



2017 Mid-Year Progress Report



USEPA PROJECT XL

Buncombe County Bioreactor Project

Buncombe County Solid Waste Management Facility

Alexander, North Carolina

November 2017



**CDM
Smith**

Table of Contents

Executive Summary	E-1
Section 1 Introduction.....	1-1
1.1 Site Description	1-1
1.2 Project Goals	1-3
1.3 Public Awareness.....	1-3
Section 2 Project Description	2-1
2.1 Retrofit Bioreactor System	2-1
2.1.1 Leachate Recirculation	2-1
2.1.2 Gas Collection	2-4
2.2 Build-As-You-Go Bioreactor.....	2-4
2.2.1 Leachate Recirculation and Gas Collection	2-4
2.2.2 Temperature Probes.....	2-4
2.3 Landfill-Gas-To-Energy	2-10
Section 3 Monitoring Program	3-1
3.1 Program Overview	3-1
3.2 Leak Detection	3-1
3.3 Leachate.....	3-2
3.4 Leachate Recirculation	3-3
3.5 Landfill Gas.....	3-3
3.6 Landfill Settlement	3-3
3.7 Landfill Temperature	3-3
3.8 Effective Waste Density	3-3
3.9 Cell 6 Landfill Gas Collection.....	3-3
3.10 Cell 6 Sump Data.....	3-3
Section 4 Collected Data	4-1
4.1 Leak Detection	4-1
4.2 Leachate Collection System.....	4-9
4.3 Leachate Recirculation	4-18
4.4 Landfill Gas.....	4-19
4.5 Settlement.....	4-20
4.6 Effective Waste Density	4-21
4.7 Temperature of Waste in Cell 6	4-23
4.8 Cell 6 Landfill Gas Collection.....	4-25
4.9 Cell 6 Sump Data	4-26
Section 5 Project Assessment	5-1
5.1 Leachate Detection and Collection Systems Analysis	5-1
5.1.1 Determination of Liquid Source in the LDZ.....	5-1
5.1.2 Leachate Quality	5-3
5.1.3 Leachate Pond	5-3
5.2 Gas Collection System and Gas Migration Control.....	5-4

5.3 Reduction of Leachate Hauling to the Wastewater Treatment Facility.....	5-4
5.4 Settlement of Waste in Cells 1 through 5.....	5-4
5.5 Relocation of Condensate Discharge Line in Cell 4.....	5-4
5.6 Operations in Cell 6 Build-As- You-Go Bioreactor	5-4
5.7 Waste Stabilization.....	5-5
5.8 Greenhouse Gas Reductions	5-7
5.9 Alternative Cover Material.....	5-8
Section 6 Stakeholders Meeting.....	6-1
6.1 September 2012 Stakeholders Meeting.....	6-1
6.1.1 Monitoring of the Alternative Liner System	6-1
6.1.2 Discharge Liquids from Cell 1 LDZ.....	6-2
6.1.3 Landfill Settlement.....	6-2
6.1.4 Liquid Addition in Cell 6.....	6-2
6.1.5 Gas Collection System.....	6-3
6.2 November 2016 Stakeholders Meeting.....	6-3
6.2.1 Review of Existing Bioreactor and System Operation.....	6-4
6.2.2 Recouped Airspace	6-4
6.2.3 Evaluation of Monitoring Data.....	6-4
6.2.4 Regulatory Issues	6-4
Section 7 Recommendations.....	7-1
7.1 Modifications to the Monitoring Program.....	7-1
7.1.1 Measuring Settlement	7-1
7.1.2 Water Balance Monitoring	7-1
7.1.3 Leachate Recirculation Impacts to Head on Liner	7-1
7.2 Recommended Modifications to Design and Operation.....	7-1
7.2.1 Leak Detection Zones.....	7-1
7.2.2 Strategy for Operation of Cell 6 HITs.....	7-2
7.2.3 Cells 1-5 HITs Maintenance	7-2

List of Tables

Table ES- 1 CO ₂ Equivalents of Methane Converted to Energy and Vehicle Emissions Offset	E-3
Table ES- 2 Renewable Energy Generated Converted to Equivalent Homes Energy	E-4
Table 2-1 Energy Generated by LFGTE Facility.....	2-10
Table 3-1 Monitoring Parameters and Frequencies.....	3-1
Table 4-1 Liquid Collected from LDZ	4-1
Table 4-2 Leachate Collected from Cells 1-6.....	4-9
Table 4-3 Leachate Recirculation Volumes	4-19
Table 5-1 Carbon Monoxide Readings in Cell 6 HITs	5-5
Table 5-2 Carbon Credits Registered	5-8

List of Figures

Figure ES-1 Gallons Recirculated Compared with Truck Hauling Cost Savings	E-2
Figure ES-2 Truck Hauls vs. Recirculation.....	E-2
Figure ES-3 Settlement in Cells 1 through 5 since November 2010.....	E-3
Figure 1-1 Buncombe County Solid Waste Management Facility.....	1-2
Figure 2-1 Retrofit Bioreactor System	2-1
Figure 2-2 Horizontal Injection Trench Detail.....	2-2
Figure 2-3 Surficial Gravity Trench Detail.....	2-3
Figure 2-4 Vertical Gas Well Collection System in the Retrofit Area.....	2-5
Figure 2-5 Landfill Gas Projections Using Land GEM Model.....	2-6
Figure 2-6 Build-As-You-Go Bioreactor System.....	2-7
Figure 2-7 Horizontal Injection Trench Installation in Cell 6.....	2-8
Figure 2-8 Temperature Sensors in Cell 6	2-9
Figure 2-9 Installation of Thermocouples in Cell 6	2-9
Figure 2-10 Inaugural Ribbon Cutting Ceremony.....	2-10
Figure 4-1 Semi-Annual Leak Detection Volumes.....	4-2
Figure 4-2 pH	4-3
Figure 4-3 Specific Conductance.....	4-4
Figure 4-4 Oxidation Reduction Potential	4-5
Figure 4-5 BOD5	4-6
Figure 4-6 COD	4-7
Figure 4-7 Ammonia	4-8
Figure 4-8 Leachate Generation vs. Rainfall	4-10
Figure 4-9 BOD5 of Leachate.....	4-11
Figure 4-10 Specific Conductance of Leachate	4-12
Figure 4-11 COD of Leachate	4-13
Figure 4-12 Ammonia of Leachate	4-14
Figure 4-13 pH of Leachate	4-15
Figure 4-14 ORP of Leachate	4-16
Figure 4-15 TDS of Leachate.....	4-17
Figure 4-16 Cumulative Volume of Leachate Recirculated	4-18
Figure 4-17 Total Gas Flow and Percent Methane at the LFGTE Facility	4-19
Figure 4-18 Settlement Plates in Cells 1-5.....	4-20
Figure 4-19 Cumulative Settlement.....	4-21
Figure 4-20 Settlement in Cells 1 through 5 since November 2010.....	4-22
Figure 4-21 Temperature Sensors in Cell 6	4-23
Figure 4-22 Waste Temperature Readings in Cell 6.....	4-24
Figure 4-23 Temperature of Waste at Various Depths in Cell 6.....	4-24
Figure 4-24 Average Percent Methane in HITs 6A, 6D, and 6E.....	4-25
Figure 4-25 Flow Rate in HITs 6A, 6D, and 6E	4-26
Figure 4-26 Cell 6 Sump Level, Recirculation Events, and Rainfall.....	4-27
Figure 5-1 Leak Detection Zone in Cells 1-6 and Leachate Pond.....	5-1
Figure 5-2 Conductance of Leachate, LDZ, and GW Samples.....	5-2
Figure 5-3 Toluene of Leachate, LDZ and GW/SW Samples	5-2

Figure 5-4	ORP of LCS and LDZ.....	5-3
Figure 5-5	Exhumed Waste from Drilling of Vertical Well 24.....	5-6
Figure 5-6	Exhumed Waste from Drilling of Vertical Well 13.....	5-6
Figure 5-7	BOD5/COD Ratio of LCS in Cells 1-6	5-7
Figure 6-1	An Option Discussed at the Stakeholders Meeting for Cell 6 HIT Operation.....	6-3
Figure 7-1	Revised LDZ Design.....	7-1

2017 Mid-Year Bioreactor Progress Report

Executive Summary

Introduction

The Buncombe County Solid Waste Management Facility is located in the mountains of western North Carolina, approximately nine miles north of the City of Asheville. The 557-acre solid waste management facility opened in 1997 with a Subtitle D landfill disposal area that comprises approximately 100 acres. Under the United States Environmental Protection Agency's Project XL, Buncombe County is operating a combined leachate recirculation and gas recovery system at its Subtitle D landfill. The purpose of the project is to determine if liquid addition has any adverse effects on alternative liner systems. The County is also monitoring the effects of liquids addition on waste density and settlement to determine if it is increasing the life of the landfill and gas generation for energy production. This project differs from other Project XL projects in that it is a full-scale project that is being operated over an extended period of time. This project was granted regulatory flexibility to apply water sources other than leachate to the waste and to apply water sources to the waste in landfill cells with alternative liners. To date, only leachate has been used since there has been adequate leachate available onsite to meet the needs of the project. Although application at the working face is allowed it has not been employed in the bioreactor operation and there are no plans to use it going forward. Additional water sources may be required after the build-as-you-go system is in full operation due to the additional capacity for receiving leachate.

Operation of Cell 6 Horizontal Injection Trenches (HIT)

Based on the discussions held at the 2012 stakeholders meeting, it was decided that some of the HITs would be dedicated to leachate recirculation and others would be dedicated to gas collection in order to maximize early gas capture in Cell 6.

The strategy currently being utilized is to recirculate in HITs 6A and 6B and collect landfill gas from HITs 6C, 6D, and 6E while evaluating landfill gas quality and flow to determine their effectiveness. Landfill gas monitoring data for HITs 6A, 6D, and 6E collected in 2014 and 2015 indicate a high percent methane and good flow. Therefore, landfill gas collection should continue from the HITs. In addition, Buncombe County has been moving toward doing injections year-round in Cell 6.

Data collected from April 2015 through September 2015 for the Cell 6 sump indicates no effect on the sump levels from the recirculation events. This data will continue to be collected and analyzed in future reports.

Cells 1-5 Slope Changes

Buncombe County has received approval to steepen the slopes in Cells 1-5 from 4H:1V sideslopes to 3H:1V sideslopes. This will allow airspace to be recaptured due to settlement from the bioreactor. Work began in the second half of 2017 and will be further discussed in the 2017 year-end progress report.

Benefits of the Bioreactor Program

Approximately 6.3 million gallons of leachate has been recirculated since the program began, resulting in 1,268 less truck trips to the wastewater treatment plant (WWTP). That has provided a savings of \$483,630.93 in avoided hauling costs as shown in **Figure ES-1** below. With the expansion of the leachate recirculation system into Cell 6, the largest cell of the landfill, the amount of leachate that can be recirculated is significantly increased. **Figure ES-2** shows the recirculated leachate in equivalent truck hauls compared with rainfall.

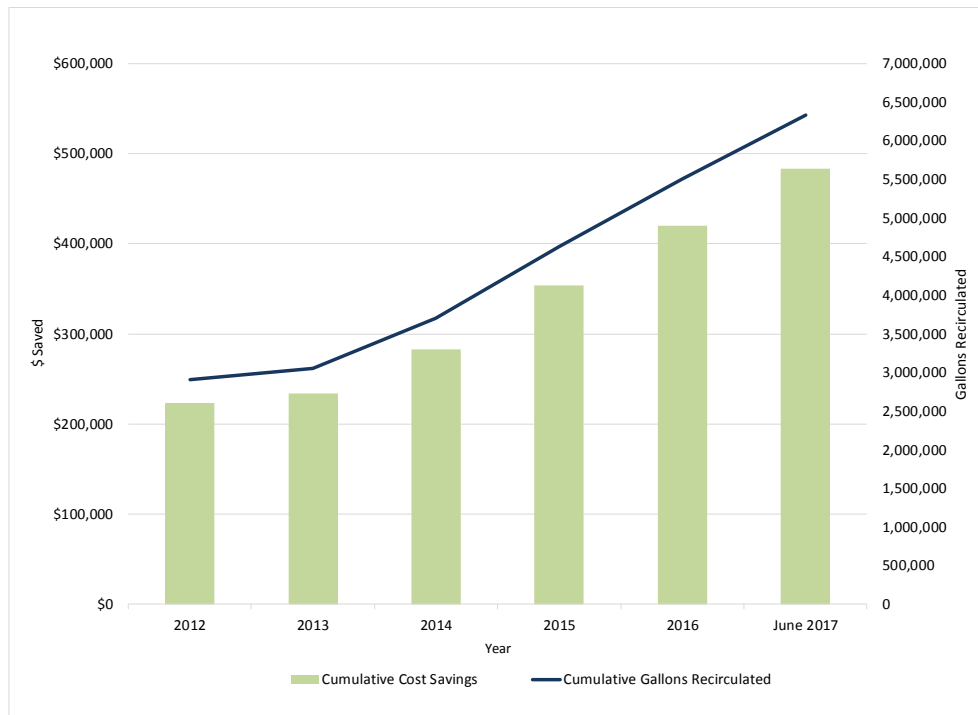


Figure ES-1: Gallons Recirculated Compared with Truck Hauling Cost Savings

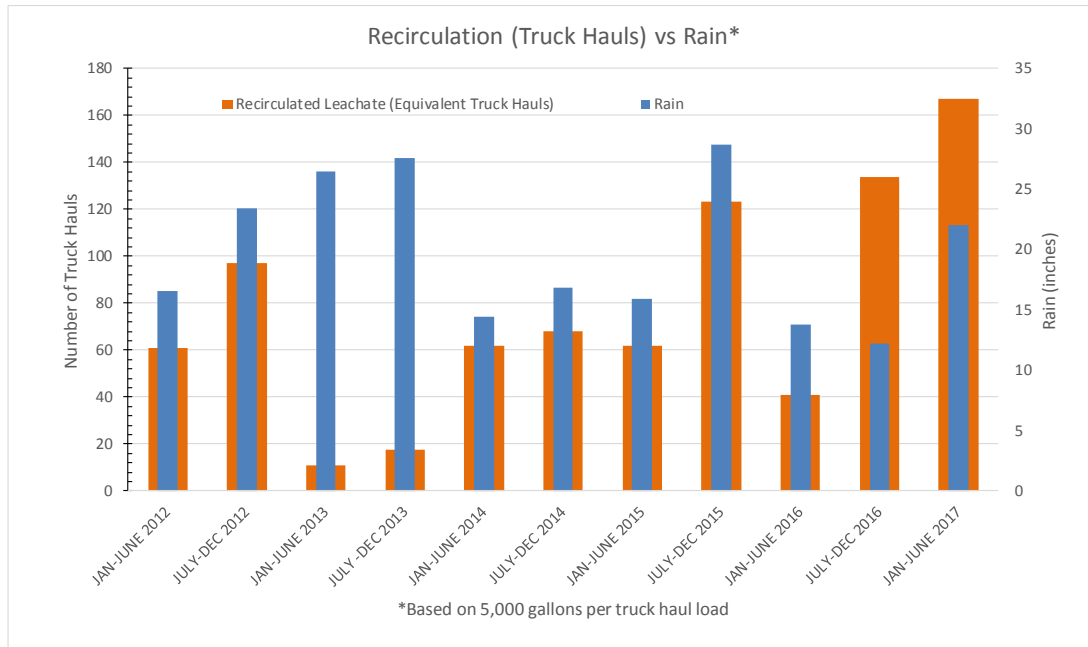


Figure ES-2: Truck Hauls vs. Recirculation

Settlement plates installed in Cells 1-5 show an average settlement of 1.72 ft. from January 2006 to July 2017. Comparison of topographic surveys of Cells 1-5 taken in 2010 and 2016, show 0-1 ft. settlement on the slopes and 1-8.5 ft. settlement over the waste plateau as shown in **Figure ES-3** (see also Figure 4-20). The prominent settlement areas correspond with the locations of the recirculation trenches but also benefit from stormwater that is captured on the waste plateau. The settlement in Cells 1-5 is estimated to be approximately 51,000 cy which is equivalent to five months of capacity valued at nearly \$2 million.

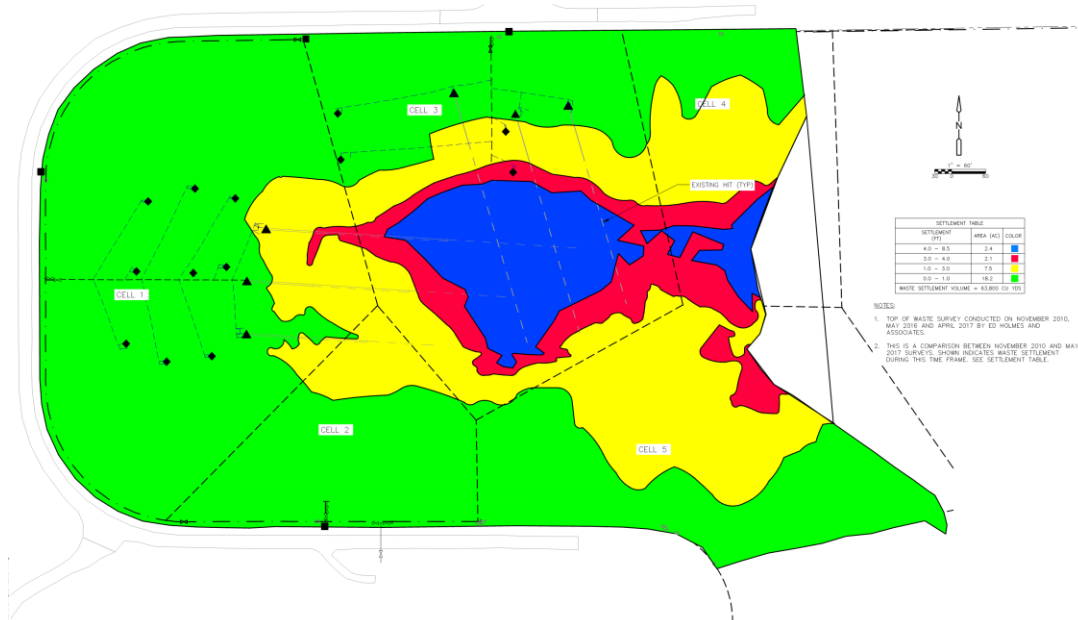


Figure ES-3: Settlement in Cells 1 through 5 since November 2010

Landfill gas generation is enhanced by the bioreactor operation and is used to produce renewable power. The power generation facility is registered on the Climate Action Reserve to receive carbon credits for the voluntary capture and destruction of methane. No carbon credits were issued in 2017, and carbon credits will not be recorded in future years. Past carbon credits and equivalent passenger vehicle gas emissions offset are shown below:

Table ES- 1: CO₂ Equivalents of Methane Converted to Energy and Vehicle Emissions Offset

Year	CO ₂ Equivalents (tons)	Equivalent Passenger Vehicle Emissions Offset ¹
2012	28,784	5,997 vehicles
2013	29,490	6,208 vehicles
2014	33,016	6,951 vehicles
2015	30,407	5,827 vehicles
2016	3,243	621 vehicles
Total	124,940	23,942 vehicles

1. Calculated using EPA's Greenhouse Gas Equivalencies Calculator (<http://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator>).

The renewable energy generated and the number of equivalent homes' electricity usage are shown below:

Table ES- 2: Renewable Energy Generated Converted to Equivalent Homes

Year	MWh Renewable Energy Generated	Equivalent Homes' Annual Electricity Usage ^{1,2}
2011	498	37
2012	8,937	656
2013	9,379	688
2014	8,953	657
2015	9,874	724
2016	7,915	581
January-June 2017	5,182	380

1. Calculated using residential energy data for North Carolina from the U.S. Energy Information Administration (http://www.eia.gov/electricity/sales_revenue_price/pdf/table5_a.pdf).
2. Based on 1,136 kwh/month average usage in North Carolina.

System Designs: Retrofit vs. Build-As-You-Go

The retrofit system, which refers to the shallow, wetting/gas collection trenches that were installed in Cells 1-5 after the cells were filled to capacity has been in operation since April 2007. A Build-As-You-Go wetting system, which means that the infrastructure is installed in phases as the waste is being placed, provides better wetting of the waste, earlier capture of landfill gas, and increased gas generation for energy production. The first stage of the Build-As-You-Go system was installed in Cell 6 at 2060 National Geodetic Vertical Datum (NGVD) in July 2012, and began operation in June 2014 after the trenches were completely covered by a 10-ft minimum layer of waste. The next stage will be installed at elevation 2100 ft NGVD which is anticipated to be reached in 2020.

The first stage included installation of five trenches ranging in length from 700 to 950-ft. Six temperature sensors were installed in strategic locations between the trenches to monitor the extent

of wetting and the impact of cold weather wetting on the biological processes. Readings from the sensors are recorded by a datalogger installed at the Cell 6 pump station control panel. If decomposition is determined to be unaffected by cold weather recirculation, then the operators will move to a year-round wetting program that will further reduce the amount of leachate hauled to the WWTP.

Liner System Monitoring and Performance

The landfill is currently monitored quarterly for leak detection quality and quantity, and leachate quality. In 2016, this monitoring was changed to semi-annually. Leachate quantity will continue to be measured weekly.

Analysis of leak detection data indicates that the cells equipped with alternative liner systems are functioning at a comparable level to those with prescriptive Subtitle D liner systems. In addition, the leakage rates of all cells were compared to the industry standard of 20 gallons/acre/day as shown in **Table ES-3**. The data indicates that Cells 1-6 are performing better than the industry standard.

Table ES-3: Leakage in Cells 1-6 Comparison to Industry Standard

Cell	Area (acres)	Average Annual Leakage 2007-2016 (gal/yr)	Max Annual Leakage 2007-2016 (gal/yr)	Industry Standard (gal/yr)	Liner Type
1	9.7	0	0	70,636	Subtitle D
2	3.1	81	115	22,876	Subtitle D
3	8.2	876	3,105	59,786	Alternative
4	4.1	3	25	30,019	Alternative
5	7.1	2,145	6,465	51,855	Alternative
6	22.7	3,011	10,475	165,986	Alternative

While liquids have been observed in the leak detection zones in nearly all of the landfill cells, testing of the liquids indicate it is groundwater. For Cells 7-10, it is recommended that the design of the leak detection zone (LDZ) be revised to eliminate the 3-foot separation between the LDZ and the bottom of the base liner system, as this will greatly reduce the potential for groundwater infiltration.

Stakeholder Meetings

Stakeholder meetings are held periodically to discuss project status and issues. The project stakeholders include: Buncombe County, NCDENR, USEPA, WNCRAQA, CDM Smith and the University of Florida. The first stakeholder meeting, held in September 2012, established new criteria for determining liner performance. Leachate levels in the sump of Cell 6 are being recorded in 1-minute intervals to see if head on the liner ever increases more rapidly during periods of leachate recirculation. Rapid increases in leachate levels in the sump would indicate abnormal head build-up on the liner system which could lead to higher rates of leakage. Results to date show no impact on head on the liner due to the recirculation of leachate. The last stakeholder meeting was held in November 2016. This meeting reviewed the results of the operation of the bioreactor system demonstrating that the recirculation has helped recoup airspace and has had no impact on the pumping or liner systems.

This text report provides an update of the Buncombe County Bioreactor Program for the first half of 2017. To view the report in its entirety please visit the project website at:

<http://buncombebioreactor.com/>.

Section 1

Introduction

The Buncombe County (County) Solid Waste Management Facility is a host site for a research project being conducted under the USEPA Project XL Program. The purpose of this Mid-Year report is to present the data collected in January – June 2017. This report was prepared by Kristy Smith - Buncombe County Bioreactor Manager, Christopher Gabel – CDM Smith Inc., and Amy Hightower – CDM Smith Inc.

1.1 Site Description

The Buncombe County Solid Waste Management Facility is located in the mountains of western North Carolina, approximately nine miles north of the City of Asheville. The 557-acre solid waste management facility (refer to **Figure 1-1**) opened in 1997 and comprises a Subtitle D landfill, construction and demolition (C&D) landfill, wood waste mulching facility, convenience center for residential drop-off, a household hazardous waste (HHW) facility, and a white goods and tires holding facility.

The Subtitle D landfill is 95 acres and consists of 10 disposal cells that are being constructed sequentially over the estimated 30+ year life of the facility. Cells 1 and 2 were constructed with a prescriptive RCRA Subtitle D liner system consisting of a 24" soil barrier layer with a maximum permeability of 1×10^{-7} cm/sec, a 60-mil high density polyethylene (HDPE) liner and a 24-inch rock drainage layer. Cells 3-6 were constructed with an alternative liner system that uses an 18-inch soil barrier layer with a maximum permeability of 1×10^{-5} cm/sec, a geosynthetic clay liner (GCL), a 60-mil HDPE liner and a 24" rock drainage layer.

