Commonwealth Energy Biogas/PV Mini-Grid Renewable Resources Program

Making Renewables Part of an Affordable and Diverse Electric System in California

Contract No. 500-00-036

Landfill Bioreactor Conceptual Design Report

Project No. 2.1 Enhanced Landfill Gas Production Using Bioreactors

Task 2.1.3a Final Report

Prepared For:
California Energy Commission
Public Interest Energy Research Renewable Program

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Preface

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Commission), annually awards up to $62 million to conduct the most promising public-interest energy research by partnering with Research, Development, and Demonstration (RD&D) organizations, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following six RD&D program areas:

- Buildings' End-Use Energy Efficiency
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy
- Environmentally Preferred Advanced Generation
- Energy-Related Environmental Research
- Strategic Energy Research

For more information on the PIER Program, please visit the Commission's Web site at http://www.energy.ca.gov/research/index.html or contact the Commission's Publications Unit at 916-654-5200.

For Commonwealth Program–specific information, please visit http://www.pierminigrid.org.

What follows is a report for the **California Energy Commission, Public Interest Energy Research Program, Contract Number 500-00-036,** conducted by the **Commonwealth Energy Team**. The report is entitled **Landfill Bioreactor Conceptual Design Report**. This project contributes to the **Renewable Energy** component of the PIER program.

SECTION 1

Overview

In June 2001, the Commonwealth Energy Team was awarded a programmatic contract under the California Energy Commission's (Commission) Public Interest Energy Research (PIER) Program to conduct research on strategies for making renewable energy more affordable in California. The Commonwealth Energy approach involves assessing the combined potential of biogas and photovoltaic (PV) resources in a defined study area and identifying how these resources could be developed in a complementary and cost-effective manner. The Commonwealth Energy Team conducted this research in a real-world setting so that the findings could be applied elsewhere in California and thereby benefit more California ratepayers. The local area Commonwealth Energy selected for its renewable energy research activities is the Chino Basin, referred to in this report as the "study area."

1.1 Background

The Chino Basin is rich in PV and biogas resources. Moreover, it is a rapidly growing area with substantial and increasing electrical loads. The underlying goal of the Commonwealth PIER Renewables Mini-Grid Program is to identify potential building-integrated PV (BIPV) and biogas energy projects, bring innovative technologies and business practices to these projects, assess the benefit to the local electricity distribution system (the "mini-grid"), and then use the findings to develop a business model for siting cost-effective, renewable energy projects. A description of the Commonwealth Energy PIER Program, including the results of some of the work undertaken to date, is presented in the project Web site, http://www.pierminigrid.org.

An important element of the Commonwealth PIER Renewables Mini-Grid Program is a project devoted to research and demonstration of energy production from landfill gas (LFG) produced in a bioreactor landfill. Bioreactor landfills are designed to enhance biogas production through controlled moisture addition. The project is identified as Project 2.1, Enhanced Landfill Gas Production Using Bioreactors. The work summarized in this report (Task 2.1.3a) is the third activity of Project 2.1, and follows the results of waste feedstock characterization and potential amendments that were identified in the Landfill Feedstock Characterization Report that was prepared for Tasks 2.1.1 and 2.1.2.

In accordance with its business plan, Commonwealth Energy is interested in advancing the landfill bioreactor technology and expanding its involvement in the LFG market. Its interest in the near-term is to strengthen the renewable energy portion of its resource portfolio. This is needed to: (1) replace existing contracts that will expire, (2) meet the requirements of California's Renewable Portfolio Standard (RPS), and (3) further its overall business approach of offering customers renewable energy at an affordable price. In the long-term, Commonwealth is seeking to expand its business in California by selling services to communities that take advantage of legislation fostering community aggregation. Participating in this PIER project will help Commonwealth achieve both its near- and long-term objectives.

1.2 Results of Project 1.1—Planning and Analysis: Host Site Selection

The results of Task 1.1.3, "Inventory Landfill Facilities which Serve as Host for Bioreactor Demonstration Project," led to selection of the San Bernardino County Mid-Valley Landfill Unit 3 as the preferred host site through a process of identifying and ranking all of the operating and permitted landfill sites in a four-county[1] area in Southern California. The four-county area was selected so as to have similar climatic characteristics to that of the mini-grid on which the PIER renewable energy demonstration project focused. The mini-grid is located in the Chino Hills area and contains only a single potential host landfill site that was considered unlikely to be suitable. The process of evaluating and ranking potential host sites is described in more detail in the *Inventory Report for Potential Landfill Bioreactors,* February 10, 2003 by CH2M HILL.

Discussions with San Bernardino County Solid Waste Management Department since the completion of the inventory report have indicated that San Bernardino County (County) is interested in making the Mid-Valley Landfill a host site for the demonstration project. The discussions with the County, its landfill operating contractor, and its design engineering consultant have indicated that the landfill will be suitable for conversion to bioreactor operation. The project contemplated is the development of the next expansion area of the currently operational landfill cell into a bioreactor operation. Only a small portion of the total capacity of the cell has been filled to date, and a large portion of the cell bottom has not yet received any waste. Conversion of this area to bioreactor operation will allow a full commercial-scale demonstration of the bioreactor concept.

Commonwealth has a strong interest in the bioreactor demonstration project and in the long-term LFG energy production that could result from the operation of the entire Mid-Valley Landfill Unit 3 as a bioreactor (and possible later applications in Units 4 and 5). This Commonwealth interest is in concert with the County's need to operate in conformance with its permits, to collect and dispose of the LFG, and to reduce costs when possible.

1.3 Overview of Project 2.1

The goals of the Enhanced Landfill Gas Production Using Bioreactors project are:

- Advance the state of knowledge for using bioreactors at landfills to increase landfill gas production and improve waste characteristics to accelerate reclamation
- Work with environmental regulators to develop and implement strategy for developing bioreactors while meeting applicable groundwater and other environmental standards
- Establish the economic and environmental benefits of landfill bioreactor use

The objectives of this project are:

- Develop a conceptual design for two types of landfill bioreactors

[1] San Bernardino, Riverside, Los Angeles, and Orange Counties.

  - MSW or organic waste landfill bioreactor (first bioreactor)
  - MSW or organic waste landfill bioreactor supplemented by food or animal waste (second bioreactor)
- Develop environmental documentation to satisfy regulators
- Quantify greenhouse gas and pollution reduction benefits
- Develop two types of landfill bioreactors
  - MSW or organic waste landfill bioreactor (first bioreactor)
  - MSW or organic waste landfill bioreactor supplemented by food or animal waste (second bioreactor)

Tasks 2.1.1 and 2.1.2 evaluated the potential feedstocks and amendments for the bioreactor landfill. Based on the results and the considerations for developing a full-scale operating commercial bioreactor demonstration project (rather than two smaller research scale bioreactors), it was concluded that only one bioreactor landfill should be developed under Project 2.1. This report fulfills the scope of work under Task 2.1.3a, which includes development of an energy and material balance, process and instrumentation diagrams, detailed design drawings, and a conceptual design report for the landfill bioreactor.

1.4 Physical and Operating Parameters of the Mid-Valley Landfill Unit 3

All waste disposed at the Mid-Valley Landfill is currently disposed in a landfill cell labeled Unit 3. Two other cells have already been filled at the site and the locations of later cells have been defined for the future.

1.4.1 Unit 3 Physical Characteristics

Unit 3 is a 150-feet-deep excavation covering approximately 40 acres near the southwest corner of the Mid-Valley Landfill site for a total volume of about 90 million cubic yards. The Unit (cell) has or will have a double composite lining system, meaning that two polyethylene liners, each underlain by geocomposite clay or natural clay, line the excavation to prevent seepage from the landfill into the soil below and surrounding it. A leachate collection and recovery system, consisting of drainage layers (both synthetic and gravel) and perforated pipes, carries leachate generated by the solid wastes to a sump in the southeast corner of the cell. Three 24-inch-diameter access pipes into this sump carry smaller discharge pipes from pumps located in the sump up to two 10,000-gallon leachate storage tanks adjacent to the cell. Several 6-inch access pipes rise up the cell sideslopes from the leachate collection pipe network at other points along the cell sidewall. Landfill gas collection piping has not yet been installed in Unit 3, except for perforated piping installed in the leachate collection drain layer specifically designed to extract gas from this layer on the sideslope.

Based on a July 2003 aerial survey, approximately 1.23 million cubic yards of the cell volume have been placed. One to two lifts of waste have been placed over part of the southerly landfill bottom lining. In the northerly part of the cell, no wastes have yet been placed as of this writing, and the lining system has not yet been constructed.

Landfill gas collection systems have been constructed in Units 1 and 2, with piping leading to an exhauster and flare system at the south end of the site. Also at the south end of the site is the existing landfill gas-to-energy system, which became operational in early 2003. The system is operated by a third-party energy system developer. Its electrical output capacity is reportedly 3.8 megawatts (MW). This facility would need to be expanded to accommodate the landfill gas from Unit 3, if it is sized to use only the gas generated in Units 1 and 2.

Water (supplied by the City of Rialto) is available at the site. Water is used onsite for dust control.

1.4.2 Unit 3 Operating Parameters

San Bernardino County has retained the Unit 3 landfill gas rights. Currently, the right to collect all landfill gas from Units 1 and 2 has been sold to Neo-Montauk Genco LLC (NEO), which owns and operates existing two onsite Deutz 16-cylinder, 1.9 MW engine-generators located adjacent to Unit 3. However, much of the gas produced at these units is currently being flared. The engine-generators are not currently operating full-time; the reason for the downtime is not clear.

During the bioreactor Demonstration Project (2005) at Unit 3, the projected 2005 Unit 3 LFG production is estimated to be equivalent to 10.4 million kWh over the year, which represents an average capacity of 1.19 MW. The bioreactor-only LFG production is estimated to be equivalent to 2.2 million kilowatt-hours (kWh), an average capacity of 249 MW.

At this generation level, the electricity could be used to offset electricity purchases at the landfill from Southern California Edison Company (SCE) under a "net energy metering" arrangement. Commonwealth has a high level of interest in providing the demonstration project power generation in exchange for the "net metering revenue" savings obtained from the generation and for a first right of refusal for the rights to the LFG from the potential continued operation of Unit 3 as a bioreactor.

Projections indicate that if Unit 3 were operated as a bioreactor over its life, LFG production would peak in 2034 at the equivalent of 45 MW. Assuming that a 10-year LFG supply is needed to justify the investment cost of any generation installation, the maximum generation would be 33 MW in 2028. The additional LFG production over 2028 levels would not last for at least 10 years and would therefore most likely be flared. A total of 45 MW of LFG-based generation represents a significant investment and level of power production that is well above the electrical loads of the landfill or SCE's net metering program. As a result, the power production would need to be marketed offsite and would enjoy the advantages of being "green" or "renewable" power, which is a major part of Commonwealth's business strategy. Development of this amount of LFG generation could represent a cost of more than $45 million in today's dollars.

1.5 Integration with Commercial Landfill Operations

The bioreactor cell will be constructed as the next cell within Unit 3. It will be located immediately north of the existing lined area at the south end of Unit 3. To facilitate monitoring as well as to handle the increased liquid and gas volumes in the bioreactor cell, modifications will be made to the leachate collection and gas collection systems as described later in this report.

The bioreactor cell will be operated as part of the ongoing commercial landfill operation under the supervision of the County. The bioreactor will be designed so as to minimize interference with normal landfill disposal operations, which are performed by a third-party waste management firm, BurrTec, under contract to the County. Monitoring of gas and leachate in the bioreactor cell will not be done by BurrTec but by CH2M HILL or its subcontractors. The County will retain control of the leachate and landfill gas management and control systems; recommendations for adjustments to these systems will be made by CH2M HILL to the County and/or its contractors. These arrangements will require close coordination. At least weekly meetings will be held onsite and frequent telephone and Email communications among the points of contact for San Bernardino County, the County's consultants including Bryan A. Stirrat and Associates (BAS), BurrTec, and CH2M HILL will be required.

