Landfill Gas Investigation and Characterization Study Yale Landfill

Prepared for **City of Albuquerque**
Albuquerque, New Mexico

April 5, 2002

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Acronyms and Technical Terms

AEHD	Albuquerque Environmental Health Department
AP-42	1995 EPA publication entitled *Compilation of Air Pollutant Emission Factors,* which provides default values for k and L_0
bgs	below ground surface
Campbell 21X	self-contained datalogger
cf/lb-yr	cubic feet per pound per year
cfm	cubic feet per minute
CH_4	methane
City	City of Albuquerque
CO_2	carbon dioxide
DBS&A	Daniel B. Stephens & Associates, Inc.
Dwyer DL8	multi-channel datalogger that interfaces with common transducer and transmitter outputs and can monitor temperature, relative humidity, pressure, wind speed, current, voltage and power
Dwyer Minihelic	compact gauge designed for panel mounting in a single 2⅝-inch-diameter hole
EPA	U.S. Environmental Protection Agency
ft^3/lb	cubic feet per pound
ft^3/min	cubic feet per minute
ft^3/ton	cubic feet per ton
GasTech monitor	gas monitor with built-in datalogging capability that allows for short-term, stand alone monitoring
GPS	global positioning system
H_2S	hydrogen sulfide
hp	horsepower
IDLH	immediately dangerous to life and health
k	methane generation rate constant (estimated fraction of waste that decays annually and produces methane to project annual landfill gas generation at 50 percent methane equivalent)
LandGEM	U.S. Environmental Protection Agency Landfill Gas Emissions Model
Landtec GA™-90	portable datalogging field analyzer designed to monitor methane, carbon dioxide, and oxygen
Landtec GEM™ 500	portable datalogging field analyzer designed to analyze gas content and determine flow from LFG collection wellheads using an on-board computer to integrate nine LFG instruments

Acronyms and Technical Terms (continued)

lbs/yd^3	pounds per cubic yard
LEL	lower explosive limit
LFG	landfill gas
LFG generation rate	rate at which a given landfill will produce landfill gas (influenced by the volume of waste, the percentage of degradable materials in the waste, the age of the waste, and the amount of moisture in the waste)
L_0	ultimate methane generation rate (ultimate amount of methane which a ton of refuse produces over time)
Mcf	millions of cubic feet
Mg	megagrams
MSW	municipal solid waste
NIOSH	National Institute for Occupational Safety and Health
NSPS	New Source Performance Standards
O_2	oxygen
PID	photoionization detector
ppm	parts per million
ppbv	parts per billion, volume
psi	pounds per square inch
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
RFP	request for proposal
ROI	radius of influence
scfm	standard cubic feet per minute
SCS	SCS Engineers
Summa canister	1-liter stainless steel vessel with chemically inert internal surfaces
TSI VelociCalc® meter	handheld instrument that measures volumetric flow rate, velocity and other parameters
TO-14	EPA-approved method for determining VOCs in ambient air using a Summa canister for sampling and gas chromatography or gas chromatography/mass spectroscopy
Usft.	U.S. survey foot (equals 0.3048006096 meters)
VOC	volatile organic compound
WC	water column

Executive Summary

Executive Summary – Yale Landfill
Landfill Gas Investigation and Characterization Study

This report presents the findings of a study conducted for the City of Albuquerque Environmental Health Department (City) by the engineering firms of Daniel B. Stephens & Associates, Inc. and SCS Engineers (study team) between July 2001 and March 2002. The study assessed whether landfill gas is present in seven closed landfills formerly owned and/or operated by the City. The study is part of the City's effort to prevent current and future risks related to landfill gas.

The study was conducted with the primary goal of providing new information to assist future land use plans regarding properties in close proximity to the former landfills. The City has established *Interim Guidelines for Development Within 1,000 Feet of Landfills* (Interim Guidelines), which provides for City review of development plans to ensure protection of public health and safety.

The former City owned and/or operated landfills covered by this report are:

- Atrisco Landfill
- Coronado Landfill
- Eubank Landfill
- Nazareth Landfill
- Sacramento Landfill
- San Antonio Landfill
- Yale Landfill

This Executive Summary provides (1) an overview of the investigation methods used in the landfill gas study and (2) presents the results and recommendations specific to the Yale Landfill.

1. Overview of the Study

1.1 Landfill Gas Characteristics

Landfills have the potential to emit gases as a result of natural decomposition of the materials they contain. Landfill gas is typically composed of methane (about 50 to 60 percent) and carbon dioxide (about 40 to 50 percent). Neither methane nor carbon dioxide is toxic to humans in small amounts. However, methane concentrations between 5 and 15 percent (of the total gas in air) can create a risk of explosion. The minimum concentration that can be explosive (5 percent) is called the lower explosive limit.

Landfill gas may also contain trace amounts of toxic substances such as volatile organic compounds (VOCs), some of which are classified by the U.S. Environmental Protection Agency (EPA) as carcinogens. Hydrogen sulfide, an inorganic gas that is toxic at relatively low concentrations, can be produced in landfills from the degradation of gypsum wallboard.

The rate of landfill gas generation is influenced by the percentage of degradable materials in the waste (i.e. food, paper, lawn clippings, textiles, wood, etc.) and the amount of moisture in the waste (increased moisture causes more rapid degradation). Larger landfills with more waste have a greater potential to generate gas and present a more significant likelihood of landfill gas migrating off-site.

The study team measured gas concentrations underground at the seven former landfills to identify the potential for present and future problems. Landfill gas detected underground may never reach the surface and pose a public health threat. However, landfill gas can migrate underground, through soils or along utility corridors, and therefore can present a concern for nearby properties.

1.2 Study Methods

The study team reviewed existing documents and records about each landfill, then performed field investigations to determine landfill gas concentrations and waste characteristics. Using the data obtained, modeling was performed for each landfill to estimate current and future landfill gas generation rates.

Site History and Access

Site histories were compiled that summarize the types of materials that may have been disposed of at each landfill and the time periods during which disposal occurred. General background information was also collected on landfill boundaries, site hydrogeology, and existing development in the area.

The landfill properties have numerous public and private owners. The study team obtained formal access agreements with property owners at each site for permission to conduct field investigations.

Field Investigations

Several methods were used to determine the current and future behavior of landfill gas at each of the seven landfills studied. These methods include:

1) Landfill gas surveys using underground sampling with field and laboratory gas testing
2) Waste characterization to sample and describe waste types
3) Landfill gas pumping tests to establish site-specific gas generation rate parameters
4) Gas generation modeling to estimate the long-term gas generation potential.

The study was performed according to customary engineering practices and industry standards.

- *Landfill gas survey.* The study team performed a landfill gas survey at each site between September 10 and October 5, 2001 to establish concentrations of landfill gas. Boreholes were driven 10 feet below ground surface to collect gas samples in the underlying waste. Temporary and/or permanent monitoring probes were drilled on a grid pattern across the surface of each landfill.

  Landfill gas samples were tested in the field for methane, carbon dioxide, oxygen, and hydrogen sulfide using portable instruments. Gas samples were also submitted to a laboratory for additional testing of volatile organic compounds. A total of 163 gas sampling points were field tested during the study, and samples for laboratory testing were collected at approximately half of these sampling points. All samples were carefully collected, labeled, and transported to the laboratory for testing following established procedures.

- *Waste characterization.* A bucket auger drill rig or a backhoe was used to sample landfill materials at 12 locations. The study team maintained logs of waste composition and samples were collected for moisture content testing. Waste material decomposition rates were categorized as follows:

  - Rapidly degradable – food waste
  - Moderately degradable – green waste, paper, and cardboard
  - Slowly degradable – wood and textiles
  - Inert/inorganic – rubber, glass, metal, plastics, concrete, and construction debris
  - Fines/unknown – soil and fines

- *Landfill gas pumping tests.* Multi-day landfill gas pumping tests were conducted at the two largest landfills studied (Eubank and Yale Landfills) where the gas surveys indicated relatively high landfill gas concentrations. These tests established site-specific data related to gas generation rates.

  Pumping tests indicate whether accumulated gases within a landfill consist of a limited reservoir of gas (i.e. one that can be extracted and depleted in a short time), or if gas is continually generated at a sustainable rate. The gas generation rate affects the likelihood of potential gas migration and provides information for the design of venting or containment systems, if needed.

- *Landfill gas generation modeling.* The study team estimated how much gas may be generated at each site using the EPA's LandGEM computer model. The model used various input parameters based on industry standards and site-specific data from the field investigation. Model calculations consider the volume and age of waste at each landfill as key factors in potential gas generation.

2. Yale Landfill Study Results and Recommendations

2.1 Landfill History

The Yale Landfill is located in southeast Albuquerque. The major portion of the landfill is west of the Albuquerque International Sunport, east of University Boulevard, north of Access Road B, and south of Randolph Road. A smaller portion of the landfill is located near the Wyndham Hotel immediately north of the airport.

Currently, there is development around portions of the landfill perimeter. Development includes the airport, a post office, the newly completed rental care facility, and the Wyndham Hotel parking lot. A City water supply well and water storage tank are located near the northwest corner of the landfill. Some waste has been excavated during construction of roads and buildings in the landfill area.

The City operated the Yale Landfill as its primary waste disposal site from 1948 to 1965. The landfill is unlined and has a combined total area of approximately 137 acres with a waste depth of about 25 feet.

2.2 Landfill Gas Survey

The landfill gas survey at the Yale Landfill consisted of (1) installing 51 temporary gas sampling probes that extend 10 feet underground on the landfill areas, (2) testing gas samples for methane, carbon dioxide, oxygen, and hydrogen sulfide using field instruments, and (3) conducting laboratory analysis of 28 samples for 35 volatile organic compounds commonly found in landfill gas. The findings of this investigation included:

- *Methane concentrations ranged from 0 to 50.8 percent*. The elevated methane concentrations, which were found in various portions of the landfill, indicate a moderate potential for off-site gas migration.

- *Low to moderate levels of 18 volatile organic compounds* were detected in landfill gas samples taken beneath the ground surface. This volatile organic compound data will be used in further studies.

2.3 Waste Characterization

A waste characterization study was conducted at the Yale Landfill and included (1) drilling three borings with a large-diameter bucket auger to depths of 17 to 21 feet, and (2) collecting and analyzing the waste samples to establish their composition, percentage of degradable material, and moisture content. Results of the Yale Landfill waste characterization study included:

- *Waste was encountered from 3 to 20 feet below the ground surface.* Most of the waste found at the site consisted of soil, as well as glass, paper, plastic, wood, metal, green waste, cloth, and cardboard.

- *Moisture content ranged from 37.2 to 42.5 percent by weight.* This level of moisture indicates relatively rapid waste decomposition and high gas generation rates.

2.4 Landfill Gas Pumping Tests and Landfill Gas Generation Modeling

A landfill gas pumping test was conducted at the Yale Landfill, which included (1) installing a landfill gas extraction well and three monitoring probes (located 50, 100, and 200 feet away from the extraction well), and (2) a three-day pumping test to measure methane flows and concentrations. Based on landfill gas generation rates measured during the pumping test, site-calibrated methane generation values were calculated.

The landfill gas generation rate at the Yale Landfill was estimated with the EPA computer model, LandGEM, using input values based on site-specific data from the study. Five different projections were modeled using a combination of site-calibrated and “typical” landfill values. The results of the modeling indicate that for the Yale Landfill:

- The peak year for landfill gas generation was 1966, which was one year after the landfill closed. The model indicates that landfill gas generation will continue to steadily decline as long as conditions do not change.

- The projected landfill gas generation rate in 2002 ranges from 46 to 106 standard cubic feet per minute. This is a moderate gas generation rate and suggests there is moderate potential for off-site gas migration.

2.5 Recommendations

This report makes a number of recommendations as to actions that should be taken by the City. These recommendations are worded in terms of actions that should be taken by the City because the City is the party that requested recommendations. It is the City that has taken the lead in dealing with landfill gas problems. This report takes no position on whether it is properly the City's role or responsibility to deal with the concerns raised by these recommendations.

Reduce the Buffer Zone in the City’s Interim Guidelines

The City could reduce the buffer zone in the Interim Guidelines to 500 feet, provided a landfill gas monitoring plan is implemented (see recommendation below) and methane is not found above specified limits after two years of monitoring on-site and perimeter wells, and selected underground utilities. Maintaining a minimum 500-foot setback is recommended because the landfill is expected to continue to generate gas and pose a potential risk for the long term.

Develop a Comprehensive Landfill Management Plan

The City should consider developing a landfill management plan for the Yale Landfill to include:

- *Implement a landfill gas monitoring plan.* This monitoring plan should include the installation of perimeter monitoring probes spaced approximately 250 to 500 feet apart to verify the limits of gas migration. Closer spacing is needed near areas of existing and future development, while wider spacing is appropriate for areas planned as open space. The final number of probes and their locations will need to be determined with particular consideration of existing development, including the Wyndham Hotel and airport facilities. Methane should be monitored quarterly for at least two consecutive years at probes and selected underground utilities. If methane is not detected above safe limits for two years, the monitoring period can be extended to every six months. If elevated levels are detected, the monitoring frequency should be increased. If impervious surfaces (e.g., pavement or structures) are developed on the landfill, increased monitoring may be necessary.

- *Maintain positive drainage* across the landfill to minimize water infiltration into the waste. Storm water channels currently exist on the landfill cover that collect runoff. A site drainage study is recommended to identify improvements that may minimize methane generation.

- *Continue to require design, monitoring, and/or landfill gas abatement* as stated in the Interim Guidelines, such as directing storm water away from the landfill, sealing off underground utilities, installing venting systems beneath structures, and/or installing interior monitors in buildings.

- *Implement a landfill gas control plan* if sustained, elevated methane levels are found. Install passive or active gas control systems capable of reducing methane to safe levels.

For further detail on study methods, findings, and recommendations, please refer to the full report.

Part 1

General Section

1. Introduction

This report details the approach used to perform a landfill gas (LFG) investigation to characterize the gas generation potential of former City of Albuquerque (City) owned and/or operated landfills being studied as part of the City's Landfill Gas Investigation and Characterization study. The study is being conducted under the direction of the Albuquerque Environmental Health Department (AEHD) by Daniel B. Stephens & Associates, Inc. (DBS&A) and SCS Engineers (SCS). The purpose of the study is to determine if LFG currently exists or could be generated at former City owned and/or operated landfill sites and how LFG might impact development and the public.

The City of Albuquerque currently has issued *Interim Guidelines for Development within 1,000 feet of Landfills*. The City's guidelines provide for review of development plans for public and private properties on or within a 1,000-foot buffer around former landfills. This includes not only City owned and/or operated landfills, but also permitted private landfills. This review is intended to ensure that appropriate landfill gas abatement measures are taken, based on the site-specific LFG conditions for a particular development. This LFG investigation and characterization study, as well as future studies, will assist the City in revising these Interim Guidelines, if needed, for each individual former City owned and/or operated landfill, and will provide planning and development guidance for future and existing development on and/or near the former City owned and/or operated landfills.

Part 1 of this report, which contains the first two sections, presents information on the overall Landfill Gas Investigation and Characterization study, which includes seven former City owned and/or operated landfill sites located within the City and Bernalillo County (Figure 1). These seven sites include:

- Atrisco Landfill
- Coronado Landfill (north cell only)
- Eubank Landfill
- Nazareth Landfill

City of Albuquerque Zone Atlas Map

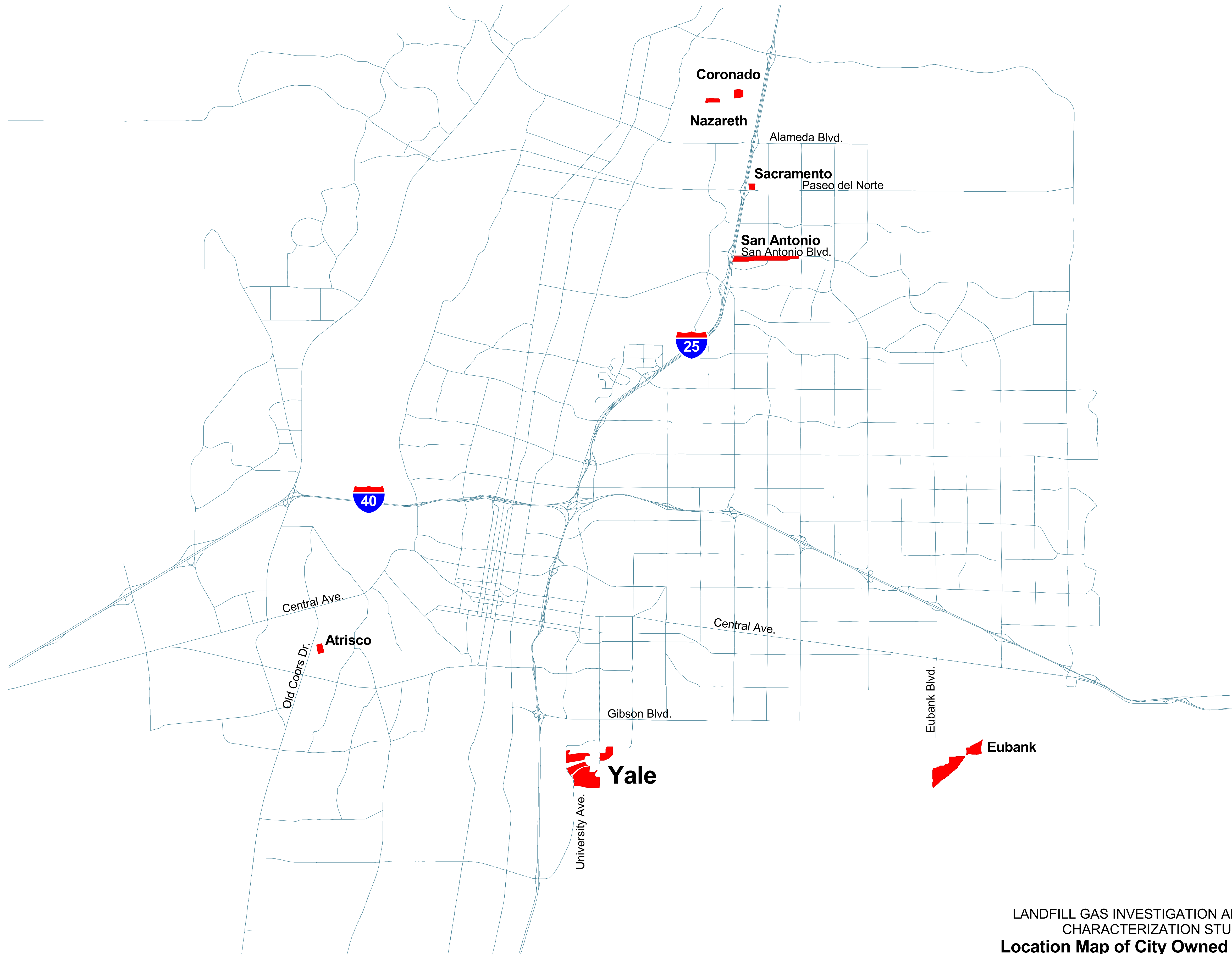
Landfill	Page
Atrisco	K-11
Coronado	B-18
Eubank	M-12
Nazareth	B-17
San Antonio	E-18
Sacramento	C-18
Yale	M-15

N

0 1 2 miles

Explanation

Landfill



LANDFILL GAS INVESTIGATION AND CHARACTERIZATION STUDY

Location Map of City Owned or Operated Landfills Studied

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Figure 1

T:\VDR\PROJECTS\9398\AlbLF_Landfill Locations- all-sites.apr (Layout = L5 - Yale Landfill Location Map, B-size, 1:96,000)

- Sacramento Landfill
- San Antonio Landfill
- Yale Landfill

Components of the investigation include a LFG survey, waste characterization study, and LFG gas pump tests. Part 2 of this report presents the landfill-specific field investigation methods and results for the Yale Landfill. Results from individual landfill investigations were combined with modeling results and formed the basis for the conclusions and recommendations presented at the end of this report.

