitored under Subtitle-D regulations for Appendix I constituents in the Detection Monitoring Program.

**Phase 4A**

Phase 4A will be constructed as a "piggy-back" landfill in the valley created between Phases 3 and 4 by the waste masses. One additional well will be installed at the northern edge of the landfill downgradient of the sump of the landfill, but upgradient of the sedimentation basin located further north. The location of this well (MW-17) is shown on **Figure 1**. In addition, this Phase will be constructed with an alternative liner containing two base geomembranes. A monitoring system will be placed between the first and second geomembrane to evaluate any leakance from the uppermost liner.

Additionally, there are currently wells located immediately downgradient of where Phase 4A is to be constructed (MW-8 and MW-8d). Although MW-8 has been dry during recent sampling events, a replacement well will be installed immediately adjacent to MW-8d. This well, MW-8A will be added to the ground water monitoring network for Phase 4a. This well will replace MW-8 and will be located immediately downgradient of the drainage feature in which Phase 4a will be constructed. Due to the location of these wells, any significant change in ground water impact would be noticed.

Additionally, leachate samples from the leachate collection system will be monitored semi-annually for the same Appendix I constituents that ground water is monitored for. Also, leachate that may be present in the leak detection system will also be sampled and analyzed on a semi-annual basis for Appendix I constituents. The combination of using a double liner system and the proximal location of wells should provide adequate warning of a release from the Phase 4A landfill.

This Water Quality Monitoring Plan (WQMP) has been prepared to meet the field sampling and laboratory analysis requirements of the site. The WQMP details field and laboratory protocols that must be followed to meet the data objectives for the site.

## 1.2 Purpose & Scope

This WQMP has been designed to insure that accurate and representative field and laboratory results are obtained for all ground and surface water quality monitoring points. The WQMP addresses the following subjects:

- Ground water sample collection
- Surface water sample collection
- Sample preservation and shipment
- Laboratory analytical procedures
- Sample Chain-of-custody control
- Quality assurance/quality control programs

The methods and procedures described in the following sections are intended to facilitate the collection of true and representative samples and test data. Field procedures are presented in **Sections 3.0 through 7.0** in their general order of implementation. Equipment requirements for each field task are presented within the applicable section. Laboratory procedures, quality assurance methods and record keeping requirements are presented in **Sections 7.0 and 8.0**.

Strict adherence to these procedures stipulated in this plan is required. Any variations from these procedures should be throughly documented in the assessment report.

## 1.3 Sampling Program Overview

The ground water monitoring well designations, completion type, installation information and analytical requirements are included as **Table 1**. The surface water monitoring station designations, locations, sources and sampling frequency are included as **Table 2**.

## 2.0 Ground Water Sample Collection

This section presents details of the procedures and equipment required to perform ground water field measurements and sampling from monitoring wells during each monitoring event. A description of proposed ground water monitoring well locations and completion details are presented in **Table 1**. Ground water monitoring well locations for each Phase are shown in **Figure 1**.

### 2.1 Water Level Measurements

Static water level and total depth to the bottom will be measured in each well prior to any purging or sampling activities. Static water level and well depth measurements are necessary to calculate the volume of stagnant water in the well prior to purging. Additionally these measurements provide a field check on well integrity, degree of siltation, and are used to prepare potentiometric maps, calculate aquifer flow velocities and monitor changes in site hydrogeologic conditions.

Upon opening each well, new latex or nitrile surgical gloves will be donned. New gloves will be worn when taking water level measurements at each well. Appropriate measures will be taken during all measurement activities to prevent soils, decontamination supplies, precipitation, and other potential contaminants from entering the well or contacting clean equipment.

An electronic water level indicator will be used to accurately measure depth to ground water in each well and/or piezometer. Ground water depths will be measured to a vertical accuracy of 0.01 feet relative to established wellhead elevations. Each well will have a permanent, easily identified reference point on the lip of the well riser from which all water level measurements will be taken. The elevation of the reference point will be established by a Registered Land Surveyor.

The electronic water level indicator will be constructed of inert materials such as stainless steel and Teflon. Between well measurements the device will be thoroughly decontaminated by washing with non-phosphate soap and triple rinsing with deionized water to prevent cross contamination from one well to another.

The following measurements will be recorded in a dedicated field book prior to sample collection:

- Well Identification
- Depth to static water level and well bottom (to the nearest 0.01 foot)
- Height of water column in the riser (based upon known depth of well)
- Condition of wellhead protective casing, base pad and riser
- Changes in condition of well and surroundings.

## 2.2 Monitor Well Evacuation

Water accumulated in each well may be stagnant and unrepresentative of surrounding aquifer conditions, and therefore must be removed to insure that fresh formation water is sampled. Each well will be purged of standing water in the well casing following the measurement of the static water level.