The demonstration project operation will continue for approximately 1 year, with a report and recommendations for further expansion of the bioreactor operations in Unit 3 to be produced in early 2006. Following the one-year demonstration period, the County may choose to continue to expand Unit 3 bioreactor operations, with the concurrence of permitting agencies.

1.6 Generation Development Options

Participating in the Mid-Valley Project would help Commonwealth achieve its objectives of replacing some of its existing resources and help it meet the requirements of the California RPS. These near-term objectives can be achieved in several ways.

First, Commonwealth could attempt to work out an arrangement with NEO, the owner of the two existing engine-generators that use LFG from Units 1 and 2. This arrangement could involve purchasing output from the existing reciprocating engine units and then working with San Bernardino County to use the bioreactor-produced gas over some test period to either supplement the existing generation over time or to support added generation capacity at the site by NEO.

Second, Commonwealth could develop new generation that it would use to serve its California customers. Initially, it could develop approximately 1 to 1.5 MW and then add further generation capacity as additional LFG becomes available.

Third, it could develop a small-scale demonstration project that would offset retail electricity purchases (net-metered energy use) at the Mid-Valley biogas compressor and/or flare stations. During the demonstration project, Commonwealth could negotiate for the rights to develop the electric generation potential from the operation of Unit 3 as a bioreactor, with an estimated maximum generating capacity of up to 33 MW.

Each of these development alternatives has its advantages and disadvantages and Commonwealth is currently evaluating each of them. Note that the third option could be implemented in sequence with the second should the small-scale demonstration prove successful. Commonwealth plans to work with San Bernardino County in the context of its Cooperative Agreement for the Mid-Valley Landfill Bioreactor Demonstration Project over a longer term to develop an approach that maximizes benefits of using the bioreactor-produced LFG to both entities. All three of these options would satisfy Commonwealth's longer-term objective of enhancing its position and business in Community Aggregation of electric loads in California. Each of these three development scenario options is discussed further below.

1.6.1 Option 1—Pursue Arrangement with NEO, the Developer Currently Producing Power at Mid Valley

Under this option, Commonwealth would work with NEO to take advantage of the fact that NEO currently has more than three MW of generation on site adjacent to Unit 3. These units are constructed and operating and have already secured the necessary interconnection and power purchase agreements and permits. Moreover, there is space adjacent to these units for additional engine generators. It would seem most logical and cost effective for NEO to expand its facilities and take the bioreactor gas to generate electricity. Unfortunately, the ability and interest in such an arrangement are currently uncertain. NEO is in the process of selling assets and the future status of the existing engine-generator units and associated facilities is uncertain. It is understood that the tax credits associated with those units expire in 2007. Given the uncertainties of NEO, Commonwealth will continue to follow the situation, recognizing that utilizing the existing facilities is potentially the most cost effective for all involved. At the same time, it is recognized that it would not be prudent to base the Commonwealth PIER program's success on working out a suitable power or facilities purchase agreement with NEO.

1.6.2 Option 2—Develop New Generation That Commonwealth Would Own and Schedule To Serve Its Customers

Commonwealth could proceed with the development of a project approximately 1 to 1.5 MW in size using the LFG from Unit 3. This demonstration project would be completed within the timeframe of the PIER project, but would represent to Commonwealth the initial phase of a much larger (30+ MW project). Based on preliminary engineering done for a 30 MW LFG project, the capital costs can be expected to be about $1,000 per installed kW of capacity and operation and maintenance costs at about $0.01 to $0.02 per kWh. This roughly translates into a generation cost of $0.04 to $0.05 per kWh, without any payment for the LFG. This compares to a current payment for electrical energy to SCE of over $0.09 per kWh. This margin would provide for transmission losses to ultimate users, the cost of using the SCE transmission/distribution system, metering and billing, administration and other costs for delivering energy to Commonwealth customers.

The feasibility of the Project will depend greatly on the quality of the LFG and the need to "clean" it for use by engine-generators, the size of the Project and the economies of scale involved, incentives that might be available, and the cost to transmit the power to Commonwealth customers.

1.6.3 Option 3—Develop Small-Scale Self-Generation Demonstration Project To Offset Retail Load At Mid-Valley

The Mid-Valley site purchases approximately 25,000 kWh of electricity per month from SCE. This corresponds to an average load of approximately 49 kW. A small biogas fueled microturbine could be installed to serve this load and take advantage of the State's existing Self-Generation Incentive Program as a Level 3-R project and receive up to 40% matching funds on qualified installed costs -- as administered by SCE.

Under this scenario, Commonwealth, through the PIER program, would install a small microturbine demonstration project. At the same time, Commonwealth would be working with NEO and San Bernardino County to participate in an expanded LFG project, or (at a minimum) for Commonwealth to purchase the Unit 3 bioreactor project LFG. This gas is expected to over time be sufficient to support 30+ MW of renewable generation over a 10 year period starting later this decade.

The initial demonstration project would likely be a 30 to 70 kW microturbine. Assuming an installed cost of approximately $120,000, the use of the self generation incentive program, and assuming Edison's existing energy rates are used to determine the retail purchase offset benefits, this project could have a payback period of 5 years. As noted earlier, this Project would also help Commonwealth meet its longer term objectives of a much larger generation project at Mid-Valley and for future community aggregation opportunities.

1.6.4 Summary of Generation Development Options

Commonwealth is evaluating the three options described above. In conjunction with its discussions with NEO, it is evaluating the different ways to work with NEO and its assets. Once the outcome of those discussions is clear, it will be possible to define the best path forward for this project. In the mean time, the Commonwealth Team plans to define a test program for the third option, development of a small demonstration project intended to offset retail load for incorporation into the test plan. At the same time it will continue to pursue discussions with NEO and San Bernardino County on how it can participate in the much larger 40+ MW project at Mid-Valley's Unit 3 as described above.

With these objectives in mind, Sections 2 through 7 of this report address the conceptual design of a bioreactor for Unit 3 at the County of San Bernardino's Mid-Valley Landfill.

1.7 Waste Materials Characterization

The Mid-Valley Landfill accepts household and commercial solid waste from the County. Table 1-1 contains the best data available on the composition of the waste in the Mid-Valley Landfill. More information on the derivation of the data in Table 1-1 is available in the *Landfill Feedstock Characterization Report* (CH2M HILL 2003a).

The categories of waste listed in Table 1-1 are those typically used for solid waste planning. While they are not designed for precisely measuring the biodegradable vs. nonbiodegradable fractions of the waste and other parameters useful for designing a bioreactor landfill operation, they can be used to estimate the biodegradable and nonbiodegradable fractions. Because of the general availability of this kind of data, it is often used in estimating the biodegradable fraction of municipal wastes for the purpose of estimating landfill gas production.

TABLE 1-1
CEC Bioreactor Demonstration Project
San Bernardino County Waste Characterization

Category	Annual Tonnage (Residential)	Annual Tonnage (Commercial)	Annual Tonnage (Total)	Percent	Percent Adjusted for ADC	Percent (Typical for U.S.)
Construction & Demolition	31,019	91,818	122,837	9.64	7.87	8.7
Glass	27,954	23,081	51,035	4.00	3.27	5.5
Metal	32,045	47,164	79,209	6.22	5.07	7.80
Mixed residue	27,715	4,650	32,365	2.54	2.07	NA
Other organic	221,513	193,040	414,553	32.53	26.54	29.90
Paper	190,123	251,085	441,208	34.62	28.25	37.4
Plastic	61,271	71,882	133,153	8.53	8.53	10.7
Alternative Daily Cover (ADC)	NA	NA	287,356[a]	NA	18.4	NA

Note: Based on *Landfill Feedstock Characterization Report* (CH2M HILL 2003). Minor modifications have been made to the table based on further evaluation.

[a] Number based on back calculation for 18.4 percent of waste stream.

Small quantities of hazardous wastes reported and "special wastes" have been removed from the disposal data listed in Table 1-1. It is assumed that these materials are or will be removed from the waste stream before landfilling. These wastes account for less than 3 percent of total waste, so do not significantly affect overall composition.

Table 1-1 also lists the percentages of each waste category for typical U.S. mixed municipal solid waste (MSW), as reported by USEPA.[2] A comparison to San Bernardino County's waste shows there is relatively good alignment between the data reported by San Bernardino and typical U.S. mixed MSW.

1.8 Report Content and Organization

This report is organized as follows:

- **Section 1** introduces the report and provides an overview of landfill gas production and power generation.
- **Section 2** provides the energy and material balance for the proposed bioreactor operation.
- **Section 3** establishes the design criteria for the bioreactor project.

[2] www.epa.gov/eaposwer/non-hw/muncpl/facts.htm

- **Section 4** describes the process control and instrumentation that will be used to control the bioreactor operation and provide the data for evaluating and managing the project.
- **Section 5** describes the construction of the bioreactor cell in the Mid-Valley Landfill Unit 3.
- **Section 6** describes the modifications to the landfill gas-to-energy recovery system for utilizing the biogas produced in the bioreactor.
- **Section 7** describes the operation of bioreactor cell.

SECTION 2

Materials and Energy Balance

This section focuses on the materials and energy balance anticipated for the Mid-Valley Landfill bioreactor demonstration project. Input to the bioreactor consists of MSW, soil and alternative daily cover (ADC) materials, water, and leachate. Output includes leachate and landfill gas (LFG), the latter of which can be converted to energy. The flowchart showing the following information is presented on Figure 2-1.

2.1 Waste Materials and Cover Materials

2.1.1 Waste Materials

The composition of the waste materials was reported in the *Landfill Feedstock Characterization Report* (CH2M HILL 2003a). Discussions with San Bernardino County Solid Waste Management Department indicated that the best source of information is the reported information sent to the California Integrated Waste Management Board (CIWMB), last updated in 1999. The commercial and residential waste streams were reported separately on the CIWMB website (http://www.ciwmb.ca.gov/Profiles/County/CoProfile1.asp) and were combined to represent the typical waste stream. Results of the waste characterization are presented in Table 1-1.

In addition to the typical waste stream, the County tracked its use of green waste (yard and garden trimmings, grass clippings, etc. which are collected separately from other household solid waste), which is used as an ADC. The average percentage used by weight during the 1999 to 2001 period was 18.4 percent.

The information presented in Table 2-1 was prepared by BAS in conjunction with the site operator, BurrTec. This information was used to estimate the quantity of waste within Unit 3 over both the demonstration project time period and the life of the landfill. The results were used to help estimate the LFG generation rates from the start of placement (2002) to final closure in 2033. The final closure date was obtained from the Joint Technical Document, which is the permitting document that satisfies both the CIWMB and Regional Water Quality Control Board (RWQCB) requirements for a Solid Waste Facilities Permit and Report of Waste Discharge, respectively.

