HUMAN HEALTH RISK ASSESSMENT FOR THE GRAND CENTRAL SANITARY LANDFILL PLAINFIELD TOWNSHIP, NORTHAMPTON COUNTY, PENNSYLVANIA

Prepared by:

CPF Associates, Inc.
Takoma Park, Maryland

EarthRes Group, Inc.
Pipersville, Pennsylvania

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LIST OF ACRONYMS

AEGL	USEPA acute exposure guideline level
ATSDR	Agency for Toxic Substances and Disease Registry
CALEPA	California Environmental Protection Agency
ERG	EarthRes Group, Inc.
ERPG	emergency response planning guideline
GCSL	Grand Central Sanitary Landfill
HEAST	USEPA Health Effects Assessment Summary Tables
IRIS	USEPA Integrated Risk Information System
ISCST	Industrial Source Complex Short-Term air model
MSW	Municipal solid waste
NAAQS	National Ambient Air Quality Standard
NWS	National Weather Service
OSHA	Occupational Safety and Health Administration
PADEP	Pennsylvania Department of Environmental Protection
PM10	Particulate matter less than 10 microns in diameter
PM2.5	Particulate matter less than 2.5 microns in diameter
REL	Acute inhalation reference exposure level
RfD	Non-cancer reference dose
SCAPA	Subcommittee on Consequence Assessment and Protective Actions
TEEL	Temporary emergency exposure limit
TSP	Total suspended particulate matter
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WHO	World Health Organization
WM	Waste Management, Inc.

HUMAN HEALTH RISK ASSESSMENT FOR THE GRAND CENTRAL LANDFILL IN PLAINFIELD TOWNSHIP, NORTHAMPTON COUNTY, PENNSYLVANIA

EXECUTIVE SUMMARY

Introduction

This report presents the results of a human health risk assessment for the Grand Central Sanitary Landfill (GCSL) in Plainfield Township, Northampton County, Pennsylvania. The risk assessment was performed to respond to community concerns that have been raised about potential health effects associated with landfill gases and dust. The team of scientists and engineers retained by Waste Management to perform the risk assessment consisted of CPF Associates, Inc., EarthRes Group, Inc. (ERG) and Trinity Consultants.

The risk assessment was conducted according to a May 2003 risk assessment protocol that was reviewed and approved by an independent third party, Dr. Arthur Frank, a professor of Environmental and Occupational Health at Drexel University in Philadelphia who was recommended by the Pennsylvania Department of Health. The protocol was presented to the public at a press conference held in Plainfield Township in April 2003.

Site Setting

The GCSL is located on a 516.7-acre tract of land which includes a municipal solid waste (MSW) landfill, a stone crushing operation, and a landfill gas-to-energy electric generating plant. These three operations are owned by separate entities and operate under permits issued by the Pennsylvania Department of Environmental Protection (PADEP). The MSW landfill at GCSL consists of two separate disposal areas that encompass roughly 139 acres. The 52-acre original landfill began accepting waste in the 1950's, was closed in 1991 and completely capped by 1993. The 87-acre more recent landfill, also referred to as the Northern Expansion, began accepting waste in 1991 and is currently permitted to accept waste until 2007.

Landfill gas is generated at all MSW landfills as a by-product of biodegradation of the waste. Landfill gas at GCSL is collected through a system of underground perforated pipes. The gas is used to generate electricity in a plant owned by the Green Knights Economic Development Corporation and is also treated in two enclosed flares. The flares and power plant effectively destroy organic compounds and methane present in landfill gas.

Dust control measures taken at GCSL include regular road sweeping of parking areas, the paved landfill access roadways from the public highway to the landfill and other haul roads inside the landfill. Water is regularly applied to road surfaces to reduce fugitive dusts.

Risk Assessment of Landfill Gas

The risk assessment included an evaluation of the potential long-term and short-term human health risks associated with inhalation of landfill gas emissions in nearby areas. The landfill gas risk assessment followed human health risk assessment methods and guidance that are well-established by both the U.S. Environmental Protection Agency (USEPA) and the U.S. National Academy of Sciences.

Potential inhalation risks were evaluated for 39 chemicals that were detected in GCSL landfill gas samples. Inhalation exposures were calculated by developing emission rates for each compound from the landfill, calculating air concentrations beyond the GCSL property boundary and then determining the magnitude of possible exposures due to inhalation in nearby areas. The emission sources included the landfill surface areas, the gas-to-energy facility and the enclosed flare stacks. Chemical concentrations in air were calculated in three nearby areas surrounding the Waste Management property; these three areas are representative of the areas where concentrations were predicted to be highest. Exposures in these areas were calculated using USEPA recommended exposure parameters for adults and children.

Chronic long-term risks were calculated by combining the exposure estimates for each compound in each area with human health toxicity criteria. The toxicity criteria were compiled for each of the 39 compounds from federal and state regulatory agency and research institution databases. Both cancer risks and the potential for non-cancer effects were calculated for each hypothetical adult and child receptor. The landfill gas risk assessment results were all below the Pennsylvania State target risk levels, as described below:

- Excess lifetime cancer risks from long-term inhalation exposure to landfill gas in areas near GCSL were well below regulatory target cancer risk levels. Excess lifetime cancer risks reflect the upper bound probability that an individual may develop cancer over a 70-year lifetime due to the assumed exposure conditions. The target cancer risk level commonly used by PADEP is one in one hundred thousand (1 in 100,000 or $1x10^{-5}$). This means that an individual could have, at most, a 1 in 100,000 chance of developing cancer over a 70-year lifetime under the evaluated exposure conditions. In comparison, each person in the U.S. has a background risk of developing cancer over a lifetime of about one in three. The excess lifetime cancer risks due to inhalation exposure to GCSL landfill gas ranged from one in ten million (1 in 10,000,000 or $1x10^{-7}$) to one in one million (1 in 1,000,000 or $1x10^{-6}$). These results were 10-100 times lower than the one in one hundred thousand ($1x10^{-5}$) Pennsylvania State target cancer risk level.

- Non-cancer health effects are not expected to occur from long-term inhalation exposure to landfill gas emissions in areas near the GCSL. The non-cancer hazard index values (conservatively summed across all compounds regardless of type of health effect) ranged from 0.01 to 0.1. These values were 10-100 times below the Pennsylvania State target level of one.

- Short-term health effects are not expected to occur in areas near the GCSL as a result of exposure to landfill gas emissions. The calculated short-term air concentrations were 10 to more than 70 million times below the corresponding acute reference inhalation criteria.

Risk Evaluation of Particulate Matter

The risk assessment also included an evaluation of particulate matter (dust) levels in air around the GCSL property boundary. Particulate matter (PM) is the term used for particles found in the air which are emitted from many manmade and natural sources or are formed from other compounds in the air.

Three PM size categories were addressed in the risk assessment: TSP which is total suspended particulate matter, PM10 which refers to particles less than 10 microns (10 μm) in diameter, and PM2.5 which refers to particles less than 2.5 μm in diameter. TSP is predominantly formed from materials in the earth's crust (e.g., soil) that are suspended due to erosion or human activities such as driving on paved or unpaved roads. PM10 and PM2.5 are more relevant to human health because they can be inhaled into the lungs. Particles between 2.5 μm and 10 μm in diameter generally result from dust from paved and unpaved roads, tire and asphalt wear, and crushing or grinding operations. PM2.5 sources include fuel combustion (emissions from cars, trucks, buses), power plants, residential fireplaces and wood stoves, and gas compounds in the air that react to form fine particles. Larger particles, particularly TSP, deposit on the ground more rapidly than small particles such as PM2.5, and they are more likely to reflect impacts from local sources. PM2.5 particles stay airborne for longer times and are more likely to reflect regional rather than local sources.

Regulatory and public health agencies have developed standards and criteria for exposure to PM. These include USEPA's national ambient air quality standards (NAAQS) for PM2.5 and PM10, USEPA's PM2.5 and PM10 concentrations used in air quality index determinations, USEPA's 1971 NAAQS for TSP, and the Occupational Safety and Health Administration 8-hour average permissible exposure limit for dust in the workplace. Measured PM levels in air from counties in the GCSL region and in the U.S. are also available.

Two monitoring studies were conducted for this assessment. Instantaneous monitoring for TSP was conducted at many locations around the perimeter of the GCSL property boundary and at a few off-site locations between October 2002 and June 2003. This was followed by longer-term (24 hour) PM10 and PM2.5 monitoring at four sampling locations on or within the GCSL property boundary in June and July 2003.

An evaluation of the instantaneous TSP data showed that vehicle traffic (e.g., along the landfill vehicle access road as well as other roads) and the date of sampling were the most important factors affecting the measured concentrations, rather than wind direction. The TSP measurements collected at sampling locations within the Borough of Pen Argyl were not substantially different from one another regardless of distance from the landfill. The average TSP levels at the GCSL property boundary and at the Pen Argyl locations were lower than TSP levels in U.S. metropolitan areas, the 1971 NAAQS and the workplace dust limit.

An evaluation of the PM10 and PM2.5 monitoring results yielded the following conclusions:

- The PM10 concentrations were predominantly from local sources. There was a relationship between PM10 concentrations and proximity to roads, but no consistent pattern with respect to wind direction.

- The PM2.5 concentrations were predominantly from regional sources rather than local sources or landfill-related activities. The PM2.5 levels did not vary substantially between the four sampling stations; this similarity of concentrations indicated that proximity to roads and wind direction were not critical factors affecting the measurements.

- The PM10 concentrations were below regulatory standards and criteria. The PM10 concentrations at all sampling locations were below the PM10 NAAQS and were similar to measurements available from USEPA sampling stations in the region. According to USEPA's air quality index classification, the PM10 measurements would not be of concern to the general public or sensitive individuals.

- The PM2.5 concentrations were below regulatory standards and criteria for the general public and also, with the exception of measurements on one sampling day, for sensitive individuals. The PM2.5 concentrations at all sampling locations were below the PM2.5 NAAQS and were similar to measurements available from USEPA sampling stations in the region. According to USEPA's air quality index classification, the PM2.5 measurements collected on or within the property boundary would not be of concern to the general public and, except for one sampling day, also not of concern to sensitive individuals. The PM2.5 concentrations on one sampling day were at or just above the level at which USEPA recommends that people with respiratory or heart disease, and the elderly and active children, should limit outdoor exertion. The concentrations across the four monitoring sites on this sampling day did not vary markedly, however, indicating a predominantly regional impact on air quality rather than a local source of particulate matter.

All risk assessments involve the use of assumptions, judgment and incomplete data to varying degrees. This results in uncertainty in the final estimates of risk. Overall, the combination of assumptions and methods used in this risk assessment were considered more likely to overestimate than underestimate risks. For example, the calculated chemical emission rates from the landfill surface are likely to overestimate actual emissions and, therefore, also overestimate potential risks.

In conclusion, the risk assessment showed that potential inhalation exposures to landfill gas near the Grand Central Landfill were below regulatory and other target risk levels for both chronic long-term and acute short-term human health effects. Particulate matter levels at the landfill property boundary were below regulatory standards and criteria and would not be of concern to the general public.

INTRODUCTION

This report presents a human health risk assessment for the Grand Central Sanitary Landfill (GCSL) in Plainfield Township, Northampton County, Pennsylvania. The risk assessment was performed to respond to community concerns that have been raised about potential health effects associated with the landfill. Specifically, the risk assessment addresses possible health concerns related to landfill gases and dusts. The risk assessment evaluates the potential public health risks to surrounding communities due to landfill gases and dust that may be associated with current landfill operations.

Waste Management requested that a team of scientists and engineers with expertise in risk assessment, environmental engineering and air dispersion modeling perform the risk assessment work. CPF Associates, Inc. performed the health risk evaluations for both landfill gas and dust. CPF is a Washington, D.C.-based scientific and health consulting firm with expertise in performing environmental health evaluations for a variety of different types of waste treatment technologies, including landfills. Key technical information regarding landfill gas composition and emissions was provided by EarthRes Group, Inc. (ERG). In addition, ERG conducted ambient particulate matter monitoring efforts at the landfill. ERG is a full-service environmental engineering firm that specializes in providing design and environmental services to the solid waste industry. ERG has been the primary environmental consultant to GCSL since 1995, and ERG personnel have been active in environmental affairs at the site for over 20 years. Trinity Consultants, a nationally recognized air dispersion modeling firm, performed site-specific air dispersion modeling for this assessment. Biographies of the study participants are provided in Appendix A.

This risk assessment was performed following the approach presented in a risk assessment protocol developed for this project (see Appendix B). A draft risk assessment protocol, dated April 4, 2003, outlined the proposed approach for performance of the risk assessment for the landfill. This protocol was discussed with local representatives and the media at a press conference in Plainfield Township on April 10, 2003. The protocol was also reviewed by an independent third party, Dr. Arthur Frank, a professor of Environmental and Occupational Health at Drexel University in Philadelphia. Dr. Frank was recommended as an independent reviewer by the Pennsylvania Department of Health. Dr. Frank completed his review of the protocol on May 14, 2003 and did not recommend changes to the proposed approach (see Appendix C). However, in response to information received from the Borough of Pen Argyl in early April, the protocol was expanded to include evaluation of the potential for acute health risks, in addition to chronic health risks. The protocol was finalized on May 15, 2003.

SITE SETTING

The Grand Central Sanitary Landfill (GCSL) is located in Plainfield Township, Northampton County, Pennsylvania (Figure 1). The site is located in Northampton County's Slate Belt Region which runs along the northern edge of the Lehigh Valley. GCSL occupies land that in the last century was historically disturbed by slate mining activities. Landfill operations have and continue to include the clean-up of old slate spoil piles and the backfilling of old open slate quarries with material from the slate spoil piles and native rock. The general landscape in abutting areas is comprised of rolling hills, farmland and woodland, with both residential and industrial development. Northampton County, with a population of 267,066 (based on the 2000 U.S. Census) is comprised of many townships and boroughs. The boroughs located closest to the landfill include Pen Argyl and Wind Gap (with populations of 3,615, and 2,812, respectively, based on the 2000 U.S. Census).

The GCSL is located on a 516.7-acre tract of land which includes a municipal solid waste landfill, a stone crushing operation[1], and a landfill gas-to-energy electric generating plant. All three operations are owned by separate entities and operate under permits issued by the Pennsylvania Department of Environmental Protection (PADEP).

The municipal solid waste landfill at GCSL consists of two separate disposal areas that encompass roughly 139 acres (Figure 2). The 52-acre original landfill (referred to as Area A on Figure 2) began accepting waste in the 1950's, was closed in 1991 and completely capped by 1993. The 87-acre more recent landfill, also referred to as the Northern Expansion (Areas B and C on Figure 2), began accepting waste in 1991 and is currently permitted and projected to accept waste until 2007. A portion of the Northern Expansion has been filled and is capped (approximately 39 acres as of 2003). Another portion is currently used for municipal solid waste disposal activities (approximately 43 acres as of 2003). USA Waste Services assumed ownership of the landfill in the spring of 1996. In the summer of 1998, Waste Management, Inc. assumed ownership of the landfill when it merged with USA Waste Services.

Landfill gas is generated as a by-product of biodegradation of the waste within all landfills. Landfill gas at GCSL is controlled and collected through an extensive system of vertical and horizontal underground perforated pipes. The gas collection system is monitored and adjusted daily, and subsurface landfill gas probes are monitored weekly, to protect against possible gas migration. Methane gas readings are also collected at least quarterly at the landfill surface as required by federal regulation.[2] The gas collection piping system is connected to a 9.9 MW gas-to-energy plant within the GCSL property boundary (owned by the Green Knights Economic Development Corporation). Gas from the landfill is directed through the pipes to the gas-to-energy plant which uses three turbines to produce electricity from the combusted landfill gas. There are also two enclosed flare facilities at the landfill which are connected to the gas collection piping system and are used if the landfill gas

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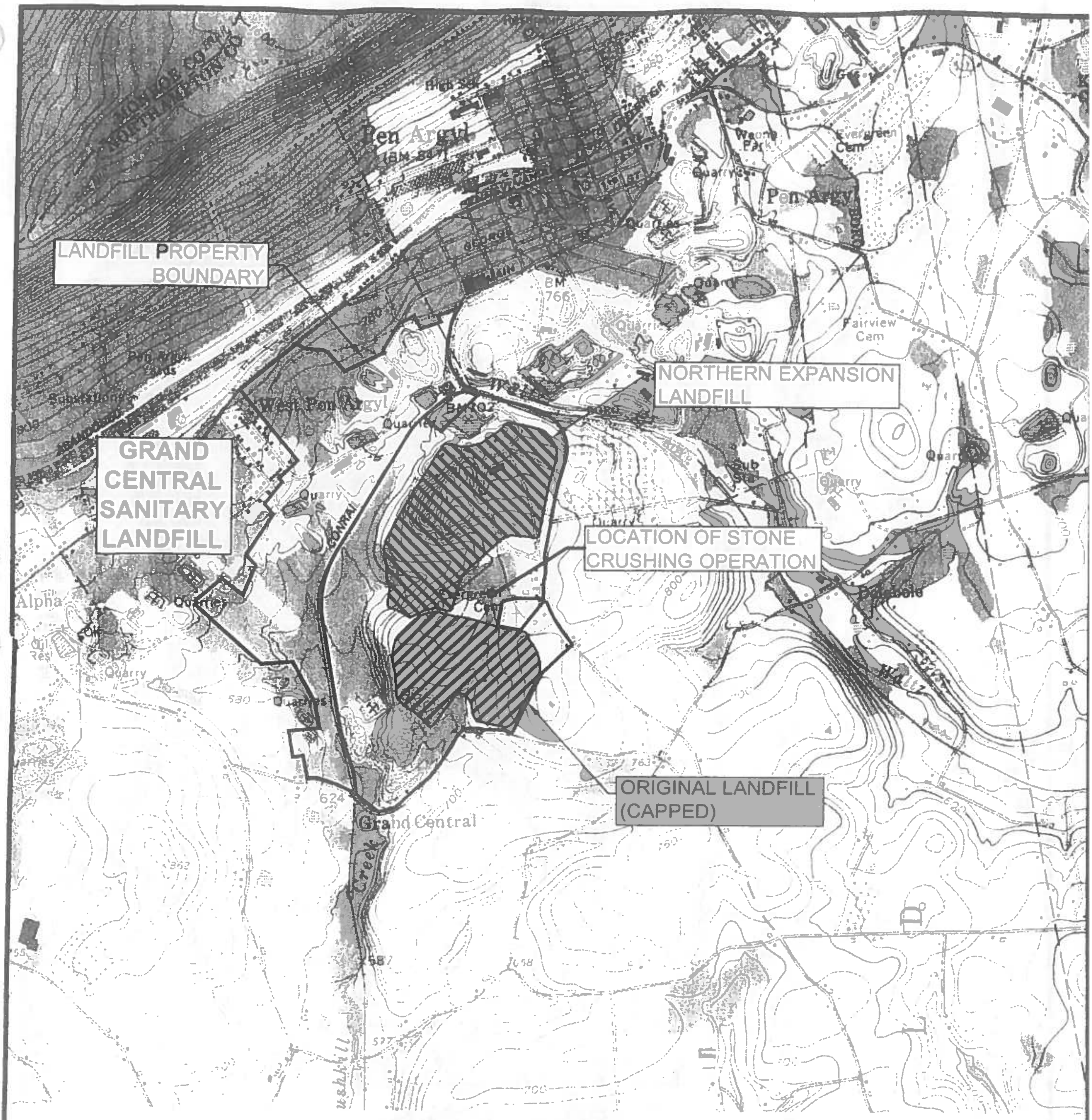
[1] The rock crushing plant located within the landfill property boundary is owned by NAPA Development Corporation, Inc. The crushed rock, which is obtained from the landfill property, is used on site.

[2] 40 CFR Chapter 1 Part 60 Subpart WWW.