Cells 1-5 are filled to capacity and Cell 6 has been the active disposal cell since 2006.



1.2 Project Goals

Municipal solid waste (MSW) landfills in the United States are designed in accordance with the technical guidelines provided in Subtitle D of the Resource Conservation and Recovery Act (RCRA), which requires that landfills be equipped with impermeable base liners and caps. While this requirement has been very successful in preventing groundwater contamination, it has also led to the dry entombment of waste at many landfill sites. Some concern has been raised regarding the long term containment of undecomposed waste and the potential for leachate releases after the post-monitoring period ends (typically 30-years) in the event the liner systems fail.

One approach to addressing this concern is to operate MSW landfills as bioreactors. A bioreactor landfill uses controlled methods of liquids addition to increase waste moisture content as a means for promoting decomposition of waste. The goal of a bioreactor operation is to achieve a stabilized condition while the landfill is still being monitored. Liquids addition has been applied at numerous landfill sites in the US with favorable results.

Federal regulations governing solid waste management restrict liquids addition to only those landfills equipped with prescriptive Subtitle D liner systems. The Buncombe County Bioreactor Project seeks to determine what impact, if any; liquids addition has on alternative liner systems by comparing the performance of the prescriptive Subtitle D liner system in Cells 1 and 2 to the alternative liner systems in Cells 3-10. The data obtained from this project may provide support for modifying federal regulations to allow liquids addition in MSW landfills equipped with alternative liner systems. A Final Project Agreement (FPA) was issued by the USEPA under the Project Excellence and Leadership Program (Project XL) approving Buncombe County's proposal to incorporate a liquids addition process as an integral part of their landfill operation and providing the design, execution, and monitoring framework developed for the project.

1.3 Public Awareness

Public awareness has been an important part of the County's solid waste program since the siting of the facility in the early 1990's. To increase public awareness of the bioreactor project, the County staff have given presentations to various groups, led tours for local area colleges and high schools, and performed a live interview at the bioreactor site for Buncombe County Television. The County also has a website that is available to the public to learn about the project. The website is updated semi-annually with new monitoring data and other information and is accessible at: <http://www.buncombebioreactor.com>.

Buncombe County convenes periodic meetings of stakeholders to obtain comments on the Project as well as to report on the progress during the duration of the XL Agreement. Stakeholders include any individuals, government organizations, neighborhood organizations, academic centers, and companies with an interest in the progress of the Buncombe County Solid Waste Management Facility Bioreactor Project. The first stakeholders' meeting was held in August 2008, the second stakeholders' meeting was held on September 20th, 2012, and the third stakeholders' meeting was held on November 10, 2016. The first stakeholder meeting was attended by Western North Carolina Regional Air Quality Agency, EPA by teleconference, NCDENR, University of Florida, Buncombe County management, and CDM Smith engineers.

Section 2

Project Description

This project was granted regulatory flexibility under Project XL to add liquids to cells with alternative liner systems and to apply liquids other than leachate to the waste mass. To date, only leachate has been used since there has been adequate leachate available onsite to meet the needs of the project. Leachate recirculation is not performed during the winter months due to concern of the adverse impacts of cold leachate on decomposition. The project team, in consultation with the project academic advisors, Dr. Morton Barlaz of North Carolina State University, Dr. Timothy Townsend of University of Florida, and Dr. Debra Reinhart of University of Central Florida, established a minimum temperature of 50° F for the recirculation operation as measured at the leachate pond.

2.1 Retrofit Bioreactor System

2.1.1 Leachate Recirculation

Cells 1-5 was nearing capacity when the project began, prompting the need to install a retrofit system. The retrofit system is equipped to recirculate leachate using a combination of horizontal injection trenches (HIT) and surficial gravity trenches (SGT) as shown in **Figure 2-1**.

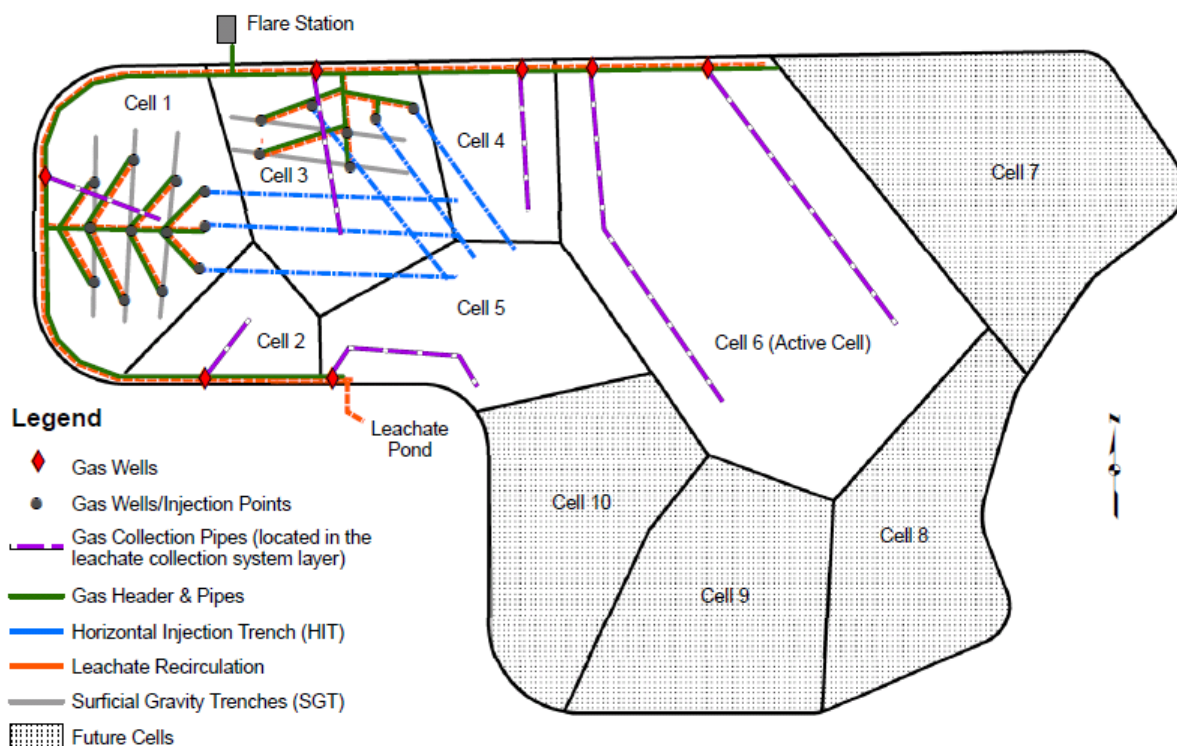


Figure 2-1 Retrofit Bioreactor System

Six HIT were installed in the retrofit area. The first three HIT were installed in anticipation of the project being approved when the top of waste was at Elevation 2040. They extend approximately 400

ft. south into the waste mass and are spaced 100 ft. apart. Three more HIT were installed at Elevation 2080 using the same spacing and extend approximately 800 ft. east in the waste. Due to the longer length of these HIT, two pipes were used in each of the trenches to provide more uniform distribution of leachate. This is achieved by using a short pipe that wets the first 400 ft. of the trench and a long pipe that wets the latter half of the trench.

Five SGT ranging in length from 450 to 600 ft. were installed on the side slopes at Elevations 2030 (SGT 1), 2050 (SGT 2 and 4) and 2070 (SGT 3 and 5). The trenches were excavated 11 ft. into the waste and capped with a clayey soil to provide containment of the recirculated leachate and allow gas collection without air intrusion. Due to their shallowness, the SGT are operated differently than the HITs. The HITs are allowed to be pressurized up to 10 psi while recirculating leachate to provide greater lateral distribution while the SGT are operated as a gravity-feed system to avoid leachate seeps.

Construction details of the HIT and SGT are shown in **Figures 2-2** and **2-3**.

All future trenches will be installed during the operational phase of the cells to provide earlier implementation and more thorough wetting.

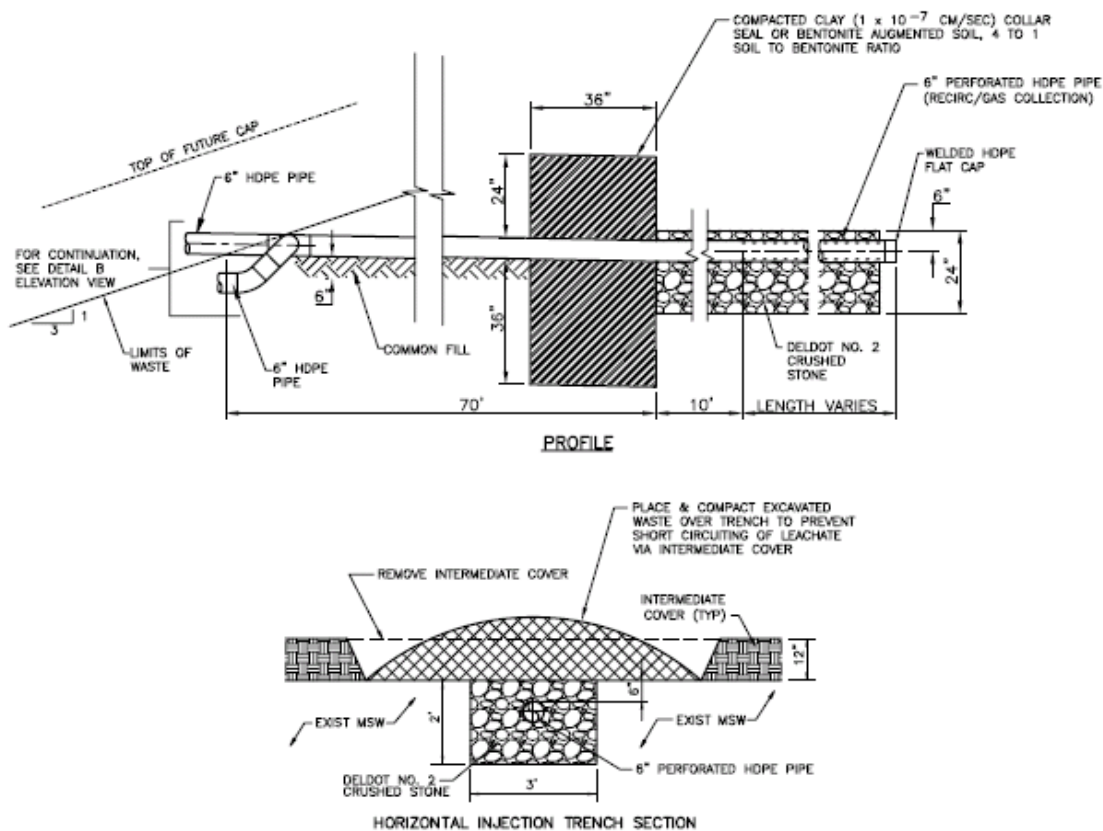


Figure 2-2 Horizontal Injection Trench

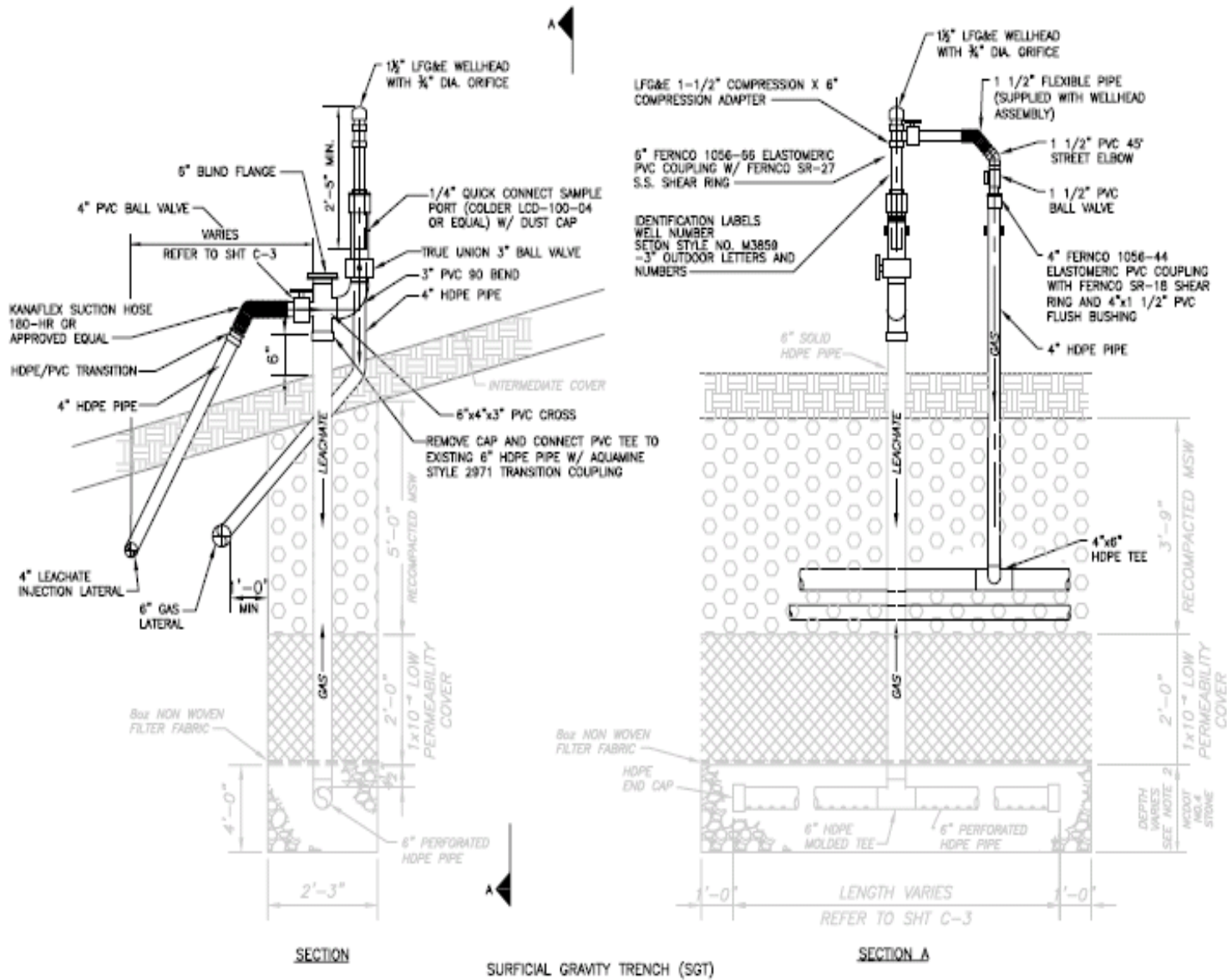


Figure 2-3 Surficial Gravity Trench Detail

2.1.2 Gas Collection

Twenty five vertical gas collection wells were installed in Cells 1-5 as shown in **Figure 2-4**. At the time of the new well field installation the gas collection component of the HIT and SGT was de-activated. Landfill gas is also collected from the cleanouts of the leachate collection system of each cell.

Based on the EPA LandGEM model, the peak flow rate for the site is estimated to be 1,500 scfm in 2030 as shown in **Figure 2-5**. Gas flow to the landfill gas-to-energy (LFGTE) facility will increase over time and will experience an incremental increase once all the HIT in Cell 6 are in operation. A second generator can be added to the LFGTE facility when the flow rate exceeds 900 scfm.

2.2 Build-As-You-Go Bioreactor

Phase 2 is a build-as-you-go bioreactor system – meaning that the infrastructure is installed in stages as the waste is being placed. The build-as-you-go approach allows for more extensive wetting of the waste and earlier capture of landfill gas. The first stage of the Phase 2 system was installed in Cell 6 in 2012 and began operation in June 2014. The next stage will be installed at elevation 2100 ft. NGVD which is anticipated to be reached in 2020.

2.2.1 Leachate Recirculation and Gas Collection

The first phase in Cell 6 includes five HIT for leachate recirculation and gas collection as shown in **Figures 2-6 and 2-7**. A 100-ft. solid section of pipe is used for the front end of the HIT to maintain the injection process an adequate distance from outer slope to minimize seeps. The solid pipe sections are sloped 3% to drain towards the outer slope of the landfill. P-traps were installed at the head of each HIT and drain down the slope to the leachate sump riser pipe to allow excess recirculated leachate to be removed from the HIT after injection events. This is intended to prolong gas collection capability of the system.

The liquids addition process typically takes between 2 to 6 hours per event and is continuously supervised by the Bioreactor Manager. A rotation schedule is used to allow time between injection events for leachate to drain from the trenches. The rotation schedule is adjusted as needed to account for the varying rates of drainage of the HIT and SGT. Leachate recirculation is reduced or suspended during periods of rainfall until the area dries out sufficiently. The landfill side slopes are carefully inspected during and after each injection event for leachate seeps. Further discussion of the leachate recirculation and gas collection strategy is provided in Section 6.

2.2.2 Temperature Probes

Thermocouples were installed in six (6) locations around the Cell 6 Phase 1 HIT in July 2012 as shown in **Figure 2-8**. The thermocouples consist of a stainless steel temperature sensor with a lead cable as shown in **Figure 2-9**. The thermocouples were placed in 4-inch perforated PVC pipe packed with concrete sand. The cable end of the pipe was left open to allow cable movement during settlement. The sensors transmit temperature data to a datalogger installed adjacent to the Cell 6 pump station control panel that is downloaded monthly. Temperature readings are being used to monitor decomposition as active mesophilic bacteria typically results in a range between 80°F and 115°F. The sensors are also helpful in assessing the impacts of leachate temperature during injection. As ambient air temperatures drop in the winter, the leachate in the pond will get colder.

