PERMIT MODIFICATION APPLICATION
VOLUME 2 of 3
for
VERTICAL EXPANSION
DRPI Industrial Landfill
New Castle, Delaware

Prepared by:
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Geosyntec Project No.: ME1571
July 2018
PART VI

ENGINEERING REPORT
PERMIT MODIFICATION APPLICATION

PART VI – ENGINEERING REPORT

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1 INTRODUCTION

1.1 Terms of Reference

In accordance with the requirements of the Delaware’s Regulations Governing Solid Waste (DRGSW), specifically Section (§) 4.2.1.4 (i.e., Engineering Report), §6.1 (i.e., Siting), and §6.2 (i.e., Design), this Engineering Report was prepared to support the permit modification application (PMA) for the proposed vertical expansion of the Delaware Recyclable Products, Inc., (DRPI) Industrial Waste Landfill located in New Castle, Delaware.

This Engineering Report provides analyses relevant to the proposed grading changes associated with the vertical expansion. The Engineering Report was prepared by Geosyntec Consultants Inc. (Geosyntec) in October 2004, and revised in February 2005, for the Cell 6 Expansion. In October 2014 and revised in March 2015, the engineering design and analyses for the Cell 6 Expansion were updated by Golder Associates Inc. (Golder) to reflect the modifications to the layout of Cell 6-2 and the Cells 1-3 Overlay Liner Area. This Engineering Report applies to the vertical expansion and the remaining portion of the Cells 1-3 Overlay Liner Area, but relies on previous calculations where applicable.

The proposed vertical expansion design and this Engineering Report were prepared by Geosyntec of Columbia, Maryland under the direct supervision of Ms. Carrie Pendleton, P.E., a professional engineer licensed in the State of Delaware. The individuals who prepared the design and this Engineering Report include: Dr. David Espinoza, P.E., Dr. Chunling Li, Dr. Sean O’Donnell, Jennifer Padgett, Andrew Stallings, and Simone Smith, all of Geosyntec. The Vertical Expansion Design and this Engineering Report were reviewed by Ms. Carrie Pendleton, P.E., who is a professional engineer licensed in the State of Delaware, in accordance with Geosyntec’s internal review policies.

1.2 Project Overview

The DRPI Landfill is located in New Castle, Delaware, near the intersection of U.S. Route 13 and Interstate 495. The location of DRPI Landfill is identified on Figure VI-1. The DRPI Landfill was initially permitted in 1983 for construction demolition debris (CDD) management and has been an active CDD disposal facility since 1985. The DRPI Landfill currently includes six disposal cells having a combined area of approximately 146 acres. The general layout of DRPI Landfill is illustrated on Figure VI-2 and is described in detail in Section 3.2 of this Engineering Report. The vertical expansion is intended to provide DRPI with approximately 8.4 million cubic yards (mcy) of additional disposal capacity for a total approximate remaining airspace of 10.7 mcy. The vertical expansion will occur entirely over the previously permitted footprint of Cells 1-6.
Between 1954 and 1982, the DRPI Landfill was operated as a sand and gravel pit in the general area of present day Cells 1, 2, and 3. Sand and gravels of the Columbia Formation were excavated to approximately the top of the silty clay Potomac Formation. The development history of the six DRPI Landfill disposal cells is summarized below.

- Disposal of CDD waste started in 1983 in the unlined Cells 1 through 3.
- Cell 4 was constructed north of Cell 3 and waste placement began in 1994.
- Cell 5 was constructed to the west of Cells 1 through 4 in 1998, and waste placement began in 1999.
- Portions of Cell 6 were constructed (i.e., Subcells 6-1A, 6-1B, and 6-2A) and waste placement began in 2010.
- Approximately 9.1 acres of the Cells 1, 2, and 3 overlay liner were constructed in 2015, 7.8 acres in 2017, and approximately 11.2 acres were completed in 2018. Approximately 5.0 acres are planned for overlay liner construction in 2019.

Currently, the active disposal area is in the Cells 1-3 overlay liner area.

The proposed vertical expansion design is illustrated in detail in the drawing set entitled, “Vertical Expansion, Design Modification Application, DRPI Industrial Waste Landfill, New Castle, Delaware” (i.e., Permit Drawings), prepared by Geosyntec, dated July 2018. A reduced set of the Permit Drawings are provided in Appendix VI-A. As shown on the Permit Drawings, the proposed vertical expansion involves extending the vertical limits of the DRPI Landfill to elevation 190 feet above mean sea level (ft-msl).

The proposed vertical expansion will also provide a synthetic layover liner above the remainder of Cells 1, 2, and 3 area to allow DRPI to remove the restriction in the current permit (i.e., SW-15/02, Section III.G.) regarding the types of waste allowed over Cells 1, 2, and 3. Until that area is lined, the existing waste restriction described in the current permit remains in effect. As of April 2018, approximately 16.9 acres of overlay liner have been constructed above the existing placed waste of Cells 1, 2, and 3.

In addition to this Engineering Report, the PMA for the vertical expansion includes the following reports and plans:

- Operation and Maintenance Plan (DRGSW §4.2.1.3), presented as PMA Part V;
- Hydrogeologic Assessment Report (DRGSW §4.2.1.5), presented as PMA Part VII;
- Environmental Assessment Report (DRGSW §4.2.1.6), presented as PMA Part VIII; and
- Closure/Post-Closure Plan (DRGSW §6.10.3), presented as PMA Part XI.
1.3 Engineering Report Organization

This Engineering Report is organized such that the specific siting, design, and general permit modification application requirements of DRGSW §6 and §4.2 are completely addressed. The DRGSW requirements, and the location in this report where the requirements are addressed, are described below:

- the regulatory requirements of DRGSW §6.1 and §6.2 are presented and addressed in Section 2;
- an overview of the layout and the design components of the vertical expansion as required by DRGSW §6.2.2, which includes the estimated disposal capacity associated with the vertical expansion, in terms of total volume and volume of waste received per day, as required by DRGSW §4.2.1.4.4, are described in Section 3, and included in Appendix VI-B;
- descriptions of the design components of the vertical expansion, as required by DRGSW §6.2.2, including the manner in which the design complies with the specific design requirements of DRGSW §6.3 through §6.8, are presented in the following sections:
  - Section 4: Liner System with associated calculations are presented in Appendix VI-D,
  - Section 5: Leachate Management System with associated calculations presented in Appendix VI-E,
  - Section 6: Landfill Gas Management System with associated calculations presented in Appendix VI-F,
  - Section 7: Stormwater Management System with associated calculations presented in Appendix VI-G, and
  - Section 8: Cover System with associated calculations presented in Appendix VI-H;
- the anticipated construction schedule for the proposed facility, as required by DRGSW §4.2.1.4.3, is not included because the facility is already constructed, and the proposed modification affects the filling sequence and maximum height of waste placement, which is included in Drawing 21;
- an updated erosion and sediment control plan is provided in Appendix VI-I and will be submitted with the stormwater management plan under separate cover to Delaware Department of Natural Resources and Environmental Control (DNREC);
- a description of the proposed installation methods and procedures for the vertical expansion design components (i.e., Technical Specifications), as required by DRGSW § 4.2.1.4.2, are presented in Appendix VI-J
a construction quality assurance plan, as required by DRGSw § 4.2.1.4.5, is provided in Appendix VI-K; and

references are provided in Section 9.

Engineering calculations and other supporting documentation for the vertical expansion are presented in the Appendices to this Engineering Report.
2 REGULATORY REQUIREMENTS

2.1 Overview

The regulatory requirements for landfill siting and design are addressed in this section. In the following two sections, the siting requirements of DRGSW §6.1 and the design requirements of DRGSW §6.2 are identified, along with a description of the manner in which the proposed DRPI Landfill vertical expansion meets these requirements.

2.2 Siting Requirements

Siting requirements for industrial waste landfills are presented in DRGSW §6.1.1 through 6.1.3. The manner in which the proposed expansion design meets these siting requirements is presented below.

- **DRGSW §6.1.1** requires industrial landfills to be located in an area where the potential for degradation of land, air, or water quality is minimal. As described in the Environmental Assessment Report, the proposed vertical expansion will be located on top of an active industrial landfill (i.e., DRPI Landfill Cells 1 through 6). In addition, the area adjacent to the DRPI Landfill is located in an industrialized area that was previously impacted by soil mining and landfilling activities. As described in this report, the design of the vertical expansion was developed in a manner that is highly protective of the environment. As such, the vertical expansion is anticipated to have minimal potential for the degradation of air, land, or water quality.

- **DRGSW §6.1.2**, requires industrial landfills be constructed to meet the design standards of DRGSW §6.2 which is specifically addressed in Sections 3 through 8 of this Engineering Report.

- **DRGSW §6.1.3** has multiple requirements as described below.
  a. *No new cell shall be located within the 100-year floodplain.* As described in the Environmental Assessment Report, the vertical expansion is located over the existing permitted cells. Therefore, the vertical expansion design is in compliance with this requirement.
  b. *No new cell shall be located in an area that may cause or contribute to the degradation of any state or federally regulated wetlands unless it is demonstrated that there is no impact to the wetland or the impact is mitigated.* As described in the Environmental Assessment Report, the vertical expansion is located over the existing permitted cells. Therefore, the vertical expansion design is in compliance with this requirement.
c. **No new cell shall be located within one mile of any state or federal wildlife refuge, wildlife area, or park, unless specifically exempted from this requirement by the Department.** The DRPI landfill is located within approximately 0.25 miles from the Russell Peterson Wildlife Refuge, across the Christina River. However, no new cells are proposed, and the vertical expansion is located over the existing permitted cells, and therefore the vertical expansion design is in compliance with this requirement.

d. **No new cell shall be located so as to be in conflict with any locally adopted land use plan or zoning requirement.** The vertical expansion is in compliance with the local land use plan and local zoning requirements. DRPI Landfill is specifically identified as the facility that will be used for disposal of CDD for the duration of the landfill life.

e. **No new cell shall be located within the wellhead protection area of a public water supply well or well.** As shown in the Hydrogeological Assessment Report, when originally permitted, the DRPI Landfill was not constructed within a wellhead protection area. To the best of DRPI’s knowledge, no new wells have been installed since that time. Therefore, the vertical expansion design is in compliance with this requirement.

f. **No new cell shall be located in areas where valuable aquifers would be threatened by contaminant releases, unless viable alternatives have been dismissed and stringent design measures have been incorporated to minimize the possibility and magnitude of releases.** As described in the Hydrogeological Assessment, the aquifer underlying the DRPI Landfill is not classified as a valuable aquifer. Furthermore, a state-of-the-practice composite liner system is in place in the cells underlying the vertical expansion and an overlay composite liner system will be constructed over unlined cells. Therefore, the vertical expansion design, which is: (i) not located above a valuable aquifer; and (ii) includes measures to minimize releases to groundwater, complies with this requirement.

g. **No cell shall be located within 200 ft of the facility boundary unless otherwise approved by DNREC.** As shown on the Permit Drawings, the vertical expansion is located over the existing permitted cells. In addition, the vertical expansion design will improve the environmental condition of the property by: (i) constructing a liner system over the remaining existing unlined waste in Cells 1, 2, and 3; and (ii) allowing for the enhancement of the stormwater management system of the DRPI Landfill, which will have a direct and positive impact on neighboring properties to the south. Therefore, the vertical expansion design is in compliance with this requirement.
h. No cell shall be located in an area that is environmentally unique or valuable. As described in the Environmental Assessment Report, the vertical expansion is located over the existing permitted cells. Therefore, the vertical expansion design is in compliance with this requirement.

