FULL SCALE BIOREACTOR LANDFILL FOR CARBON SEQUESTRATION AND GREENHOUSE EMISSION CONTROL

Quarterly Technical Progress Report

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ABSTRACT

The Yolo County Department of Planning and Public Works is constructing a full-scale bioreactor landfill as a part of the Environmental Protection Agency's (EPA) Project XL program to develop innovative approaches for carbon sequestration and greenhouse emission control. The overall objective is to manage landfill solid waste for rapid waste decomposition and maximum landfill gas generation and capture for carbon sequestration and greenhouse emission control. Waste decomposition is accelerated by improving conditions for either the aerobic or anaerobic biological processes and involves circulating controlled quantities of liquid (leachate, groundwater, gray water, etc.), and, in the aerobic process, large volumes of air.

The first phase of the project entails the construction of a 12-acre module that contains a 6-acre anaerobic cell, a 3.5-acre anaerobic cell, and a 2.5-acre aerobic cell at the Yolo County Central Landfill near Davis, California. The cells are highly instrumented to monitor bioreactor performance. Construction is complete on the 3.5-acre anaerobic cell and liquid addition has commenced. Construction of the 2.5-acre aerobic cell is nearly complete with only the biofilter remaining and construction of the west-side 6-acre anaerobic cell is nearly complete with only the liquid addition system remaining. The current project status and preliminary monitoring results are summarized in this report.

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1 EXECUTIVE SUMMARY

In 1996, Yolo County began operation of a pilot-scale project to evaluate the costs and benefits of a relatively new concept in landfill operation, often termed “bioreactor” or “enhanced” landfilling. The basic concept of a bioreactor landfill is to increase the biological activity of the waste (through the addition of water) to maximize the production of landfill gas for carbon sequestration and greenhouse emission control. The results of this pilot project were favorable and, as a result, Yolo County requested and gained approval from state and federal regulatory agencies to conduct this full-scale demonstration of bioreactor landfilling.

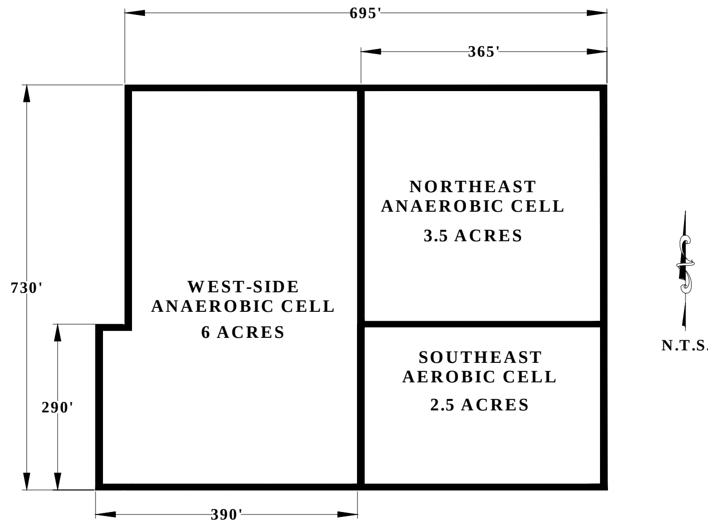
Because current Federal and California State regulations generally do not allow the addition (or recirculation) of leachate and other supplemental liquid to a lined landfill module, special regulatory flexibility was required to conduct this project. Yolo County applied for, and was granted the necessary flexibility through the Unites States Environmental Protection Agency XL Program which stands for "eXcellence and Leadership.” The XL program allows state and local governments, businesses and federal facilities to develop with EPA innovative strategies to test better or more cost-effective ways of achieving environmental and public health protection.

This report provides an update on Phase 1 of the Yolo County Accelerated Anaerobic and Aerobic Composting (Bioreactor) Project where carbon sequestration and greenhouse emission is controlled through either the anaerobic or aerobic process. Phase 1 of the project encompasses a 12-acre area of a 20-acre landfill module (Unit 6, Module D) at the Yolo County Central Landfill. Phase 2 of the project has begun with the construction of the primary liner system and installation of 12 temperature and moisture sensors. Waste placement in Phase 2 began in November 2002.

1.1 Summary of Current Project Status

The majority of the bioreactor project continues on schedule with the only deviations related to the aerobic cell’s air collection system. The project schedule is located in Appendix A, Table 1-1 and has been altered since the previous project schedule prepared in January 2003.

The project bioreactors are separated into three landfill cells, two cells will be operated anaerobically and one aerobically (Detail 1-1). We have designated the three bioreactor cells as the west-side anaerobic cell, the northeast anaerobic cell, and the southeast aerobic cell. This configuration allowed the northeast anaerobic cell to be constructed and operated prior to completion of the west-side anaerobic cell. By separating the anaerobic bioreactor into two separate cells, experiences gained from construction of the northeast cell were incorporated into the west-side anaerobic cell.



Detail 1-1. Overview of Module D Bioreactor Cells

The northeast anaerobic cell, the west-side anaerobic cell, and the southeast aerobic cell have been filled with waste and instrumentation. A total of 65,104 tons of waste was placed in the northeast anaerobic, 11,942 tons of waste was placed in the southeast aerobic module, and 166,294 tons of waste was placed in the west-side anaerobic cell. The gas collection systems have been completed in the northeast anaerobic cell and the west-side anaerobic cell while the biofilter remains to be completed for the aerobic cell. The leachate injection system has been completed in the northeast anaerobic cell and aerobic cell and is near completion in the west-side anaerobic cell.

The installation of a reinforced polypropylene (RPP) membrane surface cover over the northeast anaerobic cell was completed in November 2001 and will allow precise quantification of the amount of landfill gas produced by eliminating surface emissions. The aerobic cell received a cover of 12-inches of soil overlaid by 12-inches of greenwaste alternative daily cover (ADC). The surface membrane cover for the west-side anaerobic cell is similar to the northeast anaerobic cell, with the exception that 40-mil linear low-density polyethylene (LLDPE) was used instead of RPP. Surface liner installation for the west-side anaerobic cell was completed in October 2002.