TABLE 2-1
CEC Bioreactor Demonstration Project

Projections of Tonnage and Airspace Consumption

	Tonnage				Airspace		
	MSW	GWADC	Total of MSW and GWADC	Cumulative at End of Period	Applicable Index	Airspace this Period (CY)	Cumulative Airspace
January 2004	55,615	10,069	65,684	1,169,677	1,177	11,640	1,988,058
February 2004	55,615	10,069	65,684	1,235,360	1,177	11,640	2,099,698
March 2004	55,615	10,069	65,684	1,301,044	1,177	11,640	2,211,338
April 2004	55,615	10,069	65,684	1,366,727	1,177	11,640	2,322,978
May 2004	55,615	10,069	65,684	1,432,411	1,177	11,640	2,434,618
June 2004	55,615	10,069	65,684	1,498,094	1,177	11,640	2,846,258
July 2004	55,615	10,069	65,684	1,563,778	1,177	11,640	2,657,898
August 2004	55,615	10,069	65,684	1,629,461	1,177	11,640	8,769,898
September 2004	55,615	10,069	65,684	1,695,145	1,177	11,640	2,769,538
October 2004	55,615	10,069	65,684	1,760,828	1,177	11,640	2,881,178
November 2004	55,615	10,069	65,684	1,826,512	1,177	11,640	3,089,897
December 2004	55,615	10,069	65,684	1,892,195	1,177	11,640	3,186,975
2004 Total	667,378	120,827	788,202			1,310,557	
2004 avg daily (306 days)	2,181	395	2,576			4,283	
January 2005	58,395	10,572	68,968	1,961,163	1,353	101,932	3,288,907
February 2005	58,395	10,572	68,968	2,030,131	1,353	101,932	3,390,839
March 2005	58,395	10,572	68,968	2,099,099	1,353	101,932	3,492,772
April 2005	58,395	10,572	68,968	2,168,066	1,353	101,932	3,54,704
May 2005	58,395	10,572	68,968	2,237,034	1,353	101,932	3,696,636
June 2005	58,395	10,572	68,968	2,306,002	1,353	101,932	3,798,568
July 2005	58,395	10,572	68,968	2,374,969	1,353	101,932	3,900,500
August 2005	58,395	10,572	68,968	2,443,937	1,353	101,932	4,002,432
September 2005	58,395	10,572	68,968	2,512,905	1,353	101,932	4,106,365
October 2005	58,395	10,572	68,968	2,581,873	1,353	101,932	4,206,297
November 2005	58,395	10,572	68,968	2,650,840	1,353	101,932	4,308,229
December 2005	58,395	10,572	68,968	2,719,808	1,353	101,932	4,410,464
2005 Total	700,745	126,868	827,613			1,223,186	
2004 avg daily (306days)	2,290	415	2,705			3,997	

TABLE 2-1
CEC Bioreactor Demonstration Project

Projections of Tonnage and Airspace Consumption

	Tonnage				Airspace		
	MSW	GWADC	Total of MSW and GWADC	Cumulative at End of Period	Applicable Index	Airspace this Period (CY)	Cumulative Airspace

Notes:
1. MSW = Municipal solid waste; GWADC = green waste alternative daily cover
2. Used an average of 25.5 days per month x 12 = 306 days per year.
3. Basis of tonnage projection is the total of 2003 MSW and GWADC tons (omit Newcastle Chicken tonnage for projection purposes). Per Chuck Tobin, BurrTec is seeing base tonnage in contributory waste shed surrounding Mid-Valley Landfill grow in excess of 5 percent per year recently resulting from many new housing units, so waste quantities may be even higher than assumed here. These numbers have been confirmed with the County's current assumptions. Assume this applies to both MSW and GWADC. Therefore, projections are based on 2003 actual quantities increased by a 5 percent growth rate per year.
4. Quantities shown are average tons per month and do not account for seasonal variations. Seasonal variations will be addressed during actual operations.
5. Applicable Index is density of waste material (waste, soil, GWADC) in landfill. Density of 1,177 lbs/cy was generated by dividing total waste material tonnages from 2002 through June 2003 and dividing by computed volume placed within that time period. Volume was computed between the top of the as-built operations layer and the July 2003 flyover.

Based on the information in Table 2-1, the average waste placement rate is projected to be 2,290 tons per day for the year 2005. The rate of placement is anticipated to increase over the life of the landfill at a rate of approximately 5 percent per year.

2.1.2 Cover Materials

Daily cover materials used to cover the solid waste at the end of each day are composed of ADC and soil. The ADC consists of shredded and ground green wastes, and the soils are obtained from the cover soil stockpile area.

ADC is used primarily on the sloped working face, with a minimum of 12 inches placed at the end of the day. The total ADC used in 2005 would be approximately 415 tons per day based on the projections presented in Table 2-1. The material is biodegradable and will contribute to the overall generation of LFG within the landfill. In addition, the material is relatively permeable and will generally maintain hydraulic continuity between adjacent lifts.

Soils are typically used on the upper deck of the working face. Generally, a minimum of 6 inches is placed daily, both acting as daily cover and as the base for the tipping areas, haul roads, and other temporary operational structures. The soil is not as permeable as the adjacent waste, and could potentially cause perching of leachate within the waste and seeps along the sideslopes. However, with the generally thin layer of material and resulting disturbance during placement of subsequent lifts, it is unlikely that the daily cover will present a problem with distribution of leachate. Also, this is a typical landfill practice and will therefore allow applicability of the demonstration project results to full-scale landfill operations.

2.2 Water Balance

Water balance within the bioreactor landfill is the focus of operations. Balance within the system will allow for obtaining field capacity within the waste while optimizing recirculation and reuse of leachate. Field capacity (an agronomic term) is defined as the moisture content at which a material begins to drain water. At field capacity, the material does not accumulate more moisture unless drainage is blocked. Field capacity occurs at a lower moisture content than saturation. In general, balance is met when the water entering the landfill is equal to the water exiting the landfill. When this happens, the field capacity of the waste has been met, and added water begins balanced recirculation through the waste.

Water entering the landfill typically is composed of precipitation, make-up water (additional water needed to meet demand when leachate generated is less than injection quantities needed to reach field capacity for incoming waste), leachate, and LFG condensate. Precipitation cannot be controlled, but it can be modeled, whereas leachate, make-up water, and LFG condensate recirculation can be controlled. This allows for flexibility in balancing the system during periods of fluctuation caused by periods of precipitation.

2.2.1 HELP Model

An initial water balance was determined before considering water additions. The landfill was modeled using the Hydraulic Evaluation of Landfill Performance (HELP) computer program developed by the U.S. Army Corp of Engineers. The model was used to develop the water balance within the landfill under conventional landfill operations. The HELP model is considered to be a conservative model that develops steady-state, saturated flow through the various layers of the landfill cross-section. The results of the HELP model provide the balance between precipitation, evapotranspiration, runoff, water storage within waste materials, and leachate generated.

The HELP model evaluates the landfill system by generating precipitation, runoff, evapotranspiration, drainage collected, percolation through layers, water storage, and hydraulic head build-up over the landfill cover. Typical inputs include precipitation, temperature, solar radiation, and relative humidity. HELP simulates the hydraulic characteristics of the landfill on a monthly basis for each year, and on a monthly basis for the average over the time periods analyzed. The user can select either a particular year to examine the leachate production (a wet year, for instance) or an “average year” as represented by the monthly leachate production, on average, over the entire block of data.

Output data includes the moisture stored in each layer of the landfill, water transmitted through drainage layers, modeled evapotranspiration amounts, maximum hydraulic head on the bottom lining and the total amount of leachate recirculated and the amount of leachate discharged each month. HELP also computes the peak daily leachate flow that occurs each year.

The HELP model allows the user to specify leachate re-circulation as a percentage of leachate collected. For this study, it was assumed that 100 percent of the leachate was recirculated. This is a reasonable assumption based on the general lack of precipitation and generation of leachate, and as long as the amount of recirculated leachate does not exceed the amount discharged.

Modeling of the leachate collection and removal system (LCRS) for Unit 3 was performed using identical information obtained from the previous modeling performed by GeoLogic Associates GLA in May 1997. Results are based on a unit acre and can be applied to the actual acreage of the biocell.

Average annual totals from the HELP model, without recirculation, are as follows:

- Precipitation: 61,964 ft^3/year/acre
- Runoff: 11,521 ft^3/year/acre
- Evapotranspiration: 39,937 ft^3/year/acre
- Leachate collected: 4,581 ft^3/year/acre
- Change in water storage: 10,506 ft^3/year/acre

With the functional biocell area of 12 acres, the average annual totals are:

- Precipitation: 743,568 ft^3/year or 5,562,275 gallons/year
- Runoff: 138,252 ft^3/year or 1,034,197 gallons/year
- Evapotranspiration (ET): 479,244 ft^3/year or 3,584,994 gallons/year
- Leachate collected: 54,972 ft^3/year or 411,219 gallons/year
- Change in water storage: 126,072 ft^3/year or 943,084 gallons/year

Stormwater will be collected and used within the biocell, so runoff is included as input to the biocell.

The model assumes that all leachate is stored within the waste because of recirculation. However, the net amount of storage (the total water added to the system per year) is the change in water storage minus the leachate collected. Therefore, the net amount of water added to the waste is 943,084 – 411,219 = 531,865 gallons per year.

Based on the model results, the total amount of water that actually impacts the waste (evapotranspiration and runoff are removed before they impact waste) is the net storage amount noted previously plus the leachate, or 943,084 gallons/year. The percentage of water that impacts the waste reaching the LCRS is 411,219/943,084* 100% = 43.6%. This number will be used to determine the amount of storage within the landfill as the waste is approaching field capacity.

The HELP model also generates peak daily values that can be used for design. Under peak conditions, it is assumed that all stormwater impacts the LCRS. The result for peak precipitation from the model is 5,200 ft^3/day/acre, or 38,900 gallons/day/acre. For the 12-acre demonstration biocell, this would amount to a total of 467,000 gallons/day. If stormwater is adequately controlled, as is anticipated, the peak from the HELP model output is 54.7 ft^3/day/acre, or 4,910 gallons/day for the 12-acre site.

2.2.2 Water Addition

Additional water will be required to achieve the field capacity of approximately 40 percent by weight. With the demonstration biocell waste quantity of 959,000 tons (includes 14 months' worth of waste) as discussed in Section 2.1.1, the total amount of water that must be added to the biocell during the demonstration project is 57.5 million gallons per year, or 187,900 gallons per day (306-day year). The net amount to be added is the total amount minus the amount stored (as determined by HELP analysis), or 57.5M – 943,000 = 56.6M gallons per year (184,800 gallons per day).

The quantity of water that must be added was determined as follows:

$W_{added} = 0.25*W_{in}$

Where

W_{added} = weight of water that must be added

W_{in} = weight of waste at 25 percent moisture by weight

This equation was developed using the following relationships:

$W_{in} = W_r + W_{w(25\%)}$, with $W_r = 0.75*W_{in}$ and $W_{w(25\%)} = 0.25*W_{in}$,

$W_{tot} = W_r + W_{w(40\%)}$, with $W_{w(40\%)} = 0.4*W_{tot}$, and

$W_{added} = W_{w(40\%)} – W_{w(25\%)}$

Where:

W_r = weight of dry waste

$W_{w(25\%)}$ = weight of water in waste at 25 percent moisture by weight

W_{tot} = weight of waste at field capacity, 40 percent moisture by weight

$W_{w(40\%)}$ = weight of water in waste at 40 percent moisture by weight

The quantity stored within the waste as modeled by HELP is then subtracted from this number, because this amount is added to the incoming 25 percent moisture content.

Using the percentage of water that reaches the LCRS from the HELP modeling results, the total quantity of leachate generated (outflow) is the amount of leachate modeled plus the net amount of leachate generated from recirculation (based on net amount added), or 411,219 + 43.6% * 56.6M = 25.1M gallons per year, or 81,900 gallons per day.

Additional water will be generated during LFG collection operations in the form of condensate. Condensate will be collected from the various condensate traps and the knockout pot located in the system. Based on calculated flow from the bioreactor of 1,750 standard cubic feet per minute (scfm), a typical vacuum of 45 inches water in H_2O, and using Appendix A.13 from the *Landfill Gas Operations & Maintenance Manual of Practice* (SWANA 1997), the total quantity of condensate generated is 1,750 scfm x 1.5 gal/hr/100 cfm x 24 hrs/day, or 630 gallons per day (229,950 gallons per year). This quantity is a minuscule amount compared to the overall water balance amounts described previously. It is assumed that this quantity will remain relatively constant during the operation of the demonstration biocell.

The net amount of water stored within the waste per year is 31.9M gallons ([1-43.6 percent] x 56.6M gallons per year) plus the modeled quantity of 531,865 gallons minus the condensate quantity of 229,950 gallons, for a total of 32.2M gallons per year, or 105,200 gallons per day.