2.3 Design Requirements

The design requirements for industrial landfills are identified in DRGSW §6.2 through §6.8. The general and minimum design requirements of DRGSW §6.2.1 are identified below along with the manner that the proposed design meets these requirements.

- DRGSW §6.2.1 requires industrial landfills to be planned and designed by professional engineers registered in the State of Delaware, and that the planning and design of the landfill be consistent with the applicable DRGSW requirements and be based on empirically derived data and state of the art technology. The design of the DRPI Landfill vertical expansion was performed under the direct supervision of Ms. Carrie Pendleton, P.E., a professional engineer licensed to practice engineering in the State of Delaware, as evidenced by Ms. Pendleton’s stamp and signature on the cover sheet of this report. In addition, the design is consistent with the purpose and intent of the DRGSW, based on both: (i) empirically derived data regarding landfill design and performance; and (ii) state-of-the-practice engineering technology.

- DRGSW §6.2.2 has multiple requirements as described below.
  a. Industrial landfills must be designed to include a setback area, including a buffer zone with appropriate screening, if deemed necessary by DNREC. As previously noted, the vertical expansion is located over the existing permitted cells. The DRPI Landfill does currently have a buffer zone with screening, and DRPI is proposing to plant additional trees near the entrance of the facility, which will provide further screening from neighboring residents and traffic along nearby roadways.
  b. A liner that meets the requirements of DRGSW §6.3. As part of the vertical expansion PMA, DRPI is proposing to include a composite liner in locations where a liner is not already present as defined in DRGSW §6.3.2.1. Section 4 of this Engineering Report addresses the design of the vertical expansion liner system.
  c. Leachate collection, treatment and disposal, and monitoring systems that meet the requirements of DRGSW §6.4. Section 5 of this Engineering Report describes the components of the leachate management system and how their design is adequate to accommodate the vertical expansion.
d. A gas control system that meets the requirements of DRGSW §6.5. The DRPI Landfill currently has an active landfill gas (LFG) management system, which is operated in compliance with applicable air quality regulations (i.e., Title V of the Clean Air Act and the NSPS and the Delaware Air Quality Standards). For the vertical expansion, the LFG management system will be modified to allow for continued LFG extraction/collection: (i) in existing waste, both above and below the liner systems, as appropriate; and (ii) from waste to be placed in the vertical expansion. The design of these LFG management system modifications is described in Section 6 of this Engineering Report.

e. A surface water management system that meets the requirements of DRGSW §6.6. The DRPI Landfill currently has a permitted stormwater management system, which is maintained in compliance with applicable regulations. For the vertical expansion, the existing stormwater management system will be expanded to include the added height as well as new stormwater features. The design of these stormwater management system modifications is described in Section 7 of this Engineering Report.

f. A groundwater monitoring system that meets the requirements of DRGSW §6.7. The DRPI Landfill currently has a groundwater monitoring plan, as described in the Hydrogeologic Assessment Report. No modifications are proposed.

g. A capping system that meets the requirements of DRGSW §6.8. The vertical expansion was designed to include a final cover system as defined in DRGSW §6.8. Section 8 of this Engineering Report addresses the design of the vertical expansion final cover system.
3 BASIS FOR EXPANSION DESIGN

3.1 Introduction

The basis for the design of the vertical expansion is described in this section. Specifically, this section is organized as follows:

- an overview of the existing landfill operational features is presented in Section 3.2;
- the design criteria for the vertical expansion is presented in Section 3.3; and
- the primary features of the vertical expansion are presented in Section 3.4.

3.2 Existing Features

The existing features of DRPI Landfill are shown on Figure VI-2. A brief description of each of the primary features is presented below.

- **Facility Entrance.** Entrance to the DRPI Landfill is from Route 13. The entrance area includes a scalehouse, a maintenance building, and administrative offices.

- **Waste Disposal Area.** The waste disposal area at the DRPI Landfill currently consists of six landfill disposal cells, which are referred to throughout this report, and the various PMA documents, as Cells 1, 2, 3, 4, 5, and 6. Approximately 28.1 acres of Cells 1, 2, and 3 have been lined with overlay liner and approximately 5.0 acres of Cells 1, 2, and 3 are unlined and remaining to be lined in 2019. The overlay liner system of Cells 1, 2, and 3 and the liner system for Cells 4, 5, and 6 meet the requirements of DRGSW §6.3.2.1 (i.e., Composite Liner). In addition, Cells 4, 5, and 6 are underlain by a drainage blanket that suppresses the groundwater table to a depth of five feet below the bottom of the liner system (DRGSW §6.3.1.3).

- **Leachate Management System.** Leachate is collected only in the lined disposal cells (i.e., Cells 4, 5, and 6) and in the overlay portion of cells 1-3. Leachate generated in these cells is intercepted by a leachate collection system (LCS) located immediately above the cell composite liner system. The LCS for each cell consists of a drainage layer and a series of lateral and main collection pipes. The main pipes route the collected leachate to collection sumps located along the perimeter of the cell. In Cells 1, 2, and 3, leachate drains towards a collection header within Cell 6. In Cells 4, 5, and 6, leachate collected in the sumps is pumped to a leachate storage tank located on the northwest corner of the site. In each of these sumps, submersible pumps transfer the leachate through a forcemain to the leachate storage tank.
Landfill Gas Management System. Landfill gas is actively collected through a series of vertical collection wells in Cells 1 through 6. Landfill gas is removed from the wells and routed through above-ground transmission pipes to a gas blower and flare station located near the northwest corner of the site.

Stormwater Management System. Stormwater runoff from the DRPI Landfill is currently discharged to two ponds that are located on the northeast and northwest side of DRPI Landfill. These ponds ultimately discharge to water bodies directly connected to the Christina River.

3.3 Expansion Objectives

The primary purpose for the vertical expansion is to increase the waste disposal capacity of the DRPI Landfill. As shown on the Permit Drawings, the vertical expansion will be located over Cells 1 through 6. An added benefit of the vertical expansion is the ability to increase the lined disposal area, which will serve as a final cover over those areas in Cells 1, 2, and 3 where waste disposal occurred in unlined areas.

The vertical expansion is projected to provide 8.4 mcy of additional disposal capacity at the DRPI Landfill. This increase in disposal capacity will extend operational life of the DRPI Landfill by approximately 21 years (for a total site life of 24 years), based on average projected waste receipts of approximately 279,000 tons/year and an average waste density of 0.65 tcy. As such, the vertical expansion will allow the DRPI Landfill to continue to provide environmentally safe and secure CDD disposal services to the northern Delaware community. Calculations for the vertical expansion design capacity are provided in Appendix VI-B of this Engineering Report.

3.4 Design Criteria

As previously discussed, the vertical expansion will serve two main purposes: (i) extend the service life of the DRPI Landfill; and (ii) cover the remaining waste area of three unlined cells. The basis of design for the vertical expansion is founded on nine design criteria. These design criteria, and the locations in this Engineering Report and/or this PMA where the criteria are addressed, are presented below.


3. Expand and modify, as needed, the existing components of the DRPI Landfill infrastructure (e.g., leachate, LFG, and stormwater management). Addressed in Sections 5, 6, and 7, respectively, of this Engineering Report.

4. Ensure that an appropriate minimum factor of safety for slope stability is achieved for short- and long-term conditions. Addressed in Section 4 of this Engineering Report.

5. Ensure that adequate capacity for LFG control is provided for the existing waste mass, as well as the proposed vertical expansion area. Addressed in Section 6 of this Engineering Report.

6. Ensure that the stormwater management system accommodates the anticipated flows from the vertical expansion. Addressed in Section 7 of this Engineering Report.

7. Ensure that the final cover system vertical expansion area accommodates future post-closure uses. Addressed in Section 8 of this Engineering Report.

8. Ensure that waste located beyond the permitted disposal limits is properly covered. Addressed in Section 8 of this Engineering Report.

9. Comply with DRGSW regulations for industrial landfills. Addressed throughout this PMA.

3.5 Vertical Expansion Design Components

As shown on the Permit Drawings, the vertical expansion consists of five primary components listed below. A brief description of the components is presented below. The detailed design of each component is presented in Sections 4 through 8 of this Engineering Report.

1. A composite liner system that also extends over all of Cells 1, 2, and 3.

2. A leachate management system that will: (i) collect leachate generated in the vertical expansion and direct it towards a sump; and (ii) remove and transmit the collected leachate from the existing DRPI Landfill leachate transmission system for pre-treatment and storage.

3. A LFG management system that will: (i) accommodate the composite liner system to be constructed over portions of Cells 1, 2, and 3; and (ii) continue to collect LFG generated from the existing and vertical expansion waste mass.