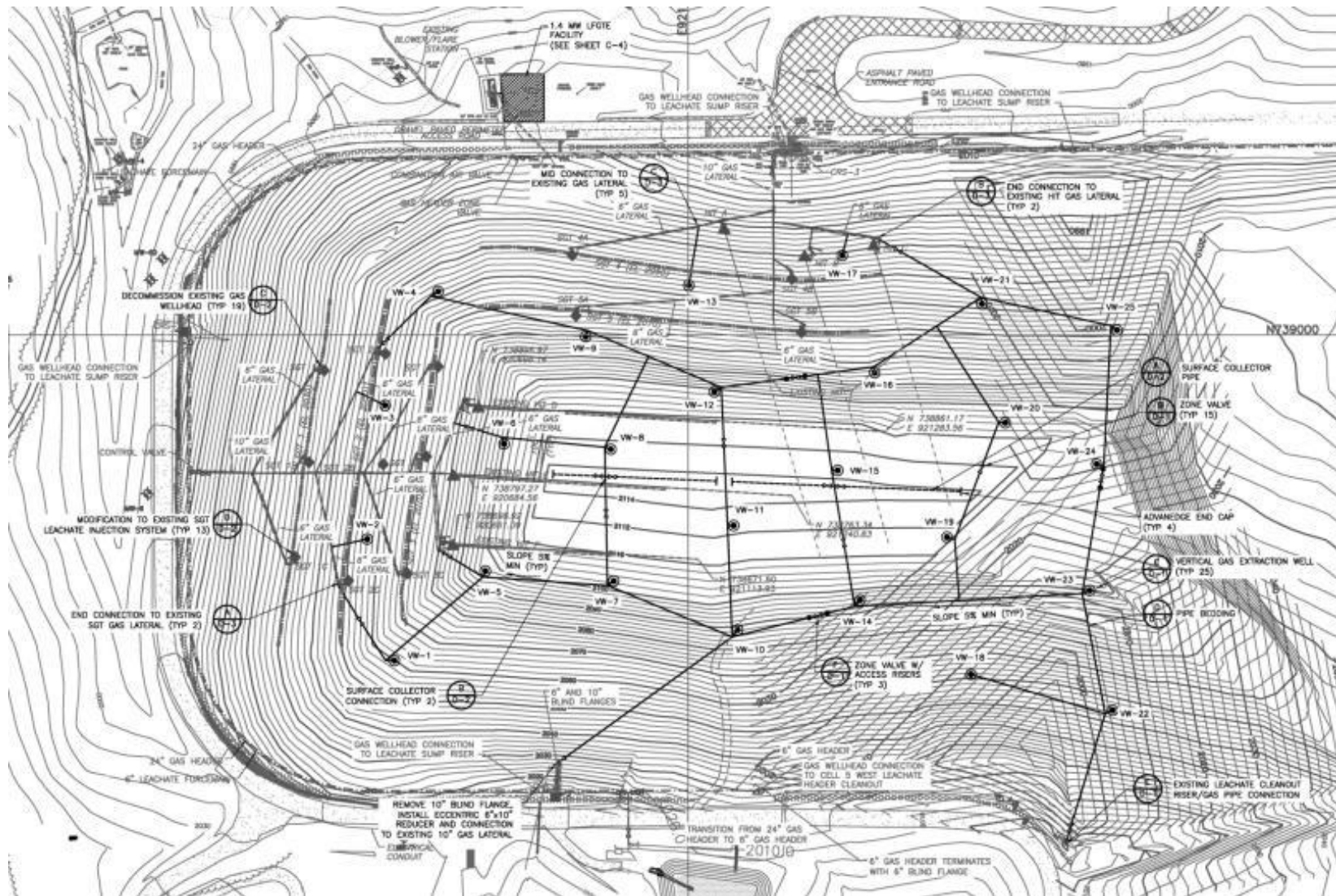


Figure 2-4 Vertical Gas Well Collection System in the Retrofit Area

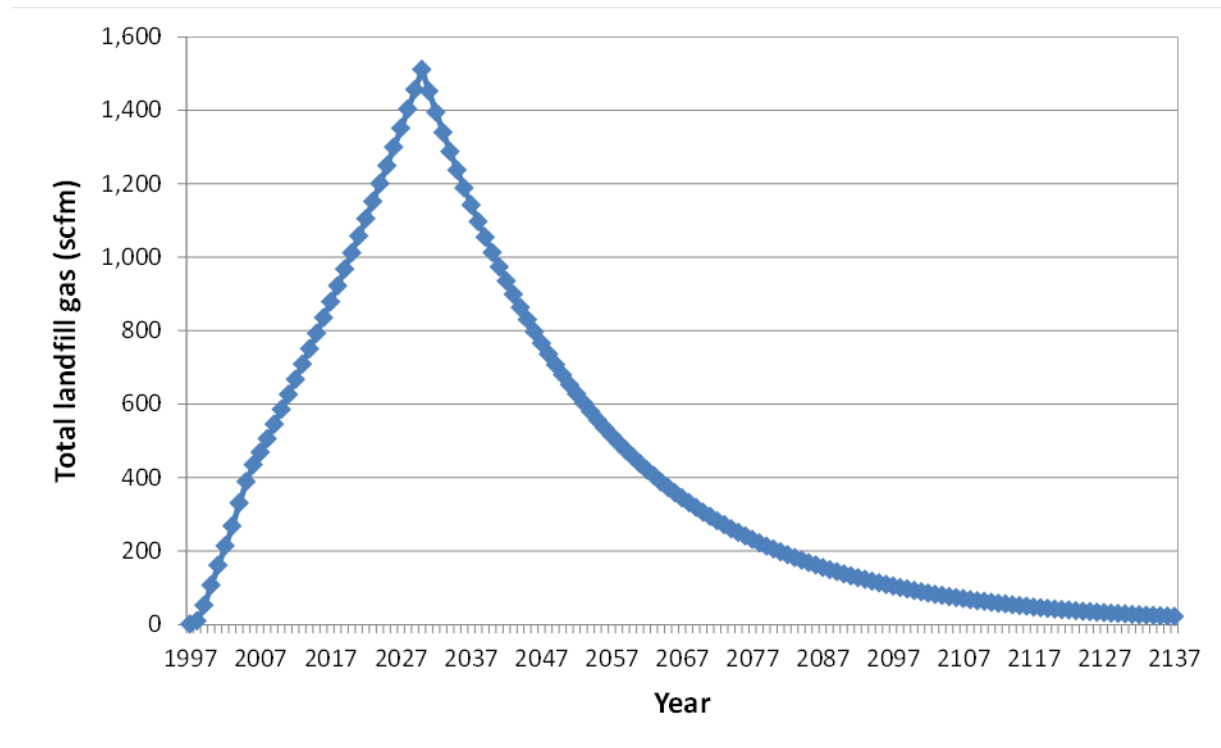


Figure 2-5 Landfill Gas Projections Using LandGEM Model

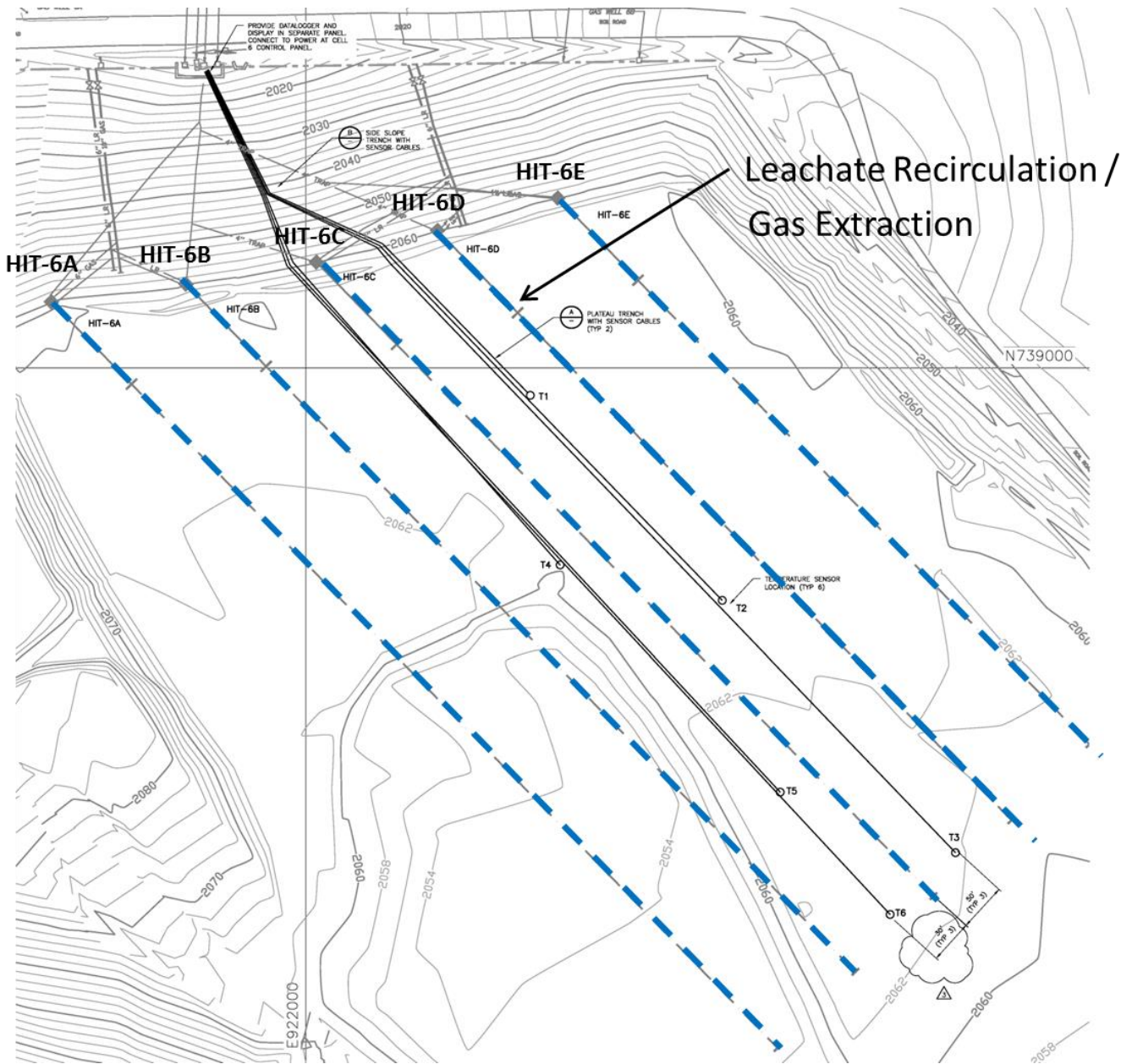


Figure 2-6 Build-As-You-Go Bioreactor System



Figure 2-7 Horizontal Injection Trench Installation in Cell 6

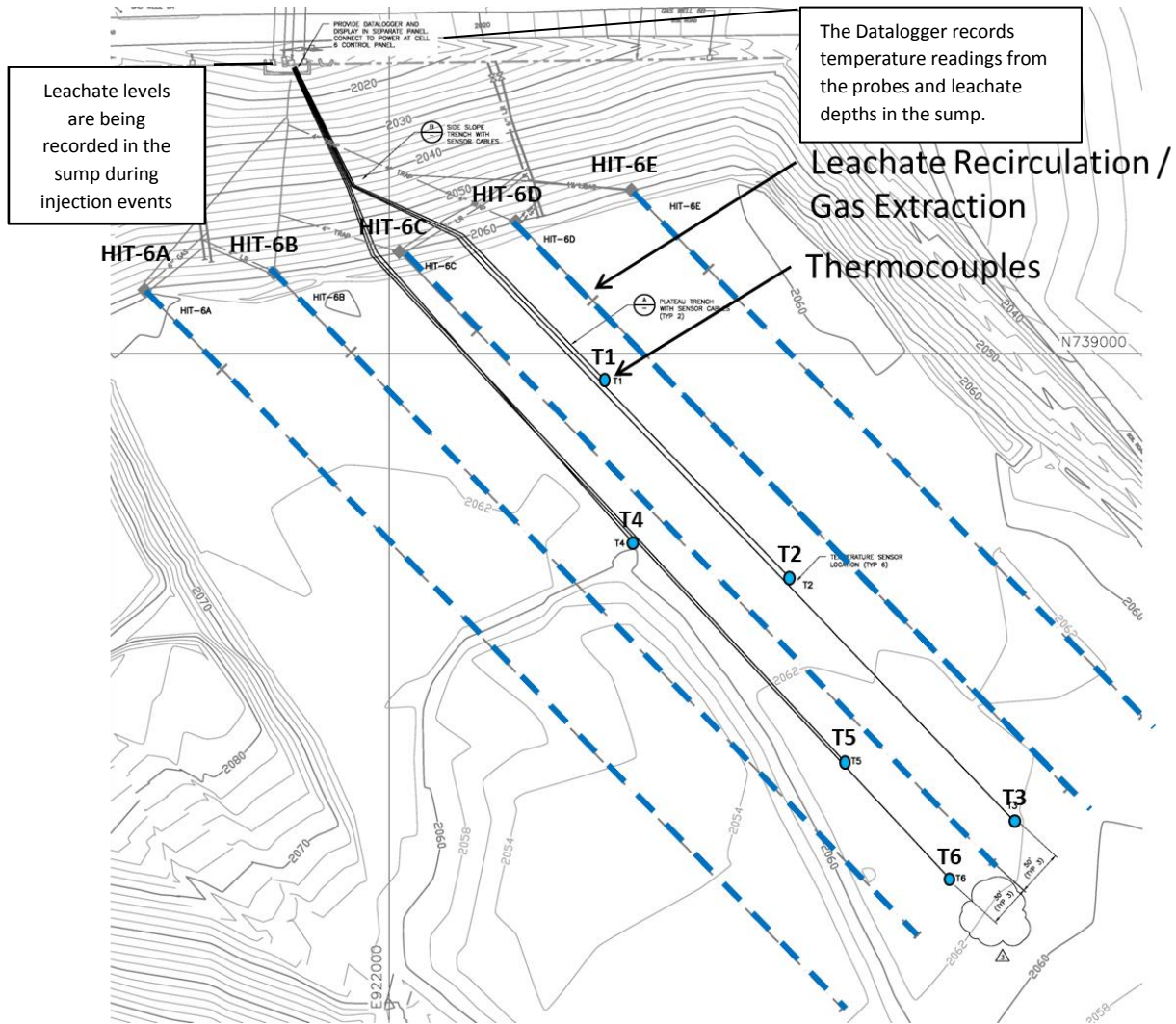


Figure 2-8 Temperature Sensors in Cell 6



Figure 2-9 Installation of Thermocouples in Cell 6

2.3 Landfill-Gas-To-Energy

Buncombe County built a LFGTE facility at its bioreactor landfill to take advantage of the accelerated gas generation. A request for proposals (RFP) was advertised to evaluate private sector interest. At the same time, CDM Smith developed project cost and revenue estimates under a scenario where the County would self-finance the project.

Comparison of nine energy developer proposals to the self-financing option showed that the net revenue would be substantially more if the County self-financed the project. The County elected to proceed without a developer. CDM Smith designed and permitted the LFGTE facility which includes a 1.4-MW generator set, gas conditioning system, and a well field consisting of 25 vertical wells. CDM Smith completed design and permitting of the facility under a fast track approach to reach “shovel-ready” status for ARRA funding. After successfully demonstrating the project’s merits, the County was awarded a \$3 million grant. The County completed construction of the LFGTE facility in November 2011. The inaugural ribbon cutting ceremony in May 2012 is shown in **Figure 2-10**.



Figure 2-10 Inaugural Ribbon Cutting Ceremony

The energy generated by the LFGTE facility through 2016 is summarized in **Table 2-1**.

Table 2-1: Energy Generated by LFGTE Facility

Year	MWh Generated
2011	498
2012	8937
2013	9379
2014	8953
2015	9874
2016	7915
January – June 2017	5,182

Section 3

Monitoring Program

3.1 Program Overview

The monitoring program was developed with assistance from the project academic advisors, Dr. Debra Reinhart and Dr. Morton Barlaz. **Table 3-1** shows the monitoring parameters and frequency of data collection for the project.

As part of facility operation, Buncombe County performs semi-annual testing of the leak detection zones (LDZ), groundwater monitoring wells, leachate pond, and stormwater collection points for the 2L groundwater standards established by North Carolina Department of Environment and Natural Resources. This data is also being used in assessment of the alternative liner system performance.

Table 3-1 Monitoring Parameters and Frequencies

Parameter	Frequency
Leak Detection Quantity	Semi-Annually
Leak Detection Quality	Semi-Annually
Leachate Quality	Semi-Annually
Leachate Quantity	Weekly
Leachate Recirculation Quantity	Ongoing
Gas Composition	Ongoing
Gas Volume and Flow Rates	Ongoing
Settlement Plates	Quarterly
Settlement Survey	Annually
Waste Density	Quarterly
Waste Temperature	Ongoing
Cell 6 Sump Level	Ongoing

3.2 Leak Detection

The landfill cells and leachate pond are equipped with leak detection zones (LDZ) located beneath the leachate collection system sumps. The LDZ, as shown in **Figure 5-1**, are approximately 1 acre in size and consist of a 60 mil HDPE geomembrane and a 24-inch rock drainage layer located 3-ft below the subgrade of the liner system. The geomembrane is sloped to direct liquid to a collection pipe located directly below the leachate sumps. For Cells 3-6, liquid captured in the LDZ is pumped out through vertical stand pipes located along the perimeter berm. Cells 1 and 2 drain liquid through gravity pipes that protrude from the outer slope of the landfill perimeter access road. The drain pipes are equipped with gate valves that the operator opens to check for liquid. Quantity data is not recorded for Cell 1 as it appears to be impacted by a steady supply of groundwater from an underground spring. Further

investigation of flow from the Cell 1 LDZ was discussed at the stakeholders meeting held on September 20th, 2012 and is presented in Section 6.

If liquid is present in the LDZ, samples are tested onsite using a Horiba U-22 water quality meter for:

- ORP (oxidation reduction potential)

In addition, liquid samples are collected in sample bottles and sent to Pace Analytical for analysis of:

- BOD5 (Biological Oxygen Demand)
- pH
- COD (Chemical Oxygen Demand)
- Ammonia
- Specific Conductance

The sampling process is dated and recorded in a monitoring log by the Bioreactor Manager.

3.3 Leachate

The quantity of leachate collected is also tracked separately for each cell on a weekly basis. Each cell has a dedicated leachate pump system equipped with a flowmeter that allows the Bioreactor Manager to monitor the number of operating hours for the pumps, the quantity of leachate pumped, and the leachate level in the sumps at the time of monitoring. This data is recorded onto a field form by the Bioreactor Manager.

Leachate quality sampling occurs semi-annually. Samples are collected from the leachate pond and from Cells 1-6. The samples are taken from sampling ports located in the valve vaults of the leachate pump stations. Leachate samples are collected in sample bottles and sent to Pace Analytical for analysis of:

- BOD5
- pH
- COD
- Ammonia
- Specific Conductance

On-site analysis of the leachate is also performed using a Horiba U-22 water quality meter. The Horiba unit tests for:

- ORP
- TDS

The sampling process is dated and recorded in a monitoring log by the Bioreactor Manager.

3.4 Leachate Recirculation

The quantity of leachate recirculated is recorded for each injection event using the magnetic flow meter installed at the leachate pond pump station. The Bioreactor Manager records the quantity of leachate injected and identifies the specific HIT/SGT used for the injection event.

3.5 Landfill Gas

The gas collection component of the Retrofit System has been replaced with a gas to energy system and has been in operation since November 2011. Gas composition and flow data is being continually monitored and recorded.

3.6 Landfill Settlement

Settlement plates were installed in 10 locations within the retrofit area. The plates are surveyed quarterly to monitor the rate of waste settlement. In addition to the settlement plates, an annual topographic survey of Cells 1 through 5 is being carried out using a 50-foot grid for taking measurements.

3.7 Landfill Temperature

Temperature has been monitored in Cell 6 since July 2012. Leachate below 50°F is not allowed to be recirculated for fear of impacting decomposition. Colder leachate may be injected into Cell 6 HIT to see if it causes any significant drop in temperature. If no significant drop in temperature occurs then the project team will consider allowing leachate colder than 50°F to be used on a regularly basis.

3.8 Effective Waste Density

Since settlement plates are difficult to maintain in active cells, effective waste density was added to the monitoring program for Cell 6 to assess the impact of wetting on landfill capacity. A topographic survey of Cell 6 is used to compute the volume of waste and cover soil in Cell 6 on a quarterly basis. Waste tonnage records are used to calculate the effective density of the waste which is defined as: the weight of disposed waste/the combined volume of waste and cover soil. Effective density is not the actual density since cover soils are not weighed prior to placement.

3.9 Cell 6 Landfill Gas Collection

As HIT 6A, 6D, and 6E are being utilized for landfill gas collection while recirculation is occurring in HIT 6B and 6C, the landfill gas composition is being monitored and recorded. This data is being monitored to determine if landfill gas collection should continue or if the HIT should be used for recirculation.

3.10 Cell 6 Sump Data

A datalogger is used to record the leachate level in the Cell 6 sump every minute. The data is being analyzed and compared with recirculation events and daily rainfall data to evaluate impacts of recirculation on leachate generation and head on the liner system.

Section 4

Collected Data

The monitoring data collected from 2007 through June 2017 is presented below in summary graphs and tables. A complete compilation of all data collected to date can be found on the website:

<http://buncombebioreactor.com>.

4.1 Leak Detection

Table 4-1 shows the annual quantity of liquid collected from the leak detection zone (LDZ). Liquids have been observed in the Cell 1 LDZ but the project team is unable to measure the quantity due to the remote location of the discharge. A method to measure quantity from Cell 1 was discussed during the 2016 stakeholders meeting and is presented in Section 6.

Table 4-1 Liquid Collected from LDZ

Sample Year	Leachate Pond (gallons)	Cell 1 (gallons)	Cell 2 (gallons)	Cell 3 (gallons)	Cell 4 (gallons)	Cell 5 (gallons)	Cell 6 (gallons)	Yearly Total (gallons) ¹
	Subtitle D Liner			Alternative Liner				
2007	0	NA	NA	427	0	0	340	767
2008	0	NA	NA	3,105	25	2,925	10,475	16,530
2009	0	NA	NA	1,375	0	3,300	5,500	10,175
2010	0	NA	NA	1,040	0	6,465	3,835	11,340
2011	0	NA	93	555	0	3,800	2,015	6,463
2012	3	NA	115	530	1	1,850	1,220	3,716
2013	9	NA	80	500	0	850	1,150	2,580
2014	65	NA	80	450	0	1,150	1,775	3,455
2015	50	NA	101	425	0	655	2,450	3,631
2016	18	NA	25	350	0	450	1,350	2,175
Jan-June 2017	15	NA	25	200	0	150	450	825
Cumulative	160	NA	509	8,957	26	21,595	30,560	61,647

1. Yearly total is for cells only and does not include the leachate pond.

NA – Unable to measure quantity.

Figure 4-1 shows the monthly quantities of liquid collected from the LDZ. **Figures 4-2** through **4-7** show qualitative data from testing of the liquid. The parameters are pH, conductance, ORP, BOD5, COD and ammonia.