1.1 Composition and Measurement of Landfill Gas

LFG is composed primarily of methane (CH_4) and carbon dioxide (CO_2), naturally occurring byproducts of waste degradation that are not considered toxic to humans. Waste degradation occurs when organic landfill materials are exposed to moisture. The amount of methane generated by waste degradation depends on a number of factors, but primarily on the amount of water exposed to the organic waste under anaerobic (no oxygen) conditions.

Methane is a concern because concentrated accumulations of methane can be explosive and can displace oxygen, which may lead to asphyxiation. LFG can also carry trace concentrations of other gases with potential toxicity concerns. The most significant trace gases carried by LFG are volatile organic compounds (VOCs), some of which are classified by the U.S. Environmental Protection Agency (EPA) and other national public health organizations as carcinogens. In addition, LFG may include hydrogen sulfide (H_2S), an inorganic gas that can be toxic at relatively low concentrations, and is produced in landfills primarily from the degradation of gypsum wallboard.

Pure LFG within waste disposal cells typically contains approximately 50 to 60 percent methane and 40 to 50 percent carbon dioxide. LFG may also be diluted with air in the subsurface, which reduces methane and carbon dioxide concentrations and adds oxygen and nitrogen. Natural atmospheric barometric pressure changes, otherwise known as barometric pumping, mix air into the soil, and closed landfills that are covered with relatively permeable soil may have significant gas exchange with the atmosphere. This barometric pumping both dilutes the LFG deeper in the subsurface and oxygenates the soil gas. Through this process, methane breaks down in the subsurface and is prevented from reaching the shallow soils or the atmosphere.

Methane gas concentrations are measured using one of two reporting scales: (1) as a percentage of methane gas in the total gas or simply “percent”, or (2) as a percentage of the lower explosive limit (LEL). The LEL for methane is equivalent to 5 percent methane gas in atmospheric air, which contains approximately 20 percent oxygen. The upper explosive limit is 15 percent methane in air. Methane is explosive only in the range of 5 to 15 percent and is not explosive if methane concentrations exceed 15 percent or if oxygen is depleted. In this report, methane and other gas constituents are reported as percent of total gas, and the methane concentration is referred to as being above or below the LEL, depending upon whether the methane concentration exceeds 5 percent total gas. A methane concentration of 100 percent of the LEL is the lower range of methane that will explode.

1.2 Landfill Gas Standards

Standards for allowable levels of LFG have been established to avoid explosion hazards. LFG can accumulate in enclosed structures and migrate away from the landfill through soils and along subsurface utility corridors. The rate of LFG generation is influenced by the percentage of degradable materials in the waste (i.e. food, paper, lawn clippings, textiles, wood, etc.) and the amount of moisture in the waste. Larger landfills with more waste have a greater potential to produce LFG and present a more significant likelihood of off-site LFG migration. The City of Albuquerque Fire Marshall’s standard requires that methane concentrations must not exceed 10 percent of the LEL (0.5 percent) in an occupied structure.

Additional standards address the potential toxic hazard associated with VOCs and H_2S that may be present in LFG. Relatively low concentrations of certain gases, in the parts per million (ppm) range, may be a concern for human exposure. Allowable exposure limits for workers are published in a guide sponsored the National Institute for Occupational Safety and Health (NIOSH). These standards are not intended to protect non-workers against short- or long-term exposure, but may be used as an available guideline to evaluate potential hazards posed by trace gases in LFG.

The NIOSH guide provides standards for exposure limits to many VOCs that can be present in LFG. The NIOSH guide indicates a long-term permissible exposure limit for hydrogen sulfide of 10 ppm for workers. The guide also indicates that a hydrogen sulfide concentration of 300 ppm is immediately dangerous to life and health (IDLH). These NIOSH standards may be used as a guide to consider the relative toxicity of various trace gases that can be carried with LFG.

The results of the VOC sampling at each of the landfills indicate whether or not these trace gases exist below the ground surface of the landfills. However, the results obtained do not provide a basis to determine whether these values are toxic to the public, since it is unknown how these gases will migrate to the surface or how they may degrade and become diluted as they migrate up to the surface.

1.3 Future Land Use Considerations

Final land use plans are an integral part of landfill closures, and considerable work has been done across the country to complete landfill closures in a manner that provides for safe development of closed landfill sites. Development of closed landfills has included parks, industrial development, golf courses, and open space. The solid waste management industry in the United States has devised technologies to develop closed landfill sites in a manner that is protective of human health and safety and the environment.

Many of the significant issues concerning the development of a closed landfill are related to structures and facilities that are built directly on the closed landfill disposal cells. The following issues are generally addressed in developing a closed landfill:

- *LFG accumulation in enclosed structures*. LFG consists primarily of methane and carbon dioxide. If allowed to accumulate within a confined area in the presence of an ignition source, methane can explode if the concentration exceeds 100 percent of the LEL (5 percent). Development must prevent the potential for accumulation of explosive methane concentrations within buildings and smaller enclosures such as light poles, fence posts, and utility corridors and vaults.

- *Settlement of waste that affects structures built on the landfill*. Permanent structures and utilities must be designed in a manner to account for differential settlement that occurs as landfill waste degrades and consolidates over many years.

- *Infiltration of water into the landfill as a result of precipitation and irrigation*. The infiltration of water into a landfill from irrigation or precipitation must be minimized to prevent generation of leachate that can contribute to groundwater contamination. An increase in moisture content of the waste can also cause accelerated generation of LFG. Synthetic membranes or earthen covers are often used to cover landfills to prevent infiltration of precipitation/irrigation water into the waste. Landfill covers should also be graded to maintain positive drainage at all times.

By ensuring that these issues are addressed, development has been completed safely at many closed landfill sites.

2. Technical Approach

The technical approach for the landfill gas investigation and characterization project is described in this section. Several tasks were conducted including:

- Review of records on site history
- Obtaining permission for site access to landfill property
- LFG survey using push-probe sampling with field and laboratory gas testing
- Drilling waste characterization borings to characterize waste types
- LFG pumping tests to establish site-specific gas generation rate parameters
- LFG generation modeling to estimate the long-term gas generation potential

This section presents the methodology used for these tasks. Field investigation methods to implement the technical approach are provided in Section 4, and results are provided in Section 5.

2.1 Site History Records Review

The site history of each former landfill was obtained through a review of available records related to the landfill's operating history and previously completed investigations. Sources of data for this section were compiled by AEHD and include reports and files prepared by various organizations. A primary source of data was a report entitled *Past and Present Solid Waste Landfills in Bernalillo County, New Mexico* (Nelson, 1997), which focused on all seven landfills covered in the present study, as well as other private landfills not owned or operated by the City. Nelson's report provided details on the general backgrounds of the landfills including site history, landfill operational data, and site hydrogeology. Most importantly, Nelson (1997) carefully considered the landfill boundaries using past records such as aerial photographs and more recent on-site observations. These boundaries were used in the current investigation and are presented in the site maps included in this report.

2.2 Site Access

The seven former landfills being investigated have numerous landowners, and most are subdivided into several parcels under different ownership. The majority of properties are privately owned, with some public owners including the City of Albuquerque and the New Mexico State Land Office. The first task in arranging the LFG survey was to establish formal access agreements with property owners at each landfill to ensure access for field investigation.

Site access activities were initiated by obtaining zone atlas pages and identifying lots within the boundaries of the seven landfills. Property owners were identified using the Bernalillo County Tax Assessor’s website in conjunction with the City of Albuquerque website. Information gathered from these websites was confirmed at the Bernalillo County Tax Assessor’s office because the websites are updated only on an annual basis. Therefore, any changes in property ownership that had occurred during 2001 could be found only in the tax assessor’s database at the County Assessor’s office.

Once ownership was determined, formal access agreements were requested from property owners at each landfill to allow access for field investigation. Information gathered from the tax assessor’s records was entered into a database and written access agreements were sent to each property owner for signature.

2.3 Landfill Gas Survey

A LFG survey was performed to establish the existing concentration of LFG at each of the seven former landfills. The survey fieldwork was conducted during September 10 to October 5, 2001. The LFG survey involved collection of LFG samples using a probe driven 10 feet below ground surface (bgs), through the landfill cover and into the underlying waste. The survey was performed using temporary and/or permanent probe installations distributed across each landfill and in selected off-site locations. LFG samples were tested in the field using portable instruments, and samples were also collected and submitted to a laboratory for additional testing.

Sampling was performed on a grid pattern submitted to and approved by the City prior to sampling. Sampling locations were staked/marked using global positioning system (GPS) survey equipment. This survey method allowed for efficient sampling point identification during the LFG survey and provided the ability to make adjustments in the field. The sampling grids at the landfills were based on the following general spacing and adjusted to fit the landfill configuration.

• Atrisco Landfill	200 x 200-foot grid
• Coronado Landfill	200 x 200-foot grid
• Eubank Landfill	400 x 400-foot grid
• Nazareth Landfill	200 x 200-foot grid
• Sacramento Landfill	200 x 200-foot grid
• San Antonio Landfill	200 x 200-foot grid
• Yale Landfill (northern, central, and hotel areas)	200 x 200-foot grid
(southern area)	400 x 400-foot grid

LFG samples were collected at each landfill location using a hydraulically driven, truck-mounted geoprobe. ESN Rocky Mountain, of Golden, Colorado was retained by DBS&A to perform the gas probe drilling at all of the landfills. In addition, Geo-Test, Inc. of Albuquerque was retained to provide a four-wheel drive drill rig to access steep terrain at the Yale Landfill for installation of seven gas probes. Temporary gas probe installations used a small-diameter drive probe to penetrate the landfill cover and allow LFG extraction and sampling from the underlying waste. At certain locations, where the City intends to conduct additional monitoring, permanent monitoring probes were installed. Details of the gas probe installation methods are provided in Section 4.3.

At each probe installation, several field instruments were connected in a sampling train to test for LFG constituents. The sampling train (Figure 2) consisted of a Landtec GA™-90 infrared gas analyzer, a hydrogen sulfide meter, and a Summa canister connection valve to facilitate the collection of VOC samples for laboratory analysis. The Landtec GA™-90 was used to measure concentrations of methane, carbon dioxide, and oxygen as well as LFG pressure and

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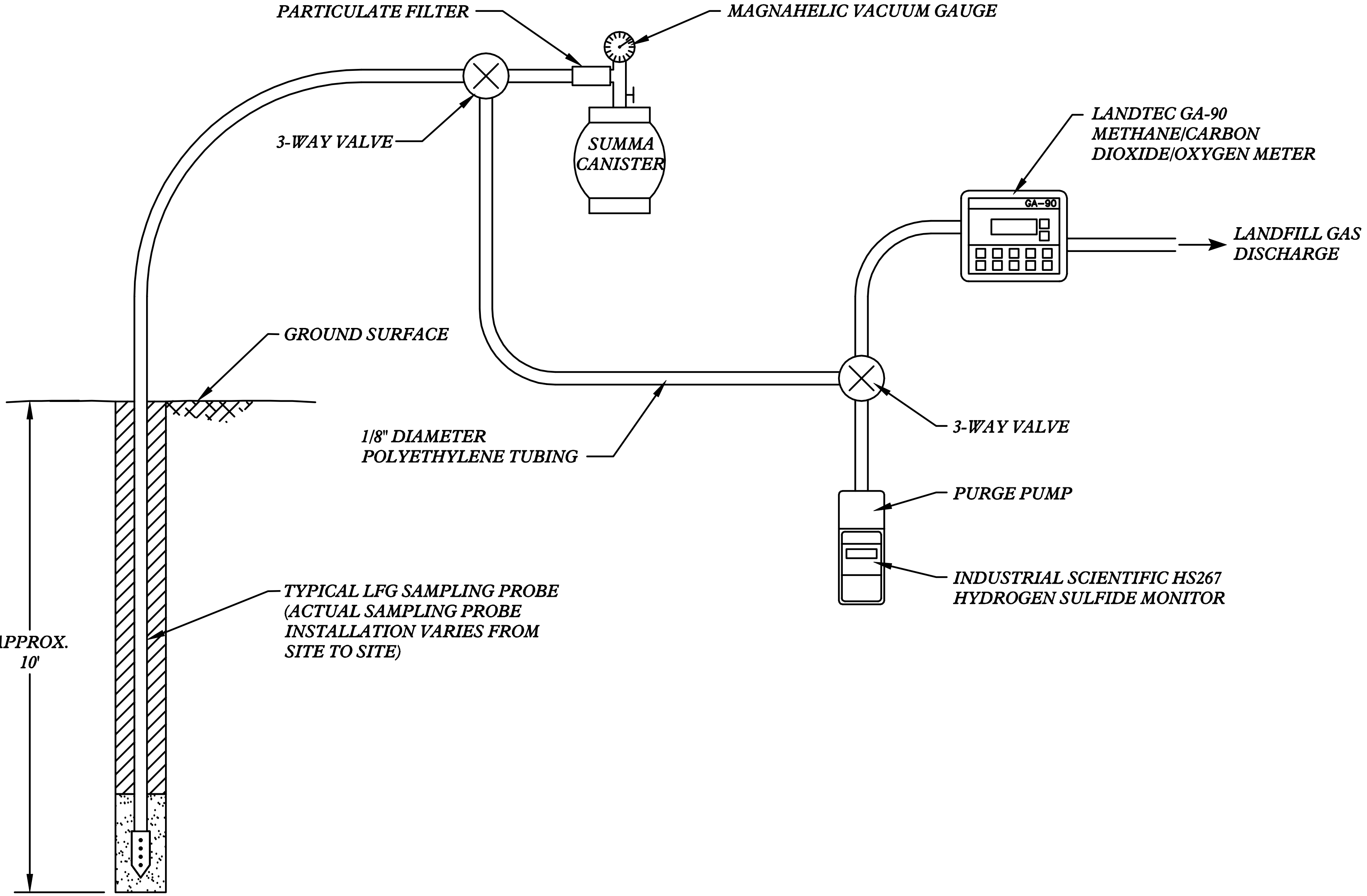

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LANDFILL GAS INVESTIGATION AND CHARACTERIZATION STUDY

Landfill Gas Survey Sampling Train Detail

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Figure 2

atmospheric pressure. Calibration of field instruments was performed daily during the survey, using bottled calibration gas with standard gas concentrations.

The LFG static pressure is measured relative to atmospheric pressure; negative readings indicate a pressure lower than atmospheric and positive readings indicate a pressure greater than atmospheric. These pressure measurements show the influence of barometric pumping (Section 1.1). At the time a given sample is collected, negative LFG pressure indicates that atmospheric air has a tendency to move downward through the landfill cover. Positive LFG pressure indicates that LFG has a tendency to move upward through the landfill cover. LFG static pressures tend to be negative in the morning hours when atmospheric pressure is rising and neutral or positive in the mid to late afternoon when atmospheric pressure is falling.

LFG samples were collected for laboratory analysis in accordance with AEHD's guidance regarding the number, and for some landfills, the location of sampling sites. Samples for VOC analysis were collected from all seven landfills studied. Additional samples were collected for laboratory analysis of methane, carbon dioxide, oxygen, and nitrogen for quality assurance/quality control (QA/QC) purposes. These QA/QC samples were collected in duplicate on 5 percent of the samples tested with field instruments.

Samples for laboratory analysis were collected by attaching a Summa canister to the sampling train ahead of the field instruments (Figure 2). The entire sampling train was then purged while the field parameters were measured. Once the purge was complete and stable readings were measured, the valve on the Summa canister was opened, allowing the canister to fill with LFG. Samples were sent to Air Toxics Ltd. in Folsom, California, where they were analyzed for 35 of the most commonly found LFG constituents using a modified version of the standard test for toxic organics at ambient air temperature (TO-14 test). Samples for QA/QC purposes were analyzed by U.S. EPA Method 3C. Chain-of-custody forms provided by the laboratory were filled out and signed by DBS&A's field technician and submitted with the samples.

2.4 Waste Characterization Analysis

A waste characterization program was implemented to determine whether the former landfills contain decomposable materials that may continue to produce LFG in the future. Waste characterization describes the type of waste present, its current state of decomposition, and its moisture content. These waste characteristics identify both the degree of degradation that has occurred since waste deposition and the potential for further waste degradation.

2.4.1 Waste Sampling, Testing, and Monitoring

Waste characterization exploration was conducted by drilling with a large-diameter bucket auger or excavating a test pit with a backhoe. Koda Drilling, Inc., of Grapevine, Texas, was retained by DBS&A to drill bucket auger borings at four of the landfills in the study (Coronado, Eubank, San Antonio, and Yale). Rodgers Environmental, Inc., of Albuquerque, was retained to excavate a test pit at the Atrisco Landfill. Waste characterization was not performed at the Nazareth Landfill, which is under City ownership, or at the Sacramento Landfill, which is the smallest landfill in the study.

Key elements conducted during the waste sampling task were:

- Documentation of drilling and excavation
- Preparation of waste logs
- Gas monitoring for health and safety
- Collection of waste samples for moisture content analysis
- Characterization of waste into waste types and degradability categories

All sampling activities were observed and logs were prepared that contained specific waste data such as odor, color, temperature (when available), organic content, and general material description of the waste samples. The temperature of the debris retrieved from the borehole was recorded by inserting either a standard thermometer or a probe-mounted thermocouple connected to a Campbell 21X datalogger. Temperature measurements, odor, color, and organic content of the waste are included in the boring logs (Appendix A).

A GasTech gas monitor (Model 90) was used to monitor levels of hydrogen sulfide and methane for health and safety purposes of the drill crew and field staff. All air monitoring results were below the short-term health and safety thresholds of 15 ppm for hydrogen sulfide and 5 percent for methane. A photoionization detector (PID) was also used to monitor for the presence of VOCs. All readings were collected from the breathing zone.