4. A stormwater management system that controls the runoff associated with the proposed land development.

5. A final cover system that will accommodate the intended post-closure use of DRPI Landfill while enhancing the level of long-term environmental protection.
4 LINER SYSTEM

4.1 Introduction

This section describes the design of the liner system for the cells over which the vertical expansion will be located. The liner system was previously designed in accordance with the requirements of DRGSW §6.3.1, §6.3.2, and §6.3.3 as part of the Cell 6 Expansion Permit Application and the Amended Permit Application prepared by Golder and dated March 2015. The following criteria were applied to the design of the existing and Cells 1-3 overlay liner systems.

- **DRGSW §6.3.1.1** – An impermeable liner shall be provided to restrict the migration of leachate from the landfill and to prevent contamination of the underlying groundwater.

- **DRGSW §6.3.1.2** – A composite liner system (DRGSW §6.3.2.1) shall be used unless a more stringent liner system is required by DNREC.

- **DRGSW §6.3.1.3** – The bottom of the liner system shall be at least 5 ft above the seasonal-high water table, as measured by the uppermost aquifer beneath the landfill.

- **DRGSW §6.3.2.1** – The composite liner system shall be comprised of a minimum 45-mil thick geomembrane underlain by a 2-ft thick compacted clay layer exhibiting a hydraulic conductivity of $1 \times 10^{-7}$ cm/s (or equivalent material, i.e., geosynthetic clay liner - GCL).

- **DRGSW §6.3.3.1.2** – The liner system shall be installed on a subbase capable of supporting the loads and withstanding the stresses that will be imposed on it through the active life and post-closure care period, and will resist the pressure gradient above and below the liner caused by settlement, compression, or uplift.

- **DRGSW §6.3.3.1.3** – The minimum post-loading slopes of the liner system shall be either two percent on “controlling” slopes and 0.5 percent on “remaining” slopes, where the “controlling” slopes are the cell-floor cross slopes (i.e., the slopes in the direction of leachate flow toward leachate collection pipes); the “remaining” slopes are the slopes of the leachate collection pipes; or the “controlling” and “remaining” slopes shall be designed to prevent the leachate head on the liner system from exceeding 12 in., except in leachate collection sumps.

- **DRGSW §6.3.3.1.4** – There shall be minimal penetrations through the liner system. If a penetration is essential, a liquid-tight seal must be accomplished between the penetrating structure and the synthetic membrane. Compaction of areas adjacent to the penetrating structure shall be to the same density as the surrounding soil to minimize differential settlement. Sharp edges on the penetrating structure must not come in contact with the synthetic material.
• **DRGSW §6.3.3.1.5** – Bridging or stressed conditions in the liner shall be avoided with proper slack allowance for shrinkage of the liner during installation and before the placement of a protective soil layer.

• **DRGSW §6.3.3.1.8** – The geomembrane shall be protected from waste by at least two feet of drainage layer/protective cover.

• **DRGSW §6.3.3.1.9** – The geomembrane shall be underlain by a secondary liner per DRGSW §6.3.2.1.2.

The remainder of this section is organized as follows: (i) a description of the liner system layout and cross section is presented in Section 4.2; and (ii) demonstrations that the expected performance of the liner system is in accordance with the applicable requirements of DRGSW are presented in Sections 4.3 and 4.4.

### 4.2 Composite Liner System Layout

The composite liner system beneath the vertical expansion area is laid out in a configuration that meets the grading and containment requirements of DRGSW. The layout of the liner system (i.e., the design grades) is shown on the Permit Drawings. As stated previously, the expansion area overlays Cells 1 through 6. Liner will only be added over the remaining portion of unlined Cells 1, 2, and 3. This area is graded to drain to low points, where leachate collection pipes will discharge. The areas over Cells 4, 5, and 6 will continue to drain into the existing leachate collection system. The minimum post-settlement slope in all six existing cells after accounting for the additional loading imposed by waste in the vertical expansion is two percent on controlling slopes and one-half percent on remaining slopes, as required by DRGSW.

The design of the liner system incorporated characterization of the subsurface soils. A summary of the soil characterization is provided in Appendix VI-C of this Engineering Report.

### 4.3 Proposed Liner System Components

The existing and proposed liner systems are comprised of the following components, listed from top to bottom.

- a 24-in. thick drainage layer/protective cover with permeability greater than $10^{-3}$ cm/s;
- a geocomposite drainage layer;
- a 60-mil geomembrane liner;
- a GCL (an equivalent to 24-in. thick of compacted clay liner); and
- a compacted subbase.
If the permeability of the drainage layer/protective cover is higher than $10^{-3}$ cm/s, the geocomposite drainage layer may be substituted with an 8 oz/sy geotextile.

Each of these liner system components is described below.

- **Drainage Layer/Protective Cover.** The drainage layer/protective cover will protect the underlying geosynthetics from the overlying waste and will serve as an additional drainage media for leachate collection. Details on the drainage layer/protective cover are provided in Section 5 of this Engineering Report.

- **Geocomposite Drainage Layer.** The geocomposite drainage layer provides added protection of the underlying geomembrane and enhances leachate collection by reducing the leachate head on the liner. Details on the geocomposite drainage layer are provided in Section 5 of this Engineering Report.

- **Geomembrane Liner.** The geomembrane liner serves as the primary hydraulic barrier between the waste and the environment. The 60-mil thick geomembrane liner will be textured to maximize sideslope stability and will be manufactured from high-density polyethylene (HDPE), the industry standard geosynthetic landfill liner material. HDPE is considered to be chemically inert to landfill leachate [Haxo et al., 1982; Schwope et al., 1985].

- **Geosynthetic Clay Liner.** The GCL serves as the lower component of the composite liner system. Alternatively, a 24-in. compacted clay layer with a permeability equal to or lower than $1 \times 10^{-7}$ cm/s may be used for this layer.

- **Compacted Subbase.** The synthetic liner over existing waste in Cells 1-3 will be installed above a compacted subbase having a minimum thickness of two feet. The subbase will be compacted soil that has a smooth surface and is free of rocks, stones, roots, sharp objects, or debris. The compacted subbase will be graded to the slopes indicated on the Permit Drawings to facilitate the installation of the overlying liner system components. Large objects on the surface will be removed and disposed of in the landfill.

### 4.4 Liner System Performance

#### 4.4.1 Introduction

In this section, an analysis of the performance of the existing and proposed liner systems is presented. Specifically, the following issues are addressed: (i) protection of the liner system (Section 4.4.2); (ii) stability of the liner system (Section 4.4.3); (iii) settlement of the liner system (Section 4.4.4); and (iv) separation distance between the liner system and seasonal high groundwater table (Section 4.4.5).
4.4.2 Protection of the Liner System

Protection of the liner system was previously evaluated for various loading conditions. These conditions include the potential impacts from: (i) the load of overlying waste; and (ii) construction equipment during waste placement activities. The calculations are provided in Appendix VI-D.1 of this Engineering Report. According to these calculations, the pressure exerted by the overlying waste for the expanded final condition will not cause excessive pressures on the liner system that could puncture the liner system. Furthermore, heavy construction equipment, such as a Caterpillar D6H Series II LGP and D6H Series II, operating over a minimum of a 1-ft thick layer of drainage layer/protective cover will not compromise the geomembrane via puncture or cause a bearing capacity failure of the underlying soil. Other vehicles with equal or lower ground pressures may also operate safely.

4.4.3 Stability

The veneer stability analysis of the vertical expansion liner system components, which is provided as Appendix VI-D.2 of this Engineering Report, was previously prepared for the Cell 6 Expansion and is described below. This analysis was performed in accordance with the USEPA technical manual entitled, “Solid Waste Disposal Facility Criteria” [USEPA, 1993], where the minimum recommended factor of safety against slope stability failure for permanent conditions is 1.5. For temporary conditions, the minimum recommended factor of safety against static slope stability failure is 1.25.

The veneer stability of the vertical expansion liner system components was evaluated using a two-part wedge analysis [Giroud and Beech, 1989]. The liner system has been designed to have a factor of safety for temporary conditions (i.e., during construction) of 1.25 against veneer failure. The results of the analysis show that the liner system can be placed over the full length of the sideslopes at once. Since the most critical condition for veneer stability is during initial waste placement, it is not expected that the additional waste placed over the liner will have an effect on the liner stability.

4.4.4 Settlement

Settlement of the vertical expansion liner system was calculated to demonstrate that: (i) the liner system design satisfies post-loading slope criteria; and (ii) the predicted settlement will not cause excessive straining of geosynthetic components. The liner system settlement was evaluated considering the final configuration of the landfill (loading) and the various underlying material layers (i.e., waste and soil). The settlement calculation is provided in Appendix VI-D.3 and the results are summarized below.
• The magnitude of calculated total liner settlement for Cells 1 through 6 ranges from 0 ft to 6.1 ft.

• Based on the post-settlement slopes, the largest expected drainage slope reduction along the leachate collection pipes (i.e., remaining slopes) is 1.6 percent. The largest expected drainage slope reduction along the liner slope (i.e., controlling slopes) is 0.7 percent. Both of these expected grade changes occur in the overlay liner area. In other areas, the reduction in drainage slope is generally less than 0.2 percent.

• The post-settlement drainage slopes along the leachate collection pipes (i.e., remaining slopes) are expected to be 0.5 percent or greater, while those along the liner slopes (i.e., controlling slopes) are expected to be two percent or greater (as shown in Appendix VI-D.3).

• The maximum liner strain is expected to be approximately 0.1%, much smaller than the typical yield strain of HDPE geomembrane (about 13%).

In conclusion, the design of the proposed liner system meets or exceeds the requirements of DRGSW.

4.4.5 Separation Distance between the Liner System and Groundwater

Based on the regional hydrogeology, the groundwater elevation at the DRPI Landfill property varies from approximately 5 ft-msl to 30 ft-msl in the existing Cells 1 through 3 (see the Hydrogeologic Report).

Based on the settlement calculation presented in Appendix VI-D.3, the projected settlement of the liner system for Cells 1 through 3 is less than 7 ft, while the liner system is placed at 30 to 40 ft above the groundwater table. Liner settlement in other areas is calculated to be less than 1 ft, whereas the minimum separation distance between the groundwater table and the liner system is 7 ft. Thus, the minimum separation distance between the liner system and the groundwater table is approximately 6 ft.
5 LEACHATE MANAGEMENT

5.1 Introduction

This section describes the design of the leachate management system. The impact of the vertical expansion on the existing leachate management system design was evaluated in accordance with the requirements of DRGSW §6.4. The following criteria were applied to evaluate the vertical expansion to the leachate management system.