GRAND CENTRAL SANITARY LANDFILL
PLAINFIELD TOWNSHIP, NORTHAMPTON COUNTY
PENNSYLVANIA

SOURCE: USGS 7.5 MINUTE QUADRANGLES - WIND GAP AND BANGOR, PA

ENVIRONMENTAL ENGINEERING *and* SCIENCE

ERG
EARTHRES GROUP

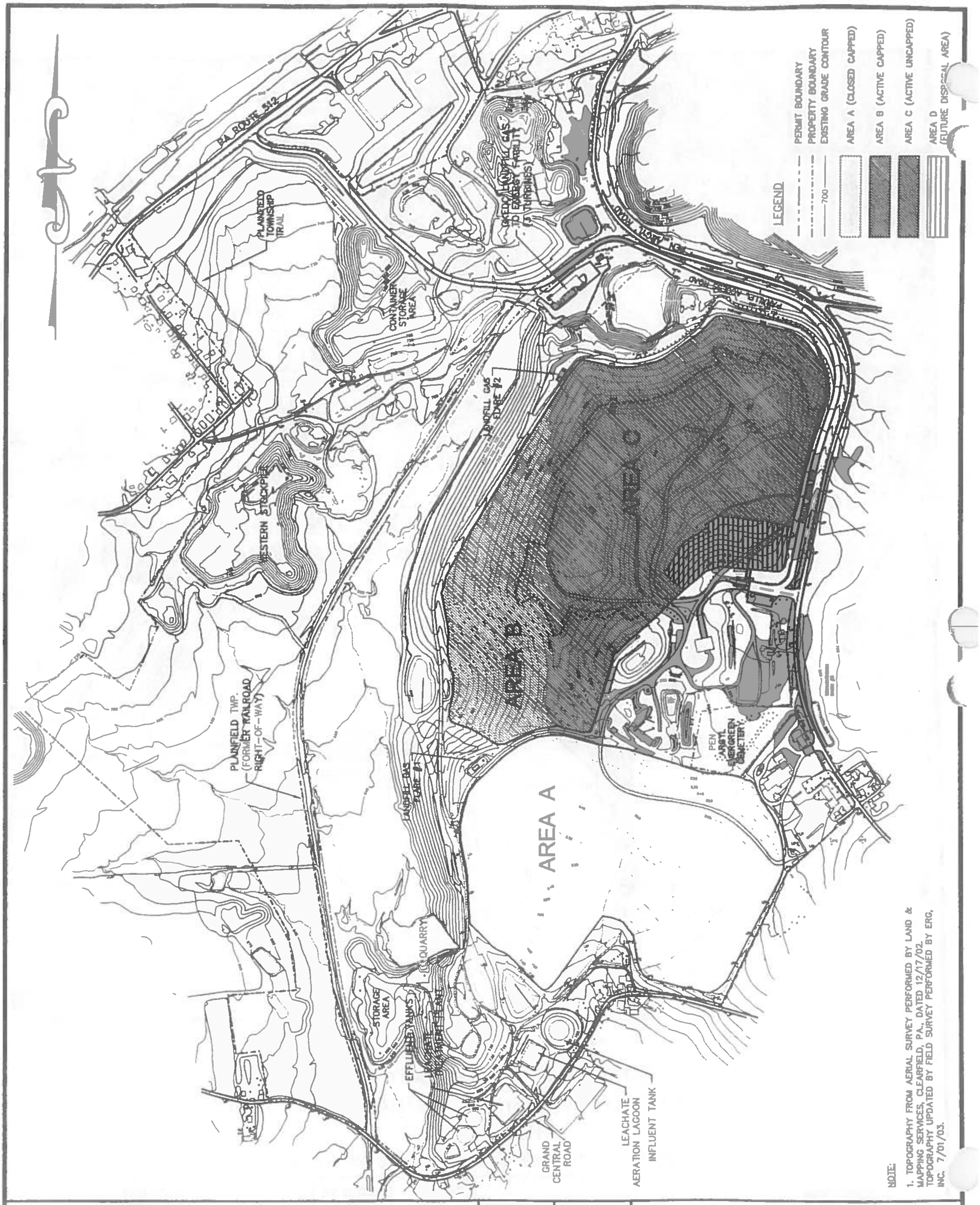
EarthRes Group, Inc.
P.O. Box 468
7137 Old Easton Road
Pipersville, PA 18947 USA
www.earthres.com
215-766-1211

DRAWN BY:	CHECKED BY:
JJB	JCH
DATE: 09/24/03	PROJECT NO: 951001.078
DRAWING SCALE: 1" = 2000'	

FIGURE 1
SITE LOCATION PLAN

GRAND CENTRAL SANITARY LANDFILL, INC.
FACILITY I.D. 100265
PLAINFIELD TOWNSHIP, NORTHAMPTON COUNTY, PA

Figure 2



NOTE:

1. TOPOGRAPHY FROM AERIAL SURVEY PERFORMED BY LAND & MAPPING SERVICES, CLEARFIELD, PA., DATED 12/17/02. TOPOGRAPHY UPDATED BY FIELD SURVEY PERFORMED BY ERG, INC. 7/01/03.

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EARTHRES GROUP

ENVIRONMENTAL ENGINEERING *and* SCIENCE

EarthRes Group, Inc.
P.O. Box 468
7137 Old Easton Road
Pipersville, PA 18947 USA
www.earthres.com
215-766-1211

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2003 SITE BOUNDARY
AND LANDFILL AREAS

HEALTH RISK ASSESSMENT
GRAND CENTRAL SANITARY LANDFILL, INC.
FACILITY I.D. 100265
PLAINFIELD TOWNSHIP, NORTHAMPTON COUNTY, PA

production exceeds the capacity of the gas-to-energy plant.[3] The flares and power plant effectively destroy organic compounds and methane present in landfill gas.

The power plant generates enough electricity to supply roughly 8,000 homes daily. Currently, gas is preferentially directed to the power plant in order to generate electricity. If the amount of landfill gas generated in the landfill exceeds the capacity of the power plant, the excess landfill gas is directed to either or both enclosed flares #1 and #2. Typically, the amount of landfill gas generated can be handled by the gas generation plant and one of the two enclosed flares.

Dust control measures taken at GCSL include road sweeping and watering to reduce generation of fugitive dusts. The paved landfill access road, Pen Argyl Road and internal paved and unpaved active landfill roads are sprayed with water at least once per hour (typically twice). A sweeper truck operates full-time to sweep Waste Management's landfill access road, parts of Pen Argyl Road, and parts of Route 512. An additional sweeper truck is used once a week (twice during the winter) to sweep parts of Route 512 and Pen Argyl Road. Water trucks and an effluent recirculation tanker[4] are also used to control dust from the daily cover placed on active landfill areas and on the active working area when waste is being placed in the landfill.

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[3] The emission controls on the gas-to-energy plant and the enclosed flares are state-of-the-art and meet or exceed applicable federal and state regulations. Federal requirements are addressed in Subpart WWW -- Standards of Performance for Municipal Solid Waste Landfills (40 CFR Chapter 1 Part 60 Subpart WWW). The Commonwealth of Pennsylvania requires installation and use of "Best Available Technology" to control emissions, as codified in 25 Pa. Code §121, 25 Pa. Code §127.12(a)(5) et al.

[4] The tanker uses treated water from the landfill's wastewater treatment plant. Use of treated water from the wastewater treatment plant for dust control in active landfill areas is permitted by PADEP.

RISK ASSESSMENT OF LANDFILL GAS

This section of the risk assessment presents an evaluation of the potential long-term and short-term human health risks associated with inhalation of landfill gas emissions in the nearby surrounding community. Potential chronic (long-term) excess lifetime cancer risks and the potential for chronic non-cancer health effects were evaluated for nearby areas around the landfill. The potential for short-term irritant effects from landfill gas was also evaluated for nearby areas around the landfill.

The landfill gas risk assessment conforms to general human health risk assessment methods that are well-established by both the U.S. Environmental Protection Agency (USEPA) and the U.S. National Academy of Sciences. The key steps in this process, which are briefly discussed below, consist of:

- Hazard Identification,
- Exposure Assessment,
- Risk Characterization, and
- Discussion of Uncertainties.

The risk assessment was based on USEPA guidance documents. These guidance documents included USEPA's *Risk Assessment Guidance for Superfund* (USEPA 1989), USEPA's *Guidelines for Exposure Assessment* (USEPA 1992), and USEPA's *Draft Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (USEPA 1998a).

The remainder of this section describes how each step of the landfill gas risk assessment was performed and presents the results of this evaluation. This includes a description of the methods used to calculate environmental concentrations, exposures and potential risks associated with landfill gas emissions.

HAZARD IDENTIFICATION

The first step in the risk assessment is the Hazard Identification, which involves the identification of landfill gas compounds that will be addressed in the risk assessment, as well as toxicity data for these landfill gas constituents.

Landfill Gas Composition

Landfill gas is generated as a by-product of biodegradation of the waste within a landfill. The amount of landfill gas generated depends on many factors including the type and amount of waste present in the landfill, the age of the waste, and environmental characteristics inside the landfill (e.g., oxygen content, moisture content, pH, and temperature). Typical landfill gas is composed of about 50% methane and 50% carbon dioxide with small amounts of other compounds. Generally, less than 1% of landfill gas (by volume) is made up of non-methane organic compounds.

The landfill gas composition at Grand Central Landfill has been determined from samples collected at the inlet piping to the two enclosed flares. Data were available for volatile organic compounds from a 1999 test (ERG 1999) and for sulfur compounds from a 2003 test (ERG 2003). The landfill gas samples were analyzed for 60 volatile organic compounds and 20 sulfur compounds. Quantifiable concentrations were observed in at least one of the available landfill gas samples for 33 of the volatile organic compounds and six of the sulfur compounds. All of the 39 detected compounds were quantitatively evaluated in this risk assessment.

For each of the 39 detected compounds, the average concentration from the flare inlet sampling data was calculated. These averages were weighted based on the flow rates of landfill gas going to each flare unit during the 1999 or 2003 tests. For compounds detected in only one of the samples, but not detected in other samples, the concentration for the nondetect results were set at one-half the reported detection limit; this is a commonly used method for evaluating environmental sampling measurements. The resulting landfill gas concentrations, shown in Table 1, are estimates of the average landfill gas concentrations based on the inlet piping data collected in the 1999 and 2003 monitoring efforts.

The concentrations of compounds measured in the inlet piping reflect levels that are present deep within the body of the landfill. These concentrations do not, however, reflect processes that attenuate (i.e., diminish) the release of compounds from the landfill surface, such as oxidation and the effect of cover materials (Bogner et al. 2003, Scheutz et al. 2003, Kjeldsen et al. 1997). As a result, emission rates from the landfill surface that are calculated directly from the inlet piping data are likely to be overestimated.

Toxicity Criteria for Landfill Gas Constituents

The next step in the Hazard Identification is compilation of chronic (long-term) and acute (short-term) toxicity criteria for each compound that was evaluated in this risk assessment.

The toxicity data used to evaluate chronic, long-term risks includes cancer slope factors for predicting excess lifetime cancer risks and reference doses (RfDs) for predicting the potential for long-term non-cancer effects. Chronic toxicity data for both cancer and non-cancer effects for each chemical were obtained from a variety of regulatory agency and research institution databases. These sources of data included USEPA's Integrated Risk Information System (IRIS), USEPA's Health Effects Assessment Summary Tables (HEAST), the Agency for Toxic Substances and Disease Registry (ATSDR) minimum risk levels, and the USEPA Region III Risk-Based Concentration Table. Table 2 provides the chronic toxicity criteria used in this risk assessment.

These toxicity data were derived by regulatory and public health agencies using very conservative (i.e., health protective) assumptions. This means, for example, that exposures calculated to be above a reference dose do not necessarily mean that there are likely to be actual health effects. Although exposures at, or below, comparison values such as reference doses are unlikely to result in health effects, it does not automatically follow that any environmental concentration or exposure that exceeds a comparison value would be expected to produce adverse health effects. The principle reason why regulatory and health agencies develop protective health-based toxicity data, such as cancer slope factors and reference doses, is to enable health professionals to recognize and resolve potential public health hazards. If a calculated exposure is found to exceed a comparison toxicity value, then additional research into the specific compound at issue is required to more fully evaluate the potential for public health effects.

Table 1
Landfill Gas Measurements From Grand Central Landfill (Detected Compounds)

Compound (a)	Flare #1 Inlet Data (ug/m3)	Flare #2 Inlet Data (ug/m3)	Weighted Average Landfill Gas Concentration from Flare Inlet (ug/m3) (c)
Volatile Organic Compounds			
1,1,1-Trichloroethane	2400	3500	3,152
1,1-Dichloroethane	2000	4300	3,572
1,2,4-Trimethylbenzene	11000	14000	13,051
1,3,5-Trimethylbenzene	4100	5300	4,920
1,4-Dichlorobenzene	2200	3200	2,884
2-Butanone (Methyl Ethyl Ketone)	24000	120000	89,631
2-Propanol	7500	59000	42,708
4-Ethyltoluene	9900	13000	12,019
4-Methyl-2-pentanone	2900	13000	9,805
Acetone	37000	62000	54,091
Benzene	1600	2200	2,010
Carbon Disulfide	ND (<1000)	2200	1,662
Chlorobenzene	600 (<380)	ND (<740)	443
Chloroethane	780	1300	1,136
cis-1,2-Dichloroethene	2600	ND (<640)	1,041
Cyclohexane	5400	11000	9,228
Ethanol (b)	32000	370000	263,076
Ethyl Benzene	29000	34000	32,418
Freon 11	8800	8100	8,321
Freon 114	940	1100	1,049
Freon 12	10000	14000	12,735
Heptane	11000	20000	17,153
Hexane	12000	24000	20,204
m,p-Xylene	31000	50000	43,989
Methyl tert-Butyl Ether	1600	3900	3,172
Methylene Chloride	8100	23000	18,286
o-Xylene	10000	16000	14,102
Styrene	4500	10000	8,260
Tetrachloroethane	3800	17000	12,824
Tetrahydrofuran	4900	9600	8,113
Toluene	39000	95000	77,285
Trichloroethene	1900	6100	4,771
Vinyl Chloride	2700	3800	3,452

Table 1 (Cont.)
Landfill Gas Measurements From Grand Central Landfill (Detected Compounds)

Compound (a)	Flare #1 Inlet Data (ug/m3)	Flare #2 Inlet Data (ug/m3)	Weighted Average Landfill Gas Concentration from Flare Inlet (ug/m3) (c)
Sulfur Compounds			
2-Ethylthiophene	5130	ND (<3265)	3,835
2,5-Dimethylthiophene	4664	ND (<3265)	3,692
Diethyl disulfide	7626	ND (<3560)	4,802
Hydrogen sulfide	184178	297518	262,877
Isopropyl mercaptan	ND (<1900)	4274	3,548
Methyl mercaptan	2700	3800	3,464

Notes:

ND = not detected. Concentration shown is the sample detection limit.

(a) Samples were collected by ERG on the flare inlet piping on 11/18/99 and 7/22/03. Samples were analyzed and results reported by Air Toxics Ltd. on 12/07/99 and 7/24/03.

(b) The ethanol result for the Flare #2 sample is estimated because it was measured above the calibrated range.

(c) For compounds with "ND" values for one sample and detectable concentrations for the second sample, 1/2 of the sample detection limit was substituted for the "ND" value to calculate the compound weighted average concentration. The weighted average was calculated to reflect different landfill gas inlet flow rates observed during the 1999 and 2003 sampling programs as follows: weighted average = ((Flare 1 concentration * Flare 1 gas inlet flow) + (Flare 2 concentration * Flare 2 gas inlet flow) / (Flare 1 inlet flow + Flare 2 inlet flow). Flare 1 inlet flows = 1320.49 ft^3/min in 1999 and 2301.7 ft^3/min in 2003. Flare 2 flows = 2853.74 ft^3/min in 1999 and 5229 ft^3/min in 2003.

Table 2
Chronic Inhalation Dose-Response Toxicity Criteria

Chemical (a)	Inhalation Chronic Non-Cancer Reference Dose		Inhalation Reference Dose Source	Inhalation Cancer Slope Factor		USEPA Weight of Evidence (b)	Inhalation Slope Factor Source
	(mg/kg/day)	Note		$(mg/kg/day)^{-1}$	Note		
Volatile organic compounds							
1,1,1-Trichloroethane (Methyl chloroform)	6.3E-01	(d)	EPA Region III	--		D	IRIS
1,1-Dichloroethane	1.0E-01		HEAST	--		C	IRIS
1,2,4-Trimethylbenzene (Pseudocumene)	1.7E-03	(d)	EPA Region III	--		--	--
1,3,5-Trimethylbenzene (Mesitylene)	1.7E-03	(d)	EPA Region III	--		--	--
1,4-Dichlorobenzene (p-dichlorobenzene)	2.3E-01	(c)	IRIS	2.2E-02	(d)	--	EPA Region III
2-Butanone (Methyl Ethyl Ketone)	2.9E-01	(c)	IRIS	--		D	IRIS
2-Propanol (Isopropyl alcohol)	2.0E+00	(k)	NYS ACG	--		--	--
4-Ethyltoluene (1-methyl-4-ethylbenzene)	2.9E-02	(c,l)	Surrogate compound - xylenes/IRIS	--		--	--
4-Methyl-2-pentanone (MIBK)	8.6E-01	(c)	IRIS	--		--	--
Acetone	8.8E+00	(e)	ATSDR	--		D	IRIS
Benzene	8.6E-03	(c)	IRIS	2.7E-02	(c,g)	A	IRIS
Carbon disulfide	2.0E-01	(c)	IRIS	--			--
Chlorobenzene	5.7E-03	(c,f)	HEAST	--		D	IRIS
Chloroethane (Ethyl chloride)	2.9E+00	(c)	IRIS	--		--	--
cis-1,2-Dichloroethene	1.0E-02	(h)	HEAST/Rt-to-Rt	--		D	IRIS
Cyclohexane	7.1E+00	(j,k)	NYS ACG	--		--	--
Ethanol	1.3E+00	(m)	ACGIH TLV	--		--	--
Ethylbenzene	2.9E-01	(c)	IRIS	--		D	IRIS
Freon 11 (trichlorofluoromethane)	2.0E-01	(c,f)	HEAST	--		--	--
Freon 114 (1,2-dichloro-1,1,2,2-tetrafluoromethane)	4.9E+00	(j,k)	NYS ACG	--		--	--
Freon 12 (dichlorodifluoromethane)	5.7E-02	(c,f)	HEAST	--		--	--

Table 2
Chronic Inhalation Dose-Response Toxicity Criteria

Chemical (a)	Inhalation Chronic Non-Cancer Reference Dose		Inhalation Reference Dose Source	Inhalation Cancer Slope Factor		USEPA Weight of Evidence (b)	Inhalation Slope Factor Source
	(mg/kg/day)	Note		$(mg/kg/day)^{-1}$	Note		
Heptane	1.1E+00	(m)	ACGIH TLV	--		D	IRIS
Hexane	5.7E-02	(c)	IRIS	--		--	--
m,p-Xylene	2.9E-02	(c)	IRIS (xylenes)	--		--	--
Methyl tert-Butyl Ether	8.6E-01	(c)	IRIS	--		--	--
Methylene Chloride (dichloromethane)	8.6E-01	(c)	HEAST	1.6E-03	(c)	B2	IRIS
o-Xylene	2.9E-02	(c)	IRIS (xylenes)	--		--	--
Styrene	2.9E-01	(c)	IRIS	--		--	--
Tetrachloroethene	1.4E-01	(d)	EPA Region III	2.0E-02		D	EPA Region III
Tetrahydrofuran	8.6E-02	(d)	EPA Region III	6.8E-03	(d)	--	EPA Region III
Toluene	1.1E-01	(c)	IRIS	--		D	IRIS
Trichloroethene	1.0E-02	(d)	EPA Region III	4.0E-01	(d)	--	EPA Region III
Vinyl Chloride	2.9E-02	(c)	IRIS	3.0E-02	(c,i)	A	IRIS
Sulfur compounds							
2-Ethylthiophene	2.5E-01	(h,n)	Surrogate compound - thiophene/GINC	--		--	--
2,5-Dimethylthiophene	2.5E-01	(h,n)	Surrogate compound - thiophene/GINC	--		--	--
Diethyl disulfide	2.9E-04		Surrogate compound – hydrogen sulfide/IRIS	--		--	--
Hydrogen sulfide	2.9E-04	(c)	IRIS	--		--	--
Isopropyl mercaptan	6.6E-04		Surrogate compound – methyl mercaptan/ NYS AGC	--		--	--
Methyl mercaptan	6.6E-04	(j,k)	NYS ACG	--		--	--

Notes for Table 2
Chronic Inhalation Dose-Response Toxicity Criteria

Notes for toxicity data table:

-- = No data available

(a) List of chemicals detected during the 1999 and 2003 GCSL Flare 1 and Flare 2 sampling programs.