2.4.2 Degradation Rates

Waste material from each waste characterization boring was observed, categorized, and percentages assigned. Examples of the waste categories used include:

- Food waste
- Wood
- Metal
- Green waste
- Rubber
- Plastics
- Paper
- Textiles
- Concrete
- Cardboard
- Glass
- Soil

Percentages were assigned to each waste category by volume, according to what was observed during the removal of the waste from the borehole or excavation pit. The percent volume was then converted to percent weight using the average densities provided by Peavy, et al. (1985) (Appendix B). After the weight percentages were calculated, decomposability ratings were estimated. The waste types listed above were divided into the following subjective categories:

- Rapidly degradable – food waste
- Moderately degradable – green waste, paper, and cardboard
- Slowly degradable – wood and textiles
- Inert/inorganic – rubber, glass, metal, plastics, concrete, and construction debris
- Fines/unknown – soil and fines

2.4.3 Moisture Content Analysis

Samples were collected for moisture content testing from the waste characterization borings that recovered substantial waste (Yale, Eubank, Atrisco, and San Antonio). Soil and other inert materials such as concrete encountered during drilling were not sampled for moisture content. Moisture content samples were collected only from the degradable portion of waste, since this is the only component of the waste stream that will have the potential to generate landfill gas.

Samples were selected at varying depths in the upper, middle, and bottom of each waste boring. The samples were placed in 5-gallon buckets with sealed lids and transported to the DBS&A Hydrologic Testing Laboratory in Albuquerque for moisture content analysis. The samples were labeled with a unique identification number indicating the date, time, and depth of each sample. Chain-of-custody was maintained and documented from the time of sample collection to completion of analyses.

2.5 Landfill Gas Pumping Tests

The purpose of pumping tests is to indicate whether the accumulated LFG within a landfill is a limited reservoir of gas (i.e., one that can be extracted and depleted in a short time) or whether high rates of gas generation will continue to replenish the gas extracted by pumping. The gas generation rate affects the likelihood of off-site LFG migration. During the multi-day pumping test, the rate of gas generation was estimated by observing whether LFG concentrations and flow rates were sustained during long-term extraction or whether LFG concentrations declined substantially after the initial reservoir of accumulated LFG was removed.

As part of this study, LFG pumping tests were conducted only at the two largest landfills studied (Yale and Eubank), in portions of the landfills where the LFG survey indicated relatively high LFG concentrations. For the Yale Landfill, the pump test was conducted from December 27, 2001 through December 30, 2002. For the Eubank Landfill, the pump test was conducted from January 4, 2002 through January 8, 2002. These tests were conducted to establish site-specific data pertaining to LFG generation for these two Albuquerque landfills. The data was used as a check on the validity of the LFG generation model used to estimate LFG generation for all seven landfills studied.

The LFG pumping tests were conducted by installing a LFG extraction well and three pressure monitoring probes at both the Eubank and Yale Landfills. Koda Drilling, Inc., of Grapevine, Texas, installed the extraction wells at the Eubank and Yale Landfills within one of the bucket auger borings drilled for waste characterization sampling. Rodgers Environmental, Inc. was retained by DBS&A to drill and construct three monitoring probes at each landfill using a hollow-stem auger drill rig.

LFG was pumped from the extraction well with a blower powered by an electric generator. Vacuum was measured in the three pressure probes installed at distances of 50, 100, and 200 feet from the extraction well. By monitoring the pressure drop resulting from LFG pumping, the radius of influence of the pumping well can be determined. Based on the LFG extraction rate and radius of influence, site-calibrated LFG generation input parameters were calculated for use in modeling LFG generation rates, as discussed in Section 2.6.

2.6 Landfill Gas Generation Modeling

Landfill gas generation projections were performed for each landfill evaluated in this study. Several input variables were assessed and used in the LFG generation estimations. The volume of in place waste at each landfill is a primary input variable and varying this number greatly influences the projected LFG generation rate. Another key factor in the estimation of LFG generation is the age of the in-place waste. Numerous information sources were used to determine the modeling input parameters, to provide for valid estimates of the expected range of LFG generation rates. Landfill gas generation projections were performed up to year 2020. Beyond 2020, the accuracy of the model declines without more recent site-specific data. The site-specific LFG generation model input and results are described in Section 5.

LFG generation was estimated using SCS's spreadsheet version of the EPA's Landfill Gas Emissions Model (LandGEM). LandGEM is a first-order decay model required by the EPA to be used for New Source Performance Standards (NSPS) evaluations, Title V permitting, and other

Clean Air Act permitting projects. This model is the industry recognized standard for predicting LFG generation rates. SCS has converted the LandGEM model to an Excel spreadsheet format for ease of use. LandGEM uses (1) annual waste disposal rates, (2) the ultimate amount of methane which a ton of refuse produces over time (ultimate methane generation rate or "L_0" value), and (3) the estimated fraction of waste that decays annually and produces methane (the methane generation rate constant or "k" value) to project annual LFG generation at 50 percent methane equivalent.

2.6.1 LFG Model Inputs: Annual Waste Disposal Rates

Information used to establish the waste disposal history needed as input for LFG models was obtained from the following sources:

- Information provided by the City of Albuquerque in Appendix C of the Request for Proposals (RFP) for the current project, including site acreage, refuse depths, and years that the landfill was open for disposal.
- Historical documents provided by the City of Albuquerque, which include reports documenting the results of field investigations and other prior studies with information relevant to waste disposal at the landfills.
- The present study, including drawings that define landfill areas, and field investigations to determine the locations, composition, and moisture content of refuse.

Based on data from previous studies and this field investigation, certain assumptions were made regarding the size, average soil cover thickness, average refuse thickness, and estimated volume and weight of refuse at the landfill.

Some of the landfills studied contain more than one disposal cell. In particular, the Yale Landfill is divided into four cells and the Eubank Landfill is divided into two cells. Other landfills may be divided into individual cells, although the configuration of cells is unknown. Detailed information on the age, acreage, and depth of the waste in individual waste cells is unavailable for the landfills studied. As a result, each landfill was modeled to estimate the total LFG production from the entire waste mass.

2.6.2 LFG Model Inputs: Ultimate Methane Generation Rate (L_0)

The L_0 value is estimated based on information from the following sources:

- U.S. EPA's estimated default (AP-42) L_0 value for dry landfills (EPA, 1995).

- The SCS default L_0 value, which is based on the SCS LFG database. This database includes actual LFG recovery data from over 100 U.S. landfills, representing over 300 years of flow data. The data indicate that the L_0 value is influenced by moisture and provide a correlation between average annual precipitation and the L_0 value.

- Waste characterization data, which include information on degradability categories (percentage of waste that is rapidly degradable, moderately degradable, etc.) and moisture content. The characteristics of wastes at each landfill were compared to the typical waste characteristics of landfills in the U.S. to estimate the likely effects of any deviation from average landfill conditions on the L_0 value.

Waste characterization data were generated for the landfills where waste borings and test pits were excavated (Atrisco, Coronado, Eubank, San Antonio, and Yale Landfills). At the Nazareth and Sacramento Landfills, where waste characterization was not studied, only default values were available.

2.6.3 LFG Model Inputs: Methane Generation Rate Constant (k)

The k value was estimated based on the following information sources:

- U.S. EPA's estimated default (AP-42) k value for dry landfills (EPA, 1995).

- The SCS default k value, which is based on the SCS LFG database. Data in this database indicate that the k value is strongly influenced by moisture, and provide a correlation between average annual precipitation and the k value.

- Results of the field evaluation of the moisture content of waste samples from the landfill under investigation. The moisture content of the sampled waste was compared to the moisture content of typical U.S. waste to estimate the likely effects of a significant variation from average refuse moisture content on the k value.

Waste moisture content data were generated from waste characterization sampling at the Atrisco, Eubank, San Antonio, and Yale Landfills. At the Coronado, Nazareth, and Sacramento Landfills, waste moisture was not studied through field testing, and only default values were available.

2.6.4 LFG Generation Projections

Multiple LFG model runs and resulting LFG generation projections were prepared for each landfill to cover the range of possible LFG generation rates. These included projections to delineate potential minimum and maximum LFG generation, and to estimate the effect of increasing moisture at selected landfills. The LFG generation projections used the following variables:

- EPA default (AP-42) projection using the default values for L_0 and k (EPA, 1995).

- The SCS default projection using the SCS precipitation-based values for L_0 and k.

- Site-calibrated projection(s) using the L_0 and/or k values derived from analyses of field data.

- Modified site-specific projection that uses the L_0 and k values derived from analyses of field data, but also shows the potential effects of adding moisture on LFG generation.

LandGEM simulates increased LFG generation rates when the waste moisture is increased. A projection with added moisture was modeled for the larger landfills in the study (Yale, Eubank, and San Antonio), where relatively high overall LFG generation rates are expected because of the large amounts of solid waste. A projection with added moisture was also modeled for the Sacramento Landfill, because this landfill has very poor drainage and is at a low topographic level that collects storm water runoff from surrounding areas. The added moisture scenario was not examined for the smaller landfills with positive drainage and/or no detection of methane during the LFG survey (Atrisco, Coronado, and Nazareth), because the added moisture would simulate a relatively small change in LFG generation.

LFG generation rates are adjusted to 50 percent methane content (standard normalization procedure) to reflect the typical methane content of LFG as it is generated.

2.6.5 Model Validation

Model validation of LandGEM is provided by the results of the LFG pumping tests conducted at the Eubank and Yale Landfills. These tests provided site-calibrated k values based on actual measurements of LFG production. The calibrated k values for Eubank and Yale were found to be consistent with k input parameters assigned through default values for the Albuquerque region. The consistency between pumping test results and regional default values for these two Albuquerque landfills support the application of the model to other landfills investigated in this study where no pumping tests were conducted. Adjusting LandGEM input parameters to reflect site-specific conditions for the remainder of the landfills should then provide reasonable estimates of the LFG generation rate.

The pumping test results for Eubank and Yale indicated the range of k values appropriate for the Albuquerque region and guided the adjustment to the k values made for these landfills based on waste moisture content. At the Atrisco and San Antonio Landfills, where no pumping tests were conducted, site-calibrated k values were assigned based on site-specific testing for the waste moisture content. At the Sacramento Landfill, which is characterized by storm water ponding and poor site drainage, a modeling scenario was analyzed using a k value adjusted upward from the default value to reflect a probable elevated waste moisture. For Coronado and

Nazareth Landfills, where neither pumping test nor waste moisture content results were obtained, the default k input values are expected to provide for reasonable estimates of the LFG generation rate using LandGEM.

Site-calibrated L_0 values were assigned by adjusting the regional default L_0 based on the percentage of degradable waste determined from waste characterization studies (Atrisco, Coronado, Eubank, San Antonio, and Yale). At the Nazareth and Sacramento Landfills, where waste characterization was not conducted, the default L_0 values were used to provide reasonable estimates of the LFG generation rate using LandGEM.

Part 2

Landfill-Specific Section

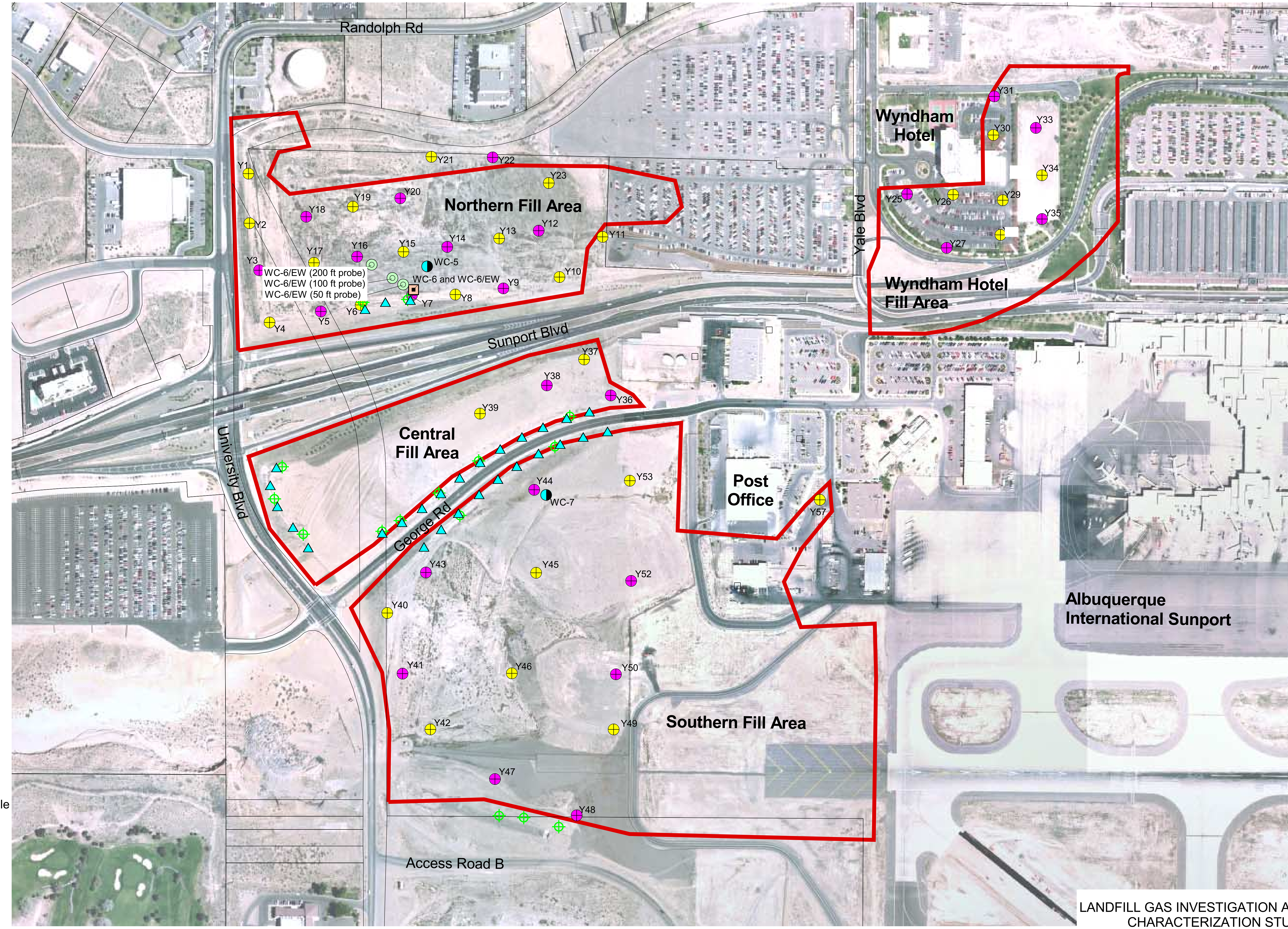
3. Site Background and Previous Investigations

The Yale Landfill is located in southeast Albuquerque in Zone M15 (Figure 1). The main portion of the landfill is west of the Albuquerque International Sunport, east of University Boulevard, north of Access Road B, and south of Randolph Road. A smaller portion of the landfill is further east, to the south and east of the Wyndham Hotel. The landfill layout along with significant landmarks and roads is shown in Figure 3.

Currently, there is development around part of the landfill perimeter. Development includes the airport and the post office to the east of the landfill as well as other airport facilities including the newly completed rental care facility located south of the landfill. The Wyndham Hotel has waste beneath the parking lot to the south and east of the hotel. All waste is reported to have been removed from beneath the hotel itself prior to construction. Other development near the landfill includes parking facilities and commercial buildings. A City water supply well and water storage tank are located near the northwest corner of the landfill.

The City operated the Yale Landfill as its primary waste disposal site from 1948 to 1965. Prior to its use as a landfill, the site contained several scattered gravel pits (Nelson, 1997). The landfill is unlined and is composed of four distinct fill areas: the northern, central, southern, and Wyndham Hotel (hotel) fill areas (Figure 3). These fill areas have a combined total area of approximately 114.4 acres. The northern, central, and southern fill areas were once part of a single large fill area, but were split into three fill sections as a result of the excavation and removal of waste for the construction of roads (George Road and Sunport Boulevard) through the landfill. The waste depth is in the range of approximately 4.5 to 34 feet (Geo-Test, 2000). It is reported that material placed at the site was mainly residential and commercial waste (Nelson, 1997).

Since the closure of the landfill, several construction projects have led to the excavation of waste at various locations around the site. All waste was excavated from beneath the airport terminal exit road between the airport and the Wyndham Hotel parking lot (COA, 2001). In 1988 approximately 400,000 cubic yards of waste were removed for construction of the post office (Nelson, 1997). Also, in 1995 through 1997, approximately 285,000 tons of waste were



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1999 Aerial photograph provided by Bernalillio County

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Explanation

- Sampling probe locations
- Sampling probe/lab sample locations
- Tubing left in place for future sampling
- Methane monitor well (installed by others)
- Landfill gas vent (installed by others)
- Waste characterization sample point
- Waste characterization sample point and extraction well
- Pressure probe
- Parcels
- Landfill boundary

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LANDFILL GAS INVESTIGATION AND CHARACTERIZATION STUDY
Yale Landfill Test Locations

Figure 3

removed from the Yale Landfill during the construction of Sunport Boulevard. During this project both George Road and University Boulevard were relocated and all waste beneath them was removed (Nelson, 1997).

A soil cover exists over the northern, central, and southern fill areas. This cover material consists mainly of silty sands (Fox, 1986). Borings taken in 2000 indicate variable cover thickness from 5 to 19 feet (Geo-Test, 2000). The cover is sparsely to moderately vegetated. Most of the soil cover has moderate to steep westerly slopes. Steeply sloping areas exist below the western end of the east-west airport runway. The northern and central fill areas generally provide positive drainage to shed storm water runoff. The southern fill area has many small surface water channels incised across the landfill cover. One relatively large storm water channel flows across the northern and western portions of the southern fill area.

The hotel fill area is covered by an asphalt parking lot, a dirt parking lot, and surrounding landscaped areas. The paved area will shed storm water and reduce infiltration into the underlying waste, but will also seal the ground surface, which may contribute to accumulation of LFG and subsurface migration. Water and electric lines are located over the landfill that serve irrigation systems and outdoor lighting between the hotel and airport.

The geology in the area of the Yale Landfill includes sediments from the Ceja Member of the Arroyo Ojito Formation of the Upper Santa Fe Group and the upper pumice-bearing fluvial unit. The Ceja Member, which is approximately 350 feet thick, consists of light red to strong brown and yellowish gray sandstone and pebbly sandstone with minor siltstone and claystone interbedding. The upper pumice unit consists of pumiceous sand and pebbles to cobbly sand deposited by the ancestral Rio Grande (Kelley, 1977). Depth to groundwater varies between approximately 180 to 420 feet bgs, and groundwater flow directions are variable across the site area (COA, 2002).

Methane monitoring has been conducted on this site for several years by various firms. In 1986, Fox and Associates conducted an environmental and geotechnical assessment of the Yale Landfill for the City of Albuquerque Solid Waste Management Department. This assessment included a methane survey across the landfill, excavation of test pits, and evaluation of refuse and subsurface conditions (Fox, 1986). Fox also installed and sampled 15 monitor wells (Geo-Test, 2000). Most wells had methane concentrations in the range of 7 to 40 percent. Fox also found elevated levels of barium, nitrate/nitrite, and methylene chloride in soil samples collected on-site.