New latex or nitrile surgical gloves will be donned for all well purging and sampling activities and whenever handling decontaminated field equipment. Appropriate measures will be taken during all measurement, purging and sampling activities to prevent surface soils, decontamination supplies, precipitation, and other potential contaminants from entering the well or contacting cleaned equipment.

The volume of standing water in the well riser and screen will be calculated immediately before well evacuation during each monitoring event. A standing water volume will be calculated for each well using measured static water level, well depth and well casing diameter according to the following equation:

$$V = (TD - SWL) \times C$$

Where:

V = One well volume

TD = Total depth of the well (in feet)

SWL = Static water level (in feet)

C = Volume constant for given well diameter (gallons/foot)

C = 0.163 gal/ft for two-inch wells.

C = 0.653 gal/ft for four-inch wells.

After the volume of standing water within the casing is established, a minimum of three to five well casing volumes of water will be evacuated from each well that is not outfitted with a MicroPurge ™ system.

New, disposable bailers with either double or bottom check-valves will be used to purge each well if the MicroPurge system is not used. Disposable purge bailers will be constructed of fluorocarbon resin (Teflon) suitable for the well and ground conditions. Each bailer will be certified factory-cleaned according to approved EPA protocol and remain sealed in a plastic sleeve until use. A new Teflon-coated stainless steel, inert mono-filament line or nylon cord will be used for each well to retrieve the bailers.

Wells will be purged at a rate that will not cause recharge water to be excessively agitated or cascade through the screen. Care will also be taken to minimize disturbance to the well sidewalls and bottom which could result in the suspension of silt and fine particulate matter. The volume of water purged from each well and the relative rate of recharge will be documents in sampling field notes. Wells which are of very low recharge rates will be purged once until dry. Damaged, dry or low yielding, and high turbidity wells will noted for reconsideration before the next sampling event.

Purge water will be managed to prevent possible soil and surface water contamination. Well site management options may include temporary containment and disposal as leachate or portable activated carbon filtration.

There are several wells on-site that are outfitted with MicroPurge™ pumps. All MicroPurge™ pumps are constructed of stainless steel and teflon components and are equipped with teflon lined tubing from the pump to the surface of the well. These pumps have been installed to maximize pump efficiency and data reliability.

Wells that are outfitted with the MicroPurge™ system T1200M pumps will be developed until the field parameters of temperature, pH and Conductivity stabilize to within 10%. The use of the MicroPurge low-flow system allows a sample to be collected from a discreet interval of the well, thus limiting the amount of purging necessary. The pumps operate at a flowrate of approximately

200 ml/min during purging. The stabilization of field parameters indicates that water from the formation is being removed. A "Flow Cell - FC4000" is used to continuously monitor the field parameters of the purge water. This cell evaluates the pH, temperature, and conductivity on a constant basis and provides an ongoing continuous readout of the parameter levels. Once three readings taken 3 to 5 minutes apart have stabilized to within 10% of each other, a sample may be immediately collected from the pump. The pumping rate during sampling shall be 100 ml/min.

Durable, non-dedicated equipment to be lowered into the well (such as water level indicators) will be thoroughly decontaminated before each use. Equipment shall be disassembled to the degree practical, washed with (non-phosphate) soapy potable tap water, and triple rinsed using de-ionized water. Detailed equipment decontamination procedures are detailed in **Section 2.6**.

## 2.3 Ground Water Sample Collection

After purging activities are complete, ground water samples will be collected for laboratory analysis. Additional care commensurate with the importance of this stage will be taken. All monitoring wells should be sampled in as short a time period as possible, generally within 48 hours.

Sampling will occur within 24 hours of the purging of each well and as soon after well recovery as possible. Wells which fail to recharge or produce an adequate sample volume within 24 hours of purging will be sampled and a notation as to the amount of elapsed time since purging will be placed in the "notes" section of the chain of custody sheet and in the field notes for future evaluation. If particular wells are consistently slow in recharging, a remedy should be proposed for the problem.

Field measurements of temperature, pH, specific conductivity and turbidity will be made immediately prior to sampling each monitoring point. The field test specimens will be collected with the sampling bailer and placed in a clean, non-conductive glass or plastic container for observation. The calibration of the pH, temperature, conductivity and turbidity meters will be completed according to the manufacturers' specifications and consistent with Test Methods for

Evaluating Solid Waste -Physical/Chemical Methods (SW-846). A pocket thermometer and litmus paper will be available in case of meter malfunction.

Each well outfitted with a dedicated MicroPurge™ pump (MW-3, MW-4b, MW-6, MW-7, MW-10, MW-12b and all MW- and LL-wells associated with Phase 5) will be sampled using the pump immediately upon completion of purging. Field measurements of pH, temperature and conductivity will be collected at the time of sample collection. The flowrate of pumping at the time of sampling shall be 100 ml/min or less.