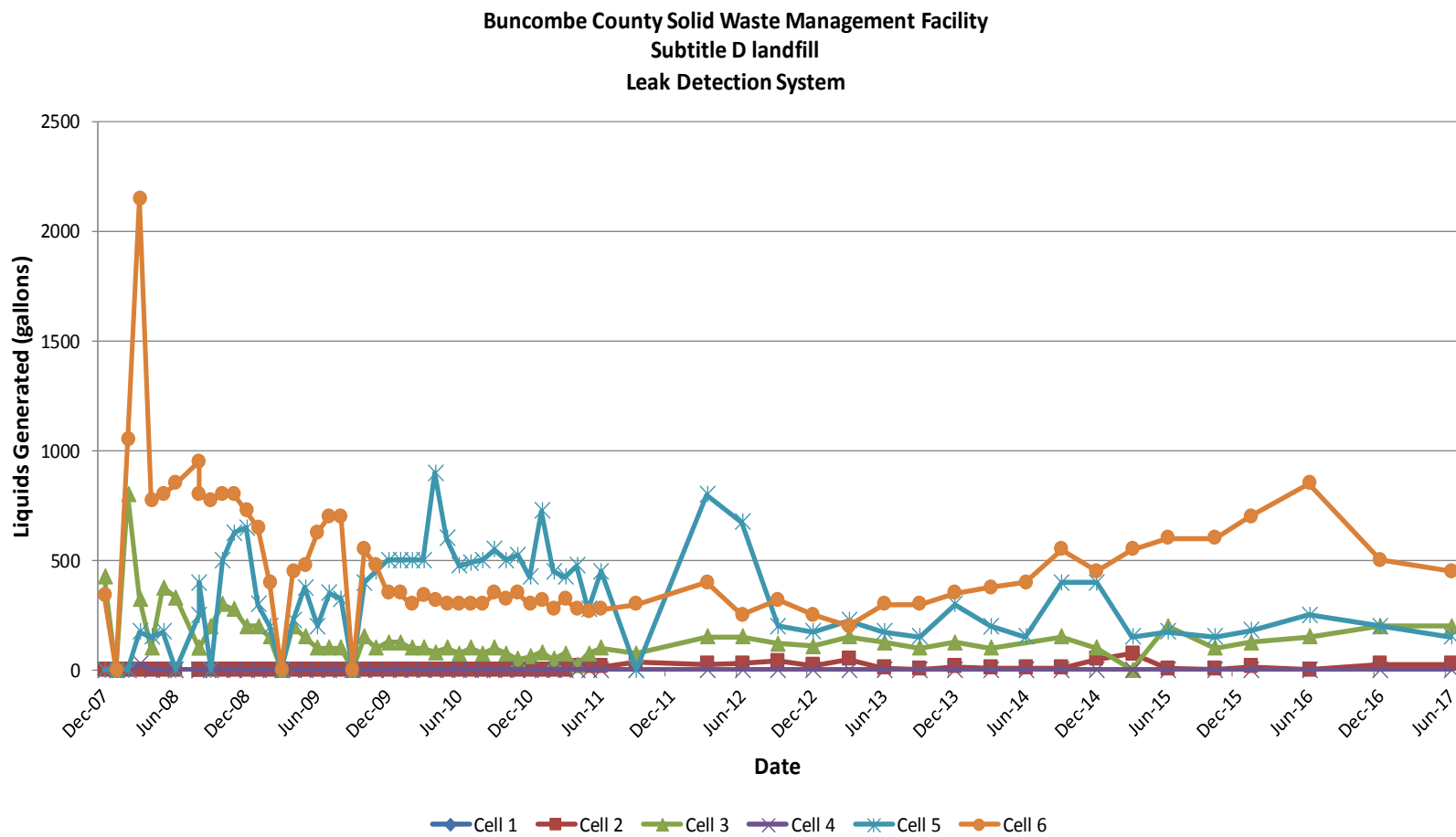


Figure 4-1 Semi-Annual Leak Detection Volumes

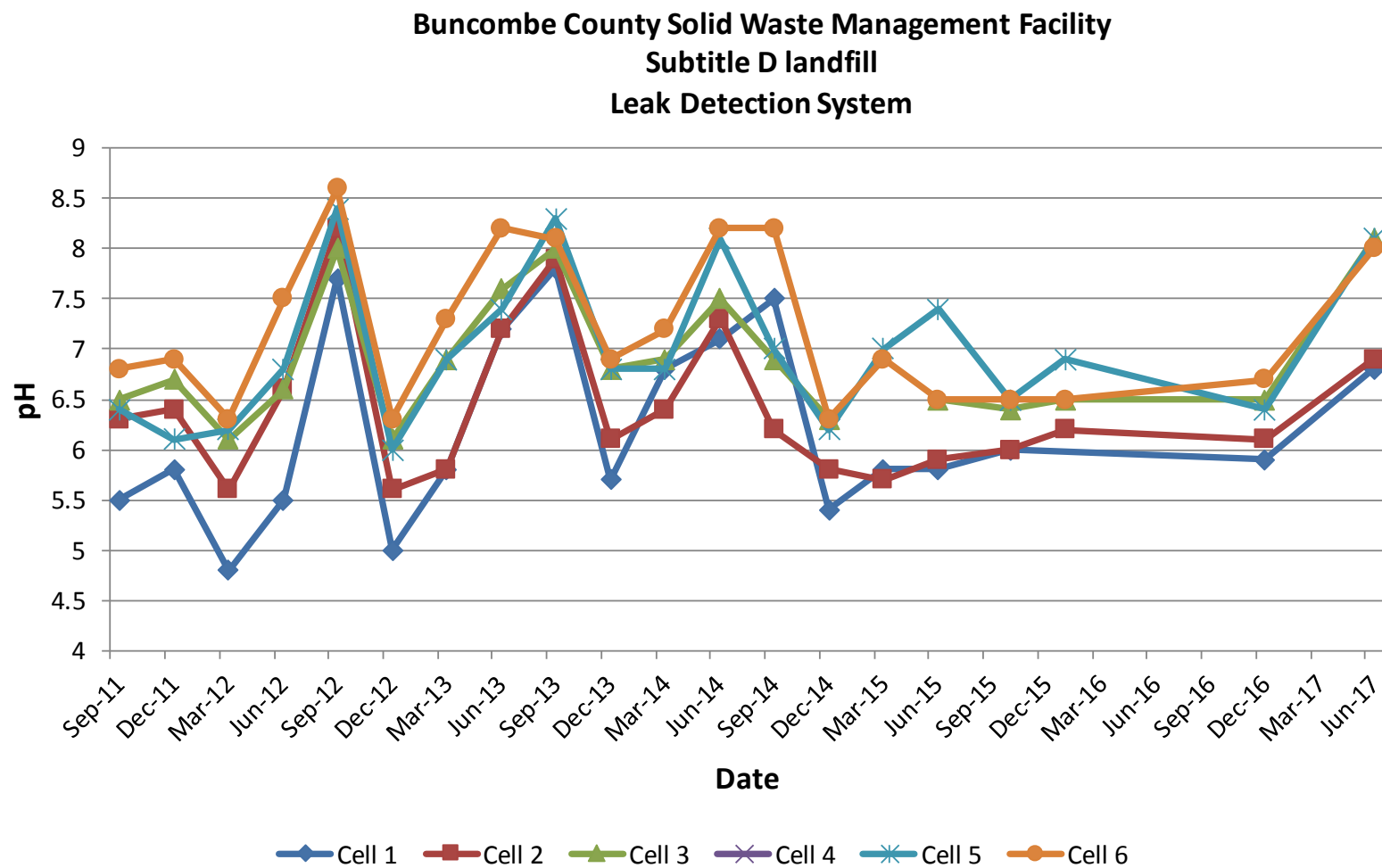


Figure 4-2 pH

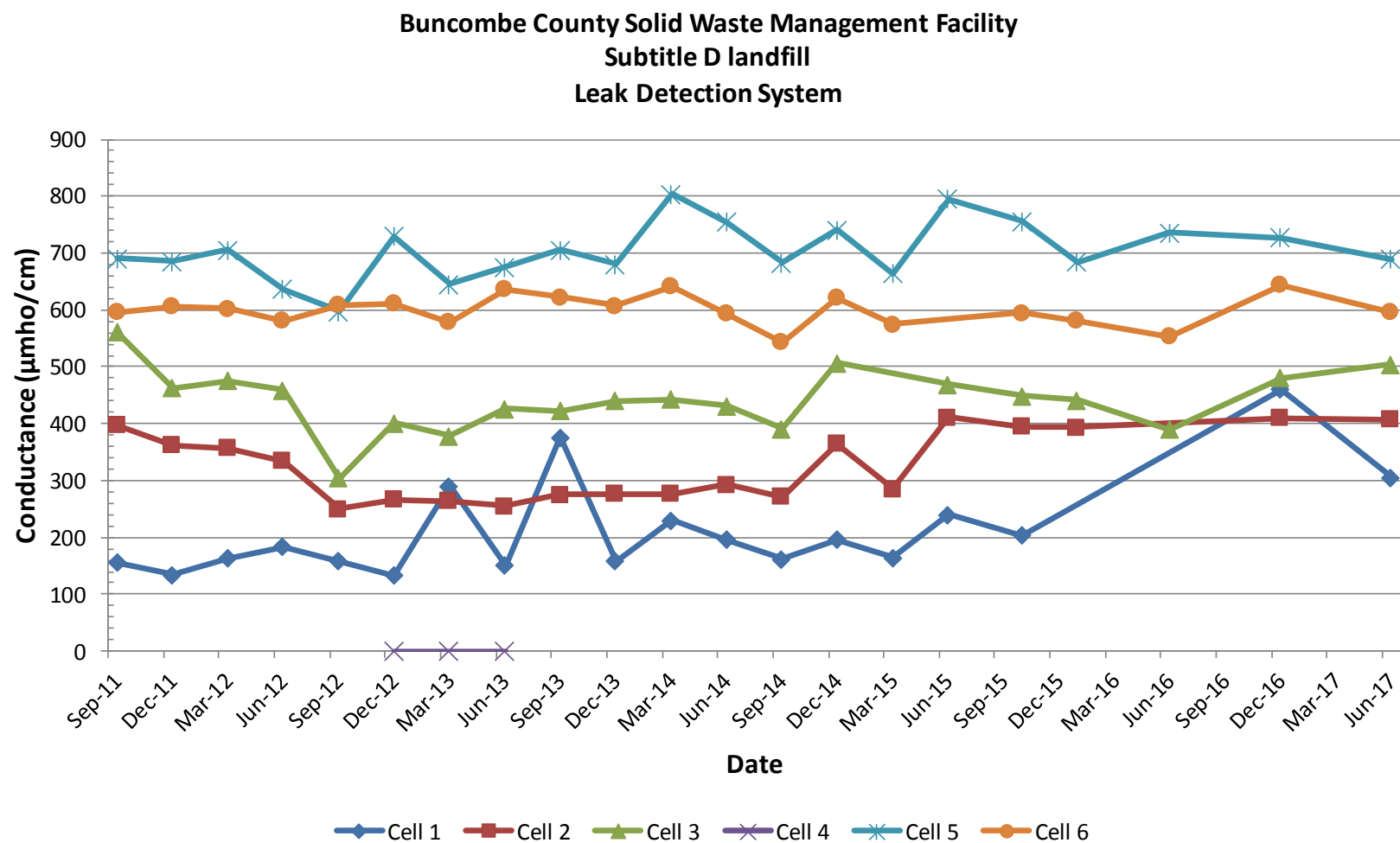


Figure 4-3 Specific Conductance

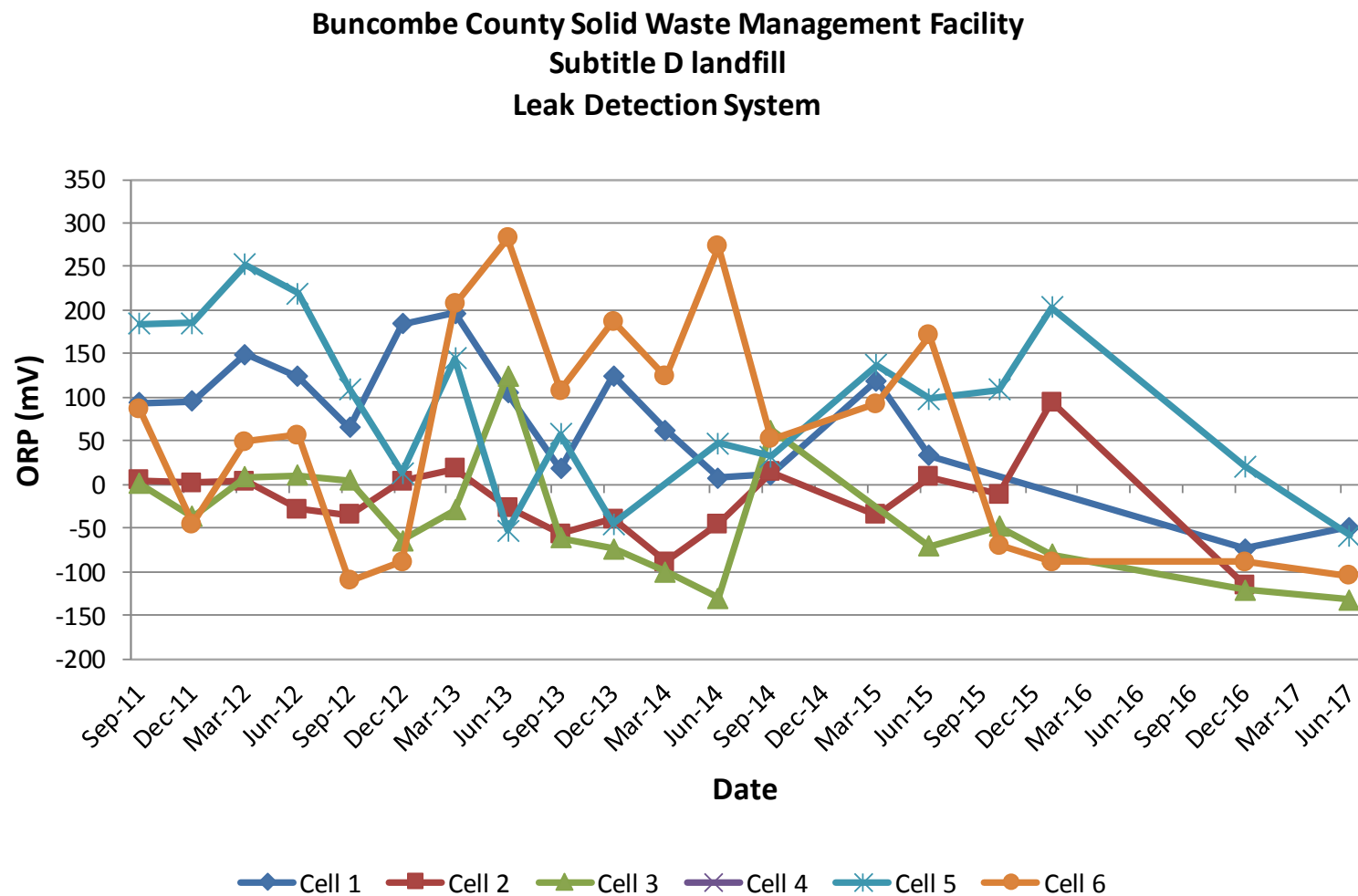


Figure 4-4 Oxidation Reduction Potential

**Buncombe County Solid Waste Management Facility
Subtitle D landfill
Leak Detection System**

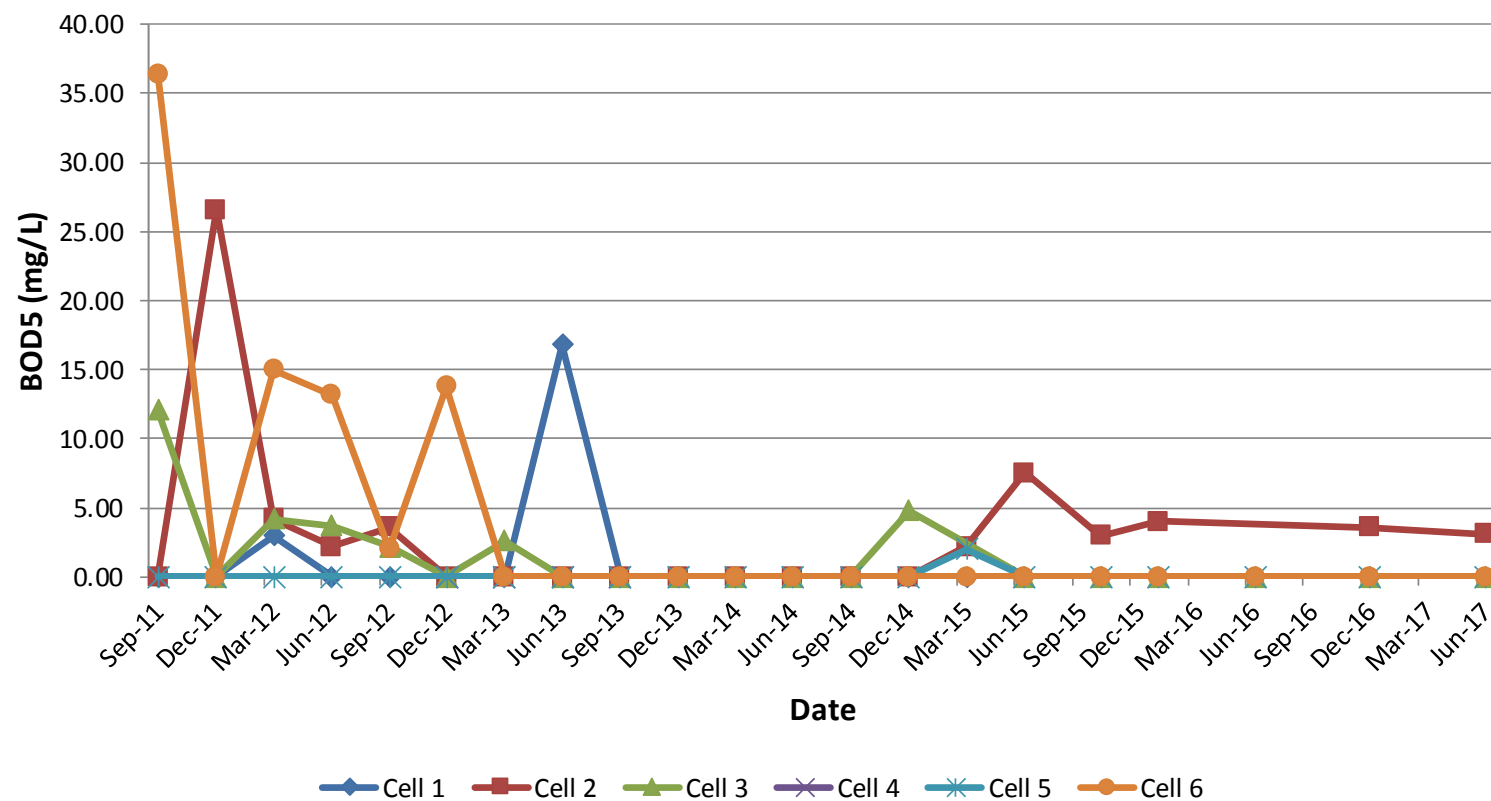


Figure 4-5 BOD5

Buncombe County Solid Waste Management Facility
Subtitle D landfill
Leak Detection System

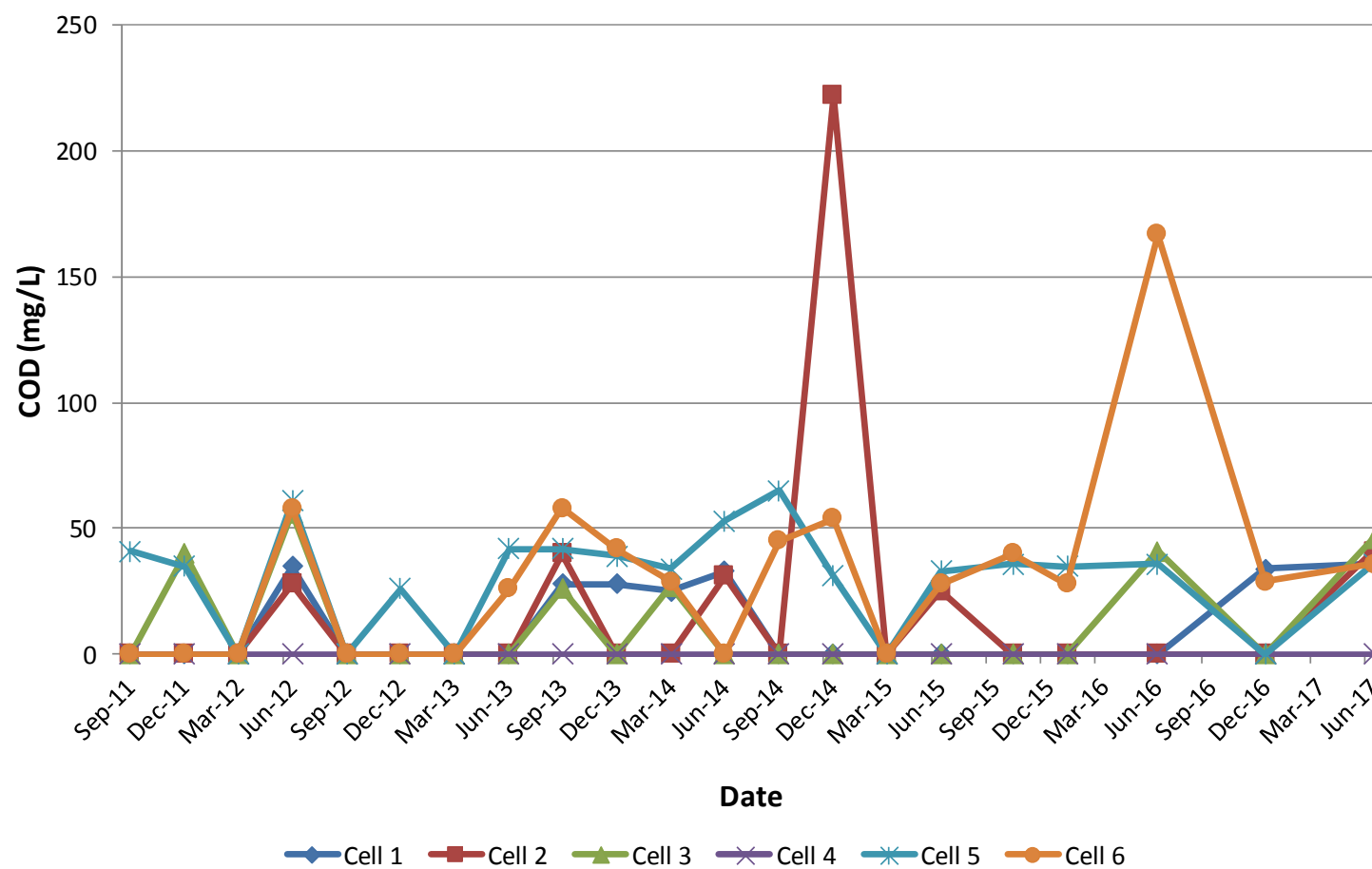


Figure 4-6 COD

**Buncombe County Solid Waste Management Facility
Subtitle D Landfill
Leak Detection System**

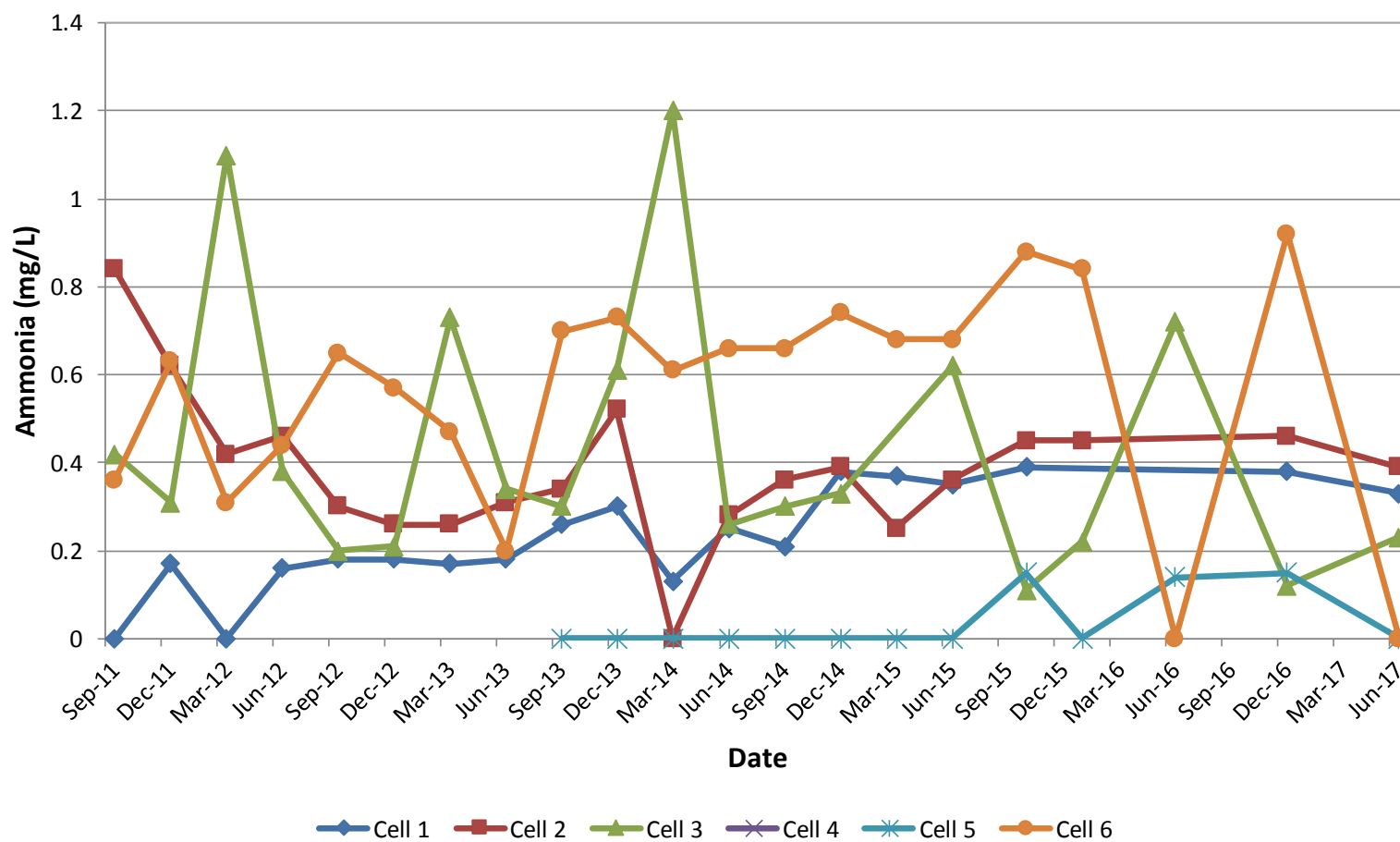


Figure 4-7 Ammonia

4.2 Leachate Collection System

Table 4-2 shows the quantity of leachate collected from the leachate collection system (LCS) of each cell. **Figure 4-8** shows the quantity of leachate generated in comparison to the rainfall. Leachate samples from Cells 1-6 and the leachate pond were analyzed for BOD5, conductance, COD, ammonia, pH, temperature, ORP, and TDS as shown in **Figures 4-9** through **4-15**.

Table 4-2 Leachate Collected from Cells 1-6

Sample Year	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Total	Rainfall
	(gallons)	(gallons)	(gallons)	(gallons)	(gallons)	(gallons)	(gallons)	(inches)
	Subtitle D Liner		Alternative Liner					
Nov.-Dec. 2007	9,723	487	20,898	11,382	11,675	981,305	1,035,470	
2008	288,526	8,860	94,705	173,647	164,467	8,904,461	9,634,666	33
2009	101,777	35,102	103,371	333,067	356,580	14,610,720	15,540,617	43
2010	173,878	34,813	283,867	419,454	124,089	7,097,590	8,133,691	33
2011	156,900	36,027	44,096	124,478	402,831	6,589,437	7,353,769	37
2012	191,608	71,821	92,225	355,101	332,049	5,441,508	6,484,312	40
2013	351,389	225,251	403,484	652,494	905,800	4,563,843	7,102,261	51
2014	184,767	329,346	111,053	82,890	481,695	1,458,189	2,647,940	31
2015	46,104 ¹	270,968	145,390	99,538	633,353	2,150,375	3,345,728	44
2016	215,590	289,412	121,855	92,718	625,964	2,457,079	3,802,618	26
Jan-June 2017	52,530	70,345	132,324	156,925	332,634	2,106,372	2,851,130	22
TOTAL	1,795,484	1,386,509	1,562,852	2,509,038	4,453,311	56,588,375	68,295,569	364

1. Leachate generation value low due to broken air compressor resulting in less condensate discharge.

Buncombe County Solid Waste Management Facility
Subtitle D Landfill
Leachate Generation - Total