A Supervisory Control and Data Acquisition (SCADA) system has been installed and will monitor and control the operation of the bioreactor cells. To date, all instrumentation installed in the northeast and west-side anaerobic cells, the aerobic cell, and on the Module 6D composite liner have been connected to a central processor which is radio linked to a computer located in our Woodland office. In March 2002, the SCADA system started to electronically collect temperature and moisture data from in the northeast anaerobic cell, the aerobic cell, and on the Module 6D composite liner. In January 2003, the SCADA system started to electronically collect temperature and moisture data from in the west-side anaerobic cell.

Landfill gas collection began in the northeast anaerobic cell in mid-December 2001. Through the end of March 2003 a total of 22.3 x 10^6 scf of methane (which is equivalent to approximately

3500 barrels of oil) has been collected and utilized at the on-site gas to energy facility. Landfill gas from the main gas extraction header line on the northeast anaerobic cell was sampled and submitted for laboratory analysis in March 2003. Gas composition (methane, carbon dioxide, and oxygen) and pressure continues to be monitored on a weekly basis.

Landfill gas collection began in the west-side anaerobic cell in May 2002, and through the end of March 2003 a total of 5.3 x 10^6 scf of methane (which is equivalent to approximately 850 barrels of oil) has been collected and utilized at the on-site gas to energy facility.

Leachate addition to the northeast cell began on March 27, 2002. Through the end of March 2003, a total of 1,563,042 gallons of supplemental liquid has been added and 548,462 gallons of leachate recirculated to the northeast anaerobic cell. Leachate was monitored for field chemistry and sampled for laboratory analysis in February 2003.

Monitoring for methane surface emissions has been performed quarterly since April 2002. During March 2003, a surface scan was performed on the northeast anaerobic cell and the west-side anaerobic cell. The surface scan for the aerobic cell was postponed until April 2003 because of technical difficulties with the surface monitoring equipment. The highest methane surface emissions to date on the northeast anaerobic cell were detected in March 2003 at 70 parts per million (ppm). The high surface emissions in March 2003 can attributed high background readings, ranging between 60 and 65 ppm, that may be due Module D Phase II construction and changing wind currents carrying emissions from the west-side anaerobic cell. The highest methane surface emissions detected to date on the west-side anaerobic cell were also detected in March 2003 at 150 ppm. The high readings for the west-side anaerobic cell are due to a combination of high background readings, ranging between 60 and 75 ppm, and small gaps (less than 1 inch) between the surface liner and where the gas collection and leachate injection piping exits the cell (pipe penetrations). A follow-up surface scan will be performed in April 2003 to confirm these readings and steps will be taken to seal the pipe penetrations.

2 INTRODUCTION

Sanitary landfilling is the dominant method of solid waste disposal in the United States, accounting for about 217 million tons of waste annually (U.S. EPA, 1997). The annual production of municipal solid waste in the United States has more than doubled since 1960. In spite of increasing rates of reuse and recycling, population and economic growth will continue to render landfilling as an important and necessary component of solid waste management.

In a Bioreactor Landfill, controlled quantities of liquid (leachate, groundwater, grey-water, etc.) are added to increase the moisture content of the waste. Leachate is then recirculated as necessary to maintain the moisture content of the waste at or near it's moisture holding capacity. This process significantly increases the biodegradation rate of waste and thus decreases the waste stabilization and composting time (5 to 10 years) relative to what would occur within a conventional landfill (30 to 50 years or more). If the waste decomposes (i. e., is composted) in the absence of oxygen (anaerobically), it produces landfill gas (biogas). Biogas is primarily a mixture of methane, a potent greenhouse gas, carbon dioxide, and small amounts of Volatile Organic Compounds (VOC's). This by-product of anaerobic landfill waste composting can be a substantial renewable energy resource that can be recovered for electricity or other uses. Other benefits of a bioreactor landfill composting operation include increased landfill waste settlement and a resulting increase in landfill capacity and life, improved opportunities for treatment of leachate liquid that may drain from fractions of the waste, possible reduction of landfill post-closure management time and activities, landfill mining, and abatement of greenhouse gases through highly efficient methane capture over a much shorter period of time than is typical of waste management through conventional landfilling.

2.1 Description Of The Project And Its Purpose

The County of Yolo Planning and Public Works Department (Yolo County) is operating its next 20-acre landfill module near Davis, California as a controlled bioreactor landfill to attain a number of superior environmental and cost savings benefits. In the first phase of this 20-acre project, a 12-acre module will be constructed. This 12-acre module contains a 6-acre cell and a 3.5-acre cell, which will be operated anaerobically, and a 2.5-acre cell, which will be operated aerobically. The County began construction the second phase of Module 6D in Fall 2002 and, depending on the results of the first phase of Module 6D, Yolo County may operate the second phase either anaerobically or aerobically.

Co-sponsors of the project with Yolo County are the Solid Waste Association of North America (SWANA) and Institute for Environmental Management (IEM, Inc.). As part of the EPA Project XL, Yolo County requested that U.S. EPA grant site-specific regulatory flexibility from the prohibition in 40 CFR 258.28 Liquid Restrictions, which may preclude addition of useful bulk or non-containerized liquid amendments. The County intends to use leachate and groundwater first but if not enough liquid is available then other supplemental liquids such as gray-water from a waste water treatment plant, septic waste, and food-processing wastes will be used. Liquid wastes such as these, that normally have no beneficial use, may instead beneficially enhance the biodegradation of solid waste.

Yolo County also requested similar flexibility on liquid amendments from California and local regulatory entities. Several sections of the California Code of Regulations (CCR), Title 27, Environmental Protection, address the recirculation of liquids in lined municipal solid waste landfills. While the regulations do not specifically endorse bioreactors, regulatory flexibility is provided by the State of California Title 27, Chapter 3, Subchapter 2, Article 2, section 20200, Part (d)(3), *Management of liquids at Landfills and Waste Piles*. For additional information on this regulatory flexibility, see Section IV A of the FPA.