Geo-Test conducted LFG monitoring activities at the site in 1993 and is currently conducting additional monitoring for the City of Albuquerque Aviation Department. In 1993, Geo-Test conducted a soil gas assessment of the area in the vicinity of George Road and Sunport Boulevard (Geo-Test, 2000). Analysis of soil samples did not detect the presence of volatile and/or chlorinated compounds, and methane concentrations in this area were only 2 percent of the LEL or less (Geo-Test, 2000). Recent monitoring conducted by Geo-Test at three points located on the north side of Access Road B and east of University has shown no measurable amounts of methane (Geo-Test, 2001).

4. Field Investigation Methods

The field investigation methods used at the Yale Landfill are described in this section. The field investigation tasks included:

- Obtaining permission for site access to landfill property
- Clearing underground utilities prior to subsurface investigation activities
- LFG survey using push-probe sampling with field and laboratory gas testing
- Waste characterization borings to sample and categorize waste composition
- LFG pumping test to determine site-specific landfill gas generation characteristics

Sections 4.1 through 4.5 present the detailed methodology used for these tasks at the Yale Landfill.

4.1 Site Access

The Yale Landfill property is owned by the City of Albuquerque and is under the control of the Aviation Department; therefore, site access was granted without a formal access agreement. At the request of the Aviation Department, an access agreement was obtained from the Wyndham Hotel, which is located on City property leased by the hotel. DBS&A contacted the hotel management about the plans for on-site investigation.

Only very small portions of the landfill extend outside City property onto other private property at the northern edge of the landfill. These small areas did not need to be accessed to conduct the on-site investigation; therefore, access agreements were not pursued with the private property owners.

At the request of the Aviation Department, DBS&A contacted airport operations personnel by telephone at least 24-hours in advance of field work, to provide notice of on-site activities planned for City property outside the airport perimeter. Portions of the Yale Landfill are located within secured areas of the airport at the western end of the east-west runway. These secured areas could not be accessed for the study.

4.2 Utility Survey

Before the investigation commenced, New Mexico One Call was contacted to ensure that no utilities would be encountered during subsurface work. Due to the size of the Yale Landfill, meetings with some utility locators were necessary to explain precisely where sampling was to occur. Utility locations at the Yale Landfill were also examined directly by contacting the Aviation Department and Wyndham Hotel management.

Few utilities were found to exist across most of the landfill, and utilities near roadways were easily avoided during the sampling activities. The Aviation Department provided airport development site plans showing a water line near end of the east-west airport runway. This line is located within the airport secured area, and therefore, did not affect the study. Wyndham Hotel management provided limited verbal information on the location of their irrigation water lines and electric lines for outdoor lights.

4.3 Landfill Gas Survey

LFG sampling locations at the Yale Landfill are shown on Figure 3. The sampling grid at Yale Landfill was established at approximately 200 x 200-foot spacings in the northern, central, and hotel areas, and on 400 x 400-foot spacings for the southern area. A total of 51 sampling locations were established across the landfill surface.

At the Yale Landfill, a geoprobe drill rig was used to drive a 1-inch-diameter drive probe to a depth of 10 feet bgs and install stainless steel, screened sampling points (⅜-inch diameter by 2.5-inch length, perforated with eight 0.1-inch-diameter holes)(see photographs, Appendix C). Once the sampling tip was in place, 10-20 silica sand was poured into the lower 1 to 2 feet of the borehole, around the tip, to provide for landfill gas transmission. The remainder of the borehole was sealed with a slurry of hydrated bentonite. Polyethylene tubing (⅛-inch diameter) connected to the sampling point was left protruding from the ground surface with a cap on the end. After installation of the tubing, a LFG sample was obtained and analyzed as discussed in Section 2.3.

4.4 Waste Characterization Analysis

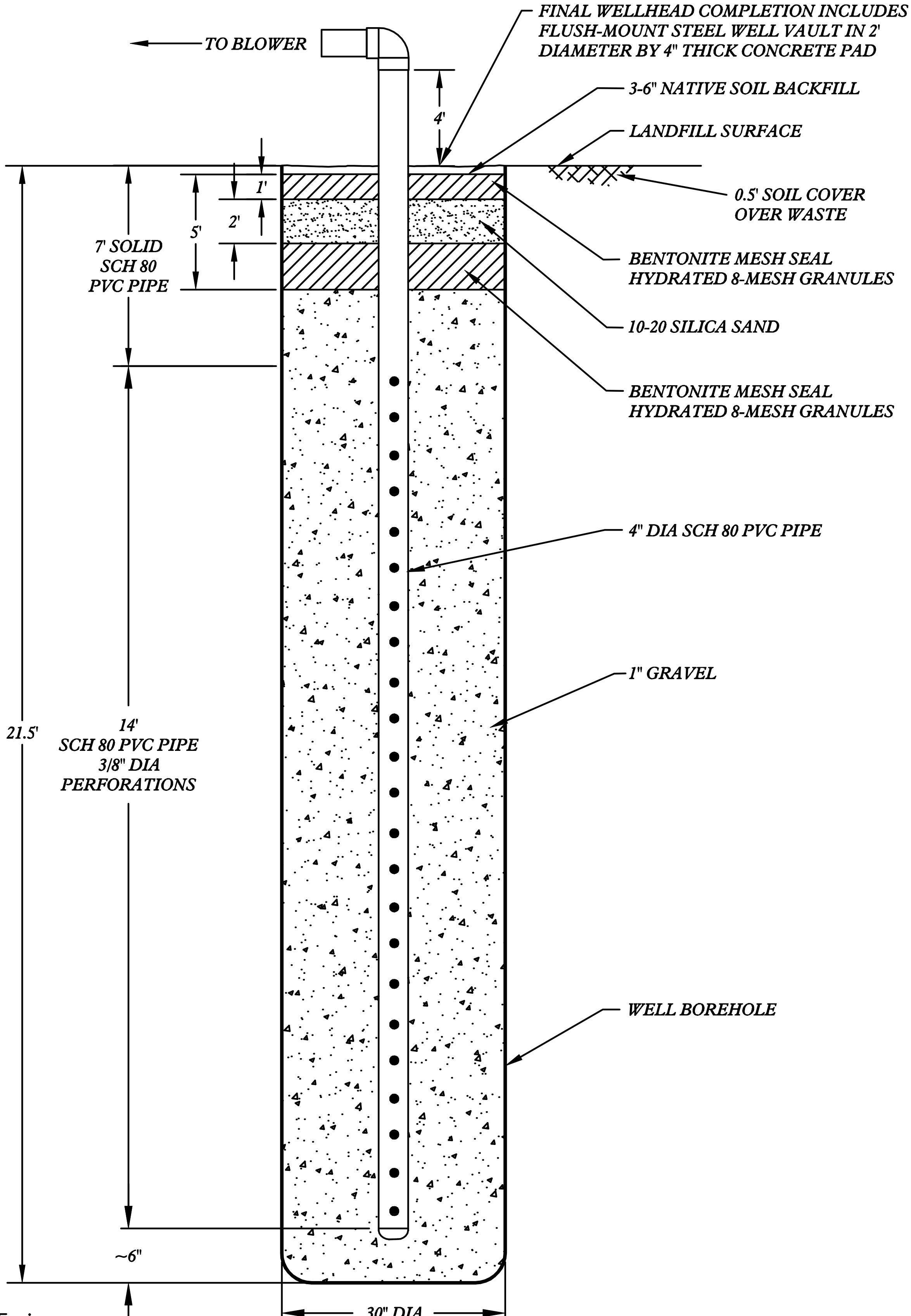
At the Yale Landfill, three borings were drilled through the waste to allow for examination of the waste characteristics (Figure 3). Waste borings were drilled with a 30-inch-diameter bucket auger to collect samples of waste materials and soil, as shown in photographs provided in Appendix C. Boring locations were selected based on the results of the LFG survey, and recommended locations were submitted to AEHD for approval prior to drilling.

4.5 Pumping Tests

A pumping test was performed at the Yale Landfill from December 27, 2001 through December 30, 2001. The following sections describe the field methodology used to conduct the test. Results of the test are discussed in Section 5.4.

4.5.1 LFG Pumping Test Extraction Well

In conjunction with drilling the waste characterization borings (Section 4.4), Koda Drilling, Inc. installed a LFG pumping test extraction well (WC-6/EW) at Yale Landfill (Figure 3). Waste characterization boring WC-6 was completed as an extraction well (EW), after which the designation of this well was changed to WC-6/EW. The extraction well was drilled using a 30-inch-diameter bucket auger to a depth of 21 feet bgs. The well was constructed with 4-inch-diameter, Schedule 80 PVC casing. The lower 14 feet of casing was perforated with ⅜-inch diameter holes and the upper 7 feet was solid blank casing. To facilitate airflow into the perforated portion of the casing, the lower 16 feet of the borehole was backfilled with 1-inch diameter gravel. Hydrated bentonite was emplaced from 3 feet bgs to 5 feet bgs to form a "seal" above the gravel. The well was completed with sand from 1 to 3 foot bgs and a 1-foot-thick hydrated bentonite seal was placed at the surface. Initially, the well casing extended above ground surface for piping connection during the pumping test. Following completion of the pumping test, the wellhead was completed with a permanent, flush-mount steel well vault installed in a 2-foot-diameter by 4-inch-thick concrete pad. Details of the extraction well are illustrated in Figure 4 and photographs of the well installation process are provided in Appendix C.



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LANDFILL GAS INVESTIGATION AND CHARACTERIZATION STUDY

Yale Landfill

Extraction Well Detail

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Figure 4

4.5.2 Pressure Monitoring Probes

Three pressure monitoring probes were installed at the Yale Landfill to detect vacuum response during the pumping test. A 4-inch diameter hollow-stem auger drill rig installed the monitoring probes. The monitoring probes were installed approximately 50, 100, and 200 feet from the extraction well (Figure 3) to measure vacuum responses at varying distances. The probes were designated as WC-6/EW 50-foot probe, WC-6/EW 100-foot probe, and WC-6/EW 200-foot probe.

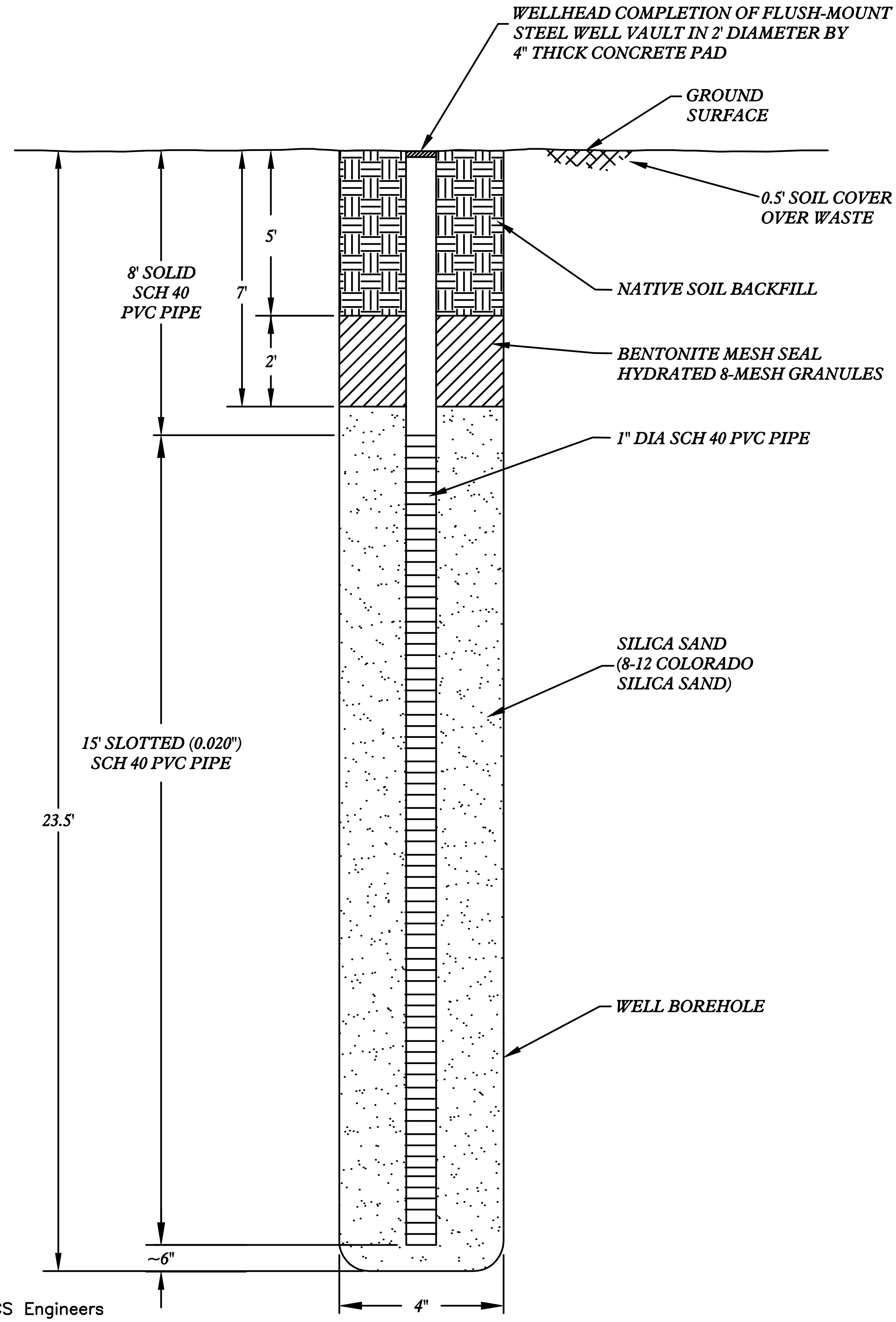
Each of the monitoring probes was installed to approximately 23 feet bgs. The probes were constructed with 1-inch-diameter Schedule 40 PVC casing. The bottom 15 feet of casing was factory slotted screen with 0.02-inch slots, and the upper 8-foot section was solid blank casing. Each probe was backfilled with 8-12 Colorado silica sand from 7 to 23 feet bgs, with a seal of hydrated granular bentonite from 5 to 7 feet bgs and native soil fill from the ground surface to 5 feet bgs. Each wellhead was completed with a permanent, flush-mount steel well vault installed in a 2-foot-diameter by 4-inch-thick concrete pad. A well completion diagram for the monitoring probes is shown in Figure 5.

4.5.3 LFG Pumping Test Blower and Test Equipment

The pumping test was performed using a 3 horsepower (hp), Paxton regenerative blower powered by a portable generator. The blower was connected to the extraction well with a field-fabricated PVC piping manifold. The manifold included an air dilution valve, a flow control valve, and three sample ports. A schematic of the manifold is depicted in Figure 6.

Equipment used to gather data during the pumping tests included the following:

- Landtec GEM™ 500 to measure methane, carbon dioxide, and oxygen (O_2)
- Dwyer Flow Sensor (Series 600, various models used depending on sensitivity) to measure differential pressure (used to calculate air flow)



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LANDFILL GAS INVESTIGATION AND CHARACTERIZATION STUDY

Yale Landfill

Pressure Probe Detail

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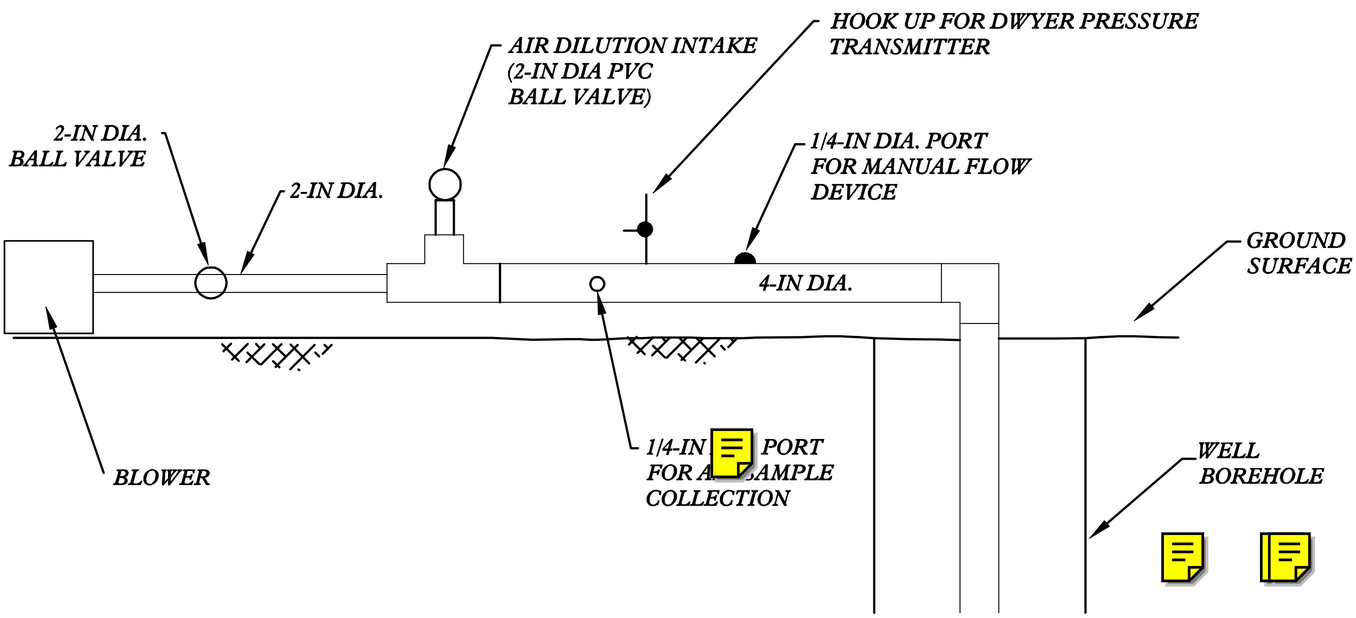
Figure 5



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LANDFILL GAS INVESTIGATION AND CHARACTERIZATION STUDY

Yale Landfill

Extraction Well Pump Test Setup

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Figure 6

S:\PROJECTS\9398\SHEETS\FIGURES\YALE\Figure_6.dwg

- TSI VelociCalc® (Model 8345) to measure air temperature, velocity, and flow rate

Dwyer Minihelic differential pressure indicating transmitters (Series 600), powered by a portable generator, were mounted to each monitoring probe to measure the vacuum response during the pumping tests. At the Yale Landfill, the transmitters installed on the 50- and 100-foot probes had a sensitivity of 0 to 1 inch of water column (WC), and the transmitter installed on the probe 200 feet from the test well had a sensitivity of 0 to 0.5 inch of WC. The monitoring probes were connected to a datalogger for continuous data collection. The transmitters relayed readings to a datalogger (Dwyer Model DL8). The datalogger recorded the vacuum readings, converted the vacuum readings from WC to pounds per square inch (psi), and graphed the data points.