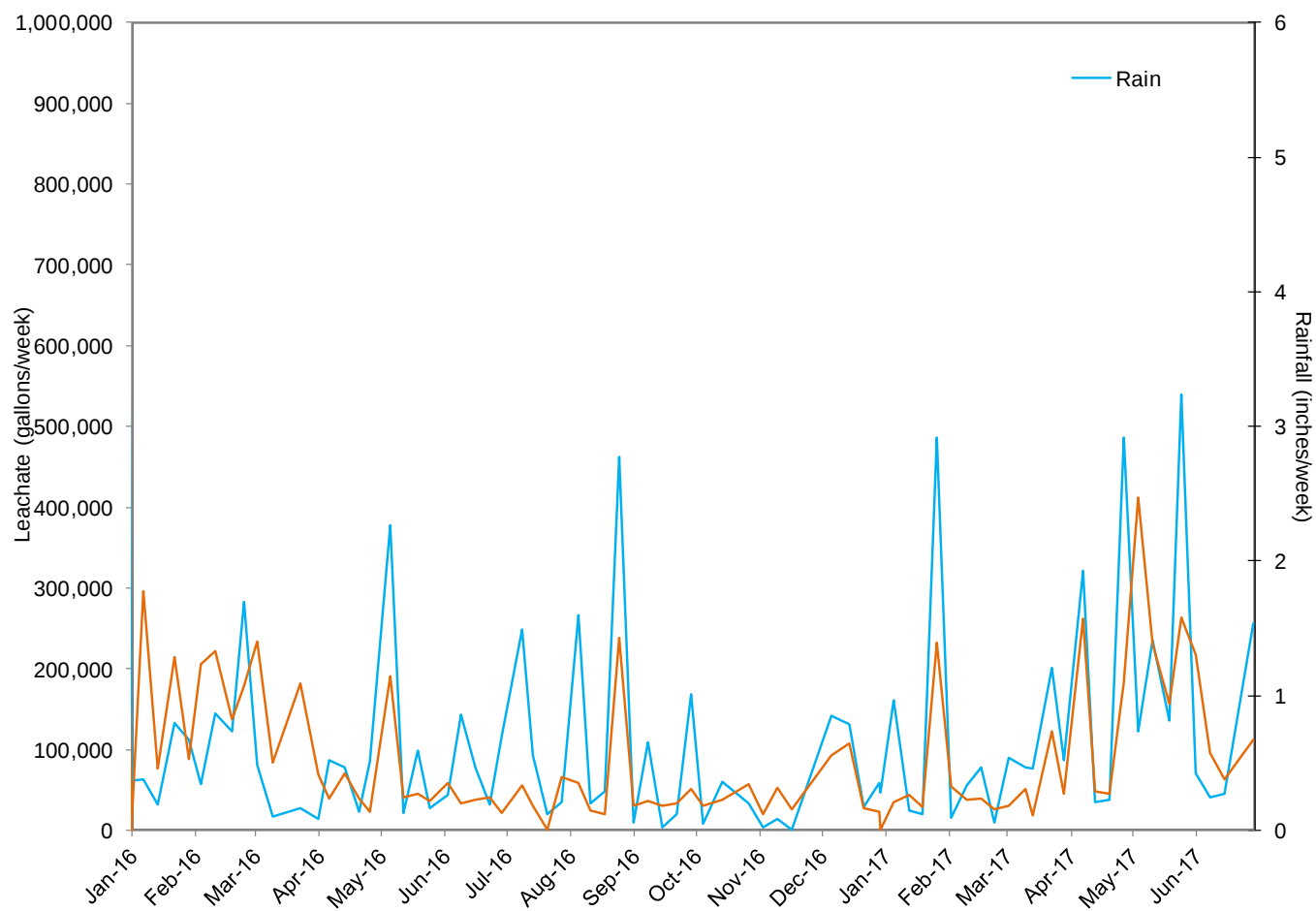


Figure 4-8 Leachate Generation vs. Rainfall

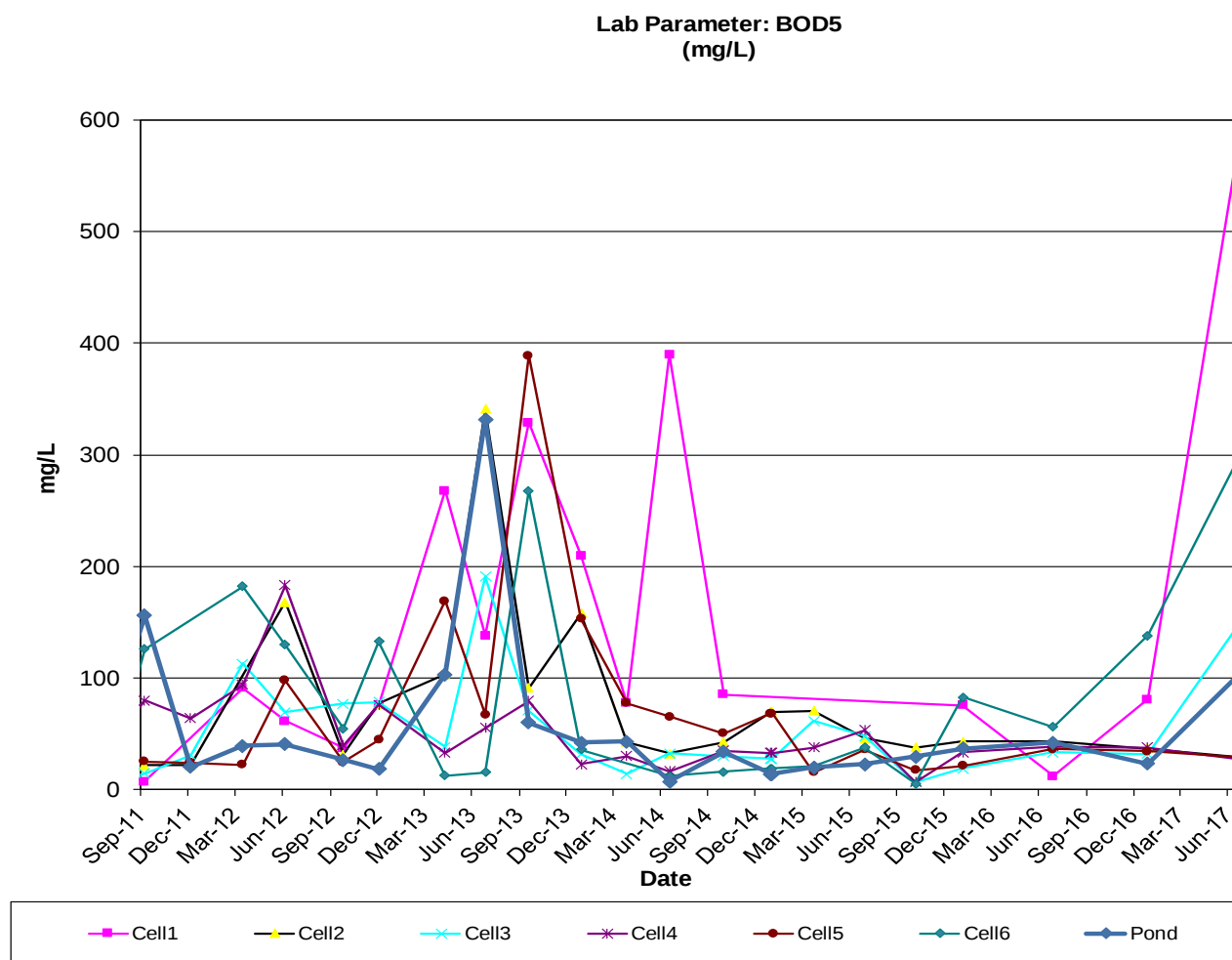


Figure 4-9 BOD5 of Leachate

***Note:** No readings were taken in Cell 1 during the January-December 2015 period due to a clogged sampling port.

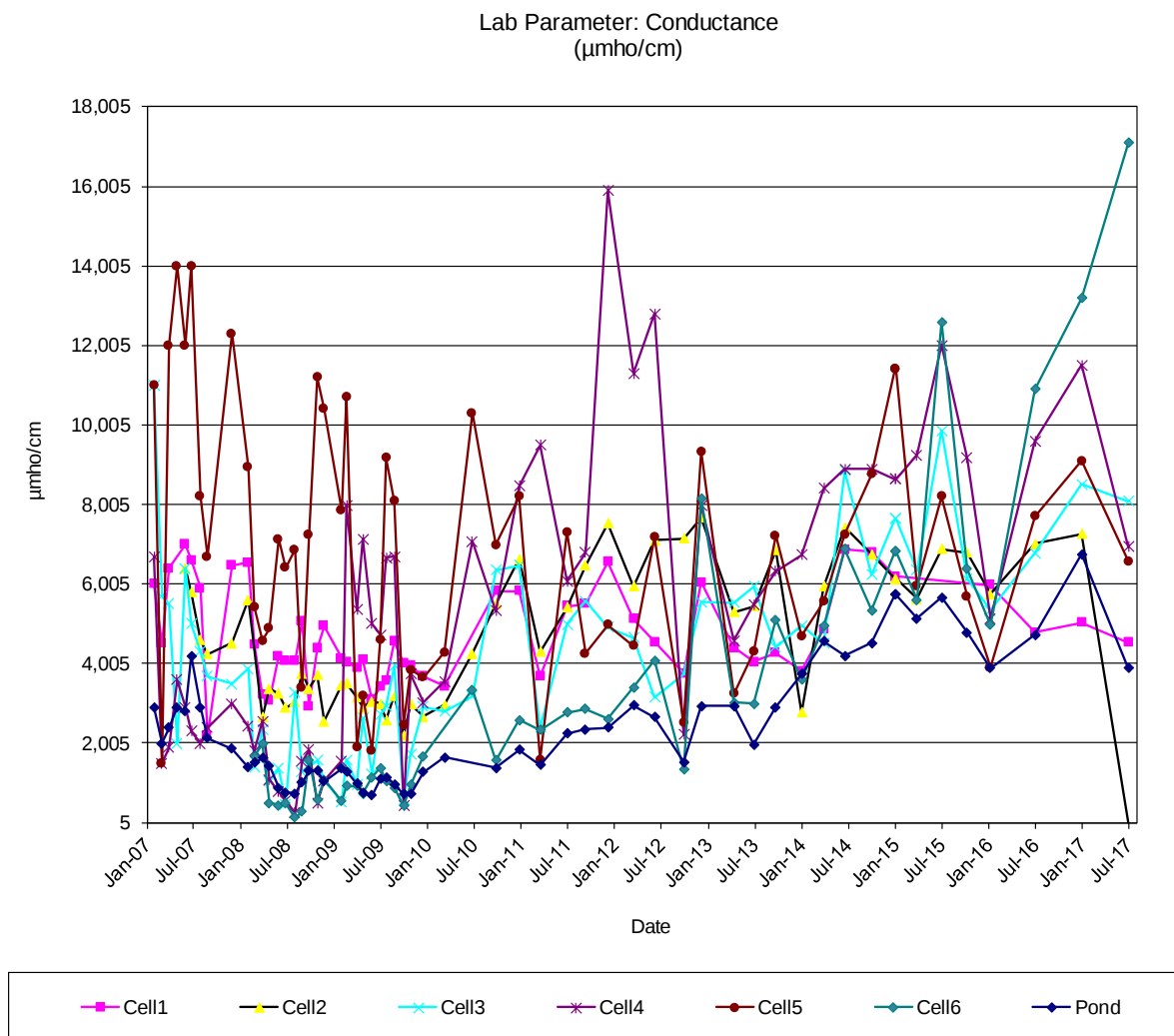


Figure 4-10 Specific Conductance of Leachate

***Note:** No readings were taken in Cell 1 during the January-December 2015 period due to a clogged sampling port.

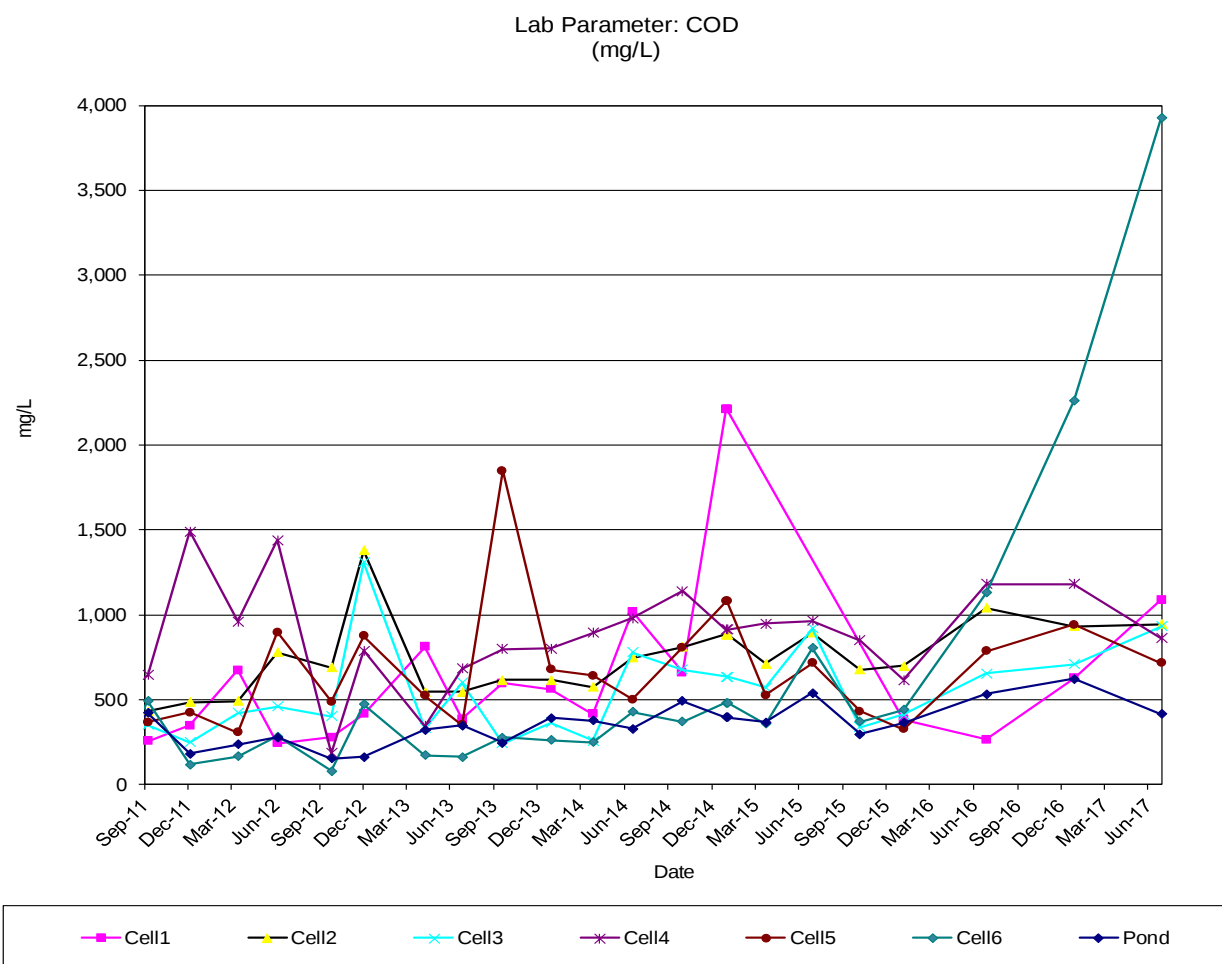


Figure 4-11 COD of Leachate

*Note: No readings were taken in Cell 1 during the January-December 2015 period due to a clogged sampling port.

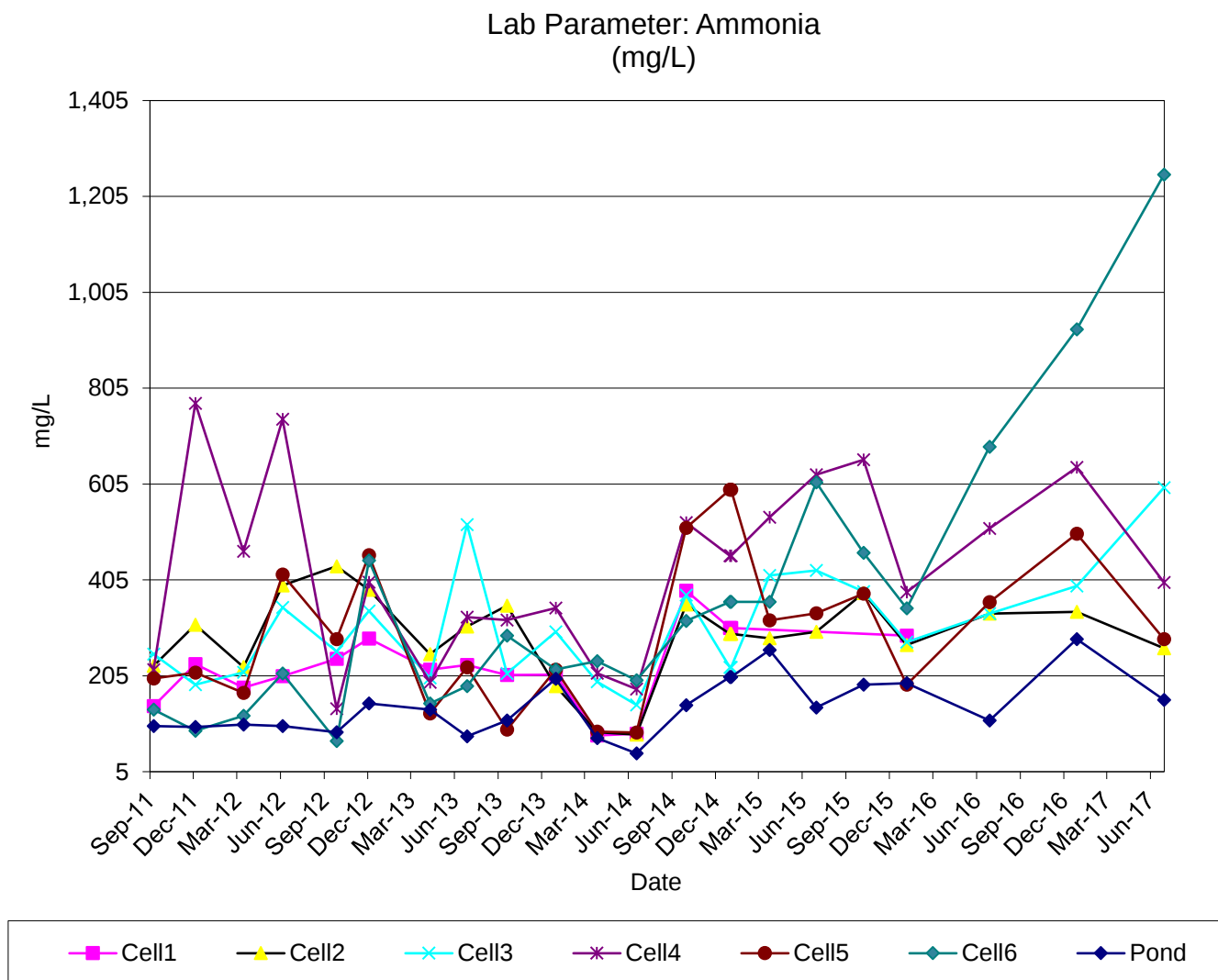


Figure 4-12 Ammonia of Leachate

*Note: No readings were taken in Cell 1 during the January-December 2015 period due to a clogged sampling port.

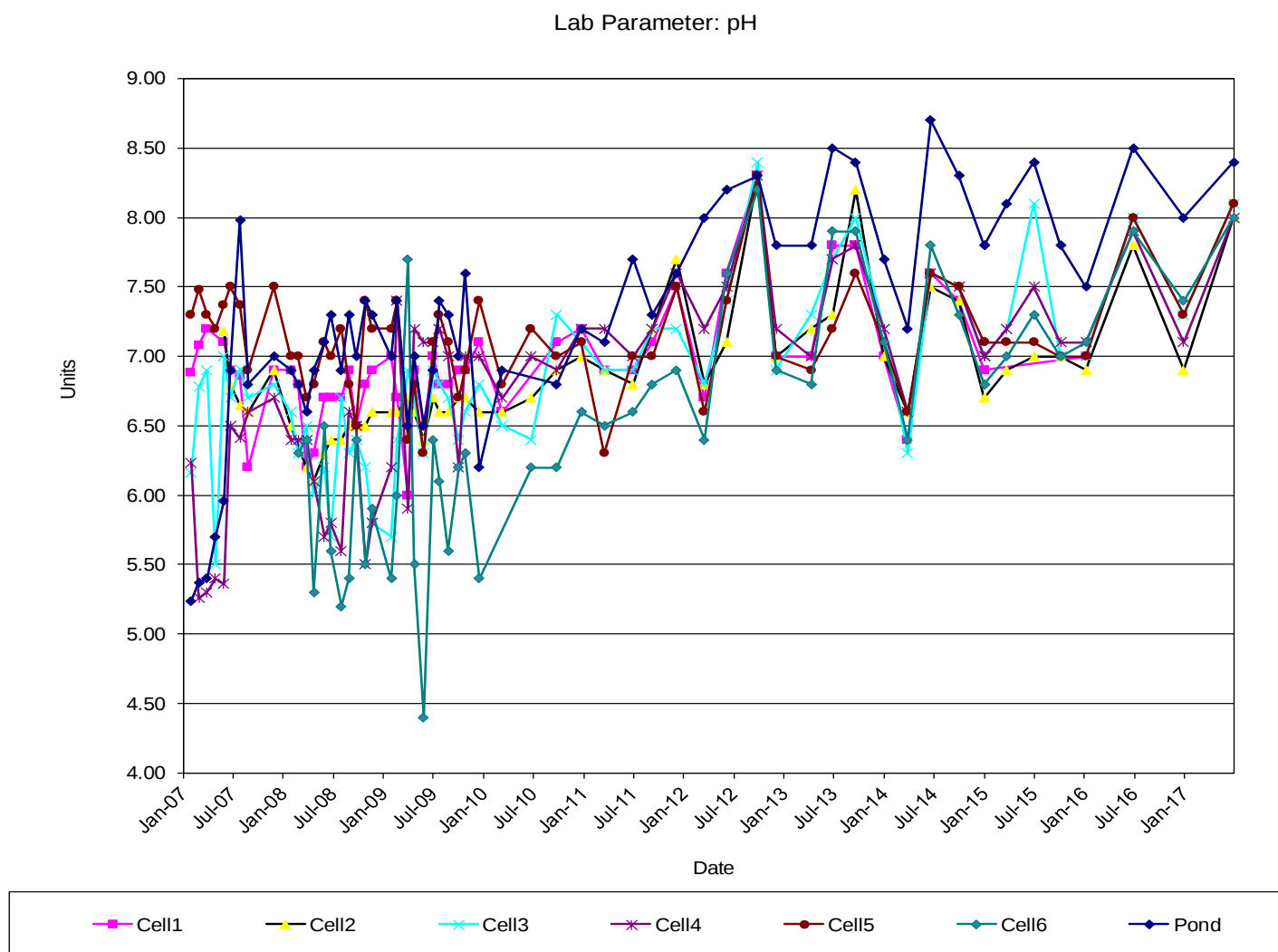


Figure 4-13 pH of Leachate

*Note: No readings were taken in Cell 1 during the January-December 2015 period due to a clogged sampling port.

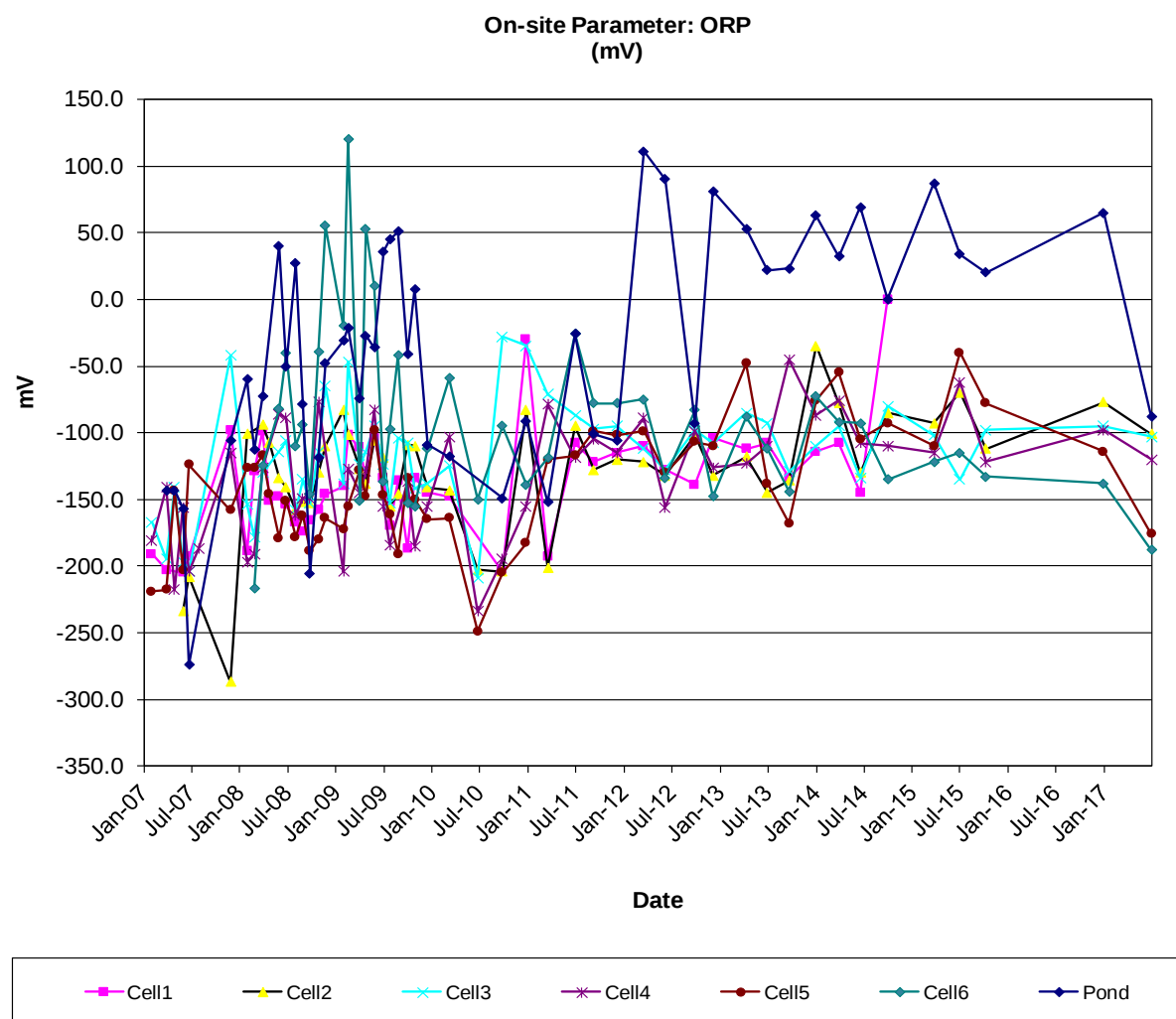


Figure 4-14 ORP of Leachate

***Note:** No readings were taken in Cell 1 during the January-December 2015 period due to a clogged sampling port.

****No readings were taken in January-June 2016 as the meter was being repaired.**

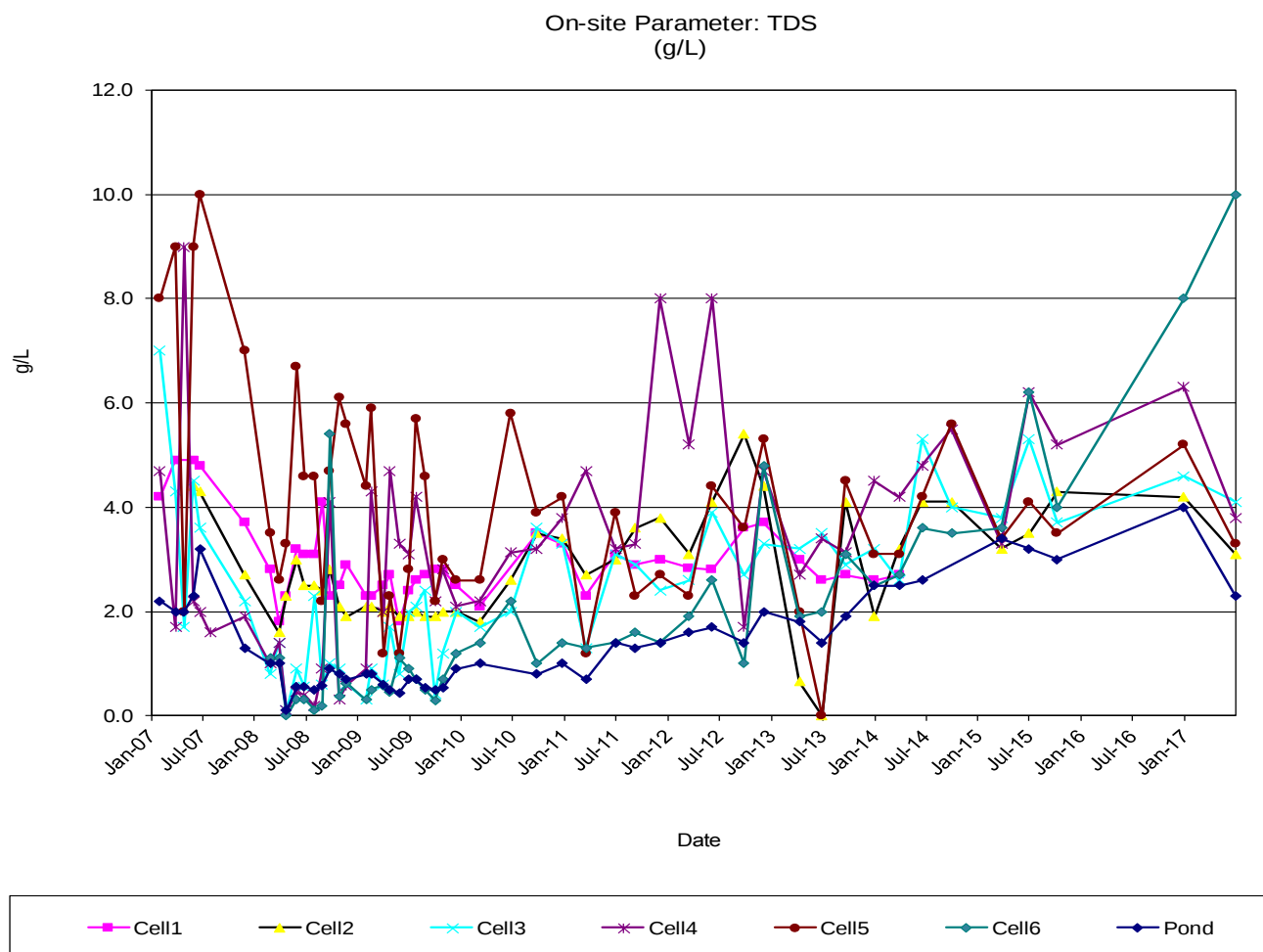


Figure 4-15 TDS of Leachate

*Note: No readings were taken in Cell 1 during the January-December 2015 period due to a clogged sampling port.