Each well without a dedicated pump will be sampled using a new, factory-cleaned, disposable Teflon bailer with bottom check-valve and sample discharge mechanism. A new segment of Teflon-coated stainless steel wire, inert mono-filament line or nylon cord will be used to lower and retrieve each bailer. The bailer will be lowered into each well to the point of ground water contact, then allowed to fill as it sinks below the water table. Bottom contact will be avoided in order to avoid suspending sediment in the samples. The bailer will be retrieved and emptied in a manner which minimizes sample agitation.

Samples will be transferred directly from the Teflon bailer into a sample container that has been specifically prepared for the preservation and storage of compatible parameters. A bottom emptying device provided will be used to transfer samples from bailer to sample container. The generation air bubbles and sample agitation will be minimized during bailer discharge.

Ground water samples will be collected and contained in the order of volatilization sensitivity. Initially, only purgeable organics and total metals specimens will be collected for laboratory analysis. Subsequently, other analytical methods may required. When collected, the following order of sampling will be observed:

- Initial measurements of pH, temperature, conductivity and turbidity
- Volatile and Purgeable Organics
- Base Neutral and Acid Extractable Organics
- Total Metals

- Final measurements of pH, temperature, conductivity and turbidity

All samples will be collected and analyzed in an **unfiltered** state during all sampling events.

All reusable sampling equipment including water level probes, pH/conductivity meters, interface probes, and filtering pumps which might contact aquifer water or samples will be thoroughly decontaminated between wells by washing with non-phosphate soapy, de-ionized water and triple rinsing with deionized water. Detailed equipment decontamination procedures are detailed in Section 2.6.

## 2.4 Field Quality Assurance

Field and trip blanks will be prepared, handled and analyzed as ground water samples to ensure cross-contamination has not occurred. One set of trip blanks, as described later in this document, will be prepared before leaving the laboratory to ensure that the sample containers or handling processes have not affected the quality of the samples. One set of field (equipment) blanks will be created in the field at the time of sampling to ensure that the field conditions, equipment, and handling during sampling collection have not affected the quality of the samples. A duplicate ground water sample may be collected from a single well as a check of laboratory accuracy. Blanks and duplicate containers, preservatives, handling, and transport procedures for surface water samples will be identical to those noted for ground water samples.

## 2.5 Sample Containers

Sample containers will be provided by the laboratory for each sampling event. Containers must be either new and factory-certified analytically clean by the manufacturer, or cleaned by the laboratory prior to shipment for sampling. Laboratory cleaning methods will be based on the bottle type and analyte of interest. Containers for metals analysis are to be thoroughly washed with non-phosphate detergent and tap water, and rinsed with (1:1) nitric acid, tap water, (1:1) hydrochloric acid, tap water, and deionized water, in that order. Organic sample containers are thoroughly washed with non-phosphate detergent in hot water and rinsed with tap water, distilled water, acetone, and pesticide quality hexane, in that order. Other sample containers are thoroughly washed with non-phosphate detergent and tap water, rinsed with tap water, and rinsed with deionized water. The

laboratory shall provide proper preservatives in the sample containers prior to shipment (see Section 7.0).

### 2.6 Equipment Decontamination

All non-dedicated sample collection equipment that will come in contact with the well casing and water will be decontaminated. The procedure for decontaminating non-dedicated equipment is as follows:

1. Phosphate-free soap and tap water wash
2. Tap water rinse
3. 10% nitric acid or 10% hydrochloric acid soak
4. Deionized or distilled water rinse
5. Isopropyl alcohol rinse
6. Deionized or distilled water rinse and air dry
8. Aluminum foil wrap with shiny side out

## 3.0 Surface Water Sample Collection

This section present details of the procedures and equipment required to perform surface water field measurements and sampling from springs, streams and ponds during each monitoring event. A description of proposed surface water monitoring station locations is presented in **Table 2**. The proposed surface water monitoring station locations are shown in **Figure 2**.

### 3.1 Surface Water Level Observations

Surface water quality analyses are particularly sensitive to site hydrologic conditions and recent precipitation events. Water levels may fluctuate drastically in comparison the ground water table and may result in either diluting or increasing contaminant loadings. The scheduling of sampling events and the interpretation surface water data must take into account climatic, recent weather and sampling station conditions.

Surface water level and sampling station conditions will be observed one day prior to, and during each sampling event. Surface water observations will include the flood stage in streams, seasonal

base flow conditions, and confirm location and timing for meaningful surface water quality sampling. The following objective observations will be recorded in a dedicated field book prior to sample collection:

- Sample location designation
- Relative stream water level
- Surface water clarity
- Rate of flow and degree of stagnation
- Physical conditions of sampling station
- Changes in surface monitoring station conditions and surroundings.