The overall water balance is summarized below:

Water in:

- Precipitation: 5,562,257 gallons per year
- Runoff: 1,034,197 gallons per year
- Evapotranspiration: 3,584,994 gallons per year
- Recirculation of leachate: 25,068,901 gallons per year
- Water addition: 56,554,316 gallons per year

Water out:

- Leachate: 25,068,901 gallons per year
- Gas condensate: 229,950 gallons per year

Water stored:

- 32,198,549 gallons per year

Based on the preceding summary, it is evident that a large volume of additional water will be required to achieve the field capacity target. This water, termed makeup water, will be obtained from stormwater, potable water, or other available sources. Based on the modeling, a total of 1,034,197 gallons are generated each year as runoff from the biocell portion of the landfill. This alone can make a significant contribution to the total water addition required. (The total makeup water from sources other than this stormwater would be reduced to 56.6M – 25.1M – 1.0M – 229,950 = 30.4M gallons per year, or 98,800 gallons per day based on a 306-day operating year.) If stormwater from other parts of the landfill site can also be collected, it will further reduce the required makeup water.

2.3 Water Sources and Quantities

2.3.1 Sources

Several water sources were identified as presented in the *Mid-Valley Landfill Bioreactor Concept* report (CH2M HILL 2003c). The report suggested that further investigation had to be performed to determine the appropriate water source(s). For the bioreactor demonstration project and bioreactor operations beyond the designed project, it is suggested that the existing water source located along Alder Avenue be utilized. This water source is currently being utilized for dust suppression around the site and could be expanded to meet the demand for bioreactor operations.

In addition to the existing water source, stormwater drainage should be retained and utilized to reduce the draw from the potable water source. This may require the addition of a sump pump that can pump either directly into the recirculation system or into the storage tanks located at the southwestern corner of the site. If the stormwater is discharged directly into the recirculation system, additional flow metering will be required to capture the quantities added.

If, in the future, reclaimed water from a nearby publicly owned treatment works (POTW) becomes available at a reasonable price, consideration should be made to utilize this source.

This will reduce the draw on the potable water system, while increasing reuse of reclaimed water.

2.3.2 Quantities

Design liquid quantities are determined primarily based on reaching and maintaining the field capacity of waste. Typically, the daily or weekly quantity of waste would be used to determine the injection rates for meeting the field capacity. However, for the demonstration project, projected 2005 volumes were added with the final two months of 2004 because of operational constraints (assumed two months' worth of careful waste placement operations to facilitate full unrestrained operations). The total volume of waste for 2005 was estimated to be 827,600 tons per year based on an overall 5 percent escalation rate per year from reported 2003 quantities (Table 2-1). Adding in the final two months of 2004 gives a total waste quantity of 959,000 tons for the project.

The total quantity of water needed to reach field capacity is determined for the entire year. Assuming a moisture content of 25 percent by weight upon arrival at the landfill (typical throughout the United States), it would take approximately 240,000 tons (57.5 million gallons) per year, or 187,900 gallons per day, of water to reach an assumed field capacity of 40 percent moisture. The assumed field capacity is based on the maximum achievable control technology (MACT) definition of bioreactor. The MACT rule is designed to limit the emissions of hazardous air pollutant (HAP) emissions from sites categorized as major sources.

Based on Mid-Valley Landfill site experience, there is very little leachate generated to date. Therefore, under typical landfill conditions, the total quantity of leachate that would be collected from the LCRS per day would be 80,850 gallons per day. However, peak periods should be anticipated following storm events. Under peak conditions, up to 467,000 gallons per day could be generated.

The total quantity of makeup water required, from either collected stormwater drainage or potable water source, would be 102,100 gallons per day (56.6M water added – 25.1M leachate generated – 229,950 condensate). Under peak conditions, the total impacting the system would exceed the recirculation amounts. Therefore, no additional water would be necessary during peak storm events. Every effort should be used to capitalize on the use of stormwater when available.

2.4 Leachate Constituent Flows

Typical parameters of concern regarding leachate constituent flows include physical, chemical, and biological transformation. Actual leachate data from the Mid-Valley Unit 3 Landfill are not yet available. Leachate characteristics in leachate recirculating landfills were studied by Reinhart and Townsend (Reinhart and Townsend, 1998), who collected data from five full-scale recirculating landfills. They found that leachate data in recirculating landfills are similar to leachate data in conventional landfills, moving through acidogenesis, methanogenesis, and maturation. Data obtained from several full-scale landfills indicate that contaminants do not extensively concentrate in leachate.

2.4.1 Acid Production

Acidogenesis has shown to be more pronounced within recirculating landfills. This likely results from the constant flows of leachate through the waste, which provides more opportunities for contact with waste.

With the increase in acid production, many metals are mobilized, increasing aggressiveness of the leachate and potentially making it more threatening. However, with the subsequent development of anaerobic conditions, sulfates are reduced to sulfides, rendering many metals to potentially undetectable concentrations (EPA 1995).

2.4.2 Nutrient Recycling

With the increase in biological decay resulting in part from the nutrient recycling, the biomass is reduced much more quickly than in conventional landfills. This induces quicker settlement of the landfill because of biological decay, while increasing the production of methane from augmented microbial activity.

Recirculation also promotes nutrient recycling, providing for increased biological decay. With the increased recycling of nutrients and more continual, complete contact of liquids with the active biomass and substrates, the landfill reaches microbial acclimation, allowing for further attenuation capacity with toxic organic compounds when coupled with LFG control.

2.4.3 Organic Loading

Reinhart and Townsend showed that biochemical oxygen demand (BOD) and chemical oxygen demand (COD) in landfill leachate vary considerably over time, in both conventional and recirculating landfills. The concentrations also vary considerably from site to site. Leachate organic concentrations typically peak during the acid-forming phase, with BOD and COD concentrations that may exceed 50,000 and 70,000 milligrams per liter (mg/l), respectively, then decline during the methanogenic and final maturation phases. All phases are expected to be greatly accelerated in a bioreactor recirculating landfill.

Reinhart and Townsend compared literature data on the reduction of COD concentration over time in conventional vs. recirculating landfills. They found that the COD half-life for conventional landfills was approximately 10 years, and for recirculating landfills it was approximately one year.

2.5 Waste Volume Reduction

A major benefit to bioreactors is the relatively quick settlement time of the waste mass and subsequent increase in landfill airspace. This allows the bioreactor landfill to possibly operate longer or accept more waste than a conventional landfill by increasing the density of the waste, resulting in a greater volume available for waste placement.

Generally, settlement is a result several mechanisms, including:

- Mechanical: reduction in void space due to general compression and reorientation of materials due to overburden

- Ravelling: movement of fine particles into voids
- Physico/chemical change: changes due to oxidation, corrosion and combustion
- Biochemical decay: aerobic or anaerobic decay of organic waste materials
- Interaction: decay caused by combustion, corrosion from organic acids, and changes from consolidation potentially causing ravelling (Sowers 1973)

Settlement of bioreactors has been in the range of 13 to 20 percent of the waste depth, but could be greater. Additional benefits from the decrease in volume resulting from settlement are the meeting of waste volume goals and the reduction of long-term post-closure care.

2.6 Gas/Energy Production

In pilot scale and full-scale studies of landfills recirculating leachate that reported gas production, the gas production rate has shown an increase of 2.1 to 4.5 times over "normal" operation (Reinhard and Townsend). This arises from the accelerated gas production rates obtained from stimulating anaerobic conditions supporting methanogenesis, as well as the continued recirculation of the organically rich leachate into the waste mass.

An additional benefit is that the development of the methanogenic phase of the landfill is accelerated when compared to conventional landfills. LFG within conventional landfills may take several years to reach high concentrations, but LFG within bioreactor landfills develops in a much shorter time period. This means that a LFG collection system must be installed concurrently with the recirculation system to control LFG emissions from the landfill efficiently.

With the accelerated LFG production comes the potential for incremental energy production. An LFG-to-energy system is currently located at the Mid-Valley Landfill site. The system will be operated using the LFG from the bioreactor cell to demonstrate energy production from the gas generated in this project. The system will ultimately be expanded to utilize all of the gas generated in other areas of the Mid-Valley Landfill as well as that generated in the bioreactor cell.

Figure

2-1 Flow Diagram—Energy and Materials Balance

8.5 x 11

SECTION 3

Design Criteria

This section presents the general design criteria used during the design process. The criteria reflects the design parameters that have been established through experience gained from other full-scale bioreactor landfills, prior studies, analysis, design, and professional judgment. As the criteria are established, they will form the basis for all subsequent work performed for the Mid-Valley Landfill bioreactor project.

The Mid-Valley Landfill has been designed and constructed in conformance with all applicable federal and state regulations, with the requirements of the local air quality and water quality regulatory agencies, and with site-specific requirements specified in its permitting documents. This section presents an overview of design criteria pertinent to this biocell demonstration project.

3.1 Design Criteria for Unit 3 Prior to Biocell

Current regulations require that landfills be designed to eliminate as much moisture as possible from infiltrating into the waste mass. Therefore, drainage controls must be provided to prevent stormwater from entering the waste area as much as practical and for the rapid removal of stormwater without ponding for the stormwater that does fall on the landfill area. For that portion of the precipitation that infiltrates into the landfill, a liner system and LCRS are required. The regulations contain several specific criteria, such as the Design Storm, the requirement that leachate not build up more than 30 cm (12 inches) on the liner system, and performance of and component parts of the liner system and leachate collection system. Under current regulations and the permits at Mid-Valley Landfill, the leachate collected may be disposed on the landfill over only the lined areas. The relatively small amounts of leachate now being collected at the landfill are now sprayed by water truck for dust control purposes. Landfill gas collection and management systems are also subject to an elaborate set of design criteria. Site-specific design features of Unit 3 are addressed in Section 5.

3.2 Additional Design Criteria for Biocell

The fact that a biocell operates by *adding* moisture to the waste is a fundamental departure from the basic design criteria for a modern landfill; therefore, permit revisions are required. These permit revisions will address the addition of extra liquids to create extra leachate so that a larger volume of liquid is available to inject into and keep circulating throughout the waste mass so that waste degradation is enhanced. Thus, additional design criteria for a biocell are that: 1) the additional volumes of liquid are properly managed in a way that does not undermine the integrity of the groundwater protection system (i.e., the liner and LCRS system), and that 2) the more rapid and higher rates of landfill gas production are properly managed in a way that conforms to all permit requirements. Changes in the permits will also address site drainage features so that stormwater can be retained on the waste mass for the purpose of enhancing infiltration rather than its rapid removal from the surface of the waste mass. Site specific design features for the operation of Unit 3 as a biocell are address in Section 6.

3.3 Water Addition and Leachate Recirculation Rates

A maximum liquids injection rate of 2 cubic meters/day per meter of trench (161 gallons/day per foot of trench) (CH2M HILL 2003a) is suggested for use in the landfill. This number is based on successful liquids injection rates that were modeled and applied at different landfills. With approximately 435.6 feet of trench per acre (at 100-feet spacing), this equates to a total of 70,100 gallons/day per acre of distribution system. With 12 acres, this is approximately 841,200 gallons/day infiltration capacity. This maximum capacity is substantially greater than the anticipated water quantity needs of 184,800 gallons per day to adequately increase the moisture content of the waste, and therefore provides a high factor of safety. This quantity should be used for design of the system.

Pipe sizes for the distribution laterals should be based on the rate of 161 gallons/day per foot of trench. This equates to 0.11 gallons per minute (gpm) per foot of trench.

3.4 Gas Collection System

Landfill gas production in the bioreactor was modeled using the waste composition obtained from the CIWMB and CH2M HILL's proprietary model of landfill gas production, LFGGEN. The waste stream composition obtained from the CIWMB was sorted into organic and inorganic fractions, as presented in Table 3-1.

TABLE 3-1
CEC Bioreactor Demonstration Project
San Bernardino County Waste Composition

Material Type	Annual Total Disposal Tonnage	Total Percentage Organic /Inorganic	Total Percentage All Wastes
Readily decomposable (food waste)	269,679	22.47	17.27
Moderately decomposable (paper, green waste)	872,889	72.73	55.89
Slowly decomposable (wood)	57,666	4.80	3.69
Inorganic (C&D, metal, glass, plastic, mixed residue)	361,482	0	23.15

Waste filling was based on the information presented in Table 2-2. Waste from years 2002 to 2004 were modeled separately by using a moisture content of 25 percent. Waste from years 2005 through 2033 (assumed closure of the landfill) tonnages were expanded each year by 5 percent based on the historical growth rate presented by BAS.