- **DRGSW §6.4.1.1** – An industrial landfill shall be designed and constructed to have leachate collection system, a leachate treatment and disposal system, and a leachate monitoring system.

- **DRGSW §6.4.2.1.1** – The leachate collection system shall be designed to operate without clogging through the post-closure care period.

- **DRGSW §6.4.2.1.2** – All elements of the leachate management system shall be sized according to water balance calculations and be capable of handling peak flows.

- **DRGSW §6.4.2.1.3** – Leachate collection pipes shall be sized and spaced to efficiently remove leachate from the bottom of the waste and the side walls of the cells. The capacity of the collection mains shall be at least equal to the sum of the contributing laterals.

- **DRGSW §6.4.2.1.4** – The leachate collection and transmission pipes shall be designed to withstand the weight, stress, and disturbances from the overlying waste, waste cover materials, equipment operation, and vehicular traffic.

- **DRGSW §6.4.2.1.5** – The leachate collection pipes shall be designed to gravity drain to a sump system. Sumps shall function automatically and shall contain a leachate removal system.

- **DRGSW §6.4.2.1.6** – Manholes or cleanout risers shall be located around the perimeter of the leachate collection system. The number and spacing of the cleanouts shall be sufficient to ensure proper maintenance of the leachate collection system by water jet flushing or equivalent method.

- **DRGSW §6.4.2.1.8** – The leachate management system shall be designed to prevent the leachate head on the liner system from exceeding a depth of 12 in.

- **DRGSW §6.4.2.2.1** – The leachate collection system shall be installed immediately above an impermeable liner and at the bottom of the drainage layer/protective cover. The drainage layer/protective cover shall be no less than 12-in. thick with a hydraulic conductivity of not less than $1 \times 10^{-2}$ cm/s and a minimum post-loading slope of two percent on controlling slopes and 0.5 percent on remaining slopes.
• **DRGSW §6.4.2.2.3** – The leachate collection system and manholes or cleanout risers shall be constructed on materials that can withstand the chemical attack that results from exposure to leachate.

• **DRGSW §6.4.2.3.1** – The leachate collection system shall operate automatically whenever leachate is present in the sump to remove accumulated leachate.

The remainder of this section is organized as follows: (i) a description of the leachate management system components is presented in Section 5.2; and (ii) demonstrations that the expected performance of the leachate management system is in accordance with the applicable requirements of DRGSW are presented in Sections 5.3 through 5.5.

### 5.2 Leachate Management System Components

The vertical expansion leachate management system consists of three distinct but interrelated components: (i) leachate collection; (ii) leachate removal; and (iii) leachate transmission. Details of the leachate management system are shown on the Permit Drawings. As previously noted, the existing and proposed cells over which the vertical expansion will be located are graded to drain to low points, or sumps, where leachate collection pipes will discharge. The leachate collection system, which consists of a drainage layer/protective cover, underlain by a geocomposite or geotextile, with a network of collection corridors, is designed to: (i) operate without clogging and withstand the expected waste loading and chemical impacts from leachate; (ii) handle the anticipated leachate flows; and (iii) be periodically cleaned. The leachate removal system is designed to function automatically based on the head of leachate in the collection sump. The leachate removal pumps will transfer the liquid to the existing leachate transmission forcemain that connects to the existing on-site leachate storage tank. In total, the leachate management system will prevent the leachate head on the liner system from exceeding 12 in.

### 5.3 Leachate Collection System

#### 5.3.1 Introduction

The purpose of the leachate collection system is to continue to route leachate from the waste to leachate collection sumps. As noted in Section 4, the composite liner system will continue to be graded such that leachate will gravity drain to the sump. The leachate will be transmitted through the drainage layer/protective cover layer into a series of leachate collection trenches. Each of these trenches discharges leachate to the collection sump.
5.3.2 Leachate Collection System Layout

The layout of the leachate collection system is shown on the Permit Drawings. As shown, leachate drains by gravity from all portions of the landfill to leachate drainage corridors that consist of either: (i) a multilayer geonet; or (ii) an 8-in. diameter HDPE pipe, depending on the volume of leachate the corridor is designed to convey. These drainage corridors convey the leachate to leachate collection sumps.

5.3.3 Leachate Generation

Leachate generation rate estimates were calculated using USEPA’s Hydrologic Evaluation of Landfill Performance (HELP) Model, Version 3.07 [USEPA, 1997]. Experience on similar projects has shown that the HELP Model tends to overestimate leachate generation rates as compared to those measured in the field. Therefore, use of the results from the HELP Model will result in a conservative design for the leachate collection system.

The previous calculation conducted for the Cell 6 lateral expansion showed that the estimated maximum daily volume of leachate in Cell 6 is approximately 31,000 gpd. This volume was calculated assuming that 15 acres will be in open condition and 70 acres will be in intermediate condition. The maximum head on the liner at this leachate production rate is 0.33 in. Geosyntec re-evaluated the leachate generation rates for the vertical expansion condition, assuming a waste thickness ranging from 10 to 180 ft. The analysis shows that the leachate generation for the proposed vertical expansion is less critical than the condition previously analyzed for the Cell 6 lateral expansion. The updated leachate generation analysis is presented in Appendix VI-E.

5.3.4 Leachate Corridor Sizing

The leachate collection corridors were sized to handle the peak flow estimated from the HELP Model. As shown in the previous leachate management analysis conducted for Cell 6 lateral expansion, leachate corridor types A and E consist of a multilayer geonet as shown on the Permit Drawings. The multilayer geonet was used in these corridors in lieu of pipe because cleaning of these corridors would not be possible due to access limitations. The use of the multilayer geonet will eliminate the need for cleaning. Leachate Corridors B, C, and D consist of 8-in. diameter HDPE pipe surrounded by bedding material with a hydraulic conductivity of greater than 10^{-2} cm/s. The bedding material is designed to provide: (i) a highly permeable media that will rapidly convey leachate to the leachate collection pipe; (ii) open spaces to resist clogging; and (iii) structural support for the leachate collection pipe. Leachate pipe flow capacity was also verified to be sufficient. Each leachate corridor that contains a pipe will have a cleanout riser. Because leachate generation rates for the proposed vertical expansion are less critical than the condition
previously analyzed, the original leachate management design is considered to have sufficient capacity.

5.3.5 **Leachate Sump Sizing**

Leachate from the Cells 1-3 lined area will be conveyed to the existing Cell 6 sump. Details of the Cell 6 leachate collection sump are shown on the Permit Drawings. The sump consists of an 18-in. diameter HDPE SDR-17 sideslope riser with a perforated end section surrounded by a 20-ft long by 9-ft wide by 3-ft high volume of AASHTO No. 57 aggregate. The aggregate serves as the main storage media for leachate prior to being pumped out of the sump. Previous leachate management analyses show that there is sufficient storage volume in the sump and waste to store an excess of three days of leachate without breaching above the perimeter containment berm.

5.3.6 **Effects of Settlement**

*Introduction*

Due to the fact that the Cells 1-3 liner system will be constructed over existing waste, the effect of settlement on the liner system must be evaluated to ensure that leachate continues to be collected effectively and leachate head remains within acceptable limits throughout the post-closure care period of DRPI Landfill. In this section, a description of the effects of settlement on the proposed leachate collection system is presented. Detailed settlement calculations are included as Appendix VI-D.3 and described in Section 4.4.4 of this Engineering Report.

*Post-Settlement Liner Grades*

The maximum expected head of leachate on the liner is a function of several factors including: (i) the maximum length of flow in the drainage layer/protective cover before reaching a leachate corridor; (ii) the permeability of the drainage layer/protective cover; (iii) the slope of the liner system; (iv) the rate of impingement of leachate on the liner; and (v) the total settlement that will occur over the disposal period and post-closure care period. Because settlement of the existing, underlying waste may affect the slope of the liner system, post-settlement grades must be considered for long-term performance of the leachate collection system. As shown in the settlement calculations, under worst case conditions, the leachate collection system will retain a minimum positive grade of two percent towards the leachate collection piping. Therefore, leachate will continue to flow into the leachate corridors and the leachate removal sump throughout the disposal and post-closure care periods.

*Post-Settlement Leachate Head*

The maximum anticipated head of leachate on the liner system was obtained from the HELP Model assuming intermediate cover over 30 ft of waste. Based on this calculation, the post-settlement
slopes in these areas are adequate to provide collection of leachate and to minimize the head of leachate on the liner. The calculations, presented in Appendix VI-E and in the Cell 6 lateral expansion calculations, show that the leachate head on the liner remains less than 12 in. throughout the disposal and post-closure care periods.

5.4 Leachate Removal System

The leachate removal system consists of the components used to transport leachate from the leachate collection sump to the existing leachate forcemain. Details of the leachate removal system are shown on the Permit Drawings. The leachate removal system consists of pumps and sloped HDPE riser pipes, as well as miscellaneous floats, flow meters, valves, and other control devices.

Leachate removal pumps will transmit leachate from the sump to the existing leachate forcemain. Leachate will continue to be removed from leachate collection sumps using submersible pumps that are explosion proof and are capable of being operated either automatically or manually. The leachate removal pump will typically be operated in the automatic mode. In this mode, the pump will be controlled by level sensors.

An 18-in. diameter HDPE SDR-17 solid-wall riser pipe with a perforated end section that extends into the leachate sump will continue to provide access to the leachate collection sump from the top of the perimeter berm. The relationship of the existing riser, sump, and perimeter berm is shown on the Permit Drawings.

Above-ground controls were installed and are currently operational near the upper end of the leachate riser pipe for the installation of flow meters and necessary valves. Flow meters will continue to be used to measure the quantity of leachate passing through the leachate removal system. Flow will continue to be measured at the leachate collection system discharge line to the leachate forcemain. Details of these controls are shown on the Permit Drawings. Check valves will continue to be used to prevent backflow through components of the system that are designed to transmit flow in only one direction. A check valve is installed downstream of the flow meter and the leachate removal pump. A gate valve is used as an on/off valve to control flow through a pipe. The gate valve was installed to facilitate the removal or replacement of the pump, flow meter, or other valve without requiring shutdown of the leachate removal system.