Modifications to surface sampling station conditions may be required prior to each sampling event. These modifications may include the removal of surface and submerged debris, slightly deepening the station to allow sample container immersion, or channeling/piping to consolidate local discharge. When modifications are required, sufficient time will be allowed for settlement of suspended solids between the disturbance and sample collection. A minimum settling period of four hours prior to sampling will be observed.

### 3.2 Surface Water Sample Collection

Surface water samples will be obtained from areas of minimal turbulence and aeration. New latex or nitrile surgical gloves will be donned prior to sample collection. The following procedure will be implemented regarding sampling of surface waters:

1. Put on new latex or nitrile surgical gloves.
2. Hold the bottle in the bottom with one hand, and with the other, remove the cap.
3. Push the sample container slowly into the water and tilt up towards the current to fill. A water depth of six inches is generally satisfactory. Care will be taken to avoid breaching the surface or losing sample preservatives while filling the container.
4. If there is little current movement, the container should be moved slowly, in a lateral, side to side direction, with the mouth of the container pointing upstream.

Temperature, pH, specific conductivity and turbidity will be taken at the start of sampling as a measure of field conditions and check on the stability of the water samples over time. Measurements of temperature, pH, specific conductivity and turbidity will be recorded for all surface water samples. The calibration of the pH, temperature, conductivity , and turbidity meters will be completed at the beginning of each sampling event, according to the manufacturers' specifications and consistent with Test Methods for Evaluating Solid Waste - Physical/Chemical Methods (SW-846).

Surface water samples will be collected and contained in the order of volatilization sensitivity of the parameters as follows:

- Measurements of pH, temperature, conductivity and Turbidity
- Volatile and Purgeable Organics
- Base Neutral and Acid Extractable Organics
- Total Metals

All surface water samples will be collected in an unfiltered state.

All field meters which might contact surface water samples will be thoroughly decontaminated between stations by washing with non-phosphate soapy, de-ionized water and triple rinsing with deionized water.

A total of five surface water samples will be collected at this site. These are shown on **Figure 2** and listed in **Table 2**. Samples will be collected directly from the station in the container that has been specifically prepared for the preservation and storage of compatible parameters. Samples will be collected in a manner that assures minimum agitation. Additional blanks and duplicate samples will not be taken with the surface water samples.

Sample containers shall be prepared and provided by the laboratory for each surface water sampling event. Each sample containers' preparation and preservatives shall be the same as those utilized for ground water sampling and addressed previously in Section 2.5.

## 4.0 Field QA/QC Program

Field Quality Assurance/Quality Control (QA/QC) requires the routine collection and analysis of trip blanks to verify that the handling process has not affected the quality of the samples. Any contaminants found in the trip blanks could be attributed to:

1) interaction between the sample and the container,
2) contaminated source water, or
3) a handling procedure that alters the sample.

The laboratory will prepare a trip blank by filling each type of sample bottle with distilled or deionized water. Trip blanks will be placed in bottles of the specific type required for the analyzed parameters and taken from a bottle pack specifically assembled by the laboratory for each ground water sampling event. Trip blanks will be taken prior to the sampling event and transported with the empty bottle packs. The blanks will be analyzed for volatile and purgeable organics only.

The concentration levels of any contaminants found in the trip blank will be reported but will not be used to correct the ground water data. In the event that elevated parameter concentrations are found in a blank, the analysis will be flagged for future evaluation and possible re-sampling.

All field instruments utilized to measure ground water characteristics will be calibrated prior to entering the field, and recalibrated in the field as required, to insure accurate measurement for each sample. The specific conductivity and pH meter shall be recalibrated utilizing two prepared solutions of known concentration in the range of anticipated values (between 4 and 10). A permanent thermometer, calibrated against a National Bureau of Standards Certified thermometer, will be used for temperature meter calibration. The turbidity meter will be calibrated using Lucite standard blocks provided by the manufacturer.

## 5.0 Sample Preservation and Shipment

Methods of sample preservation, shipment, and chain-of-custody procedures to be observed between sampling and laboratory analysis are presented in the following sections.

### 5.1 Sample Preservation

Proper storage and transport conditions must be maintained in order to preserve the integrity of samples between collection and analysis. Wet ice will be used to cool and preserve samples, as directed by the analytical laboratory. Samples will be maintained at a temperature of 4° C. Dry ice is not to be used.

Pre-measured chemical preservatives will be provided in the sample containers provided by the analytical laboratory. Hydrochloric acid will be used as a chemical stabilizer and preservative for volatile and purgeable organic specimens. Nitric acid will be used as the preservative for samples for metals analysis.