(b) USEPA Weight of evidence classification scheme for carcinogens:

A--Human Carcinogen, sufficient evidence from human epidemiological studies; B1--Probable Human Carcinogen, limited evidence from epidemiological studies; B2--Probable Human Carcinogen, inadequate or no evidence from epidemiological studies and adequate evidence from animal studies; C--Possible Human Carcinogen, limited evidence in animals in the absence of human data; D--Not Classified as to human carcinogenicity; and E--Evidence of Noncarcinogenicity.

(c) The reported inhalation toxicity value was calculated from a reference concentration (RfC) or inhalation unit-risk using USEPA assumptions (i.e., assuming a 70-kg individual inhales 20 m^3 of air per day).

(d) USEPA National Center for Environmental Assessment (NCEA) provisional value reported in EPA Region III RBC Table.

(e) Value based on ATSDR chronic inhalation MRL (13 ppm * MW 58.08/24.45 * 20 m^3/day / 70 kg).

(f) Value represents HEAST alternate value (obtained from Table 2 of HEAST 1997).

(g) Based on high end of unit risk factor range presented in IRIS.

(h) The reported toxicity value is based on route-to-route extrapolation from the oral toxicity criteria for chemicals which exhibit systemic toxicity assuming that similar absorption efficiencies and pharmacokinetics exist for the oral and inhalation routes of exposure.

(i) Vinyl chloride value for continuous lifetime exposure from birth. (The value based on adult exposure is two times lower than the value for exposure from birth.)

(j) Value was derived by New York State based on the ACGIH workplace threshold limit value.

(k) The reported value was calculated from a chronic air guideline concentration assuming a 70-kg individual inhales 20 m^3 of air per day (i.e., mg/kg-day = mg/m^3 * 20 m^3/day / 70 kg).

(l) Inhalation reference dose based on a structurally similar compound due to lack of toxicity criteria from the listed data sources.

(m) Value was derived from the 8-hour time weighted average permissible exposure limit from OSHA and ACGIH, adjusted for differences in exposure duration between a worker and the general public (40 hours/week versus 168 hours/week) and for potential differences in susceptibility (factor of 100 based on factor of 10 for worker to general public and factor of 10 for interindividual variability). This adjustment method is used by New York State in deriving ambient guideline concentrations.

Notes for Table 2
Chronic Inhalation Dose-Response Toxicity Criteria

(n) Value obtained from the Global Information Network on Chemicals (GINC, National Institute of Health Sciences, Japan) based on a reference dose derived from a chronic No Observed Effect Level (NOEL) of 25 mg/kg-day from an oral rat study and using an uncertainty/safety factor of 100. The oral rat study was sponsored by the Organization for Economic Cooperation and Development (OECD).

Sources of toxicity data:

IRIS =	Integrated Risk Information System (06/17/03), inhalation toxicity criteria.
HEAST =	Health Effects Assessment Summary Tables (July 1997), inhalation toxicity criteria.
EPA Region III =	US Environmental Protection Agency, Risk-Based Concentration (RBC) Table, 04/25/03, inhalation dose-response data.
ATSDR =	Agency for Toxic Substances and Disease Registry, chronic Minimum Risk Level for inhalation (January 2003 table).
IRIS =	Integrated Risk Information System (06/17/03), route-to-route extrapolation from oral dose-response data.
HEAST Rt-to-Rt =	Health Effects Assessment Summary Tables (July 1997), route-to-route extrapolation from oral dose-response data.
EPA Region III =	US Environmental Protection Agency, Risk-Based Concentration (RBC) Table, 04/25/03, route-to-route extrapolation from oral dose-response data.
NYS ACG =	New York State Department of Environmental Conservation. Division of Air Resources. Guidelines for the Control of Toxic Ambient Air Contaminants. DAR-1 AGC/SCG Tables. http://www.dec.state.ny.us/website/dar/boss/toxics.html. July 2000.
ACGIH TLV =	8-hour time weighted average Threshold Limit Value from the American Conference of Governmental Industrial Hygienists, 2002.
GINC =	Global Information Network on Chemicals, National Institute of Health Sciences, Japan (http://wwwdb.mhlw.go.jp/ginc/dbfile1/file/file110-02-1.html, accessed 9/2003.)

Hierarchy for selection of toxicity criteria (in order of preference):

I. Inhalation toxicity criteria from EPA's IRIS, EPA's HEAST, EPA's Region III RBC Table.

II. If inhalation toxicity criteria were not available from the sources above, then values were obtained from ATSDR, route-to-route extrapolation from EPA's IRIS, route-to-route extrapolation from EPA's HEAST, route-to-route extrapolation from EPA's Region III RBC Table.

III. In the absence of data from the sources listed above, values were obtained from alternative sources, as indicated in the table.

The types of non-cancer health effects potentially associated with long-term inhalation exposure to each of the 39 compounds in landfill gas were also identified, as shown in Table 3. These health effects endpoints were identified so that the potential for adverse health effects from exposure to mixtures of compounds having a similar type of health effect could be evaluated if warranted. Health effects endpoints were identified from databases of toxicity information maintained by the USEPA, ATSDR, and the California Environmental Protection Agency (CALEPA). If information was not available from these sources for a specific compound, the health effects endpoint was identified based on the published literature or on data for a similar compound. For most compounds, the health endpoints were identified from animal studies rather than from humans. In addition, more than one endpoint was identified for most compounds even though the sensitivity of each endpoint to exposure differs. Since the non-cancer reference doses developed by regulatory and public health agencies are based on the most sensitive endpoints, these reference doses will be protective for other less sensitive endpoints as well.

In addition to long-term toxicity data, the potential for short-term acute effects from emissions to air were evaluated using acute reference air concentrations. These reference concentrations were compiled from regulatory agencies and the published literature in accordance with USEPA (1998a) guidance. This guidance provides a hierarchy of sources from which acute reference air concentrations should be compiled for comparison to calculated 1-hour average air concentrations, including USEPA's acute exposure guideline levels (AEGLs), emergency response planning guidelines (ERGPs) from the American Industrial Hygiene Council, acute inhalation reference exposure levels (RELs) from the California Environmental Protection Agency, and temporary emergency exposure limits (TEELs) from the Department of Energy's Subcommittee on Consequence Assessment and Protective Actions (SCAPA). The acute reference concentrations reflect maximum levels in air below which nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient health effects (e.g., eye irritation) or perceive a clearly defined objectionable odor. These are the standard types of reference concentrations recommended for use by regulatory agencies to evaluate short-term inhalation exposures to compounds in the air. Table 4 presents the acute reference air concentrations used in this risk assessment.

Concentrations in air above acute reference concentrations do not necessarily indicate that an individual will experience even a mild transient effect, because of the conservative assumptions used by regulatory and health agencies in deriving the reference concentrations. If a concentration is found to exceed an acute reference concentration, then additional research into the specific compounds at issue is required to more fully evaluate the potential for public health effects.

The acute reference concentrations were compared to available odor thresholds reported for the landfill gas constituents (Ruth 1986, Georgia-Pacific 2001, WHO 2003). This comparison showed that the concentrations at which odors from these compounds could be detected are lower than the acute reference concentrations. This indicates that concentrations of landfill gas compounds present at their odor thresholds would not result in short-term acute health effects.

Table 3
Non-Cancer Health Effects Endpoints

Chemical	Nervous System	Kidney	Body weight	Liver	Respira-tory / nasal / eyes	Develop-mental / fetus	Gastro-intestinal	Blood	Reproduc-tive/ sperm	Cardio-vascular	Endocrine/ adrenal
Volatile organic compounds											
1,1,1-Trichloroethane (Methyl chloroform)	x										
1,1-Dichloroethane		x				x				x	
1,2,4-Trimethylbenzene (Pseudocumene)	x										
1,3,5-Trimethylbenzene (Mesitylene)	x										
1,4-Dichlorobenzene (p-dichlorobenzene)				x							
2-Butanone (Methyl Ethyl Ketone)						x					
2-Propanol (Isopropyl alcohol)	x										
4-Ethyltoluene (1-methyl-4-ethylbenzene)	x										
4-Methyl-2-pentanone (MIBK)		x		x		x					
Acetone		x		x							
Benzene								x			
Carbon disulfide	x								x		
Chlorobenzene		x		x		x	x		x		
Chloroethane (Ethyl chloride)						x	x				
cis-1,2-Dichloroethene				x				x			
Cyclohexane	x										
Ethanol	x										

Table 3
Non-Cancer Health Effects Endpoints

Chemical	Nervous System	Kidney	Body weight	Liver	Respira-tory / nasal / eyes	Develop-mental / fetus	Gastro-intestinal	Blood	Reproduc-tive/ sperm	Cardio-vascular	Endocrine/ adrenal
Ethylbenzene		x		x		x					x
Freon 11 (trichlorofluoromethane)		x			x						
Freon 114 (1,2-dichloro-1,1,2,2-tetrafluoromethane)			x	x							
Freon 12 (dichlorodifluoromethane)			x	x							
Heptane	x										
Hexane	x				x						
m,p-Xylene	x		x		x						
Methyl tert-Butyl Ether		x		x	x						
Methylene Chloride (dichloromethane)	x			x						x	
o-Xylene	x		x		x						
Styrene	x										
Tetrachloroethene		x		x							
Tetrahydrofuran	x	x		x	x						
Toluene	x	x		x	x	x					
Trichloroethene	x				x						
Vinyl Chloride				x							
Sulfur Compounds											
2-Ethylthiophene	x			x					x		
2,5-Dimethylthiophene	x			x					x		
Diethyl disulfide					x						

Table 3
Non-Cancer Health Effects Endpoints

Chemical	Nervous System	Kidney	Body weight	Liver	Respira-tory / nasal / eyes	Develop-mental / fetus	Gastro-intestinal	Blood	Reproduc-tive/ sperm	Cardio-vascular	Endocrine/ adrenal
Hydrogen sulfide					x						
Isopropyl mercaptan					x						
Methyl mercaptan					x						

Table 4
Acute Inhalation Reference Concentrations

Chemical (a)	Acute Reference Air Concentration (mg/m^3)	Note (b)	Source (c)
Volatile organic compounds			
1,1,1-Trichloroethane (Methyl chloroform)	1,300	interim value	EPA AEGL-1
1,1-Dichloroethane	1,250		DOE TEEL-1
1,2,4-Trimethylbenzene (Pseudocumene)	150		DOE TEEL-1
1,3,5-Trimethylbenzene (Mesitylene)	150	Surrogate compound - 1,2,4-trimethylbenzene	DOE TEEL-1
1,4-Dichlorobenzene (p-dichlorobenzene)	600		DOE TEEL-1
2-Butanone (Methyl Ethyl Ketone)	300	proposed value	EPA AEGL-1
2-Propanol (Isopropyl alcohol)	1,000		DOE TEEL-1
4-Ethyltoluene (1-methyl-4-ethylbenzene)	125		DOE TEEL-1
4-Methyl-2-pentanone (MIBK)	300		DOE TEEL-1
Acetone	480	proposed value	EPA AEGL-1
Benzene	160	proposed value	EPA AEGL-1
Carbon disulfide	12	proposed value	EPA AEGL-1
Chlorobenzene	125		DOE TEEL-1
Chloroethane (Ethyl chloride)	2,500		DOE TEEL-1
cis-1,2-Dichloroethene	550	interim value	EPA AEGL-1
Cyclohexane	3,000		DOE TEEL-1
Ethanol	5,000		DOE TEEL-1
Ethylbenzene	500		DOE TEEL-1
Freon 11 (trichlorofluoromethane)	2,500		DOE TEEL-1
Freon 114 (1,2-dichloro-1,1,2,2-tetrafluoromethane)	20,000		DOE TEEL-1
Freon 12 (dichlorodifluoromethane)	15,000		DOE TEEL-1
Heptane	1,500		DOE TEEL-1
Hexane	500		DOE TEEL-1
m,p-Xylene	560	proposed value - based on mixed xylenes	EPA AEGL-1
Methyl tert-Butyl Ether	500		DOE TEEL-1
Methylene Chloride (dichloromethane)	690		AIHA ERPG-1
o-Xylene	560	proposed value - based on mixed xylenes	EPA AEGL-1

Table 4
Acute Inhalation Reference Concentrations

Chemical (a)	**Acute Reference Air Concentration (mg/m^3)**	**Note (b)**	**Source (c)**
Styrene	210		AIHA ERPG-1
Tetrachloroethene	240	interim value	EPA AEGL-1
Tetrahydrofuran	750		DOE TEEL-1
Toluene	310	interim value	EPA AEGL-1
Trichloroethene	670	proposed value	EPA AEGL-1
Vinyl Chloride	180		CALEPA REL
Sulfur compounds			
2-Ethylthiophene	--		
2,5-Dimethylthiophene	--		
Diethyl disulfide	0.71	Surrogate value - hydrogen sulfide	
Hydrogen sulfide	0.71	Interim value	EPA AEGL-1
Isopropyl mercaptan	0.01	Surrogate value – methyl mercaptan	
Methyl mercaptan	0.01		AIHA ERPG-1

-- = No data available.

(a) List of chemicals detected during the 1999 and 2003 GCSL Flare 1 and Flare 2 sampling programs.

(b) Interim AEGLs are established following review and consideration of public comments on proposed AEGLs by the National Advisory Committee for AEGLs. Proposed AEGLs have been published for public comment following review and concurrence by the National Advisory Committee for AEGLs.

(c) Sources of acute inhalation reference concentrations in order of preference (based on USEPA 1998a guidance):

EPA AEGL-1 = U.S. Environmental Protection Agency, National Advisory Committee for Acute Exposure Guideline Levels, level 1 acute inhalation exposure guideline levels for 1-hour period, table dated March 2003. Received from P. Tobin, USEPA, Office of Pollution Prevention and Toxics, Washington, D.C. May 2003.

AIHA ERPG-1 = American Industrial Hygiene Council emergency response planning guidelines, level 1 ERPG (www.bnl.gov/scapa/scapawl.htm, table of ERPGs updated as of 7/2/2002).

CALEPA REL = California Environmental Protection Agency acute inhalation reference exposure levels, values as of May 2000 downloaded 6/2003 (www.oehha.ca.gov/air/acute_rels).

DOE TEEL-1 = U.S. Department of Energy (DOE), Subcommittee on Consequence Assessment and Protective Actions (SCAPA), temporary emergency exposure limits (TEELs), Table 4. Recommended TEELs Rev. 19, dated 12/6/2002 (tis.eh.doe.gov/web/chem_safety/teel/Table1.pdf). TEELs are derived for a 15-minute exposure period rather than a 1-hour period.

EXPOSURE ASSESSMENT

The next step in the risk assessment is the Exposure Assessment. An exposure assessment involves determining the amount, duration and pattern of exposure to chemicals selected for evaluation. This is accomplished in a series of steps, as follows:

- quantification of emission rates,
- air dispersion modeling,
- population analysis,
- identification of exposure pathways,
- calculation of environmental concentrations, and
- calculation of human exposures.

A discussion is provided below for each of these exposure assessment steps.

Calculation of Emission Rates

An important input to a landfill exposure assessment is the chemical emission rate. Landfill gas emission rates were developed to address releases associated with current and projected future facility operations. These emission rates included not only ground-level surface releases, but also stack emissions from the gas-to-energy plant and the enclosed flares. A description of the methods used to calculate chemical emission rates is provided in Appendix D. A summary of these methods is provided in the section below and the calculated emission rates are shown in Table 5.

The emission rates for each landfill area were calculated in units of grams chemical per square meter land surface area per second (g/m^2-sec). The emission rates for each stack were calculated in units of grams chemical per second (g/sec). These are the standard units of measurement for emission rates from area sources (such as a landfill) and from stack sources (USEPA 1995).

Emission Rates from Landfill Surfaces

Ground-level surface emission rates were calculated for each of the three landfill areas that comprise the Grand Central Landfill. The three areas were identified to reflect differences in potential landfill gas generation rates as well as potential differences in the efficiency of the facility's landfill gas collection system. The three areas, which are shown in Figure 2, consisted of:

- Area A – the closed original landfill (56.8 acres)[5]
- Area B - capped landfill areas in the Northern Expansion (39.7 acres)
- Area C - active uncapped areas in the Northern Expansion (43.2 acres)

The size of each area was based on current (2003) landfill conditions. The emission rates from each area were developed using the following information: total gas generation rates in the inactive landfill and the Northern Expansion landfill, the collection efficiency of the gas

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[5] The old landfill area is 52 acres in size. The acreage used here includes the area of the cap that overlaps the landfill perimeter.

Table 5
Emission Rates for Landfill Gas Compounds from Landfill Areas and Stack Sources

Compound	Fugitive Emission Rates (g/m^2-s)			Stack Emission Rates (g/s)				
	Landfill Area A	Landfill Area B	Landfill Area C	Turbine 1	Turbine 2	Turbine 3	Flare 1	Flare 2
Volatile organic compounds								
1,1,1-Trichloroethane	2.98E-11	1.03E-09	9.15E-09	5.35E-05	5.65E-05	5.17E-05	2.15E-04	4.18E-04
1,1-Dichloroethane	3.37E-11	1.17E-09	1.04E-08	6.07E-05	6.40E-05	5.86E-05	2.44E-04	4.74E-04
1,2,4-Trimethylbenzene	1.23E-10	4.27E-09	3.79E-08	2.22E-04	2.34E-04	2.14E-04	8.91E-04	1.73E-03
1,3,5-Trimethylbenzene	4.65E-11	1.61E-09	1.43E-08	8.35E-05	8.82E-05	8.07E-05	3.36E-04	6.53E-04
1,4-Dichlorobenzene	2.72E-11	9.44E-10	8.37E-09	4.90E-05	5.17E-05	4.73E-05	1.97E-04	3.83E-04
2-Butanone	8.47E-10	2.93E-08	2.60E-07	1.52E-03	1.61E-03	1.47E-03	6.12E-03	1.19E-02
2-Propanol	4.03E-10	1.40E-08	1.24E-07	7.25E-04	7.65E-04	7.00E-04	2.91E-03	5.67E-03
4-Ethyltoluene	1.14E-10	3.93E-09	3.49E-08	2.04E-04	2.15E-04	1.97E-04	8.20E-04	1.59E-03
4-Methyl-2-pentanone	9.26E-11	3.21E-09	2.85E-08	1.66E-04	1.76E-04	1.61E-04	6.69E-04	1.30E-03
Acetone	5.11E-10	1.77E-08	1.57E-07	9.18E-04	9.69E-04	8.87E-04	3.69E-03	7.18E-03
Benzene	1.90E-11	6.58E-10	5.84E-09	3.41E-05	3.60E-05	3.30E-05	1.37E-04	2.67E-04
Carbon Disulfide	1.57E-11	5.44E-10	4.83E-09	2.82E-05	2.98E-05	2.73E-05	1.13E-04	2.21E-04
Chlorobenzene	4.18E-12	1.45E-10	1.29E-09	7.52E-06	7.93E-06	7.26E-06	3.02E-05	5.88E-05
Chloroethane	1.07E-11	3.72E-10	3.30E-09	1.93E-05	2.03E-05	1.86E-05	7.75E-05	1.51E-04
cis-1,2-Dichloroethane	9.83E-12	3.41E-10	3.02E-09	1.77E-05	1.87E-05	1.71E-05	7.11E-05	1.38E-04
Cyclohexane	8.72E-11	3.02E-09	2.68E-08	1.57E-04	1.65E-04	1.51E-04	6.30E-04	1.22E-03
Ethanol	2.48E-09	8.61E-08	7.64E-07	4.47E-03	4.71E-03	4.31E-03	1.80E-02	3.49E-02
Ethylbenzene	3.06E-10	1.06E-08	9.41E-08	5.50E-04	5.81E-04	5.32E-04	2.21E-03	4.30E-03
Freon-11	7.86E-11	2.72E-09	2.42E-08	1.41E-04	1.49E-04	1.36E-04	5.68E-04	1.10E-03
Freon-114	9.91E-12	3.43E-10	3.05E-09	1.78E-05	1.88E-05	1.72E-05	7.16E-05	1.39E-04
Freon-12	1.20E-10	4.17E-09	3.70E-08	2.16E-04	2.28E-04	2.09E-04	8.69E-04	1.69E-03
Heptane	1.62E-10	5.61E-09	4.98E-08	2.91E-04	3.07E-04	2.81E-04	1.17E-03	2.28E-03
Hexane	1.91E-10	6.61E-09	5.87E-08	3.43E-04	3.62E-04	3.31E-04	1.38E-03	2.68E-03
m,p-Xylenes	4.15E-10	1.44E-08	1.28E-07	7.47E-04	7.88E-04	7.21E-04	3.00E-03	5.84E-03

Table 5
Emission Rates for Landfill Gas Compounds from Landfill Areas and Stack Sources

Compound	Fugitive Emission Rates (g/m^2-s)			Stack Emission Rates (g/s)				
	Landfill Area A	Landfill Area B	Landfill Area C	Turbine 1	Turbine 2	Turbine 3	Flare 1	Flare 2
Methyl tert butyl ether	3.00E-11	1.04E-09	9.21E-09	5.39E-05	5.68E-05	5.20E-05	2.17E-04	4.21E-04
Methylene chloride	1.73E-10	5.98E-09	5.31E-08	3.11E-04	3.28E-04	3.00E-04	1.25E-03	2.43E-03
o-Xylene	1.33E-10	4.61E-09	4.10E-08	2.39E-04	2.53E-04	2.31E-04	9.62E-04	1.87E-03
Styrene	7.80E-11	2.70E-09	2.40E-08	1.40E-04	1.48E-04	1.35E-04	5.64E-04	1.10E-03
Tetrachloroethene	1.21E-10	4.20E-09	3.72E-08	2.18E-04	2.30E-04	2.10E-04	8.75E-04	1.70E-03
Tetrahydrofuran	7.66E-11	2.66E-09	2.36E-08	1.38E-04	1.45E-04	1.33E-04	5.54E-04	1.08E-03
Toluene	7.30E-10	2.53E-08	2.24E-07	1.31E-03	1.38E-03	1.27E-03	5.27E-03	1.03E-02
Trichloroethene	4.51E-11	1.56E-09	1.39E-08	8.10E-05	8.55E-05	7.82E-05	3.26E-04	6.33E-04
Vinyl Chloride	3.26E-11	1.13E-09	1.00E-08	5.86E-05	6.18E-05	5.66E-05	2.36E-04	4.58E-04
Sulfur compounds								
2-Ethylthiophene	3.62E-11	1.25E-09	1.11E-08	NC	NC	NC	NC	NC
2,5-Dimethylthiophene	3.49E-11	1.21E-09	1.07E-08	NC	NC	NC	NC	NC
Diethyl disulfide	4.54E-11	1.57E-09	1.39E-08	NC	NC	NC	NC	NC
Hydrogen sulfide (a)	2.48E-11	8.60E-10	7.63E-09	NC	NC	NC	NC	NC
Isopropyl mercaptan	3.35E-11	1.16E-09	1.03E-08	NC	NC	NC	NC	NC
Methyl mercaptan	3.27E-11	1.13E-09	1.01E-08	NC	NC	NC	NC	NC

NC = Not calculated. The sulfur compounds present in landfill gas are destroyed in the combustion process. Potential impacts associated with sulfur dioxide stack emissions resulting from combustion of the sulfur-containing landfill gas compounds are discussed in the uncertainty section.