2.2 Description Of The Facility And The Operations / Geographic Area

The Yolo County Central Landfill (YCCL) is an existing Class III non-hazardous municipal solid waste landfill. The site encompasses a total of 722 acres and is comprised of 17 distinct Class III solid waste management units and two Class II leachate surface impoundments. The YCCL is located at the intersection of Road 104 and Road 28H, 2 miles northeast of the City of Davis. The YCCL was opened in 1975 for the disposal of non-hazardous solid waste, construction debris, and non-hazardous liquid waste. Existing on-site operations include a thirteen-year-old landfill methane gas recovery and energy generation facility, a drop-off area for recyclables, a metal recovery facility, a wood and yard waste recovery and processing area, and a concrete recycling area.

There are approximately 28 residences scattered within a 2-mile radius of the landfill. The closest residence is located several hundred feet south of the landfill, on the south side of Road 29 south of the Willow Slough By-pass.

Groundwater levels at the facility fluctuate between 8 to 10 feet during the year, rising from lowest in the Fall to highest in the Spring. Water level data indicate that the water table level is typically 4 to 10 feet below ground surface during winter and spring months. During summer and fall months, the water table is typically 5 to 15 feet below ground surface. In January 1989, the County of Yolo constructed a soil/bentonite slurry cutoff wall to retard groundwater flow to the landfill site from the north. The cutoff wall was constructed along portions of the northern and western boundaries of the site to a maximum depth of 44 feet. The cutoff wall has a total length of 3,680 feet, 2,880 feet along the north side and 800 feet along the west. In the fall of 1990, irrigation practices to the north of the landfill site were altered to minimize the infiltration of water.

Additionally, sixteen groundwater extraction wells were installed south of the cutoff wall in order to lower the water table south and east of the wall, to provide vertical separation between the base of the landfill and groundwater.

Prior to placement of the slurry wall and dewatering system, the groundwater flow direction was generally to the southeast. Under current dewatering conditions, the apparent groundwater flow paths are towards the extraction wells located along the western portion of the northern site boundary. In essence, a capture zone is created by the cone of depression created by the ground water extraction system, minimizing the possibility of off-site migration of contamination.

3 NORTHEAST ANAEROBIC CELL

The northeast anaerobic cell occupies approximately 3.5 acres in the northeast quadrant of Phase 1, Module 6D.

3.1 Experimental

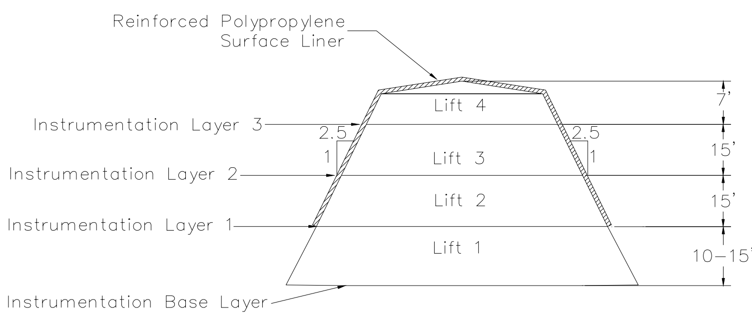
The experimental methods utilized are grouped into three categories: construction, monitoring, and operation. Each of these categories is discussed below.

3.1.1 Construction

Construction of the northeast anaerobic cell can be generally broken down into four major tasks: waste placement, liquid addition, gas collection, and surface liner installation. Each of these four tasks is discussed below. A summary of current monitoring data for the northeast anaerobic cell is provided in Appendix A, Table 3-1.

3.1.1.1 Waste Placement

Waste placement began on January 13, 2001 and was completed on August 3, 2001. Waste was placed in four separate lifts with an average thickness of 15 feet (Detail 3-1). In general, all waste received at the landfill was deposited in the northeast cell with the exception of self-haul waste. Because of the difficulties handling large volumes of self-haul vehicles in the limited area of the upper lifts, self-haul waste was not placed in lifts 3 and 4. The use of daily cover soil during waste filling was minimized to aid in the overall permeability of the waste. Whenever possible, greenwaste or tarps were used as alternative daily cover (ADC) and, in the event soil was placed (for example, access roads or tipping pad), the soil was removed prior to placing the next lift of waste. All side slopes were constructed at approximately 2.5 to 1 (horizontal to vertical) and received at least one foot of soil cover. Instrumentation Layers 1, 2, and 3 were placed between lifts, and base layer instrumentation was installed on the Module 6D base liner. A summary of sensors installed on each layer is provided in Appendix A, Table 3-2.



Detail 3-1. Northeast Anaerobic Cell Cross Section

3.1.1.2 Liquid Addition

Horizontal liquid injection lines were installed in each lift of waste (Image 3-1). Injection lines within the waste (between lifts 1 and 2, 2 and 3, 3 and 4) were placed approximately every 40 feet. Injection lines installed on top of lift 4 were installed every 25 feet, with an additional injection line following the perimeter of the top deck. Each injection line consists of a 1.25-inch-diameter high-density polyethylene (HDPE) pipe placed horizontally (north to south), which extends completely through the waste. Each injection line was perforated by drilling a $^{3}/_{32}$-inch hole every 20 feet. A total of 8,130 feet of injection piping was installed with a total of 342 injection holes.

Each of the injection laterals is connected to a 4-inch-diameter HDPE injection header. Leachate injection for each lateral will be monitored and controlled by individual solenoid valves connected to the SCADA system. A flow meter will monitor the total volume and injection flow rate for the entire northeast anaerobic cell.

Image 3-1: Horizontal LFG and leachate injection lines installed and being coverd by shredded tires.

3.1.1.3 Gas Collection

Horizontal landfill gas (LFG) collection lines were installed between each lift of waste (Image 3-1) and directly under the reinforced polypropylene (RPP) geomembrane cover. LFG collection lines consist of various combinations of alternating 4 and 6-inch–diameter, schedule 80 polyvinyl chloride (PVC) pipe (Image 3-2) as well as several variations using corrugated HDPE pipe. A summary of gas collection lines for the northeast anaerobic cell is provided in Appendix A, Table 3-3. At each line, shredded tires were used as the permeable media. The gas collection lines between layers are spaced approximately 40 feet apart and the lines directly under the RPP membrane are spaced at 25 feet. A total of sixteen LFG collection lines were installed.