Upon collection, samples will be placed on ice in high impact polystyrene coolers and cooled to a temperature of 4°C. Samples will be packed and/or wrapped in plastic bubble wrap to inhibit breakage or accidental spills. Chain-of-Custody control documents will be placed in a waterproof pouch and sealed inside the cooler with the samples for shipping. Tape and/or custody seals shall be placed on the outside of the shipping coolers, in a manner to prevent and detect tampering with the samples.

Samples shall be delivered to the analytical laboratory within a 24-hour period in person or using an overnight delivery service to insure holding times are not exceeded. Shipment and receipt of samples will be coordinated with the laboratory.

Chain-of-Custody control will be maintained from sampling through analysis to prevent tampering with analytical specimens. Chain-of-Custody control procedures for all samples will consist of the following:

1. Chain-of-Custody will originate at the laboratory with the shipment of prepared sample bottles and a sealed trip blank. Identical container kits will be shipped by express carrier to the sampler or site or picked up at the laboratory in sealed coolers.

2. Upon receipt of the sample kit, the sampler will inventory the container kit and check its consistency with number and types of containers indicated in the Chain-of-Custody forms and required for the sampling event.

3. Labels for individual sample containers will be completed in the field, indicating the site, time of sampling, date of sampling, sample location/well number, and preservation methods used for the sample.

4. Collected specimens will be placed in the iced coolers and will remain in the continuous possession of the field technician until shipment or transferral as provided by the Chain-of-Custody form has occurred. If continuous possession can not be maintained by the field technician, the coolers will be temporarily sealed and placed in a secured area.

5. Upon delivery to the laboratory, samples will be given laboratory sample numbers and recorded into a logbook indicating client, well number, and date and time of delivery. The laboratory director or his designee will sign the Chain-of-Custody control forms and formally receive the samples. The field technician, project manager and the laboratory director will work together to insure that proper refrigeration of the samples is maintained.

6. Copies of the complete Chain-of-Custody forms will be placed in the laboratory's analytical project file and attached to the laboratory analysis report upon completion.

Chain-of-Custody forms will be used to transfer direct deliveries from the sampler to the laboratory. A coded, express delivery shipping bill shall constitute the Chain-of Custody between the sampler and laboratory for overnight courier deliveries.

## 6.0 Field Logbook

The field technician will keep an up-to-date logbook documenting important information pertaining to the technician's field activities. The field logbook will document the following:

- Site Name and Location
- Date and Time of Sampling
- Climatic Conditions During Sampling Event
- Sampling Point/Well Identification Number
- Well Static Water Level
- Height of Water Column in Well
- Purged Water Volume and Well Yield (High or Low)
- Presence of Immiscible Layers and Detection Method
- Observations on Purging and Sampling Event
- Time of Sample Collection
- Temperature, pH, Turbidity, and Conductivity Readings
- Signature of Field Technician.

## 7.0 Laboratory Analysis

The ground and surface water parameters to be analyzed will be those specified in Table 1. These will include field indicators of water quality (pH, conductivity, temperature and turbidity) and selected purgeable organic as listed in Appendix I and Appendix II of 40 CFR.258 and 15 RCRA metals constituents (total metals analysis). All analytical methods are taken from Test Methods For Evaluating Solid Waste - Physical/Chemical Methods (SW-846) or Methods For the Chemical Analysis of Water and Wastes and will be consistent with DSWM's policies regarding analytical methods and PQLs. Analysis will be performed by a laboratory certified by the North Carolina DENR for the analyzed parameters.

Formal environmental laboratory Quality Assurance/Quality Control (QA/QC) procedures are to be utilized at all times. The owner/operator of the landfill is responsible for selecting a laboratory contractor and insuring that the laboratory is utilizing proper QA/QC procedures. The laboratory must have a QA/QC program based upon specific routine procedures outlined in a written laboratory Quality Assurance/Quality Control Manual. The QA/QC procedures listed in the manual shall provide the lab with the necessary assurances and documentation that accuracy and precision goals are achieved in all analytical determinations. Internal quality control checks shall be undertaken regularly by the lab to assess the precision and accuracy of analytical procedures.

During the course of the analyses, quality control data and sample data shall be reviewed by the laboratory manager to identify questionable data and determine if the necessary QA/QC requirements are being followed. If a portion of the lab work is subcontracted, it is the responsibility of the contracted laboratory to verify that all subcontracted work is completed by certified laboratories, using identical QA/QC procedures.

## 8.0 Data Evaluation

Copies of all laboratory results and water quality reports for the Johnston County Landfill will be kept at the Johnston County Landfill office. Reports summarizing all ground water quality results and data evaluation will be submitted to the DSWM for each sampling event. Upon receipt of each monitoring event's data, the water quality database of analyses will be updated.