**No readings were taken in January-June 2016 as the meter was being repaired.

4.3 Leachate Recirculation

Figure 4-16 shows the cumulative quantity of leachate recirculated from 2006 through June 2017. Approximately 5.5 million gallons of leachate have been recirculated. The annual leachate recirculated is presented in **Table 4-3**.

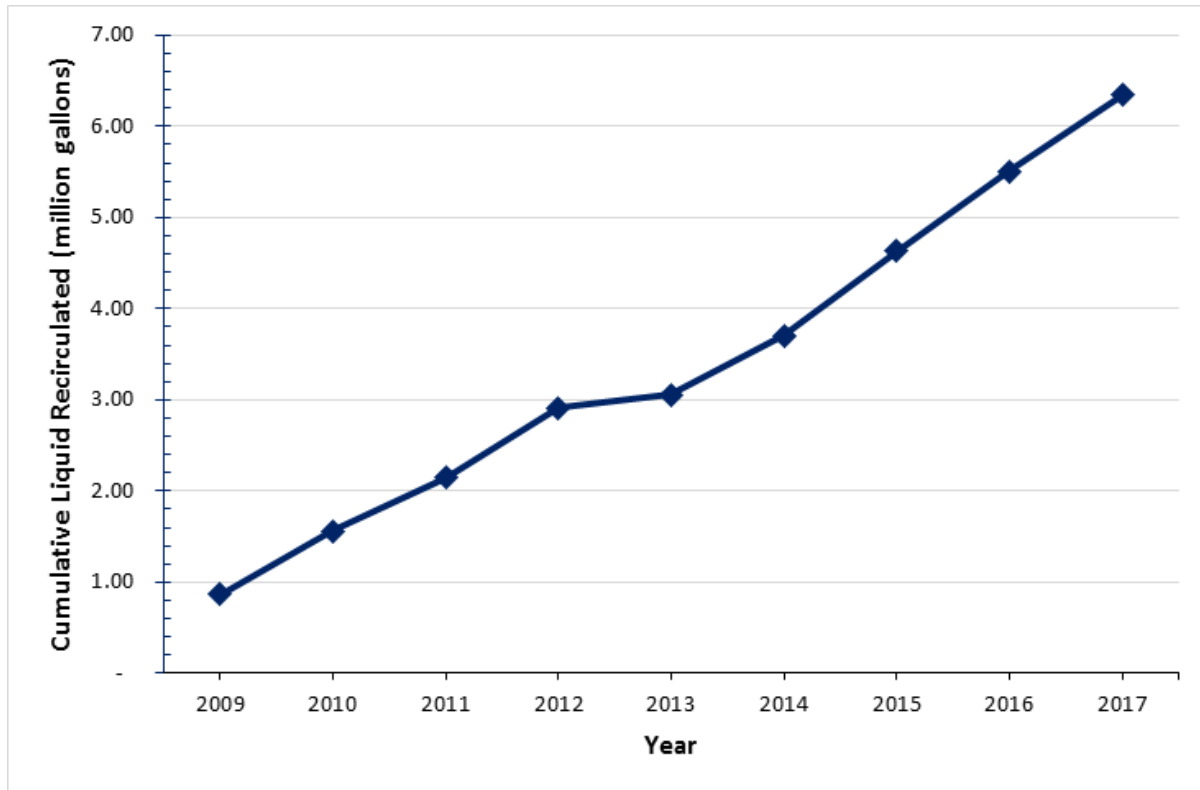


Figure 4-16 Cumulative Volume of Leachate Recirculated

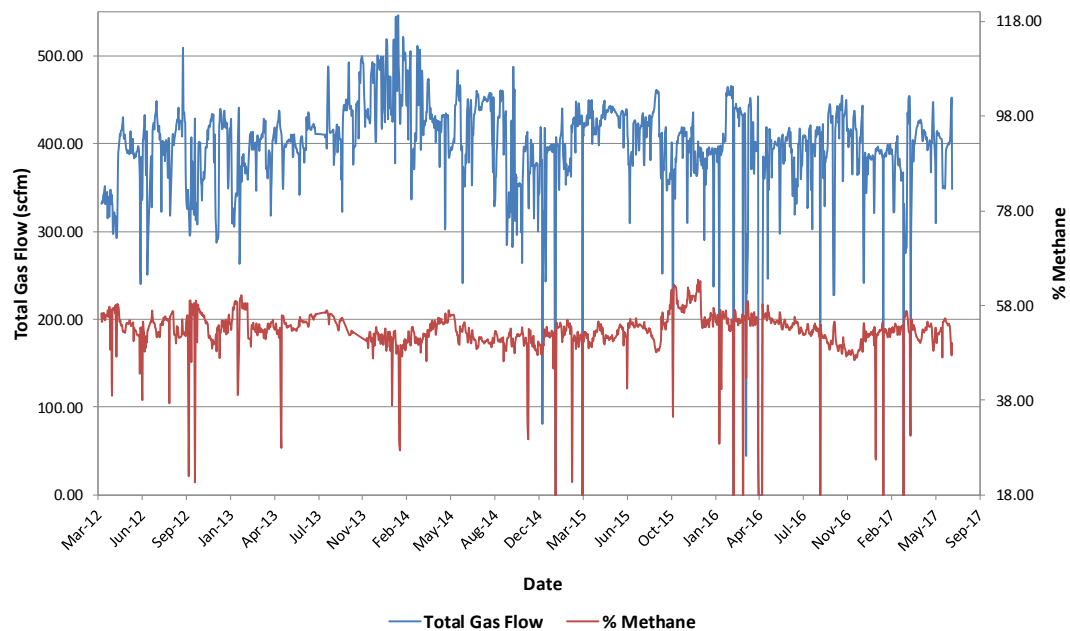
Table 4-3 Leachate Recirculation Volumes

Date	HITs D, E, and F (gal)	SGTs 1A, B, and C (gal)	SGTs 2A, B, and C (gal)	SGTs 3A, B, and C (gal)	HITs A, B, and C (gal)	SGTs 4A and 4B (gal)	SGTs 5A and 5B (gal)	HITs 6A, 6B and 6C (gal)	Annual Total (Gallons)
2006	32,093	48,140	48,140	48,140	32,093	10,698	10,698		230,000
2007	27,907	41,860	41,860	41,860	27,907	9,302	9,302		200,000
2008	116,108	51,914	42,883	35,985	14,720	0	0		261,610
2009	48,210	3,670	1,720	3,590	105,330	8,510	0		171,030
2010	296,600	20,000	24,100	21,300	307,733	21,667	10,000		701,400
2011	298,490	14,129	27,654	21,867	161,068	32,922	29,690		585,820
2012	425,620	24,867	33,968	25,765	213,010	19,955	18,235		761,420
2013	87,820	5,730	12,485	12,195	20,420	2,180	2,050		142,880
2014	420,470	0	11,600	5,290	116,630	6,200	3,680	85,520	649,390
2015	622,291	0	0	0	86,100	0	0	217,160	926,181
2016	609,910	-	-	-	127,710	-	-	136,810 ¹	874,430
Jan-June 2017	499,484	-	-	-	51,130	-	-	285,380	835,994
Total	3,485,633	210,310	244,410	215,992	1,263,851	111,434	83,655	724,870	6,340,155

1. Recirculation values decreased from 2015 as HIT 6A was unable to be used due to short circuiting when injecting. The clay plug was redone in September 2016, and injection in HIT 6A resumed in November 2016.

4.4 Landfill Gas

The total gas flow and methane percentage of the gas collected from the landfill is monitored continuously at the LFGTE facility as presented in **Figure 4-17**.

**Figure 4-17 Total Gas Flow and Percent Methane at the LFGTE Facility**

4.5 Settlement

The location of the ten (10) settlement plates installed within the retrofit area is shown in **Figure 4-18**.

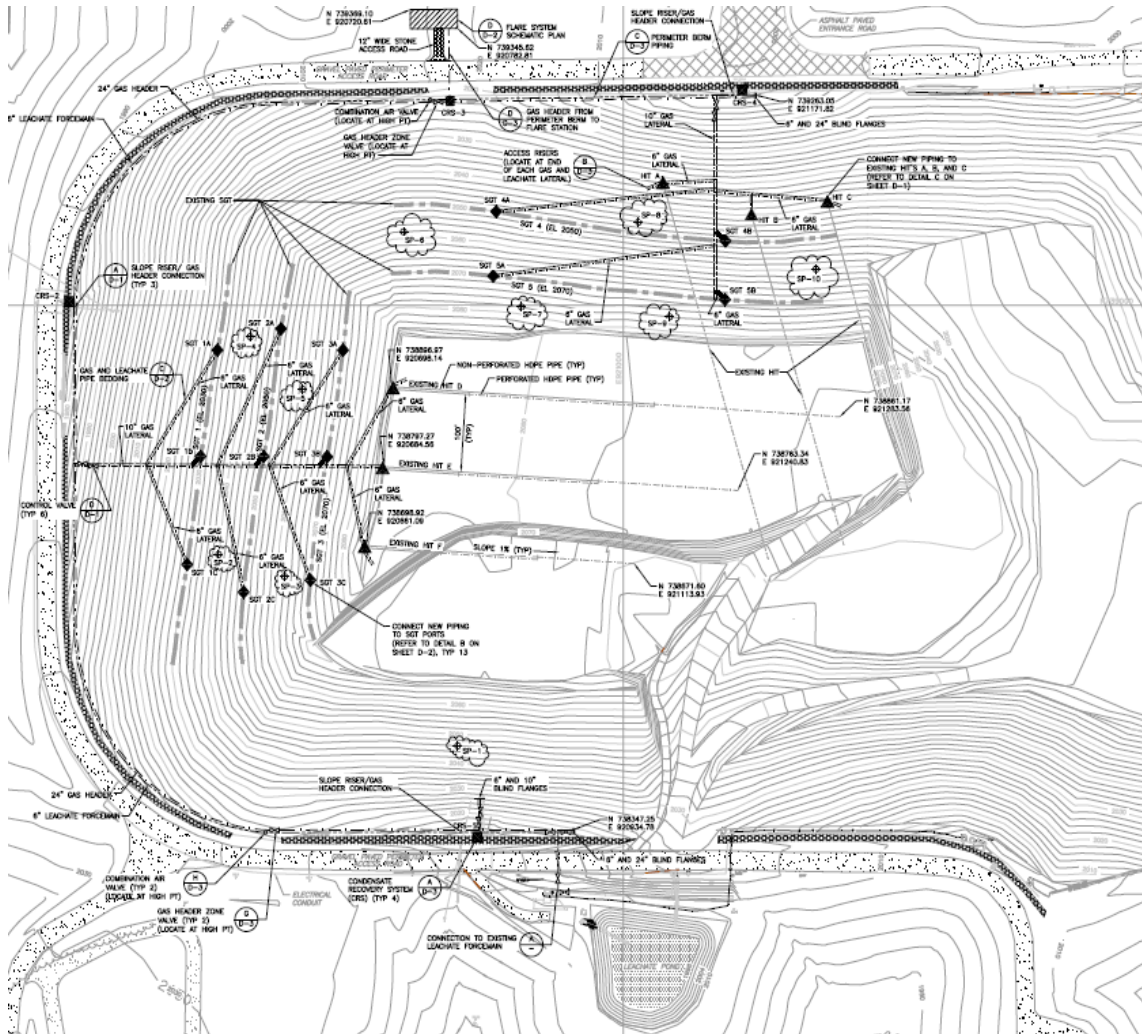


Figure 4-18 Settlement Plates in Cells 1-5
(Plate locations are shown circled with cloud outline.)

Figure 4-19 compares the measured settlement in the settlement plates from July 2006 through June 2017 to the quantity of leachate recirculated in Cells 1-6.

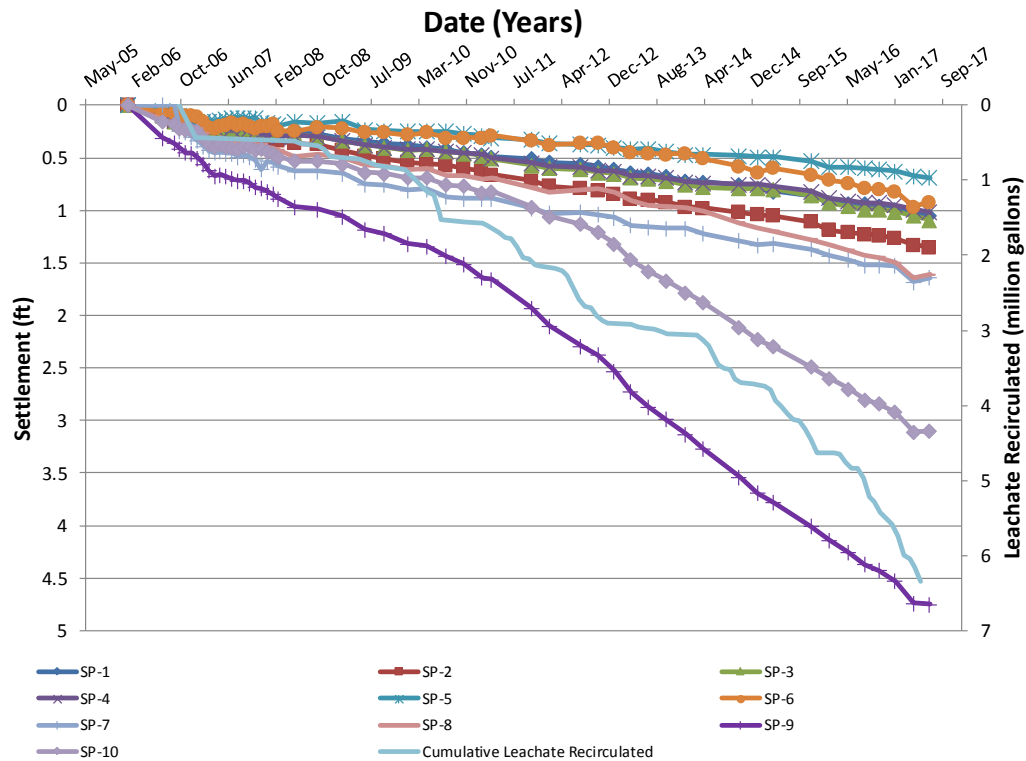


Figure 4-19 Cumulative Settlement

The latest survey of Cells 1 through 5 was done in April 2017. These cells were first surveyed in November 2010. **Figure 4-20** compares the settlement in Cells 1 through 5 since November 2010.

4.6 Effective Waste Density

The County tracks the effective waste density of the active cell as part of the landfilling operation to assess impacts of liquids addition on compaction. Density values for Cell 6 include:

- 2017: 0.84 tons/cy
- 2016: 0.79 tons/cy
- 2015: 0.82 tons/cy
- 2014: 0.76 tons/cy
- 2013: 0.77 tons/cy
- 2012: 0.86 tons/cy
- 2011: 0.63 tons/cy

The County replaced their Terex TC550 compactor with a Caterpillar 836K. The weight of the Terex TC550 was 110,000 pounds while the Caterpillar is 123,319 pounds.



Figure No. 4-20
COUNTY LANDFILL
E SETTLEMENT
SEPTEMBER 2017

4.7 Temperature of Waste in Cell 6

Thermocouples were installed in six (6) locations around Cell 6 HIT in assessing the impacts of leachate temperature during injection as shown in **Figure 4-21**.

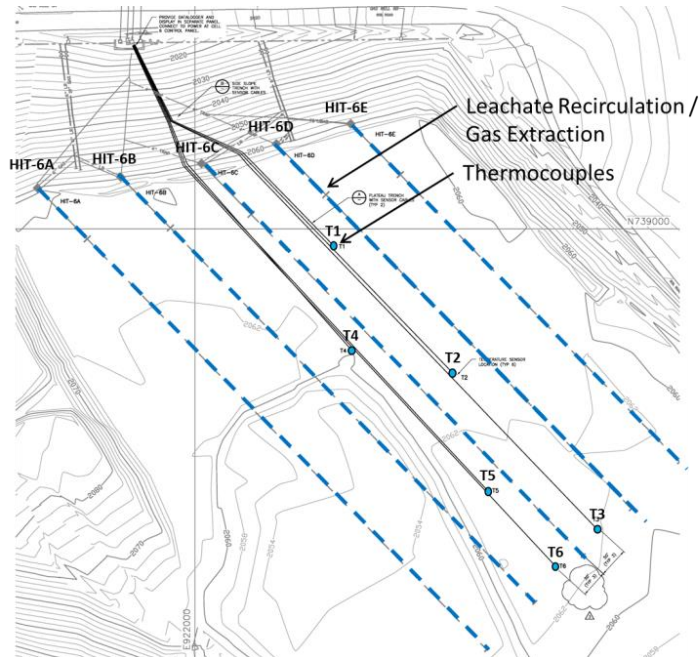


Figure 4-21 Temperature Sensors in Cell 6

The temperature of waste in Cell 6 is shown in **Figure 4-22**. Thermocouple T6 seems to have failed as of April 2016 as evidenced by erratic jumps from negative to positive temperatures in under a minute. This has continued into 2017. Leachate recirculation in this cell began in June 2014.

The temperature of waste in Cell 6 compared with the depth of waste is shown in **Figure 4-23**. The temperature data in Figures 4-22 and 4-23 was not able to be updated for the January-June 2017 time period due to corrupt data from the datalogger.

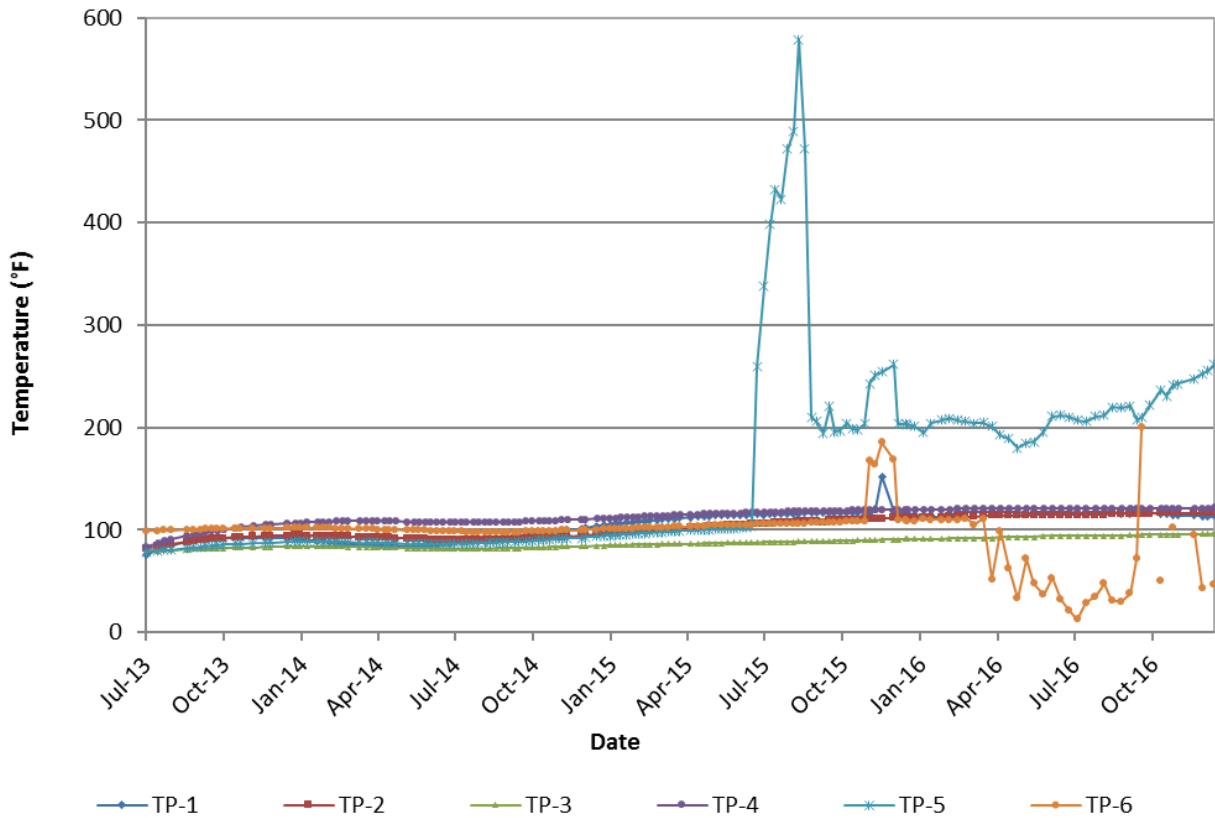


Figure 4-22 Waste Temperature Readings in Cell 6

*Thermocouple TP-6 has failed as of April 2016.

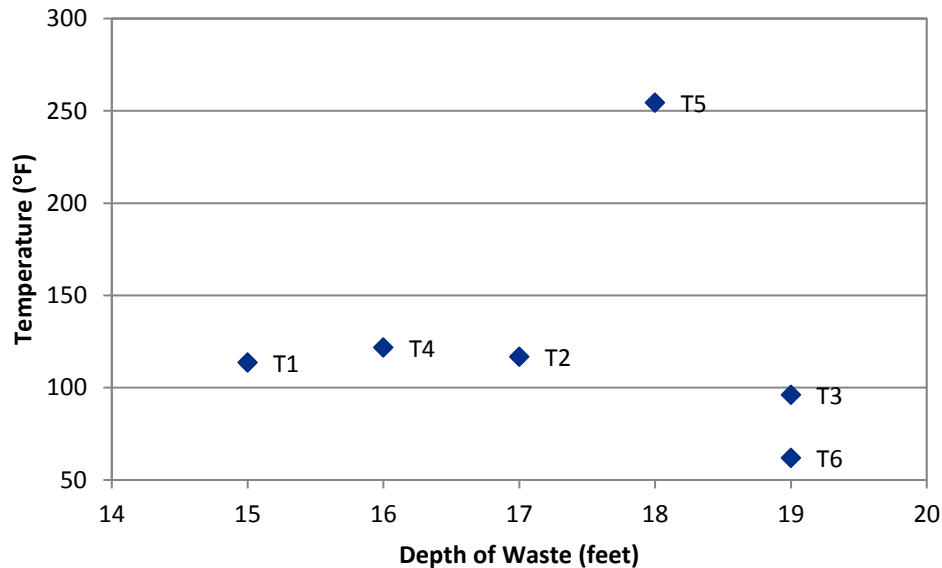


Figure 4-23 Temperature of Waste at Various Depths in Cell 6

(Note: Waste Depths from January 2016 Topographic Survey and Temperature Reading from December 2016)

*Thermocouple T6 has failed as of April 2016.