Each LFG collection line is connected to a 6-inch-diameter LFG collection header that conveys the gas to the on-site LFG-to-energy facility. Each LFG collection line incorporates a pre-manufactured wellhead capable of controlling flow and monitoring flow rate, temperature and pressure.

Image 3-2: Horizontal LFG collection line

3.1.1.4 Surface Liner

The County retained the services of Vector Engineering (Vector) to design the surface membrane covers for each of the bioreactor cells (Image 3-3). Their scope of work included the following subtasks:

- Research the different commercially available membrane materials, including high and low density polyethylene, polyvinyl chloride, and reinforced polypropylene;
- Design of a biofilter to treat the off-gas from the aerobic cell;
- Prepare plans and specification for the installation of the surface liners; and
- Provide on-site construction quality assurance for the installation of the surface membrane.

Vector's scope of work was modified to include preparation of plans and specifications for the tie-in of the leachate injection and landfill gas collection piping.

Image 3-3: Northeast anaerobic surface liner

Based on Vector and County staff research, it was determined that a 36-mil reinforced polypropylene geomembrane (RPP) would be the preferred choice for an exposed geomembrane cover[1]. Reinforced polypropylene offered distinct advantages over the other potential materials including long service life (a 20-year warrantee was obtained), superior strength due to the nylon reinforcement, and low thermal expansion and contraction.

To expedite construction and reduce the overall cost of the project, the County decided to directly purchase the necessary membrane material and provide it to the contractor for installation. On June 29, 2001, the County issued a request for quotes for 350,000 square feet of 36-mil RPP. Quotes were received on July 9, 2001 with the lowest priced quote received from Colorado Linings International (Colorado).

The plans and specifications for the installation of the RPP surface liner were issued for bid on June 15, 2001. Later that month, Addendum Number 1 was issued to include a majority of the leachate injection and gas collection piping. Bids were due on July 13, 2001; however, no bids were received. The County inquired to each of the plan holders and generally found that bids were not submitted because the liner companies could not locate a subcontractor to perform the earthwork.

The County reissued the plans and specifications on July 23, 2001 and allowed three separate bid options. Option A was the entire project. Option B was only the installation of the liner, and Option C was only the earthwork. Bids were received on August 6, 2001 with the selected contractor being Colorado Linings International. Because Colorado's winning bid was significantly higher than the engineer's estimate and the potential difficulties with excessive pressure buildup under the aerobic liner, the covering of the aerobic cell was eliminated (for further discussion refer to Section 5.1).

The installation of surface liner and associated piping was completed in November 2001.

3.1.2 Monitoring

Temperature, moisture, leachate quantity and quality, and LFG pressure and composition are monitored through an array of sensors placed within the waste and in the leachate collection and recovery system (LCRS). Each sensor location received a temperature sensor (thermistor), a linear low-density polyethylene (LLDPE) tube, and a moisture sensor (a PVC moisture sensor and in some cases a gypsum block). For protection, each wire and tube was encased in either a 1.25-inch HDPE pipe or run inside the LFG collection piping (Image 3-4). Refer to Appendix B, Details 3-2 through 3-5 for sensor location diagrams.

[1] Vector Engineering, "Design Report for the Surface Liners of the Module D Phase 1 Bioreactors at the Yolo County Central Landfill", October 2001.

Image 3-4: Moisture, temperature , and tube

Sensors on instrumentation Layers 1, 2, and 3 were placed on either a bedding of greenwaste (shredded yard waste), wood chips (chipped wood waste), bin fines (fine pieces of greenwaste), or pea gravel to protect against damage from the underlying waste. Sensors installed on the primary liner (prior to any waste placement) were placed on geocomposite and covered with pea gravel prior to the placement of the chipped tire operations layer.

3.1.2.1 Temperature

Temperature is monitored with thermistors manufactured by Quality Thermistor, Inc. Thermistors with a temperature range of 0°C to 100°C were chosen to accommodate the temperature ranges expected in both the anaerobic and aerobic cells. To prevent corrosion, each thermistor was encased in epoxy and set in a stainless steel sleeve. All field wiring connections were made by first soldering the connection, then covering each solder joint with adhesive lined heat shrink tubing, and then encasing the joint in electrical epoxy. Changes in temperature are measured by the change in thermistor resistivity (ohms). As temperature increases, thermistor resistance decreases.

3.1.2.2 Moisture

Moisture levels are measured with polyvinyl chloride (PVC) moisture sensors and gypsum blocks. Both the PVC moisture sensors and gypsum blocks are read utilizing the same meter. The PVC sensors are perforated 2-inch-diameter PVC pipes with two stainless steel screws spaced 8 inches apart and attached to wires to form a circuit that includes the gravel filled pipe. The PVC sensors were designed by Yolo County and used successfully during the pilot scale project[2]. The PVC moisture sensor can provide a general, qualitative assessment of the waste's

[2] Yazdani, R., Moore, R. Dahl. K. and D. Augenstein 1998 Yolo County Controlled Landfill Bioreactor Project. Yolo County Public Works and I E M, Inc. Yolo County Public Works and I E M, Inc. report to the Urban Consortium Energy Foundation (UUCETF) and the Western Regional Biomass Energy Program, USDOE.

moisture content. A reading of 0 to 40 equates to no free liquid, 40 to 80 equates to some free liquid, and 80 to 100 means completely saturated conditions.

The gypsum blocks are manufactured by Electronics Unlimited and are typically used for soil moisture determinations in agricultural applications. Gypsum blocks establish equilibrium with the media in which they are placed and are, therefore, reliable at tracking increases in the soil's moisture content. However, the gypsum block can take considerable time to dry and therefore may not reflect the drying of the surrounding environment.

3.1.2.3 Leachate Quantity and Quality

Leachate that is generated from the northeast anaerobic cell drains to the eastside Module D leachate collection sump (Image 3-5). A dedicated pump is then used to remove the leachate and pump it to one of the on-site leachate storage ponds. A flow meter measures rate and total volume pumped from the sump.