5.5 Leachate Transmission System

The leachate transmission system consists of piping, flow meters, and valves that are used to transmit the leachate from the leachate riser piping to the existing leachate forcemain, and eventually to the existing leachate storage tank. The layout of the leachate transmission system is shown on the Permit Drawings.
The leachate transmission forcemain is 4-in. diameter HDPE pipe. The pipes are designed to resist damage due to overburden stress, flexure, chemical attack, clogging, and freezing, and are designed to transmit the maximum quantity of leachate that is generated at any time throughout the life of the vertical expansion.
6 LANDFILL GAS MANAGEMENT SYSTEM

6.1 Introduction

A permitted active landfill gas management system (system) is used to control landfill gas (LFG) at the landfill. The existing system comprises vertical extraction wells and horizontal collectors connected via a transmission piping network to a central blower/flare station. This section describes the design approach to upgrade and expand the existing system to control the increased quantity of LFG expected to be associated with the vertical expansion. The expanded system was designed in accordance with the requirements of DRGSW §6.5. The following design criteria were applied.

- DRGSW §6.5.1.1 - An industrial landfill shall have an LFG management system if LFG generation is expected.
- DRGSW §6.5.1.2.1 – The LFG shall be managed to evacuate gas from within the waste to prevent the accumulation of LFG on-site or off-site.
- DRGSW §6.5.1.2.2 – The LFG management system shall be designed and constructed to prevent and control damage to vegetation.
- DRGSW §6.5.1.2.3 – The LFG management system shall be designed and constructed to prevent odors from being detected at the landfill property boundary in sufficient quantities to cause or create a condition of air pollution.
- DRGSW §6.5.2.1 – Both active and passive LFG management systems shall be considered and an evaluation of the proposed system shall be provided.
- DRGSW §6.5.2.2 – An analysis of the spacing of gas control features to provide an effective system shall be performed.
- DRGSW §6.5.2.3 – The LFG management system shall be designed to remove gas from all levels within the waste.
- DRGSW §6.5.2.4 - The LFG management system shall not interfere with or cause failure of the liner or leachate systems.
- DRGSW §6.5.3.1 – A sufficient number of LFG monitoring wells shall be installed to evaluate LFG production rates in the landfill.

The remainder of this section is organized as follows: (i) a description of the expanded system components is presented in Section 6.2; and (ii) demonstrations that the expected performance of the expanded system is in accordance with the applicable requirements of DRGSW are presented in Section 6.3.
6.2 Landfill Gas Management System Components

LFG generated by both the existing waste and waste to be disposed of in the proposed vertical expansion will be extracted by application of vacuum to the LFG collection components located within the footprint of the landfill. Currently, LFG generated at the landfill is actively collected via a blower/flare station located at the northwest corner of the site. In 2018, DRPI installed an additional flare at the facility; the combination of the existing blower/flare station and the 2018 flare will have sufficient capacity to handle the increase in LFG production expected as a result of the vertical expansion. The expanded LFG collection system will therefore utilize the expanded blower/flare station (with the additional flare), but will add additional components to manage LFG underneath the overlay liner to Cells 1-3, within the remaining undeveloped areas in the Petrillo waste area (i.e., Cell 6-2B), and in the vertical expansion. The components of the expanded system are as follows:

- vertical gas extraction wells;
- horizontal gas collection trenches;
- vertical conduits (i.e., stone columns) connected to horizontal gas collection trenches located in the Petrillo Waste;
- vertical gas extraction wells connected to remote wellheads via horizontal gas collection trenches located beneath the Cells 1-3 overlay liner;
- lateral LFG conveyance pipes (laterals); and
- a perimeter HDPE header pipe (header).

The design of each of the above components, as well as a description of how the design meets the requirements of DRGSW, is discussed in Section 6.3 below. Calculations supporting the LFG management system design are provided in Appendix VI-F.

6.3 Landfill Gas Management System Design

6.3.1 Gas Collection from Beneath the Cells 1-3 Overlay Liner

LFG will be collected from the existing waste in Cells 1-3, located underneath the proposed overlay liner, via: (i) conversion of existing vertical extraction wells located beneath the footprint of the overlay liner; and (ii) proposed horizontal gas collection trenches. This system is designed to protect the liner from damage caused by buildup of gas pressure underneath the liner before sufficient waste can be placed to counteract the uplift forces. This system will also provide protection to the vegetation of the east slopes of Cells 1-3 by preventing the lateral redirection of LFG flow from underneath the liner to the outside slopes.
The horizontal gas collection trenches will be connected to remote wellheads along the east slopes of Cells 1-3. This will enable separate control of the LFG flow from and vacuum applied to each type of collection device. These wellheads will in turn be connected to the proposed header, of varying diameter, that runs along the east inside perimeter of the waste footprint and conveys LFG to the flare station.

6.3.2 Gas Collection from the Petrillo Waste

The system for collecting gas from the former Petrillo Landfill (i.e., beneath the Cell 6 liner) was designed as part of a previous permit application for the landfill. Significant portions of that system have been installed to date, which on completion will include 13 vertical stone columns and a network of gas collection trenches. Each trench contains a perforated HDPE pipe to extract gas that may collect below the Cell 6 liner system. LFG from these collection devices is directed to the existing 10-in. diameter header located around the south end of the site. A portion of this header will be replaced with a 12-in. diameter header as part of the expansion of the LFG system. LFG directed to the existing/proposed header will be conveyed to the blower/flare station.

6.3.3 Gas Collection from Remaining Areas

LFG will be collected from Cells 4, 5, and 6, and the vertical expansion waste through a network of vertical extraction wells. The design for the expanded LFG collection system includes existing vertical extraction wells and proposed vertical extraction wells. A wellhead fitted with individual flow control and sample port(s) will be installed for each well. If needed, additional wells may be installed and added to the LFG system. Wells will be installed with a minimum 15-foot vertical offset from the top of the cell liner system to protect liner system components from damage due to installation. Vertical extraction wells will be installed with appropriate slotted pipe lengths to provide optimal radii of influence without excessive air entrainment through the cover or sideslopes. Based on differences in waste thickness, this slotted length varies depending on well location.

LFG collected by the vertical extraction wells will be conveyed to the header by lateral pipes, which will be installed to provide slope to the header. When completed, the header will run in a closed loop around the perimeter of the landfill. All transmission piping (i.e., header and laterals) will be buried in the landfill cover soil layer. If additional vertical extraction wells are required after the system is in place, these wells will be drilled and, depending upon the capacity of the transmission pipe, they will be either connected to an existing lateral or to a new lateral.
6.3.4 Condensate Management

Each horizontal lateral is sloped to drain into the header to minimize buildup of condensate. LFG condensate will be managed using four condensate traps situated at low points on the header. Where it runs over the limits of waste, the header will be installed at a minimum slope of three percent to minimize obstruction due to liquid buildup. The condensate traps will drain to leachate force mains located along the east and west sides of the perimeter of the landfill, and then to the leachate lift station. Calculations supporting the design of the condensate management system are provided in Appendix VI-F.

6.3.5 Gas Migration Monitoring

Twenty-four LFG migration probes currently used to monitor gas migration at the landfill will continue to be used as part of the monitoring network for the proposed expansion project. The locations of these probes are shown on the Permit Drawings.
7  STORMWATER MANAGEMENT SYSTEM

7.1  Introduction

This section describes the design of the stormwater management system associated with the vertical expansion. This stormwater management system was designed in accordance with the requirements of DRGSW §6.6, including the following criteria:

- **DRGSW §6.6.1.1** – The stormwater management system for an industrial landfill shall prevent erosion of the waste and cover.
- **DRGSW §6.6.1.2** – The stormwater management system for an industrial landfill shall prevent collection of standing water.
- **DRGSW §6.6.1.3** – The stormwater management system for an industrial landfill shall minimize stormwater runoff onto and into the waste.
- **DRGSW §6.6.2.1** – The stormwater management system shall be designed to control, at a minimum, the runoff from the discharge of a 2-hour, 10-year storm.
- **DRGSW §6.6.2.2.1** – The stormwater management system shall be designed to include detention basins to provide temporary storage of the expected stormwater runoff from the design storm with sufficient reserve capacity to contain accumulated precipitation and sediment prior to discharge.
- **DRGSW §6.6.2.2.2** – The stormwater management system shall be designed to include diversion structures designed to prevent stormwater runoff generated within the active cells from moving off site of the lined areas.
- **DRGSW §6.6.3.1** – The stormwater management system shall be designed to channel stormwater runoff from the active cells into the leachate treatment and disposal system.
- **DRGSW §6.6.3.2** – The stormwater management system shall be designed to channel stormwater runoff from closed cells to detention basins or other approved sedimentation control systems.
- **DRGSW §6.6.4** – The stormwater management system shall be designed such that discharge from the detention basins is in compliance with all applicable federal and state regulations.

Other applicable regulatory requirements pertaining to erosion and sediment control and stormwater management for the vertical expansion are contained in multiple state and local regulations. The following summarizes the governing regulations and the primary requirements contained in each regulation.
Natural Resources Conservation Service (NRCS) Practice Standard Pond Code 378 (effective September 2015), which requires that stormwater management basins be sized to convey the 24-hour, 25-year design storm for auxiliary spillway; Also, the sediment basin is required to pass the 24-hour, 25-year design storm with a minimum of 1-ft of freeboard between the design water surface elevation and the crest of the embankment for the dams with a drainage area greater than 20 acres. In addition, the primary outlet elevation must be at least 1 ft below the crest elevation of the emergency spillway for dams with a drainage area greater than 20 acres. If there is no emergency spillway, the required freeboard is 2 ft. An emergency spillway is required if the sediment basin cannot pass the peak flow expected from the design storm.

DNREC regulation 3.06.2.10 (effective April 2016) requires that detention practices meet the water quality routing requirements by controlling discharge rate. Detention practices shall be sized to store a volume equivalent to the Resource Protection storm (i.e., the runoff volume from the 1-year 2.7” Type II storm event) and be sized to detain the RPv for a minimum period of 24 hours, not to exceed 48 hours.