CH2M HILL's LFG generation model estimates the production of landfill gas over time using the data presented in Table 3-1. Results of the model are provided as a graph, shown in Figure 3-1. The peak gas production of 23,244 cubic feet per minute at 39.4 percent methane is expected to occur one year following the last year of waste filling, and will decline steadily thereafter.

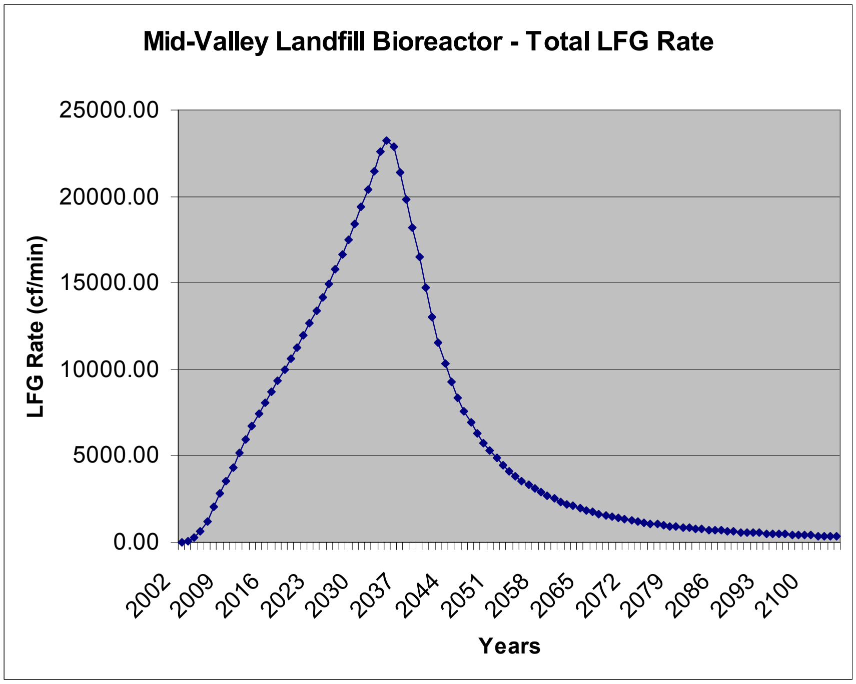

FIGURE 3-1
Production of Landfill Gas

Note that gas production during the one-year demonstration project in 2005 will reach only a small fraction of the ultimate gas production rate shown in Figure 3-1. The estimated gas production in 2005 is only 1,751 cfm at 39.4 percent methane. The projections assume that the Mid-Valley Landfill Unit 3 will continue to be operated as a bioreactor landfill after the one-year demonstration project.

To convert the estimated gas production to power, the following conversions were used:

- An estimated 1,000 British Thermal Units (Btu) per standard cubic foot of methane
- A LFG gas concentration of 39.4 percent methane by volume (i.e., 394 Btu/scfm of LFG)
- 0.293 watts (W) per Btu/hr
- An assumed 28 percent efficiency in converting gas to power.

With the factors above, the estimated power production from Unit 3 LFG in 2005 is 1.19 MW. If Unit 3 continues to be operated as a bioreactor over its life, projections indicated that in 2034, production would peak at 45 MW. If a 10-year LFG supply is needed to justify the investment in installed generation, the maximum generation would be about 33 MW in 2028.

The primary criterion for the gas collection system is the gas production rate just described. A second criterion will be to design the gas collection piping such that the pressure drop created at the peak gas production rates does not exceed the capacity of the system exhauster.

Finally, the condensate handling system must be able to handle the peak gas condensate production. This is estimated to be 630 gallons/day during 2005.

Spacing of gas collectors must provide overlapping zones of influence within the waste; this spacing will be 200 feet horizontally and 40 feet vertically. This spacing has shown to be effective at very wet landfills in the Pacific Northwest.

3.5 Water/Leachate Recirculation Distribution System

The water/leachate recirculation distribution system will be installed incrementally during waste placement, and should begin operation with installation of the first distribution lateral. The system will consist of separately controlled subsystems: one for the second lift of waste, one for the fourth lift of waste, and continuing every other lift. The system will terminate immediately below the landfill final cover if the bioreactor is continued following completion of the demonstration project.

Each subsystem consists of a 6-inch solid HDPE header pipe that distributes leachate to several 2-inch solid HDPE distribution pipes. The solid distribution pipes are then changed to perforated pipe when placed within the waste. The perforated pipes will be placed within trenches excavated in the waste, and will be protected by a gravel layer that will allow for distribution of leachate throughout the trench. The perforated pipe should be placed within no less than 50-feet from either sideslope. The system should be designed to meet the following requirements:

- Peak leachate flow from LCRS in bioreactor into recirculation system: 467,000 gallons/day
- Average leachate flow from LCRS in bioreactor into recirculation system: 25.1M gallons per year, or 81,900 gallons/day (306-day operating year)
- Peak recirculation rate: 161 gallons/day per foot of trench

The existing two 10,000-gallon leachate storage tanks will not be adequate to contain the anticipated leachate and makeup water volumes. Therefore, the system must be expanded to meet the design demand. The system should be designed to contain up to three times the peak daily flows. This would allow for adequate capacity in the tanks if the recirculation system is shut down. In addition, a safety factor of 1.5 should be used to obtain the required capacity. Using the peak leachate generation rate of 467,000 gallons/day, that would be an approximate 2.1M-gallon water tank. However, if the stormwater is adequately controlled, the total storage requirement would be based on 82,700 gallons per day of leachate and condensate generated, or 372,000 gallons total. Baker tanks, which range from 4,000–6,500 gallon poly tanks up to 17,850-gallon steel double-walled tanks, can be used in the interim until a larger tank can be built. To meet the requirements for a 372,000-gallon tank, it would take up to 21 17,850-gallon Baker tanks to meet demand. A smaller number of tanks could be used, but contingencies should be built in to operations to remove leachate from the

LCRS and treat it separately from the landfill should the injection system be inoperative and tank storage is maximized. The connection of each 2-inch distribution line at the 6-inch main line must have access to the distribution line to allow for flushing of the system or inserting pipe cleaning tools. The cleanout must remain above the waste, and be capped with a blind flange when not in use. Flexible hosing must be used at the connection to allow for settlement of waste and associated movement of the pipes within the waste mass.

As part of the distribution system, a potable water line 4 inches or larger must be installed to supply makeup water to the distribution system. This line is required to provide the additional water necessary to meet the demand. The line must be sized to deliver up to 102,100 gallons/day. This quantity includes stormwater because stormwater is unavailable for most of the year.

A control system must be constructed at the LCRS storage tanks to control distribution of liquids while monitoring system performance. The system must have the ability to separately measure and automatically record the rates and totals of clean and recirculated water.

3.6 Monitoring Systems

The potential buildup of leachate over the landfill liner system is a concern with the addition of liquids to the bioreactor. Monitoring the hydraulic head built up over the liner is used to demonstrate conformance with regulatory requirements while providing an indication of the performance of the liner system. To address this, four pressure transducers will be installed on the floor of the landfill to monitor the leachate levels over the cell floor at different locations. The transducers will be removable and will be installed along the eastern and western portions of the landfill. They will be placed within riser pipes running up the sideslopes, allowing for removal during sampling events (riser pipes double as sample ports) and routine maintenance.

Liquid quantities must be monitored to assist with balancing of the system between inflow and outflow. For this demonstration project, quantities of leachate generated will be monitored within the newly installed LCRS main pipeline. The flows will be diverted to a solid pipe placed within a clay plug. A riser pipe will be installed to allow for placement of a flowmeter. The flowmeter may be installed directly into the solid pipe, with the riser protecting the power and signal cable, or it may be a portable flowmeter that can be removed periodically for maintenance. However, the meter must be designed to provide generally accurate measurements.

The quantity of water and leachate being supplied to the system will be monitored with a flowmeter and totalizer installed at the discharge end of the injection pump. The flows and quantities will be recorded and used to help balance the system.

Temperatures within the waste stream will be generally monitored at each control point in the LFG system. This task will be performed during typical maintenance, operations, and monitoring rounds. High temperatures greater than 120°F would indicate there is the potential for a fire, and would require action.

Samples will be extracted from the floor of the bioreactor through the transducer riser pipes and will be tested to provide important parameters regarding the decomposition process in the waste. A list of leachate liquid parameters is:

- pH
- Biochemical oxygen demand (BOD)
- Chemical oxygen demand (COD)
- Nutrients (NH_3, TKN, TP)

Management of the pH will be important because of the potential for acids to accumulate in the early phases of anaerobic decomposition.

Landfill gas flow and composition are other important factors to measure. At the same sample port locations on each extraction lateral, landfill gas flowrates and composition will be monitored. The process instrumentation and control system (PICS) will be programmed to display and trend manually entered vacuum readings from sample ports along gas collection system piping. The PICS will also display and trend landfill gas pressure, methane content, carbon dioxide, and oxygen content.

Settlement must also be monitored to develop the general rate and extent of subsidence within the landfill mass. The settlement of the bioreactor landfill will be monitored using ground survey/GPS methods to determine the surface elevation of an established network of grid points at predefined intervals of no greater than 12 months.

SECTION 4

Process and Instrumentation

The process and instrumentation design for the proposed landfill bioreactor will allow for variability of landfill characteristics and operations. The system will be able to provide flow measurements and head over the liner, and will allow monitoring of critical functions within the system. The designs must follow the guidelines set forth by the typical established codes and regulations for electrical systems, addressing the hazardous nature of the landfill environment. The conceptual process and instrumentation diagram (P&ID) and associated legend is included as Figures 4-1 and 4-2, respectively.

4.1 Process Variables and Ranges

Process variables include the quantity of wastes placed, moisture content of waste, organic content of waste, quantity of liquids applied, quantities of liquids generated and recirculated, leachate pH, and gas composition and flow rates. Variations of the waste stream, from rate to characteristics, will vary from year to year. The system has the flexibility to conform to the rate of waste placement, with adjustments made to the amount of moisture added to achieve field capacity.

As the quantities and characteristics of waste change, the inflow and outflow will be varied to reach the field capacity of the waste, optimizing the amount of moisture added with the amount of leachate generated. Using the previously recorded peak leachate generated of 47 percent (Moore et al 1997) as a milestone, and monitoring both the flow of liquids applied and liquids generated, the system can be calibrated to account for any variability of waste rates and characteristics.

4.2 Instrumentation

Instrumentation includes liquid level monitoring instruments, leachate flow and totalization monitoring instruments, and leachate storage tank level monitoring instruments. Transducers will be used to measure the liquid levels over the liner, and must be able to read from 0 to approximately 2 feet (depth of LCRS main line trench and floor of landfill) with good accuracy. Therefore, the accuracy of the transducers should be specified as being within 0.25 of the full scale. In addition, the transducers must be able to withstand harsh environments. Suggested manufacturers include Druck and Pressure Systems, Inc.

Leachate flow and totalization monitoring equipment includes flowmeters and totalizers located at the inflow and outflow. The flowmeters should be electromagnetic meters (magmeters), and should be capable of reading up to 100 gpm. A suggested manufacture is Marsh-McBirney, Inc.

With the increase in storage tank levels, the tanks must be fitted with level monitoring instruments. Float levels or ultrasonic levels should be used to monitor tank levels.

Other parameters that must be measured include LFG temperature, flow, and composition, leachate liquid (pH, BOD, COD, Nutrients (NH_3, TKN, TP), and settlement. However, these parameters will be used to gauge the overall state of waste degradation and, unless a gross problem is indicated, will not be used for day-to-day operational control.

Additional instrumentation will be installed within the LFG collection system. A gas flowmeter/totalizer and continuous pressure measurement (thermal mass flow meter, totalizer, and pressure transmitter) will be installed to monitor the development of LFG within the system. Manufacturers include Fluid Components International, Kurz Instruments, and Sierra Instruments for thermal mass flow meters and totalizers, and Rosemount, SMAR, and Foxboro for gauge pressure units.