Methods to evaluate the data are taken from North Carolina Solid Waste Rules and the EPA RCRA Ground Water Monitoring Technical Guidance Documents. Statistical methods are required and will be employed as warranted. The goal of the statistical analysis is to determine whether statistically significant evidence of contamination exists and to identify the constituents and points of concern. The North Carolina Solid Waste Rules provide several methods for statistical analysis of ground water data. These methods are:

1. Parametric analysis of variance (ANOVA)
2. Rank-based (non-parametric) ANOVA with multiple comparisons
3. Tolerance prediction interval
4. Control chart
5. Test of Proportions
6. An alternative statistical test method that meets the performance standards of 40 CFR 258.53 (h)

The choice of appropriate methods for data analysis and presentation, including statistical tests, depends on the type of monitoring, the nature of the data, and the proportion of values in the data set that are below detection limits. The statistical analysis will be conducted separately for each detected organic constituent based on the EPA's Statistical Analysis of Ground Water Monitoring Data at RCRA Facilities, Interim Final Guidance Document (1989) and Addendum to the Interim Final Guidance Document (1992). Any statistical analyses will be performed in general accordance methods outlined in the North Carolina State Regulations 15A NCAC 13B.1632.

## 9.0 Record Keeping and Reporting

### 9.1 Sampling Reports

Copies of all laboratory analytical data will be forwarded to the DWM within 45 calendar days of the sample collection date. The analytical data submitted will specify the date of sample collection, the sampling point identification and include a map of sampling locations. Should a significant concentration of contaminants be detected in ground and surface water, as defined in North Carolina Solid Waste Rules, Ground Water Quality Standards, or Surface Water Quality Standards, the owner/operator of the landfill shall notify the DWM and will place a notice in the landfill records as to which constituents were detected.

### 9.2 Well Abandonment/Rehabilitation

Should wells become irreversibly damaged or require rehabilitation, the DWM shall be notified. If monitoring wells and/or piezometers are damaged irreversibly they shall be abandoned under the direction of the DWM. The abandonment procedure in unconsolidated materials will consist of over-drilling and/or pulling the well casing and plugging the well with an impermeable, chemically-inert sealant such as neat cement grout and/or bentonite clay. For bedrock well completions the abandonment will consist of plugging the interior well riser and screen with an impermeable neat cement grout and/or bentonite clay sealant.

### 9.3 Additional Well Installations

The data will be analyzed to verify the correct placement of wells and determine locations for future monitoring wells, if necessary. Any additional well installations will be carried out in accordance with DWM directives. If the potentiometric maps reveal that the depths, location, or number of wells is insufficient to monitor potential releases of solid waste constituents from the solid waste management area, new well locations and depths will be submitted to the DWM for approval.

All monitoring wells shall be installed under the supervision of a geologist or engineer who is registered in North Carolina and who will certify to the DWM that the installation complies with the North Carolina Regulations. Upon installation of future wells the documentation for the construction of each well will be submitted by the registered geologist or engineer within 30 days

after well construction. Plans to install MicroPurge™ pumps in any additional well installed on-site shall be submitted to DSWM for approval prior to pump installation.

## 9.4 Implementation Schedule

This program is currently in place and being utilized at the site, with the exception of the addition of MW-8a, MW-14d, MW-15d, MW-16d and MW-17 and the leachate samples. These wells have also been proposed in a letter from GNRA to NCDENR dated July 18, 2001 regarding a recent geophysical evaluation of portions of the site and the proposed installation of additional wells. These well installations will be implemented upon approval from NCDENR.

**Table 1**
**Ground Water Monitoring Well Network**
**Johnston County Landfill**
**Johnston County, North Carolina**
**Phases 1 through 4a**