(a) The hydrogen sulfide emission rates from the landfill surfaces were adjusted downward by a factor of 100 based on a comparison of modeled and measured concentrations at 4 inches above the surface of active landfill area (see text and appendix on calculation of emission rates for more information). This comparison showed that the average modeled hydrogen sulfide concentration, calculated using the inlet piping landfill gas concentration and gas generation rates calculated from a USEPA model, was 175 times higher than the average measured concentration, calculated from more than 90 hydrogen sulfide surface concentration measurements collected August 25 and 26, 2003 at the active landfill.

collection system in each landfill area, and the concentrations of compounds in landfill gas as measured in the flare inlet piping. Gas generation rates were calculated using a combination of USEPA landfill gas modeling methods, actual measurements of landfill gas collection rates, and surface methane measurement data.

The modeling used to calculate chemical emission rates from the landfill surface, which was based on a combination of modeled landfill gas generation rates and chemical concentrations measured in the flare inlet piping, was likely to overestimate emissions. Modeled landfill gas generation rates were likely to be overestimated due to assumptions about the gas collection system efficiency and uncertainties and assumptions used in the USEPA model (Bogner et al. 1997). Although the USEPA model was adjusted against historical gas generation rates at GCSL, these historical gas generation rates were likely overestimated by assuming 90% collection efficiency for the entire landfill. GCSL has, however, installed a more extensive gas collection system within active landfill areas than a typical landfill, which means the actual collection efficiency is likely to be greater than 90%, and the modeled gas generation rates are likely to be lower than calculated for this assessment. As noted above, the use of landfill gas data from inlet piping to the flares does not take into account processes that attenuate the release of compounds from the landfill surface (Bogner et al. 2003, Scheutz et al. 2003, Kjeldsen et al. 2003).

The degree of overestimation of the landfill surface emission rates was evaluated by comparing measured and modeled air concentrations of hydrogen sulfide 4 inches above the active landfill surface. Hydrogen sulfide was selected for detailed examination because a readily available monitoring method exists for measuring hydrogen sulfide in the field (Jerome hydrogen sulfide analyzer, Arizona Instrument, Tempe, AZ), this method has been applied at other landfills (Townsend et al. 2000), and hydrogen sulfide is often one of the dominant compounds found in landfill gas, including the landfill gas measured at GCSL. The average measured hydrogen sulfide concentration 4 inches above the active landfill surface, based on measurements collected at more than 90 locations in August 2003, was 0.004 parts per million (5.6 $\mu g/m^3$). The corresponding average modeled hydrogen sulfide concentration at the same height was calculated to be 0.7 parts per million (980 $\mu g/m^3$), using the modeled landfill surface emission rate and a simple area source mixing box model (ASTM 1994, also see Appendix D). This analysis showed that the modeled concentration was 175 times higher than the measured concentration. Accordingly, the modeled hydrogen sulfide emission rates for each landfill area were adjusted downwards by a factor of 100, although these adjusted hydrogen sulfide emission rates were still likely to be overestimated (by using an adjustment factor of 100 rather than 175). It is also likely that other compounds present in landfill gas have substantially smaller emission rates compared to those that were modeled. However, no adjustment was made to emission rates for compounds other than hydrogen sulfide in this assessment since the surface measurements used in comparison with modeled data were specific to hydrogen sulfide.

Emission Rates from Point Sources

Emission rates from the gas-to-energy plant and enclosed flares were calculated based on operating data from these facilities, including data provided in stack test reports, measured stack gas flow rates and chemical destruction efficiency data. The destruction efficiencies for organic compounds in the flares (90% for flare #1 and 86% for flare #2) were based on air compliance testing performed at Grand Central (1993 test for flare #1 and 1998 test for flare #2) (Air Compliance 1993, ETS 1998). The destruction efficiency for the three gas turbines (97.4%) was based on a stack test performed at a similar facility located in

California (Delta Air Quality 2002), because data from the specific facility at Grand Central were not available. Stack emission rates for the sulfur landfill gas constituents were not calculated since these compounds will not be emitted in their original form as a result of the combustion process. Instead, sulfur emissions from the stacks were evaluated by conservatively assuming that all sulfur in the inlet gas would be converted to sulfur dioxide, a criteria pollutant regulated under the Clean Air Act. The calculated sulfur dioxide stack emissions are evaluated in the uncertainty discussion later in this report.

Air Dispersion Modeling

Air dispersion modeling is required in order to calculate chemical concentrations in air surrounding the landfill and, ultimately, human exposures from landfill-related emissions. The air dispersion modeling was performed by Trinity Consultants using the USEPA-approved Industrial Source Complex Short-Term 3 (ISCST3) model (USEPA 2001, USEPA 1995). This model can calculate ambient air concentrations from a wide variety of sources including area sources (such as a landfill surface) and point sources (such as a stack). An overview of the modeling is provided in this section. A more detailed description of Trinity's modeling analysis is provided in Appendix E.

The ISCST3 model results were used to calculate annual average and 1-hour average ambient air concentrations for each landfill gas constituent across a study area surrounding the GCSL property boundary. Annual average concentrations were used to evaluate potential chronic exposures and risks. One-hour average concentrations were used to evaluate the potential for acute short-term health effects.

The necessary ISCST3 input parameters for each landfill area and stack were based on information specific to each of these sources. These inputs include stack height, gas exit velocity and temperature, and stack diameter for each modeled stack, and the size, shape and emission release height for each of the landfill areas. Based on maps showing the landfill areas and the location of the enclosed flares and the gas generation plant provided by ERG, Inc., the boundary of each landfill area and location of each stack was digitized and imported into ISCST3 by Trinity Consultants. The shape of each landfill area source was represented in ISCST3 as a polygon. The emission height for each landfill area was calculated as the average between the lowest and highest elevations for each area. The stack input parameters were based on stack test information performed for the flares and turbines.

Consistent with USEPA guidance, each landfill area and each stack was modeled using a "unitized" emission rate of either 0.001 g/m^2-sec for the areas or 1 g/sec for the stacks (USEPA 1995, 1998a). Therefore, the modeled ambient air concentrations produced from ISCST were "unitized" concentrations, expressed in units of µg/m^3 per 0.001 g/m^2-sec for the landfill areas and µg/m^3 per 1 g/sec for the stacks. Chemical air concentrations were then calculated by multiplying the unitized results by the chemical-specific emission rates for area and stack sources, as follows:

$$C_{i/area} = [\, ER_{i/area} * C_{unitized/area} \,] / 0.001 \text{ g/m}^2\text{-sec}$$

$$C_{i/stack} = [\, ER_{i/stack} * C_{unitized/stack} \,] / 1 \text{ g/sec}$$

where

$C_{i/area}$ = air concentration (annual average or 1-hour average) for chemical i associated with surface emissions from one of the three landfill areas ($\mu g/m^3$),
$C_{unitized/area}$ = unitized air concentration (annual average or 1-hour average) associated with surface emissions from one of the three landfill areas ($\mu g/m^3$ per 0.001 g/m^2-sec),
$ER_{i/area}$ = emission rate for chemical i from one of the three landfill areas (g/m^2-sec),
$C_{i/stack}$ = air concentration (annual average or 1-hour average) for chemical i associated with stack emissions from a flare or turbine ($\mu g/m^3$),
$C_{unitized/stack}$ = unitized air concentration (annual average or 1-hour average) associated with stack emissions from a flare or turbine ($\mu g/m^3$ per 1 g/sec),
$ER_{i/stack}$ = emission rate for chemical i from one of the stack sources (g/sec),
0.001 g/m^2-sec = unitized emission rate used for the area sources in ISCST modeling, and
1 g/sec = unitized emission rate used for the stack sources in ISCST modeling.

The air concentrations associated with all emission sources were then calculated for each chemical by summing the results for each of the modeled sources, as follows:

$$C_{i\text{-total}} = C_{i/area\ A} + C_{i/area\ B} + C_{i/area\ C} + C_{i/flare\ \#1\ stack} + C_{i/flare\ \#2\ stack} + C_{i/turbine\ \#1\ stack} + C_{i/turbine\ \#2\ stack} + C_{i/turbine\ \#3\ stack}$$

where

$C_{i\text{-total}}$ = total air concentration for chemical i ($\mu g/m^3$),
$C_{i/area\ A}$ = air concentration for chemical i from landfill Area A ($\mu g/m^3$),
$C_{i/area\ B}$ = air concentration for chemical i from landfill Area B ($\mu g/m^3$),
$C_{i/area\ C}$ = air concentration for chemical i from landfill Area C ($\mu g/m^3$),
$C_{i/flare\ \#1\ stack}$ = air concentration for chemical i from enclosed flare #1 ($\mu g/m^3$),
$C_{i/flare\ \#2\ stack}$ = air concentration for chemical i from enclosed flare #2 ($\mu g/m^3$),
$C_{i/turbine\ \#1\ stack}$ = air concentration for chemical i from turbine #1 ($\mu g/m^3$),
$C_{i/turbine\ \#2\ stack}$ = air concentration for chemical i from turbine #2 ($\mu g/m^3$), and
$C_{i/turbine\ \#3\ stack}$ = air concentration for chemical i from turbine #3 ($\mu g/m^3$).

This approach assumes that both flares and the power plant are all operating continuously and at the same time, even though both flares are not always required to operate simultaneously.

The ISCST3 model was run using five years (1991-1995) of preprocessed meteorological data obtained from the U.S. National Weather Service (NWS). These years of data were the most recent quality assured datasets available from the National Weather Service that are acceptable to PADEP. The nearest NWS stations are Allentown, Pennsylvania (NWS Station No. 14737) which provided surface meteorological data (e.g., wind speed and direction) and Sterling, Virginia (NWS Station No. 93734) which provided upper air data (e.g., atmospheric mixing height). The results from the year producing the highest concentrations for residential areas beyond the property boundary were used in this evaluation.

Air concentrations were calculated by ISCST3 at over 1,500 points (called receptors) that extended outwards for 4 km (2.5 miles) from Waste Management's property boundary. The receptors were evenly spaced at 100 m (330 feet) intervals out to 1 km (0.62 miles) from the boundary. The receptor spacing was set at 500 m (1,640 feet) from 1 km out to 4 km beyond the property boundary. The elevations above sea-level of each receptor were included in the modeling based on U.S. Geological Survey (USGS) data.

Figure 3 illustrates the location of the modeled sources and the fine (100 m) receptor grid used in the air dispersion modeling.

Population Analysis

The next step in the exposure assessment involved identifying populations in the landfill area through demographic and land use data. This information was used in conjunction with the ISCST3 modeling results to identify surrounding areas near to the landfill for which risks were calculated.

Areas near to the landfill currently used for residential purposes were identified based on a review of maps of the facility area and a driving survey. The ISCST3 modeling results within these areas were then examined to identify several areas that include residential land uses for detailed evaluation. Each evaluated area was roughly 500 meters by 500 meters in size (approximately 0.3 miles by 0.3 miles, or 1600 feet by 1600 feet). The areas selected for evaluation consisted of the following:

- Area 1: an area immediately to the east of the active landfill where modeled concentrations nearest to the active landfill were predicted to be highest,
- Area 2: an area immediately to the east of the closed landfill where modeled concentrations nearest to the closed landfill were predicted to be highest, and
- Area 3: an area in Pen Argyl to the north of the landfill where modeled concentrations associated with the landfill were predicted to be highest.

These three areas include very few locations that are currently used for residential purposes, are comprised mostly of undeveloped land, and are representative of the areas where concentrations were predicted by the ISCST3 model to be highest. The three areas evaluated in this assessment are shown on Figure 4.

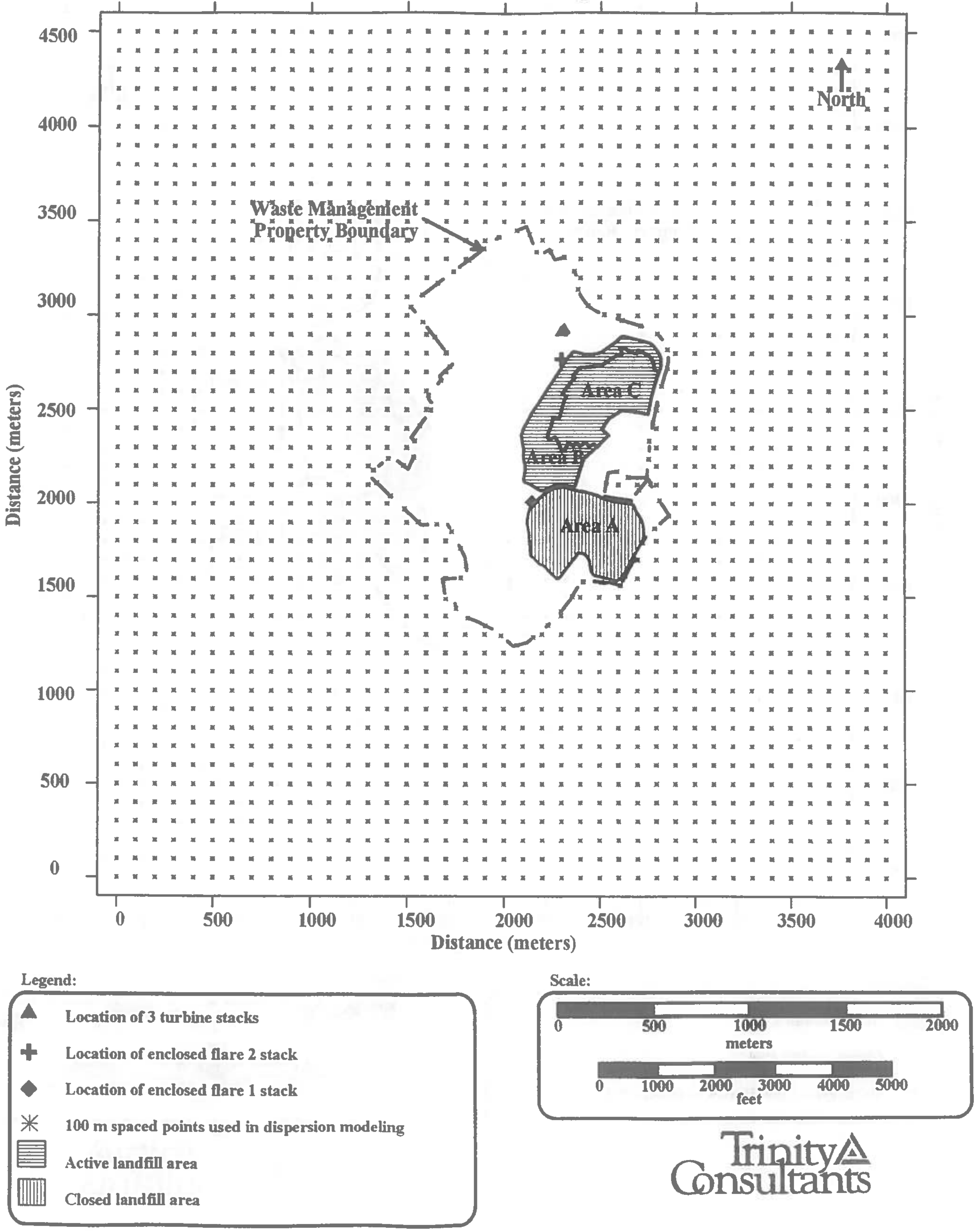
Identification of Exposure Pathways

The next step in the Exposure Assessment is the selection of exposure pathways for evaluation in the risk assessment. The most important exposure pathway relevant for gas emissions from a landfill is inhalation and, accordingly, this risk assessment focused on the inhalation pathway of exposure. Potential inhalation exposures to both children and adults were addressed. The volatile compounds that are typically present in landfill gases tend to remain in the air phase and generally do not accumulate or partition to any appreciable extent into soil or edible plants. As a result, potential exposures due to indirect pathways such as soil ingestion or ingestion of homegrown produce will be negligible relative to the direct inhalation pathway.