Methane, oxygen and CO_2 can be measured manually with a Landtec GEM 500 or 2000.

4.3 Control Mechanisms and Equipment

The process and instrumentation control system (PICS) design for the proposed landfill bioreactor will specify and integrate industry standard and approved instrumentation, programmable logic controller, human and machine interface module (HIM), and site communication (alarm dialer).

PICS design will facilitate safe control and monitoring of landfill bioreactor processes including:

- Landfill bioreactor liner integrity.
- Landfill bioreactor liquid levels.
- Landfill bioreactor leachate injection, collection, storage and re-injection.
- LFG flow rate and pressure

PICS design will control landfill bioreactor package systems including the existing leachate collection and removal system control panel and the leachate storage tank and injection delivery pumps and safety control valves.

PICS design will incorporate small programmable logic controller (SLC) hardware and software for the purpose of integrating sequential automatic control of process equipment, collecting and storing process data, alarming, and provide for the safe shutdown of process equipment. PICS Programmable Log Controller (PLC) equipment will include:

- PLC Processor
- PLC input/output modules
- PLC ancillary power supplies, chassis and cabling
- PLC application and development software and hardware

The PICS design will incorporate Human Machine Interface (HMI) hardware and software to allow operators to monitor process system data and interface with the bioreactor.

HMI will collect and log process variables and generate reports and display process trends.

PICS will incorporate the following key design components:

- Integrating package system controls with existing landfill gas-to-energy package system.

- Identifying and integrating existing process signals into PICS
- Instrumentation selection and sizing
- Instrumentation control panel(s) layout and construction
- Control hardwire safety interlocks
- Materials and methods of PICS construction (i.e., wire, control and safety devices, and enclosure selection)

4.4 Recordkeeping and Management

Records must be maintained at a centralized location at the site, and be available for review by supervisory and regulatory personnel. The types of records that should be maintained with respect to the bioreactor landfill include:

- Waste tonnage
- Inspections
- Liquids flow monitoring
- LFG operating system

Waste disposal tonnage must continue to be recorded in accordance with current site operations. However, the data must be provided to the bioreactor operations manager daily to allow for tuning of the system.

Inspection records must be maintained to track the operation of the bioreactor. The records must be periodically reviewed to determine whether there are any deficiencies that must be addressed through either routine maintenance or modifications to the system.

Liquids flow monitoring data must be maintained to provide a basis for modifications to the bioreactor system. The records must include data on the amount of leachate being generated, as well as the amount of leachate being recirculated within the landfill.

LFG operating system monitoring data recorded must include measurements of static pressure, velocity pressure, flow rates, and LFG composition. These records are used in conjunction with records of system adjustments to vary system flow rates as LFG generation rates decrease or increase in the various waste areas at the site. These records are collected and maintained by the LFG system staff at the site.

Parameters that will be automatically recorded include:

- hydraulic head built up over the liner
- liquid flowrates and quantities, including bot h inflow and outflow
- Landfill gas flowrate, pressure, and quantity

Figure

4-1 Process and Instrumentation Diagram

11 x 17

front

back

Figure

4-2 ____________________________

11 x 17

front

back

SECTION 5

Biocell Construction

5.1 Overview of Unit 3 Design Prior to Biocell

This section addresses specific design features of Unit 3 that establish its overall function as a waste disposal unit. Section 5.2 will address how some of these underlying design elements act as constraints for the biocell project and what design changes have been incorporated into Unit 3 to meet the additional design criteria for the biocell operation.

5.1.1 Unit 3 Configuration and Overall Functional Design

As shown in Figures 5-1, 5-3 and 5-4, Unit 3 is an excavated pit with a bottom size of approximately 1800 feet by an average of approximately 400 feet. The side of the excavation slopes at 2:1 (horizontal to vertical ratio) between 15-foot-wide benches placed every 40 feet of elevation. The excavation is approximately 150 feet deep, with a size at ground level of approximately 2500 feet by 1200 feet. The base of the excavation is intended to direct leachate to the south end of the excavation where it is collected by a sump and pumping system located in the southwest corner of Unit 3.

The side slope benches, when unlined, are configured to trap storm water and direct it to the north end of Unit 3 where it is contained in a storm water basin and is pumped up the side slope and discharged into the surface water management system at the top edge of the Unit 3 excavation. Storm water from the surface of the waste fill progressing south to north also flows to the north.

As the benches are lined, they are converted from use for storm water collection and control to leachate collection and control. Once the benches are lined, storm water/leachate (depending upon the progression of the waste fill along the lined slope) is captured at various points along the lined bench and transmitted instead to LCRS bench downdrains that connect to the LCRS piping system in the base of the landfill.

Figures 5-2 and 5-3 show that waste will ultimately be placed approximately 250 thick over Unit 3 and merge with the waste in the surrounding units.

5.1.2 Development Plan and Liner Phasing

The waste filling plan for Unit 3 is intimately integrated with the leachate and stormwater management plans. With the intent that leachate is directed to the south and storm water to the north, the waste fill was planned to progress south to north to maximize the removal of storm water from the area and to minimize leachate during all stages of landfill development. Liner is constructed in phases also starting from the south and progressing to the north. Figure 5-5 shows the limits of liner in plan view; note that due to the sloped surface of the north-facing landfill face, the liner limit in plan view is “chevron-shaped” with the bottom part of the liner progressing farthest to the north but with liner placed up the slope to conform to the leading edge of waste. The liner is terminated at one of the benches, thus resulting in the stair-stepped configuration shown. When the next phase of liner is constructed, it is welded on the edges of the existing liner and advanced farther to the north to accommodate the next phase of refuse disposal. For management purposes, the County periodically obtains an aerial topographic survey of the landfill and Figure 5-5 shows the refuse in place as of that survey in July 2003 (black) against the base grades of the operations layer in the landfill (gray). As shown, approximately 1.23 million cubic yards of airspace in Unit 3 had been consumed as of that survey.

5.1.3 Base Grading Plan and Leachate Collection and Removal System

A shown in Figure 5-5, the base of Unit 3 slopes to the south at a grade of 2.5 percent. The elevations shown are the top of the "operations layer" which is a 2-foot-thick layer placed above the 1-foot-thick LCRS system to protect it from damage during the first layer of refuse disposal operations. Therefore, Figure 5-5 shows elevations 3 feet above the liner elevation.

The gray layer of Figure 5-5 also shows the layout of the LCRS piping system. The "mainline" of the LCRS piping system is located along the west side of the landfill base, and is intended to collect leachate from lateral pipes and bench downdrains and conduct it as quickly as possible to the leachate sump in the southwest corner of Unit 3. Branching into the LCRS mainline are eight LCRS lateral branch lines with a slope of 1 percent placed every 200 feet across the base of the landfill. These lateral lines are intended to provide for the rapid transmission of leachate from the floor of the landfill to the LCRS mainline. The mainline and all of the lateral lines are 6 inch (nominal) pipe placed in a gravel filled trench cut into the base grading plan to provide for flow of leachate along those preferred efficient pathways.

The bench downdrains also tie in directly to the LCRS piping system, preventing leachate that impinges on the side slopes from entering the floor of the landfill. The LCRS pipes are also built in phases and progress northward with the liner construction.

Above the level of the base LCRS pipes and gravel-filled trenches is a continuous layer of gravel 1 foot thick above the grade of, and following the grade of, the membrane system. Therefore, even if leachate flow were to exceed the capacity of the pipe/trench system that is "incised" into the base grading plan, leachate can still flow southward toward the sump though a continuous highly-porous gravel layer and still never be more than 12 inches deep above the liner.

5.1.4 Leachate Removal Sump and Pumping System

All of the leachate formed in Unit 3 flows toward the southwest corner of Unit 3 and enters a sump which is depressed below the floor level of the base of the landfill so that pumping head can be established for its removal. Three 24-inch diameter risers extend from the sumps to the top edge of the excavation there. Each riser contains a submersible pump, its discharge line to the surface, a trolley for raising and lowering the pump, a deployment cable, and electrical cables. At the surface are located winches for raising and lowering the pumps, winches, storage tanks, pumps to empty the storage tanks, and operation and monitoring instrumentation and equipment. The pumps have a combined pumping capacity of 136 gallons per minute, comprised of two 60-gpm pumps and one 16 gpm pump. The pumps are programmed to come on in a defined sequence depending upon the quantity of leachate and load sharing. In addition to the three riser pipes for the pumps, a riser pipe is also provided for the extraction of landfill gas from the LCRS system at the sump location.

5.1.5 Phased Storm Water Management

As described in Section 3.1, the overall Unit 3 development plan calls for storm water to be transmitted to the north end of Unit 3 where it is retained by a temporary storm water basin. The phased design of the storm water basin is integrated with the rest of the development plan of the landfill so that it is, at all stages of landfill development, properly sized for the tributary drainage area in compliance with regulations and is located in a manner that optimizes its function.

The first storm water basin occupied most of the northern half of the Unit 3 floor because all storm water from the entire excavated area would be retained there. As the fill progresses northward and upward, more and more drainage area from within the excavated area is “tipped out” of the footprint and diverted to surface drainage systems outside the excavated area, thus allowing the storm water basin to be smaller, as is now shown in Figures 5-3 and 5-5 through 5-11. Figure 5-3 also shows that the liner limits of the next liner to be constructed in the summer of 2004 follows the top edge of the excavation for approximately 60 percent of the distance from along the excavation from its south end. Without the present current biocell project, the fill sequence would have generally followed that liner limit, which would have tipped all of the top deck drainage southward out of the excavation.

Subsequent relocations of the storm water basin as the filling proceeds northward in Unit 3 is to place it at the toe of refuse and against the north slope of the excavation at successively higher positions up the side slope until it eventually is not needed when the fill elevation emerges above the rim of the excavation. At each successive location, the present storm water pumping equipment is relocated, along with the discharge piping.

5.1.6 Liner Details

The liner system in Unit 3 exceeds the regulatory requirements because of the location of the Mid-Valley Landfill over important ground water resources. The liner sections are described below, top to bottom:

Base Liner Section (away from LCRS pipe/trench section):

- 24 inches of protective soil cover
- 8 oz geotextile separator
- 12 inches of LCRS gravel
- 12 oz cushion geotextile
- 60 mil double-sided textured HDPE geomembrane (1)
- Geosynthetic clay liner
- 60 mil double sided textured HDPE geomembrane (2)
- 24 inches of low-permeability compacted soil (1 x 10^{-7} cm/sec)

Slope Liner Section:

- 24 inches (vertical) of protective soil cover

- 16 oz cushion geotextile
- 60 mil single-sided textured (textured side down) HDPE geomembrane (1)
- Geosynthetic clay liner
- 60 mil double-sided textured HDPE geomembrane (2)
- 24 inches (vertical) of low-permeability compacted soil (1 x 10^{-6} cm/sec)

Bench Liner Section:

- 24 inches of protective soil cover
- 16 oz cushion geotextile
- Tri-planar geocomposite bench drain
- 60 mil HDPE geomembrane-backed geosynthetic clay liner [GCL down] (1)
- 60 mil single-sided textured (textured side down)HDPE geomembrane (2)
- Geosynthetic clay liner
- 60 mil double-sided textured HDPE geomembrane (3)
- 24 inches of low permeability compacted soil (1 x 10^{-6} cm/sec)

5.1.7 Landfill Gas Management

Landfill gas control in Unit 3 without the biocell project would consist of the following features:

- Extraction of landfill gas from within the LCRS system via the riser pipe at the sump location (constructed with liner system and to be connected when needed for gas control).
- Extraction of landfill gas from within the LCRS system via a riser pipe from the downdrains that connect the bench LCRS system with the base LCRS system (constructed with the liner system and to be connected when needed).
- Placement of lateral gas collection wells approximately every 40 feet of elevation and approximately 200 feet apart (construct when refuse filling has progressed to the required locations and connect when needed).
- Placement of vertical gas wells as needed (construct and operate when needed).