4.5.4 Pumping Test Procedures

One pumping test was conducted at the Yale Landfill at a flow rate which stabilized (i.e., reached near constant flows) at about 43 standard cubic feet per minute (scfm) after reaching as high as 152 scfm. Vacuum readings measured by the datalogger at the pressure probes were monitored throughout the test to ensure proper data collection. Manual vacuum readings were also recorded with a magnahelic pressure gauge to provide an alternate source of data to the datalogger. Vacuum measurements were recorded approximately every 15 minutes. Since only the differential pressures between the probes and extraction well were used for the analysis, atmospheric pressures were not recorded or used. Gas stream readings, temperature, and flow rates at the extraction well were recorded approximately every 15 minutes for the first two and one-half hours, every 30 minutes for the second two and one-half hours, and periodically (every 2 to 6 hours) thereafter, except overnight. Details of the duration of the pumping tests are presented along with a discussion of the data and results in Section 5.4.

5. Results

Results of the LFG investigation and characterization study of the Yale Landfill are presented in this section. The results include the following:

- LFG survey results for methane, carbon dioxide, oxygen, VOCs, and hydrogen sulfide
- Waste characterization results that categorize the waste composition from borings
- LFG pumping test field procedures and results
- LFG generation modeling results

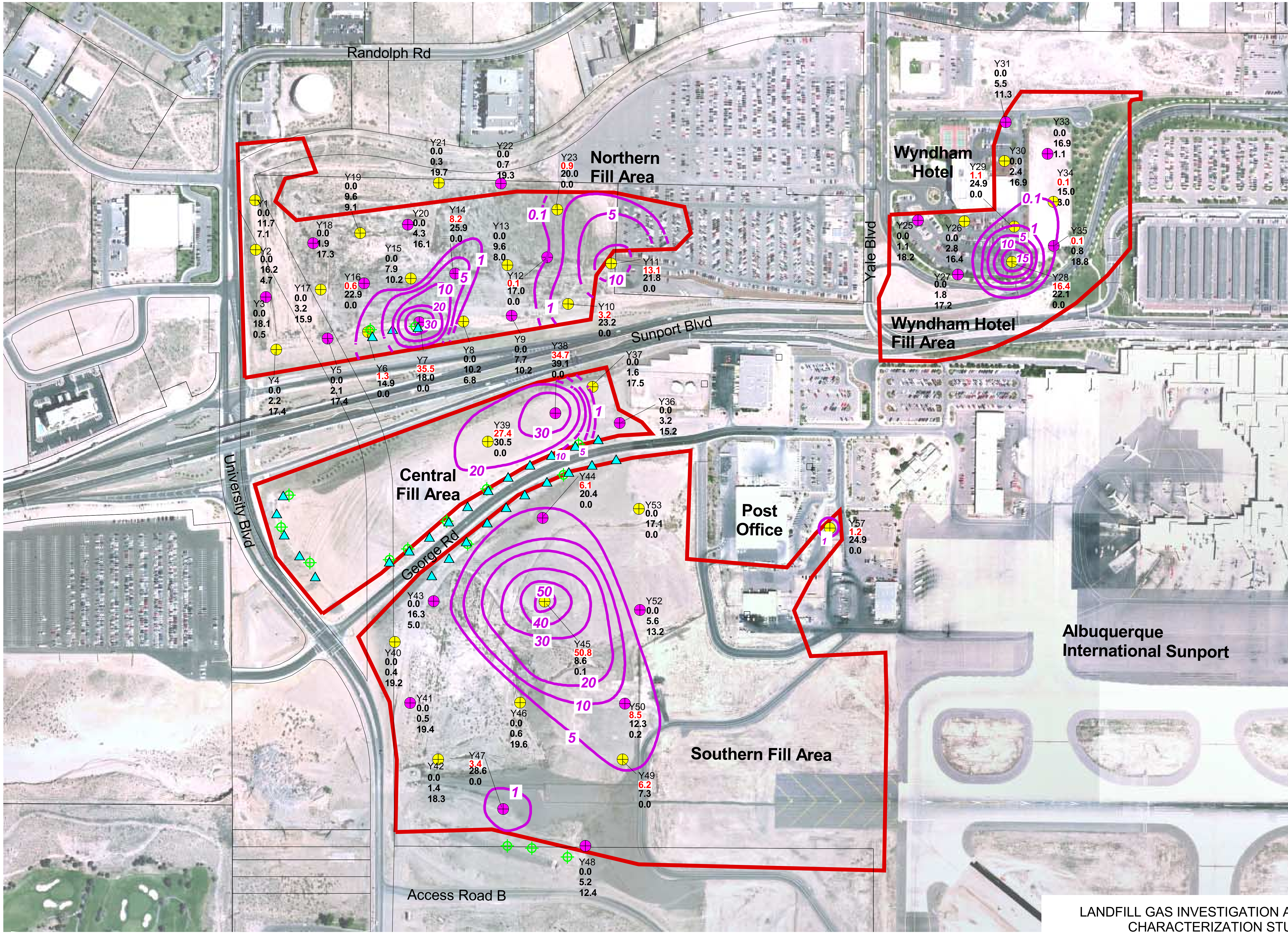
These items are addressed in Sections 5.1 through 5.5.

5.1 LFG Survey Field Analysis Results

A methane concentration map is presented on Figure 7 to graphically show the LFG concentrations at the site. The map displays numeric results for methane, carbon dioxide, and oxygen. Methane concentrations at the Yale Landfill ranged from 0 to 50.8 percent (Table 1, Figure 7). The Yale Landfill is split up into four distinct fill areas (northern, central, southern, and hotel), and elevated methane concentrations were found at certain points in each of the four portions of the landfill. Many sampling locations with no methane seemed to show only moderate levels of carbon dioxide, while still indicating the presence the oxygen. This may indicate the mixing of atmospheric air and landfill gas in these areas.

The northern fill area of the landfill had two distinct areas with elevated methane concentrations. The first area was located in the south-central part of the northern fill area (Figure 7). Methane concentrations up to 35.5 percent were measured. The second area was located at the eastern edge of the northern fill area, where methane concentrations up to 13.1 percent were measured.

The central fill area of the Yale Landfill possessed methane concentrations up to 34.7 percent. These readings were from the eastern half of the central portion of the landfill (Figure 7). Samples were not taken from the western half of this portion, because the City has already



Source:
1999 Aerial photograph provided by Bernalillo County

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Explanation

- Sampling probe locations
- Sampling probe/lab sample locations
- Tubing left in place for future sampling
- Methane monitor well (installed by others)
- Landfill gas vent (installed by others)
- Parcels
- Landfill boundary
- 20 Methane concentration contour (%), dashed where inferred
- 35.5 Methane (%)
- 18.0 Carbon dioxide (%)
- 0.0 Oxygen (%)

Notes:

1. Methane concentrations of 0.0 are shown in black text
2. Only survey data used to determine methane concentration contours

(T:\VDR0-VDR-PROJECTS\9398 (PROJECT = albf_yale.apr) (VIEW EXTENTS = Temp) (VIEW NAME = V4-Yale) (LAYOUT = L4-Yale)

Daniel B. Stephens & Associates, Inc.
3-27-02 5:00 PM JN 9398

LANDFILL GAS INVESTIGATION AND CHARACTERIZATION STUDY
Yale Landfill Gas Survey Results

Figure 7

Table 1. Landfill Gas Survey Results
Yale Landfill
Page 1 of 3

Sampling Point	Date	Time	Methane Concentration (%)	Carbon Dioxide Concentration (%)	Oxygen Concentration (%)	Hydrogen Sulfide Concentration (ppm)	Landfill Gas Temperature (°F)	Landfill Gas Static Pressure [a] (inches H_2O)	Atmospheric Pressure [a] (inches Hg)	Lab Sample Collected (Y or N)	Approximate Cover Thickness [b] (feet)
Y1	09/17/01	9:38 AM	0.0	11.7	7.1	0.0	74.3	–0.20	24.8	Y	0.5
Y2	09/17/01	9:51 AM	0.0	16.2	4.7	0.0	74.7	0.00	24.7	Y	0.5
Y3	09/17/01	10:02 AM	0.0	18.1	0.5	0.0	75.0	–0.10	24.7	N	1.5
Y4	09/17/01	10:11 AM	0.0	2.2	17.4	0.0	73.8	–0.10	24.7	Y	2.0
Y5	09/17/01	10:21 AM	0.0	2.1	17.4	0.0	74.6	–0.20	24.7	N	1.5
Y6	09/17/01	10:31 AM	1.3	14.9	0.0	1.0	76.6	–0.20	24.7	Y	2.0
Y7	09/17/01	10:48 AM	35.5	18.0	0.0	3.0	77.0	–0.10	24.7	N	2.0
Y8	09/17/01	10:59 AM	0.0	10.2	6.8	0.0	NM [c]	0.00	24.6	Y	2.0
Y9	09/17/01	11:10 AM	0.0	7.7	10.2	0.0	78.3	0.00	24.6	N	2.0
Y10	09/17/01	11:28 AM	3.2	23.2	0.0	2.0	77.7	–0.20	24.6	Y	2.0
Y11	09/17/01	11:47 [illegible]	13.1	21.8	0.0	1.0	76.8	0.00	24.6	Y	U
Y12	09/17/01	1:34 PM	0.1	17.0	0.0	0.0	78.0	0.00	24.6	N	0.5
Y13	09/17/01	1:46 PM	0.0	9.6	8.0	0.0	78.0	0.00	24.6	Y	1.5
Y14	09/17/01	2:12 PM	8.2	25.9	0.0	8.0	79.6	0.00	24.6	N	2.5
Y15	09/17/01	2:19 PM	0.0	7.9	10.2	0.0	NM [c]	0.10	24.6	Y	3.0
Y16	09/17/01	2:29 PM	0.6	22.9	0.0	1.0	NM [c]	0.00	24.6	N	3.0
Y17	09/17/01	2:44 PM	0.0	3.2	15.9	0.0	85.3	0.10	24.6	Y	1.5
Y18	09/17/01	3:03 PM	0.0	1.9	17.3	0.0	NM	0.10	24.6	N	3.0

[a] Landfill gas static pressure and atmospheric pressure measurement was provided by the Landtec GA™-90.
[b] Approximate cover thickness is based on driller's "feel" of breakthrough from cover soil to waste; this data is subjective and is not a scientific measurement.
[c] Hole collapsed.

Notes:
Some probes originally planned (Y24, Y32, Y51, Y54, Y55, and Y56) were not installed in the final survey.

ppm = Parts per million
°F = Degrees Fahrenheit
H_20 = Water
Hg = Mercury
NM = Not measured
U = Unknown, could not be determined by the driller

Table 1. Landfill Gas Survey Results
Yale Landfill
Page 2 of 3

Sampling Point	Date	Time	Methane Concentration (%)	Carbon Dioxide Concentration (%)	Oxygen Concentration (%)	Hydrogen Sulfide Concentration (ppm)	Landfill Gas Temperature (°F)	Landfill Gas Static Pressure [a] (inches H_2O)	Atmospheric Pressure [a] (inches Hg)	Lab Sample Collected (Y or N)	Approximate Cover Thickness [b] (feet)
Y19	09/17/01	3:18 PM	0.0	9.6	9.1	0.0	NM	0.00	24.5	Y	U
Y20	10/05/01	3:07 PM	0.0	4.3	16.1	0.0	NM	0.00	24.6	N	2.0
Y21	09/19/01	10:00 AM	0.0	0.3	19.7	0.0	NM	–0.20	24.7	Y	U
Y22	09/19/01	10:30 AM	0.0	0.7	19.3	0.0	NM	–0.20	24.7	N	U
Y23	10/05/01	3:31 PM	0.9	20.0	0.0	1.0	NM	–0.50	24.6	Y	2.0
Y25	09/18/01	2:50 PM	0.0	1.1	18.2	0.0	NM	0.00	24.5	N	4.0
Y26	09/18/01	3:20 PM	0.0	2.8	16.4	0.0	NM	0.10	24.5	N	3.5
Y27	09/18/01	3:05 PM	0.0	1.8	17.2	0.0	NM	0.10	24.5	N	4.5
Y28	09/18/01	3:45 PM	16.4	22.1	0.0	6.0	NM	–0.10	24.5	N	2.5
Y29	09/18/01	3:30 PM	1.1	24.9	0.0	0.0	88.7	0.00	24.5	N	2.75
Y30	09/19/01	9:15 AM	0.0	2.4	16.9	0.0	NM	–0.20	24.6	Y	U
Y31	09/19/01	9:30 AM	0.0	5.5	11.3	0.0	71.4	–0.20	24.6	N	U
Y33	09/19/01	8:45 AM	0.0	16.9	1.1	0.0	NM	–0.10	24.6	Y	U
Y34	09/18/01	4:26 PM	0.1	15.0	3.0	0.0	NM	0.10	24.5	Y	2.5
Y35	09/18/01	4:08 PM	0.1	0.8	18.8	0.0	NM	0.00	24.5	N	3.0
Y36	09/17/01	3:53 PM	0.0	3.2	15.2	0.0	NM	0.00	24.5	N	1.0
Y37	09/17/01	4:08 PM	0.0	1.6	17.5	0.0	NM	0.00	24.5	Y	1.0
Y38	09/17/01	3:59 PM	34.7	39.1	0.0	2.0	NM	0.00	24.5	N	1.0

[a] Landfill gas static pressure and atmospheric pressure measurement was provided by the Landtec GA™-90.
[b] Approximate cover thickness is based on driller's "feel" of breakthrough from cover soil to waste; this data is subjective and is not a scientific measurement.
[c] Hole collapsed.

Notes:
Some probes originally planned (Y24, Y32, Y51, Y54, Y55, and Y56) were not installed in the final survey.

ppm = Parts per million
°F = Degrees Fahrenheit
H_20 = Water
Hg = Mercury
NM = Not measured
U = Unknown, could not be determined by the driller

Table 1. Landfill Gas Survey Results
Yale Landfill
Page 3 of 3

Sampling Point	Date	Time	Methane Concentration (%)	Carbon Dioxide Concentration (%)	Oxygen Concentration (%)	Hydrogen Sulfide Concentration (ppm)	Landfill Gas Temperature (°F)	Landfill Gas Static Pressure [a] (inches H_2O)	Atmospheric Pressure [a] (inches Hg)	Lab Sample Collected (Y or N)	Approximate Cover Thickness [b] (feet)
Y39	09/17/01	4:45 PM	27.4	30.5	0.0	135.0	86.5	0.00	24.5	Y	1.0
Y40	09/18/01	11:15 AM	0.0	0.4	19.2	1.0	NM	0.00	24.6	Y	3.0
Y41	09/18/01	10:00 AM	0.0	0.5	19.4	0.0	NM	–0.20	24.7	N	3.0
Y42	09/18/01	10:20 AM	0.0	1.4	18.3	0.0	NM	–0.10	24.6	Y	3.0
Y43	09/18/01	9:30 AM	0.0	16.3	5.0	0.0	NM	–0.10	24.7	N	3.0
Y44	09/18/01	9:15 AM	6.1	20.4	0.0	0.0	NM	–0.30	24.7	N	3.0
Y45	10/05/01	10:55 AM	50.8	8.6	0.1	0.0	NM	–1.30	24.7	Y	>10.0
Y46	10/05/01	12:56 PM	0.0	0.6	19.6	0.0	NM	–1.70	24.7	Y	4.5
Y47	09/18/01	11:00 AM	3.4	28.6	0.0	4.0	NM	–0.10	24.7	N	1.0
Y48	09/18/01	10:45 AM	0.0	5.2	12.4	0.0	80.2	–0.30	24.6	N	3.5
Y49	10/05/01	12:11 PM	6.2	7.3	0.0	0.0	NM	–0.80	24.6	Y	4.0
Y50	10/05/01	11:37 AM	8.5	12.3	0.2	0.0	NM	–0.90	24.6	N	4.0
Y52	10/05/01	10:21 AM	0.0	5.6	13.2	0.0	NM	–0.80	24.8	N	>10.0
Y53	09/18/01	9:00 AM	0.0	17.1	0.0	0.0	74.5	–0.20	24.6	Y	3.0
Y57	09/18/01	1:05 PM	1.2	24.9	0.0	0.0	82.6	0.00	24.5	Y	1.0

[a] Landfill gas static pressure and atmospheric pressure measurement was provided by the Landtec GA™-90[illegible]
[b] Approximate cover thickness is based on driller's "feel" of breakthrough from cover soil to waste; this data i[illegible]jective and is not a scientific measurement.
[c] Hole collapsed.

Notes:
Some probes originally planned (Y24, Y32, Y51, Y54, Y55, and Y56) were not installed in the final survey.

ppm = Parts per million
°F = Degrees Fahrenheit
H_20 = Water
Hg = Mercury
NM = Not measured
U = Unknown, could not be determined by the driller

conducted monitoring in this area and development plans for this property by the City Aviation Department include removal of waste in this area.

The southern fill area of the Yale Landfill possessed methane concentrations up to 50.8 percent. These readings were from a large, central area of the southern portion of the landfill (Figure 7).

The hotel fill area of the Yale Landfill is the area located south and east of the Wyndham Hotel and immediately north of the airport (Figure 7). Methane concentrations up to 16.4 percent were found at the southeastern corner of the Wyndham parking lot.

Hydrogen sulfide concentrations at the Yale Landfill generally ranged from 0 to no more than 20 ppm (Table 1). A single LFG sample from gas probe Y39 indicated a hydrogen sulfide concentration of 135 ppm in the central portion of the landfill (Figure 7). This elevated concentration may be caused by an isolated portion of the landfill that contains construction debris with gypsum wallboard, which decays to produce hydrogen sulfide. The generally low concentrations suggest that hydrogen sulfide is being generated only at low rates in the landfill and is not likely to present a high likelihood of significant adverse impacts.

5.2 LFG Survey Laboratory Results

During the LFG survey (described in Section 2.3), 28 vapor samples were collected at the Yale Landfill for laboratory analysis (Figure 3). Each sample was analyzed using a modified version of Method TO-14, which analyzes for the most commonly occurring VOCs in LFG. The laboratory also analyzed three samples (Y10, Y17 and Y42) as duplicates to provide laboratory QA/QC. In addition, two samples (Y39 and Y45) were tested for methane, carbon dioxide, oxygen, and nitrogen. The results of the quality control laboratory analyses show good agreement with the field measurements for methane, carbon dioxide, and oxygen.