4.8 Cell 6 Landfill Gas Collection

Landfill gas is being collected from HITs 6A, 6D, and 6E and monitoring data has been collected since mid-2014. As no recirculation was done in HITs 6B and 6C during the January-June 2016 period due to weather conditions, landfill gas was collected from these as well. Recirculation has been conducted in HIT 6E in January-June 2017 and landfill gas collected from HITs 6A, 6B, 6C, and 6D. **Figure 4-24** shows the percent methane in each of these HITs and **Figure 4-25** shows the flow rate in standard cubic feet per minute (SCFM).

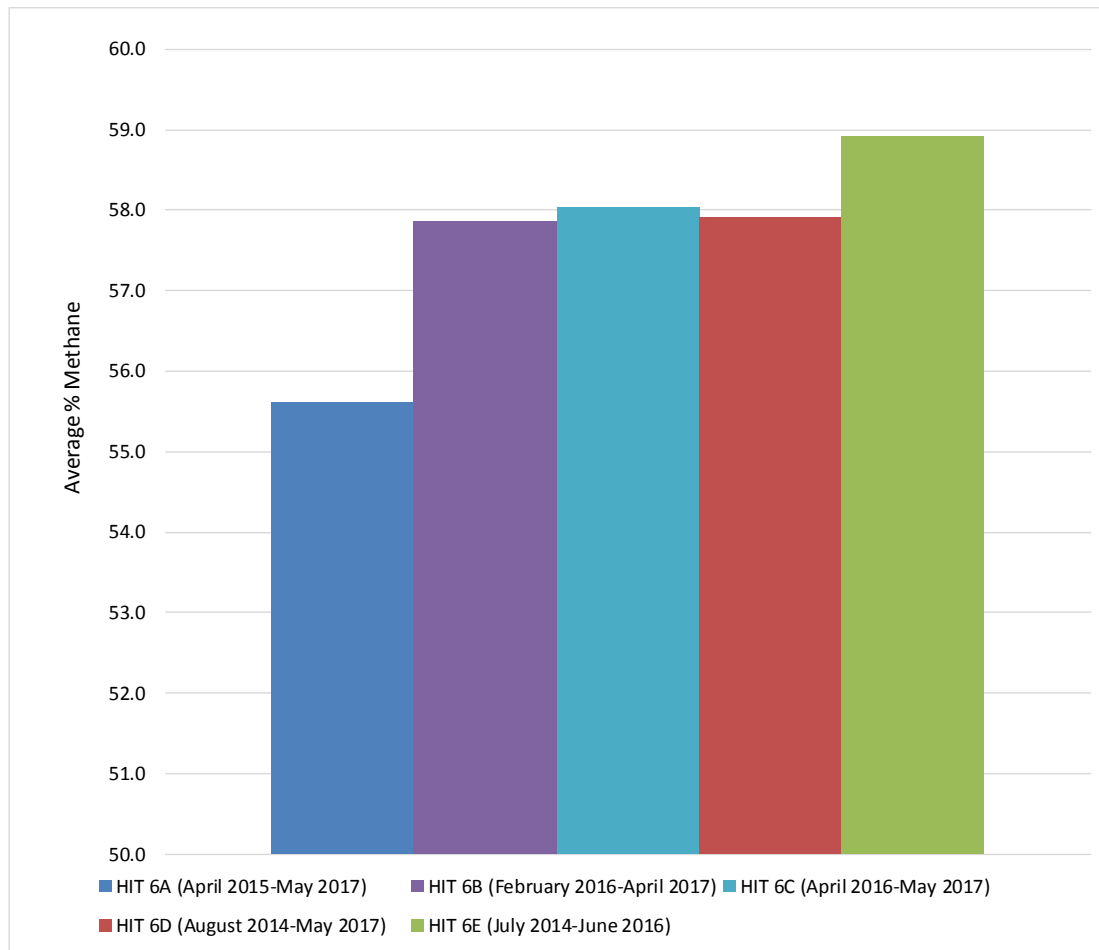


Figure 4-24 Average Percent Methane in HITs 6A, 6B, 6C, 6D, and 6E

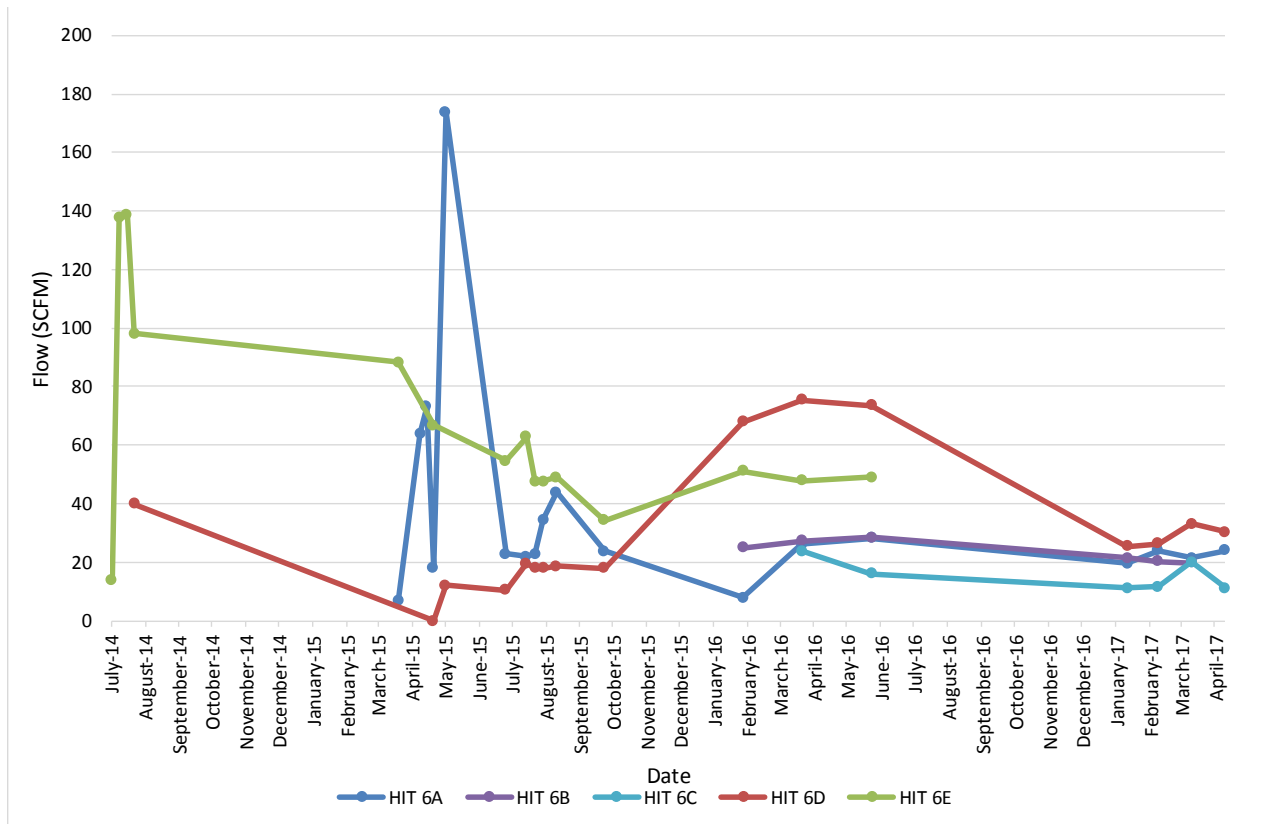


Figure 4-25 Flow Rate in HITs 6A, 6B, 6C, 6D, and 6E

(*Flows were calculated using the differential pressure, vacuum, and orifice plate size for the HITs.)

4.9 Cell 6 Sump Data

Data has been collected from the Cell 6 pump datalogger to record the sump level. The Cell 6 sump pump is set to turn on at a level of 30 inches and off at a level of 12 inches. **Figure 4-26** shows a graph of the sump levels from June through September 2015 along with the recirculation events and daily rainfall. As no recirculation was done in Cell 6 during the January through June 2016 period, there is no update to this graph from the 2015 year-end report. The datalogger data has been corrupt since June 2016, and the figure was not able to be updated. Some data was able to be extracted for March through June 2017 as is shown in Figure 4-27. The datalogger is in the process of being repaired.

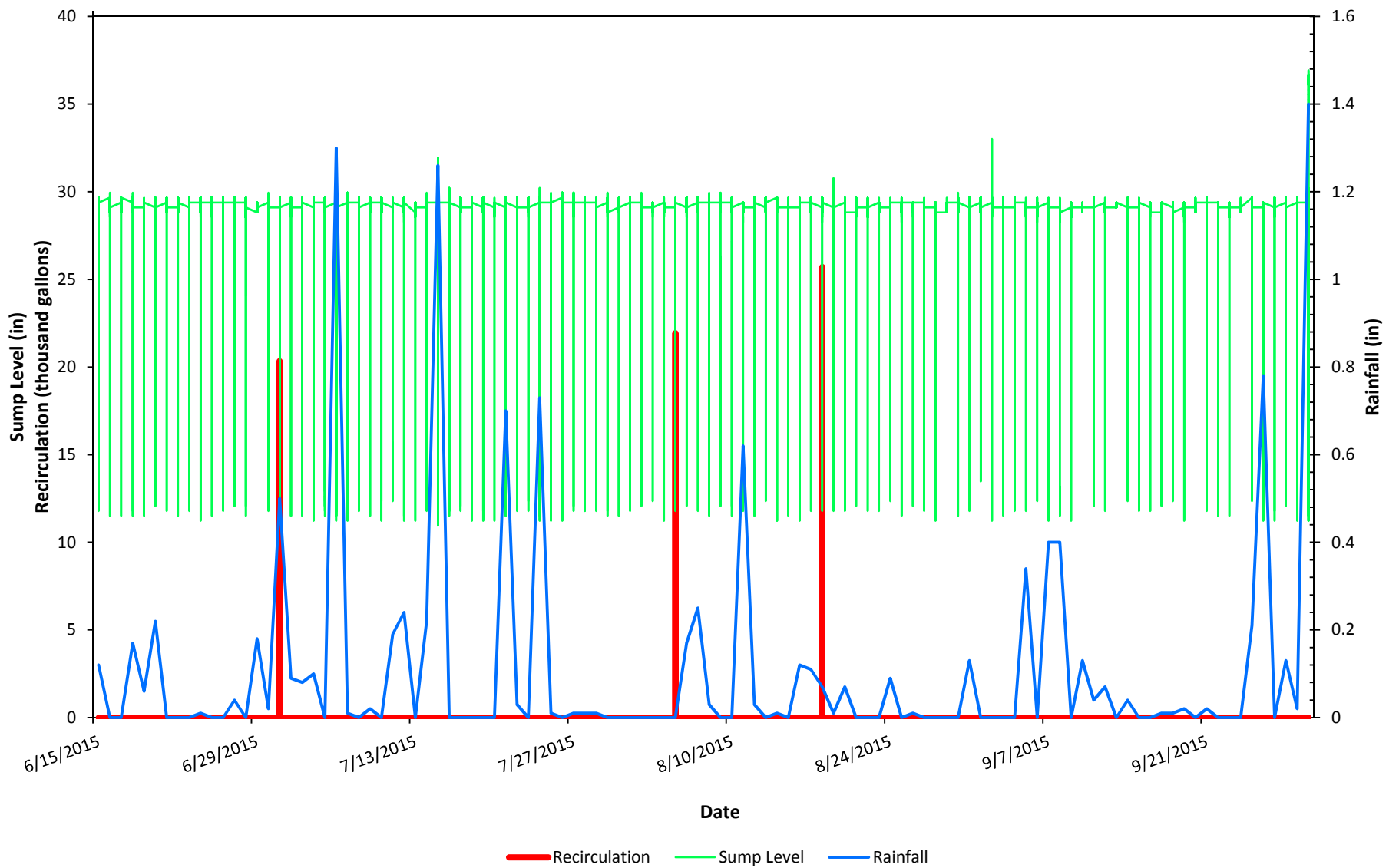


Figure 4-26 Cell 6 Sump Level, Recirculation Events, and Rainfall

Section 5

Project Assessment

5.1 Leachate Detection and Collection Systems Analysis

5.1.1 Determination of Liquid Source in the LDZ

Liquid present in the LDZ could be leachate that has leaked through the base liner system, groundwater or a combination of both. As shown in **Figure 5-1**, the LDZ are open on the sides and therefore are subject to potential groundwater infiltration. This is particularly evident in Cell 1 where it appears that the LDZ is being impacted by an underground spring based on the amount of flow witnessed during sampling events and the high quality of the water. Comparison of test data between the LDZ, leachate and groundwater was made in an effort to determine the source of the liquid.

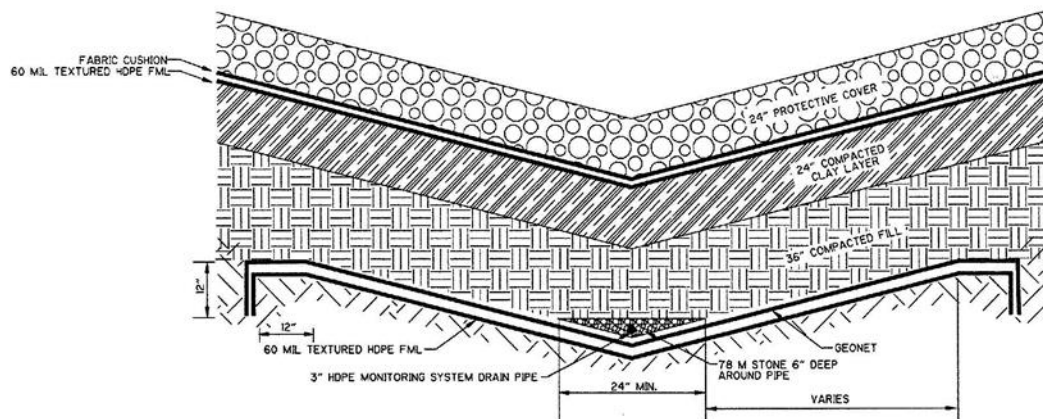


Figure 5-1 Leak Detection Zone in Cells 1-6 and Leachate Pond

The conductance levels of leachate are much higher than the samples tested for the Cell 1 LDZ. The conductance of leachate is in the range of 800-15,000 $\mu\text{mho}/\text{cm}$ compared to 200-800 $\mu\text{mho}/\text{cm}$ for the LDZ. The LDZ conductance is similar to the levels tested from groundwater well samples in the area as shown in **Figure 5-2**.

Toluene, which is often present in leachate, was found to be much lower in the LDZ samples, which correlate closely with groundwater testing results as shown in **Figure 5-3**.

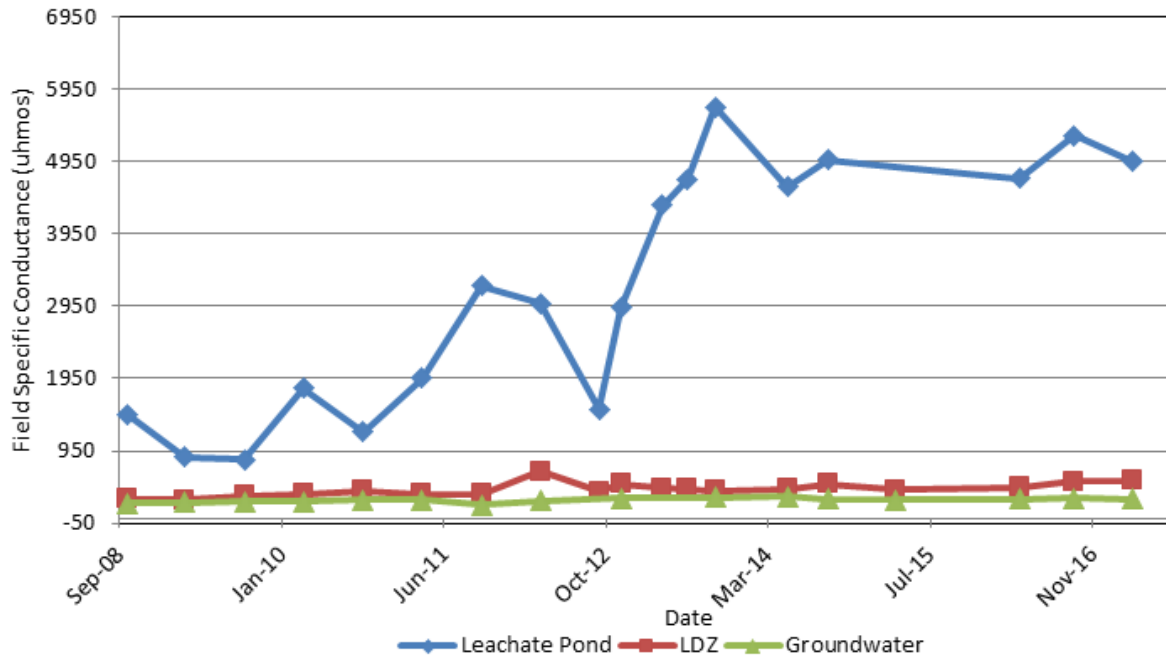


Figure 5-2 Conductance of Leachate, LDZ, and GW Samples
(Values are averages of testing results for the six cells and all GW monitoring wells)

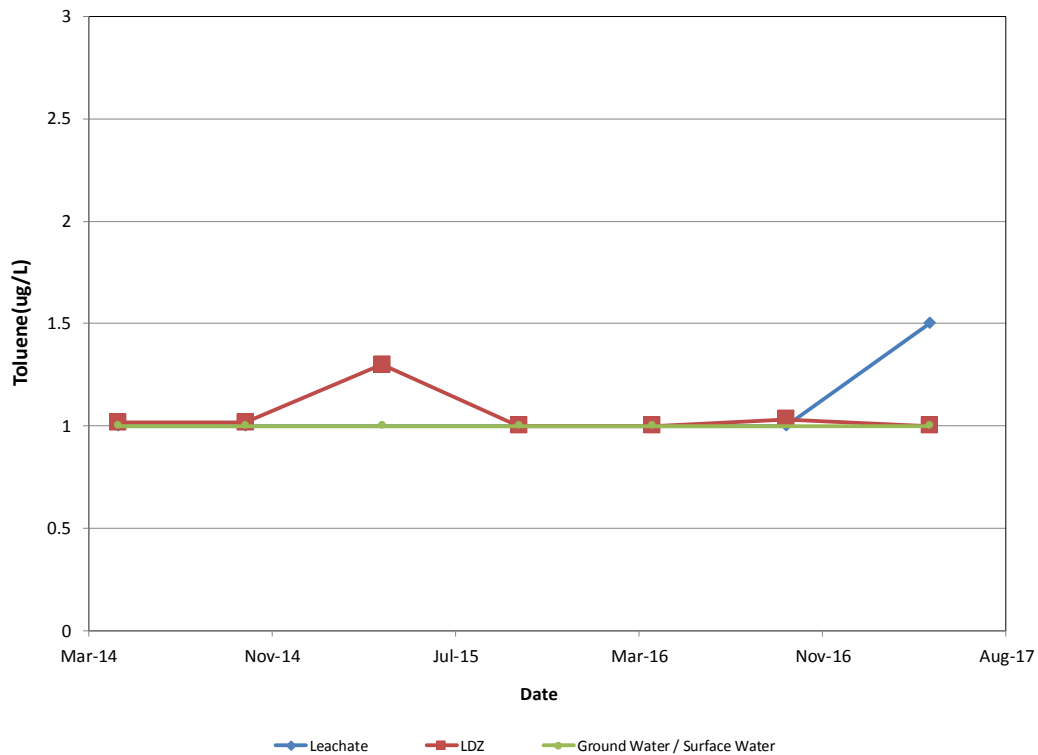


Figure 5-3 Toluene of Leachate, LDZ and GW/SW Samples
(Values are averages of testing results for the six cells and all GW/SW monitoring wells)

Figure 5-4 shows the ORP values for the leachate and LDZ samples for all cells. Comparison of ORP values from 2007 to 2015 shows a distinction between leachate and the liquid sampled from the LDZ. However, the most recent data does not show a distinction.

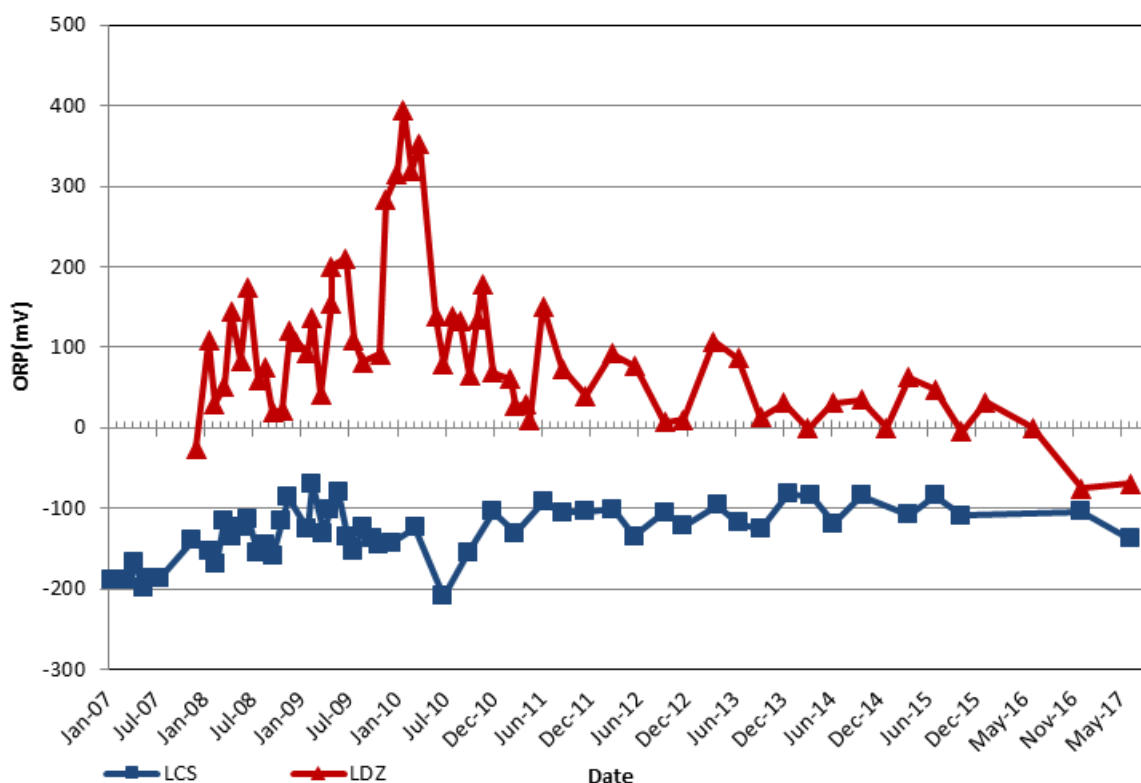


Figure 5-4 ORP of LCS and LDZ

(Values are averages of testing results for the six Cells)

*No readings were taken between January-June 2016 as the meter was being repaired.

5.1.2 Leachate Quality

The COD reading in Cell 2 in December 2014 was 222 mg/L. Except for in June 2012, COD has been not detected in the Cell 2 LDZ. The COD was ND in March 2015, 25 mg/L in June 2015, ND in October 2015, ND in 2016, and 41 mg/L in June 2017 which is similar to what is seen in Cell 5 and Cell 6. The cause of the high reading in December 2014 is unknown.

5.1.3 Leachate Pond

It was observed in 2014, that the quantity of leachate in the LDZ for the pond was significantly higher than in past years. This could be the result of the pond being kept half-full for a major part of the year.

It was also observed that the pH of the leachate in the pond was higher than the leachate in the cells as shown in Figure 4-13. However, the pH trend for the pond follows the leachate pH trend for the cells. It is thought that the concrete liner could possibly contribute to the higher pH in the pond. The liquid in the LDZ of the pond is mostly groundwater based on a comparison of conductance.

5.2 Gas Collection System and Gas Migration Control

The average gas flow for January through June 2017 was 387 scfm, and the average methane concentration of the gas was 52%.

An active gas collection trench was installed in the North Slope of Cells 1 and 3 in September 2014. This trench is a perforated pipe embedded in rock trench surrounded by an air tight tarp. The purpose of the trench is to mitigate landfill gas migration, and it has been working effectively.

5.3 Reduction of Leachate Hauling to the Wastewater Treatment Facility

As of June 2017, a total of 6.3 million gallons of leachate has been recirculated, resulting in 1,268 avoided truck trips to the wastewater treatment plant and a savings of \$483,630.93 in hauling costs. The savings attributed to January through June 2017 is \$63,535.54.

5.4 Settlement of Waste in Cells 1 through 5

Settlement plates in Cells 1 through 5 indicate that the landfill has settled an average of 1.72 ft since January 2006. Approximately 6.3 million gallons of leachate has been recirculated in the landfill from 2006 through June 2017.