Leachate is monitored for the following field parameters: pH, electrical conductivity, dissolved oxygen, oxidation-reduction potential, and temperature. The following parameters will be analyzed by a laboratory: dissolved solids, biochemical oxygen demand, chemical oxygen demand, organic carbon, nutrients (NH_3, TKN, TP), common ions, heavy metals and organic priority pollutants. For the first year, monitoring will be conducted monthly during the first six months and quarterly for the following six months. After the first year, monitoring will be conducted semi-annually (pH, conductivity, and flow rate will continue to be monitored on a monthly basis as required by the State of California's Waste Discharge Requirements in Order 5-00-134).

3.1.2.4 Pressure

Pressure within the northeast anaerobic cell is monitored with ¼-inch inner diameter and $^3/_8$-inch outer diameter LLDPE sampling tubes. Each tube can be attached to a pressure gage and supplemental air source. By first purging the tube with the air source (to remove any liquid blockages), and then reading the pressure, an accurate gas and/or water pressure can be measured at each sensor location.

3.1.2.5 Landfill Gas Composition and Flow

Landfill gas composition and flow are measured from the pre-manufactured well heads utilizing a GEM-500 combustible gas meter, manufactured by LANDTEC. The GEM-500 is capable of measuring methane (either as a percent by volume or percent of the lower explosive limit), carbon dioxide, and oxygen. A reading for "balance" gas is also provided, which is assumed to be nitrogen.

Image 3-5: Gravel drainage layer and leachate collection sump

3.1.2.6 Waste Sampling

Yolo County conducted the first waste sampling event for the northeast anaerobic cell on June 5, 2002. Waste was sampled to quantify the methane generation potential of the waste. Waste was drilled to an approximate depth of 50 feet with samples taken at 5-foot intervals. Waste will be sampled from the northeast anaerobic cell annually for the next two years to monitor the progress of waste decomposition and compare actual methane generation to laboratory methane generation.

3.1.2.7 Surface Scan

Under current federal guidelines (40 CFR 60.752), landfills exceeding a specific size must monitor for methane surface emissions and any reading in excess of 500 PPM (40 CFR 60.755 (c)) requires corrective action to be taken. The Yolo County Central Landfill is not currently required to test for methane surface emissions, however, as part of the FPA, the County has proposed to conduct quarterly surface scans to demonstrate the emissions (or lack of) from a controlled bioreactor landfill.

Surface emissions were monitored with a model OVA-108 Flame Ionization Detector (FID) instrument in March 2003. The OVA-108 is capable of detecting methane in the parts-per-million (PPM) range and has an accuracy of ± 20 percent of reading. Surface emissions were previously monitored with a model TVA-1000 FID/Photo Ionization Detector (PID) instrument. Under the FID setting, the TVA-1000 is capable of detecting methane in the parts-per-million (PPM) range and has an accuracy of ± 2.5 PPM or 25 percent of the reading, whichever is greater. In the event significant methane was detected, the unit could be switched to PID mode to detect volatile organic compounds (VOC). Methane surface concentrations are monitored along the perimeter of the collection area and along a pattern that transverses the landfill at 15 meter intervals. Due to high winds and inclement weather, the surface scan scheduled for December 2002 was postponed until January 2003. A summary of the surface scans performed on the northeast anaerobic cell is presented below in Table 3-4.

Table 3-4. Summary of Surface Scans Performed on the Northeast Anaerobic Cell with Synthetic Surface Cover System

Surface Scan No.	Date	Max. Emissions Detected	Location of Max. Emissions
1	April 3, 2002	No fugitive emissions detected	Not Applicable
2	June 6, 2002	9 ppm	Southwest corner of the cell
3	September 19, 2002	8 ppm	Northwest corner of the cell
4	January 7, 2003	No fugitive emissions detected	Center north face of the cell
5	March 19, 2003	70 ppm	Along the entire northern perimeter of the cell.

The detection of surface emissions is most likely due to landfill operations in nearby areas. While background concentrations were monitored prior to conducting the surface scan (and in some cases following the surface scan), changes in wind currents could have transported methane from adjacent areas. During June 2002 and September 2002, grading and waste filling activities in the adjacent west-side 6-acre area could have promoted the detection of gas emissions in the northeast 3.5-acre cell. Additionally, activities from Module D Phase II construction (which involved exposing waste form an adjacent unit to facilitate base liner installation) could have promoted the detection of gas emissions during the September 2002 surface scan. The high surface emissions in March 2003 can be attributed to high background readings, ranging between 60 and 65 ppm, that may be due to Module D Phase II construction. Changing wind current during the surface scan could have also carried emissions from the west-side anaerobic cell where higher emissions have been measured due to leakage from small gaps in the surface liner (less than 1 inch) where piping exits the cell.

As presented in the table above, methane surface emissions from the northeast 3.5-acre cell are extremely low, and essentially negligible. There are two major items that are responsible for this effective control of surface emissions, they are: 1) The installation of a synthetic cover over the entire cell, and 2) The use of an active landfill gas extraction system. The synthetic membrane not only limits gas transfer from the surface of the cell, it allows the active gas collection system to be operated at higher vacuum rates (without drawing in excess oxygen) thus further limiting the possibility if surface emissions.

The true methane emissions detected are also a function of the accuracy of the surface scan equipment. The TVA-1000 FID instrument has an accuracy of ±25 percent of reading or ±2.5 ppm, whichever is greater, from 1.0 to 10,000 ppm. Thus many of the surface emissions are outside (below) the accuracy range and thereby assumed to be negligible.

3.1.3 Operation

Operation of the northeast anaerobic cell as a bioreactor will began March 27, 2002 when supplemental liquid was first added to the cell.

3.1.3.1 Leachate Recirculation

Leachate addition to the northeast cell began on March 27, 2002 (Image 3-6). Each of the horizontal liquid injection lines was initially tested by pumping approximately 1000 gallons into the line to confirm operation and correlate flow versus pressure for each injection lateral.

Image 3-6: Leachate injection header and laterals

With the initial testing phase complete, full-scale liquid addition has commenced. Once the waste reaches field capacity, only enough liquid to maintain field capacity will be added.