5.2 Overview of Unit 3 Design Changes to Incorporate Biocell

This section addresses how some of the underlying design elements for Unit 3 are beneficial to the development of a biocell there, how some of the design elements act as constraints on the design of the biocell, and the specific design changes that have been incorporated into Unit 3 in order to meet the additional design criteria for biocell operation.

5.2.1 Features of Existing Design Conducive to Biocell Implementation

The Mid-Valley Landfill is attractive as the site for this biocell demonstration project for several reasons that relate to its design and to other factors, as listed below:

- Unit 3 provides a relatively isolated cell that can be dedicated to the biocell project, with only one side of the biocell in contact with previously placed waste.

- Unit 3 is double-lined on the base and side slopes and triple-lined on the benches, offering an improved degree of assurance considering the greater volume of liquids to be used for the biocell project.
- Unit 3 has an existing LCRS design that can efficiently transmit the extra volumes of liquid involved in the biocell project.
- A significant amount of new liner will be constructed in Unit 3 this summer that can be incorporated into the biocell project in an advantageous manner.
- During the biocell period, a significant amount of organic material consisting of municipal solid waste and green waste alternative daily cover will be available at the Mid-Valley Landfill. This large amount of material, approximately 960,000 tons, will allow the biocell demonstration project to be operated on the scale of a large landfill.

5.2.2 Design Constraints on Biocell Development

As described in Section 3, many elements of the overall design and function of Unit 3 are integrated and master-planned for consistency over the long term. As such, there are a few elements of the design that act as potential constraints to the biocell project, as described below:

- Existing Liner Limits: As the County's major asset, the liner construction planned for this summer can not be delayed. Given the time available before the scheduled construction, it would not be feasible to significantly change the liner configuration for this project without creating the potential of delay and the resulting impacts on the solid waste disposal service provided by the County to its residents. As described in Section 5.2.3, the disposal phasing plan was adapted to the existing liner limits.
- Existing Downstream LCRS Pipe: Because Unit 3 is developed south to north, the LCRS mainline pipe that will be extended into the biocell area of Unit 3 is already in place and covered with refuse. The capacity of this pipe is more than sufficient for the expected liquid application rate, but the fact that it is already in place may act as a constraint to increases in the planned liquid application rate.

5.2.3 Revised LCRS Lateral Piping

Since the system is being installed against the existing landfill, it is difficult to define where the bioreactor begins, and thus provide proper control. Therefore, in an effort to contain most, if not all, biocell leachate, an additional lateral will be installed along the southerly end of the landfill, tying into the main line at or near the new diagonal lateral. The lateral will be placed parallel to the toe of the existing waste slope, and will become the delineation for the biocell. The LCRS main line trench will then be bermed to channelize flows through a solid length of HDPE main line pipe located immediately downgradient, and a flow meter will be installed within the solid section.

5.2.4 Revised Disposal Phasing Plan

As described in Section 5.1.5 and as illustrated in Figure 5-3, the disposal phasing plan without the biocell project was to place waste higher on the south end of Unit 3 to generally conform to the liner limits before moving waste disposal to the north portion of Unit 3. For biocell operations, it is desirable to provide the maximum amount of waste within the biocell period placed as deep as possible over a footprint as small as possible. To accommodate that, the disposal phasing plan was revised as follows:

- Prior to the biocell period, from the present through the end of October 2004, waste will continue to be placed on the south portion of Unit 3 while the liner is being constructed on the north portion. The waste on the south end will be sloped to drain into the biocell area in order to preserve storm water for biocell purposes. See Figures 5-3 and 5-6.
- During the biocell period of November 2004 through December 2005, waste will be placed on the newly-constructed liner in the north portion of Unit 3, the "biocell area." During the biocell period, refuse will be disposed in horizontal lifts with level top decks, also to preserve storm water and enhance infiltration. Daily cover soil is used only on the horizontal surfaces of the daily waste cells, with the sloping sides of the waste cells covered with green waste alternative daily cover. See Figure 5-3.
- The first lift of waste in the biocell area will be a "leveling lift" to elevation 1495 that will correct for the sloping floor of the landfill base and bring waste up to the first level deck. This lift will be advanced in two stages (a) approximately 4 feet of select waste placed first on the operations layer, and (b) normal disposal operations to elevation 1495. See Figures 5-3 and 5-7.
- A second lift of waste 20 feet thick will be placed over the first lift to elevation 1515. See Figures 5-3 and 5-8.
- A third lift of waste 20 feet thick will be placed over the second lift to elevation 1535. See Figures 5-3 and 5-9.
- A fourth lift of waste 20 feet thick will be placed over the third lift to elevation 1555. Note that the north edge of the lift is an extension of the 3:1 north-facing slope but that the waste in this lift is placed such that it conforms to the liner limits at the east and west sides. See Figures 5-3 and 5-10.
- A fifth lift of waste 20 feet thick will be placed over the fourth lift to elevation 1575. This lift also is configured to conform to the liner limits. See Figures 5-3 and 5-11.

Table 5-1 presents the tonnage and airspace for the biocell area. As shown the planned configuration of the biocell can accommodate all of the waste expected to arrive at the landfill within the biocell period.

TABLE 5-1
Biocell Tonnage and Capacity

	Biocell Lift	Tonnage of Municipal Solid Waste and Green Waste ADC	In-Place Volume (Cubic Yards)
Capacity Provided in Biocell Area	1	84,400	124,740
	2	172,040	254,271
	3	246,445	364,238
	4	269,808	398,768
	5	291,302	430,536
	Total Capacity	1,063,995	1,572,553
Incoming Waste Expected in Biocell Period	Total Expected from Nov 04 through Dec 05	958,980	1,417,343

5.2.5 Revised Storm Water Management Plan

The revised phasing of the waste placement requires that the storm water management plan for the site be revised as follows during the biocell period:

- Storm water falling on the deck of the south portion of Unit 3 will be diverted downslope to the biocell area, contained with operational controls, and used for biocell purposes, either for infiltration through the top deck or to be pumped and used for infiltration through the lateral injection wells.
- Storm water falling on the deck of the north portion of Unit 3 will be contained within the biocell area and used for biocell purposes, either for infiltration through the top deck or to be pumped and used for infiltration through the lateral injection wells.
- Storm water falling on the north-facing slope of the biocell will be diverted to the storm water basin at the north edge of Unit 3 and used for biocell purposes.
- Storm water falling on the unlined benches throughout Unit 3 will be diverted to the storm water basin at the north edge of Unit 3 and used for biocell purposes.

5.2.6 Access for Instrumentation in LCRS System

Changes to the LCRS system piping/trench system will be made to accommodate instrumentation for biocell purposes. Four riser pipes will be installed running up the side slopes to accommodate the installation of four pressure transducers; two on the westerly edge and two on the easterly edge. An additional riser pipe will be installed to house the flow meter installed within the LCRS main trench, located downgradient of the southerly-most new LCRS lateral pipe. Access will be from the top of the landfill.

5.2.7 Revised Side Slope Liner Design

Due to the increased potential for liquids accumulating against the side slope liner as a result of liquid injection for biocell operations, the side slope liner design described in Section 3.6 will be revised to incorporate a geocomposite drainage layer at the location of, and instead of, the 16 oz cushion geotextile.

5.2.8 Revised Protective Operations Layer

Because the biocell operations will require an increased volume of liquid to be recirculated throughout the biocell area, the specifications for the protective operations layer will be revised to reflect:

- 24 inches of soil with a maximum particle size not to exceed one inch and which has a permeability of in the range of 10^{-4} cm/sec when compacted to 85 percent relative density, placed over 8 oz geotextile.

  OR

- 24 inches of compacted 2-inch nominal tire chips, placed over 8 oz geotextile. The permeabilty of this layer when initially placed is expected to be approximately 10 cm/sec and long term permeability after compression due to overlying 250 feet of waste at final grades is expected to be approximately 10^{-4} cm/sec.

The protective operations layer on the side slopes and benches will be the soil section. However, the protective operations layer over the base of the landfill will be either the soil section or the tire chip section, depending on relative cost and on the timely availability of the tire chip product. Final specifications for the protective operations layer are still be developed.

5.2.9 Access for Backup Leachate Collection

Recognizing that the protective operations layer appears to be the component in the landfill drainage system most susceptible to long term clogging failure (either the soil or the tire chip section) there may be a potential that leachate may pond at some time in the future above the operations layer and along the south margin of the biocell, the location where the toe of waste is now located. To provide access to that location in the event any problem occurs, an additional slotted leachate removal pipe will be placed horizontally at that location across the width of the landfill base. A riser up the side slope will provide access to the slotted lateral pipe.

5.2.10 Upgraded LCRS Pumping System

It may be necessary to upgrade one or more of the three existing LCRS pumps located in the risers in the southwest corner of Unit 3 to accommodate increased pumping requirements. It is anticipated that a wide range of pumps can be accommodated within the constraint imposed by the diameter of the existing riser pipes. It may also be necessary to upgrade the variable frequency drive mechanisms to match to the new pumps.

5.2.11 Additional Landfill Gas Management Features in Liner System

As described in Section 3.7 the Unit 3 liner system has provisions for the collection of landfill gas via riser pipes from the downdrains that connect the bench LCRS system to the base LCRS system. In the south portion of Unit 3, at each such riser location, there is a single pipe up the side slope which acts as the single downdrain to the base from all of the bench LCRS drain pipes above it, and which acts as the single riser from which gas can be extracted from the interconnected LCRS piping at that point. Thus, applying vacuum to that riser induces vacuum to the base LCRS system and to each of the interconnected bench drains.

Under non-biocell operations, the fill advances fast enough such that almost all of the benches are covered with trash before landfill gas is generated in sufficient quantities that would require extraction. When extraction is undertaken, short circuiting is minimized because almost all of the area is covered by trash at that time.

However, in the case of the biocell operations, it is envisioned that landfill gas will be generated more quickly and in greater quantities sooner. Such a condition could require that vacuum be applied to the LCRS riser pipes sooner, perhaps even before trash fully fills the section to the higher benches. Therefore, applying vacuum to the riser would allow more air intrusion into the system through the benches that have not yet been covered with trash. This makes effective control of the gas extraction well more difficult and potentially causes too much air to enter into the waste, undermining the anaerobic biocell processes and increasing the potential for other problems.

To allow for improved landfill gas control, the riser/downdrain configuration will be revised to provide a separate riser/downdrain pipe between the base liner system and each bench LCRS system. This will allow different levels of vacuum to be applied to each bench as may be appropriate for effective landfill gas removal. It is recognized that, due to the overall interconnection of the LCRS system at the base level, that not all control issues are solved with this approach, but we expect that the flexibility provided by this approach will allow better overall well adjustment throughout Unit 3.

A horizontal landfill gas collection system will be installed as the waste placement progresses. On the same lift the distribution system is installed, multiple collection laterals spanning the landfill cell will be placed and connected to a manifold located on a bench above the placed waste. Each collection lateral will be constructed by excavating a trench into the placed waste with a backhoe. The lower half of the trench will be backfilled with a porous media, a perforated pipe will be laid, and the media backfill will be completed to the waste surface. Slip joints will be installed as needed. The primary consideration in configuring the pattern of collection laterals is even coverage and sufficient distance from liquids injection laterals. A typical spacing pattern is shown in Figures 5-8 and 5-10. The gas collection pipes in the waste will be connected to non-perforated sideslope risers designed to accommodate settlement of the waste. Each manifold will be connected to a main extraction pipe installed upslope and connected to the gas-to-energy plant. The laterals will be located horizontally no closer than 50 feet from the waste face. All gas collection piping will be fabricated of HDPE with adequate wall thickness to handle external loads. Control valves and sample ports will be installed in each lateral near the manifold.

The flow of LFG from the collection system is controlled by valve stations that are located on the lateral collector piping at each connection of the lateral collectors to the headers. The valve stations allow for the adjustment of LFG flow and vacuum at each location, and have monitoring ports to facilitate the measurement of LFG flow, composition, temperature, and pressure during operations. The flow control valves at the stations are adjusted as necessary during operation and monitoring of the system.