Delaware Erosion and Sediment Handbook (DNREC 3.06.1), which requires that stormwater structures be designed according to either local, state or NRCS standards, whichever is more stringent.

The remainder of this section is organized as follows: (i) an overview of the existing stormwater management system, drainage patterns, and relationship of the vertical expansion to the existing features are described in Section 7.2; (ii) a description of the erosion and sediment control and stormwater management aspects related to the vertical expansion are presented in Sections 7.3 and 7.4, respectively; and (iii) a description of the design basis and analysis results for the individual components of the stormwater management system are presented in Section 7.5.

7.2 Existing and Future Conditions

The existing sediment and stormwater management system at the DRPI Landfill was designed and constructed in support of Cells 1 through 6. Cells 1 through 6-2A have been constructed in accordance with the approved permit design plans. The final cells to be constructed, Cell 6-2 B and the rest of the Cells 1-3 Overlay, will be constructed according to the approved plans and the vertical expansion constructed over the entire footprint of Cells 1 through 6-2.

The predominant features of the existing system and proposed features associated with the vertical expansion are identified on the Permit Drawings and include downchutes, drainage terraces, and a herringbone cap with diversion berms. Existing stormwater management features include perimeter drainage channels, the East Sediment Basin (and engineered wetland), the West Sediment Basin, and associated basin outfalls. Proposed stormwater management features to support the vertical expansion design include gabion lined downchutes, and road-side channels.
The proposed design also includes modifications to existing features such as stormwater management pond inlet structures.

The existing site drainage patterns are characterized as follows:

- Runoff from the 146-acre cap (at approximate elevation of 190-ft) is conveyed via berms or swales that discharge directly from the top of the 3:1 landfill sideslopes to the base on all sides of the landfill.
- Runoff from the southeastern and eastern sides of the landfill (Cells 1 through 4) is conveyed via an existing perimeter drainage channel and road culverts into the East Sediment Basin.
- Runoff from the southwestern and western sides of the landfill (Cell 5, Cell 6-1, and Cell 6,2A) is conveyed via an existing perimeter drainage channel and road culverts into the West Sediment Basin.
- Offsite areas located to the south of the site (Cells 1 and Cell 6-1) generally drain toward the west, discharging to a tidal marsh area.
- Outflow from the East Sediment Basin is controlled by a multi-stage outlet riser structure, which discharges into an engineered wetland. The wetland discharges over a broad crested weir and into a 60-in. diameter reinforced concrete pipe (located beneath Interstate 495), which in turn discharges directly to the Christina River.
- Outflow from the West Sediment Basin is controlled by a multi-stage outlet riser structure, which discharges into a box culvert located under an abandoned railroad bed. The box culvert in turn discharges to a tidally-influenced pool connected to the Christina River via a culvert beneath Interstate 495.

Development related to the vertical expansion will not disturb any new area beyond the currently permitted waste disposal limits (i.e., Cell 1 through Cell 6-2). Further, the drainage areas associated with the current landfill permit are generally maintained with runoff from the landfill intermediate and final cover slopes being directed to either the East Sediment Basin or the West Sediment Basin. The location and/or size of some previously designed stormwater management features, including sideslope terraces, downchutes, road culverts, and perimeter drainage channels are slightly modified to conform to the vertical expansion grading plans and runoff volume conveyance requirements. The proposed post-development drainage patterns and stormwater management features associated with the vertical expansion design are shown on the Permit Drawings.
7.3 Sediment and Stormwater Management Plan

7.3.1 Overview

For the purpose of this solid waste landfill vertical expansion permit application, Section 7.3.2 includes a general discussion of typical best management practices for sediment and stormwater control that are employed as part of the routine industrial waste landfilling operational practices. Separately, in the Sections 7.4 and 7.5 of this report, discussion of the post-development stormwater management plan drawings and computations are presented. Altogether, Section 7 of this report is intended to provide information consistent with a Sediment and Stormwater Management Conceptual Plan submittal to the Delaware Sediment and Stormwater Program.

Prior to initiating specific construction activities associated with implementation of the vertical expansion design, which are not directly associated with day-to-day operations of the industrial landfill, engineering plans, a design narrative, and an application for Sediment and Stormwater Management Plan Approval will be submitted to the Delaware Sediment and Stormwater Program. Those construction plans will include information regarding specific sediment and erosion controls for the construction activity that are consistent with applicable regulations and design standards at the time of permit application. Permanent stormwater management feature location and sizing on the construction plans will be consistent with design plans presented in this solid waste permit application.

7.3.2 Sediment and Stormwater Management for Operations

Sediment and stormwater management best management practices (BMPs) are temporary features or actions that are expected to change with site conditions and waste placement locations on the landfill. The intent of the temporary BMPs is to minimize soil erosion, minimize ponding water, and provide on-site control of sediment laden runoff from landfill operations. Typical structural and vegetative BMPs that may be implemented as part of landfill operations include: (i) silt fence; (ii) temporary sediment traps; (iii) permanent and temporary vegetation; (iv) temporary diversion berms; and (v) rock check dams. The routine implementation of BMP practices associated with routine waste placement operations is described within the Operation and Maintenance Plan for the site (Permit Application Part V).

In addition to the temporary BMPs associated with the changing site conditions, the two existing sediment basins, the East and West Sediment Basins are permanent site features that will remain in operation as sediment control devices throughout the duration of the landfill vertical expansion operations and final closure cap construction. These basins were originally designed to accommodate construction and operations associated with Cells 4, 5, and 6, and were reanalyzed and verified for this permit application to address stormwater control associated with the vertical expansion. Hydraulic analysis of the basins is discussed in Section 7.5 of this report.
To meet the freeboard requirements for the perimeter channels, the modifications of basin inlets are incorporated into the design. Details of the modifications are shown on the Permit Drawings.

7.4 Stormwater Management Plan

As described in the 5101 Delaware Sediment and Stormwater Regulations (DSSR) §10.3, management of stormwater quantity and quality are important components of site-wide stormwater management. The regulations also recognize that certain exceptional circumstances do exist, and case-by-case variances from the regulations may be granted by the approving agency. Stormwater from the vertical expansion will be discharged to a tidally influenced area of the Christina River. Therefore, stormwater water quantity control (i.e., design storm detention) is not evaluated as part of this project based on DSSR §3.2.2, which states:

“A project may be eligible for a waiver or variance of stormwater management for water quantity control if the applicant can demonstrate that...Provisions will be made or exist for a non-erosive conveyance system to tidewater by either a closed drainage system or by open channel flow that has adequate capacity to contain runoff events being considered as a requirement of these regulations.”

Channels that convey site runoff from the existing Sediment Basin outfalls to the Christina River in a non-erosive manner currently exist. Because the vertical expansion project will not significantly alter the drainage area or hydraulic function of each sediment basin, the existing channels are considered adequate and in compliance with the requirements of DSSR §3.2.2.

As defined by the DSSR, stormwater management for water quality control includes:

“...a system of vegetative, structural, and other measures that controls adverse effects on water quality that may be caused by land disturbing activities or activities upon the land.”

During construction and operation of the vertical expansion, erosion and sediment controls will be maintained, and temporary and permanent vegetation will be established. The combination of these activities will be the primary water quality control during operation. In its final configuration, the landfill cover system and stabilization area will incorporate a system of natural vegetation (i.e., permanent seeding) and the two existing sediment basins for water quality control. An analysis of the water surface elevation within each basin and the drawdown time during the 2.7-inch, 24-hour rainfall event, prepared in consideration of the proposed post-development drainage areas flowing to each existing sediment basin, is provided in Appendix VI-G.3.
7.5 Stormwater Management System Design

7.5.1 Overview

The post-closure stormwater management system design for the vertical expansion incorporates a series of conveyance and discharge features that direct runoff from the final cover system to either one of the existing sediment basins. The following is a list of the permanent stormwater management features analyzed or designed:

- Perimeter Drainage Channels and Culverts;
- Plateau Edge Diversion Berms;
- Sideslope Terraces;
- Cover System Downchutes; and
- Sediment Basins.

Supporting design calculations and analysis for these features are presented in Appendix VI-G and sub appendices, which include:

- Appendix VI-G.1: Selection of Post-Development Hydrologic Parameters;
- Appendix VI-G.2: Design of Stormwater Management Features; and

7.5.2 Stormwater Management Feature Design Basis

The design basis for each structural stormwater management feature is presented below.

Permanent stormwater management features associated with the vertical expansion include conveyance features (i.e., plateau edge diversion berms, sideslope terraces, downchutes, perimeter drainage channels and culverts) and discharge features (i.e., sediment basins). In general, the site-wide stormwater management system is designed to convey and discharge stormwater based on the following criteria:

- stormwater conveyance features are sized to convey the peak discharge resulting from the 24-hour, 25-year design storm without overtopping, which exceeds the requirements of DRGSW §6.6.2.1 (i.e., features must convey 2-hour, 10-year design storm);
- stormwater conveyance and discharge feature linings are designed to be stable during the 24-hour, 25-year design storm discharge;
- sediment basins are verified to conform to detention practices design in the requirements of DNREC 3.06.2.10; and
stormwater discharge features are sized to detain and convey the 24-hour, 25-year design storm, in accordance with the requirements of NRCS Pond 378 regulations.

7.5.3 Stormwater Management Feature Design and Analysis Results

Sideslope terraces, plateau edge diversion berms, downchutes, and perimeter drainage channels and culverts each provide a means of intercepting and transmitting runoff in a controlled manner at non-erosive velocities. These features are designed based on consideration of required flow capacity, and resistance to erosion. Design analyses were calculated using equations for open channel flow, velocity, and tractive stress, presented in Appendix VI-G.2 and the results are as follows.

The calculated maximum flow depth within sideslope terraces, downchutes, and perimeter drainage channels stormwater conveyance features during the 24-hour, 25-year design storm are:

- sideslope terraces: 1.23 ft;
- plateau edge diversion berms: 1.52 ft
- downchute: 0.58 ft; and
- perimeter drainage channels: 3.05 ft.

Cross-section geometries for each channel and downchute are shown on the Permit Drawings and summarized in Appendix VI-G.2.