During August 2002, leachate injection was temporarily halted due to scale buildup in the injection laterals which was significantly reducing the flow in the injection lines. On September 11, 2002, approximately 3000 gallons of a citric acid solution (pH approximately 4) was added to the injection laterals on the northeast anaerobic cell to dissolve the scale buildup. The citric acid was added to the injection laterals and allowed to set overnight (approximately 14 hours). Groundwater was then flushed through the lines to remove the citric acid and scaling residue.

Liquid injection resumed in the northeast cell on September 24, 2002. Approximately 1,563,042 gallons of supplemental liquid has been added and 548,462 gallons of leachate recirculated through the end of March 2003 with 48 percent added to Layer 1, 35 percent added to Layer 2, and 16 percent added to Layer 3 (Appendix C, Figure 3-1).

3.1.3.2 Landfill Gas Collection

Landfill gas collection began December 13, 2001 once the necessary piping was installed at the end of November 2001. Gas collection prior to leachate addition was necessary to prevent "billowing" or excess gas pressure under the surface liner.

3.2 Results And Discussion

Sensor names are represented numerically by the instrumentation layer in which the sensor is located, followed by the assigned sensor number. Layer 1 is represented by a 1, Layer 2 is represented by a 2, and so forth. The complete name of the sensor is denoted by the layer number – the sensor number. For example, the second sensor on Layer 1 is named 1-02.

3.2.1 Temperature

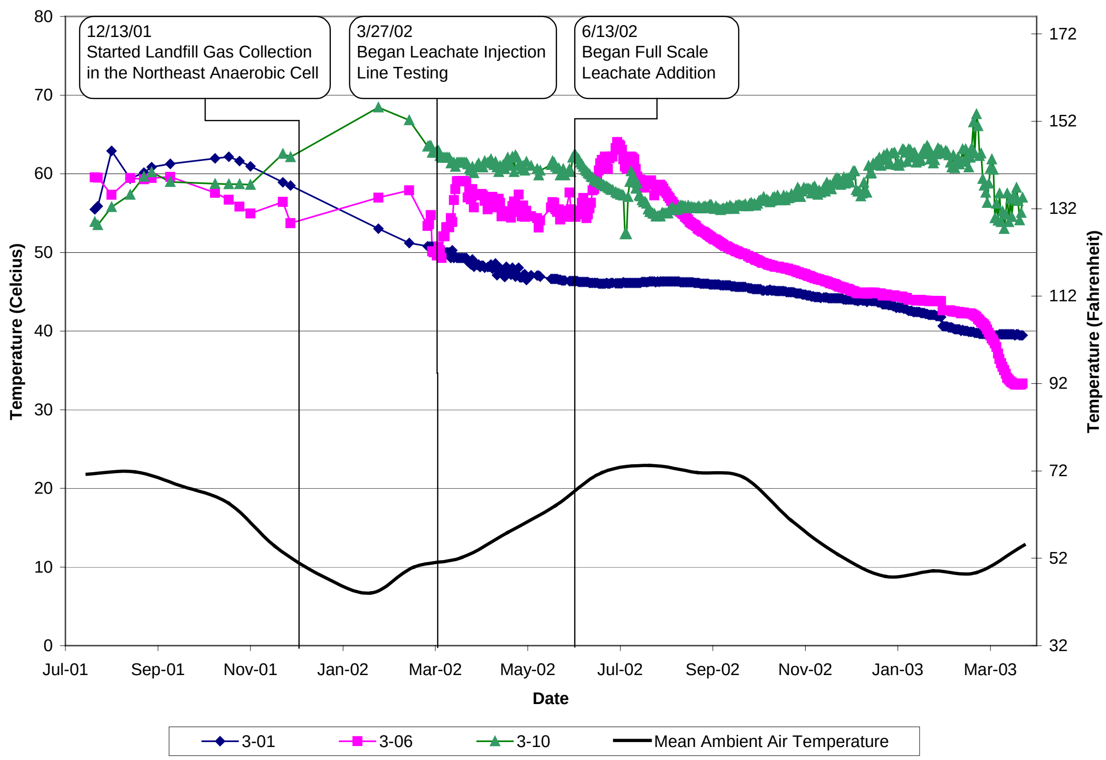
Temperature is monitored with thermistors manufactured by Quality Thermistor, Inc. Thermistors with a temperature range of 0°C to 100°C were chosen so they would be able to accommodate the temperature ranges expected in both the anaerobic and aerobic cells. Resistance was measured by the SCADA system located in the instrumentation shed starting in March 2002. Resistance was previously measured manually by connecting the sensor wires to a 26 III Multimeter manufactured by Fluke Corporation.

Temperature results are presented in Appendix C, Figures 3-2 to 3-4. Recent temperature fluctuations in Layer 3 correspond to the addition of cool water (approximately 70°F) to the waste. Representative sensors that demonstrate the cooling trend during liquid injection and subsequent warming trend following liquid injection are provided in Appendix C, Figure 3-5. A summary of the results is presented below in Table 3-5 and Figure 3-6.

Table 3-5. Temperature Summary for the Northeast Anaerobic Cell

	Previous Reporting Period (10/1/02 to12/31/02)			Current Reporting Period (1/1/03 to 3/31/03)		
Layer	**Minimum Temp. (°C)**	**Maximum Temp. (°C)**	**Average Temp. (°C)**	**Minimum Temp. (°C)**	**Maximum Temp. (°C)**	**Average Temp. (°C)**
1	23.4	48.2	38.4	29.5	55.1	40.3
2	32.6	62.9	51.2	38.3	57.1	47.7
3	33.3	63.3	50.4	7.6	67.6	43.1