Utilizing the April 2017 survey which is based on a 50 ft foot grid system, it was determined that Cells 1 through 5 have settled as shown in **Table 5-1** and Figure 4-20 since November 2010. Most of the settlement has occurred in the areas where leachate has been periodically recirculated.

Table 5-1: Settlement in Cells 1-5

Settlement (ft)	Area (acres)	% of Total Area
0-1	18.2	60%
1-3	7.5	25%
3-4	2.1	7%
4-8.5	2.4	8%
Total	30.2	100%

This settlement in Cells 1-5 is equal to approximately 63,800 cy which valued at nearly \$2.4 million. This is estimated based the settlement areas in Figure 4-20, a density of 0.8 tons/cy, and a tipping fee of \$47/ton.

5.5 Relocation of Condensate Discharge Line in Cell 4

The condensate discharge line from the gas wells around Cell 4 was constructed incorrectly and connected to the Leak Detection Zone Riser. All condensate discharge lines connect directly to the leachate sump riser; the condensate line for Cell 4 was disconnected from the leak detection zone and reinstalled correctly into the leachate sump riser at Cell 4.

5.6 Operations in Cell 6 Build-As-You-Go Bioreactor

There is approximately 16 to 34 feet of waste on top the HITs of Cell 6. Leachate recirculation started in HITs 6B and 6C in June 2014. Through June 2017, 398,464 gallons of leachate have been injected in

these two lines. Temperature sensors have been installed in these areas to access the impact of leachate temperature during injection.

Leachate recirculation into HIT 6A started in August 2016. Through December 2016, 65,346 gallons of leachate have been injected into this line. In 2016, leachate was recirculated into HITs 6A and 6B. In 2017, leachate recirculation began in HIT 6E. Through June 2017, 264,060 gallons of leachate have been injected into HIT 6E. Landfill gas was collected from HITs 6A, 6B, 6C, and 6D.

Landfill gas monitoring data has been collected since mid-2014 for HIT 6D and 6E and since early 2015 for HIT 6A as reported in Section 4.8. Landfill gas monitoring data has been collected since early 2016 for HITs 6B and 6C. The landfill gas collection from the HITs has been successful. Methane contents are between 55% and 59% and the wells have steady flow rates. Therefore, it is recommended that landfill gas continue to be collected from the HITs that are not being used for recirculation and even in the ones being used for recirculation after they are dry.

Data has been collected from the Cell 6 pump datalogger to record the sump level. This data was compared to the recirculation events and daily rainfall to determine if recirculation impacts the sump level. The data gathered from July to September 2015 shown in Figure 4-26 does not indicate the sump levels are affected by the recirculation events. The sump levels will continue to be monitored and reported in future reports as more data is gathered.

The temperature in TP-5 had elevated readings between 200 and 578 degrees Fahrenheit starting in July 2015 as can be seen in Figure 4-22. The temperature peaked on August 26, 2015 and has gradually been coming down to around 200 degrees in December 2015. The carbon monoxide (CO) levels were tested with the gas meter in this area to determine if there was a possible landfill fire. The readings are summarized in **Table 5-2** and do not indicate a landfill fire as they are less than 1000 ppm.

Table 5-2: Carbon Monoxide Readings in Cell 6 HITs

HIT	CO Reading
6A	24 ppm
6B	140 ppm
6C	248 ppm
6D	188 ppm
6E	70 ppm

5.7 Waste Stabilization

Twenty-five vertical wells were installed in Cells 1-5 in November 2010 for the landfill gas-to-energy project. Photographs were taken of the exhumed waste to observe the degree of stabilization as shown in **Figure 5-5** and **5-6**. Waste temperatures were taken immediately after waste was extracted from the boreholes with an infrared thermometer. Most locations showed waste temperatures in the mid-90s with the exception of the following five wells, which showed elevated temperatures:

- VW-6: 100 deg F
- VW-24: 110 -130 deg F
- VW-10: 104 -108 deg F
- VW-18: 110 deg F

- VW-11: 105 -108 deg F

The waste from these five boreholes was observed to be noticeably wetter than the waste for the other boreholes. Steam emanating from the waste of VW-24 was indicative of the elevated temperatures. The waste from this borehole appeared to be well decomposed.



Figure 5-5 Exhumed Waste from Drilling of Vertical Well 24



Figure 5-6 Exhumed Waste from Drilling of Vertical Well 13

The BOD5/COD ratio of the landfill leachate has dropped steadily since 2007 indicating that stabilization of the organic waste fraction is occurring as shown in **Figure 5-7**.

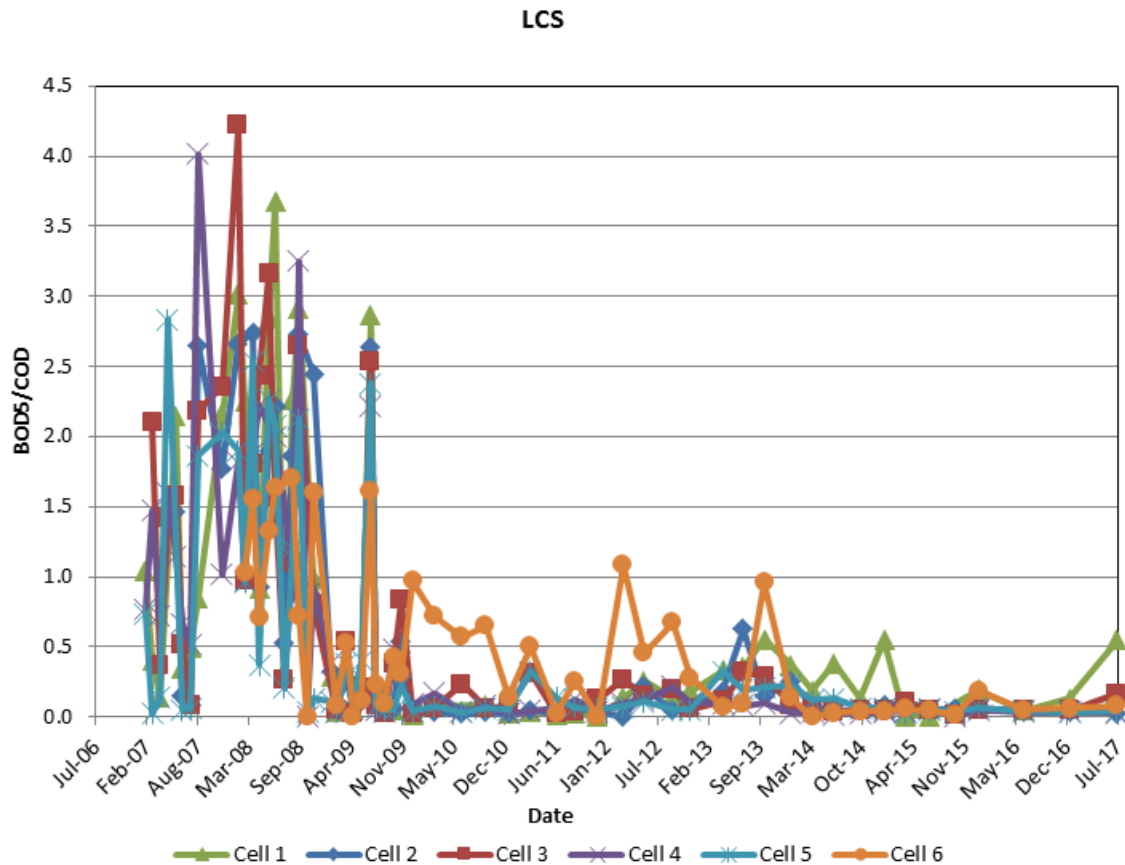


Figure 5-7 BOD5/COD Ratio of LCS in Cells 1-6

5.8 Greenhouse Gas Reductions

The HIT installed in the active disposal cell will provide early capture of LFG that would normally be released to the atmosphere until final grades are obtained and wells are installed. Collected gas from the active area will be measured to determine the amount of greenhouse gas reduction directly attributable to the project and renewable energy generation at the LFGTE facility. Combustion of LFG also produces carbon credits for the County as the site is registered with the Climate Action Reserve. No carbon credits were registered in 2017, and carbon credits will no longer be registered moving forward. The County has registered the carbon credits (CO₂ equivalent tons), equivalent passenger vehicles gas emissions, and green power generation shown in **Table 5-3** below:

Table 5-3: CO₂ Equivalents and Renewable Energy Generation

Year	CO ₂ Equivalent (tons)	Equivalent Passenger Vehicle Emissions Offset ¹	Renewable Energy Generation (MWh)	Equivalent Number of Homes' Annual Electricity Use ²
2011	N/A	N/A	498	37
2012	28,784	5,997	8,937	656
2013	29,490	6,208	9,379	688
2014	33,016	6,951	8,953	657
2015	30,407	5,827	9,874	724
2016	3,243	621	7,915	581
January-June 2017	N/A	N/A	5,182	380

1. Calculated using EPA's Greenhouse Gas Equivalencies Calculator (<http://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator>).
2. Calculated using residential energy data for North Carolina from the U.S. Energy Information Administration (http://www.eia.gov/electricity/sales_revenue_price/pdf/table5_a.pdf).
3. Based on 1,136 kwh/month average usage in North Carolina.

5.9 Alternative Cover Material

The use of alternative daily cover improves distribution of wetting from the HIT; uses less airspace than soil, and allows the onsite borrow soils to be saved for new cell and capping construction. It may also contribute to improved compaction of waste. It is recommended that alternative cover material be used to the largest extent possible in the ongoing landfill operation,

The County received approval from the North Carolina Department of Environment and Natural Resources to use Posi-Shell as an alternative daily cover at the Buncombe County landfill. This material has been used as an alternative daily cover since 2008 and as the primary daily cover material for the past five years.

Section 6

Stakeholders Meeting

6.1 September 2012 Stakeholders Meeting

A project stakeholders meeting was held on September 20, 2012 at Buncombe County solid waste management facility to provide an update and discuss project issues. The meeting was attended by the following people:

NCDENR:	Ed Mussler, Allen Gaither, Andrea Keller
USEPA:	Craig Dufficy, on conference call
WNCRAQA:	David Brigman, Ashley Featherstone
Buncombe County:	Jerry Mears, Jon Creighton, Kristy Smith, Aaron McKinzie, Donna Cottrell
CDM Smith:	Chris Gabel, Ravi Kadambala
University of Florida:	Dr. Timothy Townsend

The following are the various topics discussed during the meeting along with follow-up activities that were performed.

6.1.1 Monitoring of the Alternative Liner System

Ed Mussler inquired if the project has sufficient data to reach a conclusion regarding the performance of the alternate liner system and, if so, should we consider revising the project goals of Project XL and writing a final report addressing the performance of the alternative liner system.

Chris Gabel stated that further data is required to reach a conclusion and that Cell 6 will provide a means of tracking an accurate water balance. This will allow us to determine if the liner system is being subjected to higher leachate flows as a result of the newly installed build-as-you-go leachate recirculation system. The retrofit system applies leachate at elevations that are 100+ feet above the leachate sump. The Phase 1 trenches installed in Cell 6 are 20 to 40-feet from the drainage layer.

Ed Mussler inquired if the leachate level at the sump is being monitored as it could be used to determine if leachate recirculation is over-capacitating the collection system. Kristy Smith responded that leachate levels are monitored daily but are not recorded. This prompted the idea of using the existing temperature sensor data logger to record leachate level data in Cell 6.

Follow-up Activities: The level sensors were installed in the sump of Cell 6, and connected to the datalogger to record the head on the liner over time. Preliminary results showed negligible change in the level after one day of adding 13,170 gallons of leachate. The level sensor will be closely monitored with time as more leachate is recirculated.

6.1.2 Discharge Liquids from Cell 1 LDZ

The Cell 1 LDZ has a large quantity of liquid in it that has been tested numerous times. The test results indicate that it is groundwater. The meeting attendees discussed options for draining the LDZ to determine if groundwater is still recharging this area. The proposed plan is to test the liquid to ensure it is not leachate and then drain into the adjacent stormwater channel. Onsite staff would monitor the process to see how long it takes to drain the accumulated volume. NCDENR representatives suggested submitting a letter describing how the process will be performed and the safeguards to be used to ensure protection of the environment.

Follow-up Activities: A large tank will be used to collect liquids from Cell 1 LDZ, and disposed at the leachate pond. The most recent groundwater results should be submitted to NCDENR for approval to release the liquids collected.

6.1.3 Landfill Settlement

Settlement plates are used to track settlement resulting from wetting. We could consider using topographic surveys to supplement the plate information. The surveys could be performed on a 25-ft grid over the final slope areas for comparison from year to year to see where settlement is occurring. The cost is estimated at \$3,500 per survey. Graphic representation could include color coded areas based on the amount of the settlement.

Settlement measurements can be taken internally by installing a level sensor into the HIT. The device, known as a settlement profiler consists of a pressure transducer which is connected to a liquid reservoir. The transducer is inserted into the HIT pipe using a push rod allowing measurements to be taken at various points of the trench. The transducer gives a measure of the elevation profile of the pipe relative to the reservoir located on stable ground. The liquid tube is stored on a reel.

Follow-up Activities: Cells 1 through 5 are surveyed on a 50-ft grid annually. The results of this survey are presented in Section 4.5. These Cells will be surveyed again in May 2017 and continue on an annual basis.

6.1.4 Liquid Addition in Cell 6

Kristy Smith suggested dedicating HIT 6E to gas collection to reduce the likelihood of side seeps of leachate. Dr. Townsend suggested using only HITs 6B and 6D for leachate recirculation to determine the lateral extent of wetting using the temperature probes (refer to **Figure 6-1**). HITs 6A, 6C and 6E will be used for collecting gas. Temperature data and gas flow rates will be measured prior to leachate recirculation to get a background reading. The change in gas flow and temperature data will indicate the impact of leachate recirculation on gas generation.

Potential design changes for the next phase of lines in Cell 6:

1. Consider adding a vertical gas well intersecting the HITs.
2. Consider installing temperature probes inside the HITs.
3. Consider utilizing waste heat from the LFGTE system to heat leachate for year-long leachate recirculation.

Follow-up Activities: Refer to section 5.6 for details on liquid addition in Cell 6.

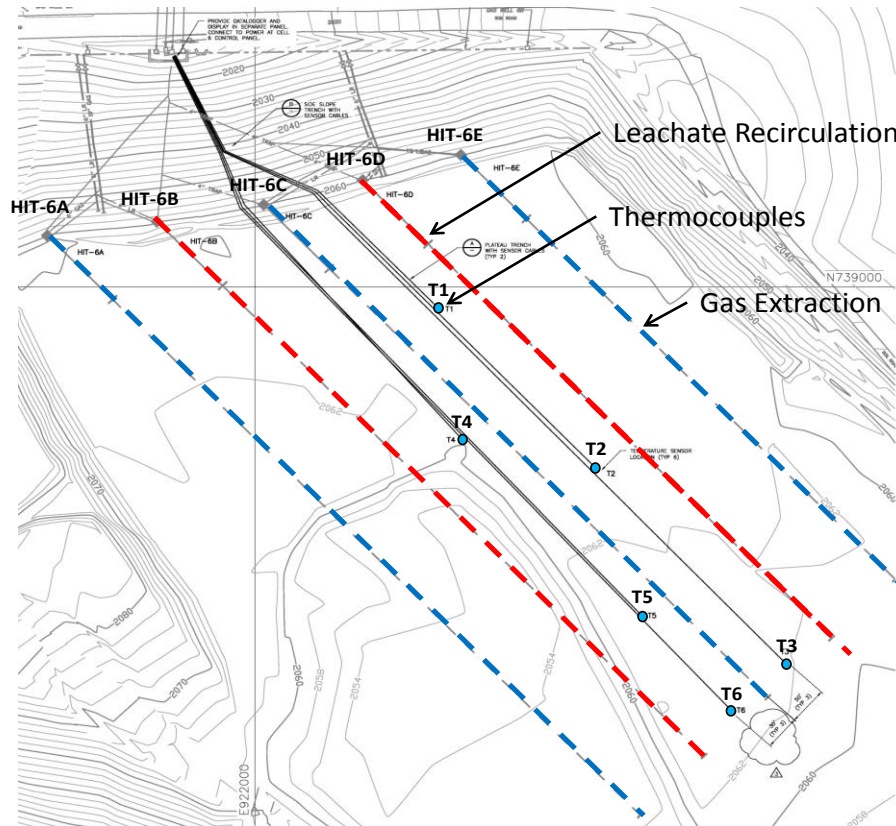


Figure 6-1 An Option Discussed at the Stakeholders' Meeting for Cell 6 HIT Operation

6.1.5 Gas Collection System

Aaron McKinzie stated that operation of the small flare was problematic as it keeps going out. Further investigation of the flare revealed that the orifice plate needs to be re-welded.

CDM Smith to perform wellfield adjustments with Buncombe County periodically to optimize gas extraction. Well 6A in the Cell 6 drainage layer is functioning now that leachate sump levels were re-set to provide a lower elevation for Pump ON.

Follow-up Activities: Small flare has been fixed and is currently operational. Refer to section 5.2 for details on the gas collection system. Wellfield adjustments will be made as needed.

6.2 November 2016 Stakeholders Meeting

A project stakeholders meeting was held on November 10, 2016 at the Buncombe County solid waste management facility to provide an update and discuss project issues. The meeting was attended by the following people:

NCDEQ:	Ed Mussler, Allen Gaither, Kris Riddle
USEPA:	Craig Dufficy, Davy Simonson, Sherri Walker, on conference call
Buncombe County:	Jon Creighton, Donna Cottrell, Stephen Hunter, Kristy Smith, Aaron McKinzie,
CDM Smith:	Chris Gabel
EIC:	Joe Wiseman

The following are the various topics discussed during the meeting.

6.2.1 Review of Existing Bioreactor and System Operation

The project was reviewed including the goal to determine if recirculation has any negative impacts on alternate liner systems. The operation of the bioreactor was discussed including using all SGT and HITs in Cell 1-5 only for recirculation and the Cell 6 build-as-you-go area bioreactor. The system operation in Cell 6 includes recirculating in two lines and collecting gas in the other three. Approximately 20,000 to 30,000 gallons are recirculated per event. Waste instability due to recirculating is achieved by maintaining a low injection pressure (less than 10 psi).

The gravity drain lines with traps are working well to clear Cell 6 HIT of leachate after a recirculation event. That allows them to be used for gas collection sooner after recirculating and may extend their useful life for gas collection. Also, the HIT are sloped to drain towards the trap. 30% of the LFG being collected for the genset is now coming from Cell 6 which shows that LFG collection in active cells can be effective. Combined flow from Cell 6 HITs is about 150 scfm.

6.2.2 Recouped Airspace

Settlement grid survey readings were started in 2010. The highest recorded settlement is 4'-6' settlement in the middle of Cells 1-5 on top. Settlement plate readings date back to 2006 and provide data in 10 locations. It is estimated that a 30-40% increase in capacity would be achieved by increasing the slope angle from 4:1 to 3:1 slopes in Cells 1-6.

Craig Dufficy suggested landfill mining as a means of extending landfill life indefinitely. Ed Mussler is not opposed to mining option. Davy Simonson thinks it was being considered near Athens, GA.

6.2.3 Evaluation of Monitoring Data

Leakage rates for all of the cells are very low in comparison to industry standard. A typical ALR is 20 gals/acre/day. Cell 5 has the highest leakage rate of all cells and is only 0.9 gals/acre/day. Also, much of the water being collected from the LDZ is groundwater so leakage through the liner is even less.

Waste density in Cell 6 is over 0.8 tons/cy due to recirculation, greater compaction and use of alternate daily cover.

Monitoring of leachate levels in the Cell 6 sump demonstrates that recirculation has no impact on the pumping system. This indicates that head on the liner is being maintained at a very low levels thus posing no additional driving force for leachate migration through potential holes in the liner system.

6.2.4 Regulatory Issues

Craig Dufficy said that he will be sending out a notice of proposed rulemaking soon (maybe by March 2017). He is looking for input from industry experts/operators for recirculation, gas collection and other issues. NCDEQ will do rulemaking in the next 2-3 years and will be considering allowing recirculation over alternative liners. Davy Simonson to discuss leachate recirculation over alternative liners at the next meeting with regulators from states in EPA Region 4.

Section 7

Recommendations

7.1 Modifications to the Monitoring Program

7.1.1 Measuring Settlement

Cells 1 through 5 were surveyed on a 50-ft grid in April 2017. The results of this survey are presented in Section 4.5. The next survey will be performed in April 2018.

7.1.2 Water Balance Monitoring

Water balance monitoring should be added to more accurately track the effects of moisture addition in Cell 6. Leachate, precipitation, and leachate recirculation data are being collected and will be used in a water balance calculation.

7.1.3 Leachate Recirculation Impacts to Head on Liner

Based on discussions with the North Carolina Department of Environment and Natural Resources (NC DENR), it was recommended to monitor and record levels of leachate in the Cell 6 sump during recirculation events. This monitoring will help determine any impacts to the leachate collection system from the recirculation. The pump level sensors in the sump of Cell 6 are connected to a datalogger, which continuously records the sump level every minute. Fluctuations are monitored to indicate changes in the head on the liner. Preliminary results are discussed in Section 6.1. Detailed sump monitoring data was evaluated and discussed in Section 5.6. This data will continue to be collected and will be further analyzed in the next progress report.

7.2 Recommended Modifications to Design and Operation

7.2.1 Leak Detection Zones

For Cells 7-10, it is recommended that the design of the LDZ be revised to eliminate the 3-foot separation between the LDZ and the bottom of the base liner system, as this will greatly reduce the potential for groundwater infiltration. This is shown in **Figure 7-1**.

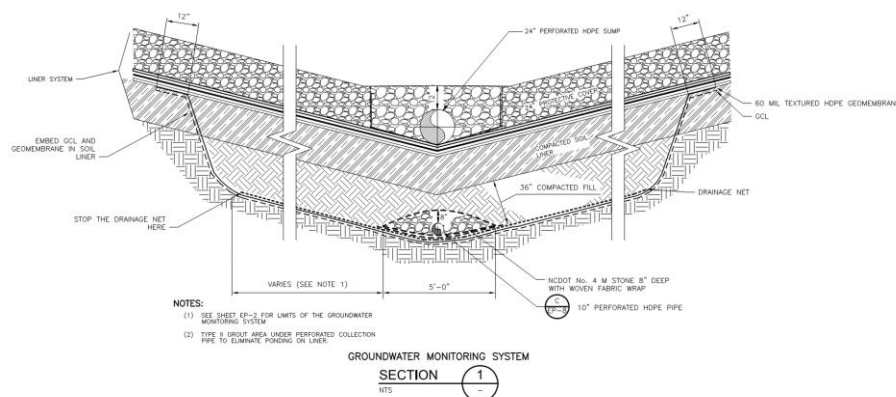


Figure 7-1: Revised LDZ Design

7.2.2 Strategy for Operation of Cell 6 HITs

Based on the discussions held at the stakeholders meeting, a combination of dedicated recirculation and gas collection HIT is desirable for determining the effectiveness of the wetting operation and maximizing early gas capture.

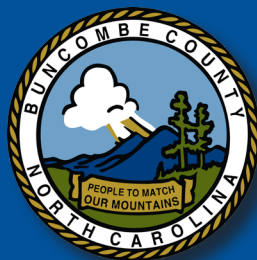
The original strategy had been to recirculate in HITs 6B and 6C and temporarily collect landfill gas from HITs 6A, 6D, and 6E. The landfill gas data from 2014-2016 shows the gas collected in HITs 6A, 6D, and 6E has a high methane content. In addition, gas flow rates have been steady. However, in 2016 and 2017, recirculation began in HIT 6A and 6E. Landfill gas was collected from the HITs not being used for recirculation.

As no recirculation was done in HITs 6B and 6C during the January-June 2016 period due to weather conditions, landfill gas was collected from these as well. The gas collected in HITs 6B and 6C has a high methane content as well. HITs 6B and 6C should continue to be used to recirculate, but can be used for gas collection when no recirculation is occurring. Recirculation in HIT 6A began in August 2016. This HIT should continue to be used for gas collection when no recirculation is occurring.

Recirculation in HIT 6E began in January 2017, and HITs 6A, 6B, 6C, and 6D were used for landfill gas collection. The landfill gas collection from the HITs has been successful. Methane contents are between 55% and 59% and the wells have steady flow rates. Therefore, it is recommended that landfill gas continue to be collected from the HITs that are not being used for recirculation and even in the ones being used for recirculation after they are dry. Data should be collected bi-weekly. The data will be evaluated to determine if the HITs should continue to be used for gas collection.

7.2.3 Cells 1-5 HITs Maintenance

In order for continued optimal operation, it is recommended that HITs A, B and C be cleaned using high-pressure water jetting to remove clogging.



**CDM
Smith**
cdmsmith.com