Sideslope terraces, downchutes, and perimeter drainage channels linings designed to resist the 24-hour, 25-year design storm erosive forces. Lining materials include:

- sideslope terraces: turf-reinforced matting and permanent vegetation;
- downchute: 1.5-ft thick gabion baskets backfilled with riprap ($d_{50} = 0.5$-ft); and
- perimeter drainage channels: turf-reinforced matting and permanent vegetation.

Lining materials for each channel and downchute are shown on the Permit Drawings and design analysis provided in Appendix VI-G.2.

Stormwater discharge features are constructed to safely detain and discharge runoff in a non-erosive manner from the Site. The existing East and West Sediment Basins provide detention and controlled release of stormwater to tidally influenced areas of the Christina River. For the vertical expansion, these features are analyzed for hydraulic performance during the 24-hour, 25-year design storm. Results of the analysis are as follows.

The maximum water surface elevations (WSE) are:
• East Sediment Basin maximum WSE: 22.5 ft; and
• West Sediment Basin maximum WSE: 24.9 ft.

Existing sediment basin inlets result in high water level in the perimeter channels, which does not meet the channel freeboard requirements of DNREC 3.06.1. Therefore, upgrades to the existing basin inlets are incorporated into the design to accommodate the required freeboard for the perimeter channels. Details are provided on the Permit Drawings and computations presented in Appendix VI-G.3.
8 FINAL COVER SYSTEM

8.1 Introduction

This section describes the design of the final cover system associated with the vertical expansion. This final cover system was designed in accordance with the requirements of DRGSW §6.8. The following criteria were applied to the design of the final cover system.

- **DRGSW §6.8.1.1** – Upon closure of an industrial landfill, a final cover system shall be installed that will control the emission of LFG, promote the establishment of vegetative cover, and minimize infiltration and percolation of water into, and prevent erosion of, the waste throughout the post-closure care period.

- **DRGSW §6.8.1.3** – The final cover system shall extend beyond the edge of the lined area.

- **DRGSW §6.8.2** – The final cover system shall consist of at least the following.

  a. **§6.8.2.1** - A 6-in. thick (minimum) final grading layer to attain the final slope and provide a stable base for subsequent final cover system components. Daily and intermediate cover may be used for this purpose.

  b. **§6.8.2.2** - A 30-mil thick geomembrane underlain by a geotextile, or 24-in thick layer of clay, with a hydraulic conductivity of $1 \times 10^{-7}$ cm/s, or depth of equivalent material having a hydraulic conductivity less than $1 \times 10^{-7}$ cm/s.

  c. **§6.8.2.3** – The final cover system shall consist of the following:

     1. 18-in. thick layer of soil to provide rooting depth and moisture for plant growth; and

     2. 6-in. thick layer of topsoil, or other approved material, to support vegetation.

     3. A suitable layer of alternative material or combination thereof to assure adequate rooting and moisture retention to support the proposed vegetation.

- **DRGSW §6.8.3.1** – The grades of the final slope of the landfill shall be constructed in accordance with the following minimum standards.

  1. The final grade of the top slope, after allowing for settlement and subsidence, shall be designed to promote stormwater runoff;

  2. The final grade of the sideslopes shall be a maximum of 3 horizontal to 1 vertical (3H:1V).

- **DRGSW §6.8.3.2** – The top and side slopes shall be maintained to prevent erosion of the final cover system and to insure complete vegetation cover.
The landfill final grades will be surveyed to confirm that the minimum slope (i.e., 4% at the flat portion of the landfill) as well as the maximum slopes (i.e., 3H:1V on the sideslopes) are achieved prior to installing the final cover system. The remainder of this section is organized as follows:

- a description of the final cover system components is presented in Section 8.2;
- an analysis of the hydraulic performance of the final cover system is presented in Section 8.3;
- an analysis of the stability of the final cover system is discussed in Section 8.4;
- a discussion regarding the impact of settlement on the final cover system is presented in Section 8.5; and
- the durability of the final cover system is discussed in Section 8.6.

### 8.2 Description of Final Cap System

The DRPI Landfill final cover system design meets the requirements of DRGSW §6.8. A cross-section of the proposed capping system is provided on the Permit Drawings. The final cover system will be constructed over all areas where waste disposal activities have permanently ceased. The final cover system geometry for the DRPI Landfill will consist of four percent slopes along the top of the landfill. Based on settlement analyses presented in Section 8.5, this will provide drainage off the top slope (as required by DRGSW § 6.8.3.1.1) after settlement has occurred. On the sideslopes, the final cover system will be constructed at a maximum slope of 3H:1V (as required by DRGSW § 6.8.3.1.2), with drainage terraces approximately every 30 ft of change in elevation. At the toe of the landfill, the final cap system will tie into the liner system.

The components of the proposed final cover system are presented below, listed from top to bottom:

- 6-in. thick layer of vegetative growth material (topsoil or equivalent);
- 18-in. thick layer of granular borrow soil (vegetative rooting layer);
- 250-mil geocomposite drainage layer;
- 40-mil textured geomembrane; and,
- 6-in. thick layer of granular borrow soil (final grading layer) placed as daily or intermediate cover material.

An alternate final cap system may be used consisting of the following components, listed from top to bottom:

- 6-in. thick layer of vegetative growth material (topsoil or equivalent);
18-in. thick layer of granular borrow soil (vegetative rooting layer);
8 oz/s.y non-woven geotextile filter layer;
50-mil combination HDPE or LLDPE geomembrane/drainage layer (130-mil); and
6-in. thick layer of granular borrow soil (final grading layer) placed as daily or intermediate cover material.

The existing final clay cover over the sideslopes on the east side of Cells 1-4 and north side of Cell 4 will be left in place and the proposed geomembrane cap will tie in to the clay liner. The extent of the existing clay cover is provided in a drawing entitled “Capping Inventory” by Vandermark and Lynch, dated 31 August 1999.

8.3 Hydraulic Performance

One of the primary functions of the final cover system is to control the infiltration of precipitation into the landfill. In this section, the hydraulic performance of the final cover system is evaluated based on its ability to prevent the infiltration of stormwater into the landfill. The adequacy of the design of the drainage and filter components of the final cover system for the proposed vertical expansion is verified by the design analysis presented in Appendix VI-H.1. In the following paragraphs, the methods, assumptions, and the results of the calculations are discussed.

Leakage through the cover system was estimated for the 3H:1V sideslopes and the four percent top slopes of the DRPI landfill final cover system. The effectiveness of the geomembrane as a hydraulic barrier is a function of its hydraulic conductivity and is directly proportional to the hydraulic head of liquid acting on the geomembrane. The hydraulic head of water acting on the geomembrane is directly related to the precipitation remaining within the final cover system materials and can be calculated through consideration of the water balance of a specific volume of final cover system material.

The water balance for the final cover system was evaluated using USEPA’s Hydrologic Evaluation of Landfill Performance (HELP) computer model [USEPA, 1991] using synthetically generated precipitation data for the vicinity. The hydraulic head of water acting on the geomembrane was calculated for the four percent top slopes of the cap system using the HELP model. The maximum hydraulic head above the geomembrane and the impingement rate of water into the drainage layer was calculated using the HELP model. As shown in the analysis, the heads above the geomembrane component of the proposed (40-mil conventional geomembrane) and alternative (50-mil geomembrane/drainage layer combination) final cover systems are 0.039 and 0.008 inch (annual average value), respectively, which are less than the thickness of the drainage layer (0.13 inch). The rate of leakage through the geomembrane impermeable layer was also evaluated by the HELP model. For the final cover system top slopes inclined at two percent, the HELP model
predicts a percolation rate of 0.0071 inch out of a 40.7 total annual precipitation for the worst case of the two alternatives of the final cover system, which provides a hydraulic efficiency for the cap system top slope of 99.98 percent.

8.4 Stability

8.4.1 Final Cover System Veneer Stability

The final cover system must be stable when subjected to conditions anticipated during the post-closure period. Slope stability of the final cover system is a function of the following factors: (i) the final cover system soil properties; (ii) the interface shear strength between various components of the final cover system; (iii) the slope length and angle of inclination; and (iv) the forces due to hydraulic head on the impermeable layer of the cover system (i.e., seepage forces).

The final cover system consists of layers of geosynthetic and soil materials that are placed parallel to the final landfill grades. The Stability of the sideslope layers against downslope, veneer-type movements was analyzed using the two-part wedge analysis presented by Giroud and Beech [1989]. Slope stability analyses for the final cover system require shear strength parameters for the weakest interface or material within the final cover system. For final cover systems with 3H:1V sideslopes, experience indicates that the weakest interface or material within these components is likely to be one of the following: (i) interface between the vegetative rooting layer and the geocomposite; (ii) interface between geocomposite and textured geomembrane; or (iii) interface between textured geomembrane and the final grading layer. The calculations conducted for the proposed vertical expansion are included as Appendix VI-H.2. The two alternatives of the final cover system configurations were analyzed. As shown in the Appendix VI-H.2, the factors of safety obtained from the analyses are 1.29 or greater for the 3H:1V sideslopes of the DRPI Landfill and are therefore greater than the minimum required factor of safety of 1.25.

8.4.2 Global Landfill Stability

According to the technical manual published by the USEPA entitled, “Solid Waste Disposal Facility Criteria” [USEPA, 1993], the minimum recommended factor of safety against slope stability failure for permanent conditions is 1.5. For the temporary conditions, the minimum recommended factor of safety against static slope stability failure is 1.25. In general, waste placement is a temporary condition; therefore, the recommended minimum factor of safety during waste placement is 1.25. For long-term conditions, after waste placement has ended, a minimum factor of safety of 1.5 is used. Under seismic condition, the minimum recommended factor of safety is 1.0, based on the USEPA Guidance entitled RCRA Subtitle D (258) Seismic Design Guidance for Solid Waste Landfill Facilities [Richardson, et al., 1995]
Four sections located in the expansion area were selected for analysis (i.e., A-A through D-D). These cross sections were selected to take into consideration unique features of the landfill geometry and foundation stratigraphy (e.g., thickness of existing waste, and thickness of the underlying clay and sand layers). Stability analysis results for intermediate and long-term conditions for the analyzed cross sections are presented in Appendix VI-H.3.