Figure 3-6. Average Temperatures for the Northeast Anaerobic Cell



3.2.2 Moisture

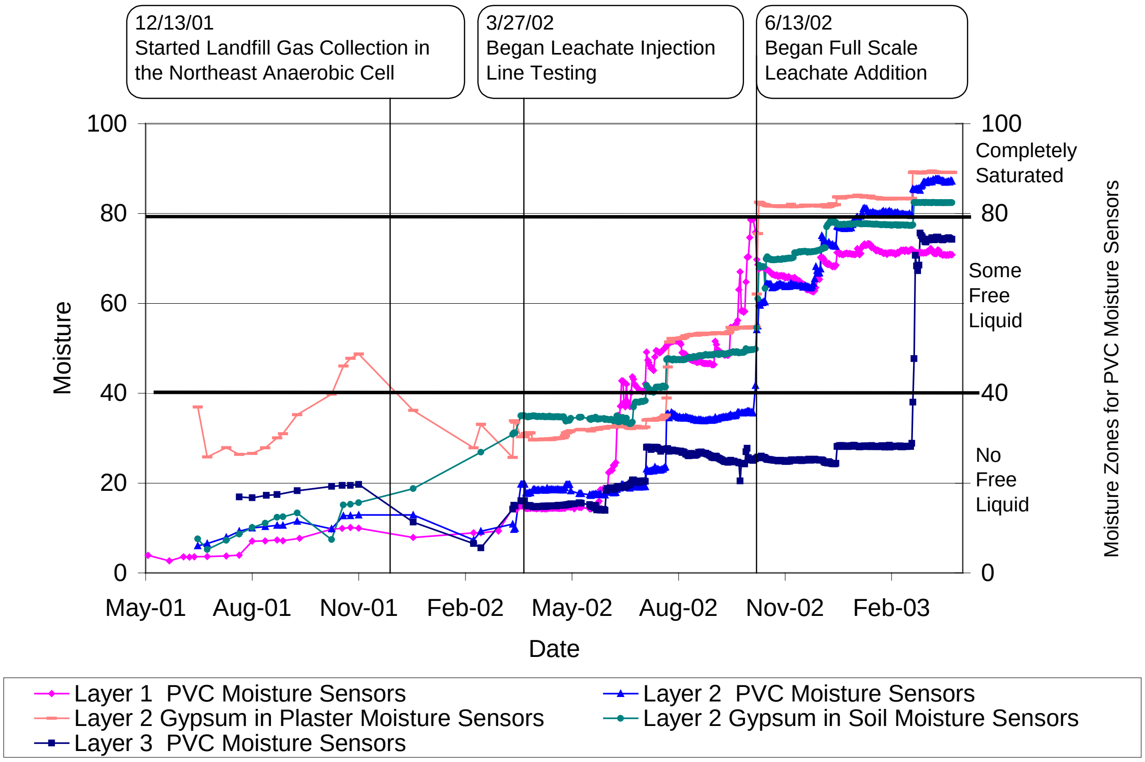
The SCADA system started electronically measuring moisture in March 2002. Moisture was previously measured manually with a Model MM 4 moisture meter manufactured by Electronics Unlimited. During the pilot scale project, Yolo County conducted laboratory tests with the PVC sensors to determine the relationship between the multimeter readings and the presence of free liquid in the PVC sensor. It was determined that a meter reading of less than 40 corresponded to an absence of free liquid. A reading between 40 and 80 corresponds to the presence of free liquid in the PVC pipe but less than saturated conditions. Readings of greater than 80 indicate saturated conditions; i.e. the PVC sensor is full of liquid.

Moisture results are presented in Appendix C, Figures 3-7 to 3-11. Since the start of full-scale liquid addition in June 2002, the average moisture levels in Layer 1 and Layer 2 have increased to moisture levels in the some free liquid zone and completely saturated zone. In Layer 3, full-scale liquid addition commenced in February 2003 and moisture levels increased to the some free liquid zone. A summary of the results is presented below in Table 3-6 and Figure 3-12.

Table 3-6. PVC Moisture Summary for the Northeast Anaerobic Cell

	Previous Reporting Period (10/1/02 to12/31/02)			Current Reporting Period (1/1/03 to 3/31/03)		
Layer	**Minimum Moisture**	**Maximum Moisture**	**Average Moisture**	**Minimum Moisture**	**Maximum Moisture**	**Average Moisture**
1	1.9	94.8	66.9	6.0	94.8	71.5
2	2.8	94.8	61.9	5.4	94.8	82.4
3	1.9	91.3	25.3	4.9	94.8	39.8

Figure 3-12. Average Moisture Levels for the Northeast Anaerobic Cell



3.2.3 Landfill Gas Collection System

Gas composition is measured from the wellheads located on top of the northeast anaerobic cell with the GEM-500. Gas flow is measured by differential pressures at the well heads with a DWYER Instruments, Inc., “Magnehelic” pressure gage. A thermal mass flow meter installed in the main header pipeline near the instrumentation shed records flow rate and total for all of the northeast cell. The meter is equipped with two separate calibration curves (for different gas constituent concentrations) and automatically corrects for temperature and pressure and records in standard cubic feet.

Gas collection lines are represented numerically by the layer the line is located, followed by a “G” and the number that denotes the line on a specific layer. For example, the first gas collection line on layer 3 is denoted 3-G1.