Figure

5-1 ____

11 x 17

front

back

Figure

5-2 ____

11 x 17

front

back

Figure

5-3

11 x 17

front

back

Figure

5-4

11 x 17

front

back

Figure

5-5

11 x 17

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Figure

5-6

11 x 17

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Figure

5-7

11 x 17

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Figure

5-8

11 x 17

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Figure

5-9

11 x 17

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back

Figure

5-10

11 x 17

front

back

Figure

5-11 ______________________________

11 x 17

front

back

SECTION 6

Energy Recovery System

This section addresses the current beneficial use of landfill gas at the site, how the landfill gas from Unit 3 is expected to be managed during the biocell demonstration period, and the options for the longer term use of the Unit 3 landfill gas.

6.1 Existing System and Landfill Gas Rights Agreement

There is a large landfill gas collection and management system in place at the Mid-Valley landfill that addresses mostly the gas being generated in Units 1 and 2. The system consists of an extensive system of vertical and horizontal gas collection wells located throughout Units 1 and 2, looped headers surrounding Units 1 and 2, an array of associated mechanical equipment and controls/monitoring instrumentation, and three flares with a capacity of 4500 scfm and permitted to operate at 138 million BTU per hour.

Several years ago the County conducted a competitive process to select a developer. NEO, was selected and then entered into an agreement for the rights to landfill gas from four County landfills in exchange for payments to the County. In the case of the Mid-Valley Landfill, that agreement encumbers rights to landfill gas that is produced only by Units 1 and 2, leaving the County the owner of the landfill gas in Unit 3 and subsequent waste disposal units. NEO installed a 3.8 MW energy recovery facility at Mid-Valley in approximately April 2003 that includes two electrical generators turned by internal combustion engines running on landfill gas extracted from the main header of the landfill gas collection system at a point immediately upstream of the flares. The County flares continue to operate to destroy the landfill gas that is not used by the existing NEO electrical generating facility.

Flare records have been used to infer that the generators are using approximately one quarter of the total biogas expected to have been collected, and that the flares are destroying approximately 1500 scfm of landfill gas for an average run rate of about 320 decatherms per year. The energy facility has a permit to increase the number of engine/generators to a total of four, but it is not known if or when these additional engines are planned to be installed.

6.2 Use of Unit 3 and Biocell Landfill Gas During Biocell Test Period

Although the County retains ownership of the landfill gas in Unit 3, it has not yet determined how it will utilize the gas from Unit 3. As described in Section 5.1.7, landfill gas collection has recently been initiated in the south portion of Unit 3 to comply with surface gas emission regulations but the amount of gas is small compared to the total amount of gas being collected from Units 1 and 2. During the rest of 2004 and during the biocell period from November 2004 through December 2005, the amount of landfill gas generated in Unit 3 is expected to increase. The gas from Unit 3 is now consolidated into the main headers leading to the flares. The County has options for beneficial use of the gas from Unit 3, including the gas generated from the biocell. Gas from Unit 3 during the biocell test period is expected to continue to be fed into the main header line that ties into the power generating facility and the existing flare station.

6.3 Future Use of Unit 3 and Biocell Landfill Gas

With increasing quantities of gas in Unit 3 as a result of existing filling practice and the biocell demonstration project, the County has options for the use of that gas. The options include: (1) negotiate an amended landfill gas rights agreement with the party presently operating the existing facility, (2) enter into discussions with parties associated with this biocell demonstration project with a goal of developing a mutually-beneficial agreement, (3) acquire the existing electricity generating facility and the remaining gas rights to gas from Units 1 and 2 and, together with the additional gas from Unit 3, expand the existing facility in an appropriate manner, (4) contract with a third party to implement Unit 3 on behalf of the County, and (5) develop a new and separate electrical generating facility itself just for the gas to which the County retains rights, or contract with a third party to do so. Given the extensive technical, legal, procurement, permitting, design, and construction steps involved in these options, it is anticipated that these options, and possibly others, will be explored and implemented as the biocell demonstration is implemented.

SECTION 7

Operations

7.1 Method of Adding Moisture to Waste

Two methods for adding moisture to the waste were evaluated, including spraying/pre-wetting and horizontal injection (CH2M HILL 2004, attached). Based on the results, horizontal injection was determined to be the most cost-effective over the life of a bioreactor, less labor-intensive, and less intrusive to operations with the elimination of water trucks that could conflict with operations.

Moisture will be added to the waste by injecting leachate and makeup water into the waste column through trenches fitted with 2 inch perforated pipe. Liquids will be injected on a daily basis, operating up to 24 hours per day. The rate of injection will vary based on a balance achieved by determining the peak percentage of leachate generated to liquids applied.

For the demonstration project, it would be beneficial to begin wetting the waste prior to starting the horizontal injection process. This will allow the waste to reach field capacity quicker, increasing the time the waste column experiences the benefits of recirculation. Prewetting may be accomplished by using hoses and/or water trucks to wet the waste as it is being placed. The quantities added during this period must be recorded, and included in the inflow totals.

7.2 Water Addition and Leachate Recirculation

As previously discussed, the quantity of liquids required for recirculation is primarily based on the field capacity of the waste. The following is a list of criteria that should be used to determine liquid injection quantities:

- Daily or weekly waste quantities.
- Moisture content of waste. May be based on historical data or assumed 25 percent (typical).
- Field capacity of waste. May be assumed 40 percent minimum.

The quantity of liquid required is then determined by using the methodology presented in Section 2.2.2. Water injection rates between 2.0 and 4.0 m^3/day per meter of trench (161 and 322 gallons/day per foot of trench) have reportedly been successful at leachate recirculating landfills. However, to minimize the potential for seeps and excess buildup of hydraulic head over the liner system, the rate should be maintained at less than 2.0 m^3/day per meter of trench. Initial water injection rates will be at 2.0 m^3 per day per meter of trench. These will be adjusted downward gradually to the minimum rates required to bring the incoming waste to field capacity, as leachate flows into the LCRS system begin to increase in response to the injection.

An injection rate program will be developed each week based on a review of the incoming waste tonnage and leachate outflow records from the previous week, and the calculations described above. Injection rates will be set manually; on and off times will be pre-programmable. Makeup water (clean water or sewage treatment effluent amendment) addition and flow rate adjustment will be automatic to maintain a storage level set point.

Shutdown of the system will occur when water reaches critical levels either within the storage tanks, LCRS, or floor of the landfill. For the storage tanks, the following shutdown sequences will be programmed:

- If the tank water levels are too low, the recirculation pump will shut down, and the leachate/makeup water pumps will remain on.
- If the tank water levels are too high, the leachate/makeup water pumps will shut down, and the recirculation pump will remain on.

For the LCRS, shutdown sequences will be programmed:

- If, the leachate pumps will shut down to keep from cavitation and burning out. The pumps will remain on using the existing system startup/shutdown configuration.

For control of levels over the floor of the LCRS, the recirculation pump will be programmed to shut down when water levels reach the programmed maximum.

When both leachate/makeup water and recirculation pumps are shut down due to high levels in the tanks and high levels on the floor or LCRS, an alarm 1.

7.3 Gas Collection and Transport to Energy Recovery System

The LFG collection and conveyance system is designed to withdraw LFG generated by the waste and thereby prevent the buildup of pressure within the landfill. Because the rate of LFG production in the landfill varies, the amount of gas withdrawn by the LFG collection system must also be adjusted to respond to changes in the rate of LFG production over time and changes in atmospheric pressure that affect the rate of withdrawal. If LFG is withdrawn from the landfill at a rate that is greater than the rate at which it is generated (i.e., overdrawn), oxygen could be drawn into the landfill from the surrounding soils, causing an underground waste fire. The amounts of oxygen and carbon dioxide present in the LFG being withdrawn from the wells is used to evaluate the withdrawal rate at the wells, as described below.

The LFG collection system will be operated at a flow rate that prevents pressure buildup while maintaining the safe operation of the system. Operation of the LFG collection system requires the monitoring of both the LFG collection system and the LFG monitoring probes located around the perimeter of site. Data collected from the perimeter probes will be used to confirm that offsite LFG migration is not occurring.

Landfill gas collection system monitoring is conducted to evaluate the performance of the system. Data collected at each of the riser and valve stations during monitoring include static pressure, temperature, extraction rate, and LFG composition. These parameters should be monitored every two weeks, although unusual circumstances may require more frequent monitoring.

7.3.1 Static and Velocity Pressure

Static pressure is the pressure (or vacuum) of the gas within the collection system. Velocity pressure of the flowing LFG is measured and used to determine the volumetric flow rate of the gas. The static and velocity pressures are measured using an instrument specifically designed for that purpose.

7.3.2 Landfill Gas Composition

Landfill gas is composed primarily of methane and carbon dioxide. However, nitrogen, oxygen, carbon monoxide, and minor quantities of other gases also can be present in LFG. Landfill gas monitoring instruments are typically designed to measure methane, carbon dioxide, and oxygen. Data collected during LFG composition monitoring is used to assess the performance of the extraction system and make adjustments to the collection system as necessary. The composition of LFG within the landfill will vary from one collector to another as well as from one waste area to another depending on the age, depth, and decomposition rate of the waste.

In addition to LFG composition, temperature is also recorded. The temperature is an indication of the type of decomposition taking place in the waste (the temperature will rise if the system becomes aerobic). If temperatures reach or exceed 120°F, operations staff should check the field for aerobic conditions and any potential waste fires within the landfill.

7.3.3 Collection System Monitoring, Adjustment, and Recordkeeping

Monitoring of the collection system wells should be performed as discussed in Section 7.5, although unusual circumstances may require more frequent monitoring. Adjustments made to the collection system are based on data from individual extraction points, the collection system as a whole, and the perimeter LFG monitoring probes.

Each valve should be opened as much as possible to maximize gas extraction without drawing in excess air. Excess air is indicated by methane concentrations below 40 percent, oxygen concentrations exceeding 5%, or CO_2 to CH_4 ratios above 1.2. The latter criterion is indicative of how much aerobic decomposition is occurring due to excess air; aerobic decomposition produces CO_2 but no CH_4. If left unchecked, excess air intrusion will cause high temperatures because aerobic decomposition produces more heat than anaerobic (i.e. methane-producing) decomposition. This can ultimately cause a fire in the landfill. For this reason, temperature should be monitored at each control point during each monitoring round. If the temperature ever exceeds 120°F, the valve at that collector should be shut immediately and reopened slowly after at least one day shut down.

7.4 Monitoring Methods and Frequency

Monitoring of the liquids and gas is important to confirm compliance with regulatory requirements and performance of the landfill, as well as providing input to balancing recirculation. Typical monitoring requirements are included in Table 7-1.

TABLE 7-1
CEC Bioreactor Demonstration Project
Performance Monitoring for first year

Parameter	Frequency	Purpose	Comment
Leachate Quantity	Continuous	Balance system, determine system capacity	Flowmeters at both inflow and outflow
Leachate Quality			
pH, electrical conductivity, dissolved oxygen, oxidation-reduction potential, and temperature	Monthly. May be reduced based on stabilization of leachate quality	Determine quality of leachate and phase of degradation	Monitored in the field
dissolved solids, BOD, COD, organic carbon, nutrients (phosphorous and ammonia), common ions, heavy metals, and organic priority pollutants	Monthly. Could be reduced following first 6 months of operation	Determine quality of leachate and phase of degradation	Laboratory analysis based on field sampling
Gas			
Methane, carbon dioxide, oxygen	weekly	Determine gas quality	GEM-500 or similar
Pressure and temperature	weekly	Determine phase of degradation and possible air intrusion	GEM-2000 or similar
Monitoring required by WDR	NA	NA	Per current monitoring plan
Volume	continuous	Determine gas production potential	Meter at flare station/energy plant
Flow rate	monthly	Determine gas production potential	GEM-2000 or similar

Suggested performance monitoring for first year of operation. Monitoring requirements must be modified if landfill remains an active bioreactor.