Results of the laboratory analysis are summarized in Table 2. Yale Landfill VOC maps illustrating the concentrations measured for selected VOCs are included in Appendix D. The VOCs shown were specified by AEHD, based on a review of the VOC data to determine the

Table 2. Laboratory Results
Yale Landfill

Compound Name	Y1	Y2	Y4	Y6	Y8	Y10	Y10 (dup)	Y11	Y13	Y15	Y17	Y17 (dup)	Y19	Y21	Y23	Y26	Y28	Y29	Y30	Y33	Y34	Y37	Y39	Y40	Y42	Y42 (dup)	Y45	Y46	Y49	Y53	Y57
Modified Method TO-14 [a] (ppbv)																															
1,1,1-Trichloroethane	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
1,1,2-Trichloroethane	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
1,1-Dichloroethane	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
1,1-Dichloroethene	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
1,2,4-Trimethylbenzene	---	---	---	670	69	210	190	620	33	33	44	47	24	24	1300	---	---	---	---	27	---	53	44	---	---	---	40	---	---	---	160
1,2-Dichlorobenzene	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
1,2-Dichloroethane	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
1,2-Dichloropropane	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
1,3,5-Trimethylbenzene	---	---	---	300	34	120	100	600	20	17	28	28	---	---	480	---	---	---	---	---	---	21	33	---	---	---	---	---	---	---	110
1,3-Dichlorobenzene	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
1,4-Dichlorobenzene	---	---	---	61	12	31	26	---	---	---	---	---	---	---	33	---	---	---	---	---	---	---	---	---	---	---	36	---	---	---	57
2-Propanol	---	---	---	---	---	---	---	---	66	---	---	---	---	---	---	---	---	---	---	45	---	---	---	---	---	---	---	---	---	---	---
Benzene	---	---	---	14	---	16	13	35	---	---	---	---	---	---	38	---	92	20	---	---	---	---	59	---	---	---	120	---	21	---	---
Bromomethane	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Carbon tetrachloride	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Chlorobenzene	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Chloroethane	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Chloroform	---	24	---	---	---	---	---	---	---	12	---	---	16	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Chloromethane	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
cis-1,2-Dichloroethene	---	---	---	120	---	38	34	15	---	---	---	---	---	---	140	---	---	---	---	---	---	---	180	---	---	---	190	---	140	---	40
Ethylbenzene	---	---	---	260	18	71	72	170	---	---	---	---	---	---	370	---	900	---	---	---	---	---	82	---	---	---	290	---	---	---	45
Ethylene dibromide	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Freon 11	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	13	---	---
Freon 113	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Freon 114	---	---	---	17	22	28	23	120	14	---	---	---	---	---	17	---	---	---	---	---	---	---	---	---	---	---	53	---	120	52	140
Freon 12	16	72	39	90	140	130	120	200	55	49	55	60	27	18	140	---	69	---	---	---	---	---	---	---	53	55	---	41	230	69	86
m,p-Xylene	---	---	---	170	26	54	76	250	---	---	---	---	---	---	890	---	760	---	---	19	---	---	14	---	---	---	43	---	---	---	50
Methyl tertiary-butyl ether	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Methylene chloride	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
o-Xylene	---	---	---	140	16	48	58	140	---	---	---	---	---	---	480	---	470	---	---	---	---	---	19	---	---	---	19	---	---	---	38
Tetrachloroethene	38	---	36	---	29	---	---	---	---	---	23	28	---	18	23	---	---	---	---	---	---	21	---	---	16	19	---	30	17	---	---
Toluene	37	---	15	100	---	22	22	59	13	---	---	---	---	---	480	---	100	---	---	27	---	---	67	---	---	---	42	---	17	---	18
trans-1,2-Dichloroethene	---	---	---	---	---	---	---	---	---	---	---	---	---	---	32	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Trichloroethene	---	---	---	20	---	---	---	---	---	---	---	---	---	---	130	---	26	---	---	---	15	---	---	---	---	---	13	---	---	---	26
Vinyl chloride	---	---	---	12	---	---	---	---	---	---	---	---	---	---	---	---	36	---	---	---	---	---	41	---	---	---	230	---	440	---	---
Method 3C [b] (% volume)																															
Carbon dioxide	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	27	NS	NS	NS	8.96	NS	NS	NS	NS
Methane	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	26	NS	NS	NS	55.4	NS	NS	NS	NS
Nitrogen	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	43	NS	NS	NS	34.8	NS	NS	NS	NS
Oxygen	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.82	NS	NS	NS	0.842	NS	NS	NS	NS

[a] Detection limit for method is 5 ppbv; reporting limits vary depending on dilution factor (see laboratory results, Volume II).
[b] Detection limit for method is 0.10 percent of volume for all analytes.

--- = Not detected
NS = Not sampled
ppbv = Parts per billion by volume

significant parameters detected. Full laboratory reports and laboratory chain-of-custody forms are provided in Volume II.

5.3 Waste Characterization Analysis

Three waste characterization borings (designated WC-5, WC-6, and WC-7) were drilled at the Yale Landfill. The depths of WC-5, WC-6, and WC-7 were approximately 17, 21, and 20 feet bgs, respectively. Waste was found to extend to just 9 feet bgs in WC-5, 11 feet in WC-7, and up to 20 feet bgs in WC-6. No odors were present from WC-5, strong odors were present from WC-6, and slight odors were observed from WC-7. Methane and hydrogen sulfide gas were not detected during monitoring for worker health and safety purposes at any of the boring locations. The soil encountered in the waste characterization borings at the Yale Landfill generally consisted of slightly moist, light-brown to black coarse sand with some silt and gravel.

A summary of the waste composition encountered in each boring is provided in Table 3, and additional details for each waste sample are provided in the boring logs in Appendix A and field notes in Volume II.

The primary types of materials encountered at WC-5 (along with the estimated percentage by weight) included soil (95.5 percent), glass bottles (2.8 percent), paper (1.2 percent), and plastic (0.5 percent).

The primary types of materials encountered at WC-6 included soil (22.7 percent), wood (19.5 percent), glass (15.8 percent), and metal (13 percent). In addition, the following materials were encountered in small quantities: cloth (7.9 percent), plastic (7.9 percent), paper (6.9 percent), green waste (4.3 percent), and cardboard (2 percent).

The types of materials encountered at WC-7 included soil (94.6 percent), wood (4.3 percent), and plastic (1.1 percent).

Table 3. Waste Characterization Boring Summary
Yale Landfill

Boring Number	Depth of Boring (feet)	Boring Location [a]	Depth Interval of Waste/Debris	Weight Percentages and Nature of Waste/Debris	Decomposability Rating
WC-5	17	• N 1473718 Usft. • E 1527286 Usft.	Intermittent waste from 3 to 9 feet bgs	• Bottles 2.8% • Paper 1.2% [b] • Plastic 0.5% • Silty sand 95.5%	Degradable fraction • 1.2% Moderate Non-degradable fraction • 0.5% Inert • 95.5% Fines
WC-6	21	• N 1473622 Usft. • E 1527230 Usft.	4.5 to 20 feet bgs	• 4.3% Green waste [b] • 2.0% Cardboard [b] • 13.0% Metal • 7.9% Cloth [b] • 22.7% Soil • 6.9% Paper [b] • 15.8% Glass • 7.9% Plastic • 19.5% Wood [b]	Degradable fraction • 0% Rapid • 13.2% Moderate • 27.4% Slow Non-degradable fraction • 36.7% Inert • 22.7% Fines
WC-7	20	• N 1472778 Usft. • E 1527776 Usft.	Intermittent waste at 10 feet bgs	• Wood 4.3% [b] • Plastic 1.1% • Silty sand 94.6%	Degradable fraction • 4.3% Slow Non-degradable fraction • 1.1% Inert • 94.6% Fines

[a] New Mexico Planes Central Zone (NAD 83).
[b] Compose degradable fractions (see Table 6).

Usft. = U.S. survey foot (equals 0.3048006096 meters)
feet bgs = Feet below ground surface

NA = Not applicable

Three samples of waste were collected from WC-6 and analyzed for moisture content. The moisture content determined in the laboratory was found to be relatively high and ranged from 37.2 to 42.5 percent. A summary of moisture content data is included in Table 4. Complete laboratory moisture content results are contained in Appendix E.

Table 4. Waste Moisture Content Laboratory Results
Yale Landfill

Location	Depth (feet)	Sample Number	Moisture Content (%, g/g)
Boring WC-6	6-7	6-7	42.5
	11-12	11-12	37.2
	14-15	14-15	39.0

g/g = Gram per gram

5.4 Pumping Test Results

A pumping test was performed on extraction well WC-6/EW at the Yale Landfill from December 27, 2001 through December 30, 2001. Information about well installation and pumping test equipment is provided in Sections 2.6 and 4.5. The pumping test results are summarized in Table 5 and additional pumping test data is provided in Appendix F. Operating procedures for the test are summarized below:

- The pumping test began at approximately 11:37 p.m. on Thursday, December 27, 2001, and ended at 8:10 a.m. on December, 30, 2001.

- An initial flow rate of approximately 140 scfm was used for approximately the first two hours of the test to initially extract methane at a high rate.

- The flow rate was adjusted to approximately 43 scfm for the remainder of the test.

- The methane concentration initially was at 4.2 percent and declined to approximately 0.3 percent.

Table 5. Pump Test Landfill Gas Readings
Yale Landfill

Date	Time	CH_4 (%)	CO_2 (%)	O_2 (%)	Balance (%)	Temperature (°F)	Flow Rate (ft^3/min.)
12/27/01	12:00	4.2	17.4	3.3	75.1	NA	136
	12:15	4.0	16.6	4.1	75.3	NA	143
	12:30	3.4	15.9	5.3	75.4	77	NA
	13:00	3.2	15.2	5.5	76.1	NA	152
	13:15	3.0	15.0	5.8	76.2	NA	139
	13:30	3.0	14.7	5.9	76.4	71	NA
	14:00	3.0	14.6	6.0	76.4	NA	NA
	14:15	2.7	14.2	6.2	76.9	[illegible]	NA
	14:30	2.5	14.0	6.6	76.9	71	36.0
	15:00	2.7	14.2	6.1	77.0	NA	NA
	15:30	2.5	14.2	6.2	77.1	NA	50.0
	16:00	2.4	14.1	6.2	77.3	71	NA
	16:30	2.3	14.1	6.2	77.4	NA	NA
	17:00	2.1	14.0	6.6	77.3	NA	NA
12/28/01	07:00	1.5	11.7	8.5	78.3	NA	72.0
	11:00	1.4	11.6	7.6	79.4	70	44.0
	17:07	4.7	12.6	10.7	72.0	NA	44.2
12/29/01	07:08	1.8	6.4	15.8	76.0	68	43.0
	12:25	1.3	5.0	16.8	76.9	69	43.4
	14:25	1.4	5.0	16.7	76.9	69	43.8
	16:25	1.4	5.0	16.6	77.0	70	44.1
12/30/01	07:53	0.3	2.3	19.2	78.2	68	43.5

CH_4 = Methane
CO_2 = Carbon dioxide
O_2 = Oxygen

°F = Degrees Fahrenheit
ft^3/min. = Cubic feet per minute
NA = Not available

Figures 8 and 9 summarize the results of the pumping test, including projections of the radius of influence, defined as the horizontal distance from the extraction well to where measured vacuum is estimated to reach a value of zero (through a linear regression of the data). Figure 8 shows probe data measured with an electronic datalogger; Figure 9 shows the manually-measured probe data. The transmitters and datalogger were initially used to collect vacuum measurements; however, due to the sensitivity of the transmitters, early test measures were deemed invalid. Therefore, only the manual readings were used. As seen in the figures, only the manually-measured data yielded results that allowed for a projection of the radius of influence.

As shown in Figure 9, a radius of influence of 130 feet was estimated. Using the 130-foot radius of influence, a volume of waste under the influence of the extraction well was estimated and converted to mass, assuming a refuse density of 1,000 pounds per cubic yard (lbs/yd^3) (Appendix B). A unit LFG generation rate was then calculated based on the measured flow rate and the estimated amount of waste within the influence of the extraction well, as shown in the calculations below.

$$\text{Unit generation rate} = \frac{\text{Average flow rate during pump test x Number of minutes per year}}{\text{Tons in place x 2,000 lbs/ton}}$$

Using the estimated tons of waste in place (11,205 tons) provided in Appendix B and an average flow rate of 1.3 scfm (standardized to 50 percent methane from 43.6 scfm at 1.47 percent methane), the following unit generation rate is obtained:

$$0.0301\,\text{ft}^3\text{/lb - yr} = \frac{1.3\text{ ft}^3\text{/min x 525,600 min/yr}}{\text{11,205 tons x 2,000 lbs/ton}}$$

As calculated in the above equation, a unit generation rate of 0.0301 ft^3/lb per year was estimated for the Yale Landfill pumping test. From this unit generation rate, a site-calibrated k value was estimated for Yale Landfill based on the LFG generation model. The k-calibration model run is described in Section 5.5.1.3.

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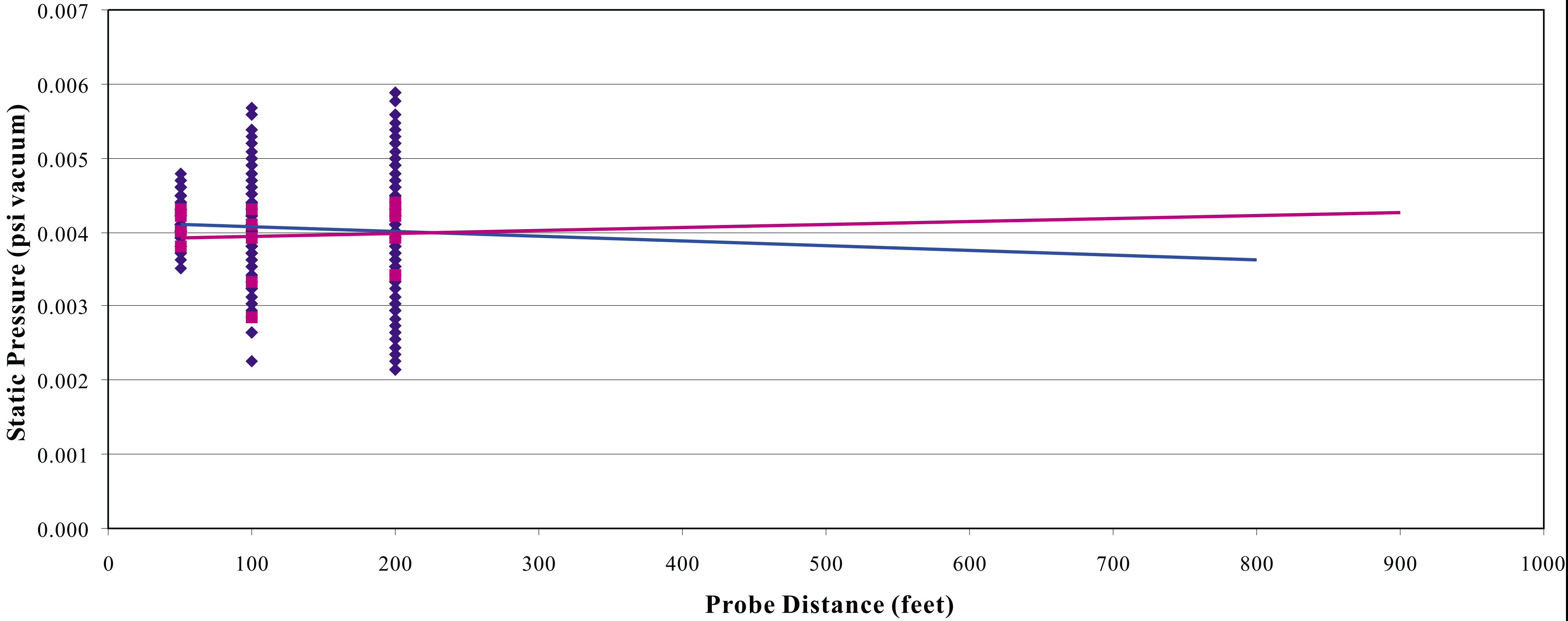

Explanation

◆	Test 1	—	Linear (Test 1)
■	Last Hour	—	Linear (Last Hour)

psi = pounds per square inch
scfm = standard cubic feet per minute

LANDFILL GAS INVESTIGATION AND CHARACTERIZATION STUDY

Yale Landfill
Results of Pumping Test 1 (Datalogger)
Flow Rate of 43 scfm

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3-19-02 JN 9398

Figure 8

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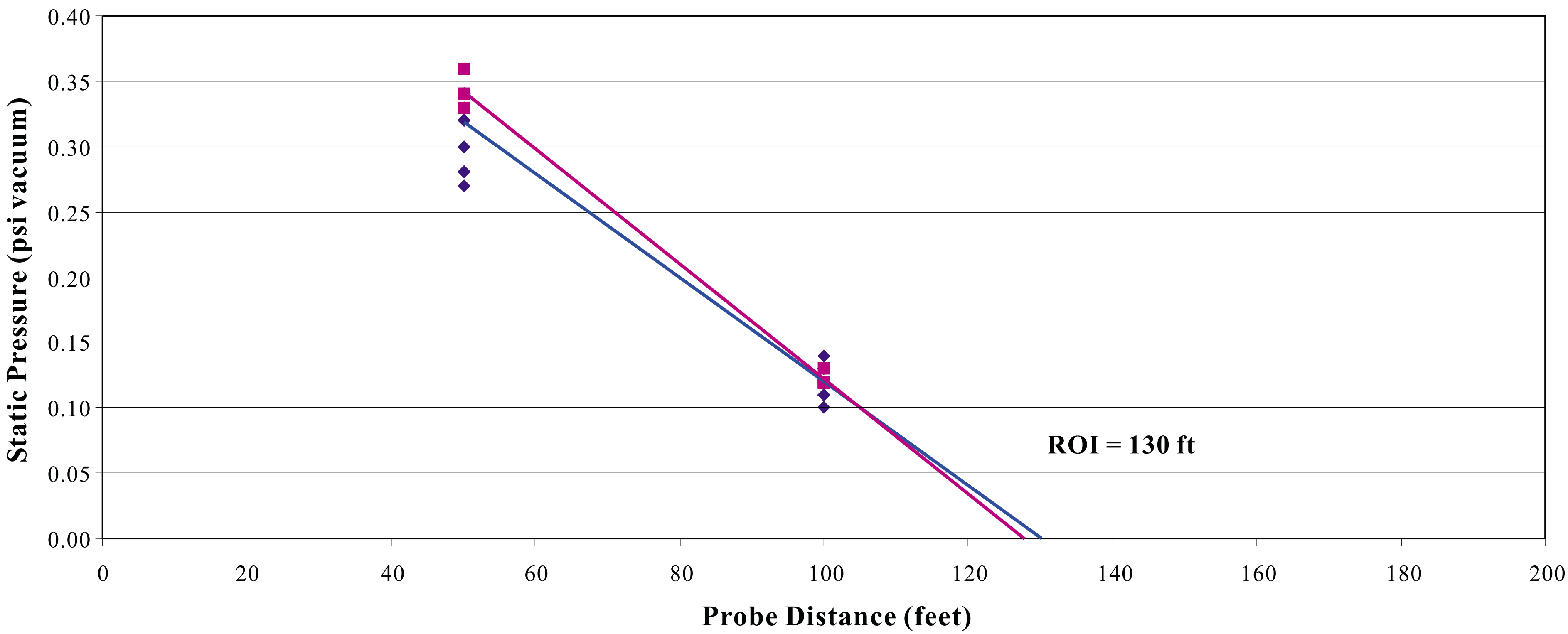

Explanation

Manual Record	Linear (Manual Record)
Last Hour	Linear (Last Hour)

ROI = radius of influence
psi = pounds per square inch
scfm = standard cubic feet per minute

LANDFILL GAS INVESTIGATION AND CHARACTERIZATION STUDY

Yale Landfill
Results of Pumping Test 1 (Manual)
Flow Rate of 43 scfm

Figure 9

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5.5 Landfill Gas Generation Modeling Results

This section presents the model inputs used for estimating LFG generation at the Yale Landfill and summarizes the model results.