| Monitoring Well | Completion Type | Associated Wells | Screened Interval | Monitoring Program |
|---|---|---|---|---|
| MW-3 | Shallow | none | 17.83' - 27.83' | Subtitle-D Assessment Monitoring |
| PZ-3 | Shallow | none | 5.0' - 15.0' | Subtitle-D Assessment Monitoring |
| MW-4b | Shallow | MW-4d | 8.0' - 18.0' | Subtitle-D Assessment Monitoring |
| MW-4d | Deep | MW-4b | 63.0' - 68.0' | Subtitle-D Assessment Monitoring |
| PZ-2* | Shallow | none | 14.0' - 24.0' | Subtitle-D Assessment Monitoring |
| MW-6 | Shallow | none | 30.0' - 50.0' | Subtitle-D Assessment Monitoring |
| MW-7b | Shallow | MW-7d | 9.5' - 19.5' | Subtitle-D Assessment Monitoring |
| MW-7d | Deep | MW-7b | 25.0' - 30.0' | Subtitle-D Assessment Monitoring |
| MW-8a** | Shallow | MW-8d | NA | Subtitle-D Assessment Monitoring |
| MW-8d | Deep | MW-8 | 28.0' - 33.0' | Subtitle-D Assessment Monitoring |
| MW-9c | Shallow | MW-9d | 10.0' - 15.0' | Subtitle-D Assessment Monitoring |
| MW-9d | Deep | MW-9c | 35.0' - 40.0' | Subtitle-D Assessment Monitoring |
| MW-10 | Shallow | none | 19.0' - 34.0' | Subtitle-D Assessment Monitoring |
| MW-11 | Shallow | none | 14.0' - 24.0' | Subtitle-D Assessment Monitoring |
| MW-12b | Shallow | none | 23.0' - 38.0' | Subtitle-D Assessment Monitoring |
| MW-13 | Shallow | MW-13d | 9.0' - 19.0' | Subtitle-D Assessment Monitoring |
| MW-13d | Deep | MW-13 | 48.0' - 53.0' | Subtitle-D Assessment Monitoring |
| MW-14d | Deep | none | TBD | Subtitle D - Detection Monitoring |
| MW-15d | Deep | none | TBD | Subtitle D - Detection Monitoring |
| MW-16d | Deep | none | TBD | Subtitle D - Detection Monitoring |
| MW-17 | Shallow | none | TBD | Subtitle D - Detection Monitoring |
| Leachate | Collect Sys. | none | -- | Subtitle D - Detection Monitoring |
| Leachate | Detect Sys. | none | -- | Subtitle D - Detection Monitoring |

Notes: 1.) * - PZ-2 (MW-5A) replaces MW-5 which has consistently been dry during past sampling events.
2.) ** - MW-8a will replace MW-8 as this well has been consistently dry during recent sampling events.
3.) TBD = To Be Determined

**Table 1 (continued)**

**Ground Water Monitoring Well Network**
**Johnston County Landfill**
**Johnston County, North Carolina**

**Phase 5**

| Monitoring Well | Completion Type | Screened Interval | Monitoring Program |
|---|---|---|---|
| MW-5-1 | Shallow | 14.0' - 29.0' | Subtitle-D Detection Monitoring |
| MW-5-2 | Shallow | 5.0' - 20.0' | Subtitle-D Detection Monitoring |
| MW-5-3 | Shallow | 5.0' - 20.0' | Subtitle-D Detection Monitoring |
| MW-5-4 | Shallow | 5.0' - 20.0' | Subtitle-D Detection Monitoring |
| MW-5-5 | Shallow | 5.0' - 20.0' | Subtitle-D Detection Monitoring |
| MW-5-6 | Shallow | 21.0' - 36.0' | Subtitle-D Detection Monitoring |
| MW-5-7 | Shallow | 5.0' - 20.0' | Subtitle-D Detection Monitoring |
| MW-5-8 | Shallow | 5.0' - 20.0' | Subtitle-D Detection Monitoring |
| MW-5-9 | Shallow | N/A | Subtitle-D Detection Monitoring |
| MW-5-10 | Shallow | 3.0' - 23' | Subtitle-D Detection Monitoring |
| LL-1 | Shallow | N/A | Subtitle-D Detection Monitoring |
| LL-2 | Shallow | N/A | Subtitle-D Detection Monitoring |
| LL-3 | Shallow | N/A | Subtitle-D Detection Monitoring |
| LL-4 | Shallow | N/A | Subtitle-D Detection Monitoring |

Notes: Wells installed by others during Phase 5 permitting.
LL- wells are associated with the leachate lagoon.
N/A - Not Available

**Table 2**

**Surface Water Monitoring Station Locations**
**Johnston County Landfill**
**Johnston County, North Carolina**

**Phases 1 through 4, 4a, and 5**

| Monitoring Station | Station Location | Monitoring Program |
|---|---|---|
| SWPT-1a | Phases 1-4 Upstream of entire facility | Detection Monitoring |
| SWPT-2 | Phases 1-4 Downstream of entire facility | Detection Monitoring |
| SWPT-3 | Downstream of Phase 4a | Detection Monitoring |
| SW-5-1 | Upstream of Phase 5 | Detection Monitoring |
| SW-5-2 | Downstream of Phase 5 | Detection Monitoring |

LEGEND

EXISTING GROUND WATER MONITORING WELL

PROPOSED MONITORING WELL

GROUNDWATER DATA COLLECTED OCTOBER 1, 1999.