As shown in Appendix VI-H.3, of all the cross sections analyzed, the lowest factor of safety for short-term condition is 1.26, which corresponds to a block slip surface at Section D-D. Similarly, the calculated lowest factor of safety for long-term conditions is 1.64, which corresponds to potential sliding along the most critical base liner interface surface at Section C-C. For circular and general block failure, the lowest factor of safety under long-term condition was found to be 1.66, which corresponds to a circular slip surface at Cross Section D-D. All the calculated factors of safety are greater than 1.5 for the long-term condition, and 1.25 for the short-term condition. Thus, the stability criterion are satisfied. The maximum horizontal acceleration (MHA) in lithified earth material, with 2% probability of exceedance in 50 years for the DRPI Landfill site is estimated to be 0.0987g (g = gravitational acceleration), based on the 2014 United States Geological Survey (USGS) unified hazard tool. The peak acceleration with 2% probability of exceedance in 50 years is approximately equivalent to the one with 10% probability of exceedance in 250 years. Because this MHA is less than 0.1g, the site is considered not located within a seismic impact zone, according to the definition of seismic impact zone in Section 258.14 of RCRA Subtitle D regulations. Therefore, seismic loading is not considered in the slope stability evaluation.

8.5 Settlement

8.5.1 Introduction

In order to evaluate the performance of the final cover system, it is necessary to characterize settlement of the waste with respect to the following two factors: (i) overall compressibility; and (ii) localized heterogeneity. Settlement of the final cover system will occur over time due to compression of the waste under its own weight and under the additional load imposed by the final cover system. Settlement of the final cover system will also occur as a result of local heterogeneity of the underlying waste. The impact of settlement on the final cover system is primarily associated with the potential for elongation and tensile strain of the geosynthetic components of the final cover system due to differential settlements.

The maximum acceptable tensile strain for the final cover system is taken as that of the textured geomembrane, which is the final cover system component having the smallest value of allowable tensile strain. The other components of the final cover system are considered to be less susceptible to damage from tensile strain.
8.5.2 Overall Compressibility

The term “overall compressibility” refers to the area-wide settlement potential of waste when subjected to an increase in overburden stress. Settlement resulting from overall compressibility is assumed to be characterized by two components, a rapid primary settlement and a longer-term, time-dependent secondary settlement. The mechanisms involved in the overall settlement of industrial construction demolition debris are complex and include the following [Edil et al., 1990]:

- mechanical compression due to self-weight and surface loads;
- raveling (i.e., movement of fines into voids between larger waste particles);
- chemical changes including corrosion, oxidation, and combustion; and
- biodegradation under aerobic and anaerobic conditions.

A waste layer placed in a landfill cell experiences an immediate mechanical settlement (sometimes referred to as “primary” settlement) under its own weight and the weight of layers above it. This settlement is due to the compression and rearrangement of the waste particles and usually occurs rapidly, within days to months after the waste layer has experienced a new load [Sowers, 1973; NAVFAC, 1983; and Burlingame, 1985]. Mechanical settlement results from densification, compression, breakage, and rearrangement of waste materials. Raveling of fine particles into voids between larger waste particles also usually occurs rapidly. For practical purposes, it is commonly assumed that raveling occurs in conjunction with mechanical settlement.

After mechanical settlement has occurred, waste will continue to settle due to creep, chemical reactions, and, more importantly in industrial construction demolition debris, biodegradation. This time-dependent settlement is often referred to as “secondary” settlement. The rate of secondary settlement is usually assumed to be independent of load. The rate of secondary settlement is known to be dependent on waste composition, availability of moisture and oxygen, and temperature. Secondary settlement continues for many years after waste placement; through the post closure period, but the rate of secondary settlement decreases with time as the waste becomes more decomposed and stable.

The calculation of the settlement of the final cover system is presented in Appendix VI-H.4. As shown in Appendix VI-H.4, the maximum expected settlement is 5.5 ft. The maximum calculated grade reduction in the final cover system is 2.5 percent on the sideslope and 0.08 percent on the top slope. Finally, the maximum calculated strain is 0.17 percent. This value of tensile strain is well below the recommended maximum value of five percent for HDPE geomembranes [Berg and Bonaparte, 1993]. Therefore, the calculated tensile strains are not expected to damage the geomembrane.
8.5.3 Local Heterogeneity

Waste heterogeneity can impact the performance of the final cover system. As such, the impacts of the following should be considered in evaluating the performance of the final cover system: (i) buried appliances, or other hollow metal objects, that have a potential to collapse due to either increased overburden stresses or loss of strength due to rust or corrosion; and (ii) localized differences in waste compressibility. With respect to the potential for the collapse of an appliance, such as a refrigerator buried in waste, the Operation and Maintenance Manual (PMA Part V) specifies that such appliances will not be placed in the landfill or will be crushed prior to placement in the landfill. Therefore, local depressions due to the collapse of a buried appliance will not occur.

With respect to localized differences in waste compressibility, localized differential settlement of waste can result from the compression of adjacent hard and soft waste materials, for example, construction debris adjacent to yard waste. The likelihood of adjacent placement of hard and soft waste volumes, is, however, reduced by daily landfill operations, including waste compaction, waste spreading, and placement of operational cover soil. If, however, localized differences in compressibility do occur in the waste, then an analysis of the impact on the final cap system should account for the fact that any angular distortions (i.e., defined as the differential settlement between two points divided by the distance between the points) that occur at depth in the waste mass will tend to be attenuated as the settlements propagate upward to the top of the existing waste.

The development of a depression of significant size due to a locally compressible zone adjacent to the final cover materials is not likely based on modern waste management practices. To evaluate the tensile behavior of the geomembrane impermeable barrier should a depression occur within the waste, the size and depth of the compressible zone must be established. The size and shape of the local compressible zone for this analysis was estimated taking into account modern waste placement practices and the attenuation of any displacements occurring within the waste.

The calculation for tensile strain as a result of a local compressible zone is presented in Appendix VI-H.5. As shown in the appendix, the maximum strain is 3.45 percent, which is less than the maximum allowable strain recommended for HDPE geomembranes.

8.6 Durability

8.6.1 Introduction

Final cover system durability relates to the resistance of the final cover system to progressive deterioration and the ability of the cover system to withstand construction conditions, the effects of waste subsidence, and external environmental processes. The effects of waste subsidence were discussed in the previous sections. Construction activities that affect the final cover system include the operation of construction and hauling equipment that may apply concentrated stresses to the
geomembrane component of the final cover system. External environmental processes that may affect the durability of the final cover system include: (i) freeze-thaw cycles; (ii) erosion of the final cover soils; and (iii) vegetation. These issues, and the corresponding Sections in which they are addressed, are as follows:

- analysis of the impact of concentrated stresses is presented in Section 8.6.2;
- discussion of the impact of environmental freeze-thaw cycles is presented in Section 8.6.3;
- analysis of the impact of erosion is discussed in Section 8.6.4; and
- discussion of the impact of vegetation and potential root penetration is presented in Section 8.6.5.

### 8.6.2 Impact of Concentrated Stresses

Construction activities that may damage the geosynthetics include the operation of construction equipment that may apply to concentrated stresses on the final cover system. Final cover system soils containing large particles (i.e., gravel) may cause stress concentrations large enough to damage or puncture the geomembrane layer. The geomembrane of the final cover system will not be in direct contact with aggregate or any other materials that has a high risk of the geomembrane puncture failure. Additionally, the overburden pressures applied to the final cover geomembrane is much smaller compared to a geomembrane of the base liner system. Thus, potential for geomembrane puncture is considered low for the final cover system at the DRPI landfill. Nevertheless, Geosyntec conducted a Geomembrane puncture evaluation using the methodology proposed by Koerner [1994].

The ability of the geomembrane to resist puncture is dependent upon the stress applied to the geomembrane, the maximum particle size adjacent to the geomembrane and geomembrane strength.

The types of stresses that are expected to be exerted on the geomembrane component are due to:

- the weight and operation (i.e., starting and braking) of trucks and construction equipment; and
- the weight of the cover soil.

The magnitude of stress exerted on the geomembrane is dependent upon the thickness of overlying cover soil and the loads imposed. In Appendix VI-H.6, stresses due to a typical construction equipment CAT D6R are evaluated for construction and operational condition. For this evaluation, puncture resistance of combination HDPE/LLDPE geomembrane provided by manufacturer along
with conservative assumptions on soil particle sizes and angularity. A factor of safety of 27.6 was calculated for the construction loads, which is considered sufficient.

8.6.3 Impact of Freeze-Thaw Cycles

The effect of exposure to freezing temperatures on the properties of geomembranes has been investigated by Giroud and Peggs [1990]. Exposed geomembrane materials may experience high thermal expansion and contraction during temperature fluctuation and may become brittle under extremely cold temperatures. Therefore, geomembranes should be protected from freezing temperatures. The depth of extreme frost penetration for New Castle County, Delaware is approximately 20 in. The minimum soil thickness above the hydraulic barrier layer for any of the final cover system cross sections is 24 in. Since the minimum soil layer thickness is greater than the extreme frost penetration depth, freeze-thaw cycles should not have a detrimental impact on the proposed geomembrane impermeable layer.

8.6.4 Impact of Erosion

The critical location on the DRPI Landfill final cover system with respect to soil erosion is the 3H:1V landfill sideslopes. The degree of erosion is a function of several parameters including climate, type of topsoil, slope length, slope steepness, type of vegetation, and cover management practice. Because the landfill final slopes will be the same as the slopes of the existing permitted landfill, the erosion potential of the final cover system will not be more than the current permitted final cover system. Therefore, erosion potential is not addressed further in this report.

8.6.5 Impact of Vegetation

The topsoil in the final cover system will be vegetated with a grass and legume mix of high productivity. Once the vegetation is well established, the grassed cover will be maintained (i.e., mowed) on a regular basis in order to prevent the growth of woody vegetation. The 24-in. thick soil layer above the geomembrane should be thick enough to allow for the growth of the grass roots to their normal size. The roots of grassy vegetation are not expected to penetrate or otherwise detrimentally affect the geomembrane impermeable layer or any other component of the final cover system.
9 REFERENCES


FIGURES