5.5.1 Input Parameters

As described in Section 2.6, LFG generation modeling requires setting model input parameters for (1) waste disposal history, (2) the L_0 value, and (3) the k value. The selected average waste volumes used as input to the LFG generation model are provided in Table 6. Information was gathered from field investigations, laboratory analyses of waste samples, historical documents, and the RFP. Numerous information sources were used to provide reliable estimates of the expected range for LFG generation rates. The following model input parameters were chosen.

- Waste disposal history: 966,615 tons of refuse are estimated to be present currently (Table 6)
- L_0 values ranging from 1,528 ft^3/ton to 3,550 ft^3/ton
- k values ranging from 0.019/yr to 0.030/yr

Development of the waste disposal history, L_0 values, and k values for LFG generation modeling for the Yale Landfill is described below.

5.5.1.1 Waste Disposal History

Annual waste volumes are a required input parameter for the LFG generation model. Waste disposal at the Yale Landfill occurred between 1948 and 1965, but waste has also been removed for various construction projects. Therefore, the model input considers only the existing waste at the landfill, and the modeling results provide estimates of future LFG generation rates. The modeling results do not reflect past LFG generation rates when more waste was present.

Table 6. Available Information on Waste Disposal History and Volumes
Yale Landfill

Source of Information	Dates of Operation	Size (acres)	Average Soil Cover Thickness (feet)	Average Refuse Thickness (feet)	Estimated Refuse Volume [a] (cubic yards)	Estimated Waste in Place [b] (tons)	Notes
City of Albuquerque RFP for this project	1948-1965	137.3	---	10.0	2,215,881	1,107,941	Acreage appears to include excavated areas. Reports refuse depths of 4.5 to 23 feet, for an average of 13.75 feet. Subtracts an estimated cover soil depth of 3.75 feet based on field study.
Field investigation (present study), site totals	---	114.4	3.75	10.5	1,933,229	966,615	Acreage and volume are the sum of each area. Cover and waste thickness is from NW area boreholes (WC-5 and WC-6).
Southern fill area	---	60.23	---	---	971,788	485,894	Borehole (WC-7) found only intermittent waste. Uses RFP refuse thickness (10 feet) to calculate volume. Acreage is from drawing.
Central fill area	---	14.03	---	---	248,902	124,451	Uses Geo-Test, 2000 refuse thickness (11 feet) to calculate volume. Acreage is from drawing.
Northern fill area	---	22.98	3.75	11.75	435,694	217,847	Refuse depths: Intermittent from 3 to 9 ft at WC-5; 4.5 to 27 feet at WC-6. Acreage is from drawing.
Hotel fill area	---	17.16	---	---	276,845	138,423	Acreage from drawing.
Geo-Test, 2000	---	---	8	11	2,030,282	1,015,141	Average soil and refuse thicknesses are from detailed evaluation of central fill area only.
Geo-Test, 1992	---	---	---	16.5	3,045,423	1,522,712	Reports refuse thicknesses of 1 to 30 feet
Vinyard & Associates, 2000	1948-1965	---	---	19	3,506,851	1,753,426	Reports refuse thickness of 4.5 to 34 feet, for an average of 19 feet.
Values used for present study	1948-1965	114.4	3.75	10.5	1,933,229	966,615	

[a] Uses 114.4 acres for entire site (from present study) when site acreage not reported.
[b] Assumes an average in-place density equal to 1,000 pounds per cubic yard.

RFP = Request for proposal
--- = No data

Since specific records do not exist for waste disposal at the Yale Landfill, several possible historical waste disposal rates were calculated for the Yale Landfill using the following data:

- Aerial extent of the landfill provided in the City's RFP for this project (137.3 acres) multiplied by average waste thickness provided in the City's RFP (10 feet), which yields 2,215,881 cubic yards.

- Aerial extent of the site determined from site drawings for this study (114.4 acres) multiplied by average estimated average refuse thickness based on information obtained from the waste characterization borings (10.5 feet), which yields 1,933,229 cubic yards.

- Aerial extent of the site determined from site drawings for this study (114.4 acres) multiplied by the average refuse thickness derived from various historical studies, including the following:
  - An average refuse thickness of 11 feet (Geo-Test, 2000), which yields 2,030,282 cubic yards.
  - An average refuse thickness of 16.5 feet (Geo-Test, 1992), which yields 3,045,423 cubic yards.
  - An average refuse thickness of 19 feet (Vinyard & Associates, 2000), which yields 3,506,851 cubic yards.

Additional assumptions used for the study include:

- The years of disposal reported in the RFP (1948 to 1965)
- An estimated average refuse density of 1,000 lbs/yd^3

Table 6 shows a range of in-place volume of waste based on the above information. For modeling the LFG generation for the Yale Landfill, a disposal volume of 1,933,229 cubic yards (966,615 tons) of refuse was used.

5.5.1.2 Ultimate Methane Generation Rate (L_0)

As outlined in Section 2.6.2, L_0 values used for LFG generation model runs for the Yale Landfill were assigned one of the following three values:

- EPA default value of 3,204 ft^3/ton, which is converted from the EPA (AP-42) value of 100 cubic meters (m^3) of methane per Mg of waste (EPA, 1995)

- SCS default value of 3,550 ft^3/ton based on the precipitation for the Albuquerque region, (8.7 inches per year according to the Desert Research Institute [www.wrcc.dri.edu])

- Site-calibrated valu[illegible]f [illegible] f[illegible]n based on the amount of degradable refuse found. This value was compared with the expected fraction of degradable waste remaining for a "typical" U.S. waste stream that had degraded the same number of years as the waste at Yale Landfill. The ratio of degradable waste measured in the field to the expected value was multiplied by the SCS default value to estimate the site-calibrated value.

Table 7 summarizes the waste composition data and L_0 adjustments used for developing the site-calibrated L_0 value for the Yale Landfill. Because the fraction of degradable refuse analyzed at Yale Landfill was lower than the typical value, the site-calibrated L_0 was adjusted downward to 1,528 ft^3/ton.

Table 7. Derivation of a Site-Calibrated L_0 Value for Yale Landfill

Avg. Age of Landfill Refuse (years)	Typical MSW Degradable Fraction [a]	Site Average Degradable Fraction [b]	Ratio of Site to Typical Degradable	SCS Default L_0 (ft^3/ton)	Site-Calibrated L_0 (Ratio x SCS L_0) (ft^3/ton)
44.5	48.6%	20.9%	0.43	3,550	1,528

[a] Derived from EPA's *Characterization of Waste in the United States: 1996 Update* (EPA, 1997) which shows that an average of 67.4 percent of MSW is decomposable as delivered to the landfill. Value shown is the expected fraction of decomposable refuse remaining as of the end of 2001 based on the age of waste in the landfill and the estimated rates of decomposition for waste components.

[b] Represents an average of the waste samples from WC-5 (1.2% degradable) and WC-6 (40.6% degradable) (See Table 3). Sample location WC-7 was near the landfill perimeter and was not considered representative. WC-7 was also not in the area where the pumping test was performed and therefore WC-7 data could not be used in the pumping test data analysis.

MSW = Municipal solid waste L_0 = Ultimate methane generation rate ft^3/ton = Cubic feet per ton

5.5.1.3 Methane Generation Rate Constant (k)

As outlined in Section 2.6.3, k values used for the LFG generation model runs for the Yale Landfill were as follows:

- EPA (AP-42) default k value of 0.02 per year (for landfills experiencing less than 25 inches per year of precipitation) (EPA, 1995).

- SCS default k value of 0.019 per year for the Albuquerque region.

- Site-calibrated k value of 0.023 per year based on refuse moisture data and pumping test data. Because the average refuse moisture derived from the field testing program (39.6 percent) was significantly higher than the moisture content for typical wastes (20 percent), an upward adjustment to the k value was made based on the refuse moisture content. The results of the refuse moisture data were consistent with the pumping test results, which found that the site-calibrated k value was higher than the SCS default value of 0.019, as described in Section 3.5. The site-calibrated k value was estimated by performing a k-calibration model run with the unit LFG generation rate of 0.03 ft^3/lb-yr calculated in Section 5.4.

  The k-calibration model run uses the estimated amount of waste within the influence of the extraction well based on the pumping test results. As shown in Table 8, a k value of 0.023 is required to generate 0.030 ft^3 of LFG per lb of refuse in 2001. Note that the unit generation rate estimated from the pumping test was too high to be achieved with the site-calibrated L_0 value (1,528 ft^3/ton) at any k value; thus the L_0 value had to be increased to 3,620 ft^3/ton for the k calibration model run.

- An elevated k value of 0.03 per year based on the estimated effect of adding moisture starting in 2002.

Table 8. Methane Generation Rate Constant (k) Calibration Model Run
Yale Landfill
Page 1 of 2

Year	Disposal Rate (tons per year)	Refuse In-Place (tons)	LFG Generation Rate (scfm)	LFG Generation Rate (Mcf/day)	LFG Generation Rate cf/lb-yr)
Methane content of LFG adjusted to:			*50%*		
Methane generation rate constant (k):			*0.023*		
Ultimate methane generation rate (L_0[a]):			*3,620*[b]		
1948	623	623	0.0	0.00	0.000
1949	623	1,245	0.2	0.00	0.041
1950	623	1,868	0.4	0.00	0.054
1951	623	2,490	0.6	0.00	0.060
1952	623	3,113	0.7	0.00	0.063
1953	623	3,735	0.9	0.00	0.065
1954	623	4,358	1.1	0.00	0.066
1955	623	4,980	1.3	0.00	0.067
1956	623	5,603	1.4	0.00	0.067
1957	623	6,225	1.6	0.00	0.067
1958	623	6,848	1.7	0.00	0.067
1959	623	7,470	1.9	0.00	0.067
1960	623	8,093	2.0	0.00	0.066
1961	623	8,715	2.2	0.00	0.066
1962	623	9,338	2.3	0.00	0.066
1963	623	9,960	2.5	0.00	0.065
1964	623	10,583	2.6	0.00	0.065
1965	623	11,205	2.7	0.00	0.064
1966	0	11,205	2.9	0.00	0.067
1967	0	11,205	2.8	0.00	0.066
1968	0	11,205	2.7	0.00	0.064
1969	0	11,205	2.7	0.00	0.063
1970	0	11,205	2.6	0.00	0.061
1971	0	11,205	2.6	0.00	0.060
1972	0	11,205	2.5	0.00	0.059
1973	0	11,205	2.4	0.00	0.057
1974	0	11,205	2.4	0.00	0.056
1975	0	11,205	2.3	0.00	0.055
1976	0	11,205	2.3	0.00	0.054
1977	0	11,205	2.2	0.00	0.052
1978	0	11,205	2.2	0.00	0.051
1979	0	11,205	2.1	0.00	0.050

[a] L_0 adjusted to 2% above SCS default value (3,550) to allow unit generation rate to equal 0.030 in 2001 using a k value of 0.023.
[b] Cubic feet per ton

LFG = Landfill gas
scfm = Standard cubic feet per minute
Mcf/day = Million cubic feet per day
cf/lb-yr = Cubic feet per pound per year

Table 8. Methane Generation Rate Constant (k) Calibration Model Run
Yale Landfill
Page 2 of 2

Year	Disposal Rate (tons per year)	Refuse In-Place (tons)	LFG Generation Rate		
			(scfm)	(Mcf/day)	cf/lb-yr)
1980	0	11,205	2.1	0.00	0.049
1981	0	11,205	2.0	0.00	0.048
1982	0	11,205	2.0	0.00	0.047
1983	0	11,205	1.9	0.00	0.046
1984	0	11,205	1.9	0.00	0.045
1985	0	11,205	1.9	0.00	0.044
1986	0	11,205	1.8	0.00	0.043
1987	0	11,205	1.8	0.00	0.042
1988	0	11,205	1.7	0.00	0.041
1989	0	11,205	1.7	0.00	0.040
1990	0	11,205	1.7	0.00	0.039
1991	0	11,205	1.6	0.00	0.038
1992	0	11,205	1.6	0.00	0.037
1993	0	11,205	1.5	0.00	0.036
1994	0	11,205	1.5	0.00	0.035
1995	0	11,205	1.5	0.00	0.035
1996	0	11,205	1.4	0.00	0.034
1997	0	11,205	1.4	0.00	0.033
1998	0	11,205	1.4	0.00	0.032
1999	0	11,205	1.3	0.00	0.032
2000	0	11,205	1.3	0.00	0.031
2001	0	11,205	1.3	0.00	**0.030**

[a] L_0 adjusted to 2% above SCS default value (3,550) to allow unit generation rate to equal 0.030 in 2001 using a k value of 0.023.
[b] Cubic feet per ton

LFG = Landfill gas
scfm = Standard cubic feet per minute
Mcf/day = Million cubic feet per day
cf/lb-yr = Cubic feet per pound per year

5.5.2 Model Validation Results

Validation of LandGEM's application to the Yale Landfill is provided by the site-calibrated k values, which are based on actual measurements of LFG production from pumping tests conducted at the Yale Landfill. The calibrated k value of 0.023 for Yale is close to the predicted k input parameters assigned through default values (0.019 and 0.020). This confirms the validity of the model runs using default values.

5.5.3 LFG Generation Model Results

Model results, provided in Table 9 and Figure 10, show estimated LFG generation through 2020 for the Yale Landfill under five different projection scenarios, including the effect of adding moisture to the refuse mass. Table 9 also provides the estimated disposal rates and the k and L_0 values used for each projection. All LFG generation rates shown are adjusted to 50 percent methane content (standard normalization procedure) to reflect the typical methane content of LFG as it is generated.

Except for the projection showing the effect of adding moisture starting in 2002 (Projection 5), all projections show LFG generation reaching a peak in 1966, one year following landfill closure, and declining at a rate of 2 to 3 percent annually thereafter. LFG generation in 2002 is estimated to range between 46 and 106 standard cubic feet per minute (scfm). The highest generation rates (at least through 2006) occur under the projection that uses the site-calibrated k value and the SCS default L_0 (Projection 4), which is the highest L_0 value of any projection. The lowest generation rates occur under the site-calibrated projection (Projection 3), which uses a L_0 value (1,528 ft^3/ton) that has been discounted by 57 percent from the SCS default L_0 based on the fraction of degradable waste found in waste samples taken in the field.

Estimated LFG generation rates under the SCS default projection (Projection 2) and EPA (AP-42) default projection (Projection 1) are slightly below Projection 4, with the SCS default projection showing higher generation after 2006.

Table 9. LFG Generation Projections
Yale Landfill
Page 1 of 4

Year	Disposal Rate (tons/yr)	Refuse In-Place (tons)	LFG Generation: Projection 1 (EPA default values)		Projection 2 (SCS default values)		Projection 3 (site-calibrated values)		Projection 4 (site-calibrated k value; SCS default L_0 value)		Projection 5 (site-calibrated values with k adjustment for added moisture)	
			scfm	Mcf/day	scfm	Mcf/day	scfm	Mcf/day	scfm	Mcf/day	scfm	Mcf/day
Methane content of LFG adjusted to:			*50*		*50*		*50*		*50*		*50*	
Methane generation rate constant (k):			*0.020*		*0.019*		*0.023*		*0.023*		*0.023 and 0.030* [a]	
Ultimate methane generation rate (L_0):			*3,204* [b]		*3,550* [b]		*1,528* [b]		*3,550* [b]		*1,528* [b]	
1948	53,701	53,701	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
1949	53,701	107,402	13	0.02	14	0.02	7	0.01	16	0.02	7	0.01
1950	53,701	161,102	25	0.04	27	0.04	14	0.02	32	0.05	14	0.02
1951	53,701	214,803	38	0.05	40	0.06	21	0.03	48	0.07	21	0.03
1952	53,701	268,504	50	0.07	53	0.08	27	0.04	63	0.09	27	0.04
1953	53,701	322,205	62	0.09	65	0.09	34	0.05	78	0.11	34	0.05
1954	53,701	375,906	73	0.11	77	0.11	40	0.06	92	0.13	40	0.06
1955	53,701	429,606	85	0.12	89	0.13	46	0.07	107	0.15	46	0.07
1956	53,701	483,307	96	0.14	101	0.15	52	0.07	121	0.17	52	0.07
1957	53,701	537,008	107	0.15	113	0.16	58	0.08	134	0.19	58	0.08
1958	53,701	590,709	117	0.17	124	0.18	63	0.09	147	0.21	63	0.09
1959	53,701	644,410	128	0.18	136	0.20	69	0.10	160	0.23	69	0.10
1960	53,701	698,111	138	0.20	146	0.21	74	0.11	173	0.25	74	0.11
1961	53,701	751,811	148	0.21	157	0.23	80	0.11	185	0.27	80	0.11
1962	53,701	805,512	158	0.23	168	0.24	85	0.12	197	0.28	85	0.12
1963	53,701	859,213	168	0.24	178	0.26	90	0.13	209	0.30	90	0.13
1964	53,701	912,914	178	0.26	188	0.27	95	0.14	221	0.32	95	0.14
1965	53,701	966,615	187	0.27	198	0.29	100	0.14	232	0.33	100	0.14
1966	0	966,615	196	0.28	208	0.30	105	0.15	243	0.35	105	0.15

[a] The k value changes from 0.023 to 0.030 after 2002 to reflect the addition of moisture.
[b] Cubic feet per ton.

scfm = Standard cubic feet per minute
Mcf/day = Million cubic feet per day

Table 9. LFG Generation Projections
Yale Landfill

Year	Disposal Rate (tons/yr)	Refuse In-Place (tons)	LFG Generation: Projection 1 (EPA default values) scfm	Projection 1 Mcf/day	Projection 2 (SCS default values) scfm	Projection 2 Mcf/day	Projection 3 (site-calibrated values) scfm	Projection 3 Mcf/day	Projection 4 (site-calibrated k value; SCS default L_0 value) scfm	Projection 4 Mcf/day	Projection 5 (site-calibrated values with k adjustment for added moisture) scfm	Projection 5 Mcf/day
Methane content of LFG adjusted to:			*50*		*50*		*50*		*50*		*50*	
Methane generation rate constant (k):			*0.020*		*0.019*		*0.023*		*0.023*		*0.023 and 0.030* [a]	
Ultimate methane generation rate (L_0):			*3,204* [b]		*3,550* [b]		*1,528* [b]		*3,550* [b]		*1,528* [b]	
1967	0	966,615	192	0.28	204	0.29	102	0.15	238	0.34	102	0.15
1968	0	966,615	188	0.27	200	0.29	100	0.14	232	0.33	100	0.14
1969	0	966,615	185	0.27	197	0.28	98	0.14	227	0.33	98	0.14
1970	0	966,615	181	0.26	193	0.28	95	0.14	222	0.32	95	0.14
1971	0	966,615	177	0.26	189	0.27	93	0.13	217	0.31	93	0.13
1972	0	966,615	174	0.25	186	0.27	91	0.13	212	0.30	91	0.13
1973	0	966,615	170	0.25	182	0.26	89	0.13	207	0.30	89	0.13
1974	0	966,615	167	0.24	179	0.26	87	0.13	202	0.29	87	0.13
1975	0	966,615	164	0.24	175	0.25	85	0.12	198	0.28	85	0.12
1976	0	966,615	160	0.23	172	0.25	83	0.12	193	0.28	83	0.12
1977	0	966,615	157	0.23	169	0.24	81	0.12	189	0.27	81	0.12
1978	0	966,615	154	0.22	166	0.24	79	0.11	184	0.27	79	0.11
1979	0	966,615	151	0.22	163	0.23	78	0.11	180	0.26	78	0.11
1980	0	966,615	148	0.21	160	0.23	76	0.11	176	0.25	76	0.11
1981	0	966,615	145	0.21	157	0.23	74	0.11	172	0.25	74	0.11
1982	0	966,615	142	0.20	154	0.22	72	0.10	168	0.24	72	0.10
1983	0	966,615	139	0.20	151	0.22	71	0.10	164	0.24	71	0.10
1984	0	966,615	137	0.20	148	0.21	69	0.10	161	0.23	69	0.10
1985	0	966,615	134	0.19	145	0.21	68	0.10	157	0.23	68	0.10