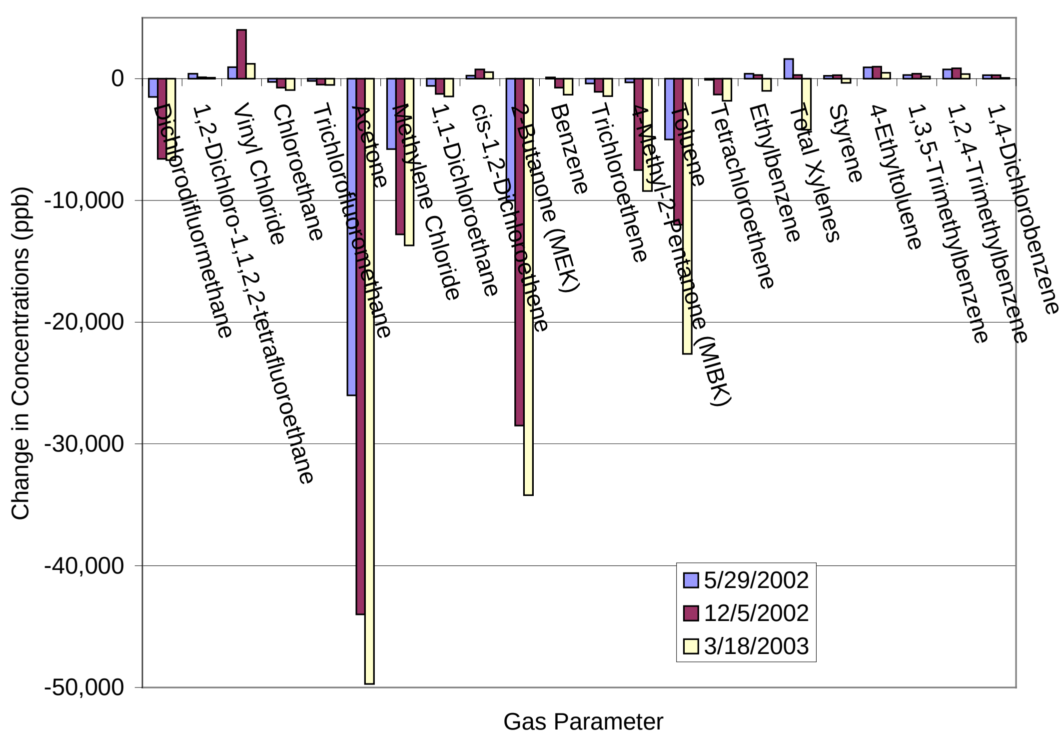
Landfill gas results are presented in Appendix C, Figures 3-13 to 3-16. Methane concentrations from the wellheads fluctuate based on the applied vacuum, barometric pressure, and the status of waste decomposition. In June 2002, the increase in oxygen and balance concentrations and the decline in methane and carbon dioxide concentrations can be attributed to the increase in vacuum applied to the gas collection system. In order to reduce landfill gas emissions while drilling for waste samples, the vacuum applied to the gas extraction system was increased resulting in air intrusion into the northeast anaerobic cell. Subsequently, a leak in the gas collection header line was discovered resulting in air intrusion into the gas collection system. A summary of the results is presented below in Table 3-7.

Table 3-7. Landfill Gas Summary for the Northeast Anaerobic Cell

Parameter	Results		
Cumulative Methane from December 16, 2001 to March 31, 2003	22.3 x 10^6 standard cubic feet (scf) (which is equivalent to approximately 3500 barrels of oil)		
LFG Flow Rate for the period of January 1, 2003 through March 31, 2003	Minimum	Maximum	Average
	114.7 scf	171.6 scf	144.3 scf
Methane Concentration for the period of January 1, 2003 through March 31, 2003	Minimum	Maximum	Average
	44.4 %	53.5 %	49.2 %

Landfill gas from the northeast cell was sampled in March 2003 and sent to an independent laboratory for analytical testing. Analytical results are presented in Appendix D, Table 3-8. Analytical results show lower methane levels at 390,000 parts per million (ppm) than methane levels detected in the field in March 2003. Higher methane levels read in the field could be due to the inclusion of other gases, such as hydrocarbons, that would be recorded as methane by the GEM. Results also show a general decline in volatile organic compounds (VOC) since the start of liquid injection as presented below in Figure 3-17.

Figure 3-17. Change in VOC Concentrations since May 2002.



3.2.4 Leachate Quantity And Quality

After July 24, 2002, all leachate generated was recirculated back to the northeast anaerobic cell with the exception of 35,460 gallons of leachate removed during injection line cleaning between September 24, 2002 and October 4, 2002. Approximately 1,563,042 gallons of supplemental liquid has been added and 548,462 gallons of leachate has been recirculated to the northeast anaerobic cell since June 2002 (Appendix C, Figure 3-1).

Leachate was sampled for analytical testing on a monthly basis from May 2002 to October 2002 and thereafter was sampled on a quarterly basis. Analytical results are presented in Appendix E, Table 3-9. Field chemistry and selected analytical results are presented below in Table 3-10.

Table 3-10. Field Chemistry and Selected Laboratory Chemistry for Leachate Sampled from the Northeast Anaerobic Cell

PARAMETER	Date:	2/14/2002	5/14/2002	6/20/2002	7/23/2002	9/26/2002	10/17/2002	2/26/2003
Field Parameters:	**Units**							
PH		7.13	7.40	7.60	7.44	7.47	7.35	8.16
Electrical Conductivity	µS	6583	6095	4054	11510	12440	10230	9351
Oxidation Reduction Potential	mV	-119	80	94	-7	-35	-25	160
Temperature	C	19.9	25.9	26.5	30.5	28.4	26.0	23.5
Dissolved Oxygen	mg/L	0.65	1.4	2.04	0.33	3.66	2.96	6
Total Dissolved Solids	ppm	5244	4059	3062	9740	10770	8640	7850
General Chemistry:								
Bicarbonate Alkalinity	mg/L	1740	1760	1110	3740	3960	4010	2680
Total Alkalinity as CO_3	mg/L	1740	1760	1110	3740	3960	4010	2680
BOD	mg O/L	20	19	10	200	1400	3000	44
Chemical Oxygen Demand	mg O/L	633	791	196	1620	2830	1810	120
Chloride	mg/L	1070	1030	617	1950	1870	1380	1470
Ammonia as N	mg/L	30	26.3	13.5	131	255	289	132
Nitrate-Nitrite as N	mg/L	<0.03	<1.5	<0.015	0.061	1.4	<0.009	17.3
Total Kjeldahl Nitrogen	mg/L	53.1	40	21.8	201	326	358	222
Total Dissolved Solids @ 180 C	mg/L	4440	3700	2500	7800	8000	6680	5720
Total (Non-Volatile) Organic Carbon	mg/L	202	123	68.8	544	943	588	325
Total Sulfide	mg/L	1.3	1.3	0.74	1.2	1.1	1.4	0.034 (tr)
Dissolved Iron	mg/L	1.1	0.39	0.19	2.9*	3.9	4	2.5
Dissolved Magnesium	mg/L	323	262	NA	535	480	437	359
Dissolved Potassium	mg/L	152	133	NA	215	319	348	371

Analytical results from the February sampling event indicate a dramatic decrease in BOD and COD and an increase in nitrate. It is unclear what has caused this dramatic change but one possible explanation would be dilution form recently injected leachate, this however is not supported by leachate pumping records (See Figure 3-1) which indicate relatively constant recirculation rates since December 2002. Follow-up monitoring will be performed to confirm these readings.