Calculation of Environmental Concentrations

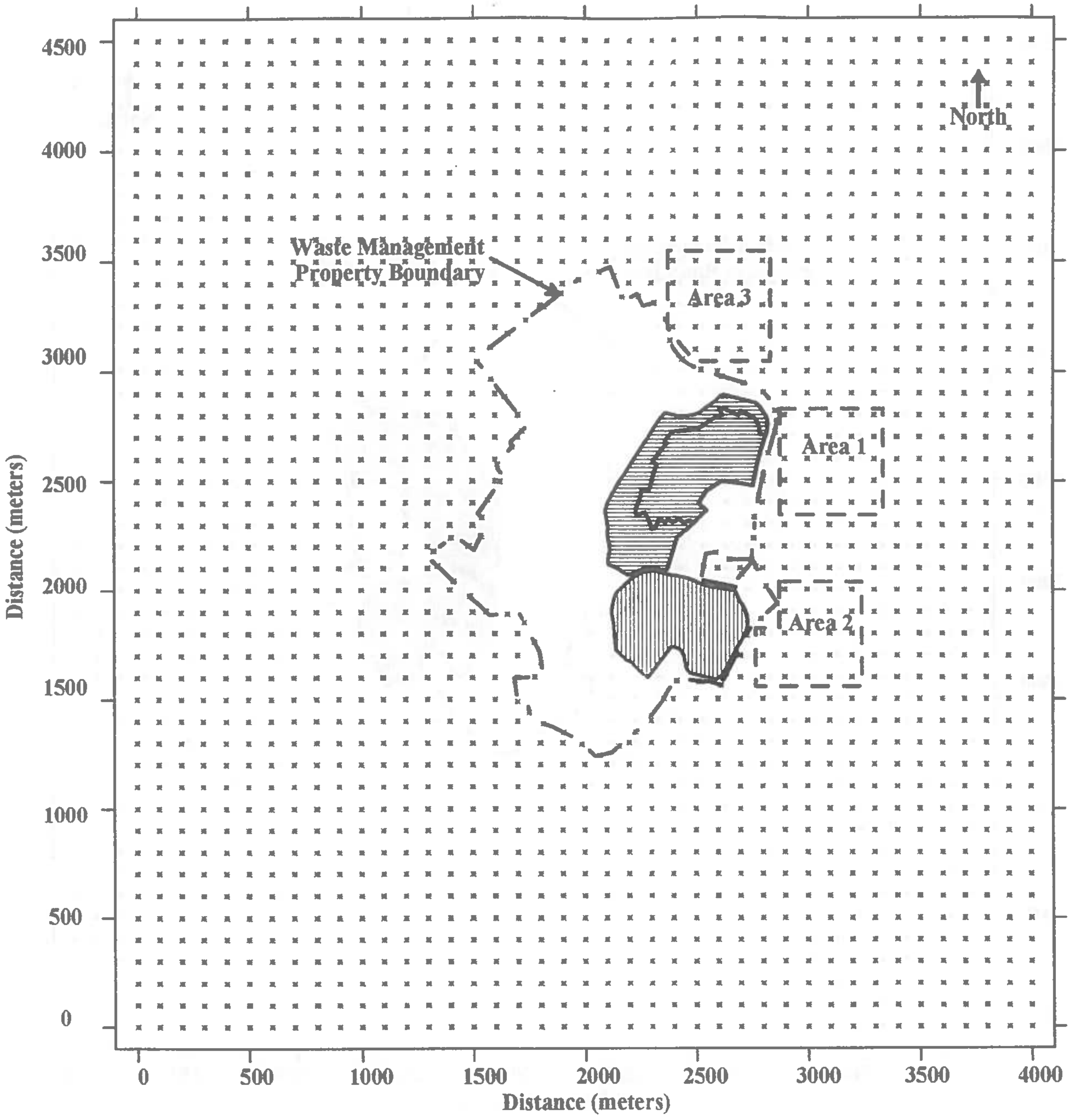
The next step is the calculation of ambient air concentrations in the areas surrounding the landfill. Long-term chronic inhalation risks were calculated using modeled annual average ambient air concentrations and chemical emission rates. Short-term acute inhalation risks

Figure 3
Grand Central Sanitary Landfill Air Dispersion Modeling
Plainfield Township, PA



Trinity Consultants

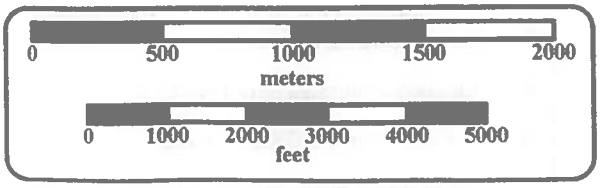
Figure 4
Areas Evaluated in the Landfill Gas Risk Assessment



Legend:

- ▤ Active landfill area
- ▥ Closed landfill area
- ✳ 100 m spaced points used in dispersion modeling

Scale:



Trinity Consultants

were predicted using 1-hour average modeling results and chemical emission rates. The ambient air concentrations were calculated within each of the three selected areas in the landfill vicinity for each of the compounds detected in Grand Central landfill gas. The concentrations within each area are based on the average of all of the ISCST3 modeling results calculated at each modeled grid receptor location.

Table 6 presents the calculated annual average and 1-hour average ambient air concentrations within each area. These concentrations reflect the combined outcome for all of the modeled area and stack emission sources. The importance of each source on the resulting total air concentrations varied depending on the area and the air concentration averaging time. However, the dominant modeled source for all results was landfill Area C (active uncapped areas in the Northern Expansion) which accounted for roughly 86% to 94% of the total concentration within each area. The power plant turbines and the flares accounted for less than 1% of the total concentration calculated within each area.

Calculation of Human Exposures

The last exposure assessment step is the calculation of chronic human inhalation exposures in the landfill area.[6] These calculations require information on the calculated annual average air concentrations, inhalation rates, and data on body weight, exposure frequency (i.e., hours/day and days/year exposed) and exposure duration (i.e., total years exposed). This analysis relied on USEPA standard exposure parameters for adults and children (USEPA 1998a), as shown in Table 7. For example, these parameters assume a 70-kg adult inhales 0.63 cubic meters of air per hour at the specific residential location being evaluated, 24 hours per day, 350 days per year for 30 years. These exposure parameters reflect USEPA recommendations for exposure assessment based on the Agency's detailed analysis of published data (USEPA 1997a). The combination of these parameters is considered more likely to overestimate than underestimate potential exposures. The exposure parameters were used with the modeled annual average ambient air concentrations in standard USEPA equations (USEPA 1992, 1998a) to calculate chronic exposures in the risk assessment.

RISK CHARACTERIZATION

The next part of the risk assessment is referred to as Risk Characterization. In this part of the assessment, potential risks associated with landfill gas emissions from the Grand Central Landfill were addressed. The risks were calculated using standard approaches that have been developed and published by USEPA (1989, 1998a).

Chronic Long-Term Risks

Chronic long-term inhalation risks were calculated by combining the exposure estimates with toxicity values for cancer and non-cancer effects. Cancer risks reflect the upper bound probability that an individual may develop cancer over a 70-year lifetime under the assumed exposure conditions. The risks are referred to as "upper bound" because they are unlikely to be underestimated and, in fact, may range from as low as zero to the upper bound value. Cancer risks were calculated separately for each chemical and also summed across chemicals. For example, a cancer risk of 1×10^{-5} (also equivalent to 1E-05 or 1 in 100,000)

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[6] Exposures are not calculated for evaluation of short-term acute effects since the 1-hour average ambient air concentrations are compared directly to short-term reference air concentrations.

Table 6
Calculated Ambient Air Concentrations in Areas Around Landfill

Compound	Total Ambient Air Concentration ($\mu g/m^3$) [a]					
	Area 1		Area 2		Area 3	
	Annual	1-Hour	Annual	1-Hour	Annual	1-Hour
Volatile Organic Compounds						
1,1,1-Trichloroethane	1.60E-02	8.10E-01	5.18E-03	5.22E-01	3.92E-03	4.46E-01
1,1-Dichloroethane	1.81E-02	9.18E-01	5.87E-03	5.91E-01	4.45E-03	5.05E-01
1,2,4-Trimethylbenzene	6.63E-02	3.35E+00	2.14E-02	2.16E+00	1.62E-02	1.85E+00
1,3,5-Trimethylbenzene	2.50E-02	1.26E+00	8.08E-03	8.15E-01	6.12E-03	6.96E-01
1,4-Dichlorobenzene	1.46E-02	7.41E-01	4.74E-03	4.77E-01	3.59E-03	4.08E-01
2-Butanone	4.55E-01	2.30E+01	1.47E-01	1.48E+01	1.12E-01	1.27E+01
2-Propanol	2.17E-01	1.10E+01	7.01E-02	7.07E+00	5.32E-02	6.04E+00
4-Ethyltoluene	6.10E-02	3.09E+00	1.97E-02	1.99E+00	1.50E-02	1.70E+00
4-Methyl-2-pentanone	4.98E-02	2.52E+00	1.61E-02	1.62E+00	1.22E-02	1.39E+00
Acetone	2.75E-01	1.39E+01	8.88E-02	8.95E+00	6.73E-02	7.65E+00
Benzene	1.02E-02	5.16E-01	3.30E-03	3.33E-01	2.50E-03	2.84E-01
Carbon Disulfide	8.44E-03	4.27E-01	2.73E-03	2.75E-01	2.07E-03	2.35E-01
Chlorobenzene	2.25E-03	1.14E-01	7.27E-04	7.33E-02	5.51E-04	6.26E-02
Chloroethane	5.77E-03	2.92E-01	1.87E-03	1.88E-01	1.41E-03	1.61E-01
cis-1,2-Dichloroethane	5.29E-03	2.68E-01	1.71E-03	1.72E-01	1.30E-03	1.47E-01
Cyclohexane	4.69E-02	2.37E+00	1.52E-02	1.53E+00	1.15E-02	1.31E+00
Ethanol	1.34E+00	6.76E+01	4.32E-01	4.35E+01	3.27E-01	3.72E+01
Ethylbenzene	1.65E-01	8.33E+00	5.32E-02	5.37E+00	4.04E-02	4.59E+00
Freon-11	4.23E-02	2.14E+00	1.37E-02	1.38E+00	1.04E-02	1.18E+00
Freon-114	5.33E-03	2.70E-01	1.72E-03	1.74E-01	1.31E-03	1.48E-01
Freon-12	6.47E-02	3.27E+00	2.09E-02	2.11E+00	1.59E-02	1.80E+00
Heptane	8.71E-02	4.41E+00	2.82E-02	2.84E+00	2.14E-02	2.43E+00
Hexane	1.03E-01	5.19E+00	3.32E-02	3.34E+00	2.51E-02	2.86E+00
m,p-Xylenes	2.23E-01	1.13E+01	7.23E-02	7.28E+00	5.48E-02	6.22E+00
Methyl tert butyl ether	1.61E-02	8.15E-01	5.21E-03	5.25E-01	3.95E-03	4.49E-01
Methylene chloride	9.28E-02	4.70E+00	3.00E-02	3.03E+00	2.28E-02	2.59E+00
o-Xylene	7.16E-02	3.62E+00	2.32E-02	2.33E+00	1.76E-02	1.99E+00
Styrene	4.19E-02	2.12E+00	1.36E-02	1.37E+00	1.03E-02	1.17E+00
Tetrachloroethene	6.51E-02	3.30E+00	2.11E-02	2.12E+00	1.60E-02	1.81E+00
Tetrahydrofuran	4.12E-02	2.08E+00	1.33E-02	1.34E+00	1.01E-02	1.15E+00
Toluene	3.92E-01	1.99E+01	1.27E-01	1.28E+01	9.62E-02	1.09E+01
Trichloroethene	2.42E-02	1.23E+00	7.84E-03	7.90E-01	5.94E-03	6.75E-01
Vinyl Chloride	1.75E-02	8.87E-01	5.67E-03	5.71E-01	4.30E-03	4.88E-01
Sulfur Compounds						
2-Ethylthiophene	1.94E-02	9.83E-01	6.24E-03	6.31E-01	4.75E-03	5.40E-01
2,5-Dimethylthiophene	1.87E-02	9.47E-01	6.01E-03	6.08E-01	4.57E-03	5.20E-01

Table 6
Calculated Ambient Air Concentrations in Areas Around Landfill

Compound	Total Ambient Air Concentration (μg/m³) [a]					
	Area 1		Area 2		Area 3	
	Annual	1-Hour	Annual	1-Hour	Annual	1-Hour
Diethyl disulfide	2.43E-02	1.23E+00	7.81E-03	7.91E-01	5.95E-03	6.77E-01
Hydrogen sulfide	1.33E-02	6.74E-01	4.28E-03	4.33E-01	3.26E-03	3.70E-01
Isopropyl mercaptan	1.80E-02	9.10E-01	5.77E-03	5.84E-01	4.40E-03	5.00E-01
Methyl mercaptan	1.76E-02	8.88E-01	5.63E-03	5.70E-01	4.29E-03	4.88E-01

(a) All concentrations are based on the maximum results from 5 years of meteorological data and reflect the combined concentrations associated with emissions from the landfill surface, the enclosed flares and the gas-to-energy plant.

Table 7
Exposure Parameters Used in Risk Assessment (a)

Parameter	Child	Adult	Units
Exposure duration (ED)	6	30	Yrs
Exposure frequency (EF)	350	350	days/yr
Exposure time (ET)	24	24	hrs/day
Inhalation rate (IR)	0.30	0.63	m^3/hr
Conversion factor (CF)	0.001	0.001	mg/µg
Body weight (BW)	15	70	Kg
Averaging time for noncarcinogenic exposures (Atnc)	2,190	10,950	Days
Averaging time for carcinogenic exposures (Atc)	25,550	25,550	Days

(a) All of the listed exposure parameters are recommended USEPA default values (provided in Tables C-2-1 and C-2-2 in USEPA 1998a).

means that an individual could have, at most, a one in 100,000 chance of developing cancer over a 70-year lifetime under the evaluated exposure conditions. In comparison, each person in the U.S. has a background risk of developing cancer over a lifetime of about one in three. The target cancer risk level commonly used by PADEP, and numerous other state regulatory agencies, is one in one hundred thousand (1 in 100,000, which is also expressed as $1x10^{-5}$ or 1E-5) (PADEP 2002).

The potential for chronic non-cancer health effects was determined by comparing the calculated exposures with non-cancer reference doses (RfDs). A hazard quotient was calculated for each chemical by dividing its exposure by its reference dose. Each chemical was evaluated separately, and then the results were initially added across all chemicals regardless of the type of health effect endpoint. The sum of a number of hazard quotients is referred to as a hazard index. A hazard index summed across all compounds, not taking into account the type of health effects associated with each compound, is a conservative first step in evaluating the potential for non-cancer effects. If the hazard index for all compounds is above a value of one (1), this indicates that the hazard index values should be recalculated for groups of compounds having similar types of health effects or the hazard quotient values for those compounds producing a hazard index above one should be examined in more detail. If the hazard index for compounds with similar types of health effects is below one, then adverse health effects are not expected to occur. Even if the hazard index for compounds with similar types of health effects is above one, this does not automatically mean that adverse health effects might occur (for example, because of the safety factors that are incorporated in the non-cancer reference doses). Rather, this type of result means that there is an increased chance that health effects might occur. In this case, further research should be conducted to evaluate the potential for public health effects. The target hazard index value commonly used in the State of Pennsylvania is 1 (PADEP 2002); this value is also used by many other regulatory agencies.

The results of the chronic risk assessment for both cancer risks and non-cancer health effects are shown in Table 8. The detailed results for each compound evaluated are provided in Appendix F. The excess lifetime cancer risks ranged from 1E-7 (one in ten million) to 1E-6 (one in one million); these results were 10-100 times lower than the PADEP target risk level. The non-cancer hazard index values (summed across all compounds regardless of type of health effect) ranged from 0.01 to 0.1; these values were 10-100 times lower than the PADEP target level of one. If the hazard index results were calculated for groups of compounds having similar types of health effects, rather than all compounds, the resulting values would be even lower and still well below the target level of one. These results show that excess lifetime cancer risks from long-term inhalation exposure to landfill gas in areas near to the Grand Central Landfill are well below regulatory target risk levels and that non-cancer health effects are not expected to occur from long-term inhalation exposure to landfill gas emissions.

Acute Short-Term Risks

The potential for short-term acute inhalation risks was evaluated by comparing modeled short-term, 1-hour average air concentrations with the acute reference air concentrations in a manner similar to the evaluation of non-cancer risks (USEPA 1998a). The 1-hour average air concentrations used for each area were the average of all the maximum 1-hour average values calculated at each ISCST modeled grid receptor location within each area. This means that the concentrations for any other hour of the year at each of the grid receptor locations were lower than the values used here. An acute hazard quotient was calculated

Table 8
Chronic (Long-Term) Risk Assessment Results

Result	Area		
	Area 1 **(area nearest active landfill [Areas B and C] where concentrations were highest)**	**Area 2** **(area nearest closed landfill [Area A] where concentrations were highest)**	**Area 3** **(area in Pen Argyl where concentrations were highest)**
Excess Lifetime Cancer Risks (a)			
Adult	1E-06	4E-07	3E-07
Child	5E-07	2E-07	1E-07
Hazard Index for Non-cancer Effects (b)			
Adult	0.06	0.02	0.01
Child	0.1	0.04	0.03

(a) The excess lifetime cancer risks reflect exposure to all potential carcinogens evaluated in the risk assessment. The regulatory target cancer risk level used by PADEP is 1E-5 (1 in 100,000). A value of 1E-5 is 10 times higher than 1E-6 and 100 times higher than 1E-7.

(b) The listed hazard index values for non-cancer effects reflect exposure to all compounds evaluated in the risk assessment, regardless of the type of health effects. If a hazard index summed across all compounds is above 1, then the hazard index values are recalculated for groups of compounds having the same type of health effect and/or a more detailed evaluation may be conducted. The common regulatory target hazard index value used by PADEP for compounds grouped according to similar types of health effects is 1.

by dividing each chemical's modeled 1-hour average air concentration within each area by its acute reference concentration. The quotients were compared to a target level of one. Quotients below one are not expected to result in adverse health effects. Quotients above one indicate an increased chance that mild transient adverse health effects might occur (e.g., eye irritation) or a clearly defined objectionable odor associated with the specific compound being evaluated might be noticed.

Table 9 summarizes the results of the acute inhalation analysis. The detailed results are provided in Appendix F. As can be seen, the hazard quotients ranged from 7E-9 (0.000000007) to 0.09; these values were all well below the target level, by factors ranging from 10 to more than 70 million. Even if the hazard quotients were added across groups of chemicals having similar types of health effects, the combined results would still be well below a target level of one. These results indicate that short-term health effects are not expected to occur in areas near to the Grand Central Landfill as a result of inhalation exposure to landfill gas emissions.

Table 9
Acute (Short-Term) Risk Assessment Results

Result	**Area**		
	Area 1 **(area nearest active landfill [Areas B and C] where concentrations were highest)**	**Area 2** **(area nearest closed landfill [Area A] where concentrations were highest)**	**Area 3** **(area in Pen Argyl where concentrations were highest)**
Minimum Hazard Quotient (a)	1E-08	9E-09	7E-09
Maximum Hazard Quotient (a)	9E-02	6E-02	5E-02

(a) The minimum and maximum results are the lowest and highest hazard quotients, respectively, calculated among all of the evaluated compounds. The typical target hazard quotient value used by regulatory agencies is 1.

RISK EVALUATION OF PARTICULATE MATTER (DUST)

The risk assessment also included a comprehensive dust monitoring program to evaluate potential dust levels in the air around the landfill. The dust monitoring program was performed to generate data for consideration in this risk assessment. The technical term commonly used for dust is particulate matter, and this term is used throughout the remainder of this text.

In the following sections, general information is provided about the sources and characteristics of particulate matter, and the potential human health effects associated with exposure to particulate matter. This background information is important to help understand the sources of and potential health effects associated with particulate matter. Benchmark levels for particulate matter that can be used to help evaluate the potential for public health risks associated with measured concentrations are also provided. A description of the particulate matter monitoring efforts conducted at GCSL and their results is also presented below. This monitoring program included instantaneous measurement of total suspended particulate matter (TSP) in ambient air at regular intervals around the perimeter of the GCSL property boundary using a mobile hand-held device. Daily (24-hour) respirable particulate matter concentrations in ambient air were also measured at several stationary sampling locations around the property boundary using USEPA-recommended sampling and analysis methods. .

SOURCES AND TYPES OF PARTICULATE MATTER

Particulate matter (PM) is the term used for solid particles or liquid droplets found in the air. Many manmade and natural sources emit particulate matter directly into the air, or emit gaseous compounds that react in the air to form particulate matter.

The size of particulate matter varies across a wide range, and each size category of particles generally reflects different sources. There are three commonly used descriptions for PM: TSP which is total suspended particulate matter (TSP), PM10 which refers to particles less than 10 microns (10 µm) in diameter, and PM2.5 which refers to particles less than 2.5 µm in diameter.

TSP refers to all large particles that can be suspended into the air, including particles greater than 10 to even 50 µm (50 µm = roughly 0.002 inches). Particles above 10 µm in diameter are predominantly formed from materials present in the earth's crust (e.g., soil) that are suspended due to natural erosion (wind) or human activities (driving on paved or unpaved roads, agriculture and mining operations, and construction and demolition work).

Particles less than 10 µm in diameter, referred to as PM10, are considered more relevant to human health because they can be inhaled. Particles between 2.5 µm and 10 µm in diameter are referred to as "coarse" particles, and generally result from dust from paved and unpaved roads, tire and asphalt wear, and crushing or grinding operations. Pollen can also be found in the coarse PM fraction. Particles less than 2.5 µm in diameter (PM2.5) are referred to as "fine" particles. Sources of PM2.5 typically include fuel combustion (emissions from cars, trucks, buses), power plants, residential fireplaces and wood stoves, agricultural burning, tobacco smoking, and gas compounds in the air that react to form fine particles.