[a] The k value changes from 0.023 to 0.030 after 2002 to reflect the addition of moisture.
[b] Cubic feet per ton.

scfm = Standard cubic feet per minute
Mcf/day = Million cubic feet per day

Table 9. LFG Generation Projections
Yale Landfill
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Year	Disposal Rate (tons/yr)	Refuse In-Place (tons)	LFG Generation: Projection 1 (EPA default values)		Projection 2 (SCS default values)		Projection 3 (site-calibrated values)		Projection 4 (site-calibrated k value; SCS default L_0 value)		Projection 5 (site-calibrated values with k adjustment for added moisture)	
			scfm	Mcf/day	scfm	Mcf/day	scfm	Mcf/day	scfm	Mcf/day	scfm	Mcf/day
Methane content of LFG adjusted to:			*50*		*50*		*50*		*50*		*50*	
Methane generation rate constant (k):			*0.020*		*0.019*		*0.023*		*0.023*		*0.023 and 0.030* [a]	
Ultimate methane generation rate (L_0):			*3,204* [b]		*3,550* [b]		*1,528* [b]		*3,550* [b]		*1,528* [b]	
1986	0	966,615	131	0.19	142	0.20	66	0.10	153	0.22	66	0.10
1987	0	966,615	129	0.19	140	0.20	65	0.09	150	0.22	65	0.09
1988	0	966,615	126	0.18	137	0.20	63	0.09	147	0.21	63	0.09
1989	0	966,615	124	0.18	134	0.19	62	0.09	143	0.21	62	0.09
1990	0	966,615	121	0.17	132	0.19	60	0.09	140	0.20	60	0.09
1991	0	966,615	119	0.17	129	0.19	59	0.08	137	0.20	59	0.08
1992	0	966,615	117	0.17	127	0.18	58	0.08	134	0.19	58	0.08
1993	0	966,615	114	0.16	125	0.18	56	0.08	131	0.19	56	0.08
1994	0	966,615	112	0.16	122	0.18	55	0.08	128	0.18	55	0.08
1995	0	966,615	110	0.16	120	0.17	54	0.08	125	0.18	54	0.08
1996	0	966,615	108	0.15	118	0.17	52	0.08	122	0.18	52	0.08
1997	0	966,615	105	0.15	115	0.17	51	0.07	119	0.17	51	0.07
1998	0	966,615	103	0.15	113	0.16	50	0.07	116	0.17	50	0.07
1999	0	966,615	101	0.15	111	0.16	49	0.07	114	0.16	49	0.07
2000	0	966,615	99	0.14	109	0.16	48	0.07	111	0.16	48	0.07
2001	0	966,615	97	0.14	107	0.15	47	0.07	109	0.16	47	0.07
2002	0	966,615	95	0.14	105	0.15	46	0.07	106	0.15	46	0.07
2003	0	966,615	93	0.13	103	0.15	45	0.06	104	0.15	57	0.08
2004	0	966,615	92	0.13	101	0.15	44	0.06	101	0.15	55	0.08

[a] The k value changes from 0.023 to 0.030 after 2002 to reflect the addition of moisture.
[b] Cubic feet per ton.

scfm = Standard cubic feet per minute
Mcf/day = Million cubic feet per day

Table 9. LFG Generation Projections
Yale Landfill
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Year	Disposal Rate (tons/yr)	Refuse In-Place (tons)	LFG Generation									
			Projection 1 (EPA default values)		Projection 2 (SCS default values)		Projection 3 (site-calibrated values)		Projection 4 (site-calibrated k value; SCS default L_0 value)		Projection 5 (site-calibrated values with k adjustment for added moisture)	
			scfm	Mcf/day	scfm	Mcf/day	scfm	Mcf/day	scfm	Mcf/day	scfm	Mcf/day
Methane content of LFG adjusted to:			*50*		*50*		*50*		*50*		*50*	
Methane generation rate constant (k):			*0.020*		*0.019*		*0.023*		*0.023*		*0.023 and 0.030* [a]	
Ultimate methane generation rate (L_0):			*3,204* [b]		*3,550* [b]		*1,528* [b]		*3,550* [b]		*1,528* [b]	
2005	0	966,615	90	0.13	99	0.14	43	0.06	99	0.14	53	0.08
2006	0	966,615	88	0.13	97	0.14	42	0.06	97	0.14	52	0.07
2007	0	966,615	86	0.12	96	0.14	41	0.06	95	0.14	50	0.07
2008	0	966,615	85	0.12	94	0.13	40	0.06	93	0.13	49	0.07
2009	0	966,615	83	0.12	92	0.13	39	0.06	90	0.13	47	0.07
2010	0	966,615	81	0.12	90	0.13	38	0.05	88	0.13	46	0.07
2011	0	966,615	80	0.11	89	0.13	37	0.05	86	0.12	45	0.06
2012	0	966,615	78	0.11	87	0.13	36	0.05	84	0.12	43	0.06
2013	0	966,615	77	0.11	85	0.12	35	0.05	82	0.12	42	0.06
2014	0	966,615	75	0.11	84	0.12	35	0.05	81	0.12	41	0.06
2015	0	966,615	74	0.11	82	0.12	34	0.05	79	0.11	40	0.06
2016	0	966,615	72	0.10	80	0.12	33	0.05	77	0.11	38	0.06
2017	0	966,615	71	0.10	79	0.11	32	0.05	75	0.11	37	0.05
2018	0	966,615	69	0.10	77	0.11	32	0.05	74	0.11	36	0.05
2019	0	966,615	68	0.10	76	0.11	31	0.04	72	0.10	35	0.05
2020	0	966,615	67	0.10	75	0.11	30	0.04	70	0.10	34	0.05

[a] The k value changes from 0.023 to 0.030 after 2002 to reflect the addition of moisture.
[b] Cubic feet per ton.

scfm = Standard cubic feet per minute
Mcf/day = Million cubic feet per day

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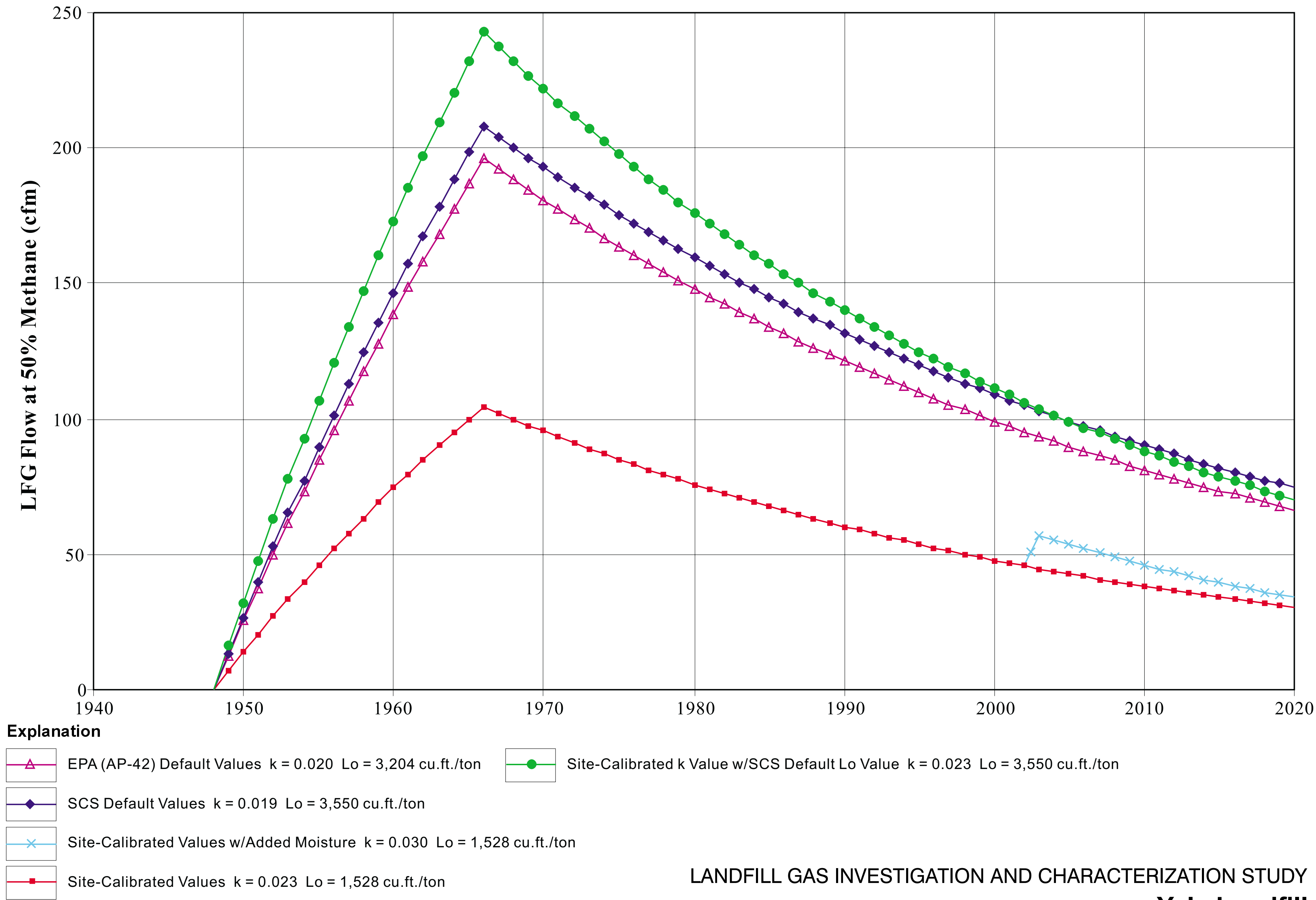

Source: SCS Engineers

LANDFILL GAS INVESTIGATION AND CHARACTERIZATION STUDY

Yale Landfill
LFG Generation Projection

Daniel B. Stephens & Associates, Inc.
3-28-02 JN 9398

Figure 10

Projection 5 is a modified (moisture added) site-calibrated projection that uses the site-calibrated k and L_0 values through 2002, but which increases the k value to 0.030 for generation after 2002 to reflect the effect of adding moisture to the refuse mass. This projection shows LFG generation increasing from 46 scfm in 2002 to 57 scfm in 2003, the first year that the effects of added moisture are reflected in the model results. LFG generation is projected to decline at 3 percent annually after 2003 under the added moisture scenario (Projection 5).

6. Conclusions and Recommendations

The landfill gas investigation and characterization study was conducted with the primary goal of providing new information to determine appropriate measures to address LFG issues related to the use of properties on and within close proximity to the former landfills. The following conclusions and recommendations related to the Yale Landfill have been made based on available information and the data collected during this investigation. Though it is impossible to precisely predict future LFG generation and migration, careful analysis of data can provide a tool for making an educated prediction of future LFG behavior. These assumptions of future LFG behavior combined with past LFG experience have allowed us to determine the possible effects of LFG on current and future development at and near the former landfills.

This report makes a number of recommendations as to actions that should be taken by the City. These recommendations are worded in terms of actions that should be taken by the City because the City is the party that requested recommendations. It is the City that has taken the lead in dealing with landfill gas problems. This report takes no position on whether it is properly the City's role or responsibility to deal with the concerns raised by these recommendations.

6.1 Conclusions

Based on the data and analysis discussed, the following conclusions can be made regarding LFG generation at the Yale Landfill:

- Based on the modeling results, the peak year for LFG generation at the Yale Landfill was 1966.

- The estimated LFG generation rate for the Yale Landfill indicates that the production of LFG is steadily declining in its current state. The projected LFG generation rate for 2002 for the Yale Landfill ranges from 46 to 106 scfm.

- Due to the LFG concentrations measured and the LFG generation rate predicted for the Yale Landfill, the potential for significant volumes of LFG to migrate off-site is moderate.

- VOCs were detected in LFG gas samples collected at the Yale Landfill; however, at this time insufficient data exist to form conclusions concerning potential impacts to public health.

6.2 Recommendations

Based on the data and analyses discussed, the following recommendations are provided to address LFG issues relevant to the Yale Landfill.

6.2.1 Buffer Zone Reduction

The basic requirements of the City's *Interim Guidelines for Development within 1,000 feet of Landfills* should remain in place; however, the buffer zone distance could be reduced contingent on implementing a LFG monitoring plan, as described below.

- *LFG monitoring plan.* The City should consider developing a LFG monitoring plan for the Yale Landfill to assess potential off-site migration of LFG. The plan should address the following:

  – *Installation of perimeter LFG monitoring probes.* These probes should be installed outside the waste disposal areas to confirm the limits of LFG migration. The probes should extend at least 10 feet below the depth of waste, or to approximately 30 to 40 feet bgs (typical). The monitoring probes should be spaced at approximately 250- to 500-foot intervals to form a monitoring perimeter that verifies the limits of LFG migration. Closer spacing of probes is needed near areas of existing and future development, while wider spacing is appropriate for areas planned as open space. Suitable and accessible locations for the monitoring probes will need to be identified. The final number, spacing, and locations of monitoring probes will need to be determined during development of the LFG monitoring plan. Particular consideration is needed near the Wyndham Hotel and near airport facilities.

- *Quarterly monitoring*. The perimeter monitoring probes and selected subsurface utility vaults should be monitored for methane gas on a quarterly basis for at least two consecutive years The utility investigation recommended in Section 6.2.2 should specify which subsurface utility vaults will be monitored on a regular basis. If methane gas is not detected during the two years of monitoring, the frequency may be reduced to once every six months.

- *Change in frequency of monitoring.* If methane gas is detected at any time exceeding 25 percent of the LEL in selected subsurface utility vaults or 50 percent of the LEL in perimeter LFG monitoring probes, the frequency of monitoring should be increased to monthly for at least six months. Subsequently, if the methane gas content stays below these limits for six months of monthly monitoring, the frequency can be decreased to quarterly.

- *Long-term monitoring and care.* Monitoring of perimeter probes and selected subsurface utility vaults should continue indefinitely, because LFG conditions in and around the landfill can change and may be affected by future development.

• *Development of property outside landfill perimeter.* Based on the results of the LFG investigation and characterization study, changes are recommended for the Yale Landfill in the City's Interim Guidelines.

- *Reduction of setbacks.* Assuming monitoring of the perimeter probes and selected utility vaults continues to verify that no methane gas is present after the initial two-year period, the setback distance from the property boundary could be decreased to 500 feet for determination of applicability of the Interim Guidelines. The recommended setback reduction is contingent on the results of continued LFG monitoring. The detection of methane above 25 percent of the LEL in selected utility vaults or above 50 percent of the LEL in any perimeter monitoring probe will result in this recommendation being rescinded and a return to a greater setback distance.

Maintaining a minimum 500-foot setback is recommended, because of the existing high methane concentrations and a predicted LFG generation rate that will remain elevated for many years. These conditions will continue to pose a potential risk, and the City may still consider some design, monitoring, and/or LFG abatement measures suitable under the Interim Guidelines. Examples of requirements that could be needed, even with a setback distance from the landfill, include directing storm water away from the landfill, sealing off subgrade utilities to prevent possible LFG migration, installation of subsurface venting systems beneath structures, and/or installing interior monitors in buildings (particularly in basements). Any requirements will depend on the site-specific development plans.

- *Monitoring conditions for reduction of setbacks.* The recommended setback distance reduction is contingent on the results of continued LFG monitoring. The detection of methane above 25 percent of the LEL in selected utility vaults or above 50 percent of LEL in any perimeter monitoring probe will result in this recommendation being rescinded and reinstatement of a setback distance of 1,000 feet (or other setback distance appropriate for the conditions observed).

6.2.2 Landfill Management Plan

The City should consider developing a comprehensive landfill management plan for the Yale Landfill, to address several items that play a significant role in reducing LFG generation and preventing adverse LFG impacts. The LFG monitoring plan, described above, is a component of the overall landfill management plan. The landfill management plan should include the recommended components described below.

- *LFG control plan.* If the methane content exceeds 25 percent of the LEL in selected subsurface utility vaults or 50 percent of the LEL in perimeter monitoring probes, the City should consider developing a LFG control plan. If the methane content exceeds the specified limits for three consecutive months, the City should immediately develop and implement a LFG control plan. The LFG control plan should consist of either passive or active LFG control systems capable of reducing the methane content to levels protective of public health and safety.

The Yale Landfill has existing development near waste disposal areas where methane levels were measured above 100 percent of the LEL. In response, a LFG control plan may be needed immediately, should implementation of the LFG monitoring plan reveal public health and safety threats due to elevated methane levels. Decisions on implementing a LFG control plan will need to consider the specific site conditions and potential threats to determine appropriate actions.

- *Utility investigation.* Selected subsurface utilities should be monitored for the presence of LFG and included with the quarterly monitoring program discussed above. Utilities should be investigated on and around the Yale Landfill to determine if existing utility corridors pose a risk by acting as conduits for the migration of LFG. Utility locations should be examined to the fullest extent possible, using all available records and possible on-site investigation. A utility monitoring plan should be developed to select utility monitoring locations where LFG may be detected and monitoring can minimize the risk for utility conduits to transmit LFG. As long as methane concentrations remain below 25 percent of LEL in selected subsurface utilities, no further utility investigation is needed. However, if methane concentrations increase above 25 percent of LEL, additional investigation of utilities should commence.

- *Development of landfill property*. If development occurs on the Yale Landfill, the developer should meet all applicable requirements of the City's Interim Guidelines. If development occurs on the landfill that may increase the potential for off-site LFG migration by sealing the landfill cover surface (e.g. buildings, paved parking areas, and densely vegetated areas), the perimeter probe monitoring frequency may need to be increased and/or additional monitoring probes added.

- *Drainage control.* The existing drainage at the Yale Landfill provides positive drainage over most of the site, but significant storm water channels exist that collect runoff, particularly on the southern fill area. This storm water may contribute to LFG generation that has caused the elevated methane concentrations observed. It is recommended that the City undertake a site drainage study to determine existing drainage patterns and identify possible improvements.

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