0 200' 400' 600'

1" = 200'


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SEAL

SEAL

PROJECT TITLE:
JOHNSTON COUNTY LANDFILL
SMITHFIELD, NORTH CAROLINA

DRAWING TITLE:
GROUND WATER
MONITORING NETWORK
PHASE 1 THROUGH 4A & 5

| DESIGNED BY: | DRAWN BY: |
|---|---|
| J.A.S. | C.T.J. |
| CHECKED BY: | PROJECT NO.: |
| G.N.R. | JOHNSTON-4 |
| SCALE: | DATE: |
| AS SHOWN | JAN. 2002 |
| FILE NAME | |
| JOHN-D0210 | |
| SHEET NO. | DRAWING NO. |
| FIG. 1 | |

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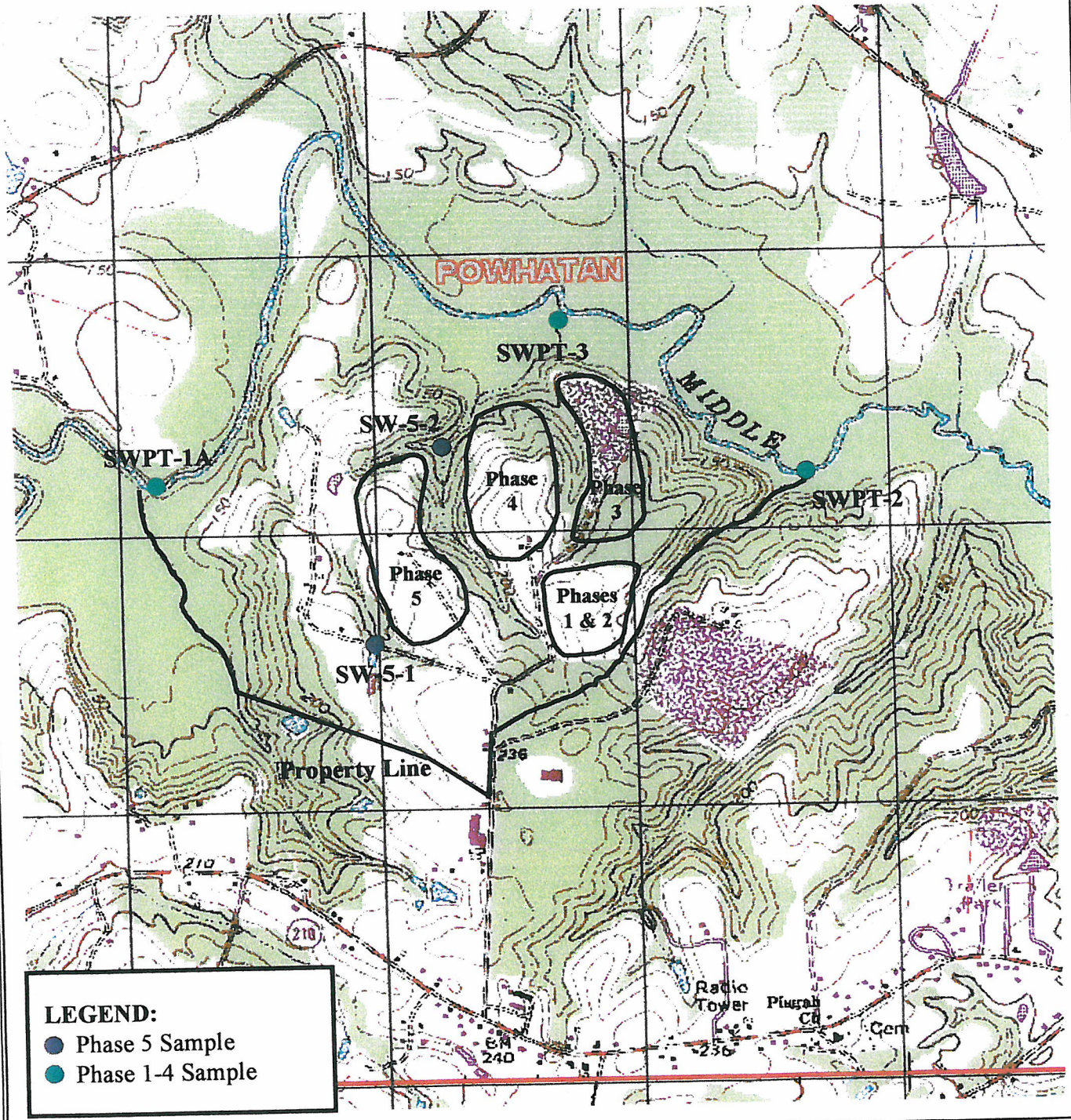


**Surface Water Monitoring Locations**
**Johnston County Landfills**
**USGS Powhatan, NC Quadrangle**

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| SCALE: | DRAWN BY: | CHECKED BY: | DATE: | PROJECT NO. | FIGURE NO. | FILE NAME |
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