Fine PM also can result from the long-range transport of dust from outside the U.S., such as dust storms in North Africa (USEPA 1999a, 2000, 2002, 2003a, WHO 2000).

Different particle sizes also behave differently in the air. Larger particles generally deposit on the ground more rapidly than small particles and have a short lifetime in the air (minutes to hours). As a result, coarse particle concentrations can vary substantially across an area and are more likely to reflect impacts from local sources. In contrast, fine particle concentrations tend to be more uniform across an area compared to coarse particles because fine particles stay airborne for longer times (days to weeks) and they can travel long distances (hundred to thousands of kilometers). PM2.5 concentrations in the Eastern U.S. tend to be highest in summer and are dominated by regional rather than local sources (WHO 2000, USEPA 1999a, 2003a).

PARTICULATE MATTER HEALTH EFFECTS INFORMATION

PM exposures are of concern to human health because they can be associated with a variety of human health effects, including respiratory effects (lung inflammation and exacerbation of asthma) and cardiovascular effects (exacerbation of pre-existing chronic heart disease) (USEPA 2003a). Exposure to inhalable PM (i.e., PM10) can have a variety of health effects. People with existing heart or lung diseases, such as asthma, chronic obstructive pulmonary disease or heart disease, and the elderly and children, are at greatest risk for adverse effects from inhalable PM exposure. Exposure to coarse particles (i.e., between PM2.5 and PM10) is primarily associated with the aggravation of respiratory conditions such as asthma. Fine particles (i.e., PM2.5) are more closely associated with decreased lung function, increased hospital admissions and emergency room visits, increased respiratory symptoms and premature death. Fine PM can also increase susceptibility to respiratory infections and can aggravate asthma and chronic bronchitis (USEPA 1999a, 1999b, 2000, 2002, 2003a).

Exposure to PM can occur both indoors and outdoors. USEPA (2003a) explains that most people spend most of their time indoors. PM concentrations indoors reflect both indoor sources of PM (e.g., cooking, cigarette smoke, cleaning) as well as outside PM that has infiltrated into indoor air.

Knowledge about the health effects of PM prompted the development of national ambient air quality standards (NAAQS) under the U.S. Clean Air Act. NAAQS are set at levels intended to protect public health with an adequate margin of safety, including sensitive subpopulations. In 1971, daily and annual NAAQS were promulgated for TSP (260 $\mu g/m^3$ for a 24-hour average and 75 $\mu g/m^3$ for an annual average). These were supplemented by NAAQS for PM10 in 1987, intended to protect against health risks associated with inhalable particles (150 $\mu g/m^3$ for a 24-hour average and 50 $\mu g/m^3$ for an annual average). In 1997, the USEPA proposed new NAAQS for PM2.5, in response to research showing that fine particles warranted regulation to protect public health. An annual PM2.5 NAAQS (15 $\mu g/m^3$) was set to protect against both short-term and long-term exposures. A 24-hour PM2.5 NAAQS (65 $\mu g/m^3$) was set to protect against unusually high peak levels of exposure. Currently, the NAAQS for both PM10 (24-hour and annual averages) as well as PM2.5 (24-hour and annual averages) are in force in the U.S.

In addition to the NAAQS, USEPA has identified PM concentrations for use in making air quality index determinations (USEPA 1999b, 1999c, 2002). Concentrations have been identified for several categories of air quality, including good and moderate air quality, where health effects from PM exposure are not expected to occur to healthy or sensitive individuals, air quality considered to be unhealthy for sensitive individuals and air quality considered to be unhealthy for the general public. USEPA has indicated that PM2.5 concentrations above 65 $\mu g/m^3$ and PM10 concentrations above 250 $\mu g/m^3$ may be of concern to the general public. Concentrations of PM2.5 above 40 $\mu g/m^3$ and of PM10 above 150 $\mu g/m^3$ may be of concern to sensitive individuals (i.e., the elderly and individuals with pre-existing chronic cardiovascular or respiratory disease. In the event 24-hour concentrations may be of concern to sensitive individuals, USEPA recommends that people with respiratory or heart disease, and the elderly and active children, should limit outdoor exertion (USEPA 1999c). The air quality index concentrations provide one source of information that can be used as benchmarks for evaluating the potential public health impacts associated with fine particulate matter levels in ambient air.

BENCHMARK PARTICULATE MATTER CONCENTRATION LEVELS

Table 10 provides a compilation of particulate matter information that can be used to put measured PM levels in context and help indicate the potential for public health risks associated with site-specific measured PM concentrations. The information presented in Table 10 has been divided into several particle size categories to be consistent with current regulatory and measurement methods used in the U.S. for particulate matter.

Table 10 also notes the averaging time associated with PM information, which is an important factor to keep in mind when referring to these data. It is inappropriate to compare concentration data that are reported with different averaging times. In other words, it is essential that averaging times for PM data are consistent and taken into account before comparing PM measurements to PM benchmark information (USEPA 1999b). In general, as the averaging time or sampling duration increases (e.g., from a 24-hour average to an annual average), associated air concentrations decrease. The reduction in concentrations is associated with averaging across many values that fluctuate between both high and low levels. For example, USEPA screening procedures for converting air concentrations to different averaging times indicate that an annual average concentration is roughly five times lower than the maximum 24-hour average concentration, and a 24-hour average concentration is roughly 2 ½ times lower than maximum 1-hour average concentration (USEPA 2003b). Accordingly, a 24-hour sample of PM should not be directly compared to an annual average benchmark level for PM, but instead, consistent averaging times should be used or taken into account.

There are relatively few information sources available that provide benchmarks for TSP. This is because TSP levels are no longer widely used to evaluate public health due to research that has shown that the finer (inhalable) PM is most relevant. In the early 1970's, the USEPA established a 24-hour average NAAQS for TSP of 260 $\mu g/m^3$. While this standard has been superceded by more recent NAAQS for fine particulate matter, it provides a rough benchmark for consideration in this analysis. The Occupational Safety and Health Administration (OSHA) has identified an 8-hour average permissible exposure limit for total dust in the workplace of 15,000 $\mu g/m^3$. Long-term measurements of TSP levels in U.S. metropolitan areas from 1982-1998 have been reported to average roughly 57 $\mu g/m^3$ (Pope et al. 2002).

Table 10
Particulate Matter Concentration Information

PM Category and Concentration Information (a)	Concentration (µg/m3)	Notes	Source
PM2.5 - Fine Particulate Matter			
1997 NAAQS (24-hour and annual averages)			
Primary NAAQS (24 hour average)	65	3-year average of 98th percentile Intended to protect against unusually high peak levels	USEPA. 2003. Fourth External Review Draft of Air Quality Criteria for Particulate Matter (June, 2003).
Primary NAAQS (annual average)	15	3-year average of the arithmetic mean. Intended to protect against both short-term and long-term exposures.	
PA and NJ measurements (24-hour averages, June and July)			
Lehigh County, PA, State Hospital (2000-2002) (mean concentration and range)	15.1 - 21.5 (range: 1.8 - 74.5)	Commercial land use, suburban area	USEPA. 2003. Office of Air and Radiation, AIRS Database Data provided by B. Johnson, USEPA, July 2003.
Northampton County, PA, Freemansburg (2000 - 2002) (mean concentration and range)	15.4 - 22.6 (range: 3 - 75.2)	Commercial land use, suburban area	
Warren County, NJ, Phillipsburg (2000 - 2002) (mean concentration and range)	12.8 - 20.8 (range: 2.1 - 84.8)	Residential land use, suburban area	
Air Quality Index Concentrations (24-hour averages)			
"Good" air quality	< 15	Levels not expected to be of concern to sensitive or healthy people.	USEPA. 1999. Air Quality Index Reporting: Final Rule. 40 CFR Part 58. 64 FR 42530. August 4, 1999; USEPA. 1999. Guideline for Reporting of Daily Air Quality - Air Quality Index (AQI). EPA-454/R-99-010.
"Moderate" air quality	> 15 - 40	Levels not expected to be of concern to sensitive or healthy people.	
"Unhealthy for sensitive groups" air quality	> 40 - 65	Sensitive individuals (people with respiratory or heart disease, the elderly and active children) should limit outdoor prolonged exertion. Levels not expected to be of concern to healthy people.	
"Unhealthy" air quality	> 65 - 150	Levels may be of concern to a greater proportion of members of the general public.	
"Very unhealthy" air quality	> 150 - 250		

Table 10
Particulate Matter Concentration Information

PM Category and Concentration Information (a)	Concentration (µg/m3)	Notes	Source
PM2.5 - Fine Particulate Matter			
US measurements (annual averages)			
Eastern US background (annual average)	2 - 5		USEPA. 2003. Fourth External Review Draft of Air Quality Criteria for Particulate Matter (June, 2003).
Annual means (1999 - 2000)	5 - 30	Highest quarterly mean values occur in summer in the Eastern U.S.	
Annual median (1999 - 2001)	13		
ACGIH Workplace Limits (8-hour averages)			
Respirable Particulates (not otherwise classified) (8-hr time weighted average)	3,000	Respirable fraction defined as having a median (50%) cutpoint collection efficiency of 4 µm.	ACGIH. 2000. Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices. Cincinnati, OH.
PM10 - Respirable Particulate Matter			
1987 NAAQS (24-hour and annual averages)			
Primary NAAQS (24-hour average)	150	Not to be exceeded more than once per year.	USEPA. 2003. Fourth External Review Draft of Air Quality Criteria for Particulate Matter (June, 2003).
Secondary NAAQS (24-hour average)	150	Not to be exceeded more than once per year.	
Primary NAAQS (annual average)	50	Arithmetic average over 3 years	
Secondary NAAQS (annual average)	50	Arithmetic average over 3 years	
1997 NAAQS (24-hour and annual averages)			
Primary NAAQS (24 hour average)	150	3-year average of the 99th percentile	USEPA. 2003. Fourth External Review Draft of Air Quality Criteria for Particulate Matter (June, 2003).
Primary NAAQS (annual average)	50	3-year annual arithmetic mean	
PA measurements (24-hour averages, June and July)			
Lehigh County, PA, State Hospital (2000) (mean concentration and range)	42 (range: 15.7 - 102)	Commercial land use, suburban area	USEPA. 2003. Office of Air and Radiation, AIRS Database. Data provided by B. Johnson, USEPA, July 2003.
Northampton County, PA, Freemansburg (2000) (mean concentration and range)	43 range: 15.0 - 104)	Commercial land use, suburban area	
Northampton County, PA, Nazareth (2000) (mean concentration and range)	26 (range: 5.1 - 61.4)	Residential land use, urban and city center	

Table 10
Particulate Matter Concentration Information

PM Category and Concentration Information (a)	Concentration (µg/m3)	Notes	Source
PM10 - Respirable Particulate Matter			
PA measurements (annual averages)			
Lackawanna County, PA (suburban) (1996-2001) (annual average)	16.1 - 28.9		USEPA. 2002. Office of Air and Radiation, AIRS Database. Monitor Summary Report for Pennsylvania.
Luzerne County, PA (suburban) (1996-2001) (annual average)	17.7 - 28.4		
Freemansburg, Northampton County (1997-2001) (annual average)	16.4 - 41.4	commercial land use, suburban area	
Nazareth, Northampton County (2000-2001) (annual average)	28.1 - 30.2	residential land use, urban/city center	
Nazareth, Northampton County (1996-1998) (annual average)	16.1 - 26.5	location not specified - likely similar to other Nazareth station	
US measurements (annual average)			
Eastern US background (annual average)	5 - 11		USEPA. 2003. Fourth External Review Draft of Air Quality Criteria for Particulate Matter (June, 2003).
Air Quality Index Concentrations (24-hour averages)			
"Good" air quality	< 50	Levels not expected to be of concern to sensitive or healthy people.	USEPA. 1999. Air Quality Index Reporting: Final Rule. 40 CFR Part 58. 64 FR 42530. August 4, 1999; USEPA. 1999. Guideline for Reporting of Daily Air Quality - Air Quality Index (AQI). EPA-454/R-99-010.
"Moderate" air quality	> 50 - 150	Levels not expected to be of concern to sensitive or healthy people.	
"Unhealthy for sensitive groups" air quality	> 150 - 250	People with respiratory disease, such as asthma, should limit outdoor exertion. Levels not expected to be of concern to healthy people.	
"Unhealthy" air quality	> 250 - 350	Levels may be of concern to a greater proportion of members of the general public.	
"Very unhealthy" air quality	> 350 - 420		

Table 10
Particulate Matter Concentration Information

PM Category and Concentration Information (a)	Concentration (µg/m3)	Notes	Source
PM10 – Respirable Particulate Matter			
OSHA Permissible Exposure Limit (8-hour average)			
Respirable Particulates (not otherwise regulated) (8-hr time weighted average)	5,000		OSHA 29 CFR Part 1910.1000, Table Z-1
ACGIH Workplace Limits (8-hour average)			
Inhalable Particulates (not otherwise classified) (note: not equal to PM10) -may be referred to as "nuisance dust" (8-hr time weighted average)	10,000	Inhalable fraction defined as having a median (50%) cutpoint collection efficiency of 100 um	ACGIH. 2000. Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices. Cincinnati, OH.
TSP – Total Suspended Particulate Matter			
1971 NAAQS (superceded by 1987 & 1997 NAAQS - 24-hour and annual averages)			
Primary NAAQS (24-hour average)	260	Not to be exceeded more than once per year.	USEPA. 2002. Office of Air and Radiation, AIRS Database. Monitor Summary Report for Pennsylvania.
Primary NAAQS (annual average)	75	Geometric mean	USEPA. 2002 Office of Air and Radiation AIRS Database. Monitor Summary Report for Pennsylvania
Secondary NAAQS (24 hour average)	150	Not to be exceeded more than once per year.	USEPA. 2002. Office of Air and Radiation, AIRS Database. Monitor Summary Report for Pennsylvania.
OSHA Permissible Exposure Limit (8-hour average)			
Total dust (not otherwise regulated) (8-hr time weighted average)	15,000		OSHA 29 CFR Part 1910.1000, Table Z-1
U.S. Metropolitan Areas (long-term averages)			
Mean concentration	56.7 (+/- 13.1)	Average (and +/- standard deviation) from 150 metropolitan areas, 1982-1998 data	Pope et al. 2002

Definitions:
PM2.5 = Fine fraction = Particles less than 2.5 um in diameter.
PM10-2.5 = Coarse fraction = Particles less than 10 um in diameter.

(a) The averaging time for each noted concentration is provided in this table. Concentrations can only be compared if they are based on the same averaging times. It is inappropriate to directly compare concentrations which have different averaging times.

A variety of information available for PM10 and PM2.5 is shown in Table 10. This information includes the Clean Air Act NAAQS, concentrations relied on for the national air quality index, recent measurements from counties in the Grand Central Landfill region, and concentrations considered generally applicable to the eastern U.S. In addition, workplace exposure limits for respirable and inhalable particulates have been developed; these are listed with the PM10 information, although they do not directly equate to PM10 (e.g., the workplace limits may include particles that are somewhat larger than PM10).

TOTAL SUSPENDED PARTICULATE (TSP) MONITORING

Sampling Program

Monitoring for TSP was conducted at many locations on the perimeter of the GCSL property boundary and at a few off-site locations eight times from October 2002 through June 2003 using a mobile device that allows measurement of instantaneous concentrations in ambient air. The measurement device was a MIE DataRAM Aerosol Monitor which provides real-time measurement (10-second average) of TSP concentrations.[7] Roughly 50 sample locations were evaluated around the entire perimeter of the GCSL property boundary and at a few locations north of the landfill property in Pen Argyl. Three consecutive 10-second samples were collected at each location and the average of these samples was the reported TSP concentration. Other information collected during sampling included meteorological data (e.g., wind speed, wind direction) and activities at the time of sampling that may have affect measured dust levels (e.g., car and truck traffic). TSP monitoring was not conducted during wet weather conditions because precipitation would reduce the amount of dust that might be generated. This means that levels measured during this sampling program were likely to be higher than those that might occur during rainy conditions.

Factors Affecting 10-Second TSP Perimeter Measurements

The information from the TSP monitoring program was used as a "screening" tool with several purposes. First, the measured TSP ambient air concentrations were examined to determine whether concentrations downwind of the landfill were generally elevated compared to concentrations upwind of the landfill. Second, the TSP monitoring program results were examined to determine whether certain activities that may have occurred during sampling tend to be associated with lower or higher dust levels (e.g., vehicle traffic on community roads and on the landfill's access road).

The TSP data were evaluated in detail by compiling information relevant for each sampling result, including measured concentration, date of sampling, classification with respect to wind direction (upwind, downwind), proximity to roads and the landfill, and the presence of vehicles at the time of sampling. This evaluation showed that the most significant factors affecting the measured concentrations were vehicle traffic followed by the specific date of sampling. The effect of vehicles on dust levels is scientifically well documented and, in fact, is the reason why roads at landfills, including Grand Central, as well as many other types of facilities, are routinely managed by wetting and sweeping (USEPA 1993, 1998b). Measured TSP concentrations were highest when trucks and/or cars were passing by at the time of sampling, and along the landfill vehicle access road (Figure 5). The median concentrations

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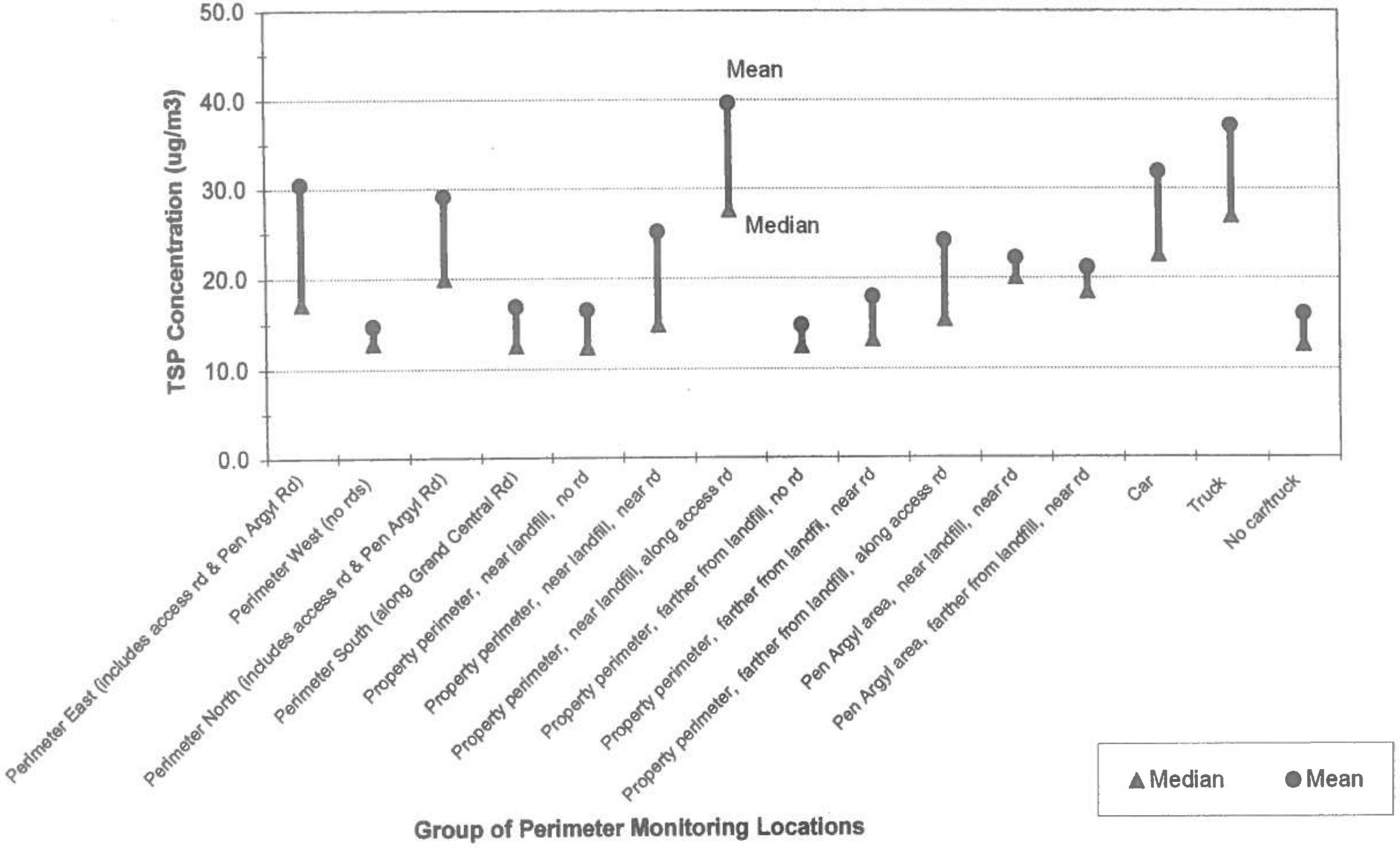
[7] http://www.iemiinc.com/Spec%20Pages/mie_dataram_dr_2000.htm

Figure 5

TSP Perimeter Data:
Average of 10-second samples collected during eight sampling events
October 2002 - June 2003



(Note: The mean is the average of all concentrations, and the median is the middle measurement among the concentrations.)

averaged across the 10-second measurements were approximately 13 μg/m^3 for samples with no vehicle traffic passing by at the time of sampling, 23 μg/m^3 for samples collected when cars were passing by, and 27 μg/m^3 for samples when trucks or large vehicles were passing by. The higher concentrations associated with passing vehicles decreased rapidly as soon as the vehicle had passed by (i.e., within a minute or two). Median concentrations immediately adjacent to the landfill access road ranged from roughly 15 μg/m^3 at locations further than roughly 1,000 feet from the landfill areas to 28 μg/m^3 at locations closer than 1,000 feet to the landfill areas.

Sampling date was also an important factor affecting the TSP sampling results. The medians of the 10-second concentrations varied from approximately 7 μg/m^3 for the March 2003 sampling event to 40 μg/m^3 for the June 2003 sampling event. When each of the eight sampling dates was examined individually, downwind levels were on average lower than, or similar to, upwind levels for five of the eight sampling events, and on average higher than upwind levels for three of the eight sampling events. Based on an examination of sample specific information, the slightly higher downwind levels for three of the eight sampling events are likely to result from a combination of the following factors: higher levels of vehicle traffic occurred during these events compared to the other five sampling events (which can suspend more road dust) and higher wind speeds were present during these events compared to the other sampling events (which can allow more transport of suspended dust).

In general, the impact of wind direction (i.e., upwind and downwind) was not as important as the effects of vehicle traffic and the date of sampling. For example, when no vehicle traffic was present on roads at the time of sampling, there was little difference between upwind and downwind concentrations. Moreover, the TSP measurements collected at sampling locations within the Borough of Pen Argyl, which were located near community roads, were not substantially different from one another regardless of distance from the landfill.

Evaluation of 10-Second TSP Perimeter Measurements

The TSP levels can be put into context by examining the available TSP benchmarks shown in Table 10. As noted above, however, scientific information on dust levels is inadequate to draw conclusions about public health from 10-second TSP measurements. At best, TSP benchmark information can be used to place the measurements into a broader context.

Before evaluating the measured 10-second concentrations against the few TSP benchmarks noted above, it is important to recognize that 10-second measurements do not reflect the longer-term sampling and averaging times more commonly used to assess air concentrations, such as 8-hour averages for the workplace, and 24-hour averages and annual averages for ambient outdoor air. As a result, the instantaneous 10-second measurements collected during the perimeter sampling cannot be directly compared to the TSP benchmarks shown in Table 10. A longer-term average TSP concentration (e.g., 24 hour average) corresponding to the instantaneous perimeter measurements would be lower than the 10-second concentrations measured during the Grand Central Landfill sampling. Although the exact magnitude of this reduction is not known, the 24-hour concentration is likely to be more than several times lower than the 10-second measurements.

The average 10-second TSP measurements from the Grand Central Landfill sampling program were compared to the benchmarks shown in Table 10. The 10-second TSP levels were below the 24-hour and annual average 1971 Clean Air Act NAAQS and the long-term concentrations reported in U.S. metropolitan areas, and orders of magnitude below the standard for workplaces, even without making any adjustments to account for differences in averaging time (these adjustments would only reduce the measured TSP concentrations). If the difference in averaging times was taken into account, the measured TSP levels would be even lower than the benchmarks. This suggests that average total dust levels at the GCSL property boundary as well as at locations sampled in Pen Argyl were lower than TSP levels in metropolitan areas, the 1971 NAAQS and the workplace dust limit.

Selection of Stationary Sampling Locations

The TSP results were also examined to help identify monitoring locations for stationary respirable dust monitors. The purpose of these monitors was to collect respirable particulate matter data, since respirable particulate matter (rather than TSP) is of concern with respect to public health.

Four stationary sampling locations on the GCSL property boundary were selected, based in part on the 10-second TSP measurements. The locations were selected to reflect the conditions found to be important based on the 10-second TSP sampling program, namely car and truck traffic and proximity to the roads. A location to the north of the landfill was also selected to address concerns that have been raised by Pen Argyl about potential dust impacts from the landfill in their community.

RESPIRABLE DUST MONITORING (PM10 AND PM2.5)

Respirable dust, which is a subset of TSP, was monitored at four stationary sampling locations on or within the GCSL property boundary. These monitors collected 24-hour samples of respirable particulate matter in ambient air.

Sampling Locations

The four stationary sampling stations were selected based on an evaluation of the 10-second TSP measurements, as described above, as well as meteorological data (e.g., predominant downwind directions), the location of nearby residential and community areas, and the locations of known or suspected dust-producing activities (e.g., roads). Relevant USEPA (1994) requirements were also considered in identifying sampling points, including sampler height, avoidance of spatial obstructions, security, and operator safety. Descriptions of the four sampling locations are provided in Table 11.

The four sampling stations were located on or within the property boundary where PM concentrations potentially associated with the landfill will be higher compared to locations beyond the boundary due to the effects of air dispersion and particle deposition. The effects of air dispersion alone will reduce concentrations by three to four times within 500 feet of the property boundary and by almost 10 times within 1,000 feet of the property boundary. The actual reductions in concentration with increasing distance will be even greater due to the added effect of particle deposition.

Table 11
Stationary Sampling Locations for Respirable Dust Monitoring

Sampling Location	Distance and Direction from Landfill	Additional Location Information
Site 1	1,200 feet west of the inactive landfill area	Not near a road In power line right of way Inside property boundary Surrounded by woods
Site 3	1,600 feet north of the active landfill area	200 feet from Pen Argyl Road 1,500 feet northeast of the loading area for the rock used by crushing company NAPA On property boundary Location selected to allow evaluation of respirable dust levels in the direction of the Pen Argyl community
Site 5	100 feet east of the active landfill area	Adjacent to landfill access road Adjacent to Pen Argyl road On property boundary 10-second TSP measurements tended to be highest in this area
Site 6	500 feet east of the inactive landfill area	Adjacent to Pen Argyl Road On property boundary Location selected to allow evaluation of respirable dust levels adjacent to the landfill and along a roadway, but not along the landfill access road 2,400 feet south of Site 5

Monitoring Methods

Two types of respirable dust concentrations were measured – PM10 and PM2.5. These particle sizes were identified based on USEPA's National Ambient Air Quality Standards for particulate matter as well as USEPA research efforts on the health effects of respirable particulate matter, as discussed earlier in this section (USEPA 2003a).

USEPA-recommended sampling methods were used to collect and analyze PM10 and PM2.5 samples (USEPA 1997b, 1998c, 1998d, 1998e). A detailed discussion of the PM10 sampling protocol, based on USEPA recommendations, is provided in Appendix A of the Health Risk Assessment Protocol (Appendix B to this document). A similar protocol is provided for PM2.5 in Appendix B of the Health Risk Assessment Protocol.

Daily 24-hour samples were collected at each location on each day of the week during June and July 2003. This was accomplished by operating the samplers simultaneously for 24-consecutive hours every sixth day for each of the two types of PM samples. Samples were collected for a 24-hour period from noon to noon. Table 12 lists the dates and days of sampling conducted at each location. The sampling results were reviewed and quality assured by an independent company, Environmental Standards (Environmental Standards 2003).

Respirable Monitoring Results

The 24-hour average concentrations from the four sampling locations are summarized in Table 13. These results were evaluated to determine whether there were landfill-related effects on measured concentrations.

The monitoring results suggested that local sources affected the PM10 levels whereas regional sources affected the PM2.5 levels. The PM10 concentrations were more variable across the sampling locations than the PM2.5 concentrations, consistent with a local influence. The PM10 concentrations measured at Site 5 were significantly higher than those measured at Site 1 and Site 3, but not significantly different than the concentrations at Site 6. In contrast, the PM2.5 concentrations were not significantly different across the four sampling locations. The PM10 levels at Sites 5 and 6 were most likely to have been influenced by vehicle traffic, since these two sites were immediately adjacent to roads (i.e., the landfill access road and Pen Argyl Road). The lack of variation in the PM2.5 results across the sampling locations suggests that local sources (e.g., vehicle traffic) did not substantially affect measured concentrations, which is consistent with USEPA's observation that PM2.5 levels are dominated by regional (rather than local) influences.

A further evaluation of the PM10 results showed a relationship between concentrations and proximity to roads but no consistent pattern with respect to wind direction. The average concentrations ranged from 24.3 $\mu g/m^3$ to 59.8 $\mu g/m^3$. The average concentration was highest at the location adjacent to the access road and Pen Argyl Road (Site 5), somewhat lower at the location adjacent to Pen Argyl Road (Site 6) and even lower at the two other sampling locations (Site 3 north towards Pen Argyl and Site 1 not near roads). The average concentrations at Site 1 and Site 3 were not substantially different from one another. Studies have shown that vehicle traffic on roads can influence nearby dust levels, producing concentrations that decrease with distance from roadways (Zhu et al. 2002, Monn et al. 1997). The association between dust and roads is not only applicable to the landfill vehicle access road, but also to other roads used by heavy vehicles for a wide variety of industrial,

Table 12
Sampling Dates for Respirable Dust Monitoring

Date	Day of Week
PM10 Sampling Dates	
6/10/03	Tues noon – Wed noon
6/16/03	Mon noon – Tues noon
6/22/03	Sun noon – Mon noon
6/28/03	Sat noon – Sun noon (a)
7/4/03	Fri noon – Sat noon
7/10/03	Thurs noon – Fri noon
7/12/03	Sat noon – Sun noon (a)
7/16/03	Wed noon – Thurs noon
PM2.5 Sampling Dates	
6/13/03	Fri noon – Sat noon
6/19/03	Thurs noon – Fri noon
6/25/03	Wed noon – Thurs noon
7/1/03	Tues noon – Wed noon
7/7/03	Mon noon – Tues noon
7/13/03	Sun noon – Mon noon
7/19/03	Sat noon – Sun noon

(a) The sample from Site 3 was invalidated on this day due to vandalism of a part of the sampling equipment. A make up sample from Site 3 was collected on 7/12/03.

Table 13
Respirable Dust Monitoring Results (a)

Sampling Site	PM10 24-Hour Average Concentrations (µg/m^3)		PM2.5 24-Hour Average Concentrations (µg/m^3)	
	Average Concentration	Range of Concentrations	Average Concentration	Range of Concentrations
Site 1	25.4	14.8 – 45.8	19.2	7.7 – 40.2
Site 3	24.3	14.2 – 49.6	20.2	6.8 – 41.4
Site 5	59.8	19.7 – 97.7	23.1	9.3 – 46.0
Site 6	45.9	23.9 – 77.0	21.9	9.3 – 45.7

(a) Reported data are based on seven samples collected at each site, with each sample collected on a different day of the week (sampling from noon to noon).

commercial or other uses, even those roads that are some distance from the landfill and are not used by landfill-related vehicles.

Winds over the 24-hour sampling periods were highly variable on most PM10 sampling days (e.g., the wind direction varied across more than 180 degrees over the 24-hour sampling period). As a result, a clear definition of upwind and downwind sampling locations could not be made for most sampling days. Even on those days when the wind was moderately stable (e.g., varying by no more than 90 degrees over the 24-hour sampling period), the results did not clearly show a relationship between wind direction and concentration. Rather, the PM10 results suggest that proximity to roads was a key factor affecting the 24-hour PM10 concentrations. The importance of vehicle traffic on PM10 levels in air adjacent to roads is well-known.

As noted above, the PM2.5 levels did not vary substantially between the four sampling stations. The PM2.5 concentrations ranged from an average of 19.2 μg/m^3 at Site 1 to 23.1 μg/m^3 at Site 5. The wind directions during the 24-hour PM2.5 sampling periods were too variable to clearly distinguish between upwind or downwind sampling locations, but the similarity of concentrations across locations indicates that wind direction was not a critical factor affecting the measurements. This is consistent with the results of the instantaneous TSP monitoring described above.

Evaluation of Respirable Monitoring Data

The PM10 and PM2.5 particulate matter sampling results were also compared with available public health benchmarks (e.g., U.S. National Ambient Air Quality Standards) as well as available information on background PM10 and PM2.5 levels in the region (see Table 10).

All of the 24-hour PM10 concentrations at all sampling locations were below the 24-hour PM10 NAAQS. The average 24-hour PM10 concentrations were also similar to 24-hour measurements available from USEPA sampling stations in the GCSL region, although the average at Site 5 (adjacent to the vehicle access road) was slightly higher than at the regional monitoring stations. However, the range of concentrations measured at GCSL was consistent with the range of values reported at the regional monitoring stations. Based on USEPA's air quality index classification, the 24-hour PM10 measurements at GCSL, even those at Site 5, would not be of concern to the general public, including sensitive people.

All of the 24-hour PM2.5 concentrations at all sampling locations were below the 24-hour PM2.5 NAAQS. The average 24-hour PM2.5 concentrations, as well as the range of concentrations, were also similar to 24-hour measurements available from USEPA sampling stations in the GCSL region. Based on USEPA's air quality index classification, all of the PM2.5 results would not be of concern to the general public. The PM2.5 measurements on one sampling day[8] were at or just above 40 μg/m^3, the level above which USEPA recommends that people with respiratory or heart disease, and the elderly and active children, should limit outdoor exertion (USEPA 1999c). Although the highest levels were measured near to or adjacent to roads, possibly indicating a vehicle traffic related effect, the concentrations across all four monitoring sites on this one day did not vary markedly and

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[8] On June 25, 2003, the concentrations at Sites 1, 3, 5 and 6 were, respectively, 40.2 μg/m^3, 41.4 μg/m^3, 46 μg/m^3 and 45.7 μg/m^3).

appeared to predominantly reflect regional conditions rather than any local source of particulate matter.

The evaluation of the PM10 and PM2.5 monitoring results yielded the following conclusions:

- PM10 levels were predominantly affected by local sources (e.g., vehicle traffic) whereas PM2.5 concentrations predominantly reflected regional sources (e.g., neither the landfill nor vehicle traffic).
- PM10 and PM2.5 concentrations on the Waste Management property were similar to measurements collected at USEPA monitoring stations in the region.
- PM10 and PM2.5 concentrations were below the USEPA's NAAQS.
- PM10 results were influenced by proximity to roads, including both the vehicle access road and Pen Argyl Road.
- PM2.5 levels did not vary substantially between the four sampling stations; the similarity of concentrations across locations indicates that proximity to roads and wind direction were not critical factors affecting the measurements.
- PM10 concentrations were below available benchmarks for the general public and sensitive individuals.
- PM2.5 concentrations were below available benchmarks for the general public and also, with the exception of measurements on one sampling day, for sensitive individuals. PM2.5 concentrations on one sampling day were at or just above the level at which USEPA recommends that people with respiratory or heart disease, and the elderly and active children, should limit outdoor exertion. The concentrations across the four monitoring sites on this sampling day did not vary markedly, however, indicating a predominantly regional impact on air quality rather than a local source of particulate matter.

DISCUSSION OF UNCERTAINTIES

All risk assessments involve the use of assumptions, judgment and incomplete data to varying degrees. This results in uncertainty in the final estimates of risk. In accordance with USEPA (1989, 1992) guidance, this section presents a discussion of key uncertainties affecting the risk assessment.

The results of any risk assessment inherently reflect uncertainty because of the many complexities involved in the analysis. This risk assessment, for example, involved the integration of many steps, each of which is characterized by some uncertainty. These steps include:

- selection of compounds for evaluation,
- calculation of chemical emission rates,
- air dispersion modeling of concentrations associated with landfill areas and stacks,
- calculation of potential exposures to humans using default exposure parameters,
- calculation of potential risks using toxicity information derived in some instances from human data but also in many cases from experimental data produced from animal studies, and
- measurement of landfill gas and PM concentrations.

The results presented in this report reflect the combination of these potential sources of uncertainty. Collectively, the assumptions used in this risk assessment are considered more likely to overestimate potential risks than underestimate them.

When evaluating the impact of uncertainty on a risk assessment, it is relevant to recognize that there are two types of uncertainty generally associated with this type of analysis - one is referred to as variability and the other is a more technical definition of uncertainty.

Variability results from differences in physical or biological processes, such as the natural differences in how much people weigh or how much they eat. Variability generally cannot be reduced by doing additional research but it can be addressed by incorporating information on the range of values that might be present in a population. In this risk assessment, single values were used for parameters that are known to vary across the population such as inhalation rates, body weight, and years of residence at a location. By choosing single values for input parameters in this risk assessment, the potential variability of risks among the population is not calculated. On the other hand, the values chosen for the input parameters were based on standard USEPA defaults that are collectively more likely to overestimate than underestimate risks for the majority of the population.

Uncertainty stems from imperfect knowledge of the true value of a variable or model, and is generally reducible through additional research and analysis (i.e., better data and better models). Uncertain elements in this risk assessment include chemical-specific input parameters (e.g., selection of compounds for evaluation, chemical emission rates, toxicity criteria), mathematical models (e.g., the ISCST air dispersion model, USEPA's landfill gas generation model), and measurement uncertainty (e.g., for PM and landfill gas compounds).

The risk assessment focused on almost 40 compounds that were detected in the landfill gas sampling data. The 1999 and 2003 landfill gas sampling programs comprehensively evaluated volatile organic compounds and sulfur compounds in landfill gas. Compounds that were not detected were not quantitatively evaluated in the risk assessment and this may result in a small underestimation of potential risks. In addition, acute toxicity data were not available for two of the sulfur compounds detected in landfill gas and this too may result in some underestimation of risk. Among the detected sulfur compounds, however, the compounds that were evaluated are expected to be most important with respect to both emissions and potential toxicity, and as a result the level of underestimation of risk due to not including two sulfur compounds is expected to be negligible.

The chemical emission rates from the landfill surface were calculated using landfill gas measurements from the flare inlet piping in conjunction with a USEPA gas generation model. These modeled surface emission rates are likely to be overestimated due to assumptions about the gas collection system, uncertainties and assumptions used in the USEPA model and the use of landfill gas data from inlet piping to the flares that does not take into account processes that attenuate the release of compounds from the landfill surface. Although the modeled landfill surface emission rates for hydrogen sulfide were adjusted to reflect this uncertainty, using actual surface measurements, it is still likely that the emission rates for this compound were overestimated. For the other landfill gas compounds, whose emission rates were not adjusted, the degree of overestimation is expected to be much greater, perhaps by more than an order of magnitude.

Emission rates for sulfur-containing landfill gas compounds were not calculated for the power plant and flare stacks since these compounds will be broken down and destroyed in the combustion process. The potential for health effects associated with stack emissions of sulfur compounds produced from landfill gas combustion was, however, evaluated. This evaluation conservatively assumed that all of the sulfur present in the landfill gas compounds would be emitted from the stacks as sulfur dioxide. Sulfur dioxide is a regulated compound under the Clean Air Act with NAAQS that have been set to protect even sensitive individuals. The sulfur dioxide annual NAAQS is 80 $\mu g/m^3$ and its 24-hour NAAQS is 365 $\mu g/m^3$. Sulfur dioxide air concentrations associated with emissions from the power plant and flare stacks combined were calculated using the same dispersion modeling methodology described above. The maximum 24-hour average sulfur dioxide concentration was calculated to be 7 $\mu g/m^3$, more than 50 times lower than the corresponding NAAQS. The maximum annual average concentration was calculated to be 0.5 $\mu g/m^3$, more than 150 times lower than the corresponding NAAQS. This analysis showed that sulfur emissions from the power plant and flare stacks at the landfill are well below regulatory standards which have been set to protect even sensitive individuals.

The chronic and acute toxicity criteria used in this analysis for landfill gas compounds are likely to overestimate risks. These criteria were obtained from regulatory agencies and the published literature and all include substantial safety factors intended to ensure that they are protective of human health.

The risk assessment also examined the potential for respiratory effects associated with simultaneous exposure to both particulate matter and landfill gas. As noted earlier in this report, a number of the detected compounds in landfill gas have the potential to affect the respiratory system by causing irritation to the respiratory tract and the nose (USEPA 2002b, USEPA 2003c, ATSDR 2003, WHO 2003). The hazard index values for respiratory effects from the landfill gas compounds were calculated to range from 0.01 to 0.09, roughly 10-100 times below the target hazard index value of 1. These results indicate that adverse respiratory effects are not expected due to inhalation exposure to landfill gas in areas near to the landfill. The respiratory effects that have been noted for PM include lung injury and inflammation, increased susceptibility to respiratory infections, and increased airway reactivity and exacerbation of asthma. The specific toxicological mechanisms of effect for PM are not fully understood and are the focus of continuing research (USEPA 2003a, 2003d). As shown above, the levels of PM10 measured on and within the GCSL property boundary were below available benchmarks for the general public and sensitive individuals. The PM2.5 concentrations did not vary markedly across sampling locations, indicating a predominantly regional impact on air quality rather than a local source of particulate matter. There is no scientific evidence indicating that PM and landfill gas compounds can act together to produce combined effects on the respiratory tract, nor that the toxicological mechanisms of effect are the same (USEPA 2003c, 2003d, ATSDR 2003). Although some landfill gas compounds and PM can have respiratory health effects at sufficiently high levels of exposure, there is no evidence indicating that there are combined effects associated with simultaneous exposure to these two classes of compounds, especially at the low levels of landfill gas constituents calculated near the landfill.

Measurement data used in this analysis included measurements of chemical concentrations in landfill gas and measurements of PM10 and PM2.5 on or within the GCSL property boundary. These data were collected following established sampling and analysis protocols, and were analyzed and reviewed for accuracy by firms that specialize in these types of studies (Air Toxics Ltd., Folsom, CA and Environmental Standards, Valley Forge, PA). The landfill gas measurements were collected at the inlet piping to the flares and, as noted above, are likely to overestimate emission rates from the landfill surface. The PM measurements were collected on or within the GCSL property boundary where concentrations potentially associated with the landfill will be higher than at more distant locations from the facility.

CONCLUSIONS

INTRODUCTION

This report presents a human health risk assessment for the Grand Central Sanitary Landfill (GCSL) in Plainfield Township, Northampton County, Pennsylvania. The risk assessment was performed to respond to community concerns that have been raised about potential health effects associated with landfill gases and dust. The team of scientists retained by Waste Management to perform the risk assessment consisted of CPF Associates, Inc., EarthRes Group, Inc. (ERG) and Trinity Consultants.

The risk assessment was conducted according to a May 2003 risk assessment protocol that was reviewed and approved by an independent third party, Dr. Arthur Frank, a professor of Environmental and Occupational Health at Drexel University in Philadelphia who was recommended by the Pennsylvania Department of Health. The protocol was presented to the public at a press conference held in Plainfield Township in April 2003.

SITE SETTING

The GCSL is located on a 516.7-acre tract of land which includes a municipal solid waste (MSW) landfill, a stone crushing operation, and a landfill gas-to-energy electric generating plant. These three operations are owned by separate entities and operate under permits issued by the Pennsylvania Department of Environmental Protection (PADEP). GCSL occupies land that in the last century was historically disturbed by slate mining activities. Landfill operations have and continue to include the clean-up of old slate spoil piles and the backfilling of old open slate quarries with material from the slate spoil piles and native rock.

The municipal solid waste landfill at GCSL consists of two separate disposal areas that encompass roughly 139 acres. The 52-acre original landfill began accepting waste in the 1950's, was closed in 1991 and completely capped by 1993. The 87-acre more recent landfill, also referred to as the Northern Expansion, began accepting waste in 1991 and is currently permitted to accept waste until 2007. As of 2003, roughly 45% of the Northern Expansion had been filled and capped, and approximately 50% is currently used for municipal solid waste disposal activities. USA Waste Services assumed ownership of the landfill in the spring of 1996. In the summer of 1998, Waste Management, Inc. assumed ownership of the landfill when it merged with USA Waste Services.

Landfill gas is generated at all MSW landfills as a by-product of biodegradation of the waste. Landfill gas at GCSL is collected through an extensive system of vertical and horizontal underground perforated pipes. The gas collection piping system is connected to a gas-to-energy plant within the GCSL property boundary that is owned by the Green Knights Economic Development Corporation. There are also two enclosed flares at the landfill which are connected to the gas collection piping system and are used if the landfill gas production exceeds the capacity of the gas-to-energy plant. The flares and power plant effectively destroy organic compounds and methane present in landfill gas.

Dust control measures taken at GCSL include regular road sweeping of parking areas, landfill access roadways from the public highway to the landfill and other haul roads inside the landfill. In addition, water is regularly applied to road surfaces to reduce fugitive dusts.

RISK ASSESSMENT OF LANDFILL GAS

The risk assessment included an evaluation of the potential long-term and short-term human health risks associated with inhalation of landfill gas emissions in nearby surrounding areas. The landfill gas risk assessment followed general human health risk assessment methods and guidance that are well-established by both the USEPA and the U.S. National Academy of Sciences.

Hazard Identification

The first step in the risk assessment, hazard identification, involved the identification of landfill gas compounds to be addressed in the risk assessment and compilation of toxicity criteria for these compounds.

The composition of landfill gas depends on many factors including the type and amount of waste present in the landfill, the age of the waste, and environmental characteristics inside the landfill. The landfill gas composition at GCSL was determined from samples collected at the inlet piping to the two enclosed flares in 1999 and 2003. These landfill gas samples were analyzed for 80 compounds and 39 of these were detected. The 39 detected compounds were examined in detail in the risk assessment.

Chronic and acute toxicity criteria were compiled for each of the 39 compounds. The toxicity criteria were obtained from federal and state regulatory agency and research institution databases, including databases available from USEPA, ATSDR, the American Industrial Hygiene Council, the California Environmental Protection Agency, and the Department of Energy's Subcommittee on Consequence Assessment and Protective Actions.

The toxicity criteria were derived using very conservative (i.e., health protective) assumptions. This means that exposures or concentrations calculated to be above a toxicity criterion do not necessarily indicate that there are likely to be actual health effects. Although exposures at, or below, comparison toxicity values are unlikely to result in health effects, it does not automatically follow that any environmental concentration or exposure that exceeds a comparison value would be expected to produce adverse health effects. The principle reason why regulatory and health agencies develop protective health-based toxicity data is to enable health professionals to identify and resolve potential public health hazards. If a calculated exposure is found to exceed a comparison toxicity criterion, then additional research into the specific compound or compounds at issue is required to more fully evaluate the potential for public health effects.

Exposure Assessment

The second step in the risk assessment, the exposure assessment, was conducted by developing emission rates for each compound from the landfill, performing air dispersion modeling of these emissions to calculate air concentrations beyond the GCSL property boundary and calculating exposures from inhalation in nearby areas.

Landfill gas emission rates were calculated from six sources at the GCSL facility:

- Landfill Area A - the surface of the closed original landfill

- Landfill Area B – the surface of the capped landfill area in the Northern Expansion
- Landfill Area C – the surface of the active uncapped area in the Northern Expansion
- Three stacks on each of the three turbines at the Green Knights gas-to-energy plant
- One stack at enclosed flare #1
- One stack at enclosed flare #2

Emission rates from the landfill surface were calculated using data describing gas generation rates from the waste in the landfill, the collection efficiency of the gas collection system, air measurements collected immediately above the landfill surface, and the concentrations of compounds in the landfill gas. Emission rates from the gas-to-energy plant and the enclosed flares were calculated based on operating data from these facilities and other similar facilities and the concentrations of compounds in the landfill gas.

Air dispersion modeling was performed to calculate chemical concentrations in air in areas surrounding the GCSL property boundary. The air dispersion modeling was performed using a USEPA-approved dispersion model. The input parameters for the dispersion model were based on data describing each of the emission sources. The dispersion model was run using the most recent quality assured datasets available from the U.S. National Weather Service that are acceptable to PADEP from the nearest weather service stations.

Long-term annual average and short-term 1-hour average ambient air concentrations were calculated for each of the 39 landfill gas compounds based on the combined influence of all six emission sources. Annual average concentrations were used to evaluate potential chronic exposures and risks. One-hour average concentrations were used to evaluate the potential for acute short-term effects. Based on a review of maps and land use in the facility vicinity, air concentrations were calculated in three areas surrounding the property boundary:

- Area 1: an area directly to the east of the active landfill,
- Area 2: an area directly to the east of the closed landfill, and
- Area 3: an area in Pen Argyl to the north of the landfill.

These three areas include very few locations that are currently used for residential purposes, are comprised mostly of undeveloped land, and are representative of the areas where concentrations were predicted by the dispersion model to be highest.

Potential chronic (long-term) inhalation exposures in each of the three areas were calculated using USEPA recommended exposure parameters for adults and children (e.g., exposure occurs 24 hours per day, 350 days per year for 30 years for an adult and for 6 years for a child).

Risk Characterization

Potential risks associated with landfill gas emissions from the Grand Central Landfill were addressed in the risk characterization. Chronic long-term inhalation risks were calculated by combining the inhalation exposures with chronic toxicity values for cancer and non-cancer effects. The potential for short-term acute inhalation risks was evaluated by comparing modeled short-term air concentrations with acute reference air concentrations.

The calculated cancer risks reflect the upper bound probability that an individual may develop cancer over a 70-year lifetime under the assumed exposure conditions. The target cancer risk level commonly used by PADEP is one in one hundred thousand (1 in 100,000 or 1E-5). The excess lifetime cancer risks calculated for landfill gas from the Grand Central Landfill ranged from 1E-7 (one in ten million) to 1E-6 (one in one million); these results were 10-100 times lower than the one in 100,000 target cancer risk level.

The potential for chronic non-cancer health effects was evaluated by dividing each chemical's calculated inhalation exposure by its non-cancer toxicity criterion to produce a hazard quotient for each compound. The hazard quotients were then added together to produce a hazard index. Hazard quotients and hazard index values below one are not expected to result in adverse health effects. The target hazard index value commonly used by PADEP for compounds having similar types of health effects is one. The non-cancer hazard index values (conservatively summed in this assessment across all compounds regardless of type of health effect) ranged from 0.01 to 0.1; these values were 10-100 times below the target level of one.

The potential for short-term acute inhalation risks was evaluated by dividing each chemical's modeled short-term average air concentration by its acute reference air concentration to produce an acute hazard quotient. The hazard quotients were compared to a target level of one. Quotients below one are not expected to result in adverse health effects. The calculated hazard quotients ranged from 7E-9 (0.000000007) to 0.09; these values were 10 to more than 70 million times below the target level of one. Even if the hazard quotients were added across groups of chemicals having similar types of health effects, the combined results would still be well below a target level of one.

Conclusions of Landfill Gas Risk Assessment

The results from the landfill gas risk assessment were as follows:

- excess lifetime cancer risks from long-term inhalation exposure to landfill gas in areas near the Grand Central Landfill were well below regulatory target cancer risk levels,
- non-cancer health effects are not expected to occur from long-term inhalation exposure to landfill gas emissions in areas near the Grand Central Landfill, and
- short-term health effects are not expected to occur in areas near the Grand Central Landfill as a result of short-term inhalation exposure to landfill gas emissions.

RISK EVALUATION OF PARTICULATE MATTER

The risk assessment also included an evaluation of particulate matter (dust) levels in air around the landfill. This portion of the risk assessment described the sources and characteristics of particulate matter, discussed the potential human health effects associated with exposure to particulate matter, and presented benchmark levels that were used to help evaluate the potential for public health risks. The methods and results of a dust monitoring program conducted at the Grand Central Landfill were also provided. The dust monitoring program included instantaneous measurements of total suspended particulate matter (TSP) in air at many locations around the perimeter of the GCSL property boundary and 24-hour respirable particulate matter monitoring (for particles less than 10 microns and less than 2.5

microns in diameter) at four stationary sampling locations on and within the property boundary.

Sources and Types of Particulate Matter

Particulate matter (PM) is the term used for solid particles or liquid droplets found in the air. Many manmade and natural sources emit particulate matter directly into the air, or emit gaseous compounds that react in the air to form particulate matter.

The size of particulate matter varies across a wide range, and each size category of particles generally reflects different sources. The three PM size categories used in the risk assessment were:

- TSP which is total suspended particulate matter,
- PM10 which refers to particles less than 10 microns (10 μm) in diameter, and
- PM2.5 which refers to particles less than 2.5 μm in diameter.

Particles above 10 μm in diameter are predominantly formed from materials present in the earth's crust (e.g., soil) that are suspended due to natural erosion (wind) or human activities (driving on paved or unpaved roads, agriculture and mining operations, and construction and demolition work). Particles less than 10 μm in diameter (PM10) are considered more relevant to human health because they can be inhaled into the lungs. Particles between 2.5 μm and 10 μm in diameter generally result from dust from paved and unpaved roads, tire and asphalt wear, crushing or grinding operations, and from pollen. Sources of PM2.5 (fine particles) typically include fuel combustion (emissions from cars, trucks, buses), power plants, residential fireplaces and wood stoves, agricultural burning, gas compounds in the air that react to form fine particles, and in some areas of the U.S, the long-range transport of dust from distant areas.

Different particle sizes behave differently in the air. Larger particles deposit on the ground more rapidly than small particles, they can vary substantially across an area and they are more likely to reflect impacts from local sources. Smaller particles such as PM2.5 stay airborne for longer times, are more uniform across an area, and are more likely to reflect regional rather than local sources.

Health Effects Information for Particulate Matter

PM exposures are of concern to human health because they can be associated with respiratory and cardiovascular effects, particularly among those with existing heart or lung diseases, chronic obstructive pulmonary disease or heart disease. Exposure to particles between PM2.5 and PM10 is primarily associated with the aggravation of respiratory conditions such as asthma. Exposure to PM2.5 is more closely associated with decreased lung function, increased hospital admissions and emergency room visits, increased respiratory symptoms and premature death. PM2.5 can also increase susceptibility to respiratory infections and can aggravate asthma and chronic bronchitis.

The USEPA has developed national ambient air quality standards (NAAQS) under the U.S. Clean Air Act for PM2.5 and PM10 that can be used to evaluate measured PM levels in air. NAAQS are set at levels intended to protect public health with an adequate margin of safety, including sensitive subpopulations. NAAQS were set for TSP in 1971 by USEPA but they are not legally in force today.

USEPA has also identified PM2.5 and PM10 concentrations for use in an air quality index that can be helpful when evaluating measured PM levels in air. Concentrations have been identified for several categories of air quality, including good and moderate air quality, air quality considered to be acceptable for the general public but unhealthy for sensitive individuals, and air quality considered to be unhealthy for the general public and sensitive individuals. In the event that PM2.5 or PM10 concentrations exceed the levels of concern for sensitive individuals, USEPA recommends that people with respiratory or heart disease, and the elderly and active children, should limit outdoor exertion.

Other PM data that were used to help evaluate measured PM levels in air included monitoring data from counties in the Grand Central Landfill region, workplace exposure limits for respirable and inhalable particles, and the Occupational Safety and Health Administration 8-hour average permissible exposure limit for total dust in the workplace.

Total Suspended Particulate (TSP) Monitoring

Monitoring for TSP was conducted at many locations around the perimeter of the GCSL property boundary and at a few locations within the Borough of Pen Argyl eight times from October 2002 through June 2003. The monitoring device measured instantaneous (10-second) TSP concentrations. A detailed evaluation of the TSP data showed that vehicle traffic (e.g., along the landfill vehicle access road) and the date of sampling were the most important factors affecting the measured concentrations, rather than wind direction. The TSP measurements collected at Pen Argyl Borough sampling locations were not substantially different from one another regardless of distance from the landfill (these locations were near community roads). The average TSP levels at the GCSL property boundary and at locations within the Borough of Pen Argyl were lower than TSP levels in metropolitan areas, the 1971 NAAQS and the workplace dust limit.

Respirable Dust Monitoring (PM10 and PM2.5)

PM10 and PM2.5 concentrations were measured at four stationary sampling locations on or within the GCSL property boundary (Sites 1, 3, 5 and 6):

- Site 1 was located inside the property boundary, 1,200 feet west of the inactive landfill area in a power line right of way and not near any roads.
- Site 3 was located on the property boundary, 1,600 feet north of the active landfill area and 200 feet from Pen Argyl Road.
- Site 5 was located on the property boundary, 100 feet east of the active landfill area adjacent to both the landfill access road and Pen Argyl Road.
- Site 6 was located on the property boundary 500 feet east of the inactive landfill area adjacent to Pen Argyl Road.

Concentrations potentially associated with the landfill will be higher at sampling stations located inside or on the property boundary than at locations beyond the boundary due to the effects of air dispersion and particle deposition. The four locations were selected based on the 10-second TSP measurements, meteorological data, the location of nearby residential and community areas, and the locations of known or suspected dust-producing activities such as roads. Samples were collected every sixth day, each for a 24-hour period, at each location during June and July 2003.

A review of the PM10 and PM2.5 monitoring results yielded the following conclusions:

- Local sources affected the PM10 concentrations whereas regional sources affected the PM2.5 levels. The PM10 concentrations were more variable across the sampling locations than the PM2.5 concentrations, consistent with a local influence. The PM2.5 concentrations were not significantly different across the four sampling locations, suggesting that local sources (e.g., vehicle traffic) did not substantially affect measured concentrations. This is consistent with USEPA's observation that Eastern U.S. PM2.5 levels are dominated by regional (rather than local) influences.

- There was a relationship between PM10 concentrations and proximity to roads, but no consistent pattern with respect to wind direction. The PM10 concentrations measured at Site 5 were significantly higher than those measured at Site 1 and Site 3, but not significantly different than the concentrations at Site 6. The PM10 levels at Sites 5 and 6 were most likely to have been influenced by vehicle traffic, since these two sites were immediately adjacent to roads (i.e., the landfill access road and Pen Argyl Road). The average PM10 concentrations at Site 1 and Site 3 were not substantially different from one another.

- The PM2.5 levels did not vary substantially between the four sampling stations and the similarity of concentrations across locations indicates that proximity to roads and wind direction were not critical factors affecting the measurements. This suggests that the measured PM2.5 concentrations were not affected by the landfill.

- The PM10 concentrations were below available benchmarks for the general public and sensitive individuals. The PM10 concentrations at all sampling locations were below the PM10 NAAQS and were similar to measurements available from USEPA sampling stations in the region. According to USEPA's air quality index classification, the PM10 measurements would not be of concern to the general public or sensitive individuals.

- The PM2.5 concentrations at all sampling locations were below available benchmarks for the general public, below the PM2.5 NAAQS and were similar to measurements available from USEPA sampling stations in the region. According to USEPA's air quality index classification, the PM2.5 measurements on all but one sampling day on or within the property boundary would not be of concern to sensitive individuals. The PM2.5 concentrations on one sampling day were at or just above the level at which USEPA recommends that people with respiratory or heart disease, and the elderly and active children, should limit outdoor exertion. The concentrations across the four monitoring sites on this sampling day did not vary markedly, however, indicating a predominantly regional impact on air quality rather than a local or landfill-related source of particulate matter.

DISCUSSION OF UNCERTAINTIES

All risk assessments involve the use of assumptions, judgment and incomplete data to varying degrees. This risk assessment, like all risk assessments, involved the integration of different types of information that contains some uncertainty. This information includes the selection of compounds for evaluation, the calculation of chemical emission rates, dispersion modeling, the calculation of potential exposures, the use of toxicity criteria conservatively derived from either human or animal data, and measurements of landfill gas composition and PM in air. Uncertainty was addressed in this risk assessment by using a combination of inputs and assumptions that collectively would produce risks that were more likely to be overestimated than underestimated.

SUMMARY

In conclusion, the risk assessment showed that potential inhalation exposures to landfill gas near the Grand Central Landfill were below regulatory and other target risk levels for both chronic long-term and acute short-term human health effects. Particulate matter levels at the landfill boundary were below regulatory standards and criteria and would not be of concern to the general public.

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